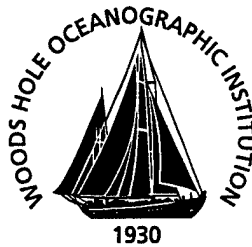


Woods Hole Oceanographic Institution



A Passive Capture Latch for ODYSSEY-Class AUVs

by

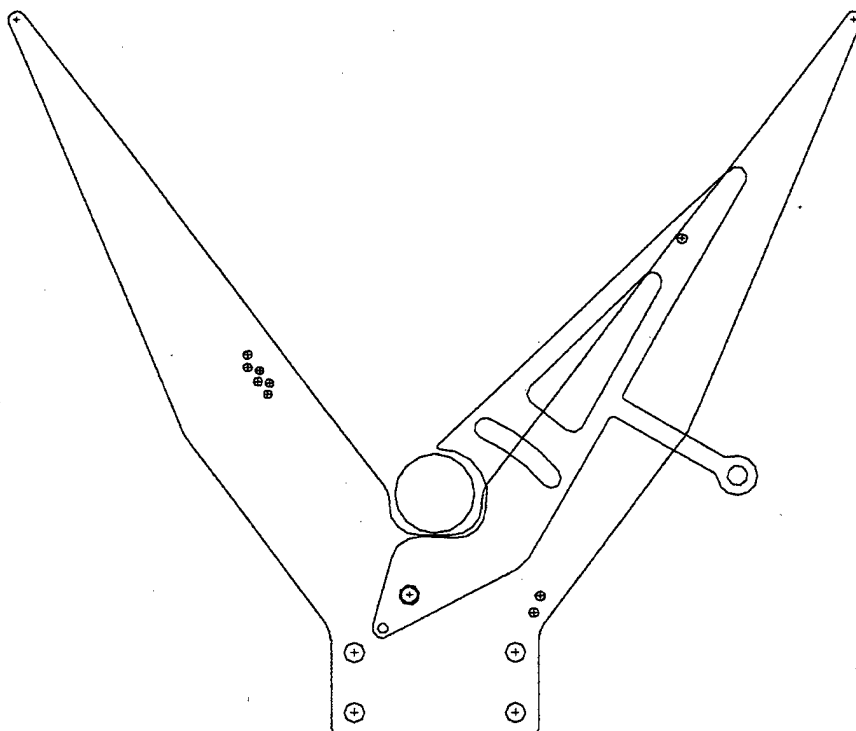
M. F. Bowen

June 12, 1998

Technical Report

Funding was provided by the Office of Naval Research under Grant No. N000-14-95-1-1316

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WHOI-98-12

A Passive Capture Latch for ODYSSEY-Class AUVs

by

M. F. Bowen

**Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543**

June 12, 1998

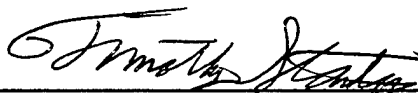
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A handwritten signature in black ink, appearing to read "Timothy Stanton", is written over a horizontal line.

Dr. Timothy Stanton

Department of Applied Ocean Physics and Engineering

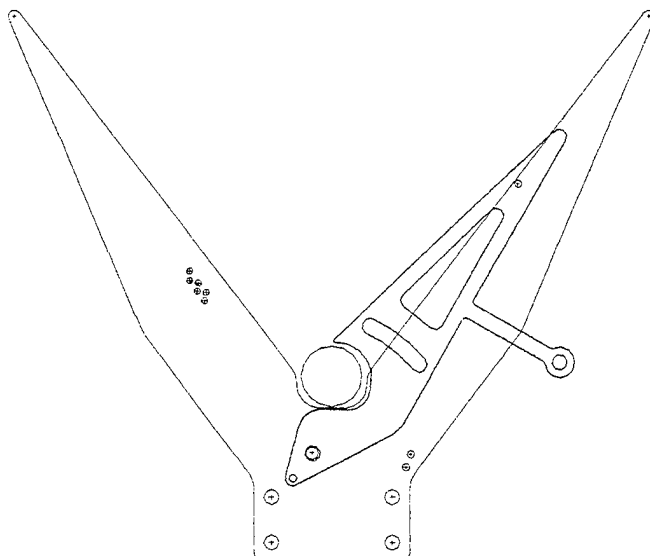
A Passive Capture Latch for ODYSSEY Class Autonomous Underwater Vehicles

Prepared By:
M. F. Bowen



Version 1.0

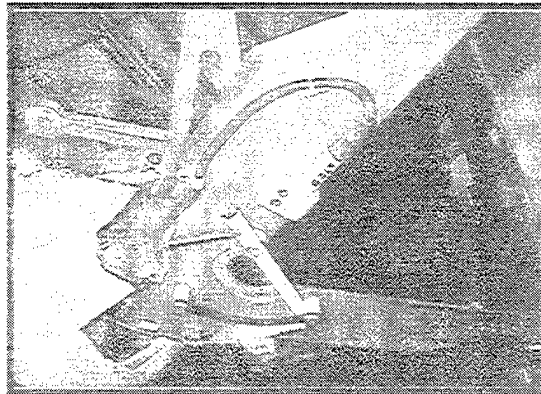
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A Passive Capture Latch for ODYSSEY Class AUVs

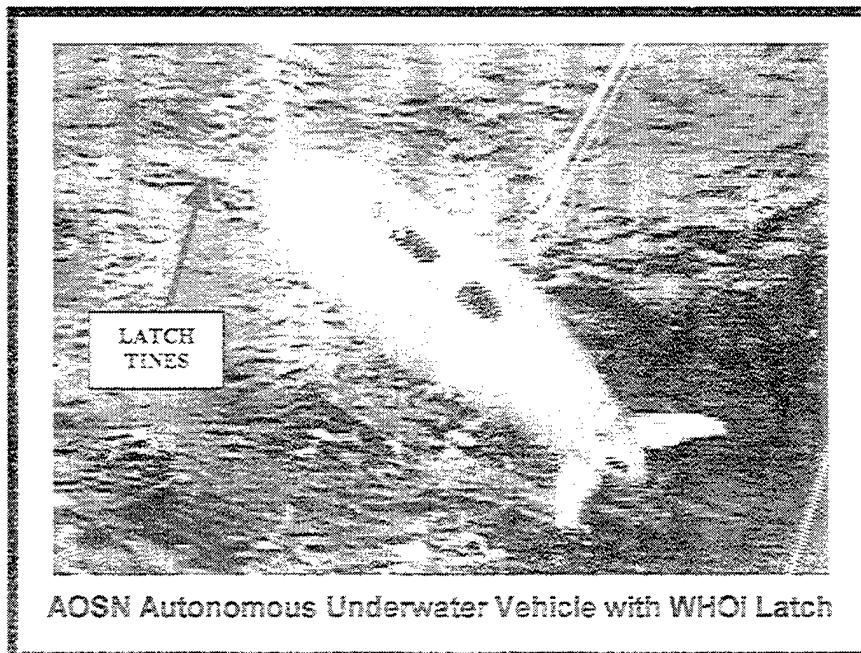
**Electro-Mechanical Design,
Fabrication and Operation
for the MIT Sea Grant Autonomous
Ocean Sampling Network (AOSN)**

Version 1.0



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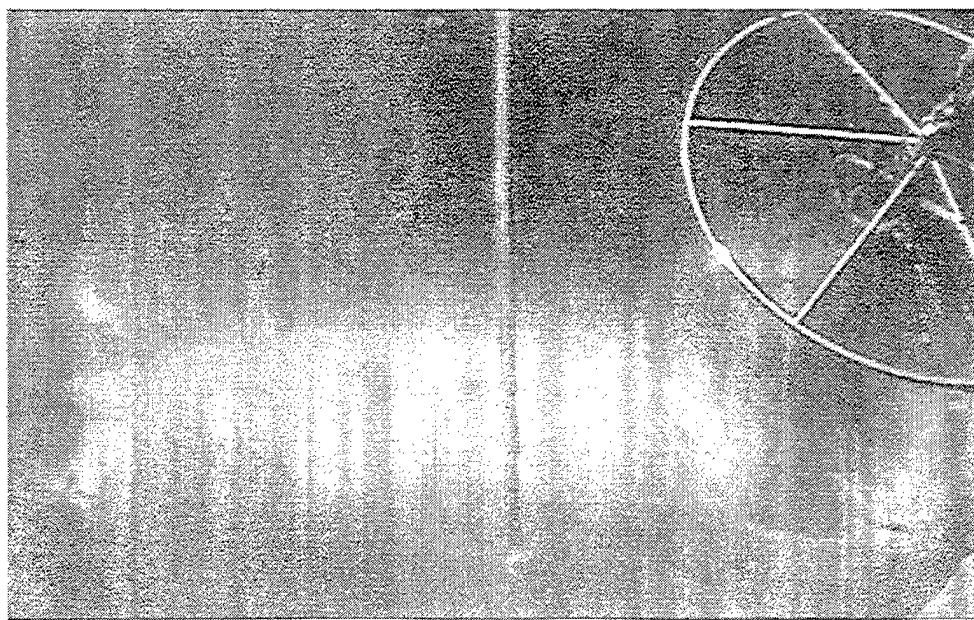
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Abstract

Under subcontract to the Massachusetts Institute of Technology's (MIT) Sea Grant Autonomous Ocean Sampling Network (AOSN) program, the Woods Hole Oceanographic Institution's Deep Submergence Laboratory (WHOI-DSL) produced a passive capture latch for ODYSSEY-class autonomous underwater vehicles (AUVs). The latch is an all-titanium, split tine device, shock-mounted to the bow of the AUV. When the AUV concludes a survey mission and returns to a moored, midwater docking station, the latch leads the AUV's approach and is the first device to collide with the station's vertical docking pole. Latching to the pole is an entirely passive event requiring only forward motion of the AUV. A positive capture indication generated by proximity switches mounted on the device initiates AUV power and data transfer servicing by the station. Unlatching action requires one revolution of a latch motor cam and a brief backing command to the AUV thruster. The possibility of system malfunction was considered in latch design. If for any reason the latched vehicle cannot perform normal unlatching behavior, or the station fails, the latch defaults by securing the AUV to the moored station indefinitely. Two WHOI AUV latches have been used successfully on three offshore engineering test cruises. (195) Keywords: AUV, latch, docking.

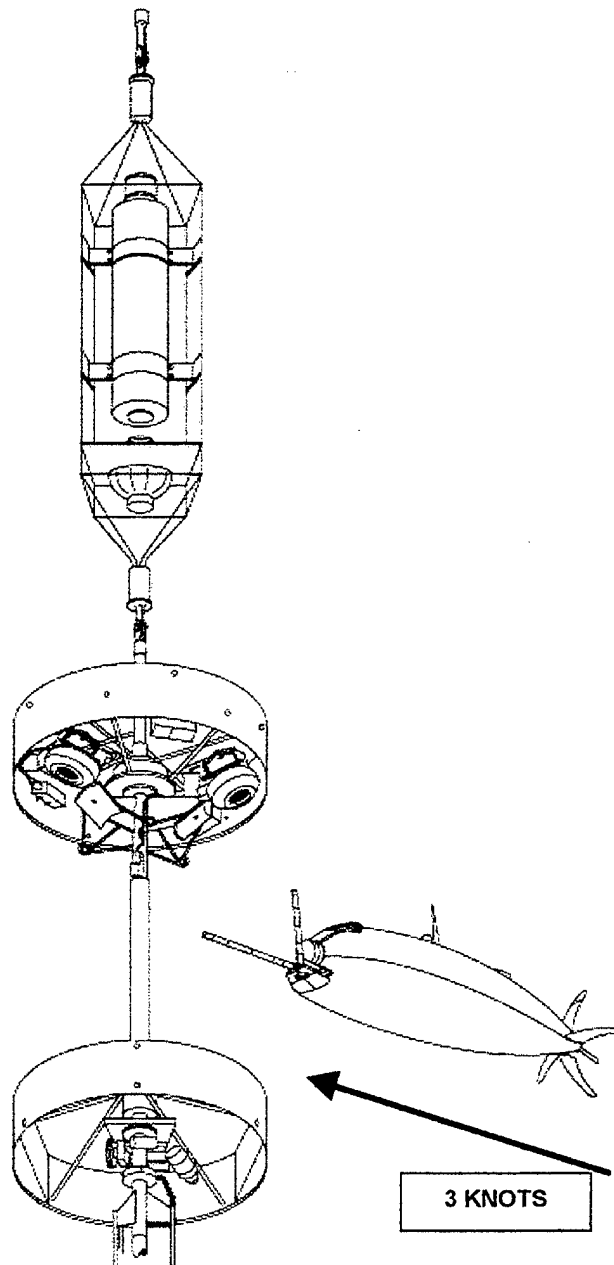
Figure [1] Odyssey AUV latched to Docking Station during testing



1.0 Introduction

The MIT Sea Grant Autonomous Ocean Sampling Network required Odyssey-class AUVs to navigate toward and couple with a midwater docking station suspended by a deep sea mooring system. The AUV, on a pre-programmed survey mission, would terminate its mission by homing in on a mooring beacon and collide with the target, a vertical stainless steel pole comprising the center of the docking station (Figures [1 and 2]). The AUV travels in the horizontal plane at a nominal speed of three knots (1.2 m/sec). A heavy-duty titanium latch was produced by WHOI that could withstand the 1G+ impact with the semi-rigid pole reliably under a wide range of approach conditions. The latch was also capable of retaining the vehicle during a variety of servicing operations, mooring translations and undocking operations prior to a new mission.

Figure [2] AUV Approach to the Midwater Docking Station



2.0 AUV Docking Latch

2.1 Background and Theory of Operation

The latch specification has gone through several iterations in three years, see Figure [3] below.

<u>Prototype Latch Design</u>	<u>Advantages</u>	<u>Disadvantages</u>
1) retractable body, hinged tines, detent trigger	hydrodynamic	mechanical complexity
2) fixed body, hinged tines, stiff spring trigger	positive capture	software dependencies
3) fixed body, fixed tines, passive latching, solenoid release	simplicity	high power consumption, poor hydrodynamics
4) fixed body, fixed tines, passive latching, motor and cam release	simplicity	hydrodynamics

The current latch mechanism is shown in plan view in Figure [4] and a photograph of the latch appears in Figure [5]. The latch consists of: a vee-shaped, symmetrical grade 2 titanium body with two fixed tines; a pivoting titanium (pole) capture bar; a titanium capture bar guide; a titanium mount with shock absorption; an isolated stainless steel extension spring; a drive motor with housing, cam and linkage; four pressure-proof magnetic proximity switches; and four magnets.

The latch specification appears in Figure [9]. In the early stages of design, MIT hydrodynamicists were concerned that the "wing-like" shape of the latch would degrade control performance of the vehicle, particularly in pitch. Field operations of the completed design proved that the latch's influence on control was negligible.

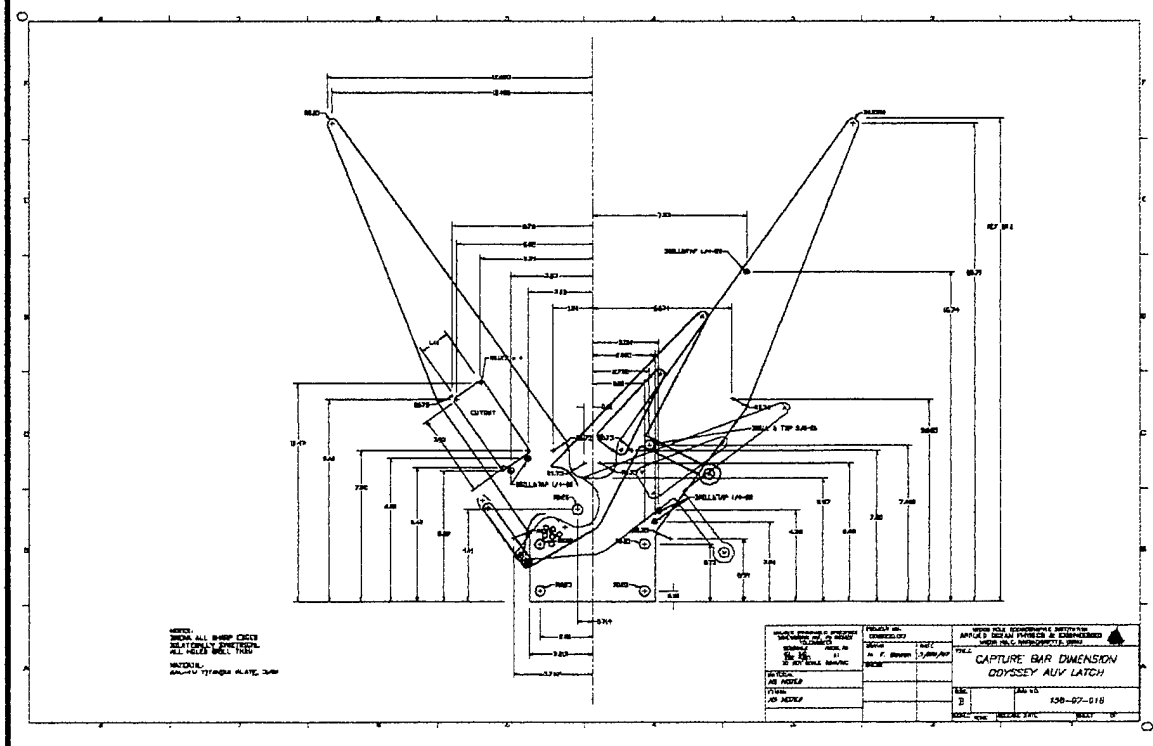


Figure [5] Docking Latch Mounted to Odyssey AUV Bow

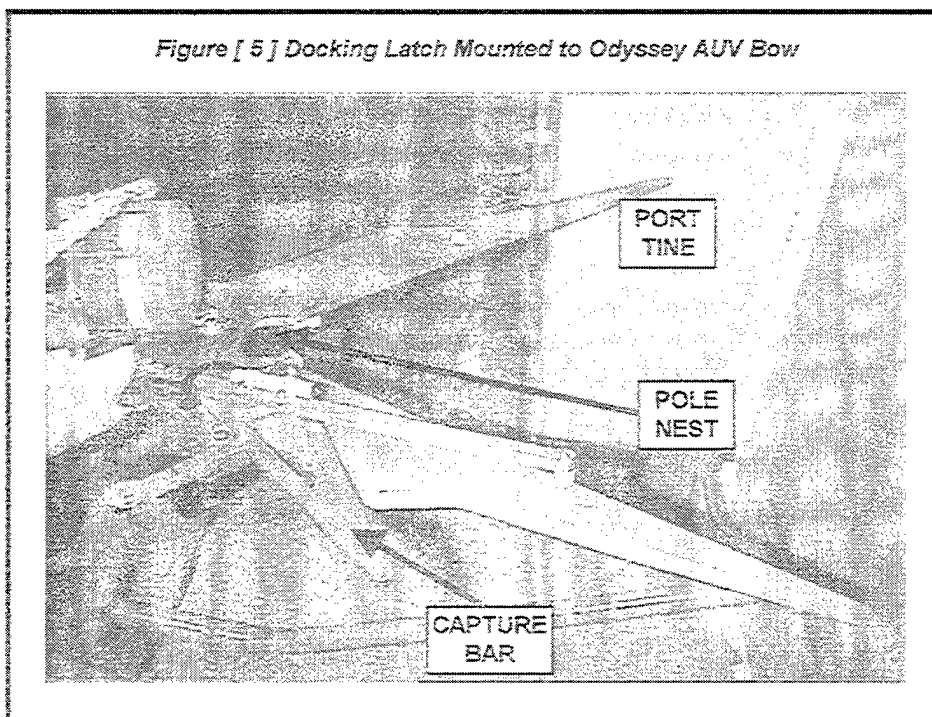


Figure [6] shows a close-up of the latch nest area. Mounted just below and forward of the ultra-short baseline homing array, the latch prohibits the docking pole collision from damaging the brow of the AUV. A manual release loop on the capture bar allows undocking from the docking pole during testing. The wedge-like shape of the capture bar aids in positive latching in "second-bounce" and low-speed docking circumstances.

Figure [6] Docking Latch Detail

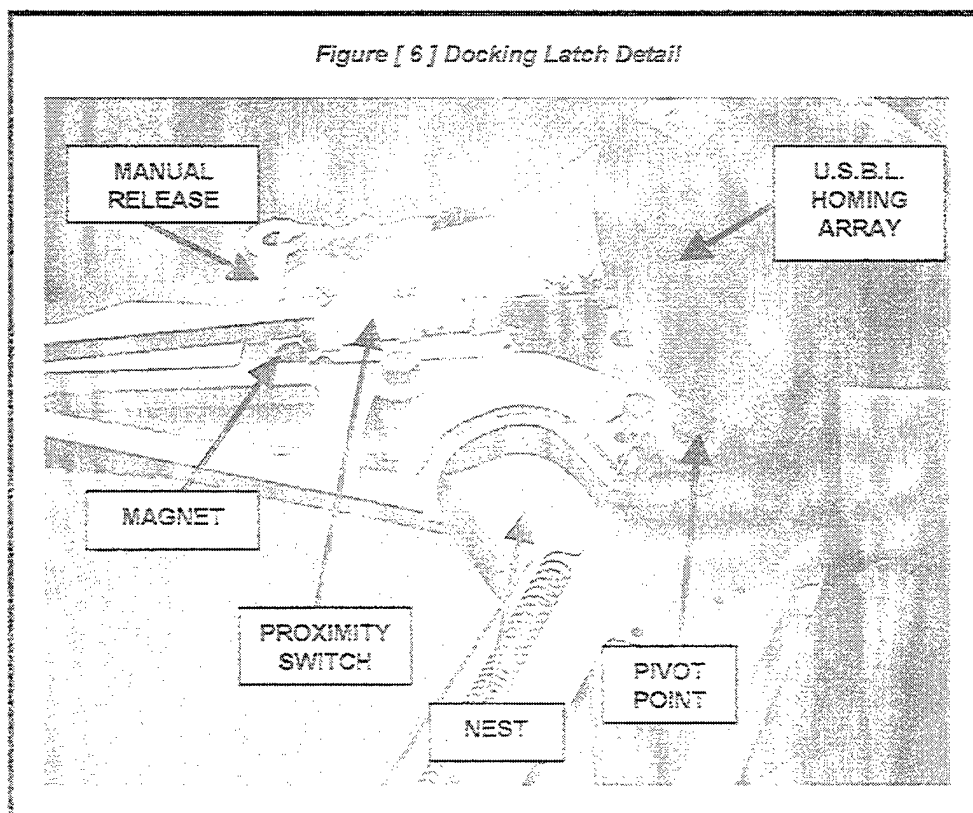
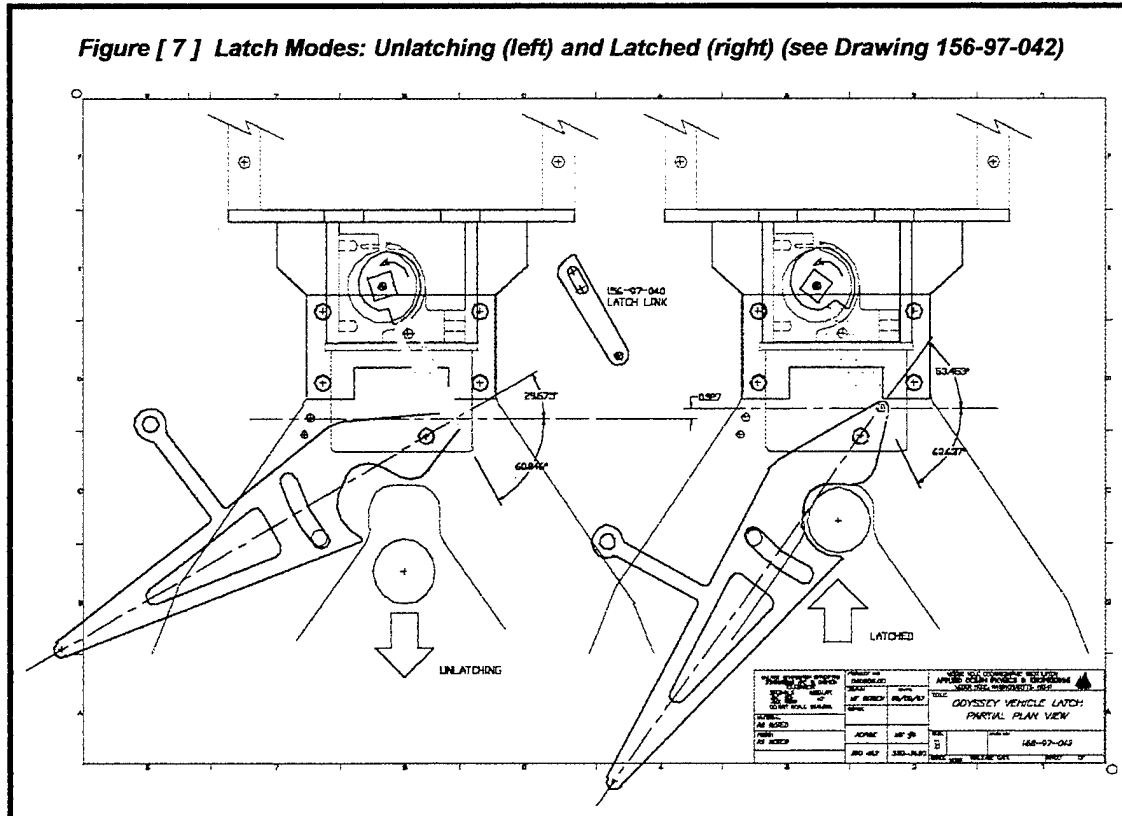
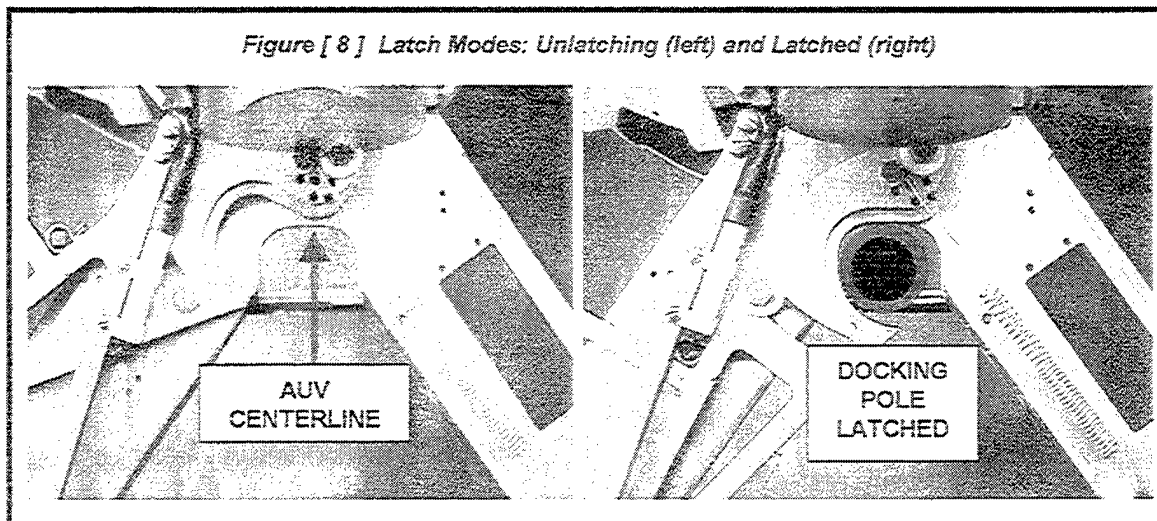


Figure [7] Latch Modes: Unlatching (left) and Latched (right) (see Drawing 156-97-042)



The docking pole enters the latch anywhere between the two fixed tines of the latch body, which are spaced twenty-four inches apart at the forward tips. The tines are angled and direct the pole toward the AUV centerline, taking advantage of the forward motion of the AUV and the relative mobility of the pole. The pole then pushes the capture bar aside and enters a nest in the latch body, where an extension spring closes the capture bar around the pole. The AUV may latch onto the pole anywhere within a one and one half-meter vertical length. When latched (Figure [7 right]), the AUV must remain safely mated to the pole by the latch alone, either temporarily as part of a mission servicing, or indefinitely as the result of an unsuccessful deployment (such as a dock and mooring recovery with the AUV still attached). To unlatch (Figure [7 left]), the motor rotates a cam one revolution and briefly opens the capture bar, allowing the pole to escape the latch nest. Figure [8] below demonstrates the same modes as built.

Figure [8] Latch Modes: Unlatching (left) and Latched (right)



2.2 Latch Specification Figure [9]

MECHANICAL

ACCEPTANCE GAP	24 IN
DESIGN, FUNCTIONAL	PASSIVE LATCHING
DESIGN, SHAPE	FIXED, VEE-SHAPED TINES
	BI-LATERALLY SYMMETRICAL
	ACTIVE UNLATCHING
FORCE OF IMPACT	≤ 1.0 VEHICLE G (600 LBS. MASS)
GEARHEAD REDUCTION	1525.7 : 1
	(MAXON PLANETARY GP032A057-1526E1A01A)
LATCH, SPEED RANGE	0.3 TO 3.0 KNOTS
LATCH, SPRING FORCE	2 LBS. OR $\leq 75\%$ BOLLARD THRUST (11 LBS. REF)
LENGTH, MOTOR & CAM	7.5 IN VERTICAL
LENGTH, TINE TO USBL	19.5 IN HORIZONTAL
LENGTH, TINE TO SHOCK MOUNT	25.0 IN HORIZONTAL
MATERIALS	GRADE 2 TITANIUM (SG 4.52)
	316 STAINLESS (SG 8.03)
	DELIN (SG 1.43)
	NYLON (SG 1.15)
MOVING PARTS, ACTIVE MODE	MOTOR SHAFT
	CAPTURE BAR
	EXTENSION SPRING
MOVING PARTS, PASSIVE MODE	CAPTURE BAR
	EXTENSION SPRING
OUTSIDE DIAMETER, MOTOR	2.25 IN
UNLATCH, FOLLOWER FORCE	≥ 18 LBS.
UNLATCH, FOLLOWER THROW	0.5 IN
WEIGHT AIR, BODY ASSY	18.6 LBS. (8.45 KG)
WEIGHT AIR, MOTOR ASSY	3.5 LBS. (1.59 KG)
WEIGHT AIR, TOTAL	22.1 LBS. (10.04 KG)
WEIGHT SEAWATER, TOTAL	13.0 LBS. (5.91 KG)

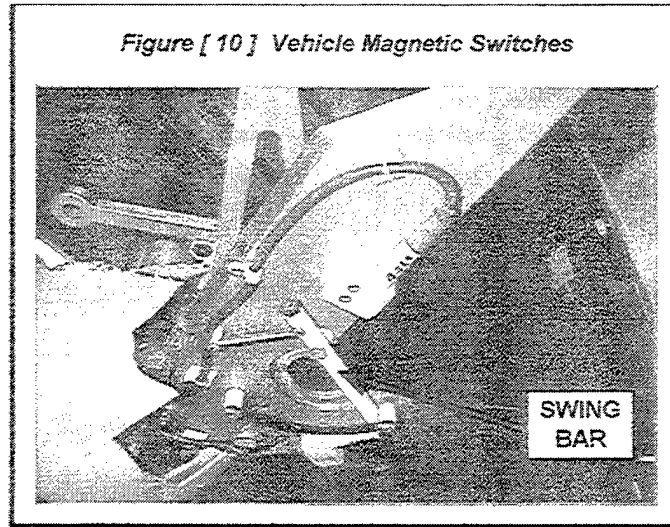
ELECTRICAL

CONDUCTORS	2
CONNECTORS	2 IE XSA-BC, 2 IE RMA-FS
CONSUMPTION, CURRENT	147 MA
CONSUMPTION, POWER	0.76 WATTS
CONSUMPTION, VOLTAGE	12 VDC NOMINAL (RANGE 5-18 VDC)
MAGNETICS	UNMEASURED (MINIMAL)
RPM, MOTOR	4790 (MAXON RE025-055-37EAA200A)
RPM, CAM SHAFT	2.0
SENSING, CAM FOLLOWER	MOVEMENT DETECT MAG SWITCH (N.O.)
SENSING, LATCHING	"POLE PRESENT" MAG SWITCHES (N.O.)
SENSING, UNLATCHING	"POLE ABSENT" MAG SWITCH (N.O.)
SENSING, CAPTURE BAR	MOVEMENT DETECT MAG SWITCH (N.O.)
TORQUE, CAM SHAFT	500 OZ-IN

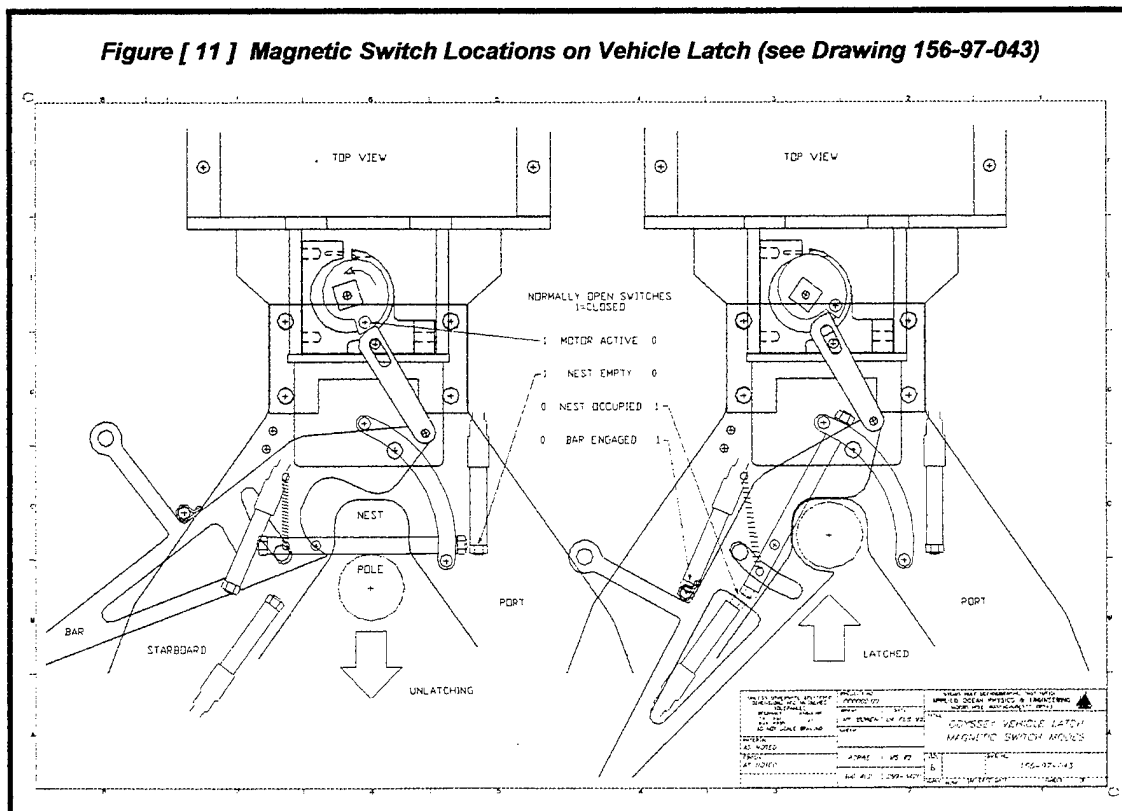
ENVIRONMENTAL

CAM FUNCTION, READY FOR POLE	90 DEG, 7.5 SEC
CAM FUNCTION, RELEASING POLE	180 DEG, 15.0 SEC
CAM FUNCTION, LATCH OPEN	90 DEG, 7.5 SEC
DEPTH RATING	2000 METERS (3000 PSI)
DUTY CYCLE	20 LATCHING COLLISIONS PER DEPLOYMENT
MTBF	4 MONTH IMMERSION
RETENTION, MAX PITCH	15 DEG UPCURRENT, 10 DEG DOWNCURRENT
RETENTION, POWER LOSS	NO UNLATCH FUNCTION
RETENTION, MAX ROLL	± 15 DEG
TEMPERATURE, OPERATING	-15C TO 80C
TEMPERATURE, STORED	-40C TO 80C

2.3 Magnetic Switch Harness



A portion of the vehicle magnetic switch harness appears in a picture taken from below a latch in Figure [10]. The location of the four switches and four matching magnets appears in Figure [11]. The function of these sensors is to indicate to the vehicle, and its behavior software, exactly what state the latch is in at any time during servicing at the Docking Station or between missions away from the Station. One magnet indicates the state of the motor, which can open the capture bar. Another switch indicates whether the capture bar is open or closed. Two switches are located at either end of a plastic swing bar. One indicates if the bar has been moved away from the nest and a pole is present (docked and latched). A second indicates whether the swing bar has sprung across the pole nest whenever the latch is off the pole (undocked and pole absent).



2.4 Performance Analysis

There are two working latches mounted onto Odyssey AUVs at the writing of this report. One of the two has been field tested prior to this cruise and has successfully latched and unlatched from a docking pole more than fifty cycles. Both latches have been wet tested with vehicles and a docking pole under controlled circumstances at WHOI. During this cruise to the Labrador Sea the latch capture bar was disabled for all missions to the Docking Station.

During this cruise one magnetic switch harness failed once due to seawater intrusion and was replaced by a spare harness.

2.5 Proposed Improvements and Modifications

2.5.1 Latch

This fixed-tine latching device will probably not change significantly in the short-term nor for the duration of the AOSN project. As the fourth revision of the original specification, this design has proven to be easily maintained, functional, immune to prolonged immersion, robust and reliable.

