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Research, development and construction of a state of the art impact testing lab for eyewear

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Research, development and construction of a state of the art impact testing lab for eyewear

Abstract
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Degree Type
Thesis

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Introduction

The purpose of this thesis project was to construct a “State of the Art” impact testing lab for dress and safety eyewear. The impact-testing lab is a two-part project. Part 1 consists of a drop ball apparatus in which various objects free fall from various heights onto selected eyewear/lens blanks. Part 2, the building of which is to be completed by our successors from the Class of 2004, is a high velocity impact testing apparatus which consists of an air cannon capable of firing various sized sports balls at various velocities. This state of the art impact-testing lab is to complement the world-class optical lab already present at Pacific University College of Optometry. Our advisors for this project are Dr. Alan Reichow and Dr. Karl Citek; both professors at Pacific University College of Optometry.

This thesis project consisted of researching the standards which different types of eyewear must comply to, designing the testing apparatus and finally constructing the actual testing equipment. In order to meet the demands of the world market, we included American (United States), Australian and European standards. In essence, these three standards are the leaders in the world, so any lab that will comply to these standards will likely comply to the world's standards. After determining the standards that needed to be included, we began designing the drop ball and high velocity apparatus so that all the required standards would be met. Now completed, the drop ball apparatus allows eyewear to be tested for all the major national and international drop ball standards. The following pages detail the research, design and construction of the drop ball apparatus.

Research and Construction

Research Description

In order to build a “State of the Art” lens impact resistance testing lab that would meet the American, European and Australian standards, it was first important to find out what the standards were. Dr. Alan Reichow provided us with the ANZI Z87.1 and Z87.3, ASTM and European EN 1836:1997 and Australian AS/NZS 1337 standards. Each of the European and Australian standards made reference to standards with more specific guidelines. With a few inquiries on the web and elsewhere, we found we were able to purchase these at www.standards.com.au and www.techstreet.com (Appendix i). We then acquired the standards EN 168:1995, AS/NZS 1337:1992 and AS/NZS 4066:1992. The cost of the standards was approximately $98 for the European and $24 for each of the Australian standards. These 3 standards along with ANZI Z87.1, Z87.3 and ASTM gave us the complete requirements to making the drop ball test and the high velocity impact test.

After finding out what was required from the standards, we had some questions posed as to how we would acquire our apparatus. We came up with two options for how to obtain our high velocity apparatus. The first was to purchase an existing, already assembled and functional high velocity apparatus that would propel a steel ball or various
sports balls to the proper velocities. We found two companies that used such an apparatus. One was ASTM who offered to sell us an apparatus that would propel a .25" steel ball to the proper velocities required. The downfall to this was it would cost us $16,500 plus it would not propel larger items such as racquetballs or baseballs (Appendix ii). They then offered to build us a customized apparatus that would propel from the .25" steel balls up to larger balls, such as basketballs or volleyballs. The lead time for this would be 16 weeks and would cost approximately $25,000. From our research of air cannons, we found we could build an equivalent device for about $6500. This cost was just for the propelling device and not for necessary items such as a protectant polycarbonate box ($1400) or a chronograph ($350) to measure the velocity of the projectiles. Plus it did not include a drop ball test. The other company that had such an apparatus was Detroit Testing Lab in Detroit, Michigan. They use a similar apparatus for testing but were not interested in building and selling us one.

Since it would be cost prohibitive to purchase a testing apparatus, we looked into the option of contracting out our testing to one of the above-mentioned labs. But on further inquiry, we determined that this option would not be feasible either. The ASTM lab charged between $537 and $866 to test 28 pieces of eyewear depending on the standard tested for (Appendix iii). The Detroit lab charged $812 to test 12 pieces of eyewear and $750 to test for each additional sport (Appendix iv).

