

Association of Rotational Molders International



Low Temperature Impact Test

Version 4.0

July 2003

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Low Temperature Impact Test Protocol

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This test was developed by the Association of Rotational Molders (ARM) International from a variety of sources, all of which ARM International and its members believe to be reliable. While ARM International has made reasonable efforts to confirm the completeness and accuracy of the data on which this test method is based, ARM International and its members make no guarantees, warranties, or other representations as to the data's completeness and accuracy, nor do ARM International and its members assume any responsibility or liability for any loss or damage suffered from the use of this test.

As with any procedure of this nature, use appropriate safety devices. Good safety practices and compliance to OSHA standards are the responsibility of the tester.

1. Scope.
 - 1.1 This method covers the determination of the energy required to cause the failure of plastic samples at low temperature by free-falling darts.
 - 1.2 Four test procedures are included.
 - 1.2.1 Procedure A requires a 10 lb. (4.536 kg) dart.
 - 1.2.2 Procedure B requires a 15 lb. (6.804 kg) dart.
 - 1.2.3 Procedure C requires a 20 lb. (9.072 kg) dart.
 - 1.2.4 Procedure D requires a 30 lb. (13.61 kg) dart.
 - 1.3 Two types of failure are described.
 - 1.3.1 Ductile failure – occurs when dart elongates the sample and punctures a hole in the test sample.
 - 1.3.2 Brittle failure – occurs when sample fails in a brittle manner, shattering or splitting into two or more pieces; or when the impacted areas break loose without elongation.
 - 1.4 Sample preparation for impact data shown in ARM International's *Listing of Resin Properties*.
 - 1.4.1 Test specimens to be impacted are to be from a rotationally molded part. The falling dart should impact the surface of the part that was in contact with the mold when it was molded.
 - 1.5 This test involves heavy weights and falling objects, cold temperatures, loud noise and a risk of flying debris. Care should be taken to wear proper personal protective equipment such as safety shoes, safety glasses or goggles, hearing protection and gloves.
2. Summary of Method.
 - 2.1 Each procedure establishes the height of a specific dart that will cause 50% of the specimens to fail. Procedures A, B, and C differ only with respect to dart weights while Procedure D differs with respect to both dart the weight and geometry of the tip.

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- 2.2 The technique used is commonly called the Bruceton Staircase Method or the Up-and-Down Method. Testing is concentrated near the mean, reducing the number of specimens required to obtain a reasonably precise estimate of it.
- 2.3 Since the 30 lb. (13.61 kg) dart has a tip of different geometry, the absolute values of impacts cannot be compared to those obtained with the other darts. In addition, as the velocity of the falling dart will be different for all of the darts, only values of different materials using the same dart can be compared. Note that the report should document the actual dart used (i.e. 10 lb., 15 lb., 20 lb., or 30 lb.).

3. Significance.

The test conditions of procedure A are the same as procedures B & C but differ in dart weight, and they serve only as an indication of low temperature serviceability without direct correlation to engineering data for use in design.

- 3.1 The main limitation of procedure A is that with the fixed dart weight and a maximum drop height, sufficient energy for failure may not be present to cause failure by any mode.
- 3.2 Procedures B & C allow for a 50 % and a 100% increase in impact by virtue of the greater dart weight. Procedure D allows for even higher impacts by virtue of the greater dart weight and more severe dart tip/tip geometry. The logical extension is that dart weight can be increased or drop height increased to induce failure, within limits of physical space.
 - 3.2.1 The dart design in all procedures is intended to give the greatest stress concentration in the fastest time so that variation of thickness on tough materials still results in one mode of failure or the other.
- 3.3 Numerical data obtained by one procedure cannot be interchanged with that from another procedure due to the different dart velocities and dart geometry. However, the mode of failure induced by procedures A, B, C or D can be a useful indicator of "properly processed samples".
 - 3.3.1 For Polyethylene, a ductile failure is the failure desired mode that generally occurs on properly processed samples.
 - 3.3.2 For Polyethylene, a brittle failure or failure by shattering, generally indicate that the optimum properties have not been obtained by the processing parameters used.
- 3.4 The height of the tester can be varied to fit the individual requirements of user space; however, maximum impact height of 10 ft. is to be used. Procedures A, B and C make it possible to select a dart weight that in most cases will cause failure at the mid-range of the tester. This will help reduce any effect of velocity on the results, but not negate it. Procedure D is the most severe test and the dart tip will effect will be the overriding factor rather than the velocity effect.
- 3.5 The specimens should be as nearly flat as possible and unrestrained.
- 3.6 The results obtained are influenced by the quality of the material of the specimen. Specimens with surface flaws or imperfections in or on either surface should be avoided.

