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TRAFFIC ACCIDENT RESEARCH UNIT

CRASH PROTECTION FOR CHILDREN AFTER THEIR THIRD BIRTHDAY

BY

D.C. HERBERT

AND

D. CUTTING

DEPARTMENT OF MOTOR TRANSPORT NEW SOUTH WALES

The Traffic Accident Research Unit was established within the Department of Motor Transport, New South Wales, in May 1969 to provide a scientific approach to the traffic accident problem.

This paper is one of a number which report the results of research work undertaken by the Unit's team of medical, statistical, engineering and other scientists and is published for the information of all those interested in the prevention of traffic accidents and the amelioration of their effects.

W Butler

Commissioner.

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TRAFFIC ACCIDENT RESEARCH UNIT,
DEPARTMENT OF MOTOR TRANSPORT,
NEW SOUTH WALES.

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ABSTRACT

Ways of improving use of child restraints after the child reaches 3 years of age, by the development of more acceptable devices, are examined. The development and testing of booster cushions is documented and the use of them by children in the 3 to 8 year age group recommended, in conjunction with adults' lap-sash belts or children's harnesses.

ACKNOWLEDGEMENTS

This project was funded in part under the Transport Planning and Research (Financial Assistance) Act 1977 of the Commonwealth Government of Australia, Project NMT 77/3 - Occupant Protection. The research has involved a review of means of improving crash protection for occupants of passenger cars. This report deals with one specific issue among the many being examined.

CONTENTS

SUMMARY

This report is a statement of philosophy, supported by information gleaned from opinion surveys, crash studies and laboratory tests and evaluations. It is intended as a guide for the use of administrators, manufacturers and others. It covers the selection of protective devices for children, and provides the technical background for such selection.

When a child reaches his third birthday he can continue to use his approved "child seat" - more precisely, his "chair-with-harness", until he is too large for it, which stage may well not be reached until he is 4 years old or more. If an available approved chair-with-harness is too small, the child can use any available child harness or, failing the availability of that, he can use any available seat belt, preferably one of the lap-sash type.

Any restraint should be adjusted to have minimum slack. Retractors are invaluable in reducing slack.

Booster cushions have been shown by laboratory test to be viable propositions provided they can be restrained in crashes by the child's back or by suitable anchoring devices. Their use with child harnesses or seat belts greatly increases the acceptability of such restraints.

1. INTRODUCTION

This report deals with the relative value, in terms of intended use and degree of crash protection, of the various means available for providing crash protection for child passengers older than 36 months, travelling in passenger cars or derivatives.

The following account is intended as a statement of philosophy supported by information gleaned by the authors and their colleagues from opinion surveys, crash studies and laboratory tests and evaluations. Reference is also made to the current Australian Standard 1754-1975 (as amended by Amendments No. 1 and No. 2 in 1976 and 1978), entitled "Child Restraints for passenger cars and derivatives", to Australian Design Rule No. 34 entitled "Child restraint anchorages" and to the related ADR 3A entitled "Seat anchorages for motor vehicles".

It is hoped that this report will prove useful to those who wish to gain an appreciation of the technical basis for the selection of the most suitable protective devices for children, and to administrators, manufacturers and others who need a clear statement of aims based on current knowledge.

2. CHAIR WITH HARNESS

The protective value of the Australian-approved (by the Standards Association) chair-with-harness type of child restraint, for children in roughly the 9 month to 4½ year age group, has been demonstrated in laboratory tests (Herbert et al. 1974) and in real crashes (Vazey 1977). It has also been shown (Freedman and Lukin 1977) that these child restraints are seen by parents, except possibly by some in low income or low education groups, to have other benefits that increase their likelihood of purchase and usage; these benefits include improved control of the child in the car, in association with the child's greater comfort and enjoyment of the car trip. Usage problems with these restraints "were minimal". Freedman and Lukin found however a tendency for children to be moved out of these chairs at about 3 years of age; they identified several reasons for this, including the reduced need to control the maturing child, and reduced need of a child once he has reached 3 years of age for the support in ordinary travel afforded by the chair and its harnesses, the needs of a younger child for the restraint (associated with the costs, and benefits, involved in the purchase of a second chair) and the limited useful life (because of limited size) of a second chair. Vazey (1977) found moreover that all the "approved bucket seats" in his study of crashes had been worn by children under 3 years of age.

In attempting to overcome the last of these problems (limited size of chair), Herbert and Lozzi (1976) established and published the dimensions required of chairs such that 98 per cent of children of 19 kg mass (the basis for chair and harness strength) could be accommodated by them. These data are under consideration by the Standards Association of Australia, with a view to possibly specifying minimum dimensions. The effect of such a specification would be to cater for practically all 36 month old children, since children rarely exceed 19 kg mass by their third birthdays. However, strictly speaking, only 50 per cent of 54 month old children would be covered because the other half would exceed 19 kg before that age. (See Figure 1 from Herbert and Lozzi (1976).)

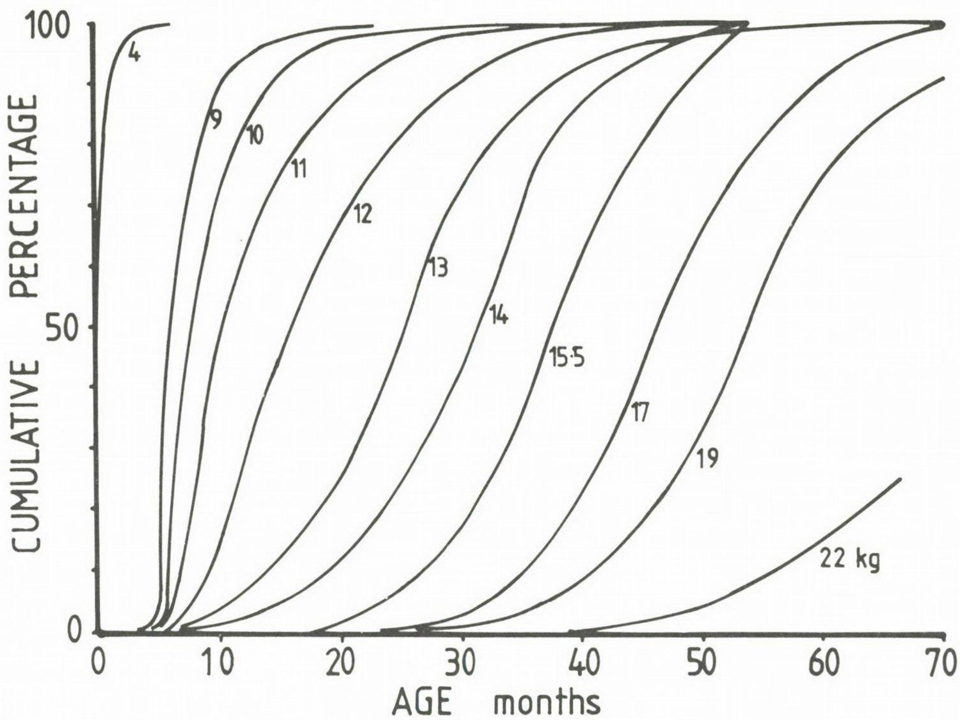

FIGURE 1: Percentage of Sydney children who reached the indicated mass at age shown or earlier.

It may safely be concluded that although a child who is small enough to use a restraint rated at 19 kg maximum mass, but who weighs more than 19 kg, does not have quite the degree of protection afforded a lighter child, he nevertheless has excellent protection in practically all crashes.

In practice, we have found that existing chairs-with-harnesses already meet many of the proposed 98 percentile dimensions and do not impose significant restrictions beyond those just stated. That is, those chairs that have been approved by the Standards Association of Australia to AS 1754 should be both large enough and strong enough (even in severe crashes) for practically all children aged 36 months and half of those aged 54 months. (See Appendix A for details). Some small increases in dimensions would however be of benefit to very large children of 19 kg mass.

The working rule to adopt is that, if the child is small enough to sit in it, any currently SAA approved chair-with harness may be (and should be) used, with every confidence in its strength. Proper adjustment to the child is however an important consideration in securing the maximum protection afforded by any particular restraint. In particular, the lap strap and any crotch strap should be adjusted to prevent a young child wriggling out of it, and shoulder straps should be adjusted (or tied together behind the child) to ensure that they restrain the shoulders in any crash.

There remain several other problems the most significant of which is probably the cost of purchase of a second chair when needed for a second child. This appears often to occur when the older child is about 3 years old.

Two further types of restraint are available for the 3 year old. One is the child harness and the other is the adult seat belt (whether of lap, sash, or lap-sash type). Each costs less than a chair-with-harness.

3. CHILD HARNESS

Australian Standards include the specification of a child's full harness. In principle, such a harness should be capable of providing better protection than an adult's belt because it utilises more suitable webbing, is more completely adjustable to the size of a child and because it distributes crash forces more widely to the skeletal structure by virtue of the larger number of straps provided and by attention to strap width and geometry.

Henderson et al. (1976), in an examination of their performance in real crashes, found that child harnesses, designed for children too large for the chair-with-harness type of restraint, "appeared to offer good protection in frontal crashes". Vazey (1977) endorsed this view but found only 18 harnesses (of which only 8 had received SAA approval) in his study of 149 children restrained in crashes. Among the 8 wearing approved harnesses, only 1 sustained a head injury and that was only a minor contusion, in a head-on crash of considerable severity. None of these 8 children sustained anything but minor injury (rated 1 on the Abbreviated Injury Scale* (AAAM , 1975).

