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Diving helmet impact testing to EN397

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Diving helmet impact testing to EN397

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Diving helmets used today by the majority of commercial divers in the UK are developed from the Standard Diving Dress of over 40 years ago. These brass helmets provided a large space around the head and fitted onto a yoke on the diver's shoulders. Any impact would have been taken on the shoulders rather than onto the head and neck. Commercial divers regularly work on sites where lifting operations are being conducted and these pose a head impact hazard both on the surface and underwater. However, most, if not all, diving helmets have not been tested to determine the level of head protection they provide. The recent introduction of the standard BS EN 15333 for Surface Supplied Diving Apparatus requires that helmets made to this standard should be classified as offering head protection to one of three classes:

- Class A: Head protection to BS EN397: the current European Standard for the Specification for Industrial Safety Helmets.
- Class B: Bump protection to BS EN812: the current Bump Hat Standard.
- Class C: No protection.

The aim of this research project was to investigate the level of protection current commercial diving helmets provide. The number of helmets available for this was limited to three from the same manufacturer. However, the results are considered to be broadly representative of helmets used in the diving industry today as one manufacturer makes most of the helmets used in the industry. Testing was carried out using the calibrated Rosand drop rig of the HSL Mechanical Engineering Section and filmed using high-speed video cameras of HSL Visual Presentation Services Section.

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Atlas Marine, for the donation of two Kirby Morgan MK17B helmet shells.

CONTENTS

EXECUTIVE SUMMARY

Objectives

To carry out impact testing on industry standard diving helmets to BS EN 397 and BS EN 812, which is a normative reference, included in BS EN 15333.

Main Findings

The helmet's shell provides protection within the requirements of BS EN 397 and BS EN 812 and provides Class A protection in accordance with BS EN 15333.

1 INTRODUCTION

Diving helmets used today by the majority of commercial divers in the UK are developed from the Standard Diving Dress of over 40 years ago. These brass helmets provided a large space around the head and fitted onto a yoke on the diver's shoulders. Any impact would have been taken on the shoulders rather than onto the head and neck. Commercial divers regularly work on sites where lifting operations are being conducted and these pose a head impact hazard both on the surface and underwater. However, most, if not all, diving helmets have not been tested to determine the level of head protection they provide. The recent introduction of the standard BS EN 15333 for Surface Supplied Diving Apparatus requires that helmets made to this standard should be classified as offering one of three classes:

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2 DIVER HELMET CONSTRUCTION

Two of the helmets used in this trial were from a previous investigation into unauthorised modifications to the helmet shells. This modification was to the area where the demand valve assembly is connected to the lower front of the helmet. As the shells were no longer suitable for in water use the owners offered HSE the helmets for this trial.

The helmet shell is hand made from a layered glass fibre cloth, which is reinforced with thermal setting polyester and measuring an average thickness of 5.37mm. The diver wears a cotton hood that is attached to the shell by means of four popper studs: two to the cheek area and two to the rear. The hood has internal pockets that are filled with open celled foam, which can be of a variety of thicknesses. This system allows the diver’s dresser to position the shell correctly and comfortably onto the diver by means of adding or removing foam from various areas of the head cushion. The standard thickness of the foam supplied with the head cushion is 35mm. The foam is cut from egg box style foam and, being of an open celled construction, is not affected by compression as the diver descends in the water and the corresponding increase in ambient pressure to which the diver is subjected.

The shell has a number of brass weights attached to the helmet as well as a brass handle; these are to counteract the buoyancy as the helmet when the diver is in the water. The weight on the diver’s right hand cheek side is smaller than the left hand cheek due to the fitment of the gas supply block. The weights are attached with screws through the shell and the screws are also used for attaching popper studs that secure the head cushion to the inside of the helmet. To ensure the screw openings are watertight the weights are sealed using a silicone sealant, which is also applied to the handle fixing point at the crown of the helmet. The handle is mounted via a screw to the crown of the shell and has a further three openings that allow screws to secure the handle to the top of the faceplate and visor. All the screws that attach the faceplate to the helmet are tightened to a specific torque recommended by the manufacturer. The faceplate is a Perspex sheet that seals to the helmet by means of an o-ring situated within an indent to the front of the helmet shell.

As the handle to the top of the helmet would be taking the brunt of most impacts, a local firm was contracted to cast a number of spare handles to enable consistent testing on the few shells. The diving helmet side weights and neck dam and clamp assembly were not fitted to the shells for these tests. All the threaded inserts for the faceplate of helmet A were missing and 10 of the 15 were missing from helmet B. It is not known why these inserts were missing. However, it was deemed a requirement to fit the inserts, as this would affect the rigidity of the shell by supporting the faceplate port retainer and lens. The cost to the project to replace these inserts with manufacturer-supplied items was prohibitive. As the helmets would not be used again for their intended purpose and similar inserts were available at the laboratory’s workshop, it was decided to use these workshop inserts. Two-part epoxy glue was used to secure the inserts to the openings in the shell. It was noted after the first series of tests that the faceplate screws loosened as the tests proceeded. This was probably due to the screws not being torqued correctly as the screws were just to hold the faceplate port retainer in place. On the second series of tests the screws were torqued to the correct amount, which did have a small effect on the results obtained.

3 TEST METHODS

BS EN 397 and BS EN 812 have eight mandatory tests. These would normally use one helmet for each test, as after an impact a standard surface worker's helmet would be discarded. However, this was not possible due to the limited number of diving helmets available. Therefore shell A was used for the impact testing and shell B for the penetration testing. The 8 mandatory tests required by both these standards are:

- Impact protection test at -10$^{\circ C}$;
- Impact protection test, following water immersion;
- Impact protection test at +50°C;
- Impact protection test, following artificial ageing;
- Resistance to penetration test at -10°C;
- Resistance to penetration test, following water immersion;
- Resistance to penetration test +50°C;
- Resistance to penetration test, following artificial ageing.