2.5.2 Specialized Recovery Device

The inherent strength of the titanium latch and bow mount was demonstrated by accident during the October engineering test cruise when the lifting bail on a deployed vehicle parted. A lifting hook and line was attached to the port latch tine and the AUV was retrieved vertically without further damage.

In response to this emergency scenario, a custom recovery tool was designed by WHOI and two were fabricated. The device is shown in Figures [12] and [13]. Known as the "staple", it can be hung over the ship's side at the end of a long stab stick and jammed into the latch where two hooks engage the outboard edge of the latch tines. The vehicle can then be safely lifted vertically out of the water by the tines in situations of high freeboard and high seastates. The staple has not been tested offshore to date.

2.5.3 Acoustically Active Latch Tines

A recommendation has been made for the long-term that the two outer tine tips be hollowed out and fitted with a revised version of the homing head elements. This scheme would give the piezo array the advantage of a wide separation, and the mechanical protection of a metal shell.

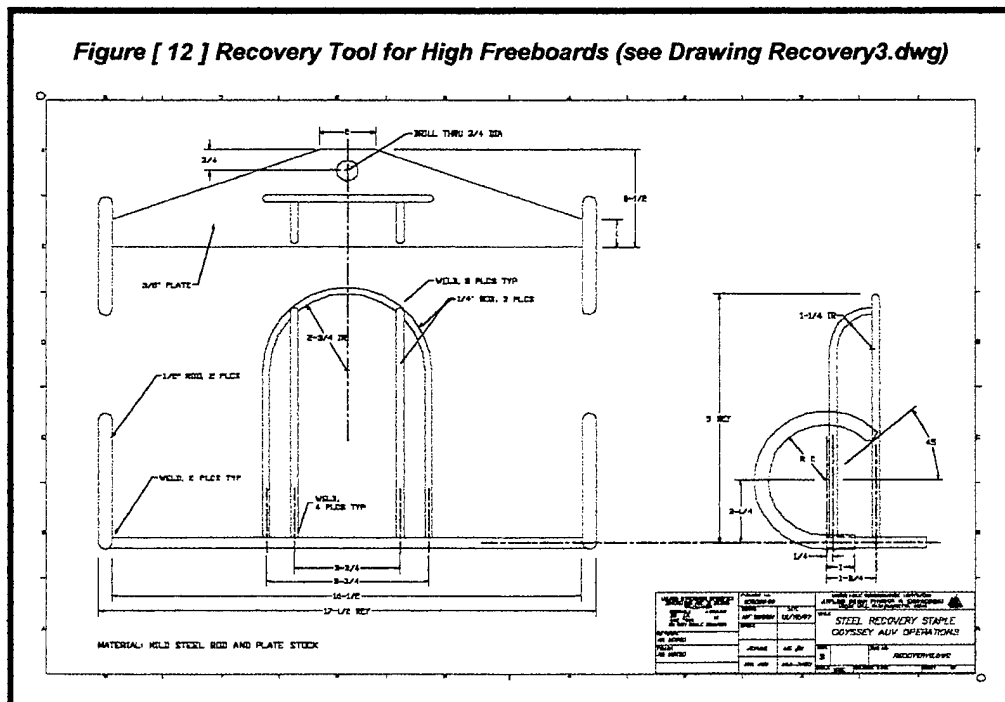
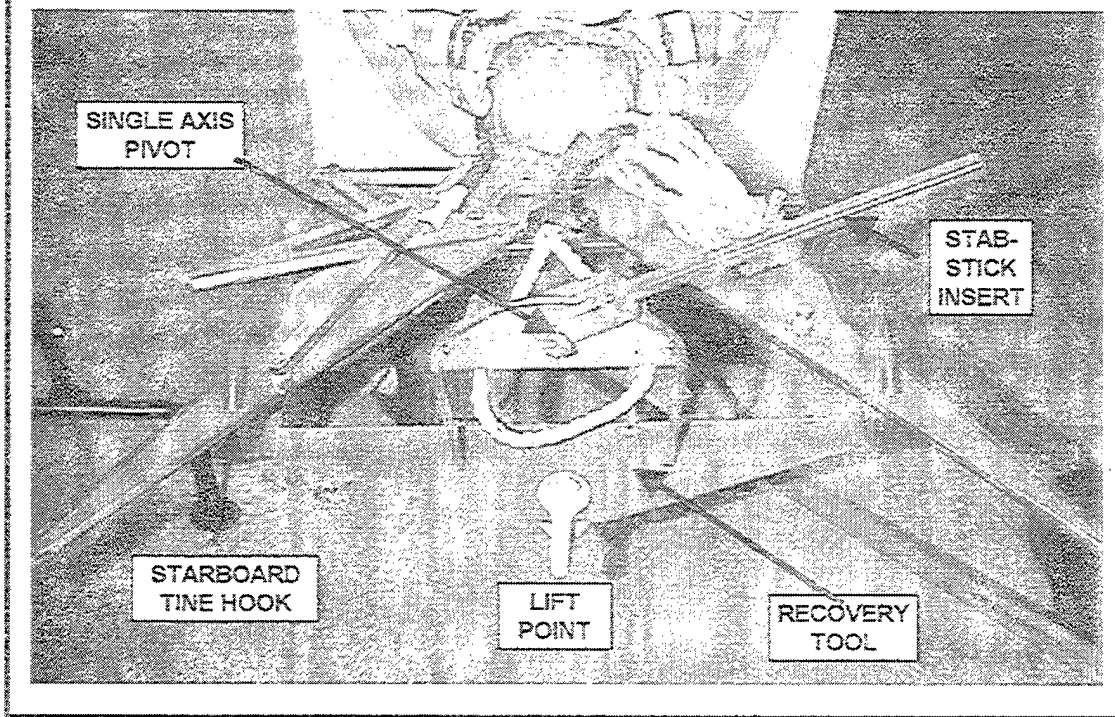


Figure [13] Specialized AUV Recovery Tool in Lifting Position on WHOI Latch



2.6 References

1. Bowen, M.F., Peters, D.B., Singh, H., A Deep Sea Docking Station for ODYSSEY Class AUVs, Woods Hole Oceanographic Institution Blue Cover Technical Report WHOI-98-11, forthcoming, 1998.
2. Conway, H.G., Landing Gear Design, Short Brothers and Harland Ltd., Belfast, Chapman & Hall Ltd., London, 37 Essex Street, W.C.2, The Royal Aeronautical Society, Catalogue number 562/4, Robert Cunningham and Sons Ltd., 1958.
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4. Currey N.S., Landing Gear Design Handbook, Lockheed-Georgia Company, A Division of Lockheed Corp., Marietta, GA 30063, 1st Edition, January 1982.
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MECHANICAL DRAWINGS

LATCH BODY

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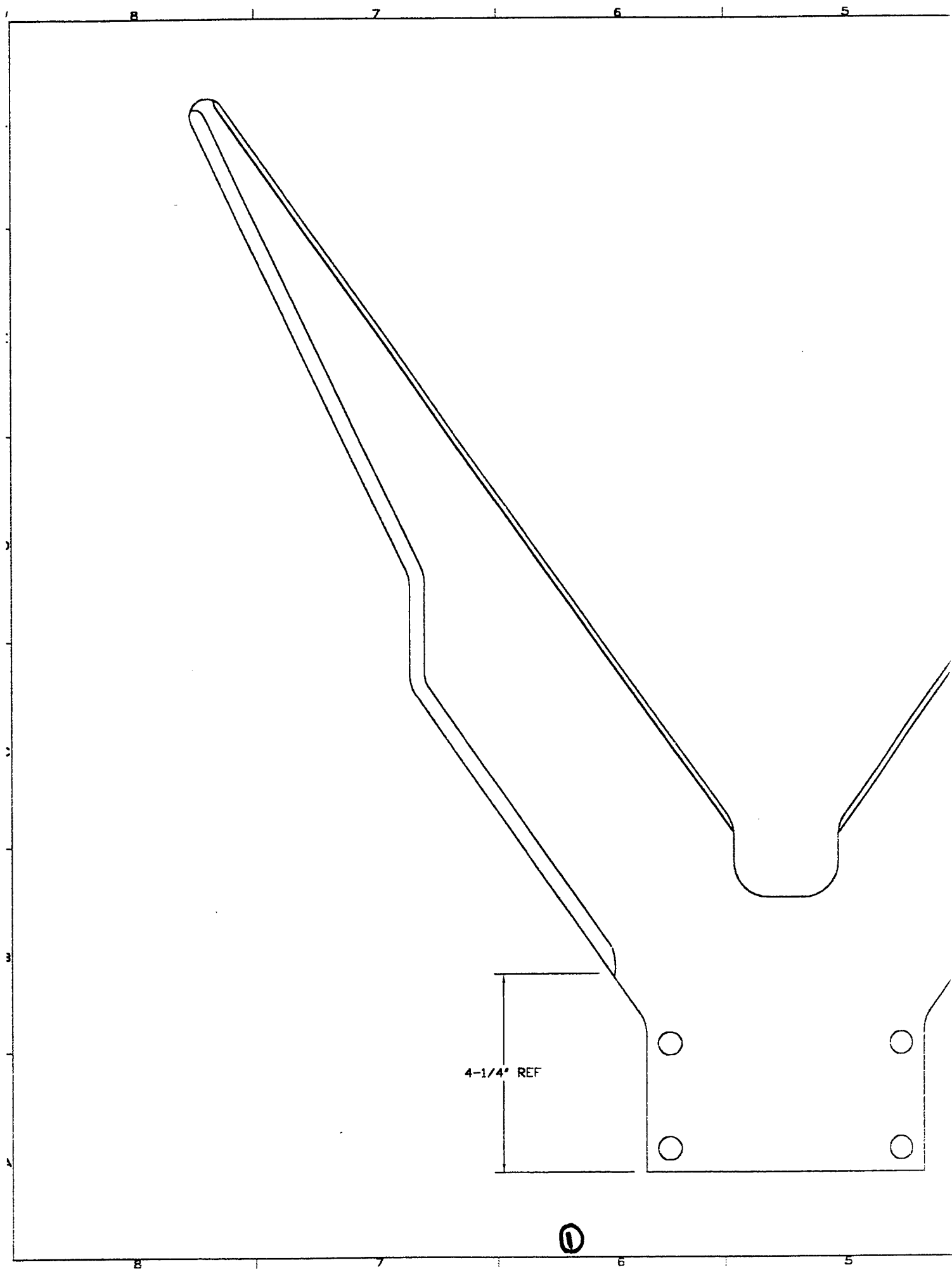
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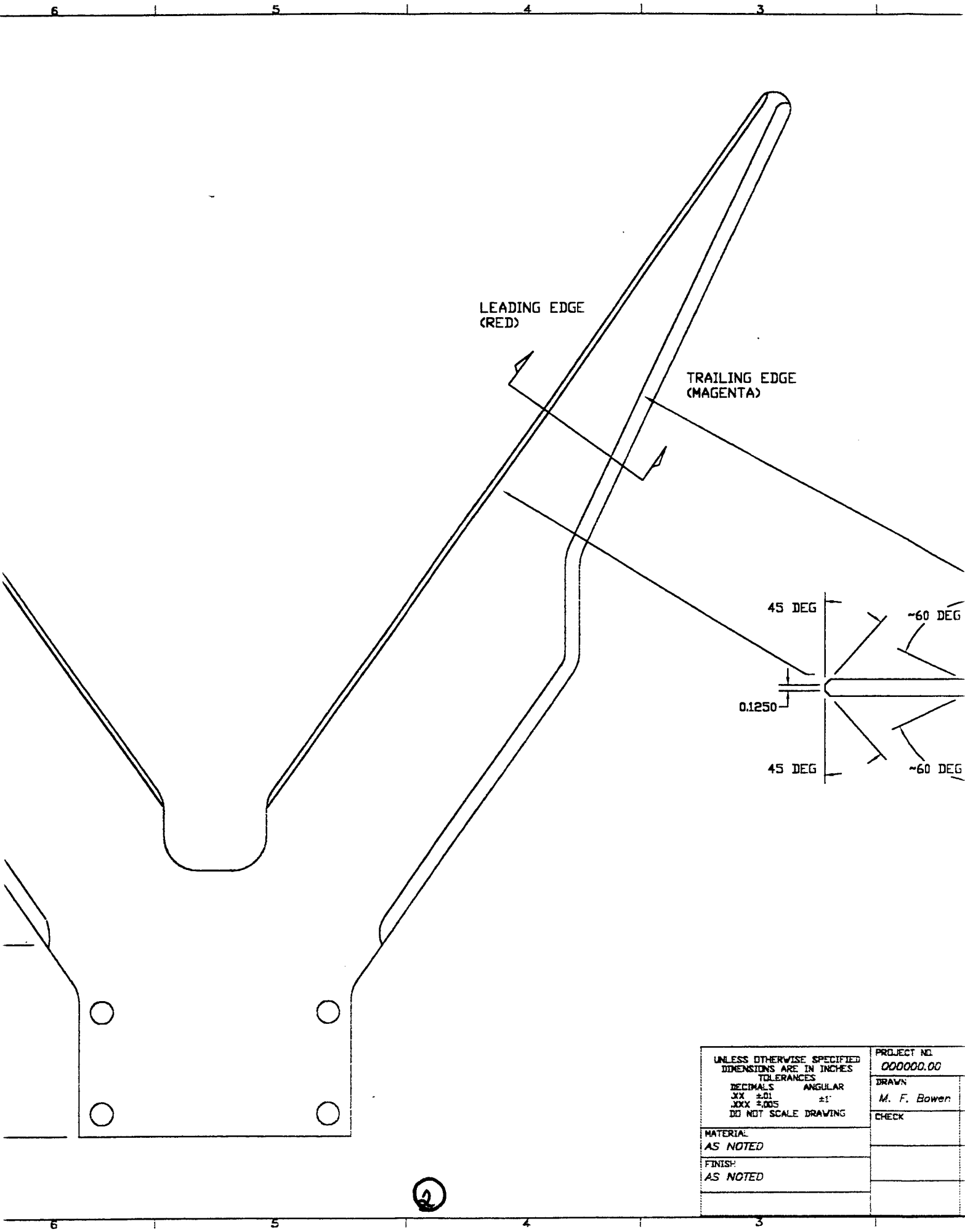
156-97-001	MOUNT ASSY, LATCH & USBL	27
156-97-008	MOUNT, LATCH, DIMENSION	28
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MOTOR

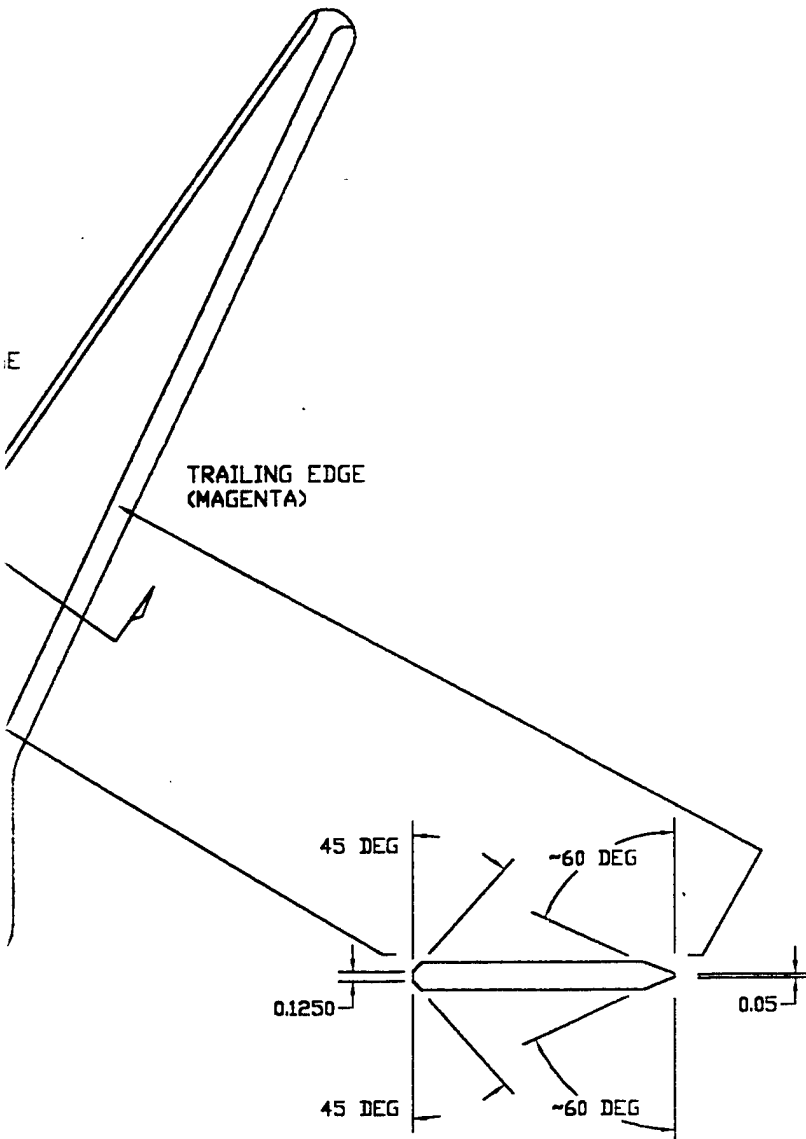
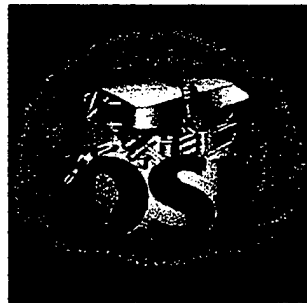
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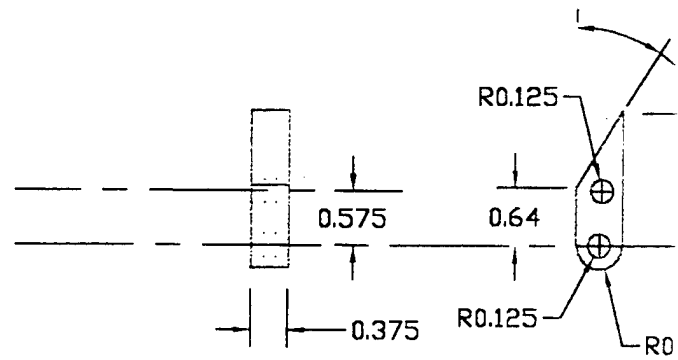
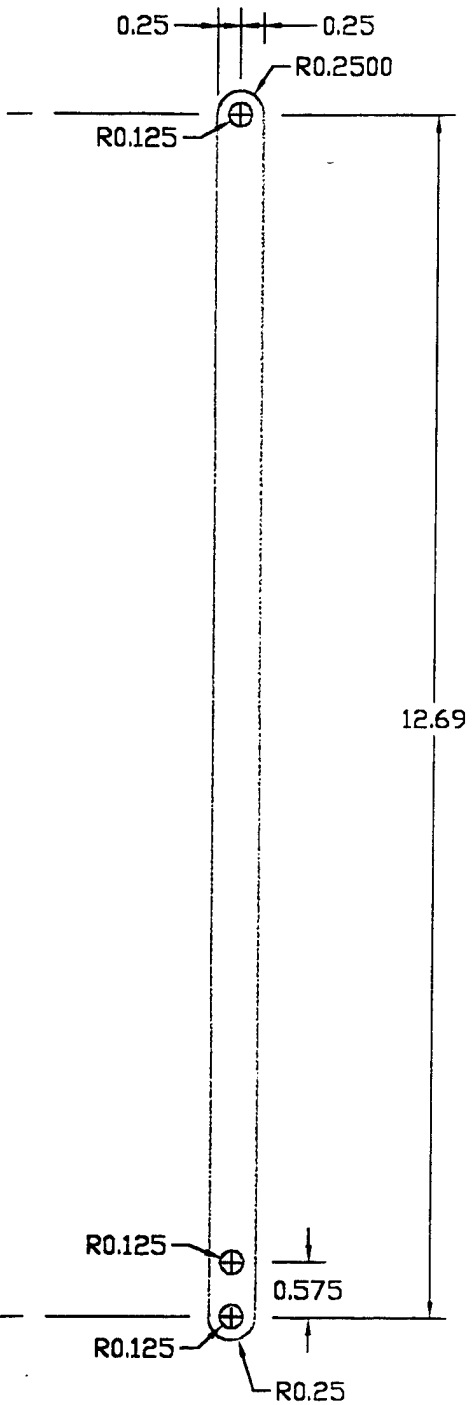


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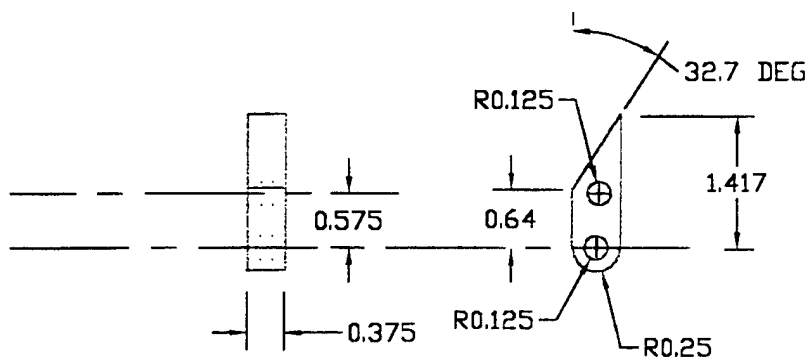
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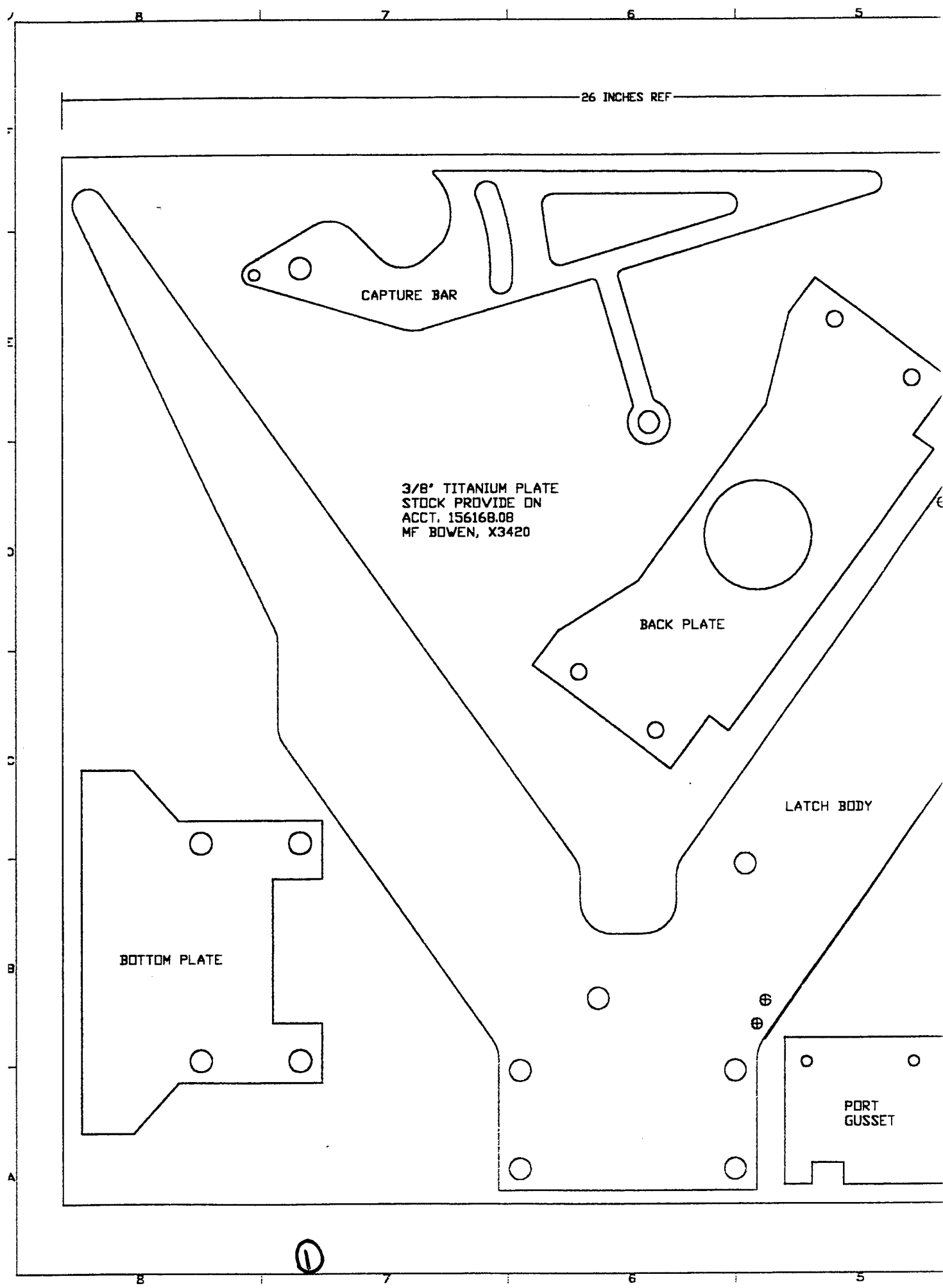
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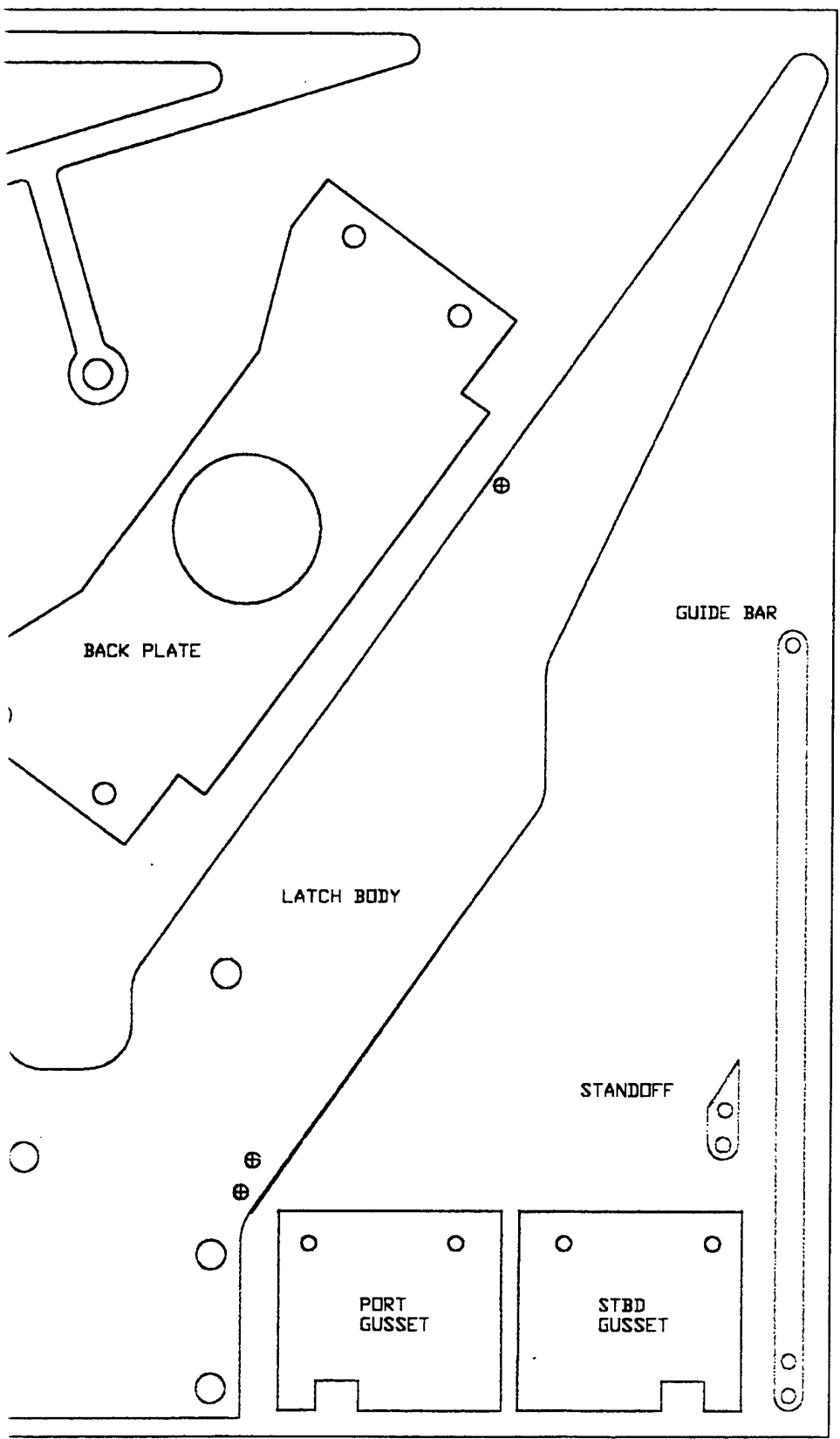


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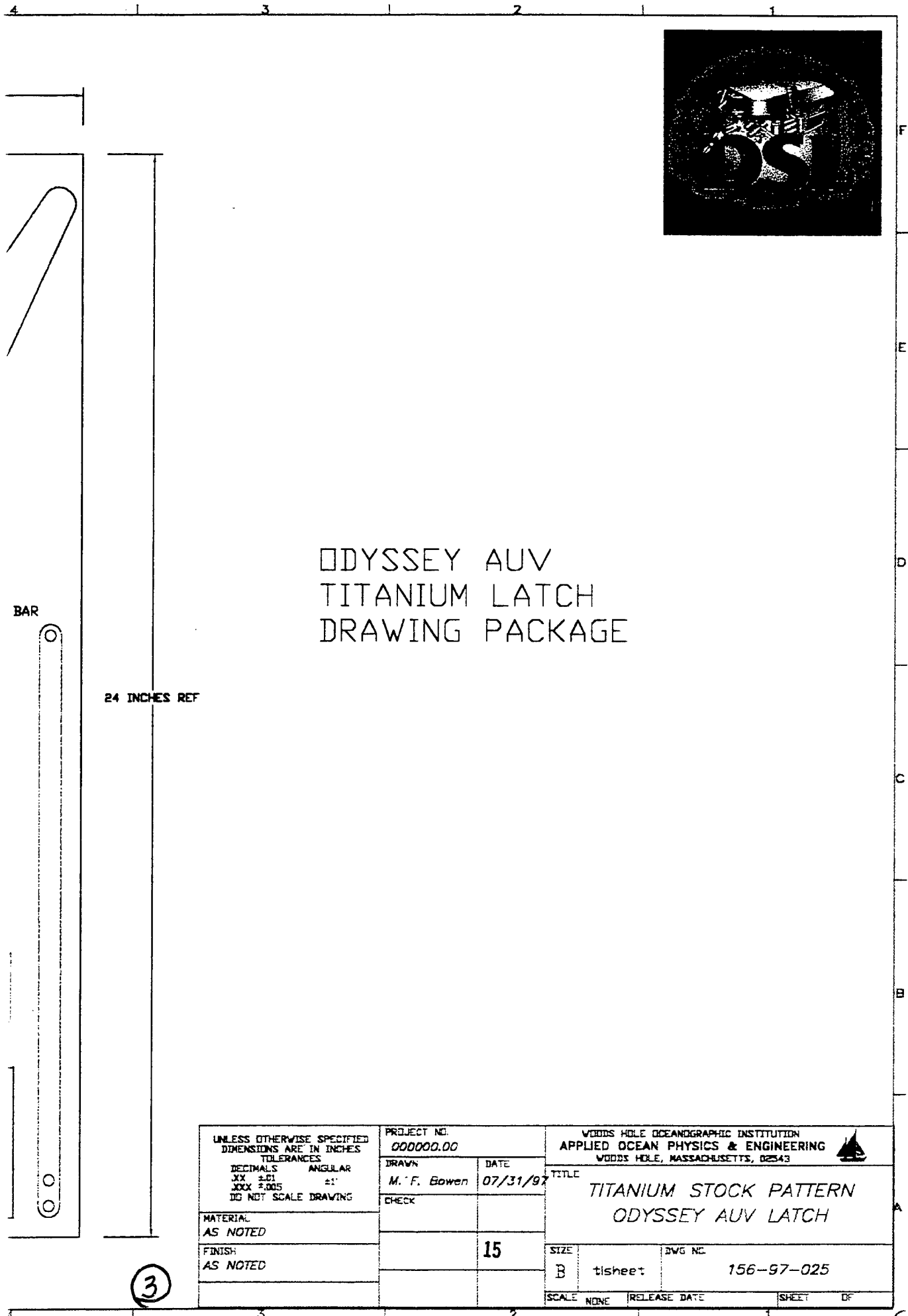
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DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS ANGULAR
XX ±.01
XXX ±.005
DO NOT SCALE DRAWING

