TP 14093E

DROP TESTS OF SELECTED STEEL DRUMS

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Environmental Simulation Lab

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By
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16. Abstract

This report details the work carried out to determine the performance level of 210 L steel drums by measuring average height at failure in drop tests. This was a follow-on study to one carried out in 1985 by Transport Canada (TP 7423E) and will help in evaluating the effectiveness of quality control measures implemented as a result of that earlier study.

A sample of 50 drums was obtained by an independent third party from each of six manufacturers located in various countries. In each sample, 20 drums were subjected to drop tests in each of two orientations, using a Bruceton Staircase method to determine the average failure height. The other 10 drums in each sample were used for preliminary tests to determine the appropriate starting test level.

The study found that most drums were well within the parameters established for shipment of dangerous goods. Drums tested in the "eight o'clock" orientation had average failure heights lower than those tested in the "six o'clock" orientation. Further work is recommended to evaluate, in a similar manner, other common types of packages used for the transportation of dangerous goods.

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16. Résumé

Le rapport décrit en détail les travaux réalisés pour évaluer la tenue de fûts en acier d'une contenance de 210 L en mesurant la hauteur moyenne des chutes causant une défaillance du fût. La recherche est le prolongement d'une étude menée en 1985 par Transports Canada (TP 7423E) et permettra d'évaluer l'efficacité des procédures de contrôle de la qualité adoptées par suite des conclusions de cette étude antérieure.

Une tierce partie indépendante a obtenu un échantillon de 50 fûts de chacun des six fabricants dans divers pays. Sur chaque échantillon de fûts, 20 ont été soumis à chacune des épreuves selon l'une ou l'autre des deux positions de chute sélectionnées. Les résultats des essais étaient colligés selon la méthode de haut en bas ou méthode de l'escalier de Bruceton. Après l'essai, on établissait la hauteur moyenne de chute ayant provoqué une défaillance. Les 10 autres fûts de chaque échantillon ont été utilisés pour les essais préliminaires, qui visaient à déterminer la hauteur de chute initiale.

Selon les résultats de l'étude, la plupart des fûts avaient une tenue bien en deçà des limites établies pour leur usage en transport de marchandises dangereuses. Avec les fûts soumis aux essais en position huit heures, la hauteur moyenne de chute causant défaillance était inférieure à celle constatée pour les essais en position six heures. Il est recommandé de poursuivre les recherches et d'évaluer de manière similaire les autres types d'emballages couramment utilisés pour transporter des marchandises dangereuses.

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EXECUTIVE SUMMARY

This project featured a series of drop tests carried out to evaluate the performance of selected steel drums used for the transport of dangerous goods. A previous study was done by Transport Canada in 1985 (TP 7423E) covering many types of packaging and several types of test. As a result of that study, Transport Canada implemented quality control provisions to address some deficiencies found in 210 L steel drums used in the study. One reason for the current study was to evaluate how well these provisions were working. Secondary objectives were to assess the merits of two different drop orientations, and to evaluate the differences in the two most common types of closures.

Sample sets of 50 drums were purchased from two manufacturers in Canada, two manufacturers in the United States, and one each in the United Kingdom and Germany. Two orientations were tested. In the six o'clock orientation, the drum is dropped diagonally on its top circumferential corner so that the point closest to the large closure strikes the target. The eight o'clock orientation is similar except that the drum is rotated so that the large closure is in the centre of the "crush pattern" that forms when the drum hits the target. Half of the drums tested used the traditional "Riecke" style closure, and the remainder used a newer "Tri-sure" style closure.

Up to 10 of each sample set were used for preliminary testing to determine the starting drop height in the six o'clock and eight o'clock orientations for that particular set. Once the most likely lowest failure height was established, 20 drums were tested in the six o'clock orientation. The average size of the crush pattern was then measured to determine the true angle to be used for the eight o'clock orientation and the remaining 20 were tested in that orientation.

An Up and Down *Bruceton Staircase* procedure was used to mathematically establish a mean failure height and standard deviation for each set of drums. The drums were filled with water to 98 percent of their maximum capacity and then subjected to the drop test as required for transport of dangerous goods. After each drum was tested it was evaluated to see whether there were leaks (failure). If there were, then the next drum was tested at a 0.2 m lower height. If not, the next was dropped from a 0.2 m higher height. This was continued until all 20 drums had been tested in each orientation, after which the data was analyzed to arrive at an estimate for the mean and standard deviation for each series.

The study found that there was a wide variation in the failure heights between manufacturers, but good consistency between drums from the same manufacturer. Most of the drums tested were more than capable of surviving the drop test required for transport of dangerous goods. One manufacturer had some failures at a height below the required test height, but most of the failures were above that level. Only one set of drums consistently failed at heights well below the required test heights, in fact failing to meet the required test height even once.

Overall, most failures occurred by the unrolling of the chime or rupture of the metal, either at the chime or in the sharpest folds of the "crush pattern". A smaller number of failures occurred at the large closure, mainly during eight o'clock tests and mainly on higher drops.

There is definitely a difference in performance between the two test orientations. The average failure drop height for the eight o'clock orientation was consistently below that of the six o'clock orientation, and the mode of failure was more likely to be by leaking at the closure during the eight o'clock tests.

There was less distinction between the two types of closure. Both types failed a similar number of times and during tests from similar heights. There was not enough difference to justify specifying one closure over another, especially since it was noted that either closure type tended to fail at heights well above the requirements.

Similar studies for other types of package such as plastic drums, 20 L pails and combination packages are recommended. It is also suggested that hydrostatic pressure tests on steel drums be conducted in a similar manner, with the possibility of seeking voluntary participation as a way to reduce costs by eliminating sample acquisition costs.

SOMMAIRE

La recherche comportait une série d'essais de chute réalisés pour évaluer la performance de fûts en acier sélectionnés et destinés au transport de marchandises dangereuses. Une étude antérieure avait été menée par Transports Canada en 1985 (TP 7423E); cette étude couvrait plusieurs types d'emballages et d'épreuves. Par suite des résultats de cette étude, Transports Canada a mis en place des procédures de contrôle de la qualité pour tenir compte de certaines défectuosités décelées chez les fûts en acier de 210 L utilisés dans l'étude. L'étude était entre autres motivée par le souci d'efficacité de ces procédures. Les objectifs secondaires de l'étude étaient d'évaluer les avantages des deux positions de chute et d'examiner les différences entre les deux types de fermetures les plus couramment montées sur ces fûts.

Des ensembles d'échantillons de 50 fûts ont été achetés de deux fabricants du Canada, de deux fabricants des États-Unis, d'un fabricant du Royaume-Uni et d'un en Allemagne. Les essais de chute ont été réalisés selon une des deux orientations sélectionnées, six heures ou huit heures. En position six heures, le fût est lâché sur son bord circonférentiel supérieur de sorte que son point le plus près de la grande fermeture frappe la cible. L'essai en position huit heures est similaire, sauf que l'on fait subir une rotation au fût de sorte que sa grande fermeture coïncide avec le centre de la zone de déformation résultant de l'impact sur la cible. La moitié des fûts testés étaient équipés du système de fermeture classique de type «Riecke»; les autres étaient munis du système «Tri-sure», plus récent.

Jusqu'à 10 fûts de chaque ensemble d'échantillons ont servi aux essais préliminaires pour déterminer la hauteur de chute initiale en positions six heures et huit heures pour l'ensemble. Après qu'on ait établi la hauteur minimale la plus probable de défaillance, 20 fûts ont été mis à l'essai en position six heures. Les chercheurs ont ensuite mesuré les dimensions moyennes des zones de déformation pour déterminer l'angle exact à donner aux fûts en position huit heures utilisée pour les 20 fûts restants.

On a employé la méthode de haut en bas ou méthode de l'escalier de Bruceton pour établir mathématiquement une hauteur moyenne de défaillance et un écart type pour chaque ensemble de fûts. Les fûts ont été remplis d'eau à 98 p. cent de leur capacité, puis soumis à l'essai de chute requis pour l'usage de transport de marchandises dangereuses. Après essai, chaque fût à été contrôlé pour la présence de fuites, constituant une défaillance. Le cas échéant, le fût suivant était lâché à une hauteur inférieure de 0,2 m. Si aucune fuite n'était décelée, le suivant était lâché à 0,2 m plus haut. Les essais se sont poursuivis ainsi jusqu'à concurrence des 20 fûts, à chacune des deux orientations. Une analyse des données a présenté un écart moyen et un écart type pour chaque série d'essais.

Les chercheurs ont constaté une forte variation des hauteurs de défaillance observées entre les produits des différents fabricants, mais également une bonne uniformité entre les fûts provenant du même fabricant. La plupart des fûts éprouvés ont pu résister très facilement à l'essai de chute requis pour le transport de marchandises dangereuses. Chez les fûts d'un même fabricant, des chutes avec défaillance se sont produites à une hauteur inférieure au seuil requis, mais dans la plupart des cas la hauteur était plus élevée. Seulement un ensemble de fûts ont régulièrement failli à des hauteurs bien au-dessous de la hauteur requise; en fait, ils n'ont pas réussi une seule fois à la hauteur requise.

Dans l'ensemble, la plupart des défaillances sont survenues par déroulage du rebord ou par rupture de la tôle, soit au rebord, soit aux plis les plus accentués de la zone de déformation. Un faible nombre de défaillances sont survenues au dispositif de fermeture obturant la grande

ouverture, principalement lors des essais en position huit heures et lors des chutes de grande hauteur.

La position ou l'orientation du fût durant l'essai influent clairement sur sa tenue au choc. La hauteur moyenne de chute causant défaillance pour la position huit heures était régulièrement au-dessous de la hauteur observée pour la position six heures. De plus, dans le cas des essais à la position huit heures, la fuite au droit du dispositif de fermeture était le mode de défaillance le plus fréquent.

La distinction entre les résultats obtenus selon le type de fermeture était moins marquée : le nombre de défaillances par type était similaire, tout comme les hauteurs de chute ayant causé ces défaillances. On n'a pas noté d'écart suffisant pour justifier l'un ou l'autre type de fermeture, particulièrement vu que les deux avaient tendance à faillir à une hauteur beaucoup plus grande que la limite requise.

Des études similaires sont recommandées sur d'autres types d'emballages, par exemple les fûts en matière plastique, les seaux de 20 L et les emballages combinés. Il est également proposé de soumettre de la même manière les fûts en acier à des épreuves hydrostatiques et de faire appel à la participation volontaire, entre autres pour réduire, voire éliminer, les coûts reliés à l'acquisition des ensembles d'échantillons.

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1. INTRODUCTION

This report describes a comprehensive performance evaluation of selected steel drums used for the transport of dangerous goods. A previous study [1] was done by Transport Canada in 1985 using larger sample sizes and covering many types of packaging, including 210 L steel drums. As a result of that study, Transport Canada implemented quality control provisions to address some deficiencies found in drums used in the study. One reason for the current study was to evaluate how well these provisions were working.

A total of 300 drums were purchased from manufacturers in Canada, the United States, the United Kingdom and Germany. Each sample set consisted of 50 drums, the first 10 of which were used for preliminary testing to determine the starting drop height in the six o'clock and eight o'clock orientations for that particular set. Twenty were used for the six o'clock drop tests and the remaining 20 for the eight o'clock drop tests.

The principal objective of this test sequence was to evaluate the performance of steel drums from North American and European suppliers. An Up and Down *Bruceton Staircase* procedure was used to mathematically establish a mean failure height and standard deviation for each set of drums.

Secondary objectives were to assess the merits of the two different drop orientations, and to evaluate the differences in the two most common types of closures. Some countries require testing in only the six o'clock orientation, while others require the eight o'clock orientation. The latter is more time consuming because six o'clock drops must be done first, to establish the correct angle for the eight o'clock drops.

Many European countries have begun using the "Tri-sure" style closures, and at least one North American manufacturer has begun to use them as well. The intention was to evaluate whether significant differences in performance are offered by this closure.

Throughout this report, drum manufacturers or closure types are referred to only by letter designation and not by name in order to maintain confidentiality when disseminating the report.

2. TEST PROCEDURE

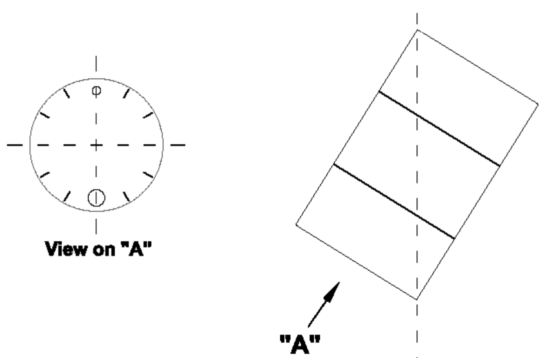
Drums were ordered through a third party supplier to ensure a random sample. They were ordered from two manufacturers chosen at random from those in Canada, two in the U.S. and one each from Germany and the U.K. A test plan was developed [2] and approved by the Transportation Development Centre. The test method was based on the National Standard of Canada [3] that deals with packaging for the transport of dangerous goods, and the 1985 study [1].

All drop tests were performed at the Innovacorp ESL facility at 101 Research Drive, in Dartmouth, Nova Scotia. Data analysis was carried out using the Bruceton Staircase method as described in Natrella [4]. Drop testing was carried out indoors with the exception of two drum sets that had to be tested outdoors because they required drop heights higher than the interior space of the building would allow. The floor in the ESL building is 0.12 m thick over very well compacted fill. The outdoor drops utilized a concrete pad measuring approximately 3 m by 3 m by 0.2 m thick.

2.1 Drop Orientations

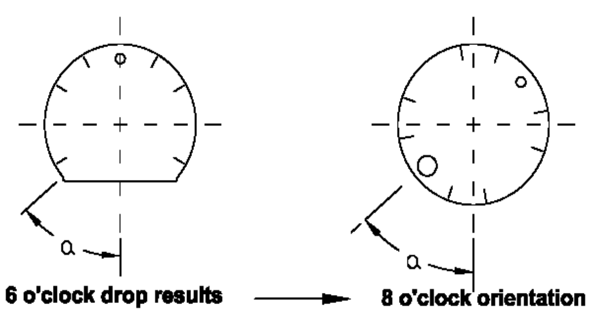
Two orientations were tested for each drum set, six o'clock and eight o'clock. The six o'clock orientation is so named because, when the drum is lying on its side, the large closure is positioned at the bottom, or six o'clock position. The bottom of the drum is then raised so that a vertical line passes through the two opposite edges and the centre of gravity. When the drum is released from this position, it impacts on the edge of the chime directly below the large closure. At the end of the impact, the drum usually has a new flat face running at an angle to the top and sides, with the large closure near the centre of the flat. See Figure 1.

Figure 1: Six O'clock Drop Orientation



The eight o'clock orientation is similar except that when the drum is lying on its side, the drum is rolled so that the large closure will be offset from the six o'clock position. See Figure 2. This orientation is intended to be the worst-case scenario, since it is intended that following the impact, the edge of the distortion pattern will pass through the large closure. The name is somewhat of a misnomer then, because the actual orientation required to accomplish this may be more or less than eight o'clock, depending on how large the distortion pattern is. For this reason it is necessary to first do a few six o'clock drops to establish the correct angle to ensure the distortion pattern edge coincides with the closure.

Figure 2: Eight O'clock Drop Orientation



In this test program, all 20 six o'clock drops were carried out for a set of drums first. Then the size of the pattern was determined and the true angle established for the so-called "eight o'clock" orientation. Twenty drums were then tested in that orientation.

2.2 *Drum Specifications*

As stated in the introduction, 50 drums were ordered from each manufacturer with the following specifications:

- Certified and marked UN 1A1/Y/100
- Wall thickness of 1.2/0.9/1.2 mm (top, body, bottom)
- Triple seam chimes
- Tri-sure 4s non-vented closures for European drums
- Reike style closures for North American drums

However, some manufacturers were unwilling to set up a separate run, given the small size of the order, and most drums arrived with one or more specifications at a higher level than was requested. Therefore, when assessing the compliance to the standard it is important to do so with a view to the actual specifications, and not those listed above. Table 1 lists the "as received" specifications of the drums.

2.2.1 Drum Closures: Closure Type P vs. Closure Type Q

The closures on the drums were of two types: Type P and Type Q. Each closure system comprises a male threaded plug and a synthetic rubber gasket that twist into a threaded flange pressed into the drumhead.

The majority of Type P closures have three evenly distributed drain holes across the threads in the drumhead. However, the drain holes were only present on Type P closures of Set C and Set D drums. Although the closures of Set A were identical in all other ways to other Type P closures, they did not have the vent holes. The Type Q closures have non-vented flanges.

Table 1: "As received" specifications

Manufacturer	A	B	C	D	E	F
Grade	Y/1.8	X**	Y /1.8	X /1.5	X /1.8	X /1.8
Pressure Rating	300	250	300	300	300	350
Thickness, t/b/b	1.2/0.9/1.2	1.0/1.0/1.0	1.2/0.9/1.2	1.2/0.9/1.2	1.2/0.9/1.2	1.2/1.0/1.2
Closure *	P	Q	P	P	Q	Q

Note:

* Closure types are defined in the legend at the start of Appendix A

** Set B did not come with a density specification, indicating it is for liquids with specific gravity up to 1.2.

2.3 Specimen Preparation

Each set of drums was labeled with a prefix, indicating the set the drum belonged to, along with a number (e.g., A1, A2, A3 … A50).

