Memorandum

SRF No. 10939

To: Clear Roads Technical Advisory Committee

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Date: April 1, 2020

Subject: CR 17-02 Standard Specifications for Plow Blades with Carbide Inserts
Task 4 Memorandum (Final) – Development of Standard Specifications and Details

Background

Using plow blades with carbide inserts is an effective option many agencies currently use to remove snow and ice from the roadway. However, there is variability in carbide quality and in the specifications used by each agency to procure the blades. Clear Roads initiated this project to develop a set of standard specifications for carbide-insert plow blades. Standard specifications will help simplify and streamline the procurement process for all agencies and potentially result in higher quality blades being procured and at lower costs.

Scope of Task 4 – Development of Standard Specifications and Details

The focus of Task 4 is to develop a set of Standard Specifications for plow blades with carbide inserts including geometry, dimensions, and metallurgical, mechanical and physical properties. These specifications were developed to be "industry wide" and apply to all vendors and agencies. This task also provides CAD drawings to illustrate the physical dimensions required for plow blade fabrication. This enables vendors to produce a template or fixtures to improve efficiency and accuracy in the production of their blades. This task also provides detailed procedures leading to the unbiased acceptance or rejection of carbide inserts to be used in blade assemblies.

Introduction

From previous studies (CR 07-01), it has been established that carbide insert quality and service life are most affected by manufacturing methods. Cracking and premature failure of the carbide inserts can and do limit the service life of the plow blades. Previous tasks in this project have provided details from vendors and agencies which give a definition of items which could be improved upon.

The formal specification developed for plow blades with carbide inserts is provided in Appendix A and Appendix B. These specifications cover the chemical composition and the metallurgical, mechanical and physical properties of the carbide inserts. In addition to these specifications, this

memorandum presents a general set of testing and inspection procedures that can be used to accept or reject a lot of carbide inserts.

For proper accommodation, the following items should be noted by all agencies:

1. The agency survey found three plow blade alloys are currently in use: AISI 1020, AISI 1045 and ASTM A-36. The type of blade alloy does not noticeably contribute to service life and all three are used through the industry (approximately 55% of agencies use AISI 1020, and 35% of agencies use ASTM A-36). AISI 1020 was selected for this standard specification because it is the most commonly used, but agencies are free to use another alloy of their choice. The standard specification also describes the blades' thickness and width (example: 3/4" x 6") and as a hot rolled bar. In addition, the blade shall contain a 3/8" slot centered on the blade thickness. While bolt hole pattern has little or no effect on service life and varies across the industry, this standard specification uses a widely accepted AASHTO spacing. Agencies may wish to customize these specifications to accommodate their desired option of material, dimensions, and other information. Appendix A and Appendix B include specifications for plow blades, including CAD drawings that illustrate dimensions.

2. Carbide inserts shall have nominal dimensions of 0.365" thick, 1" long and height of 0.635" (trapezoidal shape) to 0.750" (bullnose shape). Thickness and length are controlled by the tooling and variations are likely to be less than +/- 0.001". The thickness is also determined to provide an adequate gap for brazing alloy. The height is controlled by the tooling adjustments and can be a bit more or less, if needed or desired. Detailed specification and CAD drawings are provided for two shapes:

    a. Trapezoidal shape (see Appendix A, Figure 2A) with a 1/16" radius bullnose on the insert, which matches the vast majority of the carbide inserts available on the market, but this small bullnose shape does not affect performance and may be omitted.
    b. Bullnose shape (see Appendix B, Figure 2B) with a 3/16" radius bullnose on the insert.

