

Statement of Work
Metal Matrix Composite Sample Machining

1. The contractor will machine various mechanical property test specimens from government furnished materials (GFM). The government will furnish aluminum bronze, phosphor bronze, and metal matrix composite (MMC) castings of tungsten carbide particles in bronze. The MMC material will be supplied in the form of sedimentation cast discs with approximate dimensions of 8" diameter and 1 ¼" thickness. To make the sedimentation castings, tungsten carbide particles were added to molten bronze prior to pouring the castings. The MMC castings were poured such that the tungsten carbide particles were allowed to settle and concentrate into the bottom halves of the discs. The layer of concentrated tungsten carbide particles is approximately 5/8" thick. This layer is very hard. The MMC specimens will be removed from this layer. The government will provide at least five MMC castings.

2. The types, quantities, and sizes of samples needed are as described in the attached table with additional information as provided below.

A. **Flat Tensile Specimens** – The finished specimen dimensions are shown in Figure 1. Five specimens are to be wholly machined from the sedimented, tungsten carbide-rich layer in the GFM, 8" diameter by 1 ¼" thick, MMC bronze castings. The general location of the samples as they are to be removed from the MMC casting are shown in Figure 2. Five specimens each are to be made from GFM phosphor bronze and aluminum bronze. The phosphor bronze and aluminum bronze samples may be removed from any convenient part of the GFM of these alloys.

B. **Compression Specimens** – The finished specimen dimensions are shown in Figure 3. Five specimens are to be wholly machined from the sedimented, tungsten carbide-rich layer in the GFM, 8" diameter by 1 ¼" thick, MMC bronze castings. The general location of the samples as they are to be removed from the MMC casting are shown in Figure 4. Five specimens each are to be made from GFM phosphor bronze and aluminum bronze. The phosphor bronze and aluminum bronze samples may be removed from any convenient part of the GFM of these alloys.

- a. For all of the compression specimens the lateral surfaces in the gage length shall not vary in diameter, width, or thickness by more than 1% or 0.002", whichever is less.
- b. The centerline of all lateral surfaces shall be coaxial within 0.01".
- c. Machined surfaces of specimens shall have a surface finish of 63 micromches or better.
- d. The ends of a specimen shall be flat and parallel within 0.0005 in./in. and perpendicular within 3' of arc.

C. **Impact Specimens, Charpy V-Notch (CVN)** - The finished specimen dimensions are shown in Figure 5. Ten specimens are to be wholly machined from the sedimented, tungsten carbide-rich layer in the GFM, 8" diameter by 1 ¼" thick, MMC bronze castings. The general location of the samples as

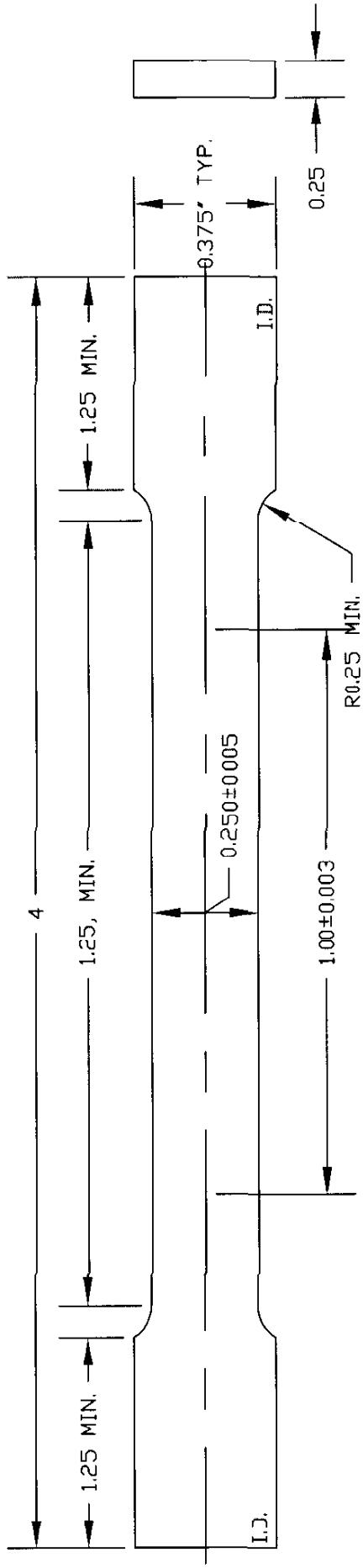
they are to be removed from the MMC casting are shown in Figure 6. Ten specimens each are to be made from GFM phosphor bronze and aluminum bronze. The phosphor bronze and aluminum bronze samples may be removed from any convenient part of the GFM of these alloys.

