Ice detection tripod modification, 2006

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SUMMARY

This document outlines the design work completed as modifications to one of the new QuickSet Hercules tripods and tripod heads purchased by the Institute for Ocean Technology. These modifications will be implemented as part of the readiness design modifications in preparing one of the tripods for the IOT Ice Detection project 42_2096_10. The design work consists of attaching two potentiometers to the pan and tilt axes of the tripod so that pan and tilt angles may be measured.

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ICE DETECTION TRIPOD MODIFICATION, 2006

SR-2006-12

T. Osmond

April 2006

Quickset Tripod Head Design Modifications

The purpose of this design modification is to attach potentiometers to the Quickset tripod head so that changes in pan and tilt angles may be read and accurately measured by a computer.

Potentiometer Selection

Experimentation and analysis into three different potentiometers yielded the results contained under CAD_User\Projects\42_2096 Ice Detection\TOsmond\Pot Linearity.xls.
The data from these experiments are contained in Appendix A.
The potentiometers tested were (for data sheets see Appendix B):
A Bourns 3540,
A Bourns 6534,
And A Vishay Spectrol 157.

Two experiments were conducted on each potentiometer, fine linear measures and full range linear measurements. The same apparatus was used for both experiments. A dial was attached to the potentiometer and a quadrant encircled the potentiometer. In this way angle readings could be taken from visually from the quadrant. The potentiometer being tested was connected to a multimeter accurate to four decimal places and set to read voltage (see Figure 1).

For fine linear measurements the voltage output of each potentiometer was measured over a range of seven degrees. Readings were taken at 1/3rd of a degree intervals for a total of 21 readings each trial. Each potentiometer was tested three times.

For the full range linear measurements six to ten readings were taken of each potentiometer voltage over the full range of the individual potentiometer. Intervals were different because the full range of each of the potentiometers is different. Again three trial measurements were taken for each potentiometer. All data was analyzed in Microsoft Excel.

The three potentiometers were selected for testing based on availability from the electronics department. Data analysis following testing and consultation with Dr. Robert Gagnon decided the Vishay Spectrol 157 to yield the most accurate and predictable results. This potentiometer was selected to measure the angles in both pan and tilt. This potentiometer also carries the advantage of being capable full 360^{o} travel without failing although the potentiometer has a dead band between 340^{o} and 360^{o}. This removes the risk of damaging the potentiometer by over-rotating it.

Following selection of the potentiometer to be used more extensive testing was conducted to gain a more accurate understanding of the linear characteristics of the piece of equipment. This involved taking voltage readings at 18 locations

over the full range of the potentiometer over a series of five test trials. The results from these experiments are also contained in Appendix A.

Experimentation has indicated that the Vishay Spectrol 157-11/03 potentiometer displays linear characteristics with variation following a fourth power curve. Measured to this curve we have an accuracy of within approximately 10 ohms over a range of 300 degrees. This curve yields an error of approximately 0.35 degrees.

Though all potentiometers will have a different error in linearity the potentiometer we tested followed a linear profile of y = 7E-11x4 - 5E-09x3 - 2E-05x2 + 0.0303x + 0.0363. Readings were taken every 20 degrees and the change in resistance or increase in resistance over 20 degrees was found to follow the curve y = -8E-08x4 + 6E-05x3 - 0.0161x2 + 1.0532x + 548.98. In both cases fourth order polynomials were found to follow the data most accurately checking trends up to the sixth order polynomial as available in Microsoft Excel.

Looking at using brass gears from the available selection on www.smallparts.com.
Brass Spur Gears – 32 pitch 20^{o} pressure angle.
http://www.smallparts.com/products/descriptions/gbs.cfm shows a table of gear selections (see also Appendix C).
The 1" gear GBS – 3232 is the smallest gear that will fit our potentiometer with no machining necessary. This attributed to the gear bore of 0.25" and the potentiometer shaft diameter of 0.249". This gear will be used in both pan and tilt applications.

Tilt Gearing
For this axis we need at least 90 degrees rotation. We can use up to 300 degrees on the potentiometer. Thus our maximum gear ratio must be 300/90 = 3.33:1. Using our available gear ration of 3:1 we will use a range of 270 degrees rotation of the potentiometer. This will yield a maximum resolution of 0.117 degrees.

Potentiometer pinion – 1" GBS – 3232
Tripod gear – 3" GBS – 3296

This gear will be mounted on the non-toothed side of tripod head and the potentiometer will attach to the base of the head (see drawing 2096U01 – Appendix D).

Pan Gearing
For this axis we need at least 180 degrees rotation. We can use up to 300 degrees on the potentiometer. Thus our maximum gear ratio must be 300/180 = 1.67:1. Using our available gear ration of 1.5:1 we will use a range of 270

degrees rotation of the potentiometer. This will yield a maximum resolution of 0.233 degrees.

Potentiometer pinion – 1" GBS – 3232
Tripod gear – 1.5" GBS – 3248

This gear will mount within the center of the tripod and the potentiometer will attach to the base of the head (see drawing 2096U02 – Appendix D).

Modifications and Design

Several modifications to the tripod are necessary. A number of unique pieces are to be fabricated by the Institute. These drawings are available under file: CAD_User\Projects\42_2096 Ice Detection\Tosmond\Tripod.ckd and is contained in Appendix D

Tilt Bracket Modification

One small modification is necessary for the Tilt Bracket. A ¼-20 hole must be drilled and tapped through the tilt axis on one side. It is imperative that this hole be dead center of the tilt axis (see drawing 2096U04 – Appendix D).

Base Modification

In order to attach a gearing system to the tilt access several modifications are necessary. First of all a potentiometer mount must be attached to the base. Two clearance holes must be drilled through the side of the base to pass through two ¼-20 bolts (see drawing 2096U04 – Appendix D).

Tilt Measurements

A potentiometer is mounted to the base of the tripod head and a gear is attached to the potentiometer. A pinion is fitted to a shafted that has been screwed into the hole in the tilt axis. The tilting of the head will cause the gear to turn the pinion and the potentiometer reads the angle of tilt when properly calibrated.

Pan Measurements

A 3/8" bolt holds the tripod head to the tripod. This bolt sets the pan axis and it is to this bolt that the shaft of the central pan gear will attach. The design proposes a drilled and tapped hole to penetrate the bolt, tapped for an 8-32 UNC-2B thread. A shaft with a threaded end will screw into the bolt passing through the center gear. Mating with that gear is a pinion. The pinion is mounted to the tripod head base using pre-existing threaded holes.

Rough Design

The design of the potentiometer mounts have been made according to rudimentary measurement methods and the accuracy is low in the wake of unavailable drawings from the fabricator. Therefore it is likely that both mounting blocks may require further adjustments in the form of, but not limited to, removing or adding material to certain surfaces and repositioning drilled holes. These

terms are in reference to the fabrication drawings 2096U13 & 2096U14 (see Appendix D).

Conclusions

Bar some minor adjustments, the design for attaching the potentiometers to both the pan and tilt axes should provide smooth and accurate measurements. This design is to be implemented into one tripod only, that is the tripod holding the telescope. Maximum accuracies have been given above for the potentiometers including increased resolution due to gear ratios. Obviously these accuracies will not be achieved due to imperfections in fabrication and unavoidable backlash in the gears*. With careful and precise fabrication an inaccuracy of 0.3-0.5 degrees may be expected.

Figures

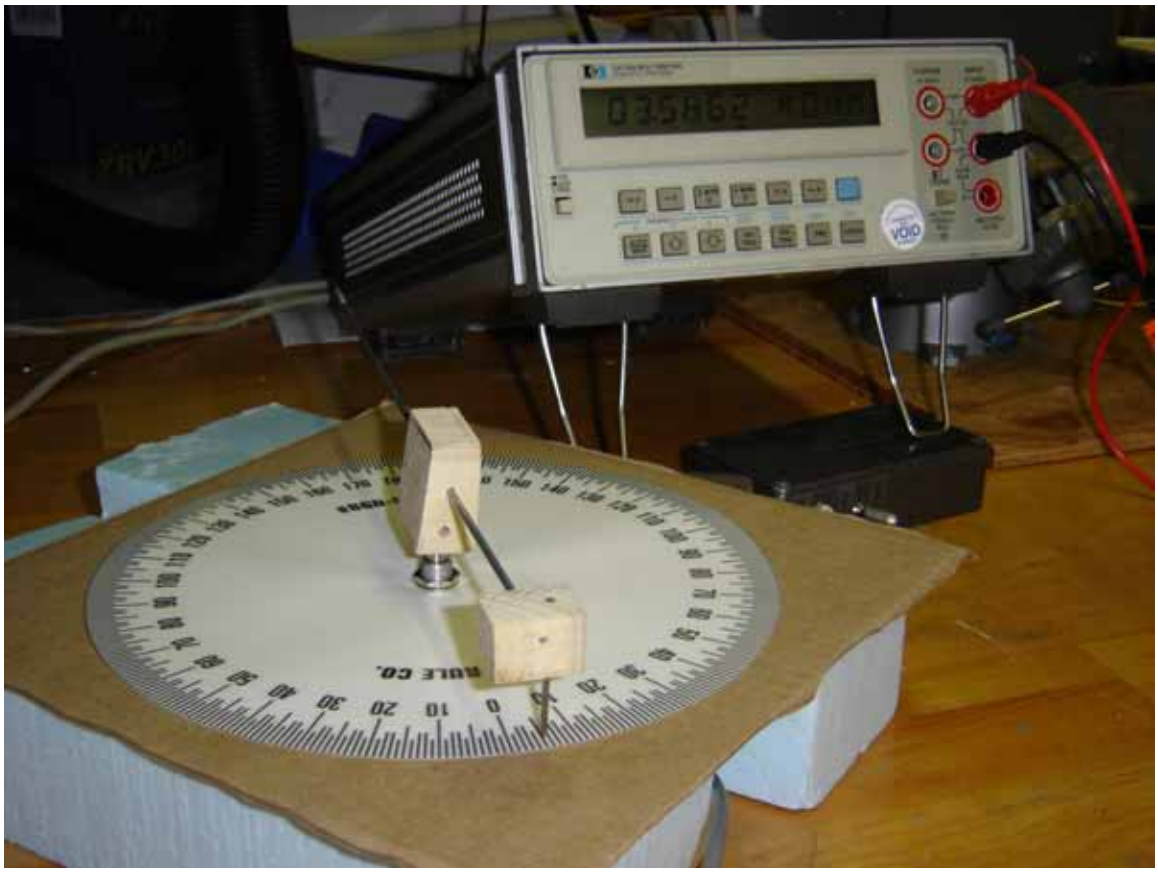


Figure 1 – Potentiometer Measuring Apparatus

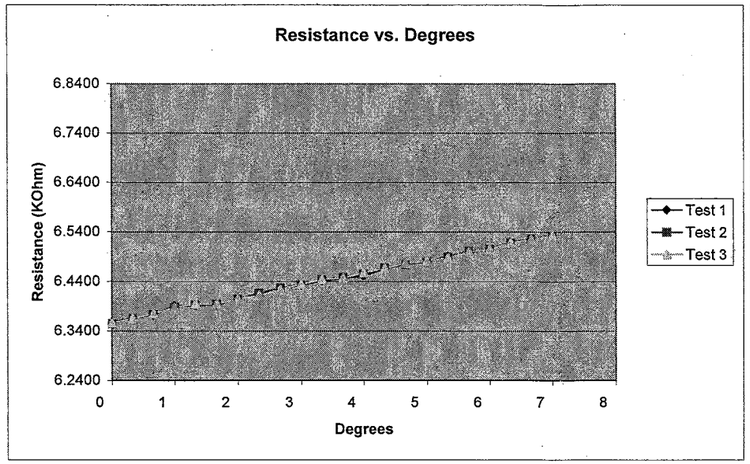
* A more accurate device has been purchased to offer remote control of the laser. This device would also be useful for controlling the telescope should the potentiometer calibration and accuracy prove to be insufficient for this project application.

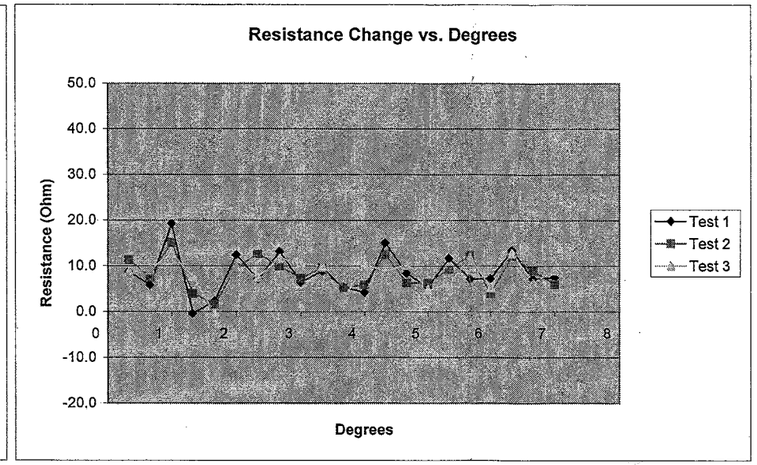
Appendices

Appendix A – Experimental Data

Continuous Pot

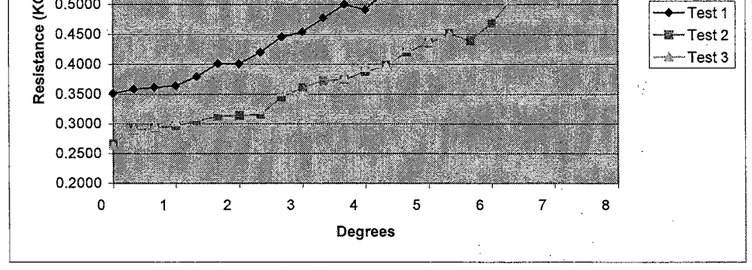
Degrees	Resistance (KOhm)			Change in Resistance (Ohm)		
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
0	6.3575	6.3551	6.3566			
1/3	6.3662	6.3664	6.3654	8.7	11.3	8.8
2/3	6.3720	6.3740	6.3745	5.8	7.6	9.1
1	6.3912	6.3891	6.3872	19.2	15.1	12.7
1 1/3	6.3908	6.3931	6.3949	-0.4	4.0	7.7
1 2/3	6.3931	6.3947	6.3945	2.3	1.6	-0.4
2	6.4055	6.4042	6.4043	12.4	9.5	9.8
2 1/3	6.4126	6.4168	6.4119	7.1	12.6	7.6
2 2/3	6.4257	6.4267	6.4236	13.1	9.9	11.7
3	6.4321	6.4340	6.4343	6.4	7.3	10.7
3 1/3	6.4410	6.4436	6.4442	8.9	9.6	9.9
3 2/3	6.4464	6.4488	6.4469	5.4	5.2	2.7
4	6.4506	6.4547	6.4574	4.2	5.9	10.5
4 1/3	6.4656	6.4672	6.4663	15.0	12.5	8.9
4 2/3	6.4740	6.4735	6.4766	8.4	6.3	10.3
5	6.4793	6.4798	6.4814	5.3	6.3	4.8
5 1/3	6.4910	6.4890	6.4876	11.7	9.2	6.2
5 2/3	6.4981	6.5013	6.4994	7.1	12.3	11.8
6	6.5053	6.5053	6.5048	7.2	4.0	5.4
6 1/3	6.5187	6.5175	6.5176	13.4	12.2	12.8
6 2/3	6.5259	6.5264	6.5239	7.2	8.9	6.3
7	6.5334	6.5324	6.5329	7.5	6.0	9.0
				8.4	8.4	8.4

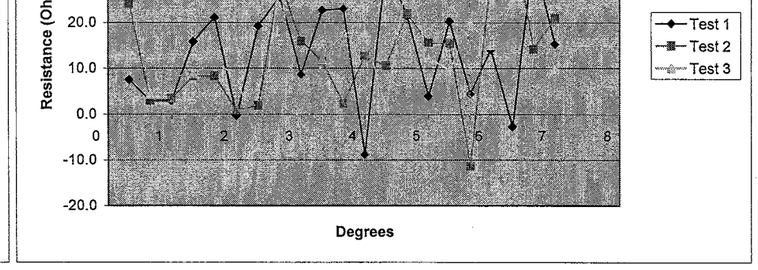




270° Pot

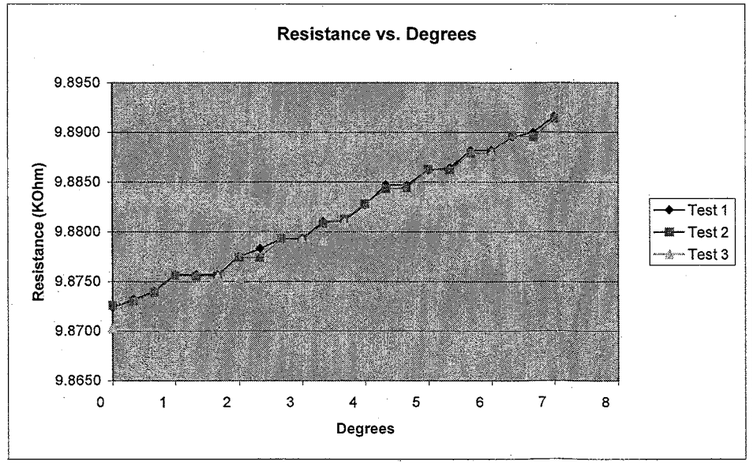
Degrees	Resistance (KOhms)			Change in Resistance (Ohms)		
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
0	0.3509	0.2662	0.2635			
1/3	0.3584	0.2902	0.2916	7.5	24.0	28.1
2/3	0.3613	0.2932	0.2960	2.9	3.0	4.4
1	0.3642	0.2966	0.3040	2.9	3.4	8.0
1 1/3	0.3800	0.3049	0.3129	15.8	8.3	8.9
1 2/3	0.4011	0.3132	0.3242	21.1	8.3	11.3
2	0.4008	0.3141	0.3326	-0.3	0.9	8.4
2 1/3	0.4200	0.3160	0.3254	19.2	1.9	-7.2
2 2/3	0.4456	0.3449	0.3551	25.6	28.9	29.7
3	0.4543	0.3608	0.3477	8.7	15.9	-7.4
3 1/3	0.4770	0.3724	0.3596	22.7	11.6	11.9
3 2/3	0.5000	0.3747	0.3773	23.0	2.3	17.7
4	0.4912	0.3874	0.3950	-8.8	12.7	17.7
4 1/3	0.5233	0.3980	0.3965	32.1	10.6	1.5
4 2/3	0.5447	0.4199	0.4268	21.4	21.9	30.3
5	0.5486	0.4355	0.4391	3.9	15.6	12.3
5 1/3	0.5688	0.4509	0.4487	20.2	15.4	9.6
5 2/3	0.5732	0.4395	0.4687	4.4	-11.4	20.0
6	0.5873	0.4690	0.4837	14.1	29.5	15.0
6 1/3	0.5846	0.5089	0.5081	-2.7	39.9	24.4
6 2/3	0.6191	0.5231	0.5338	34.5	14.2	25.7
7	0.6344	0.5440	0.5436	15.3	20.9	9.8
				13.5	13.2	13.3