Testing

The specifications provide a full and proper description of what is required of the carbide inserts. Inserts provided by industry will ideally exhibit test values within the given ranges. In reality, some or a few parts may test outside of these ranges. The properties listed in the specifications were selected for a variety of reasons. They are very well known by test labs and test procedures will yield fast, simple and cost-effective results. These properties also relate quite well to other important properties in a cost-efficient manner without additional expensive tests. The testing will be done in a sequential manner. Appendices A and B list specific ASTM test procedures for hardness (ASTM B294-92), density (ASTM 311-08) and porosity (ASTM B276-05e1). These ASTM test methods describe such items as the test equipment to use; preparation of test specimens; the calibration of equipment; testing procedures; recording numerical test results and sometimes calculations which may be necessary. The details of these ASTM testing standards give maximum assurance that the test results will be the same

for any lab at any location. Any parts which test outside of the given ranges above, shall be separated from all other sample parts and retained. It is possible for a rejection to be identified after the testing procedures and before inspections.

Inspection and Acceptable Quality Level (AQL)

The tungsten carbide inserts are referred to as "cemented carbides" in the powdered metals industry. They are made of a somewhat unique material and manufactured in a unique set of procedures. Defects are introduced in a different manner than most manufacturing processes. Due to these differences, the inspections will maintain the fundamentals of the Acceptable Quality Level (AQL) procedures, but some procedures will be customized to be appropriate to this product and its applications. AQL gives a numerical value for the maximum percent of defects which may be accepted. It is all based on statistics and probability. If there will be a rejection, it would be most desirable to determine that status as soon as possible and avoid additional procedures and expenses. The later inspections will be a bit more sophisticated and cost more than the early testing. The later procedures are where the most significant or major defects will be identified and confirmed.

General Procedures

A DOT or end user may want to consider purchasing carbide inserts themselves, especially if there are issues of trust, accuracy or bias in testing, inspection, certification or rejection of the lot of parts. A DOT or end user could easily avoid these potential problems and still cost justify this action. In order to be justifiable, the purchase quantity may need to be equal to two or more years of blade consumption. The DOT would then be required to store a quantity of inserts for an additional year or more. To use this option would give maximum quality control and selection of the independent lab to the end user, which could be an advantage.

Sample Selection

The risks and consequences of failures in this industry are significantly different than in the medical device or aerospace industries. As a result, the AQL levels will be numerically larger than in a more critical industry, which will allow more insert defects to be accepted with the lot of parts. "Lot size" is the quantity of the production run by the manufacturer, or the quantity received by the vendor for assembly into blades. Sample size is determined by the lot size and is the quantity of parts selected for testing and inspection. Recommended lot and sample sizes are listed in Table 1 below.

For the hardness and density testing, a general inspection level 1 (G1), with an AQL of 15 will be used. This results in the smallest sample size to be examined, with a maximum of 15% defects allowed for acceptance. For porosity and fractures, a special inspection level 3 (S3) will be used with an AQL of 10 for porosity (10% defects) and an AQL of 4 used for fractures (4% defects). The term "defects" refers to a test value outside of the numerical range given in the specification. The lab must certify the ASTM test procedures are used. The vendor can then present copies of the certifications to all end users for review before a purchase order is issued or after the blade assemblies are received. The value of a data review is to assure that the parts were justifiably accepted. Certifications shall be made

by a licensed or certified individual or by an official who has responsibility and the authority over the testing and lab operations.

Manufacturers may want to perform these tests and inspections in order to gain the assurance of their own quality of manufacturing. Ultimately, they must be prepared to accept rejected lots from vendors or end users which require these quality standards as a part of a contract or as a condition of purchase. Under most conditions, vendors arrange for the sampling and testing through a qualified independent lab. A qualified lab will have the capability and personnel to perform metallurgical and microscopic examinations along with a full understanding of ASTM testing standards.

Testing and Inspections

To begin the testing procedures, a "sample" of parts shall be taken from the "lot" of parts. All sample parts are then tested for hardness. They must be run on the Rockwell Hardness "A" (RHA) scale. They must not be tested on another scale and then converted to the "A" scale by using a conversion chart. Any test result falling outside the given range is considered a "defect" and that part shall be separated from the other samples. If the quantity of defects exceeds the "acceptable" limit, the lot of parts should be rejected. If the quantity of defects is less than the "reject" quantity, the defects shall be separated from the other samples and retained for further testing. After hardness testing, there could be a large group of pieces which test within the hardness range as "okay" and possibly a small group of "hardness defects".