Because of the costs mentioned above, we decided that it would be appropriate to build the impact-testing lab. Also, in our research we found that there is no current drop-ball apparatus that would satisfy our needs, so we constructed one of our own design. One difficulty, at least initially, was the fact that the standards only contain requirements. There is no recipe for how to build either apparatus. As long as we were able to obtain the correct projectile sizes and speeds to satisfy the standards, it did not matter the exact design of the apparatus. In the end, this gave us design freedom to construct the drop ball apparatus as we saw fit. We designed each apparatus based upon our own past knowledge and experience of building and building materials.

To have a complete impact-testing lab, two separate apparati needed to be built. For the drop ball test, we basically built a bench with 12 drop ball tubes that would satisfy the current standards plus any extras that might arise. Appendix v shows the standards along with the appropriate tube to use. The high velocity impact apparatus will be a separate bench with an air cannon and a protective polycarbonate box. It will be designed to shoot projectiles from .25" steel balls to baseballs and basketballs and many sizes in between. Due to the time consuming demands of researching the tests, apparati, and building the drop ball test, we would have been unable to complete the high velocity apparatus in the time allotted. The responsibility for building the high velocity apparatus was turned over to two students from the Class of 2004. They will also complete the write-up for that particular apparatus.

Building the Drop Ball Apparatus

The building of the drop ball apparatus was not overly complicated but it was extremely time consuming. When all was said and done, we calculated over 250 man-hours involved in the planning, designing, purchasing of parts and building of the apparatus. Obviously, building a second one would go much quicker due to the learning
curve of a project such as this. The issues this section will deal with are what we built, how we built it and where we bought and/or acquired the needed parts. These three issues will be interjected throughout the following paragraphs as necessary to properly explain the process. This is not intended as a step-by-step “How To” guide (although many specifics will be included) because every situation is different, be it a different time frame, allotment of space or available funds. Personal customization will have to be done for anyone wanting to construct their own drop ball apparatus. This is intended to be a summary of what we did to produce the first apparatus of a two-part project in building a state of the art impact testing lab at Pacific University College of Optometry.

Through discussions with our advisors and consulting the standards, it was decided that we would need 9 different drop tubes. Variations of drop height, object size, object shape and lens holder type necessitated this number of tubes. We decided to build in extra space for future additions so that brought the total to 12-drop ball locations. An 8-foot long bench was decided upon to hold the tubes. This allowed enough spacing between the tubes for aesthetic, as well as functional use. The Australian standards require the lenses to be mounted on a 50th percentile headform (similar to the Alderson Headform; a description can be found in the standards), where the other standards merely required a small lens holder (O-ring) of a specific rubber durometer. The added height and width of the headform had to be considered prior to construction. The height of the headform dictated the depth of the cabinet (because the head will rest on its back, as if it was facing the ceiling), now set at 24 inches. The height of the cabinet was decided upon for comfort of the operator and the height of the room. The height we chose was 30 inches, which corresponds closely with standard table heights.

Once overall size was decided upon, we began the building of the base cabinet. The frame is made of Premium 2x4 Douglas Fir. At this point it is necessary to stress the importance of choice of wood. Good wood makes a stronger cabinet, as well as making construction simpler by not having the problems associated with warped lumber. Sometimes it is necessary to dig through the entire stack at the lumberyard to procure the proper straight pieces of wood. This is a slow but necessary step. The frame is held together with a mix of $\frac{3}{4}$" and 3" wood screws, the length determined as to prevent the tips of the screws from protruding through the other side of the wood. Again, it is important to stress using quality products to connect the wood pieces together. Low quality screws have a tendency to strip out or can snap in half when even minimal torque is applied. They also have a poorer thread design, which minimizes their holding strength. Lag screws or bolts could be substituted for quality screws, although they are more time consuming to install. Nails are not a suitable choice because over time, they will loosen up and the cabinet would lose structural integrity. It is also important to pre-drill the screw holes, as we did, to prevent the wood from splitting. Split wood is weak and the screw threads cannot dig in as well for a strong bite.