The tare and 100% capacity masses were established for the drums. A drum was filled with water until the meniscus of the water rose above the opening to obtain the 100% mass. Two percent of the total mass of the water was then subtracted to obtain the 98% fill-mass of the drum.

All drums were filled with water and allowed to settle at ambient temperature. All closures were manually tightened.

2.4 Drop Testing

Two sets of drop tests were performed on each sample set of drums. Twenty drums were dropped in the six o'clock configuration and 20 were dropped in the eight o'clock configuration. The remaining 10 drums was used for preliminary drops to determine starting drop heights for the six o'clock and eight o'clock drops. A pair of grips, a sling and a quick release latch were used to lift and drop the drums. The quick release latch was actuated with the quick jerk of a rope to minimize any rotation on the drum upon release. The impacting surface used for all drops was concrete. The height was measured using a surveyor's telescoping aluminum rod. Photos of the test setup and methods are shown in photos 1 to 6, and 9 and 10 in Appendix A.

The starting drop height was determined by establishing the minimum failure height for a drum in a particular set. The preliminary drops to determine this height were started at 1.2 m in accordance with C.T.C. (D.O.T.) 17E requirements and UN recommendations, and increments of 0.2 m were used to quickly determine a potential failure height.

Once the minimum failure height was established (for each drop orientation), it was used as the starting height for the corresponding set of 20 drums. The Bruceton Staircase approach was then used to increase/decrease the drop height by 0.2 m, depending on whether the previous drop was a pass or failure.

Free flowing drops of water from the body of the drum within five minutes after impact represented a failure. A splash of water upon impact was permitted, as long as it was not followed by a continuous flow. A hole was drilled in the drum to relieve any pressure differential after the drop, allowing for leaks to be exposed and evaluated more consistently.

The preliminary drops were not included in the calculation of mean and standard deviation, because the preliminary drop heights were varied more for some drum sets than others, and more preliminary drops were required for some sets compared to others. Where possible, at least one sample from each set of drums was retained for future use if required.

The data for each drum set, along with the corresponding statistical analysis, is attached in Appendix B. The data used for the analysis ranged from the minimum pass/failure height to the maximum pass/failure height, depending on whether the number of failures for a particular set was greater or less than HALF of the total number of drops.

2.5 Drum Sections

At the request of Transport Canada, a small section was cut from one sample of each drum set. This was to verify the thickness and to view the construction of the chime. The thickness measurements shown in Table 1 were taken from the manufacturers' specifications, but confirmed by these measurements. Only the bottom thickness was measured, the assumption being made that the top would use the same thickness of steel as the bottom. Photos of the chime sections, taken at 9.5 x magnification are shown in Photos 81 to 86 in Appendix A.

3. DROP TEST OBSERVATIONS

Appendix A includes photos of a representative sample of each drum set, showing the most prevalent failure modes or any unusual observations. Appendix B contains detailed data, including calculations and plots for each set of drums.

All failures that occurred in all the drums were due to either closure leaks (rare) or cracks in the top or bottom chime where the deflection occurred. The rest of the drum remained intact and no fractures on the side seams, or ribs, were observed.

In general, most drums displayed a very common deflection pattern after dropping (i.e., a flat plane at an angle to the top and sides of the drum). (See Photo 32.) As the drop height increased, this plane was larger, and the folding of the metal more severe. In some cases, the folds became a sharp crease, and failure occurred by tearing at such creases. The top and bottom usually bulged out, causing some degree of unrolling of the chime, and often this unrolling of the chime was the cause of failure. In one set (Set E), the failures at the chime were due not so much to unrolling, but to fracture along the chime, often of considerable length.

In some cases, there was a secondary impact as the drum came down on its side following the initial impact on the corner. This would cause a flattening along that side, and sometimes slight bending of the drum on its axis (e.g., Photos 37, 60).

One set (Set B) consistently displayed quite a different deflection pattern, where the edge of the chime appeared to be “tucked in” rather than flattened (see Photo 19). This set also used the thinnest metal in the tops and bottoms of any set. It also was slightly taller than others, possibly causing more of a “kick-out” of the drum top on impact. These two factors combined probably explain the difference in deflection pattern.

There were instances where the drum turned or flipped over during a fall and fell in an unfavourable orientation. These falls were recorded as VOID, but documented nonetheless.

3.1 Drum Set A (Photos 7 to 17)

Drops in Set A reached heights of over 5 m before failure. Although there were more instances of failures in Set A than in any other set, the mean drop height was still calculated to be 5.01 m with a standard deviation of 0.64 m for the six o'clock drops, and 4.43 m with a standard deviation of 0.30 m for the eight o'clock drops. For significantly high six o'clock drops (5.0 m for example), damage to the gaskets was observed from the impact.

Out of all the failures, most closure leaks occurred during the eight o'clock drops. The majority of the chime failures occurred at the point of impact for six o'clock drops, and there were instances where the steel of the drum fractured upon crumpling, allowing leakage to occur.

3.2 Drum Set B (Photos 18 to 25)

Out of 50 drums dropped (including preliminary drops), none met the UN recommended height (1.8 m). All failures that occurred in Set B were due to cracks on the top chime. After impact, the chime would deflect and two opposite corners on the deflection would crack and cause a leak, sometimes more vigorous than others. In one case the bottom chime also split (see Photo 18), presumably from the sudden increase in pressure on impact. The closures did not leak for either the six o'clock or the eight o'clock drops.

The standard deviation was calculated at 0.79 m, with a mean of 0.74 m, for the six o'clock drops. For the eight o'clock drops, the mean was only 0.62 m with a standard deviation of 0.09 m. Neither the six o'clock nor the eight o'clock drops met the UN recommendations.

3.3 Drum Set C (Photos 26 to 34)

Of the few drums that leaked out of the six o'clock drops, one drum failed due to a leak at the closure; the remaining four failures were due to cracks on the deflection of the top chime upon impact. For the eight o'clock drops, however, five drums failed due to leaks from the closure, and only three failed due to cracks on the top chime.

The mean was calculated to be 3.50 m with a standard deviation of 0.74 m, for the six o'clock drops. For the eight o'clock drops, the mean and standard deviation were 3.15 m and 0.96 m, respectively. All drums from Set C exceeded the UN recommended drop height of 1.8 m.

3.4 Drum Set D (Photos 35 to 45)

Out of the six o'clock drops, only one closure failure occurred, and the remaining 12 failures were all associated with cracks on the chime opposite to each other, on the edges of the deflection pattern. The lowest failure was at 1.6 m for the six o'clock drops, and at 2.0 m for the eight o'clock drops, overall not satisfying the UN recommendations (2.25 m).

The mean and standard deviation for the six o'clock drops were calculated to be 1.84 m and 1.19 m, respectively, and 2.20 m and 0.67 m, respectively, for the eight o'clock drops.

3.5 Drum Set E (Photos 43 to 65)

All five failures for the six o'clock drops were due to cracks on the top chime. Significantly high drops resulted in catastrophic failures of the chime, resulting in rapid emptying of the contents of the drums upon impact. The failures were more varied on the eight o'clock drops, with a few of the closures leaking and a few drums developing cracks at one of the more severe metal folds. The majority of the eight o'clock failures were, however, still due to unrolling of the chime.

This set of drums arrived from the manufacturer with several drums damaged to the extent that they could not be used for testing. The six o'clock drops were carried out with the undamaged drums from the first shipment, and the eight o'clock drops were carried out with a second shipment, which replaced the damaged ones. There was no discernable difference between the two shipments.

The mean and standard deviation for the six o'clock drops were calculated to be 3.90 m and 0.94 m, respectively, and 3.32 m and 0.36 m, respectively, for the eight o'clock drops.

3.6 Drum Set F (Photos 66 to 78)

This set had the highest average failure height in the six o'clock drops, and second highest failure height in the eight o'clock drops. It was also the most consistent, with a very low standard deviation. All of the failures in the six o'clock drops were from unrolling of the chime. Even then, the failures were not catastrophic, with many of the drums starting to leak only after the drum was vented.

For the eight o'clock drops, the failures were all due to distortion of the large closure (bung). In several cases, the distortion was great enough that the bung could no longer be screwed out and the drum had to be drained by making a hole in some other part.

The mean and standard deviation were calculated to be 5.3 m and 0.10 m, respectively, for the six o'clock drops, and 4.34 m and 0.13 m, respectively, for the eight o'clock drops.

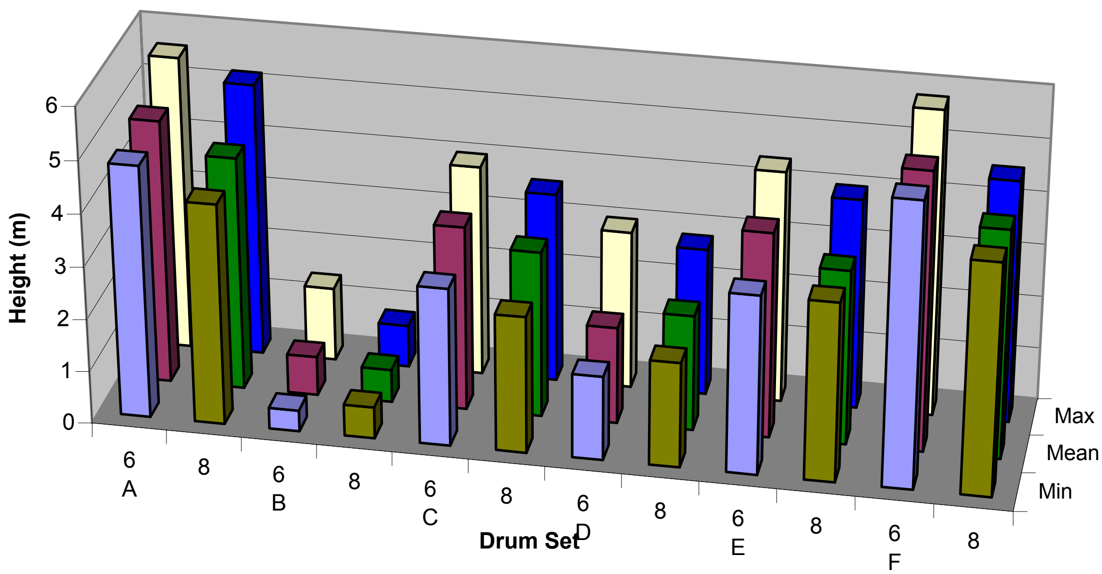
4. SUMMARY OF RESULTS

Table 2 summarizes the findings of the test program. Figure 1 shows these results graphically for comparison. In addition to the average failure heights, the minimum and maximum heights are shown to give a sense of the consistency of the data. More detailed results are given in Appendix B.

Table 2: Results Summary

Set	6 o'clock		8 o'clock .		Comments
	Ht. (m)	Std. Dev.	Ht. (m)	Std. Dev.	
A	5.01	0.46	4.43	0.30	Most failed at chime in six o'clock, more often closure in eight o'clock
B	0.74	0.79	0.62	0.09	Almost all failures at chime, for both orientations
C	3.50	0.74	3.15	0.96	Mainly failed at chime, but several at folds. Few at closure in eight o'clock
D	1.84	1.19	2.20	0.67	Failed at chime, or at folds. Only one at closure, in six o'clock
E	3.90	0.94	3.32	0.36	Most failures from large tears at chime. Two at closure, in eight o'clock
F	5.30	0.10	4.34	0.13	six o'clock failures consistently at chime. All eight o'clock failures at closure

Figure. 3: Summary of Failure Heights



	6 A	8	6 B	8	6 C	8	6 D	8	6 E	8	6 F	8
Min	4.8	4.2	0.4	0.6	3	2.6	1.6	2	3.4	3.4	5.4	4.4
Mean	5.01	4.43	0.74	0.62	3.5	3.15	1.84	2.2	3.9	3.32	5.3	4.34
Max	5.6	5.2	1.4	0.8	4	3.6	3	2.8	4.4	4	5.8	4.6

5. DISCUSSION 3

5.1 General Results

As discussed in section 2.2, the various drums were delivered with quite different specifications. Therefore, to judge whether the existing standards are adequate, it is useful to compare the results to the “as delivered” specifications, not to the specifications on the order.

Although a standard deviation was calculated for each series of drops, this parameter is suspect in some cases, particularly those with low failure heights. The calculation of standard deviation is based on the assumption of a normal distribution. In a study with a relatively small sample size such as this one, the distribution may not fit this assumption, especially for sets with low failure height sets, where the drop height increment is close to the actual failure height. In such a case it may require a much larger sample size or a smaller increment to approach normality. For this reason, and the fact that the requirements for transport of dangerous goods is for a 100% pass at a specified height, it is more informative to compare the minimum failure height (as opposed to the mean ± some multiple of the standard deviation) to the requirements. Nevertheless, the standard deviation calculations are included in the results for purposes of continuity with the 1985 study [1].

The certification tests in CAN/CGSB-43-150 require a drop height of 1.8 m for a Grade X drum, which many of the tested drums were designated. If the drum is intended for liquids of higher specific gravity than 1.2, then the drop test height is to be increased for testing with water. Therefore, drums with the "Y/1.2" designation that were ordered for this study should pass 100% of drops from 1.2 m. However, one designated "X/1.8" would have to be tested at a height of 1.5 times the maximum specific gravity (1.8), i.e., 2.7 m.

Table 3 calculates the required test height for each drum set at maximum fill density, then compares these to the minimum failure height obtained during this test program. These are the levels that were referred to in discussing the results for individual sets in Section 3.

Table 3: Minimum Drop Heights Compared to Requirements

Manufacturer	A	B	C	D	E	F
Designated drop ht (m)	1.2	1.8	1.2	1.8	1.8	1.8
Designated specific gravity	1.8	1.2	1.8	1.5	1.8	1.8
Adjusted drop ht (m) for testing with water	1.8	1.8	1.8	2.25	2.7	2.7
Minimum drop ht (m) obtained	4.2	0.4	2.6	1.6	3.4	4.4

With the exception of sets B and D, all others met or exceeded the requirements for transportation of dangerous goods for the level at which they were rated. In fact a few manufacturers exceeded requirements by a fairly wide margin.

While a majority of the drums tested for set D exceeded the rated minimum, there were a number of failures at or below this height. This set also had a fairly large standard deviation, so it may be only necessary to improve the consistency of the processes to bring this brand into compliance. The results for set B were not nearly so promising. Of the nearly 50 drums tested from this manufacturer, not one exceeded the minimum requirement. Indeed, the highest successful drop test was 1.2 m and this only occurred once.

5.2 Importance of "Venting"

A fairly significant number of the failures were not detected until after the drum was "vented". That is, a small hole was drilled in the side of the drum to equalize the pressure. Even those that initially showed a slow drip would often leak at a much faster rate as soon as the drum was vented.

When the drum impacts, the increased internal pressure bulges out the top and bottom, increasing the total volume. When the drum finally comes to rest, of course the impacted end will be crushed inward, reducing the volume. If the volume reduction from crushing is less than the volume increase from bulging, the drum will be left with a slight vacuum inside, which inhibits the release of liquid, hence the detection of leakage. A drum will then appear not to be leaking, but later as the pressure equalizes, it will start to leak.

It is therefore essential to vent the drum before deciding whether it is a pass or fail. Any standards or regulations pertaining to the drop testing of drums should require this step as part of the evaluation.

5.3 Effect of Drop Orientation

Almost all sets yielded a lower average failure height when dropped in the eight o'clock orientation than when dropped in the six o'clock orientation. Usually, the difference could be attributed to the fact that more closures are involved in the failures in the eight o'clock drops than in the six o'clock drops.

The one exception was Set D, in which the results for the eight o'clock drops were actually better than those for the six o'clock drops. This is the opposite effect to all others. However, this set had no closure failures in either orientation, and the difference between orientations was not pronounced. Given that and the relatively small sample size used in this study, the two results for set D could be considered approximately equal.

The most pronounced effect of orientation was in set F, where the failure mode changed almost completely from chime failure to closure failure when the orientation changed. For this set the failure heights were considerably lower for the eight o'clock drops.

5.4 Effect of Closure Style

Little conclusion can be drawn with regard to the closure styles used, since so few of the failures occurred at the closure. Certainly more closure failures occurred during eight o'clock than six o'clock drops, but the two types of closure appeared to fail about as often and at similar heights.

Overall the Type P and Type Q closures were both able to consistently sustain the impacts of the drum drops, in the six o'clock and eight o'clock orientations, for all sets. Out of the drums that failed due to closure leaks, 14 were Type P closures, and 12 were Type Q. All Type P closure failures occurred in Set A and Set C eight o'clock drops. The Type Q closure failures occurred mainly in the Set E and F eight o'clock drops. The drop heights at which the two types of closures leaked did not seem to favour one over the other either.

Perhaps not surprisingly, failures of both types of closure only occurred at the higher drop heights, which were well above the required heights. Overall, there were not enough failures at closures to discern any difference between closure types, but it is likely that if either type fails, the drop resistance of the overall package is more than adequate, so closure type becomes a moot point.

5.5 Shipping Considerations

Having produced a drum of a certain quality, a manufacturer still has to get it to the user with reasonable assurance that it will still perform up to specifications. The methods used to pack the drums for this study were as varied as the drums themselves.