The density test is performed in a similar fashion. All sample parts are tested for density. Any test result falling outside the given range is considered a "defect" and that part shall be separated from the other samples. If the quantity of density defects exceeds the "acceptable" limit, the lot of parts should be rejected. If the quantity of density defects is less than the "reject" quantity, the defects shall be separated from the other samples and retained for further testing. After density testing, there could be a large group of pieces which test within the hardness and density ranges as "okay". Smaller groups will consist of defects of "hardness" (only) or "density" (only) or "hardness and density" defects.

The final inspections will use a smaller quantity of sample of parts, referred to previously as a special inspection level 3, and will determine the amount of porosity and/or the presence of fractures or laminations within the carbide inserts. The samples for this inspection will come from possibly two or more sources which have previously been determined. First, recover defects from the group of "density only" defects. Second, if more samples are needed get them from the group of "density and hardness" defects. Third, if more samples are needed get them from the group of "hardness only" defects. If more samples are needed get them from the group which tested "okay" for hardness and density. The lab will now perform more of a metallurgical exam, by cutting the samples approximately in half, exposing a surface of about 5/8" x 1". This will be followed by a series of "grinding" operations which will expose any porosity, cracks or laminations within the inserts. If the quantity or size of porosity defects exceeds the "acceptable" limit, the lot of parts should be rejected. If the quantity of fracture or lamination defects exceed the "acceptable" limit, the lot should be rejected. If the two types of defects are each less than the "reject" quantity, the lots should be accepted. See the footnotes at the end of this report for a description of porosity defects and defects consisting of cracks

or laminations.

Application of Procedures

In the event that the carbide insert manufacturer not only manufactures the inserts, but also performs the assembly operations and sells directly to the DOT, the manufacturer or the lab may select the sample pieces based upon the entire production run. A new sample must be drawn for each production run, with all procedures and certifications repeated for each run. The manufacturer shall then supply copies of the certifications to any DOT or end user receiving assemblies containing these inserts. It is important to select sample parts at random throughout the lot of parts. If the lot of parts are in multiple containers, a proportional number of samples should be drawn from each container. In the event that a vendor purchases the inserts, the sample may be selected by the vendor or the lab based on the purchase quantity. The lab results and certifications then go back to the vendor, and finally copies are supplied to any end user receiving blade assemblies containing parts from that production run. The DOT or end user should make sure they get the copies of the lab results and certifications before placing the purchase order. There is a need to review the numerical tabulations to make sure that acceptance is justified by the lab results. If not, the DOT should reject assemblies containing inserts from a lot of parts which did not meet specifications. This process gives agencies an option to assure quality requirements are met.

Visual inspection for fractures should be done initially with the G1 sample, which is intended to discover surface exposure of cracks or laminations. The later exam (with the porosity exam) will discover additional cracks or laminations which are difficult to find visually and may also be hidden internally and not exposed on the surface. If these defects (from the G1 inspection) exceed the acceptable quantity, the lot of parts should be rejected and there will be no need to proceed to the porosity examinations. If the defects from this examination are less than the reject quantity, they should be separated from the samples and combined with any defects from later exams for cracks or laminations.

