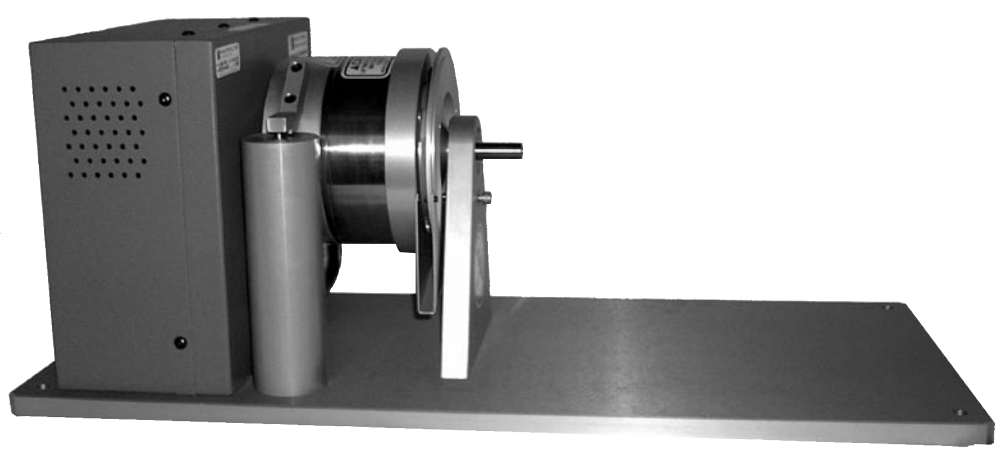
MAGTROL

HD and ED Series

Hysteresis Dynamometers



User's Manual

Purchase Record

Please record all model numbers and serial numbers of your Magtrol equipment, along with the general purchase information. The model number and serial number can be found on either a silver identification plate or white label affixed to each unit. Refer to these numbers whenever you communicate with a Magtrol representative about this equipment.

Model Number: ______________________________

Serial Number: ______________________________

Purchase Date: ______________________________

Purchased From: ______________________________

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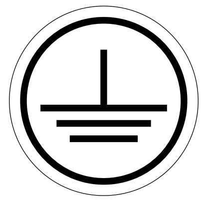
4th Edition, revision E – August 2007

MAGTROL

Safety Precautions

Several warning labels are affixed directly to the dynamometer. These warnings are discussed in further detail below. Please take the time to read this page thoroughly before connecting and using your dynamometer.

1. Make sure that all Magtrol dynamometers and electronic products are earth-grounded, to ensure personal safety and proper operation.



2. Check line voltage before operation on any dynamometer that uses AC input power.
3. Make sure that dynamometers are equipped with a protective cover to prevent contact with the rotating shaft and coupling. The protective cover must be equipped with a safety interlock to disable the test motor if the cover is removed.

4. Make sure that all motors under test are equipped with appropriate safety guards.
5. Use caution with exposed brake surfaces. They have a tendency to become very hot during long periods of operation.

6. Do not lift the unit by the brake assembly, as it may cause damage to the torque sensor.

7. When operating dynamometers with blowers, hearing protection must be worn.

Revisions To This Manual

The contents of this manual are subject to change without prior notice. Should revisions be necessary, updates to all Magtrol User's Manuals can be found at Magtrol's web site at www.magtrol.com/support/manuals.htm.

Please compare the date of this manual with the revision date on the web site, then refer to the manual's Table of Revisions for any changes/updates that have been made since this edition.

REVISION DATE

4th Edition, revision E – August 2007

TABLE OF REVISIONS

Date	Edition	Change	Section(s)
08/31/07	4th Edition - rev. E	Updated electrical power and fuse ratings	1.3
08/31/07	4th Edition - rev. E	New resistance and current values for HD-106	8.1.3.1, 8.1.3.2
08/31/07	4th Edition - rev. E	Added note about circuitry between connector and brake coil	8.1.3.1
06/11/07	4th Edition - rev. D	Deleted: Analog Outputs	7.2, 1.3
03/12/07	4th Edition - rev. C	Updated calibration drawings and procedure	6.4
03/12/07	4th Edition - rev. C	Added new section: "Calibration Beams and Weights"	6.2
02/02/07	4th Edition - rev. B	New "A", "P" and "Q" dimensions for HD-700 series dynamometers	1.3
02/02/07	4th Edition - rev. B	Change in torque, speed and power ratings.	1.3, 4.1.3.1
06/28/06	4th Edition - rev. A	Change in power and speed ratings for HD-805.	1.3, 4.1.3.1
01/23/06	4th Edition	All HD and ED data sheets condensed to one single data sheet.	1.3
01/23/06	4th Edition	HD-515 (compressed air cooled) dynamometer added to product line.	1.3, 2.2, 3.3.3, 3.3.3.2, 4.1.3.1, 4.1.3.2.1, 8.1.3.1, 8.1.3.2
01/23/06	4th Edition	New resistance and current values for HD-500 and HD-505	8.1.3.1, 8.1.3.2
10/12/05	3rd Edition - rev. D	Note to "call factory" for HD-805 power and speed ratings	1.3.3, 4.1.3.1
10/12/05	3rd Edition - rev. D	Change in power rating (5 minutes) for HD-800	1.3.3, 4.1.3.1
02/24/05	3rd Edition - rev.C	Hearing safety warnings added	2.2, 3.3.3.1, 4.1.1, 4.1.3.2.2
12/09/04	3rd Edition - rev.B	Electrical power and fuse ratings added to data sheets	1.3.1–1.3.4
03/11/04	3rd Edition - rev. A	5410 Torque/Speed Readout and 5200/5210 Power Supply removed from manual/open-loop test system configurations	1.3.1–1.3.4, 3.3.1
12/08/03	3rd Edition	HSD Series High Speed Dynamometers discontinued	throughout manual
10/27/03	2nd Edition - rev. E	Change in maximum torque rating for HSD-710-8N	1.3.5, 4.1.3.1
10/27/03	2nd Edition - rev. E	Added short base plate option	1.3.1–1.3.3
10/27/03	2nd Edition - rev. E	Change in speed encoder options	1.3.1–1.3.4
10/02/03	2nd Edition - rev. D	New dimensions for HD-700 series dynamometers	1.3.2
09/25/03	2nd Edition - rev. C	New "B" dimension for HD-400	1.3.1
09/25/03	2nd Edition - rev. C	New "B" and "E" dimensions for HD-106	1.3.1
08/19/03	2nd Edition - rev. B	New schematic drawing for HD-800–815 Brake Control Supply	B.4
03/17/03	2nd Edition - rev. A	New "F" dimension for HSD-610M	1.3.5
03/17/03	2nd Edition - rev. A	New Dynamometer Table added to System Options and Accessories	1.3.1–1.3.5
01/03/03	2nd Edition	Added more information about air cooling – air flow sensor now standard	3.3.3
01/03/03	2nd Edition	Inserted new chapter about optional features	chapter 7
01/03/03	2nd Edition	HSD High Speed Dynamometer information added	throughout manual

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Preface

PURPOSE OF THIS MANUAL

This manual contains all the information required for the setup and general use of Magtrol's Hysteresis Dynamometers. To achieve maximum capability and ensure proper use of the dynamometer, please read this manual in its entirety before operating. Keep the manual in a safe place for quick reference whenever a question should arise.

WHO SHOULD USE THIS MANUAL

This manual is intended for those operators who are planning to use any of Magtrol's Hysteresis Dynamometers.

MANUAL ORGANIZATION

This section gives an overview of the structure of the manual and the information contained within it. Some information has been deliberately repeated in different sections of the document to minimize cross-referencing and to facilitate understanding through reiteration.

The structure of the manual is as follows:

Chapter 1: INTRODUCTION – Contains the technical data sheets for Magtrol's Hysteresis Dynamometers, which describe the units and provide detailed technical characteristics.

Chapter 2: INPUTS/OUTPUTS – Description of the elements located on the rear panel of the dynamometer.

Chapter 3: INSTALLATION/CONFIGURATION – Provides information needed for setup of the dynamometer. This includes load cell shipping/restraining bolt removal, earth ground instruction and configurations for manual, computer-controlled and air-cooled test setups.

Chapter 4: TESTING – Provides information on how to run a test along with considerations that should be taken when operating the dynamometer.

Chapter 5: OPERATING PRINCIPLES – Information pertaining to theory of operation including speed, torque, torque signal amplification, decimal point control, damper cylinder and brake control power.

Chapter 6: CALIBRATION – Provides recommended calibration schedules along with step-by-step instructions for the calibration procedure.

Chapter 7: OPTIONAL FEATURES – Provides information regarding various optional features available to enhance the capability of Magtrol's Hysteresis Dynamometers including speed encoders and analog outputs.

Chapter 8: TROUBLESHOOTING – Solutions to common problems encountered during setup and testing.

Appendix A: CALIBRATION RECORD – Data sheet for tracking calibration results.

Appendix B: SCHEMATICS – For the torque amplification board, speed sensor board, load cell and brake control power supplies.

CONVENTIONS USED IN THIS MANUAL

The following symbols and type styles may be used in this manual to highlight certain parts of the text:

Note: This is intended to draw the operator's attention to complementary information or advice relating to the subject being treated. It introduces information enabling the correct and optimal function of the product.

Caution: This is used to draw the operator's attention to information, directives, procedures, etc. which, if ignored, may result in damage to the material being used. The associated text describes the necessary precautions to take and the consequences that may arise if these precautions are ignored.

WARNING! THIS INTRODUCES DIRECTIVES, PROCEDURES, PRECAUTIONARY MEASURES, ETC. WHICH MUST BE EXECUTED OR FOLLOWED WITH THE UTMOST CARE AND ATTENTION, OTHERWISE THE PERSONAL SAFETY OF THE OPERATOR OR THIRD PARTY MAY BE AT RISK. THE READER MUST ABSOLUTELY TAKE NOTE OF THE ACCOMPANYING TEXT, AND ACT UPON IT, BEFORE PROCEEDING FURTHER.

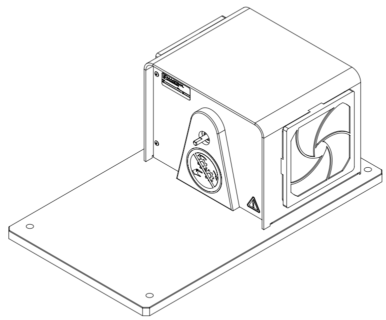
WHEN HEARING PROTECTION IS REQUIRED, THE STOP SIGN IS REPLACED WITH THE EAR MUFF SYMBOL.

1. Introduction

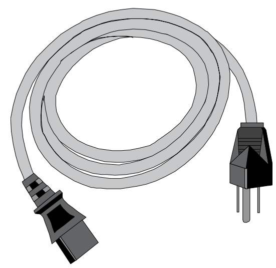
1.1 UNPACKING YOUR HYSTERESIS DYNAMOMETER

Your Hysteresis Dynamometer was packaged in reusable, shock resistant packing material that will protect the instrument during normal handling.

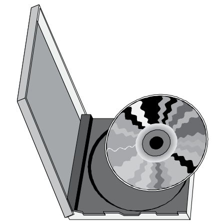
1. Make sure the carton contains the following:



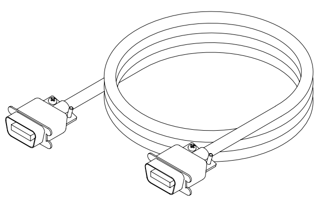
Hysteresis Dynamometer



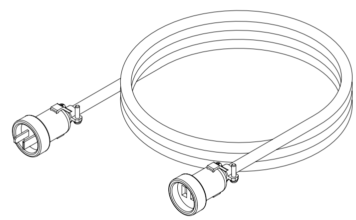
Line Cord
(not included with 700 series or HD-825)



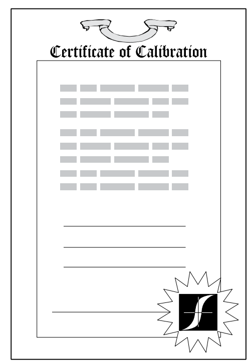
Magtrol User Manual CD-Rom



14-Pin Instrument Cable



Brake Cable



Calibration Certificate

2. Inspect the contents for any evidence of damage in shipping. In the event of shipping damage, immediately notify the carrier and Magtrol's Customer Service Department.

☞ Note: Save all shipping cartons and packaging material for reuse when returning the instrument for calibration or servicing.

3. Remove the Shipping Bolt

PLEASE TAKE NOTICE!

Before proceeding any further, you will need to remove the load cell shipping/restraining bolt if you have just unpacked a new:

HD-100	HD-500	HD-515	HD-710
HD-106	HD-505	HD-700	HD-715
HD-400	HD-510	HD-705	ED-715

This does not apply to HD-800, HD-805, HD-810, HD-815, HD-825 or ED-815 Dynamometers. For further instruction see *Section 3.1 Removal of the Load Cell Shipping/Restraining Bolt*.

☞ Note: Retain the shipping/restraining bolt for future use when moving or shipping your Magtrol Dynamometer.

1.2 FEATURES OF THE HYSTERESIS DYNAMOMETER

All Magtrol Hysteresis Dynamometers (HD and ED Series) feature the following:

- **Hysteresis Braking System:** The dynamometers do not require speed to create torque, and therefore can provide a full motor ramp from free-run to locked rotor along with precise torque loading.
- **Air Flow Sensor:** Any Magtrol Hysteresis Dynamometer that is internally ported for compressed air and/or blower cooling contains an air flow sensor that provides protection against overheating and operator error
- **Standard Torque Units:** English, metric and SI are available.
- **Easy Calibration**

Unique features of each series are listed below.

1.2.1 HD Series

Magtrol's HD Series Dynamometers are versatile and ideal for testing in low to medium power ranges. Features include:

- **Accuracy:** ±0.25% to ±0.5% full scale, depending on size and system configuration.
- **Custom Dynamometers:** For special torque and speed requirements.
- **Encoder Switch:** Optional feature that allows the user to switch between a 60 and 600-bit encoder or a 60 and 6000-bit encoder.

1.2.2 ED Series

Magtrol's ED Series Dynamometers are high performance dynamometers specifically designed to address the severe, high vibration conditions inherent in internal combustion engine testing. Features include:

- **Accuracy:** ±0.25% full scale.
- **High Speed Capabilities:** 12,000 to 25,000 rpm, depending on model.
- **Rugged Stainless Steel Shaft:** Larger shaft for additional strength.
- **Specially Reinforced Load Cell:** Stainless steel pin used at contact point to prevent premature wear from excess vibration.
- **Gusseted Pillow Blocks:** Adds additional front and rear support.
- **Brake Cooling:** Blower cooled to maximize heat dissipation.

1.3 DATA SHEET

HD Hysteresis Dynamometers
ED Engine Dynamometers

HD FEATURES

- 16 Standard Models with Maximum Torque from 2.5 oz·in to 500 lb·in (18 mN·m to 56.5 N·m)
- Hysteresis Braking System: provides precise torque loading independent of shaft speed
- Motor Testing: from no load to locked rotor
- Standard Torque Units: English, Metric and SI
- Accuracy: ±0.25% to ± 0.5% (full scale)
- Air Flow Sensor: For protection against overheating and operator error
- Base Plates: available in long or short versions
- Custom Dynamometers: for special torque and speed requirements
- Easy Calibration

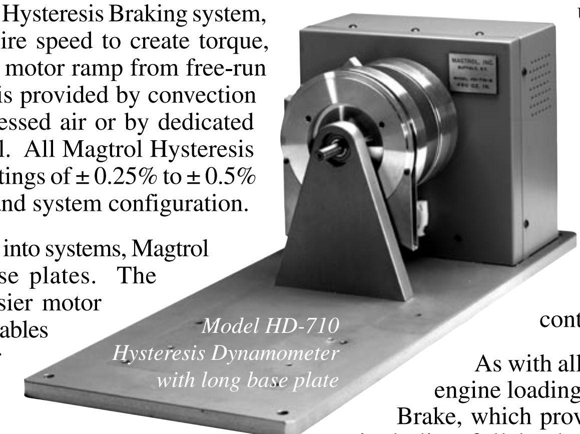
ED FEATURES

- Maximum Torque: from 55 lb·in to 250 lb·in (6.5 N·m to 28 N·m)
- Hysteresis Braking System
- Motor Testing: from no load to locked rotor
- Standard Torque Units: English, Metric & SI available
- Accuracy: ±0.25% (full scale)
- Blower Cooled: to maximize heat dissipation
- Air Flow Sensor: for protection against overheating and operator error
- Specially Reinforced Load Cell: stainless steel pin at contact point prevents premature wear from excess vibration
- Larger Shaft: for additional strength
- Gusseted Pillow Blocks: for additional front and rear support
- Easy Calibration

HD DESCRIPTION

Hysteresis Brake Dynamometers (HD Series) are versatile and ideal for testing in the low to medium power range (maximum 14 kW intermittent duty). With a Hysteresis Braking system, the Dynamometers do not require speed to create torque, and therefore can provide a full motor ramp from free-run to locked rotor. Brake cooling is provided by convection (no external source), by compressed air or by dedicated blower, depending on the model. All Magtrol Hysteresis Dynamometers have accuracy ratings of ± 0.25% to ± 0.5% full scale — depending on size and system configuration.

To better integrate dynamometers into systems, Magtrol offers both long and short base plates. The shorter base plate facilitates easier motor mounting when used with T-slot tables and Magtrol Adjustable Motor Fixtures, where as the long base plates are better suited for table top testing.



Model HD-710 Hysteresis Dynamometer with long base plate

HD APPLICATIONS

Magtrol motor test systems can be found in test labs, at inspection stations, and on the manufacturing floors of most of the world's leading manufacturers, users and certifiers of small to medium sized electric, pneumatic and hydraulic motors, as well as internal combustion engines. Magtrol supplies motor test systems for a wide array of industries including: Appliance, Automotive, Aviation, Computer, HVAC, Lawn and Garden, Medical and Dental, Electric Motor, Office Equipment and Power Tools.

ED DESCRIPTION

With Magtrol's Engine Dynamometers, high performance motor testing is available to manufacturers and users of small engines. Magtrol's Engine Dynamometers have been designed to address the severe, high vibration conditions inherent in internal combustion engine testing.

Magtrol's Engine Dynamometers are highly accurate (± 0.25% of full scale) and can be controlled either manually or via a PC based Controller. For a small engine test stand, Magtrol offers a full line of controllers, readouts and software.

As with all Magtrol Hysteresis Dynamometers, engine loading is provided by Magtrol's Hysteresis Brake, which provides: torque independent of speed, including full load at 0 rpm; excellent repeatability; frictionless torque with no wearing parts (other than bearings); and long operating life with low maintenance. Magtrol provides a NIST traceable certificate of calibration, and calibration beam with each Engine Dynamometer.

ED APPLICATIONS

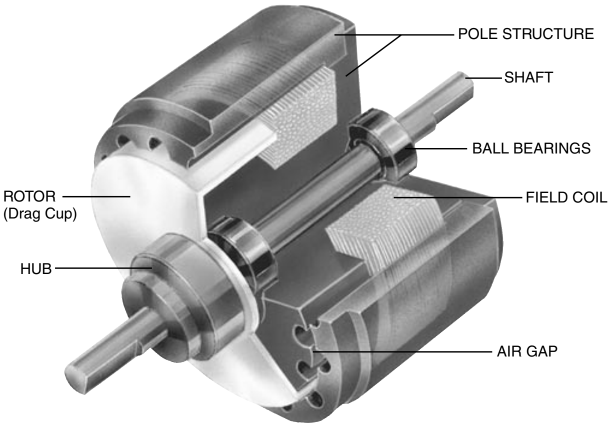
The Engine Dynamometers are ideally suited for emissions testing as set forth in CARB and EPA Clean Air Regulations. The Dynamometers will offer superior performance on the production line, at incoming inspection or in the R&D lab.

GENERAL INFORMATION

Principles and Selection

HD / ED

OPERATING PRINCIPLES



Magtrol Hysteresis Dynamometers absorb power with a unique Hysteresis Braking System which provides frictionless torque loading independent of shaft speed. The Hysteresis Brake provides torque by the use of two basic components—a reticulated pole structure and a specialty steel rotor/shaft assembly—fitted together but not in physical contact. Until the pole structure is energized, the drag cup can spin freely on its shaft bearings. When a magnetizing force from the field coil is applied to the pole structure, the air gap becomes a flux field and the rotor is magnetically restrained, providing a braking action between the pole structure and rotor.

COMPLETE PC CONTROL

Magtrol's M-TEST 5.0 Software is a state-of-the-art motor testing program for Windows®-based data acquisition. Used with a Magtrol Programmable Dynamometer Controller, Magtrol M-TEST 5.0 Software provides the control of any Magtrol Dynamometer and runs test sequences in a manner best suited to the overall accuracy and efficiency of the Magtrol Motor Test System. The data that is generated by Magtrol's Motor Testing Software can be stored, displayed and printed in tabular or graphic formats, and can be easily imported into a spreadsheet.

Written in LabVIEW™, M-TEST 5.0 has the flexibility to test a majority of motor types in a variety of ways. Because of LabVIEW's versatility, obtaining data from other sources (e.g. thermocouples), controlling motor power and providing audio/visual indicators is relatively easy.

Magtrol's M-TEST 5.0 Software is ideal for simulating loads, cycling the unit under test and motor ramping. Because it is easy to gather data and duplicate tests, the software is ideal for use in engineering labs. Tests can be programmed to run on their own and saved for future use allowing for valuable time savings in production testing and incoming/outgoing inspection.

DYNAMOMETER SELECTION

Magtrol's Hysteresis Dynamometers cover a wide range of Torque, Speed and Mechanical Power ratings. To select the appropriate size Dynamometer for your motor testing needs, you will need to determine the **Maximum Torque, Speed and Power** applied to the Dynamometer.

Maximum Torque

The Magtrol Hysteresis Absorption Dynamometer will develop braking torque at any speed point, including low speed and stall conditions ("0" rpm). It is important to consider all torque points that are to be tested, not only rated torque, but also locked rotor and breakdown torque. Dynamometer selection should initially be based on the maximum torque requirement, subject to determining the maximum power requirements.

Maximum Speed

This rating is to be considered independent of torque and power requirements, and is the maximum speed at which the Dynamometer can be safely run under free-run or lightly loaded conditions. It is not to be considered as the maximum speed at which full braking torque can be applied.