As discussed in section 3.5, one set had to be partially re-ordered when several of the drums arrived having sustained serious damage. This set had been palletized, four to a pallet, with steel strapping and shrink-wrap around the four. This type of packing was an extra cost option that was offered and accepted to ensure the drums arrived undamaged. However, in retrospect, it probably contributed to the damage rather than mitigated it. The straps were cinched tightly, drawing the chime of one drum into the side of the next one, and then movement during shipment caused the chime to rub quite severely on the adjoining drum. Further, the palletizing encouraged the use of forklifts to load and unload the drums, and there was evidence of damage caused by forks pressing into the side of drums.

At the other end of the scale, set F arrived in near pristine condition after a rather long shipment. Photo 66 shows the method used to ensure this. Other than the corrugated sleeve, these drums were packed like most others. That is, loose within the container. This meant they had to be unloaded by hand, which may have added a few minutes to the loading and unloading process, but no drums were damaged during these processes.

6. CONCLUSIONS

With the two exceptions discussed above, most drums tested met the requirements for transportation of dangerous goods. In five out of six drum sets there was a definite difference in failure height for the two orientations tested, with the eight o'clock orientation resulting in lower average failure heights. The two orientations were about equal in the sixth set. There appeared to be little difference in the performance of the two closure styles, though there were not enough closure failures to say definitively. However, when they leaked, both styles did so at well above the required drop test height.

7. RECOMMENDATIONS

The results of most drums purchased for this study fell well above the 1.2 m drop requirement requested. One manufacturer was notably deficient in its performance and Transport Canada could undertake to investigate this supplier, in conjunction with any other national authority as appropriate, to determine whether the problem is a one-time occurrence or an ongoing problem for this manufacturer. Most manufacturers did quite well, and this indicates the system is working for the most part in the steel drum industry as regards drop resistance.

The effect of "venting" of drums following a drop test was often dramatic, with the drum appearing to pass before venting but obviously failing once the pressure was relieved. Any standards relating to drop tests should make note of this fact and require the drum to be vented before determining that it has passed.

The other main factor in drum performance is hydrostatic pressure, which was not investigated in this study. It would be useful to conduct a similar study with regard to hydrostatic pressure performance on steel drums. Previous work on containers included other drum types, plastic 210 L, and plastic and steel pails in the 20 L size range. We would suggest that a similar study of these types of containers would also be useful in gauging the effectiveness of dangerous goods packaging programs in a broader sense. The plastic containers are a relatively new container type, and have a different set of manufacturing challenges that need to be addressed.

One approach for future studies might be to obtain samples from manufacturers on a voluntary basis, in order to help keep costs down. Results would then be shared in a coded fashion with the participants so they could gauge where they stand within their industry. This approach does have the drawback that "sweet" samples might be provided.

To our knowledge there have not been any similar studies of other package types, such as combination packs involving bottles and corrugated fibreboard. A similar survey of these packages would also prove interesting.

8. CERTIFICATION

THIS IS TO CERTIFY THAT THE ABOVE TESTING WAS PERFORMED ACCORDING TO REQUIREMENTS SET FORTH BY THE CLIENT IN A MANNER CONSISTENT WITH GOOD LABORATORY PRACTICES AND ANY SPECIFICATIONS REFERENCED HEREIN.

Bob Tizzard, B.Sc Lab Co-Ordinator	Neil P. Richter, P.Eng. Manager, Environmental Simulation Lab

REFERENCES

1. Transport Dangerous Goods Directorate, Report No. TP 7423E ***Evaluation of Selected Containers Used for the Shipment of Dangerous Goods***

2. Innovacorp, Test Plan 2402-1325/TP01 ***Performance Standard for Steel Drums for Transport Canada***

3. Canadian General Standards Board, CAN/CGSB 43.150-97 ***Performance Packagings for Transportation of Dangerous Goods***

4. M.G. Natrella, ***Experimental Statistics***, Handbook 91, United States Department of Commerce: Chapter 10, Sensitivity Testing

