Fermilab

Particle Physics Division
Mechanical Department Engineering Note

Number: MD-ENG-061 Date: 10/20/04

Project Internal Reference:

Project: BTEV

Title: EMCAL LEAD CRYSTAL TESTING DRIVE SYSTEM

Author(s): ED LA VALLIE

Reviewer(s):

Key Words:

Abstract Summary:

Applicable Codes:

PPD/Mechanical Department
BTEV EM-Cal Lead Tungstate Crystal Testing
Horizontal/Vertical Drive System and Cooling Enclosure

Purpose: Testing of Crystal

Location: M-Test Beam line (in detector building)

Assigned by: Dave Pushka and Herman Cease 5/10/04

Scope:

Design Remote Controlled Horizontal/Vertical Drive System with manual 90 degree radial rotation, for testing Lead Tungstate Crystal (M-Test beam line, remote controlled with data taking from West side counting house)

Horizontal Drive Table Assessment (existing in M-Test beam area)

Table size in beam oriented position is, 120.75" wide x 48.75" deep(along beam) x 43.625" high with 2- 1.5" diameter rail shafts 96" long mounted on 4-24" long aluminum v-groove shaft supports per rail (continuously supported). Riding on these shaft rails is a 48.625" wide x 36" deep x 1.25" thick aluminum tooling plate riding on 2 per rail shaft, 1.5" inside dimension Open Pillow Block Bearings. Attached to this plate is a 24" diameter x 1.25" thick turntable located at center. The current horizontal drive system running down the center of the table and driving this plate is made up of a 1.5" diameter ball screw driven by a Slo-Syn M113-FF-401 DC stepping motor, 4 connection, 200 steps per revolution, 4.5 DC volts, 6 amps per winding and a holding torque of 2150 in. oz. The controller is made up of a Superior Electric SS20006i Motor Drive and a SS2000i Programmable Motion Control. It is my understanding that last time used this drive worked well.

Note:
My initial reaction to the above is that this existing horizontal drive table appears to be in good repair, solid, well built, and with a more then adequate load capacity/travel for this test, although I have not seen it operated. I'm told that the crystal array needs to be rotated manually 90 degrees in its driven position during testing (frequency unknown). Although this horizontal drive has an existing 12" diameter turntable in all likelihood it is too small a diameter to be useful, (must be increased in diameter).

Although the cooled crystal test housing fabrication does not fall within the scope of this job, dimensionally defining this light tight, insulated/cooled housing and understanding its contents at some level is a must and the determinant of the final vertical drive parameters. Initially I will accept the horizontal drive table as a start point and propose a vertical drive system compatible with this existing horizontal drive table, if possible.

I have no written specification on material being tested but am told it is Lead Tungstate Crystal, which is in a tapered bar form with dimensions of, 27 mm(1.063") square at upstream end, 28 mm (1.102") square at downstream end and its length is 220 mm(8.661") which would be 166,320 mm^3, or 166.32 cm^3, or 9.376 cu. in. which is the volume of material per bar (exact material weight was initially unknown to me but has since been stated to be 8.28 g/cm^3) x 0.03612730 (conversion factor), or 0.299 # in^3. This crystal is to be stacked, 10 bars wide x 10 bars high or 100 bars in total, and is to be stacked flush bar to bar in four quadrants with the centerline of each quadrant squared to beam This squaring would be accomplished through shimming for purposes of minimizing angular fan about the horizontal and vertical axis. Each crystal bar will then have a Hamamatsu R5380 Photomultiplier Tube held in intimate contact with the downstream crystal bar face. It has further been stated by Herman Cease that remotely operated motion need only be horizontal and vertical, not radial to follow stacking angle of crystal bars. Verbal comment I received indirectly from Pavel Semenov indicates that the vertical drive system needs to be capable of moving 500# total weight (Crystal/ cooling/housing/contents).

The nominal beam height I measured from floor in M-Test is 67 3/16". With existing table height minus turntable being 49 1/8" a differential of 18 1/16" would remain. From this you must immediately subtract half the crystal stack height of approximately 5 1/2" leaving 12 9/16" space beneath. Within this space the minimum travel of 6" plus two support plates (cooled box base and turntable, approximately 1" each) must be subtracted. The remaining usable space beneath the crystal housing plate and the turntable plate would now now4 9/16", which precludes putting a single support beneath the box that would accommodate an approximate12" travel, with a possible exception of a scissors table, which I have already investigated. Supports outboard from the cooled Crystal housing appear to be the way to go.

Based upon gathered parameters stated above and attempting to keep a turntable to a maximum of 36" diameter, the distance along beam of the support plate upon which the housing rides (fully supported) the following is my recommendation for a vertical drive. Utilizing a 36" turntable mounting plate, a crystal mounting plate three traveling nut machine screw jacks, two right angle drives, 4 shafts, and 9 shaft couplings along with an additional DC Stepping Motor if one exists (or purchase), create a vertical drive system

With one jack end (the base) fixed and the other free (support pedestals of the vertically driven plate), and without any additional guidance system to offer lateral support the maximum jack height for a 1 ton jack with a 250# load would be limited to 17", see Nook Industries column loading chart included. A Nook Industries Inc., 1-MSJ (1 Ton Jack) with an overall extended height of 17" (12" travel requirement plus 5 1/32" base ht.) would offer a compressive load capacity of 250# for one jack based upon column loading, therefore with 3 jacks there is a lateral safety factor of 3. The 36" turntable diameter, with 3 screw jacks thereon, outside the housing profile dictate the maximum crystal housing support plate dimensions to be 36" wide x 28" along beam. I have also been lead to believe 24" height would be adequate. My sketch SK-1 included, illustrates this arrangement. Before attempting to go any further it seems appropriate to validate my information first, then verify that my proposed housing dimensions satisfy all experimental requirements.

Prior to sending this information to Pavel Semenov for approval, I did meet with Joe Howell and Herman Cease on 5/24/04 to discuss where I was, and get a sense as to my being on the right track. It appears as though my direction is on track, although I did receive a couple of comments, which have been addressed in this proposal. Herman commented that the cooled box might be too short in depth along beam and asked if the housing could be lengthened from 28" to 32". I have incorporated this change by increasing turntable diameter from 36" to 40.5". Joe commented the Crystal should be raised from vertically driven plate surface inside the cooled box due to heat transfer and accessibility issues. This can also been incorporated in the design by cutting and lowering the horizontal drive table by 9". The following is a summation of my preceding comments and references to my sketch SK-1 (included). 1. The horizontal drive table can be used as is with exception to the need to lower its overall height by 9" (in house cutting/ welding), and discard its existing turntable 2. There must be a new turntable upon which all vertical drive components, cooled housing, crystal etc. will be mounted (materials and machining required). 3. All component parts of vertical drive, base plate(materials and machining required), three jacks (483.00 each), two right angle drive gear boxes (197.00 each), nine couplings (100.00 lot) and DC stepping motor (459.00 if purchased) and motor mount/spacers/shafts must be fabricated/ordered. Cooled housing although partially specified for compatibility with drive system many unknowns remain (fabricate in house or outside?).

Nook Industries Action Jack

1 MSJ traveling nut machine screw jack (3 required)

Capacity	*2000#*
Lifting Screw Diameter	*0.75"*

Lead of Screw	*0.200*
Root diameter of screw	*0.502*
Gear Ratio	*20:1 Self Locking*
Turns worm for 1" rise	*100*
Max. Input Torque	*21 in. lbs.*
Max. Allowable input HP	*1/4*
Max. Worm speed at rated load	*750 rpm (1800 rpm max at any load)*
Efficiency (running)	*14.9*
Torque to raise 1#	*0 .0105 in. lb*
Tear Drag Torque	*3 in. lb (running less then 25% full load)*

Max. Jack height at 250# load = 17" See Column Strength Chart attached
Working load is 250# (1/8 total capacity) = (+ 3 in lbs. tear drag torque)
12" total travel x 100 turns per in. = 1200 turns full travel
60 seconds full travel = 1200 rpm
1200 rpm x 200 steps per rev.=240000 steps full travel / 60 sec. = 4000 sps
Torque at 2000# rated load 21 in. lbs. / 8 = 2.625 in lb. + 3 in lb tear drag torque = 5.625 in lb. = 90 in. oz. x 2 at startup = 180 in. oz.

C139801 Zero-Max Three-Way Crown Gear Drives 1:1 Ratio (3/8" shafts) 24# in orque/2 service factor = 12# in torque @ 1000 rpm max. rpm is 2000 (2 required)

A/L050 Lovejoy Couplings w/ Buna N Spiders max. hp at 1200 rpm = 0.5, and rated torque of 26.3 # in. 15-3/8" and 3-1/2" bodies and 9-spiders.

DC Stepping Motor Sizing:
3-Jack arrangement 500# total load, although 1 jack will see 50% of load or 250# due to un-symmetric spacing.

Worm rpm = 12" min. travel required x 100 turns per in. of travel = 1200 turns full travel (rpm) x 200 steps per revolution =240000 steps full travel / 60 seconds (full travel) = 4000 steps per second.

HP per jack = (torque to raise 1# x number lbs. per jack x rpm of worm)/63025
(0.0105 # in x 250# x 1200 rpm) / 63025 = .05 hp per jack

Arrangement hp = (HP per jack x # jacks) / (arrangement Efficiency x Gearbox Efficiency) = (0.05 x 3) / (0.90 x 0.90) = .185 hp

DC Stepper Motor same type as horizontal drive M113-FF401 if available, 200 steps per revolution 2.26 v and 6.1 A. would be more then acceptable and perhaps use same drive controller as horizontal drive @4000 steps per second would develop about 300 oz. in. torque (we have no additional motors of this type and this motor is no longer available to purchase).

Manufacturer recommended alternative DC Stepper Motor compatible with existing drive controller would be M112-FF206 ($869.00)which @ 4000 sps would develop about the same 450 oz. in torque and M111-FF206 ($454.00) at same speed would develop about 260 oz. in. of torque. I would not go any smaller then this unless the speed of travel is decreased.

This is not a total package as yet, but is my proposal, incorporating earlier comments and should be reviewed and commented upon by users with feedback to me ASAP.

Ed LaVallie 6/04/04

On 6/11/04 there was a response from Pavel Semenov giving approval on the design in principle but requested that the bottom housing height be shorter and the top be taller for accessibility although no exact split ratio was recommended. Without information on cabling requirements exiting housing (space and location), I have proposed a fixed, downstream, formed sheet metal panel which would accommodate all cabling/cooling penetrations when understood which allows me to proceed. The removable top in this case would allow access from three sides. I submitted this design to Joe Howell and Herman Cease for comments and as time to run date was drawing near for Crystal Test Run attempted to find in house, any usable materials and components for drive system. Although not cast tooling plates I did find aluminum plate large enough to fabricate turntable and crystal support plate. With this Joe Howell asked for ordering specifics for drive components specified earlier, which I supplied. Joe at this time decided to put together his version of a housing using 80/20 Industrial Erector Set Parts and aluminum sheet staying within the stated box footprint.

In the mean time further searched for and found a DC Stepping Motor suitable for the vertical drive in terms of torque. This motor is a Slo-Syn M112-FD08, 5.8v, and 3.8a, 200 steps per revolution, 4 connection, and 65 degree temp. Rise, B insulation, and with an 840 oz. in., Torque rating. What I did not no was, could this motor be operated with the same, existing Superior Electric SS2000D6 Motor Drive and SS2000i Programmable Motor Controller mentioned earlier, used on the horizontal drive. I sent an e-mail off to Dan Schoo (Accelerator Division) dated 7/19/04 asking for advice as to motor compatibility and recommendations on hook up (I knew he had experience with Slo-Syn

DC stepping motors from past jobs). As Dan was on vacation Bob Demaat, Dan's group leader offered his assistance. After some research Bob and Dan concluded that driving both motors with the same controller could be done with separate wiring for each motor setting on the controllers. We now had gathered the parts for a Vertical Drive System at minimal cost (definite criteria); workable although tooling plate would be appropriate (not perfect).

Summation:

1. Time for test run, mid July, doesn't allow for preparing a package of drawings to proceed with fabrication so I used my assembly drawing to illustrate individual parts from which fabrication/machining could/has been completed. A drawing package will come at some later date.
2. Submitted my assembly drawing with sketches to Dave Erickson for fabrication with a tight time frame which was completed. Items to be fabricated were turntable (went from round to square for ease of fabrication), Crystal/Housing Mounting Plate, motor mount assembly, four shafts of varying lengths, and right angle drive mounting adapters.
3. Pavel Semenov was to take charge of setting up, to satisfy experimental needs but was unavailable due to VISA delays, no techs were available at this time either, so setup was left to Yuichi also with the experiment, who was not up to speed as to plan of action. With my direction he started to assemble the drive which did not address housing/ cooling/ contents.
4. It was at this point that Joe Howell with his housing cooling design led the way with test assembly making changes as were necessary to address needs as they arose. My design was flexible enough to accommodate re-orientations without any re-work. I will not comment on Joe's scheme as it came directly from him.

5. Included within this commentary are plate deflection/stress, specification sheets on components as well as reference material on controllers which proved invaluable. These information sheets are in the form of attachments included at end of presented materials.

In closing I have attempted to keep this document updated as I have moved through changes in direction dictated by experimental needs, and have been successful with exception to the crystal support with integrated cooling (not part of original scope), however I did make a second assembly drawing SK-2 (included) which illustrates orientation changes made during assembly and inspired by experimental needs.

Although not present at initial test setup, it is my understanding that the drives and test setup worked as expected with only limit switches remaining to be installed.

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Crystal mounting plate stress/deflection:

Input	Name	Output	Unit	Comment
				Roark's Formulas for Stress and Strain
				Properties of Sections
				Section 2: Rectangle
	DIAGRAM	'y		Generate section diagram? ('n = no)
2	axis			Neutral Axis (1,2)
1	t1b		in	Side b
19.25	t1d		in	Side d
	A	19.25	in^2	Area, A
	t1y	0.5	in	Centroid to Extremity, y
	I	1.6042	in^4	Area moment of inertia
	I%c	3.2083	in^3	Elastic Section Modulus, I/c
	t1r	0.2887	in	Radius of Gyration, r
	Z	4.8125	in^3	Plastic Section Modulus, Z
	SF	1.5		Shape Factor, SF
	t	1	in	Depth
				Both ends simply supported
				Table 8.1: Case 3 -Roark's Formulas
				Concentrated Intermediate Moment
	case	'CASE_3e		End Restraints Reference Number
	matnum			Material Number (See Material Table)
	matl			
	plot	'y		Generate plots ? 'n=no (Default=yes)
33.5	L		in	Length of beam
17.5	a		in	Load distance from left end
8750	M0		lbf-in	Moment
2.9E7	E		psi	Young's Modulus
.5	z		in	Neutral axis to stress point

				AT SECTION:
16.75	x		in	Distance from left end
	V	-261.194	lbf	Transverse shear
	M	-4375	lbf-in	Bending moment
	theta	-4.5612455E-4	rad	Slope Angle
	y	1.1549765E-3	in	Deflection
	st	-1363.636	psi	Fiber stress at stress point
	sty	-1363.636	psi	Max Fiber stress at extremity y
				AT LEFT END:
	RA	-261.194	lbf	Vertical reaction
	MA	0	lbf-in	Bending moment
	thetaA	3.3149301E-4	rad	Slope Angle
	yA	0	in	Deflection
				AT RIGHT END:
	RB	261.194	lbf	Vertical reaction
	MB	0	lbf-in	Bending moment
	thetaB	1.9042717E-4	rad	Slope Angle
	yB	0	in	Deflection

Epilogue dated 10/20/04

Due to the hurried nature of putting a drive system together to be ready for a short window of opportunity (beam delivery to M-Test this process has not been carried out in a particularly straight forward manner thus delaying this documentation. A package of drawings has been put together as a fill in job and is now being checked on much the same basis. Upon receiving these drawings I will sign off and include a listing of numbers. It should also be noted that this drawing package is made up from some long existing as well as new components making presentation somewhat less then perfect but factual. Photographs of completed drive system with partial Lead Tungstate Crystal in place are included. A continuation of this test with a full Crystal Array is yet to be carried out at some future date.

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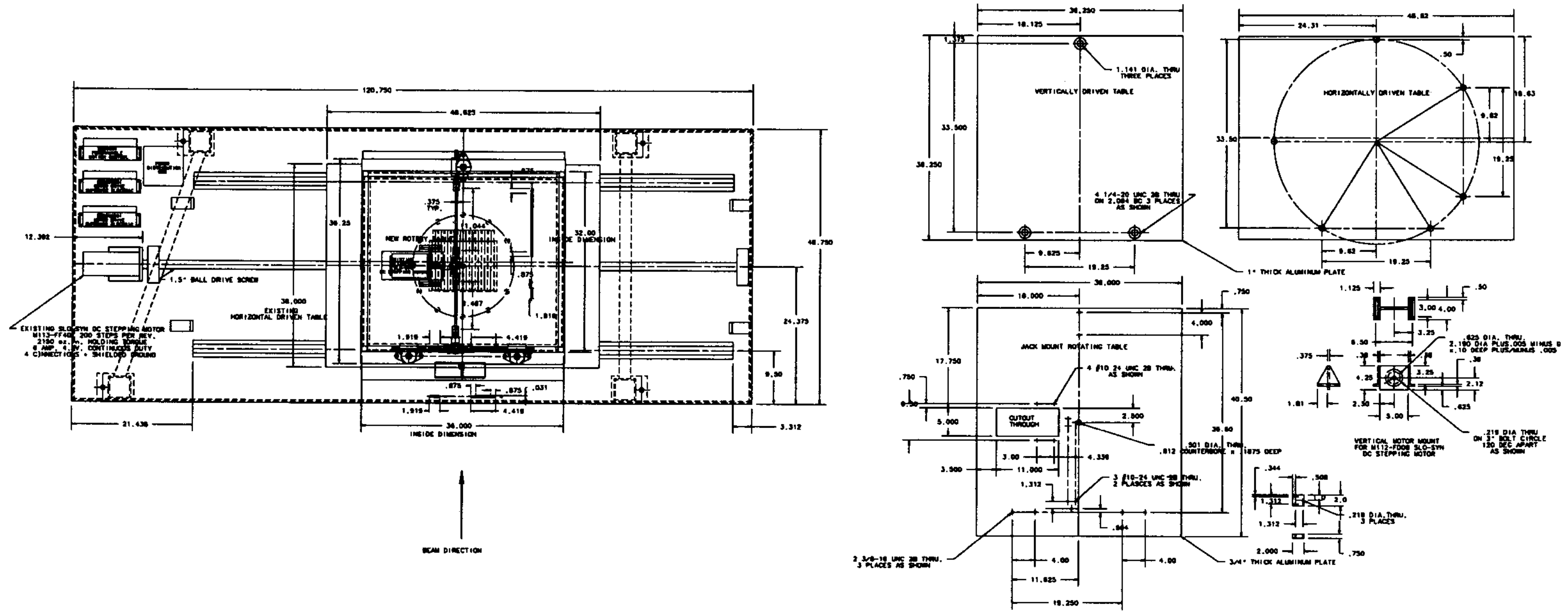