Maximum Power Ratings

These ratings represent the maximum capability of the Dynamometer Braking System to absorb and dissipate heat generated when applying a braking load to the motor under test. The power absorbed and the heat generated by the Dynamometer is a function of the Torque (T) applied to the motor under test, and the resulting Speed (n) of the motor. This is expressed in these power (P) formulas:

SI: $P\ (\text{watts}) = T\ (\text{N·m}) \times n\ (\text{rpm}) \times (1.047 \times 10^{-1})$

English: $P\ (\text{watts}) = T\ (\text{lb·in}) \times n\ (\text{rpm}) \times (1.183 \times 10^{-2})$

Metric: $P\ (\text{watts}) = T\ (\text{kg·cm}) \times n\ (\text{rpm}) \times (1.027 \times 10^{-2})$

All of Magtrol's controllers, readouts and software calculate horsepower as defined by 1 hp = 550 lb·ft / s. Using this definition:

$$hp = P\ (\text{watts}) / 745.7$$

The Dynamometer's ability to dissipate heat is a function of how long a load will be applied. For this reason, the maximum power ratings given are based on continuous operation under load, as well as a maximum of 5 minutes under load.

To safely dissipate heat and avoid Dynamometer failure, the maximum power rating is the most important consideration in selecting a Dynamometer.

Magtrol offers three types of dynamometer brakes to absorb load: Hysteresis, Eddy Current and Magnetic Powder. Each type of Dynamometer has advantages and limitations and choosing the correct one will depend largely on the type of testing to be performed. With over 50 models to choose from, Magtrol Sales professionals are readily available to assist in selecting the proper Dynamometer to meet your testing needs.

Ratings

HD / ED

Model	Torque Measure Unit Code	Maximum Torque Range	Drag Torque De-Energized at 1000 rpm	Nominal Input Inertia		Max. Power Ratings		Maximum Speed	Brake Cooling Method
						5 minute	continuous		
				lb·ft·s²	*kg·m²*	*W*	*W*	*rpm*	
HD-106	6N	2.50 oz·in	0.008 oz·in	7.04×10^{-7}	9.54×10^{-7}	35	7	30,000	Convection
	7N	180.0 g·cm	0.57 g·cm						
	8N	18.00 mN·m	0.056 mN·m						
HD-100	6N	11.00 oz·in	0.09 oz·in	3.40×10^{-6}	4.61×10^{-6}	75	20	25,000	Convection
	7N	800 g·cm	6.5 g·cm						
	8N	80.0 mN·m	0.64 mN·m						
HD-400	6N	40.0 oz·in	0.25 oz·in	1.55×10^{-5}	2.10×10^{-5}	200	55	25,000	Convection
	7N	2.80 kg·cm	0.02 kg·cm						
	8N	280 mN·m	2 mN·m						
HD-500	6N	120.0 oz·in	0.5 oz·in	8.05×10^{-5}	1.09×10^{-4}	400	80	25,000	Convection
	7N	8.50 kg·cm	0.05 kg·cm						
	8N	850 mN·m	5 mN·m						
HD-510	6N	120.0 oz·in	0.5 oz·in	8.05×10^{-5}	1.09×10^{-4}	750	375	25,000	Compressed Air* (7 CFM @ 1.75 PSI)
	7N	8.50 kg·cm	0.05 kg·cm						
	8N	850 mN·m	5 mN·m						
HD-505	6N	240 oz·in	1.0 oz·in	1.61×10^{-4}	2.18×10^{-4}	800	160	25,000	Convection
	7N	17.00 kg·cm	0.1 kg·cm						
	8N	1700 mN·m	10 mN·m						
HD-515	6N	240 oz·in	1.0 oz·in	1.61×10^{-4}	2.18×10^{-4}	1,500	900	25,000	Compressed Air* (10 CFM @ 4 PSI)
	7N	17.00 kg·cm	0.1 kg·cm						
	8N	1700 mN·m	10 mN·m						
HD-700	6N	440 oz·in	2.0 oz·in	5.51×10^{-4}	7.47×10^{-4}	700	150	25,000	Convection
	7N	31.0 kg·cm	0.14 kg·cm						
	8N	3.10 N·m	0.013 N·m						
HD-710	6N	440 oz·in	2.0 oz·in	5.51×10^{-4}	7.47×10^{-4}	1,500	935	25,000	Blower *(included)*
	7N	31.0 kg·cm	0.14 kg·cm						
	8N	3.10 N·m	0.013 N·m						
HD-705	6N	55.0 lb·in	0.2 lb·in	1.10×10^{-3}	1.49×10^{-3}	1,400	300	25,000	Convection
	7N	62.0 kg·cm	0.24 kg·cm						
	8N	6.20 N·m	0.023 N·m						
HD-715	6N	55.0 lb·in	0.2 lb·in	1.10×10^{-3}	1.49×10^{-3}	3,400	3,000	25,000	Blower *(included)*
	7N	62.0 kg·cm	0.24 kg·cm						
	8N	6.20 N·m	0.023 N·m						
HD-800	6N	125.0 lb·in	0.8 lb·in	4.43×10^{-3}	6.01×10^{-3}	2,800	1,800	12,000	Compressed Air* (7.5 CFM @ 7 PSI)
	7N	140.0 kg·cm	1.0 kg·cm						
	8N	14.00 N·m	0.10 N·m						
HD-810	6N	125.0 lb·in	0.8 lb·in	4.43×10^{-3}	6.01×10^{-3}	3,500	3,000	12,000	Blower *(included)*
	7N	140.0 kg·cm	1.0 kg·cm						
	8N	14.00 N·m	0.10 N·m						
HD-805	6N	250 lb·in	1.2 lb·in	8.81×10^{-3}	1.19×10^{-2}	5,300	3,000	12,000	Compressed Air* (15 CFM @ 7 PSI)
	7N	280 kg·cm	1.5 kg·cm						
	8N	28.0 N·m	0.14 N·m						
HD-815	6N	250 lb·in	1.2 lb·in	8.81×10^{-3}	1.19×10^{-2}	7,000	6,000	12,000	Blower *(included)*
	7N	280 kg·cm	1.5 kg·cm						
	8N	28.0 N·m	0.14 N·m						
HD-825	6N	500 lb·in	3.5 lb·in	1.85×10^{-2}	2.51×10^{-2}	14,000	12,000	8,000	Blower *(included)*
	7N	565 kg·cm	4.0 kg·cm						
	8N	56.5 N·m	0.22 N·m						

** Requires air cooling provided by user. Regulator and filter package is provided as standard equipment on these units.*

GENERAL INFORMATION

Ratings

HD / ED

Model	Torque Measure Unit Code	Maximum Torque Range	Drag Torque De-Energized at 1000 rpm	Nominal Input Inertia		Max. Power Ratings 5 minute		continuous		Maximum Speed *	Brake Cooling Method
				lb·ft·s²	*kg·m²*	*hp*	*W*	*hp*	*W*	*rpm*	
ED-715	6N	55.0 lb·in	0.3 lb·in	1.27×10^{-3}	1.72×10^{-3}	5	3400	4	3000	25,000	Blower *(included)*
	7N	62.0 kg·cm	0.36 kg·cm								
	8N	6.20 N·m	0.035 N·m								
ED-815	6N	250 lb·in	1.2 lb·in	9.61×10^{-3}	1.30×10^{-2}	10	7000	8	6000	12,000	Blower *(included)*
	7N	280 kg·cm	1.4 kg·cm								
	8N	28.0 N·m	0.14 N·m								

** The maximum speed will depend on what type of keyway (if any) is used on the shaft. Unless specified, the dynamometer shaft will be made without a keyway.*

ELECTRICAL POWER AND FUSES

Model	Voltage	VA	Style	Rating
HD-1XX-XN	120 V	30	UL/CSA	300 mA 250 V SB
HD-1XX-XNA	240 V	30	IEC	125 mA 250 V T
HD-4XX-XN	120 V	30	UL/CSA	300 mA 250 V SB
HD-4XX-XNA	240 V	30	IEC	125 mA 250 V T
HD-5XX-XN	120 V	30	UL/CSA	300 mA 250 V SB
HD-5XX-XNA	240 V	30	IEC	125 mA 250 V T
HD-800-XN	120 V	65	UL/CSA	800 mA 250 V SB
HD-800-XNA	240 V	65	IEC	315 mA 250 V T
HD-810-XN	120 V	65	UL/CSA	800 mA 250 V SB
HD-810-XNA	240 V	65	IEC	315 mA 250 V T
HD-805-XN	120 V	130	UL/CSA	1.25 A 250 V SB
HD-805-XNA	240 V	130	IEC	630 mA 250 V T
HD/ED-815-XN	120 V	130	UL/CSA	1.25 A 250 V SB
HD/ED-815-XNA	240 V	130	IEC	630 mA 250 V T
HD-825-XN	120 V	N/A	N/A	N/A
HD-825-XNA	240 V	N/A	N/A	N/A

BLOWER POWER AND FUSES

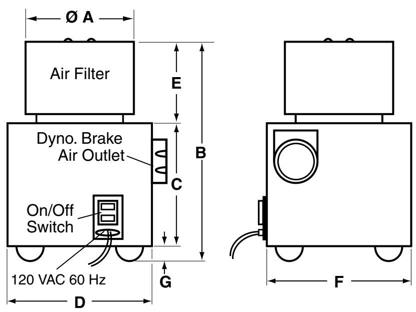
- Models HD-710, HD-715, HD-810 and ED-715 include the BL-001 blower.
- Models HD-815 and ED-815 include the BL-002 blower.
- Model HD-825 uses two BL-002 blowers for cooling its two brake sets.

Model	Voltage	VA	Style	Rating
BL-001	120 V	600	UL/CSA	6.3 A 250 V SB
BL-001A	240 V	500	IEC	3.15 A 250 V T
BL-002	120 V	1000	UL/CSA	15 A 250 V SB
BL-002A	240 V	1000	IEC	6.3 A 250 V T

BLOWER DIMENSIONS

Allow approximately 6 in to 8 in (152 mm to 203 mm) between rear of dynamometer base plate and blower for connection hardware. Required hardware is supplied with the dynamometer.

BL-002 Blower has two filter elements.



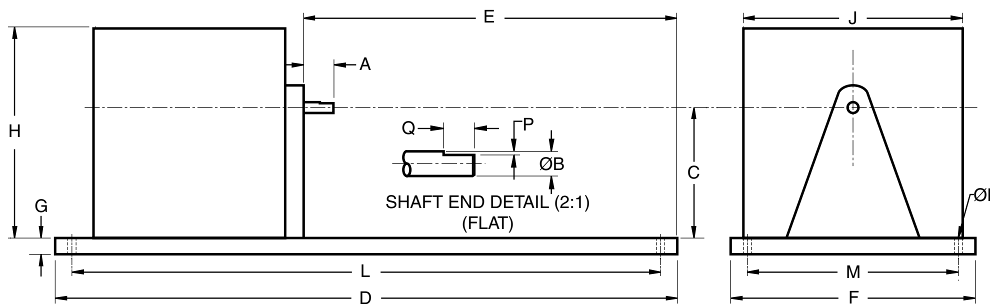
Model	BL-001		BL-002	
	in	*mm*	*in*	*mm*
Ø A	6	152	6	152
B	11	279	11	279
C	6	152	6	152
D	8	203	15	381
E	4	102	4	102
F	8	203	12	305
G	1	25	1	25
Weight	8.5 lb	3.9 kg	18 lb	8.1 kg

GENERAL INFORMATION

Dimensions HD / ED

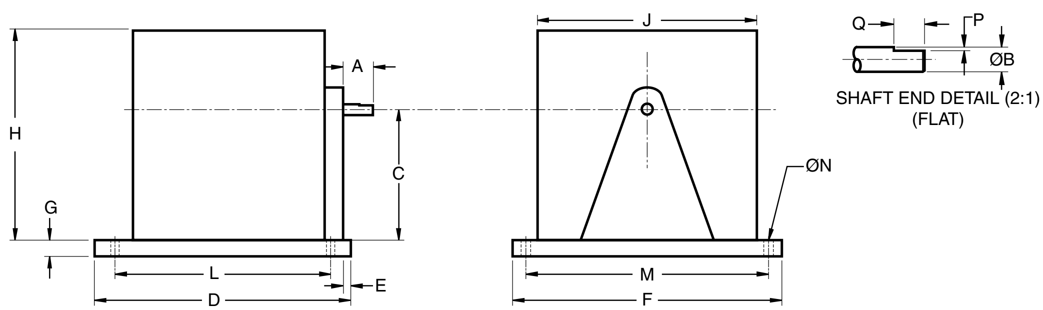
NOTE: Original dimensions are in English units. Dimensions converted to Metric units have been rounded and are for reference only.

HD-100/400/500 SERIES WITH LONG BASE PLATE



Model	units	A	Ø B	C	D	E	F	G	H	J	L*	M*	Ø N	P	Q	Weight
HD-106	in	0.50	0.1245/0.1247	3.5	17	9.38	10	0.5	6.3	8.5	15.5	8.5	0.37	0.015	0.375	12.0 lb
	mm	12.7	3.162/3.167	89	432	238.3	254	13	159	216	394	216	9.4	0.38	9.53	5.4 kg
HD-100	in	0.75	0.1870/0.1875	3.5	17	9.13	10	0.5	6.3	8.5	15.5	8.5	0.37	0.025	0.375	12.5 lb
	mm	19.1	4.750/4.763	89	432	231.9	254	13	159	216	394	216	9.4	0.64	9.53	5.7 kg
HD-400	in	0.67	0.2495/0.2497	3.5	17	9.13	10	0.5	6.3	8.5	15.5	8.5	0.37	0.03	0.438	15.0 lb
	mm	17.0	6.337/6.342	89	432	231.9	254	13	159	216	394	216	9.4	0.76	11.13	6.8 kg
HD-500	in	0.88	0.3745/0.3750	4.0	17	9.13	10	0.5	6.3	8.5	15.5	8.5	0.37	0.047	0.375	16.0 lb
	mm	22.2	9.512/9.525	102	432	231.9	254	13	159	216	394	216	9.4	1.19	9.53	7.3 kg
HD-510	in	0.88	0.3745/0.3750	4.0	17	9.13	10	0.5	6.3	8.5	15.5	8.5	0.37	N/A		16.0 lb
	mm	22.2	9.512/9.525	102	432	231.9	254	13	159	216	394	216	9.4			7.3 kg
HD-505	in	0.88	0.3745/0.3750	4.0	20	9.64	10	0.5	6.3	8.5	18.5	8.5	0.37	0.05	0.375	18.0 lb
	mm	22.2	9.512/9.525	102	508	244.9	254	13	159	216	470	216	9.4	1.27	9.53	8.1 kg
HD-515	in	0.88	0.3745/0.3750	4.0	20	9.64	10	0.5	6.3	8.5	18.5	8.5	0.37	N/A		18.0 lb
	mm	22.2	9.512/9.525	102	508	244.9	254	13	159	216	470	216	9.4			8.1 kg

HD-100/400/500 SERIES WITH SHORT BASE PLATE

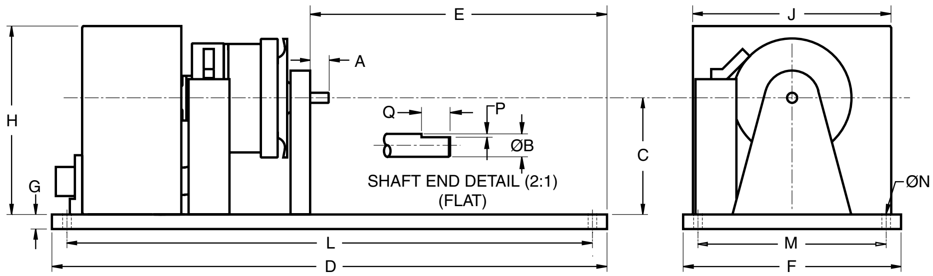


Model	units	A	Ø B	C	D	E	F	G	H	J	L*	M*	Ø N	P	Q	Weight
HD-106	in	0.50	0.1245/0.1247	3.5	7.0	0.33	11	0.5	6.3	8.5	6.0	9.84	0.35	0.015	0.375	7.5 lb
	mm	12.7	3.162/3.167	89	177.8	8.4	279.4	13	159	216	152.4	250	9	0.38	9.53	3.4 kg
HD-100	in	0.75	0.1870/0.1875	3.5	7.0	0.08	11	0.5	6.3	8.5	6.0	9.84	0.35	0.025	0.375	8.0 lb
	mm	19.1	4.750/4.763	89	177.8	2.1	279.4	13	159	216	152.4	250	9	0.64	9.53	3.6 kg
HD-400	in	0.67	0.2495/0.2497	3.5	7.0	0.08	11	0.5	6.3	8.5	6.0	9.84	0.35	0.03	0.438	11.0 lb
	mm	17.0	6.337/6.342	89	177.8	2.1	279.4	13	159	216	152.4	250	9	0.76	11.13	5.0 kg
HD-500	in	0.88	0.3745/0.3750	4.0	7.0	0.08	11	0.5	6.3	8.5	6.0	9.84	0.35	0.047	0.375	12.0 lb
	mm	22.2	9.512/9.525	102	177.8	2.1	279.4	13	159	216	152.4	250	9	1.19	9.53	5.4 kg
HD-510	in	0.88	0.3745/0.3750	4.0	8.0	0.13	11	0.5	6.3	8.5	7.0	9.84	0.35	N/A		12.5 lb
	mm	22.2	9.512/9.525	102	203.2	3.2	279.4	13	159	216	177.8	250	9			5.7 kg
HD-505	in	0.88	0.3745/0.3750	4.0	9.5	0.10	11	0.5	6.3	8.5	8.5	9.84	0.35	0.05	0.375	13.0 lb
	mm	22.2	9.512/9.525	102	241.3	2.6	279.4	13	159	216	215.9	250	9	1.27	9.53	5.9 kg
HD-515	in	0.88	0.3745/0.3750	4.0	9.5	0.10	11	0.5	6.3	8.5	8.5	9.84	0.35	N/A		13.0 lb
	mm	22.2	9.512/9.525	102	241.3	2.6	279.4	13	159	216	215.9	250	9			5.9 kg

** These dimensions represent the distance between mounting holes. There are four (4) mounting holes on each base plate.*

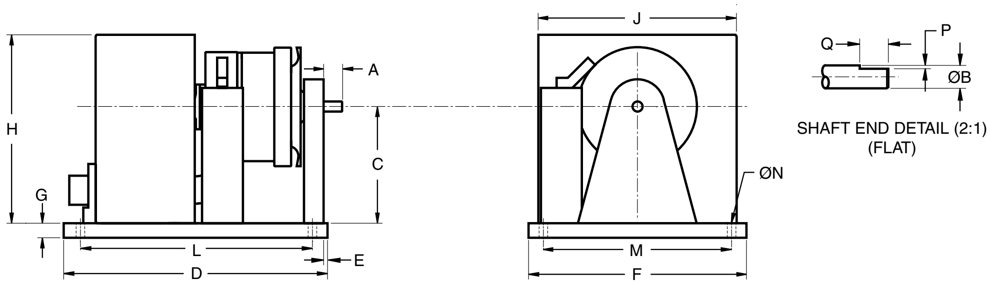
Dimensions HD / ED

HD-700 SERIES WITH LONG BASE PLATE



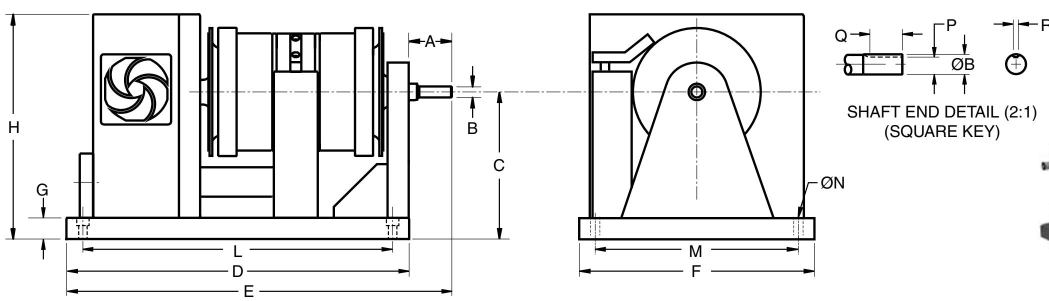
Model	units	A	Ø B	C	D	E	F	G	H	J	L*	M*	Ø N	P	Q	Weight
HD-700	*in*	1.25	0.4995/0.4997	5.875	24	12.75	11	0.625	9.5	10	22.5	9.5	0.375	0.06	0.63	39 lb
	mm	31.8	12.687/12.692	149.2	609.6	323.9	279.4	15.9	241.3	254	571.5	241.3	9.5	1.6	15.9	17.63 kg
HD-710	*in*	1.25	0.4995/0.4999	5.875	26	13.59	11	0.625	9.5	10	24.5	9.5	0.375	N/A		45 lb
	mm	31.8	12.687/12.697	149.2	660.4	345.2	279.4	15.9	241.3	254	622.3	241.3	9.5			20.30 kg
HD-705	*in*	1.25	0.4995/0.4997	5.875	28	13.62	11	0.625	9.5	10	26.5	9.5	0.375	0.06	0.63	52 lb
	mm	31.8	12.687/12.692	149.2	711.2	346.0	279.4	15.9	241.3	254	673.1	241.3	9.5	1.6	15.9	23.50 kg
HD-715	*in*	1.25	0.4995/0.4999	5.875	30	14.29	11	0.625	9.5	10	28.5	9.5	0.375	N/A		59 lb
	mm	31.8	12.687/12.697	149.2	762.0	363.0	279.4	15.9	241.3	254	723.9	241.3	9.5			26.60 kg