APPENDIX A

Photographs

Photo 1
Steel Drum 6 O'clock Drop Orientation Setup

Photo 2
Metre Stick Measuring Procedure for 1.2 Metre Drop

Photo 3
Dynamometer Used to Determine Full and 98% Full Weight

Photo 4
Small Forklift Used for Lower (Less than 2 Metres) Drops

Photo 5
Drum in Mid-air Showing Holder Release and Required Angle

Photo 6
Forklift Setup for Drop Heights Less than 4.4 Metres

Photo 7
Lot A(6) Drum after 6 O'clock from 4.4 Metres

Photo 8
Lot A(6) Drum after 6 O'clock Drop from 4.4 Metres

Photo 9
Lot A(7) Drum after 6 O'clock Drop from 4.7 Metres

Photo 10
Lot A Drum Drop Setup for Heights Greater than 4.6 Metres

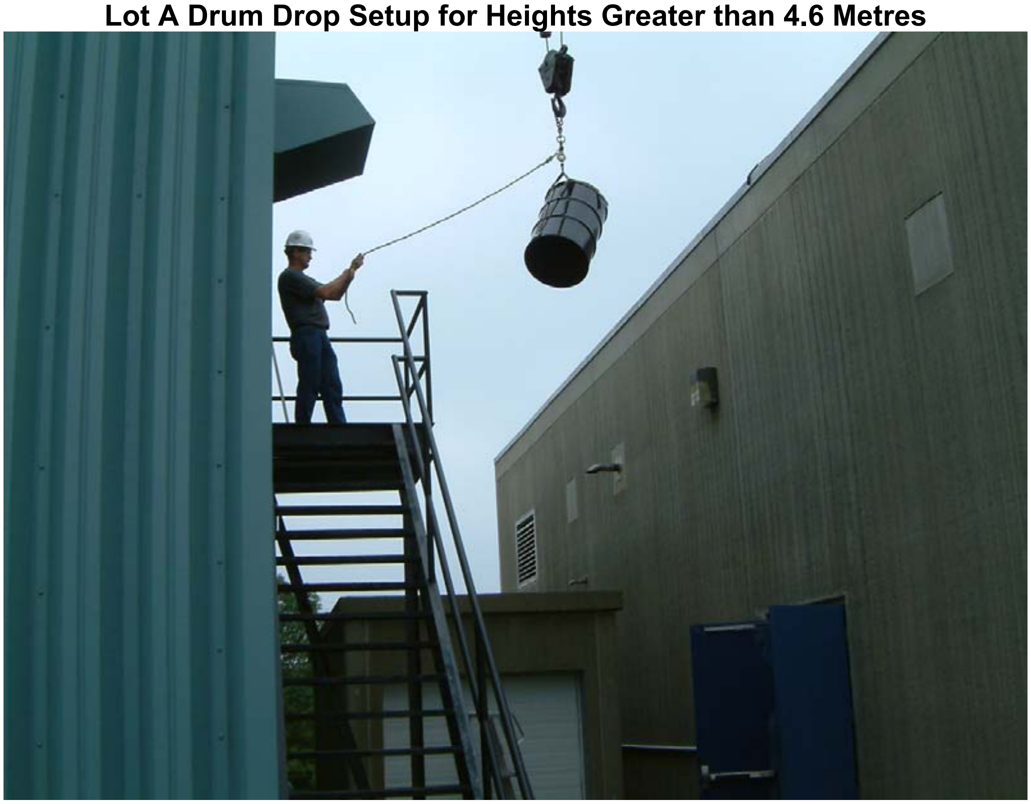


Photo 11
Lot A Drum Drop from 5.0 Metres and Above

Photo 12
Lot A Drum Showing Failure Mode (6 O'clock) at Top Chime

Photo 13
Lot A(19) Drum after 6 O'clock Drop from 5.0 Metres

Photo 14
Lot A Drum after 6 O'clock Drop from 5.0 Metres

Photo 15
Lot A(31) Drum after 8 O'clock Drop from 5.2 Metres

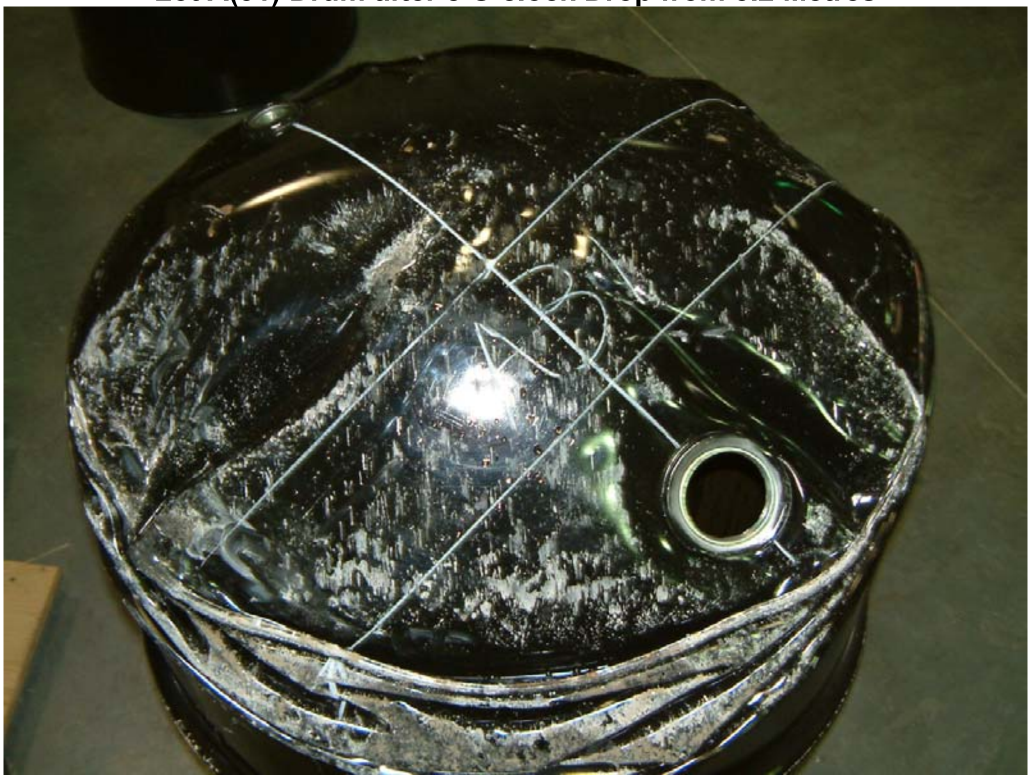


Photo 16
Lot A(39) Drum after 8 O'clock Drop from 4.8 Metres

Photo 17
Lot A(43) Drum after 8 O'clock Drop from 4.4 Metres

Photo 18
Lot B(2) Drum Showing Leak at Bottom after 2.0 Metre Drop

Photo 19
Lot B(3) Drum after 6 O'clock Drop from 1.6 Metres

Photo 20
Lot B(38) Drum after 8 O'clock Drop from 0.6 Metres

Photo 21
Passed Lot B(5) Drum after 8 O'clock Drop from 0.8 Metres

Photo 22
Failed Lot B(6) Drum after 8 O'clock Drop from 1.0 Metres

Photo 23
Lot B(12) Drum after 6 O'clock Drop from 1.4 Metres

Photo 24
Lot B(26) Drum after 6 O'clock Drop from 1.0 Metres

Photo 25
Failed Lot B(35) Drum after 8 O'clock Drop from 0.8 Metres

Photo 26
Passed Lot C(1) Drop after 6 O'clock Drop from 1.2 Metres

Photo 27
Lot C(3) Drum Prior to 6 O'clock Drop from 3.0 Metres

Photo 28
Failed Lot C(3) Drum - Showing Leak at Cover after 3.0 Metre Drop

Photo 29
Passed Lot C(7) Drum after 6 O'clock Drop from 3.2 Metres

Photo 30
Failed Lot C(8) Drum after 6 O'clock Drop from 3.4 Metres

Photo 31
Failed Lot C(33) Drum after 8 O'clock Drop from 2.8 Metres

Photo 32
Lot C Drums after Series of 8 O'clock Drops

Photo 33
Failed Lot C(9) Drum after 6 O'clock Drop from 3.0 Metres

Photo 34
Failed Lot C(30) Drum after 8 O'clock Drop from 2.6 Metres

Photo 35
Passed Lot D(2) Drum after 6 O'clock Drop from 2.0 Metres

Photo 36
Lot D(3) Drum Release for 6 O'clock Drop from 3.0 Metres

Photo 37
Lot D(3) Drum Bottom after Drop from 3.0 Metres

Photo 38
Lot D(4) Drum - Showing 6 O'clock Release from 3.6 Metres

Photo 39
Failed Lot D(5) Drum after 6 O'clock Drop from 3.2 Metres

Photo 40
Failed Lot D(11) Drum after 6 O'clock Drop from 2.8 Metres

Photo 41
Failed Lot D(12) Drum after 6 O'clock Drop from 2.6 Metres

Photo 42
Failed Lot D(36) Drum after 8 O'clock Drop from 2.4 Metres

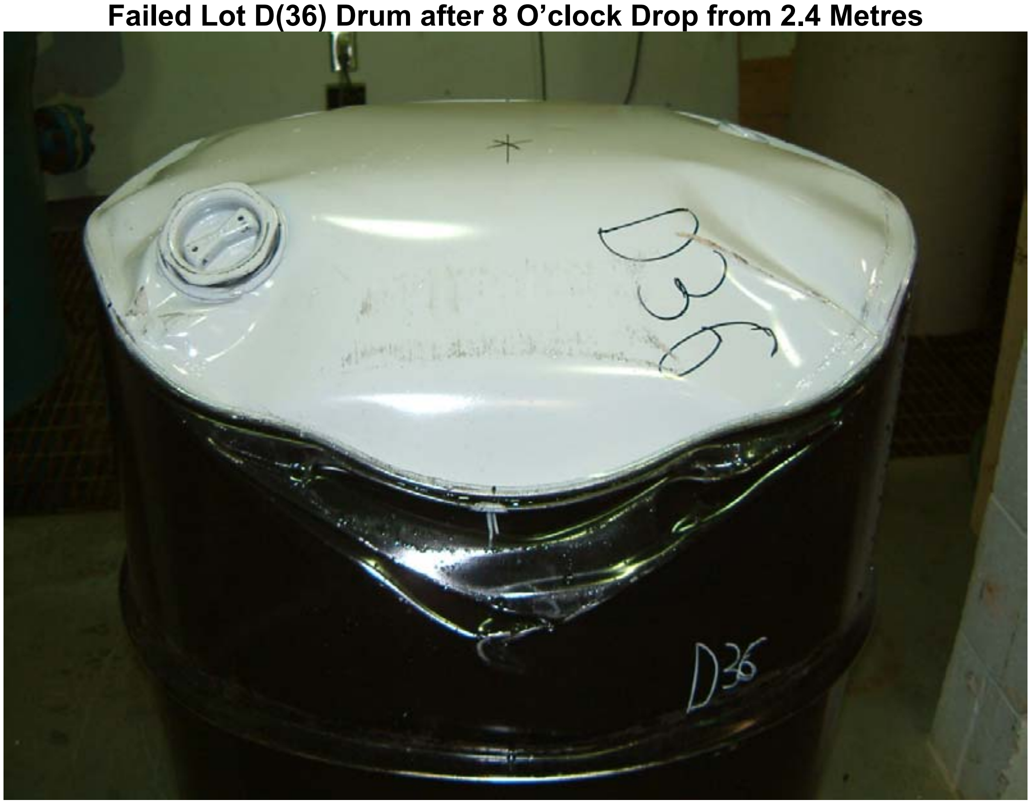


Photo 43
Failed Lot D(17) Drum after 6 O'clock Drop from 2.4 Metres

Photo 44
Passed Lot D(26) Drum after 8 O'clock Drop from 1.8 Metres

Photo 45
Passed Lot D(48) Drum after 8 O'clock Drop from 2.0 Metres

Photo 46
Lot E(1) Drum - Showing Preliminary Drop from 1.2 Metres

Photo 47
Lot E(1) Drum after 6 O'clock Drop from 1.2 Metres

Photo 48
Lot E(2) Drum Showing 6 O'clock Drop from 2.0 Metres

Photo 49
Passed Lot E(2) Drum after 6 O'clock Drop from 2.0 Metres

Photo 50
Lot E(2) Drum Bottom after 6 O'clock Drop from 2.0 Metres

Photo 51
Lot E(3) Drum Prior to 6 O'clock Drop from 3.0 Metres

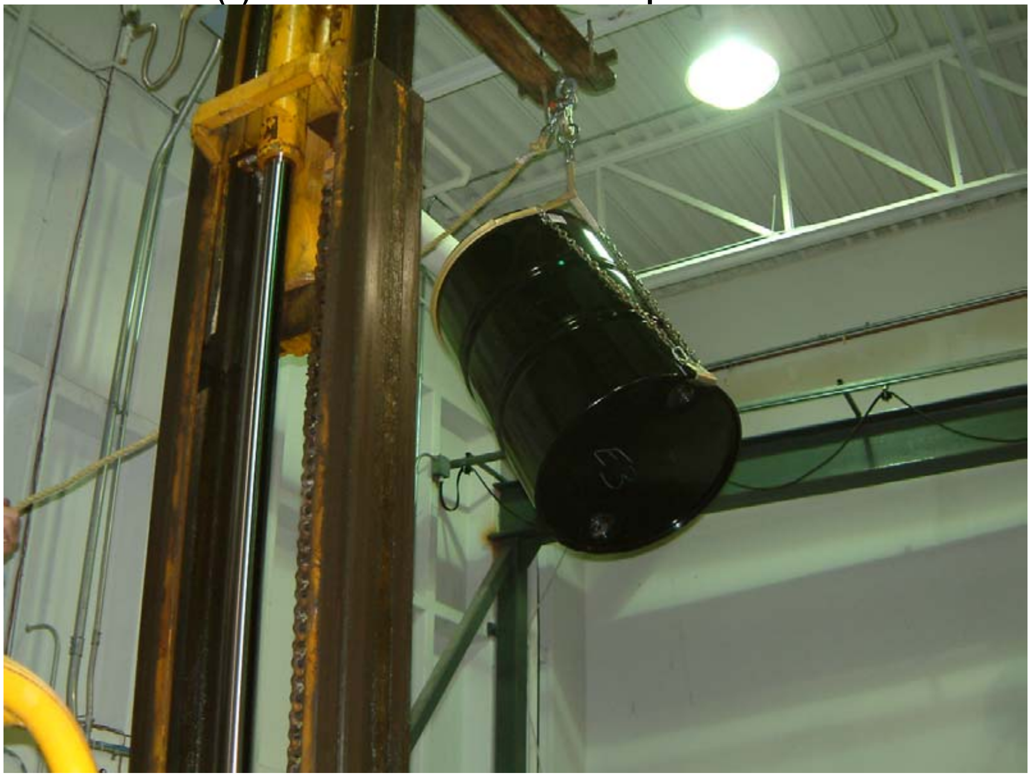


Photo 52
Failed Lot E(3) Drum after 6 O'clock Drop from 3.0 Metres

Photo 53
Passed Lot E(6) Drum after 6 O'clock Drop from 3.0 Metres

Photo 54
Failed E(11) Drum after 6 O'clock Drop from 3.6 Metres

Photo 55
Passed Lot E (13) Drum after 6 O'clock Drop from 3.6 Metres

Photo 56
Lot E (14) Drum Prior to 6 O'clock Drop from 3.8 Metres

Photo 57
Failed Lot E(17) Drum after 6 O'clock Drop from 4.4 Metres

Photo 58
Failed Lot E(18) Drum after 6 O'clock Drop from 4.2 Metres

Photo 59
Failed Lot E(21) Drum after 6 O'clock Drop from 4.2 Metres

Photo 60
Bottom of Passed Lot E(25) Drum after Drop from 3.8 Metres

Photo 61
Failed Lot E(29) Drum after 8 0'clock Drop from 3.8 Metres

Photo 62
Failed Lot E(32) Drum after 8 O'clock Drop from 3.6 Metres

Photo 63
Passed Lot E(35) Drum after 8 O'clock Drop from 3.8 Metres

Photo 64
Failed Lot E(43) Drum after 8 O'clock Drop from 3.4 Metres

Photo 65
Failed Lot E(45) Drum Showing Leak at Chime – 3.4 Metres

Photo 66
Lot F Drum Showing "As Received" Shipping Configuration

Photo 67
Failed Lot F(6) Drum after 6 O'clock Drop from 5.8 Metres

Photo 68
Failed Lot F(9) Drum after 6 O'clock Drop from 5.6 Metres

Photo 69
Failed Lot F(12) Drum after 6 O'clock Drop from 5.8 Metres

Photo 70
Lot F Drum Drop Setup Showing Metre Measuring Stick

Photo 71
Lot F Drum Drop Procedure Showing Released Drum

Photo 72
Failed Lot F(13) Drum after 6 O'clock Drop from 5.6 Metres

Photo 73
Failed Lot F(27) Drum after 8 O'clock Drop from 4.8 Metres

Photo 74
Cap from Lot F(27) Drum after 8 O'clock Drop – 4.8 Metres

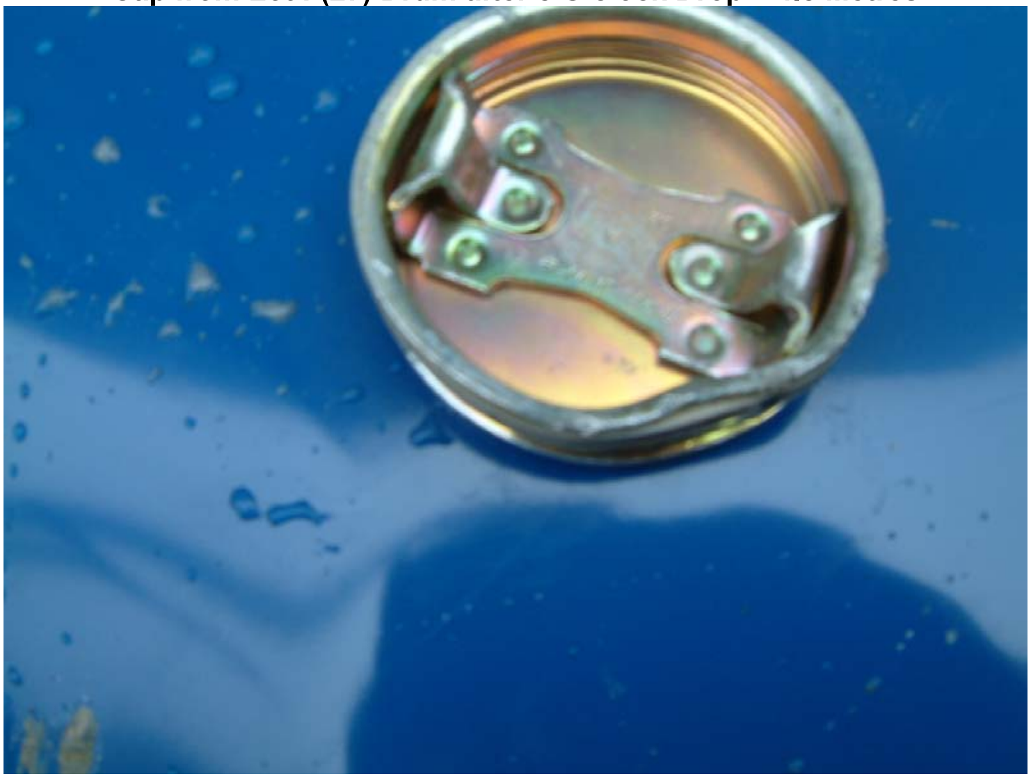


Photo 75
Failed Lot F(28) Drum after 8 O'clock Drop from 4.6 Metres

Photo 76
Failed Lot F(34) Drum after 8 O'clock Drop from 4.6 Metres

Photo 77
Failed Lot F(35) Drum after 8 O'clock Drop from 4.4 Metres

Photo 78
Lot F Drums Showing Drum Support and Release Hook

Photo 79
Cross Sections of Drums Showing Chime and Wall Thickness

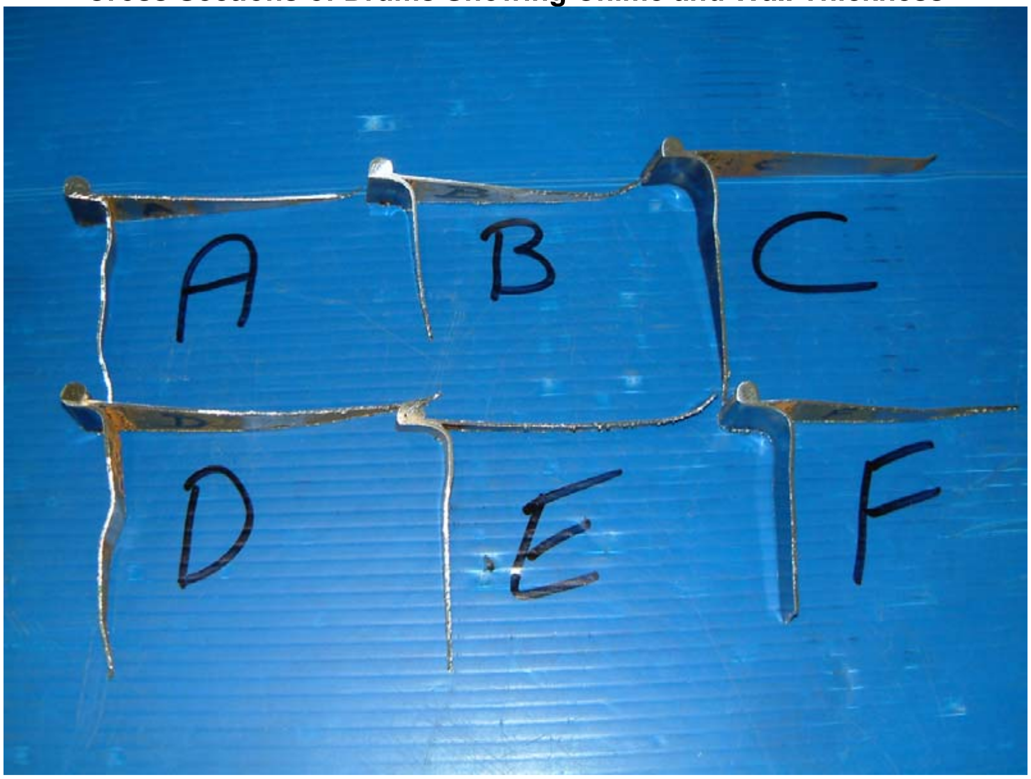


Photo 80
Cross Sections of Drums Showing Chime and Wall Thickness

Photo 81: Chime Section, Set A

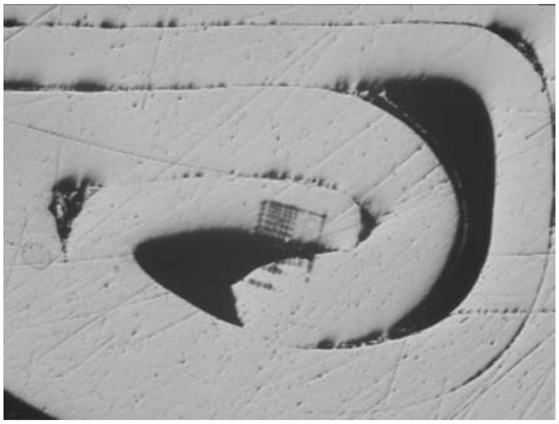


Photo 82: Chime Section, Set B

Photo 83: Chime Section, Set C

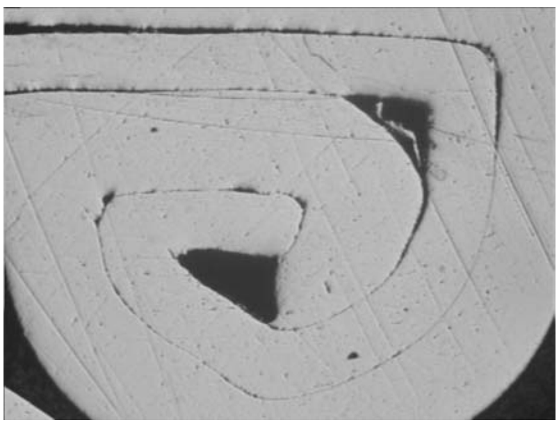
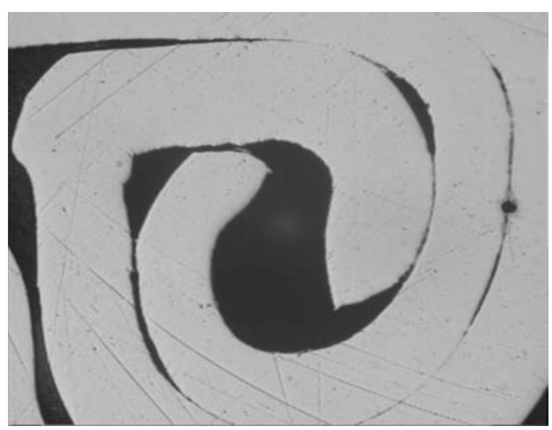


Photo 84: Chime Section, Set D

Photo 85: Chime Section, Set E

Photo 86: Chime Section, Set F



APPENDIX B

Data Sheets
Calculations
Charts

LEGEND

Statistical Analysis

N: Total number of drops per set
R: Total number of failures per set
j: Any integer (e.g., 0, 1, 2, 3 …)
y_j: Instance of a drop from a specific height
n: Total number of drops at a particular height, per set
r_j: Number of failures at a specific drop height, per set
A: Sum of the products of r_j and j, per set
B: Sum of the products of r_j and j^2, per set
d: Height increment/decrement per drop (0.2 m in this case)
m: Estimate for the mean of the distribution of drops
s: Estimate of the standard deviation of the distribution of drops

Formulas

For R ≤ N/2:

$A = \sum (j * r_j)$, where j ranges from 0 to *k*, and *k* > 0

$B = \sum (j^2 * r_j)$, where j ranges from 0 to *k*, and *k* > 0

$$m = y_o + d * [(A / R) - ½]$$

$$s = 1.620 * d [(((R * B) – (A^2)) / R^2) + .029]$$

For R > N/2:

$$A = \sum [j * (n - r_j)]$$

$$B = \sum [j^2 * (n - r_j)]$$

$$m = y_o + d * [(A / (N - R)) + ½]$$

$$s = 1.620 * d [((((N – R) * B) – (A^2)) / (N - R)^2) + .029]$$

Data Sheet 2401-1325-DS1

Manufacturer Code:_____A_.
Closure Type: ________P__.
Test Series: _6 O'clock Staircase
Test Start Date: _____Aug. 27, 2002__

Drum #

Drop height	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6.0																				
5.8																				
5.6	X				X															
5.4		X		O		X														
5.2			O				X						X							
5.0								X		X		O		X						
4.8									O		O				X		X			
4.6																O		O		
4.4																				
4.2																				
4.0																				
3.8																				
3.6																				
3.4																				
3.2																				
3.0																				
2.8																				
2.6																				
2.4																				
2.2																				
2.0																				
1.8																				
1.6																				
1.4																				
1.2																				
1.0																				
0.8																				
0.6																				
0.4																				
0.2																				
0.0																				

Key

Pass test at a height O
Fail test at a height X

Data Sheet 2401-1325-DS1

Manufacturer Code: A .
Closure Type: P .
Test Series: 8 O'clock Staircase
Test Start Date: Aug. 27, 2002

Drum #

Drop height	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6.0																				
5.8																				
5.6																				
5.4																				
5.2	X																			
5.0		X																		
4.8			X						X											
4.6				X		X		O		X		X								
4.4					O		O				O		X				X			
4.2														X		O		X		
4.0															O					
3.8																				
3.6																				
3.4																				
3.2																				
3.0																				
2.8																				
2.6																				
2.4																				
2.2																				
2.0																				
1.8																				
1.6																				
1.4																				
1.2																				
1.0																				
0.8																				
0.6																				
0.4																				
0.2																				
0.0																				

Key

Pass test at a height O
Fail test at a height X

Set A Detailed Results

Drum # (SET A)	Height (m)	Position	Result	Comments
1	1.2	6 o'clock	PASS	Preliminary 6 o'clock
2	2	6 o'clock	PASS	Preliminary 6 o'clock
3	3	6 o'clock	PASS	Preliminary 6 o'clock
4	3.6	6 o'clock	PASS	Preliminary 6 o'clock
5	3.8	6 o'clock	PASS	Preliminary 6 o'clock
6	4.4	6 o'clock	PASS	Preliminary 6 o'clock
7	4.7	6 o'clock	PASS	Preliminary 6 o'clock
8	5.2	6 o'clock	PASS	Preliminary 6 o'clock
9	5.6	6 o'clock	FAIL	Chime unrolled causing leak
10	5.4	6 o'clock	VOID	Drum swung and fell sideways
11	5.4	6 o'clock	FAIL	Leak on chime in front of closure
12	5.2	6 o'clock	PASS	Splash on back side of drum
13	5.4	6 o'clock	PASS	Splash on back side of drum
14	5.6	6 o'clock	VOID	Drum swung and fell sideways
15	5.6	6 o'clock	VOID	Drum flipped and landed on hook
16	5.6	6 o'clock	FAIL	Top chime split open on back side
17	5.4	6 o'clock	FAIL	Break on chime in front of closure
18	5.2	6 o'clock	FAIL	Break on chime in front of closure
19	5	6 o'clock	FAIL	Slow leak on chime in front of closure
21	4.8	6 o'clock	PASS	
22	5	6 o'clock	FAIL	Leak on chime in front of closure
23	4.8	6 o'clock	PASS	
24	5	6 o'clock	PASS	
25	5.2	6 o'clock	FAIL	Top chime split open on back side
26	5	6 o'clock	FAIL	Leak on chime in front of closure
27	4.8	6 o'clock	FAIL	Leak on chime in front of closure
28	4.6	6 o'clock	PASS	
29	4.8	6 o'clock	FAIL	Chime broke on back side upon impact
49	4.6	6 o'clock	PASS	
20	4.8	8 o'clock	PASS	Preliminary 8 o'clock
30	5	8 o'clock	PASS	Preliminary 8 o'clock
31	5.2	8 o'clock	FAIL	Edge of closure leaked
32	5	8 o'clock	FAIL	Edge of closure leaked
33	4.8	8 o'clock	FAIL	Edge of closure leaked
34	4.6	8 o'clock	FAIL	Edge of closure leaked
35	4.4	8 o'clock	PASS	
36	4.6	8 o'clock	FAIL	Edge of closure leaked
37	4.4	8 o'clock	PASS	
38	4.6	8 o'clock	PASS	
39	4.8	8 o'clock	FAIL	Drum broke in front of closure upon impact
40	4.6	8 o'clock	FAIL	Edge of closure leaked
41	4.4	8 o'clock	PASS	
42	4.6	8 o'clock	FAIL	
43	4.4	8 o'clock	FAIL	Edge of closure leaked
44	4.2	8 o'clock	FAIL	Leak on chime in front of closure
45	4	8 o'clock	PASS	
46	4.2	8 o'clock	PASS	
47	4.4	8 o'clock	FAIL	Leak from drum at point of impact
48	4.2	8 o'clock	FAIL	Leak from drum at point of impact