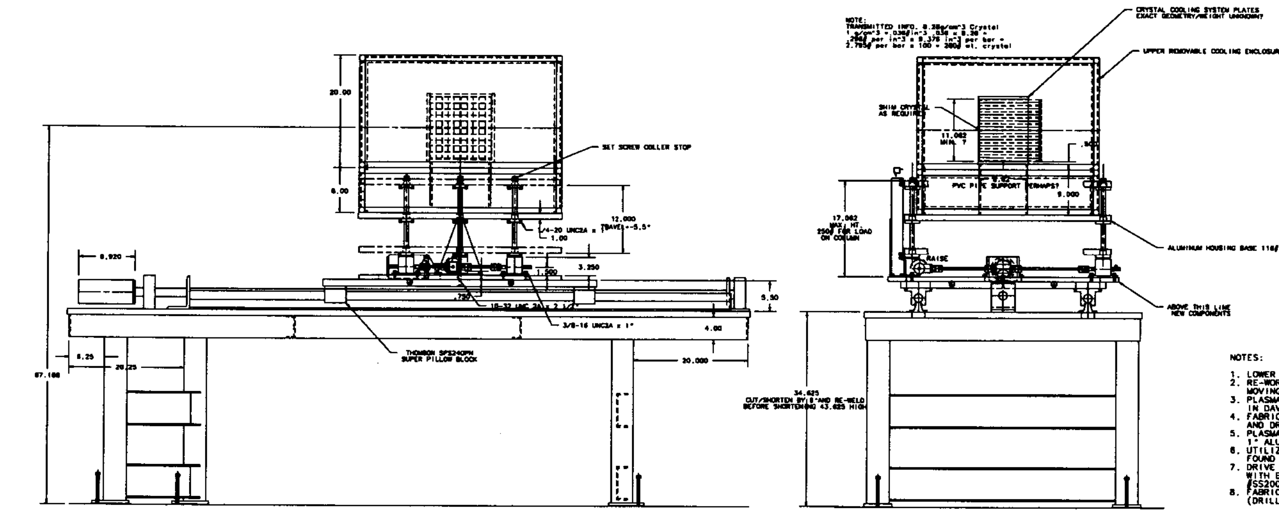

NOTES:

1. LOWER HORIZONTAL DRIVE TABLE BY 6"
2. RE-WORK HORIZONTAL DRIVEN SURFACE PLATE. MOVING ROLLER BALLS OUT TOO 34" DIAMETER.
3. PLASMA CUT 40.5" DIAMETER FROM 3/4" PLATE IN DAVE'S BONEYARD (CUTOUT/DRILLING/TAPPING)
4. FABRICATE MOTOR MOUNTING BRACKET AND DRIVE SPACER PLATES.
5. PLASMA CUT VERTICAL DRIVE PLATE FROM 1" ALUMINUM PLATE IN DAVE'S BONEYARD.
6. UTILIZE SLO-SYN DC STEPPING MOTOR M112-FD08 FOUND IN SHOP.
7. DRIVE HORIZONTAL AND VERTICAL DRIVE MOTORS WITH EXISTING SUPERIOR ELECTRIC MOTOR DRIVE #SS2000 D6.
8. FABRICATE HOUSING FROM SHEET METAL AS SHOWN (DRILLING AND TAPPING)

ORIGINATOR	E LAVALLIE
DRAWN	E LAVALLIE
CHECKED	
APPROVED	
USED ON	
MATERIAL	

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

PPD MECHANICAL DEPARTMENT
BTEV EM CALORIMETER/TEST
LEAD TUNGSTATE CRYSTAL

DRAWING NUMBER: SK-1. - - SHEET 1 OF 1

2-FRONT

Plotted by lavallie on 05-Aug-04 , File: TEST_STD_CRYSTAL.pf6

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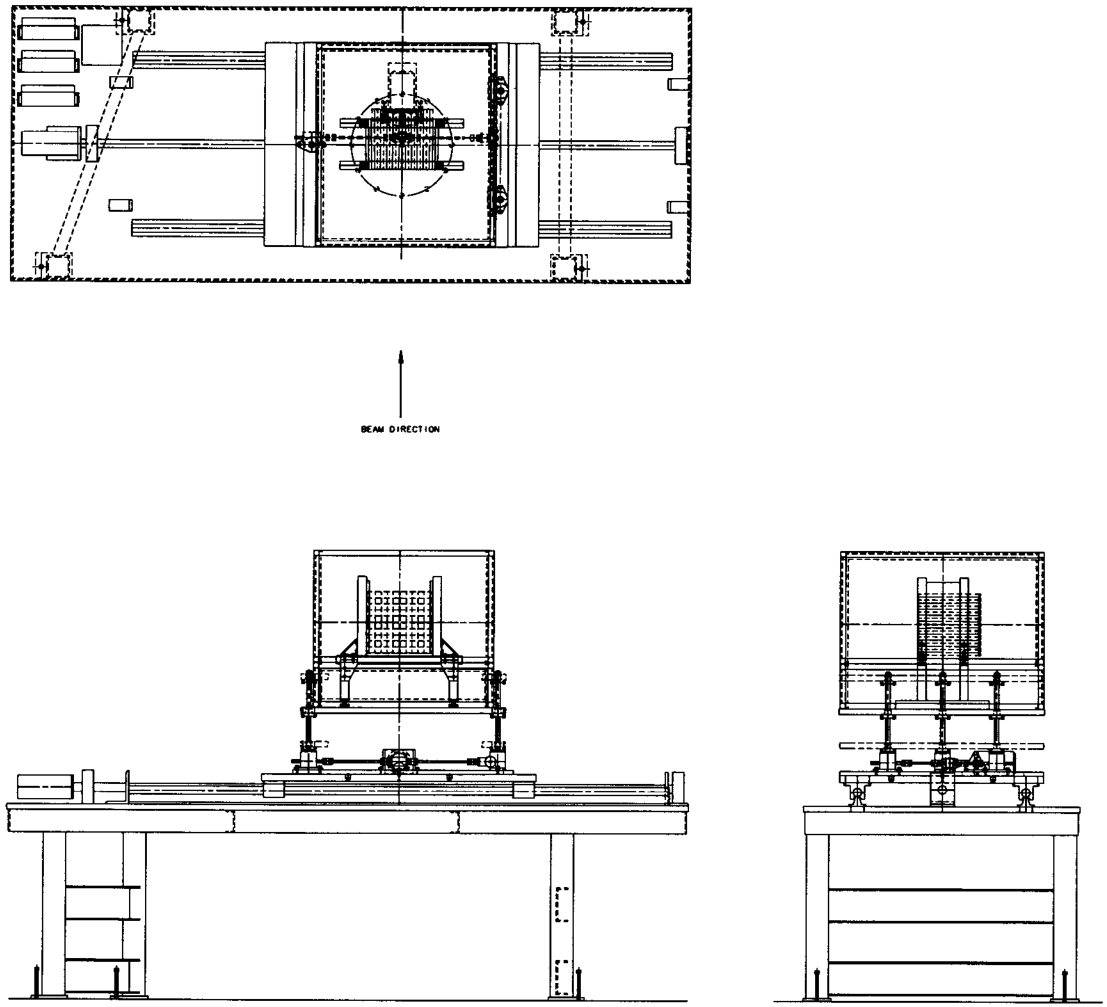
		APPROVED	DATE



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2-FRONT

UNLESS OTHERWISE SPECIFIED	ORIGINATOR	E LAVALLIE
	DRAWN	E LAVALLIE
± ± ±	CHECKED	
	APPROVED	
	USED ON	
✓	MATERIAL	

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UNITED STATES DEPARTMENT OF ENERGY

PPD MECHANICAL DEPARTMENT
BTEV EM CALORIMETER/TEST
LEAD TUNGSTATE CRYSTAL (AS BUILT)

SCALE	DRAWING NUMBER	SHEET	REV
	SK-2 - -	1 OF 1	

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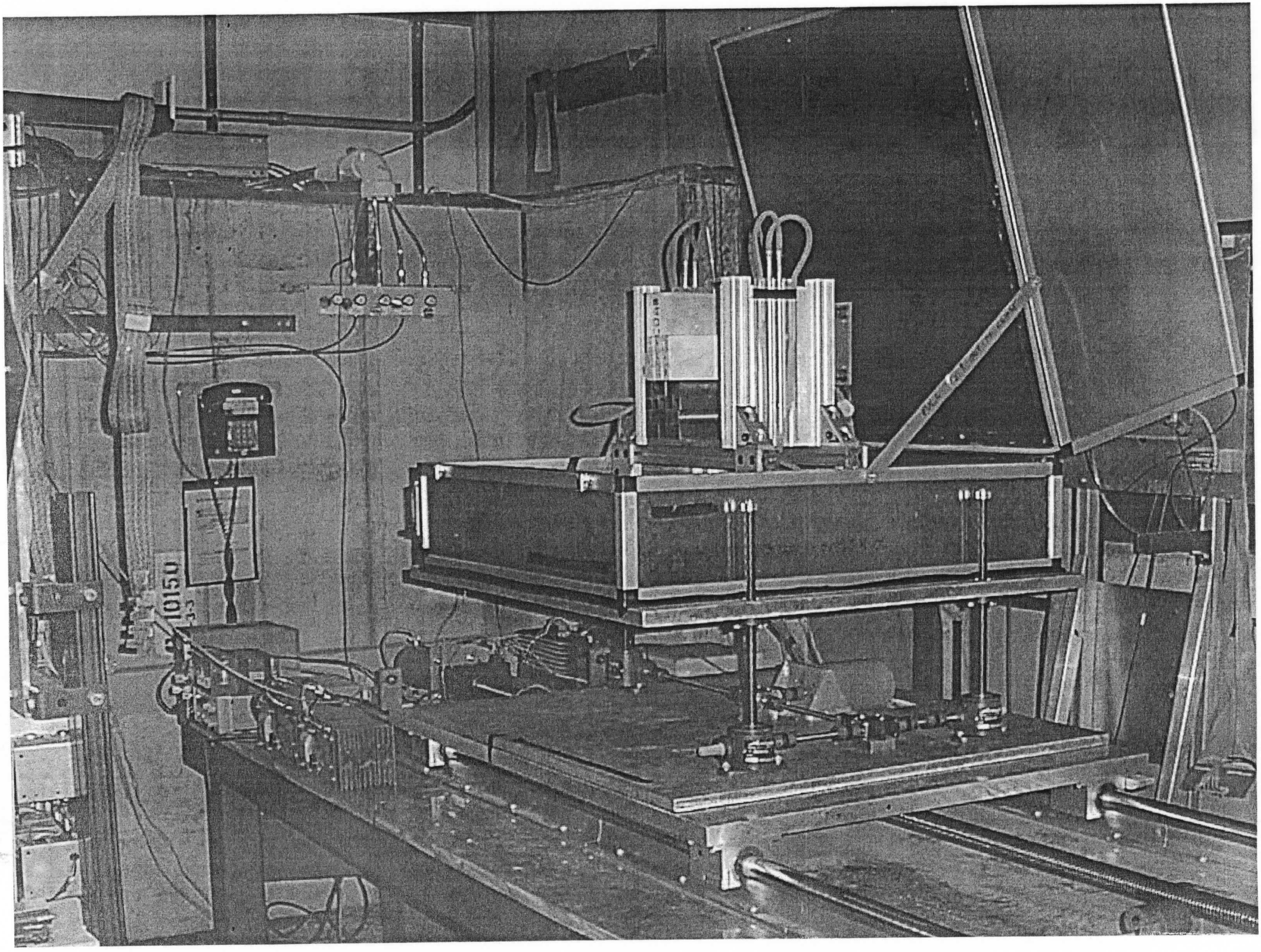
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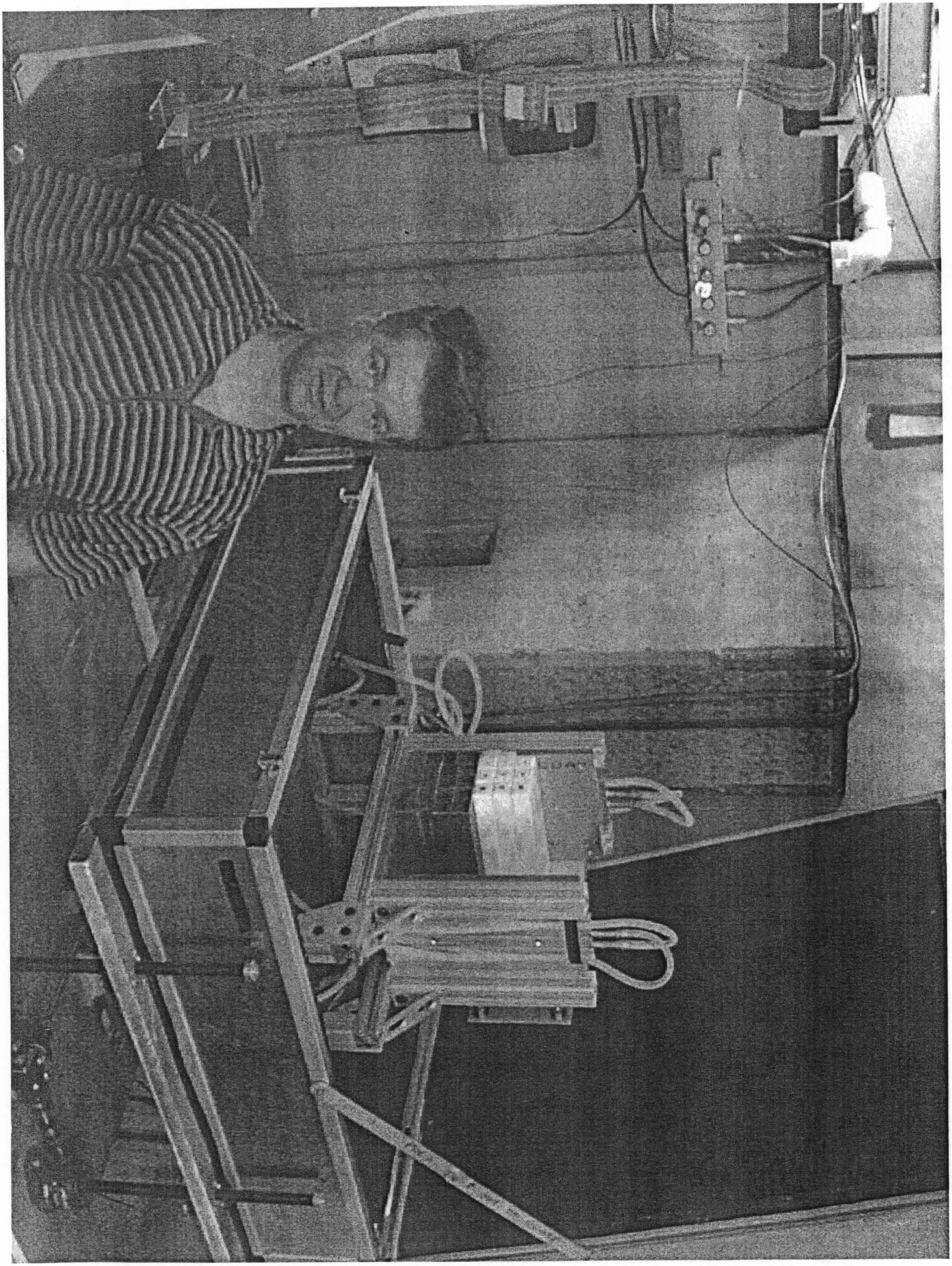