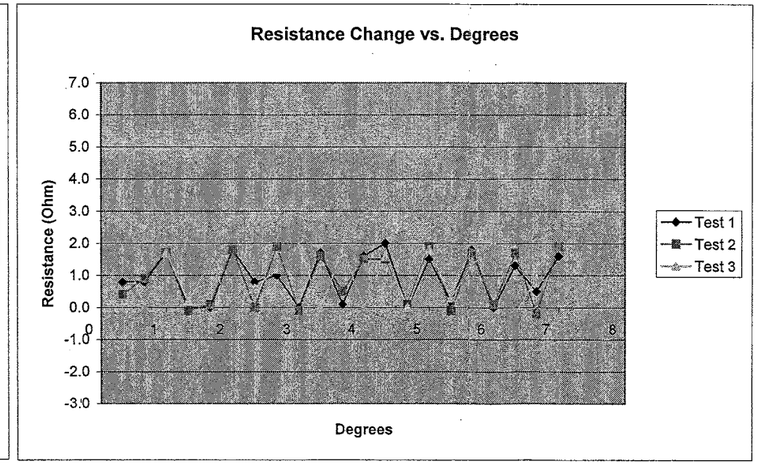




10 Turn Pot

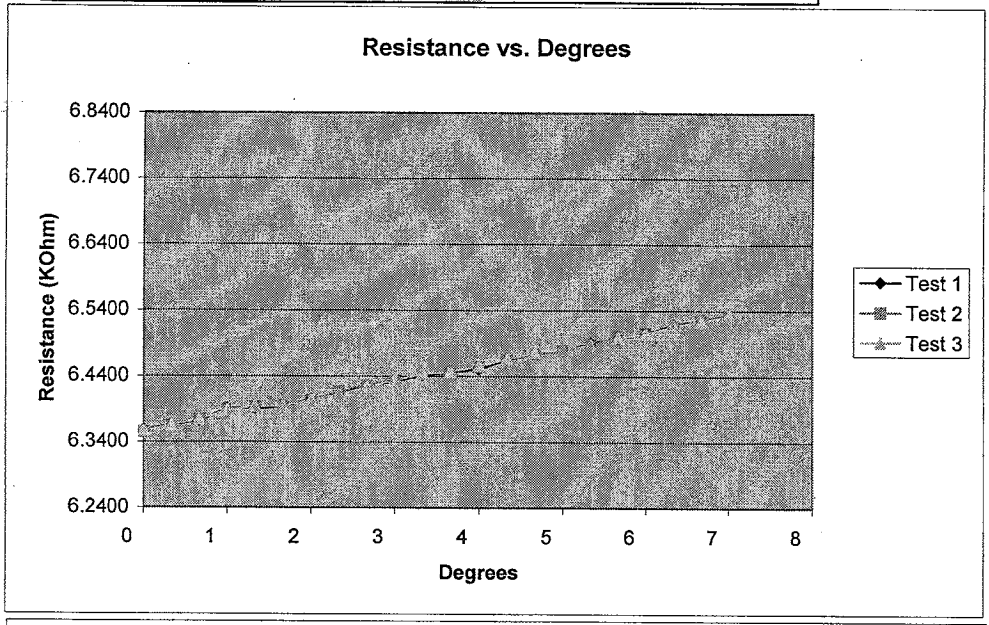
Degrees	Resistance (KOhms)			Change in Resistance (Ohms)		
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
0	9.8724	9.8726	9.8703			
1/3	9.8732	9.8730	9.8721	0.8	0.4	1.8
2/3	9.8740	9.8739	9.8721	0.8	0.9	0.0
1	9.8757	9.8756	9.8738	1.7	1.7	1.7
1 1/3	9.8757	9.8755	9.8740	0.0	-0.1	0.2
1 2/3	9.8757	9.8756	9.8754	0.0	0.1	1.4
2	9.8775	9.8774	9.8754	1.8	1.8	0.0
2 1/3	9.8783	9.8774	9.8760	0.8	0.0	0.6
2 2/3	9.8793	9.8793	9.8772	1.0	1.9	1.2
3	9.8793	9.8792	9.8791	0.0	-0.1	1.9
3 1/3	9.8810	9.8808	9.8791	1.7	1.6	0.0
3 2/3	9.8811	9.8813	9.8809	0.1	0.5	1.8
4	9.8827	9.8828	9.8809	1.6	1.5	0.0
4 1/3	9.8847	9.8843	9.8825	2.0	1.5	1.6
4 2/3	9.8847	9.8844	9.8825	0.0	0.1	0.0
5	9.8862	9.8863	9.8843	1.5	1.9	1.8
5 1/3	9.8864	9.8862	9.8846	0.2	-0.1	0.3
5 2/3	9.8882	9.8879	9.8859	1.8	1.7	1.3
6	9.8882	9.8880	9.8879	0.0	0.1	2.0
6 1/3	9.8895	9.8897	9.8877	1.3	1.7	-0.2
6 2/3	9.8900	9.8895	9.8886	0.5	-0.2	0.9
7	9.8916	9.8914	9.8894	1.6	1.9	0.8
				0.9	0.9	0.9

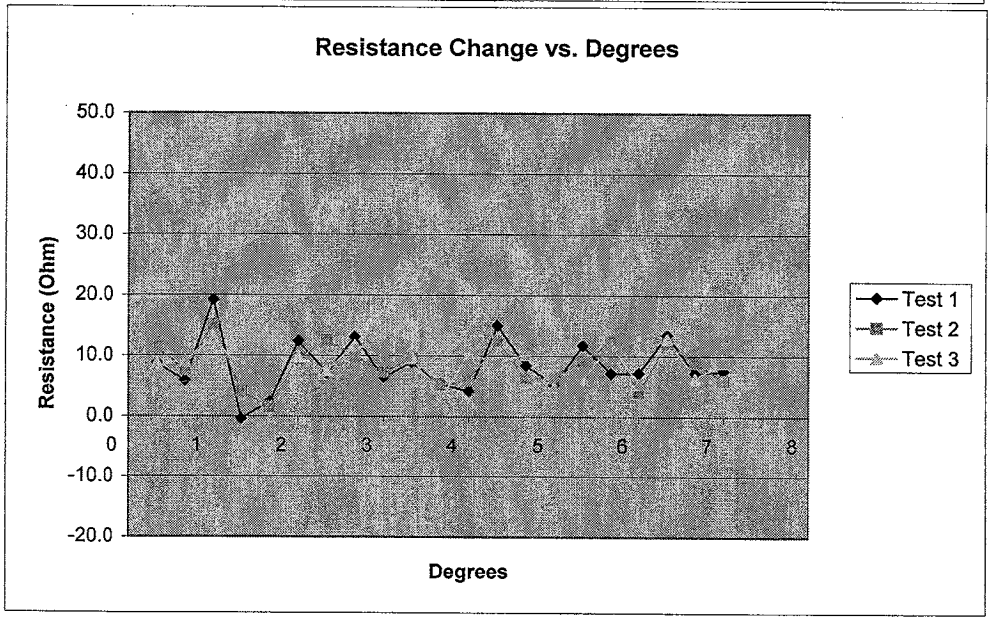




Continuous Pot

Degrees	Resistance (KOhm)			Change in Resistance (Ohm)		
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
0	6.3575	6.3551	6.3566			
1/3	6.3662	6.3664	6.3654	8.7	11.3	8.8
2/3	6.3720	6.3740	6.3745	5.8	7.6	9.1
1	6.3912	6.3891	6.3872	19.2	15.1	12.7
1 1/3	6.3908	6.3931	6.3949	-0.4	4.0	7.7
1 2/3	6.3931	6.3947	6.3945	2.3	1.6	-0.4
2	6.4055	6.4042	6.4043	12.4	9.5	9.8
2 1/3	6.4126	6.4168	6.4119	7.1	12.6	7.6
2 2/3	6.4257	6.4267	6.4236	13.1	9.9	11.7
3	6.4321	6.4340	6.4343	6.4	7.3	10.7
3 1/3	6.4410	6.4436	6.4442	8.9	9.6	9.9
3 2/3	6.4464	6.4488	6.4469	5.4	5.2	2.7
4	6.4506	6.4547	6.4574	4.2	5.9	10.5
4 1/3	6.4656	6.4672	6.4663	15.0	12.5	8.9
4 2/3	6.4740	6.4735	6.4766	8.4	6.3	10.3
5	6.4793	6.4798	6.4814	5.3	6.3	4.8
5 1/3	6.4910	6.4890	6.4876	11.7	9.2	6.2
5 2/3	6.4981	6.5013	6.4994	7.1	12.3	11.8
6	6.5053	6.5053	6.5048	7.2	4.0	5.4
6 1/3	6.5187	6.5175	6.5176	13.4	12.2	12.8
6 2/3	6.5259	6.5264	6.5239	7.2	8.9	6.3
7	6.5334	6.5324	6.5329	7.5	6.0	9.0
				8.4	8.4	8.4





270° Pot

Degrees	Resistance (KOhms)			Change in Resistance (Ohms)		
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
0	0.3509	0.2662	0.2635			
1/3	0.3584	0.2902	0.2916	7.5	24.0	28.1
2/3	0.3613	0.2932	0.2960	2.9	3.0	4.4
1	0.3642	0.2966	0.3040	2.9	3.4	8.0
1 1/3	0.3800	0.3049	0.3129	15.8	8.3	8.9
1 2/3	0.4011	0.3132	0.3242	21.1	8.3	11.3
2	0.4008	0.3141	0.3326	-0.3	0.9	8.4
2 1/3	0.4200	0.3160	0.3254	19.2	1.9	-7.2
2 2/3	0.4456	0.3449	0.3551	25.6	28.9	29.7
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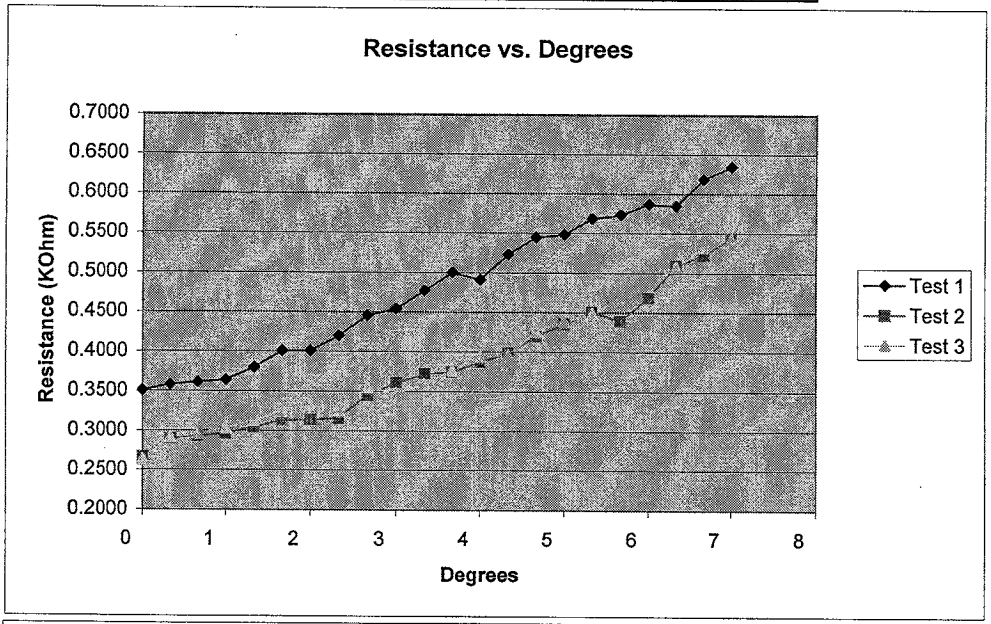
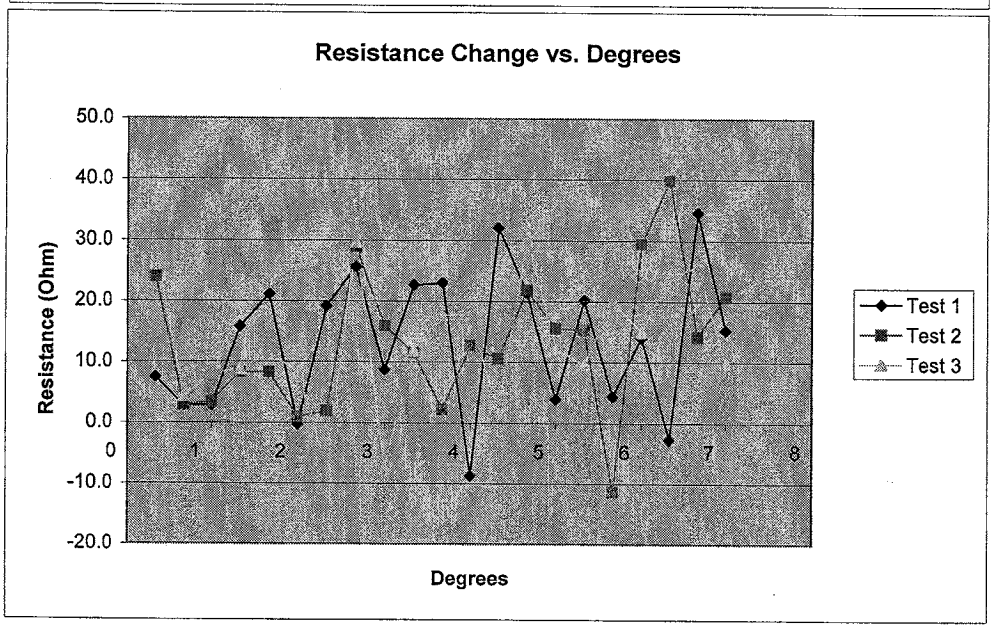
3 2/3	0.5000	0.3747	0.3773	23.0	2.3	17.7
4	0.4912	0.3874	0.3950	-8.8	12.7	17.7
4 1/3	0.5233	0.3980	0.3965	32.1	10.6	1.5
4 2/3	0.5447	0.4199	0.4268	21.4	21.9	30.3
5	0.5486	0.4355	0.4391	3.9	15.6	12.3
5 1/3	0.5688	0.4509	0.4487	20.2	15.4	9.6
5 2/3	0.5732	0.4395	0.4687	4.4	-11.4	20.0
6	0.5873	0.4690	0.4837	14.1	29.5	15.0
6 1/3	0.5846	0.5089	0.5081	-2.7	39.9	24.4
6 2/3	0.6191	0.5231	0.5338	34.5	14.2	25.7
7	0.6344	0.5440	0.5436	15.3	20.9	9.8
				13.5	13.2	13.3





