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LETTER OF INTEREST
LETTRE D'INTÉRÊT

Title - Sujet (LOI) Fragmentation Protective Vest	
Solicitation No. - N° de l'invitation W8476-165369/A	**Date** 2015-08-13
Client Reference No. - N° de référence du client W8476-165369	**GETS Ref. No. - N° de réf. de SEAG** PW-$$PR-761-67800
File No. - N° de dossier pr761.W8476-165369	**CCC No./N° CCC - FMS No./N° VME**
Solicitation Closes - L'invitation prend fin **at - à** 02:00 PM **on - le** 2015-09-15	**Time Zone** **Fuseau horaire** Eastern Daylight Saving Time EDT
F.O.B. - F.A.B. Specified Herein - Précisé dans les présentes **Plant-Usine:** ☐ **Destination:** ☐ **Other-Autre:** ☑	
Address Enquiries to: - Adresser toutes questions à: Beaumier, Julie	**Buyer Id - Id de l'acheteur** pr761
Telephone No. - N° de téléphone (819) 956-7432 ( )	**FAX No. - N° de FAX** (819) 956-5454
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Name and title of person authorized to sign on behalf of Vendor/Firm (type or print) **Nom et titre de la personne autorisée à signer au nom du fournisseur/ de l'entrepreneur (taper ou écrire en caractères d'imprimerie)** **Signature** **Date**	

Issuing Office - Bureau de distribution
Clothing and Textiles Division / Division des vêtements et des textiles
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Canada

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Letter of Interest (LOI) for the Sniper Body Armour System (SBAS)

1.0 Purpose and Nature of the Letter of Intent (LOI)

1.1 Public Works and Government Services Canada (PWGSC) is requesting Industry feedback regarding the intent of the Department of National Defence to introduce a new configuration of fragmentation and bullet resistant personal protective equipment for personnel engaged as snipers in the Canadian Army. This system will be known as the Sniper Body Armour System (SBAS).

1.2 The objectives of this LOI are the following:

- Provide Industry information about the requirement;
- Learn which companies would be interested in bidding on this opportunity;
- Learn what products are commercially available and suitable for use with the military that may be feasible for procurement and delivery within the next two years;
- Receive an indication of production capabilities and potential unit cost;
- Answer the following questions:
  a. Does the potential supplier already provide a similar model of fragmentation protective body armour and plate carriers? If so, specify make/model and features.
  b. Would the potential supplier provide a means for establishing a repair capability for non-ballistic fabrics?
  c. Does the potential supplier provide a warranty on the product? Define the applicable coverage.
  d. Is the supplier able to comply with the Canadian Content Policy? https://buyandsell.gc.ca/policy-and-guidelines/supply-manual/annex/3/6
  e. Is three months a reasonable time to have the RFP available to Industry on Buy & Sell in order to provide a bid response with ballistic and Infrared Reflectance (IRR) testing completed?
  f. Potential suppliers are encouraged to draft a list of pertinent questions relative to product design, product capabilities or terms of this LOI. Please refer to specific section(s) of the LOI.

1.3 This LOI is neither a call for tender nor a Request for Proposal (RFP). No agreement of contract will be entered into based on this LOI. The issuance of this LOI is not to be considered in any way a commitment by the Government of Canada, nor as authority to potential respondents to undertake any work that could be charged to Canada. This LOI is not to be considered as commitment to issue a subsequent solicitation or award contract(s) for the work described herein.

1.4 Although the information collected may be provided as commercial-in-confidence (and, if identified as such, will be treated accordingly by Canada), Canada may use the information to assist in drafting performance specifications (which are subject to change) and for budgetary purposes.

1.5 Respondents are encouraged to identify, in the information they share with Canada, any information that they feel is proprietary, third party or personal information. Please note that Canada may be obligated by law (e.g. in response to a request under the Access to Information and Privacy Act) to disclose proprietary or commercially-sensitive information concerning a respondent (for more information: http://laws-lois.justice.gc.ca/eng/acts/a-1/).

1.6 Respondents are asked to identify if their response, or any part of their response, is subject to the Controlled Goods Regulations.

1.7 Participation in this LOI is encouraged but is not mandatory. There will be no short listing or potential suppliers for the purposes of undertaking any future work as a result of this LOI. Similarly, participation in this LOI is not a condition or prerequisite for the participation in any potential subsequent solicitation.

1.8 Respondents will not be reimbursed for any cost incurred by participating in this LOI.

1.9 The LOI closing date published herein is not the deadline for comments or input. Comments and input will be accepted any time up to the time when/if a follow-on solicitation is published.

2.0 Background Information

2.1 A hallmark requirement for snipers is to be able to infiltrate into a firing position and operate in that position while maintaining maximum concealment and the ability to operate weapon systems. The current Fragmentation Protective Vest with Bullet Resistant Plates installed provides the requisite ballistic protection but does not provide the ability to perform these functions with the required stealth or range of motion in order to be mission successful.

2.2 Snipers require fragmentation protection during all elements of their deployment including infiltration, operating in the firing position hide and exfiltration. Bullet resistant protection is only needed during certain elements of the operation. To meet the scalable protection levels required and maintain concealment properties, a two piece system is being considered. The system will consist of a fragmentation protective vest (FPV) and a plate carrier (PC).

2.3 The FPV is to be worn at all times under the uniform shirt, similar to a concealable vest worn by law enforcement. Range of motion, ease of donning/doffing, fabric durability will be primary areas of assessment in addition to ballistic protective capability.

2.4 The plate carrier will be worn separate from the FPV and could be worn over the combat shirt/jacket/parka and must integrate with the modular fighting rig. It is undecided at this point if the material will be a single colour or CADPAT camouflage. The PC must be easily adjustable though able to retain its position on the body and have a quick release function. It is not anticipated that the outer surface of the PC will require any attachment points.

2.5 The vest must provide the same or better fragmentation protection as the current in-service FPV (defined in Annex A). The plate carrier must be able to fit the current in-service bullet resistant plate.

2.6 The SBAS will be worn under all temperature ranges from -30 degrees C to +50 degrees C. Snipers require the capability to move dismounted over various types of terrain in various positions ranging from standing to crawling. They are required to move under stealth and fire a variety of weapon systems from differing firing positions. The sniper will wear the complete SBAS for extended periods of time ranging from one to four hours. The sniper will wear the FPV component of the SBAS for extended periods ranging from a few hours to one or more days.

3.0 Potential Work Scope and Constraints

3.1 DND plans to acquire 319 sets of SBAS. This would be a complete purchase to include sizing spares and stock.

3.2 It is the intention of DND to procure both items of the SBAS under one contract.

4.0 Evaluation Methodology

4.1 The SBAS soft body armour will be evaluated using a technical evaluation of performance for ballistic and material characteristics along with workmanship.
4.2 The plate carrier will be evaluated for workmanship and fit of the ballistic resistant plate.
4.3 The SBAS system will be evaluated through a user evaluation for elements such as fit; donning and doffing; range of motion and comfort.

5.0 Legislation, Trade Agreements and Government Policies

5.1 Potential legislations that may apply include:
   a. Defence Production Act (DPA)
   b. Defence Procurement Strategy (DPS)
   c. Controlled Goods Program (CGP)
   d. Federal Contractors Program for Employment Equity (FCP-EE)

6.0 Schedule

Letter of Interest	August 2015
RFP Issued	FY 15/16
Contract award	FY 16/17

7.0 Important Notes to Respondents

Interested Respondents may submit their responses to PWGSC Contracting Authority, identified below, preferably via email:

Julie Beaumier
Spécialiste en approvisionnement / Supply Specialist
Division des vêtements et textiles / Clothing and Textile Division
Travaux publics et services gouvernementaux Canada / Public Works and Government Services Canada
6A2, Portage III, 11 Laurier
Gatineau, Québec, K1A 0S5
Telephone: (819) 956-7432
Facsimile :(819) 956-5454
E-mail address: Julie.Beaumier@tpsgc-pwgsc.gc.ca

A point of contact for the Respondent should be included in the package.

Changes to this LOI may occur and will be advertised on the Government Electronic Tendering System. Canada asks Respondents to visit buyandsell.gc.ca regularly to check for changes, if any.

8.0 Closing Date for LOI

Responses to this LOI are to be submitted to the PWGSC Contracting Authority identified above, on or before 30 days after release of this LOI.

9.0 Enclosures

Annex A Technical Purchase Description SBAS Ballistics

Annex A
TECHNICAL PURCHASE DESCRIPTION

SNIPER BODY ARMOUR SYSTEM, FRAGMENTATION PROTECTIVE VEST, BALLISTIC INSERTS

OPI : **DSSPM**
BPR: **DAPES**

Canada

1. SCOPE AND CLASSIFICATION

1.1 Scope. This document details technical, and performance requirements for the soft armour inserts of the individual Fragmentation Protective Vest (FPV) portion of the Sniper Body Armour system (SBAS).

1.2 Intended Use. The FPV provides protection on a 24 hour, global, all-weather continuum to the extent practical. The FPV is designed to provide, primarily, ballistic protection from fragmenting munitions and debris resulting from high explosive detonation or other explosive devices. Combined with the Bullet Resistant plates (BRP), this vest will optimise the protection levels to defeat multiple ballistic hazards across the battlefield continuum. Fragmentation protection is achieved with the use of flexible armour materials. These materials, when assembled and inserted into the FPV carrier, must not degrade the full range of motion necessary by a sniper to undertake mission essential tasks.

1.3 System Requirements. The FPV forms a component of the Sniper Body Armour System and the FPV flexible armour inserts are removable and consist of the front and rear carrier inserts as modular elements.

2. Armour Characteristics.

2.1 Armour Materials. Flexible armour materials used for the ballistic panels shall be of durable quality, that is, material characteristics shall not undergo appreciable alterations under the influence of ageing or environmental conditions for which the FPV is designed for wear (see Intended Use). The protective properties of the ballistic panels must be guaranteed for a minimum period of 10 years while sealed in their water-proof protective cover and used under normal service conditions. The armour material shall be free from any imperfections that may affect quality or serviceability of the finished product.

2.2 Ballistic packs. Ballistic packs include shoot-packs and armour material-packs that are provided for testing. The material used in the ballistic packs to evaluate performance characteristics shall be fully representative of the production solution proposed. Each shoot-pack shall be tacked in the four corners, unless the production solution includes a specific stitching pattern. In this case the shoot-packs shall be stitched to the same pattern.

2.3 Hybrid Solutions. Non-symmetric hybrid armour materials (non-homogeneous construction) are allowed in the construction of the ballistic solution. The ballistic fill layering order and positioning of each ply in the panel shall be defined for shoot-packs and for all component ballistic panels used in production. The strike face and alignment of the materials shall be clearly indicated on each layer (ply) of material if its direction or positioning is performance sensitive. If more than one component material is used, then the following data for each different material shall be provided: composition, layering order, and manufacturing details.

2.4 Ballistic Panel Areal Density (AD). The armour material shall be as light as possible while meeting the minimum ballistic requirements. When measured in accordance with 4.1, the maximum areal density of the armour material-packs and the ballistic panels shall not exceed 3.25 kg/m^2. The maximum variability of areal density between the test specimens shall be less than 0.15 kg/m^2.

2.5 Ballistic Panel Thickness. The thickness of the armour material-packs and the production panels should not exceed 4 mm, but shall not exceed 7mm when tested in accordance with 4.2.

2.6 Ballistic Panel Flexibility. The armour material shall be as flexible as possible while meeting the minimum ballistic requirements. As a guideline, the stiffness/flexibility of the armour material-packs should be less than 1.4 N/mm, but shall not be greater than 2.2 N/mm when tested in accordance with 4.3. The value of each production lot must remain within ± 20% of the average established during the preproduction and initial production phase (first 5 material lots).

2.7 Ballistic Panel Static Water Absorption. After static water immersion, the ballistic shoot-pack should not gain more than 20% in weight when tested in accordance with 4.4.

3. Ballistic Performance. Six tests are included for ballistic qualification of the FPV armour solution. Five ballistic limit tests (V50) using 4 projectile types (small and large sphere, right circular cylinder, and fragment simulating projectile); one proof velocity test (Vproof) with an FMJ handgun bullet for backface deformation resistance. These tests are also used in the evaluation of ballistic performance score that will determine the rating for ballistic fill proposals during a bid evaluation. During production, traceability of ballistic component materials shall be verified as specified at 4.1 and ballistic testing shall be conducted as specified at 4.2.

3.1 Ballistic Limit Resistance (Min. V50). The ballistic limit resistance (V50) of the armour solution of the FPV shall be such that it will meet or exceed the five ballistic limit test requirements as specified in Table 11.4. The average $\mathbf{MV_{50}}$ for each threat shall be calculated from the arithmetic mean of individual $\mathbf{V_{50}}$ values having a maximum velocity spread of 30 m/s. During a bid evaluation this $\mathbf{MV_{50}}$ value will be used to rate each proposal and will represent the $\mathbf{V_{50}}$ca during production. The minimum $\mathbf{V_{50}}$ value for any individual test shall not be less than minimums specified below. The zone of mixed results (ZMR) for each $\mathbf{V_{50}}$ value shall be less than 60 m/s, and the ZMR for each $\mathbf{MV_{50}}$ value shall be less than 50 m/s.

3.2 The $\mathbf{V_{50}}$ using the 17-grain FSP (5.46mm calibre) in the dry condition should be greater than 530m/s, but shall not be less than 500 m/s. This test ensures that the proposed solution meets or exceeds the performance level of the in-service vest.

3.3 The $\mathbf{V_{50}}$ using the 16-grain steel ball projectile (6.34 mm calibre) in the **wet condition** (30 minutes water immersion) should be greater than 450m/s, but shall not be less than 415 m/s and in **dry condition** should be greater than 490m/s, but shall not be less than 455 m/s.

3.4 The $\mathbf{V_{50}}$ using the 64-grain RCC (8.74mm calibre) in the dry condition should be greater than 380m/s, but shall not be less than 350m/s.

3.5 The $\mathbf{V_{50}}$ using the 1-grain steel ball projectile (2.49mm calibre) in the dry condition at ambient temperature should be greater than 560m/s, but shall not be less than 525m/s. These tests are utilised to rate the relative performance against other fragmentation solutions and to establish $\mathbf{V_{50}}$ca for each threat.

3.6 Backface Deformation Resistance (Vproof). The average backface deformation of the FPV ballistic fill supported on clay in the dry conditions should not be more than 44 mm when tested using a 124-grain FMJ bullet (9 mm calibre) impacting at an average velocity of 365 m/s. In addition, each single indentation in the clay material shall not be more than 50 mm, and no complete penetration of the armour material shall occur with the FMJ bullet.

4. Methods of Test

4.1 Ballistic Panel Areal Density (AD). The materials in the armour material-packs and the production panels shall be measured in accordance with ASTM Standard 3776 (option A, or C) or equivalent and the average areal density calculated. Equipment used for measurement shall be calibrated for accuracy and should be capable of weighing with a precision of ± 1gram. The average value of the ten (10) armour material-pack measurements will be used for qualifying each material lot.

4.2 Ballistic Panel Thickness. The thickness of the armour material-packs and the production panels shall be measured using ASTM standard D1777 (option 1) or equivalent. The average value of the ten (10) armour material-pack measurements and variance will be used for qualifying each material lot.

4.3 Ballistic Panel Flexibility. The armour material-packs flexibility shall be measured using the modified circular bend test (developed by CMC/DREV) method as specified in Section 7. The average value of the ten (10) armour material-packs and variance will be recorded for information and monitored for significant deviation from the production average.

4.4 Water Absorption. The ballistic shoot-packs used in wet target tests shall be measured as specified in section 6.6.5 and the percentage weight gain calculated. The average value of three contractor-measured samples and the three DND- measured samples will be used for pre-award qualification.