Table 1: Sample Sizes and AQL Chart

Lot Size	Sample Size G1	AQL=15 Ac/Re	Sample Size S3	AQL=10 Ac/Re	AQL=4 Ac/Re
501 to 1200	32	10 / 11	13	3 / 4	1 / 2
1201 to 3200	50	14 / 15	13	3 / 4	1 / 2
3201 to 10000	80	21 / 22	20	5 / 6	2 / 3
10001 to 35000	125	21 / 22	20	5 / 6	2 / 3
35001 to 150000	200	21 / 22	32	7 / 8	3 / 4

GENERAL NOTES:

1. Sample size G1 is used for initial testing which includes hardness and density. Sample size S3 is used for inspections which include porosity, fractures and laminations. See text material above for details.
2. Porosity is specified as "A04, B02 and C04"; where the letters "A, B, or C" indicate the size or type of pore and the numerical portion as "04, 02 and 04 respectively, indicate a "quantity" value. If any one of these numerical values is exceeded, it is considered a "defect". Unusually large pores are reported separately by their size and quantity. It is possible, as a result, for any one part to possess more than three defects (A + B + C + any unusually large pores). If the quantity of defects exceed the "acceptable" limit, the lot of parts should be rejected.
3. Cracks and laminations may appear in the inspections using G1 (early) or S3 (later) samples. Each crack or lamination is considered a "defect" and shall be added together for both inspections. If the quantity of defects exceed the "acceptable" limit, the lot of parts should be rejected.
4. It is suggested that feedback, recording and subsequent review be undertaken for possible revisions of these AQL values and the accept/reject quantities due to the unique application to the winter road maintenance industry. An attempt has been made to avoid excessive rejections but also to enforce minimum standards which will noticeably improve the service life of inserts and plow blades. These AQL criteria were selected for a maximum acceptance of 15% defects in hardness and density; 10% defects in porosity and 4% defects in cracks and/or fractures.

Conclusion

This memorandum incorporates feedback received from the TAC and presents the final standard specifications for carbide insert plow blades with accompanying CAD drawings. The carbide insert is the element that is most critical to service life of the plow blade. As such, it is critical that carbide inserts meet the specifications presented here. The testing and inspection procedures provided give the DOT assurance that quality requirements are met. The next steps in this project include preparation of a final report and webinar that summarize the project findings.

APPENDIX A

Standard Specifications for Plow Blades with Carbide Inserts (Trapezoid Shape)

Prepared by Clear Roads

1. PLOW BLADE
    a. Plow blades shall be 3/4" by 6" by 48" and shall be hot rolled AISI 1020 quality steel.
    b. Lengths other than 48" may be specified in 12" increments.
    c. Hole punching shall be 11/16" square and countersunk to receive 5/8" bolts.
    d. Location and spacing of hole punches shall be as shown on the attached Figure 1A.
    e. Tolerance of bolt hole location shall be 1/32".
    f. A 3/8" groove for the carbide inserts shall be milled in the center of the blade edge.

2. CARBIDE BLADE INSERTS
    a. Inserts shall be made of the following materials:
        i. 87-88% tungsten carbide
        ii. 11-12% cobalt
        iii. 1% maximum for all other elements
    b. Inserts shall be 25-degree trapezoidal with the following nominal dimensions (Figure 2A):
        i. Length: 1" ± 0.005"
        ii. Thickness: 0.365" ± 0.005"
        iii. Height: 0.635" ± 0.005" (measured on long side)
        iv. Nose radius: 1/16"
    c. Inserts shall have the following properties:
        i. Hardness: 88.0-90.5 HRA per ASTM B294-92
        ii. Density: 14.4-14.5 g/cc per ASTM 311-08
        iii. Porosity: A04 = 0.06%, B02 = 0.02%, C04= 0.06% per ASTM B276-05e1
    d. All surfaces (internal and external) shall be free of cracks and laminations.

3. BRAZING
    a. Carbide inserts shall be spaced in the milled groove with .010" between the inserts for the entire length of each blade section.
    b. The inserts shall be brazed on all sides.
    c. Brazing shall leave no voids or shims.
    d. Brazes shall use quality materials, best methods and qualified/certified technicians.
    e. There shall be no gaps or spacing between adjacent inserts after brazing.