Set A Calculations

SET A - 6 o'clock drops: N = 18, R = 11 therefore R > N/2

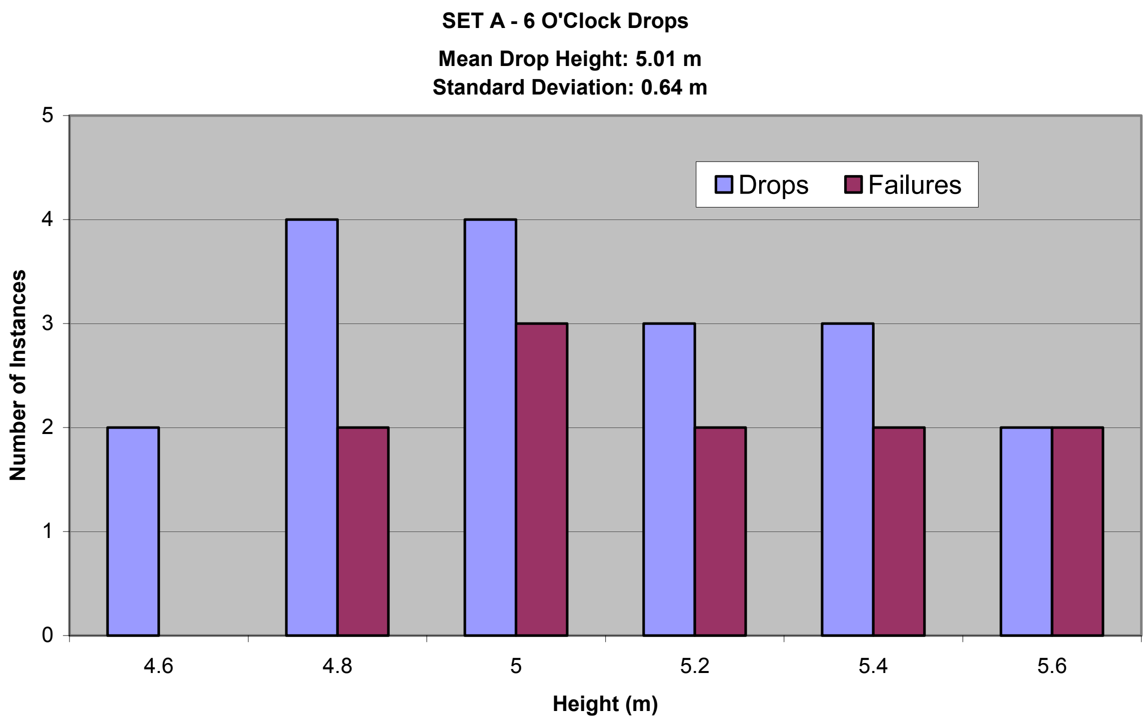
	y (m)	n - r	j	j^2	(n - r) * j	(n - r) * j^2
y_0	4.6	2	0	0	0	0
y_1	4.8	2	1	1	2	2
y_2	5	1	2	4	2	4
y_3	5.2	1	3	9	3	9
y_4	5.4	1	4	16	4	16
y_5	5.6	0	5	25	0	0

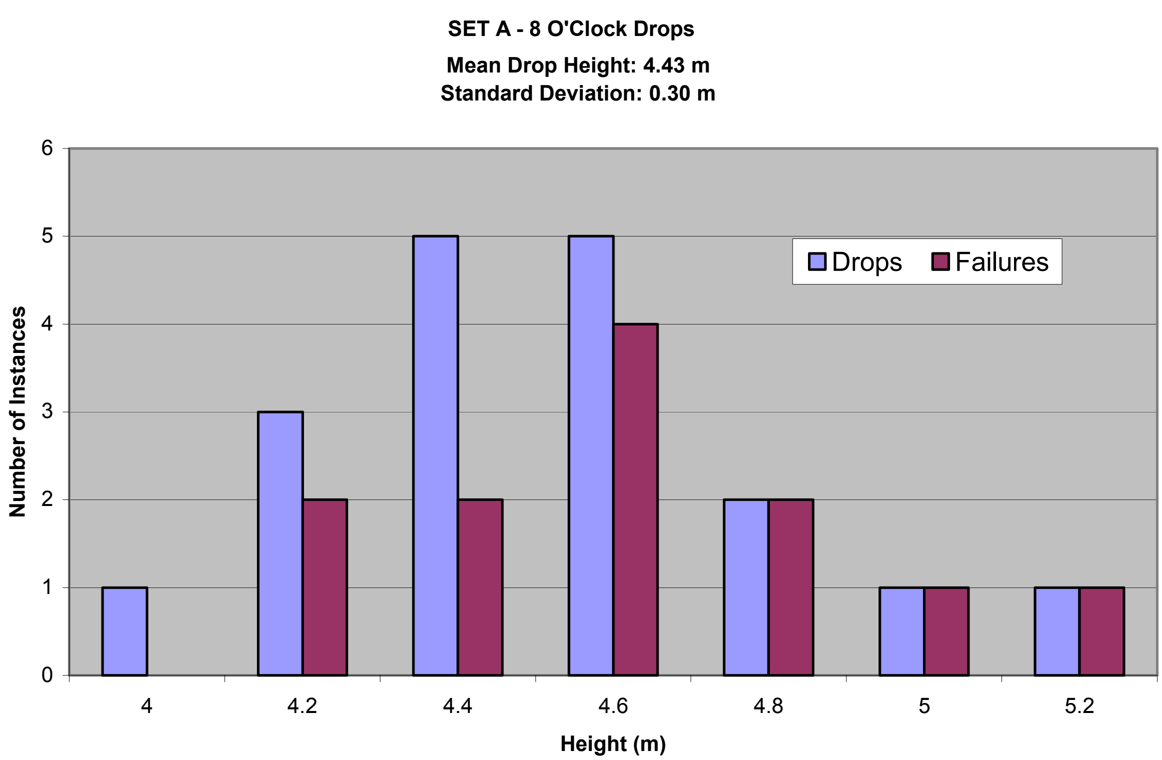
A (sum of all (n - r) * j)	**11**
B (sum of all (n - r) * j^2)	**31**
m (estimate of the mean, in metres)	**5.01**
s (estimate of standard deviation, in metres)	**0.64**

Set A - 8 o'clock drops: N = 18, R = 12 therefore R > N/2

	y (m)	n - r	j	j^2	(n - r) * j	(n - r) * j^2
y_0	4	1	0	0	0	0
y_1	4.2	1	1	1	1	1
y_2	4.4	3	2	4	6	12
y_3	4.6	1	3	9	3	9
y_4	4.8	0	4	16	0	0
y_5	5	0	5	25	0	0
y_6	5.2	0	6	36	0	0

A (sum of all (n - r) * j)	**10**
B (sum of all (n - r) * j^2)	**22**
m (estimate of the mean, in metres)	**4.43**
s (estimate of standard deviation, in metres)	**0.30**


SET A - 6 O'Clock Drops
Mean Drop Height: 5.01 m
Standard Deviation: 0.64 m
Drops
Failures
Number of Instances
0
1
2
3
4
5
4.6
4.8
5
5.2
5.4
5.6
Height (m)


SET A - 8 O'Clock Drops
Mean Drop Height: 4.43 m
Standard Deviation: 0.30 m
Drops
Failures
Number of Instances
0
1
2
3
4
5
6
4
4.2
4.4
4.6
4.8
5
5.2
Height (m)

Data Sheet 2401-1325-DS1

Manufacturer Code: B .
Closure Type: Q .
Test Series: 6 O'clock Staircase
Test Start Date: Jul. 12, 2002 .
Drum #

Drop height	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
6.0																				
5.8																				
5.6																				
5.4																				
5.2																				
5.0																				
4.8																				
4.6																				
4.4																				
4.2																				
4.0																				
3.8																				
3.6																				
3.4																				
3.2																				
3.0																				
2.8																				
2.6																				
2.4																				
2.2																				
2.0																				
1.8																				
1.6																				
1.4		X																		
1.2	O		X																X	
1.0				X												X		O		X
0.8					X										O		O			
0.6						X		X		X				O						
0.4							O		O		X		O							
0.2												O								
0.0																				

Key

Pass test at a height O
Fail test at a height X

Data Sheet 2401-1325-DS1

Manufacturer Code: B .
Closure Type: Q .
Test Series: 8 O'clock Staircase
Test Start Date: Aug. 27, 2002 .

Drum #

Drop height	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6.0																				
5.8																				
5.6																				
5.4																				
5.2																				
5.0																				
4.8																				
4.6																				
4.4																				
4.2																				
4.0																				
3.8																				
3.6																				
3.4																				
3.2																				
3.0																				
2.8																				
2.6																				
2.4																				
2.2																				
2.0																				
1.8																				
1.6																				
1.4																				
1.2																				
1.0																				
0.8	X				X		X		X						X				X	
0.6		X		O		O		O		X		X		O		X		O		O
0.4			O								O		O				O			
0.2																				
0.0																				

Key

Pass test at a height O
Fail test at a height X

Set B Detailed Results

Drum # (SET B)	Height (m)	Position	Result	Comments
1	1.2	6 o'clock	PASS	Preliminary 6 o'clock
2	2	6 o'clock	FAIL	Preliminary 6 o'clock
3	1.6	6 o'clock	FAIL	Preliminary 6 o'clock
4	1.4	6 o'clock	FAIL	Preliminary 6 o'clock
5	0.8	8 o'clock	PASS	Preliminary 8 o'clock
6	1	8 o'clock	FAIL	Preliminary 8 o'clock
7	Leftover drums, untested			
8				
9				
10				
11	1.2	6 o'clock	PASS	Start of 6 o'clock drop test, SET B
12	1.4	6 o'clock	FAIL	Break on chime in 2 places
13	1.2	6 o'clock	FAIL	Break on chime in 2 places
14	1	6 o'clock	FAIL	Break on chime in 2 places
15	0.8	6 o'clock	FAIL	Break on chime in 2 places
16	0.6	6 o'clock	FAIL	Break on chime in 2 places
17	0.4	6 o'clock	PASS	Slight moisture along edges of chime
18	0.6	6 o'clock	FAIL	Slow leak from break on chime
19	0.4	6 o'clock	PASS	Slight moisture along edges of chime
20	0.6	6 o'clock	FAIL	Vigorous leakage from break on chime
21	0.4	6 o'clock	FAIL	Slow leak from break on chime
22	0.2	6 o'clock	PASS	
23	0.4	6 o'clock	PASS	
24	0.6	6 o'clock	PASS	
25	0.8	6 o'clock	PASS	
26	1	6 o'clock	FAIL	Consistently leaking from break on chime
27	0.8	6 o'clock	PASS	
28	1	6 o'clock	PASS	
29	1.2	6 o'clock	FAIL	Slow leak from break on chime
30	1	6 o'clock	FAIL	Break on chime in 2 places
31	0.8	8 o'clock	FAIL	Start of 8 o'clock drop test, SET B
32	0.6	8 o'clock	FAIL	Chime broke in 2 places, cover is fine
33	0.4	8 o'clock	PASS	
34	0.6	8 o'clock	PASS	
35	0.8	8 o'clock	FAIL	Chime broke, cover became bowed
36	0.6	8 o'clock	PASS	Cover became bowed but no leak
37	0.8	8 o'clock	FAIL	Splash from cover, 2 breaks on chime
38	0.6	8 o'clock	PASS	
39	0.8	8 o'clock	FAIL	Leak on chime, no damage to cover
40	0.6	8 o'clock	FAIL	Break on chime
41	0.4	8 o'clock	PASS	
42	0.6	8 o'clock	FAIL	Break on chime in 2 places
43	0.4	8 o'clock	PASS	
44	0.6	8 o'clock	PASS	
45	0.8	8 o'clock	FAIL	Break on chime in 2 places
46	0.6	8 o'clock	FAIL	Break on chime in 2 places
47	0.4	8 o'clock	PASS	
48	0.6	8 o'clock	PASS	
49	0.8	8 o'clock	FAIL	Break on chime in 2 places
50	0.6	8 o'clock	PASS	Slight moisture and splash on cover

Set B Calculations

SET B - 6 o'clock drops: N = 20, R = 11 therefore R > N/2

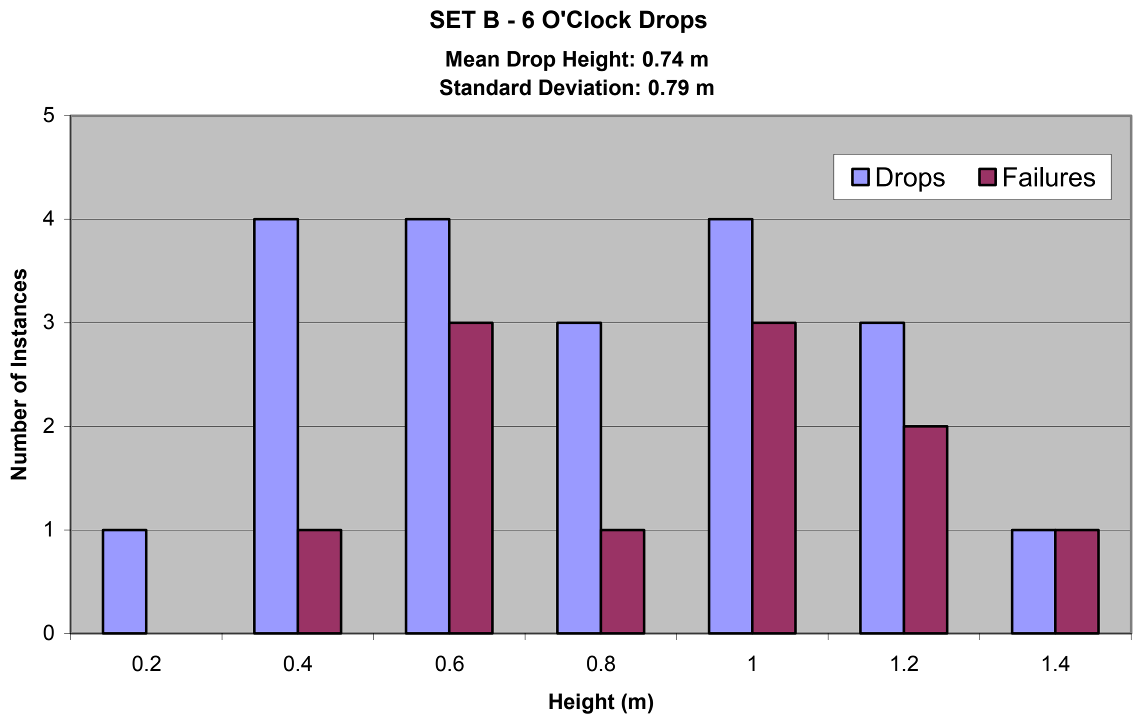
	y (m)	n - r	j	j^2	(n - r) * j	(n - r) * j^2
y_0	0.2	1	0	0	0	0
y_1	0.4	3	1	1	3	3
y_2	0.6	1	2	4	2	4
y_3	0.8	2	3	9	6	18
y_4	1	1	4	16	4	16
y_5	1.2	1	5	25	5	25