4.5 BALLISTIC PROTECTION Verification during production shall be done using shoot-packs and material-packs constructed from each ballistic material lot/sub-lot prior to cutting into plies for production panels.

4.6 Ballistic Lot Traceability. Traceability of finished production panels/inserts must be maintained in all cases to the original material lots. Ballistic material lots shall not normally exceed 4000 metres and shall be based on a woven beam. Lots shall be further broken down into finished sub-lots and rolls. A sub-lot (for test qualification) will be based on the finishing date or 1000 metres whichever is smaller. Rolls shall be strictly controlled by the prime contractor and his supplier and grouped by finish date and woven beam.

5. NOTES

5.1 BALLISTIC DEFINITIONS. Ballistic definitions shall apply only to those sections related to spall resistance and ballistic penetration performance of the ballistic fill arrangement found in the various ballistic inserts for the FPV and the ballistic shoot-packs for testing. Definitions are listed alphabetically.

Accepted hit (valid impact): accepted impacts include all fair hits; also includes any unfair hit for which the test conditions are more severe than specified (velocity too high and/or hit separation distance too short), but the performance criteria are met. It also includes any unfair hit for which the test conditions are less severe (velocity too low or impact or yaw angle too high), and the performance criteria are not met, this will then constitute a failure.

Angle of impact: The angle in degrees between the line of flight of the projectile and the perpendicular to the plane tangent to the point of impact on the target sample (see Fig. 11.1). In some documents, angle of obliquity is used with the same meaning.

Area of coverage: the area in square meters of the flexible ballistic insert used in a FPV; also area of a ballistic shoot-pack used for ballistic testing.

Areal density: a measure of the weight of the assembled ballistic material panel (assembled as a ballistic material pack, a shoot-pack, or production component) per unit area. It is expressed in $kg/m^2$and is the ratio of the mass of the material over its area of coverage. This value is used to compare the various ballistic solutions.

Backface: the surface of a test specimen designed to be positioned next to the body; also referred to as the wear face.

Backface deformation: the maximum transient displacement of the back surface of a test sample caused by a non-perforating projectile impact. This corresponds to the maximum depth of the depression made in the backing material measured from the undistorted front surface of this material.

Backing material: a block of tissue-simulating material placed next to the back face of the test sample and used to support the sample during testing. Oil-based non-hardening modelling clay is used to capture the indentation resulting from the impact during backface deformation testing (Vproof). For the V_{50} tests, no backing material is used.

Ballistic ply: a flexible armour material layer contained in the proposed ballistic solution prior to assembly into a panel.

Ballistic inserts: the finished ballistic production component, comprising the final construction of the ballistic panel, assembled and sealed in their protective cover. The core ballistic inserts include the collar and shoulder protector inserts and the front and rear ballistic inserts. All are modular and removable from their corresponding carrier shell components.

Ballistic panel: either a production or a qualification panel fully assembled in the final design construction of the ballistic fill layers, but not including the protective cover.

Ballistic shoot-pack: a 400 x 400 mm test specimen used for destructive testing. It is fully representative of the production panel solution, but used only for ballistic validation. Ballistic shoot-packs shall be assembled and corner stitched (or replicate stitching if a quilted solution is proposed) to replicate the ballistic inserts, but do not include any protective cover. Traceability shall be maintained in accordance with section 4.5.3.1.

Armour material-pack: a 152 x 152mm test specimen used only for non-destructive testing and physical measurements. Material packs shall be assembled in the final design construction, but not stitched, unless a quilted solution is proposed. If a quilted solution is provided, then four (4) additional ballistic shoot-packs (400x400mm) shall be delivered in lieu of material-packs. From these samples will be cut into necessary test coupons. Traceability shall be maintained in accordance with section 4.5.3.1.

Ballistic resistance: a measure of the capability of a protective material to stop or reduce the impact velocity of a striking projectile; in this document ballistic resistance is measured using ballistic limit tests (V_{50}) and a backface deformation resistance test (Vproof).

Ballistic retardation, R: a measure of the average attenuation of velocity or air drag deceleration of a projectile per unit distance (m/s/m) from the launcher up to the test sample.

Complete penetration (CP): a complete penetration has occurred when the projectile, or a piece of the projectile or any part of the ballistic protective material has passed completely through the test sample and is captured by or has passed through the backing material for the Vproof test, or has passed through the witness paper for the V50 test (crack or hole permitting light passage). If the projectile remains lodged in the test sample and part of it is visible from the back face of the sample this will also be considered as a complete penetration for the Vproof test.

Fair hit: a zero degree obliquity (±x degrees) impact using the specified weight and type of un-yawed projectile (x=3 degrees maximum for 9-mm bullet and 5 degrees for RCC and FSP) within the specified velocity range and at the specified location on the target sample.

Fragment simulator: a generic projectile type used in ballistic testing. Fragment simulators have various geometric and physical characteristics designed to simulate the terminal effects of fragmenting munitions.

Fragment simulating projectile (FSP): a specific fragment simulator based on a standardised cylindrical projectile with a chisel nose (see Fig. 11.5).

HPP: highest partial penetration velocity.

Indentation diameter or size: the indentation diameter of the depression made in the backing material measured from the undistorted front surface (Fig. 11.2). For non-symmetric cavity, both the smallest diameter (width) and the largest diameter (length) shall be measured and recorded.

Instrumentation velocity Vm: the velocity measured, at a given distance in front of the ballistic shoot-pack (Fig. 11.3, by a suitable device providing the required accuracy. When using a pair of detectors, measure to the middle of the two detectors.

LCP: lowest complete penetration velocity

mp: mass of the projectile or fragment simulator

Partial penetration(PP): any fair shot which is not identified as a complete penetration using the definition above, is to be recorded as a partial penetration; that is, the projectile rebounded, or remained embedded in the test sample without causing perforation of or imprint on the witness sheet or backing material.

Rejected hit (invalid impact): impacts are rejected and must be repeated if they are unfair and do not meet the special exceptions for accepted hits; a fair hit can also be rejected if it resulted in a test specimen not meeting the pass criteria and it came after an unfair but accepted hit having more severe test conditions.

Residual velocity (Vr): for complete penetration impacts, velocity of the projectile after impacting and exiting the armour material.

Right Circular Cylinder (RCC): a standardised cylindrical fragment simulator with a flat nose and sharp edges (see Fig. 11.4)

Sabot: a plastic carrier (see Figure 11.6) in which a projectile is centred to permit firing in a larger calibre barrel. The sabot is usually discarded in flight a short distance from the launcher, and only the sub-calibre projectile continues until the target.

Separation distance: the distance between the centres of any two hits or the centre of any one hit and the edge of the armour sample or the target retaining fixture.

Stand-off distance: the distance between the backface of the armour material and the witness sheet.

Strike face: the surface of a test specimen designed to face the attack of a ballistic threat.

Striking velocity (V_s): the velocity of the projectile when impacting the test sample as measured 1.5 m in front of the target.

Test range: the distance between the muzzle of the test barrel and the strike face of the target sample (see Fig. 11.3).

Twist Length: the horizontal distance along the gun barrel in which the rifling makes one complete turn; not to be confused with the actual length of the rifling over the complete barrel.

Unfair hit: a shot that does not conform to the criteria specified (see Table 11.1), that is, the yaw and obliquity exceeds the requirements or the velocity is above or below that specified for the projectile or the shot does not respect the shot pattern and sequence, i.e., too close to the edge of the specimen or to another shot. For the backface deformation test (Vproof), impact for which the velocity is outside the range specified.

V_{50} ballistic limit: the striking velocity at which 50% of the impacts of a particular projectile are expected to result in complete penetrations of a target sample of a given number of plies and physical properties at a specified angle of impact in a limited statistical test. The method involves obtaining a minimum of 14 shots using the modified up-and-down firing technique. The V_{50} is computed using the maximum likelihood method (DRDC Probit as per EXCEL file available from DRDC-Valcartier). Used as a quantitative measure of armour capability.

MV_{50}: average of the individual V_{50}'s for a specified threat having a spread of less than 30 m/s; if not, extra samples will need to be tested until the required number are found falling within the spread (refer to Tables 11.4 and 11.5 at Appendix 1).

MV_{50}qc: Minimum average value (MV_{50}) of a production material lot and is used for quality control. It must be greater than or equal to 97% of V_{50}ca.

V_{50}ca: the MV_{50} established during a bid evaluation for each specified threat.

Vproof: the minimum velocity specified for a particular projectile for a pass/fail test such as the backface deformation resistance test where a given number of rounds is fired at a test specimen and where no complete penetration is allowed.

Velocity spread: the difference between the highest velocity and the lowest velocity of a group comprising an equal number of partial and complete penetrations

Witness paper: a 0.38-mm thick Hilroy poster board sheet no 20210 (270 g/m2) placed 150±2 mm behind and parallel to the target surface at the impact point used to qualify the perforation result.

Yaw: the angle between the main axis of the projectile and its trajectory (velocity vector - refer to Figure 11.1). It should be measured as close to the target as possible. Projectile yaw at impact can noticeably alter the extent of penetration. Projectiles having a discarding sabot are more susceptible to yaw.

Yaw card: a stiff paper-type material placed in the projectile's line of flight, and used to determine the projectile yaw. The yaw card can also be used to find the exact hit location of the projectile after firing in order to assess hit fairness.

Zone of Mixed Results (ZMR): the difference in velocities between the highest partial penetration and the lowest complete penetration actually obtained during a V_{50} test (HPP-LCP).

6. BALLISTIC TEST PROCEDURES

6.1 Scope. This appendix describes reproducible test procedures defined for the evaluation of ballistic shoot-packs and the qualification of ballistic fill solutions for use in the SBAS. These procedures will be used to confirm the specified minimum ballistic performance requirements. The following test methods are defined:

[1] the Ballistic Limit V_{50} tests (large/small sphere, RCC, and NATO FSP); and

[2] the Backface Deformation Vproof test (9mm projectile).

6.2 Test Equipment

6.2.1 Projectiles. Details on the projectile types, calibre and the respective properties to be used for the ballistic tests specified herein are summarised in Table 6.1. Sources of acceptable projectiles for this purchase description are specified in the table. A precise description (mass, diameter, lot number, etc.) of all projectiles used must be included in test reports. Since the projectiles may be damaged during impact on the test specimen, they shall be used only once.

6.2.2 Launching System. The launching device (launcher and propellant) shall consist of any device capable of propelling reproducibly the specified projectiles at an acceptable impact angle and at the specified velocity range for Vproof or V_{50}, as applicable. It may be an actual powder rifle or a test barrel. Launching devices known to have velocity stability problems should not be used. The projectiles shall be single launched to obtain the number of fair hits required on each sample. When a rifled barrel is used, the barrel twist length should be recorded and it shall be as specified in Table 6.1. When the size of the launcher is larger than the calibre of the projectile or when high impact velocities are required, the projectile can be inserted into a split plastic sabot, e.g., a 6.34 mm sphere can be fired from a common 7.62 mm (.308 in) barrel. The preferred method to launch the 6.34mm sphere is a smooth bore barrel chambered for .22 cal Ramset blank cartridge. The drawing of a suitable sabot to launch the 2.5mm sphere from a 5.56mm barrel is depicted in Fig. 6.6. The launching device shall also be held in such a manner that its alignment does not change upon firing. For the ballistic tests, the launching system (launcher and propellant) must be capable of launching the projectile at velocities up 1000 m/s.

6.2.3 Launcher Calibration. To obtain the specified velocity for powder guns, hand loading of the ammunition is usually done. The muzzle velocity can also be set by adjusting the projectile seat in the barrel. A control of projectile velocity with a precision of $\pm$10 m/s of the desired velocity is required for the V_{50} and Vproof tests based on a series of 10 shots. A projectile velocity/propellant mass curve (or gas pressure curve) for the launcher system used shall be determined before any testing is performed. This curve is required to provide a basis for selecting the propellant charge to achieve a desired velocity. When firing with reduced charges, the yaw of the projectile may be greater than the yaw likely to be experienced with full charge firings.

The test weapon shall be firmly mounted 5m (refer to Figure 6.3) from the muzzle to the test sample and in such a manner that its alignment does not change upon firing. It shall be aimed to produce a zero degree obliquity to the sample at the impact location. When a new barrel is used, a minimum of 25 shots should be fired to break in the barrel.

TABLE 6.1 - Projectile and Launcher Summary

PROJECTILES	**Small Sphere**	**Large Sphere**	**NATO FSP**	**RCC**	**9x19mm FMJ**
Ballistic Test	Section 6.1 [1]	Section 6.1 [1]	Section 6.1 [1]	Section 6.1 [1]	Section 6.1 [2]
Projectile mass g *(grain)*	0.064±0.002 *(1)*	1.042±0.03 *(16)*	1.12±0.03 *(17)*	4.15±0.02 *(64)*	8.03±0.13 *(124)*
Projectile Material	Chrome Alloy Steel	Chrome Alloy Steel	4340 Steel or Equivalent	4340 Steel or Equivalent	Copper Jacket Lead Core
Projectile Hardness	60-66 RC	60-66 RC	28-32 RC	28-32 RC	---
Acceptable Source	Ball Grade G20, G28 or G40 SKF, FAG or Equivalent	Ball Grade G20, SKF, FAG or Equivalent	Figure 6.5 or Equivalent	Figure 6.4 or Equivalent	Hornady #3557 or Equivalent
Projectile Diameter mm	2.49±0.01	6.34±0.01	5.46±0.02	8.74±0.02	9.02
Projectile Length mm	2.49±0.01	6.34±0.01	6.52 nominal	9.17 nominal	---
LAUNCHER					
Barrel twist length mm	406 Sabot Separation	Smooth Bore Barrel	Max 250	Max 406	Max 250

6.3 Witness Systems

6.3.1 Penetration Witness. The witness system for V_{50} Ballistic Limit tests consists of a nominal 0.38-mm thick Bristol paper placed at a 150 ± 2mm stand-off distance behind and parallel to the target surface at the impact point (refer to Figure 6.3). The witness system must extend over a sufficient area such that all projectiles with sufficient momentum can be detected. Perforation of the sheet will be considered as perforation (complete penetration) of the target material. Impacts that are not identified as perforations using this definition are to be recorded as non-perforations.

6.3.2 Backface Deformation Witness. A clay backing material used to measure the maximum backface deformation of the target sample regardless of the tendency of the ballistic material to recover to its original shape. The backing material that has been qualified by the government is Roma Plastilina No. 1 modelling clay (oil-base, and non-hardening soft clay). It is available from Sculpture House, 38 East 30th St., New York, NY 10016, tel.: (718)-386-1354, Fax: (718)-386-3292 or from other artist supply centres. It must be calibrated to confirm that it is homogeneous and has the right consistency. If the calibration method damages the backing material then the damaged area(s) must be avoided during the ballistic testing.

Alternative modelling clays should not be used. Research has shown that correct consistency from of other products with the ball drop tests does not guarantee same backface deformation at ballistic velocity impact.

6.4 Sample Retention Method

6.4.1 Specimen Retention System (V_{50}). The ballistic shoot-pack shall be clamped along its edge to a rigid support fixture (sandwich window frame) of such size that the unsupported impact area is 30 x 30 cm and that it remains firmly in place before, during and after projectile impact. The surrounding clamping fixture shall have interlocking ribs to ensure minimal target slippage during testing. A typical target fixture is shown in Fig. 6.7. The target frame shall be tightened such that the closing force is 30±3 kN. The test sample must lie smooth and flat and must only be slightly stretched between the two frames. The target centre deflection before firing shall be such that when pushing the panel at the centre by a distance of 9 mm beyond the original front surface plan with a load cell having a cylindrical probe diameter of 12.5 ± 0.5mm, the load registered shall fall between 2 N and 30 N (see Fig. 6.13).

Fabric test specimens can be replaced to initial shape after every shot, if desired, but this is not required. The test sample may have to be readjusted between the shots when excessive pulling from the retention fixture so that the required deflection is maintained throughout the test sequence. Target restraint provides for more accurate, reproducible, and cost effective method of data acquisition.