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- 3.7 When comparing samples of varied thickness, impact resistance cannot be normalized for average specimen thickness, even if the surface conditions of specimens are roughly equivalent.
 - 3.8 All samples should be aged consistent with equilibration of the test temperature throughout the part.
 - 3.9 Rotationally molded samples are placed in the sample holder such that the dart contacts the surface that was in contact with the mold when molded. The inside surface of the sample is placed down.
4. Definitions.
- 4.1 Failures
 - 4.1.1 Ductile – signified by penetration of the dart through the specimen leaving a hole with stringy fibers at point of failure rather than cracking outwardly from point of failure. The area under the dart has elongated and thinned at the point of failure.
 - 4.1.2 Brittle – signified by the part physically coming apart or cracking at the point of impact. Sample has no or very little elongation.
 - 4.2 Drop height – dimension between impact tip of dart and surface of sample to be tested. (See Appendix A)
 - 4.3 Dart and Tup
 - 4.3.1 Dart – defined as the entire falling apparatus of given total weight depending on procedure. The dart is comprised of both the tup portion and larger diameter solid mass portion whose length is cut to meet the weight tolerance.
 - 4.3.2 Tup – defined as the 1.0 inch by 4.5 inch (25.4 mm by 114.3 mm) or 0.5 inch by 4.0 inch (12.7 mm by 101.6 mm) hemispherical ended portion of the dart that strikes the specimen.
5. Apparatus.
- 5.1 Testing machine – constructed as shown in Appendix A.
 - 5.1.1 Procedure A - 10 lb. (4.536 kg) dart as Appendix C.
 - 5.1.2 Procedure B - 15 lb. (6.804 kg) dart as Appendix C.
 - 5.1.3 Procedure C - 20 lb. (9.072 kg) dart as Appendix C.
 - 5.1.4 Procedure D - 30 lb. (13.61 kg) dart as Appendix D.
 - 5.2 Specimen support as described in Appendix B.
 - 5.3 Micrometer, for measurement of specimen thickness.