The frame basically consists of two 24"x96" rectangular wood frames with one being held approximately 25" above the other by 12 vertical 2x4 supports. This places the top of the upper rectangle at about 29" above the floor. Of the 12 vertical supports for the upper rectangle, 2 are placed in each corner and two more are placed each in the front and the back and are spaced evenly. So in summary, the cabinet frame at this point is a 29" high by 96" long by 24" wide rectangular box.
The floor of the inside of the cabinet and the top of the cabinet consists of ½” plywood. This provides good structural support without being excessively heavy. Each piece of plywood was squared and notched (to fit around the vertical supports) so a single piece could be used for each. The precise fitting greatly helped with the structural support. It is imperative that the frame be square before attaching the plywood permanently. Once the plywood is attached, the shape of the frame will not change. If the frame is not square, the shape of the cabinet may end up as a trapezoid rather than the desired rectangle. To tack down the plywood, we used 1½” screws placed about every 6” to 8” along the perimeter of the plywood.

With the plywood top and bottom in place, the next step was to support the vertical aspect of the cabinet frame. For this we employed 2x4 cross braces. Two were used on the back and one was used at each end. Again, it is important to make sure the cabinet is square before attaching these supports because once they are set, the shape of the cabinet won’t change. Upon installation of the vertical supports, the frame of the cabinet was completed.

Both the exterior and interior (walls and floor) of the cabinet was finished with ¼” hardboard. Hardboard is a compressed wood product made of sawdust-type wood fibers and is often used for cabinets in woodshops. It cuts easily with a saw but is relatively hard on the blades. This process was also very time consuming because many, very precise cuts had to be made to allow adjoining pieces to butt together cleanly. A hacksaw with a quality metal cutting blade works well for these types of cuts. The finished appearance of hardboard allows for a somewhat industrial look. In retrospect, a different method of finishing the cabinet may have been more desirable due simply to the logistical nightmare of making the numerous cuts (by hand) that required precision down to one 64th of an inch. However, the hardboard does provide a durable finish that doesn’t appreciably deteriorate over time.

The corners of the cabinet were covered by ¾” X ¾” angle aluminum. This protects the relatively vulnerable (and previously exposed) edges of the hardboard. To
be able to use the space on the inside of the cabinet, we left 3 openings in the front. These were covered with curtains. Doors would have also sufficed but the curtains were a simpler option. The top of the cabinet was finished with 3/4" white melamine. Melamine is particle-board material with a plastic laminate bonded to its surface. It is commonly used in many types of cabinets. With the cabinet completed, we moved on to the back "wall" which would become the vertical supports for the drop tubes.

The back "wall" is an exposed frame composed of 5 vertical 2X4's (extending approximately 3 and a half feet above the counter of the cabinet), 2 horizontal 2X4's (which run the entire length of the cabinet), 2 cross braces (which hold the wall square), two diagonal supports (which tie the top of the wall into the front of the cabinet) and a Lucite backing for the frame (purely for aesthetics). Lucite is a high quality clear acrylic product. Cedar 2X4's, which have a nice appearance (when properly finished), were chosen for this part of the project because they would be visible. The two horizontal boards were mounted at about 18 and 36 inches above the cabinet top onto the vertical beams. The horizontal boards are the mounting surface for the machined brackets which hold the drop tubes. The diagonal supports help to hold the wall vertical. They are attached perpendicularly to the wall, angling from the top of the wall to the front part of the counter of the cabinet.

Once all the wood pieces were cut, each end was rounded with a rasp and file to give them a finished appearance. Then all pieces were sanded with 60 grit sandpaper, followed by 100 grit and finished with 150 grit. The 60 and 100 were used to smooth out
the rough parts of the wood. The 150 grit finishing paper was the recommended grit for the Polycrylic finish that was to be used. We used an inexpensive orbital sander to reduce sanding time. On a side note, it is important to use quality sandpaper and replace it often. Even high quality sandpaper is cheap and it’s not worth the headache to mess around with worn out sandpaper. The sanding of the cedar was one of the most time consuming parts of the project but to get a nice finish, the wood must be smooth prior to applying the clear coat. The wood pieces were then wiped down with a damp rag and were dried. The pieces were then coated with Minwax Polycrylic clear coat with a satin finish. Three coats were applied in total; with a 24 hour delay between coats to ensure complete drying of each coat. Each layer of Polycrylic was sanded with 220 grit sandpaper and then wiped with a damp rag prior to applying the next coat. It is not advised to use steel wool with the Polycrylic because Polycrylic is water based and if bits of the steel wool remain on the wood (even after wiping it with the damp rag), rust spots may form. Polyurethane clear coat was also an option. It is a tougher material than the Polycrylic (often used on hardwood floors) but is a solvent based product which complicates cleanup (mineral spirits are required) whereas Polycrylic (a water based latex product) can be cleaned up with water. For our purposes, the Polycrylic was sufficiently durable and was chosen for its simplicity of use and the minimal amount of harmful vapors it produced. The results are quite nice.