The support fixture shall be capable of vertical and horizontal adjustment to ensure that the impact points can be located anywhere on the strike face, and that the projectiles strike the target surface normal (zero deg impact angle) to the line of fire. The fixture shall allow the conditioned sample to be quickly mounted or dismounted to minimise changes in conditioning temperature.

6.4.2 Specimen Retention System (Backface Deformation). The ballistic shoot-pack shall be mounted on a rigid metallic box of the following minimum internal dimensions (340 x 340 x 100 mm) filled with the clay backing material specified at 6.3.2. The ballistic shoot-pack shall be attached to the block of backing material by means of two elastic straps or by equivalent means to ensure a good contact between the specimen and the block. The distance between the two straps should be approximately

150 mm apart and the point of impact shall be at an equal distance from the two straps so that there is no interference with the shot pattern. No individual shot shall fall within 50 mm of either retaining strap or band. The block itself shall be supported on a rigid fixture so that it remains firmly in place before, during and after projectile impact. The support fixture shall be capable of adjusting the position of the block horizontally and vertically such that the prescribed shot pattern can be followed and so that zero degree obliquity can be achieved anywhere on the test specimen.

6.5 Measurements

6.5.1 Velocity Measurement. The velocity of the projectile before impact and after impact (if required) shall be measured with any suitable measurement system that can provide an accuracy of ±0.3% (e.g. a true velocity of 1000 m/s should be recorded within an accuracy of ±2 m/s). The measurement system used must be calibrated and certified for accuracy according to the manufacturer instructions on a annual basis. The calibration procedures and records shall be kept and made available upon request. If accuracy is not certified, two independent measurement systems shall be used. The difference between the two velocities measured with these two independent systems shall be less than 0.5%. When chronographs are used they shall have a precision of 1 μs.

The detectors can either be photoelectric screens, conductive screens, laser ribbons, acoustic, inductance or capacitance type. Doppler radar systems are also appropriate. When detectors are used, they shall be oriented perpendicular to the projectile trajectory. All distances must be kept constant for the whole duration of a test. The separation distance between the triggering planes of the detectors shall be measured and recorded with an accuracy of 1 mm and maintained to a tolerance of ±1 mm. The position of the gun, the velocity detectors and the target must be kept constant for the duration of a test sequence.

Before commencing a test sequence, three pre-test rounds shall be fired to verify that the required velocity for the test is obtained. Additional rounds shall be fired as required until a stable striking velocity is achieved.

Each impact velocity shall be measured and recorded and if not within accuracy required, that impact shall be disregarded. When two independent sets of instrumentation are used, velocities from each set will be recorded and the mean average of the two velocities shall be calculated.

6.5.2 Yaw Measurement. The yaw angle of the projectile at impact may be measured by any suitable method (e.g. yaw card, flash radiograph, photography) that does not in itself cause projectile instability and which is accurate within ±0.5 degrees. Yaw cards are simple and inexpensive and they should be used unless they prove unsatisfactory. Yaw cards are usually made using a stiff material from which the fragment will punch a clean hole showing its presented area at impact. Processed photographic paper, single weight, 200x200 mm in size, may be used for the yaw card.

They should be placed perpendicular to the line of flight and positioned as near the target surface as possible (desirably within 150 mm from the shoot-pack).

When using FSP or RCC, the dimensions *D1*, *D2* and *L* (see Fig. 11.8) shall be measured immediately prior to firing. Yaw is then computed by measuring, using an optical device with a magnification factor of at least 5X, the largest dimension (*A*) of the hole caused during perforation of the witness plate. For fragment simulator having no rear skirt, *D1=D2*. The yaw angle (θ) is then determined using the following formulas:

$$DM = \frac{D1 + D2}{2}$$

$$T = \sqrt{L^2 + DM^2}$$

$$\theta = \alpha - \beta = \sin^{-1}(A/T) - \tan^{-1}(DM/L)$$

When the hole in the yaw card is a perfect circle there is no yaw. For FSP and RCC, the maximum acceptable yaw (θ) must not exceed 5°, and desirably should not exceed 3°. Any round for which the measured yaw exceeds 5° shall be rejected for excessive yaw, and a further round fired under the same test conditions. If three rounds out of five exhibit unacceptable yaw, the gun barrel should be replaced with a new one. In case of dispute, yaw shall be measured using either an orthogonal photographic or flash X-ray system to an accuracy of $\pm 0.25^\circ$.

6.5.3 Measurement of Backing Material. The depth of the depression or cavity in the backing material and any other relevant information (e.g., length, width) should be recorded. The recommended set-up used to measure the backface deformation shall be similar to the one shown in Fig. 6.2.

6.6 Test Procedures

6.6.1 Test Range. The set-up used to conduct the ballistic tests shall be similar to the one shown in Fig. 6.3. When the launcher used is a powder gun in conjunction with light detectors, the following guidelines apply. The first detector should be placed at a minimum distance (F) of 1.5 m from the muzzle of the test barrel to prevent false triggering from muzzle blast. The separation distance (D) between the pair of detectors shall be at least 0.5 m, and shall not exceed 1.5 m. The exact distances used shall be specified in the test report. The ballistic shoot-pack shall be placed at a distance (R) from the launching device compatible with the velocity measurement systems used and for which the projectile is stable (impact angle less than 3 or 5 deg). When using powder guns, the recommended target distance is 5 meters. For residual velocity measurement using a pair of detectors, the measurement point shall be at a maximum distance of 0.5 m away from the target. The separation distance between the two detectors shall be 0.5 m.

6.6.2 Test Range Ambient Conditions. The ballistic testing shall be carried out in a test facility having the standard ambient conditions, i.e. a temperature of 20°±5°C and a relative humidity of 65±10%, or within a maximum time of forty-five minutes after the completion of pre-conditioning. The temperature and humidity measurements may be made with any equipment having a minimum accuracy of 1°C for temperature, and 3% for humidity. If any variations to these conditions are made then the conditions used must be recorded in the final report.

6.6.3 Test Specimen Selection and Quantity. The test specimens for both the dry and wet test conditions shall be a ballistic shoot-pack as defined at Section 6. Only new armour material samples as offered for bid or sale shall be tested. The specified quantity of specimens (refer to Statement of Work), selected at random from a distinct lot/batch, shall constitute a statistically valid test series for qualification. Prior to testing, each shoot-pack shall be weighed and visually examined to make sure that it is free from defects or other damage. A full description of each test specimen shall be provided as specified at section 6.8.1.

6.6.4 Pre-Conditioning of Test Specimens. Prior to ballistic testing, each test specimen shall be pre-conditioned to a temperature of 20°±1°C and a relative humidity of 65±5% for at least twelve hours. If conditions different from these are used, they should be clearly identified and recorded in the test report. For test conditions where the temperature of the test specimen is not the same as the range conditions, the temperature for each test specimen shall be measured in degrees Celsius before and after completion of the test. The temperature and %RH of the test laboratory shall be recorded at the beginning and completion of a test sequence. If additional requirements are specified for extreme temperature conditioning, they shall be defined in the contract or Request for Proposal.

6.6.5 Water Immersion Test Conditions (wet target). For testing requiring a wet target, the ballistic shoot-pack shall be weighed dry and then submerged vertically (using a clamp system) in water at 15° C to 25° C for a period of thirty (30) minutes. It is then removed from water and held vertically from two corners and allowed to drain for three minutes. The specimen shall be re- weighed and the ballistic test carried out using the specified test method. The first shot should be fired within 5 min of the completion of the draining period and the final shot not more than 40 min later for a maximum test duration of 45 minutes. If the testing has not been completed in the time permitted, the test data shall be discarded and wet testing must begin again with a new target sample.

6.6.6 Test Specimen Positioning and Impact Angle. Each ballistic shoot-pack shall be mounted on a rigid support with the area to be impacted perpendicular to the line of fire so that each impact is made normal to the intended impact location. The test specimen and the support fixture can be aligned using a laser sighting and mirror system so that the barrel axis coincides with a line normal to the surface of the test specimen at the intended impact location. This procedure is used to ensure the obliquity angle of the test specimen at the projectile impact point is as close as possible to zero.

6.6.7 Test Specimen Shot Location and Number. The shot spacing and sequences that will be used are illustrated in Fig. 6.10 through 11.12. A maximum of 18 shots per sample (14 shots typical) for spheres and FSP (Figures 6.10 and 6.12) and 9 shots per sample for the larger RCC and the 9mm bullet (Figure 6.11). As illustrated in Figures 6.10 and 6.11, the shot sequence for the dry tests must proceed from the centre radiating outward in a clockwise direction. For the wet test, the shot sequence is from the left top corner down to the lower right corner (see Fig 6.12). Since the fibres tend to be strained and pulled in the warp and fill directions, the aim points should be staggered at least 12 mm off the horizontal and vertical lines of any previous point.

The maximum angle of yaw for the RCC and FSP projectiles shall be as defined under 'Fair Hits" in the definitions (see Table 6.2). The intended shot locations shall be clearly marked directly on the test specimen. The exact location and sequence used shall be described in the test report.

Each impact velocity shall be measured and recorded and if not within accuracy required, that impact shall be disregarded. When two independent sets of instrumentation are used, velocities from each set will be recorded and the mean average of the two velocities shall be calculated and used for V_{50} estimation.

TABLE 6.2 - Criteria for Fair/Unfair Hits

Test Sequence	Small Sphere V_{50}	Large Sphere V_{50} (Wet & Dry)	FSP V_{50}	RCC V_{50}	9mm Vproof
Max Impact Angle	**±3°**	**±3°**	**±3°**	**±3°**	**±3°**
Max YAW Angle	**---**	**---**	**±5°**	**±5°**	**±3°**
Edge Separation	**>50 mm**	**>50 mm**	**>50 mm**	**>50 mm**	**>75 mm**
Shot Separation	**>40 mm**	**>40 mm**	**>40mm**	**>75mm**	**>75 mm**
Min. no of shots per sample	**9**	**9**	**9**	**5**	**5**
Max. no of shots per sample	**18**	**18 (16 wet)**	**18**	**9**	**9**

The angle of impact and the hit locations must conform to the previously defined values for a fair hit. All unfair hits will not count and must be repeated and reported. For the backface deformation test, there are circumstances in which the unfair hit can be accepted as a valid hit. These are defined and summarised in Table 6.3.

TABLE 6.3 - Criteria for Accepted/Rejected Hits (Backface Deformation)

Condition	Impact velocity	Shot/Edge Separation Distance	Impact Angle	Impact Fairness	Partial Penetration	Complete Penetration
Normal	OK	OK	OK	**Fair**	**Accepted** Continue	**Accepted** Failure & stop
More severe	OK but previous hit too high	OK	OK	**Fair**	**Accepted** Continue	**Rejected** Retest
More severe	Too high or OK	OK or too short	OK	**Unfair**	**Accepted** Continue	**Rejected** Retest
Less severe	Too low	OK	OK	**Unfair**	**Rejected** Retest	**Accepted** Failure & stop
Less severe	OK	OK	Too high	**Unfair**	**Rejected** Retest	**Accepted** Failure & stop

If the test conditions are more severe than specified (velocity too high and/or hit separation distance too short), but the performance requirements are met, this will be considered as a valid or accepted hit and count as a pass. If the test conditions are less severe (velocity too low or impact angle too high), and the performance requirements are not met, this will also be considered as a valid hit, but this will constitute a specimen failure.

6.6.8 Calibration of Measurement Devices. Before the test procedure begins, all measuring devices shall be calibrated to an accuracy that allows them to meet the tolerances described in the relevant section of this document.

6.6.9 Preparation and Control of the Backing Material. The forming of the clay shall be made using slow pressing in a rigid frame box (metallic or 19 mm thick wood). The minimum inside dimensions of the box shall be 100 x 340 x 340 mm, i.e., large enough to sufficiently back the sample to be tested. The clay block should be work thoroughly to eliminate any voids or imperfections, i.e., to make it as homogeneous as possible. The rigid frame shall be closed on the back side (removable plate allowed). Filling by slow melting of the clay is also allowed as long as no damage occurs.

The clay blocks shall then be conditioned at a constant temperature (+/- 1º) between 20ºC and 38ºC for at least three hours prior to testing such as to obtain the desired consistency. Additional clay, conditioned along with the rigid frame fixture, shall be used to fill voids and restore the front surface as needed.

The clay block used as backing material shall be changed at least on an annual basis to ensure consistency of the clay. The replacement date shall be recorded on the backing material fixture. Complete penetration of target with projectiles will contaminate the clay over time. In order to keep the clay block as clean and pure as possible, the surrounding area around the cavity channel should be removed and the cavity should be re-packed after each complete penetration. The clay block should also be replaced after every 50 complete penetrations.

6.6.10 Calibration of the Backing Material. Since clay consistency varies with age and date of manufacture, it shall be calibrated by the drop-weight technique using a sufficient number of samples at the beginning of each test series and at each four hours time interval. The consistency of the clay in the block during the test shall be such that when a 1041 +/-5 g steel ball with a diameter of 63.5 +/- 0.05 mm is dropped in free fall without a guide tube from a height of 2000 +/- 5 mm, as measured from the surface of the backing material, the depth of the indentations from three such drops shall each be 20 +/- 3 mm (see Fig. 6.9). This condition shall apply throughout the duration of the testing procedure. Steel ball reference RB-63.5 from SKF has been found satisfactory, although any steel sphere meeting the mass and diameter requirements is acceptable. The separation distance between any indentation centre shall be greater than or equal to 90 mm. The distance from the centre of any indentation to any edge shall be greater than or equal to 60 mm. This procedure is illustrated in Fig. 6.9. The consistency of the backing material during ballistic testing shall also be measured with a pocket penetrometer using a flat head of 8 mm diameter. The peak hardness value shall be 50 + 3 N/mm2.

6.6.11 Velocity Correction Fragment Simulators. No correction for air drag effect is required for 9mm bullets. To evaluate the velocity of fragment simulators at the target, the velocity measured at the distance **X** from the target should be corrected to allow for any velocity loss due to air drag, and slowing effects caused by detection screens. For air drag corrections the following equations shall be used:

$$V_s \text{ or } V_r = V_m + R*X$$

Where:

- **R**: ballistic retardation (m/s/m);
- **X**: distance between the measurement point and the target (m);
- V_m: measured velocity (m/s);
- V_s: velocity at the target (m/s);
- V_r: residual velocity (m/s).

When doing correction for residual velocity measurement, the distance ***X*** is negative, i.e., the impact velocity is greater than the measured velocity. To maximise the accuracy of the velocity the distance ***X*** should be kept to a low value. The recommended measurement distances are 1.5 m ahead of the target for the striking velocity, and 1.0 m behind the target for the residual velocity. The retardation used **R** (m/s/m) depends on the shape of the projectile and its velocity at the measurement point. The following sections give the relationships to be used:

RCC (64 grain)

The retardation ***R*** (m/s/m) is found from:

$\underline{\boldsymbol{R = 0.01272Vm + 0.1986}}$

where:
Vm: measured velocity (m/s)

This equation for ***R*** is valid only for:

$$\mathbf{275\ m/s < \mathit{Vm} < 450\ m/s}$$

FSP (17 grain)

The retardation ***R*** (m/s/m) is found from:

$\underline{\boldsymbol{R = 0.0185Vm}}$

where:
Vm: instrumentation velocity (m/s)

This equation for ***R(V)*** is valid only for:

$$\mathbf{450\ m/s < \mathit{Vm} < 700\ m/s}$$

Sphere (1 and 16 grain)

The retardation ***R*** (m/s/m) is found from:

$$R(V) = \frac{\rho \cdot \pi \cdot D^2 \cdot Cd \cdot Vm}{8 \cdot m}$$

where:
Vm: instrumentation velocity (m/s)
D: diameter of sphere (m);
m: mass of the projectile (kg)
ρ : air density (**1.225 kg/m³**)
C_D: drag coefficient for the projectile

The drag coefficient C_D can be found from:

$$C_D(M) = 0.1045M^3 - 0.7322M^2 + 1.6139M - 0.1245$$

where:

M: Mach number. $M = Vm/a$; a = 340 m/s (speed of sound)

This equation for C_D is valid only for:

$$340 \le Vm \le 1000$$

For lower velocities, C_D can be evaluated from:

$$C_D(M) = 0.9224M^3 - 0.8595M^2 + 0.2718M + 0.4501$$

This equation of C_D is valid only for:

$$0.0 < Vm < 340$$

An alternative method for velocity correction for air retardation is the direct measurement of the retard by means of measurements of the velocity at multiple distances, two distances being a minimum, or the use of a Doppler radar system.