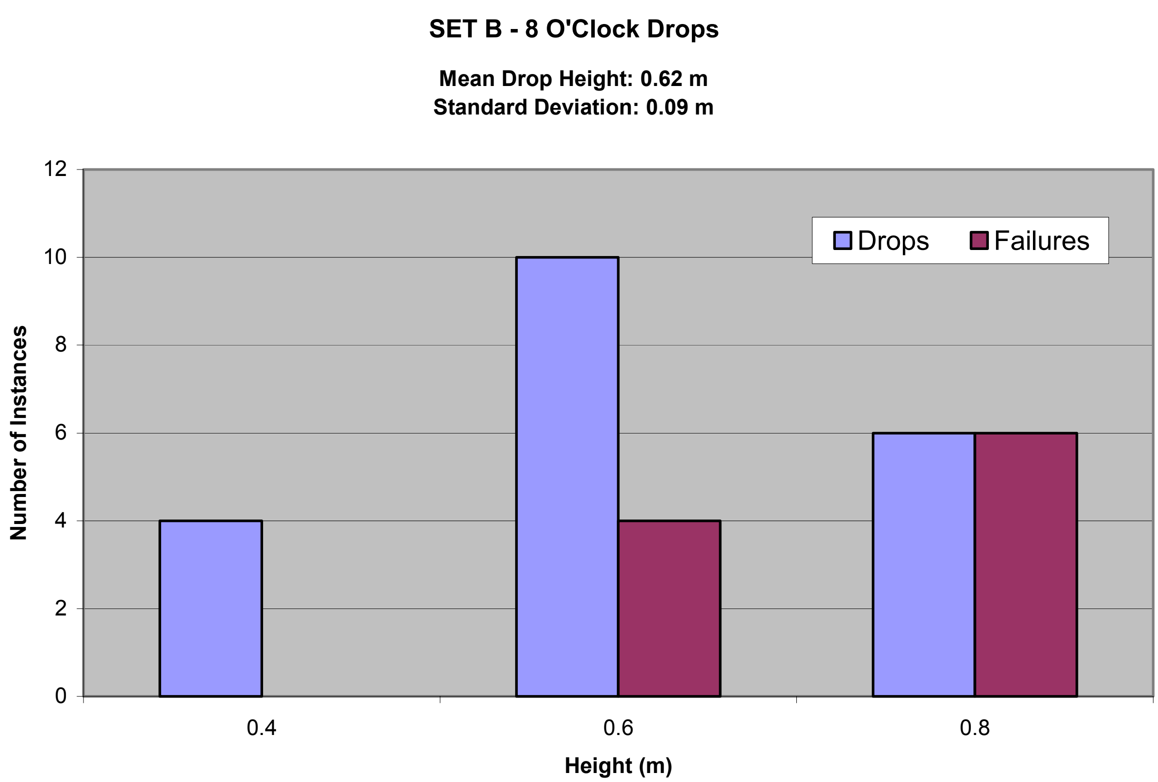
A (sum of all (n - r) * j)	**20**
B (sum of all (n - r) * j^2)	**66**
m (estimate of the mean, in metres)	**0.74**
s (estimate of standard deviation, metres)	**0.79**

Set B - 8 o'clock drops: N = 20, R = 10 therefore R <= N/2

	y (m)	r	j	j^2	r * j	r * j^2
y_0	0.6	4	0	0	0	0
y_1	0.8	6	1	1	6	6

A (sum of all r * j)	**6**
B (sum of all r * j^2)	**6**
m (estimate of the mean, in metres)	**0.62**
s (estimate of standard deviation, in metres)	**0.09**


SET B - 6 O'Clock Drops
Mean Drop Height: 0.74 m
Standard Deviation: 0.79 m
Drops
Failures
Number of Instances
Height (m)
0
1
2
3
4
5
0.2
0.4
0.6
0.8
1
1.2
1.4


SET B - 8 O'Clock Drops
Mean Drop Height: 0.62 m
Standard Deviation: 0.09 m
Drops
Failures
Number of Instances
Height (m)
0
2
4
6
8
10
12
0.4
0.6
0.8

Data Sheet 2401-1325-DS1

Manufacturer Code: __C__.
Closure Type: _____P_____.
Test Series: _6 O'clock Staircase
Test Start Date:_ Jul. 16, 2002__

Drum #

Drop height	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6.0																				
5.8																				
5.6																				
5.4																				
5.2																				
5.0																				
4.8																				
4.6																				
4.4																				
4.2																				
4.0													X							
3.8												O		X				X		X
3.6											O				X		O		O	
3.4						X		X		O						O				
3.2					O		O		O											
3.0		X		O																
2.8	O		O																	
2.6																				
2.4																				
2.2																				
2.0																				
1.8																				
1.6																				
1.4																				
1.2																				
1.0																				
0.8																				
0.6																				
0.4																				
0.2																				
0.0																				

Key

Pass test at a height O
Fail test at a height X

Data Sheet 2401-1325-DS1

Manufacturer Code: C .
Closure Type: P .
Test Series: 8 O'clock Staircase
Test Start Date: Jul. 17, 2002

Drum #

Drop height	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6.0																				
5.8																				
5.6																				
5.4																				
5.2																				
5.0																				
4.8																				
4.6																				
4.4																				
4.2																				
4.0																				
3.8																				
3.6																		X		X
3.4									X		X				X		O		O	
3.2								O		O		X		O		O				
3.0							O						O							
2.8				X		O														
2.6	X		O		O															
2.4		O																		
2.2																				
2.0																				
1.8																				
1.6																				
1.4																				
1.2																				
1.0																				
0.8																				
0.6																				
0.4																				
0.2																				
0.0																				

Key

Pass test at a height O
Fail test at a height X

Set C Detailed Results

Drum # (SET C)	Height (m)	Position	Result	Comments
1	1.2	6 o'clock	PASS	Preliminary 6 o'clock
2	2	6 o'clock	PASS	Preliminary 6 o'clock
3	3	6 o'clock	FAIL	Preliminary 6 o'clock
4	2.4	6 o'clock	PASS	Preliminary 6 o'clock
5	2.6	6 o'clock	PASS	Preliminary 6 o'clock
6	2.8	6 o'clock	PASS	Preliminary 6 o'clock
7	3	6 o'clock	FAIL	Preliminary 6 o'clock
8	2.8	6 o'clock	PASS	Start of 6 o'clock drop test, SET C
9	3	6 o'clock	FAIL	Cover leaked upon impact
10	2.8	6 o'clock	PASS	
11	3	6 o'clock	PASS	
12	3.2	6 o'clock	PASS	
13	3.4	6 o'clock	FAIL	Break on chime in 2 places
14	3.2	6 o'clock	PASS	
15	3.4	6 o'clock	FAIL	Break on corner of chime
16	3.2	6 o'clock	PASS	
17	3.4	6 o'clock	PASS	
18	3.6	6 o'clock	PASS	
19	3.8	6 o'clock	PASS	
20	4	6 o'clock	FAIL	Very slow leak on chime
21	3.8	6 o'clock	FAIL	Very slow leak from chime in front of cover
22	3.6	6 o'clock	FAIL	Crack on chime
23	3.4	6 o'clock	PASS	
24	3.6	6 o'clock	PASS	
25	3.8	6 o'clock	FAIL	Crack on chime near cover
26	3.6	6 o'clock	PASS	
27	3.8	6 o'clock	FAIL	Splash upon impact, 2 leaks on chime
28	2.8	8 o'clock	FAIL	Preliminary 8 o'clock
29	2.6	8 o'clock	PASS	Preliminary 8 o'clock
30	2.6	8 o'clock	FAIL	Start of 8 o'clock drop test, SET C
31	2.4	8 o'clock	PASS	
32	2.6	8 o'clock	PASS	
33	2.8	8 o'clock	FAIL	Cover leaked upon impact
34	2.6	8 o'clock	PASS	
35	2.8	8 o'clock	PASS	
36	3	8 o'clock	PASS	
37	3.2	8 o'clock	PASS	
38	3.4	8 o'clock	FAIL	Break around cover, chime unfolded
39	3.2	8 o'clock	PASS	
40	3.4	8 o'clock	FAIL	Leakage from deflection close to cover
41	3.2	8 o'clock	FAIL	Leak on cover upon impact
42	3	8 o'clock	PASS	
43	3.2	8 o'clock	PASS	
44	3.4	8 o'clock	FAIL	Leak from cover
45	3.2	8 o'clock	PASS	
46	3.4	8 o'clock	PASS	
47	3.6	8 o'clock	FAIL	Cover and chime leaked at pt of impact
48	3.4	8 o'clock	PASS	
49	3.6	8 o'clock	FAIL	Break on deflected corner of chime
50				Leftover drum, untested

Set C Calculations

SET C - 6 o'clock drops: N = 20, R = 8 therefore R <= N/2

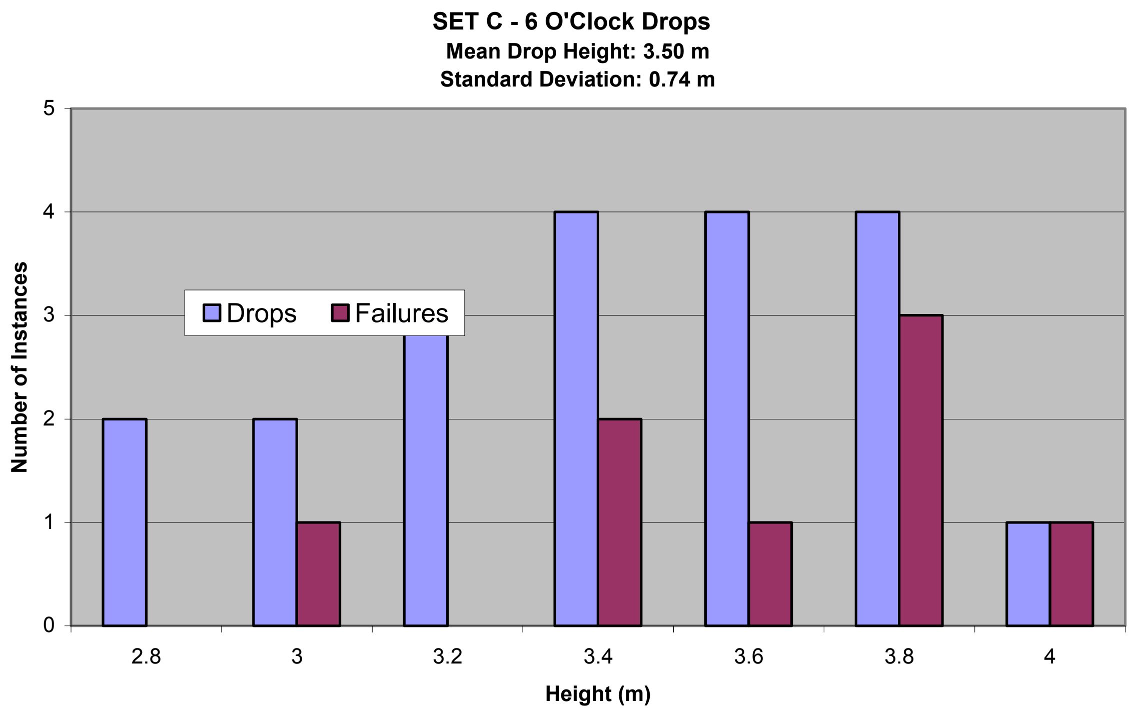
	y (m)	r	j	j^2	r * j	r * j^2
y_0	3	1	0	0	0	0
y_1	3.2	0	1	1	0	0
y_2	3.4	2	2	4	4	8
y_3	3.6	1	3	9	3	9
y_4	3.8	3	4	16	12	48
y_5	4	1	5	25	5	25

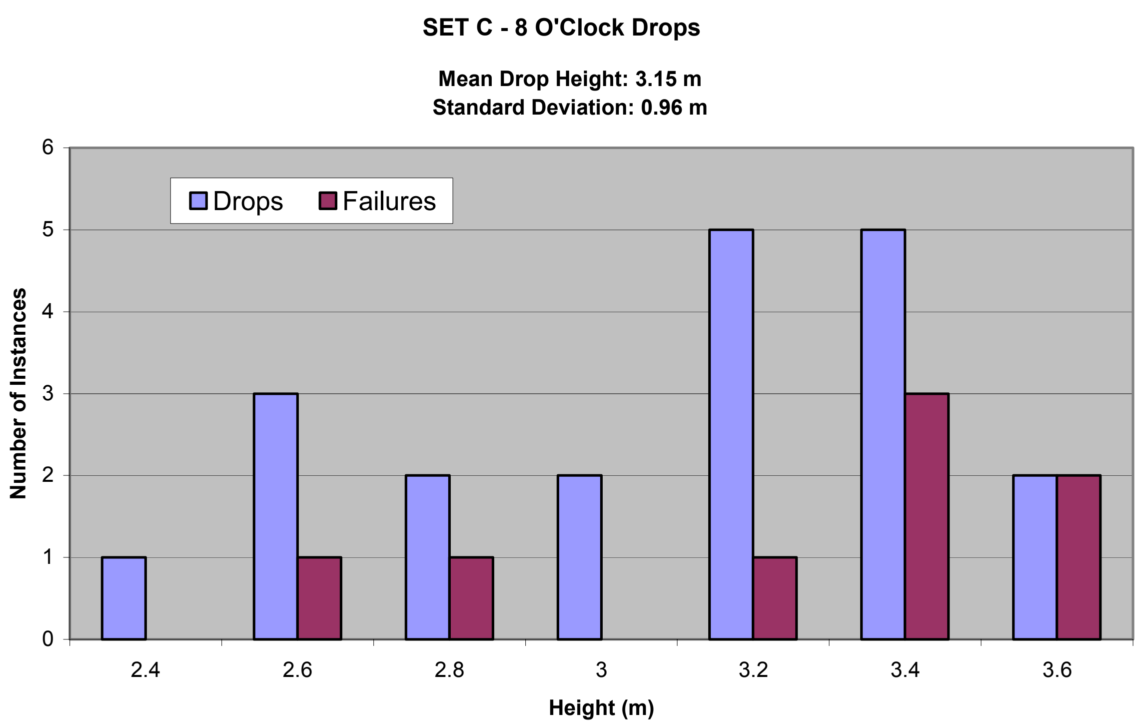
A (sum of all r * j)	**24**
B (sum of all r * j^2)	**90**
m (estimate of the mean, in metres)	**3.50**
s (estimate of standard deviation, in metres)	**0.74**

Set C - 8 o'clock drops: N = 20, R = 8 therefore R <= N/2

	y (m)	r	j	j^2	r * j	r * j^2
y_0	2.6	1	0	0	0	0
y_1	2.8	1	1	1	1	1
y_2	3	0	2	4	0	0
y_3	3.2	1	3	9	3	9
y_4	3.4	3	4	16	12	48
y_5	3.6	2	5	25	10	50

A (sum of all r * j)	**26**
B (sum of all r * j^2)	**108**
m (estimate of the mean, in metres)	**3.15**
s (estimate of standard deviation, in metres)	**0.96**


SET C - 6 O'Clock Drops
Mean Drop Height: 3.50 m
Standard Deviation: 0.74 m
Number of Instances
Drops
Failures
Height (m)
0
1
2
3
4
5
2.8
3
3.2
3.4
3.6
3.8
4


SET C - 8 O'Clock Drops
Mean Drop Height: 3.15 m
Standard Deviation: 0.96 m
Number of Instances
Drops
Failures
Height (m)
0
1
2
3
4
5
6
2.4
2.6
2.8
3
3.2
3.4
3.6

Data Sheet 2401-1325-DS1

Manufacturer Code: D .
Closure Type: P .
Test Series: 6 O'clock Staircase
Test Start Date: Jul. 19, 2002

Drum #

Drop height	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6.0																				
5.8																				
5.6																				
5.4																				
5.2																				
5.0																				
4.8																				
4.6																				
4.4																				
4.2																				
4.0																				
3.8																				
3.6																				
3.4																				
3.2																				
3.0	X		X																	
2.8		O		X		X														
2.6					O		X		X											
2.4								O		X		X								
2.2											O		X							
2.0														X						X
1.8															X				O	
1.6																X		O		
1.4																	O			
1.2																				
1.0																				
0.8																				
0.6																				
0.4																				
0.2																				
0.0																				

Key

Pass test at a height O
Fail test at a height X

Data Sheet 2401-1325-DS1

Manufacturer Code: D .
Closure Type: P .
Test Series: 8 O'clock Staircase
Test Start Date: Jul. 22, 2002

Drum #

Drop height	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6.0																				
5.8																				
5.6																				
5.4																				
5.2																				
5.0																				
4.8																				
4.6																				
4.4																				
4.2																				
4.0																				
3.8																				
3.6																				
3.4																				
3.2																				
3.0																				
2.8						X														
2.6				X*	O		X													
2.4			O					X		X										
2.2		O							O		X									
2.0	O											X		X		X		X		O
1.8													O		O		O		O	
1.6																				
1.4																				
1.2																				
1.0																				
0.8																				
0.6																				
0.4																				
0.2																				
0.0																				

Key

Pass test at a height O
Fail test at a height X

* After drum 4 was dropped, the test personnel neglected to re-set the height measurement and inadvertently tested drum 5 at the same height. It was not felt that the effect on the average would be significant so the data was included.