Because steel objects are to be dropped onto the lenses, it is inevitable that some of the lenses will shatter. The lenses therefore have to be enclosed in a protective box to prevent shards from reaching the operator. Also, photography will likely be employed in the testing process. To allow for photography, it was desired that the protective shield/box be of a transparent material. Our first idea was to have a custom box made from ½” acrylic. All the designs and exacting measurements were calculated and drawn up and were sent off to a custom plastic manufacturing plant. After about 3 weeks of failed faxes, unreturned e-mails and telephone tag, we finally found out that they were
unable to construct the box to our specifications. It fell upon our shoulders to build it. We used ¾” melamine dividers/supports and ¼” Lucite for the top and doors. The melamine was held together with 2” screws with the Lucite attached with ¼” stainless steel hardware (for aesthetics). The doors are top hinged and attached with galvanized hinges (stainless steel was not available and chrome would not have looked right), all held together with bolts, lock washers and locking nuts (nylon insert type). Blue Loc-Tite was used to ensure that the bolts stay tight. The ¼” Lucite is sufficiently strong to protect the operator while still allowing photography of the testing of the eyewear. Should the option become available in the future, we would like to replace the current protective box with the originally designed 100% acrylic box.

The most difficult pieces to acquire were the mounting brackets for the drop tubes. We designed these pieces to suspend the drop tubes about 5” from the vertical support wall. This allowed enough space to clear the forehead of the headform so the steel projectiles will hit directly on the eyewear. The brackets we designed were beyond our manufacturing capabilities but we had the good fortune of having the Nike Tooling and Machine shop at our disposal. They took our designs and entered them into their CNC machines. These machines use various cutting bits to turn a solid block of aluminum into our custom mounting brackets. We chose T-6 heat tempered 6061 aluminum (aircraft quality) for its light weight, high strength and easy machining characteristics. If not for the Nike machine shop, this part of the project would have been much more difficult and the results would not have been as aesthetically pleasing as they are. The brackets are of exceptionally fine construction. Cost for these brackets would have been in the neighborhood of $100 each; we used 24 total on the drop ball apparatus.

Figure 4
With the brackets completed and mounted, we began mounting the drop tubes. The drop tubes are also T-6 6061 aluminum, which nicely matches the brackets in appearance. The tubes were prepared before mounting by wet sanding each tube with 320-grit sandpaper two separate times. This took off the manufacturer’s identification numbers and gave the tubes an appealing shiny matte finish. Different diameters were used to allow for the free fall of the drop balls while preventing excessive bouncing of the steel balls within the tubes. The brackets have threaded holes in the mounting rings which allowed the tubes to be mounted with bolts acting as set-screws. These were secured in place with lock washers, nuts and a dab of blue Loc-Tite. The mounting rings have enough space between their inside diameter and the outside diameter of the drop tubes to allow the tubes to be adjusted exactly vertical. Once the tubes were leveled and tightened down, the construction of the drop ball apparatus was complete.