6.7 Test Sequence

6.7.1 V_{50} Test Sequence (*modified up-and-down method*). At least 14 valid impacts (N_T) (normal incidence) shall be done per V_{50} test using the shot pattern defined in Figures 6.10 through 6.12 as applicable. All firings shall be conducted after the samples have been conditioned and shall continue until the total required number of fair hits is obtained. The identification of shots as perforation or non-perforation shall be made after each firing by inspecting the paper witness sheet. Ensure that the witness sheet material is mounted in the appropriate position behind the test specimen. After each complete penetration shot on the ballistic shoot-pack, the corresponding hole in the witness sheet should be marked and numbered with a felt pen. Whenever excessive damage occurs to the witness sheet material, it shall be replaced with a new one before the next test sequence. The velocity of each shot shall be adjusted using the most appropriate technique using the recommended modified up and down sequence as follow:

- Shot no 1 to $N_T\text{-}2$ done using modified up-and-down procedure
- Shot no N_{T-1} done at the lowest complete penetration (***LCP***) velocity
- Shot no N_T done at the highest partial penetration (***HPP***) velocity

V_1 = **estimated** V_{50}

$V_i = V_{i-1} + \Delta V$, where ***Vi***= ***intended*** velocities, *i* = 2-14;
and where ΔV is the fixed velocity increment or decrement to use.

For the first V_{50} sample evaluation $(V_{50})_1$, ΔV shall be:

$\Delta V = +20$ (if previous shot is partial as per examination of paper witness plate)
$\Delta V = -20$ (if previous shot is complete)

for the subsequent ***V_{50}*** sample evaluation (***V_{50}***)$_{2\text{-}4,}$ ΔV shall be:

$\Delta V = +15$ (if previous shot is partial)
$\Delta V = -15$ (if previous shot is complete)

As described previously, the modified up and down method is based on the use of a fixed velocity increment for each V_{50}. The intended velocity is also used to specify the next firing velocity instead of the actual velocity obtained. These two modifications make the test less sensitive to test series where the control of velocity may not be as precise as needed.

The firings shall continue (more than 14 shots may be required) until the five (5) lowest velocities for complete penetrations and the five (5) highest velocities for partial penetrations are within a velocity spread of 60 m/s. A zone of mixed results (ZMR) occurs when a partial penetration occurs at a higher velocity than at least one complete penetration. The ZMR is the difference between the lowest complete penetration velocity (*LCP)* and the highest partial penetration velocity (HPP) actually obtained. The ZMR for each V_{50}shall be less than 60 m/s. If the ZMR is greater than 60 m/s, and that the difference between the HPP and the second highest partial penetration velocity is more than 20 m/s, the HPP shot could be considered as an outlier round and it could be rejected. This may allow the ZMR to be below 60 m/s. This is a conservative approach since it will effectively reduce the V_{50} measured. If one of these two conditions is not achieved, a new sample should be selected for testing.

It is also necessary that the following additional conditions are complied with in order for the Probit analysis to work adequately:
-the shot with the lowest impact velocity should be a partial penetration and it should not be separated from the LCP by more than 20 m/s.

- the shot with the highest impact velocity should be a complete penetration and should not be separated from the HPP by more than 20 m/s.

If anomalous results occur, extra rounds should be fired to provide further information or the testing should be repeated using a new set of test specimens.

6.7.1.1 Calculation of the *V_{50}*. The V_{50} and standard deviation for each sample shall be computed by applying a maximum likelihood statistical analysis (DREV Probit) based on the cumulative normal distribution using all fair shots. If the V_{50} cannot be attained using one sample (e.g. for 64 grain RCC), because the specified velocity spread is not respected or insufficient fair impacts can be done on one shoot-pack, testing should be continued on a second shoot-pack from the same lot; the V_{50} can then be computed from the results obtained with these two samples. The arithmetic V_{50} shall be also computed for reference use by taking the arithmetic average of ten (10) fair impact velocities consisting of the 5 highest velocities for partial penetration and the 5 lowest velocities for complete penetration within a velocity spread of 60 m/s. If a different method is used to compute the V_{50}, it shall be clearly indicated in the test report by referencing to the standard followed.

6.7.1.2 V_{50} Compliance Verification. A valid ballistic fill material shall be declared as being in compliance with the performance requirements if the calculated V_{50} for each solution exceeds the minimum individual value for specified conditions and all other requirements are met. The average of the combined tests (MV_{50}) for each projectile will be rated against the minimum specified requirements and the spread must be within 30 m/s. If the minimum requirements are not met, then the testing must be repeated using new samples selected at random from the same lot.

6.7.2 Backface Deformation Resistance Test Sequence. A sufficient number of pre-test rounds shall be fired to have a reasonable assurance that each test round (9mm FMJ bullets) will have a striking velocity within the defined velocity spread allowed. The test specimen shall be weighed and placed on the clay backing material using two elastic bands to restrict its movement from the original position. The placement of the elastic bands will be such that they do not interfere with the impact point on the sample and they do not introduce significant stresses in the target material. The distance between the bands shall be approximately 150 mm centered to the intended impact location.

One test specimen shall be fired at the five impact locations (see Fig. 6.11) using the appropriate weapon and projectile such as to ensure that the angle of yaw is less than 3°. Penetration by any fair shot or penetration by a projectile at a velocity lower than the minimum required impact velocity shall constitute a failure to meet the required protection level. While one specimen may be sufficient to complete the number of shots required, unfair impacts may require additional samples. A maximum number of 9 shots shall be fired per shoot-pack. Any unfair impact shall be disregarded in evaluating compliance with the requirements.

After each shot, the inside surface of the test specimen shall be examined and any visible evidence for a complete penetration shall be recorded. The backface deformation will be measured from the original planar surface of the prepared clay media using an appropriate depth gauge measurement tool (see Fig. 6.2). The test specimen shall be repositioned and flattened to ensure consistency. The specimen shall be restored as closely as practical to its original state, ensuring that the layers are smoothed as flat as possible. After every 30 min., consistency of the clay backing material should be measured using the pocket penetrometer to ensure that the required conditions are maintained.

Should the results of any fair impact produce a complete penetration, or indentation exceeding 50 mm the protective material shall be declared non-compliant with the performance requirements. Any unfair impact shall be disregarded in evaluating compliance with the requirements. A minimum of five fair impacts out of nine possible impacts on one panel must be obtained to make a valid sample test. When fewer than 5 fair impacts are obtained, the test specimen shall be rejected and replaced by a new one from the same lot and the test repeated.

6.7.2.1 Backface Deformation Compliance Verification. A test specimen shall be declared as being in compliance with the performance requirements if the backface deformation for any of the fair impacts is less than 50mm and no complete penetration of the armour material shall occur.

6.8 Test Report

6.8.1 A ballistic test report shall be prepared incorporating the following information:

a) Date(s) of test series and name and location of facility.

b) Sampling procedure, and full description of each ballistic shoot-pack set tested including: weight, size, thickness, number of plies, and plies sequence (hybrid), nominal areal density, quilting pattern (if applicable) material type, manufacturer and lot number.

c) For each test series the barrel calibre, length, and twist if applicable, the specimen mounting configuration, and the precise projectile description.

d) Temperature and humidity at the test facility, and sample pre-conditioned temperature if different from test facility.

e) For each impact, the location of impact (shot pattern no), intended and actual striking velocities obtained, partial or complete penetration, fair or unfair hit, accepted or rejected impact.

f) For each $\mathbf{V_{50}}$ test, firing sequence used, $\mathbf{V_{50}}$ computed using the maximum likelihood method, lowest complete penetration, highest partial penetration, zone of mixed results, and velocity spread for the ten values considered.

g) For the combination of all $\mathbf{V_{50}}$ test values (as specified within) using a given projectile, average values obtained ($\mathbf{MV_{50}}$), and velocity spread of the group.

h) For the backface deformation test, indentation depth and number of plies penetrated for each impact, and average depth for the 5 accepted impacts.

j) For each series, state compliance against ballistic performance requirements.

k) Provide any supplementary information or remarks pertinent to the conduct of the test, or behaviour of the material.

l) Provide names of the testing personnel, and any witnesses present.

TABLE 6.4.a – Preproduction Qualification Summary of Ballistic Fill

Test Sequence	V_{50} 17 gr FSP	V_{50} (Dry test) 16 gr Sphere	V_{50} (Wet test) 16 gr Sphere
Minimum no of shoot-packs	3	3	3
Minimum no of fair shots per V_{50}	14	14	14
Total no of fair shots	42	42	42
Nominal impact angle (deg)	0	0	0
Max. impact angle (deg)	5	3	3
Armour sample conditioning	Section 6.6.4 Dry	Section 6.6.4 Dry	Section 6.6.5 Wet
Witness/Backing material	Section 6.3.1	Section 6.3.1	Section 6.3.1
Target retention	Rigid Frame	Rigid Frame	Rigid Frame
Calibration V_{50} (m/s) (Lexan 9034 sheet)	**405±10** (12.37-mm sheet)	**405±10** (9.12-mm sheet)	**405±10** (9.12-mm sheet)
Min. individual V_{50} (m/s)	**500**	**455**	**415**
Min. average MV_{50qc} (m/s) (average of 3 V_{50})	**$\geq$0.97x*V50ca***	**$\geq$0.97x*V50ca***	**$\geq$0.97x*V50ca***
Max diff. in 3 V_{50} tests (m/s)	**30**	**30**	**40**
Max individual ZMR (m/s)	**60**	**60**	**70**
Max average ZMR (m/s) (3 V_{50} tests)	**50**	**50**	**60**

TABLE 6.4.b – Preproduction Qualification Summary of Ballistic Fill

Test Sequence	V_{50} 1 gr Sphere	V_{50} 64gr RCC	V_p 9mm FMJ bullet
Minimum no of shoot-packs	3	6 (2 samples /V_{50})	1
Minimum no of fair shots per V_{50}	14	14	---
Total no of fair shots	42	42	5
Nominal impact angle (deg)	0	0	0
Max impact angle (deg)	3	3	3
Armour sample conditioning	Section 6.6.4 Dry	Section 6.6.4 Dry	Section 6.6.4 Dry
Witness/Backing material	Section 6.3.1	Section 6.3.1	Section 6.3.2
Target retention	Rigid Frame	Rigid Frame	2 elastic bands with patting down between shots
Calibration V_{50} (m/s) (Lexan 9034 sheet)	**562±10** (5.80-mm sheet)	**275±10** (12.37-mm sheet)	**---**
Proof velocity, V_p (m/s)	---	---	**365±7** 5 shots with no perforation
Backface deformation (*BD*)	---	---	**mean *BD*<44 mm max individual *BD* <50 mm**
Min. individual V_{50} (m/s)	**525**	**350**	---
Min. average MV_{50qc} (m/s) (average of 3 V_{50})	**$\geq$0.97x*V50ca***	**$\geq$0.97x*V50ca***	---
Max diff. in V_{50} tests (m/s)	**30**	**30**	---
Max individual ZMR (m/s)	**60**	**60**	---
Max average ZMR (m/s) (combined V_{50} tests)	**50**	**50**	---

TABLE 6.5 - Quality Control Ballistic Material Lots

Test Sequence	V_{50} 1 gr Sphere	V_{50} (dry test) 16 gr Sphere	V_{50} 17 gr FSP	V_{50} (wet test) 16 gr Sphere
Min no. of shoot-packs per material lot for 3 V_{50}	3	3	N/A	N/A
Min no. of shoot-packs per sub-lot for V_{50}	N/A	N/A	1	1
Min no. of fair shots per test	14	14	14	14
Min total no of fair shots	42	42	14	14
Nominal impact angle (deg)	0	0	0	0
Max impact angle (deg)	3	3	3	3
Armour sample conditioning	Section 6.6.4 Dry	Section 6.6.4 Dry	Section 6.6.4 Dry	Section 6.6.5 Wet
Witness material	Section 6.3.1	Section 6.3.1	Section 6.3.1	Section 6.3.1
Target retention	Rigid Frame	Rigid Frame	Rigid Frame	Rigid Frame
Min individual *V50* (m/s)	**525**	**455**	**CONTROL 500**	**415**
Min average M*V50qc* (m/s) (average of 3 V_{50})	**$\geq$0.97x*V50ca***	**$\geq$0.97x*V50ca***	N/A	N/A
Max difference in 3 V_{50} tests (m/s)	30	30	N/A	N/A
Max individual ZMR (m/s)	60	60	60	60
Max average ZMR 3 V_{50} tests (m/s)	50	50	N/A	N/A