Set D Detailed Results

Drum # (SET D)	Height (m)	Position	Result	Comments
1	1.2	6 o'clock	PASS	Preliminary 6 o'clock
2	2	6 o'clock	PASS	Preliminary 6 o'clock
3	3	6 o'clock	PASS	Preliminary 6 o'clock
4	3.6	6 o'clock	FAIL	Preliminary 6 o'clock
5	3.2	6 o'clock	FAIL	Preliminary 6 o'clock
6	3	6 o'clock	FAIL	Start of 6 o'clock drop test, SET D
7	2.8	6 o'clock	PASS	
8	3	6 o'clock	FAIL	Leaks on two edges of deflection pattern
9	2.8	6 o'clock	FAIL	Leaks on chime on side away from closure
10	2.6	6 o'clock	PASS	
11	2.8	6 o'clock	FAIL	Leaks on two edges of deflection pattern
12	2.6	6 o'clock	FAIL	Leaks on two edges of deflection pattern
13	2.4	6 o'clock	PASS	
14	2.6	6 o'clock	FAIL	Leak on one edge of deflection pattern
15	2.4	6 o'clock	FAIL	Leak on two edges of deflection pattern
16	2.2	6 o'clock	PASS	
17	2.4	6 o'clock	FAIL	Leak on chime and closure
18	2.2	6 o'clock	FAIL	Leak on chime
19	2	6 o'clock	FAIL	Leak on chime
20	1.8	6 o'clock	FAIL	Leak on chime
21	1.6	6 o'clock	FAIL	Leak on chime
22	1.4	6 o'clock	PASS	
23	1.6	6 o'clock	PASS	
24	1.8	6 o'clock	PASS	
25	2	6 o'clock	FAIL	Leak on chime
26	1.8	8 o'clock	PASS	Preliminary 8 o'clock
27	2	8 o'clock	PASS	Preliminary 8 o'clock
28	2.2	8 o'clock	FAIL	Preliminary 8 o'clock
29	2	8 o'clock	PASS	Start of 8 o'clock drop test, SET C
30	2.2	8 o'clock	PASS	Moisture around closure
31	2.4	8 o'clock	PASS	
32	2.6	8 o'clock	FAIL	Leak on 2 corners of deflection pattern
33	2.6	8 o'clock	PASS	Lost count of drums, did same drop twice
34	2.8	8 o'clock	FAIL	Break on chime
35	2.6	8 o'clock	FAIL	Two leaks on edges of deflection pattern
36	2.4	8 o'clock	FAIL	Splash upon impact; break on chime
37	2.2	8 o'clock	PASS	Splash upon impact
38	2.4	8 o'clock	FAIL	Break on chime away from closure
39	2.2	8 o'clock	FAIL	Vigorous leak no chime upon impact
40	2	8 o'clock	FAIL	Slow leak on chime
41	1.8	8 o'clock	PASS	
42	2	8 o'clock	FAIL	Slow leak on chime
43	1.8	8 o'clock	PASS	
44	2	8 o'clock	FAIL	Slow leak on chime
45	1.8	8 o'clock	PASS	
46	2	8 o'clock	FAIL	Break on one corner of deflection pattern
47	1.8	8 o'clock	PASS	Splash upon impact
48	2	8 o'clock	PASS	Splash upon impact
49	Leftover drums, untested			
50				

Set D Calculations

SET D – 6 o'clock drops: N = 20, R = 13 therefore R > N/2

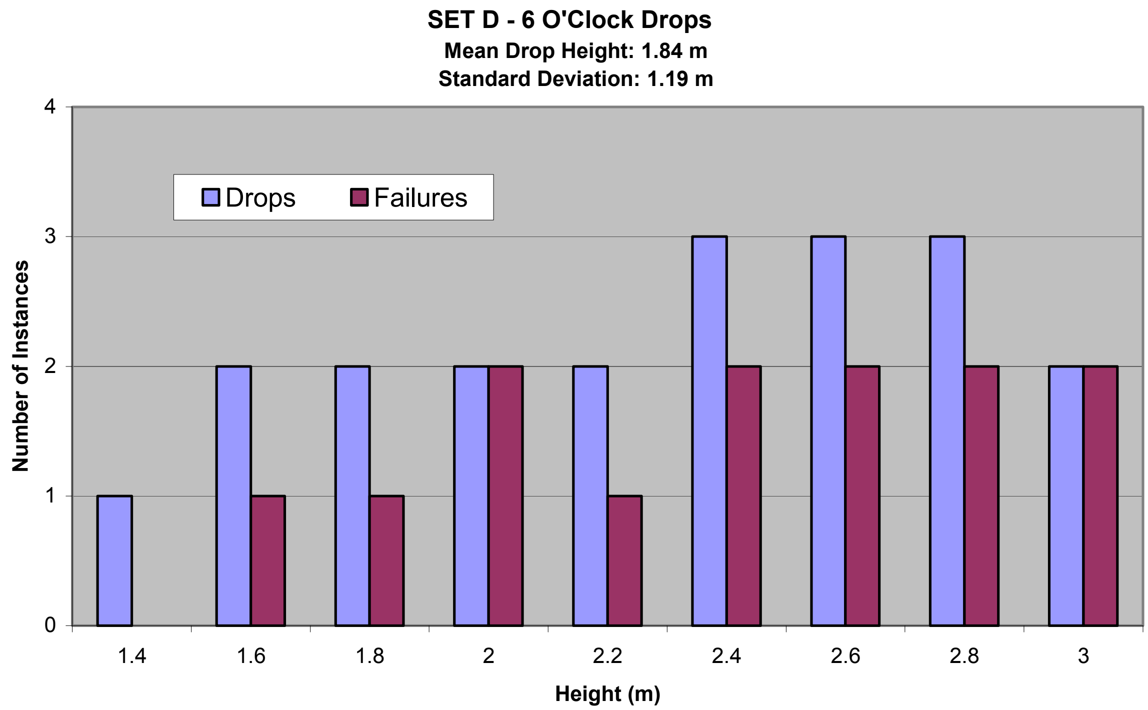
	y (m)	n – r	j	j^2	(n – r) * j	(n – r) * j^2
y_0	1.4	1	0	0	0	0
y_1	1.6	1	1	1	1	1
y_2	1.8	1	2	4	2	4
y_3	2	0	3	9	0	0
y_4	2.2	1	4	16	4	16
y_5	2.4	1	5	25	5	25
y_6	2.6	1	6	36	6	36
y_7	2.8	1	7	49	7	49
y_8	3	0	8	64	0	0

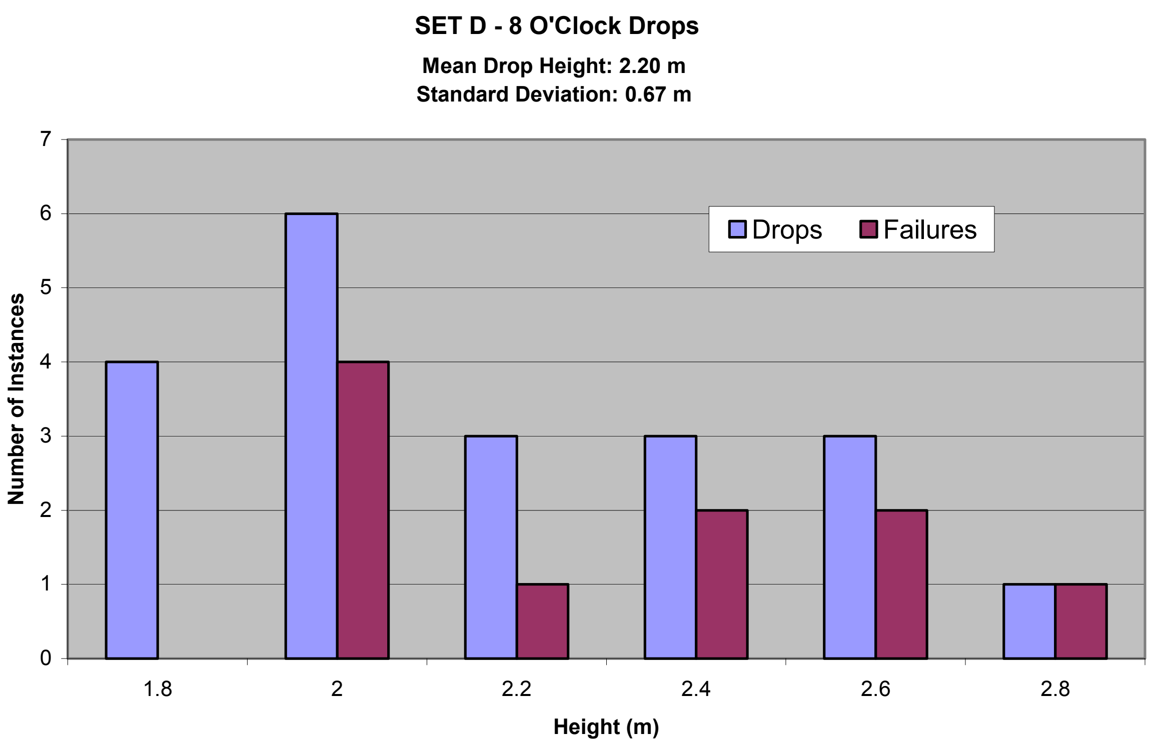
A (sum of all (n – r) * j)	**12**
B (sum of all (n – r) * j^2)	**46**
m (estimate of the mean, in metres)	**1.84**
s (estimate of standard deviation, in metres)	**1.19**

Set D – 8 o'clock drops: N = 20, R = 10 therefore R <= N/2

	y (m)	r	j	j^2	r * j	r * j^2
y_0	2	4	0	0	0	0
y_1	2.2	1	1	1	1	1
y_2	2.4	2	2	4	4	8
y_3	2.6	2	3	9	6	18
y_4	2.8	1	4	16	4	16

A (sum of all r * j)	**15**
B (sum of all r * j^2)	**43**
m (estimate of the mean, in metres)	**2.20**
s (estimate of standard deviation, in metres)	**0.67**


SET D - 6 O'Clock Drops
Mean Drop Height: 1.84 m
Standard Deviation: 1.19 m
Drops
Failures
Number of Instances
Height (m)
0
1
2
3
4
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3


SET D - 8 O'Clock Drops
Mean Drop Height: 2.20 m
Standard Deviation: 0.67 m
Drops
Failures
Number of Instances
Height (m)
0
1
2
3
4
5
6
7
1.8
2
2.2
2.4
2.6
2.8

Data Sheet 2401-1325-DS1

Manufacturer Code: E .
Closure Type: P .
Test Series: 6 O'clock Staircase
Test Start Date: Jul. 23, 2002

Drum #

Drop height	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
6.0																				
5.8																				
5.6																				
5.4																				
5.2																				
5.0																				
4.8																				
4.6																				
4.4													X							
4.2												O		X		X		X		
4.0											O				O		O		X	
3.8										O										O
3.6							X		O											
3.4				X		O		O												
3.2			O		O															
3.0		O																		
2.8	O																			
2.6																				
2.4																				
2.2																				
2.0																				
1.8																				
1.6																				
1.4																				
1.2																				
1.0																				
0.8																				
0.6																				
0.4																				
0.2																				
0.0																				

Key

Pass test at a height O
Fail test at a height X

Data Sheet 2401-1325-DS1

Manufacturer Code: E .
Closure Type: P .
Test Series: 8 O'clock Sstaircase
Test Start Date: Feb. 7, 2003

Drum #

Drop height	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6.0																				
5.8																				
5.6																				
5.4																				
5.2																				
5.0																				
4.8																				
4.6																				
4.4																				
4.2																				
4.0								X												
3.8	X						O		X		X		X							
3.6		X		X		O				O		O		X						
3.4			O		O										X		X		X	
3.2																O		O		O
3.0																				
2.8																				
2.6																				
2.4																				
2.2																				
2.0																				
1.8																				
1.6																				
1.4																				
1.2																				
1.0																				
0.8																				
0.6																				
0.4																				
0.2																				
0.0																				

Key

Pass test at a height O
Fail test at a height X

Set E Detailed Results

Drum # (SET E)	Height (m)	Position	Result	Comments
1	1.2	6 o'clock	PASS	Preliminary 6 o'clock
2	2	6 o'clock	PASS	Preliminary 6 o'clock
3	3	6 o'clock	FAIL	Preliminary 6 o'clock
4	2.8	6 o'clock	PASS	Preliminary 6 o'clock
5	2.8	6 o'clock	PASS	Start of 6 o'clock drop test, SET E
6	3	6 o'clock	PASS	
7	3.2	6 o'clock	PASS	
8	3.4	6 o'clock	FAIL	Fractured chime, caused flooding
9	3.2	6 o'clock	PASS	
10	3.4	6 o'clock	PASS	Slight splash upon impact
11	3.6	6 o'clock	FAIL	Fractured one corner of chime completely
12	3.4	6 o'clock	PASS	
13	3.6	6 o'clock	PASS	
14	3.8	6 o'clock	PASS	
15	4	6 o'clock	PASS	
16	4.2	6 o'clock	PASS	
17	4.4	6 o'clock	FAIL	Large fracture in chime, 18"
18	4.2	6 o'clock	FAIL	Large fracture in chime, 14"
19	4	6 o'clock	PASS	
20	4.2	6 o'clock	VOID	Drum flipped over and landed sideways
21	4.2	6 o'clock	FAIL	Large fracture in chime, 25"
22	4	6 o'clock	PASS	
23	4.2	6 o'clock	FAIL	Large fracture in chime
24	4	6 o'clock	FAIL	Bottom chime leaked due to crack
25	3.8	6 o'clock	PASS	
26		8 o'clock		Retained sample of 2nd batch
27	3.4	8 o'clock	PASS	Preliminary 8 o'clock
28	3.6	8 o'clock	PASS	Preliminary 8 o'clock
29	3.8	8 o'clock	FAIL	(Start 8 o'clock) Leaks at chime and cap
30	3.6	8 o'clock	FAIL	Crack at fold in top
31	3.4	8 o'clock	PASS	
32	3.6	8 o'clock	FAIL	Leak at fold
33	3.4	8 o'clock	PASS	
34	3.6	8 o'clock	PASS	
35	3.8	8 o'clock	PASS	
36	4	8 o'clock	FAIL	Leak at large closure (after venting)
37	3.8	8 o'clock	FAIL	Leak at large closure (after venting)
38	3.6	8 o'clock	PASS	
39	3.8	8 o'clock	FAIL	Leak at chime
40	3.6	8 o'clock	PASS	
41	3.8	8 o'clock	FAIL	Leak at chime
42	3.6	8 o'clock	FAIL	Leak at chime
43	3.4	8 o'clock	FAIL	Leak at fold above impact pt.
44	3.2	8 o'clock	PASS	
45	3.4	8 o'clock	FAIL	Leak at chime
46	3.2	8 o'clock	PASS	
47	3.4	8 o'clock	FAIL	Leak at chime
48	3.2	8 o'clock	PASS	
49	Leftover drums, untested			
50				

Set E Calculations

SET E - 6 o'clock drops: N = 20, R = 7 therefore R <= N/2

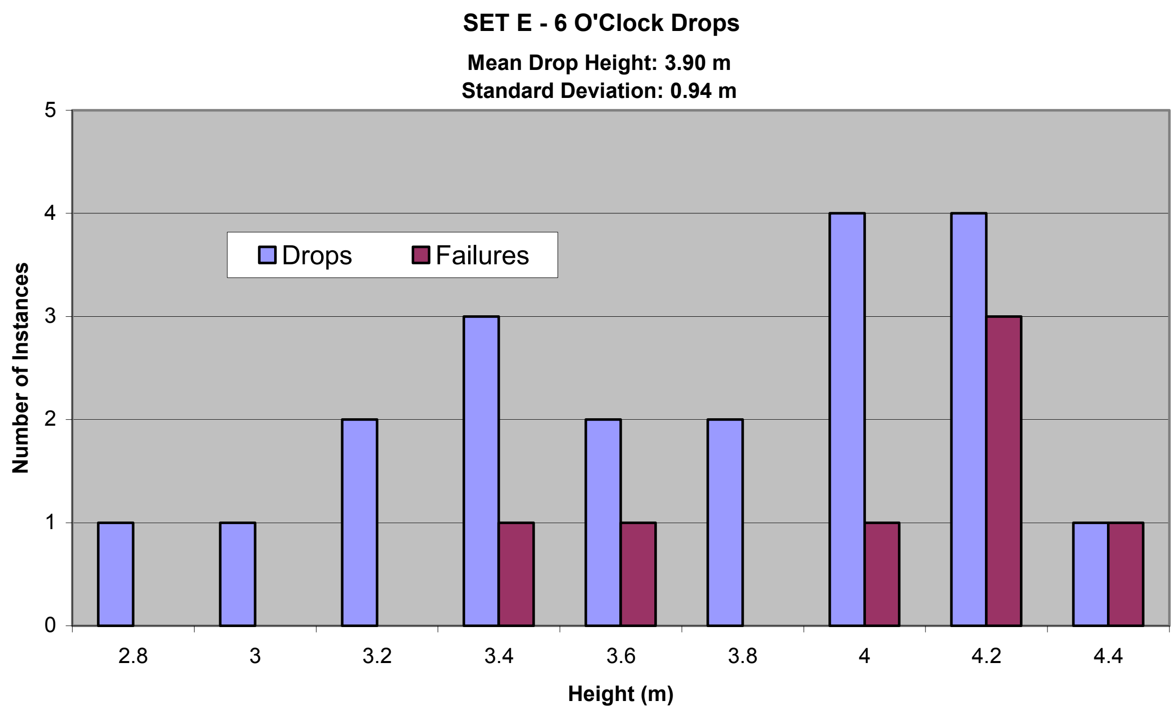
	y (m)	r	j	j^2	r * j	r * j^2
y_0	3.4	1	0	0	0	0
y_1	3.6	1	1	1	1	1
y_2	3.8	0	2	4	0	0
y_3	4	1	3	9	3	9
y_4	4.2	3	4	16	12	48
y_5	4.4	1	5	25	5	25