PROJECT NO.
000000.00

DRAWN
M. F. Bowen

DATE
07/31/97

CHECK

WOODS HOLE OCEANOGRAPHIC INSTITUTION
APPLIED OCEAN PHYSICS & ENGINEERING
WOODS HOLE, MASSACHUSETTS, 02543

TITLE
TITANIUM STOCK PATTERN
ODYSSEY AUV LATCH

MATERIAL
AS NOTED

FINISH
AS NOTED

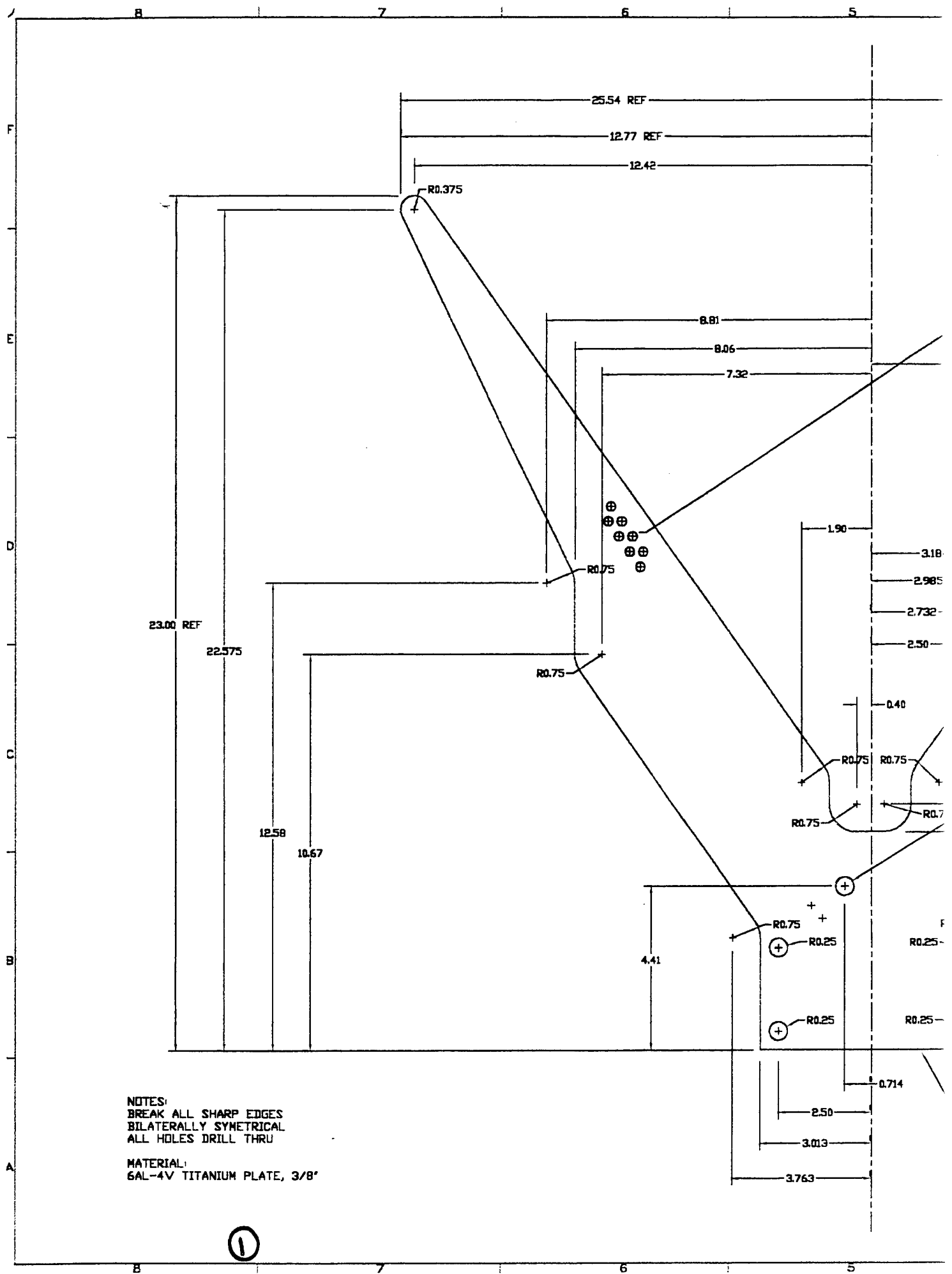
SIZE
B

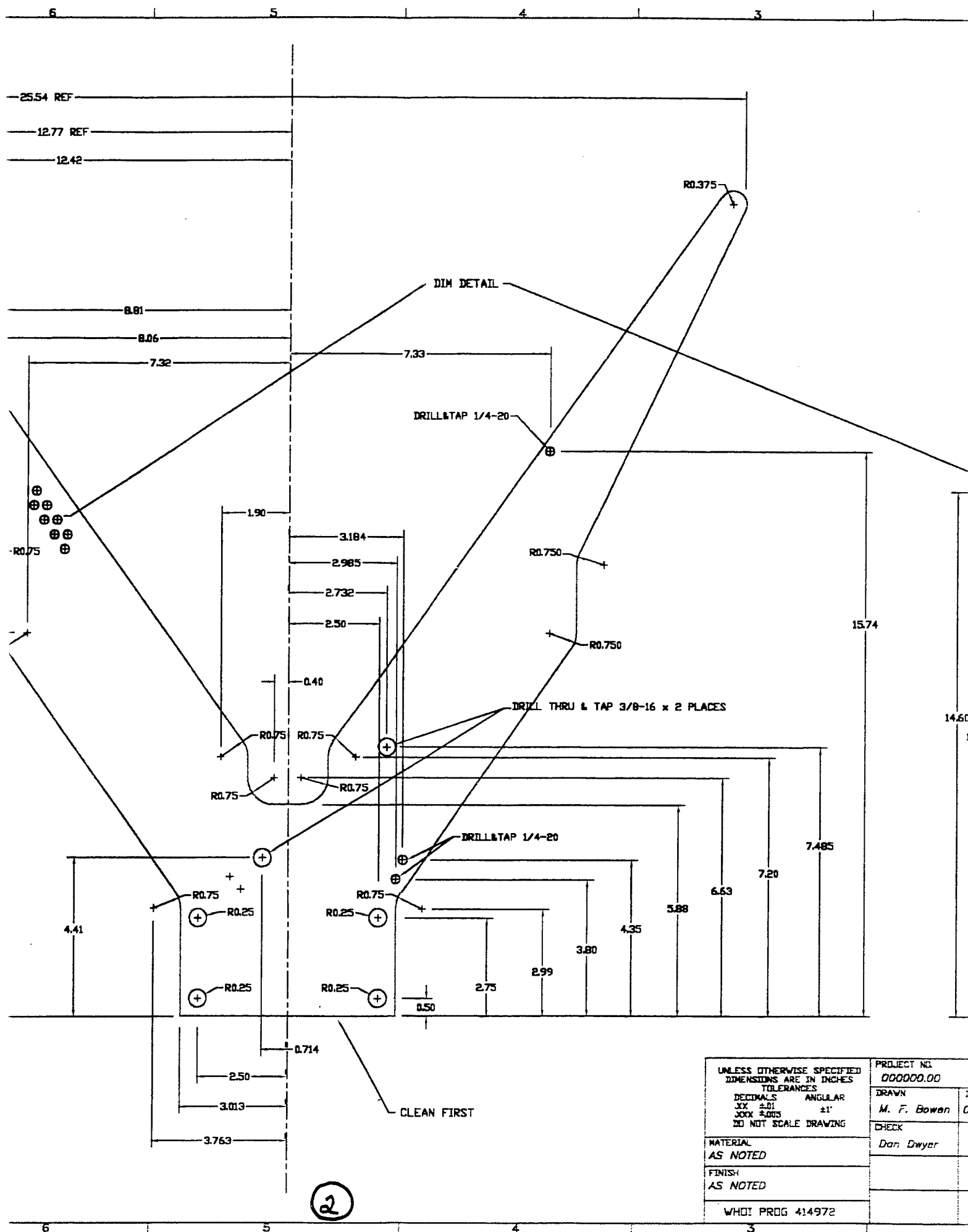
tisheet

DWG NO.
156-97-025

SCALE NONE RELEASE DATE SHEET OF

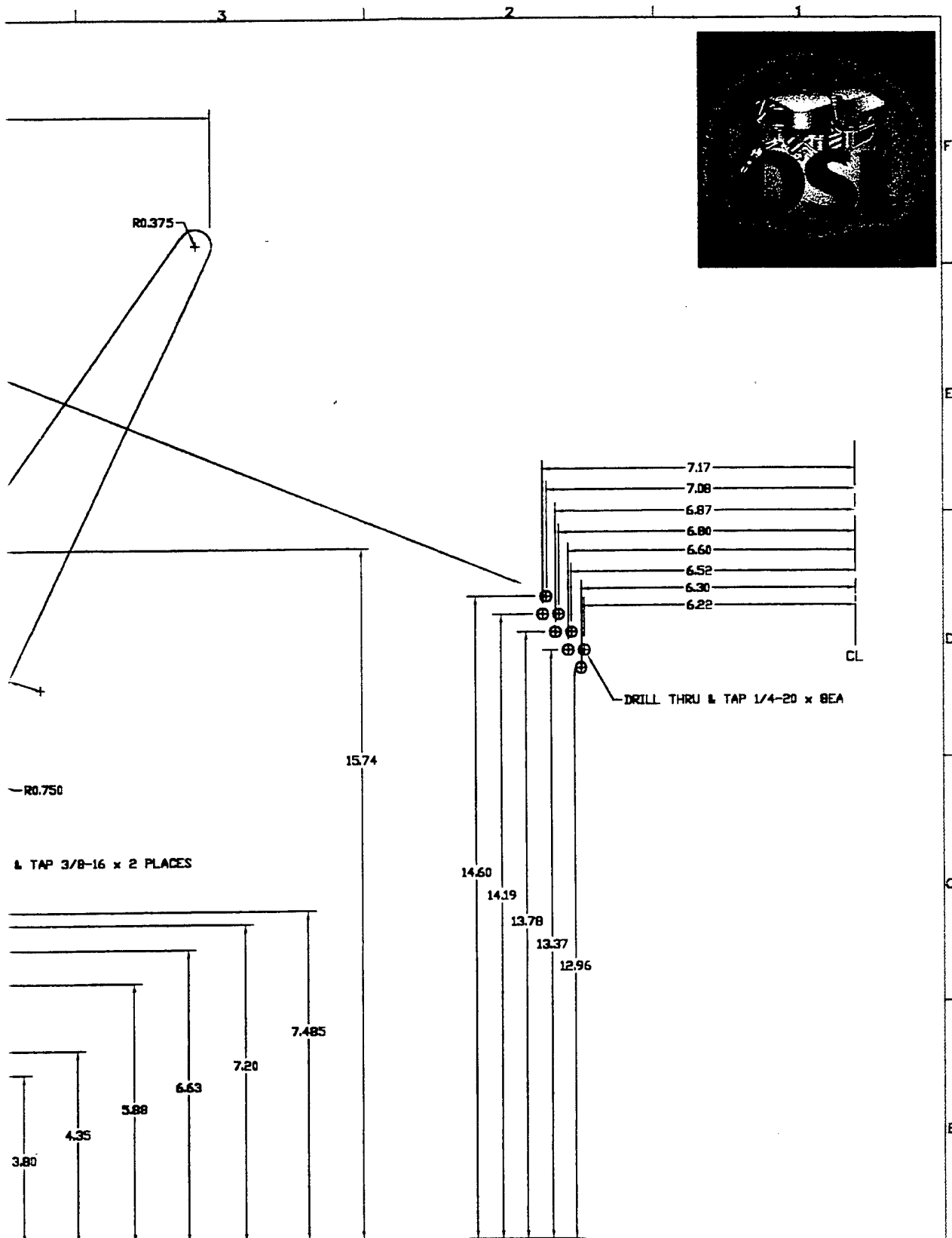
3





2

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS ANGULAR .XX ±.01 ° ±1' .XXX ±.005 ° ±1' NO NOT SCALE DRAWING	PROJECT NO.
	000000.00
	DRAWN
	M. F. Bowen
MATERIAL	CHECK
	Don Dwyer
FINISH	
AS NOTED	
WHOI PROG 414972	



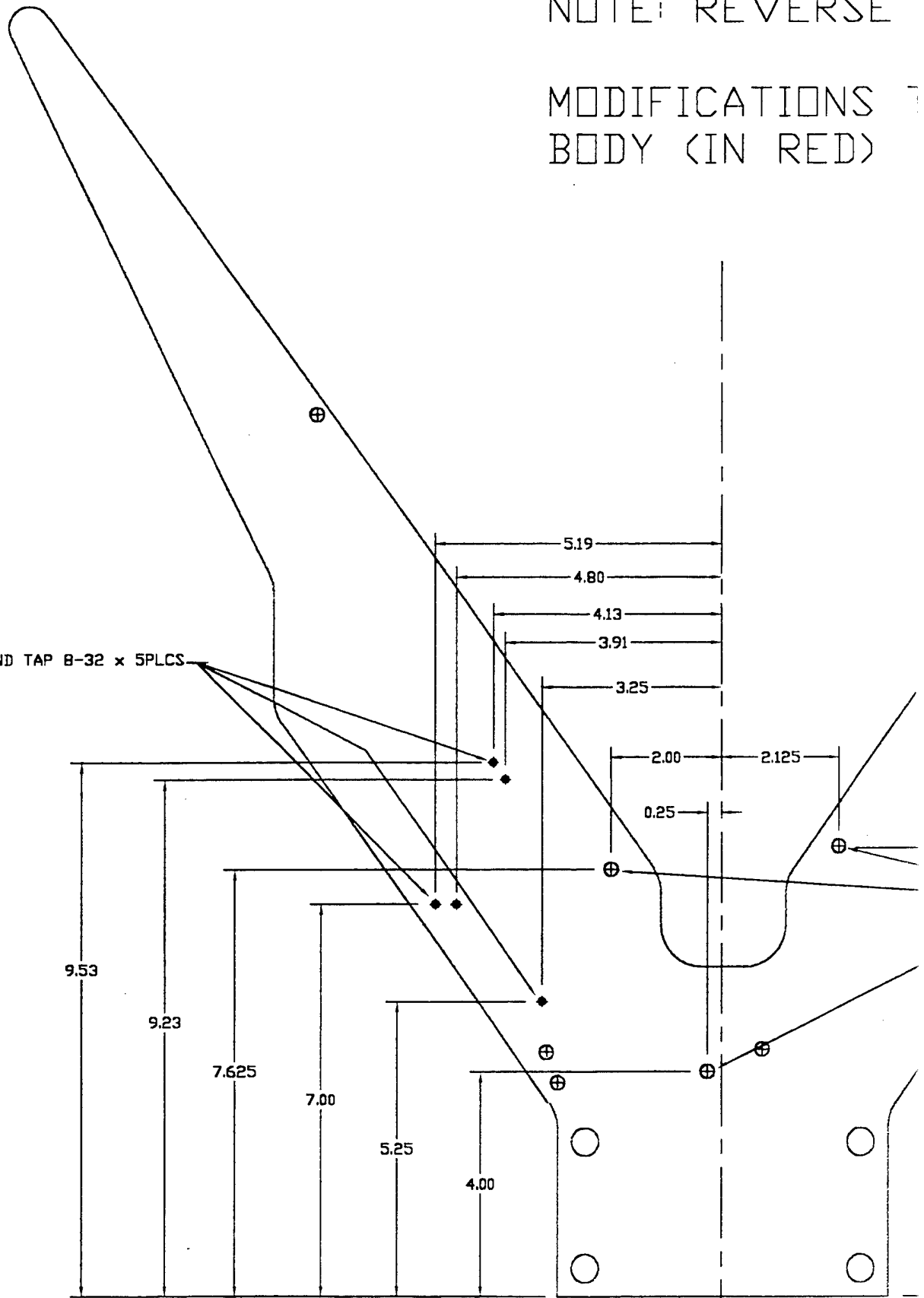
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS ANGULAR .XX ±.01 ±1° .XXX ±.005 DO NOT SCALE DRAWING	PROJECT NO. 000000.00		WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING WOODS HOLE, MASSACHUSETTS, 02543	
	DRAWN M. F. Bowen	DATE 08/01/97	TITLE DIMENSION, LATCH BODY ODYSSEY AUV LATCH	
	CHECK Dan Dwyer			
	SIZE B		DVG NO. 156-97-026	
MATERIAL AS NOTED	16		SCALE NONE RELEASE DATE SHEET OF	
FINISH AS NOTED				
WHOI PROJ 414972				

3

NOTE: REVERSE

MODIFICATIONS
BODY (IN RED)

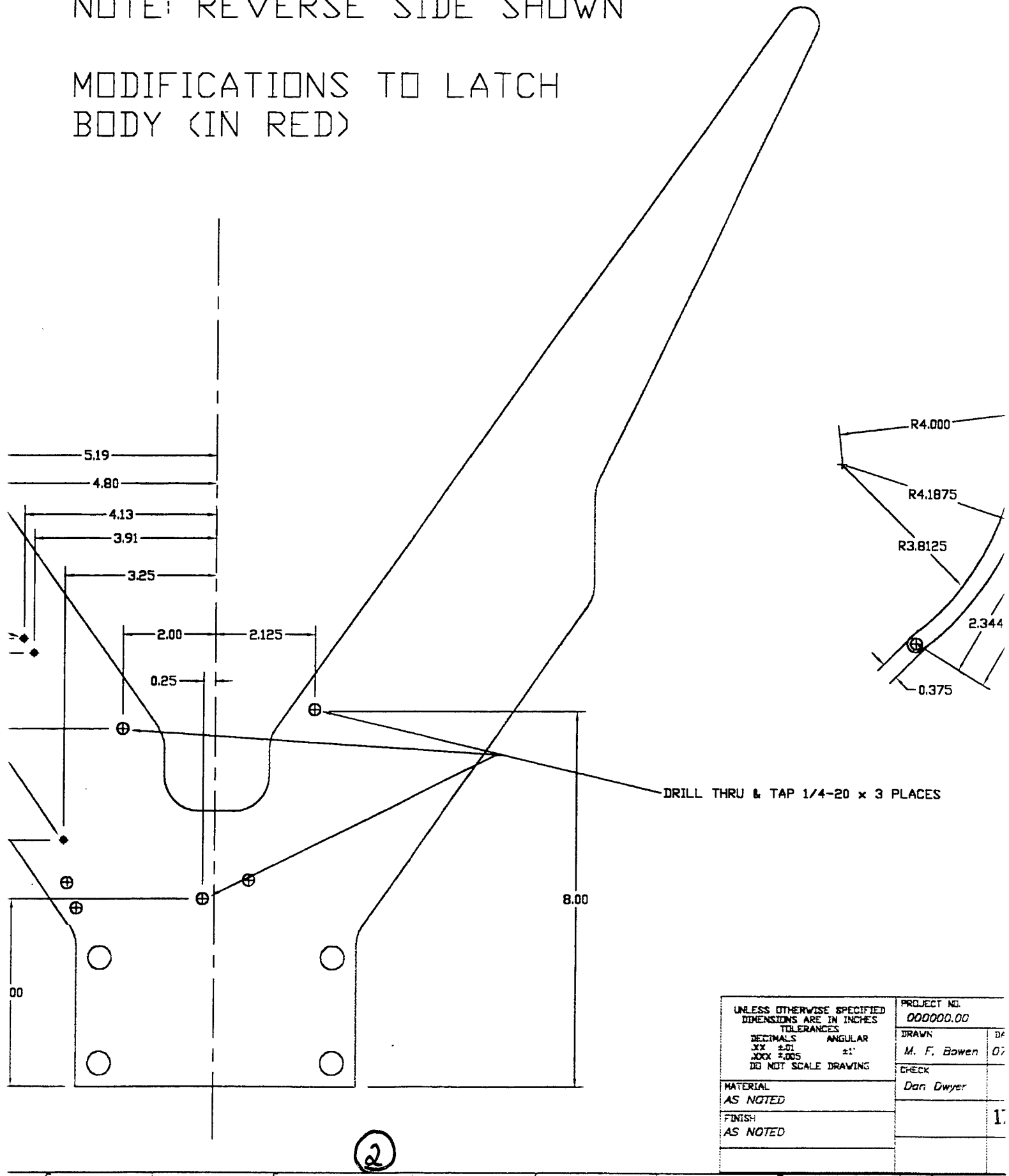
DRILL THRU AND TAP 8-32 x 5PLCS



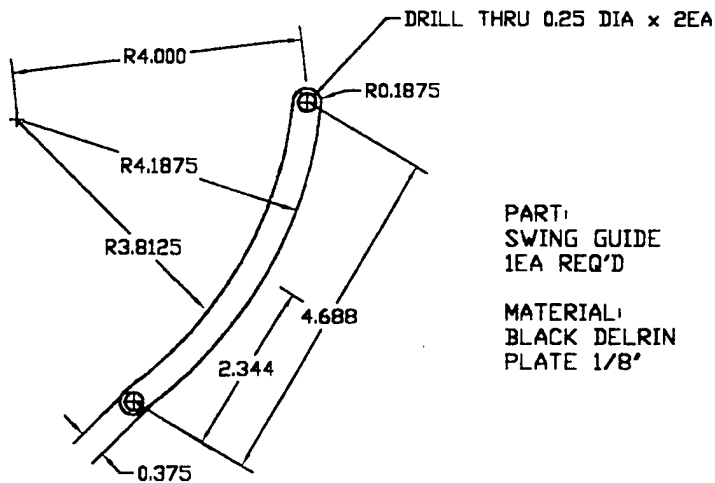
①

NOTE: REVERSE SIDE SHOWN

MODIFICATIONS TO LATCH
BODY (IN RED)



WN



PART:
SWING GUIDE
1EA REQ'D

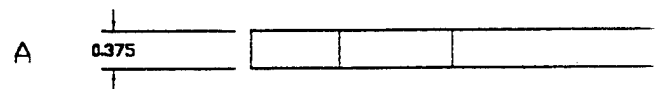
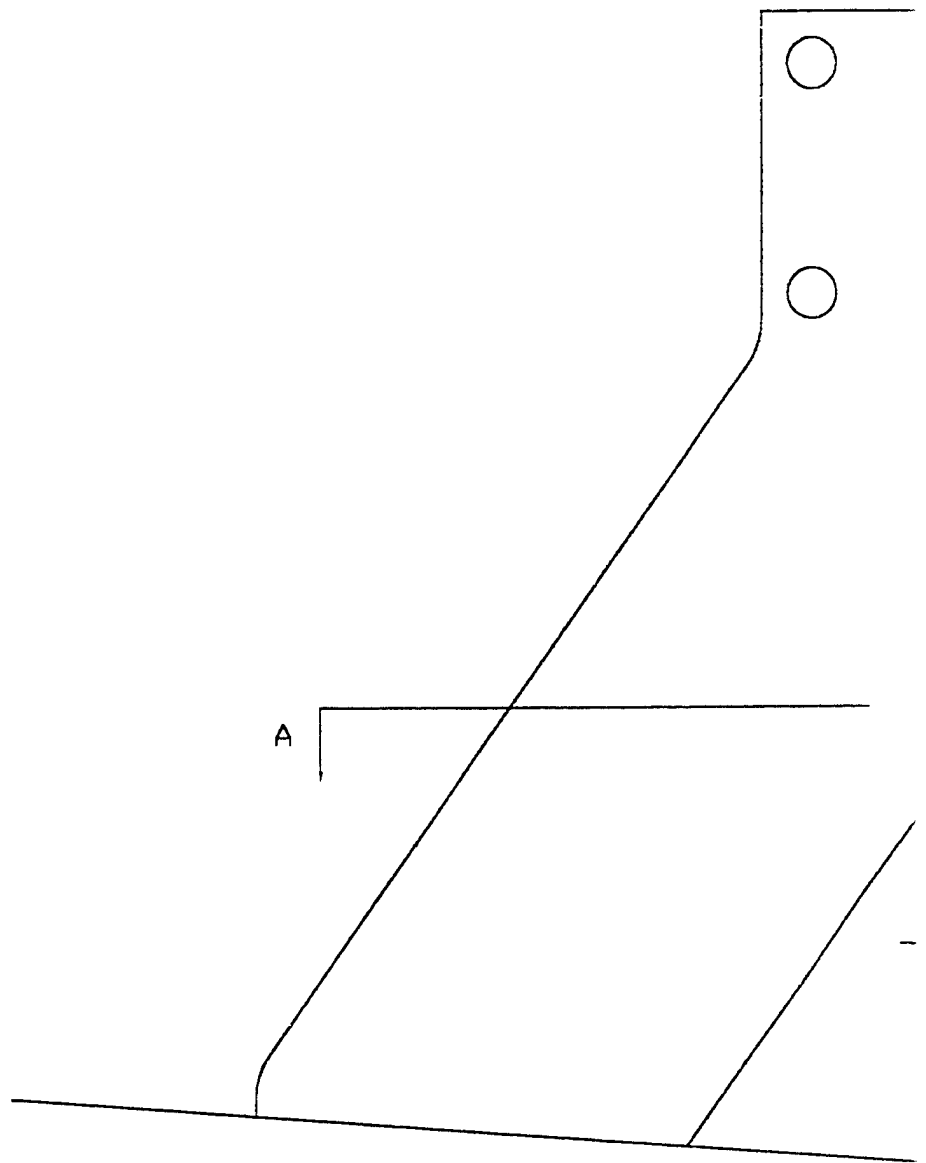
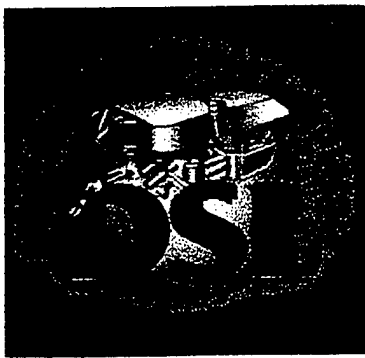
MATERIAL:
BLACK DELRIN
PLATE 1/8"

DRILL THRU & TAP 1/4-20 x 3 PLACES

1.00

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS ANGULAR .XX ±.01 ±° .XXX ±.005 ±" DO NOT SCALE DRAWING		PROJECT NO. 000000.00		WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING WOODS HOLE, MASSACHUSETTS, 02543	
		DRAWN M. F. Bowen	DATE 07/31/97	TITLE DIMENSION, POLE SENSE ODYSSEY AUV LATCH	
MATERIAL AS NOTED		CHECK Dan Dwyer	SIZE B		
FINISH AS NOTED		17		SCALE NONE	
				RELEASE DATE	
				SHEET OF	

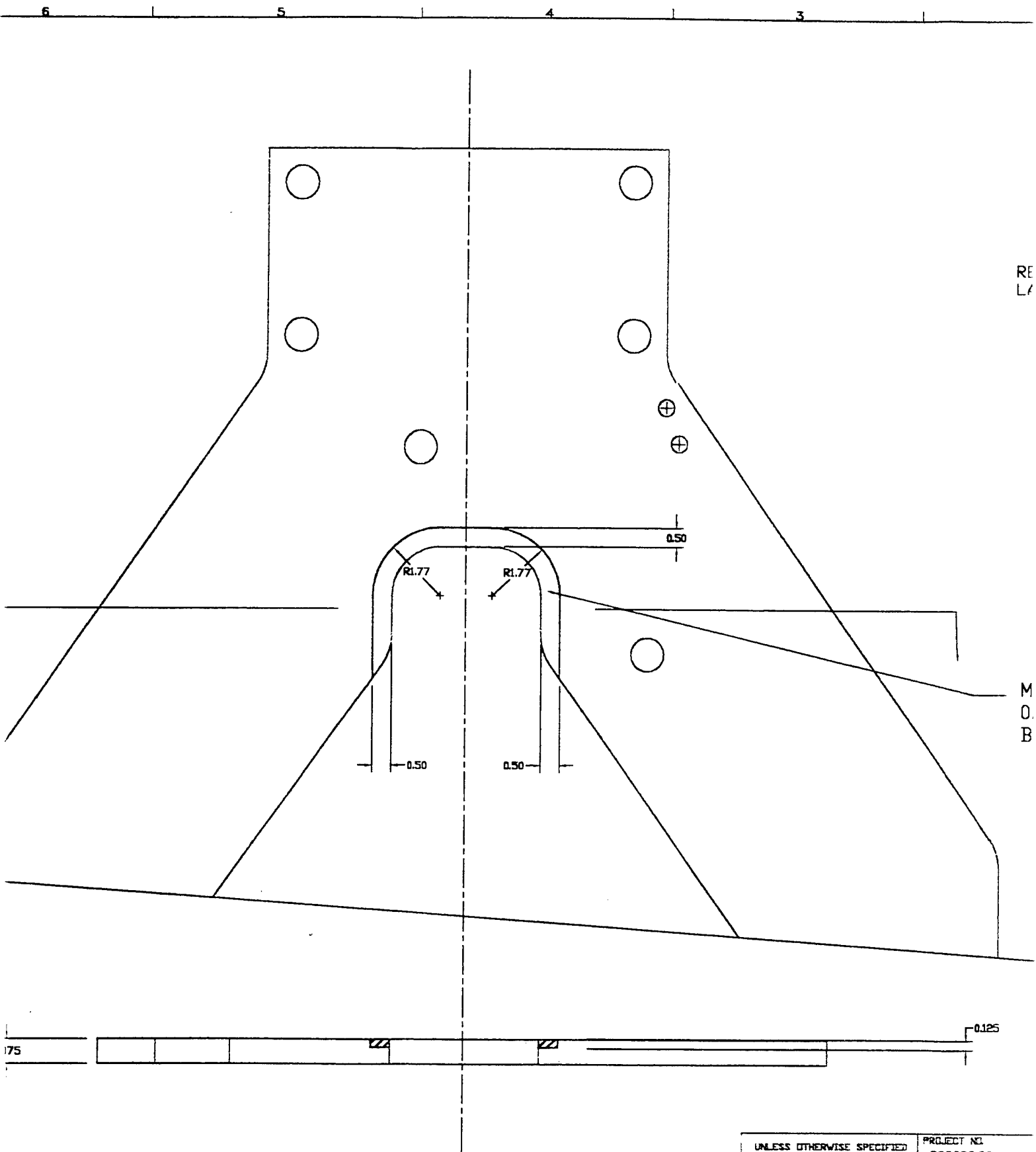
3



NOTES:
BREAK ALL SHARP EDGES
BILATERALLY SYMMETRICAL

MATERIAL:
6AL-4V TITANIUM PLATE, 3/8"

①

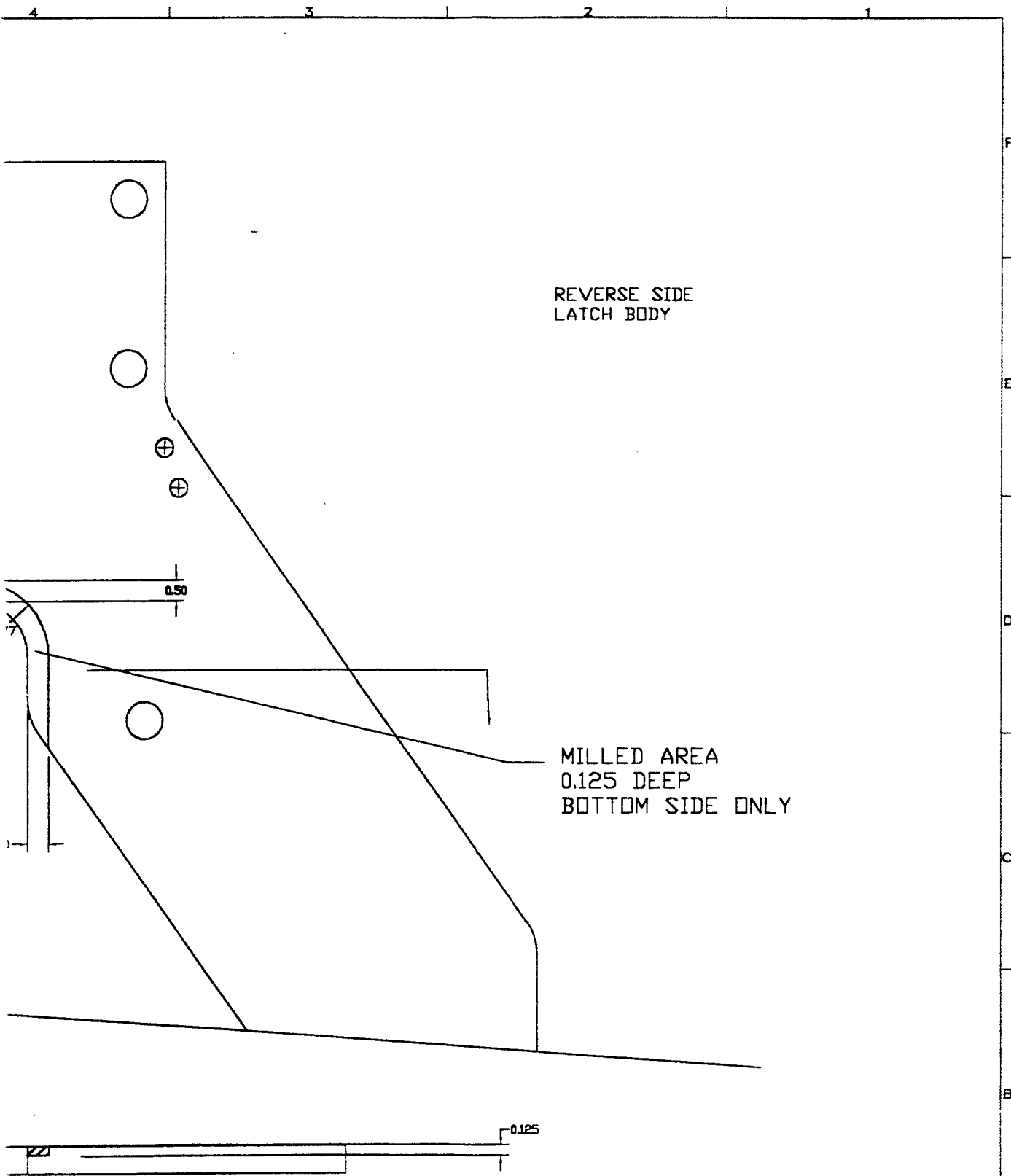


RE
L/

M
O.
B

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES		PROJECT NO. 000000.00	
TOLERANCES		DRAWN	DA
DECIMALS	ANGULAR	M. F. Bowen 07,	
.XX ±.01	±1°	CHECK	
.XXX ±.005		Dan Dwyer	
DO NOT SCALE DRAWING			
MATERIAL AS NOTED			
FINISH AS NOTED		18	

2

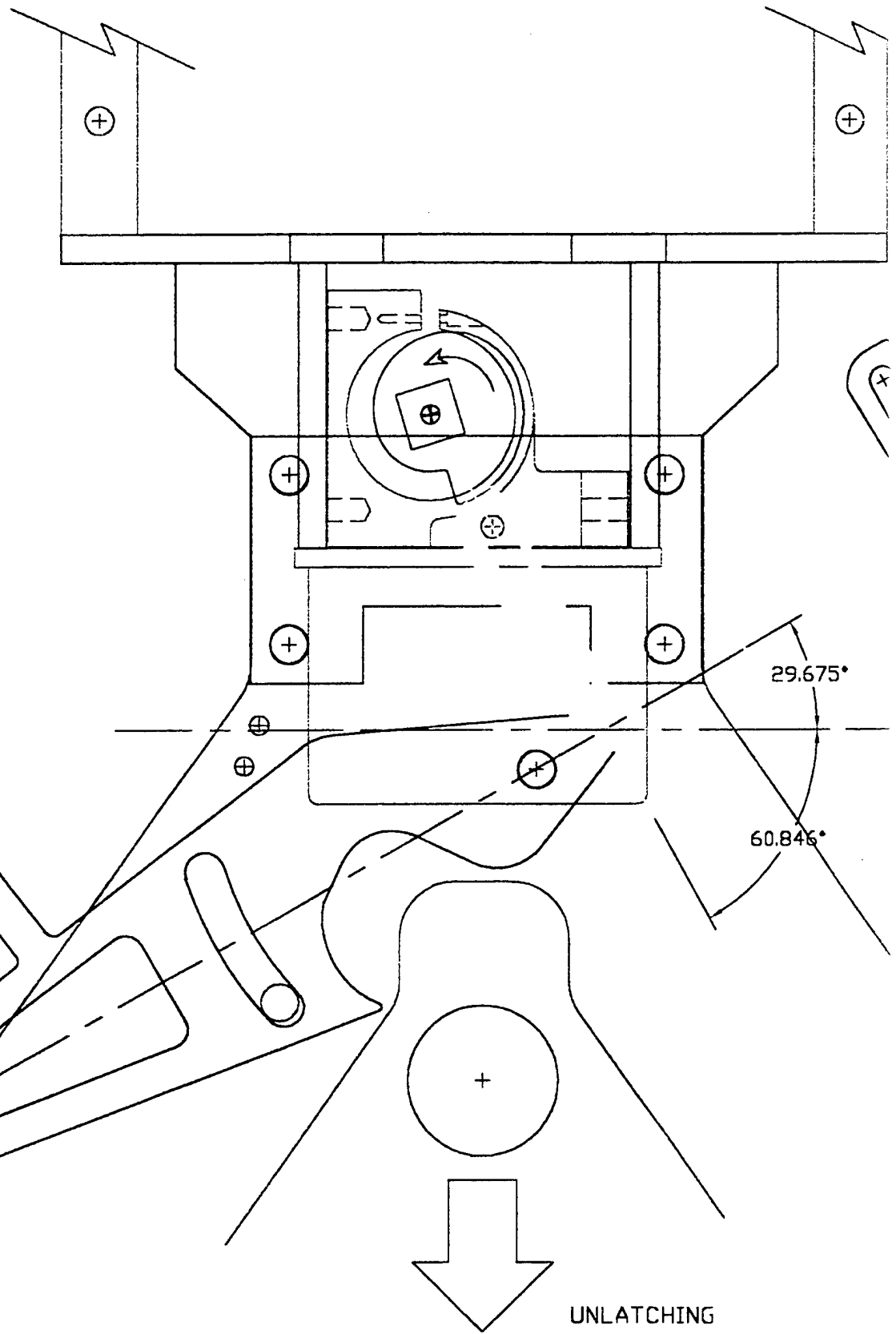


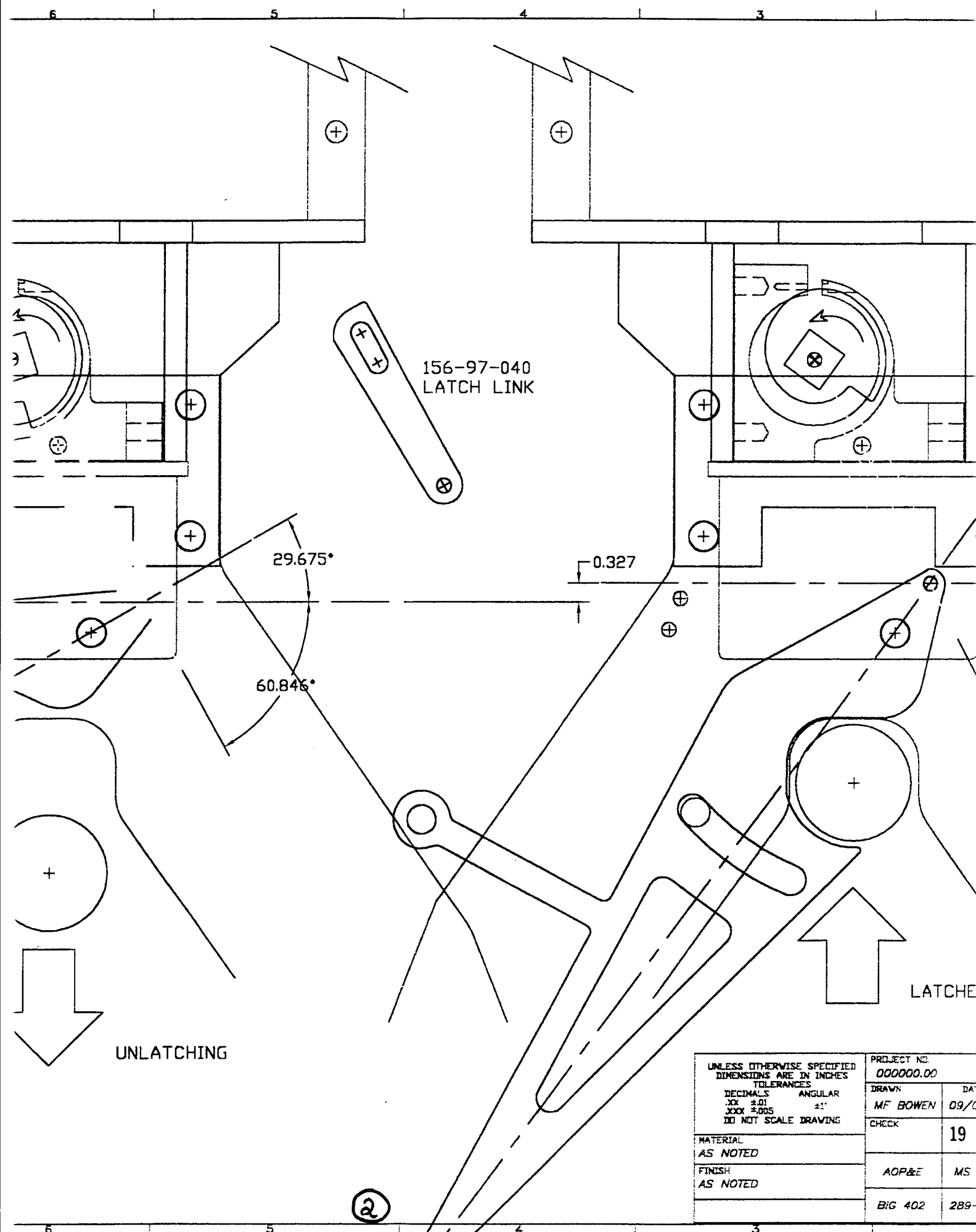
REVERSE SIDE
LATCH BODY

MILLED AREA
0.125 DEEP
BOTTOM SIDE ONLY

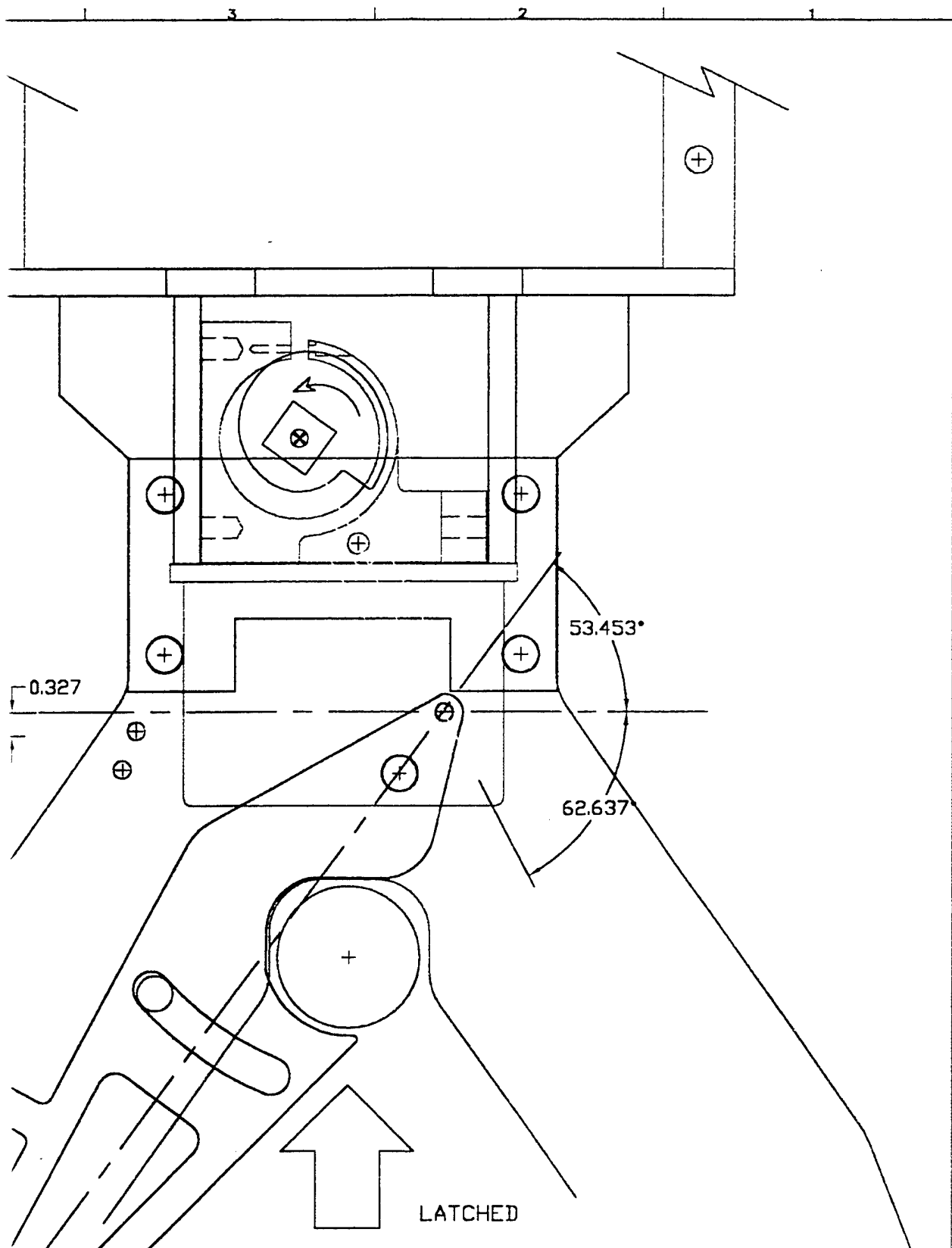
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS .XX ±.01 ANGULAR ±1° XXX ±.005 DO NOT SCALE DRAWING		PROJECT NO. 000000.00		WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING WOODS HOLE, MASSACHUSETTS, 02543	
		DRAWN M. F. Bowen	DATE 07/31/97	TITLE REVERSE SIDE, LATCH BODY ODYSSEY AUV LATCH	
MATERIAL AS NOTED		CHECK Dan Dwyer			
FINISH AS NOTED		18		SIZE B	DWG NO. 156-97-028
				SCALE NONE	RELEASE DATE SHEET OF