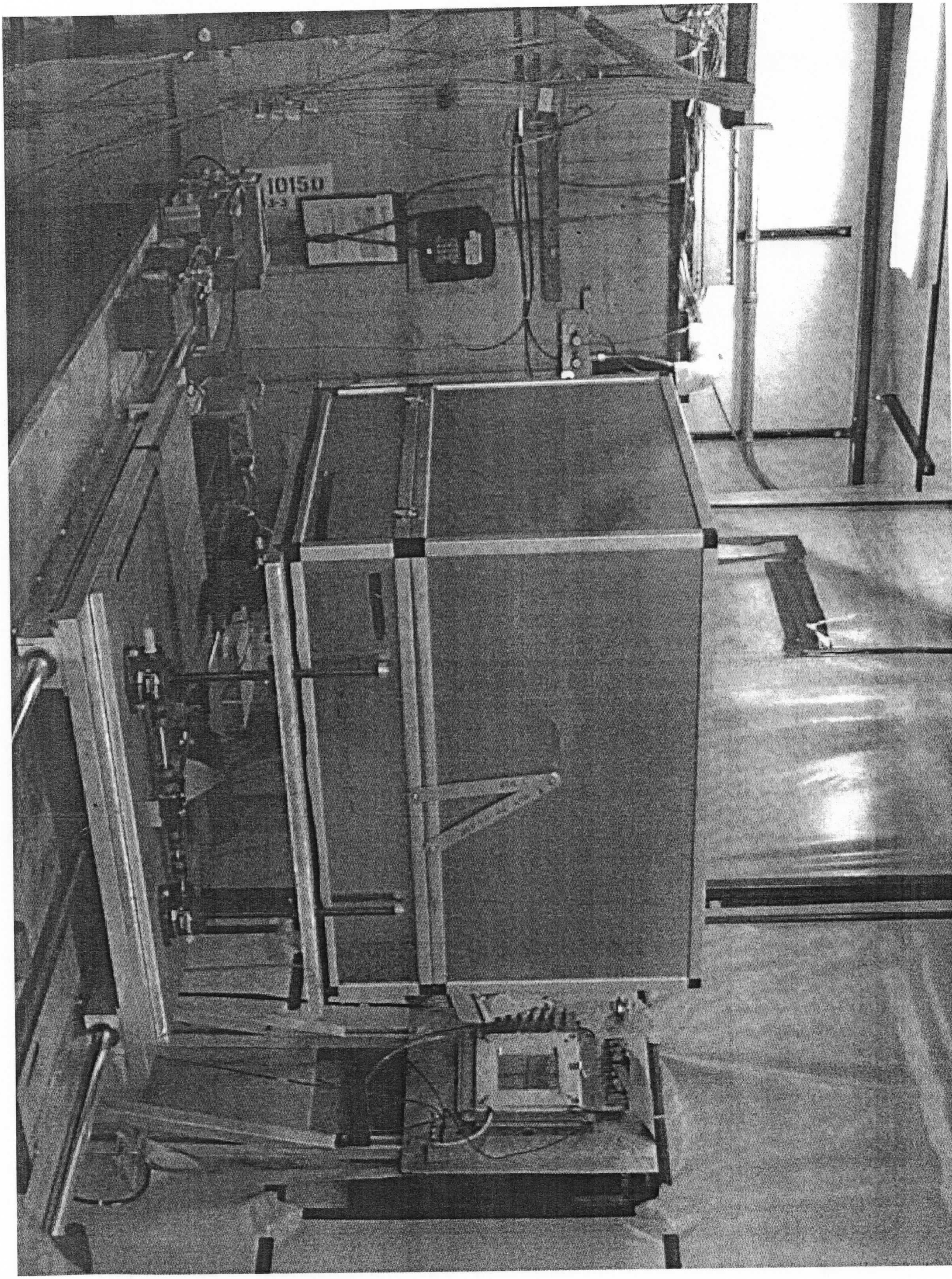
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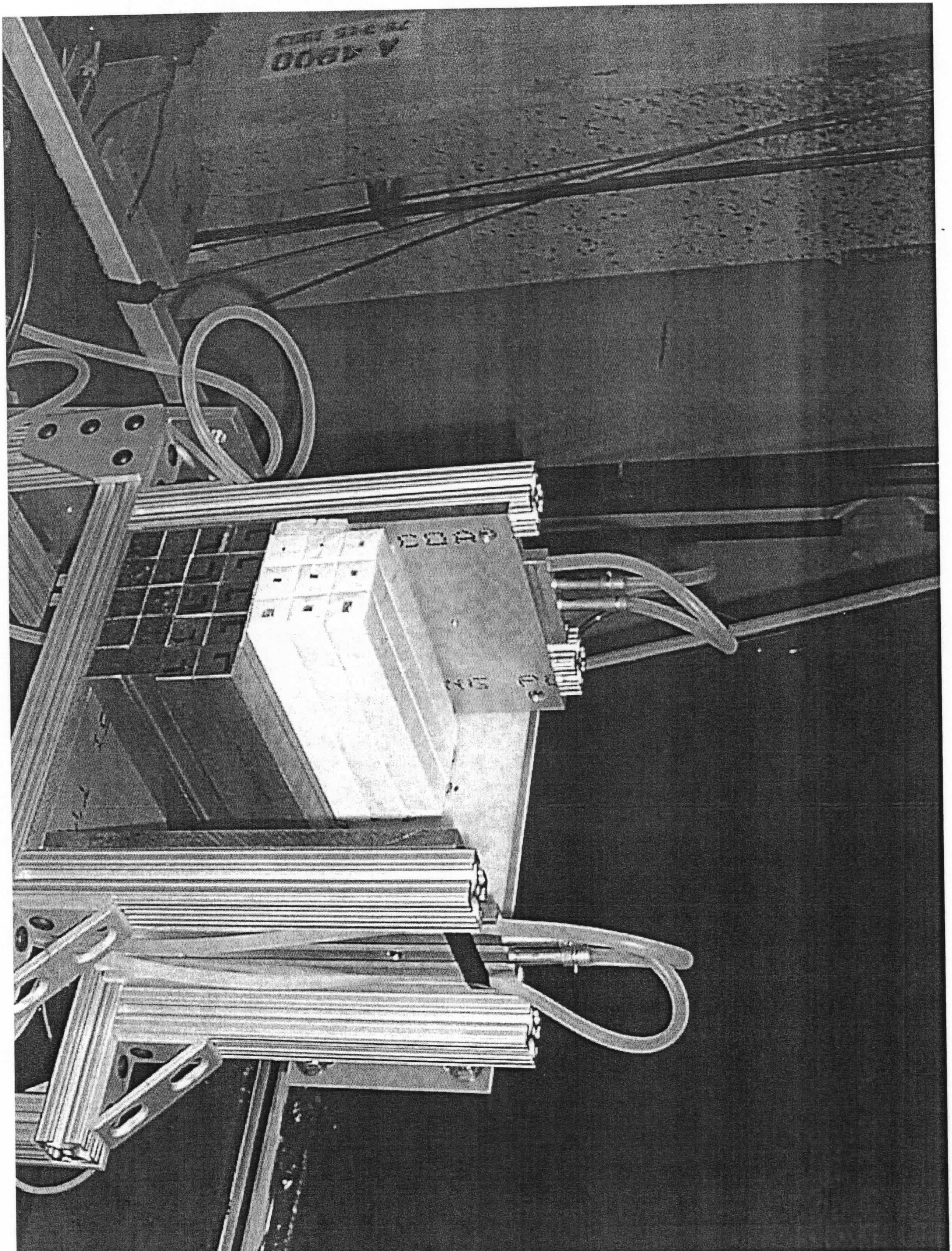
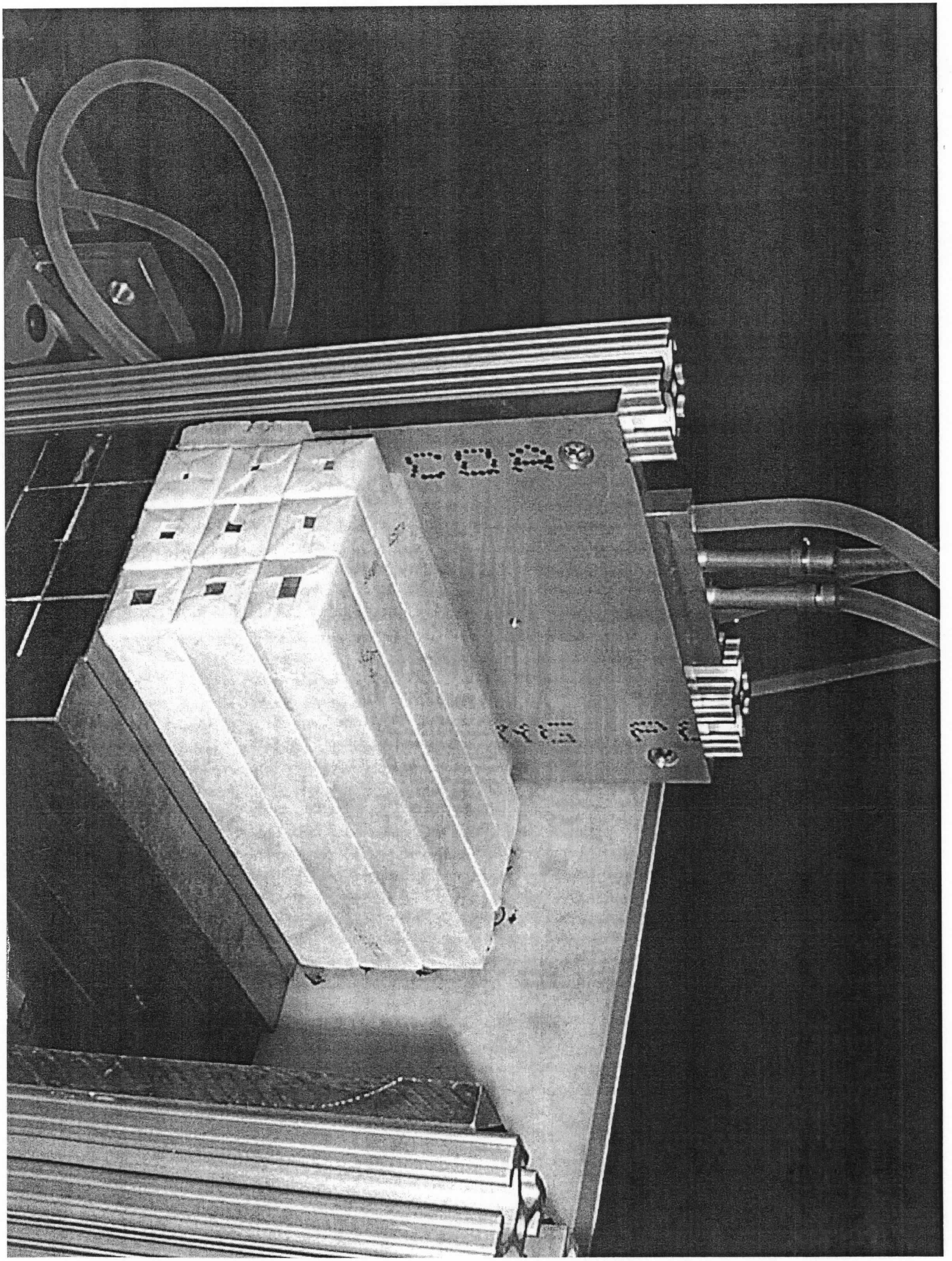
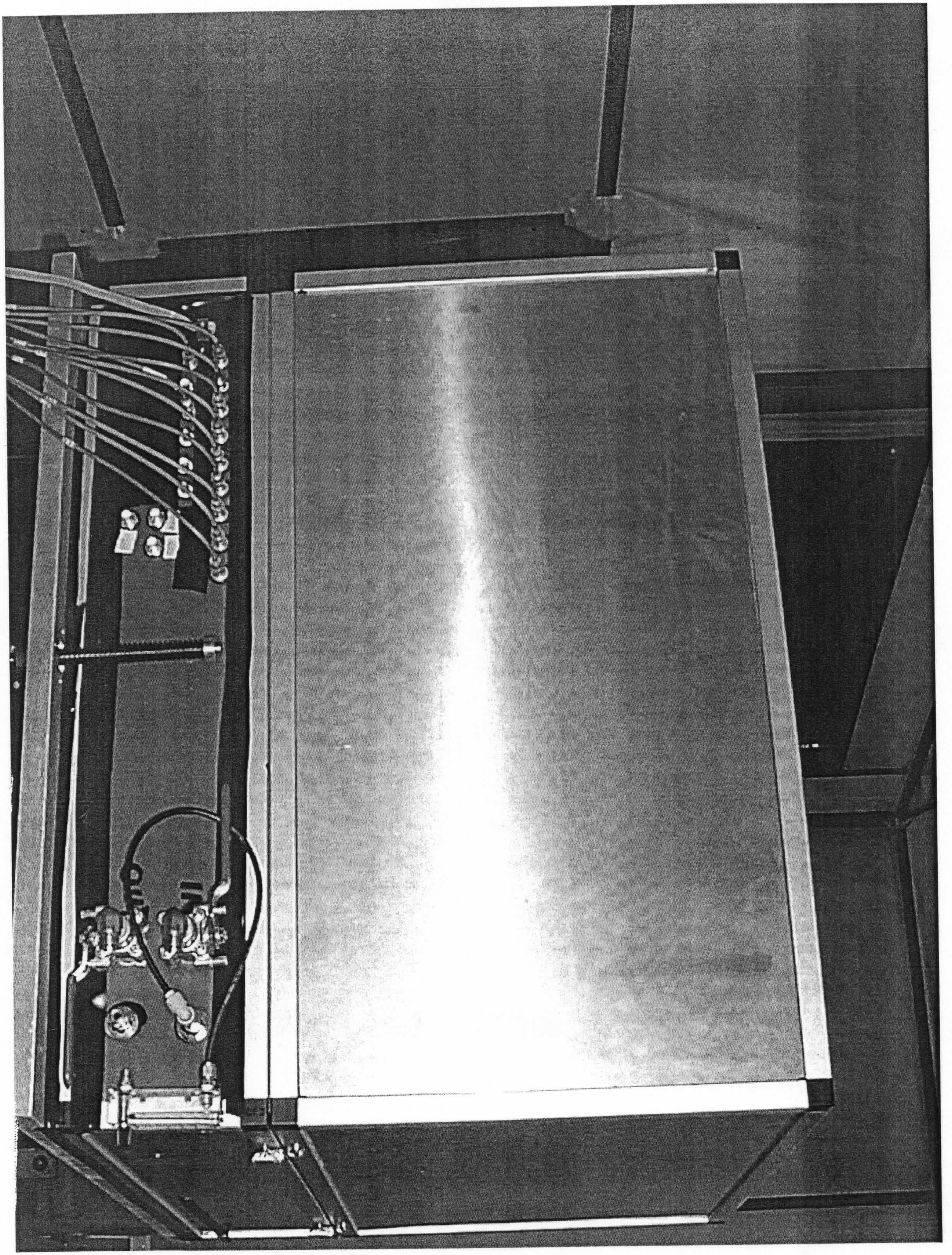


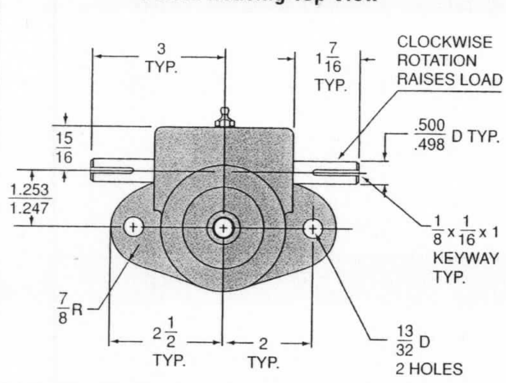




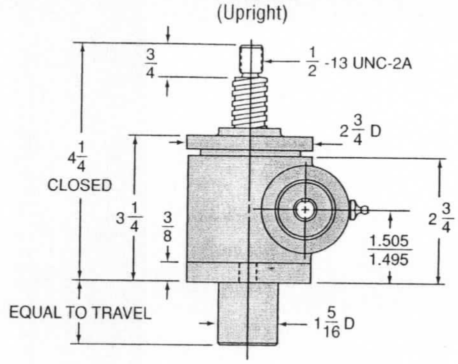
2D/3D Drawings at nookindustries.com

ACTIONJAC™ WORM GEAR SCREW JACKS

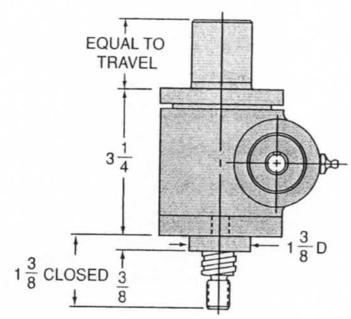
1-MSJ Housing Top View



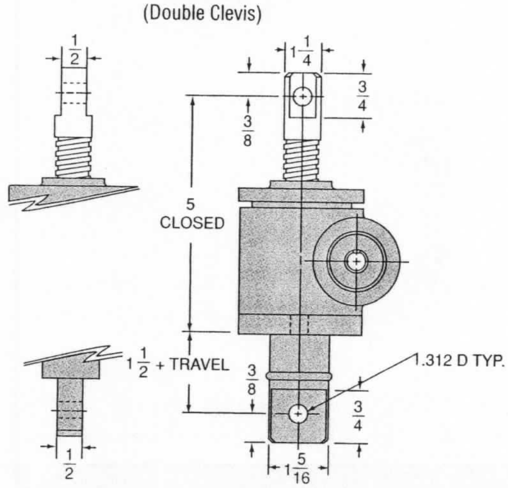
1-MSJ-U
(Upright)



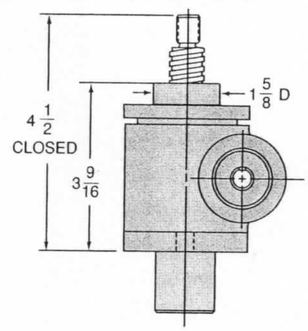
1-MSJ-I
(Inverted)



1-MSJ-DC
(Double Clevis)



1-MSJ-UK
(Upright Keyed)



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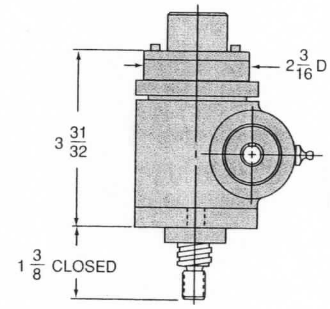
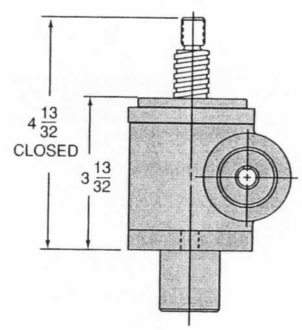


1AB-MSJ-U
(Upright Anti-Backlash)



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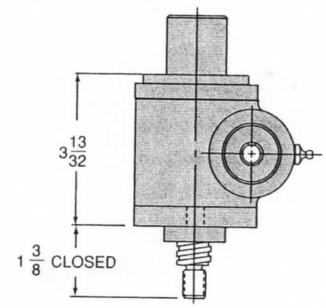
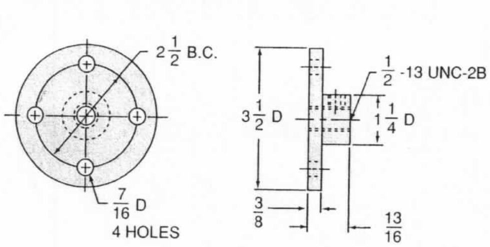


TOP PLATE (optional): B9000-00-11



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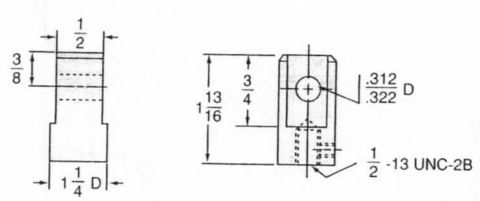
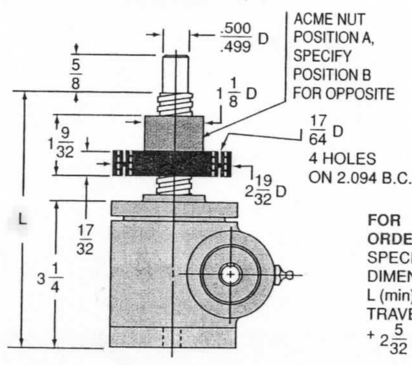


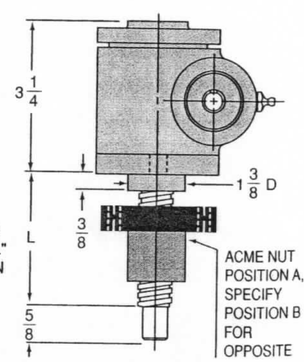
1-MSJ-UR
(Upright Rotating)

FOR ORDERING SPECIFY "L" DIMENSION L (min) = TRAVEL + 5 1/32



1-MSJ-IR
(Inverted Rotating)

FOR ORDERING SPECIFY "L" DIMENSION L (min) = TRAVEL + 2 5/32



1-MSJ STANDARD SCREW

SCREW: 3/4 - 5
ROOT DIAMETER: 0.502
DRAG TORQUE: 3 IN.-LB.
START TORQUE: 2 x Running Torque
WEIGHT (Approx. in Pounds)
"0" TRAVEL: 5.5
PER INCH TRAVEL: 0.3
GREASE: 0.5

RATIO	TURNS OF WORM PER INCH TRAVEL	TORQUE TO RAISE ONE LB.		MAX. HP	MAX. WORM SPEED AT RATED LOAD		MAX. LOAD AT 1750 RPM	
		NON-KEYED	KEYED		NON-KEYED	KEYED	NON-KEYED	KEYED
5:1	25	.0225 in.-lbs.	.0259 in.-lbs.	1/2	700 rpm	608 rpm	800 lbs.	695 lbs.
20:1	100	.0105 in.-lbs.	.0121 in.-lbs.	1/4	750 rpm	651 rpm	857 lbs.	744 lbs.

LIFTING SCREW OR NUT MUST BE SECURED TO PREVENT ROTATION FOR NON-KEYED UNITS.
CAUTION! JACK MAY BE SELF-LOWERING IN SOME OPERATING CONDITIONS.

JACK SIZES					JACK SELECTION									
MODEL	Capacity (tons)	Lifting Screw Dia. (in)	Screw Lead (in)	Root Dia. (in)	Gear Ratio	Turns of Worm for 1" Travel	Maximum Input Torque (in.-lb.)	Maximum Allowable Input (hp)	Maximum Worm Speed at Rated Load	Maximum Load at 1750 RPM	Torque to Raise 1 lb. (in.-lb.)	Tare Drag Torque (in.-lb.)	Page Ref
MJ-20	.5	1/2	.250	.332	5:1	20	19	1/3	1090	631	.019	—	291
MJ-25	.5	5/8	.200	.377	5:1	25	21	1/3	1040	571	.021	—	291
MJ-40	.5	5/8	.125	.457	5:1	40	17	1/3	1260	706	.017	—	291
MJ-50	.5	1/2	.100	.359	5:1	50	14	1/3	1560	857	.014	—	291
MJ-80	.5	1/2	.250	.332	20:1	80	8	1/6	1310	750	.008	—	291
MJ-100	.5	5/8	.200	.377	20:1	100	9	1/6	1210	667	.009	—	291
MJ-160	.5	5/8	.125	.457	20:1	160	7	1/6	1500	857	.007	—	291
MJ-200	.5	1/2	.100	.359	20:1	200	6	1/6	1800	1000	.006	—	291
1-MSJ	1	3/4	.200	.502	5:1	25	45	1/2	700	800	.0225	3	292
					20:1	100	21	1/4	750	857	.0105	3	292
2-MSJ	2	1	.250	.698	6:1	24	100	2	1260	2881	.0250	4	293
					12:1	48	62	1 1/2	1525	3456	.0154	4	293
					24:1	96	42	1/2	750	1715	.0105	4	293
2R-MSJ	2	1	.250	.698	6:1	24	100	2	1260	2881	.0250	4	294
					12:1	48	62	1 1/2	1525	3486	.0154	4	294
					24:1	96	42	1/2	750	1715	.0105	4	294
2.5-MSJ	2 1/2	1	.250	.698	6:1	24	126	2	1000	2858	.0252	5	295
					12:1	48	74	1 1/2	1277	3650	.0148	5	295
					24:1	96	53	1/2	594	1699	.0106	5	295

* Measurements listed are for non-keyed units. See individual jack pages for keyed jack info.

NOTES:

1) The recommended maximum speed is 1800 rpm provided the recommended horsepower and temperature are not exceeded.

2) Input torque is shown as torque to lift one pound of load. Starting Torque is 100% greater than torque shown. For loads less than 25% of rated loads add tare drag torque.

3) Maximum allowable horsepower ratings are based on a 25% duty cycle. For operation at higher duty cycles or repeated use over any segment of the total travel, temperature must be monitored and remain less than 200°F.

4) Overload capacity of the Machine Screw Jack is as follows: 10% for dynamic loads, 30% for static loads.