* Footnote: Briefly, the AIS scores each body region 0 to 6, that is no injury = 0, minor = 1, moderate = 2, severe (not life threatening) = 3, serious (life-threatening, survival probable) = 4, critical (survival uncertain) = 5, and maximum (currently untreatable) = 6. Unknown injuries are coded = 9.

Henderson et al (1976) reported one case where a child died wearing a harness. A boy aged four was restrained in a child harness linked with the adult seat belt in a sedan that was hit violently from the left. The child died from a fracture-dislocation at the top of the cervical spine. The injury could have been attributable to impact with a child "bucket" seat mounted to his left, or to contact with the intruding left rear door, but Henderson associated it with deep bruising from the shoulder straps of the harness and considered it probable that harness loading caused the fracture. He concluded that the child would in any case have died or been severely injured, if not restrained, because of the deep intrusion of the side door of the car. In that case, use of the harness in this rather unusual crash did not affect survival very much, one way or the other. This case drew attention to the need for improving installation and adjustability of harnesses, to minimise inappropriate loading of the wearer.

With this single exception of a severe side impact, our records show approved child harnesses to have performed well in crashes.

Child harnesses are however not without their problems. Herbert et al. (1974) found that in some small cars it was impossible to install certain models of harness without leaving excessive slack in the shoulder straps. (This problem remained in 1977 even in a harness supplied with a retractor (Herbert 1977)). They pointed out that there was no place for an upper anchorage point in central rear seats of station sedans (since corrected for new cars by implementation in 1976 of ADR 34). As to the child's view out of the car, much degraded from his accustomed "high chair", they said that a better view was sometimes provided by the parent seating the child on a cushion, however their laboratory crash simulations with dummies produced excessive submarining* even with a thin cushion, and total ejection of a thick pouffe with serious

* Footnote: The object of pelvic restraint has been stated by Herbert (1974) as follows for adults; a somewhat similar situation exists for children although the pelvis will be much less developed:- (footnote continued on next page).

submarining of the dummy under the lap strap into which large amounts of slack were introduced by cushion ejection.

These crash simulations were performed with commercially available Sierra Toddler (of mass 14.2 kg) and Sierra Sammy (of mass 23.0 kg) dummies which may not have simulated the motion of real children very well. No better dummies being available even in 1978, it remains difficult to interpret submarining seen with these dummies. The test results must in fact be viewed with some caution in the light of evidence from real crashes that children in very loose restraints of all descriptions tend to hit their heads in frontal crashes, presumably after partial ejection over the tops of the pelvic restraints. If indeed real children are submarining they appear to be doing so without receiving the abdominal, thoracic and neck injuries one would expect from studies of adults. Support for this view comes from Vazey (1977) who found 56 cases of head injury (mostly of minor severity) but only 5 of abdominal injury (all but 1 minor) among 149 restrained child passengers involved in crashes. Moreover, Wyllie (1973) reported a case of a 9 month old child ejected over the top of a harness during emergency application of the car's brakes, because the child had pushed the shoulder straps aside.

(Footnote continued from previous page)

'The life-saving objective of the lap part of the lap/sash belt is to restrain the subject by applying any deceleration load in a frontal impact to the very strong pelvic bones. As its name implies, a lap strap is intended to lie on the lap (the upper thighs) in normal use: as it tightens in a crash it should press down into the thighs whilst being dragged back, relative to the moving wearer, against the anterior inferior iliac spines. We can imagine the lap strap wedged into corners on the left and right hand sides, each corner being defined by the intersection (in side view) of the anterior surface of the femur with the anterior inferior iliac spine. In practical impacts the belt is most unlikely to be pulled so hard as to reach these bones but it will press hard into the overlying tissue and muscle and nearly reach the bones, if it has been located properly in the first place. Where the lap strap commences, before impact, in contact with the stomach, there is a grave danger that it will be pulled up the anterior superior iliac spines, over the iliac crests, to injure or rupture abdominal organs; this process is termed "submarining".

Nevertheless, in the absence of better dummies, the submarining found with Sierra and other dummies should not be ignored completely, and the belt looseness introduced by possible cushion ejection in real crashes should be viewed as unacceptable from the general standpoint that looseness leads to higher impact forces on the child and inappropriate (non-designed) distribution of crash forces to his torso.

Thus we return to the human problems involved in securing greater use of harnesses, and the need, if efforts in this direction are to succeed, of much greater attention by designers to features that children and their parents will perceive as attractive, over and above the evident crash protection afforded by child harnesses in most crashes.

4. BELTS DESIGNED FOR ADULTS

Henderson et al. (1976) approached head-on the question posed by Snyder and O'Neill (1975) that is, Are adult seat belts hazardous to children? and concluded: 'The use of adult seat belts by children of any age is not a dangerous practice, and more desirable than the use of no restraint or the use of an "unapproved" child seat.'

More data on the crash performance of adults' seat belts worn by children under 8 years old were available to Vazey (1977). He found among his 149 cases, some 37 of lap-sash belt use, 13 of lap belt and 2 of sash (diagonal) belt only. Some of these children were ejected out of their belts, namely 4 from lap-sash and 2 from lap belts.

One 7 year old child was in a lap belt adjusted loosely and was ejected completely out of the vehicle, sustaining a haematoma, abrasions and brief concussion that led to an AIS rating of 2 for the head. Another 7 year old child, in a loosely adjusted lap-sash belt in a rear seat, received a fractured mandible, probably from contact with intruding metal; his head injury was rated 3. A 5 year old in a loose sash belt sustained multiple facial lacerations and contusions rated 2 for the head. A boy aged 6 years wearing a very loose lap-sash belt was reached by intruding metal and was scored 5 to the abdominal region following a tear of the undersurface of the liver and a haematoma in the duodenum; he also scored 3 to the extremities for a fractured femur and lacerated foot. A 5 year old was ejected completely out of a loosely worn lap-sash belt and scored 3 to the head with concussion, lacerations and facial abrasions. Another 5 year old sustained concussion and a laceration to the left ear, scoring 2 to the head, when he wore a loosely adjusted lap-sash belt. Finally, a child aged 1 year and 9 months was ejected from a very loosely worn lap-sash belt, was found within the car afterwards and scored 1 for a head laceration. It should be noted that 28 of the 52 children in adults' belts received no head injury at all.

Thus Vazey was fully justified in concluding: "Whereas there is no objection to children wearing belts supplied for adults, it is of great importance that such belts should be pulled tight, to the limit of comfort. Ejection of a child from a loose seat belt is not improbable in a crash".

5. ACTION REQUIRED FOR BETTER RESTRAINT OF CHILDREN AFTER THEIR THIRD BIRTHDAY.

There appear to be at least three measures available for improving the situation outlined in the last paragraph:

(a) Delaying use by children of belts designed for larger persons, until they are large enough to fill them adequately. This involves educating parents so that they understand that the more closely a restraint has been selected by them for the size of a particular child, the better the crash protection it affords.

For the average 3 year old, the best restraint is a chair-with-harness, the next is a properly adjusted child's harness, followed by a properly adjusted adult's lap-sash belt.

(b) Improving lap-sash belts so as to be more suited to small occupants and certainly for children above 19 kg in mass. The fitting, whether voluntarily or by law, of inertia-reel automatically adjusting and locking retractors to belts in rear seating positions is probably the best means available in the short term for achieving this. With mandatory fitting in New South Wales of retractors to all 4 outboard seating positions in new taxi-cabs already implemented, it should be a simple matter to extend the rule to all vehicles. Moreover, many new cars may be purchased fitted, as for taxi-cabs, with 4 retractor belts.

(c) Extending the concept of a child's chair-with-harness to restraints for older children. In the medium term this should be pursued with vigour. There are obvious economic advantages to a parent who finds that the restraint he has bought remains suitable for his first child for say 4 years instead of the present 2 years or so. Doubtless the first manufacturer to introduce such a device to the market will find some economic advantages, too. Clearly Australian Standard 1754 should quickly be amended so as to remove any impression that chair type restraints should be restricted to 4½ year olds and to children of 19 kg mass. In the short term, the design, manufacture and use of booster cushions should be regularised, as an interim measure. This is the subject of the next section of this report.

6. BOOSTER CUSHIONS

As stated earlier, Herbert et al. (1974) found that the use of a cushion, to raise a child off the car seat so that he could see out, was not without hazard because the unrestrained cushions submarined, followed by the dummy, in their crash simulations. They suggested that further tests should be performed with the cushions restrained.

Shortly after this, Howard Micklem Pty. Ltd., of South Australia supplied us with booster cushions with side straps for securing to a seat belt or child's harness. Tests on this type of cushion were not very encouraging since submarining still occurred. (See Appendix B Test specimen MT 704 for details). Our laboratory did not pursue the matter for the next year or so.

At the end of 1975 however, Freedman and Lukin (1977) conducted 1196 household surveys of mother-child pairs in Sydney and found that mothers saw little practical benefit in restraining a child over 3 years old, unlike with a younger child. And because of the shortness of most trips. the safety aspects of restraint were not perceived to be important. They concluded that to persuade a mother to restrain the older child, the device must have perceived benefits additional to safety ones. They noted that at present the opposite was the case: approved harnesses (unlike some unapproved, "unsafe" harnesses) were inconvenient and often ensured that the trip would be "an unpleasant experience for the child, his mother and other occupants. While these problems remain, it is unlikely that the use of approved harnesses will significantly increase. For the same reasons the new law (in 1977) in New South Wales making use of an available restraint mandatory for children under eight is likely to produce a significant and sustained increase in seat belt use among young children only at the cost of stringent enforcement". It is worth quoting their conclusions and recommendations on this issue in full:

"What is urgently needed is a harness-cushion or seat belt-cushion combination, designed to comply with the current standard 1754 governing child restraints. If such a restraint were available, it is likely that many more children in the relatively poorly protected age group three to less than eight years would travel in approved child restraints. Until such a restraint system is available, attempts to persuade parents to restrain children under eight years may have a limited effect. And attempts to compel restraint use for young children may at times be felt as harsh and repressive, and at others may result in the use of seriously degraded restraint systems, modified by parents, or loosely adjusted to overcome usage problems".