HD-700 SERIES WITH SHORT BASE PLATE



Model	units	A	Ø B	C	D	E	F	G	H	J	L*	M*	Ø N	P	Q	Weight
HD-700	*in*	1.25	0.4995/0.4997	5.875	11.34	0.09	11	0.625	9.5	10	9.84	9.84	0.35	0.06	0.63	30 lb
	mm	31.8	12.687/12.692	149.2	288.0	2.2	279.4	15.9	241.3	254	250.0	250	9	1.6	15.9	13.6 kg
HD-710	*in*	1.25	0.4995/0.4999	5.875	12.50	0.09	11	0.625	9.5	10	11.00	9.84	0.35	N/A		36 lb
	mm	31.8	12.687/12.697	149.2	317.5	2.3	279.4	15.9	241.3	254	279.5	250	9			16.3 kg
HD-705	*in*	1.25	0.4995/0.4997	5.875	14.45	0.07	11	0.625	9.5	10	12.95	9.84	0.35	0.06	0.63	43 lb
	mm	31.8	12.687/12.692	149.2	367.0	1.8	279.4	15.9	241.3	254	329.0	250	9	1.6	15.9	19.5 kg
HD-715	*in*	1.25	0.4995/0.4999	5.875	15.75	0.04	11	0.625	9.5	10	14.25	9.84	0.35	N/A		50 lb
	mm	31.8	12.687/12.697	149.2	400.0	1.1	279.4	15.9	241.3	254	362.0	250	9			22.7 kg

ED-SERIES ENGINE DYNAMOMETERS

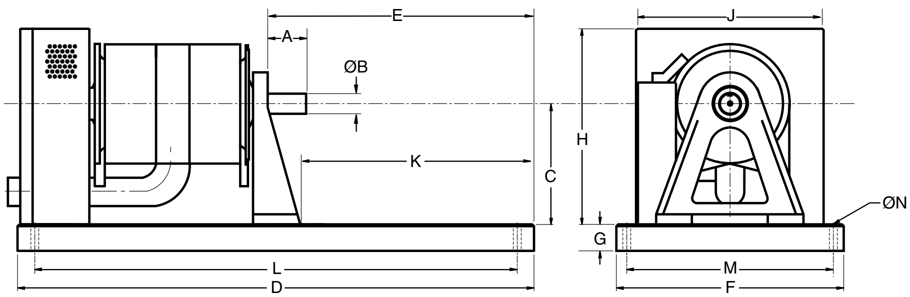


Model	units	A	Ø B	C	D	E	F	G	H	L*	M*	Ø N	P	Q	R	Weight
ED-715	*in*	1.72	0.7490/0.7495	6.87	16.00	18.13	11.00	1.00	10.50	14.50	9.50	0.37	0.64	1.00	0.187	75 lb
	mm	43.7	19.025/19.037	174.5	406.4	460.5	279.4	25.4	266.7	368.3	241.3	9.4	16.35	25.4	4.83	34 kg
ED-815	*in*	3.02	1.4995/1.5000	11.00	23.00	23.27	17.00	2.00	16.63	20.80	15.00	5/8-11	1.287	2.00	0.375	285 lb
	mm	76.7	38.087/38.100	279.4	584.2	591.1	431.8	50.8	422.4	528.3	381.0	THD	32.7	50.8	9.53	129.3 kg

* *These dimensions represent the distance between mounting holes. There are four (4) mounting holes on each base plate.*

Dimensions HD / ED

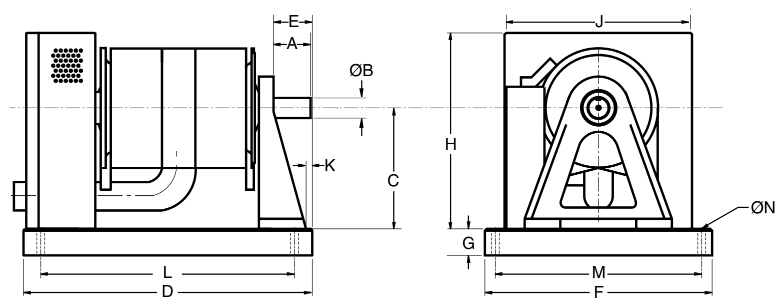
HD-800 SERIES WITH LONG BASE PLATE



NOTE: For detailed dimension drawings of dynamometers with the T-slot base plate option, visit Magtrol's Web site.

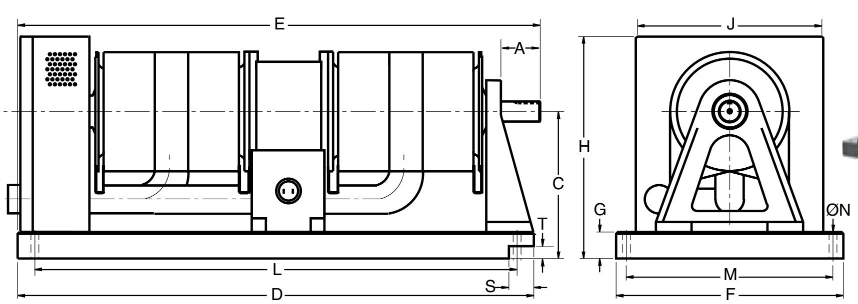
Model	units	A	Ø B	C	D	E	F	G	H	J	K	L*	M*	Ø N	Weight
HD-800	in	2.13	0.9995/1.0000	9	38.5	23.81	17	2	14.6	14	21.4	36.5	15	0.54	237.0 lb
	mm	54	25.387/25.400	229	978	605	432	51	371	356	544	927	381	13.7	107.2 kg
HD-810	in	2.09	0.9995/1.0000	9	38.5	23.19	17	2	14.6	14	20.7	36.5	15	0.54	233.0 lb
	mm	53	25.387/25.400	229	978	589	432	51	371	356	526	927	381	13.7	105.3 kg
HD-805	in	2.13	0.9995/1.0000	9	38.5	20.57	17	2	14.6	14	18.2	36.5	15	0.54	287.0 lb
	mm	54	25.387/25.400	229	978	522	432	51	371	356	462	927	381	13.7	129.7 kg
HD-815	in	2.25	0.9995/1.0000	9	38.5	18.19	17	2	14.6	14	15.7	36.5	15	0.54	288.0 lb
	mm	57	25.387/25.400	229	978	462	432	51	371	356	399	927	381	13.7	130.1 kg

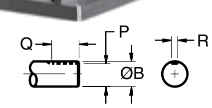
HD-800 SERIES WITH SHORT BASE PLATE



Model	units	A	Ø B	C	D	E	F	G	H	J	K	L*	M*	Ø N	Weight
HD-800	in	2.13	0.9995/1.0000	9	17.25	2.56	17	2	14.6	14	0.1	13.78	15.75	0.35	168.0 lb
	mm	54	25.387/25.400	229	438	65	432	51	371	356	2.5	350	400	9	76.2 kg
HD-810	in	2.09	0.9995/1.0000	9	18.00	2.59	17	2	14.6	14	0.1	14.06	15.75	0.35	164.0 lb
	mm	53	25.387/25.400	229	457	66	432	51	371	356	2.5	357	400	9	74.4 kg
HD-805	in	2.13	0.9995/1.0000	9	20.50	2.57	17	2	14.6	14	0.1	15.75	15.75	0.35	228.0 lb
	mm	54	25.387/25.400	229	520	65	432	51	371	356	2.5	400	400	9	103.4 kg
HD-815	in	2.12	0.9995/1.0000	9	23.00	2.59	17	2	14.6	14	0.2	19.09	15.75	0.35	236.0 lb
	mm	54	25.387/25.400	229	584	66	432	51	371	356	5.1	485	400	9	107.0 kg

An HD-825 Dynamometer with long base plate is available if ordered with the accompanying dynamometer table (TAB 0825L). Contact Magtrol for details.





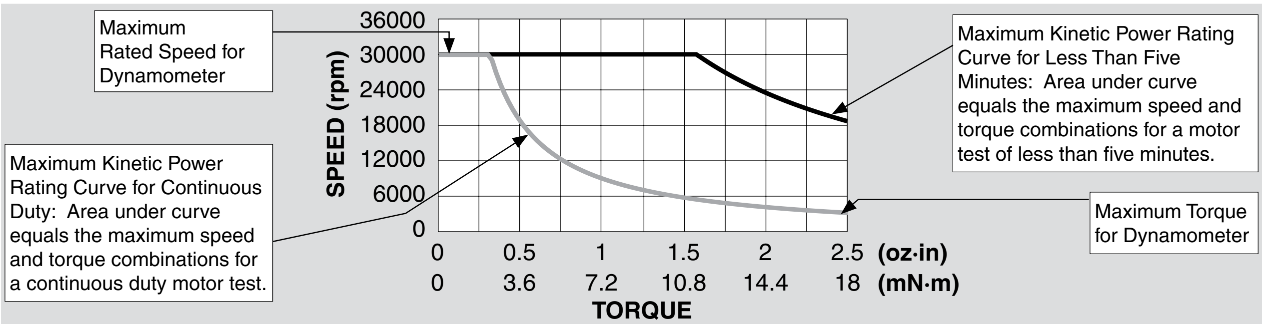
SHAFT END DETAIL (2:1)
(SQUARE KEY)

Model	units	A	Ø B	C	D	E	F	G	H	J	L*	M*	Ø N	P	Q	R	S	T	Weight
HD-825	in	2.83	1.4995/1.5000	11	38.5	38.93	17	2	16.6	14	36.5	15	0.54	1.287	2	0.376	2	1	400.0 lb
	mm	72	38.087/38.100	279	978	989	432	51	422	356	927	381	13.7	32.69	50.8	9.53	50.8	25.4	181.4 kg

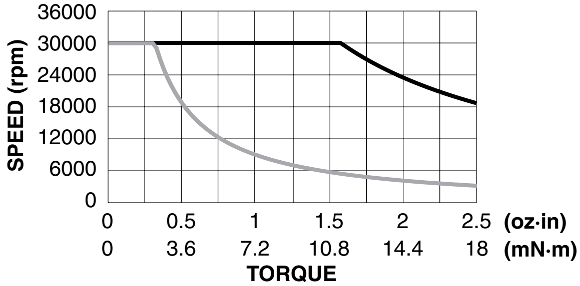
* *These dimensions represent the distance between mounting holes. There are four (4) mounting holes on each base plate.*

Power Absorption Curves

HD / ED

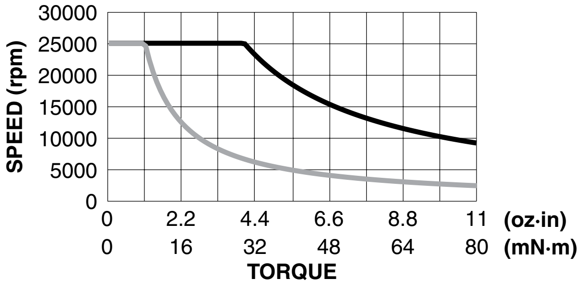


HD-106

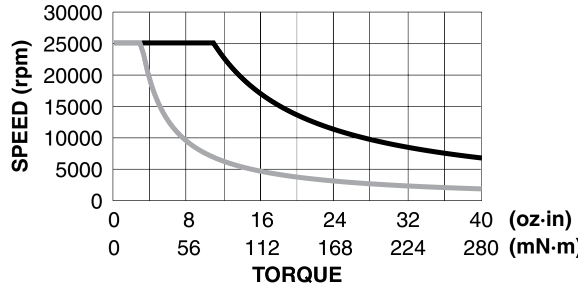


The power absorption curves represent the maximum power (heat) that the dynamometer can dissipate over time.

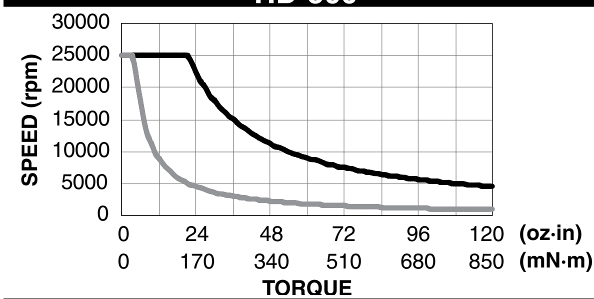
HD-100



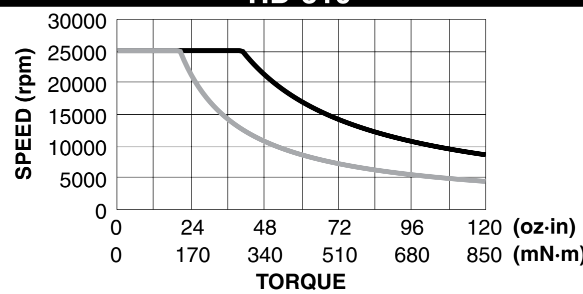
HD-400



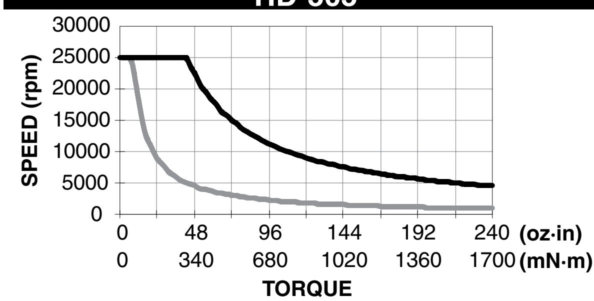
HD-500



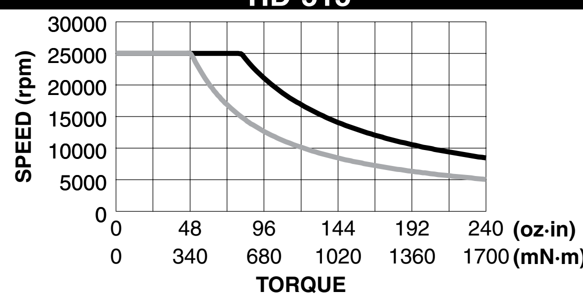
HD-510



HD-505

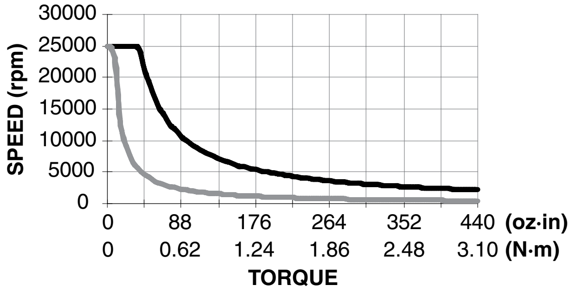


HD-515

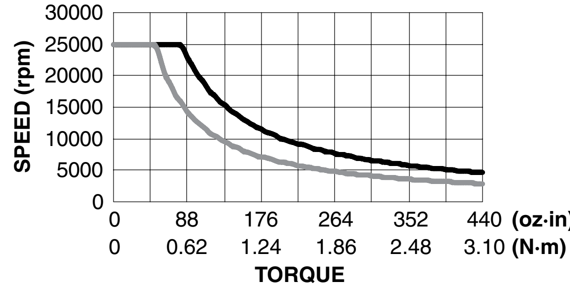


Power Absorption Curves HD / ED

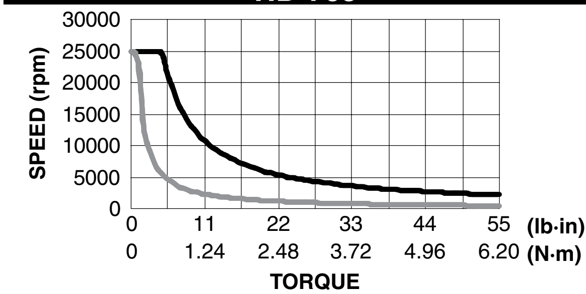
HD-700



HD-710

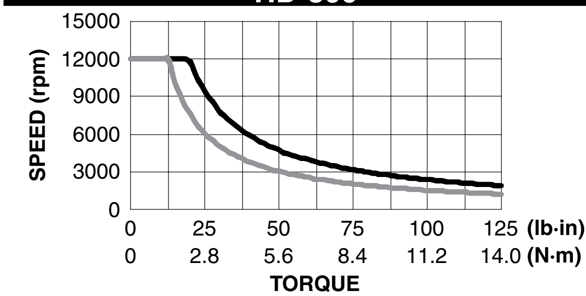


HD-705

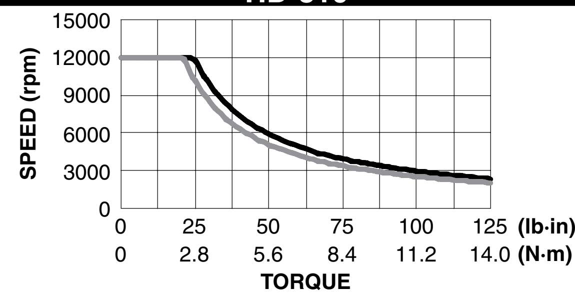


HD-715 and ED-715

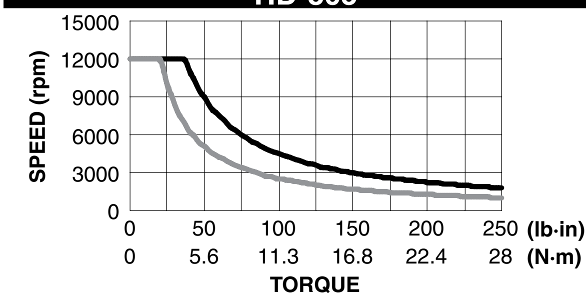
HD-800



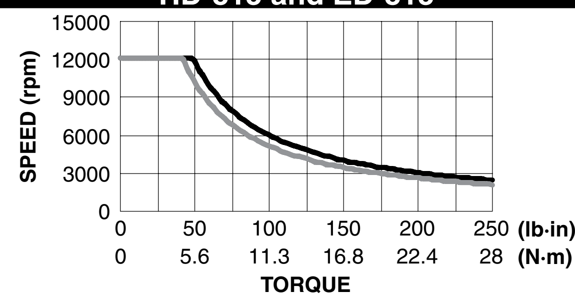
HD-810



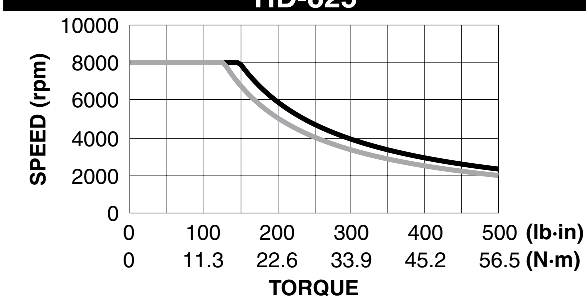
HD-805



HD-815 and ED-815



HD-825



The power absorption curves represent the maximum power (heat) that the dynamometer can dissipate over time.

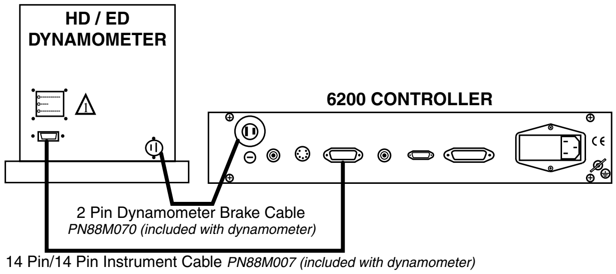
GENERAL INFORMATION

System Configurations HD / ED

OPEN LOOP SYSTEMS

Magtrol offers both open loop manual test systems and PC-based closed loop test systems. A typical open loop system will consist of a Dynamometer and a Magtrol 6200 Open-Loop Controller. A Magtrol Single or Three-Phase Power Analyzer, which allows for the capturing of volts, amps, watts and power factor, can be included as an option. An open loop system is often used for quick pass/fail testing on the production line or at incoming inspection. Magtrol's 6200 Controller provides pass/fail testing as a standard feature.

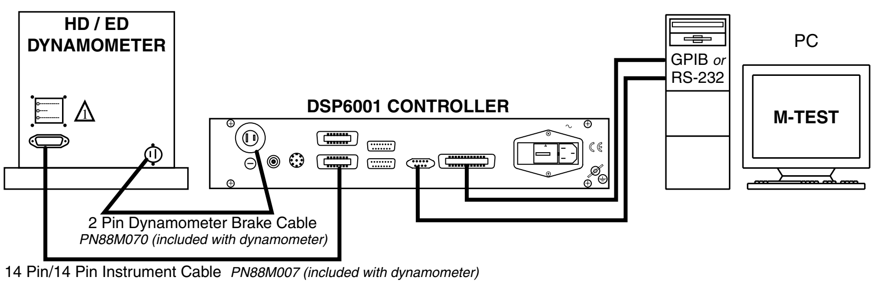
Dynamometer with 6200 Controller



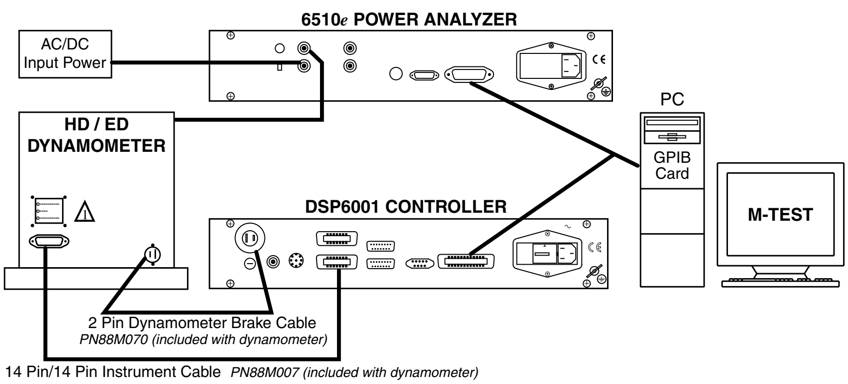
CLOSED LOOP SYSTEMS

In a closed loop motor test system, data is collected on a PC using Magtrol's M-TEST Software, DSP6001 Programmable Dynamometer Controller, and requisite interface cards and cables. Magtrol's Model 6200 and DSP6001 Controllers compute and display mechanical power (in horsepower or watts) in addition to torque and speed. A Single or Three Phase Power Analyzer, a required component in a test system measuring motor efficiency, can be integrated into this system as well as Magtrol's Temperature Testing Hardware.