The optional tests differ slightly, for Industrial safety helmets:

- 2 helmets for shock absorption and resistance to penetration tests, following exposure to very low temperatures;
- 2 helmets for shock absorption and resistance to penetration tests, following exposure to very high temperatures;
- 1 helmet for each of the 3 electrical properties tests;
- 1 helmet for lateral deformation test;
- 1 helmet for molten metal splash test;

Whereas the bump hat requires only:

- 2 bump caps for the low temperature tests;
- 1 bump cap for each of the three electrical properties tests;
- 1 bump cap for a flame resistance test;

The mandatory tests required by both these standards are almost identical, with those required by BS EN 397 being the most stringent. Therefore, due to the limited number of shells available, only the following tests were conducted.

- Impact protection (at ambient temperature);
- Impact protection following water immersion;

- Resistance to penetration.

3.1 IMPACT TEST SET UP

A steel hemispherical striker (Image a.) having a radius of 50mm and a mass of 1.3kg was machined to comply with the requirements of the standard, and this was added to the holder mass of 4.2kg of the drop rig assembly of the Rosand rig. The required drop height to give the correct impact force of 50-joule impact on the helmet was calculated to be 0.927m. The Rosand rig is fitted with a number of sensors to provide data from the tests. There is a Piezo electronic sensor in the striker to measure the force as the striker hits an object. A load cell is also in the striker to measure the energy applied to the object being struck. This also provides a further stream of data to show how far the item being struck moves after the impact has taken place. The rig also calculates the acceleration of the striker from information about the mass of the striker and impactor. A second separate calibrated load cell was placed in the column between the head form and base of the rig to measure the force of the impact applied to the head form.

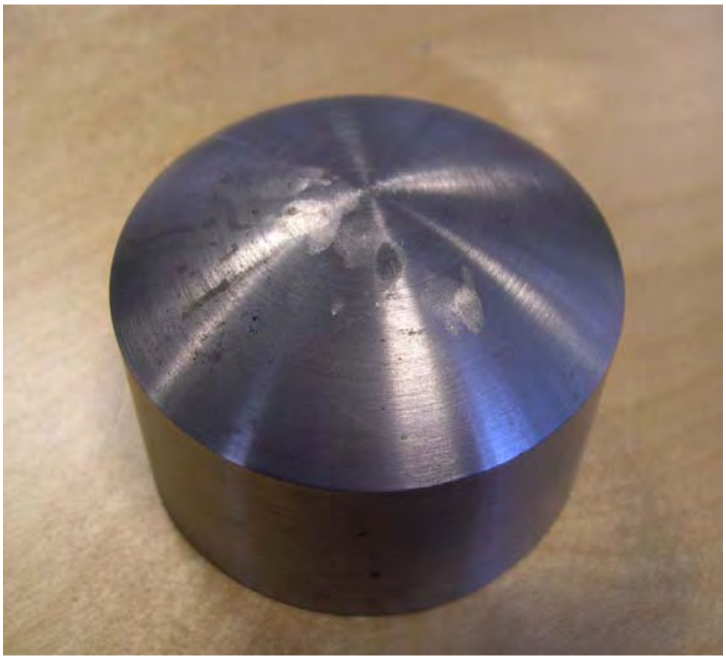


Image a. 1.3kg impactor.

The results from all the impacts were collated to provide a graph, which is in section 7.

To ensure that the test set up was correct a number of “time expired” surface work helmets were initially tested in the test rig. These helmets gave a base reading to permit comparison with the results obtained from diving helmets, allowed the head form to be positioned correctly and confirmed the timings of the high-speed camera initiators ensuring that the impact was filmed.

3.2 PENETRATION TEST SET UP

A steel cone (Image b) with a 60^0 angle of point and a radius point of 0.5mm was produced for the penetration tests. The striker was connected to the Rosand rig for the tests and a number of “time expired” surface work helmets used to confirm settings were correct. This striker was to impact the test helmet with a measured energy value of 30-joules, which was lighter than the previous run of tests. The combined mass with the rig came to 4.912kg and it was calculated that the striker would have a drop of 0.66m to reach the 30-joule energy value required for the impact.

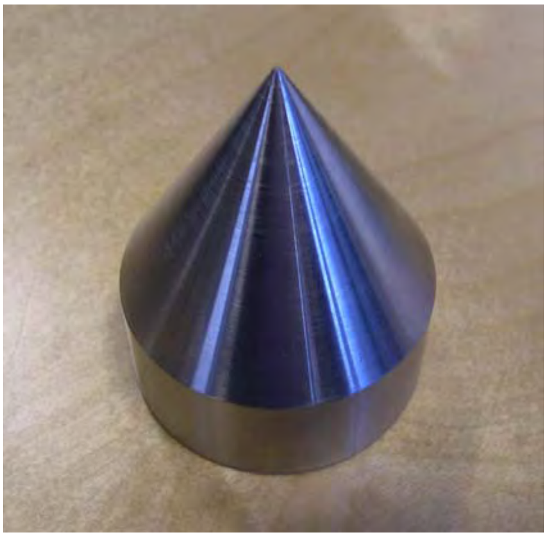


Image b. 0.412kg penetrator.