These views were shared by the present authors and, at the end of 1976, some chairs were constructed out of expanded foam materials, especially for children in the 3 to 8 year age bracket, to be used in conjunction with child harnesses or lap-sash belts. Frontal crash simulations and one side impact under the conditions specified in AS 1754 were performed, with much more satisfactory results and some results were presented orally by Herbert on 1st February, 1977 to the Sixth International Conference of the International Association for Accident and Traffic Medicine meeting in Melbourne, Australia, after his presentation of a paper on child restraints (Herbert, 1977). These results were circulated afterwards to members of SAA Committee AU 22 (Child Restraints) by means of laboratory reports (Traffic Accident Research Unit, 1977), and are included in Appendix B (Test specimens MT 637, 638 and 683).

Interest in this work was immediate and a number of manufacturers supplied us with specimens of booster cushions for test. All tests performed to date in the course of this research are included in Appendix B. (It should be noted that, although the Department performs tests to AS 1754 at cost for the Standards Association of Australia's Certification Mark Section, it does not operate a commercial testing laboratory, and only tests products, other than for the SAA, in the course of its own research work; it owns all specimens so tested and publishes all such test results).

At a meeting of SAA Committee AU 22 on 1st May 1977 we introduced proposals for authorising booster cushions as part of a new series of child restraints. This work was taken up enthusiastically by all Committee members as a result of which Amendment No. 2 to AS 1754 was agreed at the next meeting of the Committee on 1st December 1977, and after some editing in the light of comments, it was published at the end of March 1978.

In New South Wales only child restraints complying with AS 1754-1975 may be sold. Since booster cushions were not defined as child restraints by the original AS 1754, they have been offered for sale legally and with little or no external control. Manufacturers have however been encouraged to discuss their products with this Department. Once some booster cushions have been approved to AS 1754, New South Wales legislation is likely to be amended and only booster cushions complying with AS 1754 (as amended March 1978) will be able to be sold in the State.

7. CUSHIONS AND CHAISES

The desired features of booster cushions are, especially for children aged 3 to 8 years:

(a) To raise the child so that he can see out of the car, just as he could in the "high-chair" he has just vacated.

(b) To ensure that the booster cushion does not submarine completely, nor the child seated on it.

(c) To improve the pelvic restraint geometry of existing lap-sash belts and child harnesses, and

(d) To take some of the unnecessary length out of existing belts designed for adults when used by children.

Two types of booster cushion were considered for inclusion in AS 1754. One was the simple cushion with restraining straps as originally supplied to us by the firm of Micklem: This was termed "Cushion" in AS 1754. The other was a seat comprising cushion and attached seat back (as shown by Herbert in February 1977); this was termed "Chaise" in AS 1754 in order to avoid conflict with "seat" and "chair" employed separately for definition purposes.

Few design restrictions were placed on designers. Cushions were restricted to a mass of 3 kg whereas chaises, tending to load the occupant's back, were restricted to 2 kg. Each type is to be tested with the intended type of belt or harness, and has to meet all testing requirements of AS 1754. This means that ejection and submarining of cushion, chaise or dummy will need to be total for a failure in a dynamic test to be recorded. This is not a very satisfactory situation since partial ejection demonstrated with a dummy might just possibly be found with a real child, in spite of opinion to the contrary, but, in the absence of good child surrogates and a submarining criterion for dynamic testing, there is at present no alternative. Probably the chief protection for the consumer lies in the certainty that this Department and other organisations would publish any unfavourable results obtained in their independent programmes of monitoring in real crashes the performance of child restraints offered for sale in New South Wales, and the generally healthy attitude of manufacturers of child restraints in Australia.

In giving advice to would-be manufacturers and purchasers of booster cushions it has been pointed out by us that the cushion serves to elevate the child. The cushion should be anchored in position or be self-anchoring. It should be constructed of materials that give firm support for the child and that maintain their shape in normal use. Thus, our advice has been of a fairly rudimentary nature and has <u>not</u> been backed up by detailed study or testing of individual products.

From our own observations and by discussion with persons involved in the manufacture of cushions and chaises it has become apparent that some of the available flexible load bearing polyurethane foams are highly favoured practical materials for use in forming the bulk portion of flexible booster cushions and chaises. Such materials are available in many types, classes and grades, some of which are widely used for cushioning materials in automotive and railway carriage seating applications. The use of slab foam has an additional advantage because of the ready availability of a product whose mechanical properties are known, and whose consistency can be controlled. Australian Standard Specification K165-1967 Flexible Urethane Foam for seat cushioning and bedding is available as a guide to booster cushion designers and to provide quality assurance for the product. In contrast, flexible cushions or chaises relying on their outside cover to shape and contain loose filling materials present obvious problems of maintaining shape and of user hygiene.

We would expect therefore to see suitable grades of flexible foam used in the construction of cushions and chaises. The thickness and volume of material should relate to the upper mass limit of the child intended to use the device. The strength and elasticity of the covering materials are also important. In any event, with the state of our current knowledge, we would not advocate the use of materials with indentation force-deflection characteristics of lesser value than type 3 as presented in Table 1 of AS K165-1967.

In the design of a chaise we are mindful of the need to suggest keeping the mass of the squab portion to a minimum. This may best be done by reducing its thickness to the minimum that the choice of materials will allow for shape retention and durability. Materials of different characteristics may be used separately for the cushion base and squab of such a device. In such cases, the bonding of materials must result in a joint at least as strong and durable as the original material, and this would need to be maintained under the extremes of environment likely to be encountered in normal use.

8. SIGNIFICANCE OF SUBMARINING OF DUMMIES IN DYNAMIC TESTS

As stated on page 10, the Sierra and other dummies used in dynamic tests do not simulate the motion of children in crashes very well. One may well ask why then are they used. The answer is simply that nothing better has been developed. Because of this unsatisfactory situation, we are carrying out research with such a development in view.

In simple terms, the problem is that, in laboratory head-on crashes with existing dummies, the dummies invariably "submarine" to some extent. This term was explained on page 4. A simple example will however no doubt help. If we imagine a dummy in a loosely worn lap belt, in a head-on crash, we find that the dummy slides forward on the car seat, legs first, and the dummy tends to slide under the lap belt; if the belt is very loose the dummy may fall off the front edge of the seat and the lap belt may rise to its throat or armpits. In head-on crashes involving real children, this seems not to happen; instead, the heavy head of the child swings forward, bending the torso around and over the lap belt with, in some cases, a real danger of the child coming right out of the belt unless it is tightly adjusted. Submarining seems no substantial hazard to real children.

It is because of the need to stop the child being thrown over the lap belt, that shoulder harnesses or lap-sash belts are preferred to lap-belts; it is then very important to keep the shoulder straps on the child's shoulders. Fully grown adult human beings have much more rigid frames than children, so perform more like dummies, and tend to submarine under loose belts; this is why an adult's lap strap should be worn as tightly as comfort dictates.

9. LEGAL REQUIREMENTS FOR CHILD RESTRAINTS

(a) Anchorage Requirements. New passenger cars, before being registered for the first time in Australia, from 1st July 1976 are required by Australian Design Rule No. 34 to have fitted a restraint anchorage point for each rear seating position. In sedans these are usually on the parcel shelf. These upper anchorages are intended to provide for anchoring the top straps of child restraints, whereas the existing adult's lap-sash belts in outer positions and lap belts in central positions provide for anchoring the lower parts of chairs for children. The lap belt may form part of a full harness for a child, accessory shoulder straps being anchored to the parcel shelf.

Station wagons were given a further 6 months to comply with ADR 34 because of problems of finding anchorage points other than on the top of the rear seat back which was thought in a few cases to require strengthening if it was to sustain crash forces from a child restraint. Consequently, some changes were made to requirements for adult seats and were incorporated in ADR 3A. These two ADR's are at present under review because of some problems of finding suitable locations in a few vehicles. Most station wagons complied without modification.

One of the objects of this anchoring system modification was to provide for uniform quick-fit and quick-release connections of child restraints to cars, so as to facilitate transfer from car to car, and to eliminate drilling of car bodies after purchase of the car. So far, car and child restraint manufacturers have been unable to reach agreement on the design of interchangeable uniform fittings. Nevertheless, drilling of new cars should no longer be necessary.

An alternative (voluntary) anchoring system utilised by some child restraint manufacturers is the use of the existing lap-sash belt as the sole anchorage. This has been very successful and makes fitting a simple matter in cars fitted with them in front or rear seating positions. It is important however that the sash part of the belt be used effectively to restrain the upper part of restraint and child, just as the lap belt part is used to restrain the lower parts.

Since 1975 outer front seats of new cars have had to be fitted with retractor belts (usually dual sensitive reels with inertial and webbing payout sensitivity). Some cars have been fitted with retractors in rear seats and this is mandatory in new taxi-cabs in New South Wales. Retractors remove the need for manual adjustment of belt length and facilitate still further the fitting of children's chairs-with-harnesses designed for the purpose. Some concern has been expressed about children possibly wriggling their chairs off the car seats, when retractors are used; this has not been well documented; if it occurs in individual cases, it is a simple matter to clip a clothes peg on the sash strap to retard webbing payout. No problem will be experienced in a crash, since the inertia reel will lock very early in the crash sequence.