10 Turn Pot

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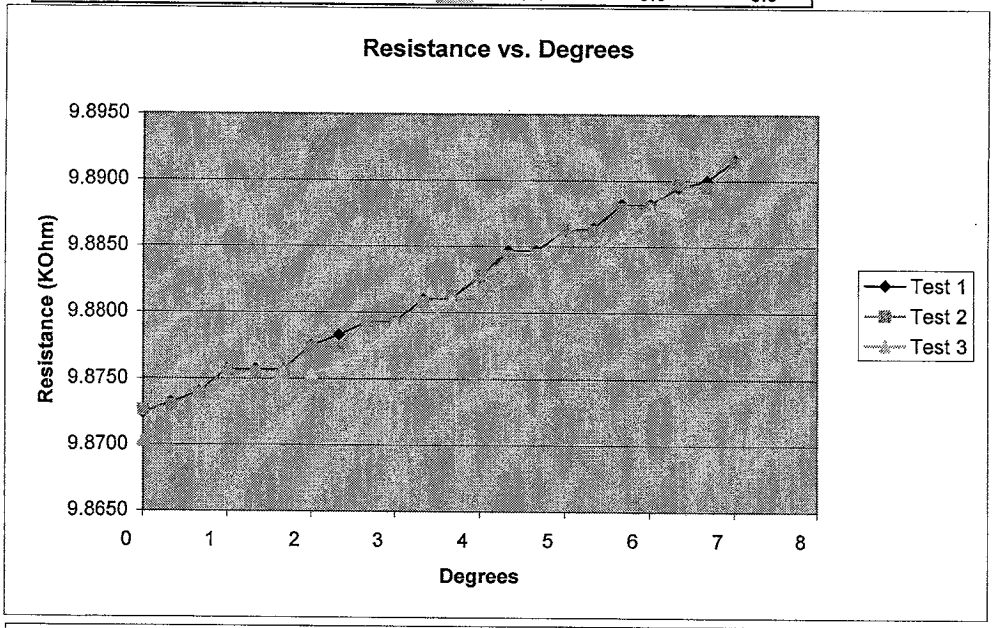
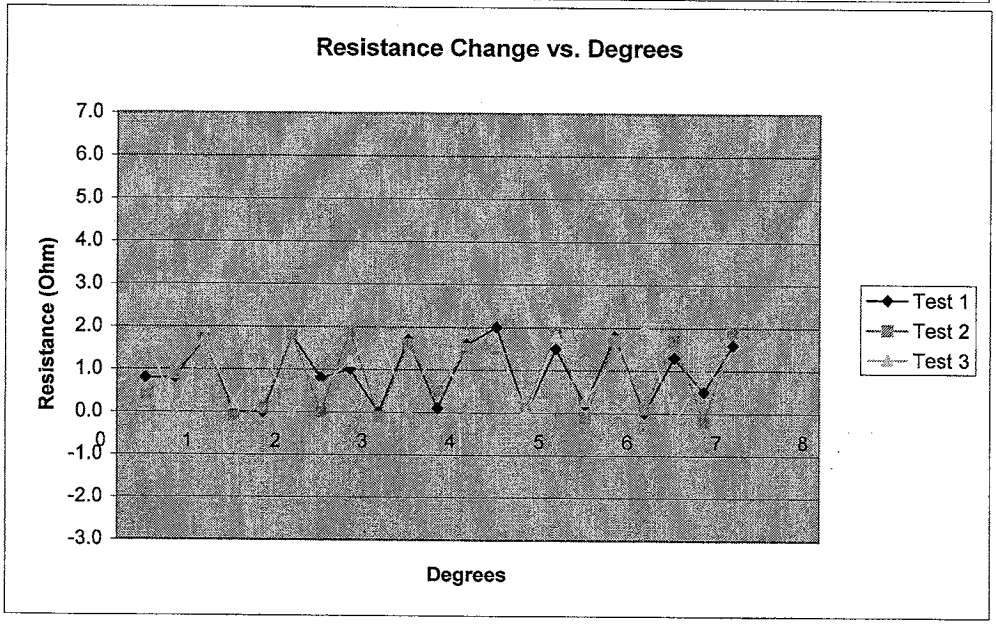
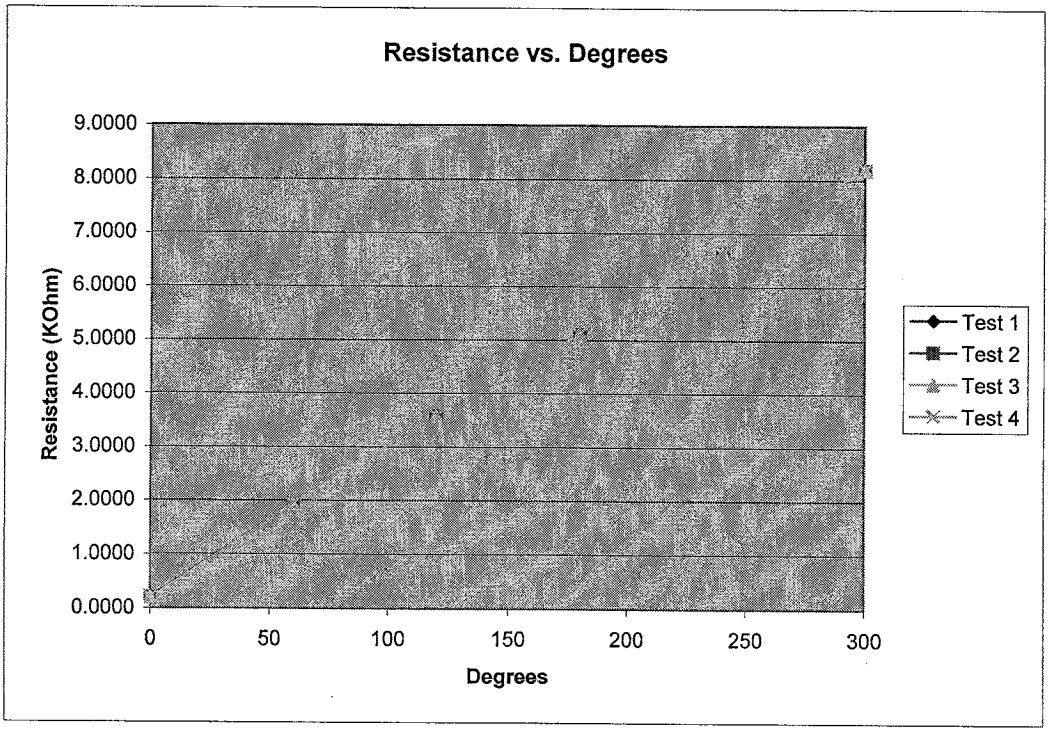
2/3	9.8740	9.8739	9.8721	0.8	0.9	0.0
1	9.8757	9.8756	9.8738	1.7	1.7	1.7
1 1/3	9.8757	9.8755	9.8740	0.0	-0.1	0.2
1 2/3	9.8757	9.8756	9.8754	0.0	0.1	1.4
2	9.8775	9.8774	9.8754	1.8	1.8	0.0
2 1/3	9.8783	9.8774	9.8760	0.8	0.0	0.6
2 2/3	9.8793	9.8793	9.8772	1.0	1.9	1.2
3	9.8793	9.8792	9.8791	0.0	-0.1	1.9
3 1/3	9.8810	9.8808	9.8791	1.7	1.6	0.0
3 2/3	9.8811	9.8813	9.8809	0.1	0.5	1.8
4	9.8827	9.8828	9.8809	1.6	1.5	0.0
4 1/3	9.8847	9.8843	9.8825	2.0	1.5	1.6
4 2/3	9.8847	9.8844	9.8825	0.0	0.1	0.0
5	9.8862	9.8863	9.8843	1.5	1.9	1.8
5 1/3	9.8864	9.8862	9.8846	0.2	-0.1	0.3
5 2/3	9.8882	9.8879	9.8859	1.8	1.7	1.3
6	9.8882	9.8880	9.8879	0.0	0.1	2.0
6 1/3	9.8895	9.8897	9.8877	1.3	1.7	-0.2
6 2/3	9.8900	9.8895	9.8886	0.5	-0.2	0.9
7	9.8916	9.8914	9.8894	1.6	1.9	0.8
				0.9	0.9	0.9

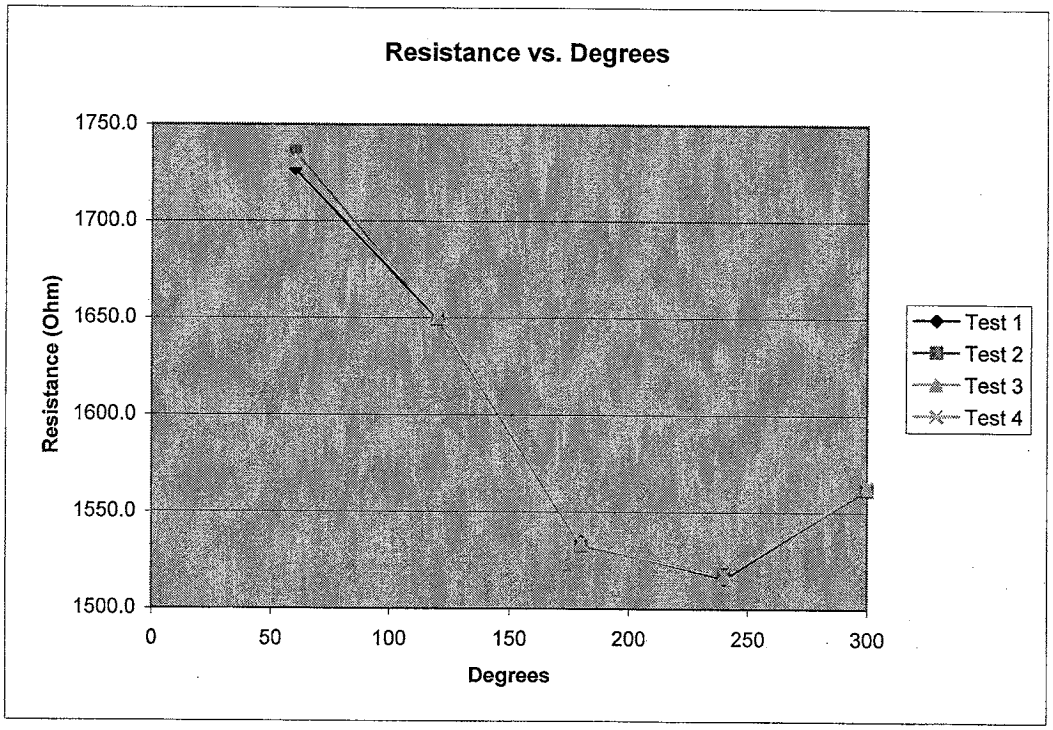




Continuous Pot

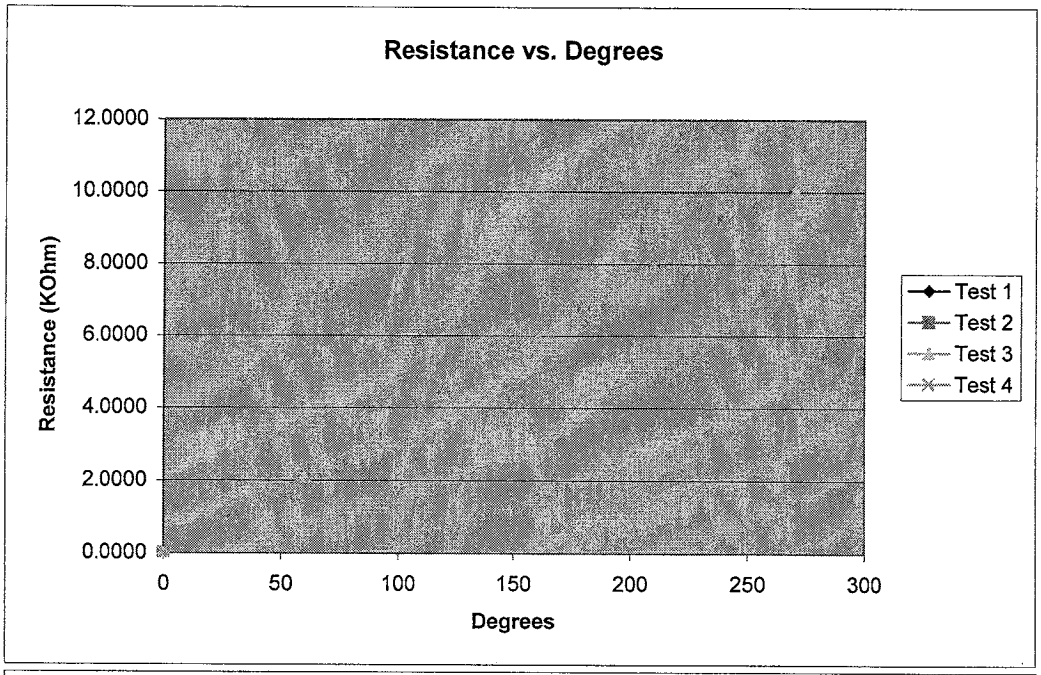
	Resistance (Kohm)				Change in Resistance (Ohm)			
Degrees	Test 1	Test 2	Test 3	Test 4	Test 1	Test 2	Test 3	Test 4
0	0.2044	0.1954	0.2004	0.1992				
60	1.9311	1.9311	1.9314	1.9303	1726.7	1735.7	1731.0	1731.1
120	3.5803	3.5802	3.5819	3.5807	1649.2	1649.1	1650.5	1650.4
180	5.1150	5.1126	5.1157	5.1155	1534.7	1532.4	1533.8	1534.8
240	6.6306	6.6309	6.6325	6.6338	1515.6	1518.3	1516.8	1518.3
300	8.1933	8.1923	8.1955	8.1970	1562.7	1561.4	1563.0	1563.2

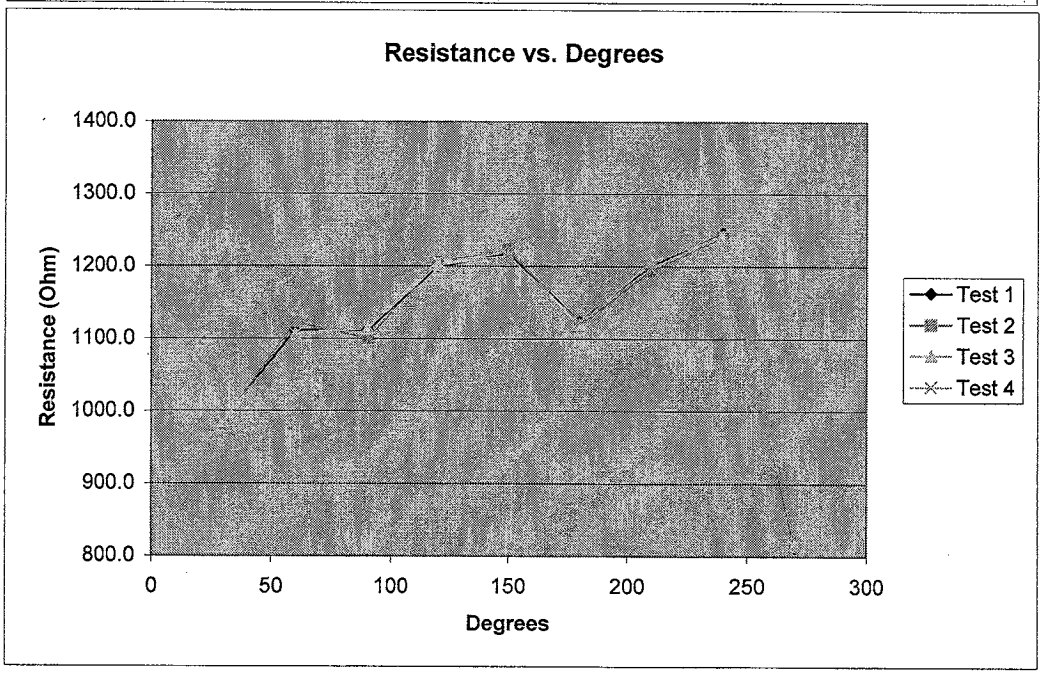




270° Pot

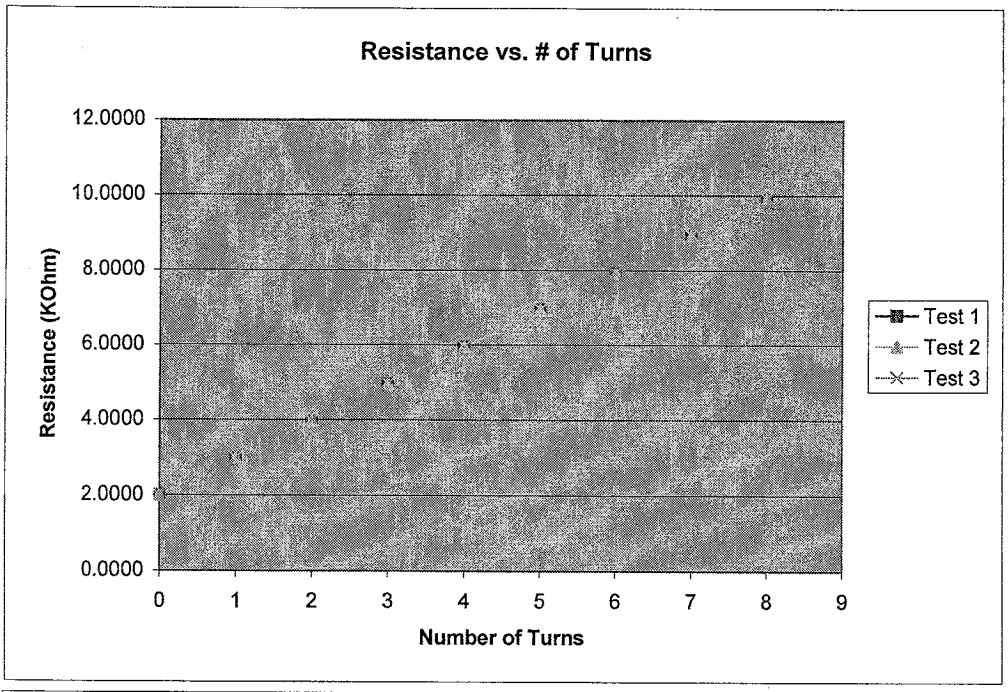
	Resistance (Kohm)				Change in Resistance (Ohm)			
Degrees	Test 1	Test 2	Test 3	Test 4	Test 1	Test 2	Test 3	Test 4
0	0.0004	0.0004	0.0004	0.0004				
30	0.9843	0.9828	0.9860	0.9842	983.9	982.4	985.6	983.8
60	2.0966	2.1056	2.0917	2.0905	1112.3	1122.8	1105.7	1106.3
90	3.2080	3.2060	3.2059	3.2066	1111.4	1100.4	1114.2	1116.1
120	4.4076	4.4111	4.4082	4.4130	1199.6	1205.1	1202.3	1206.4
150	5.6253	5.6347	5.6230	5.6268	1217.7	1223.6	1214.8	1213.8
180	6.7487	6.7526	6.7428	6.7497	1123.4	1117.9	1119.8	1122.9
210	7.9495	7.9474	7.9507	7.9475	1200.8	1194.8	1207.9	1197.8
240	9.1954	9.1878	9.1928	9.1928	1245.9	1240.4	1242.1	1245.3
270	10.0077	10.0084	10.0080	10.0074	812.3	820.6	815.2	814.6