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6. Safety Precautions.
 - 6.1 A shield cage should surround the sample and holder and extend above the drop guide tube shown in Appendix A.
 - 6.2 A cushion of plastic should be inside the sample support to prevent damage to the dart tip when the dart penetrates a sample.
 - 6.3 All specimens should be handled with tongs or gloves.
 - 6.4 Hearing protection should be worn due to the loud noise generated when the falling dart strikes the specimen.
7. Sampling.
 - 7.1 Test specimens should be representative of the part under study.
 - 7.2 Test specimens for the ARM International *Listing of Resin Properties* should be 0.125" (3.17 mm) and 0.250 inch (6.34 mm) thick. For the ARM International *Listing of Resin Properties*, the specimen thickness should have a maximum variation of $\pm 10\%$ for 0.125" (3.17 mm) thick specimens and $\pm 5\%$ for 0.250" (6.34 mm) thick specimens. Note that Procedure D is typically used for specimens that are greater than 0.4" (10.2 mm) thick.
8. Test Specimens.
 - 8.1 Test specimens should be obtained from rotationally molded parts.
 - 8.2 Test specimens should be as flat as possible and be free of surface imperfections that would otherwise negate the test.
 - 8.3 Measure part size for $5.0 \times 5.0 \pm 0.08$ in. ($127.0 \times 127.0 \pm 2$ mm). This will ensure loose fit in the sample holder.
 - 8.4 Measure and record thickness of each specimen in the area of impact. Note that parts of similar thickness (i.e. within the thickness range criteria) and tested using the same dart can be easily compared.
 - 8.5 Record the specimen thickness on the mold side of the specimen.
9. Conditioning.
 - 9.1 Test specimens should be conditioned to reach uniform chilling of the specimen cross-section to not less than $-40^{\circ}\text{F} \pm 3.5^{\circ}\text{F}$ ($-40^{\circ}\text{C} \pm 2^{\circ}\text{C}$). Practical experience shows that specimens exposed to -40°F / -40°C with full surface circulation reach uniform chilling/equilibrium in as little as two hours. Practical experience shows that stacked test specimens exposed to -40°F / -40°C with limited circulation require much longer exposure time to reach uniform chilling/equilibrium, even greater than 24 hours depending on stack configuration.
 - 9.2 Unless otherwise specified, the test specimen should be conditioned in an air circulation freezer or cold box for no less than two hours at $-40^{\circ}\text{F} \pm 3.5^{\circ}\text{F}$ ($-40^{\circ}\text{C} \pm 2^{\circ}\text{C}$) prior to test.

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10. Procedure.
 - 10.1 Raise the 10 lb., 15 lb., 20 lb. or 30 lb. dart (4.536 kg, 6.804 kg, 9.072 kg or 13.61 kg dart) to the height expected to cause half of the test specimens to fail. Record the height value.
 - 10.2 Remove the test specimen from the cold storage service using tongs or gloves and place it on the test holder with the surface from the inside of part down and the marked surface up. Ensure that it is centered in the specimen holder.
 - 10.3 Release the dart within 30 seconds of removal from the freezer/placing the test specimen on the test holder.
 - 10.4 Observe and record pass or fail. The specimen is considered to pass if the surface of impact would not leak water if in a container. (No visible hole in the slab sample). Permanent deformation is not a failure. The depth and area of the depression can indicate nearness to failure.
 - 10.5 If the first specimen fails, lower the dropping height by a Δh of usually 6 inches (152.4mm). Repeat test. Continue decreasing height by the same increment until part passes. If first specimen does not fail, increase the drop height 6 inches (152.4mm) and repeat test. Continue increasing the drop height by same increment until failure occurs. If no failure occurs before 75% of the tester height is reached, stop testing and change to a heavier dart. Discard data obtained to this point and start again. Each impact should be on a fresh test specimen.
 - 10.6 This technique allows one to determine the total dart height for each test from the previously tested specimen. The impact test can be performed on a specimen only once.
 - 10.7 Use a chart for each specimen as shown in Appendix E. Place a legend on the record to show what symbol represents pass and fail. (Note: Letters such as O for pass and X for Ductile Failure and an * for Brittle Failure clarifies the outcome of each test.)
 - 10.8 Each chart should include as much information on specimen history as possible, such as processing temperature, cycle time, conditioning time, and aging time (length of time since molding).
 - 10.9 For best results, test 20 samples and then count the total number of N (events). This number may be non-failures or failures, whichever is less. N should be 10. If $N < 10$, continue testing until $N=10$, then stop testing.
11. Calculations.
 - 11.1 On the data form (Appendix E), record under n_i the total number of events (number of failures or non-failures, whichever is less) at each drop height. (See Appendix E.)
 - 11.2 In column i , enter integers 0, 1, 2, etc., for each n_i entered. Put 0 for the lowest dart height at which an n_i value has been entered, 1 for the next higher dart height, etc.
 - 11.3 Add the n_i column. It should always equal 10 if the procedure is followed exactly. The total of the n_i column is N .