(b) Fitting Requirements. There are no requirements in Australia to fit child restraints in passenger cars. Such a requirement has been opposed in the past on the basis that available restraints had not been shown to be sufficiently convenient in use, and some of the usage difficulties of restraints for young children below about 18 months age had not been explored adequately. However, this report is concerned only with children who have reached 3 years of age. It may soon prove to be practicable to consider mandatory fitment for children in this age group. That situation could usefully be reviewed in 1979 or 1980 once sufficient experience has been gained with booster cushions.

(c) Wearing Requirements. In Victoria it is an offence for a child to travel in the front compartment of a car unless restrained; that regulation has resulted in the transfer of some children to the rear, with little improvement in the rate of restraint usage. The possible reduction in hazard by being unrestrained in the rear, as opposed to the front, in a crash, has not been established with confidence but probably is a reality, if only of marginal value.

New South Wales decided to try to improve on the Victorian legislation. Since the objective was seen to be an increase in rate of utilisation of existing restraints, it was decided also to require that any available suitable restraint was to be worn. It was moreover decided to define an adult's seat belt as suitable for a child aged 1 year or more. The driver of the car is however allowed the final say in deciding whether or not to restrain a child, since he is permitted to release any child for the comfort or safety of any occupant of the vehicle. In this report we will confine comment to experience with children who have reached their third birthday.

Use of booster cushions (promoted deliberately by the Unit simultaneously with introduction of the NSW legislation on wearing) has been found to render adult's lap-sash belts quite suitable for children of 3 years age. It is too early to draw firm conclusions but the indications are that the booster cushion has made more convenient the wearing of belts by children so that the usage rate would have increased even without a law. Knowledge of the existence of a wearing law has, in any case, been found from surveys to be poor. There is then a case for more publicity about the law and about the means by which its intent may be met. It must however take into account the greater problems of younger children.

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APPENDIX A*

I. Introduction

Four body blocks manufactured to comply with the specification listed by Herbert and Lozzi (1976) and called TARU 9 (9 kg), TARU 14 (14 kg), TARU 19 (19 kg) and TARU 38 (38 kg), were used to evaluate five child restraints of the "chair-with-harness" type. All chairs on sale in New South Wales together with one under development were included.

II. Test Method.

Except for TARU 38 which was too large for every chair, each body block was placed individually in each child seat, and the harness where possible securely tightened according to the manufacturer's instructions. Body blocks were pressed into the seats as firmly as possible. Measurements were taken based on the system of dimensions depicted in Figure A1.

III. Test Results.

The results are provided in tabular form as Table AI and refer to twenty test fittings involving five different child seats.

* After TARU Report No. SR77/235, 7th February 1978.

IV. Findings.

1. It can be seen from Table A1 that the TARU 19 body block could be fitted partially into every one of the 5 seats, indicating that they were all nearly wide enough for 98 per cent of children of the rated 19 kg mass. It should be noted that the TARU body blocks are larger than those specified in AS 1754.

2. In some of the test fittings, dimension A was negative, indicating that downwards pressure on the shoulders would be more than the limit specified in AS 1754; this occurred only when the low harness position was selected, the high position always being satisfactory.

3. In all child restraints except No. 3, the chair back was not high enough (dimension B) to provide adequate head restraint in rear impacts for 98 percentile children of 19 kg mass. This dimension is not controlled in AS 1754.

4. The body block's shoulders could not always be pushed right back into the chairs. Lack of width (dimension C) was only marginal and applied only to 98 percentile 19 kg mass.

5. Width available for buttocks (dimension D) was adequate in every case except child restraint No. 2 where it was slightly too narrow for 98 percentile, 19 kg mass.

6. Chair depth (dimension E) was rarely adequate for 100 percent of the buttock-to-popliteal length. In car seat design, 60 percent is usually catered for. As shown in Table 1, restraints 2, 3 and 4 easily complied, 1 almost complied whereas 5 failed for 19 kg.

TABLE A1

Child restraint ref No. and make	Body blocks	Selected shoulder strap position	Excess (+) or deficiency (-) in dimension (mm)				Dimension (mm)	
			A	B	C	D	E	X*
1. Safe-N-Sound KL and MK 7	TARU 9	Low	-26	+92	+54	+84	190	137
	TARU 14	Low	-67	+10	+36	+56	190	167
	TARU 14	High	+49	+10	+36	+56	190	167
	TARU 19	High	+ 5	-54	- 2	0	190	193
2. Not specified (under development)	TARU 9	Low	+23	+134	+64	+84	237	137
	TARU 14	Low	-26	+42	+20	+60	237	167
	TARU 14	High	+40	+42	+20	+60	237	167
	TARU 19	High	-12	-32	-20	-36	237	193
3. Repco RC 600	TARU 9	Low	+12	+156	+36	+68	278	137
	TARU 14	Low	-17	-82	0	+50	278	167
	TARU 14	High	+82	+82	0	+50	278	167
	TARU 19	High	+58	+26	-10	+24	278	193
4. Steelcraft C59	TARU 9	Low	-12	+90	+60	+84	201	137
	TARU 14	Low	-42	+15	+26	+66	201	167
	TARU 14	High	+56	+15	+26	+66	201	167
	TARU 19	High	+13	-42	0	+30	201	193
5. Britax B335/2	TARU 9	Low	-20	+85	+96	+96	173	137
	TARU 14	Low	-51	+14	+58	+58	173	167
	TARU 14	High	+42	+14	+58	+58	173	167
	TARU 19	High	+ 3	-45	+ 8	0	173	193

* Required 60% of b.p.l., (see text).

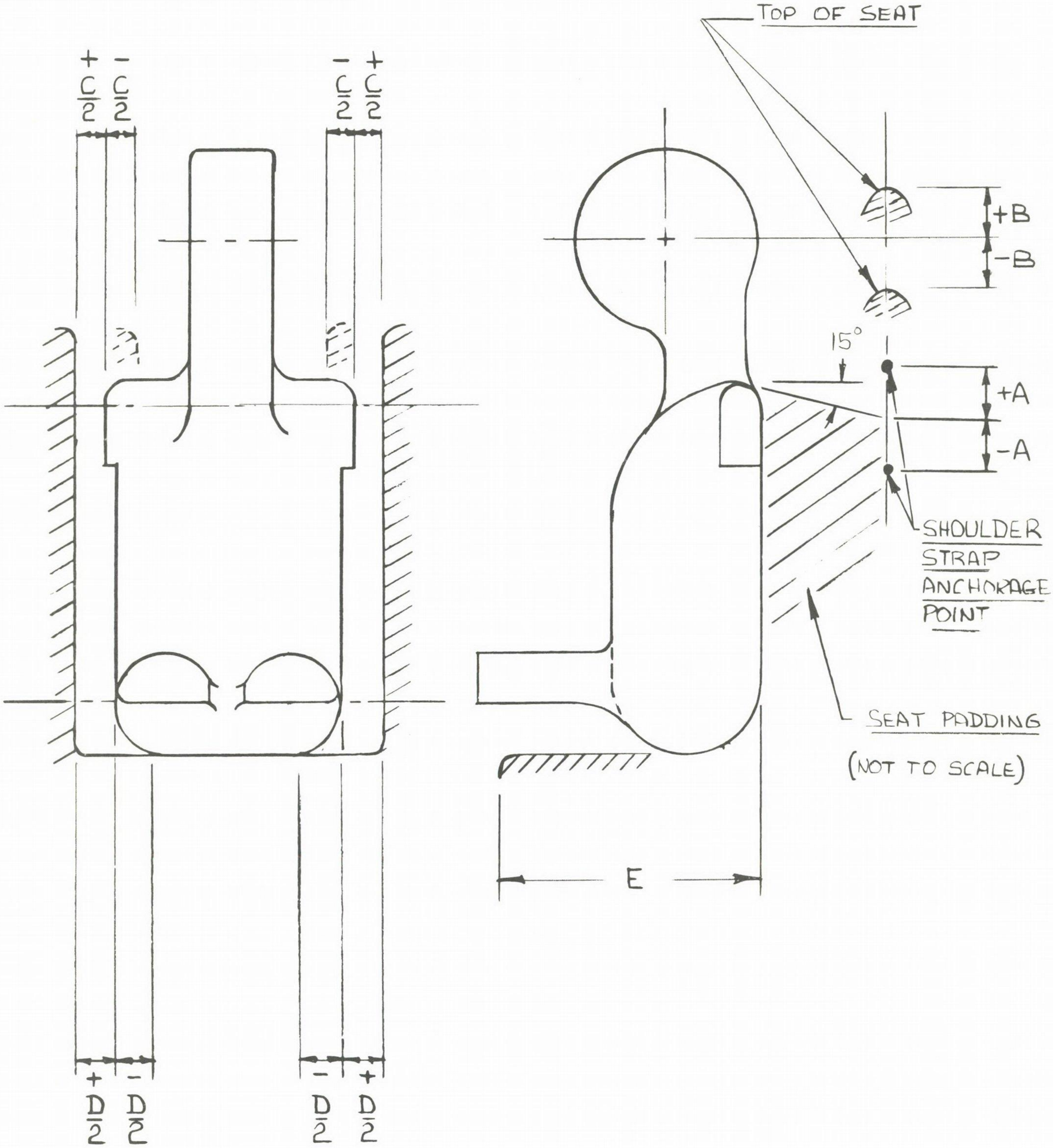


Figure A1: TARU body block dimensions.