4. TESTING PROCEDURES
    a. The vendor shall perform ASTM testing on a representative sample of each lot of carbide material that is used in the production of carbide inserts. All ASTM carbide test procedures listed above shall be conducted.
    b. Prior to delivery, the vendor shall provide the Department with all ASTM carbide test results and a statement of Acceptable Quality Level (AQL) inspection data, including acceptance and rejection findings. At its discretion, the Department will review the provided information and either accept or reject the carbide material. Accepted carbide material may move forward in the procurement process. Rejected carbide material shall result in rejection of the full lot of carbide from which the test samples were derived and cancelation of the procurement. If the vendor desires to continue with the procurement they must submit test results and AQL findings from a different lot of carbide material.

APPENDIX B

Standard Specifications for Plow Blades with Carbide Inserts (Bullnose Shape)

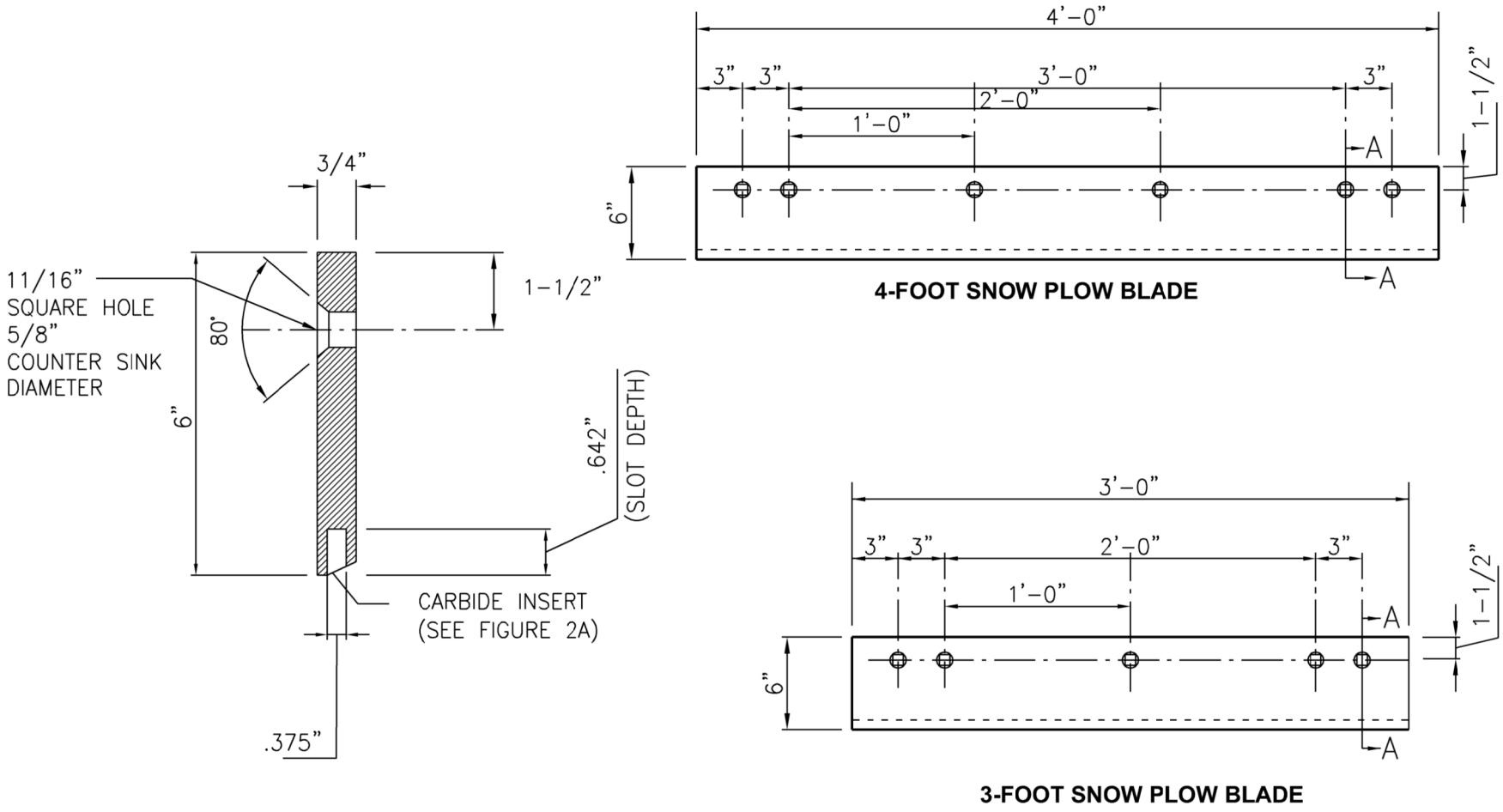
Prepared by Clear Roads

1. PLOW BLADE
    a. Plow blades shall be 3/4" by 6" by 48" and shall be hot rolled AISI 1020 quality steel.
    b. Lengths other than 48" may be specified in 12" increments.
    c. Hole punching shall be 11/16" square and countersunk to receive 5/8" bolts.
    d. Location and spacing of hole punches shall be as shown on the attached Figure 1B.
    e. Tolerance of bolt hole location shall be 1/32".
    f. A 3/8" groove for the carbide inserts shall be milled in the center of the blade edge.

2. CARBIDE BLADE INSERTS
    a. Inserts shall be made of the following materials:
        i. 87-88% tungsten carbide
        ii. 11-12% cobalt
        iii. 1% maximum for all other elements
    b. Inserts shall be bullnose shape with the following nominal dimensions (Figure 2B):