LIST OF FIGURES

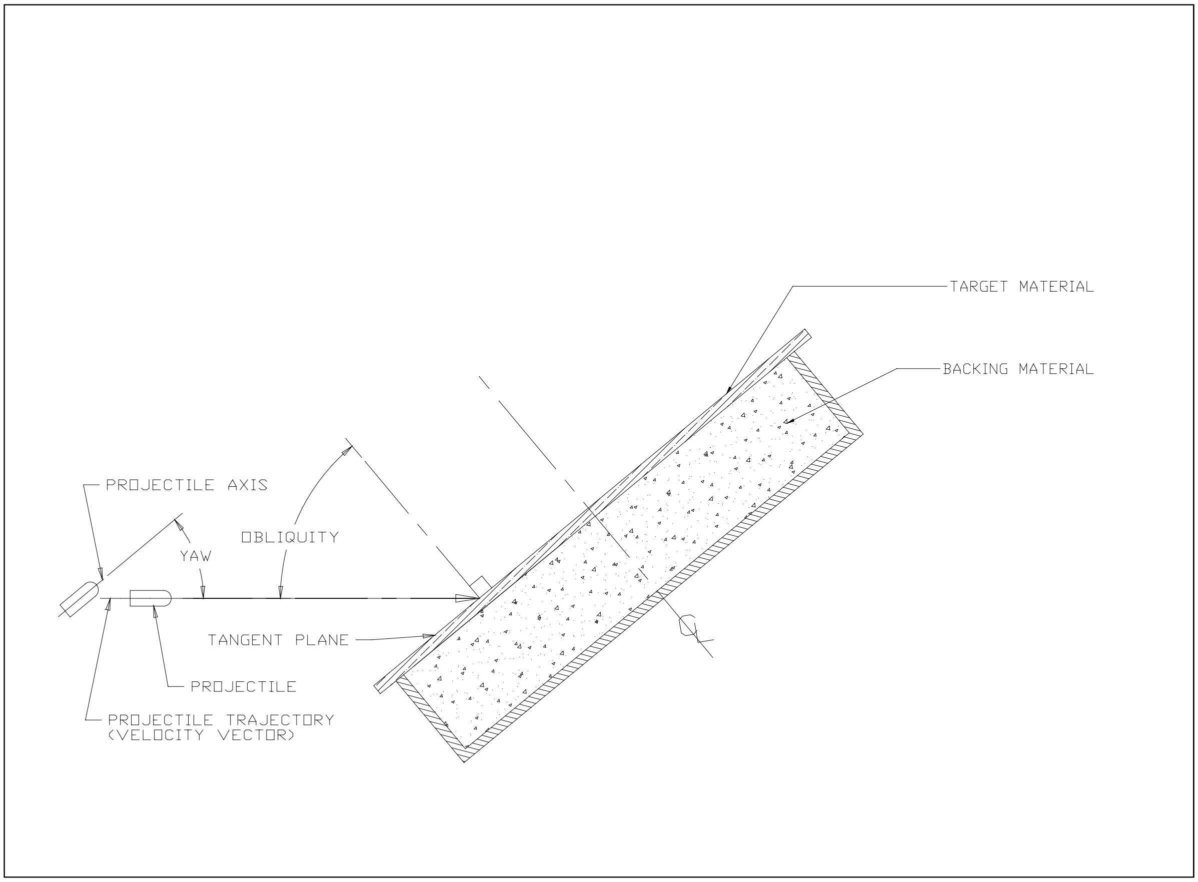


Figure 6.1 – Angle of Impact and Yaw

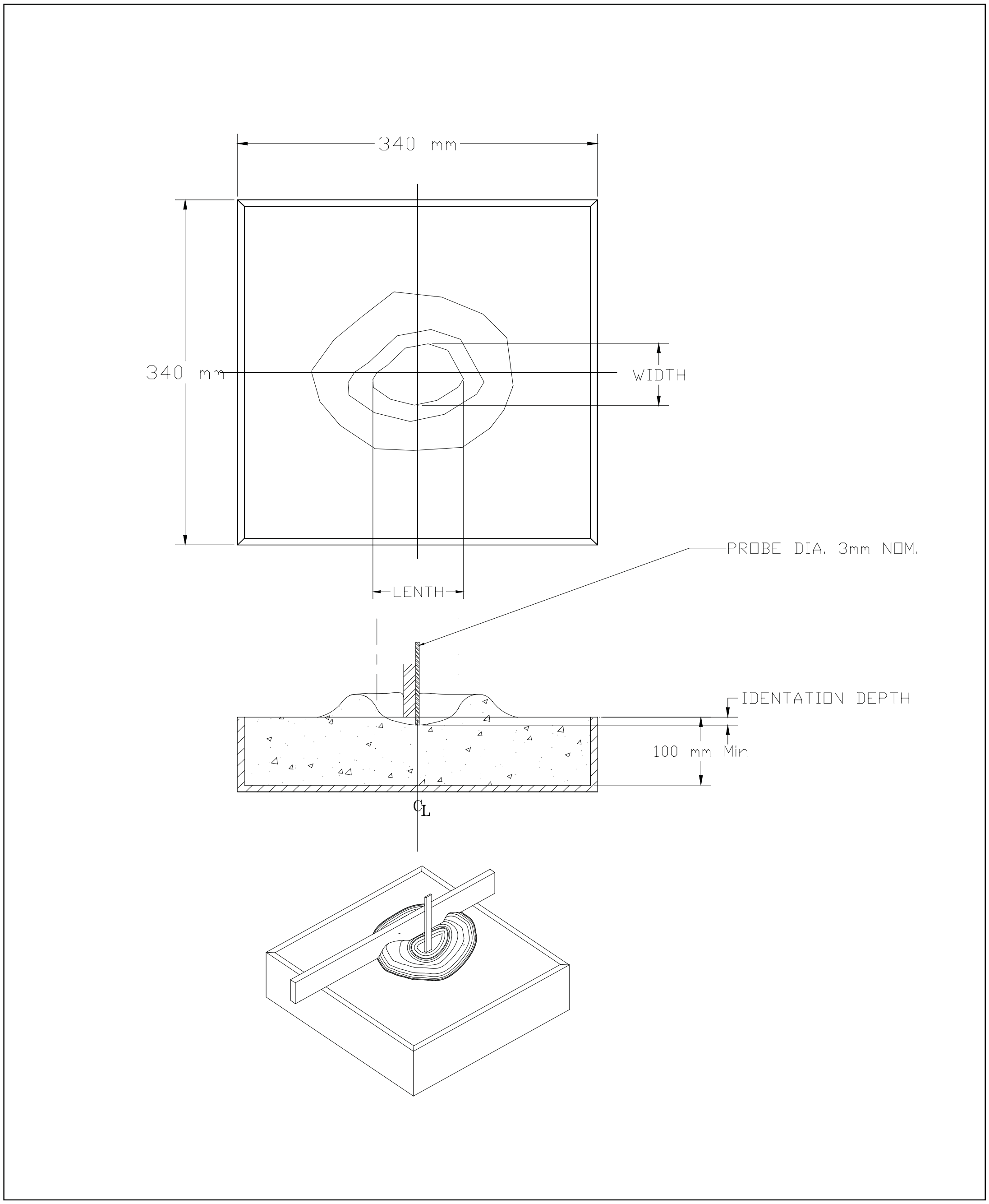


Figure 6.2 – Clay Block Dimensions and Cavity Measurement

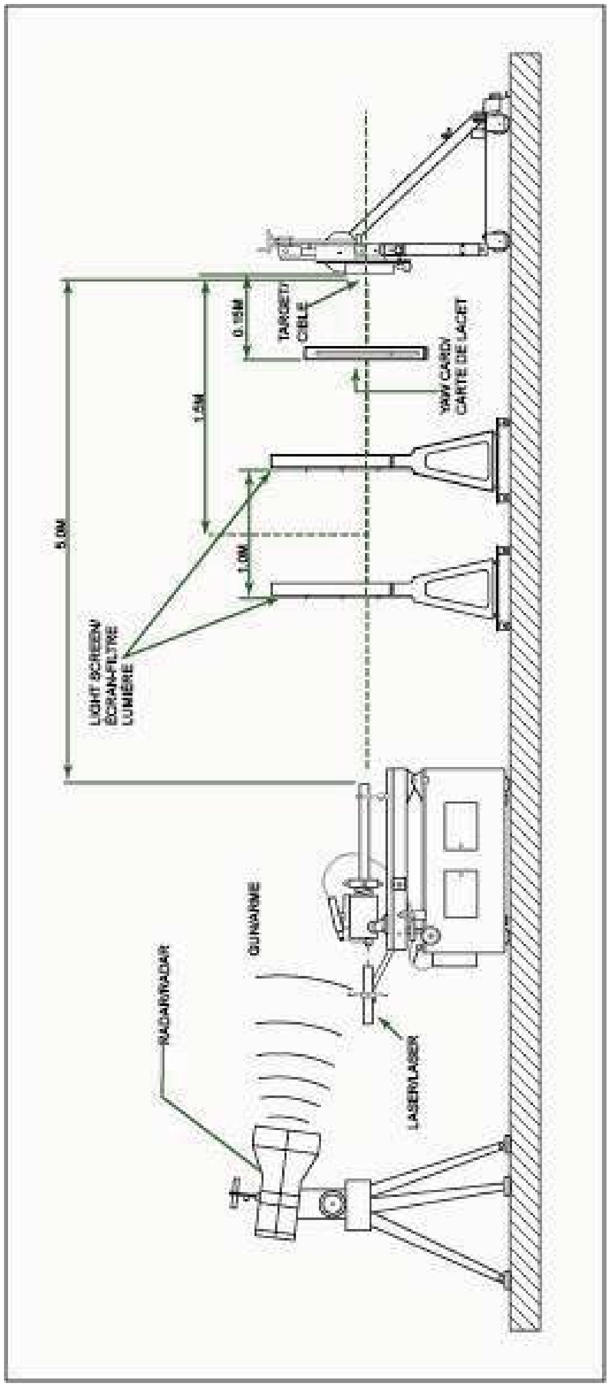


Figure 6.3 – Typical set-up used for Ballistic Testing

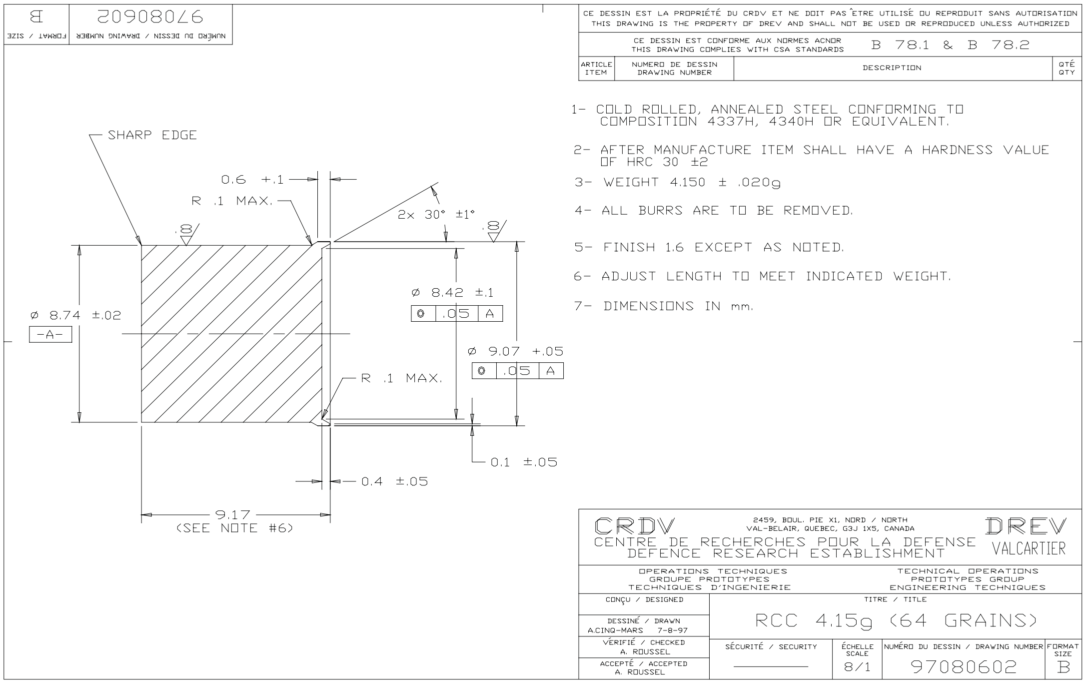


Figure 6.4 – Right Circular Cylinder (RCC) Dimensions

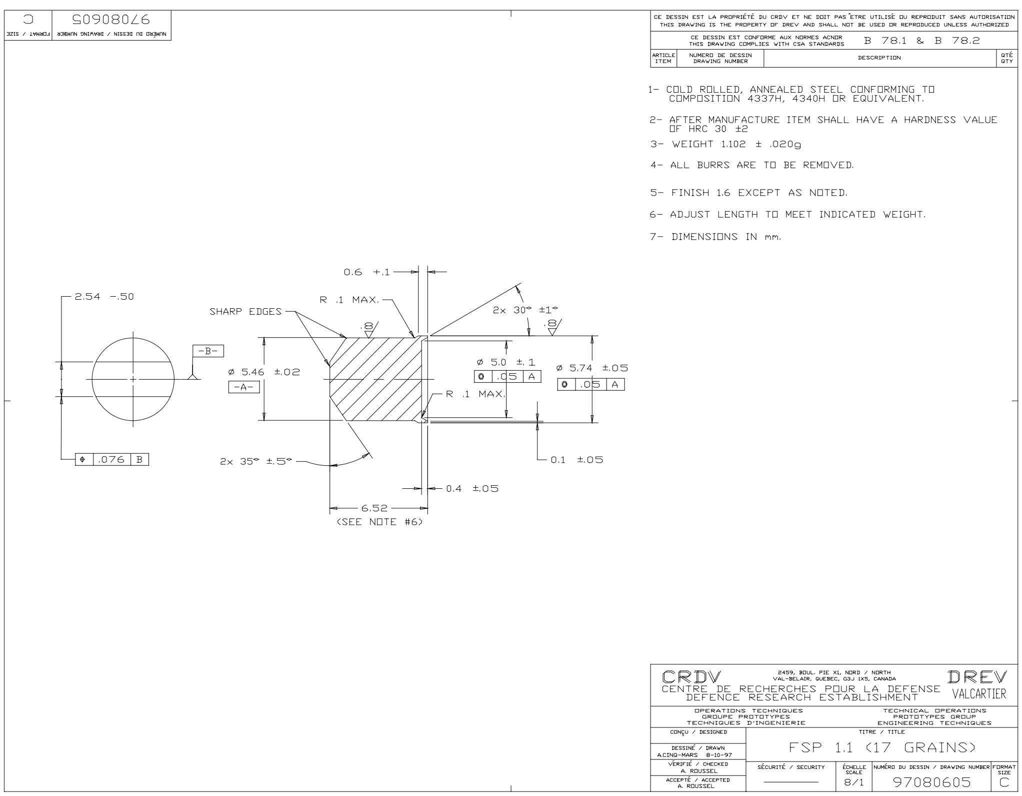


Figure 6.5 – Fragment Simulating Projectile (FSP) Dimensions