- D. **Fatigue Crack Growth** - The finished specimen dimensions are shown in Figure 7. Six specimens are to be wholly machined from the sedimented, tungsten carbide rich layer in the GFM, 8" diameter by 1 ¼" thick, MMC bronze castings. The general location of the samples as they are to be removed from the MMC casting are shown in Figure 8. Six specimens each are to be made from GFM phosphor bronze and aluminum bronze. The phosphor bronze and aluminum bronze samples may be removed from any convenient part of the GFM of these alloys.
- E. **Fracture Toughness** - The finished specimen dimensions are shown in Figure 9. Five specimens are to be wholly machined from the sedimented, tungsten carbide-rich layer in the GFM, 8" diameter by 1 ¼" thick, MMC bronze castings. The general location of the samples as they are to be removed from the MMC casting are shown in Figure 10. Five specimens each are to be made from GFM phosphor bronze and aluminum bronze. The phosphor bronze and aluminum bronze samples may be removed from any convenient part of the GFM of these alloys.
- F. **Wear, abrasion** - The finished specimen dimensions are shown in Figure 11. No MMC specimens are needed. Five specimens each are to be made from GFM phosphor bronze and aluminum bronze. The phosphor bronze and aluminum bronze samples may be removed from any convenient part of the GFM of these alloys.
- G. **Wear, pin-on-disc** - The finished specimen dimensions are shown in Figure 12. No MMC specimens are needed. Five specimens each are to be made from GFM phosphor bronze and aluminum bronze. The phosphor bronze and aluminum bronze samples may be removed from any convenient part of the GFM of these alloys.

Mechanical Property Specimens

Specimen Type	ASTM Spec.	Material	Approx. Specimen Dimensions	Quantity
Tensile, flat	E8	MMC (specimen blank removed from the predominately tungsten carbide layer in a sedimentation casting of aluminum bronze and tungsten carbide)	4" x 3/8" x 1/4"	5
Tensile, flat	E8	Aluminum bronze	4" x 3/8" x 1/4"	5
Tensile, flat	E8	Phosphor bronze	4" x 3/8" x 1/4"	5
Compression	E9	MMC (specimen blank removed from the predominately tungsten carbide layer in a sedimentation casting of aluminum bronze and tungsten carbide). Long axis of the specimen to be aligned in a direction parallel to sedimented layer of tungsten carbide.	0.5" dia. X 1" long	5
Compression	E9	Aluminum bronze	0.5" dia. X 1" long	5
Compression	E9	Phosphor bronze	0.5" dia. X 1" long	5
Charpy V-Notch	E23	MMC (specimen blank removed from the predominately tungsten carbide layer in a sedimentation casting of aluminum bronze and tungsten carbide). Long axis of the specimen to be aligned in a direction parallel to sedimented layer of tungsten carbide.	0.4" x 0.4" x 2.165"	10
Charpy V-Notch	E23	Aluminum bronze	0.4" x 0.4" x 2.165"	10
Charpy V-Notch	E23	Phosphor bronze	0.4" x 0.4" x 2.165"	10
Fatigue Crack Growth	E647	MMC (specimen blank removed from the predominately tungsten carbide layer in a sedimentation casting of aluminum bronze and tungsten carbide)	4.25" x 4" x 0.5"	6
Fatigue Crack Growth	E647	Aluminum bronze	4.25" x 4" x 0.5"	6
Fatigue Crack Growth	E647	Phosphor bronze	4.25" x 4" x 0.5"	6
Fracture Toughness	E1820	MMC (specimen blank removed from the predominately tungsten carbide layer in a sedimentation casting of aluminum bronze and tungsten carbide)	1" x 1" x 0.5"	5
Fracture Toughness	E1820	Aluminum bronze	1" x 1" x 0.5"	5
Fracture Toughness	E1820	Phosphor bronze	1" x 1" x 0.5"	5
Wear, abrasive	G65	Aluminum bronze	1" x 3" x 0.5"	5
Wear, abrasive	G65	Phosphor bronze	1" x 3" x 0.5"	5
Wear, pin-on-disc	G99	Aluminum bronze	1" x 1" x 0.5"	5
Wear, pin-on-disc	G99	Phosphor bronze	1" x 1" x 0.5"	5

Figure 1-Flat Tensile Specimen



$T = \text{AS RECEIVED THICKNESS, LESS CLEAN UP REQUIRED, MAXIMUM THICKNESS} = 0.25''.$

NOTES:

1. SPECIMEN TO BE MACHINED IN THE FREE & NATURAL STATE AS RECEIVED.
2. (NO BENDING, STRAIGHTENING OR DISTORTION ALLOWED)
3. MAINTAIN SPECIMEN IDENTIFICATION ON EACH GRIP END.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONS: DECIMALS: ANGLES:	POINTS OF CONTACT: 1) Giuseppeorio 2) Dr. Aprigiano PHONE #301 227-5094 # 301 227-4155 FILE NAME:	NSWC CARDEROCK - METALS DEPARTMENT - CODE 61 DRAWING NAME: Flat Tensile PROGRAM: MATERIAL: SCALE: REV: DATE:
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Top & Bottom
View