        i. Length: 1" ± 0.005"
        ii. Thickness: 0.365" ± 0.005"
        iii. Height: 0.750" ± 0.005" (total height, including bullnose radius)
        iv. Nose radius: 3/16"
    c. Inserts shall have the following properties:
        i. Hardness: 88.0-90.5 HRA per ASTM B294-92
        ii. Density: 14.4-14.5 g/cc per ASTM 311-08
        iii. Porosity: A04 = 0.06%, B02 = 0.02%, C04= 0.06% per ASTM B276-05e1
    d. All surfaces (internal and external) shall be free of cracks and laminations.

3. BRAZING
    a. Carbide inserts shall be spaced in the milled groove with .010" between the inserts for the entire length of each blade section.
    b. The inserts shall be brazed on all sides.
    c. Brazing shall leave no voids or shims.
    d. Brazes shall use quality materials, best methods and qualified/certified technicians.
    e. There shall be no gaps or spacing between adjacent inserts after brazing.

4. TESTING PROCEDURES
    a. The vendor shall perform ASTM testing on a representative sample of each lot of carbide material that is used in the production of carbide inserts. All ASTM carbide test procedures listed above shall be conducted.
    b. Prior to delivery, the vendor shall provide the Department with all ASTM carbide test results and a statement of Acceptable Quality Level (AQL) inspection data, including acceptance and rejection findings. At its discretion, the Department will review the provided information and either accept or reject the carbide material. Accepted carbide material may move forward in the procurement process. Rejected carbide material shall result in rejection of the full lot of carbide from which the test samples were derived and cancelation of the procurement. If the vendor desires to continue with the procurement they must submit test results and AQL findings from a different lot of carbide material.