APPENDIX B

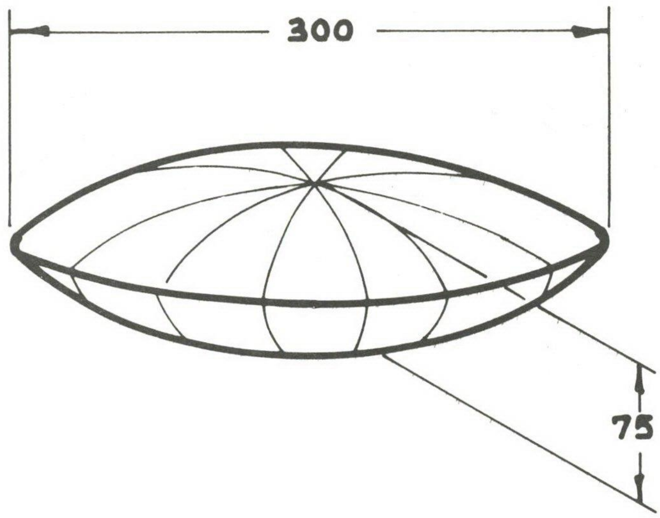
Results of preliminary dynamic tests on booster cushions

Up to the date of this report, the Traffic Accident Research Unit had not carried out testing on any booster cushion sufficient to establish compliance with Amendment No. 2 of AS 1754. Indeed, all of our tests on booster cushions were conducted prior to the preparation of that amendment, and so could not test compliance. The tests were conducted with a view to establishing the validity of the concept of booster cushions, not with proving the satisfactory nature of any particular cushion.

Test results will be found (in chronological order) in the following data sheets for all booster cushions tested namely:

Dates tested	Specimen	Manufacturer
27.6.73	MTA 903	Unknown
28.6.73 and 29.6.73	MTA 902	Unknown
20.12.73 and 26.1.77	MTA 704	Micklem
26.1.77	MTA 919	TARU
25.2.77	MTA 637	TARU
20.4.77	MTA 633	Julianne
6.10.77	MTA 911	Julianne
6.10.77	MTA 905	GTA
26.1.78	MTA 907	Playground
28.2.78 (see 25.2.77)	MTA 637	TARU
28.2.78	MTA 638	TARU

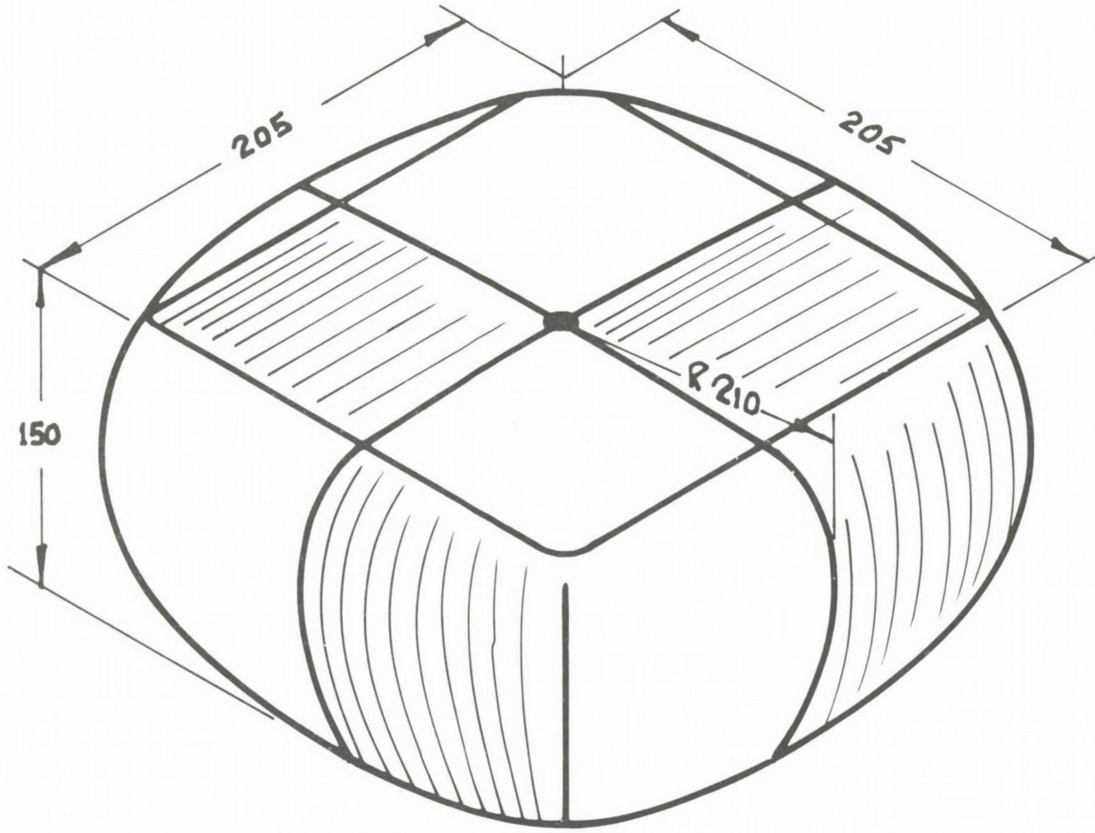
In all, twenty tests (2 side and 18 front impacts) were carried out in this developmental programme. In every instance the dummy was retained in the lap-sash seat belt or child's harness, as the case may be (see sheets for details). Cushions that were unrestrained (and therefore would not comply with AS 1754) sometimes were ejected, but all devices of the general type covered by AS 1754 performed well, except for the MT 704 (the early Micklem restrained cushion) which allowed submarining of the dummy because restraining straps were located ineffectively at the rear.



TEST SPECIMEN	:	MTA 903
MANUFACTURER	:	Unknown
DATE TESTED	:	27-6-73
MATERIAL	:	Crumbed Plastic Foam
DENSITY	:	Unknown
COVER	:	Acrylic Fabric

SLED PULSE		Run 1	Run 2
PEAK SLED DECELERATION.g.	:	17.3	17.9
SLED VELOCITY CHANGE.km/h.	:	39.0	39.0
IMPACT TYPE	:	Frontal	Frontal
DUMMY	:	Sierra Toddler	Sierra Toddler
RESTRAINT SYSTEM	:	Child Harness tightly adjusted	Child Harness with 75mm slack in each adjuster

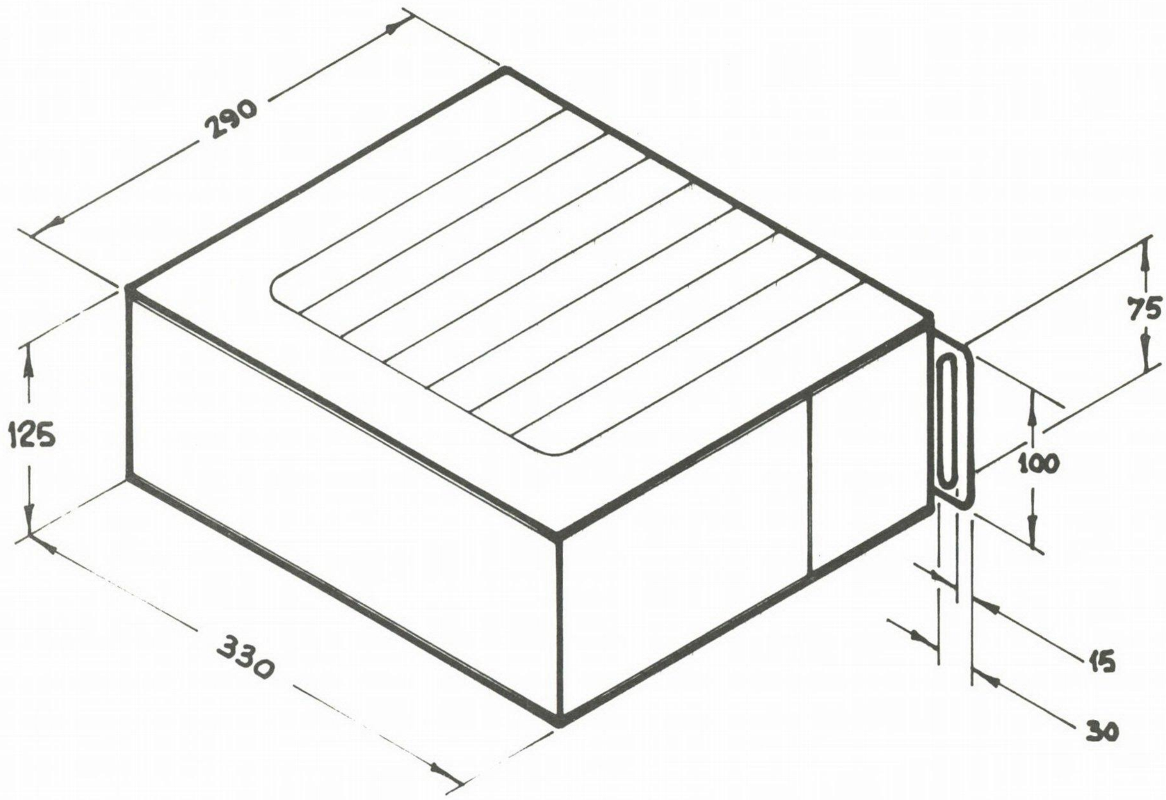
COMMENTS: In both tests the dummy was restrained, with no cushion ejection being recorded.