3.3 TEST CONDUCT

For all the tests the helmets were mounted onto a standard head form securely mounted within the rig frame (images c and d). On initially mounting the diving helmet on the head form it was found that the balance of the diving helmet was such, that even with the chin strap in place, the diving helmet would move forward to a point where the lower front edge would rest on, or below, the chin. Therefore a counterbalance weight was rigged to keep the diving helmet upright.

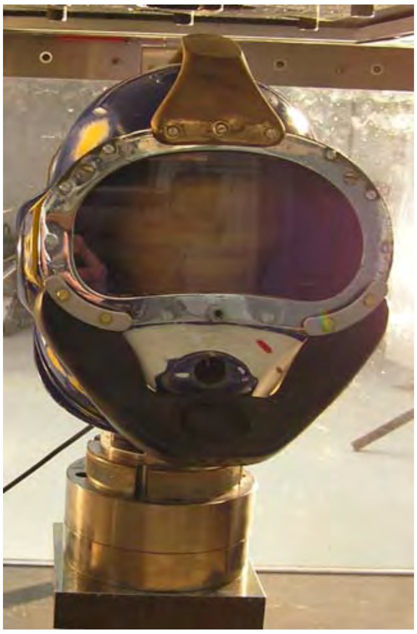


Image c. Diving helmet on the head form.

Image d. Impactor being positioned prior to a test.

The position for the impacts required by the standard are at the centre of the crown. This would be to the brass handle area. To investigate the force sent through the shell some offset impacts that missed the brass handle were also undertaken. These offset impacts are shown as some of the lower readings in the resulting data. The site of the impacts to the handle could be seen by a change in patina of the handle's surface. Those to the shell could be seen by the fine cracking to the gel coat and covering paint. There did appear to be some indentation to the area where the handle attaches to the shell as well as to the shell where direct impacts had taken place. To compare the effectiveness of the standard foam inserts in the divers hood, two different thicknesses of foam supplied from the laboratory's samples were used. One was a 45mm egg box style foam and the other a 65mm block foam. As the different foams changed the distance from the headform of the shell the striker was required to be re-zeroed prior to each test.

One request from the project customer was to have a shell preconditioned by immersed in water as per one of the mandatory tests of the testing regime to see if this made any difference to the tests. The diving helmet shell and faceplate assembly was placed in the PPE water tank for 4 hours at 20^{o} C prior to having the cushion reinserted and being fitted to the Rosand rig.

4 TEST RESULTS

4.1 IMPACT TESTS

In total 15 impact tests were carried out on the diving helmet A, 8 of these during the first batch of tests. For the first three the standard 35mm thick foam was fitted into the head cushion. On the fourth test 45mm egg box foam, which appears to be more resilient, was put into the head cushion for one test then for the fifth a block of 65mm foam was inserted. The standard foam was re-inserted into the hood for tests 6 to 8. As these foam materials could potentially be affected by compression at depth. They were placed in the HSL diving section's pressure chamber and subjected to 9-bar pressure to investigate if there was any compression.

During this compression trial no change in the thickness of the foam was observed, indicating that all foams were of an open cell construction and would not be affected by changes in ambient pressure. When the different thickness of foam was inserted, the height of the diving helmet on the head form was changed and the start position for a test was then adjusted to ensure a consistent drop height. The load cell results show a small rise in the force passing through the diving helmet with the 45mm foam inserted into the head cushion. The next impact with the 65mm foam in place again generated a slightly higher reading as seen in the first graph (Figure a) of section 7. With the standard foam back in the head cushion the impact force was again reduced indicating that the manufacturer's foam is superior to the foam supplied by the laboratory. The readings of the eighth impact are close to the results seen on the standard workers helmets. However, this may be explained by the fact that the impact to the diving helmet is away from the handle and was a glancing blow leading to the diving helmet falling away to one side.

After the water immersion of the diving helmet a series of four further impacts were carried out. On these tests, the faceplate screws had been tightened to the correct torque as laid down in chapter 8 of the manufacturer's manual. On the first impact there was a noticeable change in the sound when the striker impacted the diving helmet. On comparing the video footage there was less flexing of the diving helmet shell than had been seen in the earlier run of tests. The measurements also showed an increase in force being transmitted through to the head form. This would also raise the question of whether the fitment of the brass weight to the side of the diving helmet and the neck clamp ring would also increase the rigidity of the shell and allow more of the impact force to be transmitted into the head form.

From all the series of 50-Joule impacts only one was above the 5,0kN limit required by the standard, this strike was with the non-standard 45mm foam inserted within the head cushion. Therefore the diving helmet with the standard foam meets the impact requirement for the test. When comparing the diving helmet and surface work helmet readings taken at the load cell the surface work helmet were consistently of a lower value to those for the dive helmet; even when one work helmet was struck five times there was no change in the readings. However, one of the surface work helmets did fail after being struck twice. After the first impact the frame of the work helmet did show distinctive changes of colour in the frame. These then corresponded to the failure points on the second impact.

Apart from the marks to the handle the only other indication of impacts on the shell of the diving helmet was circular crazing to the outside gel coat of the shell. Therefore it would be difficult to tell if the shell would be able to withstand a subsequent impact without failing. Nevertheless this shell withstood fourteen separate impacts and only one of these went over the 5,0kN limit, and this test was conducted without the standard foam fitted.

4.2 PENETRATION TESTS

The penetration tests were carried out on the second of the shells. This required the swapping of the faceplate and cushion retainers from the other shell. As with the previous test runs a number of standard surface work helmets were initially used to check the set up of the camera and logging systems. The first standard work helmet when subjected to the test ended up with a small hole in the shell, with second and third impact marks in the shell material from where the impactor bounced. The second standard work helmet also suffered a puncture of the shell from the impact. The third standard work helmet, which was of a different make, was not punctured though an indent in the material was visible.