Figure 5

Conclusion

In summary, the project took us from July 2000 to the middle of May 2001 to complete the research and the drop ball apparatus. Total cost was in the neighborhood of $1500. Total weight is about 300 pounds, which comes out to about $5 per pound. Cheaper than good steak. Part 2 of the project, which is the high velocity air cannon will be completed within the next year as our successors have already begun construction. Currently, the drop ball apparatus is located in the research lab in Jefferson Room #320. It is our wish that Pacific University College of Optometry and its students will benefit from this project for years to come.
References

ANZI Z87.1
ANZI Z87.3
AS/NZS 1337
AS/NZS 1337:1992
AS/NZS 4066:1992
ASTM “Standard Eye Protective Devices”
ASTM “Face Guards for Youth Baseball”
ASTM “F803 Racket Sports”
EN 168:1995
EN 1836:1997

www.standards.com.au
www.techstreet.com
Acknowledgements

We would like to thank Nike, Inc. for grant support and access to their modeling shop.
Appendix
> — Original Message —
> From: Helena Klodt, R&D Aust
> Sent: Tuesday, October 03, 2000 10:33 PM
> To: AIG, Sunlens
> Subject: Re: European/Australian Standards
>
> > Dear AI,
> > we have the standards available in R&D, however we are not in a position
> > to copy them (due to very strict copyright laws).
> > Attached are web page addresses where you can order your own copy.
> > Please let me know if that approach will work for you.
> > &Keyword=E&Search=Search&Max=15
> > http://www.techstreet.com/cgi-bin/results?searchField_publisher=BS&searchF:
> > field_quickview=168
> > Regards,
> > Helena.
> > PS
> > Would you please give me little more background to the latest announcement
> > (i.e. what is happening to Frank and others?)
> > I would appreciate it.
> > Helena.

> — Original Message —
> From: AIG, Sunlens
> Sent: Monday, 2 October 2000 6:24
> To: Helena Klodt, R&D Aust.
> Subject: FW: European/Australian Standards
>
> Hi Helena, do you or someone in Australia have what Dr. Reichow is
> looking for? I do not have the latest updates on these standards. I have
> ANSI B100.3-1966, EN 6161997 and AS 1065.1-1990. If you have them I could
> use a copy as well. If not I will ask Ily.
> Thanks,
> AI

> — Original Message —
> From: Reichow, Alan [SMTP: Alan.Reichow@nike.com]
> Sent: Thursday, September 28, 2000 4:27 PM
> To: "Greek, AI"
> Cc: "Reichow, Alan(Univ)"
> Subject: European/Australian Standards
>
> AI,
> One of the projects we are working on at the University is creating a
> "State-of-the-Art" Lens Impact Testing Lab, complete with digital capture
Chad:

The HVBA-II as a basic configured unit can only shoot 0.25 cal steel balls. This facilitates testing to ANSI Z87.1 and the new ASTM standards under ASTM F8.57.01 for motorcycle eye protection and F8.57.02 for Optional moderate impact sports eyewear. Optional configurations to the base HVBA (0.25 cal) enable it to shoot 0.22, 0.17 and 0.15 cal (military fragment simulators) projectiles. This is all configured from the base platform of the HVBA-II.

The cost of the base HVBA-II (0.25 cal) is $16.5K.

Platforms for testing eyewear to ASTM F603, the standard for sports eyewear i.e. squash/racquet ball, lacrosse and baseball have never demonstrated demand as there is only a handful of manufacturers and most of these use outside laboratory services (such as ours) to do their testing. If you require however, we can also furnish a unit for you. It would be more or less a custom unit (unlike the HVBA) and modeled after the platform we use in our laboratory. The lead time for a unit such as this would around 16 weeks and I would estimate cost to be in the area of $25K.

Should you have further questions you can contact me at: 216 272 8817. I'll be on Pacific time through the course of work.

Best regards,

Dale B. Pfriem
Mr. Roberts,

I am resending the e-mail with the correct information. If you are still having problems, please contact me and I will gladly fax a copy to you.

Per Dale Pfriem's e-mail dated 12 Nov 00 I have listed below the pricing for the ANSI Z87.1 and ASTM F803 testing:

- ANSI Z87.1 - Spectacle Full Assessment - Clear - $537.25
- ANSI Z87.1 - Spectacle Full Assessment - Tinted - $537.25
- ANSI Z87.1 - Spectacle Full Assessment - Filtered - $566.25
- ASTM F803 - Spectacle Full Assessment - Clear - $700.50

This pricing is per model/variant - 28 samples needed for ANSI Z87.1 and 15 samples needed for ASTM F803.