5) Machine Screw Jacks having gear ratios between 20:1 and 32:1, are self-locking and will hold loads without backdriving in the absence of vibrations. All other ratios may require a brake to prevent backdriving.

6) All units are suitable for intermittent operation providing that the housing temperature including ambient is not lower than -20°F. or higher than +200°F. Factory supplied grease in standard units will operate in this range. For higher or lower operating temperature ranges consult Nook Industries, Inc.

7) Accessories such as boots, limit switches, top plates and clevises are available.

COLUMN STRENGTH: INCH MACHINE SCREW JACKS

Column strength is the ability of the lift shaft to hold compressive loads without buckling. With longer screw lengths, column strength may be substantially lower than nominal jack capacity.

If the lift shaft is in tension only, the screw jack travel is limited by the available screw material or by the critical speed of the screw. Refer to the acme screw technical section for critical speed limitations. If there is any possibility for the lift shaft to go into compression, the application should be sized for sufficient column strength.

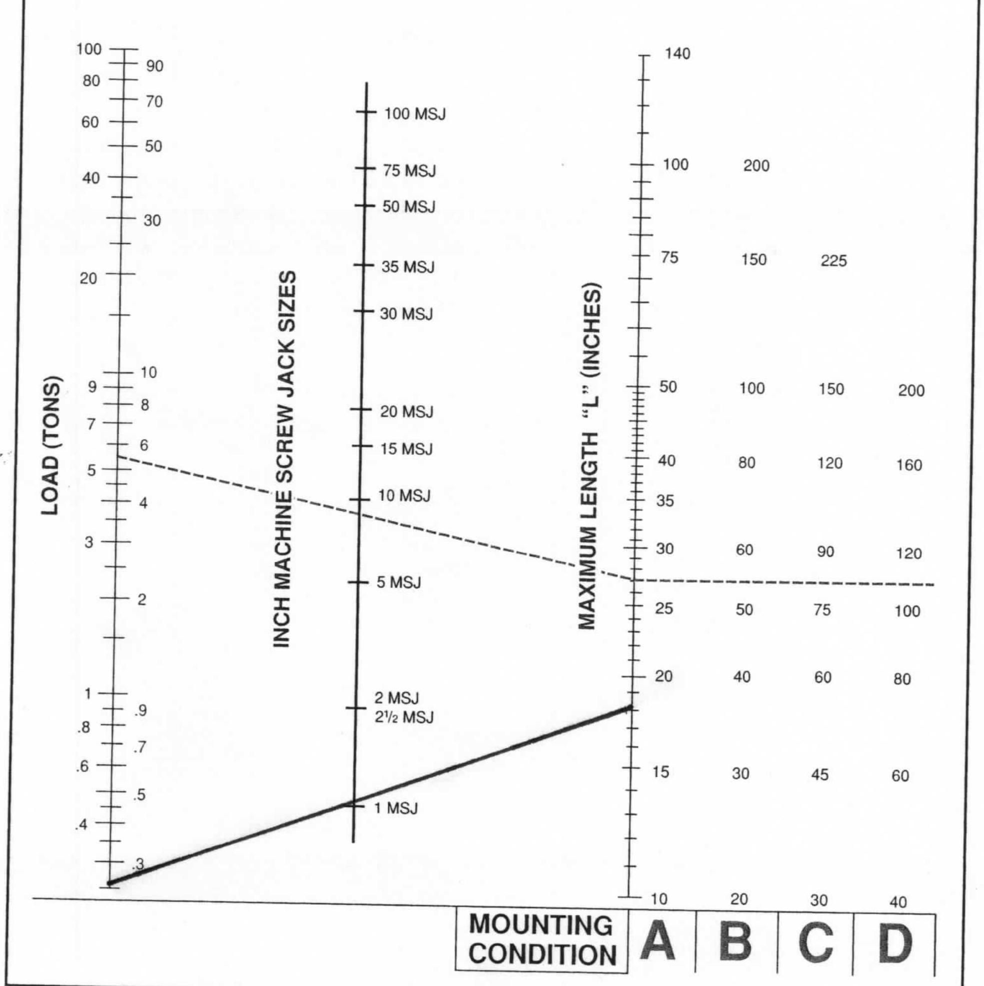
Charts are used to determine the required jack size in applications where the lift shaft is loaded in compression. To use this chart:

- Determine the mounting condition and mark a point on the "Maximum length" line.
- Mark a point on the "Load" line, applying an appropriate design factor.

CAUTION: chart does not include a design factor.

- Draw a line connecting the two marked points. Select a jack above the point where the line drawn crosses the "Jack Sizes" line.

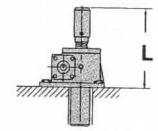
The chart assumes proper jack alignment with no bending loads on the screw. Effects from side loading are not included in this chart. Jacks operating horizontally with long lift shafts can experience bending from the weight of the screw. Consult Nook Industries. If side thrust is anticipated, operating horizontally, or maximum raise is greater than 30 times the screw diameter.



MOUNTING CONDITIONS

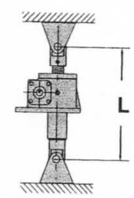
A

ONE END FIXED
ONE END FREE



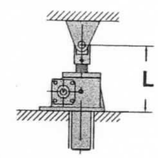
B

BOTH ENDS SUPPORTED BY CLEVIS ENDS

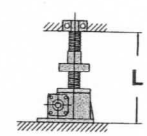


C

ONE END FIXED, ONE END SUPPORTED (CLEVIS ATTACHED TO GUIDE STRUCTURE)

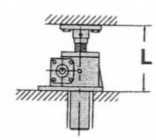


ONE END FIXED, ONE END SUPPORTED (RADIAL BEARING))



D

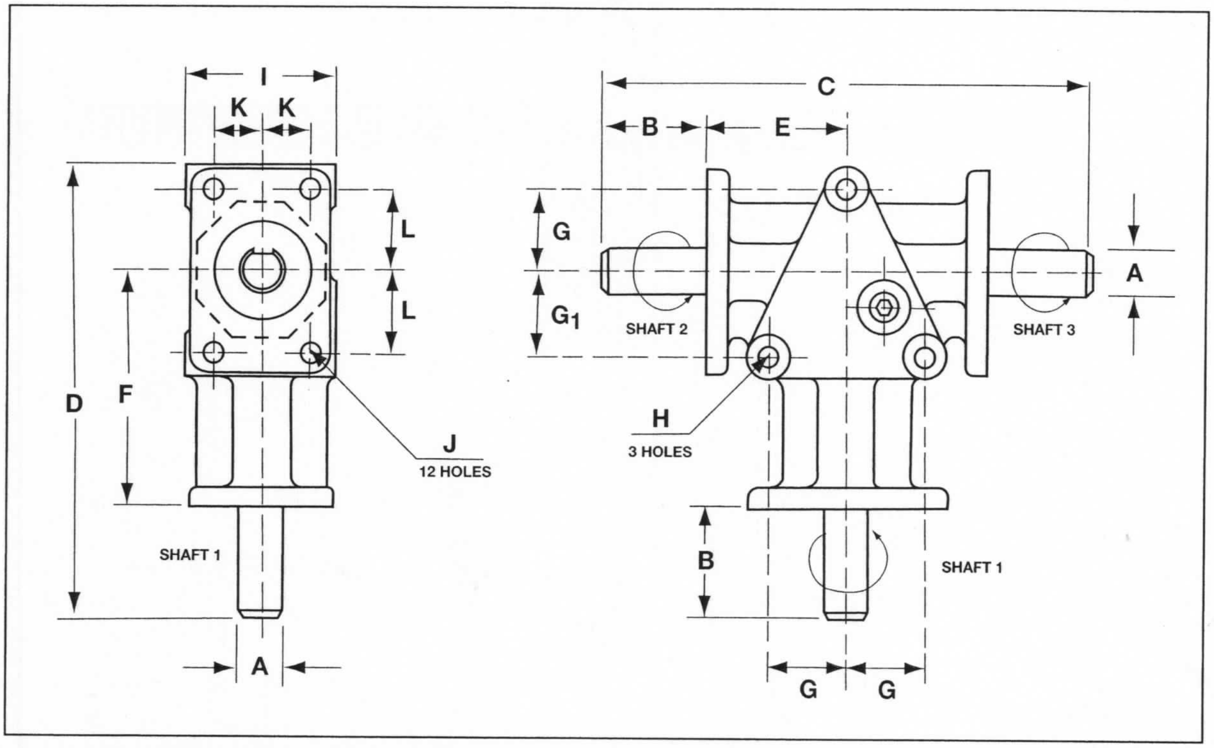
BOTH ENDS FIXED (TOP PLATE ATTACHED TO GUIDED STRUCTURE)



AVAILABLE LIFT SCREW LENGTHS

As a major manufacturer of industrial lead screws, Nook Industries stocks a broad selection of acme screws. Nook Industries has the capacity to make long acme screws for special applications. Rotating screw jacks can be built with a larger diameter lift screw for greater column strength, or a different lead to change the jack operating speed.

Three-Way Crown Gear Drives



Three-Way Crown Gear Drives Only
To obtain opposite shaft rotation for shafts 2 & 3 as shown, install (invert) Crown Drive with grease plug down.

Dimensions

1:1 Ratio

Model	A	B	C	D	E	F	G	G_1	H	I	J	K	L
C139801	3/8	5/8	4-1/16	3-21/32	1.406	2.187	.656	.656	.221 dia.	1.500	.166 dia.	.500	.656
C157806	1/2	1	5-3/4	4-15/16	1.875	2.875	.875	.875	.281 dia.	1.750	.265 dia.	.562	.812
C109806	5/8	1-1/2	7	6-3/16	2.000	3.250	1.125	1.125	.281 dia.	2.125	.265 dia.	.687	1.125
C209806	3/4	1-3/4	9-1/4	7-15/16	2.875	4.375	1.375	1.375	.344 dia.	2.625	.328 dia.	.812	1.375
C803806	1	2-3/4	12	11	3.250	6.000	1.750	2.750	.406 dia.	4.000	3/8-16**	1.500	1.500

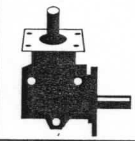
2:1 Ratio

C135801	3/8	5/8	4-1/16	3-21/32	1.406	2.187	.656	.656	.221 dia.	1.500	.166 dia.	.500	.656
C155806	1/2	1	5-3/4	4-15/16	1.875	2.875	.875	.875	.281 dia.	1.750	.265 dia.	.562	.812
C105806	5/8	1-1/2	7	6-3/16	2.000	3.250	1.125	1.125	.281 dia.	2.125	.265 dia.	.687	1.125
C205806	3/4	1-3/4	9-1/4	7-15/16	2.875	4.375	1.375	1.375	.344 dia.	2.625	.328 dia.	.812	1.375
C805806	1	2-3/4	12	11	3.250	6.000	1.750	2.750	.406 dia.	4.000	3/8-16**	1.500	1.500

**Tapped hole, .81" deep.

Keyway Dimensions

Units with 3/8 inch dia. shafts ....1/32 **Flat** x 1/2 long
Units with 1/2 inch dia. shafts...............................1/8 x 1/16 x 7/8
Units with 5/8 inch dia. shafts ....3/16 x 3/32 x 1-3/8
Units with 3/4 inch dia. shafts ....3/16 x 3/32 x 1-1/2
Units with 1 inch dia. shafts...1/4 x 1/8 x 2



Rated Horsepower And Torque Specifications

For Crown Gear Drives

1:1 Ratio Models

C138801—2-Way	C139801—3-Way	
Shaft RPM	Rated H.P.	Torque/In Lbs.
100	.04	25
200	.08	25
300	.12	25
400	.16	25
500	.20	25
1000	.38	24
2000	.67	21

Ultimate static torque 160 in. lbs. calculated on 1,000 cycle basis.

C108806—2-Way	C109806—3-Way	
Shaft RPM	Rated H.P.	Torque/In. Lbs.
100	.16	101
200	.32	101
300	.47	99
400	.62	98
500	.75	95
1000	1.37	87
2000	2.43	77

Ultimate static torque 610 in. lbs. calculated on 1,000 cycle basis.

C803806—3-Way		
Shaft RPM	Rated H.P.	Torque/In Lbs.
100	1.00	630
200	1.87	591
300	2.75	578
400	3.33	525
500	4.12	520
1000	7.75	488
2000	13.00	410

Ultimate static torque 5,100 in. lbs. calculated on 1,000 cycle basis.

C156806—2-Way	C157806—3-Way	
Shaft RPM	Rated H.P.	Torque/In Lbs.
100	.07	46
200	.14	46
300	.22	46
400	.29	46
500	.36	45
1000	.71	45
2000	1.27	40

Ultimate static torque 275 in. lbs. calculated on 1,000 cycle basis.

C208806—2-Way	C209806—3-Way	
Shaft RPM	Rated H.P.	Torque/In Lbs.
100	.30	189
200	.56	177
300	.81	171
400	1.06	167
500	1.33	167
1000	2.33	147
2000	4.25	134

Ultimate static torque 1,400 in. lbs. calculated on 1,000 cycle basis.

Models	Overhung Load Capacity (At mid-shaft)	Thrust Load Capacity
C134, C135, C138 & C139	25 Lbs.	50 Lbs.
C154, C155, C156 & C157	35 Lbs.	70 Lbs.
C104, C105, C108 & C109	50 Lbs.	100 Lbs.
C204, C205, C208 & C209	100 Lbs.	200 Lbs.
C803 & C805	160 Lbs.	320 Lbs.

2:1 Ratio Models

C134801—2-Way			C135801—3-Way	
Shaft 1 RPM	Shaft 2 RPM	Rated H.P.	Shaft 1 Rated Torque/ In. Lbs.	Shaft 2 Rated Torque/ In. Lbs.
100	50	.02	11	22
200	100	.04	11	22
300	150	.06	11	22
400	200	.07	11	22
500	250	.09	10	21
1000	500	.16	10	20
2000	1000	.30	9	18

Ultimate static torque 60 in. lbs. calculated on 1,000 cycle basis.

C204806—2-Way			C205806—3-Way	
Shaft 1 RPM	Shaft 2 RPM	Rated H.P.	Shaft 1 Rated Torque/ In. Lbs.	Shaft 2 Rated Torque/ In. Lbs.
100	50	.11	70	140
200	100	.22	70	140
300	150	.33	70	140
400	200	.44	70	140
500	250	.55	70	140
1000	500	.99	62	124
2000	1000	1.75	55	110

Ultimate static torque 540 in. lbs. calculated on 1,000 cycle basis.

C154806—2-Way			C155806—3-Way	
Shaft 1 RPM	Shaft 2 RPM	Rated H.P.	Shaft 1 Rated Torque/ Inch Lbs.	Shaft 2 Rated Torque/ Inch Lbs.
100	50	.03	20	39
200	100	.06	20	39
300	150	.09	20	39
400	200	.13	20	39
500	250	.16	20	39
1000	500	.30	19	37
2000	1000	.54	17	34

Ultimate static torque 130 in. lbs. calculated on 1,000 cycle basis.

C805806—3-Way				
Shaft 1 RPM	Shaft 2 RPM	Rated H.P.	Shaft 1 Rated Torque/ Inch Lbs.	Shaft 2 Rated Torque/ Inch Lbs.
100	50	.38	236	472
200	100	.75	236	472
300	150	1.00	210	420
400	200	1.33	210	420
500	250	1.67	210	420
1000	500	3.24	204	408
2000	1000	5.75	181	362

Ultimate static torque 2,170 in. lbs. calculated on 1,000 cycle basis.

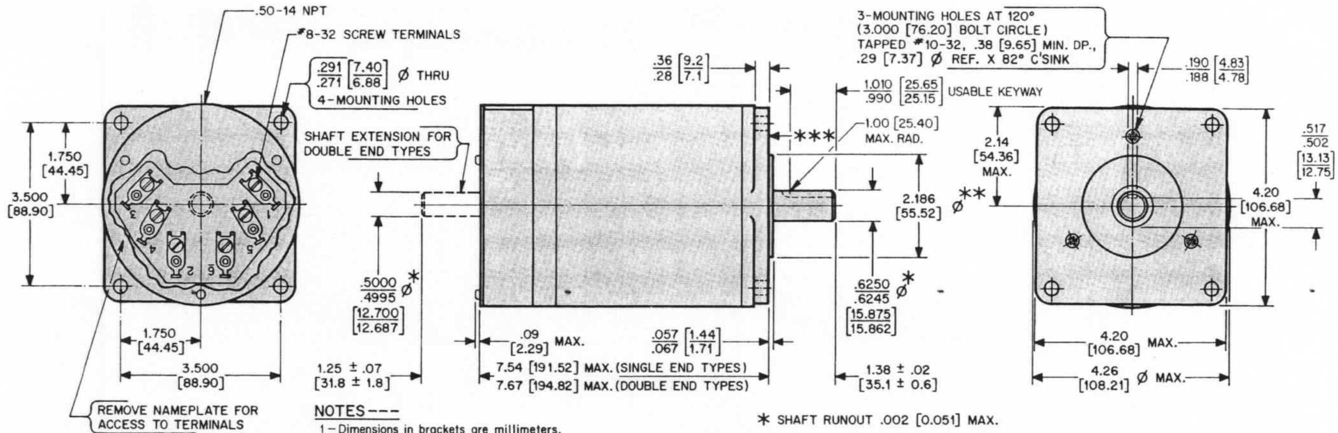
C104806—2-Way			C105806—3-Way	
Shaft 1 RPM	Shaft 2 RPM	Rated H.P.	Shaft 1 Rated Torque/ Inch Lbs.	Shaft 2 Rated Torque/ Inch Lbs.
100	50	.06	34	68
200	100	.11	34	68
300	150	.16	34	68
400	200	.22	34	68
500	250	.27	34	68
1000	500	.51	32	64
2000	1000	.92	29	58

Note: Maximum input or output shaft speed in 2,000 RPM at rated loads. For lighter duty higher speed applications, consult the factory. Input shaft may be driven in either direction.