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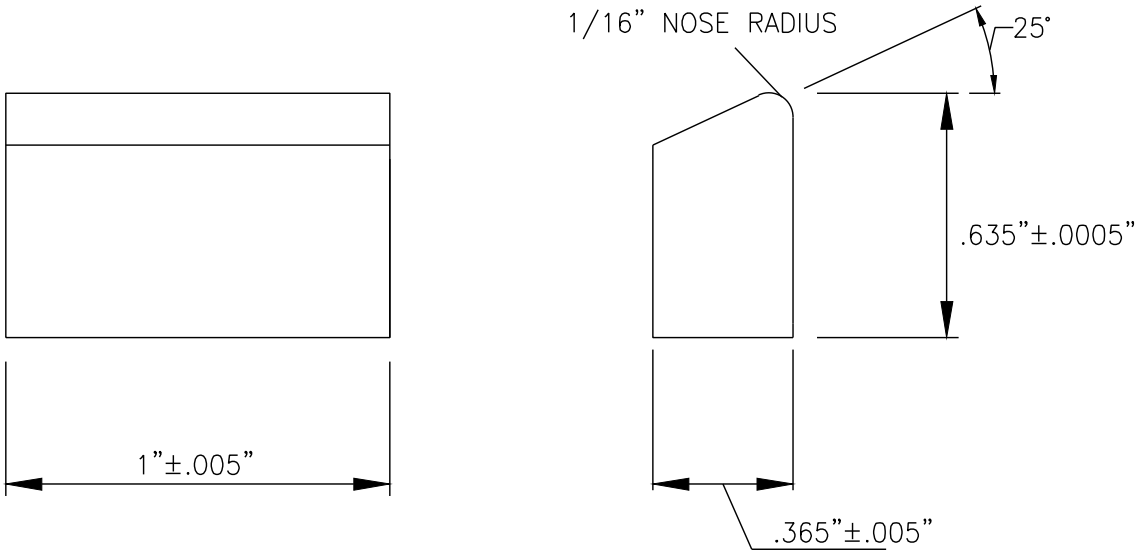
APPENDIX A: SNOW PLOW BLADE DETAIL DRAWING (TRAPEZOID)