The diver's helmet was positioned to face the camera; this did not allow for close inspection of the impact point in filming. Also, to ensure the striker point was not damaged, all impacts were aimed at the shell and away from the brass handle. Therefore no impacts were taken directly to the crown of the helmet. Following the first run and when the striker had been placed back in the safe position, the diving helmet was inspected and the mark made was significant. The impact crater (image e.) shows that the striker has passed into the fabric of the shell but there are no radiating fractures.

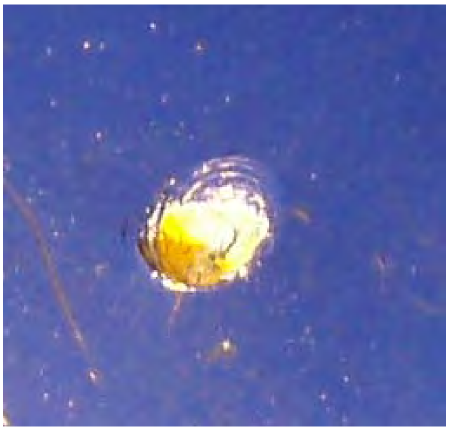


Image e. First impact of penetrator.

During later impacts two strikes were adjacent and damage between the two is visible in the gel coat of the shell (image f.).

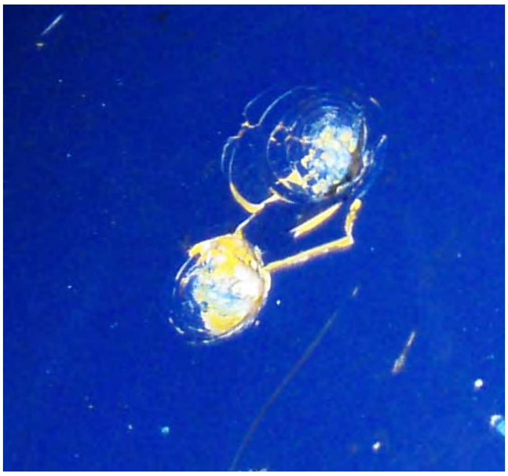


Image f. Two neighbouring impacts and damage in between.

After the tests the head cushion was removed and there was visible evidence of white marks (images g and h) where the impacts had occurred on the inside of the helmet shell, possibly where the shell had started to delaminate. Without the full diving helmet equipment being available to fit onto the shell it was not possible to test the shell to see if the integrity had been maintained for diving use.

Image g and h. Internal surface marking from penetration testing.

4.3 GRAPHICAL RESULTS

The results from all the impacts were converted into graphical form for easy comparison between the results. These are shown in the Appendix of this report.

The first chart Graph a shows the maximum impact force measured at the calibrated load cell placed in the stack below the head form. These are the individual maximum readings for each impact. The results for work helmets indicates a fairly consistent reading of a force below 2kN except for run 5 where a lower drop height of 0.3m was trialled and run 14, which indicate a force of 2.5kN. As for the diving helmets the forces measured were between 3kN and 4.5kN apart from runs 8 and 11 where the helmet and head form fell from the stack due to the slightly offset impact. Run 13 was the only impact out of all the tests, which went over the 5kN limit. This impact has the slightly thicker non-standard 45 mm foam inserted into the head cushion as well as having the faceplate screws torqued correctly.

In all but one run the measured force is lower in the work helmet than that of the dive helmet. Also, where the dive helmet reading is shown as lower than the work helmet the impact to the dive helmet is a glancing blow and the helmet topples off the stack with the load cell within.

As per the 50-joule impacts it can be seen that the dive helmet is not as effective as the work helmet for dissipating the force of an impact. However, all but one of the impacts in the 50-joule runs are successfully within the limit.

The second chart Graph b shows the maximum amount of movement each of the impacts caused to the helmets. The results are similar to those as seen from the load cell, which would indicate that the distance moved, and the amount of energy transmitted to the load cell is comparable. Graph c shows the acceleration of the helmet as the impact takes place. Impact 14 in the series of work helmets has a far higher result compared to the other work helmet tests. On examining the video footage of the run it can be seen that the helmet's internal frame had not been adjusted correctly and the helmet does remain pushed down on the head form following the impact.

Graph d shows a single impact from run 9 of the dive and work helmet runs. The x-axis is the time and runs from when the trigger is released and therefore the time scales of the two helmets differ. However, the load cell readings show that the dive helmet has almost four times the amount of force transmitted through to the head form than the work helmet.

During the penetrator testing, shown in Graphs e and f, as the force used was lower, and to avoid the handle, the impacts to the diving helmet were to the shell area and therefore away from a direct crown impact. Nevertheless the impact forces recorded at the load cell were again almost four times those when compared against the work helmet. Alongside this the shell of the helmet did not allow the striker to penetrate through the shell and therefore would pass this part of the standard.

5 DISCUSSION

The diving helmets are hand made and are extremely expensive compared to work helmets, which are mass-produced. As such the diving helmet is a specialised item providing the wearer with a breathable environment in many different mediums from clear water to raw sewage. The development of the current diving helmet can be followed through from the Brass helmets of the “Diver’s standard dress” from the late 19th century. More recent development has more to do with work of breathing and comfort for the diver.