110mm (NEMA Size 42) & 165mm (NEMA Size 66) RATINGS and SPECIFICATIONS

MOTOR TYPE 3% ACCURACY	CONNECTIONS		TYPICAL TIME FOR SINGLE STEP (mS) (1)	NOMINAL DC VOLTS (3)	RATED AMPERES PER WINDING	NOMINAL RESISTANCE PER WINDING (25°C) OHMS (2)	NOMINAL INDUCTANCE PER PHASE (MILLI-HENRYS) (2) (4)	MINIMUM HOLDING TORQUE (OZ-IN)		SERIES CONNECTION				MINIMUM HOLDING TORQUE (OZ-IN)		PARALLEL CONNECTION				MINIMUM HOLDING TORQUE (OZ-IN)	
	NUMBER	TYPE						2Ø ON	1Ø ON	VOLTS	AMPERES	R (OHMS)	L (mH)	2Ø ON	1Ø ON	VOLTS	AMPERES	R (OHMS)	L (mH)	2Ø ON	1Ø ON
M111-FD12	6	TERM.	4.4	2.26	6.1	0.37	2.3	625	375	3.2	4.3	0.74	9.2	850	500	—	—	—	—	—	—
M111-FD16	6	TERM.	4.4	1.7	8	0.21	1.1	625	375	2.4	5.7	0.42	4.4	850	500	—	—	—	—	—	—
M111-FD-327	6	TERM.	7	4.1	3.5	1.17	7.2	625	375	5.85	2.5	2.34	28.8	850	500	—	—	—	—	—	—
M111-FF-401	4	TERM.	—	4	3.4	1.14	17.7	850	500	—	—	—	—	—	—	—	—	—	—	—	—
MX111-FF-401	4	TERM.	—	4	3.4	1.14	17.7	850	500	—	—	—	—	—	—	—	—	—	—	—	—
M111-FD-8003	8	TERM.	—	6.93	1.55	4.47	26.2	625	375	9.8	1.1	8.94	105	850	500	4.9	2.2	2.24	26.2	850	500
M111-FD-8007	8	TERM.	7	4.1	3.5	1.17	7.2	625	375	5.85	2.5	2.34	28.8	850	500	2.93	5	0.585	7.2	850	500
M111-FD-8012	8	TERM.	4.4	2.26	6.1	0.37	2.3	625	375	3.2	4.3	0.74	9.2	850	500	1.6	8.63	0.185	2.3	850	500
M111-FD-8016	8	TERM.	4.4	1.7	8	0.21	1.1	625	375	2.4	5.7	0.42	4.4	850	500	1.2	11.3	0.105	1.1	850	500
M112-FD08	6	TERM.	7	5.8	3.8	1.53	14	1125	675	8.25	2.7	3.06	56	1390	830	—	—	—	—	—	—
M112-FD12	6	TERM.	5.5	3.66	6.1	0.6	5.3	1125	675	5.2	4.3	1.2	21.2	1390	830	—	—	—	—	—	—
M112-FJ12	6	TERM.	5.5	3.66	6.1	0.6	5.3	1125	675	5.2	4.3	1.2	21.2	1390	830	—	—	—	—	—	—
M112-FF-401	4	TERM.	—	1.95	4	0.49	8.8	950	570	—	—	—	—	—	—	—	—	—	—	—	—
M112-FJ-326	6	TERM.	6	1.52	15.2	0.1	0.88	1125	675	2.15	10.75	0.2	3.52	1390	830	—	—	—	—	—	—
M112-FJ-327	6	TERM.	6	2.26	9.2	0.246	2.2	1125	675	3.2	6.5	0.492	8.8	1390	830	—	—	—	—	—	—
M112-FJ-335(5)	6	TERM.	6	2.26	9.2	0.246	2.2	1125	675	3.2	6.5	0.492	8.8	1390	830	—	—	—	—	—	—
M112-FJ-344(5)	6	TERM.	6	1.52	15.2	0.1	0.88	1125	675	2.15	10.75	0.2	3.52	1390	830	—	—	—	—	—	—
M112-FJ-8008	8	TERM.	7	5.8	3.8	1.53	14	1125	675	8.25	2.7	3.06	56	1390	830	4.1	5.4	0.765	14	1390	830
M112-FD-8012	8	TERM.	5.5	3.66	6.1	0.6	5.3	1125	675	5.2	4.3	1.2	21.2	1390	830	2.6	8.6	0.3	5.3	1390	830
M112-FJ-8012	8	TERM.	5.5	3.66	6.1	0.6	5.3	1125	675	5.2	4.3	1.2	21.2	1390	830	2.6	8.6	0.3	5.3	1390	830
M112-FJ-8018	8	TERM.	6	2.1	9.2	0.242	2.1	1125	675	3	6.5	0.483	8.4	1390	830	1.5	13	0.12	2.1	1390	830
M112-FJ-8025	8	TERM.	6	1.75	12.7	0.137	1	1125	675	2.5	9	0.274	4	1390	830	1.25	18	0.069	1	1390	830
M112-FJ-8030	8	TERM.	6	1.52	15.2	0.1	0.88	1125	675	2.15	10.75	0.2	3.52	1390	830	1.1	21.5	0.05	0.88	1390	830
M113-FF-401	4	TERM.	—	4.5	6	0.75	17	2150	1290	—	—	—	—	—	—	—	—	—	—	—	—
M172-FD-306	6	TERM.	24	2.35	15	0.15	1.98	2700	1600	3.3	10.6	0.3	7.92	3300	1980	—	—	—	—	—	—
M172-FD-308	6	TERM.	24	1.45	20	0.075	1.06	2700	1600	2.1	14.1	0.15	4.24	3300	1980	—	—	—	—	—	—
M172-FF-401	4	TERM.	—	2.6	4	0.65	14.6	2000	1200	—	—	—	—	—	—	—	—	—	—	—	—
M172-FD-8030	8	TERM.	24	2.35	15	0.15	1.98	2700	1600	3.3	10.6	0.3	7.92	3300	1980	1.7	21.5	0.075	1.98	3300	1980
M172-FD-8040	8	TERM.	24	1.45	20	0.075	1.06	2700	1600	2.1	14.1	0.15	4.24	3300	1980	1	28.3	0.0375	1.06	3300	1980

(1) With 24 volt drive.
(2) Values shown are for reference information and are correct to the best of our knowledge at time of publication, but are subject to change without notice. Para meters to be used as part of a specification should be verified with the factory.
(3) Voltage shown is per phase at rated current at zero steps per second, with winding at 25°C. Resistance tolerance and winding temperature will influence voltage.
(4) Tolerance is ±20%, measured at 1 kHz with a General Radio #1650B impedance bridge having a 1 volt rms open circuit sinusoidal signal. Rotor position precoditioned by energizing same phase, then deenergizing same phase during measurement without changing rotor position.
(5) Has double end shaft.



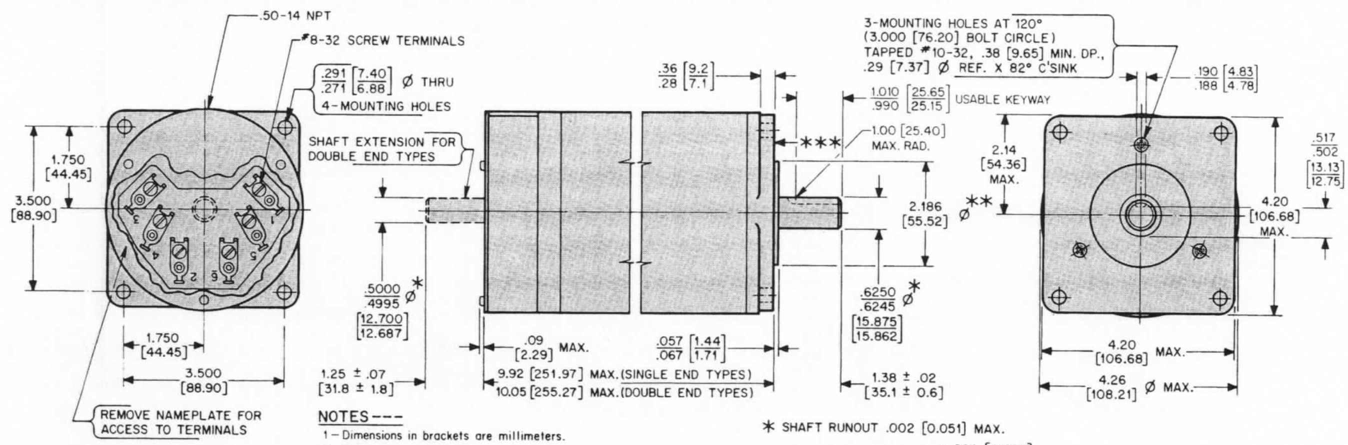
NOTES---
1 – Dimensions in brackets are millimeters.
2 – Tolerance on decimals ---
.XXX = ± 0.005 [0.13] unless otherwise specified.
3 – Dimensions shown apply before painting or plating.
4 – This drawing shows only those features which are pertinent to the form, fit, and function of the motor.

* SHAFT RUNOUT .002 [0.051] MAX.

** DIAMETER TOLERANCE +.001 [0.026] -.000 [0.000]
DIAMETER CONCENTRIC TO SHAFT DIAMETER WITHIN .003 [0.077] T.I.R.

*** SURFACE SQUARE TO SHAFT DIAMETER WITHIN .003 [0.077] T.I.R.

M112-FJ MOTORS, STANDARD AND DOUBLE END MODELS



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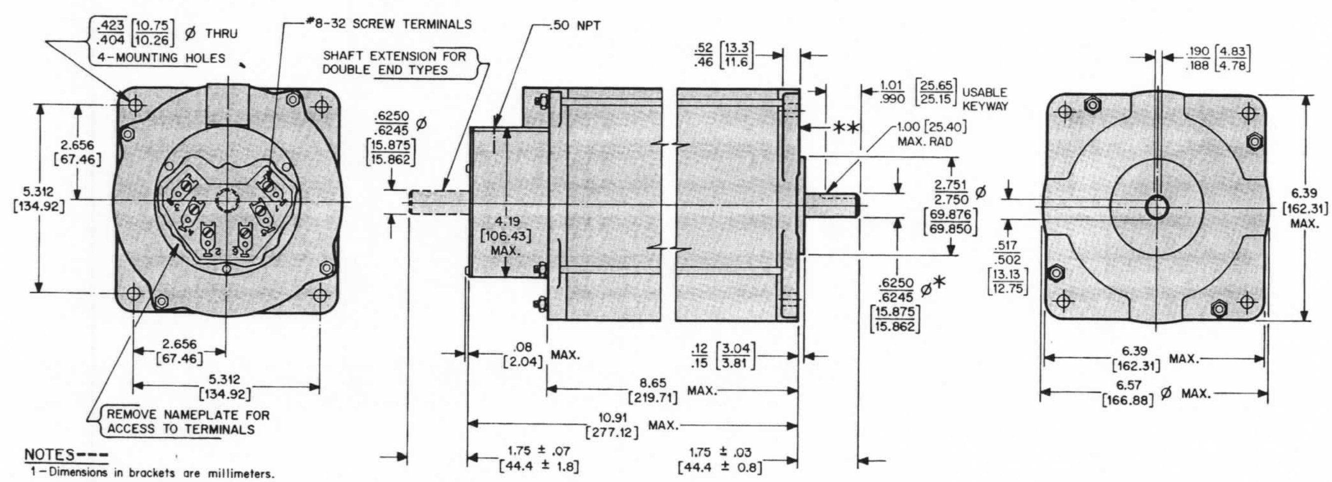
** DIAMETER TOLERANCE +.001 [0.026] -.000 [0.000]
DIAMETER CONCENTRIC TO SHAFT DIAMETER WITHIN .003 [0.077] T.I.R.

*** SURFACE SQUARE TO SHAFT DIAMETER WITHIN .003 [0.077] T.I.R.

M113-FF MOTORS, STANDARD AND DOUBLE END MODELS



NOTES---
1 – Dimensions in brackets are millimeters.
2 – Tolerance on decimals ---
.XXX = ± 0.005 [0.13] unless otherwise specified.
3 – Dimensions shown apply before painting or plating.
4 – This drawing shows only those features which are pertinent to the form, fit, and function of the motor.

* SHAFT RUNOUT .002 [0.051] MAX.

** SURFACE SQUARE TO SHAFT DIAMETER WITHIN .005 [0.127] T.I.R.

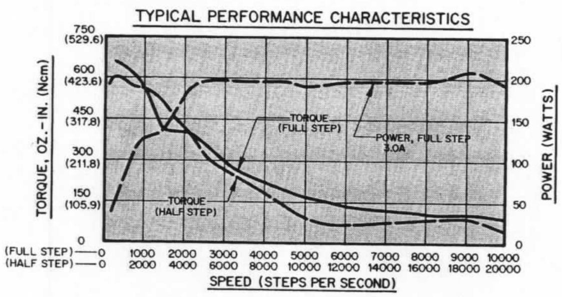
M172 MOTORS, STANDARD AND DOUBLE END MODELS

MECHANICAL SPECIFICATIONS

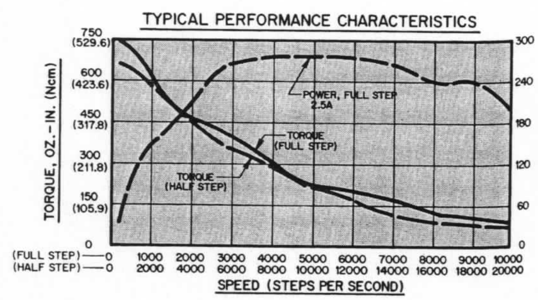
BASIC MOTOR SERIES	NOMINAL ROTOR INERTIA LB-IN² (kg-cm²)	MINIMUM RESIDUAL TORQUE LOAD LBS(kg)	TYPICAL TORQUE TO INERTIA RATIO	MAXIMUM OVERHANG LOAD LBS(kg)	MAXIMUM THRUST LOAD LBS(kg)	APPROX. WEIGHT, LBS(kg)	
						NET	SHIPPING
M111	1.34 (3.93)	6 (0.43)	11.2 x 10^3 (2) (11.2 (3))	25 (11.3)	50 (22.7)	8 (3.63)	9.25 (4.2)
MX111	1.34 (3.93)	6 (0.43)	11.2 x 10^3 (2) (11.2 (3))	25 (11.3)	50 (22.7)	9 (4.08)	10.25 (4.65)
M112-FD M112-FJ	2.75 (8.06)	12 (0.86)	9.8 x 10^3 (2) (9.8 (3))	25 (11.3)	50 (22.7)	14.5 (6.58)	16.5 (7.4)
M113	4.1 (12.0)	20 (1.44)	9.1 x 10^3 (2) (9.1 (3))	25 (11.3)	50 (22.7)	22 (10)	25 (11.4)
M172	21 (61.5)	50 (3.6)	3.1 x 10^3 (2) (3.1 (3))	50 (22.7)	100 (45.4)	50 (22.7)	56 (25.4)

(1) Both windings at rated current.
(2) Values shown are for reference information and are correct to the best of our knowledge at time of publication, but are subject to change without notice. Parameters to be used as part of a specification should be verified with the factory.
(3) Operation below rated current will reduce torque and may degrade step accuracy.

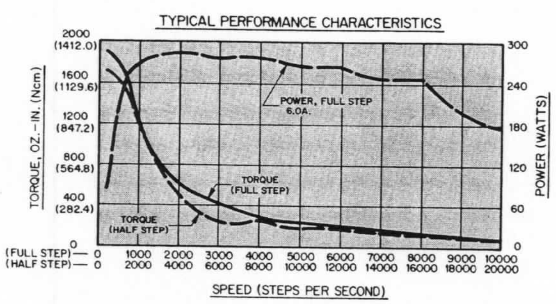
TYPICAL TORQUE VERSUS SPEED CHARACTERISTICS



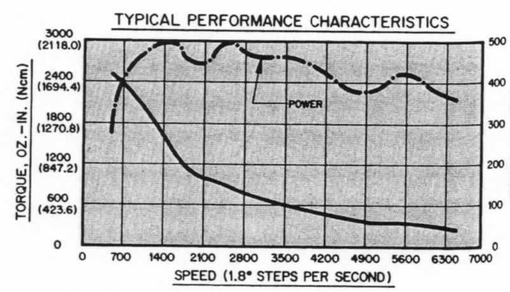
M111-FF-401 MOTOR WITH 3180 MODEL SLO-SYN MICRO SERIES MOTION CONTROLS



M112-FF-401 MOTOR WITH 3180 MODEL SLO-SYN MICRO SERIES MOTION CONTROLS

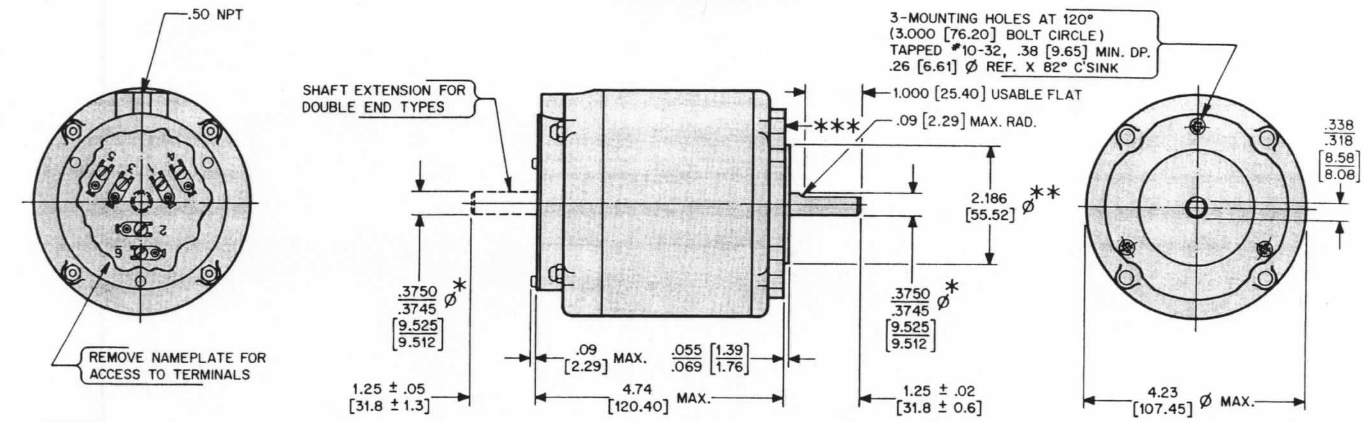


M113-FF-401 MOTOR WITH 6180 MODEL SLO-SYN MICRO SERIES MOTION CONTROLS



M172-FF-401 MOTOR WITH SLO-SYN MODEL PDM502 DRIVE

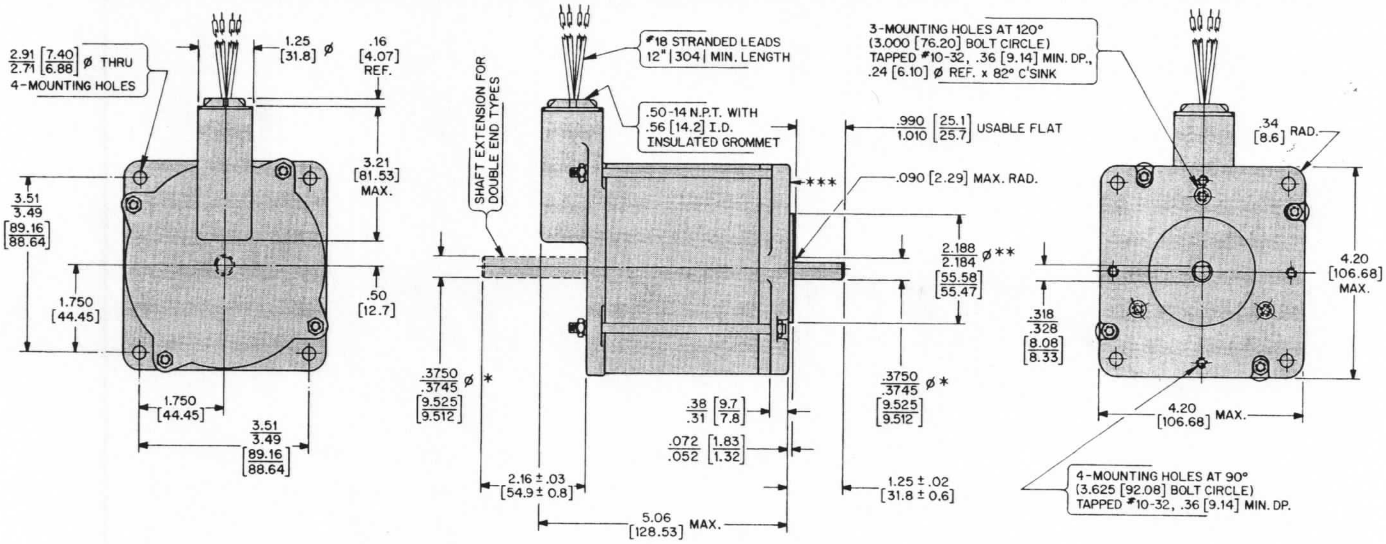
DIMENSIONS



NOTES ---
1 – Dimensions in brackets are millimeters.
2 – Tolerance on decimals ---
.XXX = ± 0.005 [0.13] unless otherwise specified.
3 – Dimensions shown apply before painting or plating.
4 – This drawing shows only those features which are pertinent to the form, fit, and function of the motor.

* SHAFT RUNOUT .002 [0.051] MAX.
** DIAMETER TOLERANCE ± .002 [0.051]
DIAMETER CONCENTRIC TO SHAFT DIAMETER WITHIN .003 [0.077] T.I.R.
*** SURFACE SQUARE TO SHAFT DIAMETER WITHIN .003 [0.077] T.I.R.