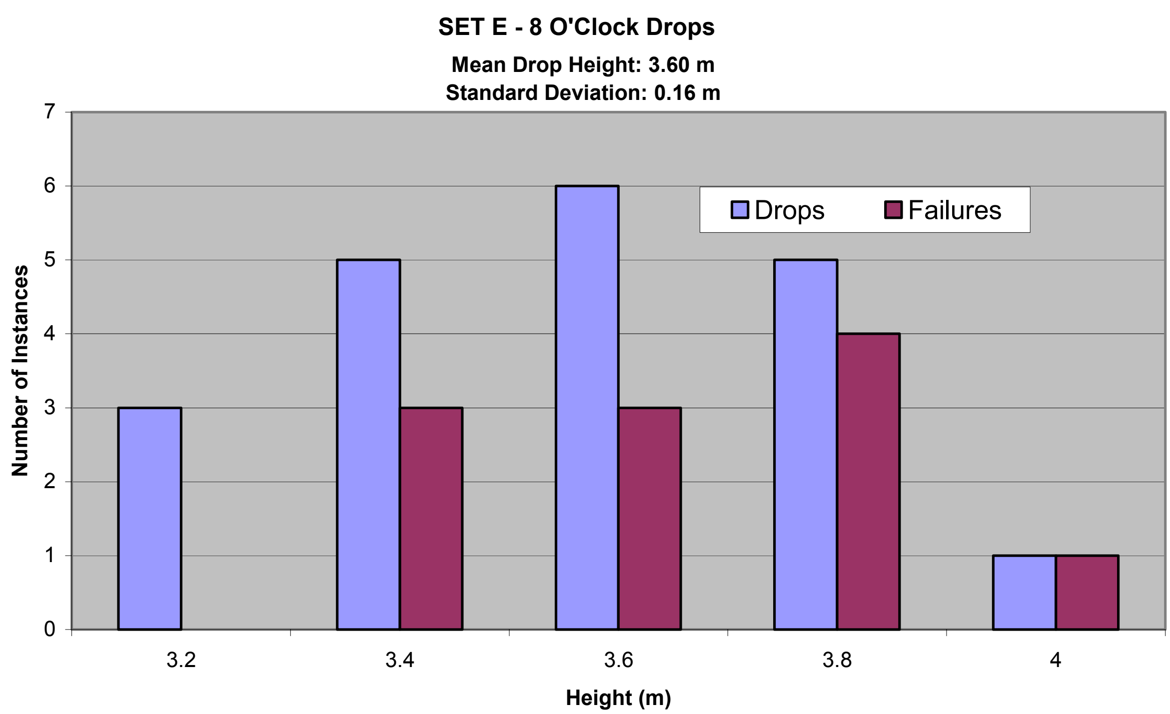
A (sum of all r * j)	**21**
B (sum of all r * j^2)	**83**
m (estimate of the mean, in metres)	**3.90**
s (estimate of standard deviation, in metres)	**0.94**

Set E - 8 o'clock drops: N = 20, R = 11 therefore R > N/2

	y (m)	n - r	j	j^2	(n - r) * j	(n - r) * j^2
y_0	3.2	3	0	0	0	0
y_1	3.4	2	1	1	2	2
y_2	3.6	3	2	4	6	12
y_3	3.8	1	3	9	3	9
y_4	4	0	4	16	0	0

A (sum of all r * j)	**11**
B (sum of all r * j^2)	**23**
m (estimate of the mean, in metres)	**3.32**
s (estimate of standard deviation, in metres)	**0.36**


SET E - 6 O'Clock Drops
Mean Drop Height: 3.90 m
Standard Deviation: 0.94 m
Number of Instances
Drops
Failures
Height (m)
0
1
2
3
4
5
2.8
3
3.2
3.4
3.6
3.8
4
4.2
4.4


SET E - 8 O'Clock Drops
Mean Drop Height: 3.60 m
Standard Deviation: 0.16 m
Number of Instances
Drops
Failures
Height (m)
0
1
2
3
4
5
6
7
3.2
3.4
3.6
3.8
4

Data Sheet 2401-1325-DS1

Manufacturer Code: F .
Closure Type: Q .
Test Series: 6 O'clock Staircase
Test Start Date: Mar. 17, 2003

Drum #

Drop height	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6.0																				
5.8	X						X													
5.6		X		X		O		X				X				X				X
5.4			O		O				X		O		X		O		X		O	
5.2										O				O				O		
5.0																				
4.8																				
4.6																				
4.4																				
4.2																				
4.0																				
3.8																				
3.6																				
3.4																				
3.2																				
3.0																				
2.8																				
2.6																				
2.4																				
2.2																				
2.0																				
1.8																				
1.6																				
1.4																				
1.2																				
1.0																				
0.8																				
0.6																				
0.4																				
0.2																				
0.0																				

Key

Pass test at a height O
Fail test at a height X

Data Sheet 2401-1325-DS1

Manufacturer Code____F____.
Closure Type: __Q__.
Test Series: __8 O'clock Staircase
Test Start Date: _Mar. 17, 2003

Drum #

Drop height	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6.0																				
5.8																				
5.6																				
5.4																				
5.2																				
5.0																				
4.8																				
4.6						X								X		X				O
4.4	X		X		O		X		X		X		O		O		X		O	
4.2		O		O				O		O		O						O		
4.0																				
3.8																				
3.6																				
3.4																				
3.2																				
3.0																				
2.8																				
2.6																				
2.4																				
2.2																				
2.0																				
1.8																				
1.6																				
1.4																				
1.2																				
1.0																				
0.8																				
0.6																				
0.4																				
0.2																				
0.0																				

Key

Pass test at a height: O
Fail test at a height: X

Set F Detailed Results

Drum # (SET F)	Height (m)	Position	Result	Comments
1	3	6 o'clock	PASS	Preliminary 6 o'clock
2	4	6 o'clock	PASS	Preliminary 6 o'clock
3	4.4	6 o'clock	PASS	Preliminary 6 o'clock
4	4.7	6 o'clock	PASS	Preliminary 6 o'clock
5	5.4	6 o'clock	PASS	Preliminary 6 o'clock
6	5.8	6 o'clock	FAIL	(Start 6 o'clock) Leak at chime
7	5.6	6 o'clock	FAIL	Leak at chime
8	5.4	6 o'clock	PASS	
9	5.6	6 o'clock	FAIL	Leak at chime
10	5.4	6 o'clock	PASS	
11	5.6	6 o'clock	PASS	
12	5.8	6 o'clock	FAIL	Leak at chime
13	5.6	6 o'clock	FAIL	Leak at chime
14	5.4	6 o'clock	FAIL	Leak at chime (after vent)
15	5.2	6 o'clock	PASS	
16	5.4	6 o'clock	PASS	
17	5.6	6 o'clock	FAIL	Leak at chime
18	5.4	6 o'clock	FAIL	Leak at chime (after vent)
19	5.2	6 o'clock	PASS	
20	5.4	6 o'clock	PASS	
21	5.6	6 o'clock	VOID	Rolled, landed on back
22	5.6	6 o'clock	FAIL	Leak at chime (after vent)
23	5.4	6 o'clock	FAIL	Leak at chime
24	5.2	6 o'clock	PASS	
25	5.4	6 o'clock	PASS	
26	5.6	6 o'clock	FAIL	Leak at chime
27	4.8	8 o'clock	FAIL	Preliminary 8 o'clock
28	4.6	8 o'clock	PASS	Preliminary 8 o'clock
29	4.4	8 o'clock	FAIL	(Start 8 o'clock) Leak at large closure
30	4.2	8 o'clock	PASS	
31	4.4	8 o'clock	FAIL	Leak at large closure (after venting)
32	4.2	8 o'clock	PASS	
33	4.4	8 o'clock	PASS	
34	4.6	8 o'clock	FAIL	Leak at large closure (after venting)
35	4.4	8 o'clock	FAIL	Leak at large closure (after venting)
36	4.2	8 o'clock	PASS	
37	4.4	8 o'clock	FAIL	Leak at large closure
38	4.2	8 o'clock	PASS	
39	4.4	8 o'clock	FAIL	Leak at large closure (after venting)
40	4.2	8 o'clock	PASS	
41	4.4	8 o'clock	PASS	
42	4.6	8 o'clock	FAIL	Leak at large closure
43	4.4	8 o'clock	PASS	
44	4.6	8 o'clock	FAIL	Leak at large closure (after venting)
45	4.4	8 o'clock	FAIL	Leak at large closure (after venting)
46	4.2	8 o'clock	PASS	
47	4.4	8 o'clock	PASS	
48	4.6	8 o'clock	PASS	
49	Leftover drums, untested			
50				

Set F Calculations

SET F - 6 o'clock drops: N = 20, R = 11 therefore R > N/2

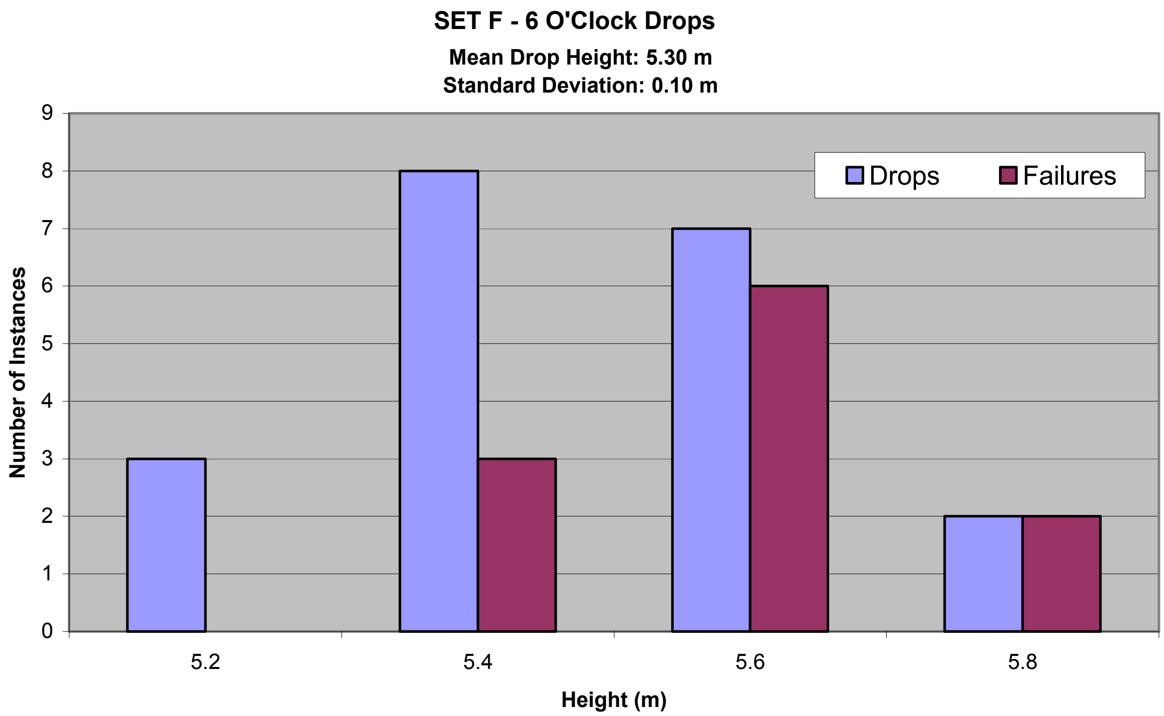
	y (m)	n - r	j	j^2	(n - r) * j	(n - r) * j^2
y_0	5.2	3	0	0	0	0
y_1	5.4	5	1	1	5	5
y_2	5.6	1	2	4	2	4
y_3	5.8	0	3	9	0	0

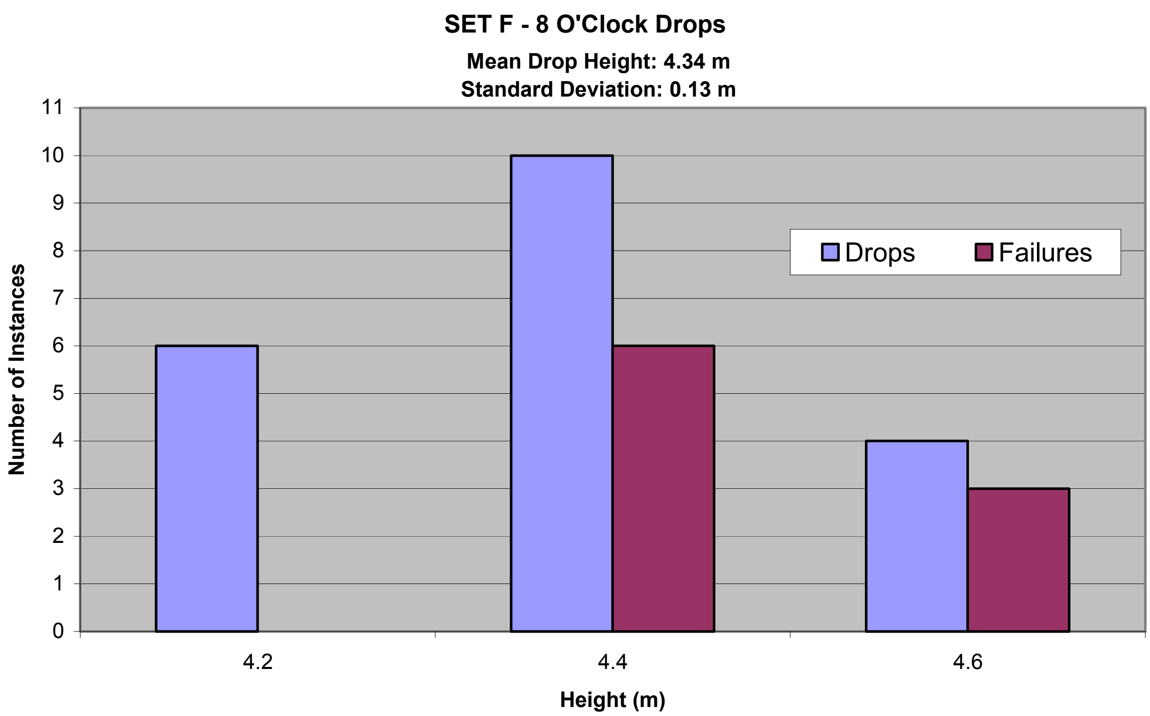
A (sum of all r * j)	**7**
B (sum of all r * j^2)	**9**
m (estimate of the mean, in metres)	**5.30**
s (estimate of standard deviation, in metres)	**0.10**

Set E - 8 o'clock drops: N = 20, R = 10 therefore R <= N/2

	y (m)	r	j	j^2	r * j	r * j^2
y_0	4.2	0	0	0	0	0
y_1	4.4	6	1	1	6	6
y_2	4.6	3	2	4	6	12

A (sum of all r * j)	**12**
B (sum of all r * j^2)	**18**
m (estimate of the mean, in metres)	**4.34**
s (estimate of standard deviation, in metres)	**0.13**


SET F - 6 O'Clock Drops
Mean Drop Height: 5.30 m
Standard Deviation: 0.10 m
Number of Instances
Drops
Failures
Height (m)
0
1
2
3
4
5
6
7
8
9
5.2
5.4
5.6
5.8


SET F - 8 O'Clock Drops
Mean Drop Height: 4.34 m
Standard Deviation: 0.13 m
Number of Instances
Drops
Failures
Height (m)
0
1
2
3
4
5
6
7
8
9
10
11
4.2
4.4
4.6

APPENDIX C

Calibration Certificate

PYLON ATLANTIC
201 Wright Avenue, Dartmouth,
NS B3B 1V6

www.pylonelectronics.com

PYLON
Calibration Technologies

CERTIFICATE OF CALIBRATION

Purchase Order	VISA		**Customer Name**	NRC-CSTT
Certificate Number	1001042426	WO#C51405	**Instrument Id**	02-1998
Model Number	0-1000 LBS		**Cal Procedure**	33K6-4-874-1
Serial Number	D19844		**Cal Date**	18 Jul 2002
Description	DYNAMOMETER		**Recall Cycle**	52 Weeks
Manufacturer	DILLON		**Next Cal Date**	18 Jul 2003

Received Condition : Within Tolerance

Completed Condition : Full Calibration

Environmental Conditions : Lab Temperature 20°C Lab Humidity 43%

Remarks Cal'd as per manufacturer specs.

STANDARDS USED TO ESTABLISH TRACEABILITY

Instrument Type	Model	Asset #
LOADCELL 5K LBF	T3P1	G572
CALIBRATION MACHINE 60K	NIL	G646

INVENTORY #02-1998

Pylon certifies that, at the time of calibration, the above listed instrument meets or exceeds all of the specifications defined in the calibration procedure(s) or specification(s) referenced on the TDS. The received and final conditions specified above and the TDS specifications are based on the procedure referenced on the TDS unless otherwise indicated. The above listed instrument has been calibrated using standards whose calibrations are traceable to the National Research Council of Canada (NRC), the National Institute of Standards and Technology (NIST) and/or other recognised international standards. Unless otherwise specified, Pylon maintains a minimum of a 4:1 ratio between the equipment under test and the measurement system.

Pylon's Electrical and Physical Properties Laboratories meet the requirements of D-QA-001-002/SF-001 for ambient temperature, relative humidity and cleanliness. Equipment is maintained by procedures that meet the requirements of ISO 9002 and ISO 10012-1.

This report consists of 2 parts with seperate page numbering schemes; the Certificate of Calibration and the Test Data Sheet(s) (TDS). Copyright of this report is owned by the issuing laboratory and may not be reproduced, other than in full, except with the prior written approval of the issuing laboratory.

Metrologist : *Craig Manuel*	Quality Assurance	JUL 18 2002 Date

FM095 Rev4