The head is positioned in the diving helmet by a cotton balaclava that has open celled foam sections inserted within pockets stitched into the balaclava. As such the foam is possibly more for comfort and not placed there for shock absorption from an impact. By comparison a work helmet, is specifically designed to deflect and absorb the force of the impact through the shell flexing and the frame allowing the shell to oscillate. It was also seen in the trial how one of the work helmets can indicate if the impact has rendered the work helmet unsafe, by a change in the colour of the frame suspension arms. The replacement foam taken from laboratory stock indicates that the foam selected for use within the helmet will be of great importance. Denser foam may provide better impact resistance but this may also be of a closed cell construction. This would lead to a reduction of foam depth due to increased ambient pressure acting on the bubble size. Further study on how different types and styles of foams affect the impact resistance may be a worthwhile for helmet manufacturers wishing to market this safety aspect.

The cost or the availability of the diving helmet shells may preclude some users from disposing of a diving helmet shell following an impact. From the results of the impact testing it can be seen that the shell can withstand a series of strikes. However, it would be difficult to ascertain how many impacts the shell would be able to withstand before failure occurred. Therefore a method of logging and inspection would need to be introduced. Alternatively a redesign of the shell would enable the end user, or dresser to inspect the shell for ‘tell tales’ and to confirm that the shell should be disposed of following an impact. The penetration testing showed that this type of impact did give indications of possible failure to the shell structure requiring the shell to be removed from use and disposed of.

The tests were carried out on a diving helmet that was not fully loaded. If all the weights and the neck dam were assembled onto the shell the diving helmet would weigh in the region of 12.27kg; the diving helmets as set up for the tests were weighed at 3.82 kg. Therefore there would be a significant difference in how much the foam would have been compressed when fitted to the head form as the thickness of foam reduced. There is a corresponding likelihood of more force coming through to the head form while on the surface. However, once the diver is below the water surface the buoyancy of the helmet would counteract the weight of the helmet allowing the foam to resume its normal density.

For a dive helmet to match the impact performance of a work helmet, a number of improvements would need to be made to the design of the dive helmet. This however, may need the whole helmet to be redesigned to allow fitment of a frame and cradle system to provide improved shock absorption as well as all the gas supply requirements for the diver.

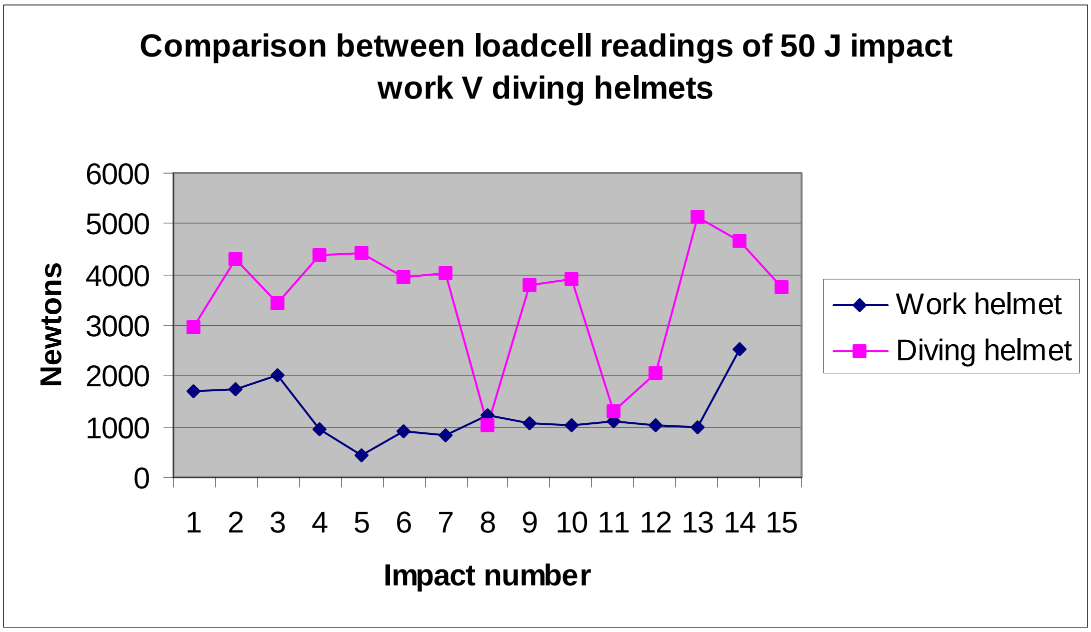
6 CONCLUSION

From the testing carried out on the diving helmets it can be seen that the shells are very robust and are able to withstand a number of 50-Joule impacts. With the current head cushion and foam inserts the force transmitted to a head form is within the 5,0kN limit. This was also the case after the shell had been immersed in water for the specified four hours conditioning. The penetration tests, which require the shell to stop the striker hitting the headform, were successful. Although the full number of tests required by the standard could not be conducted on the available helmet shells it would appear that this model of diving helmet meets the requirements of BS EN 15333 and give a head protection to Class A.

When compared to a work helmet however, the performance appears to be well short of what is available on the market. Therefore it may be appropriate for Diving helmet manufacturers to look at improving this aspect of the helmet's performance.