Dynamometer with DSP6001 Controller and M-TEST Software



Dynamometer with 6510*e* Power Analyzer, DSP6001 Controller and M-TEST Software

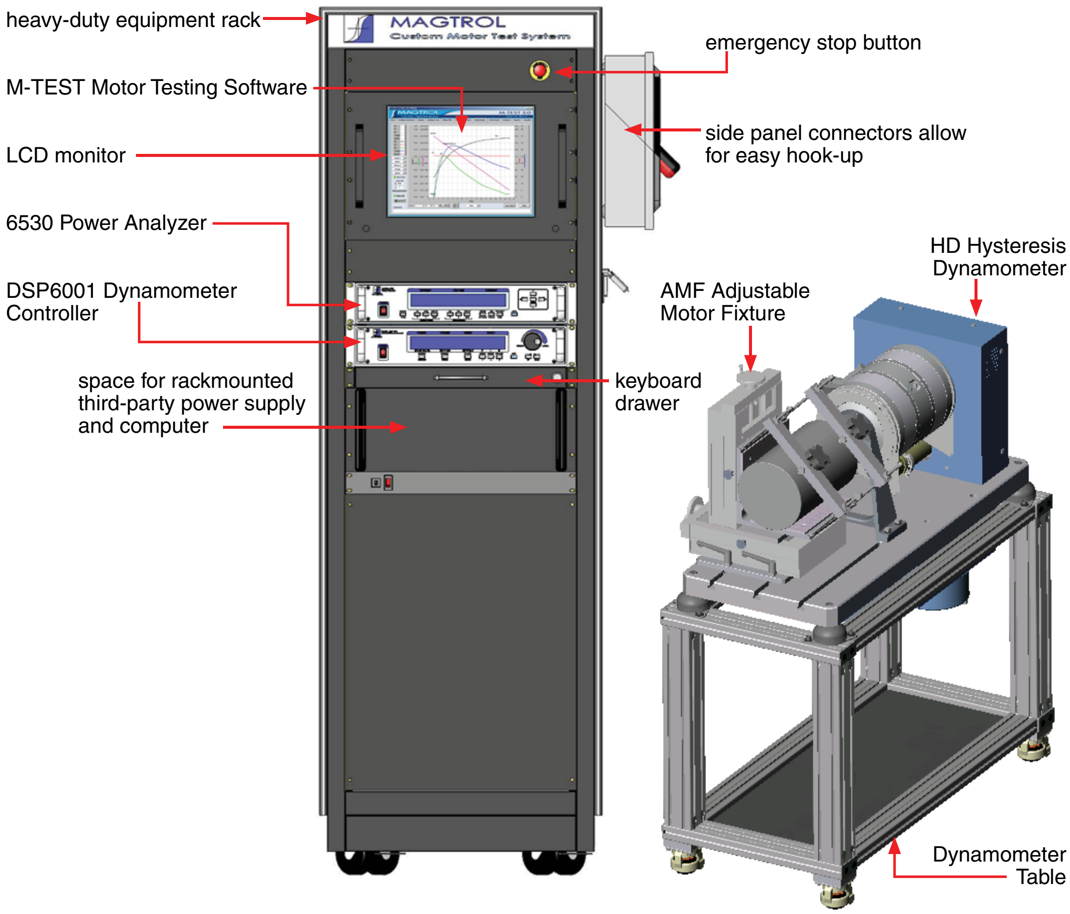


System Configurations

HD / ED

CUSTOM MOTOR TEST SYSTEM

HD Series Hysteresis Dynamometers can be incorporated into a Customized Motor Test System. These PC based, turn-key systems are custom designed and built to meet specific user requirements.



Ordering Information

HD / ED

DYNAMOMETER OPTIONS

Encoder Options For Low Speed Testing

For low speed motors, such as gear motors with maximum speeds of less than 200 rpm, Magtrol offers additional encoder options that allow for increased resolution of the speed signal.

T-Slot Base Plate

To accommodate Magtrol AMF-3 Adjustable Motor Fixtures, a grooved base plate with three M12 T-slots, one centered and two 250 mm apart, is available on all HD-800 series dynamometers.

CUSTOM DYNAMOMETERS

High Speed Testing

For certain models, Magtrol can provide Dynamometers which can operate at higher than rated speeds.

Mechanical Modifications

Magtrol can provide customized base plates, riser blocks and shaft modifications.

ORDERING INFORMATION

MODEL NUMBER: □**D** – □□□ – □**N**□ – 0 □□□

DYNAMOMETER TYPE
- Hysteresis — HD 100 – 825
- Engine — ED 715 – 815

TORQUE UNITS
- English (U.S.) — 6N
- Metric — 7N
- SI — 8N

POWER OPERATION
- 120 VAC (standard) — *(blank)*
- 240 VAC (option) — A

BASE PLATE
- long — 0
- short — 1
- long with T-slots (available on HD-800 series only) 2
- ED dynamometers — 0

SPEED ENCODER
- 60 bit (standard) — 00
- 60 and 600 bit — 30
- 60 and 6000 bit — 40

SYSTEM OPTIONS AND ACCESSORIES

CATEGORY	DESCRIPTION	MODEL / PART #
CONTROLLERS	High-Speed Programmable Dynamometer Controller	DSP6001
	Open Loop Dynamometer Controller	6200
POWER ANALYZERS	High-Speed Single-Phase Power Analyzer	6510*e*
	High-Speed Three-Phase Power Analyzer	6530
SOFTWARE	M-TEST 5.0 Motor Testing Software	SW-M-TEST5.0-WE
	Temperature Testing Hardware	HW-TTEST
POWER SUPPLIES	Closed Loop Speed Control/Power Supply	6100
	Power Amplifier – *required for all HD-825 dynamometers*	5241
MISC. ELECTRONICS	Manually Controlled Switch Box	5500
	Direction Indicator	5600
DYNAMOMETER TABLES	Table (with grooved table top) for HD-100/400/500/700 series short base plate dynamometers and ED-715*	TAB 1457S
	Table (drilled and tapped) for HD-100/400/500/700 series long base plate dynamometers	TAB 1457L
	Table for HD-800 series long base plate dynamometers and ED-815* (base of dynamometer also serves as the table top)	TAB 0800L
	Table for HD-825 long base plate dynamometers	TAB 0825L
ADJUSTABLE MOTOR FIXTURES	Motor Fixture for HD-100/400/500 series short base plate dynamometers	AMF-1
	Motor Fixture for HD-700 series short base plate dynamometers	AMF-2
	Motor Fixture for HD-800 series dynamometers with T-slot base plate option	AMF-3
CALIBRATION	Calibration Beam Assemblies and Calibration Weights	CB and WT Series

* *Mounting of ED Engine Dynamometers to dynamometer tables requires certain modifications. Contact Magtrol for details.*

Due to the continual development of our products, we reserve the right to modify specifications without forewarning.

2. Inputs/Outputs

2.1 REAR PANEL

The rear panel provides connectors and receptacles for connecting to appropriate equipment.

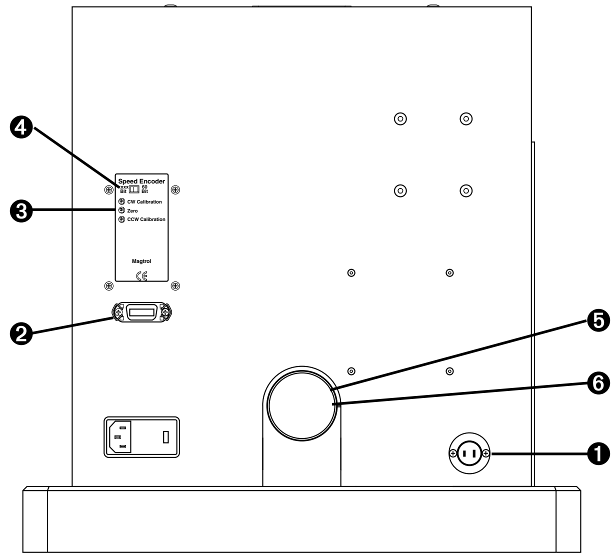


Figure 2–1 Rear Panel

2.2 REAR PANEL INPUTS AND OUTPUTS

❶	DYNAMOMETER BRAKE INPUT	Connect dynamometer brake cable here.

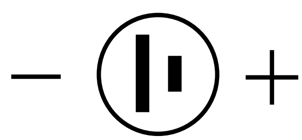
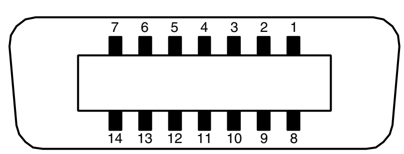


Figure 2–2 Dynamometer Brake Input

❷	DYNAMOMETER CONNECTOR	Connect dynamometer signal cable here.



1. FLOW/CLUTCH	8. +5.0 VDC COM
2. TACH. B	9. D.P. A
3. +24 VDC	10. TACH. A
4. +24 VDC COM	11. INDEX
5. -24 VDC COM	12. D.P. B
6. -24 VDC	13. TORQUE COMMON
7. +5.0 VDC	14. TORQUE SIGNAL

Figure 2–3 Dynamometer Connector

❸ CALIBRATION POTENTIOMETER

Adjust clockwise (CW), zero and counterclockwise (CCW) calibration here. See *Chapter 6 – Calibration*.

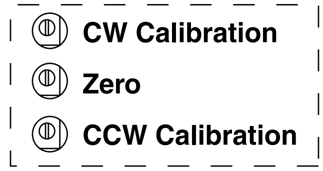


Figure 2–4 Calibration Potentiometers

❹ ENCODER SWITCH

Optional feature switches between a 60 and 600-bit encoder or a 60 and 6000-bit encoder.

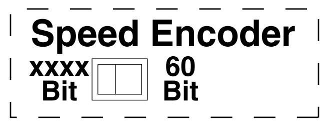


Figure 2–5 Speed Encoder Switch

❺ BLOWER INPUT

Connect blower tube here. For HD-710, HD-715, HD-810, HD-815, HD-825, ED-715 and ED-815 Dynamometers only.

WARNING! DUE TO THE NOISE LEVELS OF THE BLOWERS, HEARING PROTECTION MUST BE WORN DURING OPERATION.

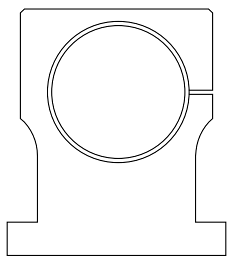


Figure 2–6 Blower Input

❻ COMPRESSED AIR INPUT

Connect compressed shop air line here. For HD-510, HD-515, HD-800 and HD-805 Dynamometers only.

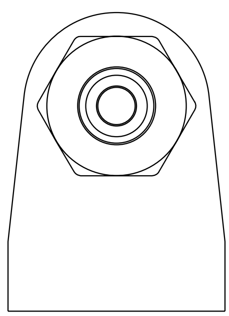


Figure 2–7 Compressed Air Input

3. Installation/Configuration

3.1 REMOVAL OF THE LOAD CELL SHIPPING/RESTRAINING BOLT

Within the dynamometer enclosure there is a load cell shipping/restraining bolt that must be removed before dynamometer operation. The bolts are identified with red heads. Refer to the diagrams below for the bolt location on your model.

☞ Note: Retain the shipping/restraining bolt for future use when moving or shipping your Magtrol Dynamometer.

SETUP

3.1.1 HD-100, -400 and -500 Series

The shipping/restraining bolt is located on the bottom of the HD 100-500 Series Hysteresis Dynamometers as shown in Figure 3–1.

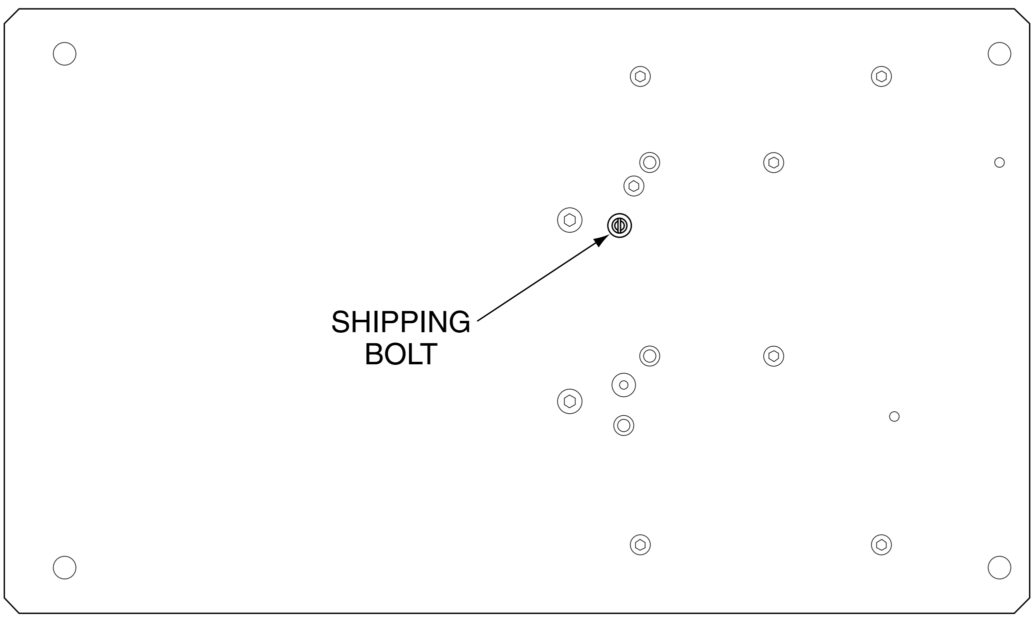


Figure 3–1 HD 100–500 Series Shipping/Restraining Bolt Location

3.1.2 HD-700 Series

The shipping/restraining bolt is located on the front side of the HD-700 Series Hysteresis Dynamometers as shown in Figure 3–2.

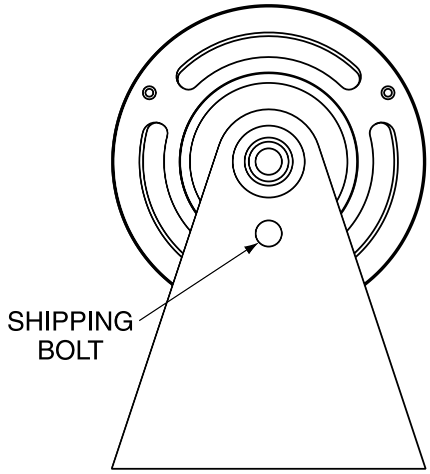


Figure 3–2 HD-700 Series Shipping/Restraining Bolt Location

3.1.3 HD-800 Series

There is no shipping/restraining bolt on an HD-800 Series Hysteresis Dynamometer.

3.1.4 ED-715

The shipping/restraining bolt is located on the front side of the ED-715 dynamometer as shown in Figure 3–3.

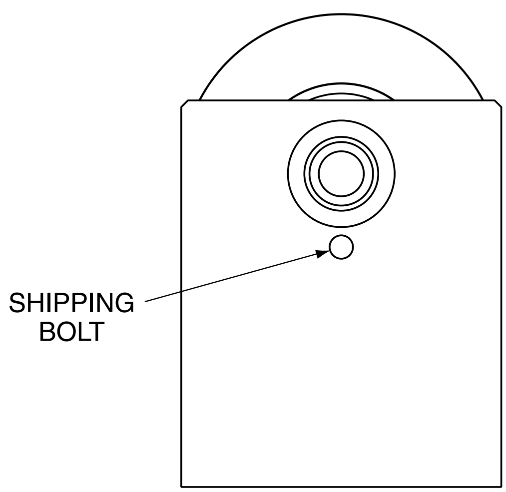


Figure 3–3 ED-715 Shipping/Restraining Bolt Location

3.1.5 ED-815

There is no shipping/restraining bolt on an ED-815 dynamometer.

SETUP

3.2 EARTH GROUND

Before proceeding any further, the dynamometer must be connected to earth ground. The earth ground is located on the top of the dynamometer as indicated in the following diagrams by the earth ground symbol.

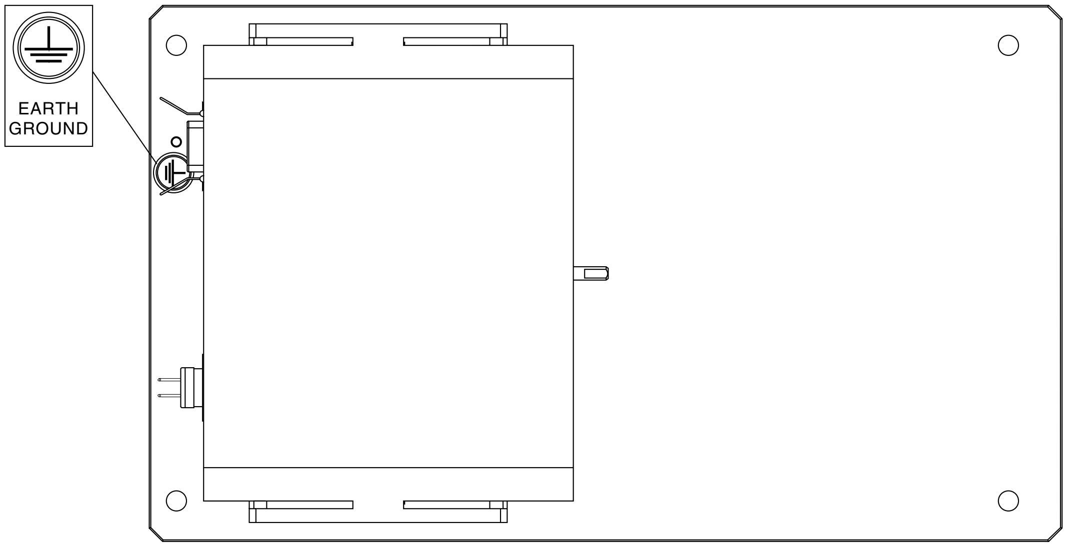


Figure 3–4 HD 100–500 Series Top View

The following diagram is to be referenced for all HD-700, -800 series and ED dynamometers.

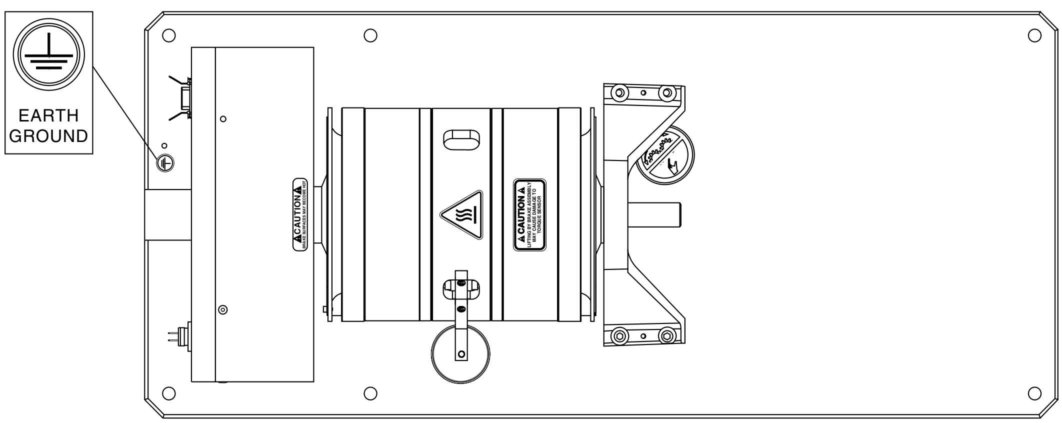


Figure 3–5 HD-800 Series Top View

3.3 SYSTEM CONFIGURATIONS

After the load cell shipping/restraining bolt has been removed and the dynamometer has been earth grounded, the unit is ready for connection to the appropriate readout instrument and power supply.

3.3.1 Manual Test Systems

The dynamometer can be set up as a manual test system for quick pass/fail testing on the production line or at incoming inspection. A typical manual test system will consist of a Magtrol Hysteresis Dynamometer used in conjunction with a Magtrol 6200 Open-Loop Controller.

SETUP

☞ Note: Magtrol's Single or Three-Phase Power Analyzer may be included as an option.

The following diagram illustrates the required cable sets and connections for a manual test system setup.

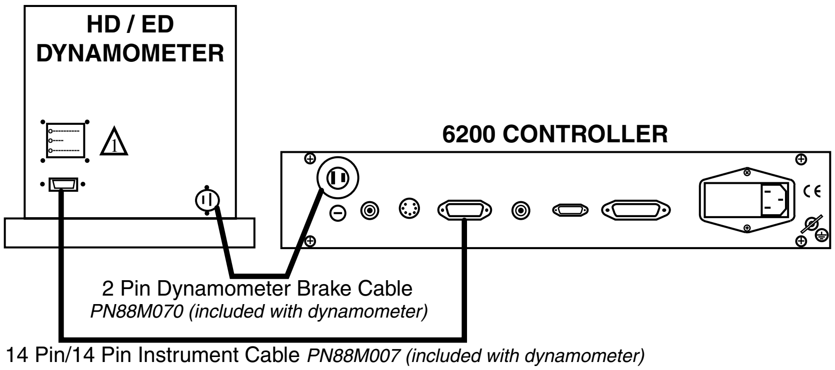


Figure 3–6 Dynamometer with 6200 Controller

3.3.2 PC-Based Test Systems

In a PC-based motor test system, data is collected on a personal computer using Magtrol's M-TEST Software, a DSP6001 Programmable Dynamometer Controller and requisite interface cards and cables.

Note: Magtrol's Single or Three-Phase Power Analyzer can be integrated into this system as well as Magtrol's Temperature Testing Hardware and Software.

SETUP

The following diagrams illustrate the required cable sets and connections for a PC-based test system setup.