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- 11.4 In column in_i at each height, enter the corresponding n_i multiplied by i to calculate in_i . (See Appendix F.)
- 11.5 Enter h used.
- 11.6 Enter h_0 which has the lowest height that an event occurred. It should be the height that the i value of zero is assigned.
- 11.7 Mean failure height. Calculate mean failure height from the data as follows:

$$h = h_0 + [\Delta h (A/N \pm 0.5)] \text{ where,}$$

h = mean failure height in feet (meters)

h_0 = shortest height at which an event occurred in feet (meters)

Δh = increment in feet (meters) of the change in dart height used (6 inches or 152.4mm)

N = total number of failures or non-failures, whichever is smaller (called events)

$i = 0, 1, 2, \dots, K$ (counting index, starts at h_0)

$$A = \sum_{i=0}^k in_i$$

n_i = number of events at h_i

$h_i = h_0 + \Delta h$ and

h_k = highest height at which an event occurred in feet (meters)

- 11.7.1 In calculating h , the negative sign is used within parentheses when the events are failures. The positive sign is used when the events are non-failures.
- 11.8 Mean Failure Energy – *MFE*. Calculate the mean failure energy as follows:

$$MBE = h \times w \text{ (for ft.-lbs.)}$$

$$MBE = h \times w \times g \text{ (for J)}$$

Where, w = dart weight used in lbs. or kg.

g = acceleration due to gravity = 9.81 m/s^2

12. Report.

- 12.1 The report will contain the following:
- 12.1.1 Complete identification of sample tested, including material type, source, manufacturers code, form dimensions, history of processing (i.e., time, temperature, and any visual observations concerning the part, bubbles, scratches, etc.)
- 12.1.2 Method of preparation of specimen.
- 12.1.3 Mean failure height.

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- 12.1.4 Dart used 10 lb., 15 lb., 20 lb., or 30 lb. (4.536 kg, 6.3804 kg, 9.072 kg or 13.61 kg).
- 12.1.5 Specimen thickness tested averages and range.
- 12.1.6 Number of specimens used for determination of mean failure height.
- 12.1.7 Mean failure energy.
- 12.1.8 Any variations from the procedure recommended.
- 12.1.9 Types of failure.
- 12.1.10 Date of test and operator.

Note: For production, it would not be realistic to impact 20 or more samples for part-to-part quality control. After the mean failure height (MFE) is established, a go-no-go quality control test using less samples could be developed.