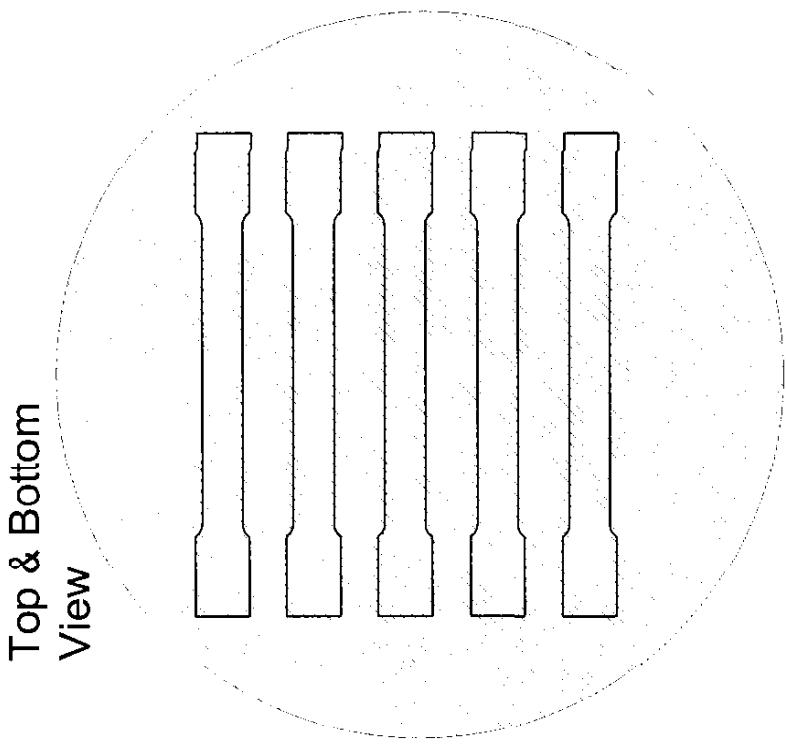
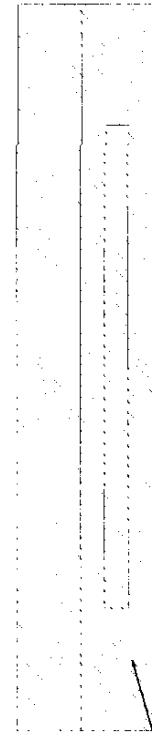


Figure 2. Placement of Tensile Specimens

Front View

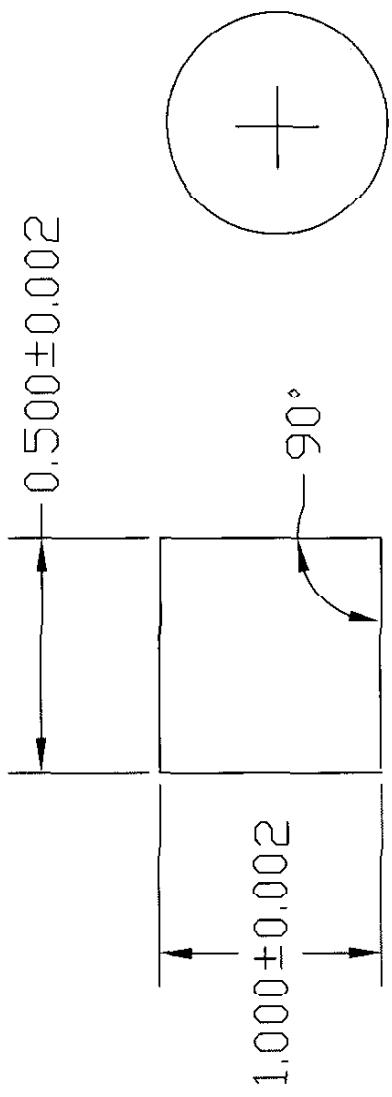


WC/Bronze Layer

Unless otherwise noted, tolerances are:
 N X ± 0.05 Y/N min of $\pm 1/32$
 N XX ± 0.01 or $\pm 1/24$
 N XXX ± 0.002

Tensile Sample configuration		Drawing	Revision C	SIZE A
MATERIAL	CONDITION:	Bronze & WC	BRONZE	SCALE
Cordierite Division, NSFC	Rough Conditions			1

Figure 3 Compression Specimen



NOTES:

1. All surfaces shall be parallel and perpendicular within 0.001" T. I. R.
2. Surface finish shall be $\text{RA} \leq 16$
3. No turning centers allowed.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONS: DECIMALS: ANGLES:	POINTS OF CONTACT: 1) 2) PHONE #:	NSWC CARDEROCK - METALS DEPARTMENT - CODE 61 DRAWING NAME: 1" Compression PROGRAM: NAME: 1.0" compression	SCALE:	REV:	DATE:
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Top & Bottom
View