TEST SPECIMEN	:	MTA 902
MANUFACTURER	:	Unknown
DATE TESTED	:	28-6-73 and 29-6-73
MATERIAL	:	Timber Shavings
DENSITY	:	Unknown
COVER	:	Vinyl

SLED PULSE		Run 1	Run 2
PEAK SLED DECELERATION.g.	:	17.7	18.0
SLED VELOCITY CHANGE.km/h.	:	39.2	39.2
IMPACT TYPE	:	Frontal	Frontal
DUMMY	:	Sierra Toddler	Sierra Toddler
RESTRAINT SYSTEM	:	Child Harness tightly adjusted	Child harness with 75mm slack in each adjuster

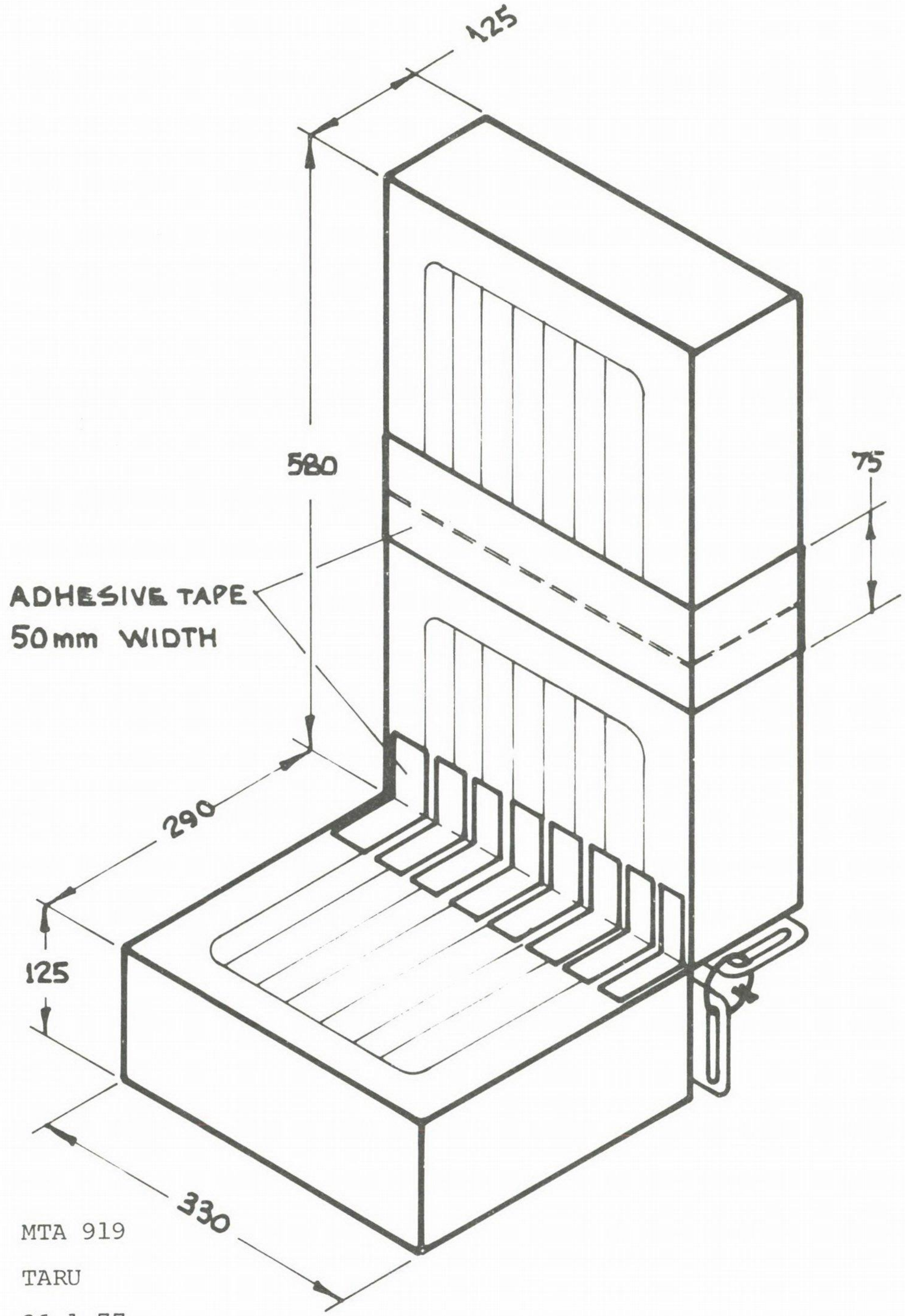
COMMENTS: The dummy was restrained in both tests, but severe submarining occurred in both instances. In the second test the cushion ejected from beneath the dummy.



TEST SPECIMEN	:	MT 704
MANUFACTURER	:	Howard Micklem Pty. Ltd.,
DATE TESTED	:	20-12-73 and 26-1-77
MATERIAL	:	Foam Plastic
DENSITY	:	Approximately 26kg/m^3
COVER	:	Vinyl

SLED PULSE		Run 1	Run 2	Run 3
PEAK SLED DECELERATION.g.	:	17.5	17.8	14.5
SLED VELOCITY CHANGE.km/h.	:	40.3	40.1	38.8
IMPACT TYPE	:	Frontal	Frontal	Frontal
DUMMY	:	Sierra Toddler	Sierra Toddler	Sierra Sammy
RESTRAINT SYSTEM	:	Child Harness	Adult Lap Belt	Adult Lap/Sash Belt

COMMENTS: The dummy was restrained in all three tests, but in the first test the dummy submarined badly.