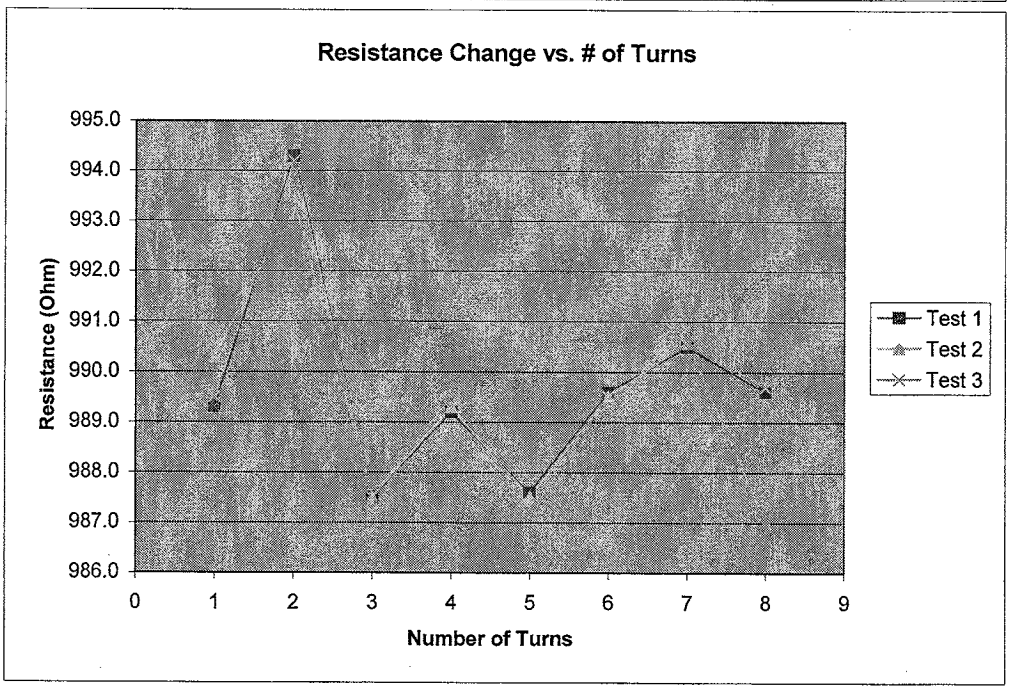




10 Turn Pot

Turns	Degrees	Resistance (Kohm) Test 1	Test 2	Test 3	Change in Resistance (Ohm) Test 1	Test 2	Test 3
0	0	1.9934	1.9933	1.9933			
1	360	2.9827	2.9836	2.9828	989.3	990.3	989.5
2	720	3.9770	3.9770	3.9770	994.3	993.4	994.2
3	1080	4.9645	4.9645	4.9645	987.5	987.5	987.5
4	1440	5.9537	5.9538	5.9540	989.2	989.3	989.5
5	1800	6.9413	6.9413	6.9413	987.6	987.5	987.3
6	2160	7.9309	7.9308	7.9308	989.6	989.5	989.5
7	2520	8.9214	8.9214	8.9214	990.5	990.6	990.6
8	2880	9.9110	9.9084	9.9111	989.6	987.0	989.7

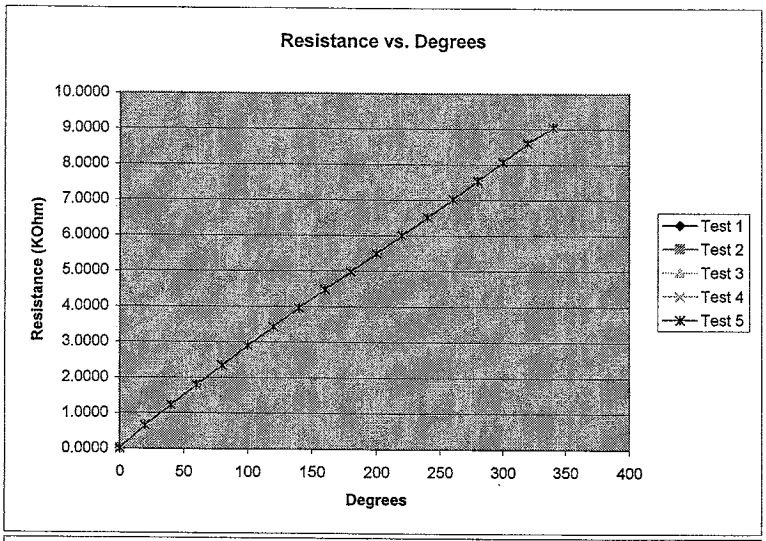




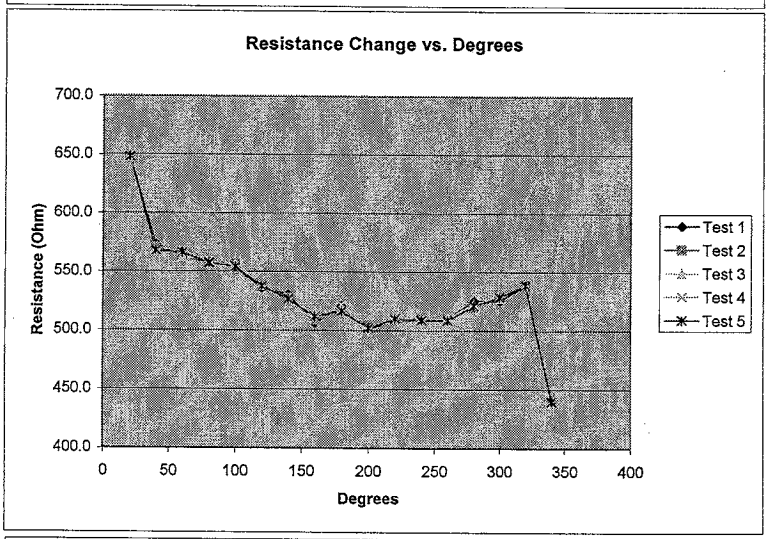
Further Testing

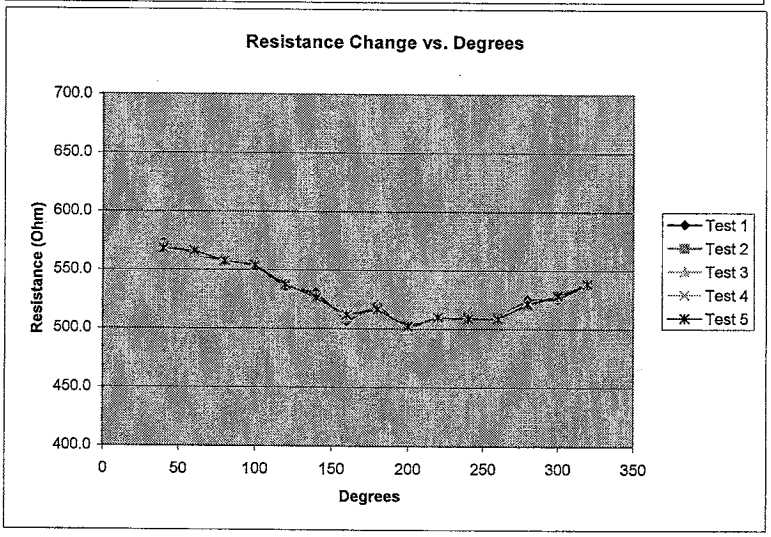
Continuous Pot

	Resistance (Kohm)				
Degrees	Test 1	Test 2	Test 3	Test 4	Test 5
0	0.0075	0.0076	0.0087	0.0080	0.0083
20	0.6548	0.6536	0.6557	0.6503	0.6564
40	1.2276	1.2247	1.2251	1.2217	1.2242
60	1.7901	1.7870	1.7870	1.7878	1.7904
80	2.3478	2.3460	2.3486	2.3473	2.3477
100	2.9017	2.9027	2.9042	2.9006	2.9019
120	3.4375	3.4412	3.4424	3.4442	3.4395
140	3.9682	3.9689	3.9650	3.9648	3.9660
160	4.4747	4.4774	4.4813	4.4751	4.4778
180	4.9954	4.9940	4.9993	4.9973	4.9945
200	5.4970	5.4985	5.4991	5.4975	5.4966
220	6.0036	6.0045	6.0053	6.0045	6.0066
240	6.5124	6.5165	6.5137	6.5184	6.5155
260	7.0226	7.0268	7.0244	7.0240	7.0240
280	7.5478	7.5461	7.5476	7.5459	7.5454
300	8.0734	8.0743	8.0752	8.0740	8.0738
320	8.6120	8.6126	8.6150	8.6131	8.6126
340	9.0512	9.0508	9.0526	9.0524	9.0524



	Change in Resistance (Ohm)				
Degrees	Test 1	Test 2	Test 3	Test 4	Test 5
0					
20	647.3	646.0	647.0	642.3	648.1
40	572.8	571.1	569.4	571.4	567.8
60	562.5	562.3	561.9	566.1	566.2
80	557.7	559.0	561.6	559.5	557.3
100	553.9	556.7	555.6	553.3	554.2
120	535.8	538.5	538.2	543.6	537.6
140	530.7	527.7	522.6	520.6	526.5
160	506.5	508.5	516.3	510.3	511.8
180	520.7	516.6	518.0	522.2	516.7
200	501.6	504.5	499.8	500.2	502.1
220	506.6	506.0	506.2	507.0	510.0
240	508.8	512.0	508.4	513.9	508.9
260	510.2	510.3	510.7	505.6	508.5
280	525.2	519.3	523.2	521.9	521.4
300	525.6	528.2	527.6	528.1	528.4
320	538.6	538.3	539.8	539.1	538.8
340	439.2	438.2	437.6	439.3	439.8



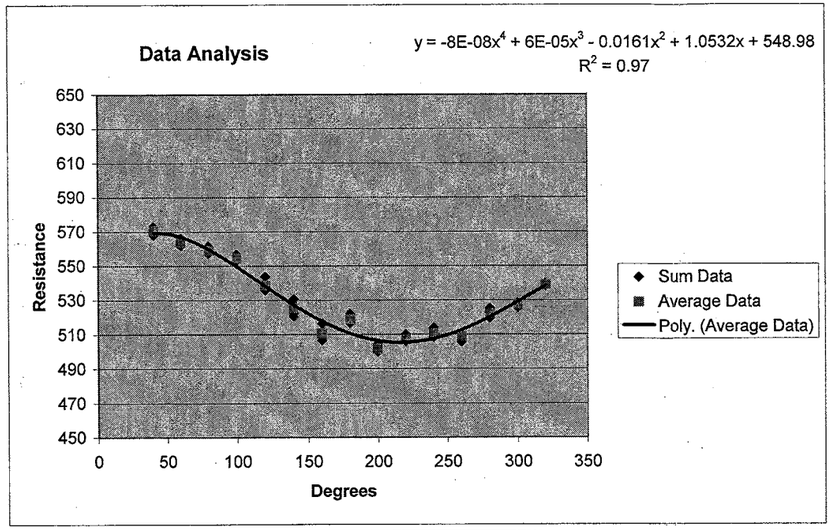


Rearranging all values to produce one continuous data set

Continuous Pot

	Resistance (KOhm)				
Degrees	Test 1	Test 2	Test 3	Test 4	Test 5
0	0.0075	0.0076	0.0087	0.0080	0.0083
20	0.6548	0.6536	0.6557	0.6503	0.6564
40	1.2276	1.2247	1.2251	1.2217	1.2242
60	1.7901	1.7870	1.7870	1.7878	1.7904
80	2.3478	2.3460	2.3486	2.3473	2.3477
100	2.9017	2.9027	2.9042	2.9006	2.9019
120	3.4375	3.4412	3.4424	3.4442	3.4395
140	3.9682	3.9689	3.9650	3.9648	3.9660
160	4.4747	4.4774	4.4813	4.4751	4.4778
180	4.9954	4.9940	4.9993	4.9973	4.9945
200	5.4970	5.4985	5.4991	5.4975	5.4966
220	6.0036	6.0045	6.0053	6.0045	6.0066
240	6.5124	6.5165	6.5137	6.5184	6.5155
260	7.0226	7.0268	7.0244	7.0240	7.0240
280	7.5478	7.5461	7.5476	7.5459	7.5454
300	8.0734	8.0743	8.0752	8.0740	8.0738
320	8.6120	8.6126	8.6150	8.6131	8.6126
340	9.0512	9.0508	9.0526	9.0524	9.0524

	Change in Resistance (Ohm)				
Degrees	Test 1	Test 2	Test 3	Test 4	Test 5
0					
20	647.3	646.0	647.0	642.3	648.1
40	572.8	571.1	569.4	571.4	567.8
60	562.5	562.3	561.9	566.1	566.2
80	557.7	559.0	561.6	559.5	557.3
100	553.9	556.7	555.6	553.3	554.2
120	535.8	538.5	538.2	543.6	537.6
140	530.7	527.7	522.6	520.6	526.5
160	506.5	508.5	516.3	510.3	511.8
180	520.7	516.6	518.0	522.2	516.7
200	501.6	504.5	499.8	500.2	502.1
220	506.6	506.0	506.2	507.0	510.0
240	508.8	512.0	508.4	513.9	508.9
260	510.2	510.3	510.7	505.6	508.5
280	525.2	519.3	523.2	521.9	521.4
300	525.6	528.2	527.6	528.1	528.4
320	538.6	538.3	539.8	539.1	538.8
340	439.2	438.2	437.6	439.3	439.8



	Resistance (Kohm)				
0	0.0075	140	3.9648	280	7.5454
0	0.0076	140	3.9650	280	7.5459
0	0.0080	140	3.9660	280	7.5461
0	0.0083	140	3.9682	280	7.5476
0	0.0087	140	3.9689	280	7.5478
20	0.6503	160	4.4747	300	8.0734
20	0.6536	160	4.4751	300	8.0738
20	0.6548	160	4.4774	300	8.0740
20	0.6557	160	4.4778	300	8.0743
20	0.6564	160	4.4813	300	8.0752
40	1.2217	180	4.9940	320	8.6120
40	1.2242	180	4.9945	320	8.6126
40	1.2247	180	4.9954	320	8.6126
40	1.2251	180	4.9973	320	8.6131
40	1.2276	180	4.9993	320	8.6150
60	1.7870	200	5.4966	340	9.0508
60	1.7870	200	5.4970	340	9.0512
60	1.7878	200	5.4975	340	9.0524
60	1.7901	200	5.4985	340	9.0524
60	1.7904	200	5.4991	340	9.0526
80	2.3460	220	6.0036		
80	2.3473	220	6.0045		
80	2.3477	220	6.0045		
80	2.3478	220	6.0053		
80	2.3486	220	6.0066		
100	2.9006	240	6.5124		
100	2.9017	240	6.5137		
100	2.9019	240	6.5155		
100	2.9027	240	6.5165		
100	2.9042	240	6.5184		
120	3.4375	260	7.0226		
120	3.4395	260	7.0240		
120	3.4412	260	7.0240		
120	3.4424	260	7.0244		
120	3.4442	260	7.0268		

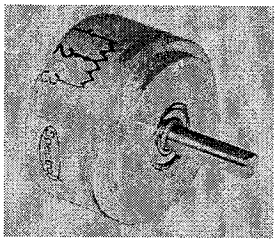
	Change in Resistance (Ohm)				
0		140	530.7	280	525.2
0		140	527.7	280	519.3
0		140	522.6	280	523.2
0		140	520.6	280	521.9
0		140	526.5	280	521.4
20	647.3	160	506.5	300	525.6
20	646	160	508.5	300	528.2
20	647	160	516.3	300	527.6
20	642.3	160	510.3	300	528.1
20	648.1	160	511.8	300	528.4
40	572.8	180	520.7	320	538.6
40	571.1	180	516.6	320	538.3
40	569.4	180	518	320	539.8
40	571.4	180	522.2	320	539.1
40	567.8	180	516.7	320	538.8
60	562.5	200	501.6	340	439.2
60	562.3	200	504.5	340	438.2
60	561.9	200	499.8	340	437.6
60	566.1	200	500.2	340	439.3
60	566.2	200	502.1	340	439.8
80	557.7	220	506.6		
80	559	220	506		
80	561.6	220	506.2		
80	559.5	220	507		
80	557.3	220	510		
100	553.9	240	508.8		
100	556.7	240	512		
100	555.6	240	508.4		
100	553.3	240	513.9		
100	554.2	240	508.9		
120	535.8	260	510.2		
120	538.5	260	510.3		
120	538.2	260	510.7		
120	543.6	260	505.6		
120	537.6	260	508.5		

Appendix B – Data Sheets

Model 157

Vishay Spectrol

Precision Industrial Potentiometer



FEATURES

- High Quality
- Short Length Behind Panel (11/32")
- Rugged One Piece Metal Housing
- Stainless Steel Shaft
- Long Rotational Life
- Wide Operating Temperature Range
- Linearities to ± 0.25% Special
- Optional Sealed Construction (Bushing Mount Only)

ELECTRICAL SPECIFICATIONS

PARAMETER	MIL-PRF-39024 TEST PROCEDURES APPLY
Resistance	1KΩ to 100
Resistance Tolerance Special to	± 20% ± 10%
Linearity Special to	± 2.0% ± 0.25%
Temperature Coefficient of Resistance	± 600ppm/°C
Power Rating Derate to	1.0 watts at 40°C Ambient 0 watts at 125°C
Rotation	340° ± 4°
End Voltage	0.5% maximum
Dielectric Withstanding	1,000V_{RMS}, 60Hz
Insulation Resistance	100MΩ minimum, 500VDC
Output Smoothness	0.1%