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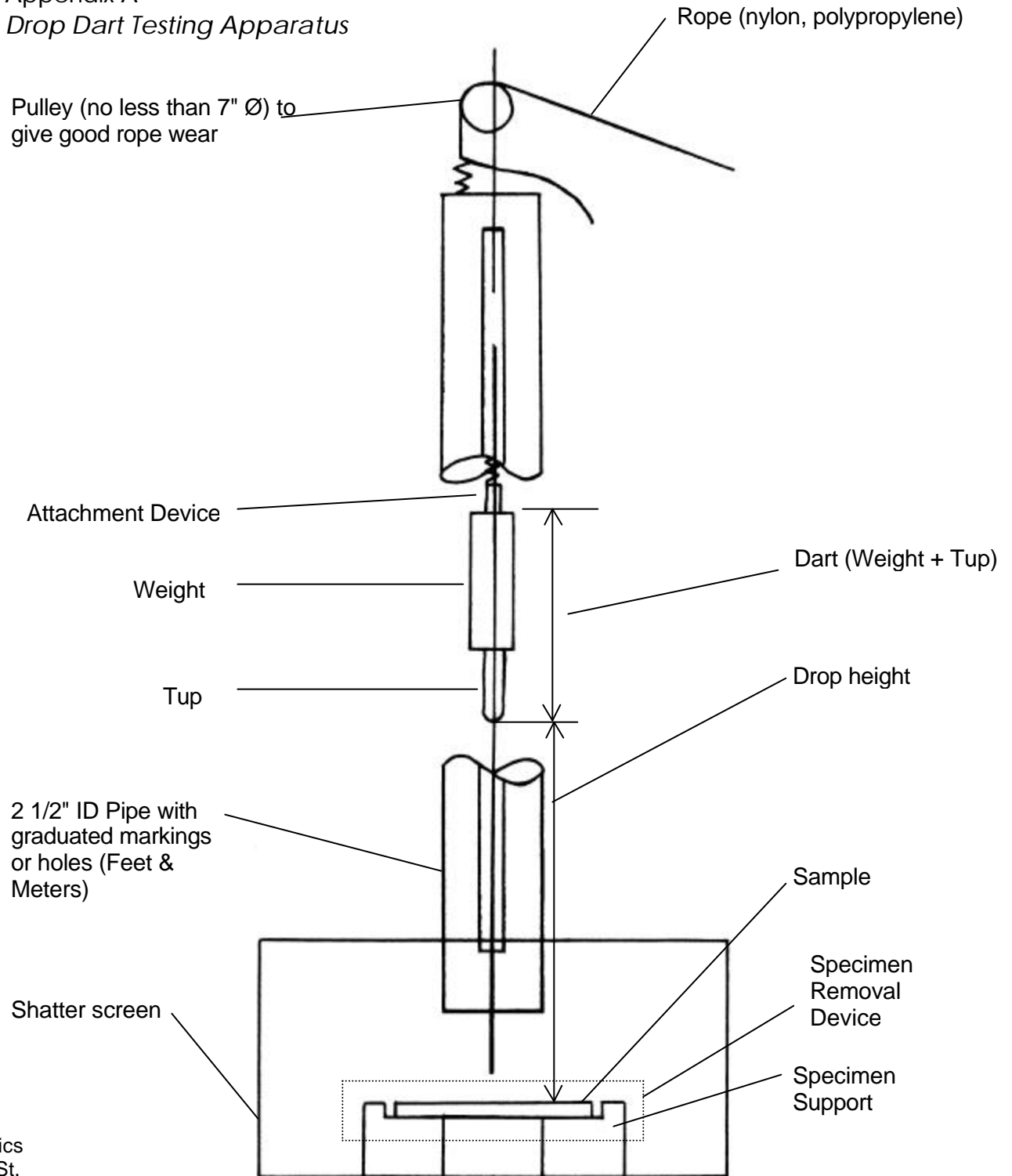
As with any procedure of this nature, use appropriate safety devices. Good safety practices and compliance to OSHA standards are the responsibility of the tester.

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Appendix A Drop Dart Testing Apparatus