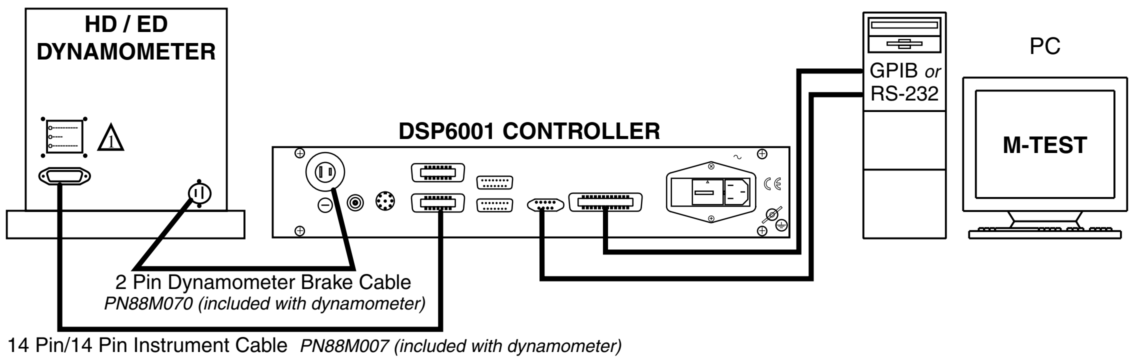


Figure 3–7 Dynamometer with DSP6001 Controller and M-TEST Software

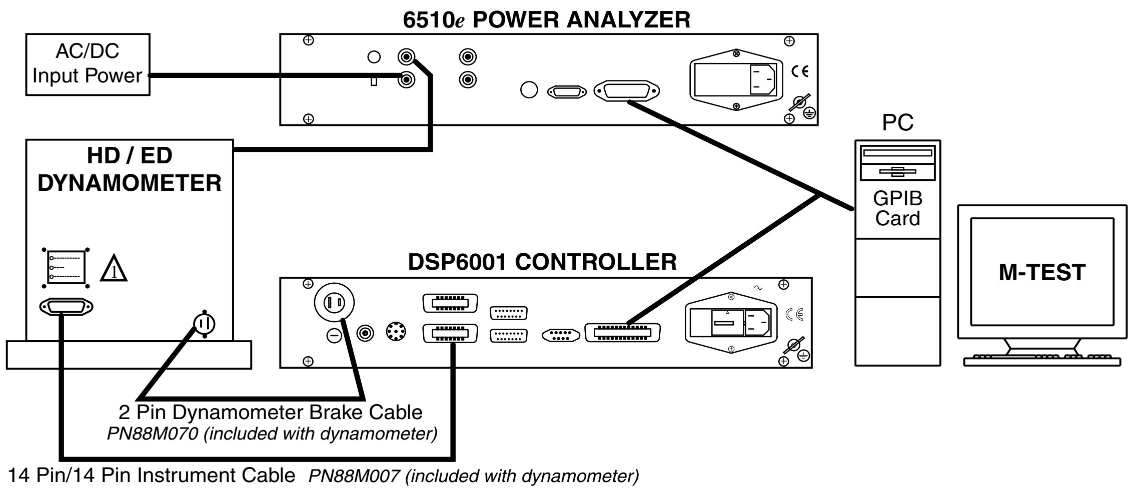


Figure 3–8 Dynamometer with 6510e Power Analyzer, DSP6001 Controller and M-TEST Software

SETUP

3.3.3 Air Cooling

Magtrol's HD-510/515/710/715, ED-715 and any 800 Series Dynamometer are all internally ported for compressed air or blower cooling and may be integrated with a manual or PC-based test setup in order to provide air cooling of the dynamometer brake. An air flow sensor has been added to these dynamometers to protect against operator error. With the air flow sensor, the dynamometer comes equipped with a pressure sensor ported into the cooling airway. The sensor, when used in combination with Magtrol's DSP6001 Dynamometer Controller, prevents the dynamometer brake from being energized until the blower or air supply has been turned on.

When the air supply to the dynamometer is turned on, the pressure sensor closes an electrical contact. Two wires from the sensor run internally to the dynamometer and attach to the torque amplification board. One of the wires from the sensor is then passed directly to the back panel connector (14-pin connector, pin 1). The other wire is tied on the board to +5 VDC COM (14-pin connector, pin 8).

When used with the DSP6001, pin 1 is internally pulled high with a resistance to 5 volts. If not using a Magtrol controller, it is assumed the user will pull pin 1 to the 5 volts supplied to the amplifier board (pin 7) with a 1 K to 10 K resistor.

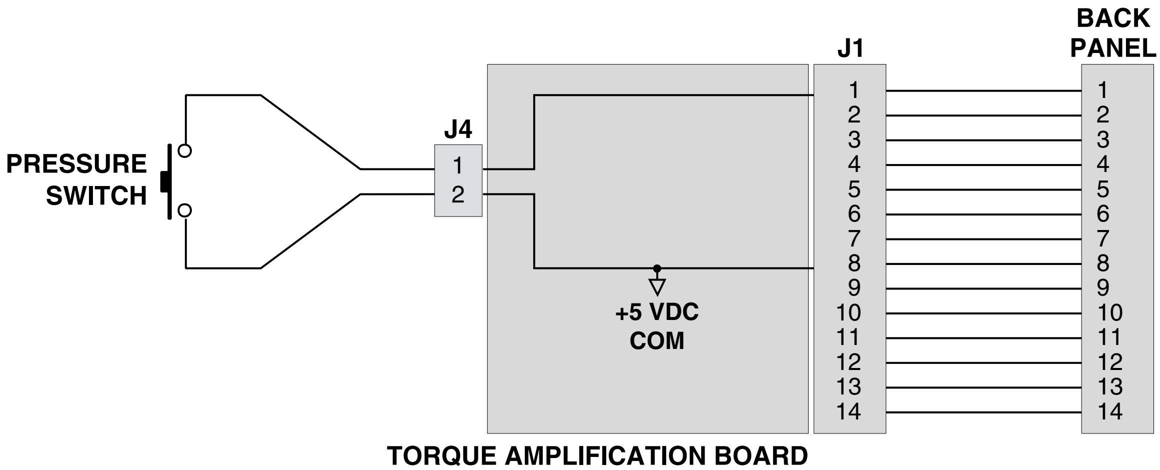


Figure 3–9 Air Flow Sensor Schematic

SETUP

3.3.3.1 Blower Setup

If an HD-710, HD-715, HD-810, HD-815, ED-715 or ED-815 dynamometer is being used, a blower input is integrated into the unit.

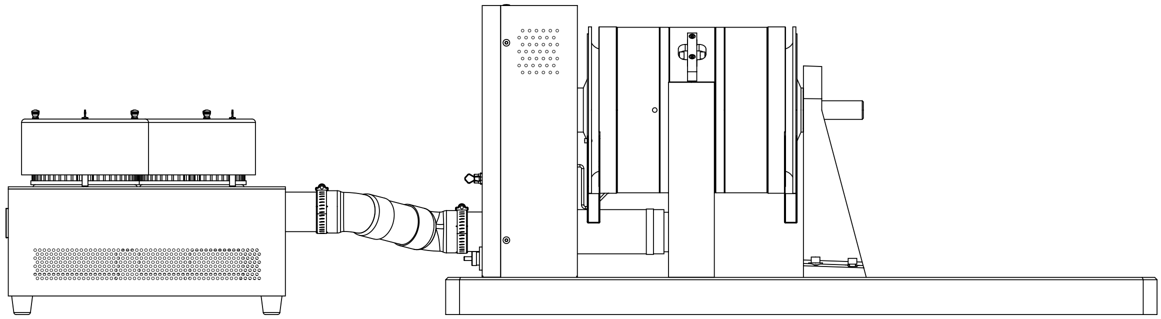


Figure 3–10 Dynamometer with Blower Connection

For more information, see *Section 4.1.3.2.2 – Blower*.

WARNING! DUE TO THE NOISE LEVELS OF THE BLOWERS, HEARING PROTECTION MUST BE WORN DURING OPERATION.

3.3.3.2 Compressed Air Setup

If a Model 510, 515, 800 or 805 dynamometer is being used, a compressed air input is integrated into the unit. The connection is illustrated in the following diagram.

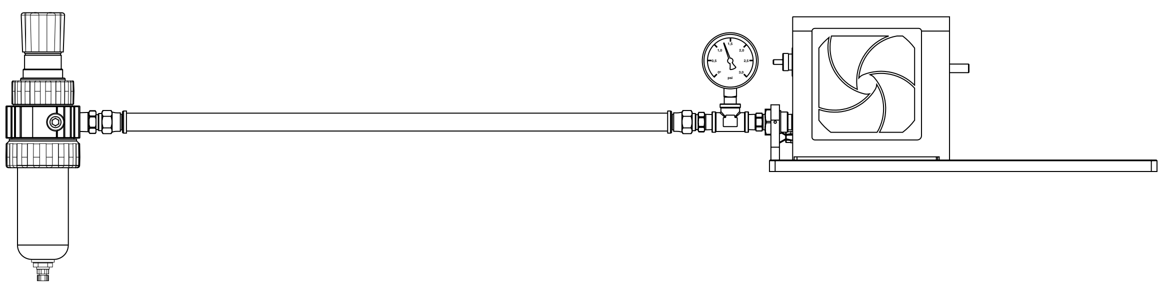


Figure 3–11 Dynamometer with Compressed Air Connection

For more information, see *Section 4.1.3.2.1 – Compressed Air*.

4. Testing

4.1 TESTING CONSIDERATIONS

A number of factors must be taken into consideration before running a test including safety, accuracy, power dissipation, fixturing, couplings, windage, friction, vibration, cogging, eddy currents and temperature rise. The following sections describe these factors, and their effects, in further detail.

4.1.1 Safety

For general safety considerations, please follow these few common-sense rules:

- Be sure that your coupling is adequately rated for the speed and torque that you intend to run.
- Make sure all rotating elements are covered.
- Always wear safety glasses when working around dynamometer test equipment.
- Do not wear loose clothing or ties when working around dynamometer test equipment.
- Never allow anyone to stand close to the side of, or lean over, a rotating shaft coupling.
- Insulate electrical (internal and external) motor connections.

CAUTION: A POWER-LINE FAULT INTO THE DYNAMOMETER FRAME COULD PASS A TRANSIENT SURGE THROUGH ALL INTERCONNECTED INSTRUMENTS, ANY COMPUTER IN USE OR OPERATING PERSONNEL WITH DANGEROUS AND COSTLY CONSEQUENCES!

- Always connect the motor frame to a high current capacity (water pipe) earth ground.
- Be sure the motor control circuit breakers cannot be bypassed by accident. Variable auto-transformers are especially hazardous!
- When operating dynamometers with blowers, hearing protection must be worn.

4.1.2 Accuracy

Following, is a list of several factors that affect the apparent accuracy of the torque readout.

- **Full Scale Torque Calibration:** This setting will be affected by an internal temperature rise of up to ±0.0015% FS/°C. For more information on full-scale torque setup and troubleshooting, refer to *Section 6.4 – Calibration Procedure* and *Section 8.1.3 – Full Scale Torque*.
- **Zero Offset:** This setting is affected by an internal temperature rise of up to ±0.002% Reading/°C. For more information on zero offset setup and troubleshooting, refer to *Section 6.4 – Calibration Procedure* and *Section 8.1.2 – Zero Balance*.
- **Coupling Losses:** If the coupling becomes hot to the touch, or if the dynamometer or motor vibrate after a period of running, coupling loss error could occur up to several percent depending on the size of the motor and dynamometer. For more detail, refer to *Section 4.1.4 – Fixtures and Couplings*.
- **Windage:** Negligible at speeds up to 6000 rpm. This effect is described more extensively in *Section 4.1.5 – Windage*.
- **Mechanical Friction:** Generally negligible on HD-400 series dynamometers and larger. On HD-106 and HD-100 the user is cautioned to be aware of the effects that friction may cause. For more detail, refer to *Section 4.1.6 – Friction*.

☞ Note: None of the above take into account the long-term drift effects on digital readout instrumentation. This is covered for each instrument by their individual specifications. Also, many of the above factors are dependent upon motor horsepower, fixturing and other circumstances beyond the control of Magtrol. If reasonable care is exercised, and calibration and maintenance are performed on a regular basis,, motor test data accuracy better than 0.25% of torque-speed value can be expected.

4.1.3 Power Dissipation

All Magtrol Dynamometers are power absorption instruments. As a dynamometer loads a test motor, it is absorbs horsepower from the motor into the hysteresis brake. The brake then converts this mechanical energy into heat.

There are finite limits to the amount of energy and resulting temperature rise that any absorption brake can withstand. Rapidly rising operating temperatures from excessive power input can cause severe mechanical distortion of the rotor assembly. This, in turn, may cause the rotating assembly to contact the stationary members that surround it. Once this happens, metal transfer and ultimately seizing of the brake assembly may occur.

Excessive power over extended periods of time may result in more obscure damage including breakdown of bearing lubricants and degradation of magnetic coil insulation. Also, exposure to temperatures over 690 °C (1275 °F) will alter the rotor's magnetic properties.

☞ Note: Do not instantaneously apply maximum power (torque-speed) to a cold dynamometer. High temperature gradients cause differential expansions resulting in misalignment of the running air gaps between the rotor and stator assembly on the load brake. Allow all dynamometers to warm up before heavy loading. This is accomplished by gradually increasing the load to the motor. If a motor must be tested cold, warm up the dynamometer with a different motor first.

4.1.3.1 Power Absorption Curves

The following graphs (*Figures 4–1 through 4–15*) represent the maximum power (heat) that the dynamometer can dissipate over time. The specifications shown are conditional upon the following:

- Maximum brake temperature = 100 °C (212 °F)
- Maximum rotor temperature = 510 °C (950 °F)
- Ambient temperature = 25±5 °C (77±9 °C)
- The dynamometer cooling system is running

The following values are sufficiently accurate (within 1%) to establish watts (W) for use in the heat rise curves.

where P = power (watts), T = torque, and n = speed (rpm)

$$P\ (\text{watts}) = T\ (\text{N·m}) \times n\ (\text{rpm}) \times (1.047 \times 10^{-1})$$
$$P\ (\text{watts}) = T\ (\text{lb·in}) \times n\ (\text{rpm}) \times (1.183 \times 10^{-2})$$
$$P\ (\text{watts}) = T\ (\text{kg·cm}) \times n\ (\text{rpm}) \times (1.027 \times 10^{-2})$$

Note: Please take a moment to familiarize yourself with any limitations that may apply to your specific dynamometer and motor testing requirements.

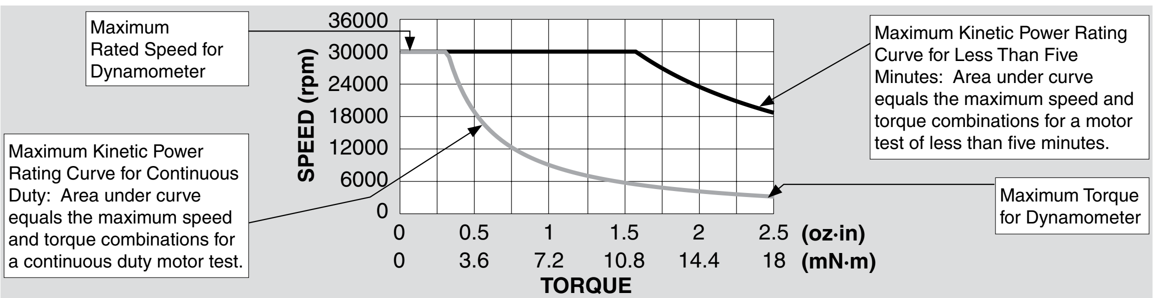


Figure 4–1 Power Absorption Curve Parameters

HD-106

Shaft Diameter	0.1245 in / 0.1250 in (3.163 mm / 3.175 mm)
Shaft Height	3.50 in (88.9 mm)
Torque Range	2.50 oz·in 180.0 g·cm 18.00 mN·m
Input Inertia	7.04×10^{-7} lb·ft·s²
Maximum Speed	30,000 rpm
Maximum Input Power	continuous duty: 7 W < 5 minutes: 35 W

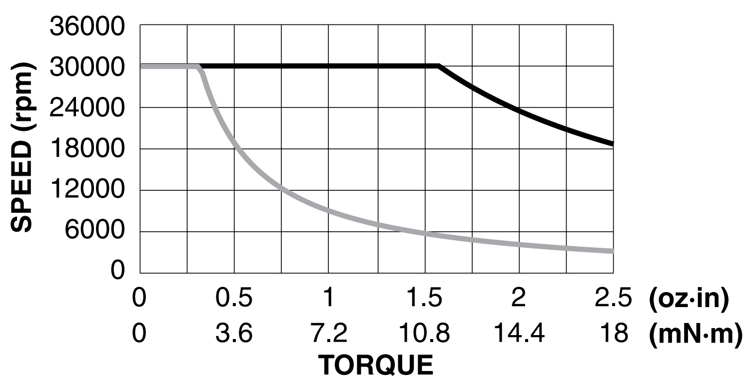


Figure 4–2 HD 106 Power Absorption Curve

HD-100

Shaft Diameter	0.1870 in / 0.1875 in (4.750 mm / 4.763 mm)
Shaft Height	3.50 in (88.9 mm)
Torque Range	11.00 oz·in 800 g·cm 80.00 mN·m
Input Inertia	3.40×10^{-6} lb·ft·s²
Maximum Speed	25,000 rpm
Maximum Input Power	continuous duty: 20 W < 5 minutes: 75 W

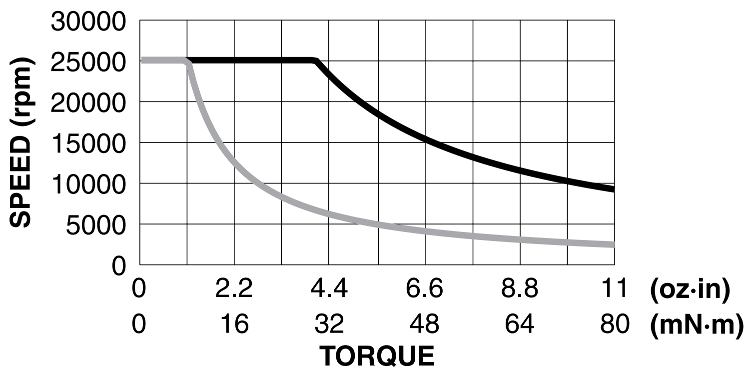


Figure 4–3 HD 100 Power Absorption Curve

HD-400

Shaft Diameter	0.2495 in / 0.2500 in (6.338 mm / 6.350 mm)
Shaft Height	3.50 in (88.9 mm)
Torque Range	40.0 oz·in 2.80 g·cm 280 mN·m
Input Inertia	1.55×10^{-5} lb·ft·s²
Maximum Speed	25,000 rpm
Maximum Input Power	continuous duty: 55 W < 5 minutes: 200 W

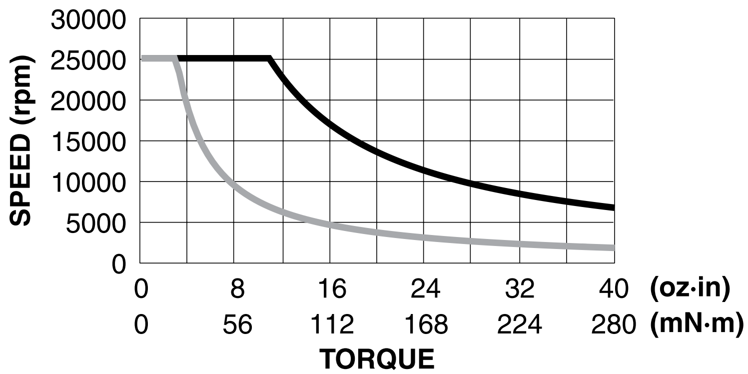


Figure 4–4 HD 400 Power Absorption Curve

OPERATION

HD-500

Shaft Diameter	0.3745 in / 0.3750 in (9.512 mm / 9.525 mm)
Shaft Height	4.00 in (101.6 mm)
Torque Range	120.0 oz·in 8.50 kg·cm 850 mN·m
Input Inertia	8.05×10^{-5} lb·ft·s²
Maximum Speed	25,000 rpm
Maximum Input Power	continuous duty: 80 W < 5 minutes: 400 W

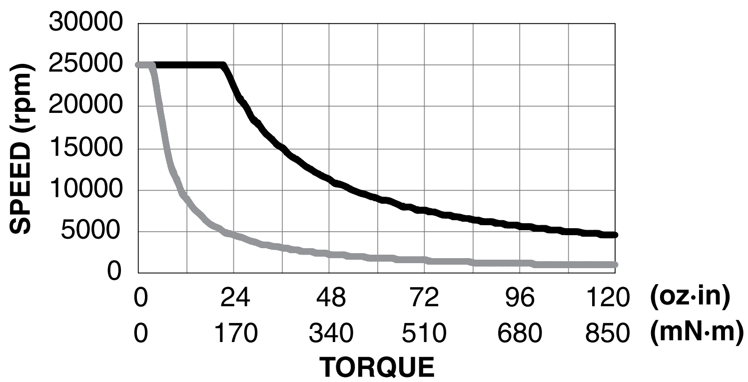


Figure 4–5 HD 500 Power Absorption Curve

HD-510

Shaft Diameter	0.3745 in / 0.3750 in (9.512 mm / 9.525 mm)
Shaft Height	4.00 in (101.6 mm)
Torque Range	120.0 oz·in 8.50 kg·cm 850 mN·m
Input Inertia	8.05×10^{-5} lb·ft·s²
Maximum Speed	25,000 rpm
Maximum Input Power	continuous duty: 375 W < 5 minutes: 750 W

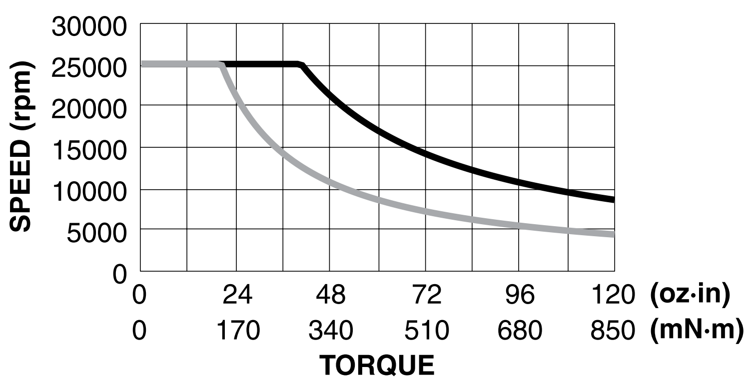


Figure 4–6 HD 510 Power Absorption Curve

OPERATION

HD-505

Shaft Diameter	0.3745 in / 0.3750 in (9.512 mm / 9.525 mm)
Shaft Height	4.00 in (101.6 mm)
Torque Range	240 oz·in 17.00 kg·cm 1700 mN·m
Input Inertia	1.61×10^{-4} lb·ft·s²
Maximum Speed	25,000 rpm
Maximum Input Power	continuous duty: 160 W < 5 minutes: 800 W