Side View

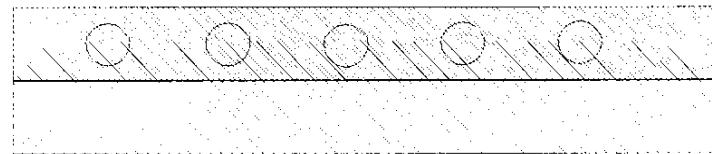
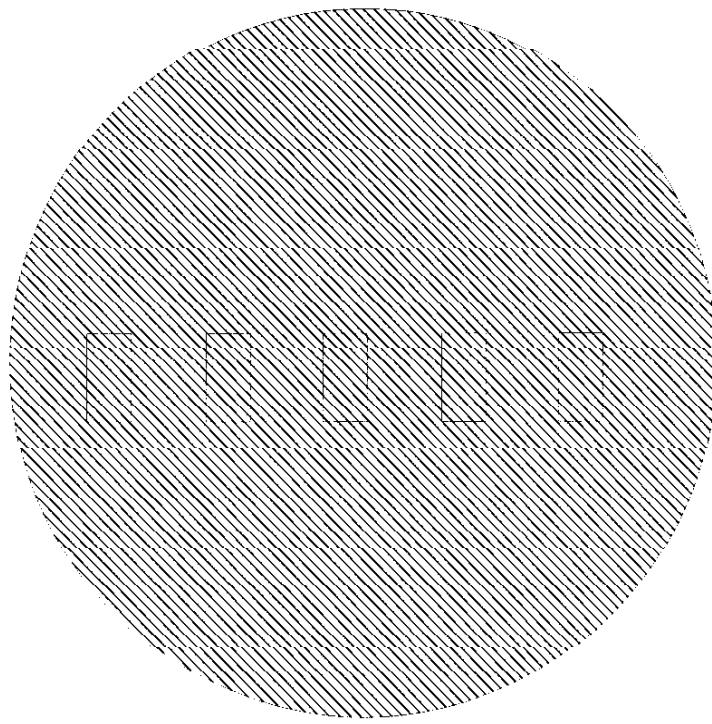
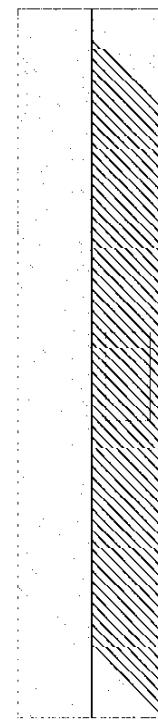


Figure 4 Placement of Compression Specimens

Front View



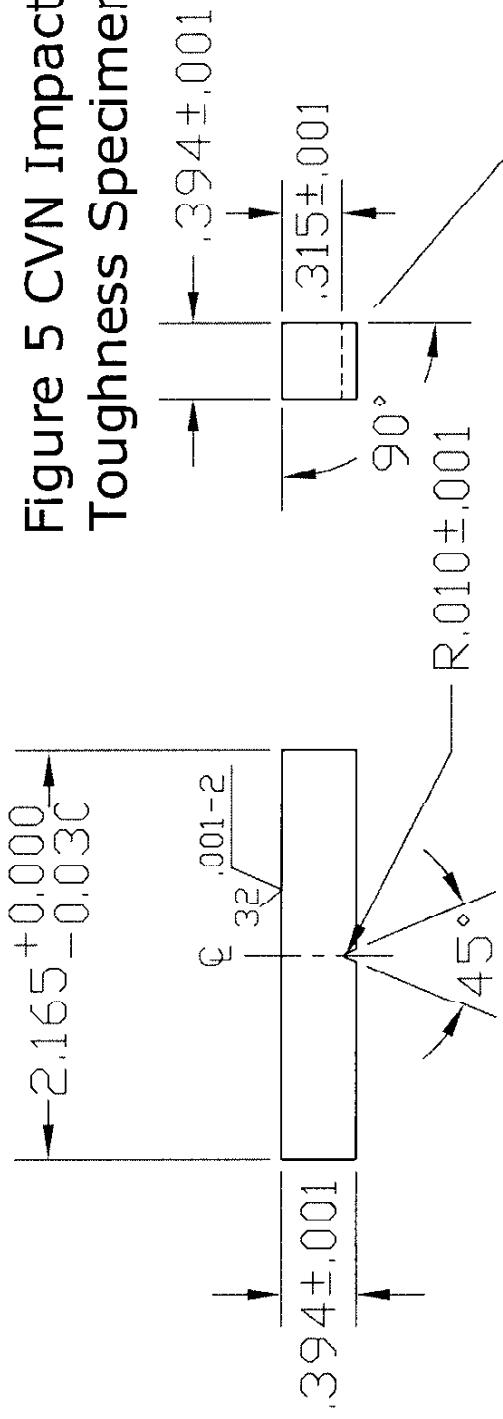
Unless otherwise noted, tolerances are
N X ± 0.05 Y/N min of $-1/12$
N XX ± 0.01 or $\pm 1/2h$
N XXX ± 0.002

DRAWN BY: GUSSEPP TORIO
REVIEWED BY:
DATE: June 25, 2004
CODE: 611
BLDG: 60, RM: 202
CONDITON: Rough Conditions
MATERIAL: Iron & WC
Cutter/Tool Division, NSFC
SCALE: 1:1
QTY: 1

Compression Specimens

Drawing Revision 0 SIZE A
Border ISD-A Glissade Torte

Figure 5 CVN Impact Toughness Specimen



NOTES:

1. SPECIMEN TO BE MACHINED IN FREE & NATURAL STATE AS RECEIVED (NO BENDING, STRAIGHTENING OR DISTORTION ALLOWED.)
2. CARAT STAMPED ON SPECIMEN END INDICATES FACE NOTCH IS TO BE MACHINED IN.
3. MAINTAIN IDENTIFICATION (I.D.) ON BOTH ENDS.
4. BOTTOM OF NOTCH MUST BE PARALLEL WITH OPPOSITE SIDE.