③





UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES		PROJECT NO. 000000.00	
DECIMALS	ANGULAR	DRAWN	DA
.XX $\pm .01$	$\pm 1^\circ$	MF BOWEN	09/C
.XXX $\pm .005$		CHECK	19
DO NOT SCALE DRAWING			
MATERIAL AS NOTED			
FINISH AS NOTED		AOP&E	MS
		BIG 402	289-



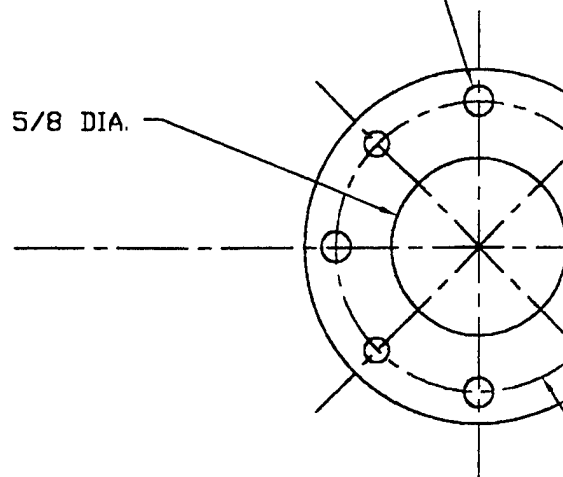
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS ANGULAR .XX ±.01 ±1° .XXX ±.005 DO NOT SCALE DRAWING		PROJECT NO. 000000.00		WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING WOODS HOLE, MASSACHUSETTS, 02543	
		DRAWN MF BOWEN	DATE '09/09/97	TITLE ODYSSEY VEHICLE LATCH PARTIAL PLAN VIEW	
MATERIAL AS NOTED		CHECK 19	SIZE 3		
FINISH AS NOTED		AOP&E BIG 402	MS #9 289-3420	DWG NO. 156-97-042	
		SCALE NONE		RELEASE DATE	SHEET 02

3



DRILL THRU & TAP 6-32
x 4 PLACES AT 90 DEGREES

DRILL THRU 5/8 DIA.



NOTES:
MATERIAL IS 6061-T6 ALUMINUM
PLEASE BREAK SHARP EDGES
2EA REQ'D
MARTIN BOWEN
(508) 289-3420 WHOI
(508) 457-2132 FAX

DRILL THRU & TAP 6-32
4 PLACES AT 90 DEGREES

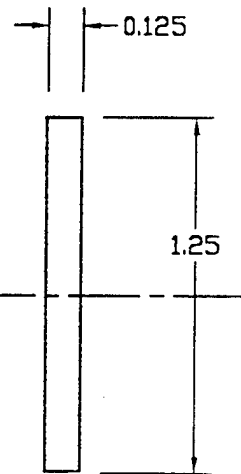
DRILL THRU 0.157 DIA (3mm)
x 4 PLACES AT 90 DEGREES

5/8 DIA.

45°

45°

1.024 DIA BOLT CIRCLE
(26mm)

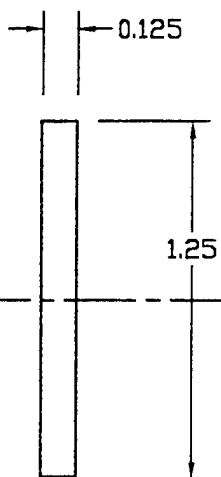


ES:
ERIAL IS 6061-T6 ALUMINUM
ASE BREAK SHARP EDGES
REQ'D
TIN BOWEN
> 289-3420 WHOI
> 457-2132 FAX

2

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES		PROJECT NO. 000000.00	
DECIMALS	ANGULAR	DRAWN	DATE
XX ±.01		MF BOWEN	09/1
XXX ±.005	±1°	CHECK	20
DO NOT SCALE DRAWING			
MATERIAL AS NOTED			
FINISH AS NOTED		AOP&E	MS
		BIG 402	289-

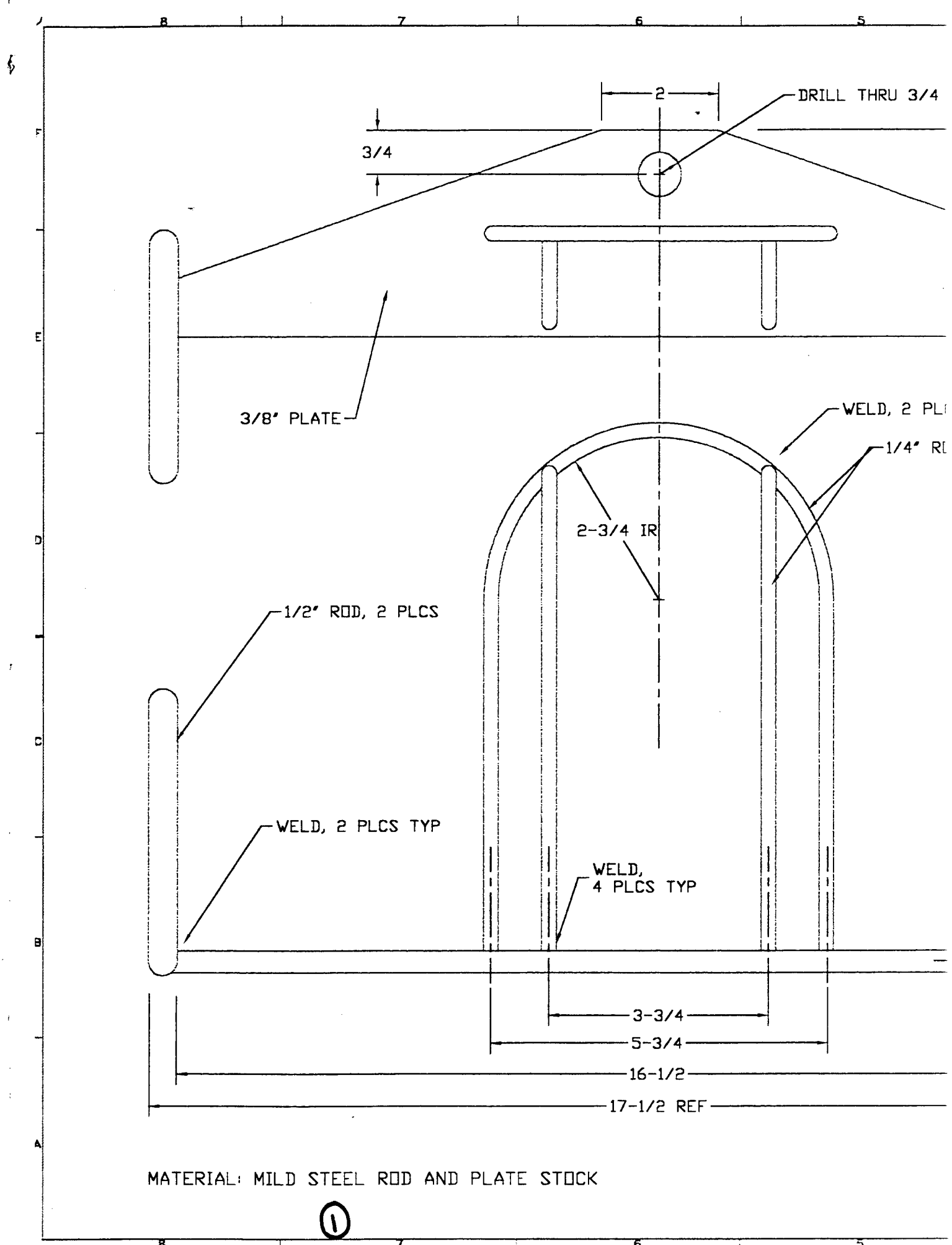
57 DIA (3mm)
 T 90 DEGREES

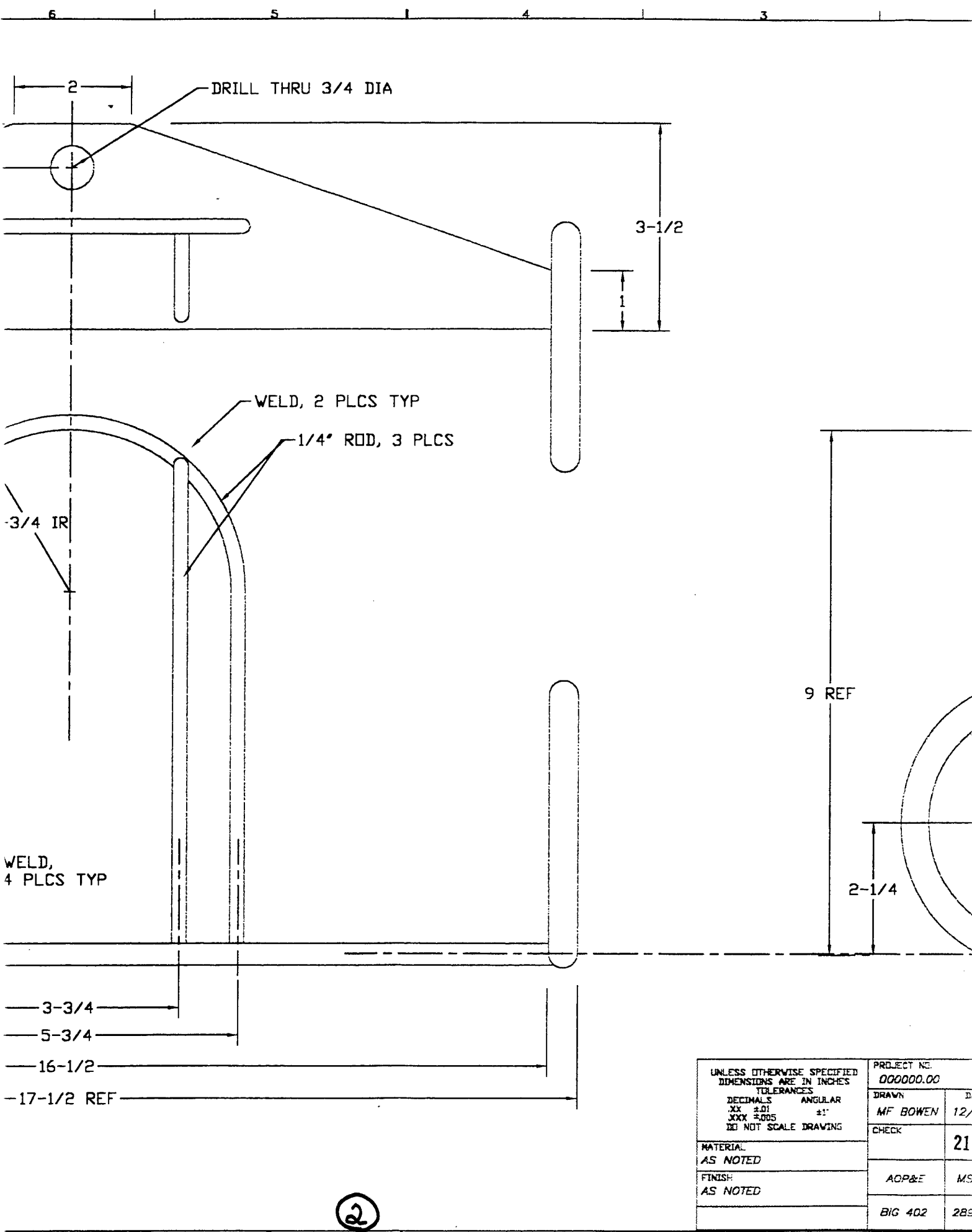


ILT CIRCLE

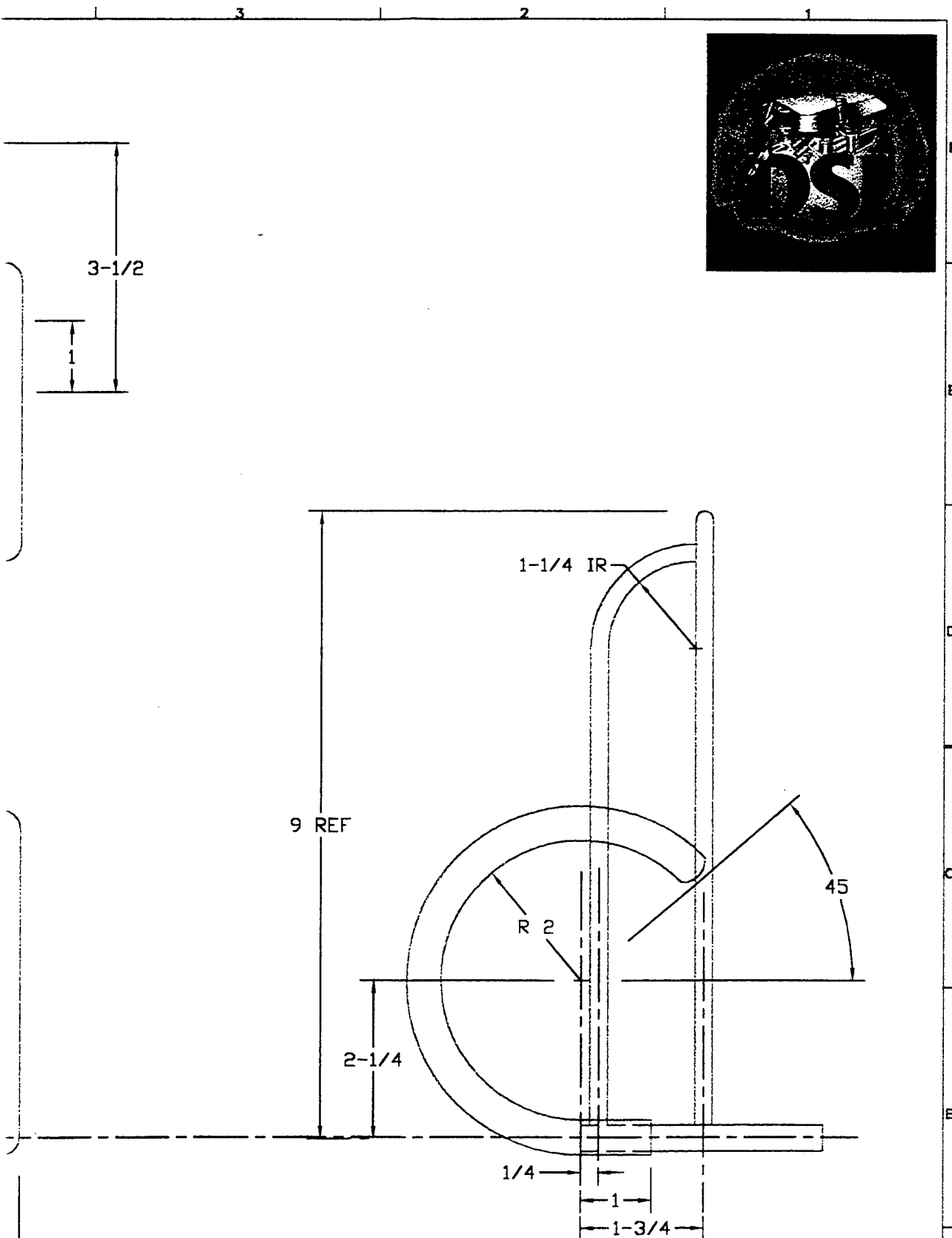
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS ANGULAR .XX ±.01 ±1° .XXX ±.005 DO NOT SCALE DRAWING	PROJECT NO. 000000.00		WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING WOODS HOLE, MASSACHUSETTS, 02543		
	DRAWN MF BOWEN	DATE 09/12/97	TITLE TRANSFER PLATE ODYSSEY LATCH MOTOR		
	CHECK	20			
	MATERIAL AS NOTED	AOP&E	MS #9	SIZE B	DWG NO. 156-97-043
FINISH AS NOTED	BIG 402	289-3420	SCALE 3:1	RELEASE DATE	SHEET OF

3

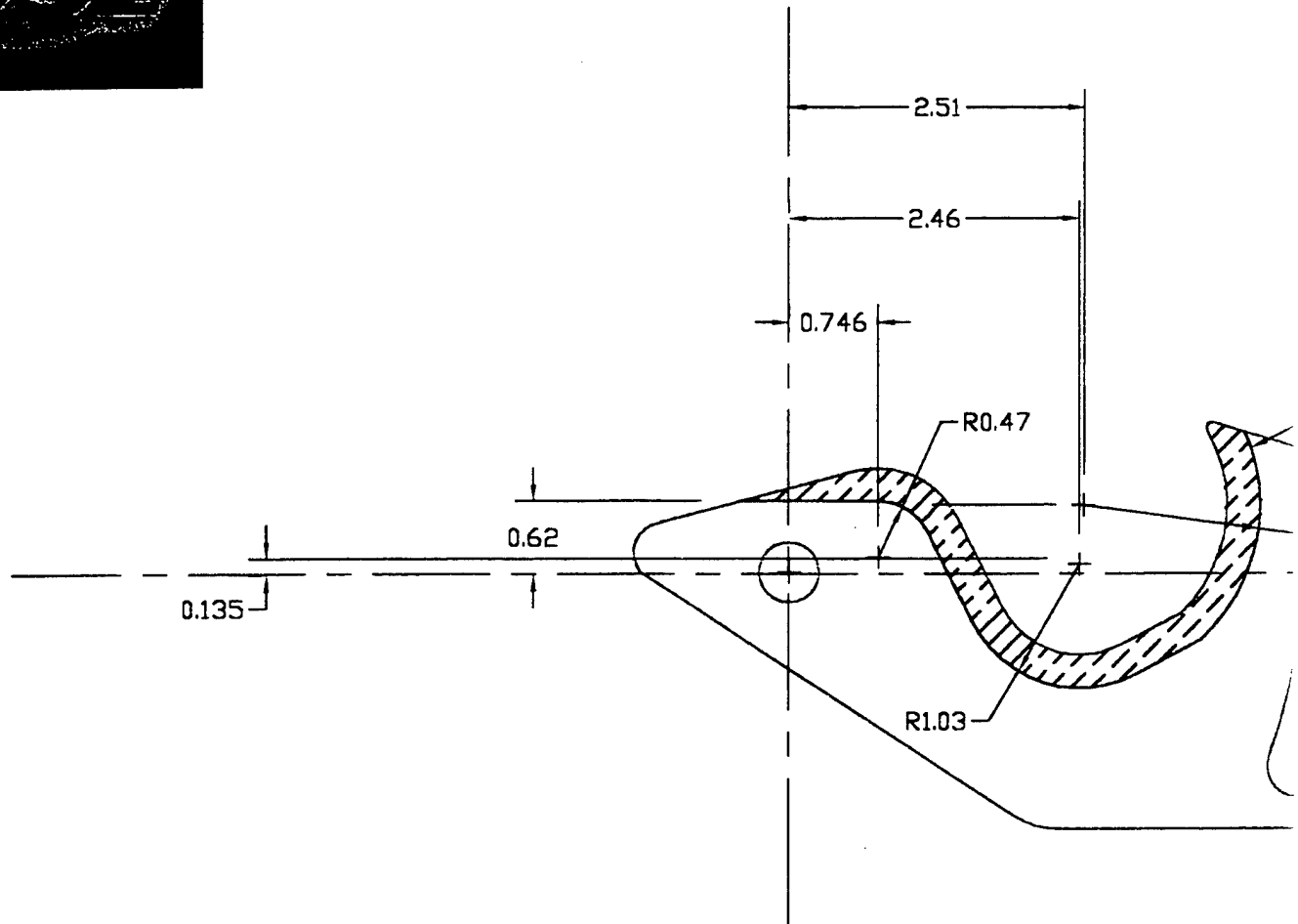
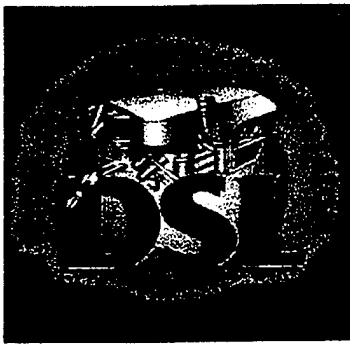


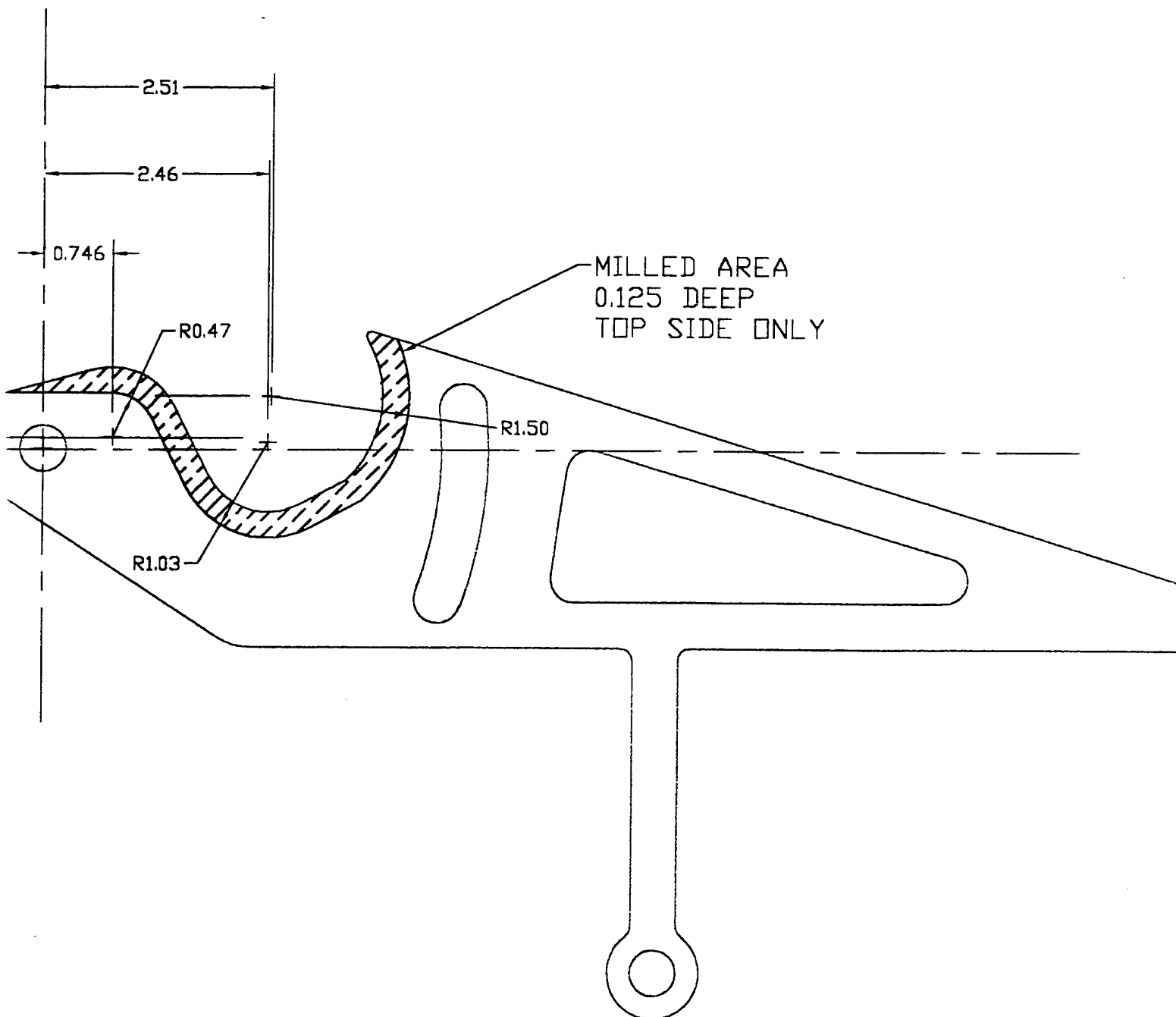


UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES		PROJECT NO. 000000.00	
DECIMALS	ANGULAR	DRAWN	BY
.XX ±.01	±1°	MF BOWEN	12/
.XXX ±.005		CHECK	21
DO NOT SCALE DRAWING			
MATERIAL AS NOTED		AOP&E	MS
FINISH AS NOTED		BIG 402	289



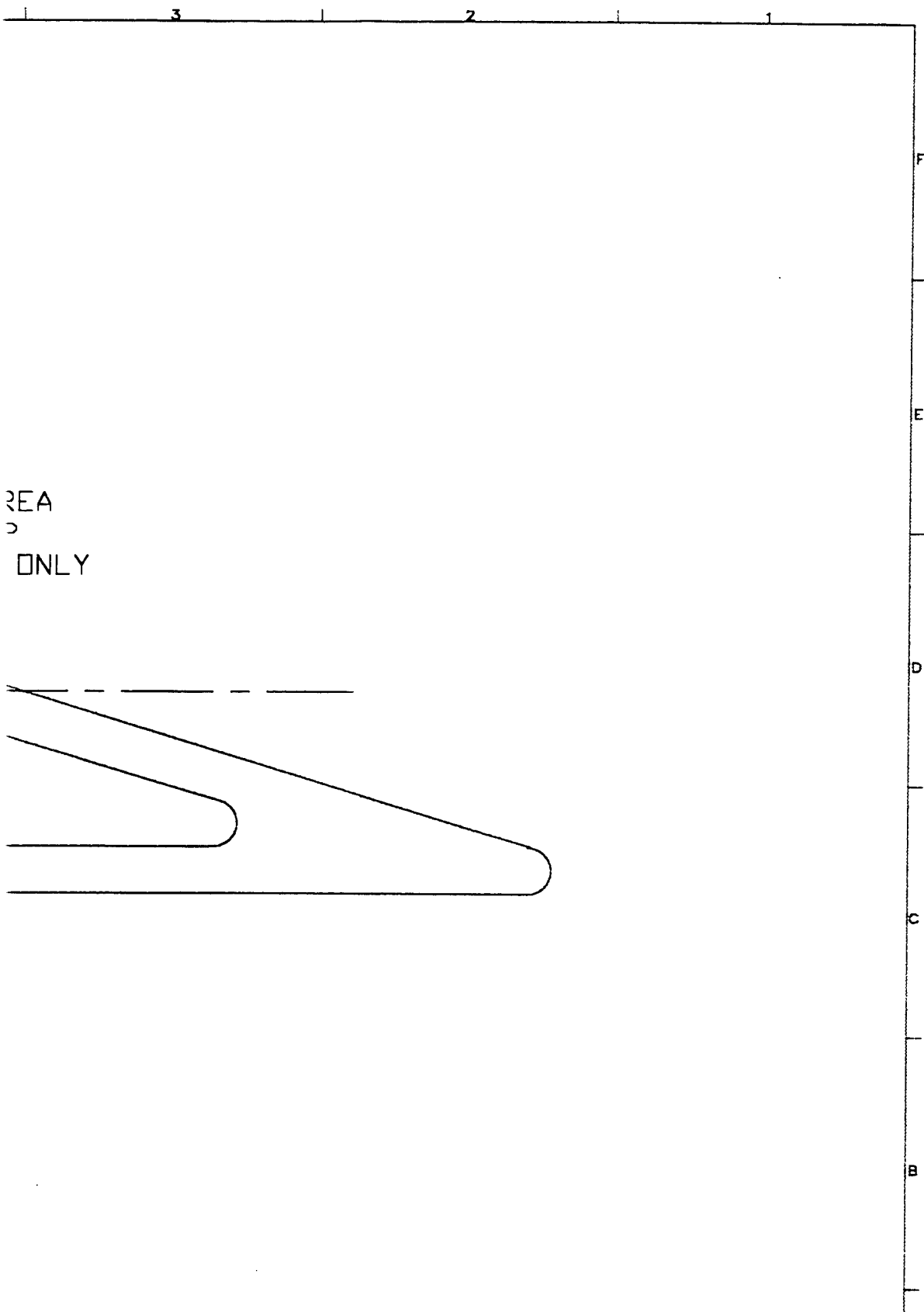
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS ANGULAR .XX ±.01 ±1° .XXX ±.005 DO NOT SCALE DRAWING	PROJECT NO. 000000.00		WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING WOODS HOLE, MASSACHUSETTS, 02543	
	DRAWN MF BOWEN	DATE 12/18/97	TITLE STEEL RECOVERY STAPLE ODYSSEY AUV OPERATIONS	
	CHECK	21		
	MATERIAL AS NOTED	AOP&E	MS #9	DWG NO. RECOVERY3.DWG
FINISH AS NOTED	BIG 402	289-3420	SCALE NONE	RELEASE DATE
			SHEET	OF





2

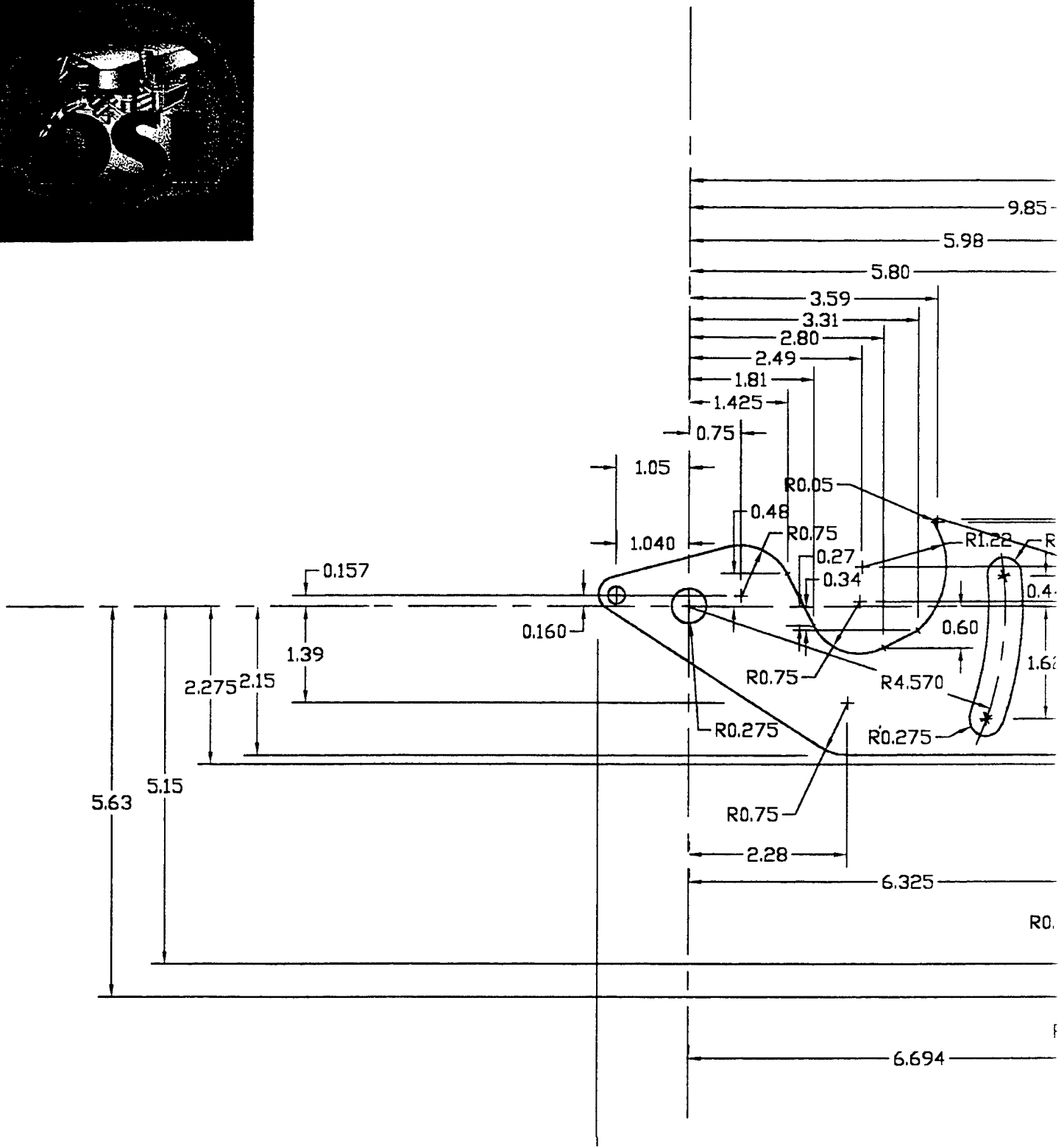
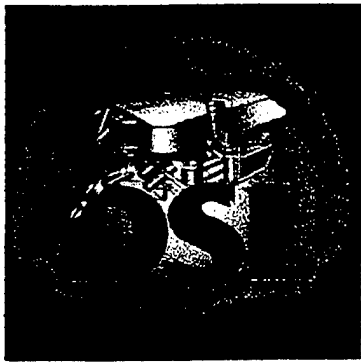
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES		PROJECT NO. 000000.00	
TOLERANCES		DRAWN	DATE
DECIMALS	ANGULAR	M. F. Bowen	3/29,
XX ±.01	±1°	CHECK	22
XXX ±.005			
DO NOT SCALE DRAWING			
MATERIAL AS NOTED			
FINISH AS NOTED			