TEST SPECIMEN : MTA 919

MANUFACTURER : TARU

DATE TESTED : 26-1-77

MATERIAL : Foam Plastic

DENSITY : Approximately 26kg/m^3

SLED PULSE

PEAK SLED DECELERATION.g. : 25.8

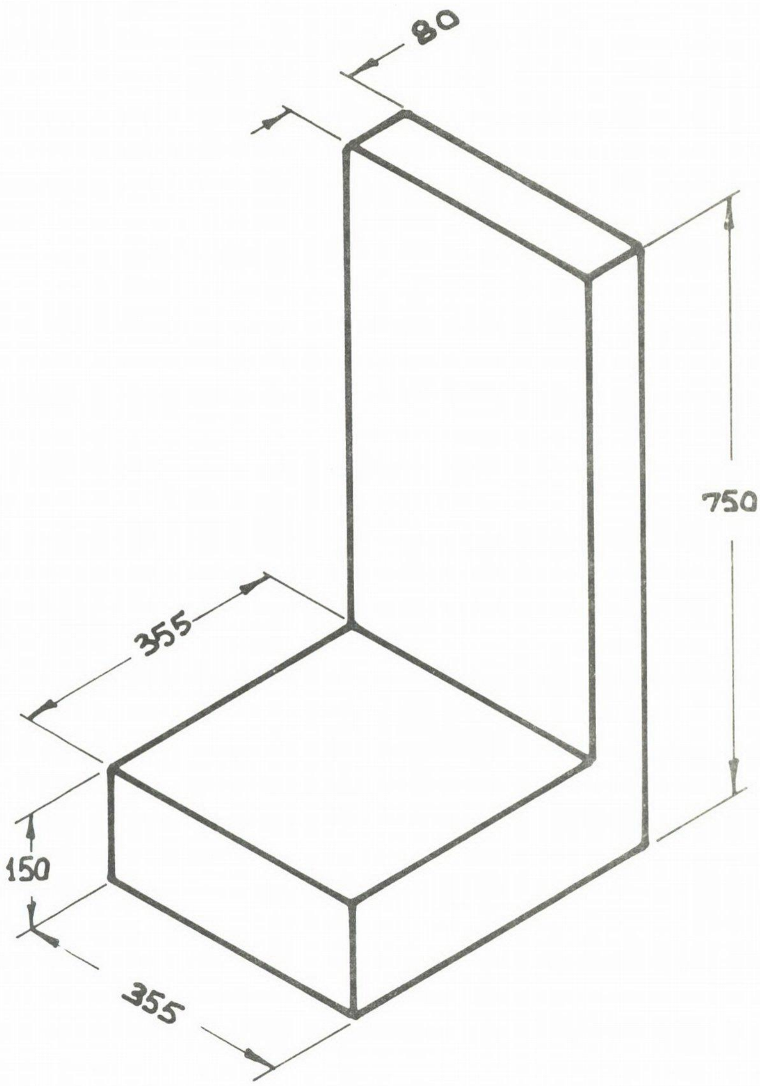
SLED VELOCITY CHANGE.km/h. : 58.4

IMPACT TYPE : Frontal

DUMMY : Sierra Sammy

RESTRAINT SYSTEM : Adult Lap/Sash Belt

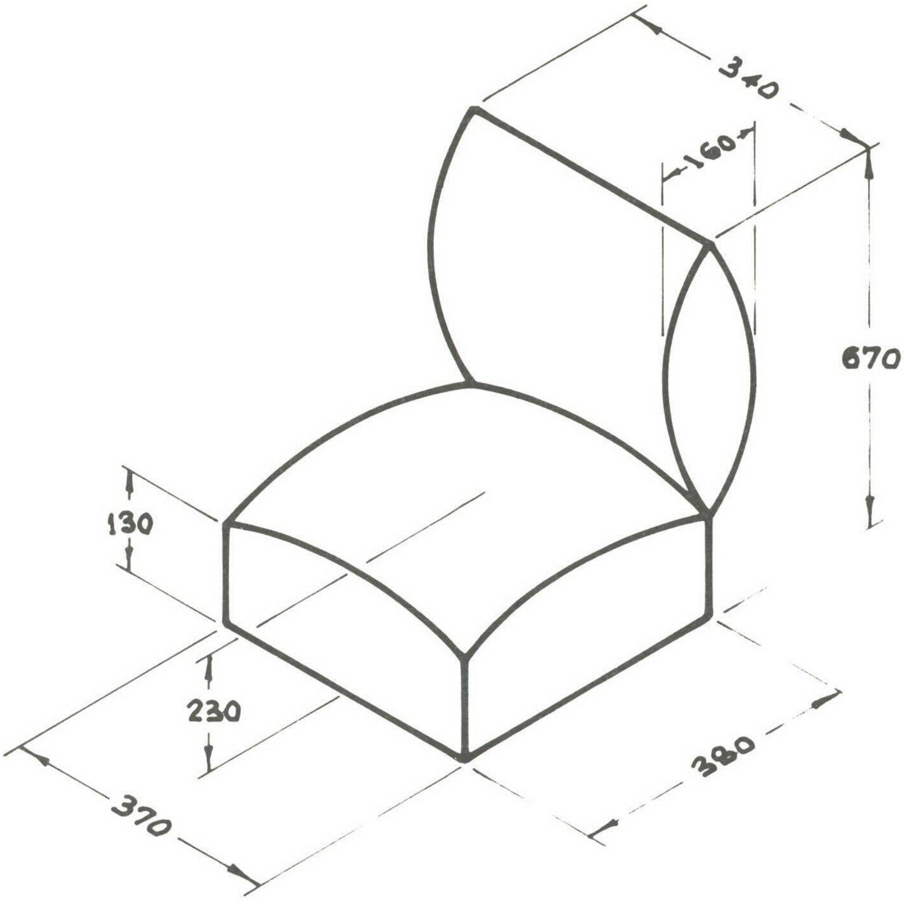
COMMENTS: The dummy was restrained without any evidence of submarining or cushion ejection.



TEST SPECIMEN	:	MTA 637
MANUFACTURER	:	TARU
DATE TESTED	:	25-2-77 and 28-2-77
MATERIAL	:	Foam Plastic
DENSITY	:	20kg/m^3
COVER	:	Cotton Fabric

SLED PULSE		Run 1	Run 2	Run 3
PEAK SLED DECELERATION.g.	:	22.2	22.2	15.5
SLED VELOCITY CHANGE.km/h	:	51.0	51.0	32.1
IMPACT TYPE	:	Frontal	Frontal	Side
DUMMY	:	Sierra Sammy	Sierra Toddler	Sierra Sammy
RESTRAINT SYSTEM	:	Adult Lap/Sash Belt	Adult Lap/Sash Belt	Adult Lap/Sash Belt

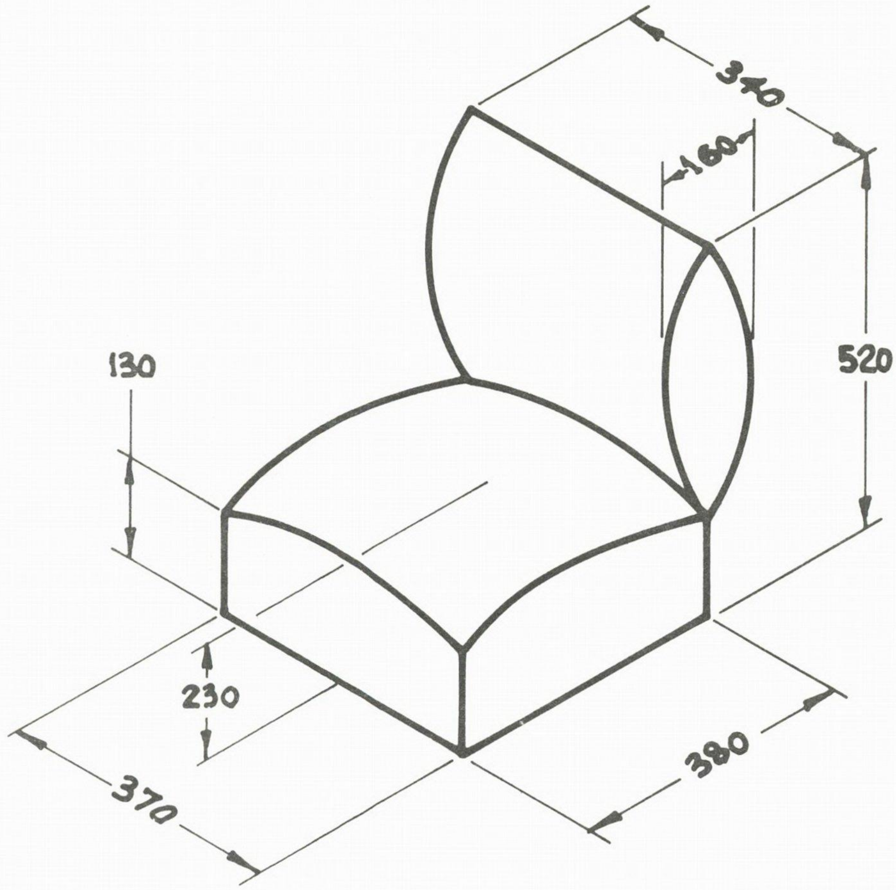
COMMENTS: The dummy was restrained in all tests with some submarining occurring in the frontal impact involving Sierra Toddler. There was no evidence of cushion ejection in any of the tests.



TEST SPECIMEN	:	MTA 911
MANUFACTURER	:	Julianne Soft Toys
DATE TESTED	:	6-10-77
MATERIAL	:	Crumbed Foam Plastic and Polystyrene Beads
DENSITY	:	Unknown
COVER	:	Acrylic Fabric

SLED PULSE		Run 1	Run 2
PEAK SLED DECELERATION.g.	:	19.9	18.8
SLED VELOCITY CHANGE.km/h.	:	47.6	46.8
IMPACT TYPE	:	Frontal	Frontal
DUMMY	:	Sierra Toddler	Sierra Sammy
RESTRAINT SYSTEM	:	Adult Lap/Sash Belt	Adult Lap/Sash Belt

COMMENTS: The dummy was restrained in both tests with some submarining occurring in the test involving Sierra Toddler. There was no evidence of cushion ejection in either test.

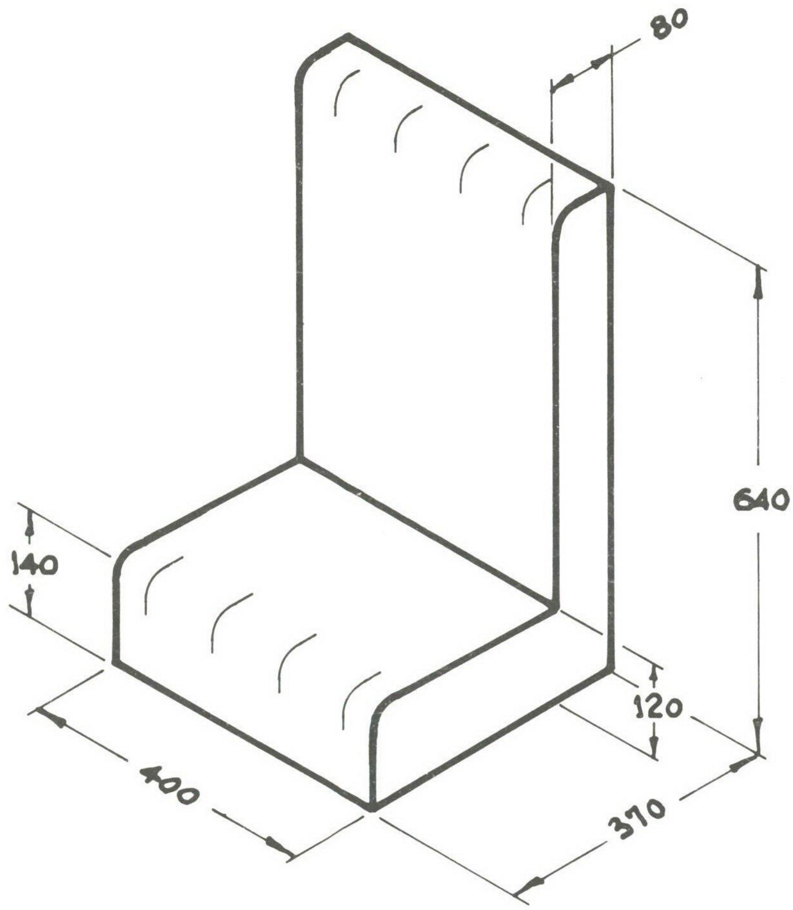


TEST SPECIMEN	:	MTA 683
MANUFACTURER	:	Julianne Soft Toys
DATE TESTED	:	20-4-77
MATERIAL	:	Crumbed Foam Plastic and Polystyrene Beads
DENSITY	:	Unknown
COVER	:	Acrylic Fabric

SLED PULSE

PEAK SLED DECELERATION.g.	:	20.5
SLED VELOCITY CHANGE.km/h.	:	49.7
IMPACT TYPE	:	Frontal
DUMMY	:	Sierra Sammy
RESTRAINT SYSTEM	:	Adult Lap/Sash Belt

COMMENTS: The dummy was restrained with some little submarining. There was no evidence of the cushion ejecting from beneath the dummy.