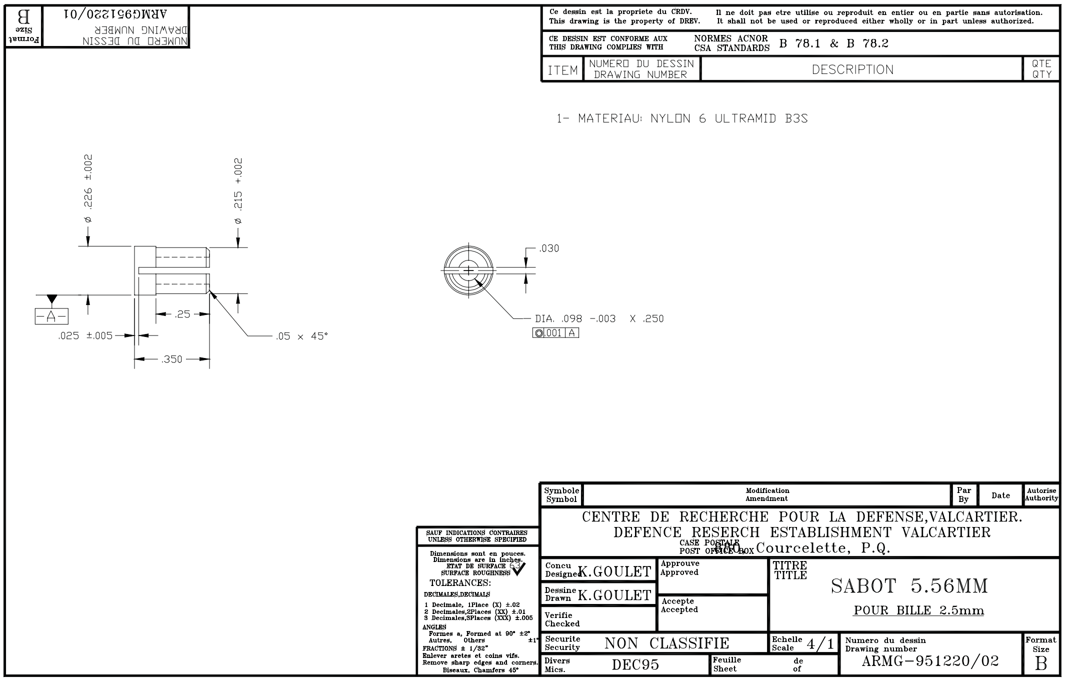


Figure 6.6 – Plastic Sabot for Launching 1-grain Sphere

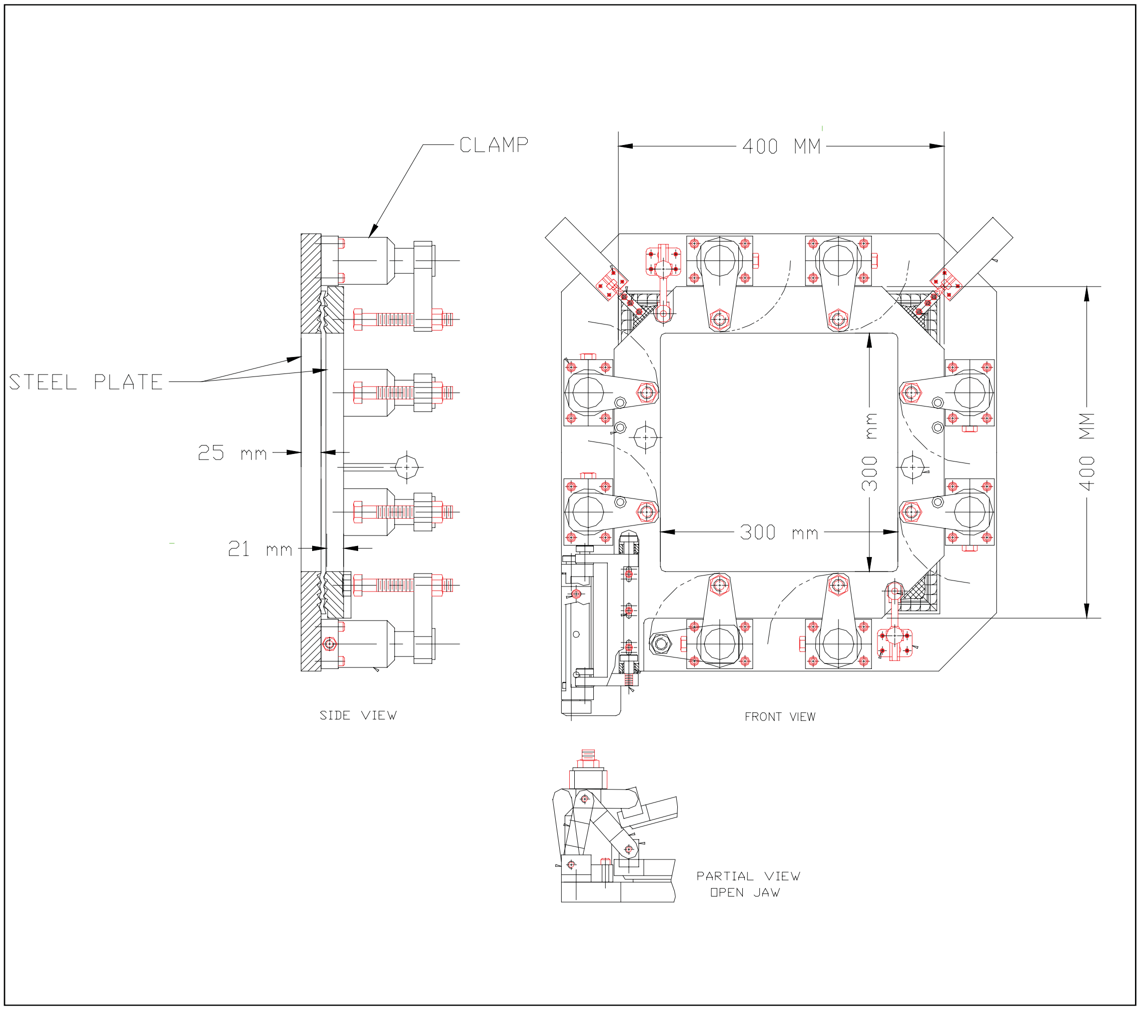


Figure 6.7 – Shoot-Pack Clamping Fixture

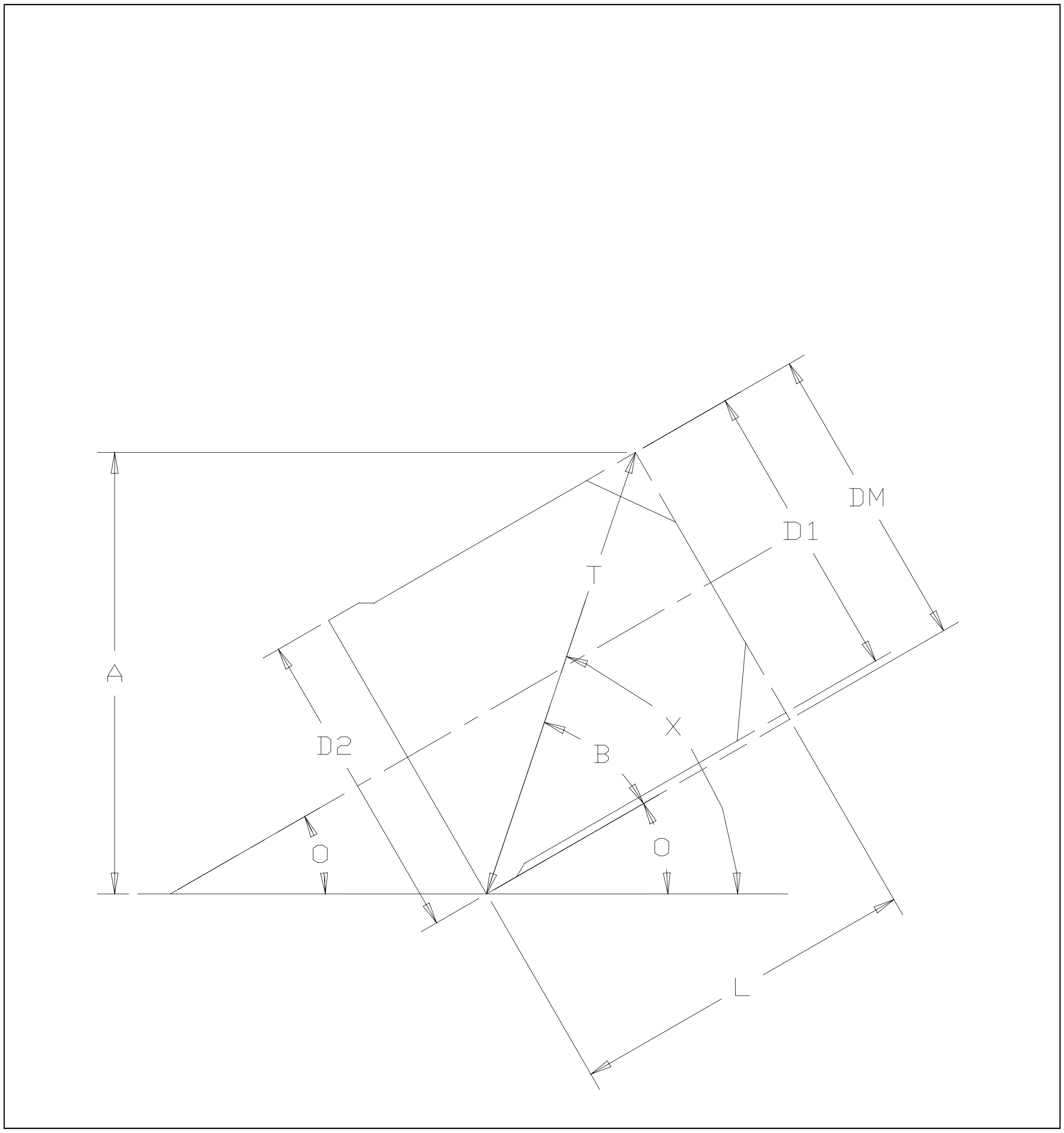


Figure 6.8 – Yaw Measurement with Paper Card

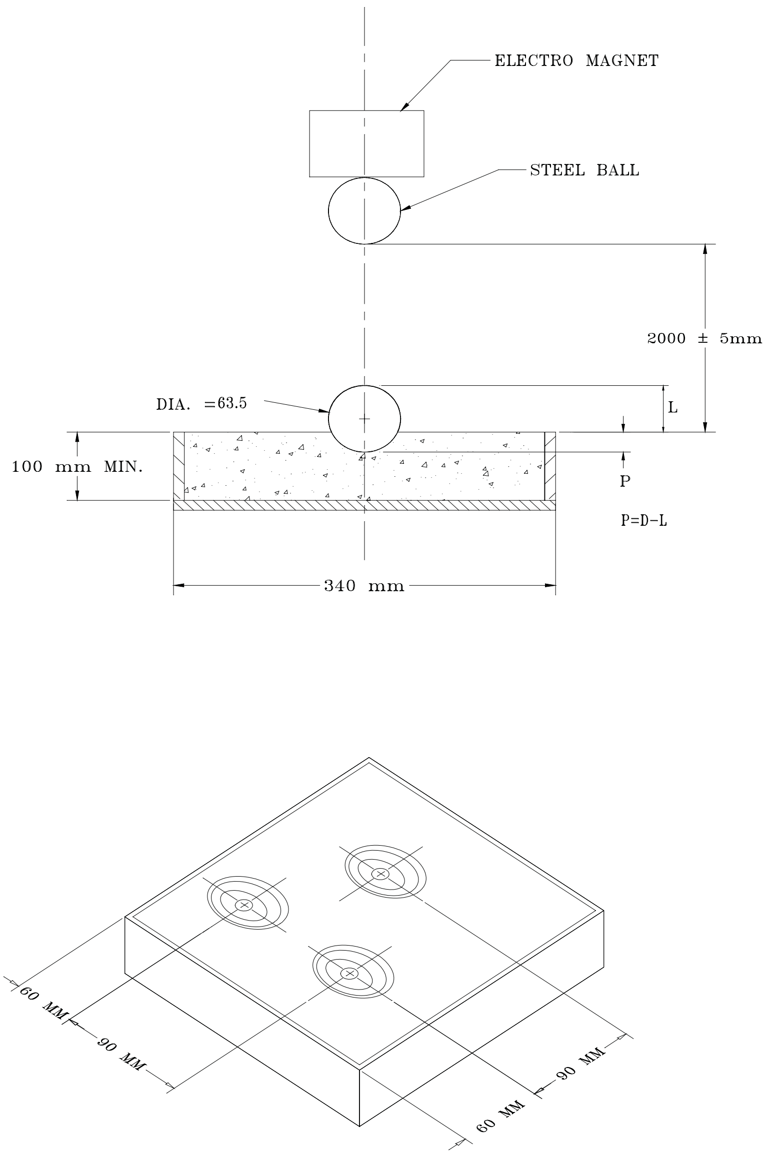


Figure 6.9 – Clay Block Calibration

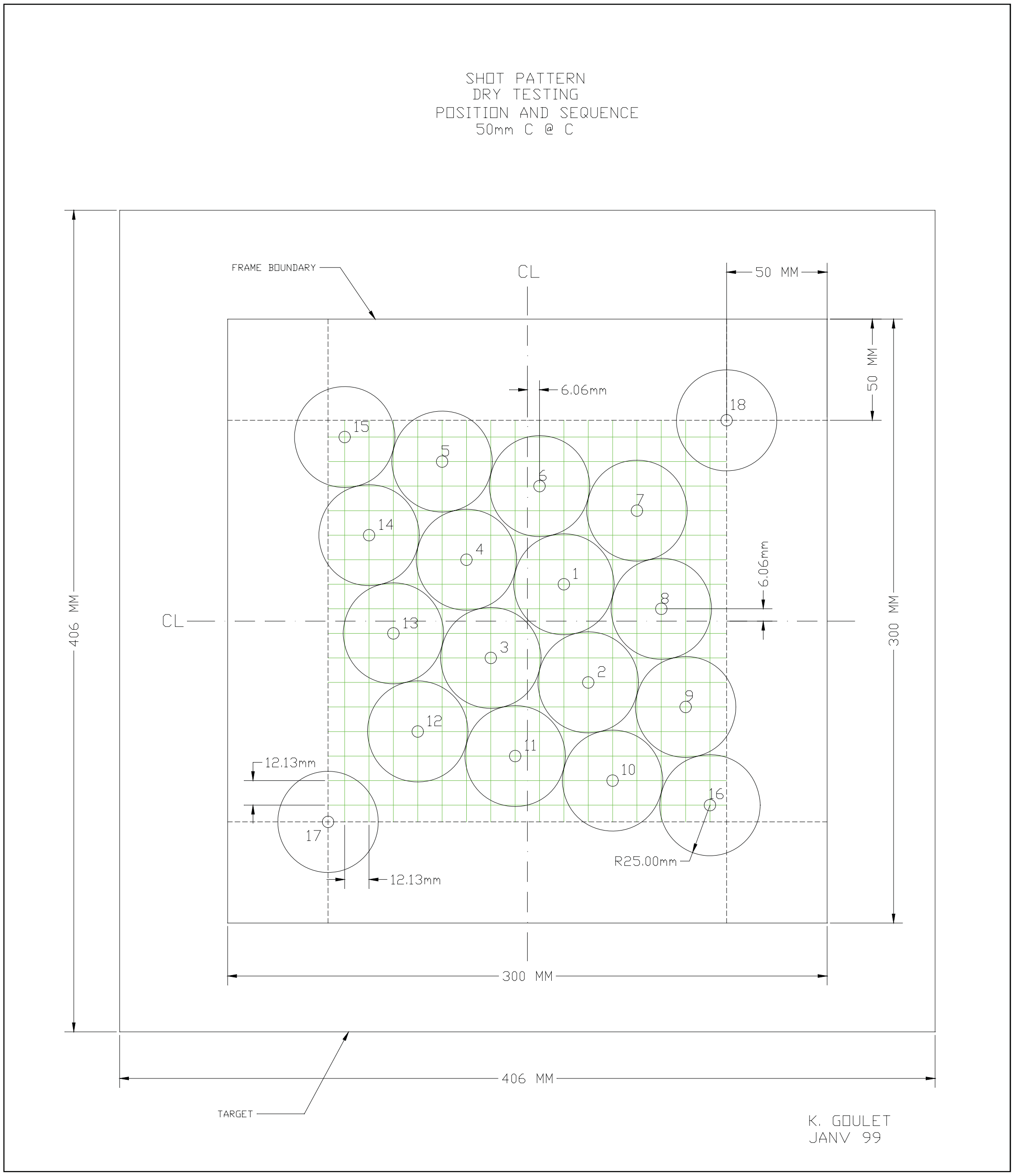


Figure 6.10 – Shot Pattern for Projectiles ≤7mm Diameter (dry target)