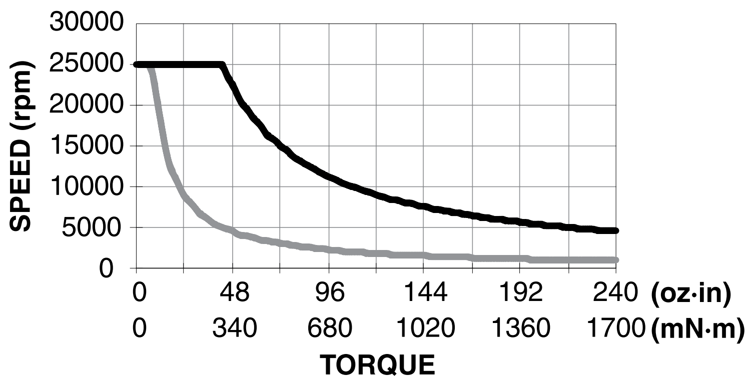


Figure 4–7 HD 505 Power Absorption Curve

HD-515

Shaft Diameter	0.3745 in / 0.3750 in (9.512 mm / 9.525 mm)
Shaft Height	4.00 in (101.6 mm)
Torque Range	240 oz·in 17.00 kg·cm 1700 mN·m
Input Inertia	1.61×10^{-4} lb·ft·s²
Maximum Speed	25,000 rpm
Maximum Input Power	continuous duty: 900 W < 5 minutes: 1500 W

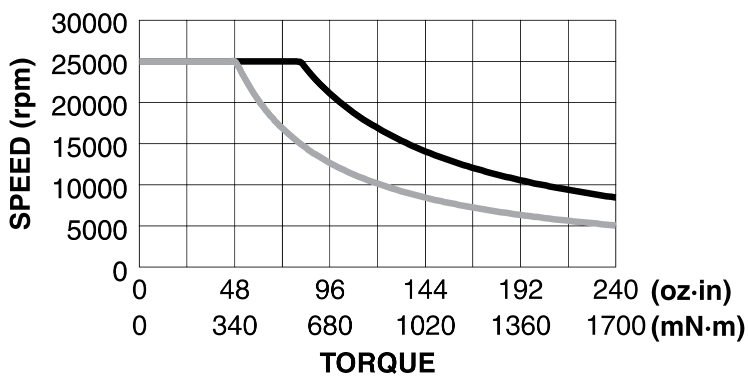


Figure 4–8 HD 515 Power Absorption Curve

HD-700

Shaft Diameter	0.4995 in / 0.5000 in (12.687 mm / 12.700 mm)
Shaft Height	5.875 in (149.2 mm)
Torque Range	440 oz·in 31.0 kg·cm 3.10 N·m
Input Inertia	5.51×10^{-4} lb·ft·s²
Maximum Speed	25,000 rpm
Maximum Input Power	continuous duty: 150 W < 5 minutes: 700 W

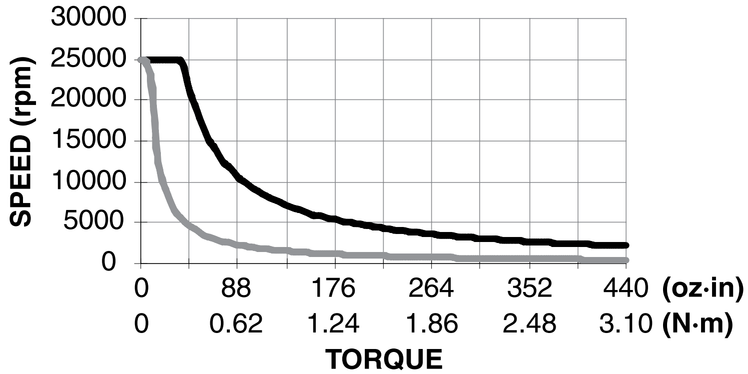


Figure 4–9 HD 700 Power Absorption Curve

HD-710

Shaft Diameter	0.4995 in / 0.5000 in (12.687 mm / 12.700 mm)
Shaft Height	5.875 in (149.2 mm)
Torque Range	440 oz·in 31.0 kg·cm 3.10 N·m
Input Inertia	5.51×10^{-4} lb·ft·s²
Maximum Speed	25,000 rpm
Maximum Input Power	continuous duty: 935 W < 5 minutes: 1400 W

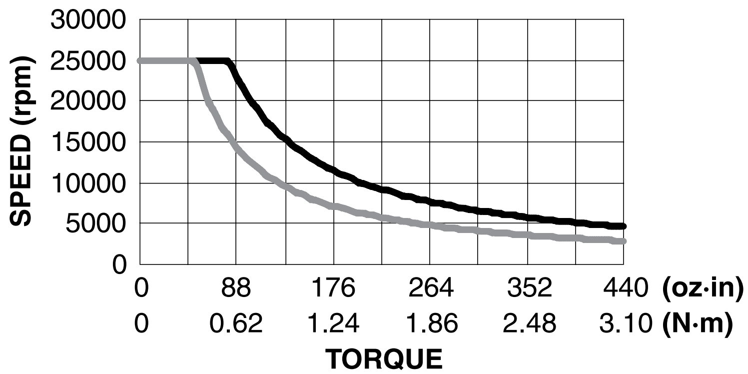


Figure 4–10 HD 710 Power Absorption Curve

OPERATION

HD-705

Shaft Diameter	0.4995 in / 0.5000 in (12.687 mm / 12.700 mm)
Shaft Height	5.875 in (149.2 mm)
Torque Range	55.0 lb·in 62.0 kg·cm 6.20 N·m
Input Inertia	1.101×10^{-3} lb·ft·s²
Maximum Speed	25,000 rpm
Maximum Input Power	continuous duty: 300 W < 5 minutes: 1400 W

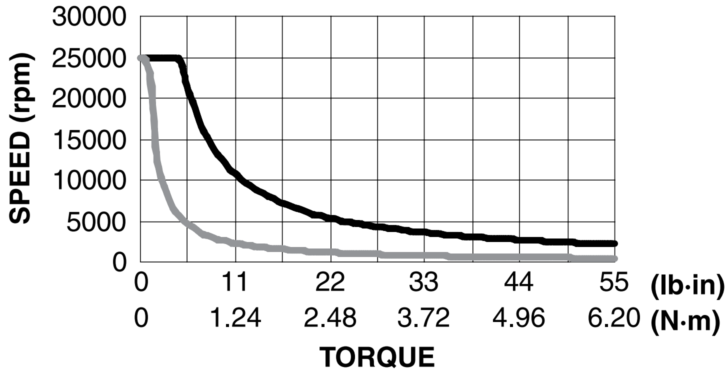


Figure 4–11 HD 705 Power Absorption Curve

HD-715

Shaft Diameter	0.4995 in / 0.5000 in (12.687 mm / 12.700 mm)
Shaft Height	5.875 in (149.2 mm)
Torque Range	55.0 lb·in 62.0 kg·cm 6.20 N·m
Input Inertia	1.101×10^{-3} lb·ft·s²
Maximum Speed	25,000 rpm
Maximum Input Power	continuous duty: 3000 W < 5 minutes: 3400 W

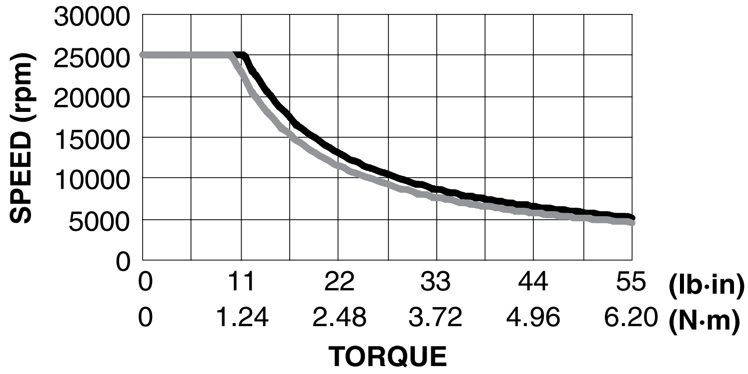


Figure 4–12 HD 715 Power Absorption Curve

OPERATION

HD-800

Shaft Diameter	0.9995 in / 1.0000 in (25.387 mm / 25.400 mm)
Shaft Height	9.00 in (228.6 mm)
Torque Range	125.0 lb·in 140.0 kg·cm 14.00 N·m
Input Inertia	4.43×10^{-3} lb·ft·s²
Maximum Speed	12,000 rpm
Maximum Input Power	continuous duty: 1800 W < 5 minutes: 2800 W

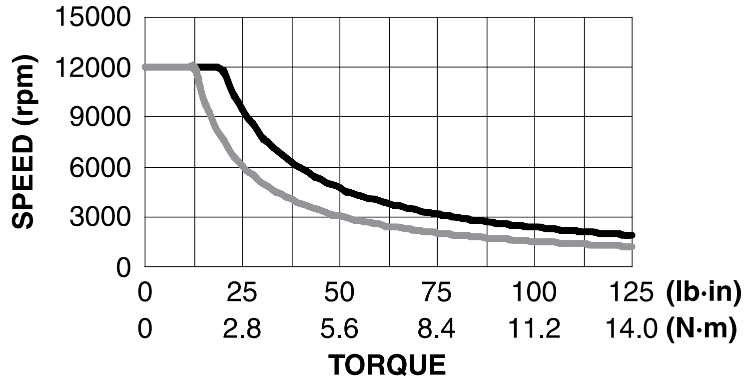


Figure 4–13 HD 800 Power Absorption Curve

HD-810

Shaft Diameter	0.9995 in / 1.0000 in (25.387 mm / 25.400 mm)
Shaft Height	9.00 in (228.6 mm)
Torque Range	125.0 lb·in 140.0 kg·cm 14.00 N·m
Input Inertia	4.43×10^{-3} lb·ft·s²
Maximum Speed	12,000 rpm
Maximum Input Power	continuous duty: 3000 W < 5 minutes: 3500 W

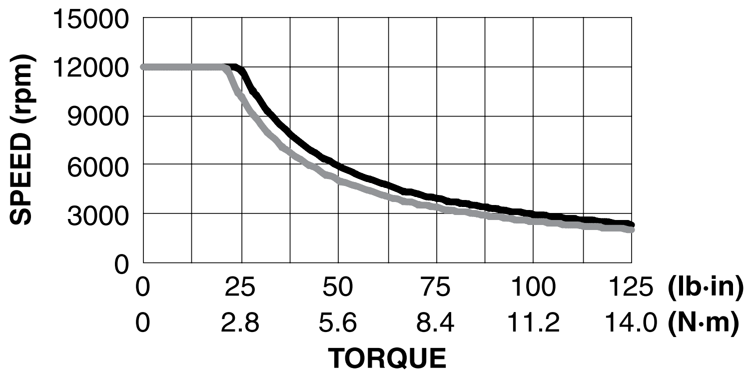


Figure 4–14 HD 810 Power Absorption Curve

HD-805

Shaft Diameter	0.9995 in / 1.0000 in (25.387 mm / 25.400 mm)
Shaft Height	9.00 in (228.6 mm)
Torque Range	250 lb·in 280 kg·cm 28.0 N·m
Input Inertia	8.81×10^{-3} lb·ft·s²
Maximum Speed	12,000 rpm
Maximum Input Power	continuous duty: 3000 W < 5 minutes: 5300 W

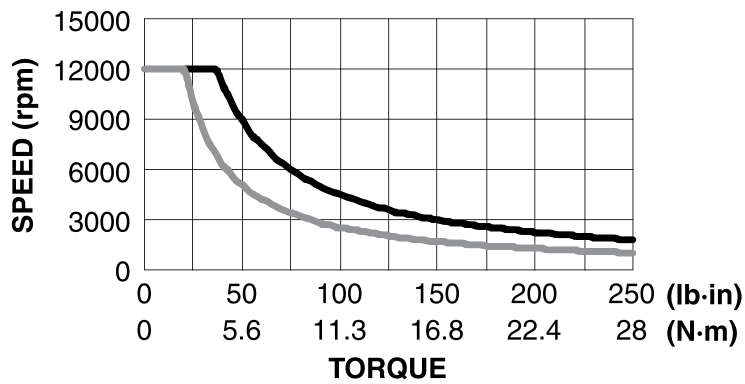


Figure 4–15 HD 805 Power Absorption Curve

HD-815

Shaft Diameter	0.9995 in / 1.0000 in (25.387 mm / 25.400 mm)
Shaft Height	9.00 in (228.6 mm)
Torque Range	250 lb·in 280 kg·cm 28.0 N·m
Input Inertia	8.81×10^{-3} lb·ft·s²
Maximum Speed	12,000 rpm
Maximum Input Power	continuous duty: 6000 W < 5 minutes: 7000 W

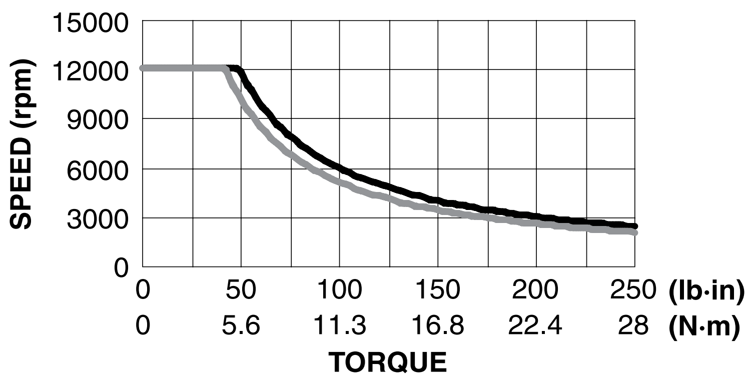


Figure 4–16 HD 815 Power Absorption Curve

OPERATION

HD-825

Shaft Diameter	1.4995 in / 1.5000 in (38.087 mm / 38.100 mm)
Shaft Height	9.00 in (228.6 mm)
Torque Range	500 lb·in 565 kg·cm 56.5 N·m
Input Inertia	1.85×10^{-2} lb·ft·s²
Maximum Speed	8,000 rpm
Maximum Input Power	continuous duty: 12,000 W < 5 minutes: 14,000 W

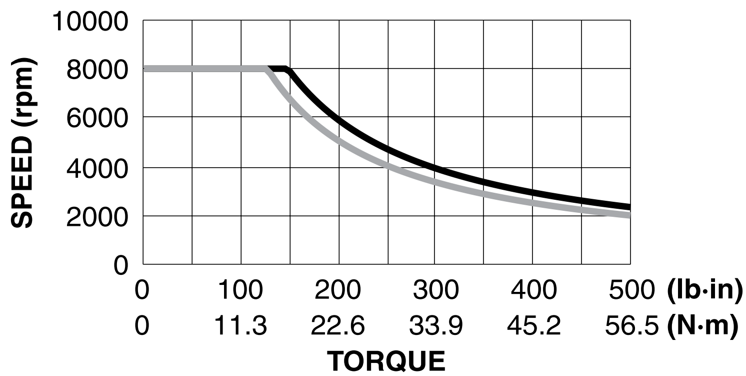


Figure 4–17 HD 825 Power Absorption Curve

ED-715

Shaft Diameter	0.7490 in / 0.7495 in (19.025 mm / 19.037 mm)
Shaft Height	6.87 in (174.5 mm)
Torque Range	55.0 lb·in 62.0 kg·cm 6.20 N·m
Input Inertia	1.27×10^{-3} lb·ft·s²
Maximum Speed	25,000 rpm
Maximum Input Power	continuous duty: 3000 W < 5 minutes: 3400 W

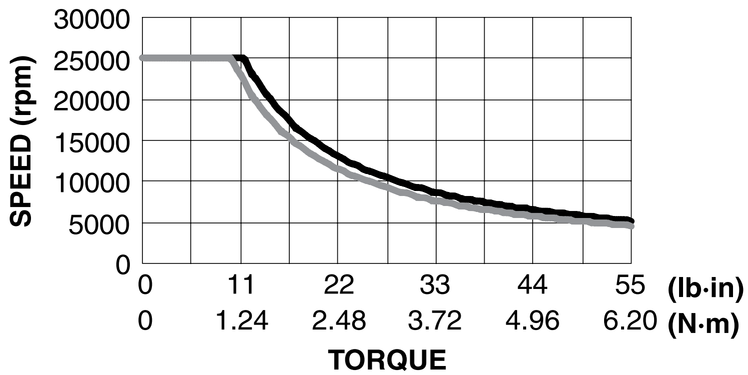


Figure 4–18 ED 715 Power Absorption Curve

ED-815

Shaft Diameter	1.4995 in / 1.5000 in (38.087 mm / 38.100 mm)
Shaft Height	11.00 in (279.4 mm)
Torque Range	250 lb·in 280 kg·cm 28.0 N·m
Input Inertia	9.61×10^{-3} lb·ft·s²
Maximum Speed	12,000 rpm
Maximum Input Power	continuous duty: 6000 W < 5 minutes: 7000 W

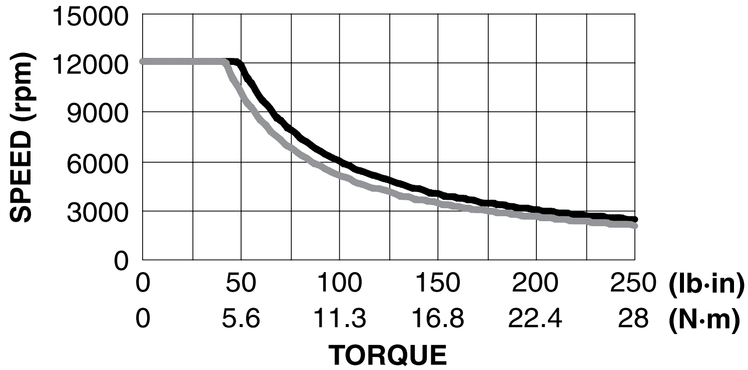


Figure 4–19 ED 815 Power Absorption Curve

4.1.3.2 Cooling Methods

Note: For additional details on compressed air and blower setup along with extensive information on the Air Flow Sensor feature, refer to *Section 3.3.3 – Air Cooling*.

4.1.3.2.1 Compressed Air

Magtrol's HD-510, 515, 800 and 805 dynamometers are internally ported for compressed air cooling. Always use the filter and line regulator supplied with the unit. These elements should be installed as shown in the following diagram.

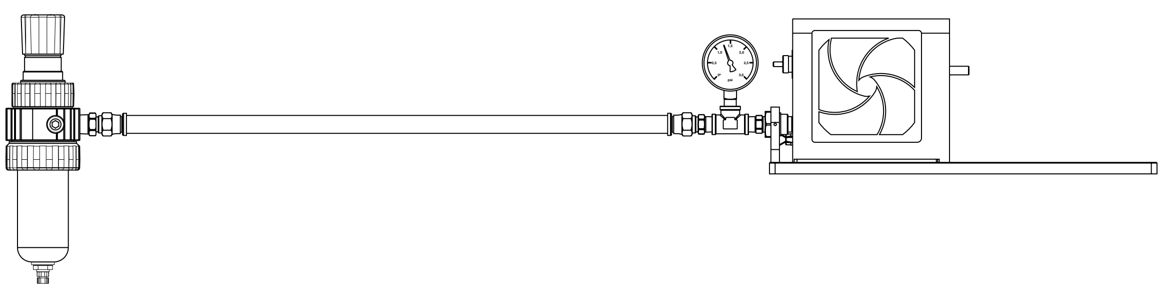


Figure 4–20 Dynamometer with Compressed Air Connection

OPERATION

For maximum air flow and cooling, set the regulator to the following:

HD Model	CFM (Cubic Feet per Minute)	PSI (Pounds per Square Inch)
HD-510	7	1.75
HD-515	10	4
HD-800	7.5	7
HD-805	15	7

WARNING! DO NOT EXCEED THE PRESSURES GIVEN.

The air supply should be enabled whenever the unit is in operation.

4.1.3.2.2 Blower

Magtrol's HD-710/715/810/815/825 and ED-715/815 dynamometers are internally ported for blower cooling. The following diagram illustrates the connection.

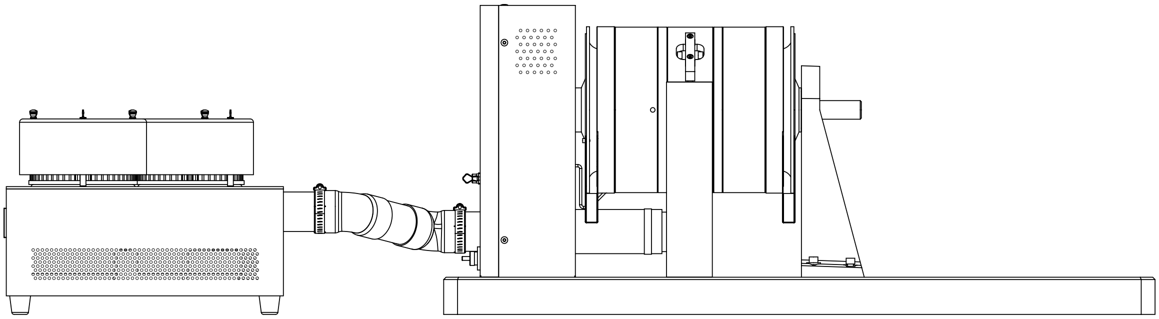


Figure 4–21 Dynamometer with Blower Connection

WARNING! DUE TO THE NOISE LEVELS OF THE BLOWERS, HEARING PROTECTION MUST BE WORN DURING OPERATION.

OPERATION

4.1.4 Fixtures and Couplings

When mounting the test motor, please consider the following:

- Construct precise fixtures that provide proper shaft alignment.
- Secure the test motor in the fixture to prevent torsional movement and bolt the fixture to the dynamometer base plate.
- Give consideration to the interaction of materials between the motor and test fixture. For example, a (magnetic) steel plate placed against the exposed lamination of an open frame motor can significantly influence performance. Some thin shell PM (permanent magnet) motors may be similarly affected.
- The dynamometer base plate material is an aluminum tool plate that is easily drilled and tapped. The use of helix thread inserts is a good idea if you are going to interchange fixtures often.

☞ Note: For an additional charge, Magtrol can perform base plate modifications.

The following diagram illustrates examples of possible shaft misalignment.