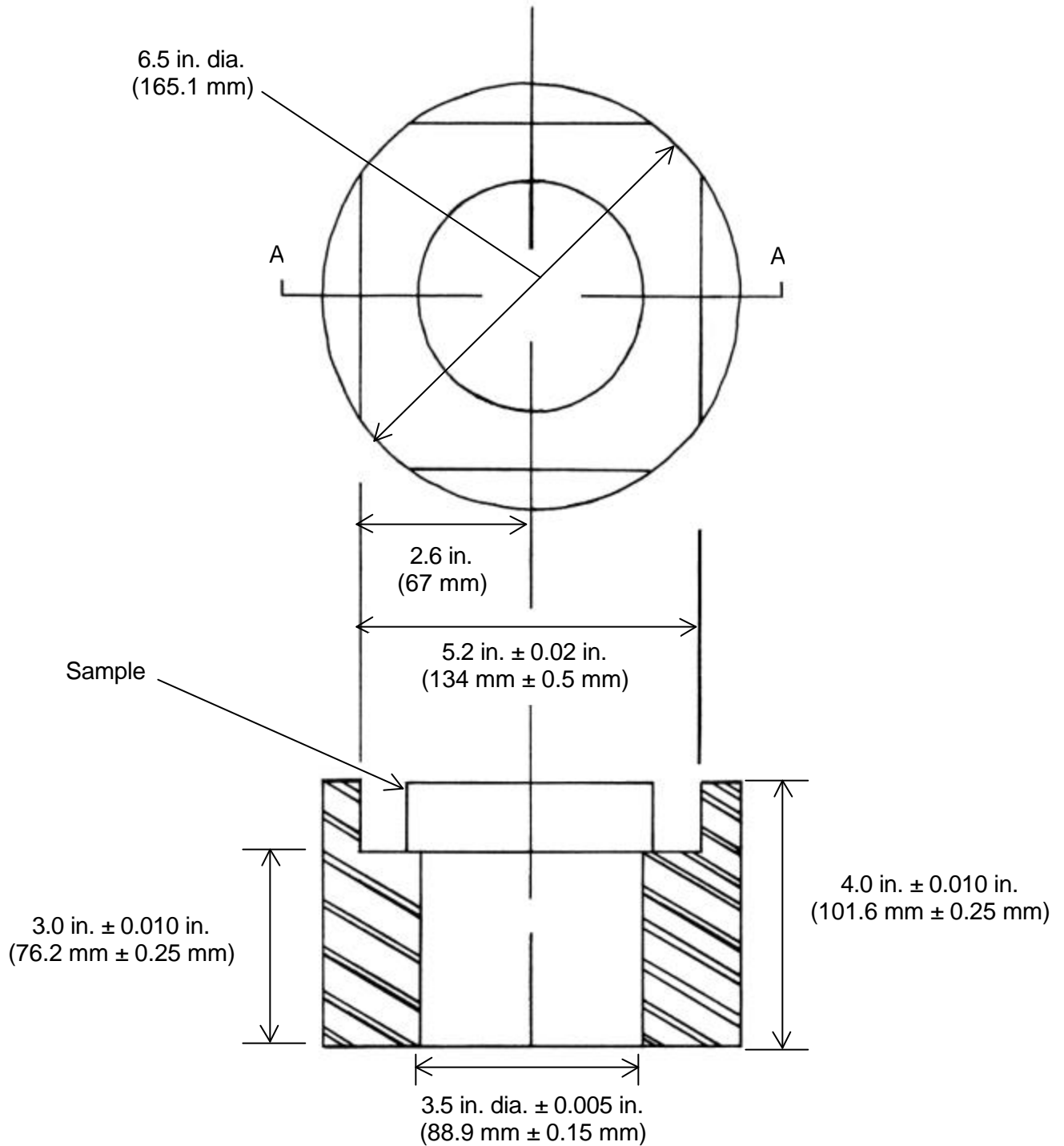
Mentor Dynamics
10-440 Phillip St.
Waterloo, ON, N2L 5R9, Canada
(or equivalent)