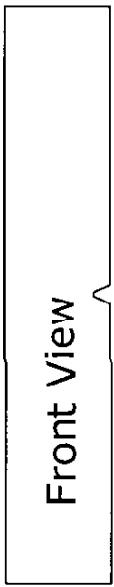
SEE NOTES 2&3

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONS: ±1/64 DECIMALS: ±0.01 ANGLES: ±1/2°	POINTS OF CONTACT: 1) 2) PHONE #:	NSWC CARDEROCK - METALS DEPARTMENT - CODE 61 DRAWING NAME: CVN (CHARPY) PROGRAM: MATERIAL: FILE NAME: CVN.DWG SPEC #:
		SCALE: REV: DATE:

Top View

1.000 ±0.000 1.000 ±0.000 1.000 ±0.000
 1.000 ±0.000 1.000 ±0.000 1.000 ±0.000

Front View



Front View

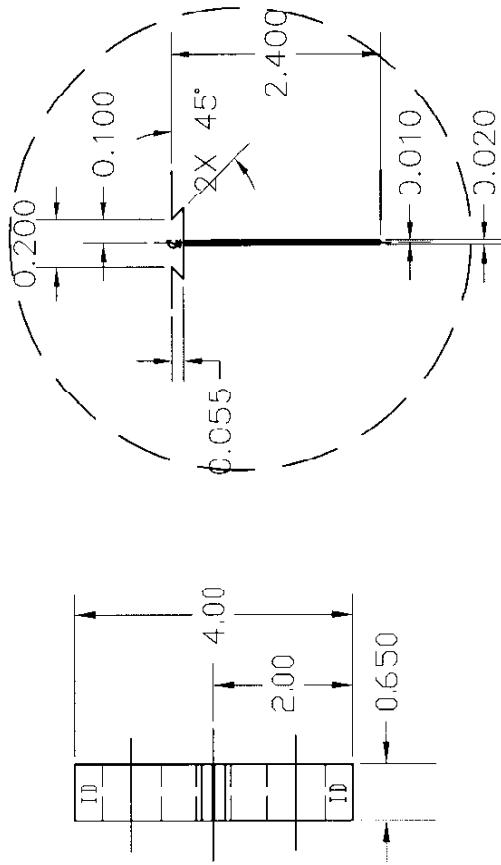
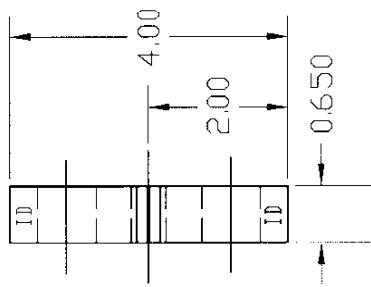
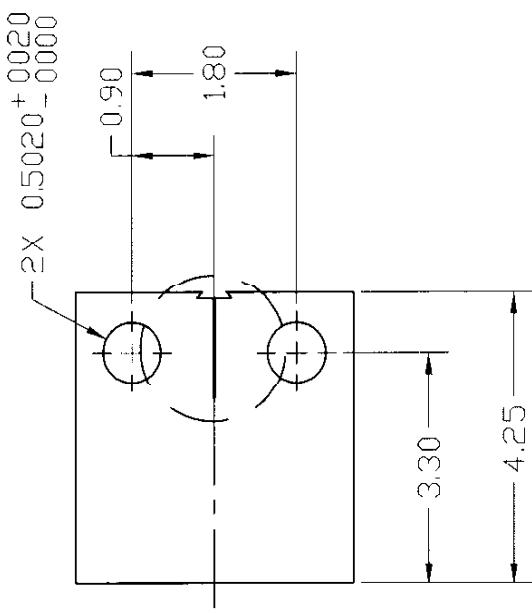
Figure 6. Impact Toughness CVN Specimens

WC-Bronze Layer

Unless otherwise noted, tolerances are
 N.X. ± 0.05 X/N min of $\pm 1/32$
 N.XX ± 0.01 or $\pm 1/24$
 N.XXX ± 0.002

DRAWN BY: GIUSEPPE TORO		DATE: CODE: 6/12 BLDG. 60, RM. 202 227-5084		SIZE A Revision 0	
REVIEWED BY:		MATERIAL: Bronze & WC		DRAWING CONDITION: Rough Conditions	
				QTY: 1	

CVN Specimen Machining	
Drawing	Condition:



NOTES:

1. STAMP SPECIMEN ID AS INDICATED.
2. SLOT WIDTH MAY BE AS SMALL AS EDM WIRE DIAMETER.
3. ALL SURFACES TO BE PARALLEL AND PERPENDICULAR
4. INTERNAL RADIUS MIN .000 AND MAX .010