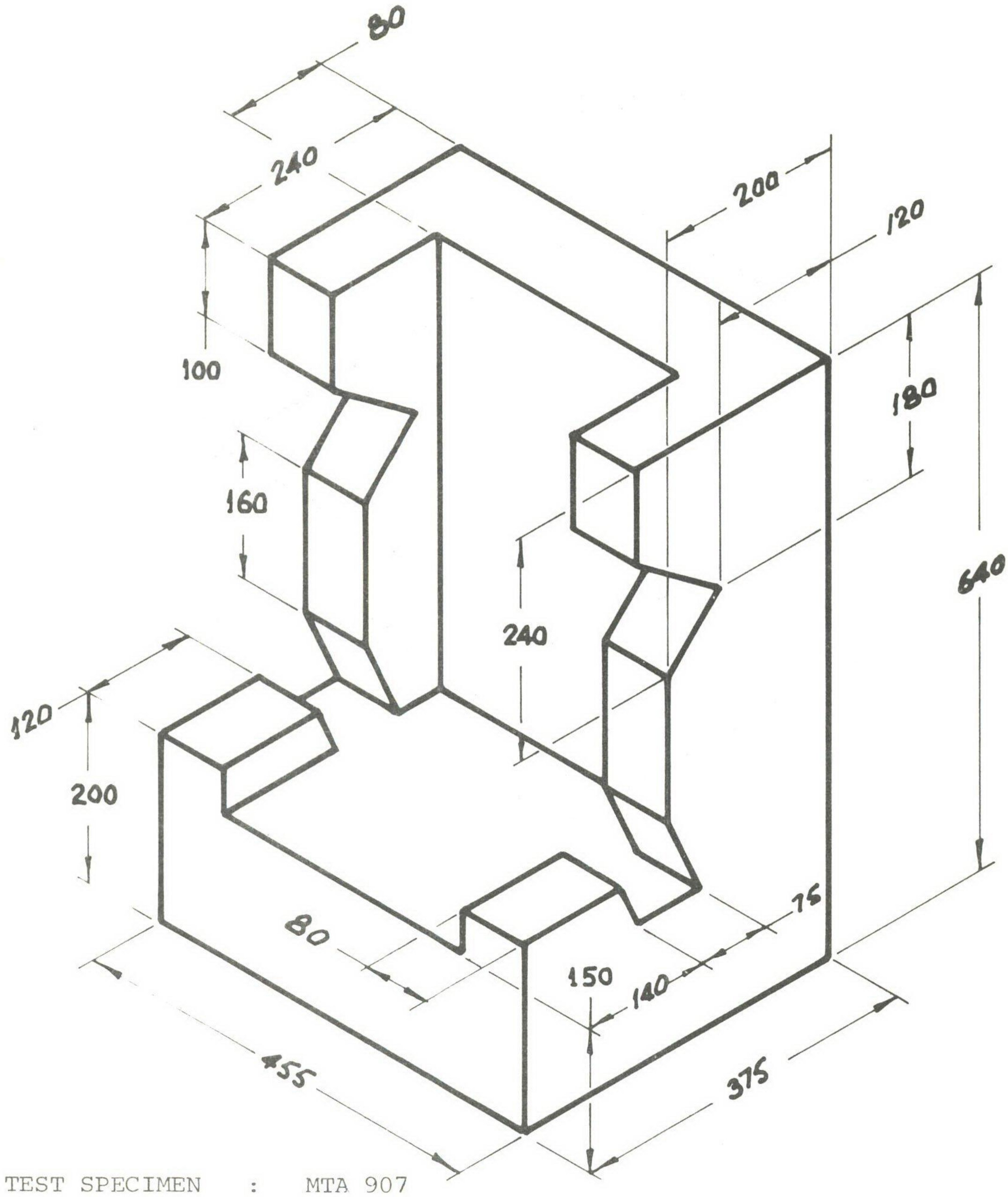


TEST SPECIMEN	:	MTA 905
MANUFACTURER	:	GTA Products*
DATE TESTED	:	6-10-77
MATERIAL	:	Foam Plastic
DENSITY	:	Approximately 26kg/m^3
COVER	:	Terry Towelling

* Similar to devices manufactured by Vita Foam Australia Pty.Ltd., J.S. Finer Furniture Pty. Ltd., Mermax Pty. Ltd., Olympic Seatcover Co.(Syd.) Pty. Ltd. and E.J. Sperling (Australia) Pty. Ltd.

SLED PULSE		Run 1	Run 2
PEAK SLED DECELERATION.g.	:	18.6	18.4
SLED VELOCITY CHANGE.km/h.	:	46.2	45.8
IMPACT TYPE	:	Frontal	Frontal
DUMMY	:	Sierra Toddler	TARU Simon
RESTRAINT SYSTEM	:	Adult Lap/Sash Belt	Adult Lap/Sash Belt

COMMENTS: The dummy was restrained in both tests with some submarining occurring in the test involving Sierra Toddler. There was no evidence of cushion ejection in either test.

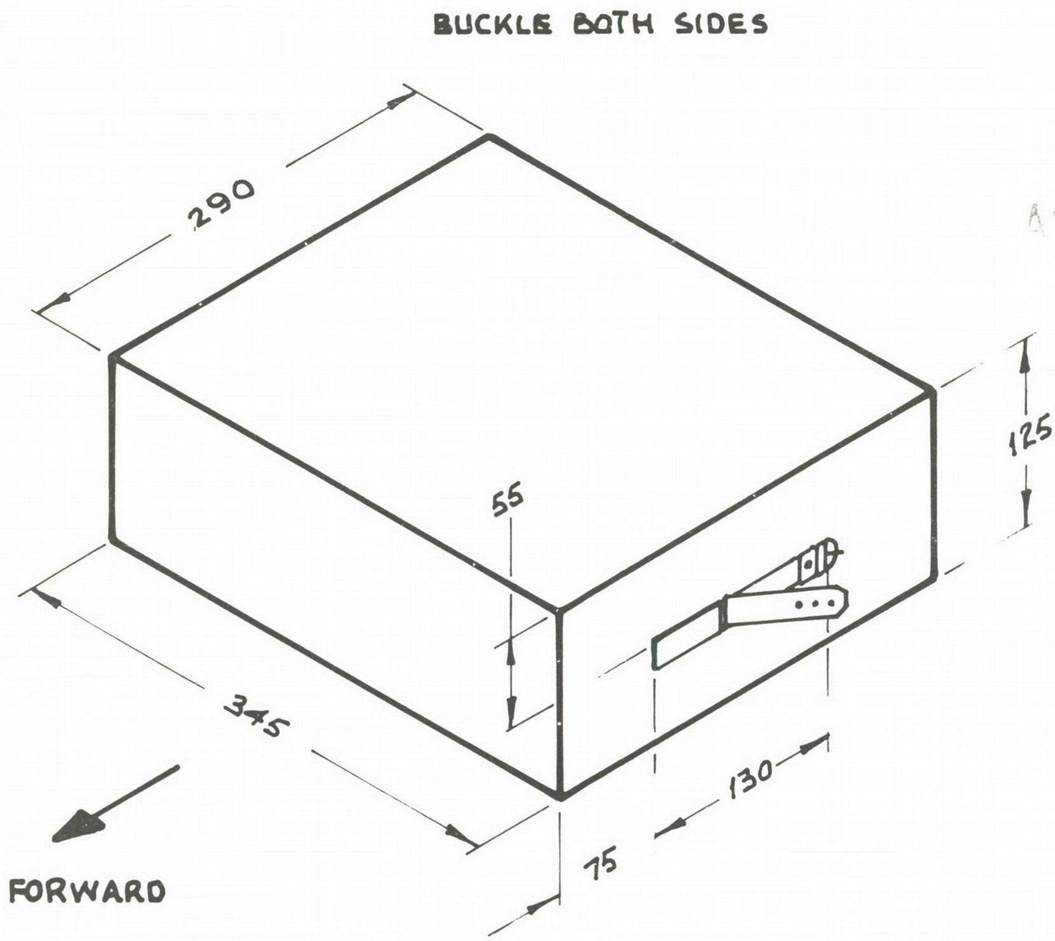


TEST SPECIMEN	:	MTA 907
MANUFACTURER	:	Playground Supplies Pty. Ltd.
DATE TESTED	:	26-1-78
MATERIAL	:	Foam Plastic
DENSITY	:	Approximately 28kg/m^3
COVER	:	Acrylic Fabric

SLED PULSE

PEAK SLED DECELERATION.g.	:	Not Recorded - approximately 20
SLED VELOCITY CHANGE.km/h.	:	Not Recorded - approximately 50
IMPACT TYPE	:	Frontal
DUMMY	:	Sierra Toddler
RESTRAINT SYSTEM	:	Adult Lap/Sash Belt

COMMENTS: The dummy was restrained with no evidence of submarining or cushion ejection.



TEST SPECIMEN	:	MTA 638
MANUFACTURER	:	TARU
DATE TESTED	:	28-2-77
MATERIAL	:	Foam Plastic
DENSITY	:	27kg/m^3
COVER	:	Cotton Fabric

SLED PULSE		Run 1	Run 2	Run 3
PEAK SLED DECELERATION.g.	:	20.9	20.8	15.5
SLED VELOCITY CHANGE.km/h.	:	51.7	51.6	32.1
IMPACT TYPE	:	Frontal	Frontal	Side
DUMMY	:	Sierra Toddler	Sierra Sammy	Sierra Sammy
RESTRAINT SYSTEM	:	Adult Lap/Sash Belt	Adult Lap/Sash Belt	Adult Lap/Sash Belt

COMMENTS: The dummy was restrained in all tests with some submarining occurring in the frontal impact involving Sierra Sammy. There was no evidence of the cushion ejecting from beneath the dummies, despite the breakage of one of the anchorage straps in the side impact.