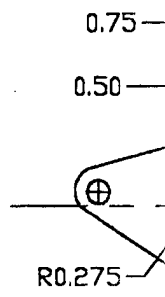
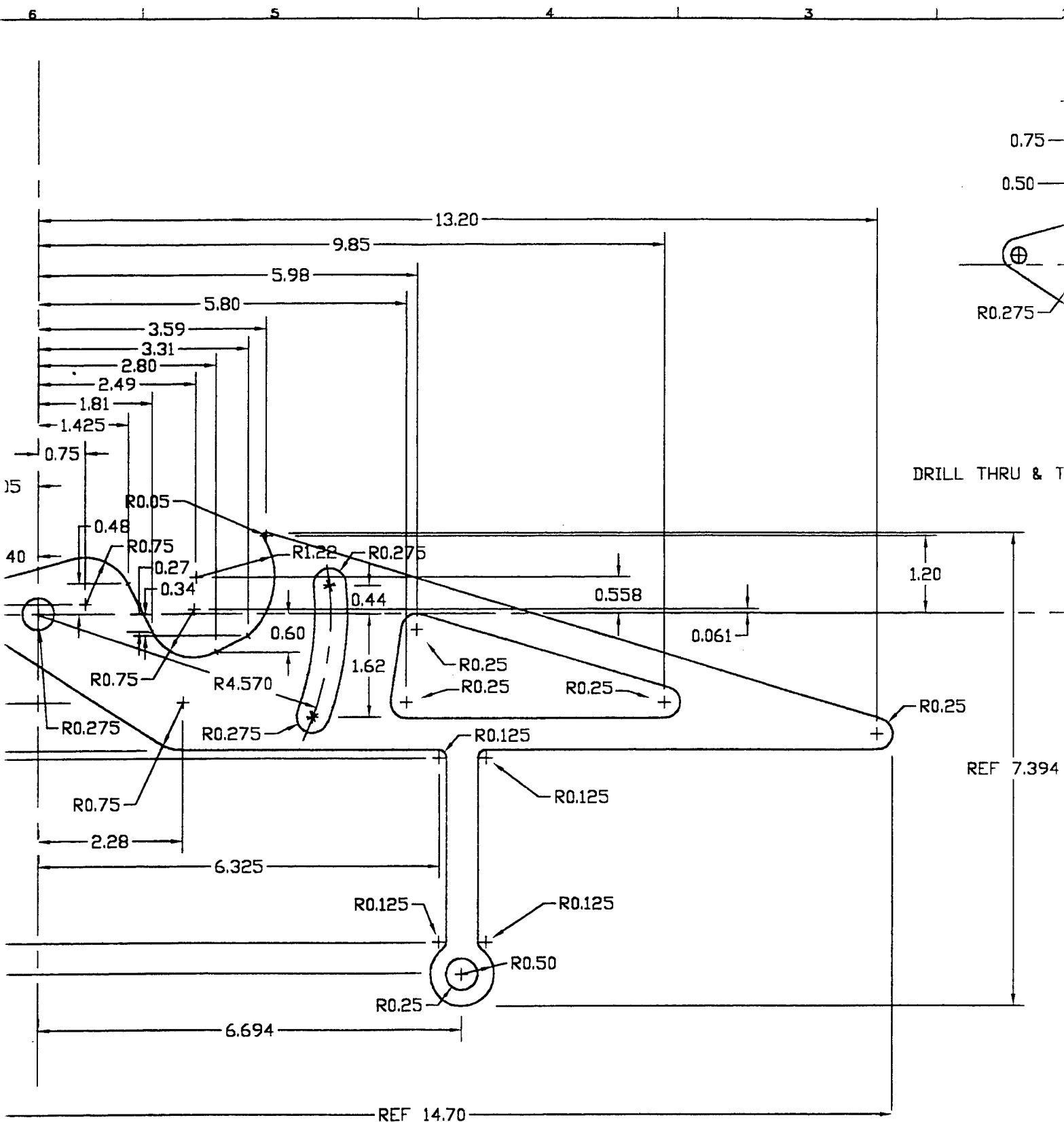
REA
ONLY

3

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS ANGULAR .XX ±.01 ±1° .XXX ±.005 DO NOT SCALE DRAWING		PROJECT NO. 000000.00		WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING WOODS HOLE, MASSACHUSETTS, 02543	
		DRAWN M. F. Bowen	DATE 3/29/97	TITLE MILL MOD, LATCH CAPTURE BAR ODYSSEY AUV LATCH	
MATERIAL AS NOTED		CHECK 22	SIZE B		
FINISH AS NOTED			SCALE NONE	RELEASE DATE	SHEET OF

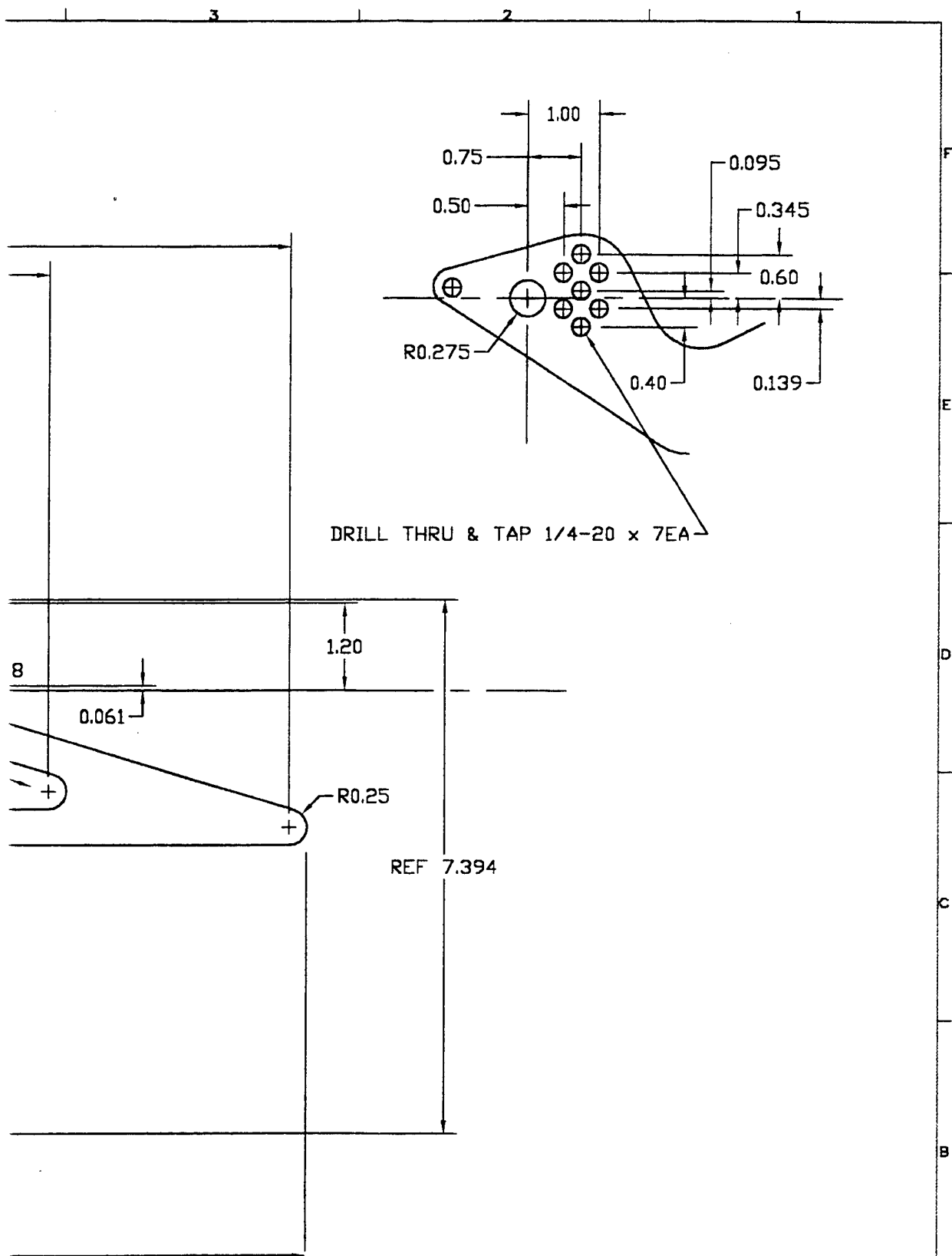


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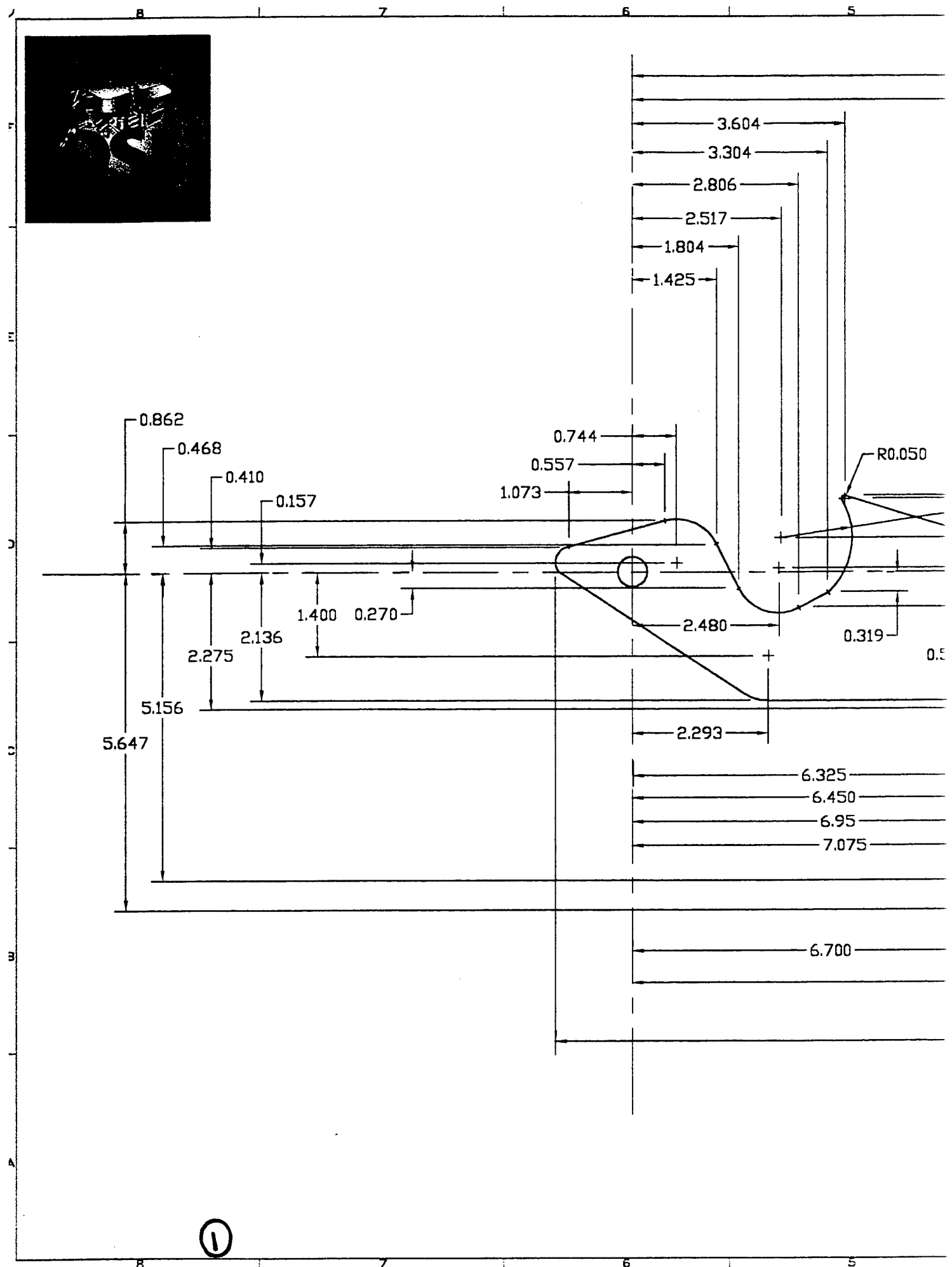
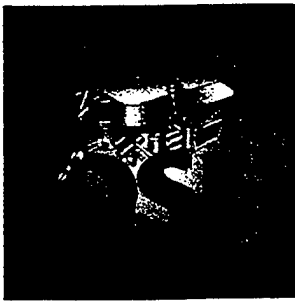
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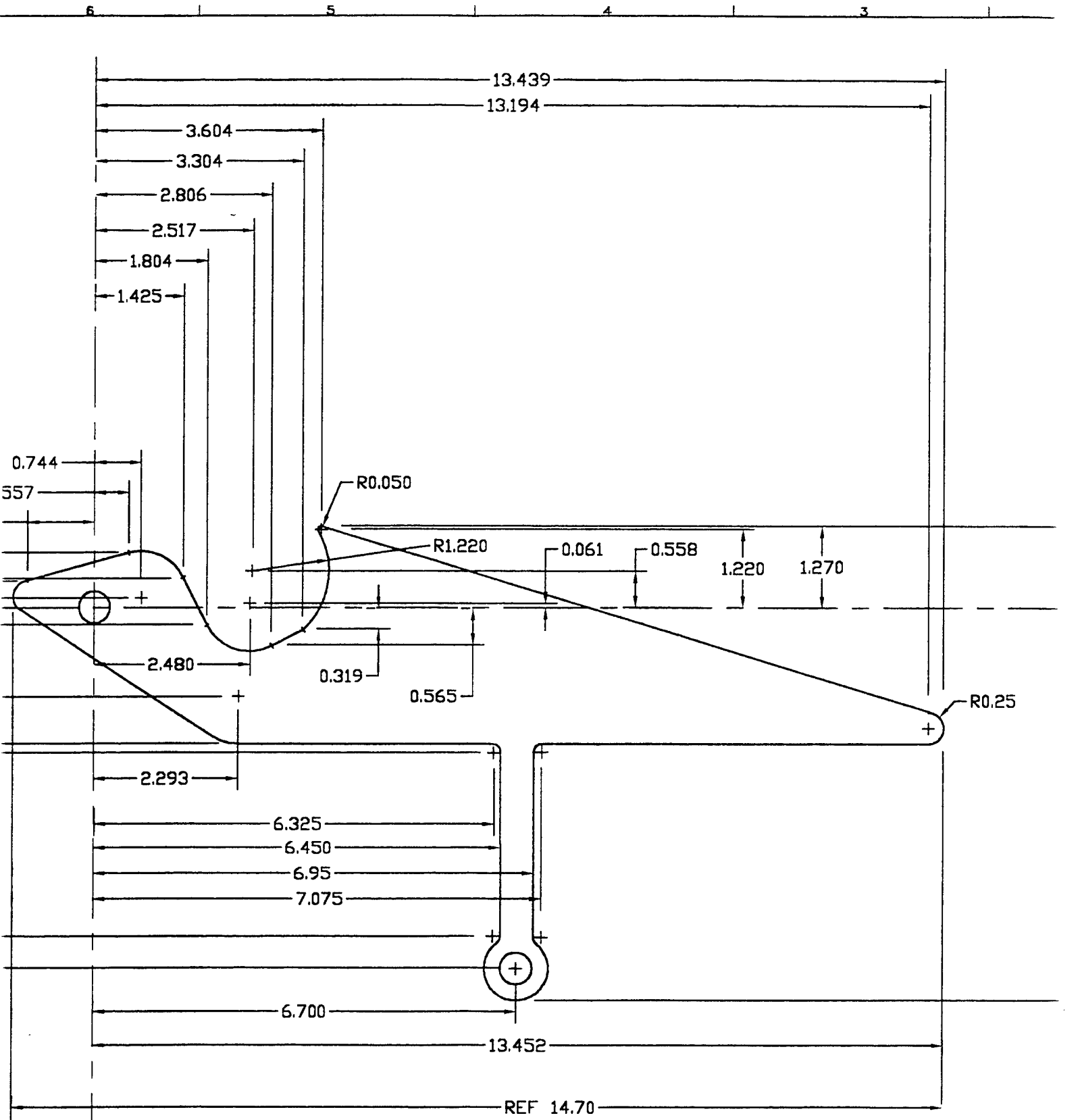
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES		PROJECT NO. 000000.00	
TOLERANCES		DRAWN	DATE
DECIMALS	ANGULAR	M. F. Bowen	08/0
XX ±.01	±1°	CHECK	24
XXX ±.005			
DO NOT SCALE DRAWING			
MATERIAL AS NOTED			
FINISH AS NOTED			



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS ANGULAR .XX ±.01 ±1° .XXX ±.005 DO NOT SCALE DRAWING	PROJECT NO. 000000.00		WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING WOODS HOLE, MASSACHUSETTS, 02543	
	DRAWN M. F. Bowen	DATE 08/01/97	TITLE CAPTURE BAR ODYSSEY AUV LATCH	
	CHECK	24	SIZE B latch5	
	MATERIAL AS NOTED		DWG NO. 156-97-029	
FINISH AS NOTED			SCALE NONE RELEASE DATE SHEET DF	

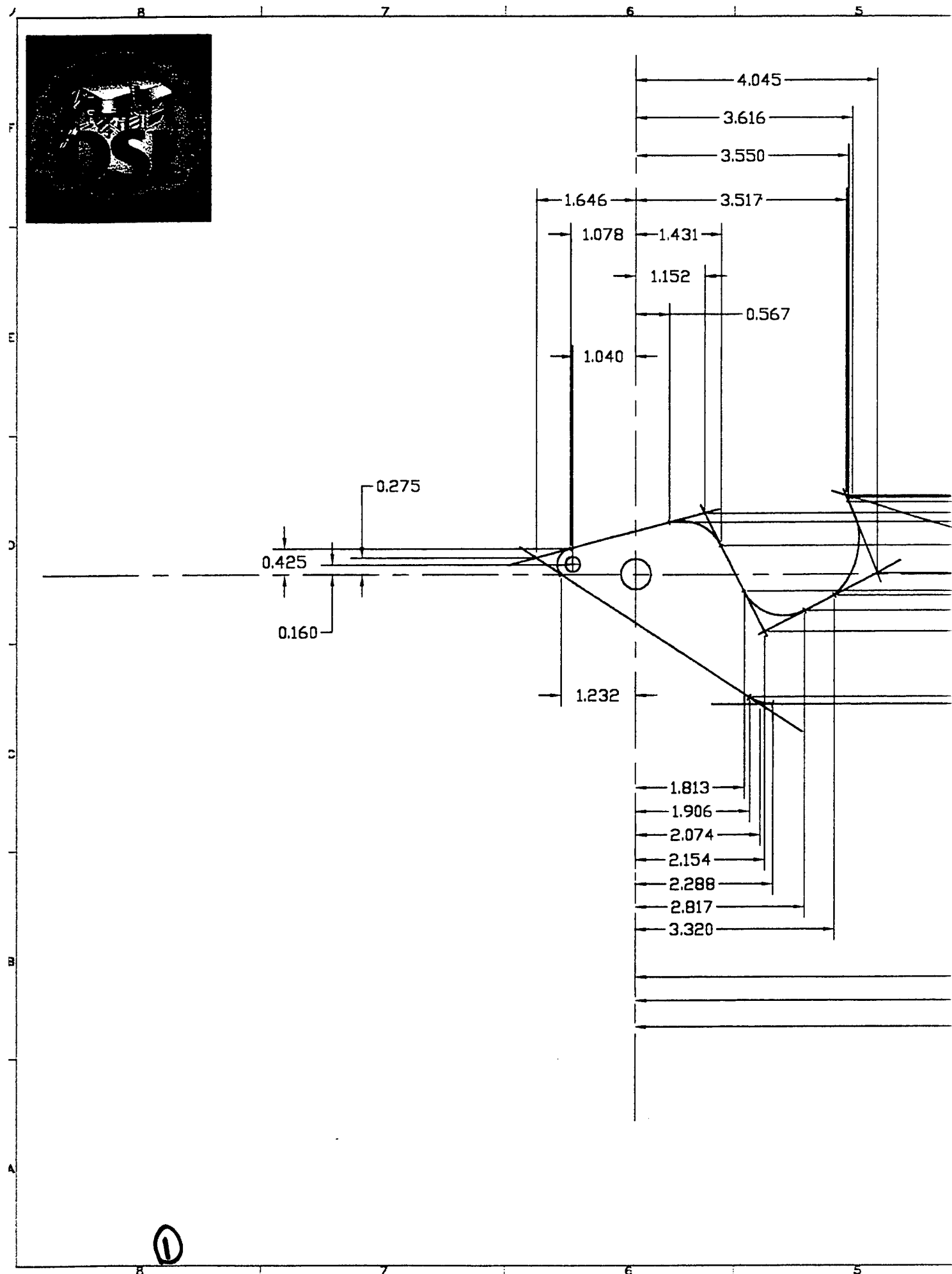
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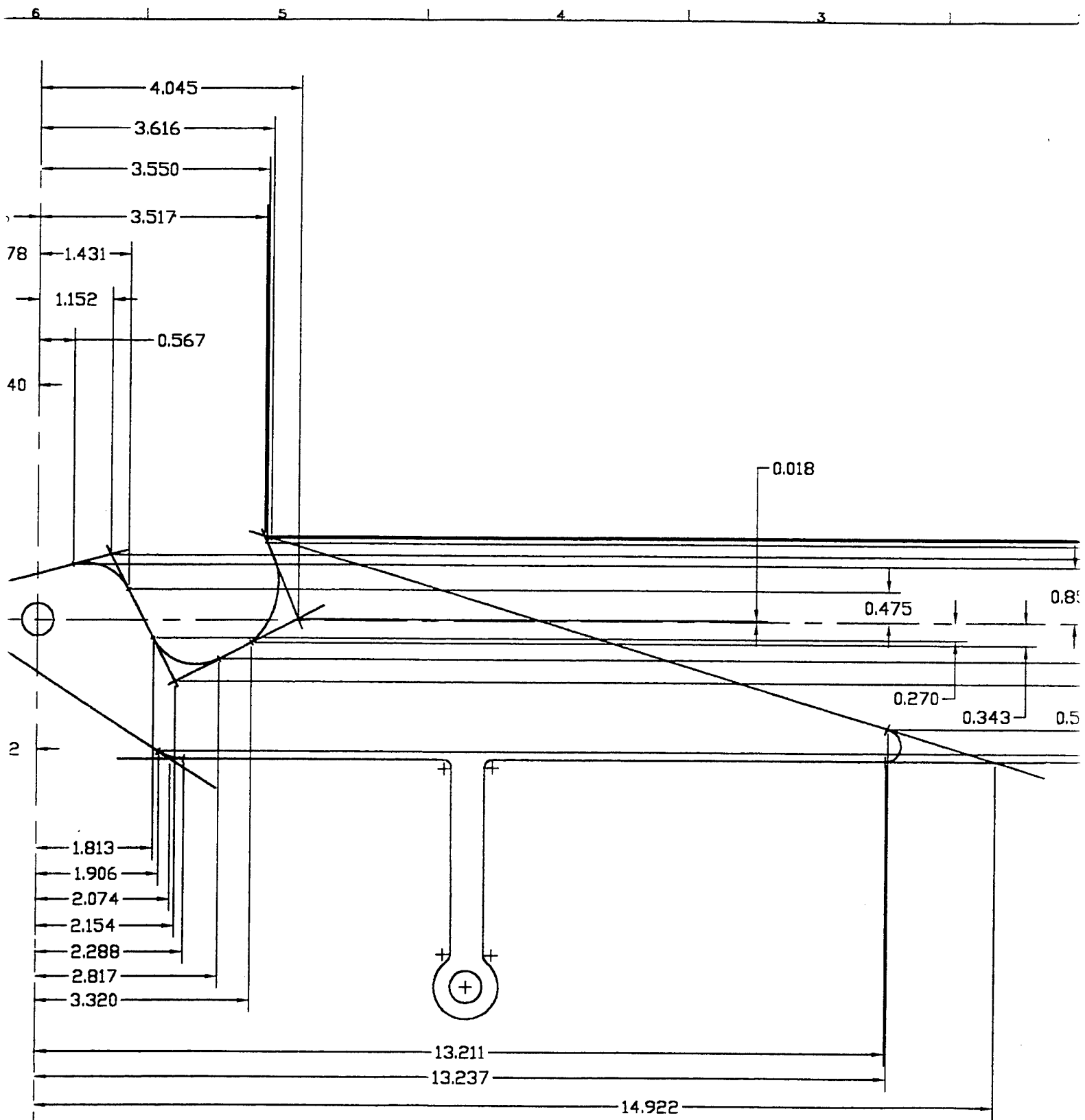




2

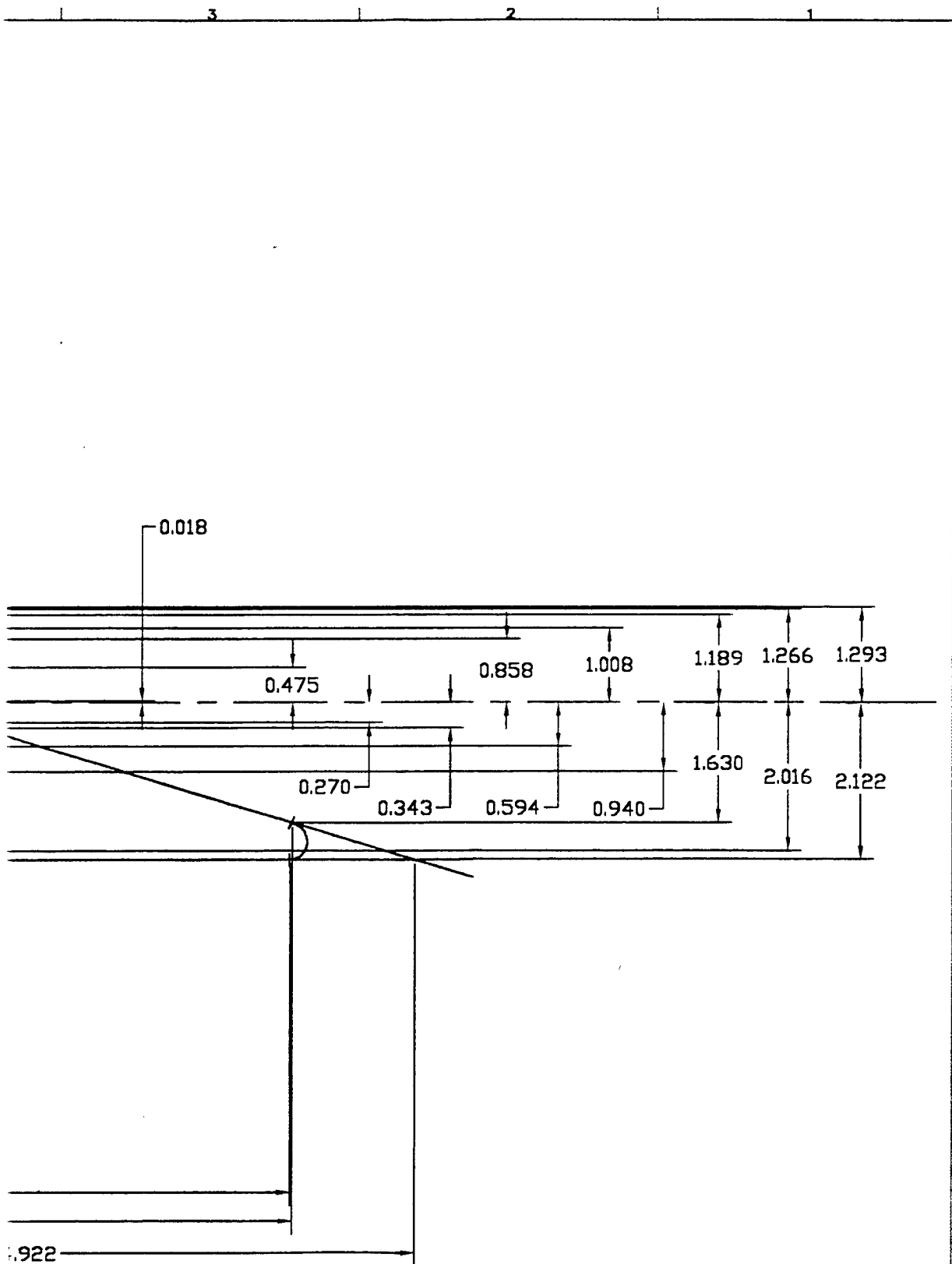
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES		PROJECT NO. 000000.00
TOLERANCES		DRAWN
DECIMALS	ANGULAR	M. F. Bowe
XX ±.01	±1°	CHECK
XXX ±.005		
DO NOT SCALE DRAWING		
MATERIAL AS NOTED		
FINISH AS NOTED		





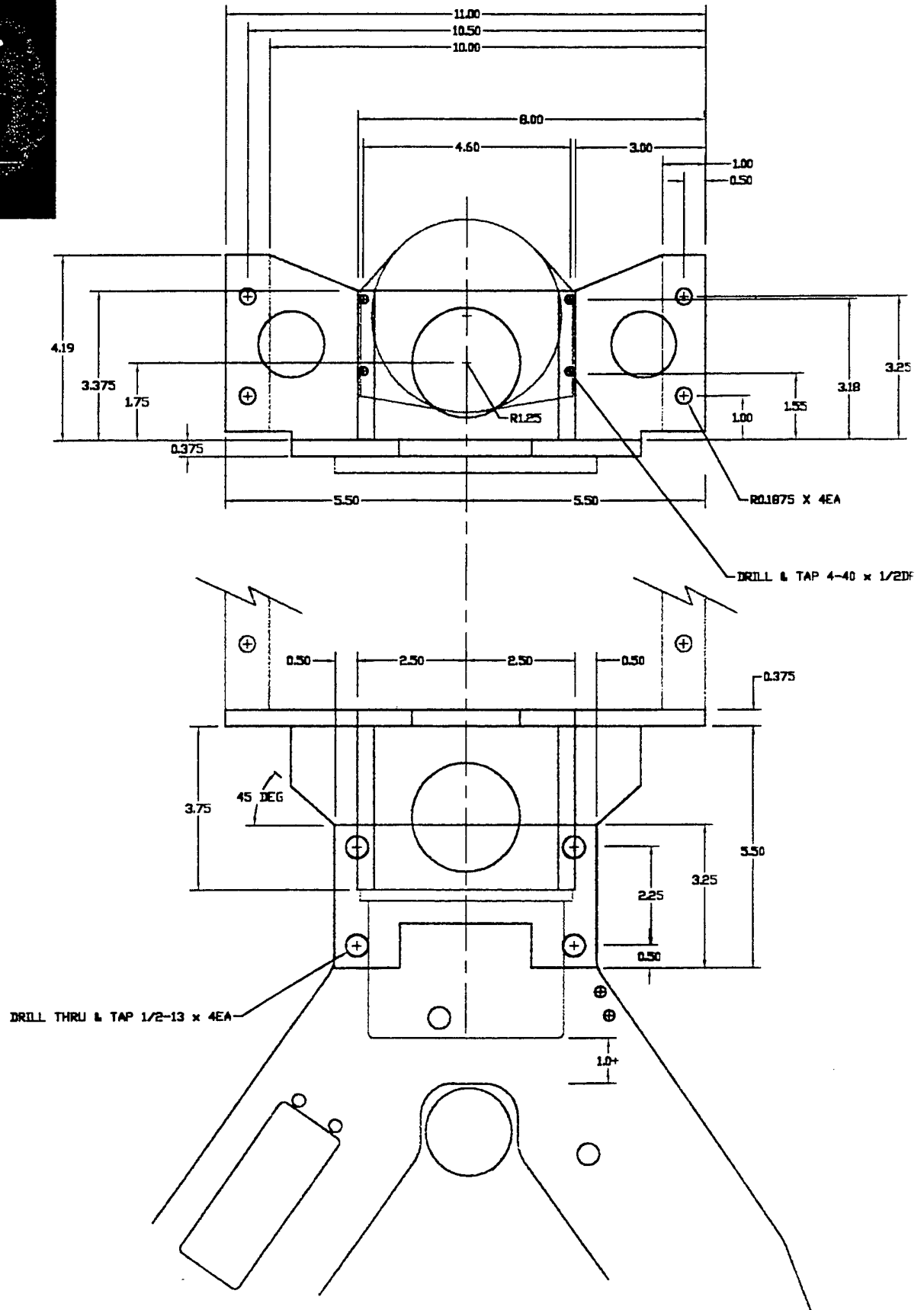
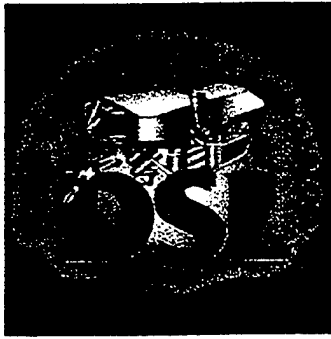
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES		PROJECT NO. 000000.00	
TOLERANCES		DRAWN	DATE
DECIMALS	ANGULAR	M. F. Bowen	6/25/
.XX ±.01	±1°	CHECK	26
.XXX ±.005			
DO NOT SCALE DRAWING			
MATERIAL AS NOTED			
FINISH AS NOTED			

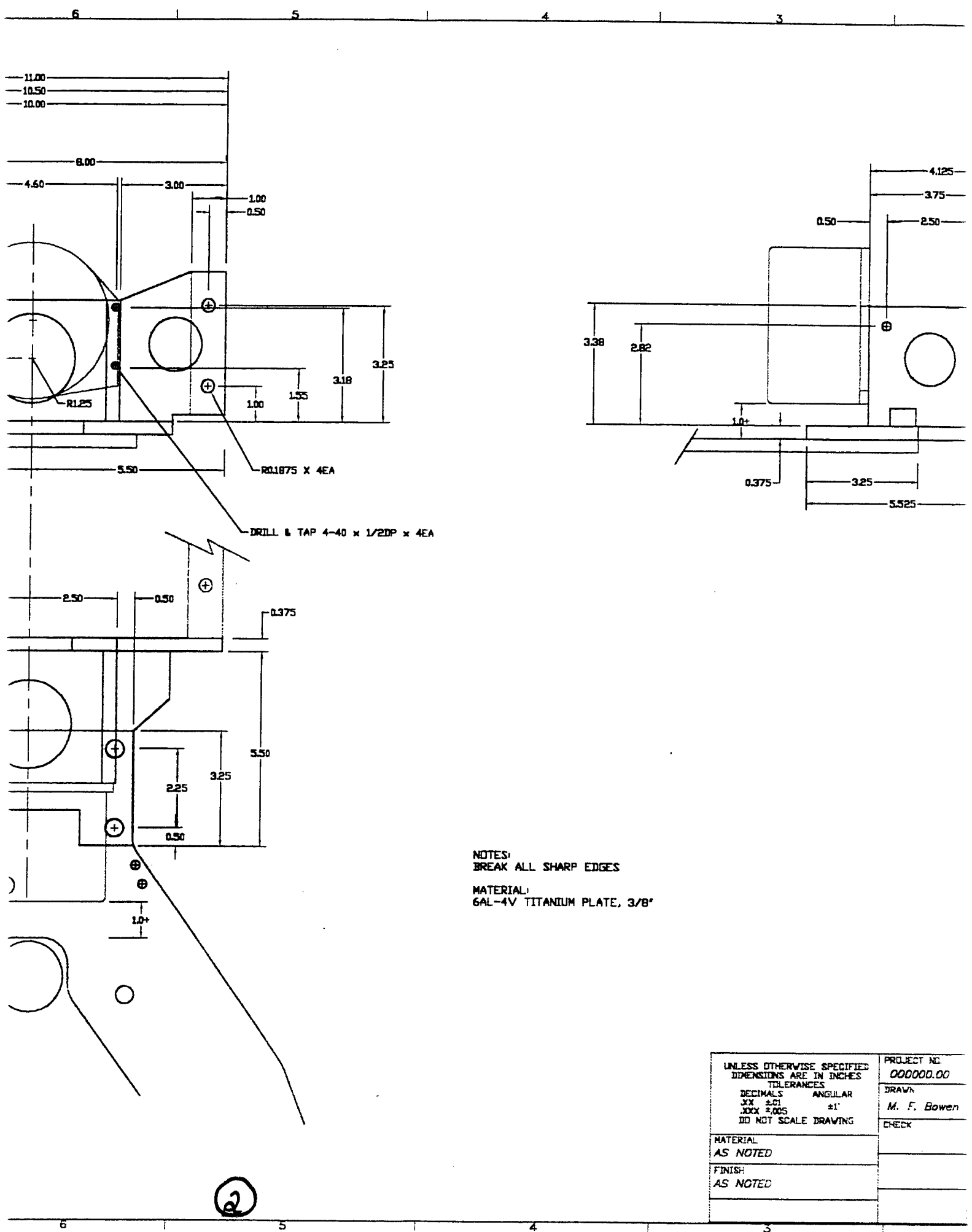
2



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS .XX ±.01 .XXX ±.005 DO NOT SCALE DRAWING	PROJECT NO. 000000.00		WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING WOODS HOLE, MASSACHUSETTS, 02543	
	DRAWN M. F. Bowen	DATE 6/25/97	TITLE CAPTURE BAR, BY CONRAD'S ODYSSEY AUV LATCH	
	CHECK	26	DWE NO. 156-97-022	
	MATERIAL AS NOTED		SCALE NONE RELEASE DATE SHEET OF	
FINISH AS NOTED				

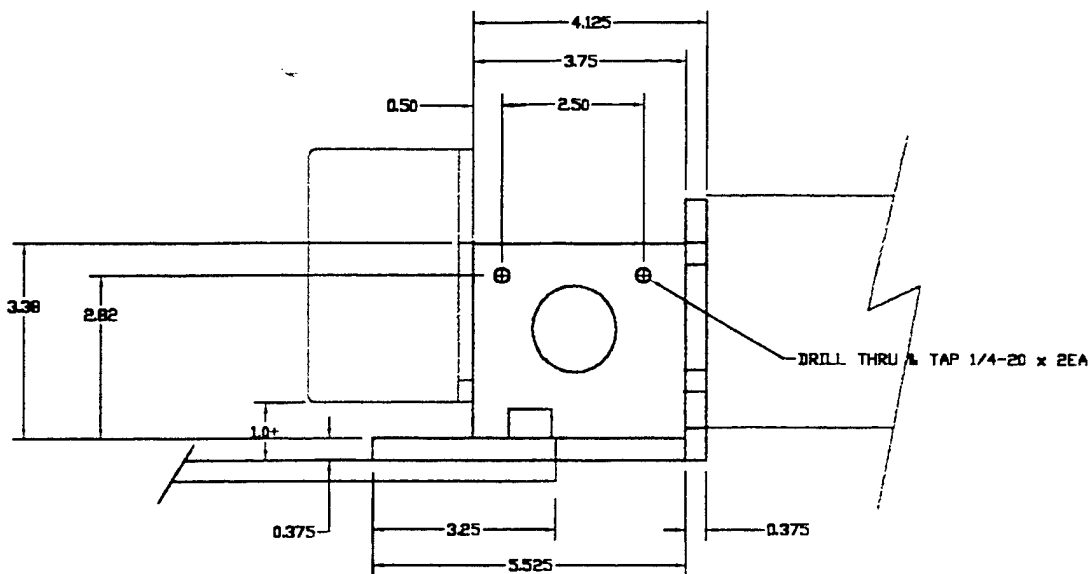
3





NOTES:
BREAK ALL SHARP EDGES
MATERIAL:
6AL-4V TITANIUM PLATE, 3/8"