Figure 7 Fatigue Crack Growth Specimen

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	POINTS OF CONTACT: 1) Closest P2 Iortic 2) Phone # 301 227-5094	NSWC CARDEROCK - METALS DEPARTMENT - CODE 61
TOLERANCES: -TRACTIONS: DECIMALS: ANGLES:	FILE NAME: DRAWING NAME: 0.65T FCGR	PROGRAM: MATERIAL:
$\pm 1/64$ ± 0.01 $\pm 1/2^\circ$	SPECIMEN NO.: /	SCALE: REV: DATE 6-25-04

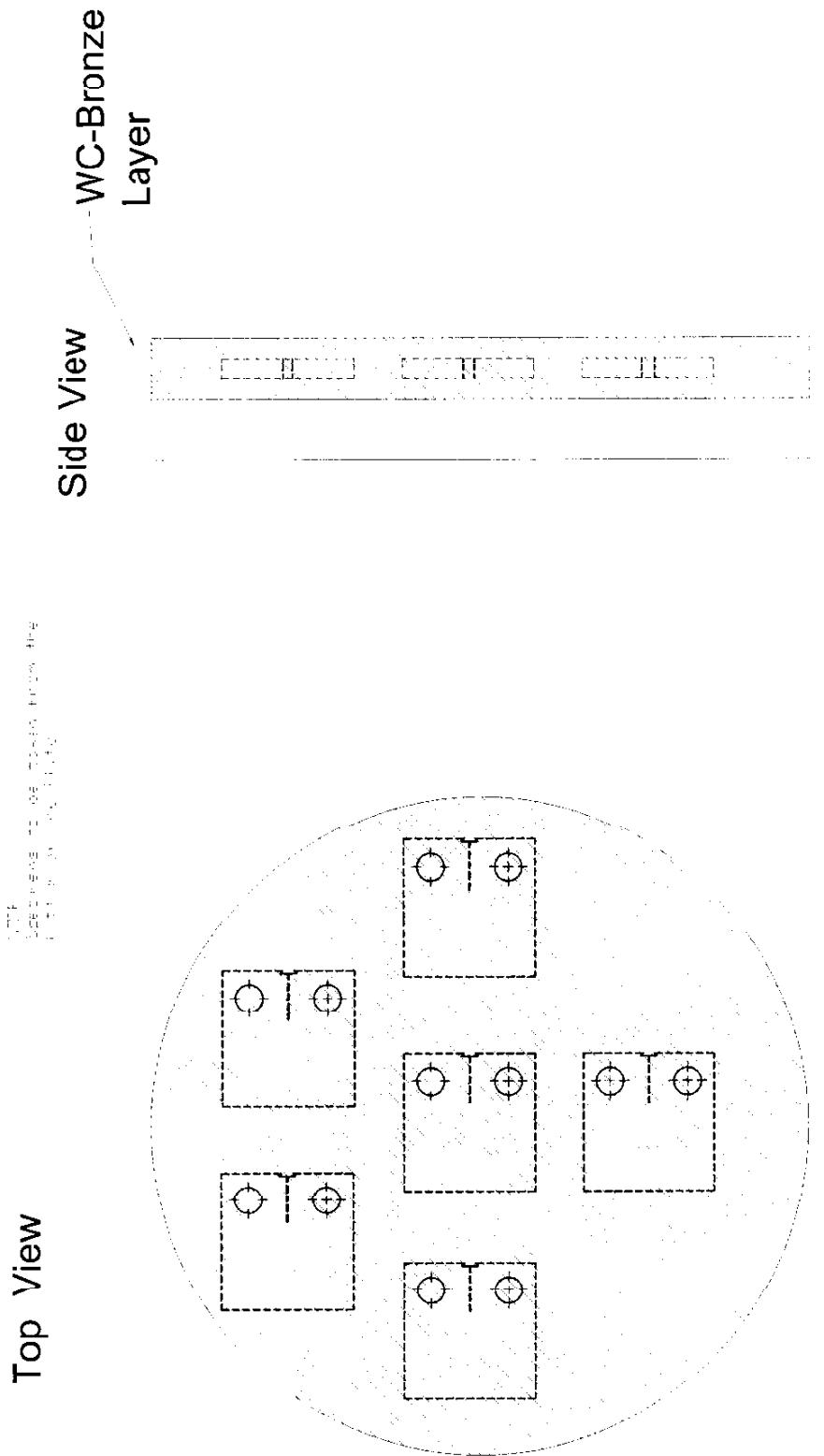


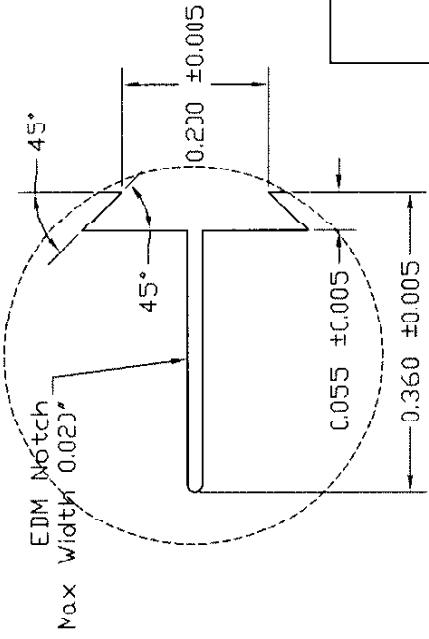
Figure 8. Placement of Fatigue Crack Growth Samples