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Appendix B Specimen Support



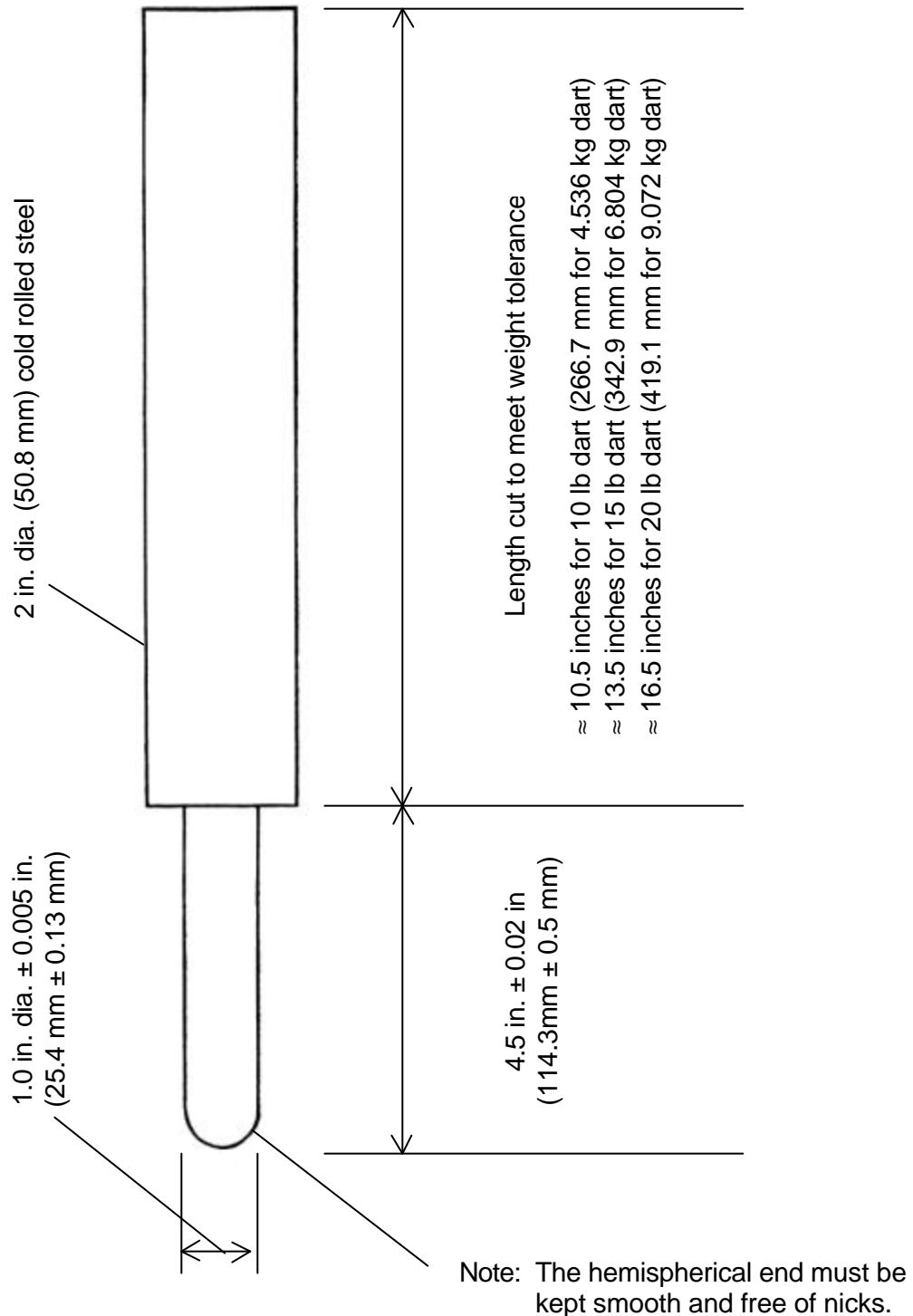
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Appendix C

Impact Dart - 10 lb. (4.536 kg), 15 lb. (6.804 kg) and 20 lb. (13.61 kg)