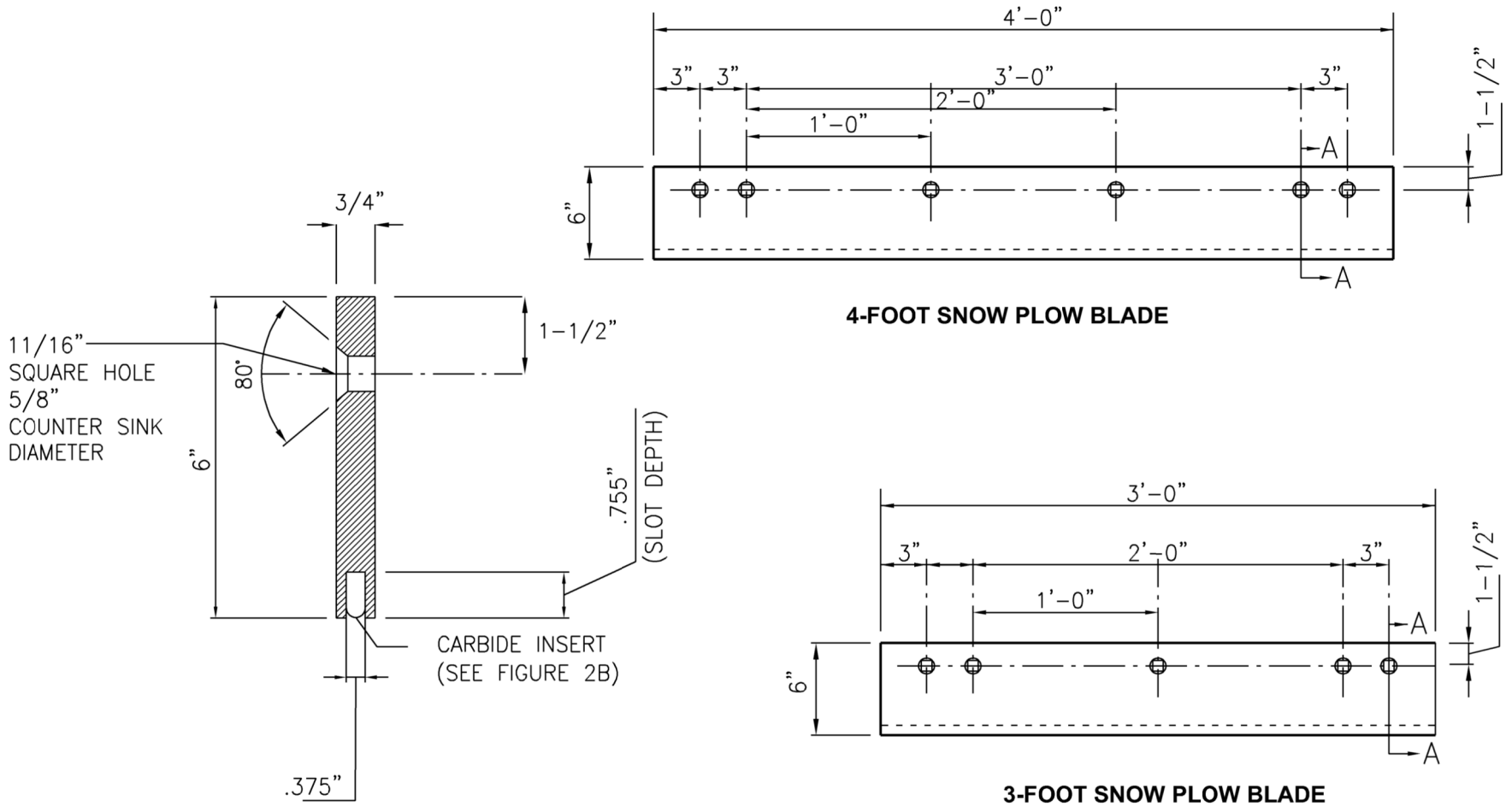
Figure 1A



CARBIDE INSERT

APPENDIX A: CARBIDE INSERT DETAIL DRAWING (TRAPEZOID)

Figure 2A



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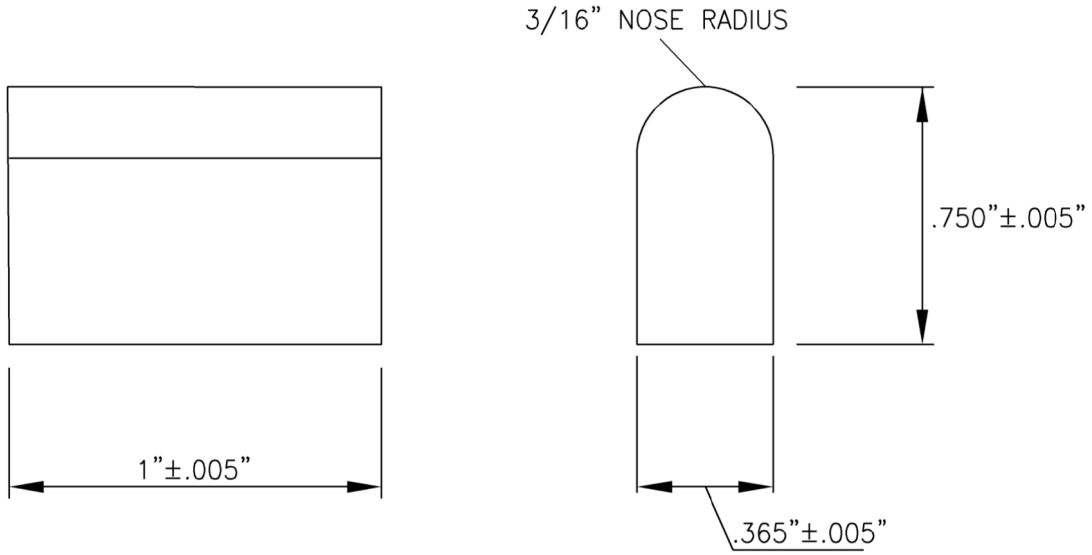
APPENDIX B: SNOW PLOW BLADE DETAIL DRAWING (BULLNOSE)

Figure 1B



CARBIDE INSERT