We appreciate the opportunity to serving your needs with competence, efficiency and professionalism. Please call our office with any questions you may have.

Best regards,

Jeanette Romaniello
Office Manager
ICS Laboratories Inc.
1072 Industrial Parkway North
Brunswick, OH 44212
Tel 330-220-0515
Fax 330

Friday, November 17, 2000 America Online: CRobe65587
Dear Mr. Roberts:

Please accept this letter as Detroit Testing Laboratory’s proposal to perform testing to ASTM F803-99. Included are the cost, timing and a detailed breakdown of your requirements.

TIMING SUMMARY

Based on our current workload, the turnaround time for this program is approximately 3-4 weeks. This timing is subject to review upon receipt of your purchase order and samples and may be revised as a result of our workload at that time.

Please contact me if detailed or accelerated timing information is required. Rush charges may apply if accelerated timing is requested.

DELIVERABLES

DTL will provide an original test report, if required, at the completion of your program, including documentation of the test procedure, test results, and equipment used. Photographs or schematics can be made available upon request.

Detroit Testing Laboratory (DTL), the largest and longest established independent testing laboratory in Michigan, is committed to providing you with rapid turnaround, and high-value testing and development services. DTL is accredited by the American Association for Laboratory Accreditation (A2LA) to ISO/IEC Guide 25 requirements. Our facilities are open to your visitation.
### COST AND TIMING ITEMIZATION

<table>
<thead>
<tr>
<th>Test Description</th>
<th>Applicable Specification</th>
<th>Quantity</th>
<th>Cost</th>
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<tbody>
<tr>
<td>Protective Eyewear</td>
<td>ASTM F803-99</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Standard Specification for Eye Protectors for Selected Sports</td>
<td></td>
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<tr>
<td>Complete test, including Racquetball Impacts</td>
<td></td>
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<td>$612.50</td>
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<tr>
<td>Each Additional Sport (Tennis, Squash) @ $375.00/each</td>
<td></td>
<td>750.00</td>
<td></td>
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<tr>
<td>Data Reduction &amp; Report</td>
<td></td>
<td>75.00</td>
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<td><strong>TOTAL</strong></td>
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<td><strong>$1,637.50</strong></td>
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**NOTES**

1. DTL will require twelve (12) samples for each sport to be tested.
2. Protectors which pass for squash, will also pass for badminton, handball, and basketball (for basketball protectors must pass penetration test requirements). Protectors which pass for racquetball will also pass for paddleball.

For faster, more expedient service, please include Detroit Testing Laboratory's proposal number (printed at the top of this document) on your purchase order and other correspondence you may be sending to us concerning this proposal.

This proposal is valid for thirty (30) days and is subject to review upon acknowledgement of your order. See the enclosed page for a statement of applicable terms and conditions.

Detroit Testing Laboratory, Inc. agrees to hold all information, products, data, and reports confidential and will not disclose this information to third parties without your prior written approval.

Payment terms are subject to credit approval and account status verification upon acceptance of this proposal. A purchase order is required to initiate this project. All shipping and handling charges are the responsibility of the customer.
Thank you for the opportunity to quote on this project. If you have any questions, or if I can be of further assistance, please feel free to contact me at (810) 754-0000 ext. 1462.

Sincerely,

DETROIT TESTING LABORATORY, INC.