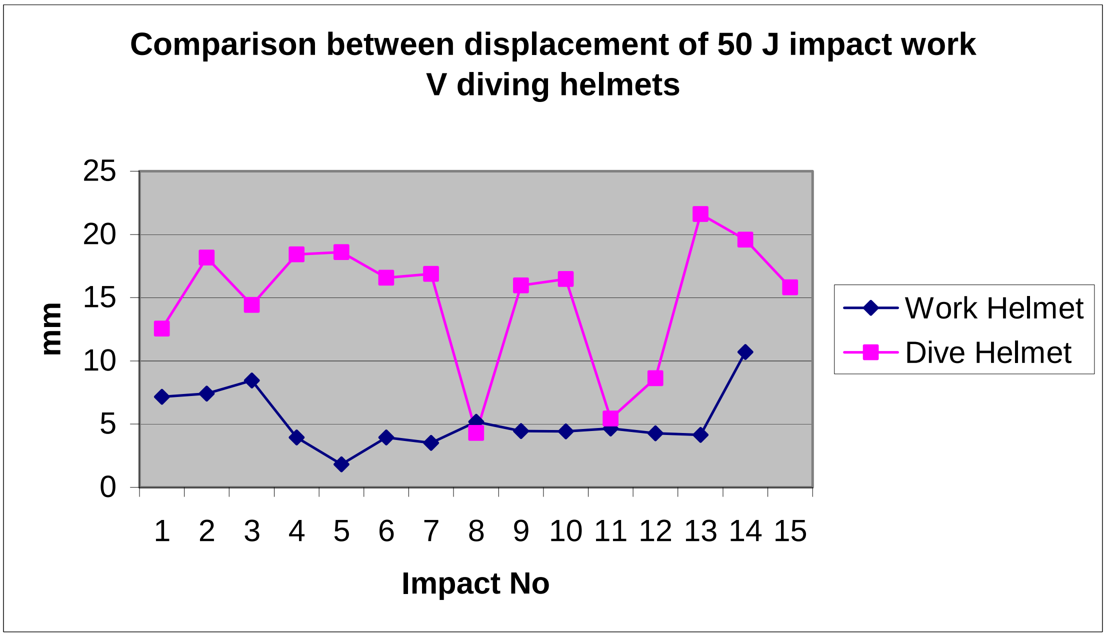
7 APPENDICES

Graph a. Comparison tables between Work helmets and Diving helmets.



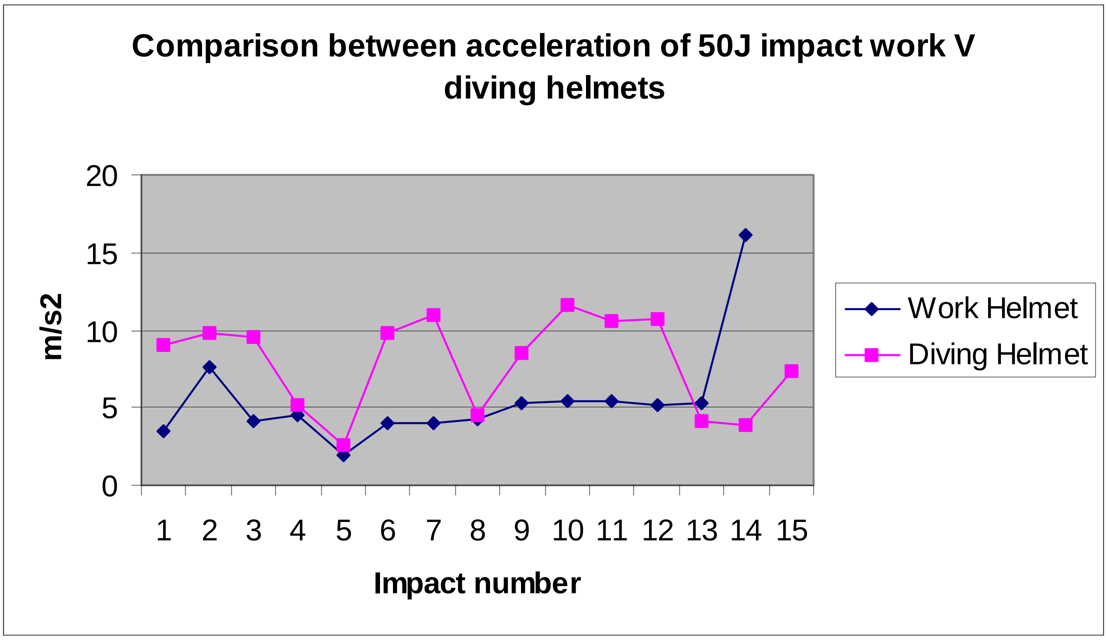
Data taken from calibrated load cell placed between headform and base. Impact 4, 5 and 6 for the dive helmet runs are with the non standard foam fitted to the head cushion.

Graph b. Amount of movement measured during impact run.