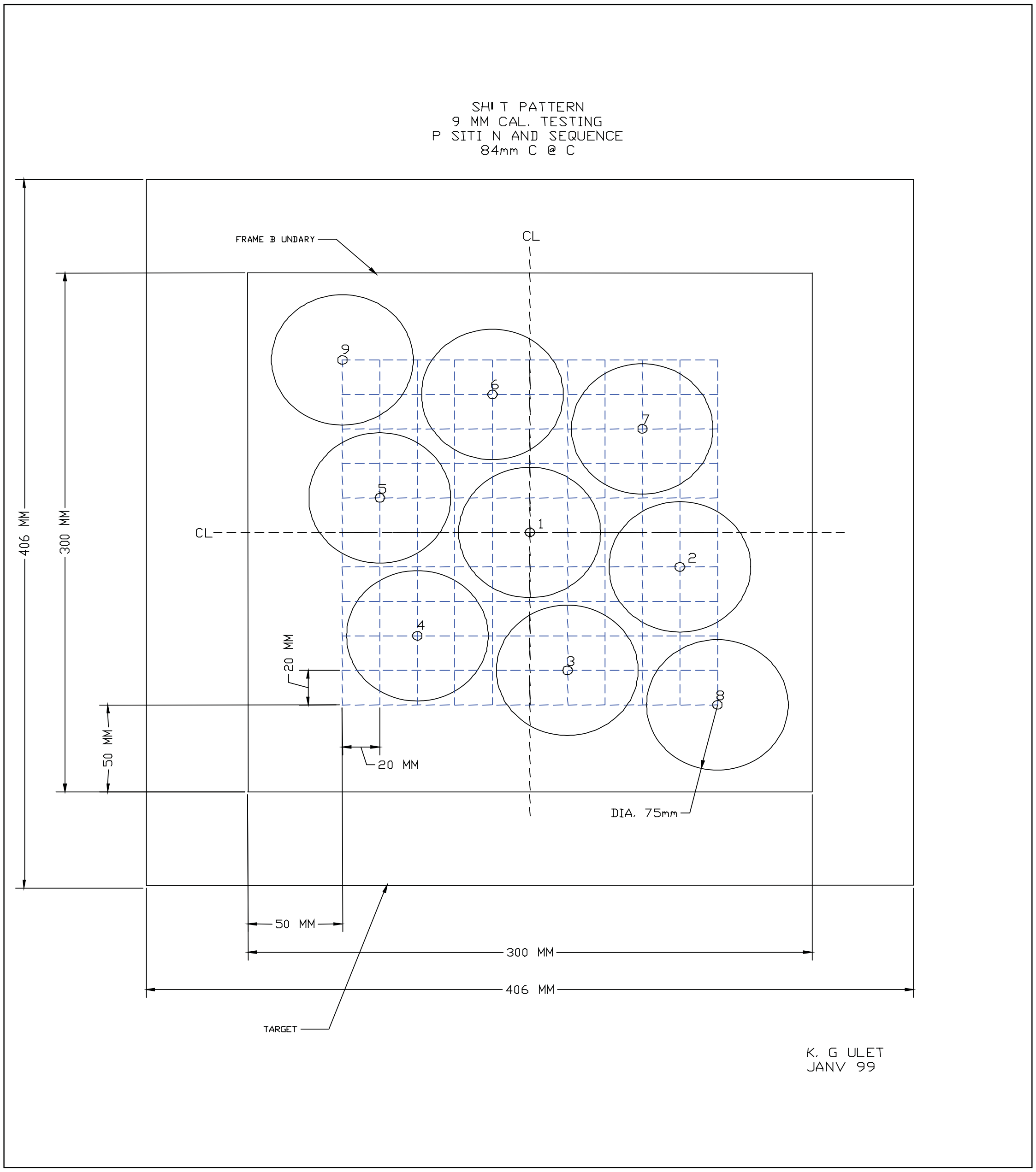

SHI T PATTERN
9 MM CAL. TESTING
P SITI N AND SEQUENCE
84mm C @ C
FRAME B UNDARY
CL
CL
1
2
3
4
5
6
7
8
9
406 MM
300 MM
20 MM
50 MM
20 MM
DIA. 75mm
50 MM
300 MM
406 MM
TARGET
K. G ULET
JANV 99

Figure 6.11 – Shot Pattern for Projectiles >7mm Diameter (dry target)

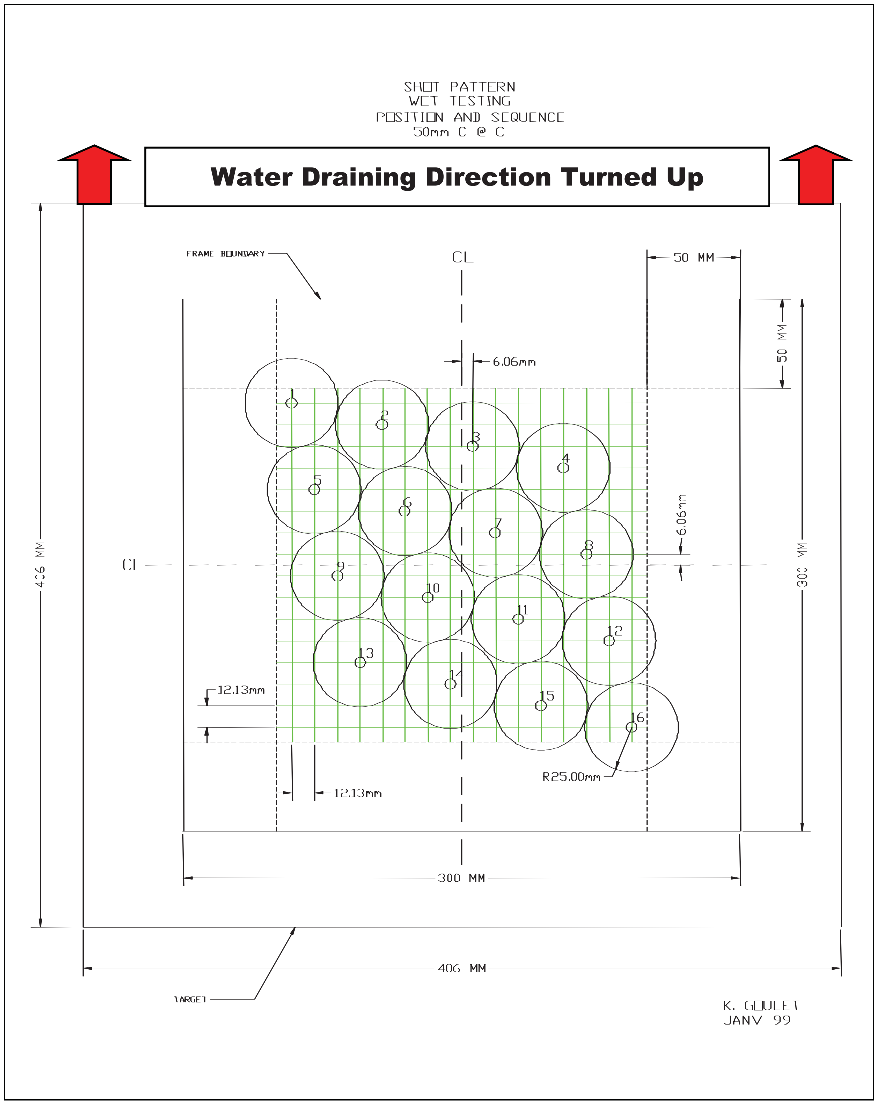


Figure 6.12 – Shot Pattern for Projectiles ≤7mm Diameter (wet target)

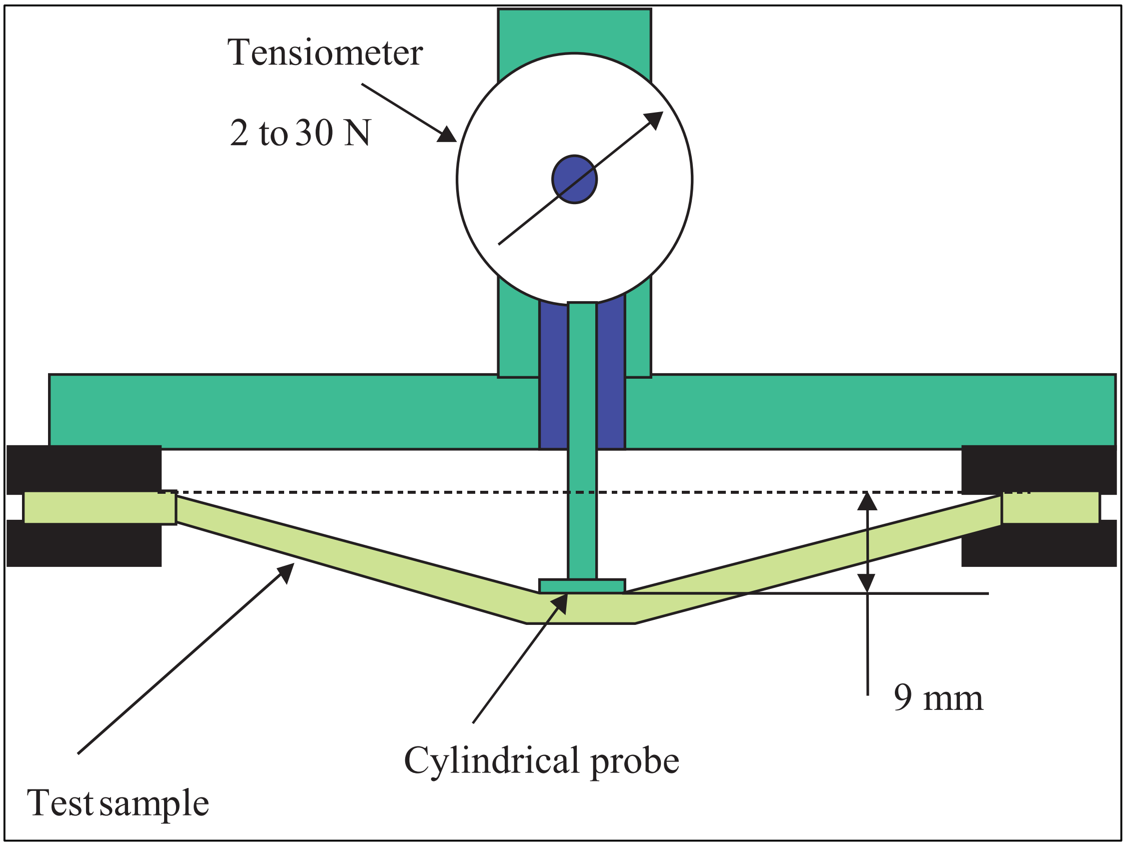


Figure 6.13 – Test Device for Measuring Ballistic Shoot-Pack Tightness

7.0 MODIFIED CIRCULAR BEND TEST METHOD

7.1 SCOPE

7.1.1 This test method covers the determination of the stiffness / flexibility of fabrics by the modified circular bend procedure.

7.1.2 This test method is applicable to most of the fabric types. The sample is a multi-layer system as in current soft armour systems.

7.1.3 This procedure does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this specification to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

7.1.4 The values stated in either SI units or inch-pound units are to be regarded separately. Within the text, the inch-pound units are shown in brackets. The values stated in each system are not necessarily exact equivalents; therefore, each system should be used independently of the other.

7.2 REFERENCED DOCUMENTS

ASTM D123 Standard Terminology Relating to Textiles.

ASTM D1776 Practice for Conditioning Textiles for Testing.

ASTM D1777 Standard Test Method for Thickness of Textile Materials.

ASTM D4032 Standard Test Method for Stiffness of Fabric by the Circular Bend Procedure.

ASTM E6 Practices for Force Verification of Testing Machines.

7.2 TERMINOLOGY

7.3.1 Circular bend - simultaneous, multidirectional deformation of a fabric in which one face of a flat specimen becomes concave and the other becomes convex.

7.3.2 Stiffness - resistance to bending. With regard to the circular bending of fabrics, resistance to multidirectional bending expressed as a predefined slope on the force-displacement curve when a specimen is pushed through an orifice.

7.3.3 Flexibility - Compared to stiffness, the lower the stiffness is, the higher the flexibility will be.

7.3.4 Areal density - mass per unit area.

7.4 SIGNIFICANCE AND USE

7.4.1 The modified circular bend test gives a force per unit length value related to fabric stiffness, simultaneously averaging stiffness in all directions. The stiffness gives the indication of the flexibility of the fabric.

7.4.2 The modified circular bend test is simple to perform and is suitable for most multi-layer systems, which cannot be accurately measured by the existing test methods. This method is a modification from ASTM D4032 in order to account for multiple-ply fabrics.

7.5 SUMMARY OF TEST METHOD

7.5.1 The modified circular bend test consists of pushing a multi-layer system through a 101.6mm (4”) ∅ orifice in a platform, using a hemispheric 25.4mm (1”) ∅ plunger. The fabric stiffness / flexibility can then be evaluated by studying the results of the average maximum secant slope found after a 30mm displacement. See secant slope definition in section 15.11 Analysis.

7.6 SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

7.6.1 Follow safety, health and environmental regulations and general laboratory precautions as given by the Material Safety Data Sheet, the Area Safety Manual and Laboratory Safety Rules.

7.7 APPARATUS

7.7.1 Testing Machine - for instance servo-hydraulic or standard screw driven machines. The testing machine shall be in conformance with practice ASTM E6, and shall satisfy the following requirements:

7.7.1.1 Testing Machine Heads - The testing machine shall have both an essentially stationary head (base) and a movable head (crosshead).

7.7.1.2 Drive Mechanism - The testing machine drive mechanism shall be capable of imparting to the crosshead a controlled velocity with respect to the base.

7.7.1.3 Load and displacement Indicator - The testing machine load and displacement sensing devices shall be capable of indicating the total load being supplied to the test specimen and the vertical displacement with an accuracy of ±1% of the indicated values or better.

7.7.2 Modified Circular Bend Stiffness Set-ups (Figures 7.1 to 7.4), having the following parts:

7.7.2.1 Supporting Frame (Fig. 15.1 and 15.2), 203 x 305 x 127 mm (8 x 12 x 5 in.), or equivalent, steel box, with a 152mm (6 in.) diameter orifice at the top surface. The top surface plate is 12 mm (0.5 in.) thick. The structure is fixed to the testing machine base.

7.7.2.2 Platform, 203 x 203 x 6 mm (8 x 8 x 0.25 in.) or equivalent, smooth-polished steel, with 102 mm (4 in.) diameter orifice (Fig. 7.2 a. and b.). The lap edge of the orifice should be rounded at a radius of 3.2mm (0.125 in.). For smoothness and uniform friction conditions, one ply of a polyester lining ∗, having the same size as the specimen, is laid on the top surface (Fig. 7.3 a.). The polyester lining has the same size as the specimen and shall bend freely with it. The platform is placed on the top the supporting structure.

7.7.2.3 Plunger, hemispherical, 25.4 mm (1 in.) ∅ (Fig. 1 and 3), smooth-polished steel. The plunger, mounted on the testing machine crosshead, should be concentric with the platform's orifice. The bottom of the plunger should be flush in contact with the specimen top surface. The downward force is applied from this position.

7.7.2.4 Scale, capable of weighing to the nearest 1.0 mg.

7.7.2.5 Thickness or Dial gauge, capable of measuring to the nearest 0.01 mm.

∗ Commercially available polyester lining with the following average characteristics:

areal weight : 66± 4gr/m² ; thickness = 0.075± .01mm (0.003in).

7.8 PREPARATION OF TEST SPECIMENS

7.8.1 Cut specimens square from new and unused material. The specimen dimensions shall be 152 x 152mm (6 x 6 in.). The specimens shall be free of any stitching pattern, unless a quilted solution is proposed (refer to Instructions to Bidders).

7.8.2 Prepare a minimum of 10 specimens for each sample. Ten individual results shall be used for the material's flexibility calculations.

7.8.3 Avoid selvages, end pieces, and creased or folded places.

7.8.4 Handle the specimens as little as possible.

7.9 CONDITIONING

7.9.1 Bring the specimens to moisture equilibrium, as directed in Practice ASTM D 1776. The standard atmosphere for testing textiles is 21 ± 1°C (70 ± 2°F) and 65 ± 2 % relative humidity. However, an environment with a temperature of 23 ± 2°C (73.4 ± 3.6°F) and a relative humidity of 50 ± 5 % is acceptable.

7.10 TEST PROCEDURE

7.10.1 Measure the dimensions of the specimen, its thickness and its weight.

7.10.2 Test the adequately conditioned specimens in a standard atmosphere for testing as described in section 7.9.1.

7.10.3 Handle the test specimens carefully to avoid altering the natural state of the material.

7.10.4 Select a load cell with a capacity in order to have the results within 10 and 90 % of its total range.

7.10.5 Mount the platform supporting structure, the platform and the selected plunger, with the plunger concentric with the orifice.

7.10.6 Set the crosshead speed to 15 mm/mn (0.6in./mn).

7.10.7 Set the data acquisition rate to a minimum of 6.67 points per second.

7.10.8 Centre the specimen on the orifice platform below the plunger, using the centering marks. For non-symmetric hybrid plies lay-up, the face in contact with the body shall be the bottom layer in contact with the lining material.

7.10.9 Lower the plunger to bring it tangent with the top of the specimen without pushing on it.

7.10.10 Re-initialise the load and the displacement.

7.10.11 Start the test and record the load versus the vertical displacement until the specimen is pushed through the orifice. Avoid touching the specimen during testing. Discard any result where the specimen undergoes any other external force than that supplied by the test machine.