MECHANICAL SPECIFICATIONS

PARAMETER		
Weight	0.5 oz maximum	
Rotation	360° (Continuous)	
Mount Bearing Type	**BUSHING** Sleeve Bearing	**SERVO** Ball Bearing
Operating Torque Starting Running	 0.30 oz - in 0.25 oz - in	 0.25 oz - in 0.15 oz - in
Mechanical Tolerance (in/mm) (maximum) Shaft Runout (TIR) Pilot Dia Runout (TIR) Lateral Runout (TIR) Shaft End Play Shaft Radial Play	 0.002 in – 0.005 in 0.006 in 0.003 in	 0.002 in 0.002 in 0.002 in 0.005 in 0.002 in

ORDERING INFORMATION

157	1	1	XXX
MODEL	MOUNTING 1. Bushing 2. Servo	NUMBER OF SECTIONS (SINGLE SECTION ONLY)	RESISTANCE EIA CODE

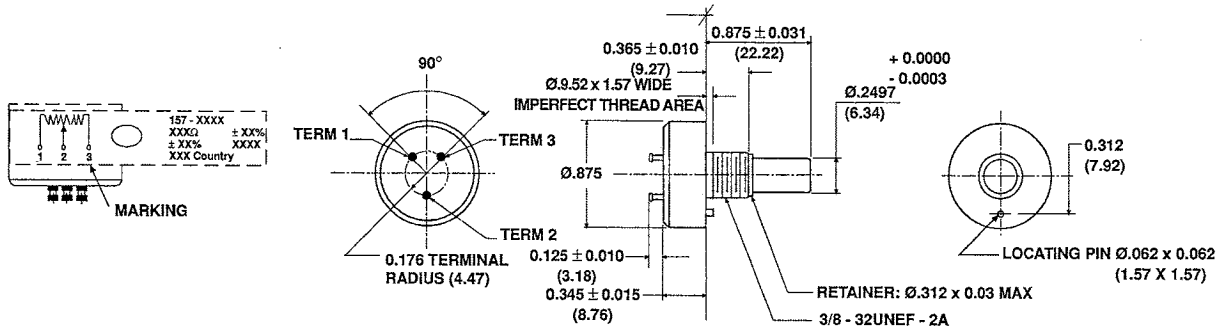
Example: **157 - 1 - 1 - XXX**

For technical questions, contact sfer@vishay.com

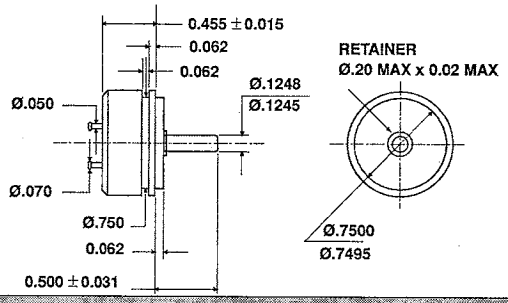
Document Number: 57042
Revision 16-Jul-03

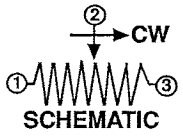
DIMENSIONS in inches (mm)

BUSHING MOUNT



SERVO MOUNT





ALL DIMENSIONS ARE IN INCHES
TOLERANCES: UNLESS OTHERWISE NOTED
DECIMALS ± 0.005
ANGLES ± 2°

MATERIAL SPECIFICATIONS

Housing/Bushing	Aluminum, anodized
Rear Lid	Ceramic
Shaft	Stainless Steel
Terminals	Solderable
Bushing Mount Hardware	Lockwasher, Internal Tooth Steel, Nickel Plated
Panel Nut	Brass, Nickel Plated

ENVIRONMENTAL SPECIFICATIONS

Temperature	- 55°C + 125°C	
Rotational Life	**BUSHING** 10 million shaft Revolutions	**SERVO** 10 million shaft Revolutions
Moisture Resistant	Yes	
Vibration	15g 10 to 2000Hz	
Shock	50g	
Salt Spray	96 Hours	
Load Life	900 Hours	

STANDARD RESISTANCE VALUES

EIA CODE	RESISTANCE
102	1KΩ
202	2KΩ
502	5KΩ
103	10KΩ
203	20KΩ
503	50KΩ
104	100KΩ

Notice

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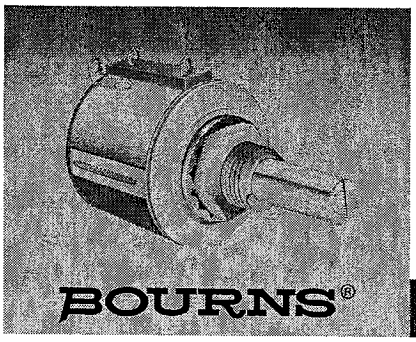


BOURNS®

3540/3541 - Precision Potentiometer

Features

- Bushing mount
- Optional center tap and rear shaft extension
- Optional AR lug feature
- Gangable with common or concentric shafts
- High torque available

Models 3540 and 3541 are currently available, although not recommended for new designs. Model 3549 is preferred.

- Optional 0.1 % linearity
- Non-standard features and specifications available

Electrical Characteristics

	3540 Wirewound Element	3541 Hybritron® Element
Standard Resistance Range	100 to 100 K ohms	1 K to 100 K ohms
Total Resistance Tolerance	±5 %	±10 %
Independent Linearity	±0.25 %	±0.25 %
Effective Electrical Angle	3600 ° +10 °, -0 °	3600 ° +10 °, -0 °
Absolute Minimum Resistance/ Minimum Voltage	1 ohm or 0.1 % maximum (whichever is greater)	0.2 % maximum
Noise/Output Smoothness	100 ohms ENR maximum	0.1 % maximum
Dielectric Withstanding Voltage (MIL-STD-202, Method 301)		
Sea Level	1,000 VAC minimum	1,000 VAC minimum
Power Rating (Voltage Limited By Power Dissipation or 447 VAC, Whichever Is Less)		
+70 °C	2 watts	2 watts
+125 °C	0 watt	0 watt
Insulation Resistance (500 VDC)	1,000 megohms minimum	1,000 megohms minimum
Resolution	See recommended part nos.	Essentially infinite

Environmental Characteristics[1]

Operating Temperature Range	+1 °C to +125 °C	+1 °C to +125 °C
Storage Temperature Range	-55 °C to +125 °C	-55 °C to +125 °C
Temperature Coefficient Over Storage Temperature Range[2]	±50 ppm/°C maximum/unit	±100 ppm/°C maximum/unit
Vibration	15 G	15 G
Wiper Bounce	0.1 millisecond maximum	0.1 millisecond maximum
Shock	50 G	50 G
Wiper Bounce	0.1 millisecond maximum	0.1 millisecond maximum
Load Life	1,000 hours, 2 watts	1,000 hours, 2 watts
Total Resistance Shift	±2 %	±5 %
Rotational Life (No Load)	1,000,000 shaft revolutions[2]	5,000,000 shaft revolutions[2]
Total Resistance Shift	±5 % maximum	±5 % maximum
Moisture Resistance (MIL-STD-202, Method 103, Condition B)		
Total Resistance Shift	±2 % maximum	±5 % maximum
IP Rating	IP 40	IP 40

Mechanical Characteristics[1]

Stop Strength	53 N-cm (75 oz-in.) minimum
Mechanical Angle	3600 ° +10 °, -0 °
Torque (Starting & Running)	0.35 N-cm (0.5 oz.-in.) max.
Mounting	170-200 N-cm (15-18 lb.-in.) max.
Shaft Runout	0.08 mm (0.003 in.) T.I.R.
Lateral Runout	0.13 mm (0.005 in.) T.I.R.
Shaft End Play	0.30 mm (0.012 in.) T.I.R.
Shaft Radial Play	0.08 mm (0.003 in.) T.I.R.
Pilot Diameter Runout	0.08 mm (0.003 in.) T.I.R.
Backlash	1.0 ° maximum
Weight	Approximately 21 gm
Terminals	Gold-plated solder lugs
Soldering Condition	Recommended hand soldering using Sn95/Ag5 no clean solder, 0.025 " wire diameter. Maximum temperature 399 °C (750 °F) for 3 seconds. No wash process to be used with no clean flux.
Marking	Manufacturer's name and part number, resistance value and tolerance, linearity tolerance, wiring diagram, and date code
Ganging (Multiple Section Pots.)	2 cups maximum
Hardware	One lockwasher (H-37-2) and one mounting nut (H-38-2) is shipped with each potentiometer.

[1]At room ambient: +25 °C nominal and 50 % relative humidity nominal, except as noted.
[2]Consult manufacturer for complete specification details.

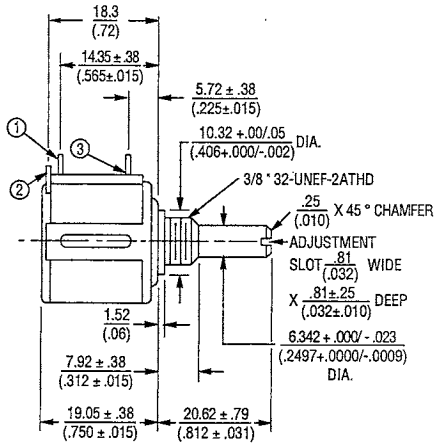
Recommended Part Numbers

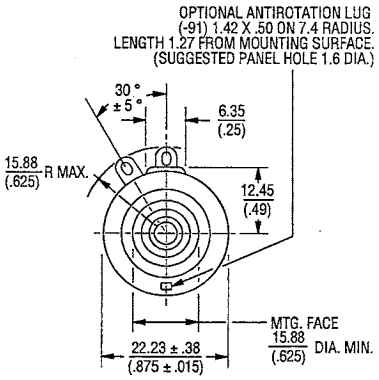
Part Number	Resistance	Resolution
3540S-1-201	200	.042
3540S-1-501	500	.031
3540S-1-102	1,000	.027
3540S-1-202	2,000	.021
3540S-1-502	5,000	.021
3540S-1-103	10,000	.019
3540S-1-203	20,000	.014
3540S-1-503	50,000	.011
3540S-1-104	100,000	.008

Part Number	Resistance
3541H-1-102	1,000
3541H-1-202	2,000
3541H-1-502	5,000
3541H-1-103	10,000
3541H-1-203	20,000
3541H-1-503	50,000
3541H-1-104	100,000

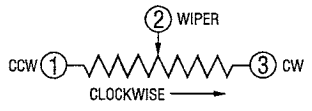
Specifications are subject to change without notice.
Customers should verify actual device performance in their specific applications.

3540S-1/3541H-1





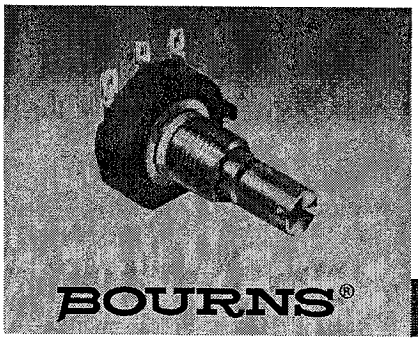
TOLERANCES: EXCEPT WHERE NOTED
DECIMALS: .XX ± .25 (.010), .XXX ± .13 (.005)
FRACTIONS: ±1/64
DIMENSIONS: MM (IN.)



BOLDFACE LISTINGS ARE IN STOCK AND READILY AVAILABLE THROUGH DISTRIBUTION.

FOR SERVO MOUNT VERSION AND OTHER OPTIONS CONSULT FACTORY.

REV. 02/06



BOURNS®

Features

- Single-turn (3851 and 3852)
- Linear and audio tapers
- 3-3/4-turn (3856)
- Wide resistance range
- Minimal depth package
- Good resolution

3851/3852/3856 - 3/4 " Diameter Panel Control

Initial Electrical Characteristics[1]

	3851 Conductive Plastic Element	3852/3856 Cermet Element
Standard Resistance Range		
Linear Tapers (A, B, E, and H)	1 K to 1 megohm	100 ohms to 1 megohm
Audio Tapers (C, D, F, and G)	1 K to 1 megohm	1 K ohms to 1 megohm
Total Resistance Tolerance	±10 % or ±20 %	±5 % or ±10 %
Independent Linearity	±10 %	(A & H tapers) ±5 %
Absolute Minimum Resistance	2 ohms maximum	2 ohms maximum
Effective Electrical Angle	250 ° ±5 °	250 ° ±5 °
Contact Resistance Variation	±1 %	±3 % of total resistance or 3 ohms (whichever is greater)
Dielectric Withstanding Voltage (MIL-STD-202, Method 301)		
Sea Level	900 VAC minimum	900 VAC minimum
70,000 Feet	350 VAC minimum	350 VAC minimum
Insulation Resistance (500 VDC)	1,000 megohms minimum	1,000 megohms minimum
Power Rating (Voltage Limited By Power Dissipation or 350 VAC, Whichever Is Less)		
+70 °C	(Linear tapers) 1 watt (Audio tapers) 0.5 watt	(Linear tapers) 2 watts (Audio tapers) 1 watt
+125 °C	0 watt	
+150 °C		0 watt
Theoretical Resolution	Essentially infinite	Essentially infinite

Environmental Characteristics[1]

Operating Temperature Range	-1 °C to +125 °C	-1 °C to +125 °C
Storage Temperature Range	-65 °C to +125 °C	-65 °C to +150 °C
Temperature Coefficient Over Storage Temperature Range	±1,000 ppm/°C	±150 ppm/°C
Vibration	20 G	20 G
Total Resistance Shift	±2 % maximum	±2 % maximum
Voltage Ratio Shift	±5 % maximum	±6 % maximum
Shock	100 G	100 G
Total Resistance Shift	±2 % maximum	±2 % maximum
Voltage Ratio Shift	±5 % maximum	±6 % maximum
Load Life	1,000 hours	1,000 hours
Total Resistance Shift	±10 % maximum	±3 % maximum
Rotational Life (No Load)	100,000 cycles	50,000 cycles
Total Resistance Shift	±15 % TRS maximum	±5 % or 5 ohms TRS whichever is greater
Contact Resistance Variation	±3 %	±3 %
Moisture Resistance (MIL-STD-202, Method 103, Condition B)		
Total Resistance Shift	±10 % maximum	±2 % maximum
IP Rating	IP 40	IP 40

Mechanical Characteristics[1]

Stop Strength	56.5 N-cm (5 lb.-in.)
Mechanical Angle	280 ° ±5 ° / 3856 – 1350 ° ±50 °
Torque (Starting and Running)	A & B bushings 0.35 to 4.23 N-cm (0.05 to 6.0 oz.-in.) C & E bushings 0.21 to 4.23 N-cm (0.3 to 6.0 oz.-in.) 3856 – 0.11 to 2.12 N-cm (0.15 to 3.0 oz.-in.)
Mounting (Torque on Bushing)	1.7-2.0 N-m (15-18 lb.-in.) maximum
Weight (Single Section)	30 grams maximum
Terminals	Printed circuit terminals or solder lugs
Soldering Condition	Recommended hand soldering using Sn95/Ag5 no clean solder, 0.025 " wire diameter. Maximum temperature 399 °C (750 °F) for 3 seconds. No wash process to be used with no clean flux. Part can be wave soldered at 260 °C (500 °F) for 5 seconds, no wash process with no clean flux.
Marking	Manufacturer's trademark, wiring diagram, resistance, date code, and part number
Ganging (Multiple Section Potentiometers)	1 cup maximum
Hardware	One lockwasher and one mounting nut is shipped with each potentiometer, except where noted in the part number.

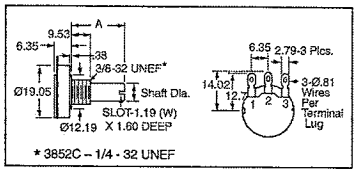
[1]AT ROOM AMBIENT: +25 °C NOMINAL AND 50 % RELATIVE HUMIDITY NOMINAL, EXCEPT AS NOTED.