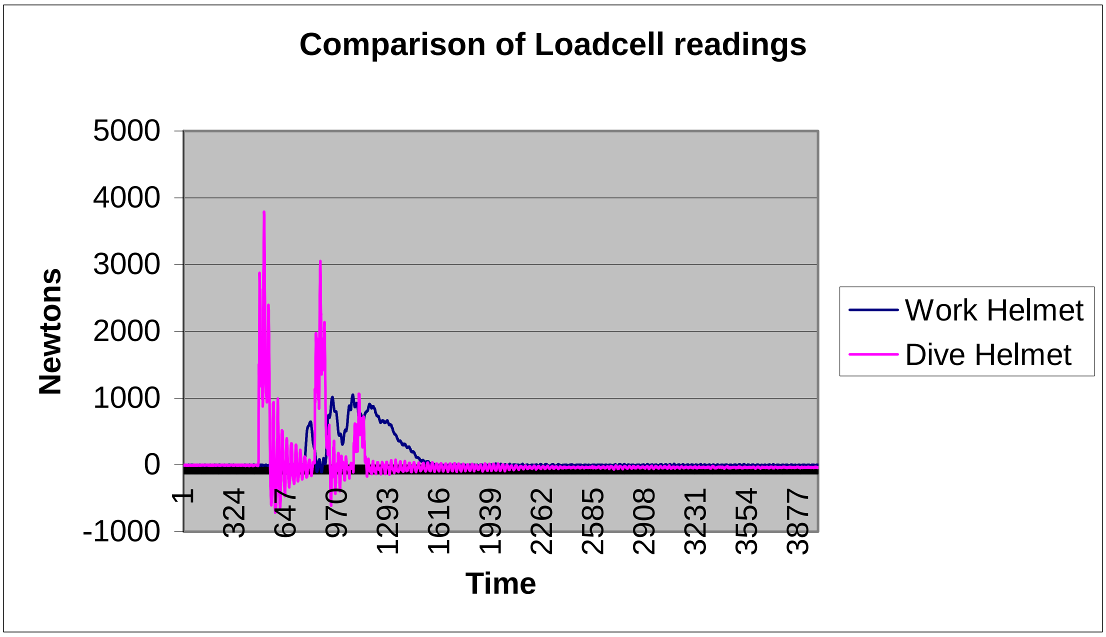
Data taken from Rosand rig system.

Graph c. Graph of acceleration measured during impact runs.



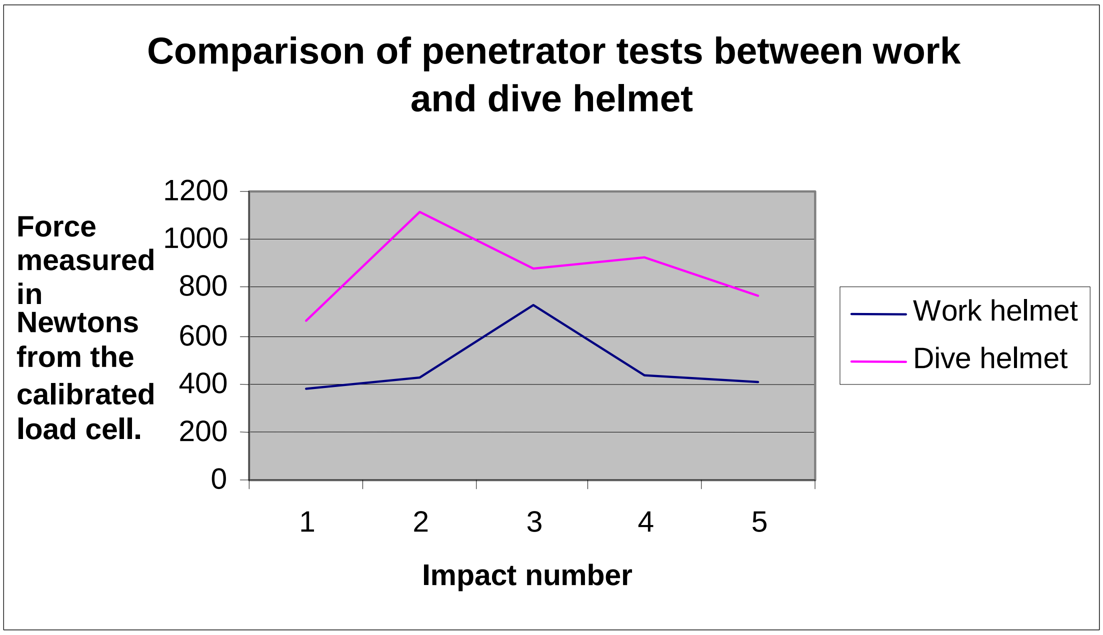
Data taken from Rosand rig system

Graph d. Single impact comparison between Dive and Work helmet.



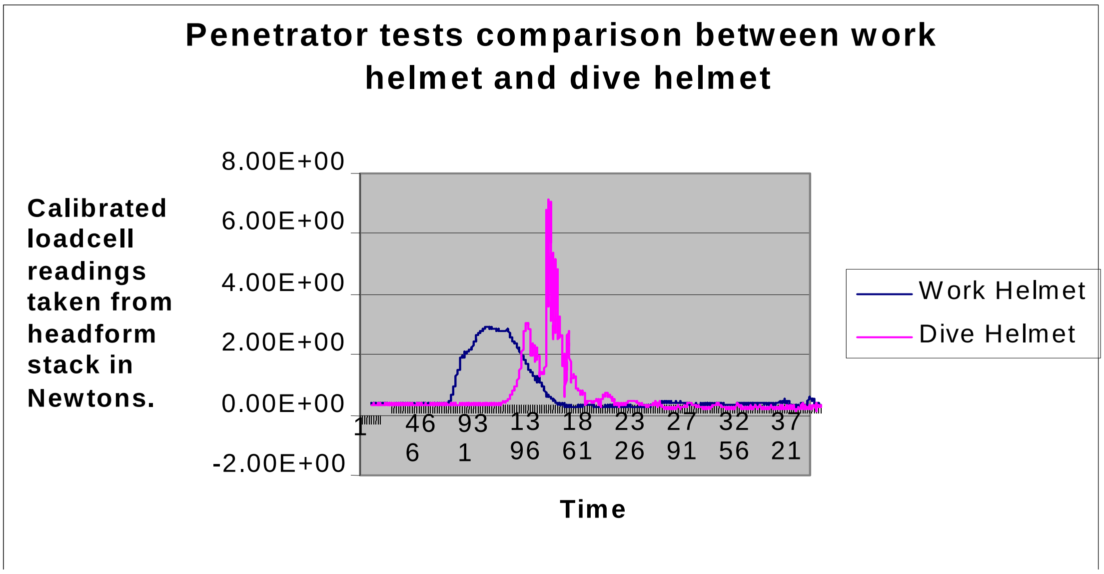
Comparison of the real time readings from impacts to Dive helmet run 9 and Work Helmet run 9. The data for the dive helmet shows a second impact from the impactor as the impactor bounces off the helmet. The work helmet for this run was a Yellow MSA Super Gard 11 date of manufacture first quarter of 1997.