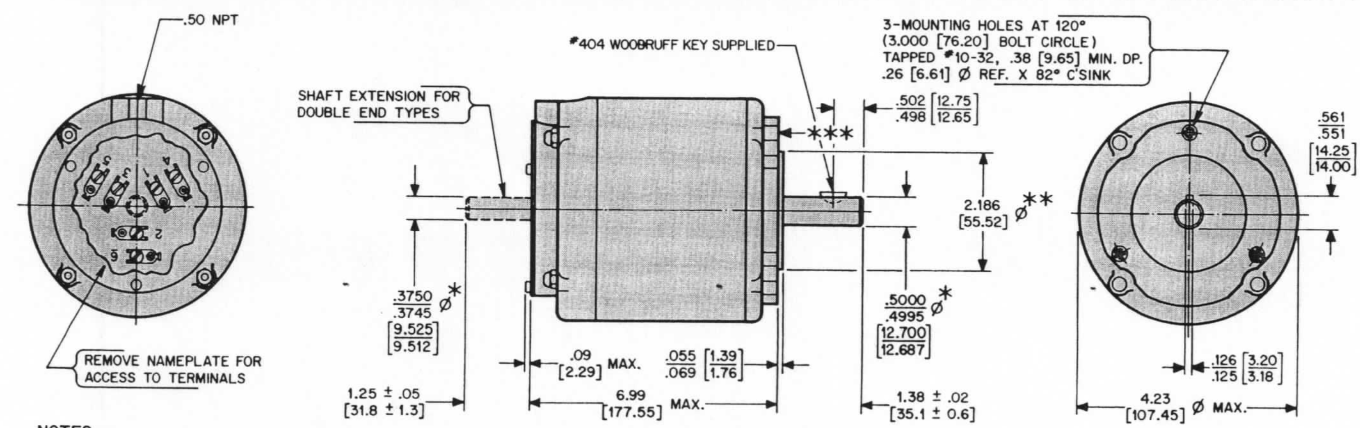
M111 MOTORS, STANDARD AND DOUBLE END MODELS



NOTES:--
1.– All dimensions apply before painting/plating.
2.– Dimensions in brackets are millimeters.

* SHAFT RUNOUT .002 [0.51] MAX.
** DIAMETER CONCENTRIC TO SHAFT DIAMETER WITHIN .003 [0.077] T.I.R.
*** SURFACE SQUARE TO SHAFT DIAMETER WITHIN .003 [0.077] T.I.R.

MX111-FF401 MOTORS, STANDARD AND DOUBLE END MODELS



NOTES ---
1 – Dimensions in brackets are millimeters.
2 – Tolerance on decimals ---
.XXX = ± 0.005 [0.13] unless otherwise specified.
3 – Dimensions shown apply before painting or plating.
4 – This drawing shows only those features which are pertinent to the form, fit, and function of the motor.

* SHAFT RUNOUT .002 [0.051] MAX.
** DIAMETER TOLERANCE ± .002 [0.051]
DIAMETER CONCENTRIC TO SHAFT DIAMETER WITHIN .003 [0.077] T.I.R.
*** SURFACE SQUARE TO SHAFT DIAMETER WITHIN .003 [0.077] T.I.R.

M112-FD MOTORS,STANDARD AND DOUBLE END MODELS

INSTALLATION INSTRUCTIONS for SLO-SYN® SS2000D3 AND SS2000D6 PACKAGED DRIVES

Superior Electric

TABLE OF CONTENTS

THINGS TO KNOW BEFORE USING THIS EQUIPMENT

- Only qualified personnel should install or perform servicing procedures on this equipment. Do not operate the unit without the enclosures in place as voltage present in this unit can cause serious or fatal injury.
- Before performing any work on the unit, allow at least five minutes for the capacitors to discharge fully.
- Voltage is present on unprotected pins when unit is operational.
- The "PWR ON" LED must be off for approximately 30 seconds before making or breaking the motor connections.
- Motors powered by these drives may develop extremely high torque. Be sure to disconnect ac power to these drive before doing any mechanical work.

CAUTION:
This unit is designed for 115 Vac input only (see Section 4.2, Electrical Specifications, Page 9).

WARRANTY RESTRICTIONS

Reconfiguration of the circuit in any fashion not shown in this manual will void the Warranty.

Failure to follow the proper wiring practices as described in Section 3.1 will void the Warranty.

SECTION 1: INTRODUCTION

1.1 USING THIS MANUAL

It is important that you understand how this SLO-SYN 2000 unit is installed and operated before you attempt to use it. **We strongly recommend that you read this manual completely before proceeding with the installation of this unit.**

This manual is an installation and operating guide to the SLO-SYN 2000 Drive. Section 1 gives an overview of the Drive and its features. Section 2 describes the steps necessary to place the drive into operation. General wiring guidelines as well as the physical mounting of the unit and connections to the drive portion are covered in Section 3.

Complete specifications, listed in Section 4, provide easily referenced information concerning electrical, mechanical and performance specifications. The procedure for setting the motor current level is also covered in this section.

Torque versus speed characteristics with all appropriate SLO-SYN Stepper Motors are given in Section 5. Section 6, Troubleshooting, gives procedures to follow if the SLO-SYN 2000 drive fails to operate properly.

Appendix A provides procedures for troubleshooting electrical interference problems.

1.2 PRODUCT FEATURES

SLO-SYN 2000 drives are bipolar, speed adjustable, two-phase chopper drives which use power MOSFET and IGBT devices. They can be set to operate a stepper motor in full or half steps or in 1/5, 1/10, 1/16, 1/36, 1/50, 1/100, 1/125 or 1/250 microsteps. The maximum running speed is 10,000 full steps per second. To reduce the chances of electrical noise problems, the control signals are optically isolated from the drive circuit.

- U.L. Recognized under Component Program, File #E146240
- Switch selectable current levels of .05 through 6 amperes depending on unit selected.
- Latched short circuit protection (phase-to-phase and phase-to-ground)
- Unlatched undervoltage and transient overvoltage protection
- Inputs are optically isolated
- Boost/Reduce Current and Windings Off capabilities
- Drive Ready output
- Built-in ac line filter plus MOV
- Self-test function
- Boost Current
- Reduce Current

SECTION 2: EXPRESS START UP PROCEDURE

The following instructions define the minimum steps necessary to make your **Drive** operational.

CAUTION:

Always disconnect the ac power to the unit and be certain that the "PWR ON" LED is OFF before connecting or disconnecting the motor leads. FAILURE TO DO THIS WILL RESULT IN A SHOCK HAZARD.

Always operate the Motor and the Drive GROUNDED. Be sure to twist together the wires for each motor phase. Six twists per foot is a good guideline.

1. Check to see that the motor used is compatible with the drive. Refer to Section 4.4 for a list of compatible motors.
2. Set the correct current level for the motor being used per the instructions in Section 4.5.
3. Select the appropriate step resolution and set the front panel switches as described in Section 4.6.
4. Wire the motor per the "Motor Connections" description in Section 3.3.
5. Connect the power source to the AC input terminal strip. The terminal labeled "L1" is line or "hot", "N" is neutral or "common" and "⊥" is ground.

NOTES:

If the motor operates erratically, refer to Section 5, "Torque Versus Speed Characteristics".

Clockwise and counterclockwise directions are properly oriented when viewing the motor from the end opposite the mounting flange.

SECTION 3: INSTALLATION GUIDELINES

3.1 GENERAL WIRING GUIDELINES

SLO-SYN 2000 drives use modern solid-state electronics to provide the features needed for advanced motion control applications. In some cases, these applications produce electromagnetic interference (EMI, or electrical "noise") that may cause inappropriate operation of the digital logic used in the drive, or in any other computer-type equipment in the user's system.

In general, any equipment that causes arcs or sparks or that switches voltage or current at high frequencies can cause interference. In addition, ac utility lines are often "polluted" with electrical noise from sources outside a user's control (such as equipment in the factory next door). Some of the more common causes of electrical interference are:

- power from the utility ac line
- relays, contactors and solenoids
- light dimmers
- arc welders
- motors and motor starters
- induction heaters
- radio controls or transmitters
- switch-mode power supplies
- computer-based equipment
- high frequency lighting equipment
- dc servo and stepper motors and drives

The following wiring practices should be used to reduce noise interference.

- **Solid grounding of the system is essential.** Be sure that there is a solid connection to the ac system earth ground. Bond the drive case to the system enclosure. Use a single-point grounding system for all related components of a system (a "hub and spokes" arrangement). Keep the ground connection short and direct.

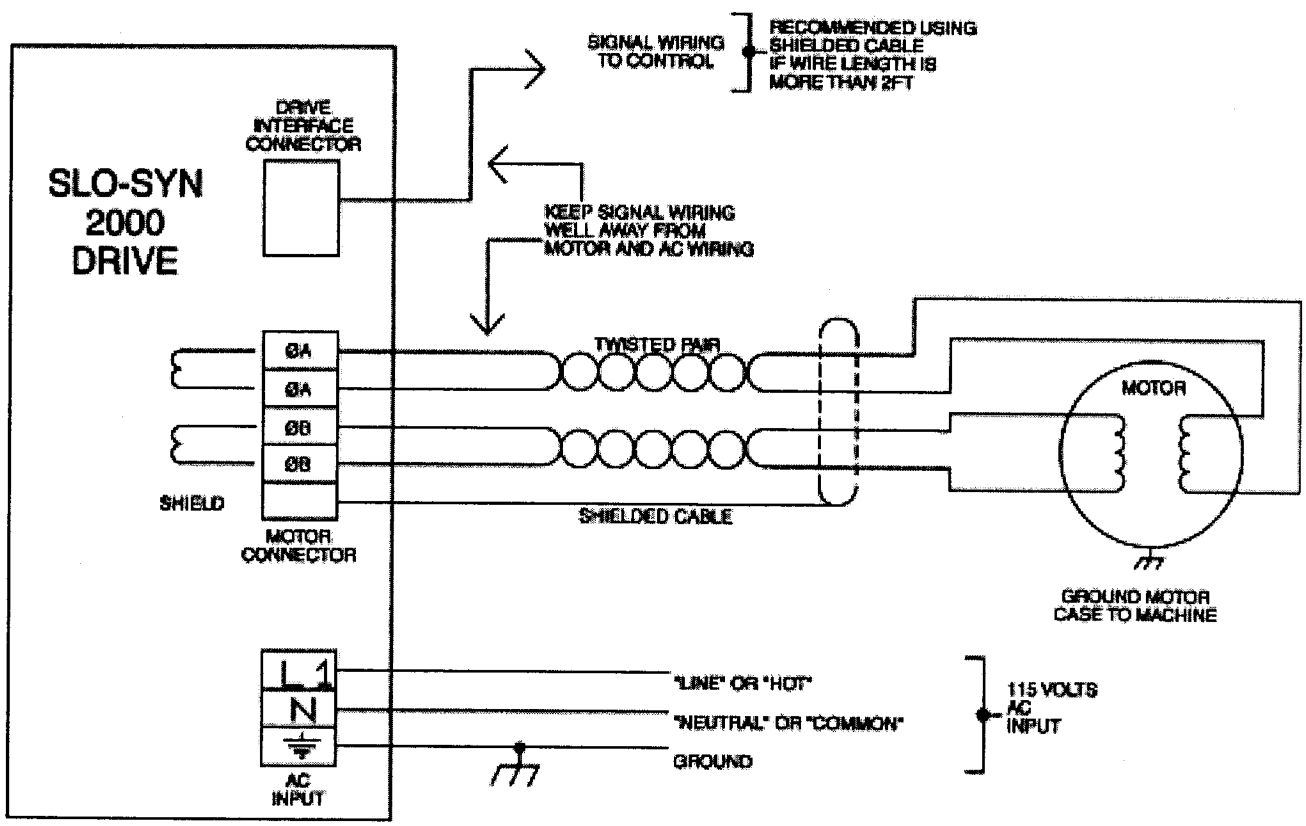
- **Keep signal and power wiring well separated.** If possible, use separate conduit or ducts for each. If the wires must cross, they should do so at right angles to minimize coupling.

- Note: Power wiring includes ac wiring, motor wiring, etc. and signal wiring includes inputs and outputs (I/O), serial communications (RS232 lines), etc.

- **Use shielded, twisted-pair cables for Indexer I/O lines. BE SURE TO GROUND SHIELDS ONLY AT ONE END, THE INDEXER/DRIVE END FOR OUTPUTS AND THE SWITCH OR SENSOR END FOR INPUTS.**

- **Suppress all relays to prevent noise generation.** Typical suppressors are capacitors or MOV s. (See manufacturers' literature for complete information). Whenever possible, use solid-state relays instead of mechanical contact types to minimize noise generation.

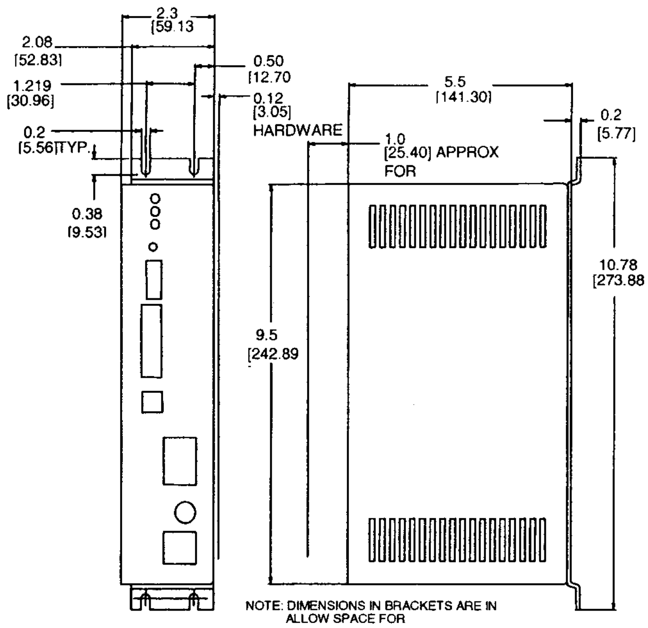
If you are experiencing problems with drive operation which might be related to EMI, refer to Appendix A for Troubleshooting pointers.



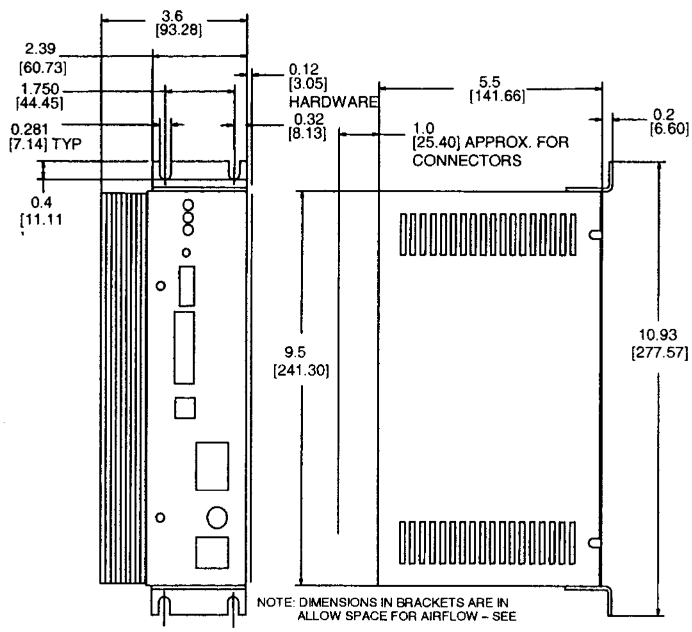
Recommended Wiring Practices For Drive Installation
Figure 3.1

3.2 MOUNTING

The SLO-SYN Drive is mounted by fastening its mounting brackets to a flat surface as shown in Figure 3.2.



D3 Mounting Diagram



D6 Mounting Diagram

Figure 3.2, Mounting Diagram

NOTE: The unit should be mounted upright (with the cooling fins vertical), or proper cooling will not occur. Air flow should not be obstructed. Case temperature should not exceed +70° C (+158° F). Forced air cooling may be required to maintain temperature within the stated limits.

When selecting a mounting location, it is important to leave at least two inches (51mm) of space around the top, bottom and sides of the unit to allow proper airflow for cooling.

It is also important to keep the drive away from obvious noise sources. If possible, locate the drive in its own metal enclosure to shield it and its wiring from electrical noise sources. If this cannot be done, keep the drive at least three feet from any noise sources.

3.3 CONNECTOR LOCATIONS AND PIN ASSIGNMENTS

Figure 3.3 shows the connector locations for the SLO-SYN 2000 drive.

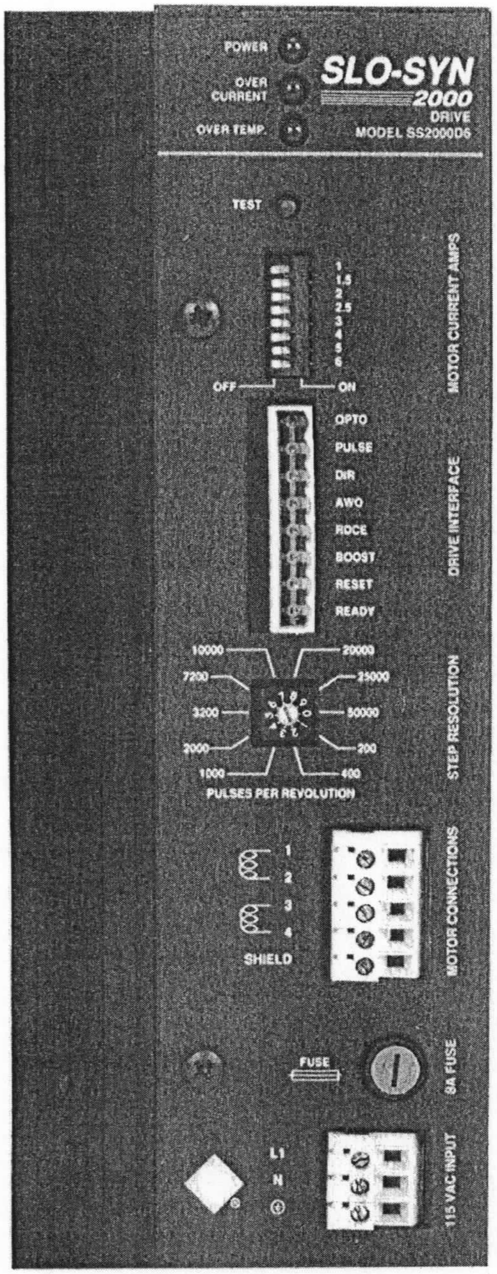


Figure 3.3, Connector Locations

MOTOR CONNECTIONS

All motor connections are made via the 5-pin connector. Pin assignments for this connector are:

Pin	**Motor Connection Assignment**
1	M1 (Phase A)
2	M3 (Phase A)
3	M4 (Phase B)
4	M5 (Phase B)
5	Shield

NOTE: Motor phase A is M1 and M3 and motor phase B is M4 and M5. The motor frame must be grounded.

Cabling from the drive to the motor should be done with a shielded, twisted pair cable. As a guideline, the wires for each motor phase should be twisted about six times per foot.

Superior Electric offers the following motor cable configurations. These cables have unterminated leads on both ends.

Length
10 ft (3 m)
25 ft (7.6 m)
50 ft (15.2 m)
75 ft (22.8 m)

Figure 3.4 shows the possible motor wiring configurations.