David Splane
Test Technician III

DS/sah
### Summary of Standards for Impact Resistance Testing

<table>
<thead>
<tr>
<th>American</th>
<th>Object</th>
<th>Object Weight</th>
<th>Drop Height</th>
<th>Projectile Speed</th>
<th>Object Specifics</th>
<th>Targeted Safety Eyewear and Notes</th>
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<tr>
<td>Z80.1</td>
<td>5/8&quot; Steel Ball</td>
<td>≤1.9g not less than 1.6g</td>
<td>50&quot;</td>
<td>NA</td>
<td>NA</td>
<td>Prescription Ophthalmic Lenses</td>
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<td>Z80.3</td>
<td>5/8&quot; Steel Ball</td>
<td>≤1.9g not less than 1.6g</td>
<td>50&quot;</td>
<td>NA</td>
<td>NA</td>
<td>Non Prescription Sunglasses and Fashion Eyewear</td>
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<tr>
<th>ASTM</th>
<th>Standard Eye Protective Devices</th>
<th>Drop Height</th>
<th>Projectile Speed</th>
<th>Object Specifics</th>
<th>Targeted Safety Eyewear and Notes</th>
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<tr>
<td></td>
<td>5/8&quot; Steel Ball</td>
<td>≤.67 oz, Not less than .56 oz</td>
<td>50&quot;</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td></td>
<td>Baseball</td>
<td>NA</td>
<td>NA</td>
<td>≤67 mph &amp; up to 80 mph</td>
<td>All testing at two extremes: 0 to 10F &amp; 35 to 45F</td>
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<td></td>
<td>Hockey</td>
<td>6.17 lb</td>
<td>3 m</td>
<td>40 to 50 mph</td>
<td>Drop test with puck pipe</td>
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<td></td>
<td>F803 Racket Sports</td>
<td>NA</td>
<td>NA</td>
<td>90 mph for r/s,1 balls, 85 mph for hball</td>
<td>Requires Pneumatic Device to Propel Balls</td>
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</table>

| EN 168-1995* | 22mm Steel Ball | 83g for 6mm or 43g for 22mm | 130cm | 12 m/s for 6mm Ball* | A head form must be used for this.* | For "Complete Eye Protectors" |
| EN 1836-1997 | 16mm Steel Ball | 16g          | 130cm | NA | "Increased Robustness" | Personal Eye Protection: Sunglasses & Sunglasses Filters for General Use |
| EN 168-1995 | 22mm Steel Ball | 43g          | 130cm | NA | "Enhanced Robustness" if fails "Increased Robustness" | Personal Eye Protection |
| EN 1836-1997 | 16mm Steel Ball | 85g          | NA | 195 m/s | High velocity impact | Personal Eye Protection |

<table>
<thead>
<tr>
<th>Australian</th>
<th>Object</th>
<th>Object Weight</th>
<th>Drop Height</th>
<th>Projectile Speed</th>
<th>Object Specifics</th>
<th>Targeted Safety Eyewear and Notes</th>
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<td>AS/NZS 1337</td>
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<td>16g</td>
<td>127cm</td>
<td>NA</td>
<td>NA</td>
<td>Non-prescription and Prescription Sunglasses and Fashion Eyewear: Spectacles</td>
</tr>
<tr>
<td>AS/NZS 1337-1992</td>
<td>22mm Steel Ball</td>
<td>42g</td>
<td>130cm</td>
<td>NA</td>
<td>NA</td>
<td>Eye Protectors for Industrial Applications: Low Impact Resistance</td>
</tr>
<tr>
<td>AS/NZS 1337-1992</td>
<td>6.35mm Steel Ball</td>
<td>8g</td>
<td>NA</td>
<td>12 m/s</td>
<td>This is the preferred method. See standard instructions for details</td>
<td>Eye Protectors for Industrial Applications: Medium Impact Resistance</td>
</tr>
<tr>
<td>AS/NZS 1337-1992</td>
<td>6.35mm Steel Ball</td>
<td>8g</td>
<td>NA</td>
<td>40 m/s</td>
<td>See standard instructions for details</td>
<td>Eye Protectors for Industrial Applications: High Impact Resistance</td>
</tr>
<tr>
<td>AS/NZS 1337-1992</td>
<td>6.35mm Steel Ball</td>
<td>8g</td>
<td>NA</td>
<td>120 m/s</td>
<td>See standard instructions for details</td>
<td>Eye Protectors for Industrial Applications: &quot;Penetration Test&quot;</td>
</tr>
<tr>
<td>AS/NZS 1337-1992</td>
<td>125 x 17 needle</td>
<td>44g</td>
<td>120cm</td>
<td>NA</td>
<td>NA</td>
<td>Eye Protectors for Industrial Applications: &quot;Penetration Test&quot;</td>
</tr>
<tr>
<td>AS/NZS 4066-1992</td>
<td>Squash Ball</td>
<td>40.5 mm in diameter</td>
<td>23.3g to 24.6g</td>
<td>NA</td>
<td>40 m/s</td>
<td>Eye Protectors for Racquet Sports</td>
</tr>
</tbody>
</table>