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES		PROJECT NO.
DECIMALS ANGULAR		000000.00
.XX ±.01 ±1°		DRAWN
.XXX ±.005		M. F. Bowen
DO NOT SCALE DRAWING		CHECK
MATERIAL		
AS NOTED		
FINISH		
AS NOTED		

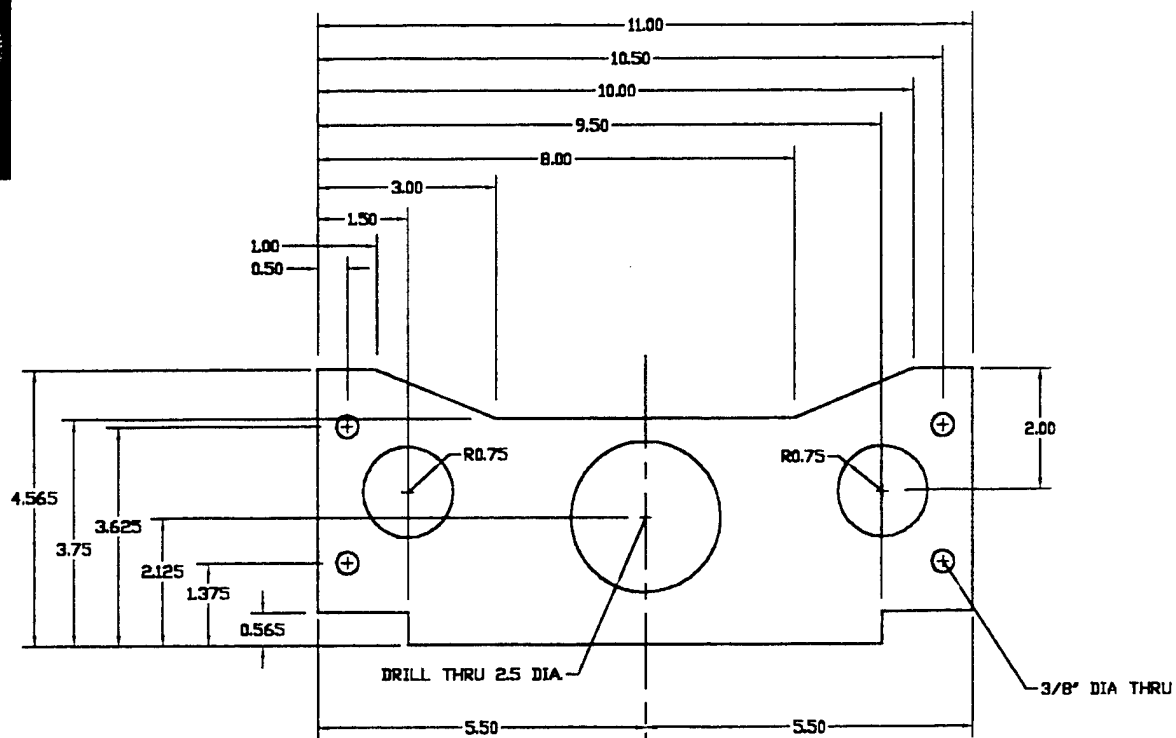


SHARP EDGES

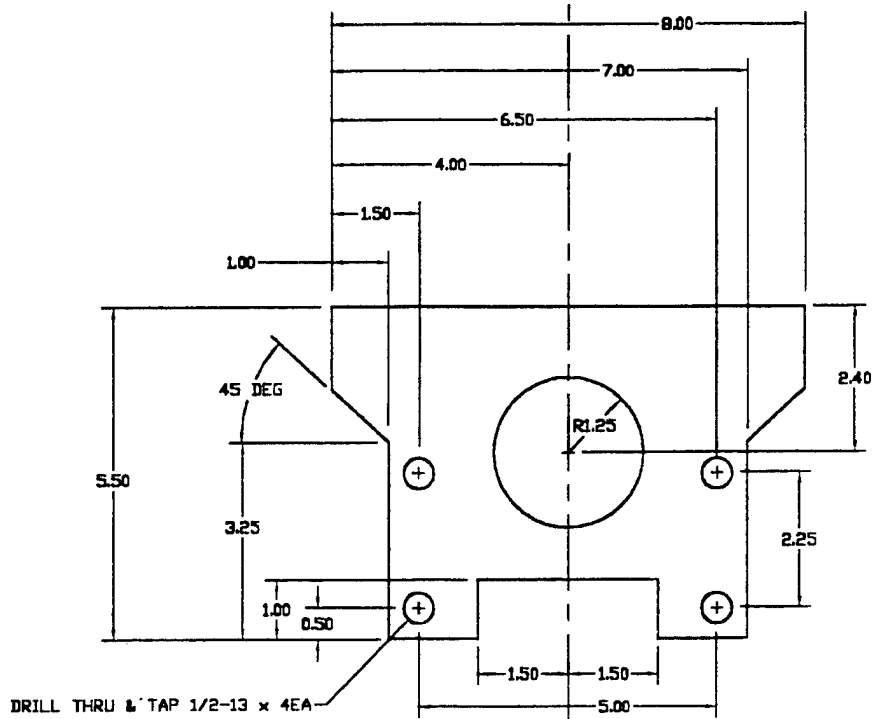
ALUM PLATE, 3/8"

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES		PROJECT NO. 000000.00		WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING WOODS HOLE, MASSACHUSETTS, 02543	
DECIMALS XX ±.01 XXX ±.005 DO NOT SCALE DRAWING	ANGULAR ±1°	DRAWN M. F. Bowen	DATE 3/29/97	TITLE MOUNT ASSY, LATCH & USBL ODYSSEY AUV LATCH	
MATERIAL AS NOTED		CHECK	27	SIZE B	
FINISH AS NOTED				DWG NO. 156-97-0001	
				SCALE NONE	
				RELEASE DATE	
				SHEET OF	

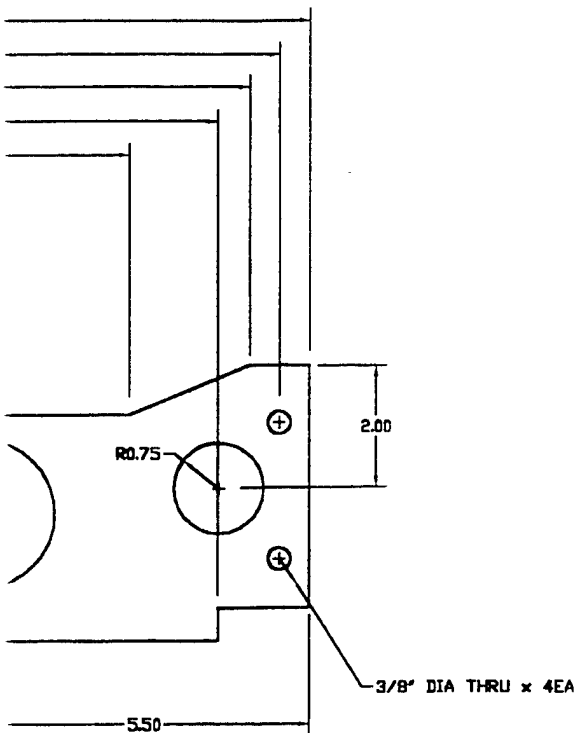
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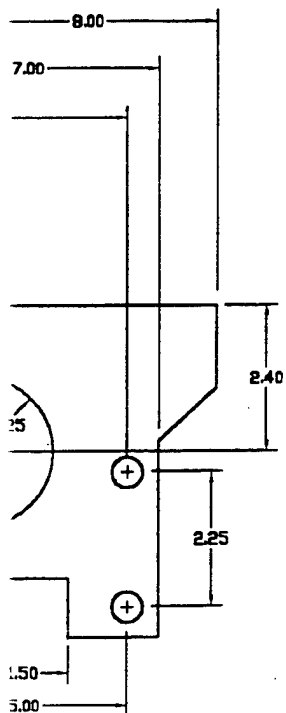
BACK PLATE, 1EA



BOTTOM PLATE, 1EA

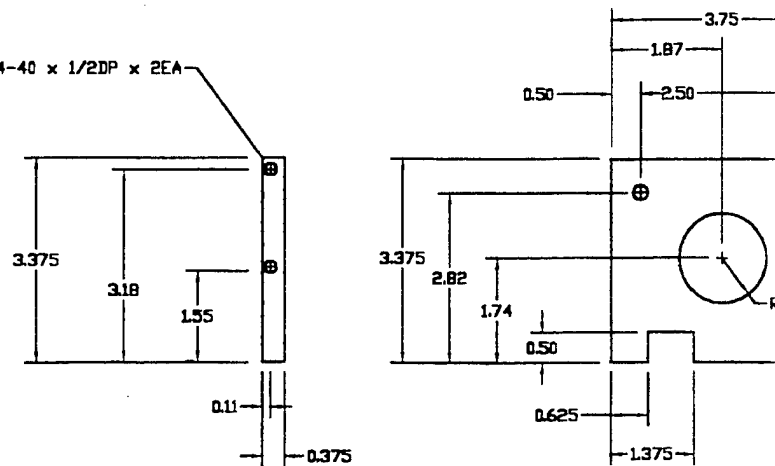


BACK PLATE, 1EA

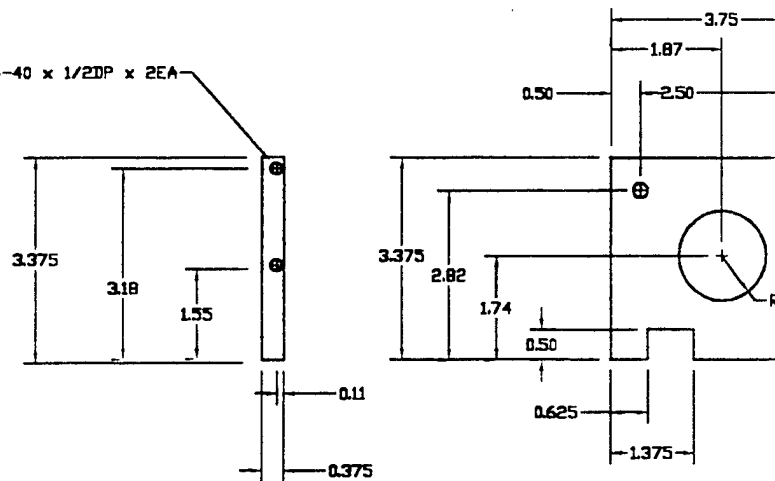


BOTTOM PLATE, 1EA

DRILL & TAP 4-40 x 1/2DP x 2EA



DRILL & TAP 4-40 x 1/2DP x 2EA

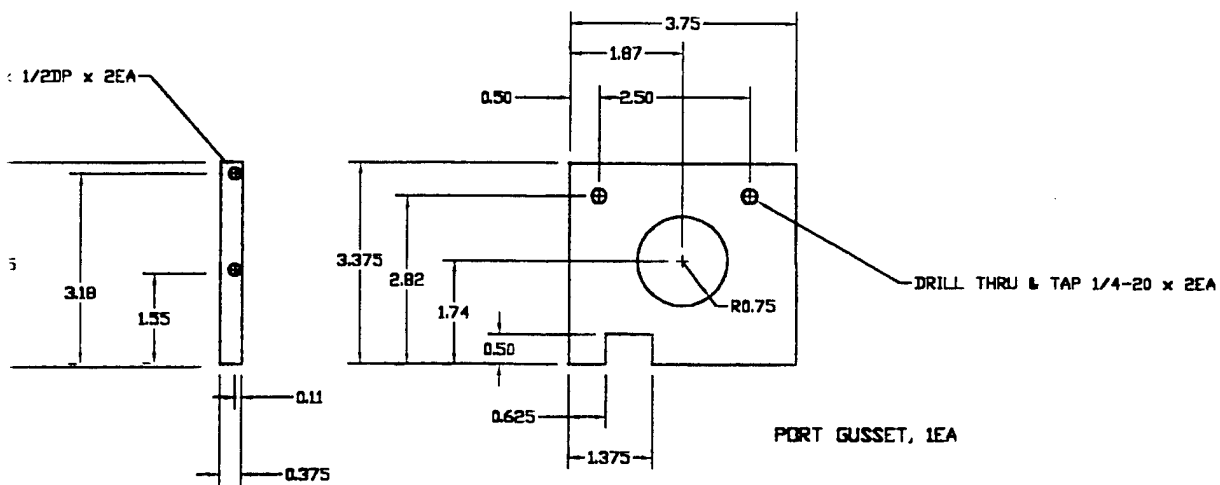
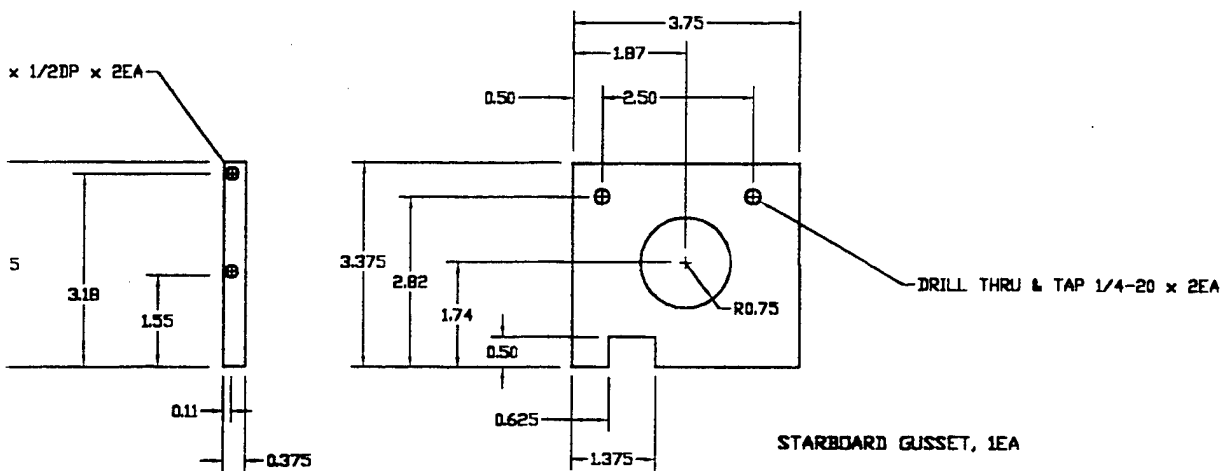


NOTES:
BREAK ALL SHARP EDGES

MATERIAL:
6AL-4V TITANIUM PLATE, 3/8"

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES		PROJECT NO 000000.00	
TOLERANCES		DRAWN	DATE
DECIMALS	ANGULAR	M. F. Bowen	4/14/97
.XX ±.01	±'	CHECK	28
.XXX ±.005			
DO NOT SCALE DRAWING			
MATERIAL			
AS NOTED			
FINISH			
AS NOTED			

2

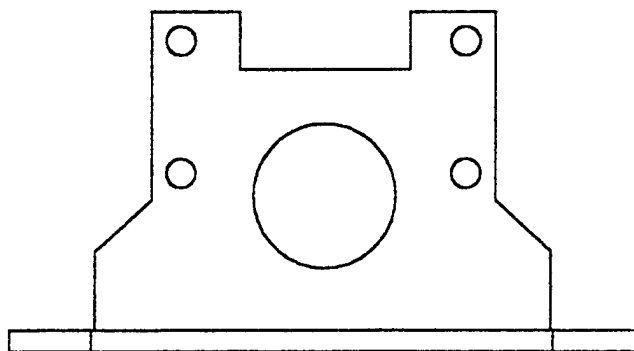
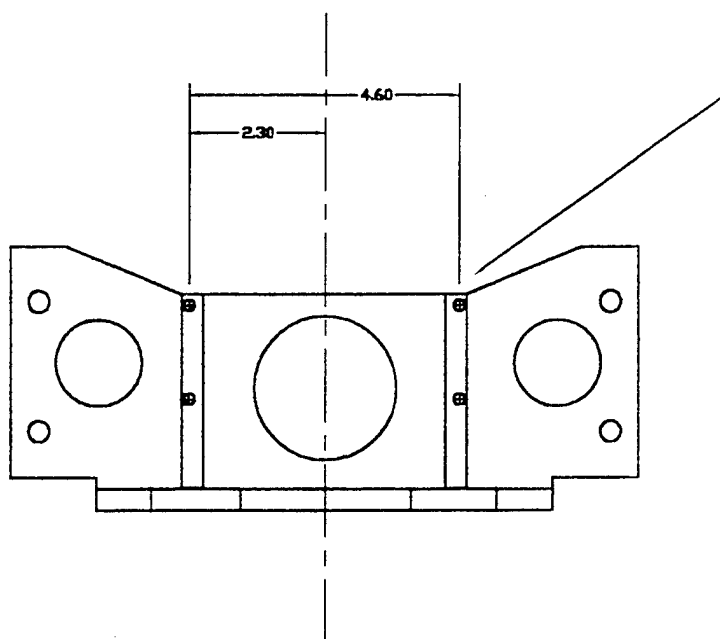
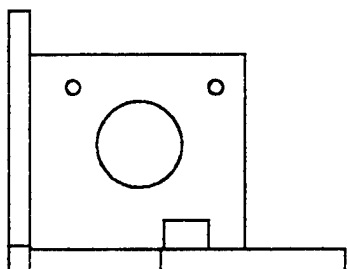
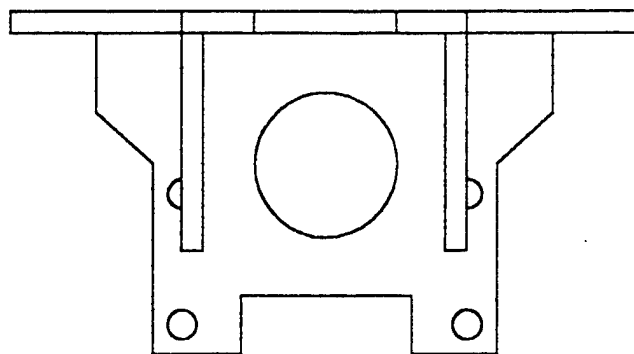
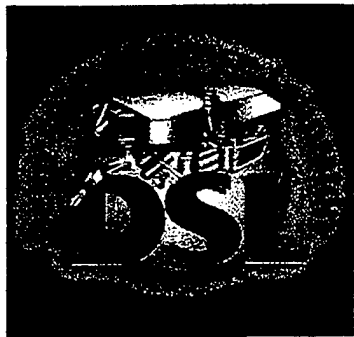


SHARP EDGES

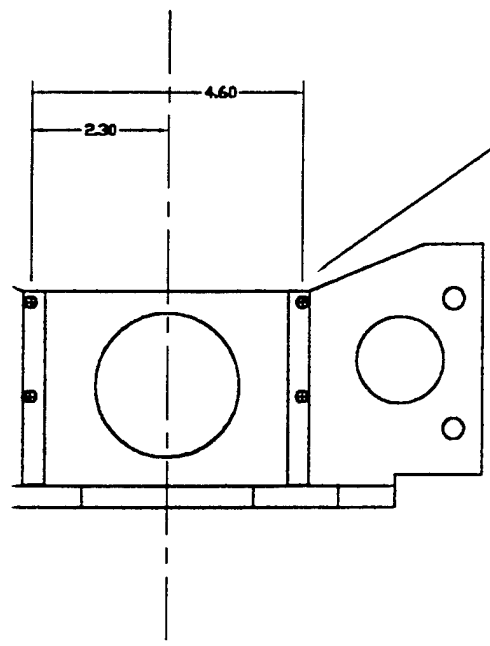
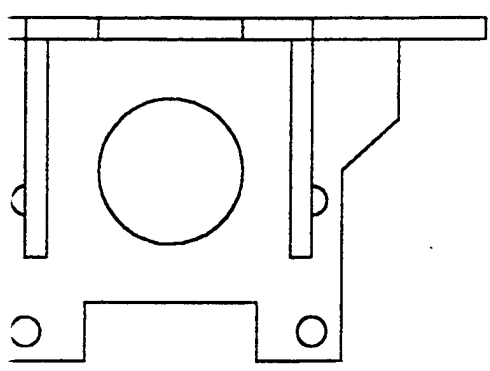
TANIUM PLATE, 3/8"

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS ANGULAR .XX ±.01 ±1° .XXX ±.005 DO NOT SCALE DRAWING		PROJECT NO 000000.00		WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING WOODS HOLE, MASSACHUSETTS, 02543	
		DRAWN M. F. Bowen	DATE 4/14/97	TITLE DIMENSION, LATCH MOUNT ODYSSEY AUV LATCH	
MATERIAL AS NOTED		CHECK	28		
FINISH AS NOTED				SIZE B	DWG NO. 156-97-008
				SCALE NONE	RELEASE DATE SHEET OF

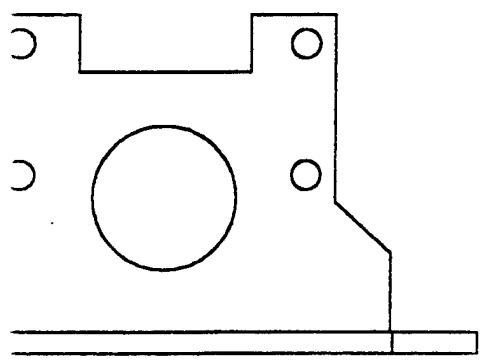
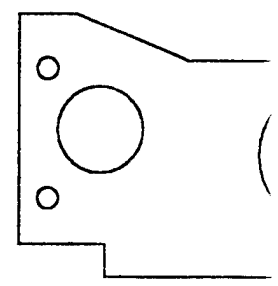
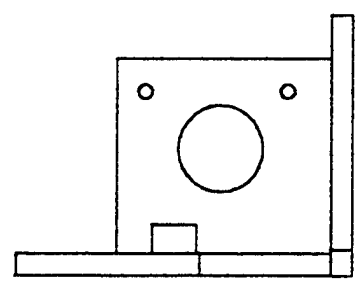
3



①

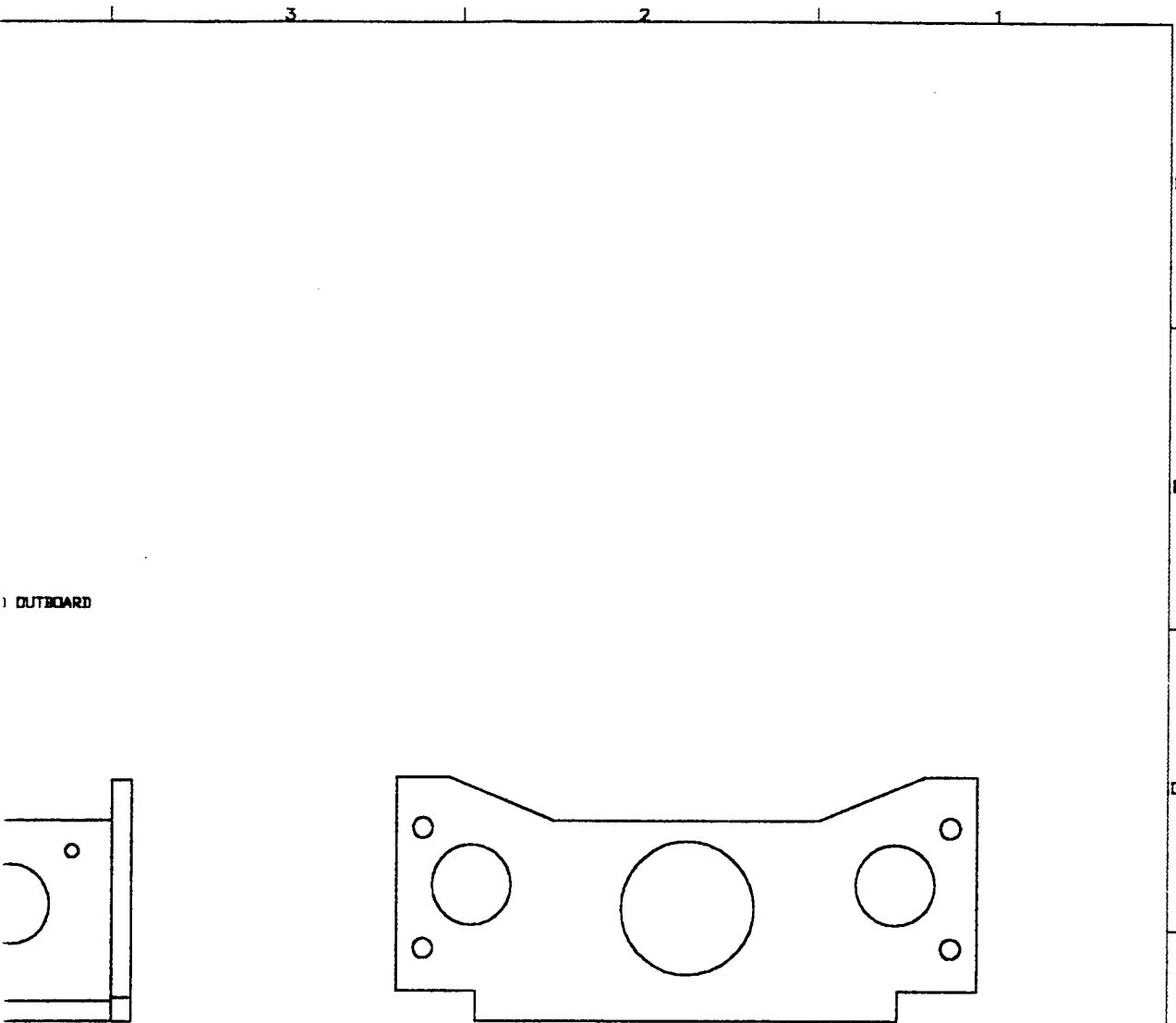


4-40 TAPPED HOLES POSITIONED OUTBOARD
LEFT AND RIGHT



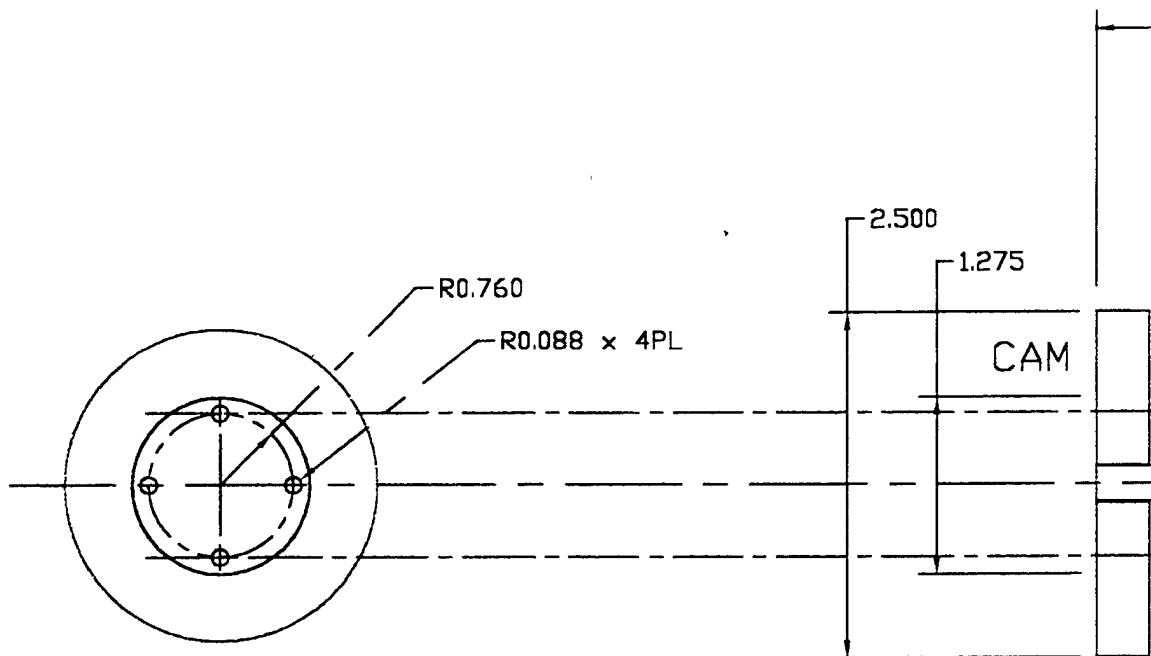
2

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES		PROJECT NO. 000000.00	
TOLERANCES		DRAWN	DATE
DECIMALS	ANGULAR	M. F. Bowen	4/12
XX ±.01	±°		
XXX ±.005			
DO NOT SCALE DRAWING		CHECK	29
MATERIAL AS NOTED			
FINISH AS NOTED			

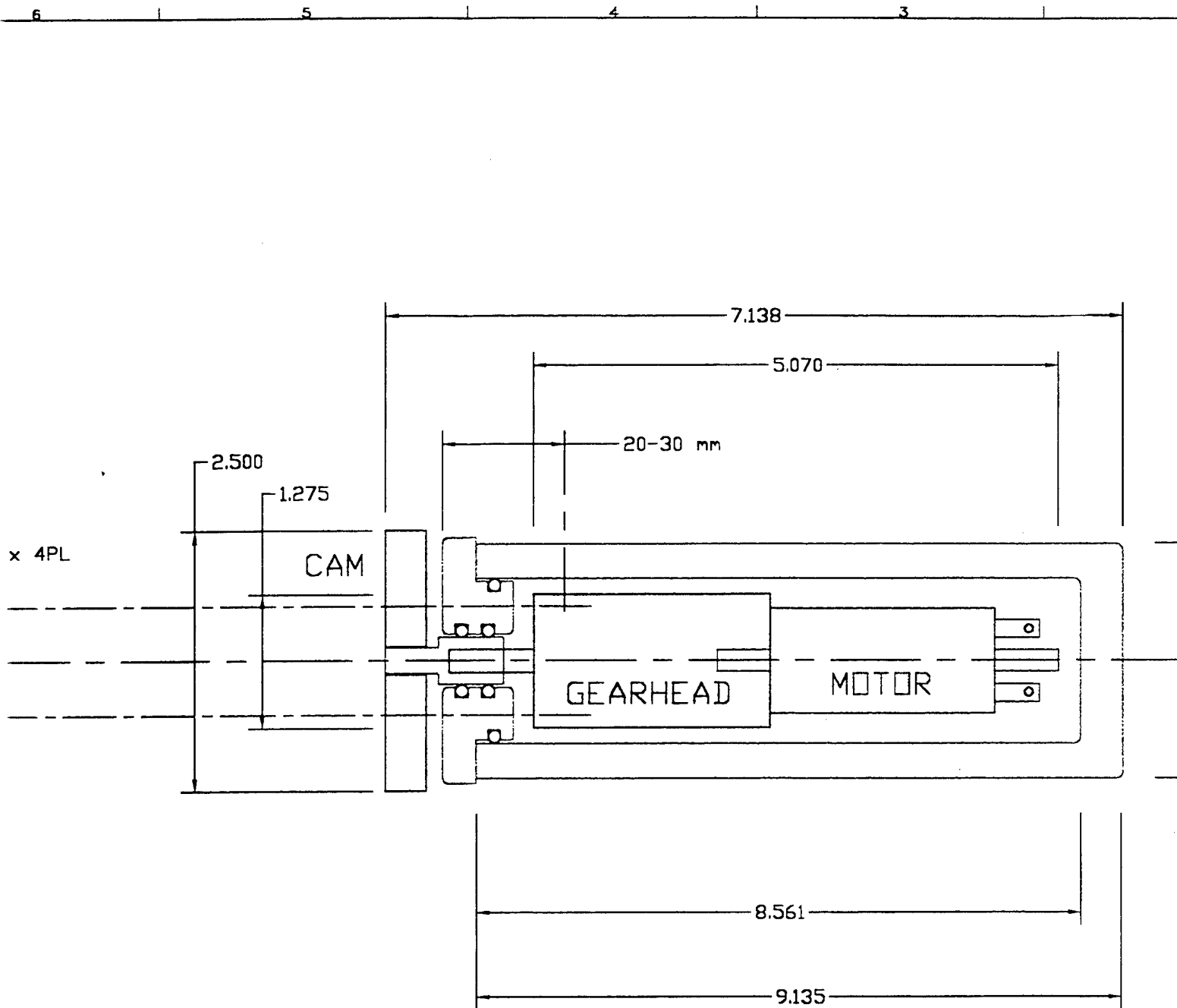


UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS ANGULAR .XX ±.01 .XXX ±.005 ±1° DO NOT SCALE DRAWING		PROJECT NO. 000000.00		WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING WOODS HOLE, MASSACHUSETTS, 02543	
		DRAWN M. F. Bowen	DATE 4/15/97	TITLE MOUNT WELDMENT ODYSSEY AUV LATCH	
MATERIAL AS NOTED		CHECK 29	SIZE B		
FINISH AS NOTED			DWG NO. 156-97-009		
			SCALE NONE	RELEASE DATE	SHEET OF

3

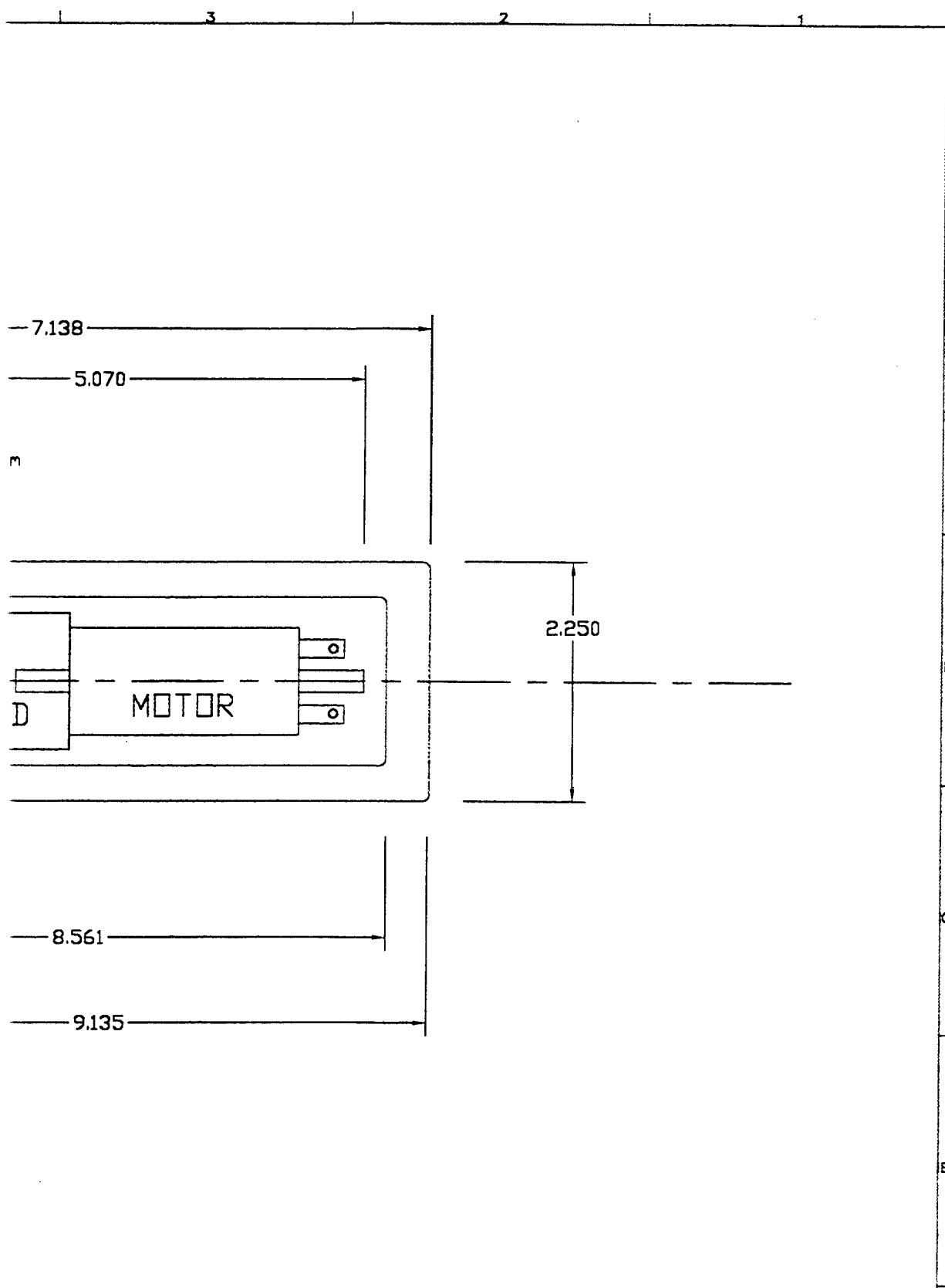


①



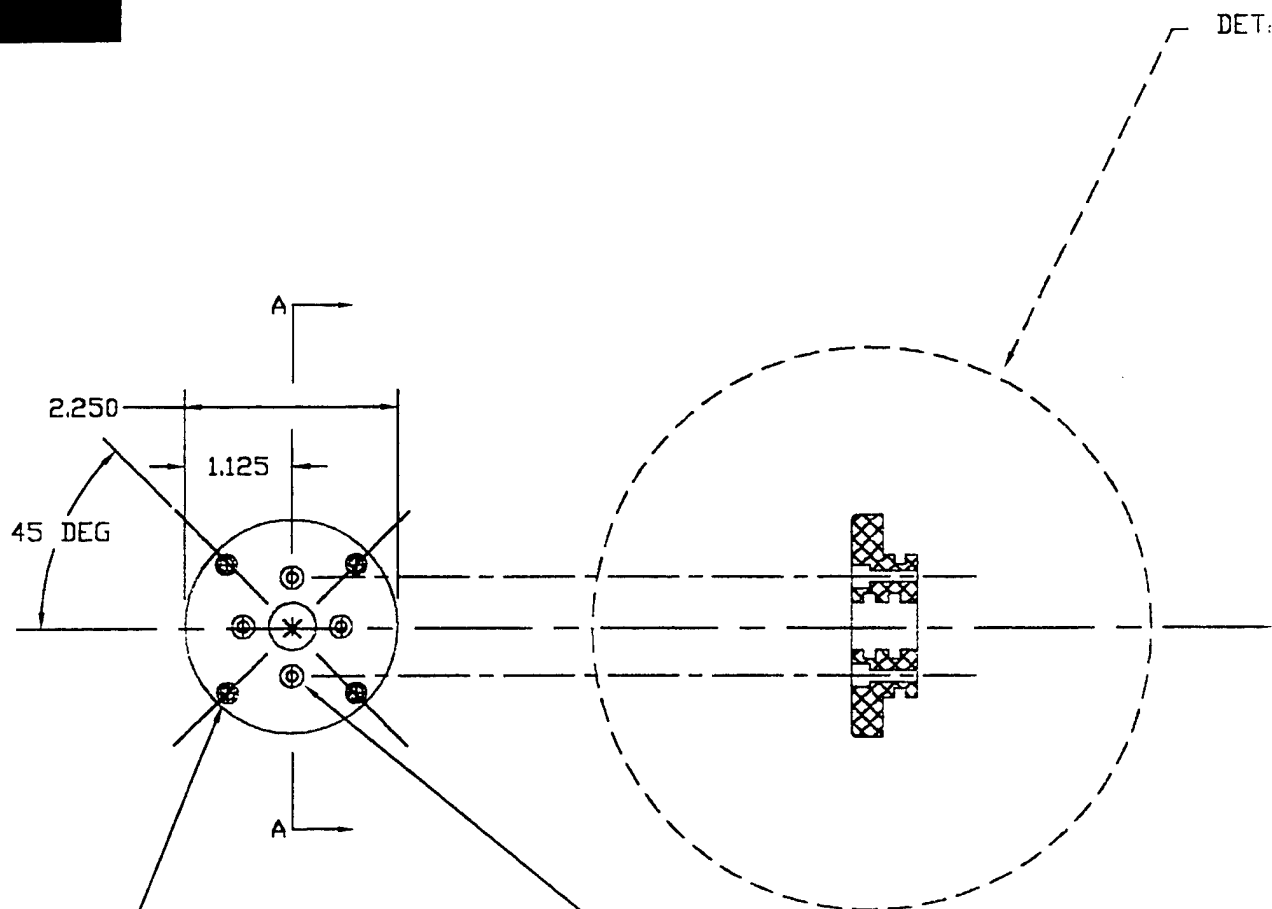
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES		PROJECT NO. 000000.00	
TOLERANCES		DRAWN	DATE
DECIMALS	ANGULAR	MF BOWEN	07/30/
.XX ±.01	±1°	CHECK	30
.XXX ±.005			
DO NOT SCALE DRAWING			
MATERIAL			
AS NOTED			
FINISH		AOP&E	MS #1.
AS NOTED			
		BIG G-3	289-34