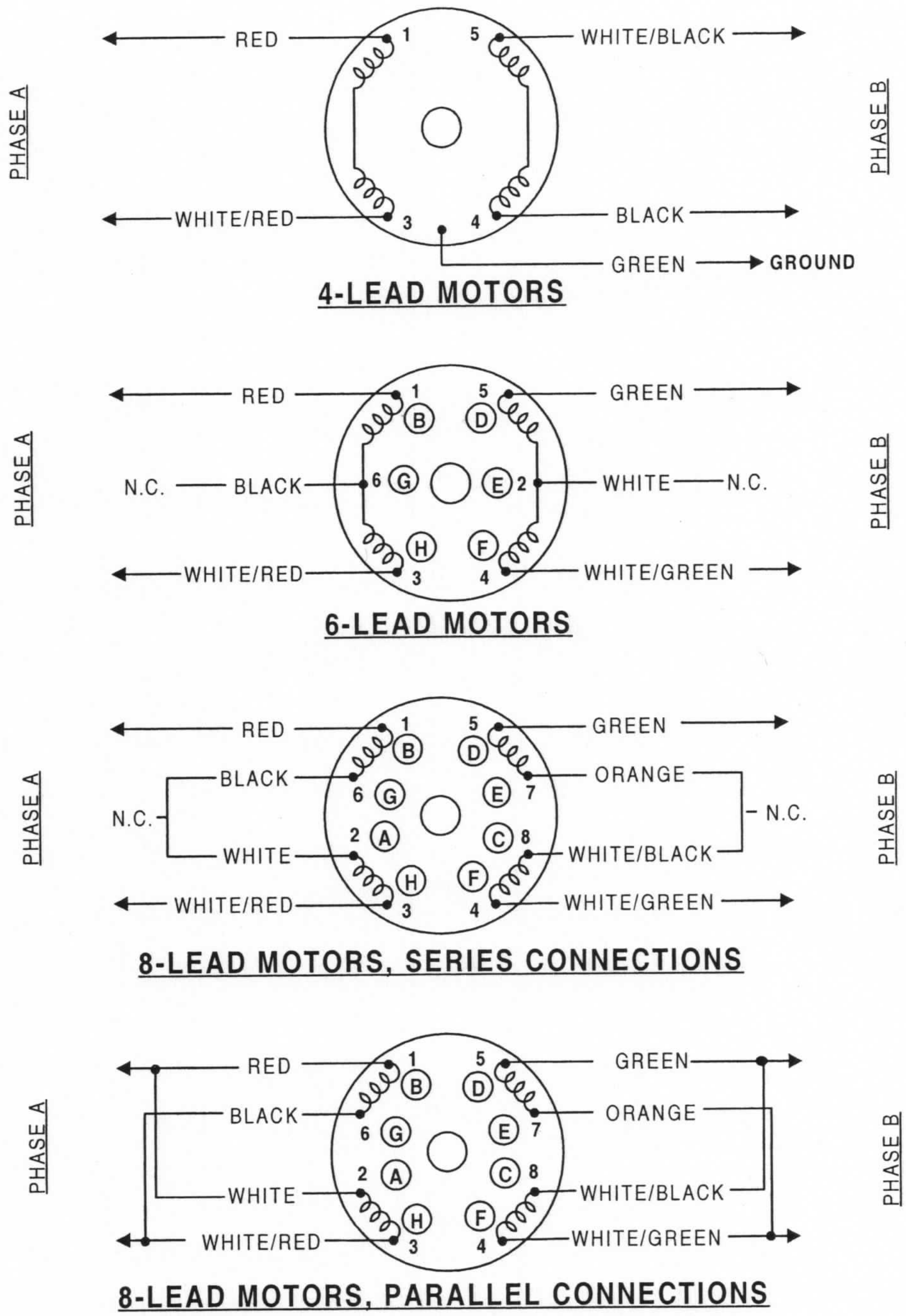


Figure 3.4, Motor Wiring Configurations

POWER INPUT

The ac input power is connected to a 3-screw terminal strip. The terminals are labeled as follows:

Terminal	**Lead Color, North American Standard**
"L1 for Line or "Hot"	Black
"N" for Common or Neutral	White
"⏚ " for Ground	Green

SECTION 4: SPECIFICATIONS

4.1 MECHANICAL SPECIFICATIONS

SS2000D3
Size
(Inches) 2.5W x 5.6 (5.8*)D x 9.6 (10.8*)H
(mm) 63W x 142 (147*)D x 244 (274*)H
Weight 3.2 pounds (1.45 kg)

SS2000D6
Size
(Inches) 3.8W x 5.6 (5.85*)D x 9.5* (10.75*)H
(mm) 97 W x 142 (149*) D x 241 (273*) H
Weight 6.5 pounds (2.95 kg)

* Includes mounting hardware.

4.2 ELECTRICAL SPECIFICATIONS

AC Input Range 90 to 132 Vac, 50/60 Hz

AC Current D3 – 5 amperes
D6 – 7 amperes

Fuse Rating** 250 volts, 8 amperes
Fuse Type** Littelfuse part number 314008 or Bussman part number ABC-8

Drive Power Dissipation
(Worst Case) D3 – 35 watts
D6 – 50 watts

** If this fuse blows, the power supply will be prevented from energizing any of its outputs, hence, the unit will not operate. Usually, this fuse will only blow if an internal failure occurs.

4.3 ENVIRONMENTAL SPECIFICATIONS

Temperature
Operating +32º F to +122º F
(0º C to +50º C) free air ambient, Natural Convection

Storage -40º F to +167º F
(-40º C to +75º C)

Humidity 95% max. non-condensing

Altitude 10,000 feet (3048 m) max.

Pollution Degree Level 2

4.4 MOTOR COMPATIBILITY

Motor Types Superior Electric KM and M Series
Frame Sizes D3: KML060 — KML091
M061 — M092
D6: KML060 — KML093
M061 — MH112

Number of Connections 4, 6, 8
Minimum Inductance 8 millihenrys
Maximum Inductance 64 millihenrys
Maximum Resistance 2 ohms at 6 amp. setting

NOTE: Maximum resistance is total of motor plus cable.

CAUTION: Do not use larger frame size motor than those listed, or the drive may be damaged.

MOTORS FOR USE WITH THE SS2000D3/D6 DRIVE

Motor	Current (amperes)	D3	D6
KML060-F02	1.5	X	X
KML061-F03	1.5	X	X
KML062-F03	1.5	X	X
KML063-F04	2	X	X
KML091-F05	3	X	X
KML091-F07	3	X	X
KML092-F07	4		X
KML093-F08	4		X
KML093-F10	6		X
M061-FF206	1	X	X
M062-FF206	1.5	X	X
M063-FF206	1.5	X	X
M091-FF206	3	X	X
M092-FF206	4		X
M093-FF206	4		X
M111-FF206	5		X
M112-FF206	6		X
MH112-FF206	6		X

NOTE: DUTY CYCLE LIMITING OR EXTERNAL MOTOR COOLING MAY BE REQUIRED TO KEEP THE SHELL TEMPERATURE BELOW ITS RATING.

4.5 CURRENT SETTINGS

The proper current setting for each motor is shown on the individual torque vs. speed curves. Use this current level to obtain the torque shown. The access hole for the switches which set the motor current level is located on the front of the unit (see Figure 4.1). Select the desired operating current by setting the appropriate switch to the "ON" position. Only one switch should be ON. If two or more switches are ON, the one which selects the highest current level will be the active switch. The switch settings are as follows:

Position	D3 Current (amperes)	D6 Current (amperes)
8	0.5	1.0
7	0.75	1.5
6	1.0	2.0
5	1.25	2.5
4	1.5	3.0
3	2.0	4.0
2	2.5	5.0
1	3.0	6.0

4.6 STEP RESOLUTION

The number of pulses per revolution is selected using the rotary switch on the front panel. The arrow on the switch knob can point to any of ten positions. The following chart shows the number of pulses per revolution selected by each switch position.

Switch Position	Pulses Per Revolution
1	200
2	400
3	1,000
4	2,000
5	3,200
6	7,200
7	10,000
8	20,000
9	25,000
0	50,000

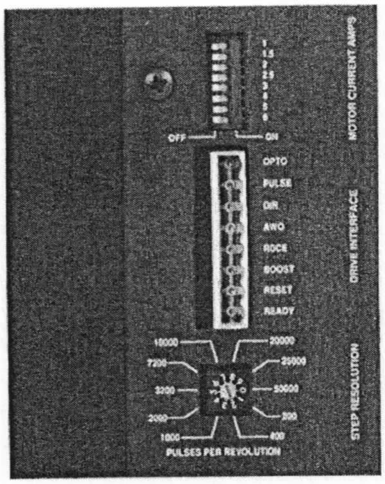


Figure 4.1
Switches For Setting Current Level
And Step Resolution

4.7 SIGNAL SPECIFICATIONS

4.7.1 Connector Pin Assignments

All connections are made via the 8-pin connector, part number 220878-008.

Pin	Assignment
1	OPTO
2	PULSE
3	DIR
4	AWO
5	RDCE
6	BOOST
7	RESET
8	READY

4.7.2 Signal Descriptions

OPTO Opto-Isolator Supply
User supplied power for the opto-isolators.

PULSE Pulse Input
A low to high transition on this pin advances the motor one step. The step size is determined by the Step Resolution switch setting.

DIR Direction Input
When this signal is high, motor rotation will be clockwise. Motor rotation will be counterclockwise when this signal is low.

Clockwise and counterclockwise directions are properly oriented when viewing the motor from the end opposite the mounting flange.

AWO All Windings Off Input
When this signal is low, AC and DC current to the motor will be zero. **Caution: There will be no holding torque when the AWO signal is low.**

RDCE Reduce Current Input
The motor current will be 50% of the selected value when this signal is low. **Caution: Holding torque will also be reduced when this signal is low.**

BOOST Boost Current Input
When this signal is low, the motor current will be 150% of the selected level up to a maximum of 6 amperes.

RESET Reset Input
The translator will go to the "power up" state when this signal goes low.

READY Ready Output
This pin is the emitter of an opto-isolator that activates when the drive is ready to run a motor.

4.7.3 Level Requirements

OPTO
Voltage .... 4.5 to 6.0 volts dc
Current................... 20 mA per signal used

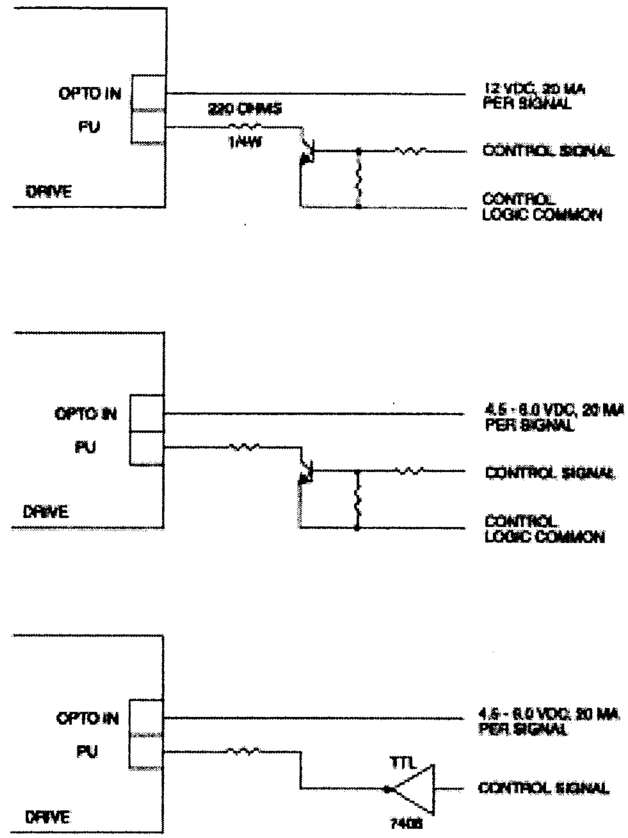
READY
Voltage .... 4.5 to 6.0 volts dc (depends on OPTO)
Current................... 0.5 mA source

Other Signals
Voltage
Low .... ≤0.8 Vdc
≥0.0 Vdc
High................. ≤OPTO
≥OPTO - 1 volt
Current
Low .... ≤20 mA
High................. ≤0.2 mA

4.7.4 Timing Requirements

PULSE
Max. Frequency..... 1 megahertz
Max. Rise And
Fall Times .... 1 microsecond
Min. Pulse
Width .... 0.4 microseconds

Other Signals
Response Time...... ≤50 microseconds



Suggested Methods For Control Interface
Figure 4.2

4.8 INDICATOR LIGHTS

"POWER" LED, Red
Lights when the drive logic power supply is present, indicating that the drive is energized.

"OVERCURRENT" LED, Red
Lights to indicate overcurrent condition. This condition is a result of motor wiring errors or a ground fault. Recovery from this condition requires removing ac power, correcting the problem, then re-energizing ac power.

"OVER TEMP" LED, Red
Lights to indicate the air temperature inside the drive has exceeded a safe level for reliable operation. Recovery from this condition requires removing and then reapplying the ac power.

4.9 TEST

A pushbutton Test switch is located on the front panel. To operate the Test function, disconnect the translator input connector and then actuate the switch. If the drive and motor are wired correctly, the motor will rotate clockwise at about 1/2 revolution per second.

SECTION 5: TORQUE VERSUS SPEED CHARACTERISTICS

5.1 MOTOR PERFORMANCE

All stepper motors exhibit instability at their natural frequency and harmonics of that frequency. Typically, this instability will occur at speeds between 50 and 500 full steps per second and, depending on the dynamic motor load parameters, can cause excessive velocity modulation or improper positioning. This type of instability is represented by the open area at the low end of each Torque vs. Speed curve.

There are also other instabilities which may cause a loss of torque at stepping rates outside the range of natural resonance frequencies. One such instability is broadly defined as mid-range instability. Usually, the damping of the system and acceleration/deceleration through the resonance areas aid in reducing instability to a level that provides smooth shaft velocity and accurate positioning. If instability does cause unacceptable performance under actual operating conditions, the following techniques can be used to reduce velocity modulation.

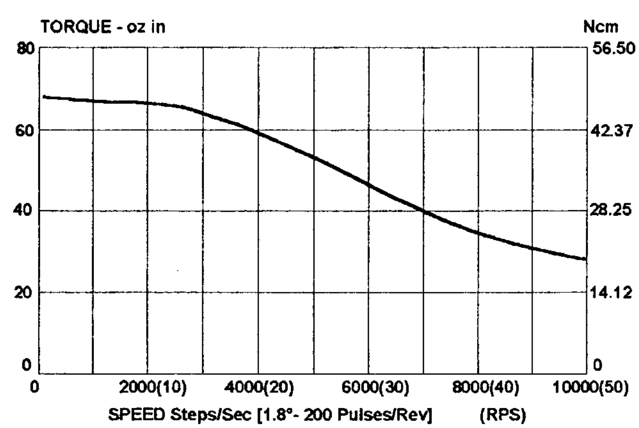
1) Avoid constant speed operation at the motors unstable frequencies. Select a base speed that is above the motors resonant frequencies and adjust acceleration and deceleration to move the motor through unstable regions quickly.

2) The motor winding current can be reduced as discussed in Section 4.5. Lowering the current will reduce torque proportionally. The reduced energy delivered to the motor can decrease velocity modulation.

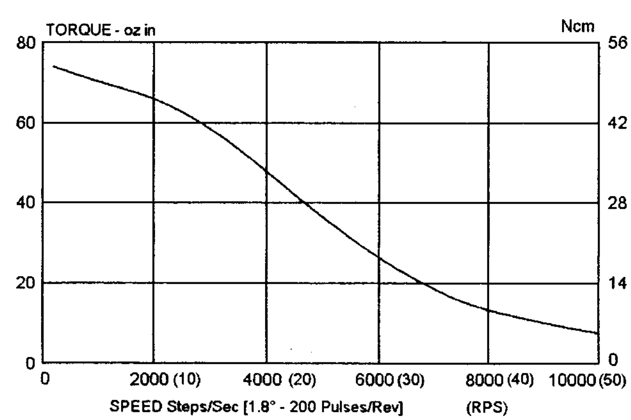
3) Use the half-step mode of operation or use microstepping to provide smoother operation and reduce the effects of mid range instability. Note that microstepping reduces the shaft speed for a given pulse input rate.

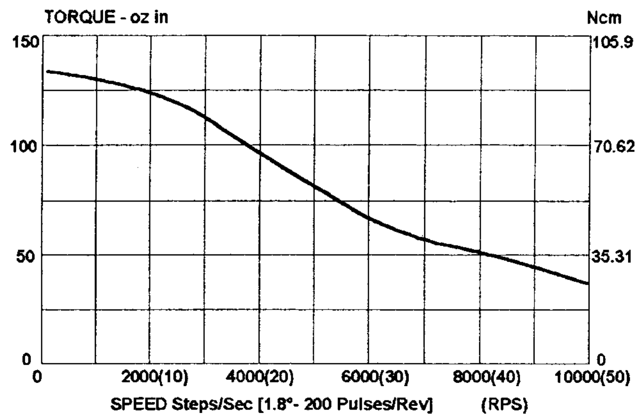
5.2 TYPICAL TORQUE VERSUS SPEED CURVES

KML060-F02 MOTOR, 1.5 AMPERES

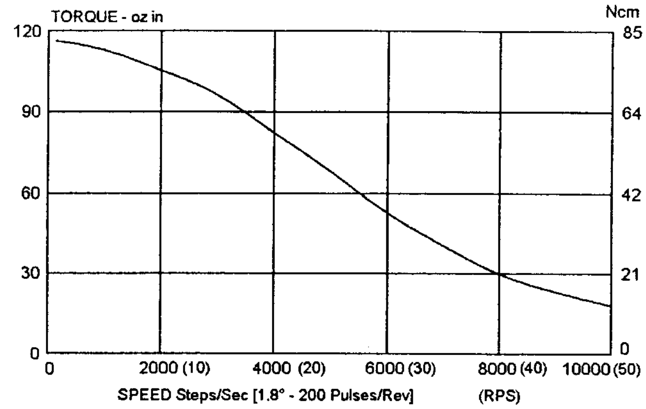


M061-FF206 MOTOR, 1.0 AMPERES





KML061-F03 MOTOR, 1.5 AMPERES



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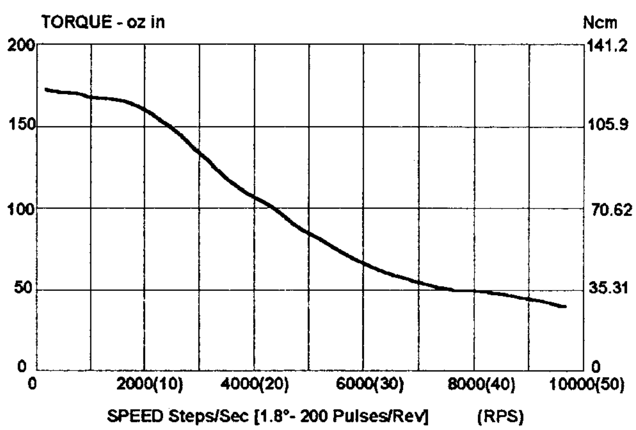

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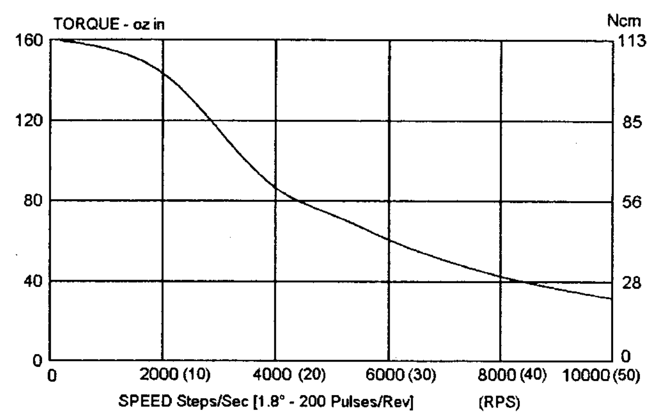

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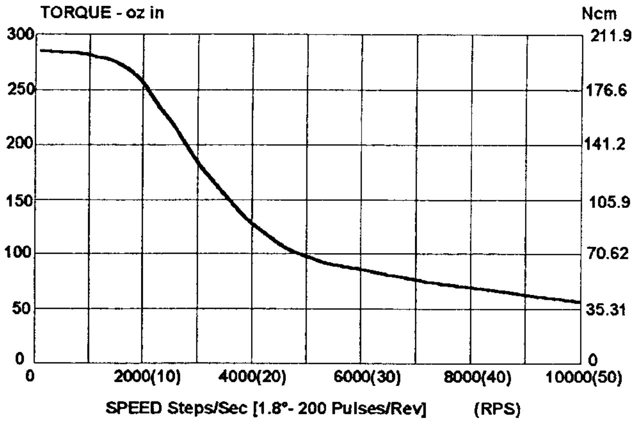