DATE	CODE 612
REVIEWED BY:	Cardocet Invasion, NSFC
DRAWN BY: Giuseppe Iorio	BLDG. 60, RM. 202
REVISED BY:	June 23, 2004

Unless otherwise noted, tolerances are
 ± 0.05 X/N min of $\pm 1/32$
 ± 0.01 or $\pm X/2N$
 ± 0.002 N.XXX

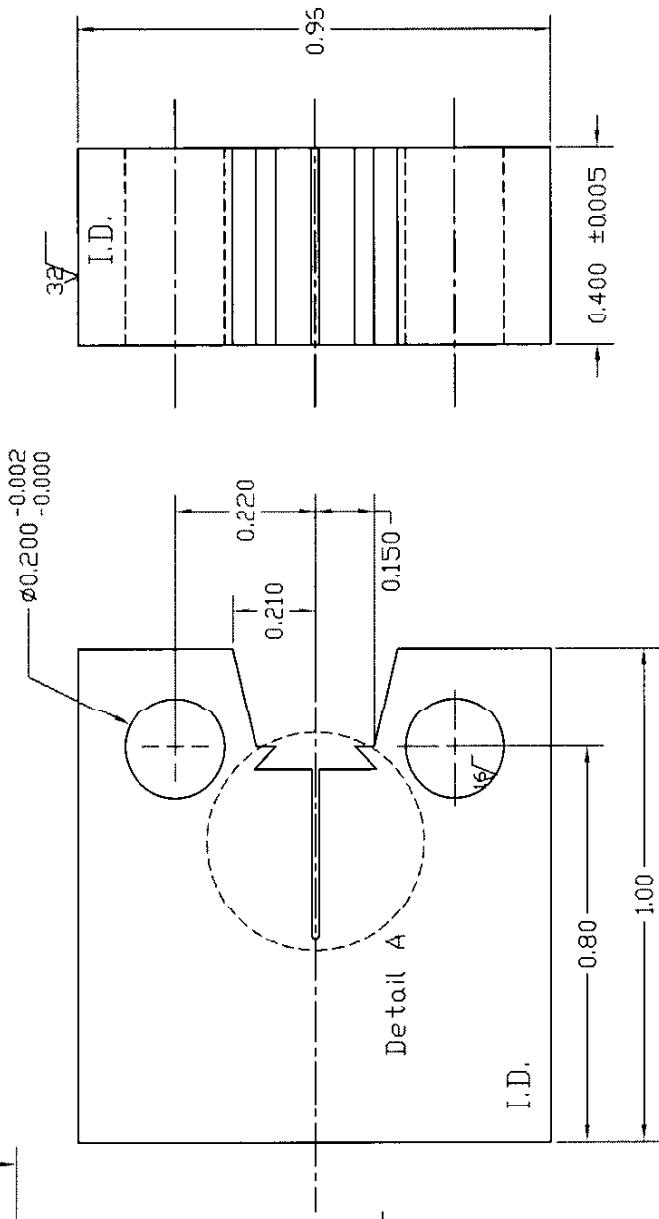
Fatigue Specimen Machining	
Drawing	Revision O
SIZE A	SCALE
Material	Bronze & WC
Condition:	Rough Conditions
QTY: 1	