2



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS ANGULAR .XX ±.01 .XXX ±.005 DO NOT SCALE DRAWING		PROJECT NO. 000000.00		WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING WOODS HOLE, MASSACHUSETTS, 02543	
		DRAWN MF BOWEN	DATE 07/30/97	TITLE ODYSSEY LATCH CAM MOTOR HOUSING OUTLINE	
MATERIAL AS NOTED		CHECK 30	SIZE B		
FINISH AS NOTED		AOP&E MS #13	SCALE NONE RELEASE DATE SHEET OF		
		BIG G-3 289-3420			

3

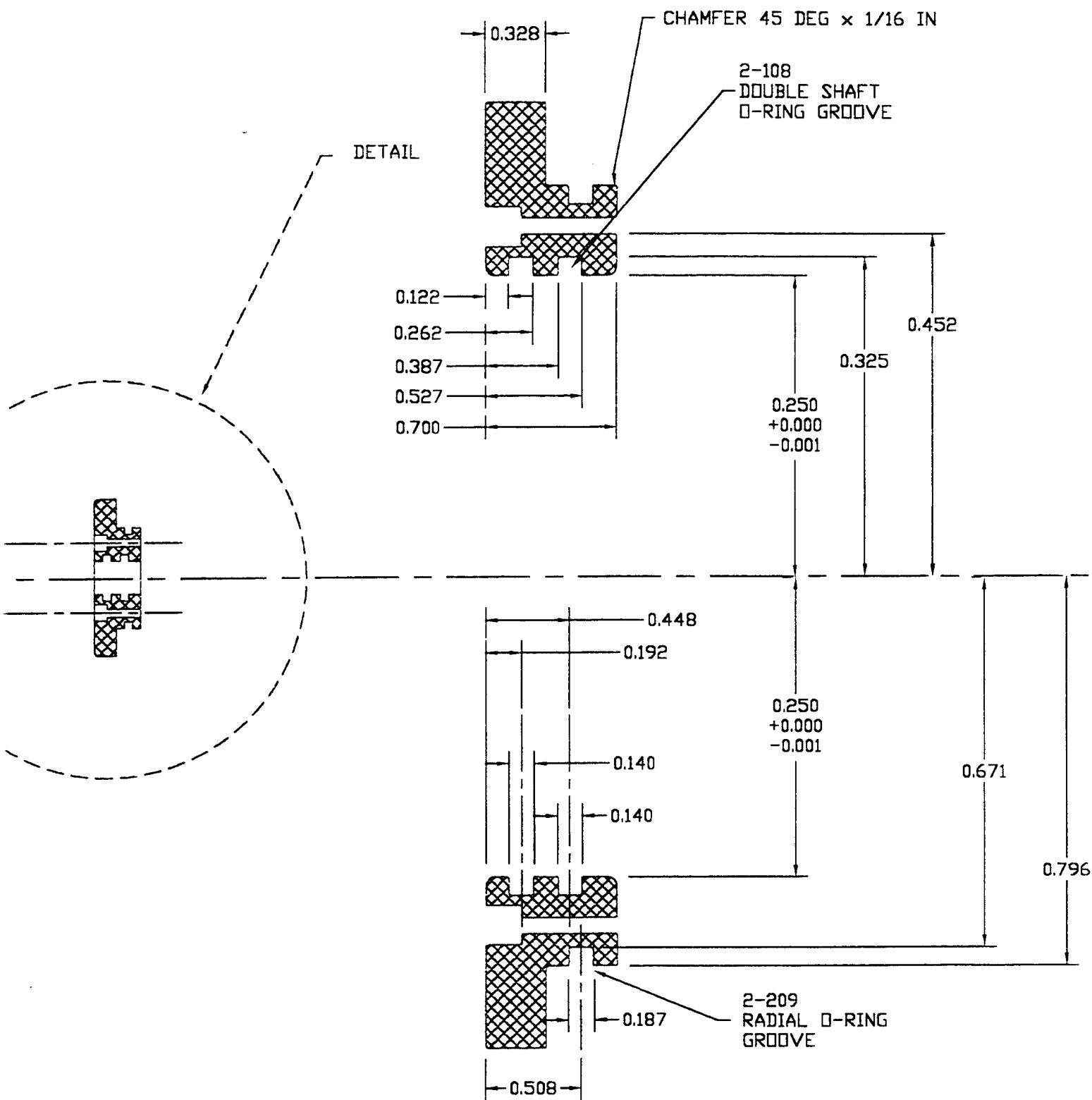


DRILL THRU 0.125 DIA x 4 PL
AND C'BORE 0.250 x 0.3 DP x 4 PL
ON A 1.024 DIA BOLT CIRCLE

DRILL THRU 6-32 BODY DRILL x 4 PL
AND C'BORE 7/32 DIA x 0.125 DP x 4 PL
ON A 1.922 DIA BOLT CIRCLE

NOTES:
MATERIAL: 6061 T6 ALUM ROUND ROD
PLEASE BREAK ALL SHARP EDGES

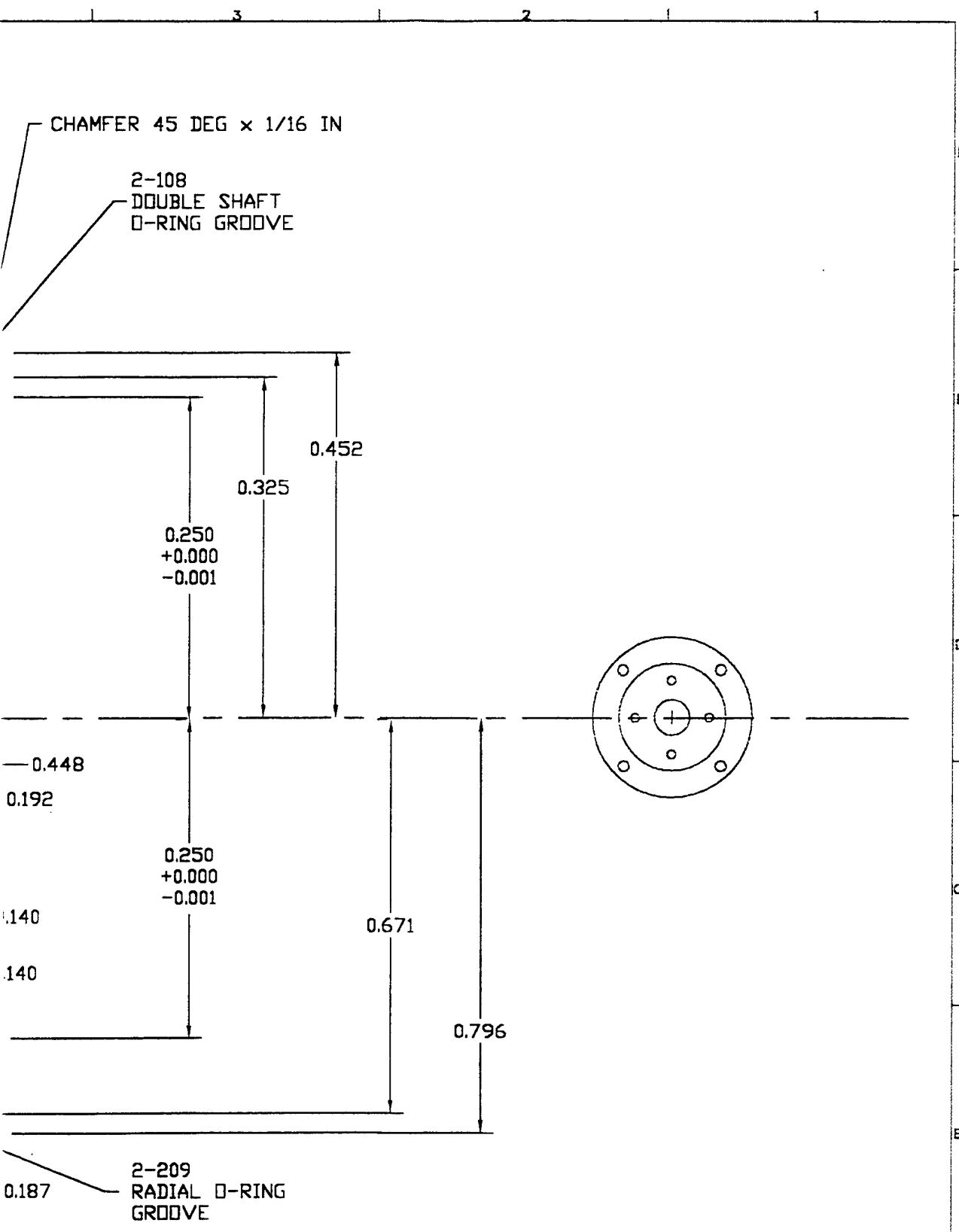
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DD

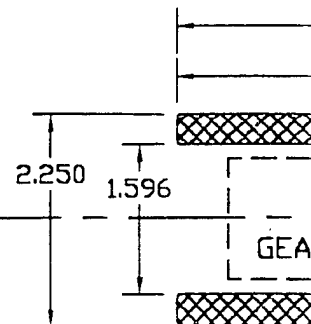
2

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES		PROJECT NO. 000000.00	
DECIMALS	ANGULAR	DRAWN	DATE
.XX ±.01	±1°	MF BOWEN	08/06/
.XXX ±.005		CHECK	31
DO NOT SCALE DRAWING			
MATERIAL AS NOTED			
FINISH AS NOTED		AOP&E	MS #
		BIG G-3	289-3

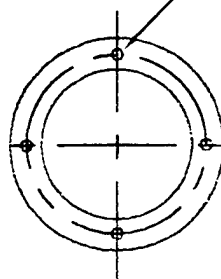


UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS ANGULAR XX ±.01 ±1° XXX ±.005 ±1° DO NOT SCALE DRAWING		PROJECT NO. 000000.00		WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING WOODS HOLE, MASSACHUSETTS, 02543	
		DRAWN MF BOWEN	DATE 08/06/97	TITLE ODYSSEY LATCH CAM ENDCAP	
		CHECK	31		
		MATERIAL AS NOTED	AOP&E	MS #13	SIZE B
FINISH AS NOTED	BIG G-3	289-3420	SCALE NONE	RELEASE DATE	SHEET 07

3

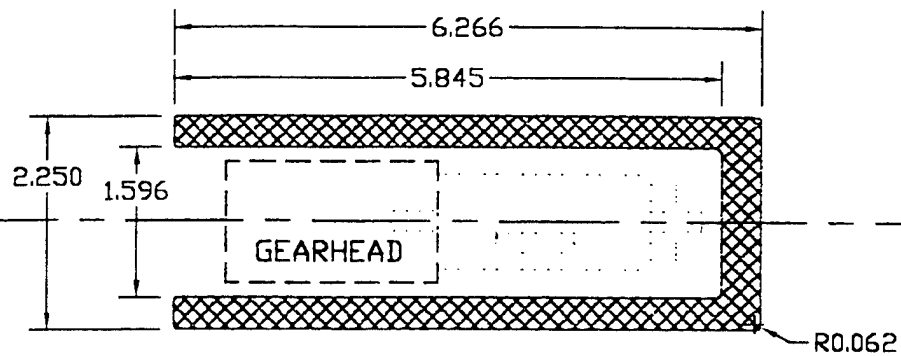


DRILL AND TAP 6-32 x 0.5
ON A 1.922 DIA BOLT CIRCLE



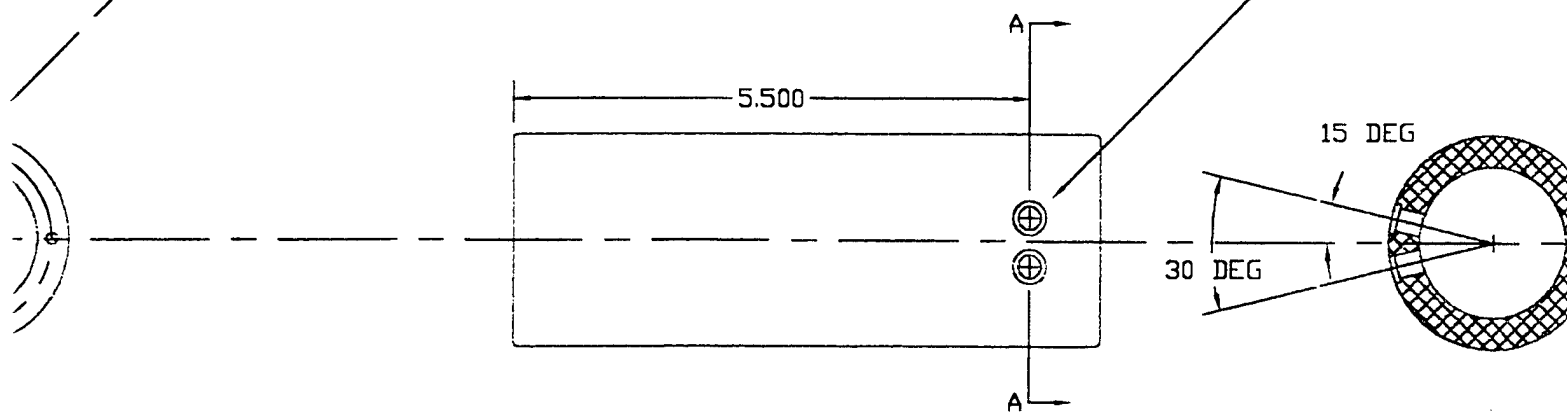
NOTES:
MATERIAL: 6061 T6 ALUM ROUND ROD
PLEASE BREAK ALL SHARP EDGES

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DRILL AND TAP 6-32 x 0.5 DP x 4 PL
ON A 1.922 DIA BOLT CIRCLE

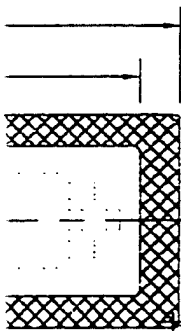
DRILL THRU AND C'BORE 0.1
TO MOUNT IMPL



M ROUND ROD
R/P EDGES

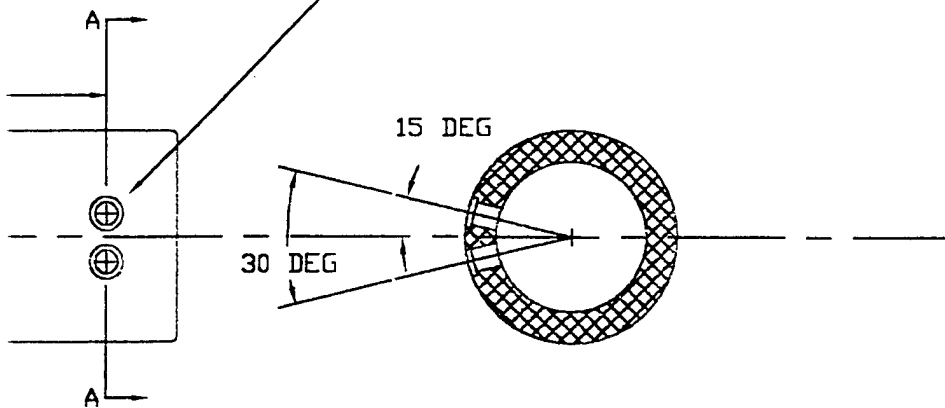
2

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES		PROJECT NO.
TOLERANCES		000000.00
DECIMALS	ANGULAR	DRAWN
XX ±.01	±1'	MF BOWEN
XXX ±.005		CHECK
DO NOT SCALE DRAWING		
MATERIAL		
AS NOTED		
FINISH		AOP&E
AS NOTED		BIG G-3



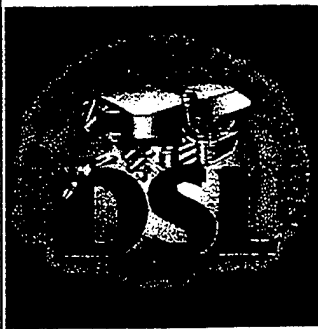
R0.062

DRILL THRU AND TAP 1/4-28 x 2 PL
AND C'BORE 0.365 DIA x 0.049 DP x 2 PL
TO MOUNT IMPULSE XSA-BC SINGLE PIN FEEDTHRU

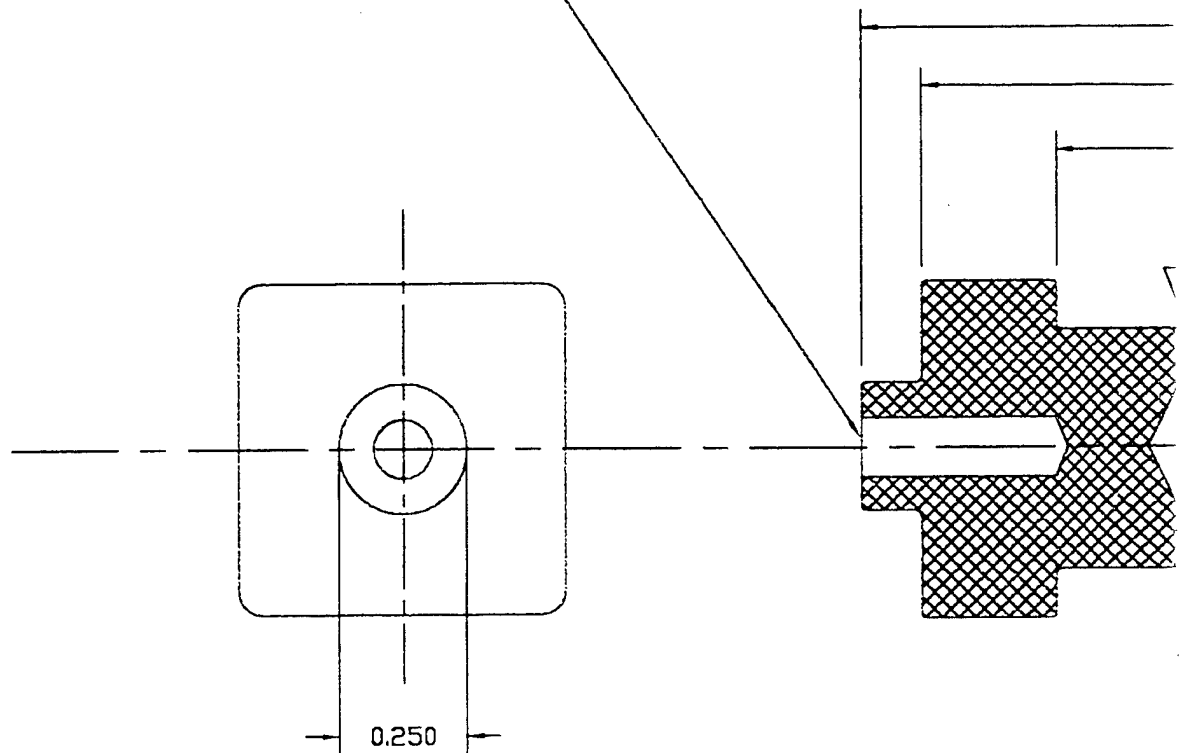


UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS ANGULAR .XX ±.01 ±1° .XXX ±.005 DO NOT SCALE DRAWING		PROJECT NO. 000000.00		WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING WOODS HOLE, MASSACHUSETTS, 02543	
		DRAWN MF BOWEN	DATE 08/06/97	TITLE ODYSSEY LATCH CAM MOTOR HOUSING DETAIL	
MATERIAL AS NOTED		CHECK	32		
FINISH AS NOTED		AOP&E	MS #13	SCALE NONE	RELEASE DATE
		BIG G-3	289-3420	SHEET OF	

3

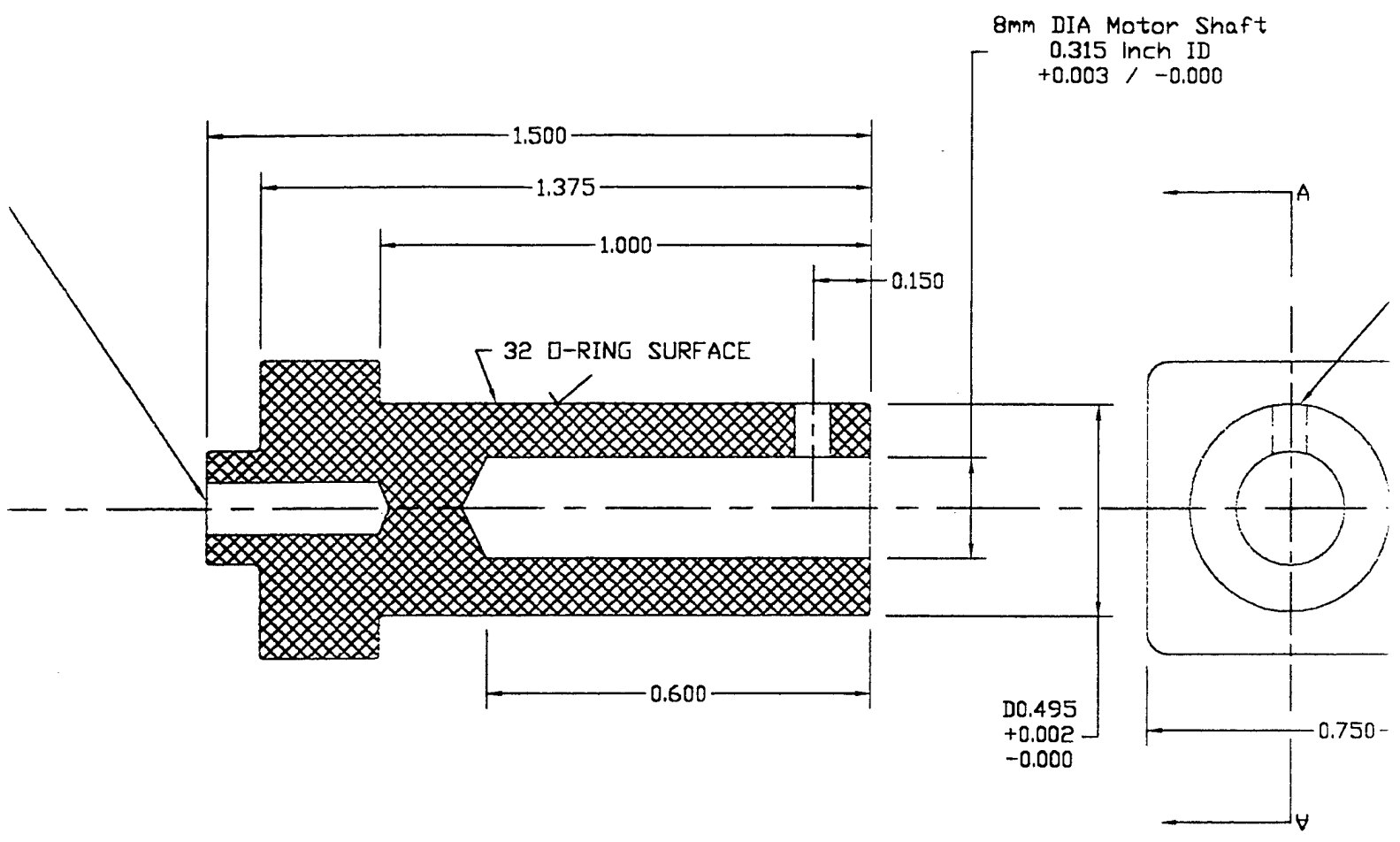


DRILL & TAP 8-32 x 1/2" DP



NOTES:
MATERIAL: 316 STAINLESS STEEL
PLEASE BREAK ALL SHARP EDGES

①

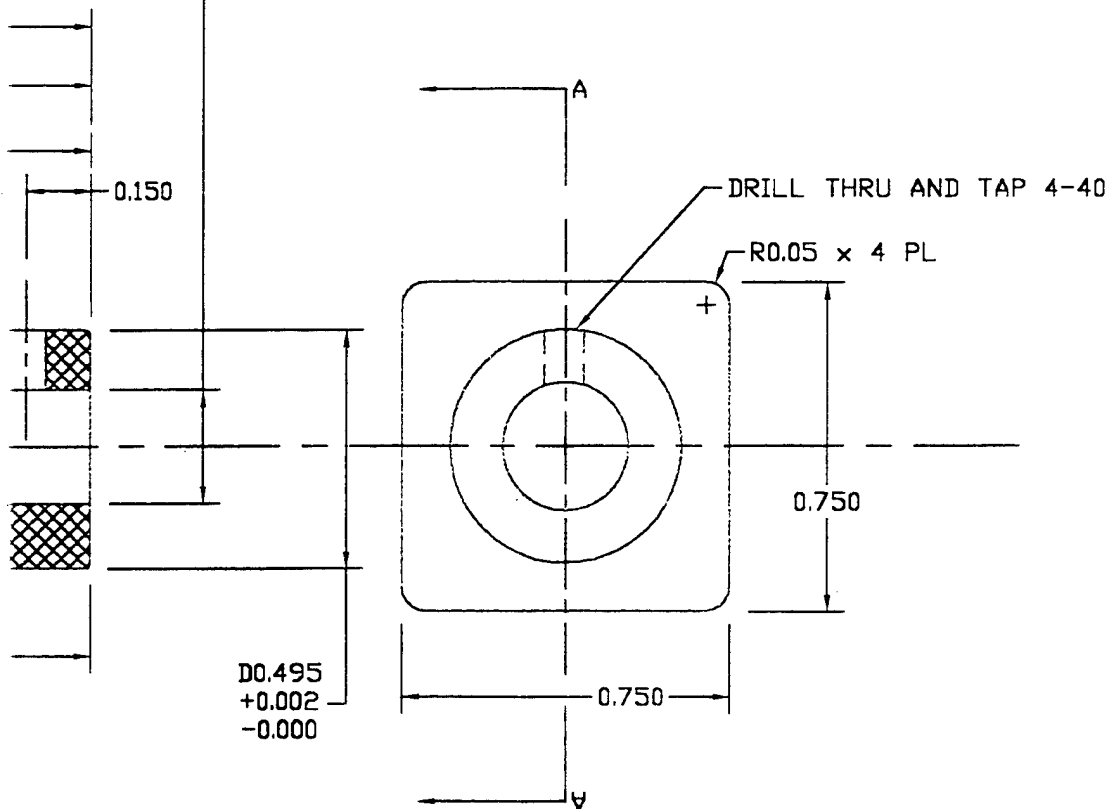


IS

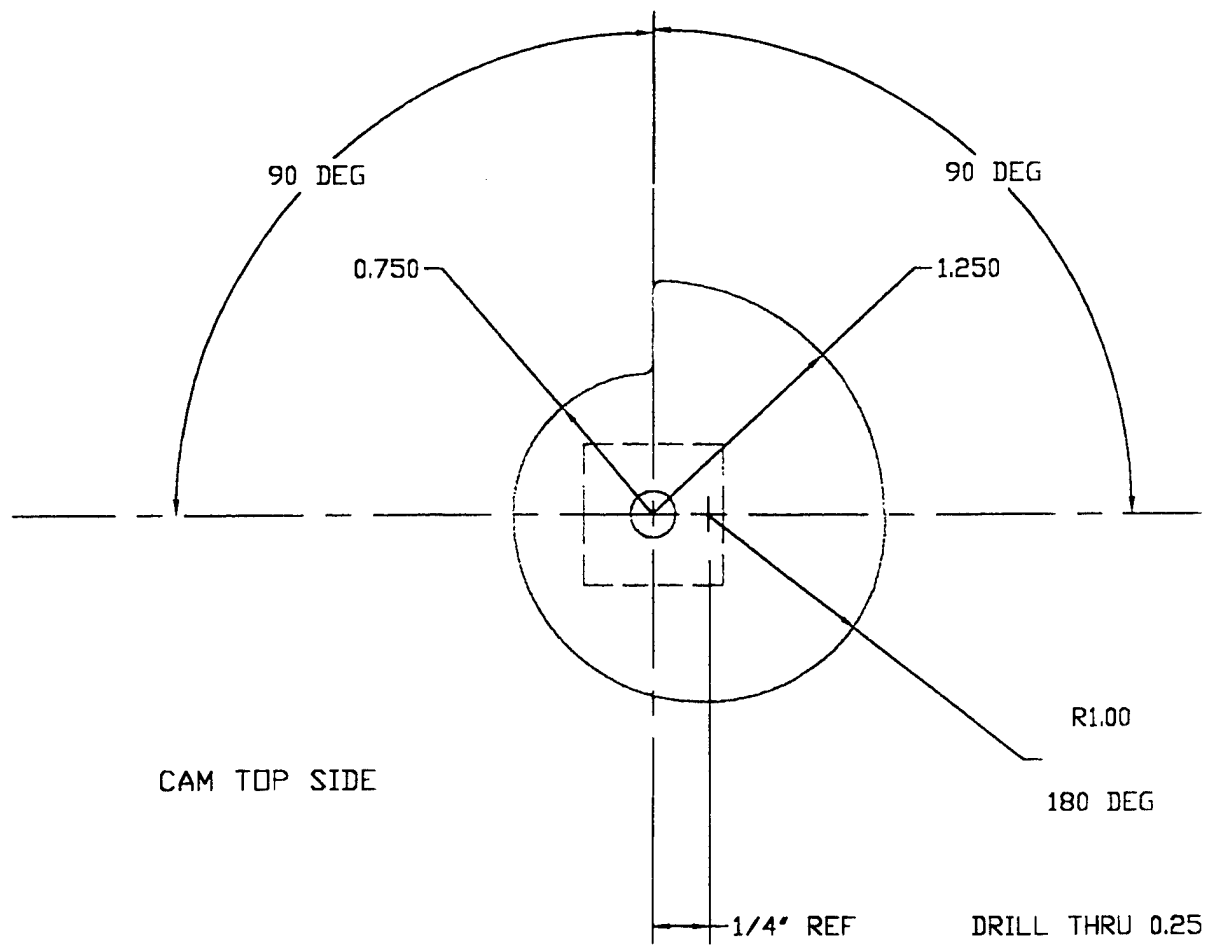
2

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES		PROJECT NO. 000000.00	
TOLERANCES		DRAWN	DATE
DECIMALS	ANGULAR	MF BOWEN	09/06/13
XX ±.01	±1°	CHECK	33
XXX ±.005	±1°		
DO NOT SCALE DRAWING			
MATERIAL AS NOTED			
FINISH AS NOTED		AOP&E	MS #13
		BIG G-3	289-341

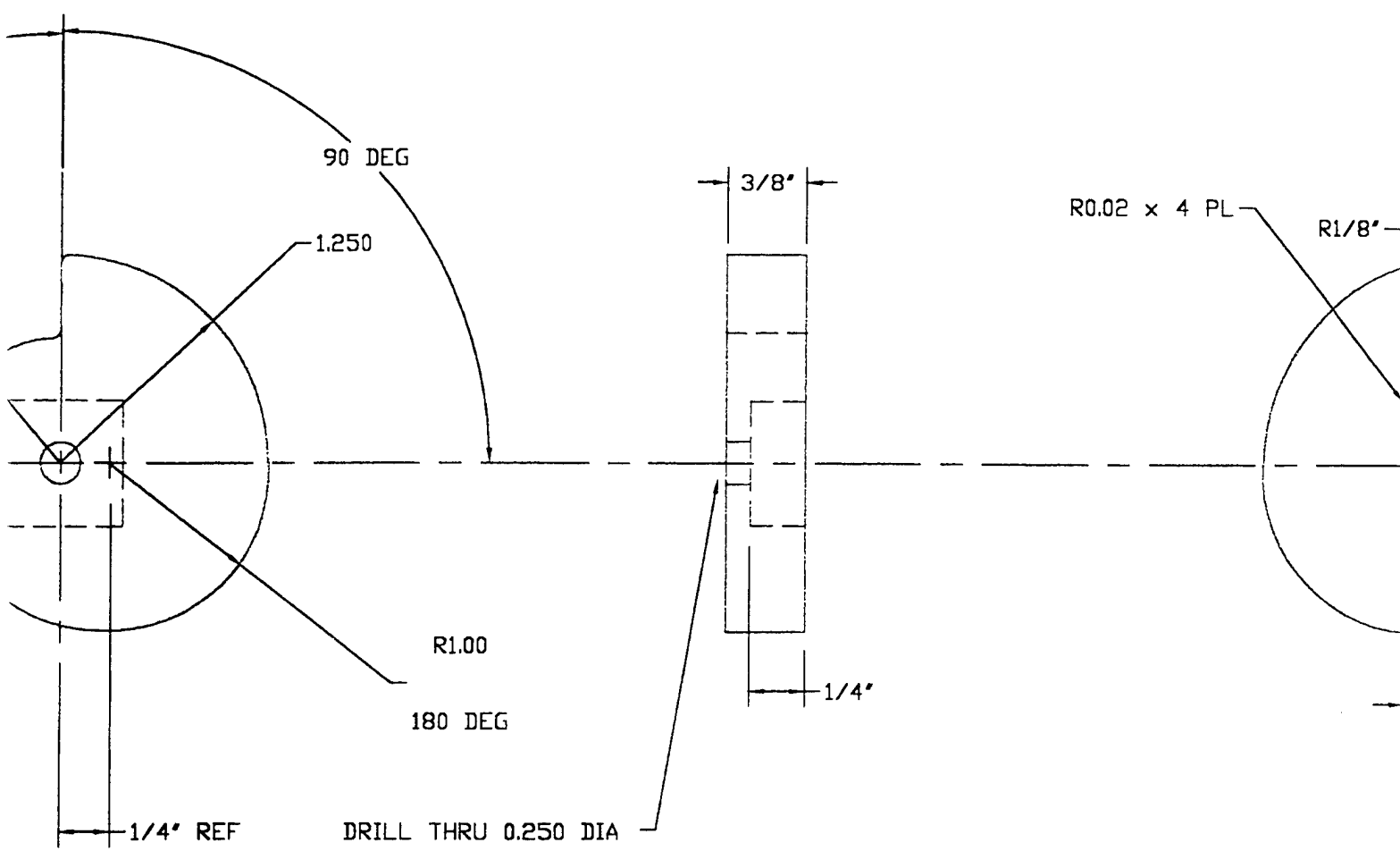
8mm DIA Motor Shaft
0.315 inch ID
+0.003 / -0.000