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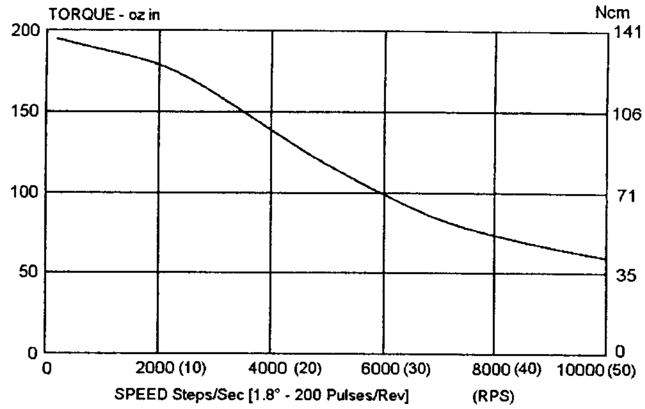
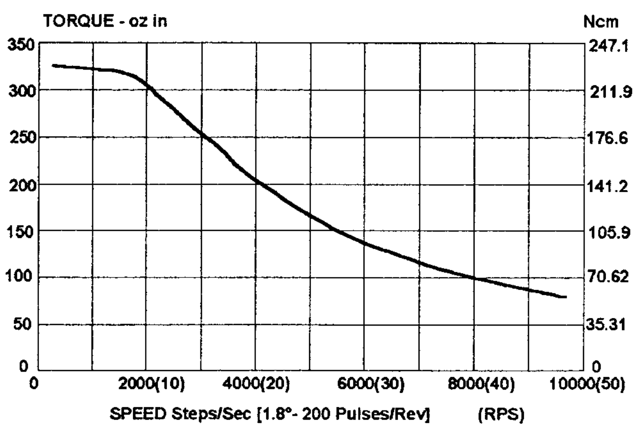


M091-FF206 MOTOR, 3.0 AMPERES



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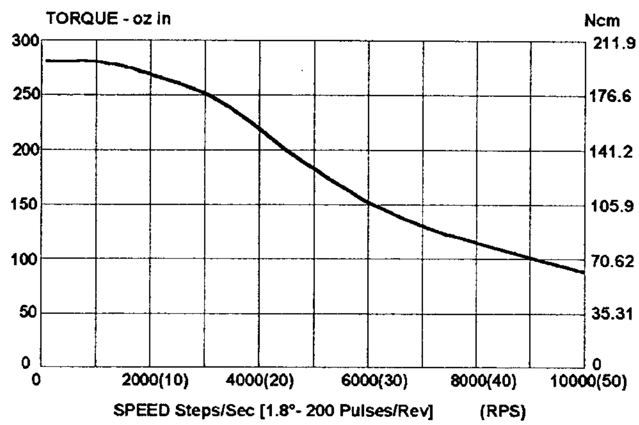

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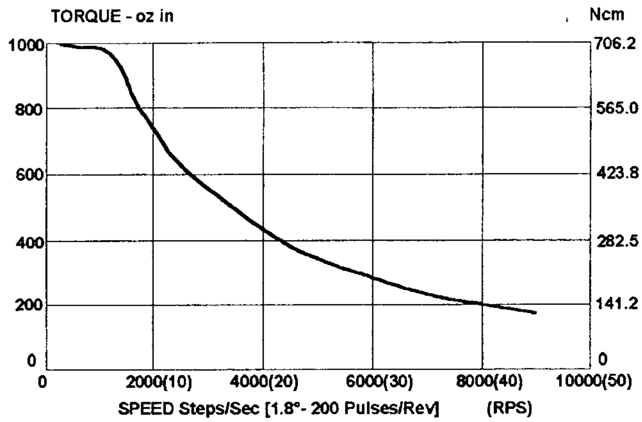
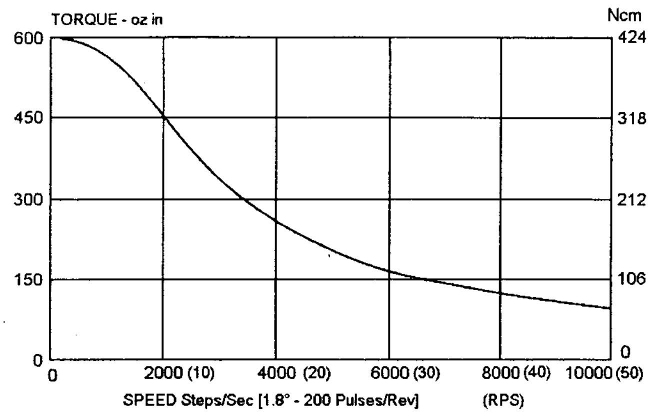
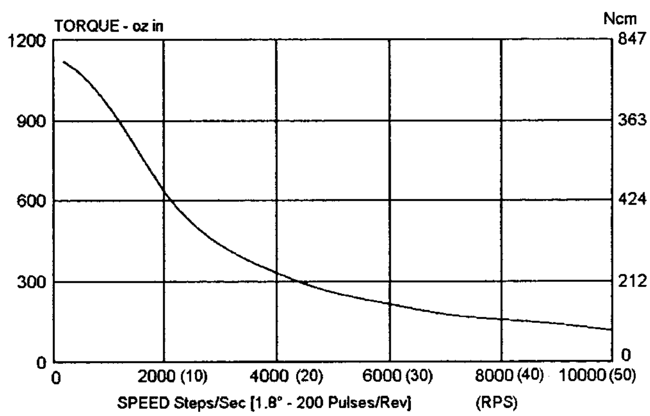


KML093-F10 MOTOR, 6.0 AMPERES



M111-FF206 MOTOR, 5.0 AMPERES



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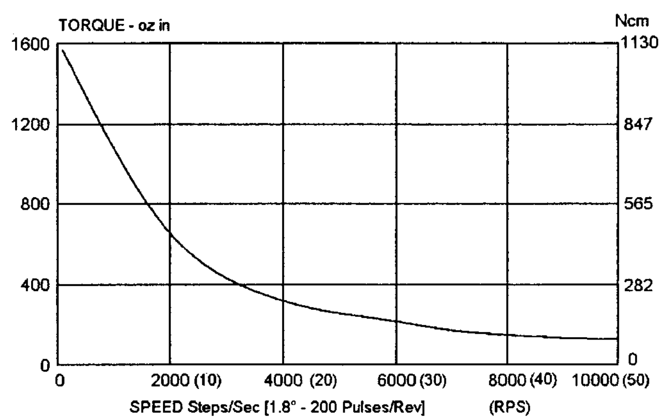

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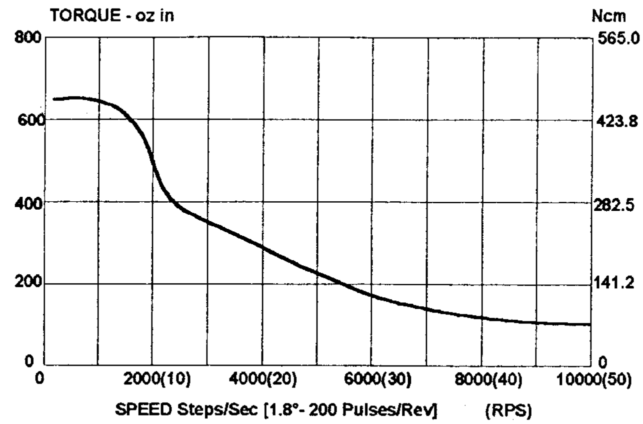
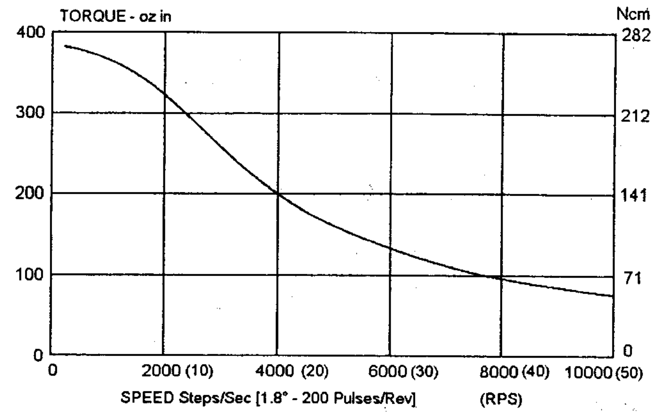
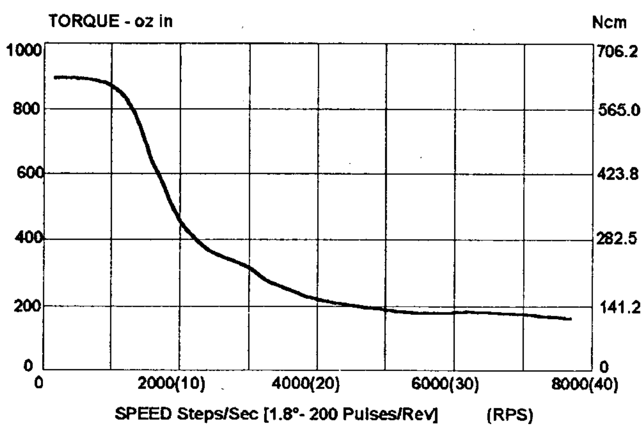


KML092-F07 MOTOR, 4.0 AMPERES



M092-FF206 MOTOR, 4.0 AMPERES

KML093-F08 MOTOR, 4.0 AMPERES



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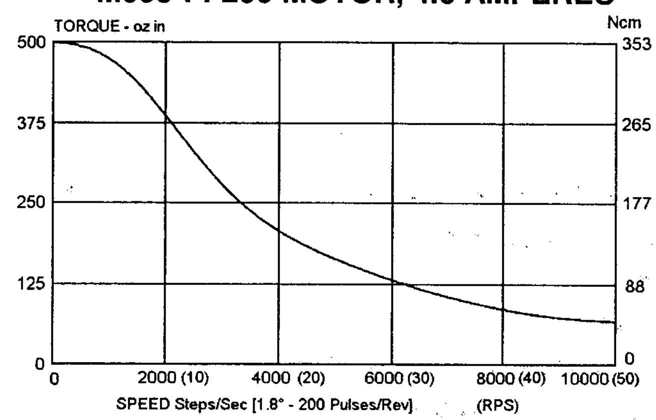
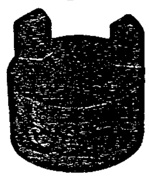
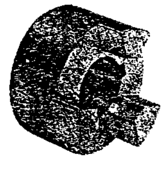


Jaw Shaft Couplings

Lovejoy



No. 4X181



No. 3KX82

Buna N Spider

Hytrel® Spider

Urethane Spider

A complete 3-pc. coupling assembly consists of two coupling bodies (ends) with desired bores and one spider (center). Coupling bodies are made of sintered iron, cast iron, or aluminum and do not require lubrication. 3-pc. coupling is easily assembled and aligned. Standard keyways on 5/8" and larger bore sizes; Nos. 4X177 and 3KX86 have no keyway. All have hollow head setscrews.

Style	Assembled Dimensions OD (In.)	Assembled Dimensions Length (In.)	Bore Range (In.)	Keyway	Bore Range (mm)	Keyway
L050	1.08	1.72	1/8 - 1/2	No Keyway	10	3 x 1.4
L070	1.36	2.00	5/8 - 7/8	3/16 x 3/32	11 - 12	4 x 1.8
L075	1.75	2.13	1 - 1¼	1/4 x 1/8	14 - 16	5 x 2.3
L090	2.11	2.15	1⅜	5/16 x 5/32	19 - 22	6 x 2.8
L095	2.11	2.50	1½ - 1¾	3/8 x 3/16	24 - 30	8 x 3.3
L100	2.53	3.50	1⅞	1/2 x 1/4	38	10 x 3.3
L110	3.31	4.22			42	12 x 3.3
L150	3.75	4.50				

COUPLING SPIDERS

Buna N Spiders
Made of oil-resistant, highly resilient long-life material. Serviceable temperature range: -40° to +212°F. Accommodates 1° angular and 0.015" of parallel misalignment. Black color.

Urethane Spiders
Provide 1.5 times greater torque capability than Buna N and offer good resistance to oil and chemicals. However, this material provides less dampening effect and operates at a temperature range of -30° to +160°F. Accommodates 1° angular and 0.015" of parallel misalignment. Blue color.

Hytrel® Spiders
Provide 2.5 times greater torque capability than Buna N. Have a wider temperature range, -60° to +250°F, and better chemical resistance than Buna N spiders. Accommodates 1/2° angular and 0.015" of parallel misalignment. Tan color.

Style	Rated Torque (In.-Lbs.)	HP Capacity at Listed RPM 300 RPM	1200 RPM	1800 RPM	3600 RPM	Stock No.	List	Each	Shpg. Wt.
BUNA N SPIDERS									
A/L050	26.3	0.13	0.50	0.75	1.5	1X409	$3.00	$1.43	0.1
A/L070	43.2	0.21	0.84	1.2	2.5	1X408	4.00	2.01	0.1
A/L075	90	0.42	1.7	2.6	5.0	2X814	6.00	3.44	0.1
A/L090/L095	144/194	0.69/0.93	2.8/3.7	4.1/5.5	8.3/11.1	1X407	7.00	4.45	0.1
A/L100	417	2.0	7.9	11.9	23.8	1X406	15.00	9.40	0.1
A/L110	792	3.8	15.1	23.0	46.0	3X715	17.00	10.81	0.1
A/L150	1240	6.0	24.0	36.0	72.0	1A413	30.00	18.76	0.2
AL150	1450	7.0	28.1	42.1	84.2	3KZ26	30.00	17.35	0.3
L190	1726	8.1	32.4	49.0	98.0	1A928	42.00	27.05	0.3
URETHANE SPIDERS									
A/L050	39.5	0.2	0.8	1.1	2.3	3KZ67	9.00	5.87	0.1
A/L070	64.8	0.3	1.3	1.8	3.7	3KX87	7.00	4.08	0.1
A/L075	135	0.6	2.5	3.9	7.7	3KX92	8.00	5.05	0.1
A/L090/L095	216/291	1.0/1.4	4.1/5.6	6.2/8.3	12.4/16.7	3KZ03	11.00	7.24	0.1
A/L100	625.5	3.0	11.9	17.9	35.7	3KZ04	29.00	19.01	0.1
A/L110	1188	5.7	22.7	34.5	69.0	3KZ05	55.00	36.30	0.1
L150	1860	9.0	36.0	54.0	108.0	3KZ06	67.00	43.90	0.2
L190	2589	12.1	48.6	73.5	147.0	3KZ07	72.00	47.25	0.3
HYTREL SPIDERS									
A/L070	114	0.5	2.1	3.3	6.5	1A923	11.00	6.75	0.1
A/L075	225	1.1	4.2	6.4	12.9	1A924	16.00	10.13	0.1
A/L090/L095	401/561	1.9/2.7	7.7/10.7	11.5/16.0	23.0/32.0	1A925	21.00	13.50	0.1
A/L100	1134	5.0	21.6	32.4	64.8	1A416	50.00	32.35	0.1
A/L110	2268	10.8	43.2	65.0	129.6	1A415	61.00	39.10	0.1
A/L150	3708	17.7	70.8	106.0	212.4	1A414	73.00	47.00	0.2
L190	4680	20.2	88.8	122.5	245.0	1A927	86.00	55.30	0.2

Style	Bore Diameter (In.) 1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	Each	Shpg. Wt.
SINTERED IRON OR CAST-IRON COUPLING BODY (TWO REQUIRED FOR EACH COMPLETE COUPLING)																		
L050	4X236	1A417	4X175	6X070	4X176	4X177#	—	—	—	—	—	—	—	—	—	—	$2.17	0.1
L070	—	—	—	5X401	4X178	4X179	4X180	—	—	—	—	—	—	—	—	—	3.36	0.3
L075	—	—	—	5X402	4X181	4X182	4X183	4X184	—	—	—	—	—	—	—	—	3.90	0.4
L075	—	—	—	1A073‡	5X447‡	—	—	—	—	—	—	—	—	—	—	—	3.90	0.5
L090	—	—	—	—	4X185	4X186	4X187	4X188	—	—	—	—	—	—	—	—	6.01	0.6
L095	—	—	—	1A914	6X071	6X072	4X191	4X192	4X193	6X073	—	—	—	—	—	—	9.24	0.8
L100	—	—	—	—	—	—	6X074	6X075	6X076	4X194	4X195	4X196	—	—	—	—	17.29	0.3
L110	—	—	—	—	—	—	1A418	3X708	3X709	3X710	3X711	3X712	3X713	3X714	—	—	23.63	5.7
L150	—	—	—	—	—	—	—	1A405	—	1A406	1A407	1A408	1A409	1A410	1A411	1A412	30.35	4.1
L190 *	—	—	—	—	—	—	—	—	1A916	1A917	1A918	1A919	1A920	1A921	—	1A922	56.00	8.0
ALUMINUM COUPLING BODY (TWO REQUIRED FOR EACH COMPLETE COUPLING)																		
L050	3KX82	3KX83	3KX84	—	3KX85	3KX86#	—	—	—	—	—	—	—	—	—	—	2.54	0.1
L070	—	—	—	3KX88	3KX89	3KX90	3KX91	—	—	—	—	—	—	—	—	—	3.90	0.2
L075	—	—	—	—	3KX93	3KX95	3KX96	3KX97	—	—	—	—	—	—	—	—	4.32	0.3
L075	—	—	—	—	3KX94‡	—	—	—	—	—	—	—	—	—	—	—	4.32	0.3
L090	—	—	—	—	3KX98	3KX99	3KZ01	3KZ02	—	—	—	—	—	—	—	—	6.60	0.5
L095	—	—	—	—	3KZ10	3KZ11	3KZ12	3KZ13	3KZ14	3KZ15	—	—	—	—	—	—	10.21	0.7
L100	—	—	—	—	—	—	3KZ16	3KZ17	3KZ18	3KZ19	3KZ20	3KZ21	—	—	—	—	20.28	1.3
L110	—	—	—	—	—	—	—	—	3KZ22	3KZ23	—	3KZ24	—	3KZ25	—	—	26.15	2.4
L150	—	—	—	—	—	—	—	—	—	3KZ27	3KZ28	3KZ29	3KZ30	3KZ31	—	3KZ32	34.15	1.8

Style	Bore Diameter (mm) 10	11	12	14	16	19	20	22	24	25	28	30	38	42	Each	Shpg. Wt.
METRIC BORE COUPLING BODY (TWO REQUIRED FOR EACH COMPLETE COUPLING)																
L050	5ZV09	5ZV10	5ZV11	—	—	—	—	—	—	—	—	—	—	—	$2.35	1.2
L070	5ZV12	5ZV13	5ZV14	5ZV15	5ZV16	5ZV17	—	—	—	—	—	—	—	—	3.69	2.2
L075	—	—	5ZV18	5ZV19	5ZV20	5ZV21	5ZV22	5ZV23	—	—	—	—	—	—	4.34	2.9
L090	—	—	—	—	—	5ZV24	—	—	5ZV25	—	—	—	—	—	6.48	3.7
L095	—	—	—	—	—	5ZV26	5ZV27	—	5ZV28	5ZV29	5ZV30	—	—	—	9.92	5.3
L100	—	—	—	—	—	—	—	—	5ZV31	5ZV32	5ZV33	5ZV34	—	—	18.07	6.0
L110	—	—	—	—	—	—	—	—	5ZV35	—	5ZV36	5ZV37	5ZV38	5ZV39	23.93	2.9
L150	—	—	—	—	—	—	—	—	—	—	—	—	5ZV40	5ZV41	30.70	4.0

(*) Cast iron. (‡) For use on hydraulic units which have 1/8 x 1/16" keyway. (#) No keyway.