7.10.12 Continue as directed in 7.10.8 through 7.10.11 to test the remaining specimens.

7.11 ANALYSIS

7.11.1 For the set-up, compute the following data for all type of materials:

7.11.2 Areal density of the individual specimens.

7.11.3 Trace load-displacement curves for each individual specimen.

7.11.4 Determine the maximum load after 30mm displacement (P).

7.11.5 Determine the displacement (D) associated with this maximum load found previously (P).

7.11.6 Secant Slope General Calculation Procedure. This slope method is defined as a line between two points: the origin (zero) and the maximum load found after 30 mm displacement. (See Figure 5)

  - Determine the slope of the linear curve (S) between zero and the displacement (D) corresponding to a maximum load found after 30mm (P) as follows: S = P/D
  - Repeat steps for each specimen.
  - To calculate the average maximum secant slope for a particular material, do the average of all calculated maximum secant slopes of each specimen.

- If a curve has a secant slope value that is **3 standard deviations away** from the average value calculated previously, eliminate that curve and recalculate the average maximum secant slope value.
- Calculate the standard deviation for each average maximum secant slope value.

7.12 REPORT

7.12.1 State that the specimens were tested as directed by this procedure. Describe the material or product tested.

7.12.2 Report the following information:

7.12.3 Individual areal density, average areal density and the standard deviation.

7.12.4 Individual thickness, average thickness and the standard deviation.

7.12.5 Load-displacement curves.

7.12.6 Average maximum secant slopes after 30mm displacement and standard deviations.

7.12.7 Bar chart histograms of all materials.

7.12.8 Number of specimens tested.

7.12.9 Test machine type and set-up description.

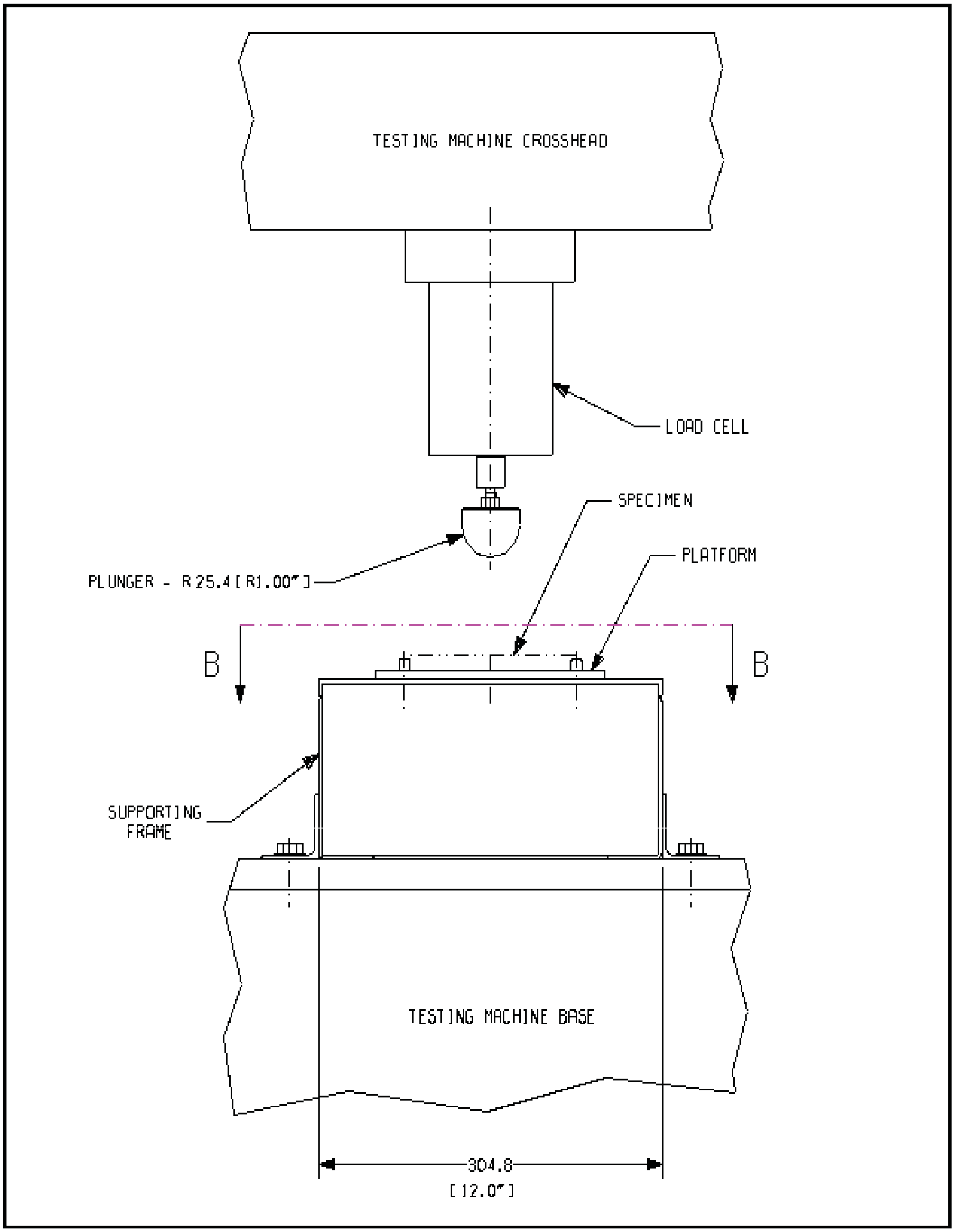
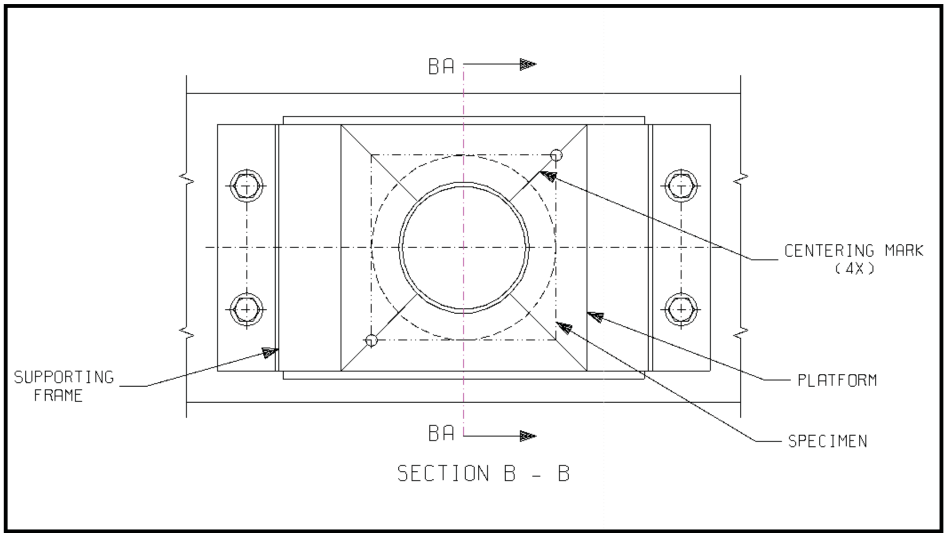
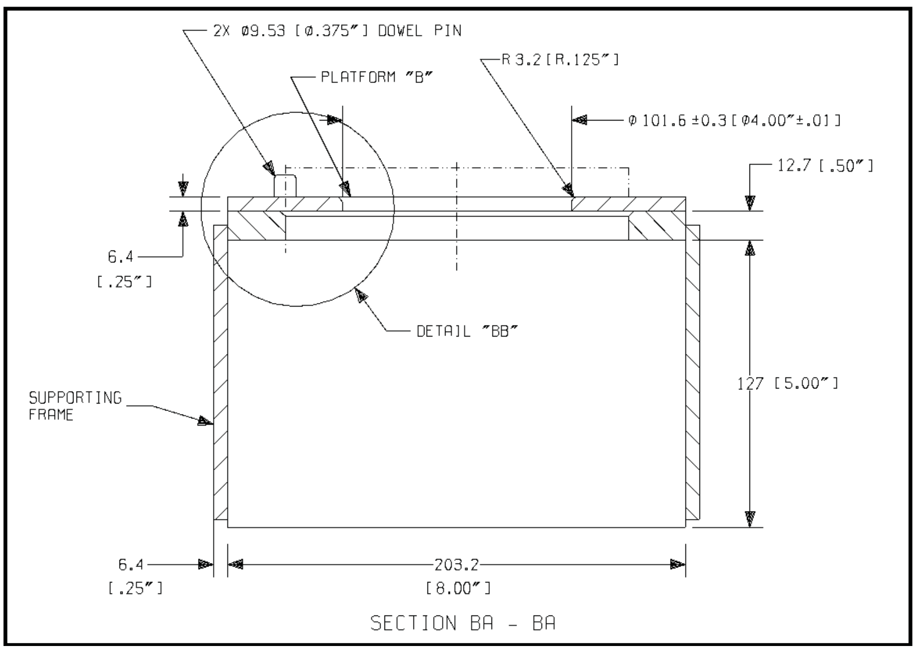


Figure 7.1. General View of the New Test Method

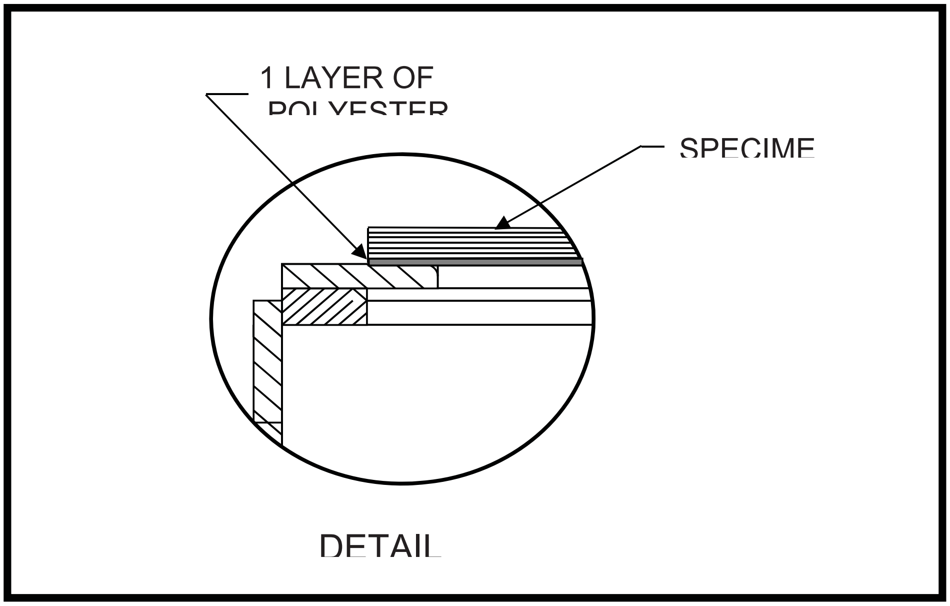


(a) Section BB from Figure 7.1

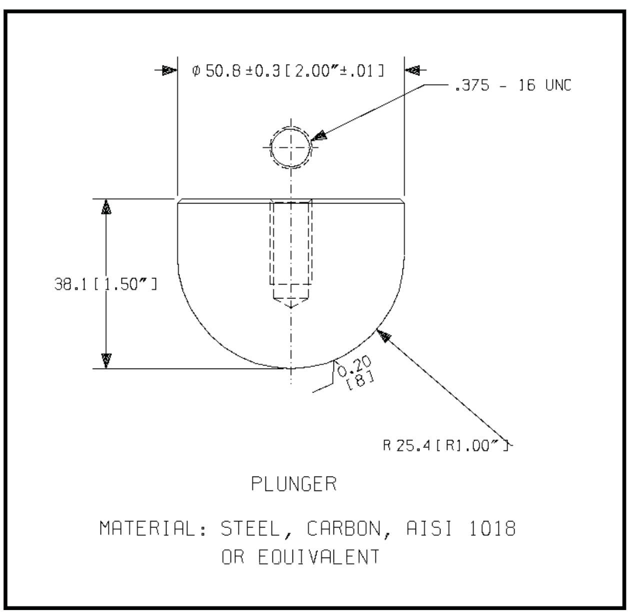


(b) Section BA-BA from Section BB

Figure 7.2. Test Set-Up: Supporting Frame and Platform



(a) Detail BB from Figure 2(b)



(c) Test Set-Up: Plunger 1"

Figure 7.3. Test Specimen and Plunger

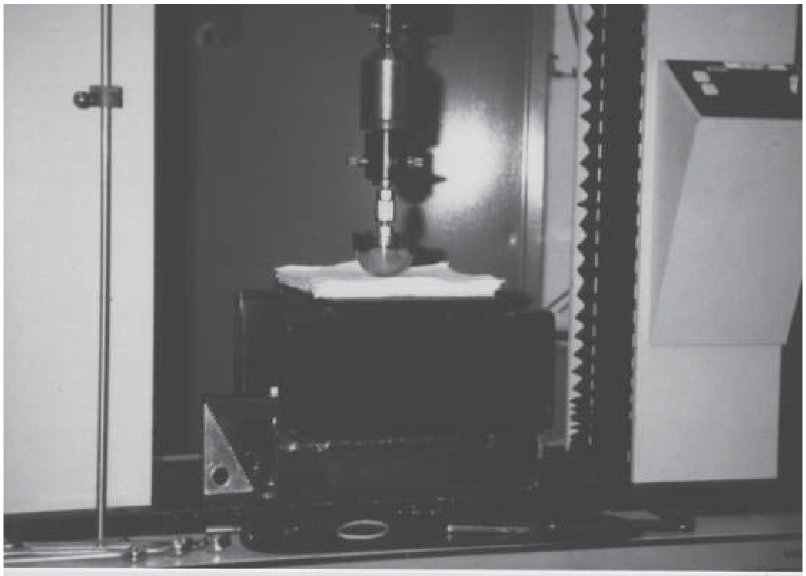


Figure 7.4. A typical Specimen Under Testing

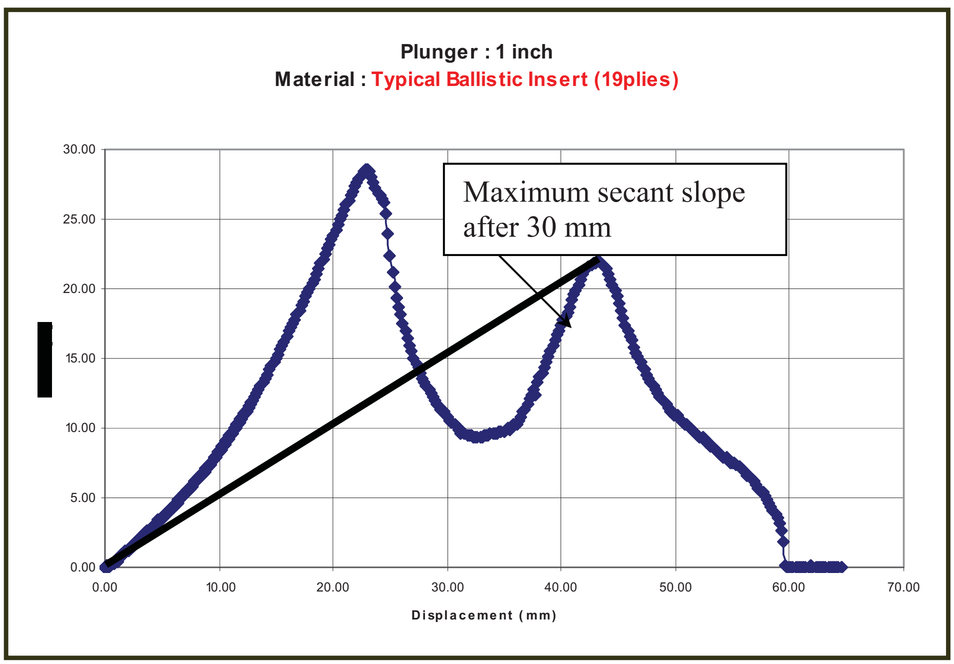


Figure 7.5. An example of maximum secant slope