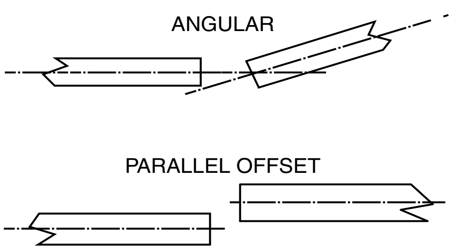


Figure 4–22 Examples of Possible Shaft Misalignment

The use of high quality double flexure couplings is recommended to help correct any misalignment problems. This type of coupling—two flexing elements separated by a solid link—inherently tolerates greater parallel offset. If you would like more specific coupling recommendations, contact Magtrol Technical Assistance. For precise misalignment tolerances, consult your coupling manufacturer.

4.1.5 Windage

Windage is proportional to the square of speed and magnifies rapidly above rated speed. The air friction is tangential to the surface and impinges upon the stationary field assembly. This acts as viscous drag and becomes part of the motor load and torque reading. However, there is a small amount of air dissipated as pumping loss. Since this appears as a load on the motor, not measured by the dynamometer, it becomes a source of error.

Windage effects on accuracy tests have been conducted on all Magtrol dynamometers. The percentage of torque loss due to windage ranges between 0.025% and 0.20% of full scale at maximum rated rpm.

Windage is proportional to the square of speed and magnifies rapidly above rated speed. Conversely, at one half of the rated speed, the effect becomes immeasurably small.

OPERATION

4.1.6 Friction

Friction of the shaft bearings is a measurable load, but some friction can exist in the carrier bearing. When correctly loaded and lubricated, the friction is insignificant. The value may be quantitatively established by the following procedure.

1. Remove all attachments to the dynamometer shaft.
2. Advance the torque control slightly, to obtain a small torque load.
3. Apply a small amount of torque (by hand) in one direction of rotation.
4. Carefully release the shaft, allow several seconds, and record the torque reading, if any.
5. Then, carefully re-apply torque in the opposite direction.
6. Slowly release the shaft as above, and compare the two readings.

The difference should be less than 1% of full scale. During actual motor testing there is usually enough system vibration to "settle" negating frictional effects. If excessive drag is present, mechanical realignment may be required, dependent upon dynamometer size. Certain mechanical factors need to be determined before corrective action proceeds. Please contact Magtrol Technical Assistance.

4.1.7 Vibration

All rotating dynamometer assemblies are precision balanced, however, the dynamometer shaft is cantilevered. This may cause vulnerability to radial forces.

At high speeds, some vibration and noise are inevitable but not necessarily harmful. However, excessive resonant vibrations, caused by bent shafts, poor alignment and out of balance couplings will produce excessive data errors and are a safety hazard.

WARNING! SHAFT COUPLINGS OPERATING AT SPEEDS ABOVE THEIR DESIGN LIMITS ARE EXTREMELY HAZARDOUS. MANY COUPLINGS CONTAIN SOMEWHAT LOOSELY SUPPORTED FLEXURE ELEMENTS. WHEN OVERDRIVEN, EXCESSIVE CENTRIFUGAL FORCE MAY DISPLACE THEM OUT OF AXIAL ALIGNMENT. AS THIS HAPPENS, THEY IMMEDIATELY BEGIN TO ABSORB ENERGY RESULTING IN SEVERE VIBRATION AND DESTRUCTION OF THE COUPLING.

4.1.8 Cogging

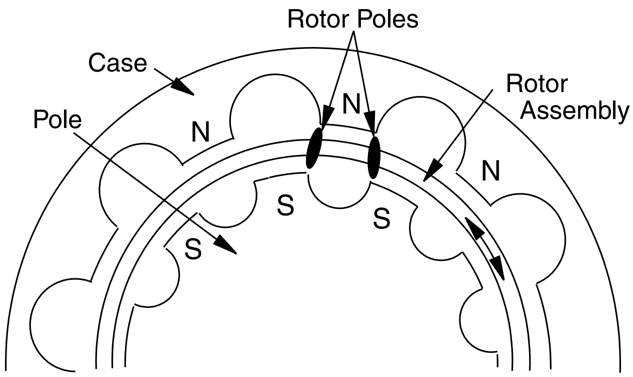


Figure 4–23 Hysteresis Brake Cross-Section

This cross-section shows (by one tooth) the magnetic relationship of the hysteresis brake elements. If the dynamometer shaft is at rest with torque applied, and if the torque control is then reduced to zero, a magnetic salient pole will be temporarily imposed on the rotor of the brake.

If the shaft is then rotated slowly, the magnetic poles on the rotor will attempt to align with the adjacent case-pole tooth form. This is often referred to as "cogging". The action is sinusoidal—first it tries to resist rotation and then, as the rotor passes through the tooth form, it subsequently supports rotation. At a few hundred rpm, these forces integrate resulting in an effective torque of nearly zero.

To avoid magnetic cogging, before the shaft comes to rest, reduce the torque control to zero.

To remove cogging, once established, reapply current on the dynamometer. Then, decrease the current to zero while simultaneously rotating the dynamometer shaft.

4.1.9 Eddy Currents

There is some Eddy current generation within the brake rotor. These magnetically induced currents cause an increase in brake torque proportional to speed.

The larger the hysteresis brake, the higher the rotor surface velocity. Additionally, as brakes become larger the rotor cross-sectional area increases. Each of these factors increase Eddy current generation. The combination results in speed-related torque increase, exhibiting a more pronounced effect on larger dynamometers.

With the HD-800 through 815 models, the Eddy-current torque component adds approximately 10%/1000 rpm to a static, fixed current, torque value. On the smaller dynamometer sizes, 2% to 4%/1000 rpm is typical.

4.1.10 Temperature Rise

Temperature rise has a more complex effect on hysteresis brake load torque and is difficult to quantify. As the temperature of the brake increases, differential expansions cause dimensional changes that tend to increase torque. Conversely, electrical resistance in the rotor increases with temperature, resulting in decreased Eddy current generation and torque, all in a variable frame.

Where current and speed remain fixed, there may be a gradual torque increase over a period of a few moments. This will generally stabilize at 0.5% (for small dynamometers, up to HD-500) to 2% of the starting torque value, per 1000 rpm of applied speed.

☞ Note: If highly accurate long-term torque stability is required, consider the Magtrol DSP6001 Dynamometer Controller. This is a computer-controlled closed loop system capable of maintaining either constant torque or speed.

5. Operating Principles

5.1 SPEED

Inside the dynamometer enclosure is an optical speed transducer. A high-speed optical switch, consisting of an Infrared (IR) LED and IR receiver, senses the passage of light through a slotted disk that is attached to the end of the dynamometer shaft. Light passing through a slot in the disk causes the speed output signal to go to a logic low (near 0 VDC). As a solid section passes in front of the IR receiver, the output signal switches to a logic high (near 5 VDC). Rotation of the disk results in the optical switch generating a pulse frequency of 60 bits per shaft revolution. For schematic, see *Section B.2 – Speed Sensor Board* in Appendix B.

5.2 TORQUE

Torsional force from the hysteresis brake assembly is measured by a load cell. The load cell consists of a flexing beam with four strain gauges. The strain gauges are in a bridge configuration, producing an analog signal proportional to torque.

The load cell schematic in Appendix B shows voltage levels and connection identifications. The mechanical diagram below illustrates how the assembly clamps onto the rear support member of the brake.

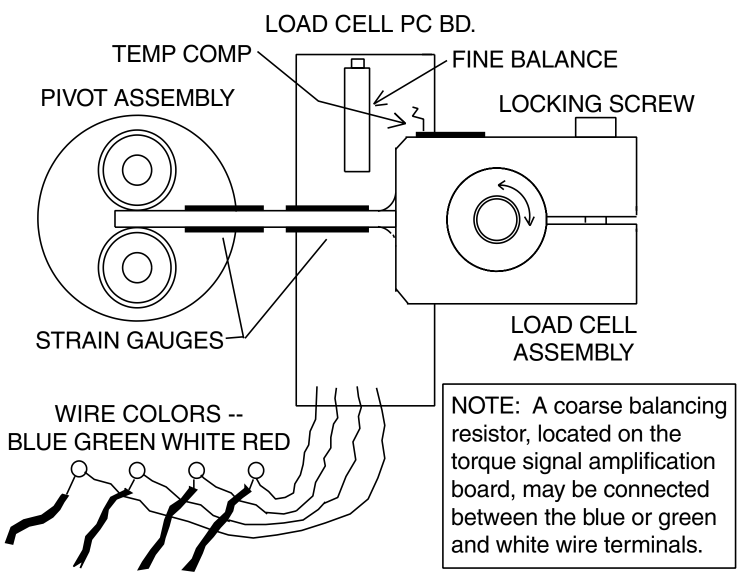


Figure 5–1 Mechanical Layout of a Load Cell

THEORY

5.3 TORQUE SIGNAL AMPLIFICATION

A printed circuit board mounted on the dynamometer rear panel, identified as part number 234-401-101-xxx, contains the torque signal amplifiers IC1, IC2 and IC3, load cell excitation supply consisting of voltage reference DZ1, amplifier IC4 and Transistors Q1-Q4.

Voltage reference DZ1 is a precision voltage source, and along with IC4 and Q1–Q4, provides +5.00 and -5.00 volts DC excitation to the load cell bridge. Transistors Q1–Q4 are NPN and PNP transistors, serving as series pass elements to boost the current output drive capability to over 30 mA. Bipolar bridge excitation is used to improve the noise immunity of the low millivolt range bridge output signal. See *B.1 – Torque Amplification Signal* in Appendix B.

Amplifier IC1 is a precision, differential input instrumentation amplifier providing amplification necessary to calibrate the torque signal. IC2 and IC3 provide additional amplification and scaling, along with the counterclockwise calibration (CCW CAL) control.

The torque signal is calibrated by adjusting the rear panel trim potentiometers P1 and P2, labeled “CW CAL” and “CCW CAL”. Torque signal zero is adjusted by using the rear panel trim potentiometer P3, labeled “ZERO”, when no torque is applied.

The load cell on all dynamometers except the HD-106, produce an output signal of 15 mV at full torque. The HD-106 output is 7.5 mV full scale. Amplifiers IC1-IC3 calibrate this so the output in millivolts equals the dynamometer full scale torque.

The torque signal zero may be affected thermally and may need periodic readjustment. Therefore, the “ZERO” adjustment can be readjusted as needed.

The clockwise calibration (CW CAL) adjustments should not typically need readjustment. In the event that a “CW CAL” adjustment is needed, a precision calibration beam and weight must be used. The calibration beam may be purchased from Magtrol.

☞ Use only an insulated screwdriver or a plastic trim pot adjustment tool when adjusting the “CW CAL,” “CCW CAL” or “ZERO” trim potentiometers.

For example, the HD-400-6 Dynamometer lists the full scale torque at 40.0 oz·in. Therefore, the amplifier gain will be set to produce 0.400 VDC output, when the load cell input is ≅0.011 VDC.

5.4 DECIMAL POINT CONTROL

Two solder links on the circuit board indicate to the digital readout instrument where the decimal point belongs. The chart below shows how this is accomplished by jumping the appropriate link on the board. Digital output “XXX” represents the result of the analog output (in millivolts) with the decimal point properly located.

Digital Output	SL13	SL12
X.XX	Closed	Open
XX.X	Open	Closed
XXX.	Closed	Closed

THEORY

5.5 DAMPER CYLINDER

Hysteresis brakes, machined from (solid bar) magnetic material, represent a heavy mass. The load cell behaves somewhat like a spring. A mass, supported by a spring, will resonate at the system's natural frequency. For this reason, the dynamometer brake assembly must be dampened to filter out torque data and to avoid stress and fatigue. The damper cylinder arm, attached to the brake, connects to a piston within the hydraulic cylinder. When the load cell shipping/ restraining bolt was removed (see *Section 3.1 – Removal of the Load Cell Shipping/Restraining Bolt*), the brake/load cell assembly was centered and the damper became functional.

5.6 BRAKE CONTROL POWER

Any Magtrol Dynamometer Controller is universal in that it must operate all dynamometers. Due to the higher level of current required by Magtrol's larger dynamometers, a booster power amplifier is used to increase the control current. These supplies, contained within the dynamometer enclosures, are in operation when the cooling fans are on.

5.6.1 HD-800/815 AND ED-815

A booster power amplifier is used with the HD-800, 805, 810, 815 and ED-815 dynamometers to increase control current by a factor of 2 and 4, respectively. The schematic in *Section B.4 – HD-800-815 Brake Control Supply* details the HD-800, 805, 810 and 815 brake power amplifier.

5.6.2 HD-825

An HD-825 uses a 5241 power amplifier to increase the control current. For the schematic, see *Section B.5 – HD-825 Brake Control Supply*.

6. Calibration

6.1 INITIAL CALIBRATION

All Magtrol instruments are calibrated prior to shipment. There is a calibration label on each unit as shown in the following figure.

Figure 6–1 Calibration Label

This label tells the user when the next calibration is required, although Magtrol does recommend that calibration be completed after the dynamometer, readout instrumentation and power supply are set up for the first time.

6.2 CALIBRATION BEAMS AND WEIGHTS

To perform a successful dynamometer calibration, a precision weight heavy enough to apply a torque at or close to the full scale rating is required. Magtrol offers precision weights (WT Series) and calibration beams (CB Series) rated specifically for each Hysteresis Dynamometer.

Note: The Pin Location represents the distance between the pin and the center of the calibration beam. See *Figure 6–4 Calibration Calculation*.

Calibration Beam Assembly	For Hysteresis Dynamometer	English				Metric and SI				
		Full Scale Torque	Pin Location	Weights		Full Scale Torque		Pin Location	Weights	
		-6N series	*in*	Size	Model	-7N series*	-8N series	*cm*	Size	Model
CB-106	HD-106	2.50 oz·in	2.500	1 oz	WT-106	183.5 g·cm	18.00 mN·m	9.18	20 g	WT-106M
CB-100	HD-100	11.00 oz·in	5.500	2 oz	WT-100	815.8 g·cm	80.0 mN·m	8.16	100 g	WT-100M
CB-400	HD-400	40.0 oz·in	5.000	8 oz	WT-400	2.86 kg·cm	280 mN·m	14.28	200 g	WT-400M
CB-500	HD-500	120.0 oz·in	7.500	1.0 lb	WT-500	8.67 kg·cm	850 mN·m	17.34	500 g	WT-500M
	HD-510									
	HD-505	240 oz·in	7.500	2.0 lb	WT-505	17.34 kg·cm	1700 mN·m	17.34	1.0 kg	WT-505M
	HD-515									
CB-700	HD-700	440 oz·in	11.000	2.5 lb	WT-700	31.61 kg·cm	3.10 N·m	31.61	1.0 kg	WT-700M
	HD-710									
	HD-705	55.0 lb·in	11.000	5.0 lb	WT-705	63.22 kg·cm	6.20 N·m	31.61	2.0 kg	WT-705M
	HD-715									
CB-800	HD-800	125.0 lb·in	15.625	8.0 lb	WT-800	142.76 kg·cm	14.00 N·m	47.59	3.0 kg	WT-800M
	HD-810									
	HD-805	250 lb·in	15.625	16.0 lb	WT-805	285.52 kg·cm	28.0 N·m	47.59	6.0 kg	WT-805M
	HD-815									
CB-825	HD-825	500 lb·in	20.000	25.0 lb	WT-825	576.14 kg·cm	56.5 N·m	38.41	15.0 kg	WT-825M

* *The -7N Full Scale Torque values are not exactly equivalant to the dynamometer ratings, but are instead representative of the actual torque produced by the WT Series weights.*

6.3 CALIBRATION PREPARATION

Before beginning the calibration procedure, the following items must be checked.

- Be sure all equipment is set for the correct power-line input voltage as specified on the original order.
- Ensure correct earth grounds on equipment.
- For instructions and operational details on how to set an open loop current, refer to your power supply manual.
- Turn on the controller or readout and power supply and allow 20 minutes for warm-up, longer if the equipment is below room temperature.

6.4 CALIBRATION PROCEDURE

The calibration procedure is as follows:

Note: Do not hang the weight until instructed to do so in step 4.

1. Place the calibration beam onto the dynamometer shaft, inserting the shaft through the center hole of the beam. Secure by tightening the clamping screws. See *Figure 6–2*.

Note: If the shaft has a flat, make sure that the flat is facing down and tighten the clamping screw(s) against the flat only.

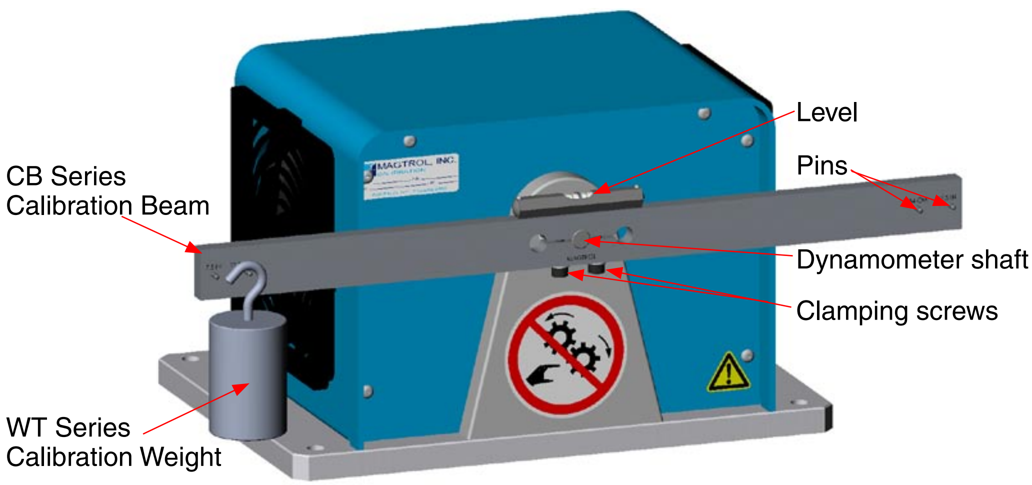


Figure 6–2 Calibration Setup

2. Apply full current to the dynamometer brake.
3. With the beam perfectly horizontal, use a flathead screwdriver to adjust the ZERO trim pot (located on the rear panel) so that the torque reading is zero ± 1 least significant dynamometer torque digit.

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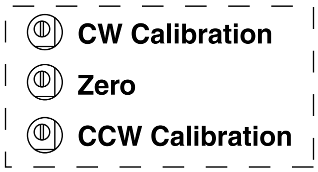

Figure 6–3 Calibration Potentiometers

4. Hang the weight from the clockwise (right) pin and level the calibration beam.

Note: To hang bottleneck weights, Magtrol recommends using only lightweight (but strong) line. Simply fashion a loop and attach it to the weight.

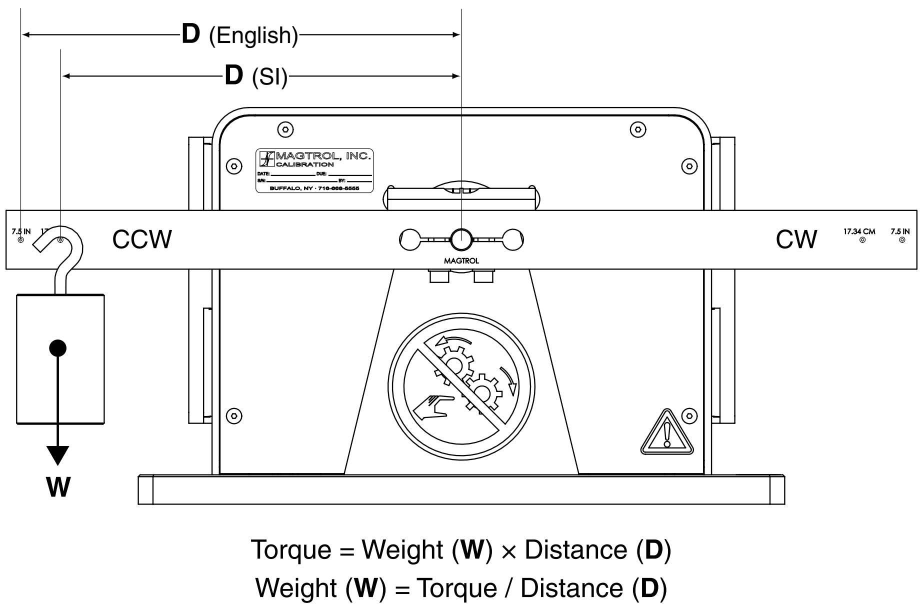

Figure 6–4 Calibration Calculation

5. Adjust the CW Calibration trim pot so that the torque reading equals the weight times the distance.

Note: If using Magtrol CB Calibration Beams in conjunction with WT Calibration Weights, simply calibrate to the full scale torque listed in the table in *Section 6.1 – Calibration Beams and Weights*.

6. Transfer the weight to the counterclockwise (left) pin and level the dynamometer.
7. Adjust the CCW Calibration trim pot so that the torque reading equals the weight times the distance. See *Note* in step #5.
8. Remove the weight from the calibration beam.

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9. Reduce the current to zero while pumping the calibration beam CW/CCW (moving it up and down). This will ensure that the rotor does not remain magnetized in one specific location (becoming "cogged"), thus preventing the shaft from rotating freely. For more information, refer to *Section 4.1.8 – Cogging*.
10. Remove the calibration beam.

The dynamometer is calibrated and ready for motor testing.

6.5 CALIBRATION FREQUENCY

Magtrol load cells are temperature compensated and designed for stability. It is a good idea to calibrate, frequently at first, maintaining a record (see *Appendix A – Calibration Record*) until you have established a history. If there appears to be excessive drift, contact Magtrol Technical Assistance.

7. Optional Features

7.1 SPEED ENCODER

All Magtrol dynamometers come standard with a 60-bit speed encoder, best suited for high-speed systems. For low speed motors, with maximum speeds of less than 200 rpm, Magtrol offers several additional encoder options, which include:

- 600-bit single encoder
- 6000-bit single encoder
- 60/600-bit dual encoder
- 60/6000-bit dual encoder

With the single higher resolution encoder option, five wires from the 600 or 6000-bit encoder run internally to the torque amplification board. All five of the wires from the encoder are then passed directly to the back panel connector.