BOURNS Precision Potentiometers

SERIES 3852

2 Watt Cermet 3/4" (19.05mm) Diameter Panel Control

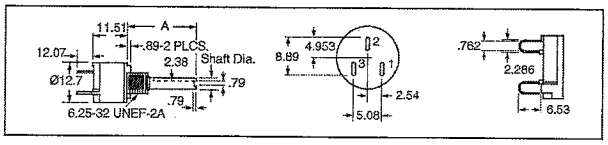
• **Resistance Tolerance:** ±10% • **Continuity:** Maintained for full mechanical angle • **Effective Electrical Angle:** 250° ±5° • **Contact Resistance Variation:** ±3% of total resistance or 3Ω (whichever is greater) • **Dielectric Withstanding Voltage:** MIL-STD-202, Method 301 (Sea Level: 900VAC minimum; 70,000 Feet: 350VAC minimum) • **Insulation Resistance (500VDC):** 1,000MΩ minimum • **Mounting hardware included**



Ω	Dim. A (mm)	Shaft Dia. (mm)	Digi-Key Part No.	1	25	50	100	250
1K	12.7	6.35	3852A-162-102A-ND	9.16	7.12	5.83	4.93	4.58
1K	22.20	6.35	3852A-282-102A-ND	9.16	7.12	5.83	4.93	4.58
5K	22.20	6.35	3852A-282-502A-ND	9.16	7.12	5.83	4.93	4.58
10K	22.20	6.35	3852A-282-103A-ND	9.16	7.12	5.83	4.93	4.58
10K	12.7	6.35	3852A-162-103A-ND	9.16	7.12	5.83	4.93	4.58
100K	22.20	6.35	3852A-282-104A-ND	9.16	7.12	5.83	4.93	4.58
10K	22.20	3.18	3852C-282-103A-ND	9.16	7.12	5.83	4.93	4.58

SERIES 3862 1 Watt Cermet 1/2" (12.5mm) Diameter Single-Turn Panel Control

• **Resistance Tolerance:** ±10% • **Continuity:** Maintained for full mechanical angle • **Effective Electrical Angle:** 260° ±10° • **Contact Resistance Variation:** ±3% of total resistance • **Theoretical Resolution:** Essentially infinite • **Dielectric Withstanding Voltage:** MIL-STD-202, Method 301 (Sea Level: 750VAC minimum; 70,000 Feet: 350VAC minimum) • **Insulation Resistance (500 VDC):** 1,000MΩ minimum • **Mounting hardware included**

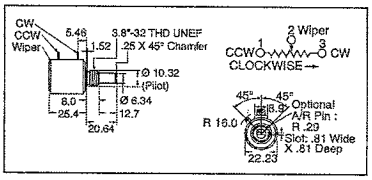


Ω	Dim. A (mm)	Shaft Dia. (mm)	Digi-Key Part No.	1	25	50	100	250
10K	12.7	3.18	3862C-162-103A-ND	14.69	11.44	9.34	7.90	7.35
10K	22.20	3.18	3862C-282-103A-ND	14.69	11.44	9.34	7.90	7.35

SERIES 3500

2 Watt - 10 Turn Wirewound

• **Resistance Tolerance:** ±3%
• **Independent Linearity:** ±0.20%
• **Effective Electrical Angle:** 3600° +10°, -0°
• **Dielectric Withstanding Voltage:** MIL-STD-202, Method 301 (Sea level: 1,500VAC minimum); 70,000 Feet: 400VAC minimum
• **Insulation Resistance (500VDC):** 1,000MΩ minimum
• **Mounting hardware included**

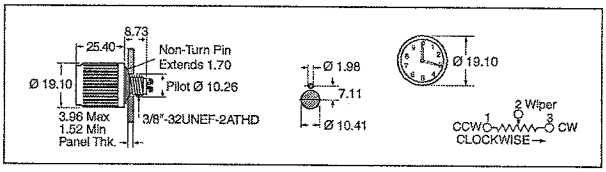


Ω	Resolution %	Digi-Key Part No.	1	25	100	500	1,000
1K	.030	3500S-2-102-ND	41.75	33.82	30.91	29.23	27.15
5K	.018	3500S-2-502-ND	41.75	33.82	30.91	29.23	27.15
10K	.019	3500S-2-103-ND	41.75	33.82	30.91	29.23	27.15

SERIES 3600

1.5 Watt - 10 Turn Wirewound Clock Face

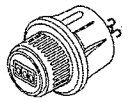
• **Resistance Tolerance:** ±5% • **Accuracy (Correlation of Dial Readout to Voltage Ratio Output):** ±0.5% Voltage ratio • **Repeatability of Dial Readout:** ±0.1% Voltage ratio • **Effective Electrical Angle:** 3600° nominal • **Dielectric Withstanding Voltage:** MIL-STD-202, Method 301 (Sea Level: 1,000VAC minimum); 70,000 Feet: 400VAC minimum



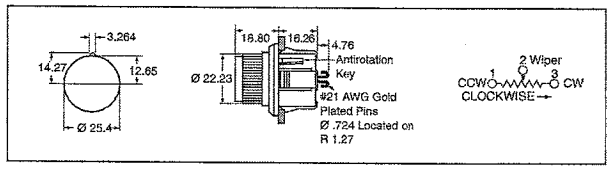
Ω	Resolution %	Digi-Key Part No.	1	25	100	500	1,000
10K	.022	3600S-1-103-ND	82.42	66.80	61.06	57.76	53.67

SERIES 3610

1.5 Watt - 10 Turn Wirewound Digital Clock Face



• **Resistance Tolerance:** ±5%
• **Accuracy (Correlation of Dial Readout to Voltage Ratio Output):** ±0.5% Voltage ratio
• **Repeatability of Dial Readout:** ±0.1% Voltage ratio
• **Effective Electrical Angle:** 3600° nominal
• **Dielectric Withstanding Voltage:** MIL-STD-202, Method 301 (Sea Level: 1,000VAC minimum); 70,000 Feet: 400VAC minimum

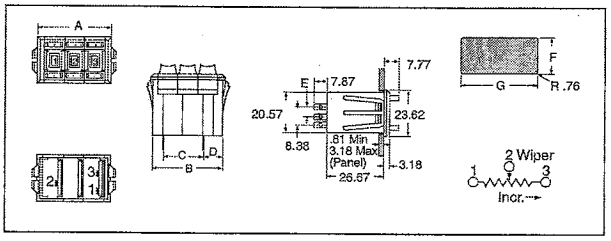


Ω	Resolution %	Digi-Key Part No.	1	25	100	500	1,000
1K	.035	3610S-1-102-ND	60.92	49.35	45.08	42.66	39.60
5K	.027	3610S-1-502-ND	60.92	49.35	45.08	42.66	39.60
10K	.022	3610S-1-103-ND	60.92	49.35	45.08	42.66	39.60

SERIES 3680

2 Watt Pushbutton Cermet

• **Resistance Tolerance:** ±3% • **Resolution:** 3682: 1%; 3683: 0.1% • **Power Rating:** +25°C: 2 Watts • **Dielectric Withstanding Voltage:** MIL-STD-202, Method 301 (Sea Level: 1000VAC minimum)



Ω	Dimensions (mm) A	B	C	D	E	F	G	Digi-Key Part No.	1	25	100	500	1,000
10K	26.67	25.15	10.67	11.94	8.38	21.08	25.91	3682S-1-103-ND	27.34	22.14	20.23	19.14	17.78
1K	37.08	35.31	18.54	11.94	4.19	21.08	36.07	3683S-1-102-ND	40.46	32.77	29.94	28.32	26.30
5K	37.08	35.31	18.54	11.94	4.19	21.08	36.07	3683S-1-502-ND	40.46	32.77	29.94	28.32	26.30
10K	37.08	35.31	18.54	11.94	4.19	21.08	36.07	3683S-1-103-ND	40.46	32.77	29.94	28.32	26.30

SERIES H-22, H-46, H-490, and H-550

Turn's Counting Dials

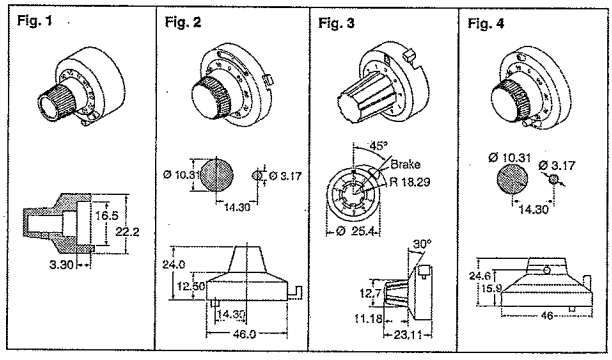
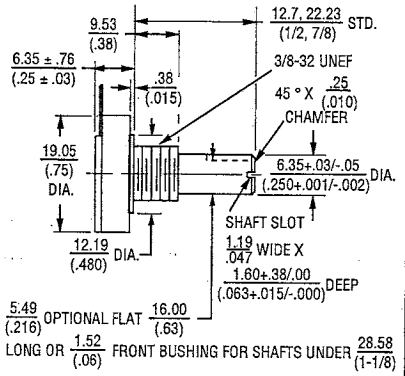


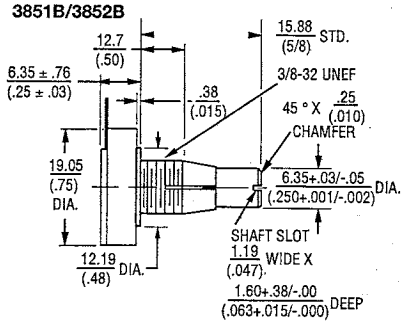
Fig.	Turns	Read Out	Division/ Turn	Brake	Diameter (mm)	Accepts Shaft Dia. (mm)	Body Finish	Digi-Key Part No.	1	Price Each 25	50
					H-22 Series						
1	0-15	Analog	50	Yes	22	6.35	Clear	H-22-6A-ND	8.54	8.12	7.69
					H-46 Series						
2	0-20	Analog	100	Yes	46	6.35	Clear	H-46-6A-ND	16.90	16.06	15.21
					H-490 Series						
3	0-30	Analog	100	Yes	25.4	6.35	Clear	H-4923-ND	28.80	22.40	18.33
	0-30	Analog	100	Yes	25.4	6.35	Black	H-4913-ND	28.80	22.40	18.33
					H-550 Series						
4	0-11	Analog	100	Yes	46	6.35	Clear	H-550-6A-1-ND	12.39	11.68	11.15

Product Dimensions

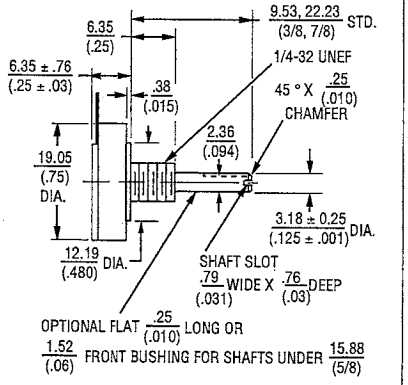
3851A/3852A



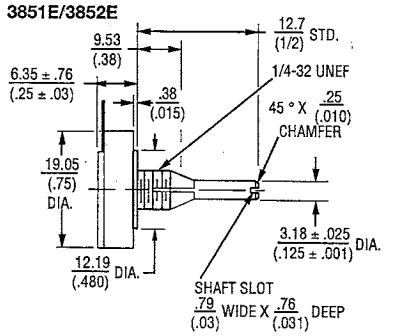
3851B/3852B



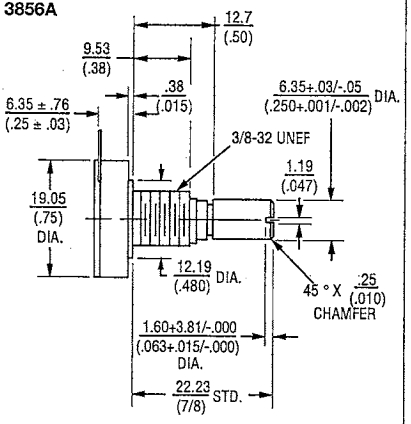
3851C/3852C



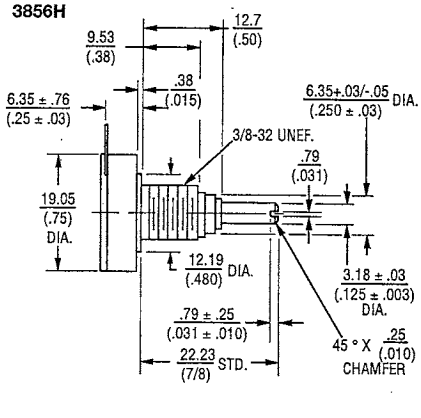
3851E/3852E



3856A



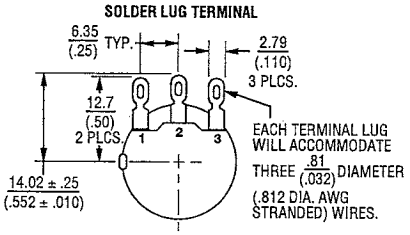
3856H



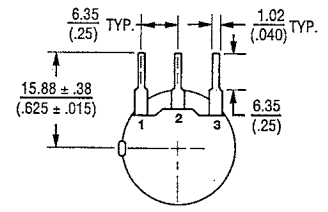
DIMENSIONS ARE: MM / (INCHES)

Terminal Configuration

SOLDER LUG TERMINAL

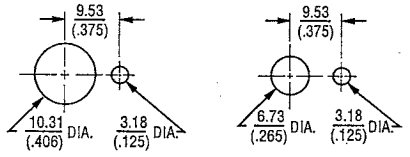


STANDARD PRINTED CIRCUIT TERMINAL

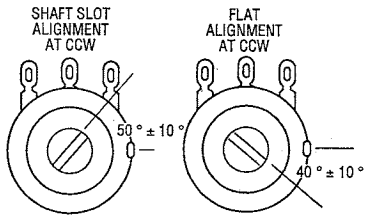


3851/3852/3856

A, B & H BUSHINGS



Shaft End Detail
3850 Family



TOLERANCES EXCEPT AS NOTED:
DECIMALS: .XXX ± .127 (.005), .XX ± .38 (.015)
FRACTIONS: ± 1/64
ANGLE: ± 3 %

Appendix C – Gear Selection Table

GBS-24054	54	2.250	0.3125	0.88	0.31	$29.70	$286.60
GBS-24060	60	2.500	0.3125	0.88	0.31	$33.20	$320.20
GBS-24072	72	3.000	0.3750	1.00	0.31	$31.80	$307.05
GBS-24084	84	3.500	0.3750	1.00	0.31	$44.25	$427.15
GBS-24096	96	4.000	0.3750	1.00	0.31	$51.40	$495.90
GBS-24120	120	5.000	0.3750	1.00	0.38	$87.70	$846.75
GBS-24144	144	6.000	0.3750	1.00	0.38	$115.15	$1,111.35

BRASS SPUR GEARS – 32 Pitch, 20° Pressure Angle

Face Width: 0.188". Outside Diameter = Pitch Diameter + 0.062". Overall Length = 0.188" + Hub Projection

	Dimensions In Inches					Price	
Part No.	Teeth	Pitch Dia.	Bore	Hub Dia.	Hub Project	Each	10
GBS-3212	12	0.375	0.125	0.28	0.25	$8.05	$60.40
GBS-3214	14	0.438	0.125	0.34	0.25	$8.50	$63.75
GBS-3216	16	0.5	0.188	0.4	0.25	$8.95	$67.15
GBS-3218	18	0.562	0.188	0.43	0.25	$9.40	$70.50
GBS-3220	20	0.625	0.188	0.47	0.25	$10.05	$75.40
GBS-3224	24	0.75	0.188	0.53	0.25	$11.40	$85.50
GBS-3228	28	0.875	0.188	0.59	0.25	$12.45	$93.40
GBS-3232	32	1	0.25	0.66	0.25	$13.35	$100.15
GBS-3236	36	1.125	0.25	0.72	0.25	$15.80	$118.50
GBS-3240	40	1.25	0.25	0.72	0.25	$17.15	$128.65
GBS-3248	48	1.5	0.25	0.78	0.25	$20.15	$151.15
GBS-3256	56	1.75	0.313	0.84	0.25	$21.85	$163.90
GBS-3264	64	2	0.313	0.9	0.25	$33.15	$248.65
GBS-3272	72	2.25	0.313	0.88	0.31	$35.80	$268.50
GBS-3280	80	2.5	0.313	0.88	0.31	$39.00	$292.50
GBS-3296	96	3	0.313	1	0.31	$43.20	$324.00
GBS-32112	112	3.5	0.3125	1	0.31	$52.15	$422.55
GBS-32128	128	4	0.3125	1	0.31	$63.65	$515.85
GBS-32160	160	5	0.3125	1	0.31	$81.00	$656.70

BRASS SPUR GEARS - 48 Pitch, 20° Pressure Angle

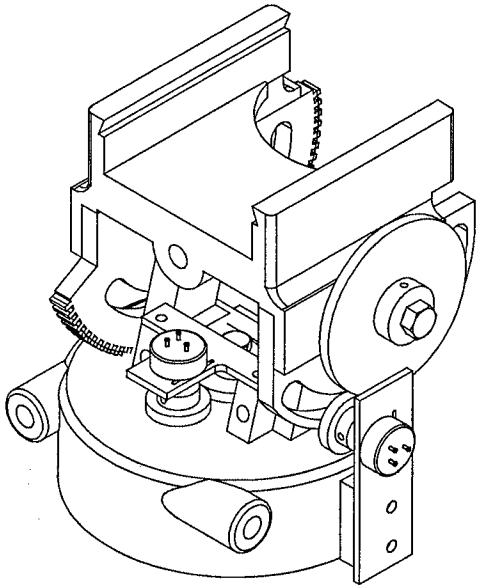
Face Width: 0.125". Outside Diameter = Pitch Diameter + 0.042". Overall Length = 0.125" + Hub Projection

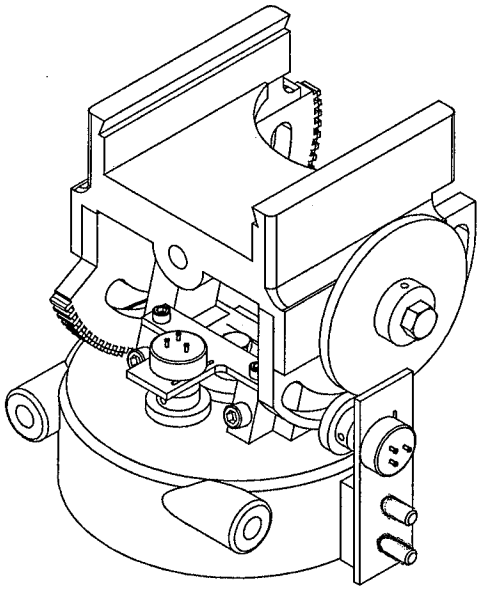
	Dimensions In Inches					Price	
Part No.	Teeth	Pitch Dia.	Bore	Hub Dia.	Hub Project	Each	10
GBS-48012	12	0.25	0.125	0.18	0.19	$6.90	$51.75
GBS-48015	15	0.312	0.125	0.22	0.19	$7.40	$55.50
GBS-48018	18	0.375	0.125	0.28	0.19	$8.05	$60.40

Appendix D – Modification Drawings

REVISIONS				
NO.	ZONE	DESCRIPTION	DATE	APPROVED

Notes:





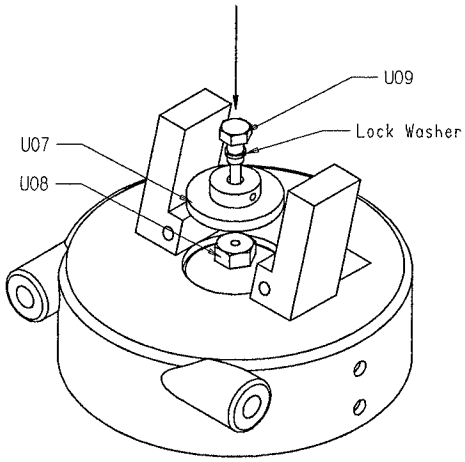
Source File
CAD_User\Projects\42_2096 Ice Detection\TOsnond\Tripod.ckd