Graph e. Comparison of penetrator impacts at 30 Joules to diving helmet and work helmet.



As per the 50-Joule impacts it can be seen that the dive helmet is not as effective as the work helmet for dissipating the force of an impact.

Graph f. Single impact comparison from penetrator run 4 between Dive and Work helmet for 30-Joule tests.



7.1 TABLE A.

Diving Helmet 50J impact, test number foam insert depth, max load cell reading and impact details.

Impact number	Foam thickness	Max load cell reading	Impact position Face plate screws
1	Std foam 35mm	2975.444	To handle Hand tight
2	Std foam	4317.375	To handle Hand tight
3	Std foam	3425	To handle Hand tight
4	Foam 45mm	4378.832	To handle Hand tight
5	Foam 65mm	4416.715	To handle Hand tight
6	Std foam	3936.011	To handle Hand tight
7	Std foam	4010.937	To shell left of handle Hand tight
8	Std foam	1015.584	To shell right of handle Hand tight
9	Std foam	3793.736	To handle Hand tight
10	Std foam	3910.755	To handle F/P Torqued
11	Std foam	1287.506	To shell right of handle F/P Torqued
12	Std foam	2046.868	To shell left of handle F/P Torqued
13	Foam 45mm	5138.193	To handle F/P Torqued
14	Foam 45mm	4655.805	To handle F/P Torqued
15	Foam 65mm	3757.536	To handle F/P Torqued

7.2 TABLE B.

Work Helmet 50J impact, test number corresponding to which helmet was used.

Impact Number	Impact Number	Make	Model	Colour	Date of Manufacture
On graph	To the shell				
1	2nd	MSA	Super V Gard 11	White	10/03
2	1st	MSA	Super V Gard 11	Green	01/05
3	1st	MSA	Super V Gard 11	Yellow	01/06
4	1st	MSA	Super V Gard 11	White	10/03
5	2nd	MSA	Super V Gard 11	White	10/03
6	3rd	MSA	Super V Gard 11	White	10/03
7	1st	Arco	HDPE	White	1st ¼ 07
8	2nd	Arco	HDPE	White	1st ¼ 07
9	1st	MSA	Super Guard 11	Yellow	1st ¼ 97
10	2nd	MSA	Super Guard 11	Yellow	1st ¼ 97
11	3rd	MSA	Super Guard 11	Yellow	1st ¼ 97
12	4th	MSA	Super Guard 11	Yellow	1st ¼ 97
13	5th	MSA	Super Guard 11	Yellow	1st ¼ 97
14	1st	MSA	Super Guard 11	Green	01/05

7.3 TABLE C

Diving helmet 30j penetration test

Impact number	Foam thickness	Max load cell reading	Impact position
1	Std foam	663.0624	To left of handle
2	Std foam	1117.443	To right of handle
3	Std foam	882.8406	To left of handle
4	Std foam	923.4447	To the left of handle
5	Std foam	764.2506	To the right of handle

7.4 TABLE D

Work Helmet 30j penetration test

Impact Number	Make	Model	Colour	Date of Manufacture
1	MSA	Small V Guard	Yellow	9/03
2	MSA	Small V Guard	Yellow	7/98
3	Tuff	Master 111	White	Jun 97
4	MSA	Super Guard 11	Yellow	1/93
5	MSA	Super Guard 11	Yellow	¾ 2000

8 REFERENCES

BS EN 15333-1 Respiratory protective devices – Surface supplied diving apparatus: Part 1: Demand valve apparatus.

BS EN 397: 1995 Industrial Safety Helmets

BS EN 812: Industrial Bump Caps

Kirby Morgan Dive Systems Inc SuperLite 17 B Operations and Maintenance Manual

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Kirby Morgan (Dive Lab Inc)	Manufacturer of diving helmets.
Rosand Rig	Instrumented Impact Testing Apparatus

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Diving helmet impact testing to EN397

Diving helmets used today by the majority of commercial divers in the UK are developed from the Standard Diving Dress of over 40 years ago. These brass helmets provided a large space around the head and fitted onto a yoke on the diver's shoulders. Any impact would have been taken on the shoulders rather than onto the head and neck. Commercial divers regularly work on sites where lifting operations are being conducted and these pose a head impact hazard both on the surface and underwater. However, most, if not all, diving helmets have not been tested to determine the level of head protection they provide. The recent introduction of the standard BS EN 15333 for Surface Supplied Diving Apparatus requires that helmets made to this standard should be classified as offering head protection to one of three classes:

- Class A: Head protection to BS EN397: the current European Standard for the Specification for Industrial Safety Helmets.
- Class B: Bump protection to BS EN812: the current Bump Hat Standard.
- Class C: No protection.

The aim of this research project was to investigate the level of protection current commercial diving helmets provide. The number of helmets available for this was limited to three from the same manufacturer. However, the results are considered to be broadly representative of helmets used in the diving industry today as one manufacturer makes most of the helmets used in the industry. Testing was carried out using the calibrated Rosand drop rig of the HSL Mechanical Engineering Section and filmed using high-speed video cameras of HSL Visual Presentation Services Section.

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