Figure 9 Fracture Toughness Specimen

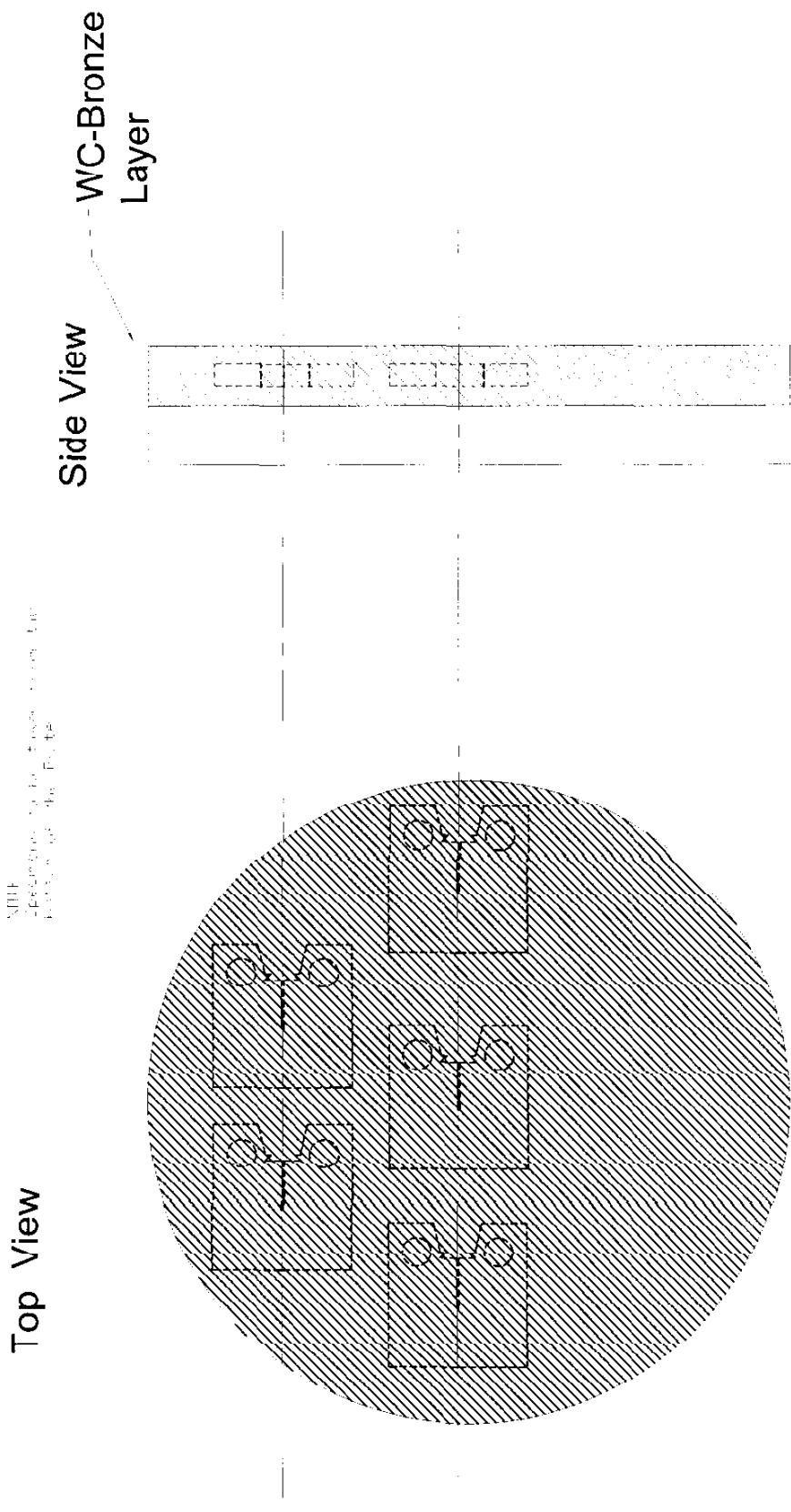


Detail A

NOTES:
 1) ALL SURFACES PARALLEL
 AND PERPENDICULAR AS
 APPLICABLE WITHIN
 $0.002"$ TIR
 2) STAMP SPECIMEN ID
 WHERE INDICATED BY 'I.D.'



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	POINTS OF CONTACT	NSWC CARDEROCK - METALS
FRACTIONS: $\frac{1}{64}$	1) Giuseppe Iorio	DEPARTMENT - CODE 61
DECIMALS: ± 0.0	2) PHONE # (301) 227-5094	DWG NAME: 0.40T C(T) 0.45a/W
ANGLES: $\pm 1/2^\circ$	PROGRAM: MATERIAL	
SPEC. #: FILE NAME: 0.40T 0.45aw C(T).dwg	SCALE: REV: DATE:	6/25/04



**Figure 10. Placement of Fracture
Toughness Samples**

Unless otherwise noted, tolerances are:
 N.X. ± 0.05 X/N min of $\pm 1/32$
 N.X. ± 0.01 or $\pm 1/2N$
 N.XXX ± 0.002

Specimen Machining		Revision O	SIZE A	SIZE B
Drawing				SCALE
CODE 612	BLDG. 60, R.M. 202	227-6024	MATERIAL	Bronze & WC
Date 23/2004	Conderate Division, ASME	CONDITION:	Rough Conditions	
DRAWN BY: Giuseppe Iorio	REVIEWED BY:			



Figure 11 Wear , Abrasion Specimen

Figure 11 Wear, Abrasion Specimen

00/05/2004 DRAFT 3 DRWERSPEE INSTRUMENTS

Wear Abrasion Specimen

Drawing		Revision 0		SIZE A	
				Bronze & Tungsten Carbide SCALE	
DRAWN BY: GIUSEPPE TORIO		CODE 612		MATERIAL	
REVIEWED BY:		DATE May 20 2004		217-5084	
N.X ±0.05 N.X ±0.01 N.XXX ±0.002		BLDG. 60, RM. 202 Carterrock Division, NSFC		CONDITION: Rough	

Unless otherwise noted, tolerances are
N.X $\pm \frac{1}{32}$ in.
N.X $\pm \frac{1}{16}$ in.
N.X $\pm \frac{1}{8}$ in.
N.XXX $\pm \frac{1}{16}$ in.



Figure 12 Wear , Pin-on Disc

Unless otherwise noted, tolerances are
N.Y. 0.00 to 0.00 or $\pm .005$
N.X. 0.00 to 0.00 or $\pm .002$
N.XX. 0.00 to 0.00 or $\pm .001$

DRAWN BY:	GIUSEPPE IORIO	DATE:	COD. 612	BUDG. 80, NW. 202	2227-5084	MATERIAL:	Brass & Turned Carbide	SCALE:
REVIEWED BY:		May 26 2004	Carderock Division, NSWC			CONDITION:	Rough	QTY: 1

Wear Pin-on Disc	
Drawing	Revision 0