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**Note:** It is important to double check each standard's "Procedure Instructions" for special instructions such as temperature, lens holding device, points of impact, whether or not pressure sensitive material is required and speed tolerances.

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See Page 4 of standard. Can use either of these steel balls but must use head form. High velocity apparatus may be best tool.

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**American Standards:**

- **Z80.1:** Eye Protectors for Youth Baseball
- **Z80.3:** Eye Protectors for Racket Sports

**European Standards:**

- **EN 168-1995:** 22mm Steel Ball
- **EN 1836-1997:** 16mm Steel Ball
- **EN 168-1995:** 22mm Steel Ball
- **EN 1836-1997:** 16mm Steel Ball
- **EN 168-1995:** 22mm Steel Ball
- **EN 1836-1997:** 16mm Steel Ball

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**Australian Standards:**

- **AS/NZS 1337:** 16mm Steel Ball
- **AS/NZS 1337-1992:** 22mm Steel Ball
- **AS/NZS 1337-1992:** 6.35mm Steel Ball
- **AS/NZS 1337-1992:** 6.35mm Steel Ball
- **AS/NZS 1337-1992:** 6.35mm Steel Ball
- **AS/NZS 1337-1992:** 125 x 17 needle
- **AS/NZS 4066-1992:** Squash Ball

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**ASTM Standards:**

- **Standard Eye Protective Devices:** 5/8" Steel Ball
- **Face Guards for Youth Baseball:** Baseball, Hockey
- **Hockey:** NHL Puck with attached weight
- **F803 Racket Sports:** Racquetball, Squashball, Tennisball, Handball

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**Summary:**

- **Impact Resistance Testing Standards:**
  - American
  - ASTM
  - European
  - Australian

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**Important Notes:**

- Use head form when testing.
- High velocity apparatus may be best tool.
- Special instructions for temperature, lens holding device, points of impact, pressure sensitive material, and speed tolerances.

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**References:**

- Page 4 of the standard.
- Use of different steel balls for various sports applications.

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**Revision:**

Rev. 5/5/01
Biography

Chad Roberts, a native of Idaho, did his undergraduate work at Utah State University, earning a Bachelor of Science degree in Rangeland Resource Science in 1996. Prior to that he worked as a backcountry guide in and around Yellowstone and Grand Teton parks teaching conservation and camping. In 1996, he visited the optometrist for the first time and after taking a few more classes at Utah State University, he was admitted to Pacific University College of Optometry in 1998. While attending Pacific, Chad worked part-time at Pacific's Continuing Education managing and up-keeping internet CE courses. Now in his 4th year, he has completed one successful preceptorship at Fort Hall, Idaho Indian Health Services and anticipates graduation in the spring of 2002. In the future, Chad hopes to build his own private practice in his home state of Idaho.

Stephen Reigstad, now an adopted Oregonian, was born in Willmar, Minnesota. He attended Ridgewater College (formerly Willmar Community College) where he received his Associate of Arts degree. Stephen then went on to Bethel College in St. Paul, MN where he earned his Bachelor of Science degree, majoring in biology. Stephen started his optometric education in the fall of 1998 at Pacific University College of Optometry and is eagerly awaiting graduation in May of 2002. Prior to his relocation to Oregon, Stephen worked in a bicycle shop in Minnesota and maintains a keen interest in mountain biking. Stephen's future plans include working in the private sector of optometry, hopefully in the beautiful Pacific Northwest.