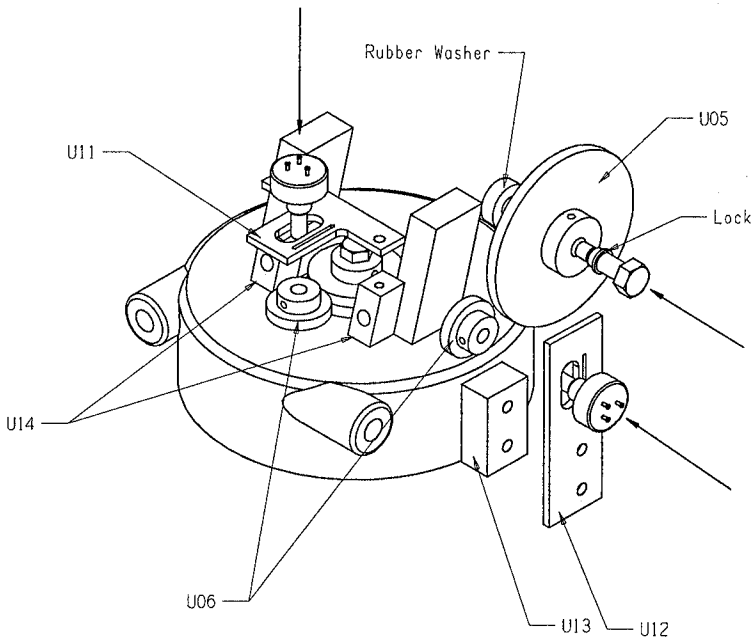
National Research Council Canada / Conseil national de recherches Canada — NRC-CNRC

TOLERANCES (unless specified)	Material	Institute for Marine Dynamics
0.X ± 0.03 0.XX ± 0.015 0.XXX ± 0.005 Angle +/- .5 deg. Fabrication +/- .04 Fraction < 6 Inch +/- 1/64 > 6 Inch +/- 1/32	N/A FINISH DIMENSIONS IN: INCHES ☒ MILLIMETERS ☐ THIRD ANGLE	Kerwin Place, P.O. Box 12093, Postal Station A St. John's, Newfoundland A1B 3T5
		YEAR 2096 — TITLE: General Assembly
		DRAWN T. Osnond
		APPROVED
		Quantity 1
		SIZE A3 — NUMBER 2096U01 — REV
		SCALE 1 : 2 — DATE 10-Apr-2006 — SHEET 1 OF 1

REVISIONS				
NO.	ZONE	DESCRIPTION	DATE	APPROVED

Notes:





Source File
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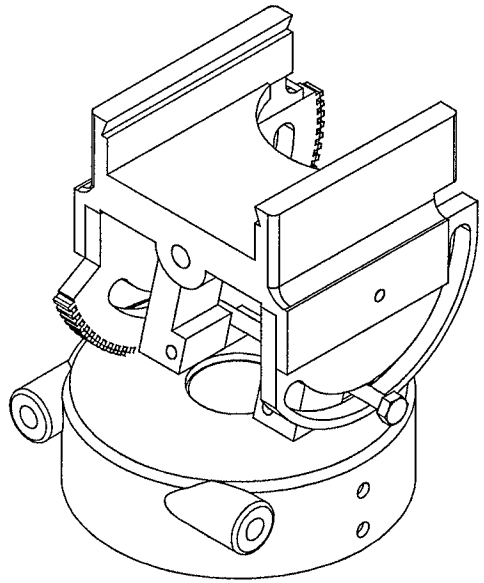
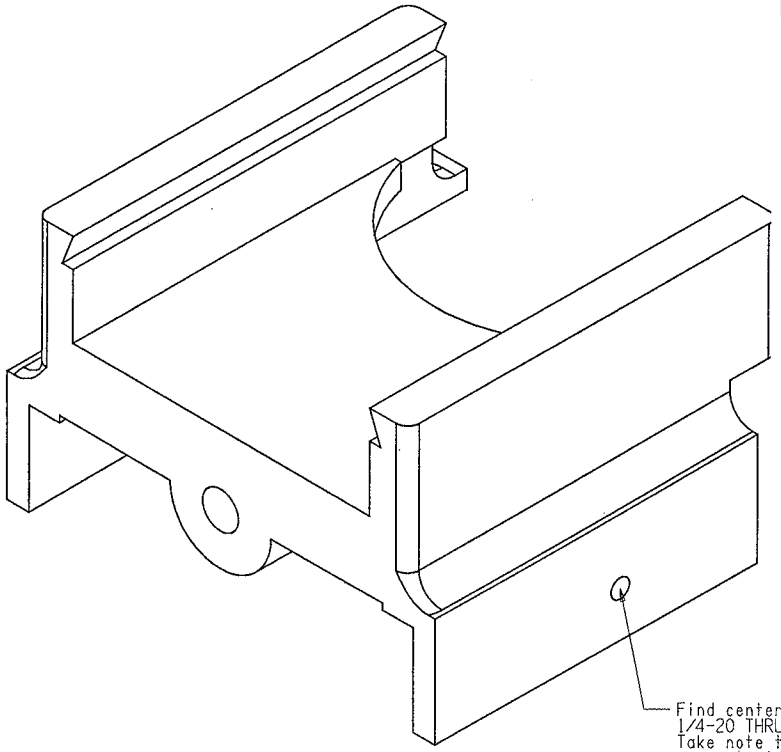
National Research Council Canada | Conseil national de recherches Canada | NRC-CNRC

Institute for Marine Dynamics
Kerwin Place, P.O. Box 12093, Postal Station A
St. John's, Newfoundland A1B 3T5

TOLERANCES (unless specified)	Material	TASK	TITLE
0.X ± 0.03 0.XX ± 0.015 0.XXX ± 0.005 Angle +/- .5 deg. Fabrication +/- .04 Fraction < 6 inch +/- 1/64 > 6 inch +/- 1/32	N/A	2096	Detail Assembly
	FINISH	DRAWN T. Osmond	
	DIMENSIONS IN: INCHES ☒ MILLIMETERS ☐	APPROVED	
THIRD ANGLE		Quantity 1	SIZE A3 NUMBER 2096U02 REV
		SCALE 1 : 2	DATE 10-Apr-2006 SHEET 1 OF 1

REVISIONS				
NO.	ZONE	DESCRIPTION	DATE	APPROVED





Notes:

Disassemble and renove
Tilt Bracket fron tripod.

Source File
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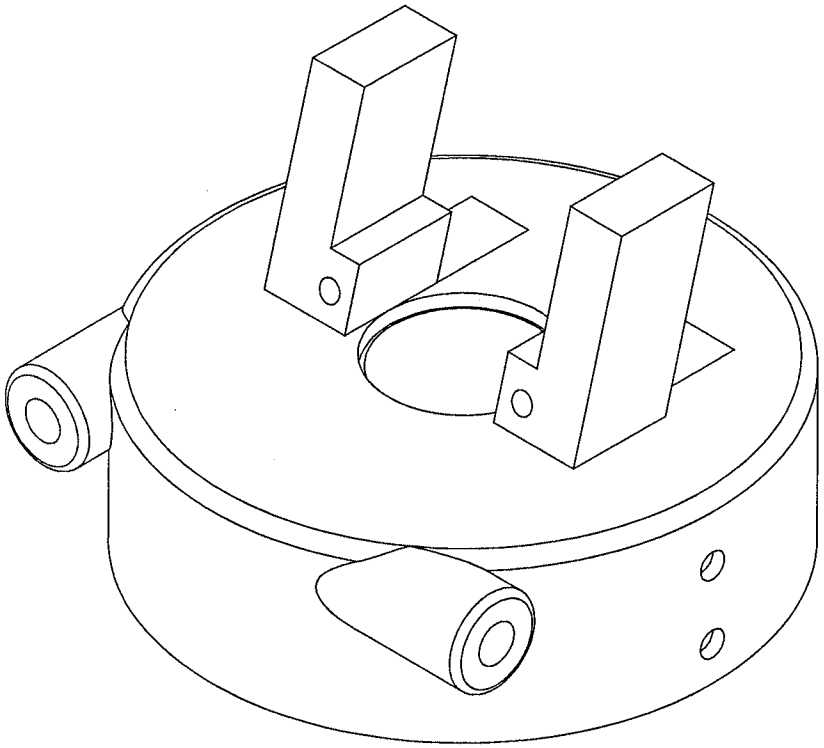
National Research Council Canada / Conseil national de recherches Canada — NRC-CNRC

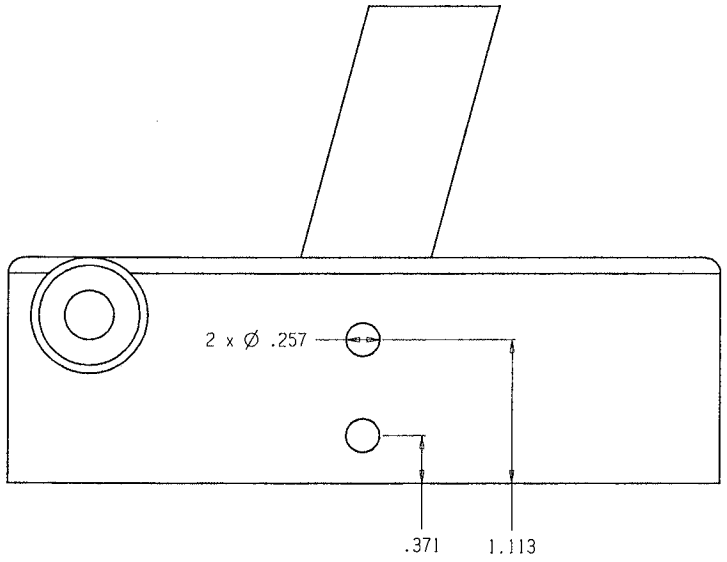
TOLERANCES (unless specified)	Material	Institute for Marine Dynamics
0.X ± 0.03 0.XX ± 0.015 0.XXX ± 0.005 Angle +/- .5 deg. Fabrication +/- .04 Fraction < 6 inch +/- 1/64 > 6 inch +/- 1/32	N/A	Kerwin Place, P.O. Box 12093, Postal Station A St. John's, Newfoundland A1B 3T5
FINISH	YEAR 2096	TITLE Tilt Bracket
DIMENSIONS IN: INCHES ☒ MILLIMETERS ☐	DRAWN T. Osmond	
THIRD ANGLE	APPROVED	
	Quantity 1	SIZE A3 NUMBER 2096LI03 REV
		SCALE 1:1 DATE 10-Apr-2006 SHEET 1 OF 1

REVISIONS				
NO.	ZONE	DESCRIPTION	DATE	APPROVED



Notes:

Deburr - Remove All Sharp Edges



Source File
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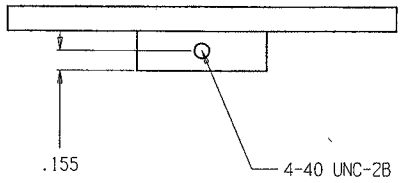
National Research Council Canada / Conseil national de recherches Canada — NRC-CNRC

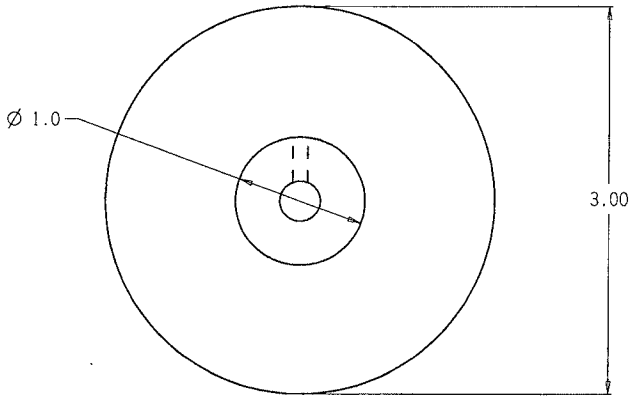
TOLERANCES (unless specified) 0.X ± 0.03 0.XX ± 0.015 0.XXX ± 0.005 Angle +/- .5 deg. Fabrication +/- .04 Fraction < 8 inch +/- 1/64 > 8 inch +/- 1/32	Material: N/A FINISH DIMENSIONS IN: INCHES ☒ MILLIMETERS ☐ THIRD ANGLE	Institute for Marine Dynamics Kerwin Place, P.O. Box 12093, Postal Station A St. John's, Newfoundland A1B 3T5 YEAR: 2096 DRAWN: T. Osmond APPROVED Quantity: 1
TITLE: Base Modification A3 NUMBER: 2096U04 REV SCALE: 1 : 1 DATE: 10-Apr-2006 SHEET 1 OF 1		

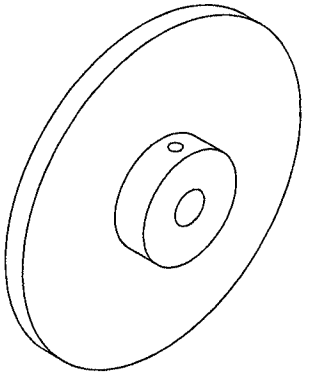
REVISIONS				
NO.	ZONE	DESCRIPTION	DATE	APPROVED

Notes:

www.smallparts.com
Part Number: GBS-3296







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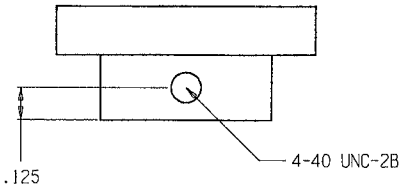
National Research Council Canada / Conseil national de recherches Canada — NRC-CNRC

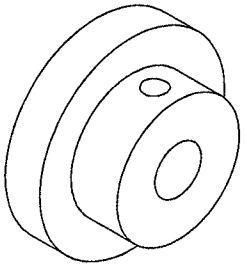
TOLERANCES (unless specified)	Material	Institute for Marine Dynamics
0.X ± 0.03 0.XX ± 0.015 0.XXX ± 0.005 Angle +/- .5 deg. Fabrication +/- .04 Fraction < 6 inch +/- 1/64 > 6 inch +/- 1/32	Brass FINISH DIMENSIONS IN: INCHES ☒ MILLIMETERS ☐ THIRD ANGLE	Kerwin Place, P.O. Box 12093, Postal Station A St. John's, Newfoundland A1B 3T5
	JOB 2096 DRAWN T. Osmond APPROVED Quantity 1	TITLE Gear 1 A3 NUMBER 2096L105 REV SCALE 2 : 1 DATE 10-Apr-2006 SHEET 1 OF 1

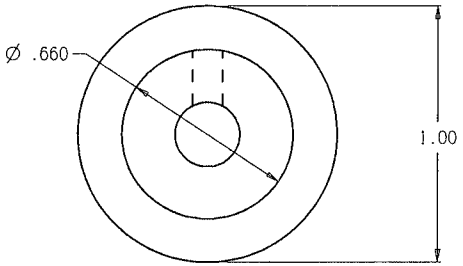
REVISIONS				
NO.	ZONE	DESCRIPTION	DATE	APPROVED

Notes:

www.smallparts.com
Part Number: GBS-3232







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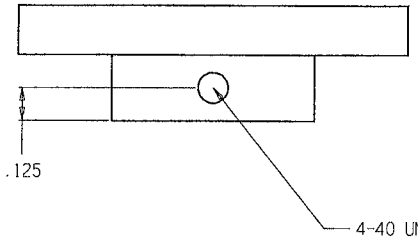
National Research Council Canada | Conseil national de recherches Canada | NRC-CNRC

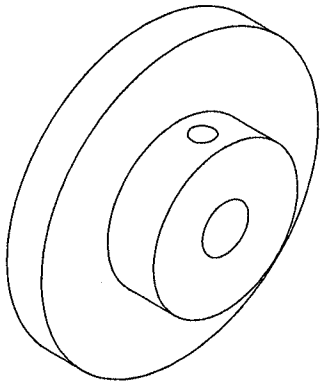
TOLERANCES (unless specified) 0.X ± 0.03 0.XX ± 0.015 0.XXX ± 0.005 Angle +/- .5 deg. Fabrication +/- .04 Fraction < 6 Inch +/- 1/64 > 6 Inch +/- 1/32	Material: N/A FINISH DIMENSIONS IN: INCHES ☒ MILLIMETERS ☐ THIRD ANGLE	Institute for Marine Dynamics Kerwin Place, P.O. Box 12093, Postal Station A St. John's, Newfoundland A1B 3T5 DRAW: 2096 DRAWN: T. Osnond APPROVED Quantity: 2 TITLE: Gear 2 SIZE: A3 NUMBER: 2096L106 REV SCALE: 2 : 1 DATE: 10-Apr-2006 SHEET 1 OF 1

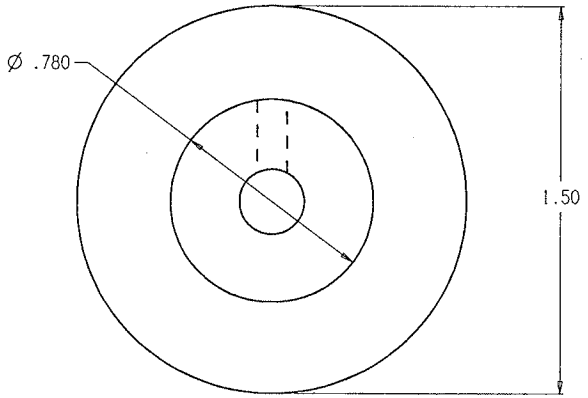
REVISIONS				
NO.	ZONE	DESCRIPTION	DATE	APPROVED