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS ANGULAR .XX ±.01 ±1° .XXX ±.005 DO NOT SCALE DRAWING	PROJECT NO. 000000.00		WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING WOODS HOLE, MASSACHUSETTS, 02543		
	DRAWN MF BOWEN	DATE 09/06/97	TITLE ODYSSEY LATCH CAM CAM SHAFT DETAIL		
	CHECK	33			
	MATERIAL AS NOTED	AOP&E	MS #13	SIZE B	DWG NO. 156-97-034
FINISH AS NOTED	BIG G-3	289-3420	SCALE NONE	RELEASE DATE	SHEET OF



NOTES:
MATERIAL: DELRIN
PLEASE MAKE ARC TRANSITIONS AS SMOOTH AS POSSIBLE

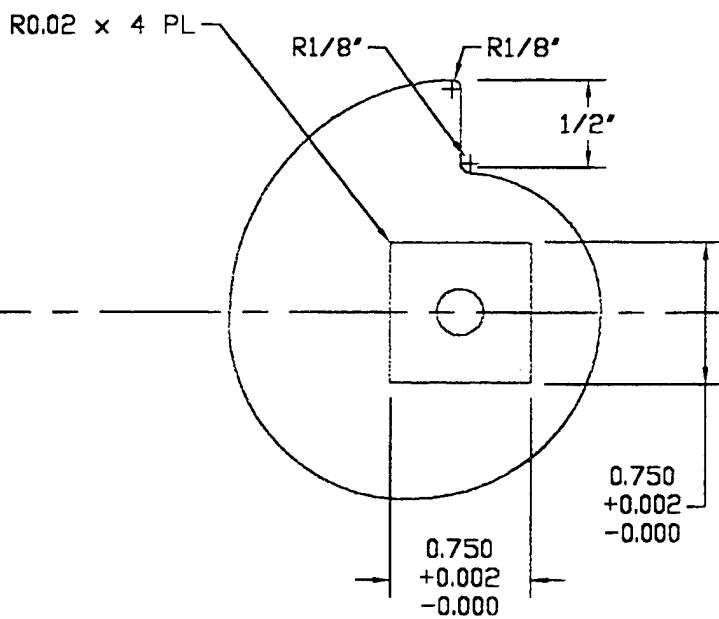


CAM MOTOR SIDE

ITIONS AS SMOOTH AS POSSIBLE

2

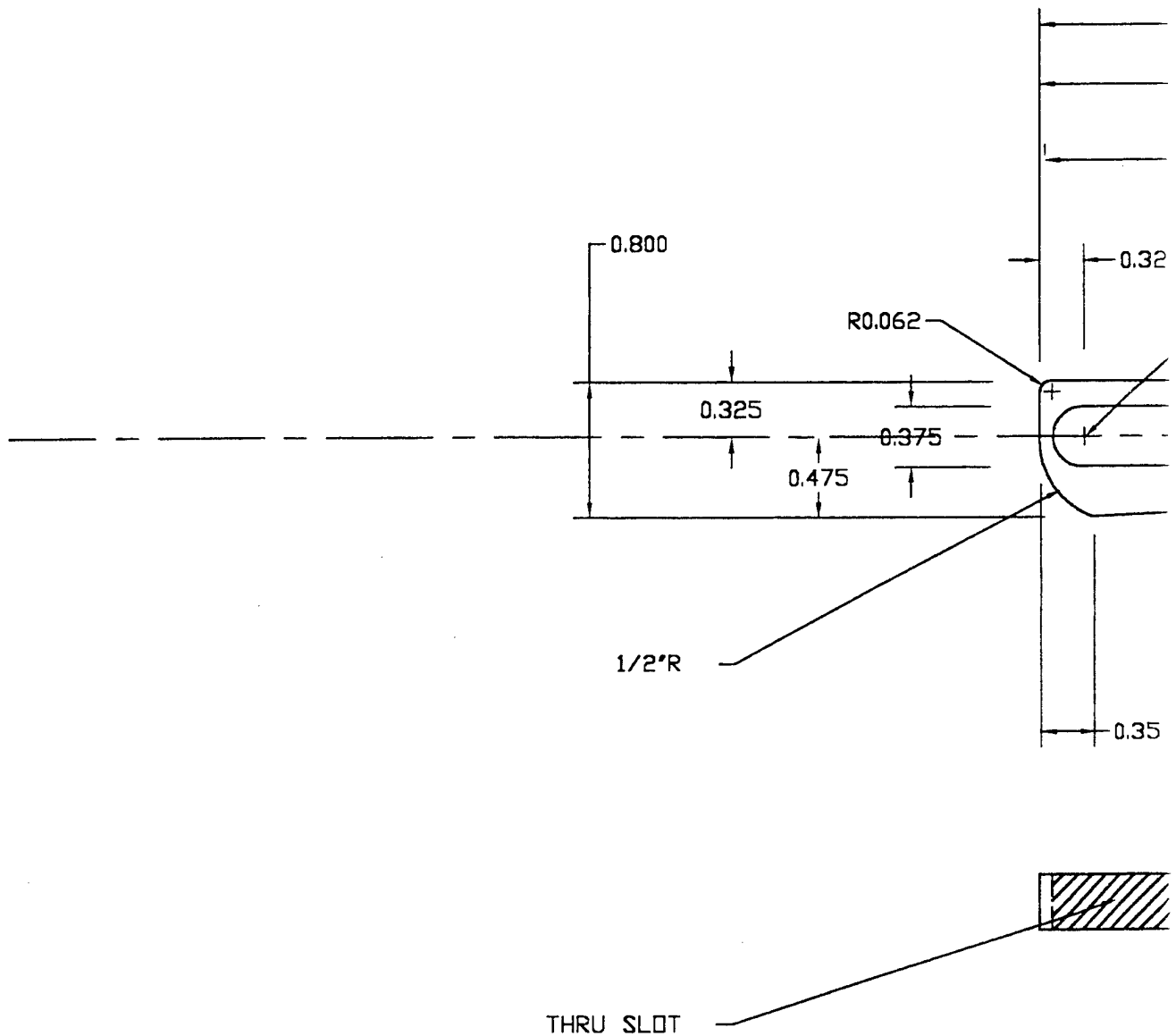
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES		PROJECT NO.
TOLERANCES		000000.00
DECIMALS	ANGULAR	DRAWN
XX ±.01	±1°	MF BOWEN
XXX ±.005		CHECK
DO NOT SCALE DRAWING		
MATERIAL		
AS NOTED		
FINISH		AOP&E
AS NOTED		
		BIG G-3



CAM MOTOR SIDE

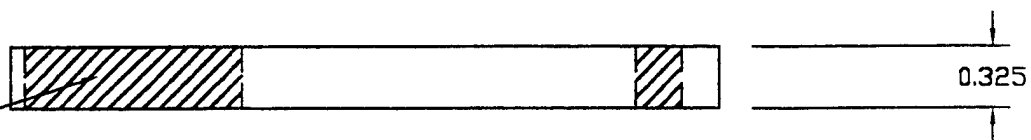
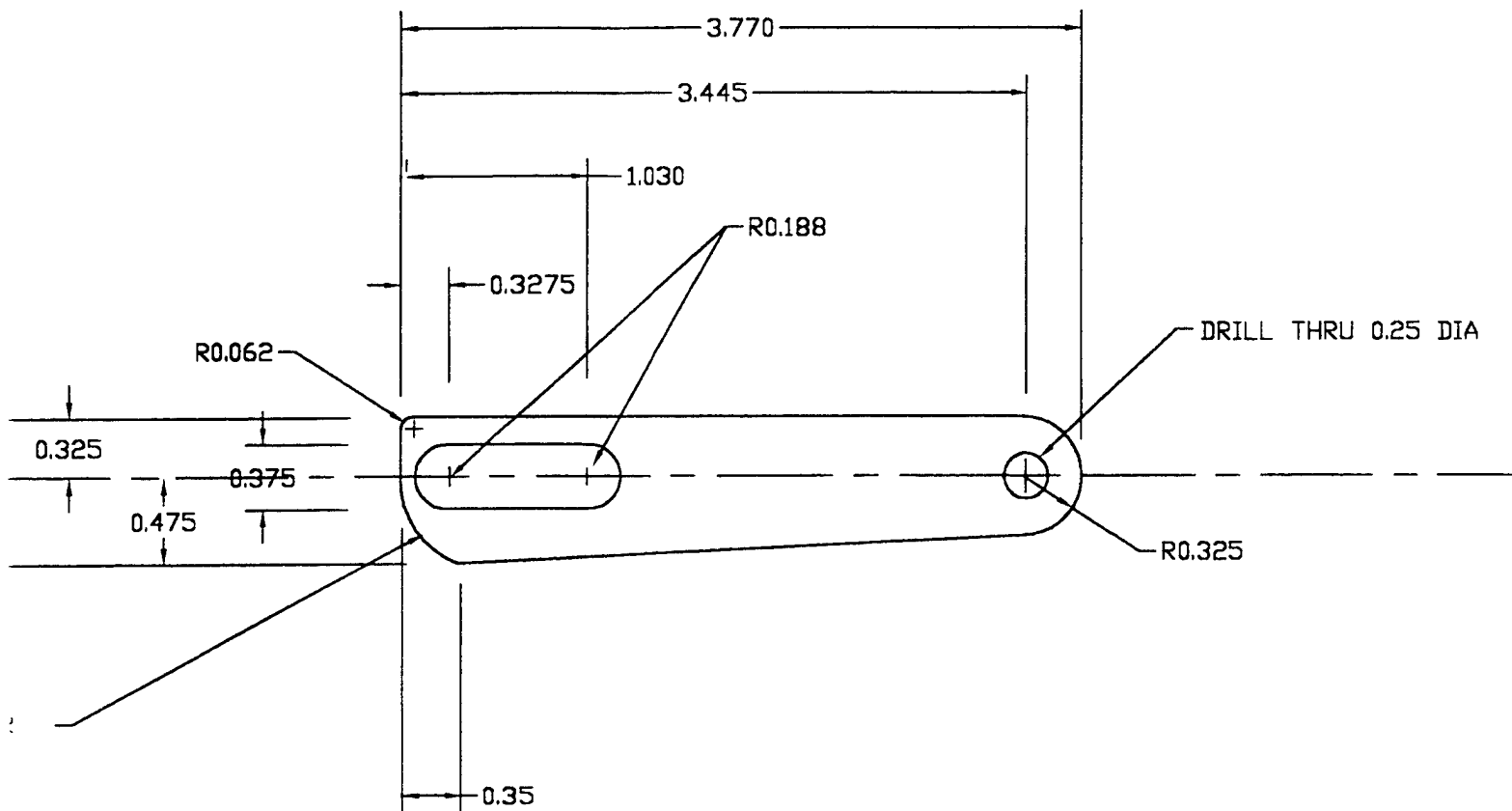
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS ANGULAR .XX ±.01 ±1° .XXX ±.005 DO NOT SCALE DRAWING		PROJECT NO. 000000.00		WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING WOODS HOLE, MASSACHUSETTS, 02543	
		DRAWN MF BOWEN	DATE 08/06/97	TITLE ODYSSEY LATCH CAM CAM DETAIL	
MATERIAL AS NOTED		CHECK 34	SIZE B		
FINISH AS NOTED		AOP&E	MS #13	DWG NO. 156-97-035	
		BIG G-3	289-3420	SCALE NONE	RELEASE DATE
				SHEET	OF

3



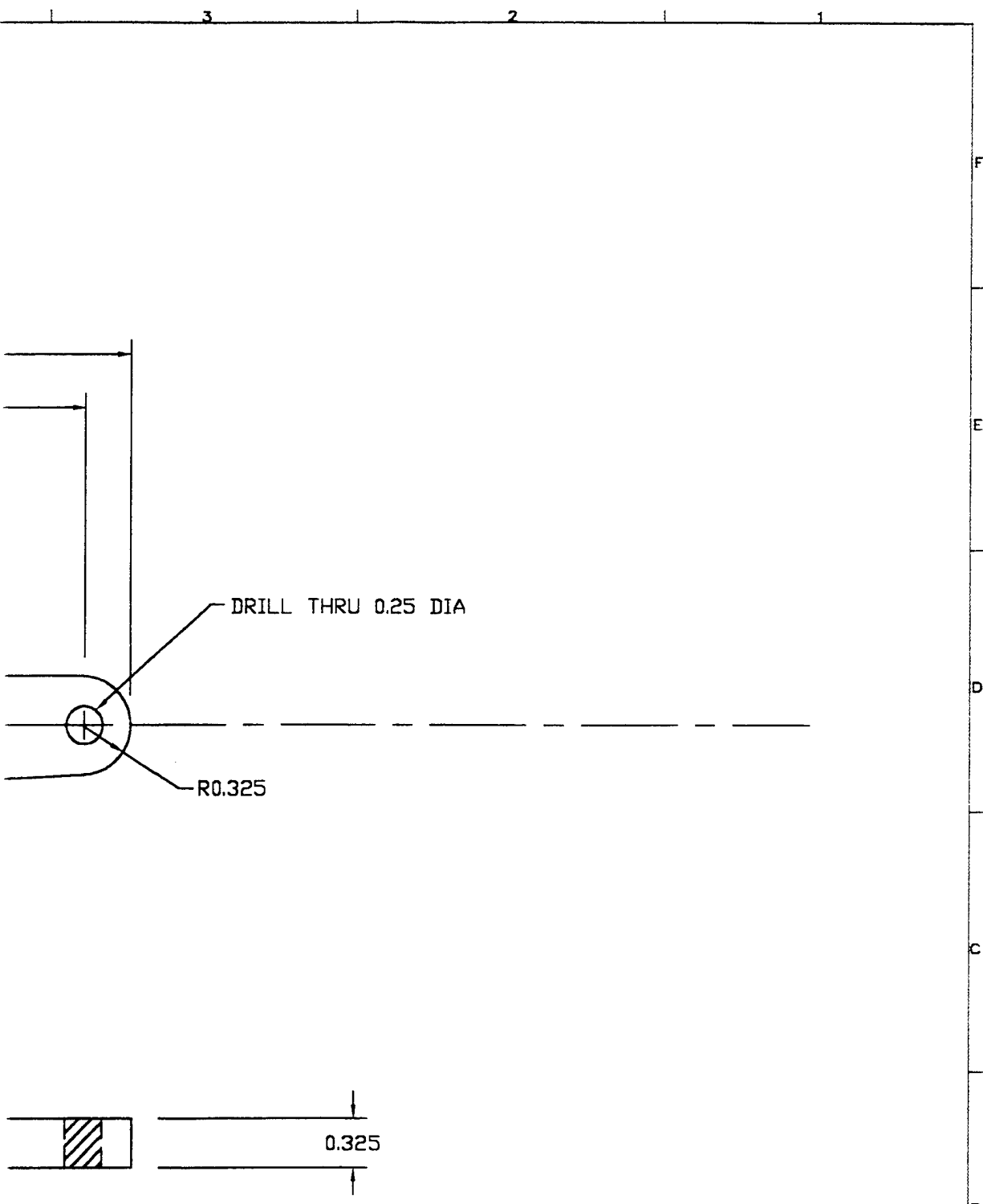
NOTES:
MATERIAL IS GRADE 2 TITANIUM
PLEASE BREAK ALL SHARP EDGES
2EA REQUIRED
MARTIN BOWEN x3420
DWG# 15697040.DWG

①



2

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES		PROJECT NO. 156077.00	
DECIMALS	ANGULAR	DRAWN	DATE
.XX ±.01	±1°	MF BOWEN	09/10
.XXX ±.005		CHECK	35
DO NOT SCALE DRAWING			
MATERIAL AS NOTED			
FINISH AS NOTED		AOP&E	MS
		BIG 402	289-

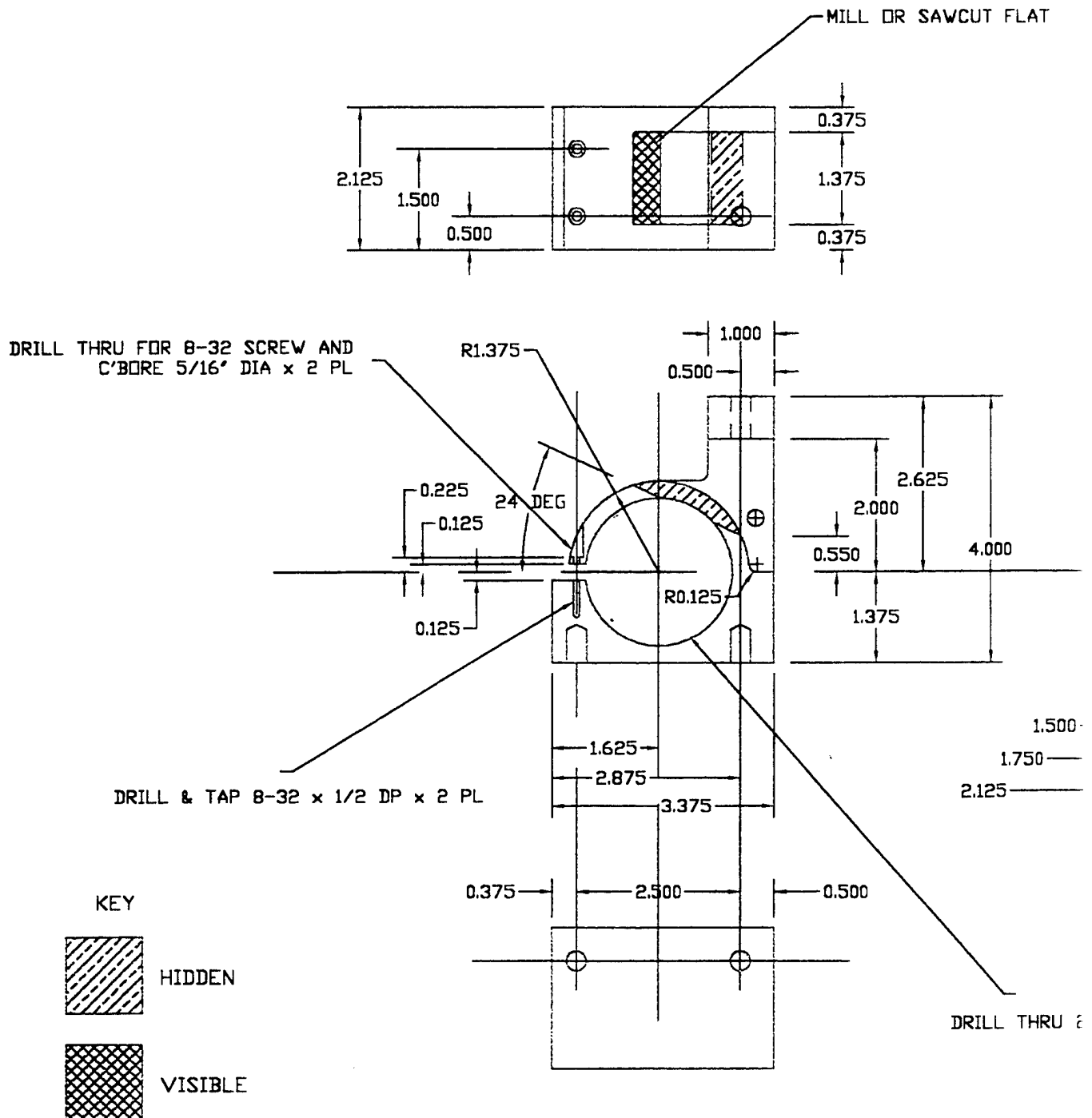


UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS ANGULAR .XX ±.01 °1' .XXX ±.005 °1' DO NOT SCALE DRAWING	PROJECT NO. 156077.00		WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING WOODS HOLE, MASSACHUSETTS, 02543	
	DRAWN MF BOWEN	DATE 09/10/97	TITLE ODYSSEY LATCH CAM LATCH LINK	
	CHECK	35		
	MATERIAL AS NOTED	AOP&E	MS #9	SIZE B
FINISH AS NOTED	BIG 402	289-3420	SCALE NONE	
			RELEASE DATE	SHEET OF

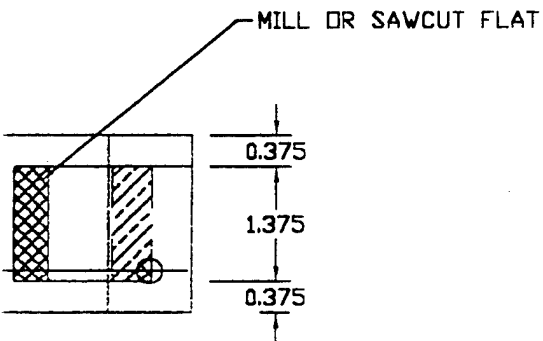
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MARTIN F. BOWEN
WHOI PHONE: 3420
ACCOUNT: _____
NO. REQUIRED: _____
COPYRIGHT 1998

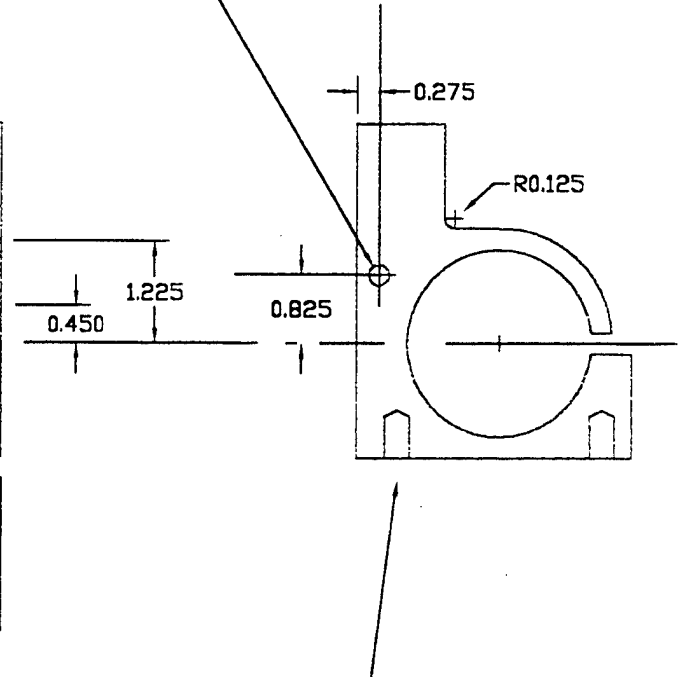
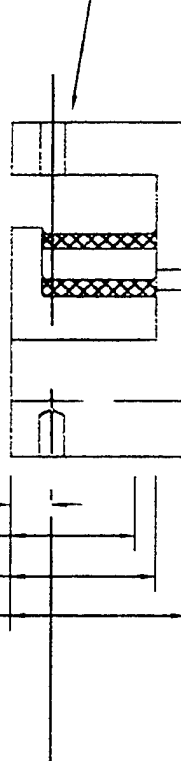
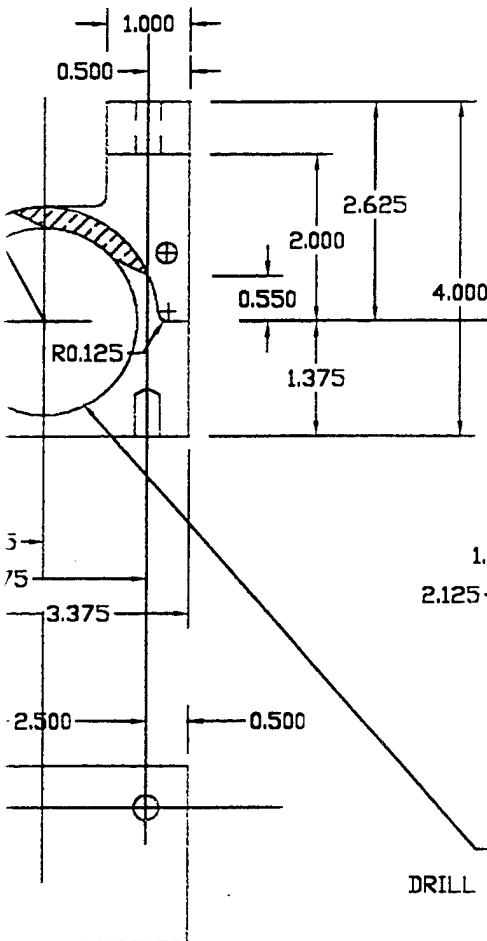


NOTES:
BLACK OR WHITE DELRIN
PLEASE BREAK ALL SHARP EDGES



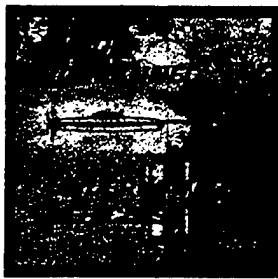
DRILL THRU & TAP FOR 1/4-20 BOLT

DRILL THRU & TAP 1/4-20



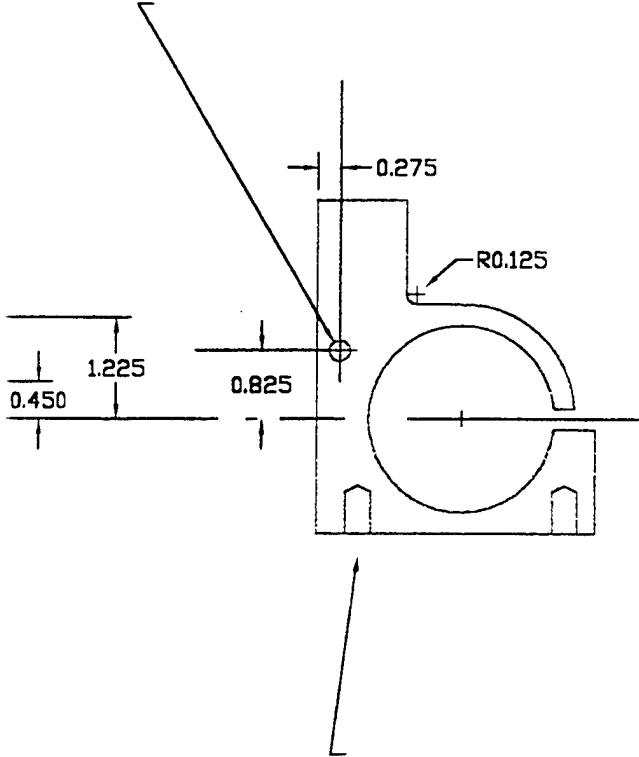
DRILL & TAP 1/4-20 x 1/2" DP x 2

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS ANGULAR .001 .015 .01° .001 .005 .01° DO NOT SCALE DRAWING	PROJECT NO. 156168.08		WOODS HOLE OCEANOGRAPHIC INST. APPLIED OCEAN PHYSICS & EN WOODS HOLE, MASSACHUSETTS.	
	DRAWN MF BOWEN	DATE 7 FEB 88	TITLE MOTOR MO ODYSSEY AUV	
	CHECK	17 x 22	SIZE C	DWG NO. 156
	MATERIAL AS NOTED	ADP&E MS #9	SCALE NONE	RELEASE DATE
FINISH AS NOTED	BIG 402	289-3420		



AP FOR 1/4-20 BOLT

DRILL THRU & TAP 1/4-20



DRILL & TAP 1/4-20 x 1/2" DP x 2 PL

36

OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES DIALS ANGULAR ±.01 ±.005 NOT SCALE DRAWING	PROJECT NO. 158168.08		WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING WOODS HOLE, MASSACHUSETTS, 02543		
	DRAWN MF BOWEN	DATE 7 FEB 88	TITLE MOTOR MOUNT ODYSSEY AUV LATCH		
	CHECK	17 x 22			
	AOP&E	MS #9	SIZE C	DWG NO. 156-98-041	
	BIG 402	289-3420	SCALE NONE RELEASE DATE		SHEET OF

③



TOP VIEW

NORTH

1

1

0

0

NEST

POLE

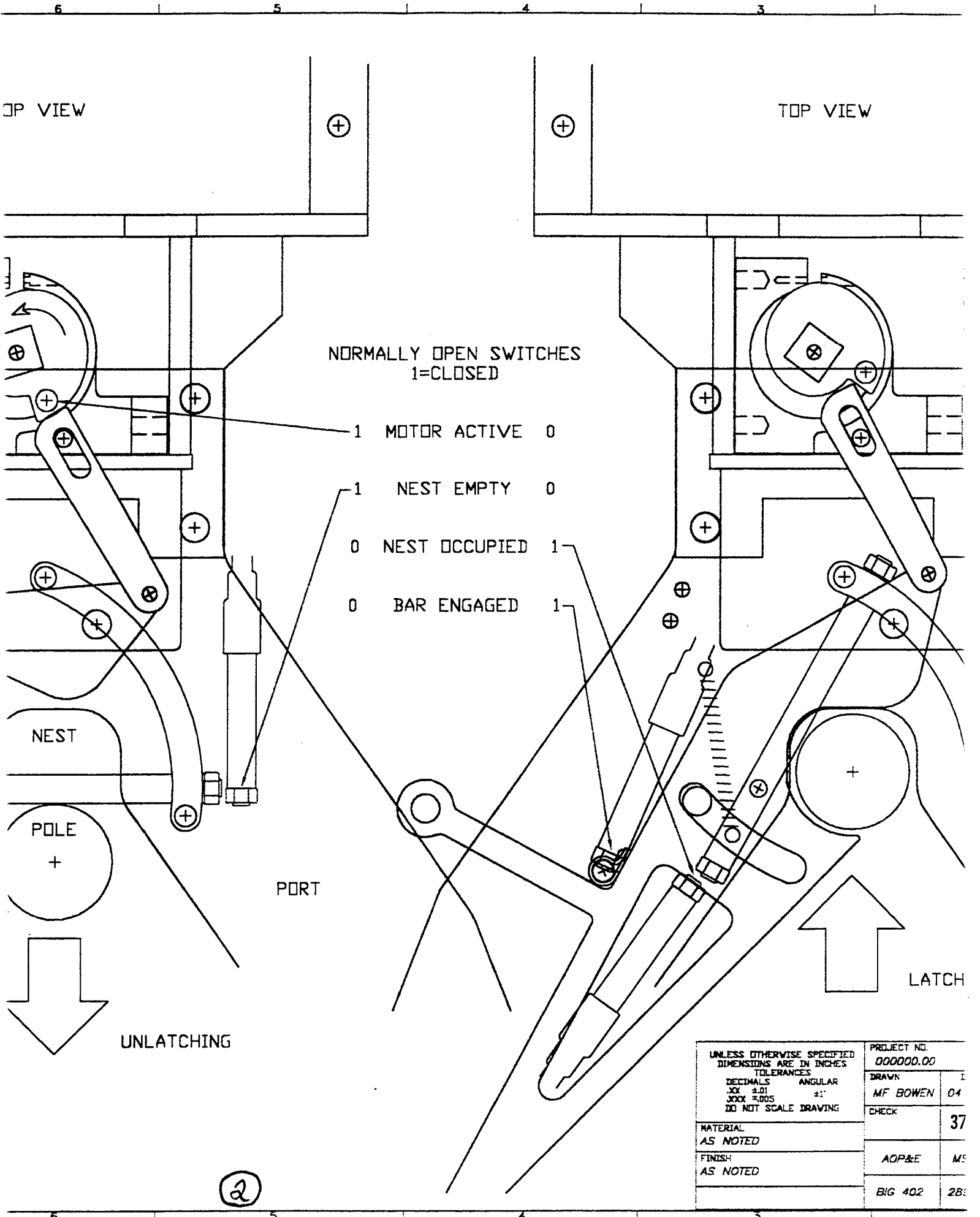
PORT

BAR

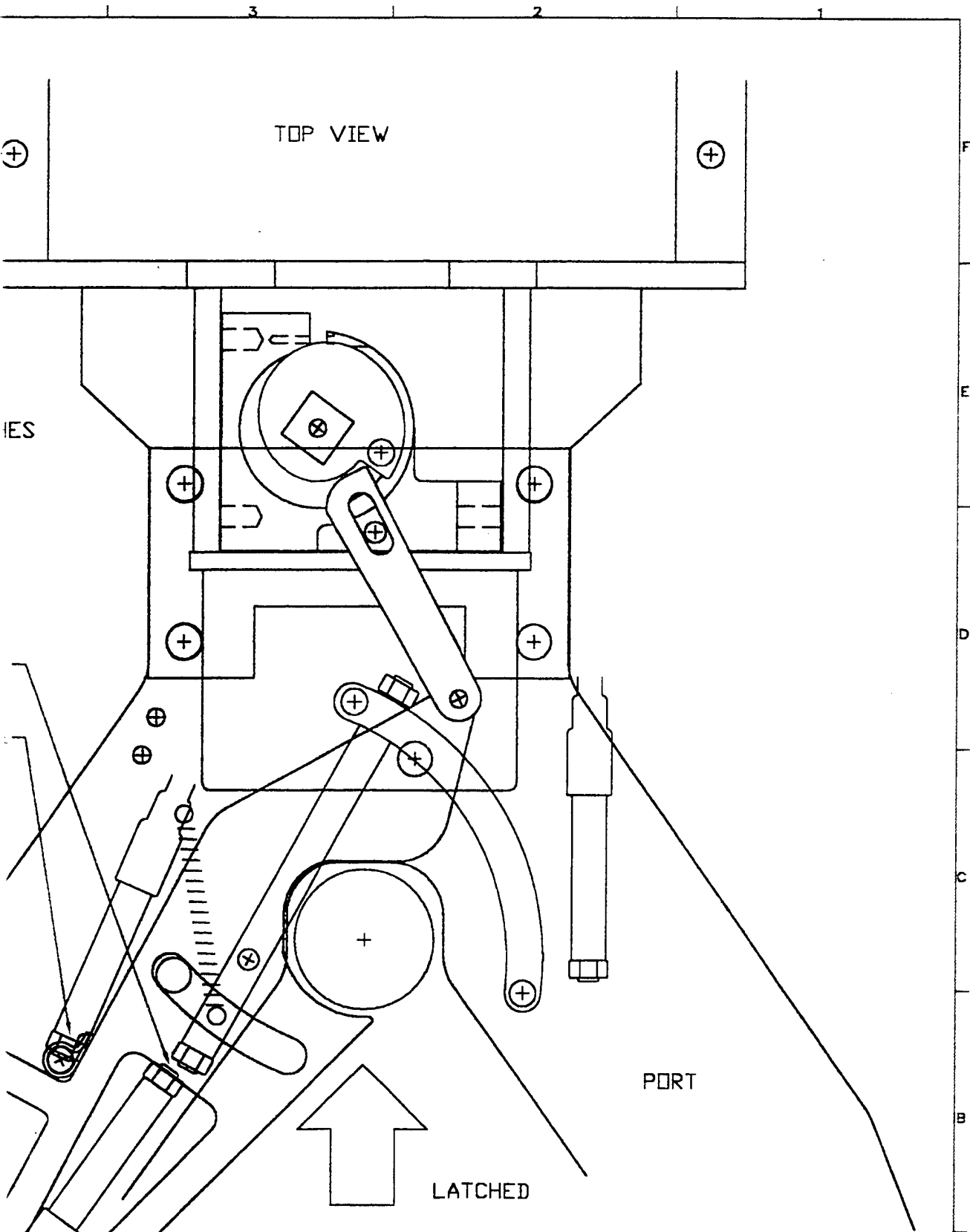
STARBOARD

UNLATCHING

①



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES		PROJECT NO. 000000.00	
TOLERANCES		DRAWN	04
DECIMALS	ANGULAR	MF BOWEN	
.XX ±.01	±1°	CHECK	37
.XXX ±.005			
DO NOT SCALE DRAWING			
MATERIAL			
AS NOTED			
FINISH		AOP&E	M5
AS NOTED			
		BIG 402	285



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS ANGULAR .XX ±.01 ±1° .XXX ±.005 DO NOT SCALE DRAWING	PROJECT NO. 000000.00		WOODS HOLE OCEANOGRAPHIC INSTITUTION APPLIED OCEAN PHYSICS & ENGINEERING WOODS HOLE, MASSACHUSETTS, 02543	
	DRAWN MF BOWEN	DATE 04 FEB 98	TITLE ODYSSEY VEHICLE LATCH MAGNETIC SWITCH MODES	
	CHECK 37			
	MATERIAL AS NOTED			
FINISH AS NOTED	AOP&E	MS #9	SIZE B	DWG NO. 156-97-043
	BIG 402	289-3420	SCALE NONE	RELEASE DATE
				SHEET OF

3

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16. Abstract (Limit: 200 words) Under subcontract to the Massachusetts Institute of Technology's (MIT) Sea Grant Autonomous Ocean Sampling Network (AOSN) program, the Woods Hole Oceanographic Institution's Deep Submergence Laboratory (WHOI-DSL) produced a passive capture latch for ODYSSEY-class autonomous underwater vehicles (AUVs). The latch is an all-titanium, split tine device, shock-mounted to the bow of the AUV. When the AUV concludes a survey mission and returns to a moored, midwater docking station, the latch leads the AUV's approach and is the first device to collide with the station's vertical docking pole. Latching to the pole is an entirely passive event requiring only forward motion of the AUV. A positive capture indication generated by proximity switches mounted on the device initiates AUV power and data transfer servicing by the station. Unlatching action requires one revolution of a latch motor cam and a brief backing command to the AUV thruster. The possibility of system malfunction was considered in latch design. If for any reason the latched vehicle cannot perform normal unlatching behavior, or the station fails, the latch defaults by securing the AUV to the moored station indefinitely. Two WHOI AUV latches have been used successfully on three offshore engineering test cruises.			
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