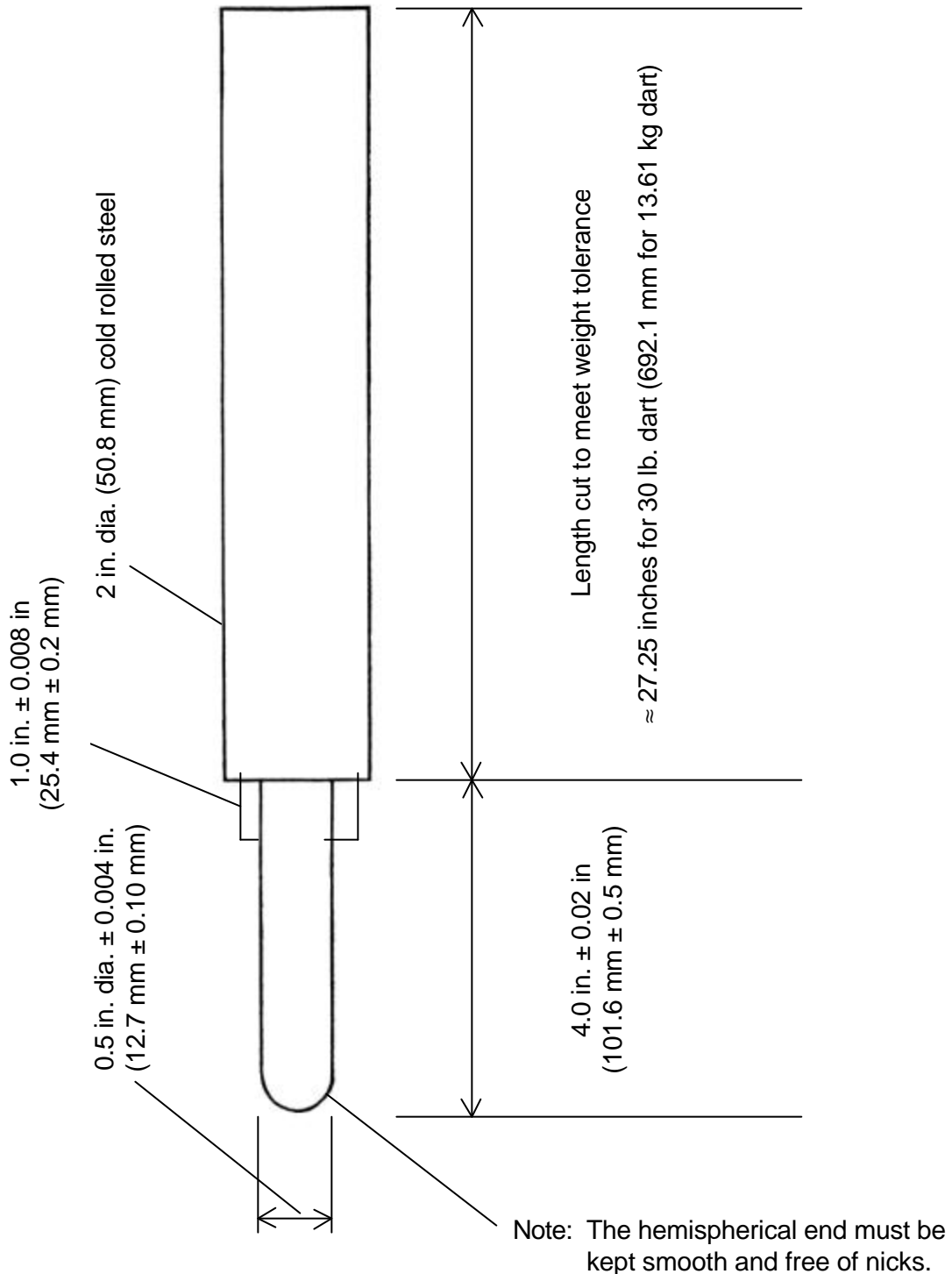


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Appendix D Impact Dart -30 lb. (13.61 kg)



Appendix E Data Recording Form

Laboratory: _____ Operator: _____ Date: _____

Sample: _____ Material Type: _____ Source: _____

Manufacturer's Code: _____ Processing History, Temperature, Cycle Time, etc.: _____

Additional Information: _____

- denotes non-failure
- X denotes failure – ductile
- * denotes failure – brittle

- Check one: Procedure A - 10 lb. (4.536 kg)
 Procedure B - 15 lb. (6.804 kg)
 Procedure C - 20 lb. (9.072 kg)
 Procedure D - 30 lb (13.61 kg)

Drop Height	Sample #																				Results							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	n_i	i	in_i					
																						Total =						

$h = h_0 + [\Delta h (A/N \pm 0.5)]$ $N =$ _____ $A =$ _____
 $MFE = h \times w$ (for ft.-lbs.)
 $MFE = h \times w \times g$ (for J) $h_0 =$ _____ $\Delta h =$ _____

MFE = _____