Notes:

www.smallparts.con
Part Number: GBS-3248







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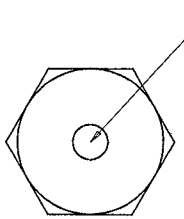
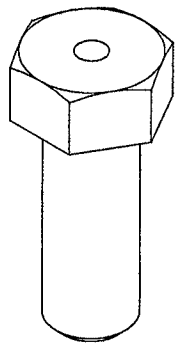
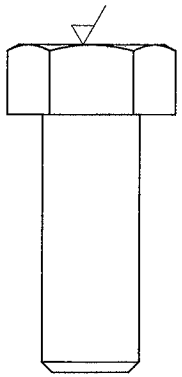
National Research Council Canada | Conseil national de recherches Canada | NRC-CNRC

TOLERANCES (unless specified)	Material	Institute for Marine Dynamics
0.X ± 0.03 0.XX ± 0.015 0.XXX ± 0.005 Angle +/- .5 deg. Fabrication +/- .04 Fraction <6 Inch +/- 1/64 >8 Inch +/- 1/32	N/A	Kerwin Place, P.O. Box 12093, Postal Station A St. John's, Newfoundland A1B 3T5
	FINISH	PROJ 2096 — TITLE Gear 3
	DIMENSIONS IN: INCHES ☒ MILLIMETERS ☐	DRAWN T. Osmond
	THIRD ANGLE	APPROVED
		Quantity 1 — SIZE A3 — NUMBER 2096L107 — REV
		SCALE 2:1 — DATE 10-Apr-2006 — SHEET 1 OF 1

REVISIONS				
NO.	ZONE	DESCRIPTION	DATE	APPROVED







Notes:

Use Bolt already in tripod head

Source File
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National Research Council Canada / Conseil national de recherches Canada — NRC-CNRC

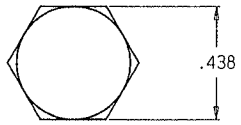
TOLERANCES (unless specified)	Material	Institute for Marine Dynamics
0.X ± 0.03 0.XX ± 0.015 0.XXX ± 0.005 Angle +/- .5 deg. Fabrication +/- .04 Fraction < 6 inch +/- 1/64 > 6 inch +/- 1/32	Steel FINISH DIMENSIONS IN: INCHES ☒ MILLIMETERS ☐ THIRD ANGLE	Kerwin Place, P.O. Box 12093, Postal Station A St. John's, Newfoundland A1B 3T5

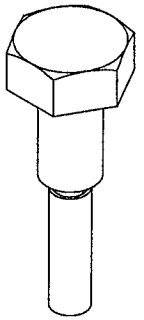
JOB	TITLE
2096	Pan Bolt
DRAWN: T. Osnond	
APPROVED	
Quantity: 1	SIZE: A3 — NUMBER: 2096U08 — REV
SCALE: 2 : 1 — DATE: 10-Apr-2006 — SHEET 1 OF 1	

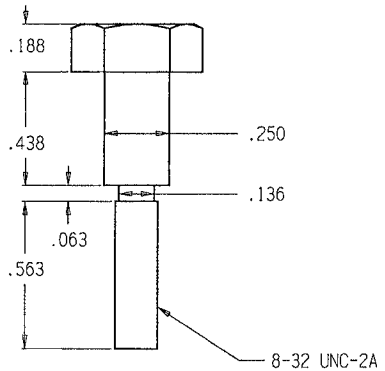
REVISIONS				
NO.	ZONE	DESCRIPTION	DATE	APPROVED

Notes:

Deburr - Renove All Sharp Edges







Source File
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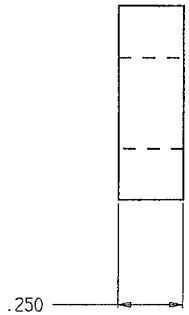
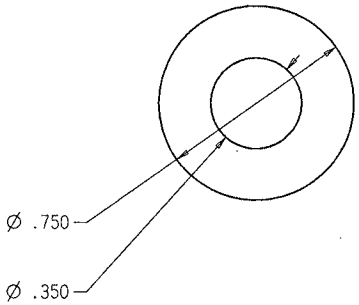
National Research Council Canada / Conseil national de recherches Canada — NRC-CNRC

TOLERANCES (unless specified) 0.X ± 0.03 0.XX ± 0.015 0.XXX ± 0.005 Angle +/- .5 deg. Fabrication +/- .04 Fraction < 6 Inch +/- 1/64 > 6 Inch +/- 1/32	Material: Steel FINISH DIMENSIONS IN: INCHES ☒ MILLIMETERS ☐ THIRD ANGLE	Institute for Marine Dynamics Kerwin Place, P.O. Box 12093, Postal Station A St. John's, Newfoundland A1B 3T5 DWG 2096 — TITLE: Pan Shaft DRAWN T. Osnond APPROVED Quantity 1 A3 — NUMBER 20961109 — REV SCALE 2 : 1 — DATE 10-Apr-2006 — SHEET 1 OF 1

REVISIONS				
NO.	ZONE	DESCRIPTION	DATE	APPROVED

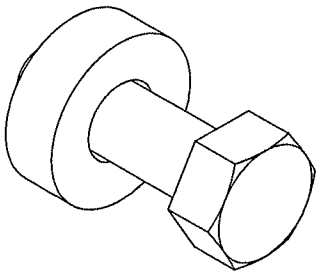
Rubber Washer

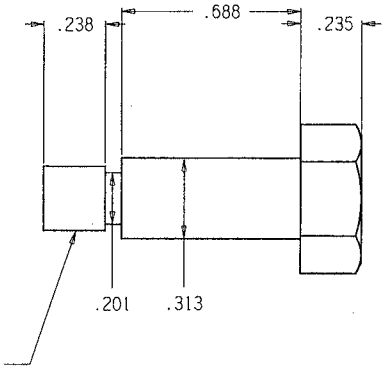


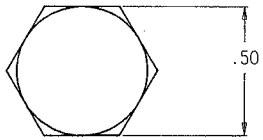


Notes:

Deburr - Remove All Sharp Edges







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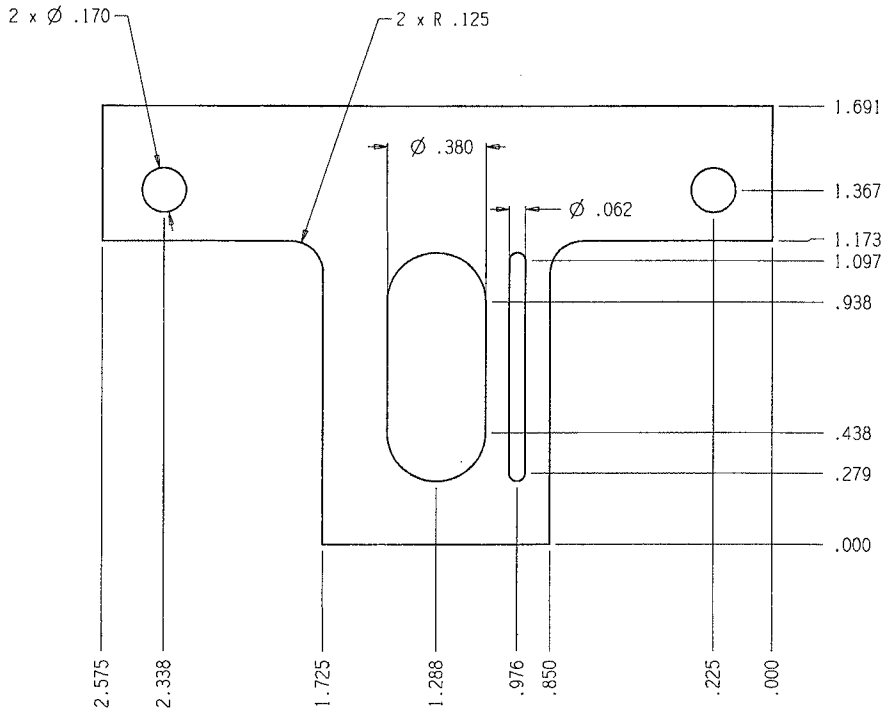
National Research Council Canada / Conseil national de recherches Canada — NRC-CNRC

TOLERANCES (unless specified) 0.X ± 0.03 0.XX ± 0.015 0.XXX ± 0.005 Angle +/- .5 deg. Fabrication +/- .04 Fraction < 6 Inch +/- 1/64 > 6 Inch +/- 1/32	Material: Steel FINISH DIMENSIONS IN: INCHES ☒ MILLIMETERS ☐ THIRD ANGLE	Institute for Marine Dynamics Kerwin Place, P.O. Box 12093, Postal Station A St. John's, Newfoundland A1B 3T5 DRAW: 2096 — TITLE: Tilt Shaft DRAWN: T. Osmond APPROVED Quantity: 1 SIZE: A3 — NUMBER: 2096LI10 — REV SCALE: 2 : 1 — DATE: 10-Apr-2006 — SHEET 1 OF 1

REVISIONS				
NO.	ZONE	DESCRIPTION	DATE	APPROVED

Notes:

Deburr - Remove All Sharp Edges



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National Research Council Canada / Conseil national de recherches Canada — NRC-CNRC

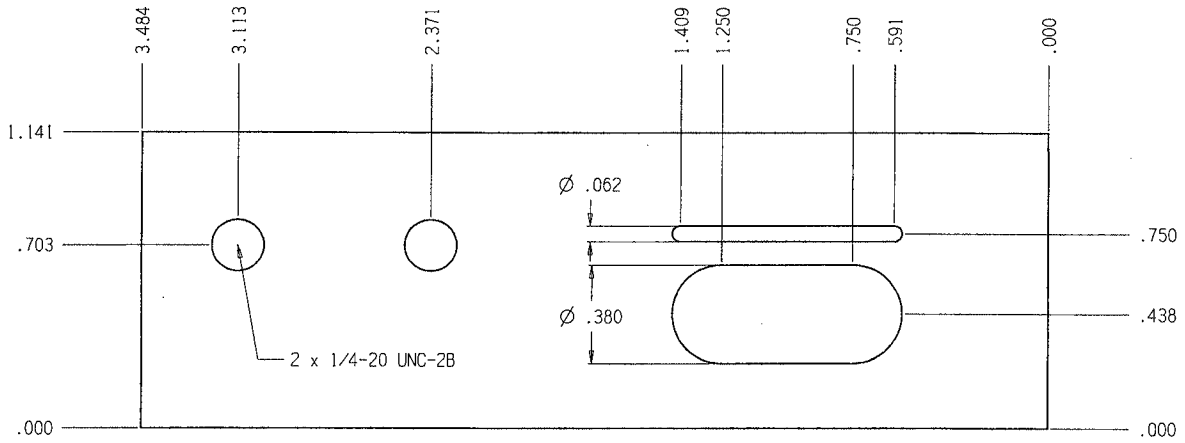
Institute for Marine Dynamics
Kerwin Place, P.O. Box 12093, Postal Station A
St. John's, Newfoundland A1B 3T5

TOLERANCES (unless specified)	
0.X ± 0.03	
0.XX ± 0.015	
0.XXX ± 0.005	
Angle +/- .5 deg.	
Fabrication +/- .04	
Fraction < 6 Inch +/- 1/64	
> 6 Inch +/- 1/32	
Material	1/8" Steel
Finish	
Dimensions are: Inches ☒ Millimeters ☐	
Third Angle	
Job	2096
Drawn	T. Osnond
Approved	
Quantity	1
Title	Pan Pot Mount
Size	A3
Number	2096U11
Rev	
Scale	2 : 1
Date	10-Apr-2006
Sheet	1 of 1

REVISIONS				
NO.	ZONE	DESCRIPTION	DATE	APPROVED

Notes:

Deburr - Renove All Sharp Edges



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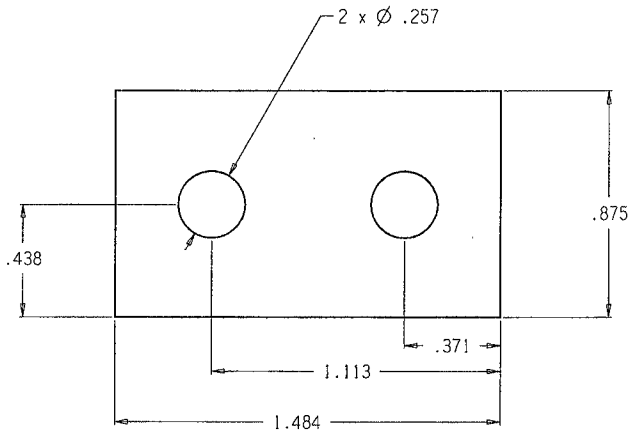
National Research Council Canada | Conseil national de recherches Canada | NRC-CNRC

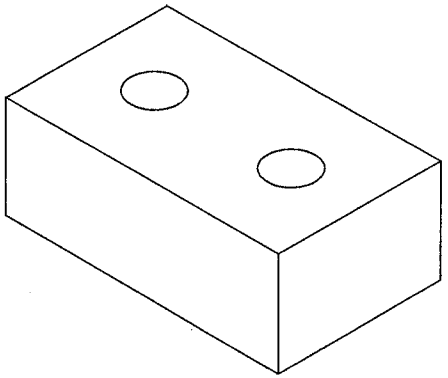
TOLERANCES (unless specified) 0.X ± 0.03 0.XX ± 0.015 0.XXX ± 0.005 Angle +/- .5 deg, Fabrication +/- .04 Fraction < 6 Inch +/- 1/64 > 6 Inch +/- 1/32	Material: 1/8" Steel FINISH DIMENSIONS IN: INCHES ☒ MILLIMETERS ☐ THIRD ANGLE	Institute for Marine Dynamics Kerwin Place, P.O. Box 12093, Postal Station A St. John's, Newfoundland A1B 3T5 DRAWN: 2096 DRAWN: T. Osnond APPROVED Quantity: 1 TITLE: Tilt Pot Mount SIZE: A3 NUMBER: 2096U12 REV SCALE: 2 : 1 DATE: 10-Apr-2006 SHEET 1 OF 1

REVISIONS				
NO.	ZONE	DESCRIPTION	DATE	APPROVED

Notes:

Deburr - Renove All Sharp Edges





Source File
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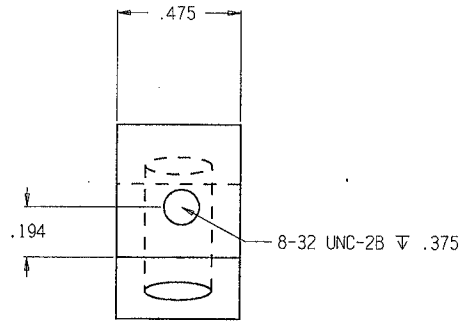
National Research Council Canada / Conseil national de recherches Canada — NRC-CNRC

Institute for Marine Dynamics
Kerwin Place, P.O. Box 12093, Postal Station A
St. John's, Newfoundland A1B 3T5

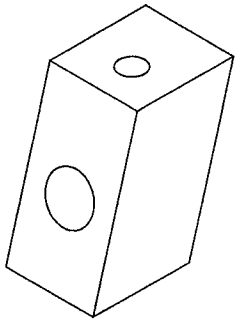
TOLERANCES (unless specified)	0.X ± 0.03 0.XX ± 0.015 0.XXX ± 0.005 Angle +/- .5 deg. Fabrication +/- .04 Fraction < 6 Inch +/- 1/64 > 6 Inch +/- 1/32
Material	Steel
FINISH	
DIMENSIONS IN: INCHES ☒ MILLIMETERS ☐	
THIRD ANGLE	
JOB	2096
DRAWN	T. Osmond
APPROVED	
Quantity	1
TITLE	Tilt Block
SIZE	A3
NUMBER	2096U13
REV	
SCALE	2 : 1
DATE	10-Apr-2006
SHEET	1 OF 1

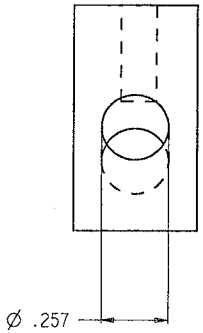
REVISIONS				
NO.	ZONE	DESCRIPTION	DATE	APPROVED

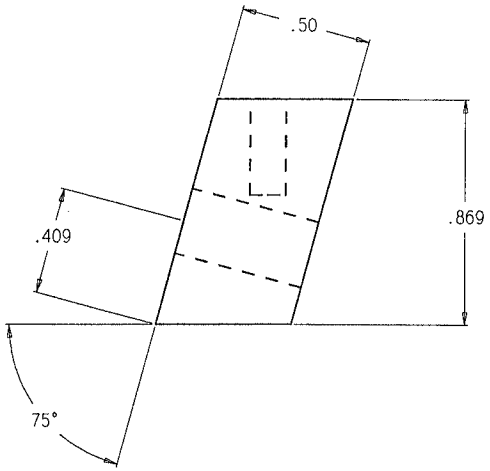


Notes:

Deburr - Renove All Sharp Edges







Source File
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National Research Council Canada / Conseil national de recherches Canada — NRC-CNRC

TOLERANCES (unless specified) 0.X ± 0.03 0.XX ± 0.015 0.XXX ± 0.005 Angle +/- .5 deg. Fabrication +/- .04 Fraction <6 Inch +/- 1/64 >6 Inch +/- 1/32	Material: Steel FINISH DIMENSIONS IN: INCHES ☒ MILLIMETERS ☐ THIRD ANGLE	Institute for Marine Dynamics Kerwin Place, P.O. Box 12093, Postal Station A St. John's, Newfoundland A1B 3T5 MAK: 2096 DRAWN: T. Osmond APPROVED Quantity: 2
TITLE: Pan Block A3 — NUMBER: 2096U14 — REV SCALE: 2 : 1 — DATE: 10-Apr-2006 — SHEET 1 OF 1		