14-pin Connector	Speed Encoder
pin 11	index pulse
pin 10	TACH_A
pin 2	TACH_B
pin 7	+5 VDC
pin 8	+5 VDC COM

With the dual encoder option, the dynamometer comes equipped with a standard 60-bit encoder and an additional 600 or 6000-bit encoder. The user can select which encoder to use via a back panel switch. (*See Figure 2–1 Rear Panel*). Five wires from the 600/6000-bit encoder run the torque amplification board. Three of the wires from the encoder are then passed directly to the back panel connector (14-pin connector, pin 11 = index pulse, pin 2 = TACH_B, pin 8 = +5VDC COM.). Two of the wires route to a double pole double throw switch. The switch selects which encoder will be powered up and routes the appropriate Tach_A signal to the 14-pin connector (14-pin connector, pin 10 = TACH_A, pin 7 = +5VDC).

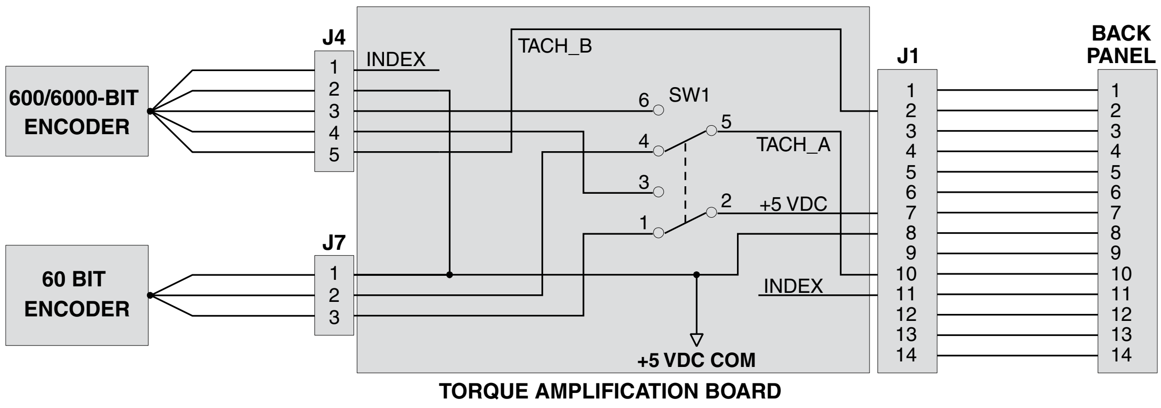

Figure 7–1 Speed Encoder Schematic

The 60 bit encoder may be used for high speed systems and the 600/6000-bit encoder for lower speed applications. Additionally the TACH_A and TACH_B signals can be quadrature decoded to give even higher resolutions and direction of rotation.

8. Troubleshooting

8.1 TORQUE READOUT PROBLEMS

8.1.1 New Dynamometer

If the dynamometer is new (never operated before) and the torque reading is near full scale and constant, the probable cause is failure to remove the shipping restraining bolt. This applies to all dynamometers with model numbers from 106 to 715. For further instruction refer to *Section 3.1 – Removal of the Load Cell/Shipping Restraining Bolt*.

8.1.2 Zero Balance

Zero balance is usually attained by the ZERO control potentiometer on the rear panel of the dynamometer. Refer to *Section 6.2 – Calibration Procedure*. If you cannot obtain a zero torque reading with zero applied torque, you will need to first make sure that your load cell is functional. To verify that the strain gauge is stable under stress, complete the following steps.

1. Install the calibration beam.
2. Set the power supply for full current.
3. Install a weight on the beam (either side) sufficient to apply close to 100% of full-scale rated torque. If the reading is stable, switch the weight to the other side of the beam.
4. Steady the weight and the beam to be sure they are motionless.

☞ Note: The torque reading may show activity, but hold steady within three or four dynamometer torque digits.

8.1.2.1 Steady Torque Reading

If the torque reading is active and steady, you will need to reestablish the zero load cell balance.

1. Adjust the zero control on the rear panel for an approximate mechanical center. This is a 20 turn control, so rotate it clockwise more than 20 turns and then counterclockwise for 10 turns.
2. Disconnect the dynamometer line cord from the line power source.
3. Turn off the digital readout device or dynamometer controller.
4. Lower the rear panel.

☞ Note: It is a good idea to clamp the rear panel to the dynamometer base plate. This will decrease the possibility of pulling on the fragile interconnection lead wires.

5. Remove resistor R20 from the torque amplification circuit board.
6. Turn on the digital readout instrument.
7. While observing (or recording) the torque reading, start with a 100 K to 200 K resistor and temporarily connect it in the R20 position on the circuit board.
8. Temporarily jumper solder link SL14. If the reading becomes larger, remove the jumper and bridge solder link SL 17. If the reading becomes smaller, remove the jumper and bridge solder link SL 14.

9. Select resistors until two adjacent resistance values, within 1% or 2% of each other, cause the reading to swing through zero. Do not use any resistance below 10K.
10. Once the correct resistance value has been established, a high quality 50 ppm/°C, 1% or better, precision resistor (RN60C or RN65C) must be obtained. Permanently solder it onto the board in the R20 position.
11. The ZERO control potentiometer, which was previously set to a mechanical center, should now trim out any remaining imbalance.

☞ Note: If something has caused the original balance to shift to such an extent that the rear panel ZERO balancing control is out of range, it is probable that more difficulties lie ahead. Whereas a new load cell might offer the best solution, these instructions may get the dynamometer operational.

8.1.2.2 Erratic Torque Reading

If the torque reading is erratic, then the problem could be a defective load cell or electronic component in the dynamometer or readout device. It will be necessary to establish specifically what is defective. At this time contact Magtrol Technical Assistance.

8.1.3 Full Scale Torque

If the dynamometer cannot obtain full torque and will not support the beam and weight at full scale, a resistance or current check may be used to help locate the problem.

8.1.3.1 Resistance Check

1. Disconnect the 2-pin connector and the dynamometer line cord.
2. Measure the resistance across the 2-pin male plug at the dynamometer.
3. Check the reading to the table below.

Dynamometer Model	Resistance @ 20 °C Ω
HD-106	171
HD-100	180
HD-400	80
HD-500	75
HD-510	75
HD-505	37.5
HD-515	37.5
HD-700	80
HD-710	80
HD-705	40
HD-715	40
HD-800	20
HD-810	20
HD-805	10
HD-815	10
HD-825	5
ED-715	40
ED-815	13

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If the reading is within ±10% of the value specified in the table, proceed to *Section 8.1.3.2 – Current Check* . If the reading is not within the values specified, contact Magtrol Technical Assistance.

Note: The resistance check in the table is accurate for Magtrol HD-106, -100, -400, -500 and -700 Series, ED-715 and HD-825 Dynamometers. The HD-800, 805, 810 and 815 Dynamometers have circuitry between the connector and the brake coil. The brake coil must be isolated from this circuitry for the resistance in the table to be accurate.

8.1.3.2 Current Check

1. Insert an ammeter between the power supply and dynamometer brake.
2. Adjust the power supply voltage until the ammeter reading is equal to the value in the following table.

Dynamometer Model	**F.S. Current** *A*
HD-106	0.145
HD-100	0.135
HD-400	0.300
HD-500	0.298
HD-510	0.298
HD-505	0.596
HD-515	0.596
HD-700	0.339
HD-710	0.339
HD-705	0.678
HD-715	0.678
HD-800	1.200
HD-810	1.200
HD-805	2.400
HD-815	2.400
HD-825	4.800
ED-715	0.678
ED-815	2.400

3. Attach the appropriate weight for full-scale torque and verify whether the brake holds the load. If it does not hold the load with proper current flowing in the brake, the power supply is not the problem. The dynamometer is probably at fault and you will need to contact Magtrol Technical Assistance for further help.

Note: The current check is accurate for all Magtrol Dynamometers.

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8.1.4 Mechanical (Rotational) Alignment

Refer to the drawing and the instructions below if the dynamometer will apply torque but the torque reading will not calibrate full scale, even though the zero balance is within tolerance. See *Figure 5–1 Mechanical Layout of a Load Cell.*

1. Disconnect all inputs and outputs on the dynamometer rear panel.
2. Disconnect the dynamometer line cord from the line power source if applicable.
3. Carefully remove the rear panel.

☞ Note: It is a good idea to clamp the rear panel to the dynamometer base plate.

4. Remove the socket-head cap screw retaining the pulse disk to the shaft.
5. Remove the pulse disk.
6. Loosen, but do not remove, the load cell clamping screw.
7. Carefully grasp the brake assembly and slowly rotate the assembly in both directions. Please note several degrees of free-swing, restrained by the damper cylinder in both directions.

☞ Note: Do not force this assembly!

The objective is to reposition the load cell in such a manner to re-establish the center of allowable rotation, restricted by the damper assembly. Devise a shim of sufficient thickness, that when inserted between the top of the damper cylinder and the damper arm, the arm will be parallel to the top of the cylinder.

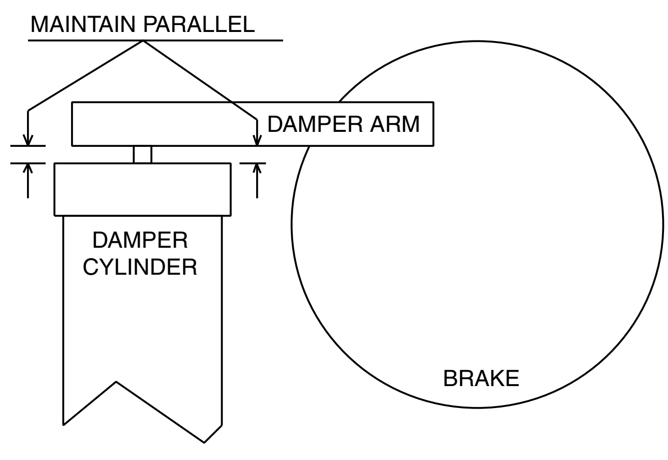


Figure 8–1 Damper Connection

The above diagram shows the location of these elements, however, you will only be able to view them from the top.

8. While pressing down on the damper arm, thus positioning the entire assembly, tighten the load cell clamping screw. Be sure the load cell assembly has not moved axially and is seated against the sleeve resting up against the inner race of the carrier bearing.
9. Remove the shim.
10. Reinstall the pulse disk, reassemble the enclosure and then recalibrate.

8.2 SPEED READOUT PROBLEMS

If there is an erratic speed reading, or no speed reading at all, remove the rear panel of the dynamometer and inspect the pulse disk. It must be tight on the rotor shaft and the shaft must rotate freely. Also, make sure that the disk is not bent or distorted. If the disk is damaged, contact Magtrol Technical Assistance for a replacement disk.

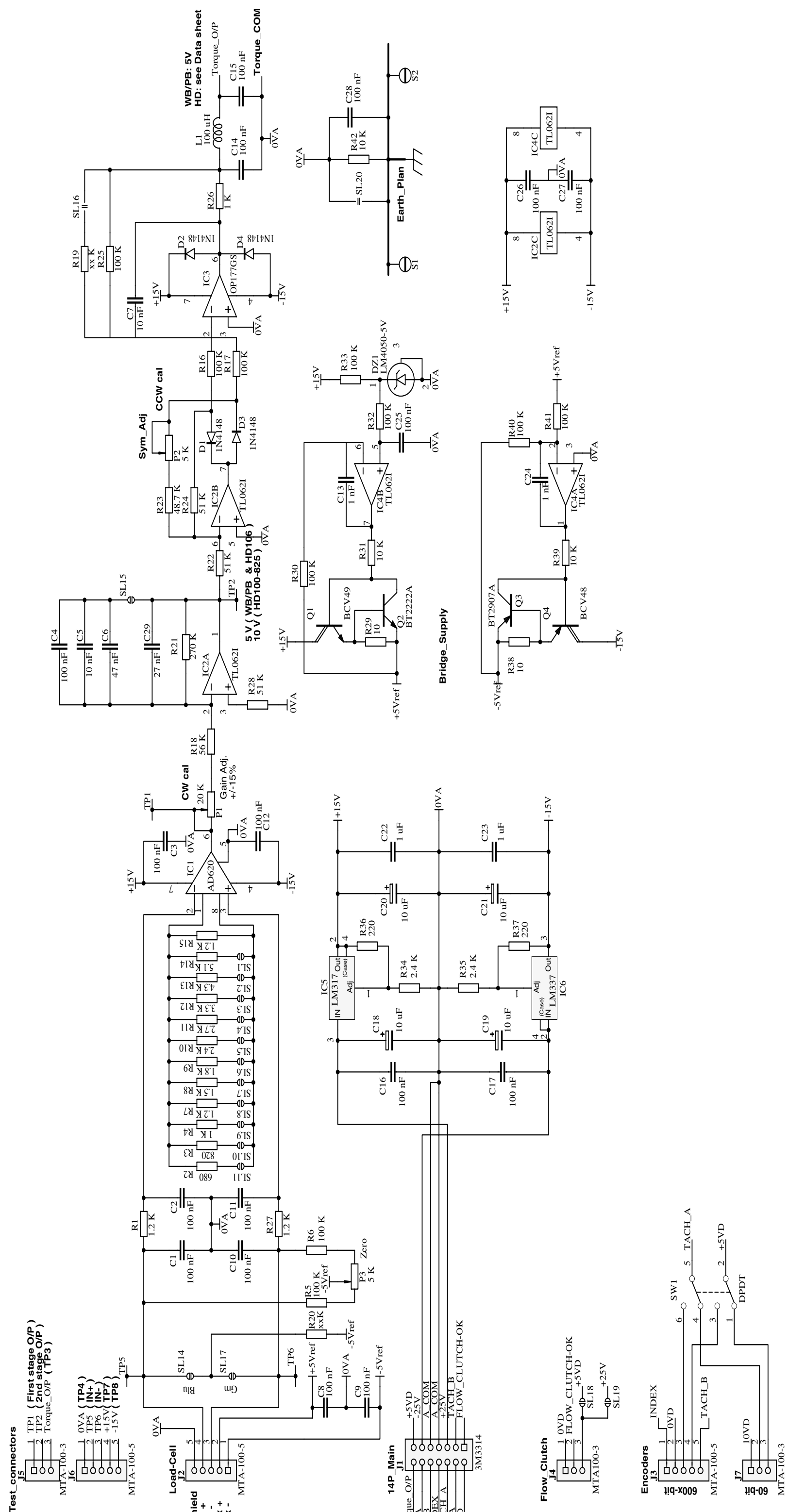
If the pulse disk appears normal, then connect an oscilloscope with the probes across pins 8 and 10 of the dynamometer 14-pin "D" connector—pin 8 is common or ground. As the disk rotates, the pulse voltage should switch between a low of about 0.4 VDC (or less) and a high of about 5 VDC. If this signal is incorrect, the problem is on the encoder optical pickup board. The encoder optical pickup is replaceable as an assembly from the Magtrol Technical Assistance Department. If this signal is correct, examine your digital readout instrument for the problem.

Appendix A: Calibration Record

DATE	DYNAMOMETER MODEL/SERIAL #	APPLIED TORQUE	INDICATED TORQUE	ERROR	TESTER

Appendix B: Schematics

B.1 TORQUE AMPLIFICATION BOARD



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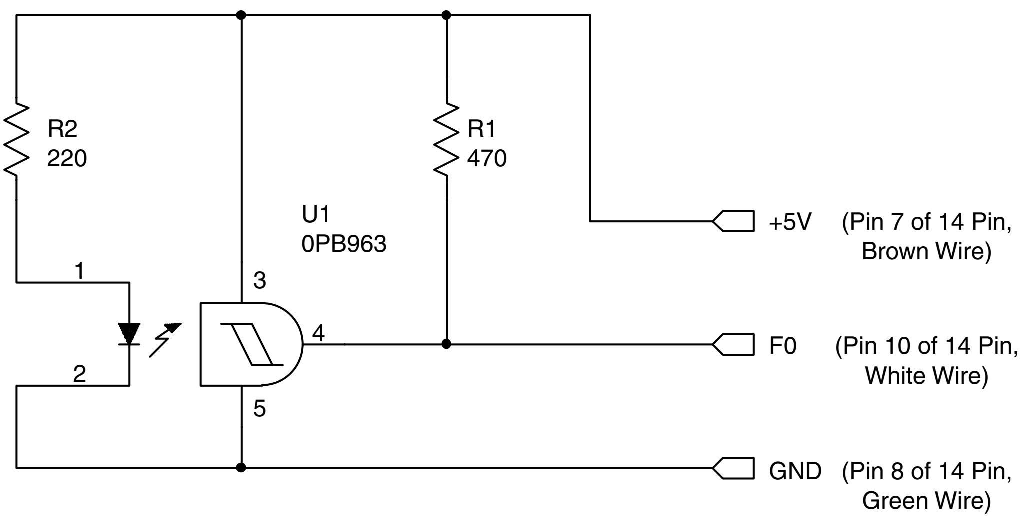
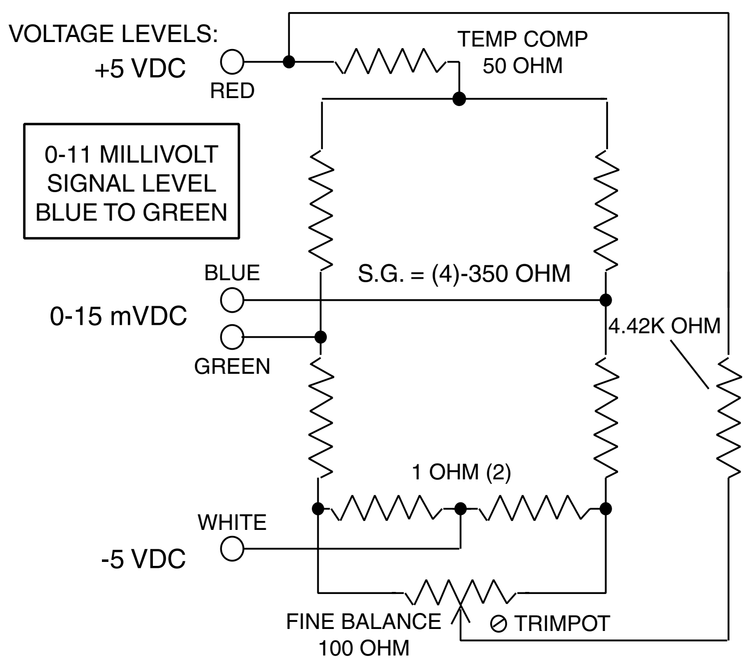
B.2 SPEED SENSOR BOARD



B.3 LOAD CELL SCHEMATIC



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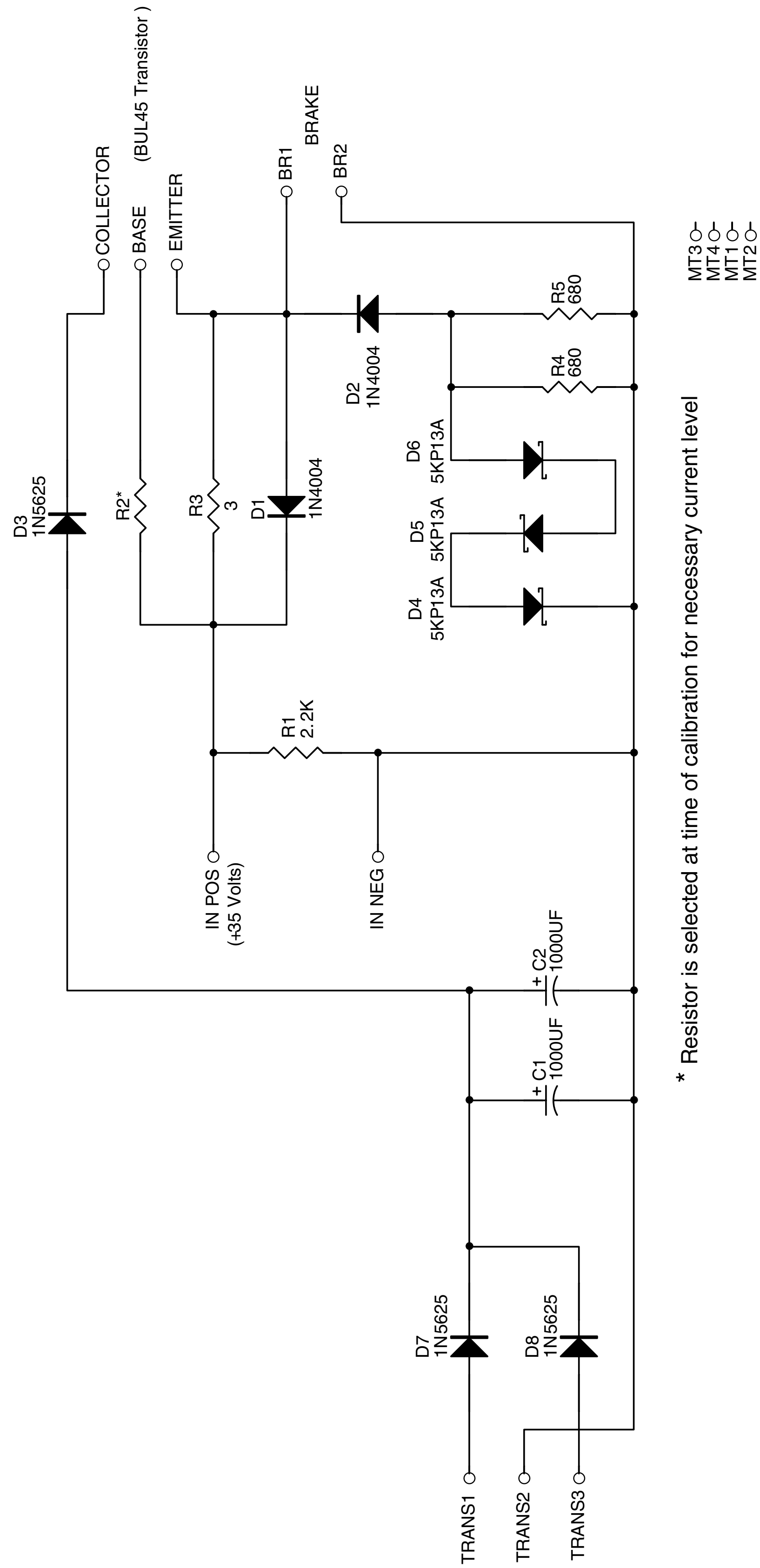
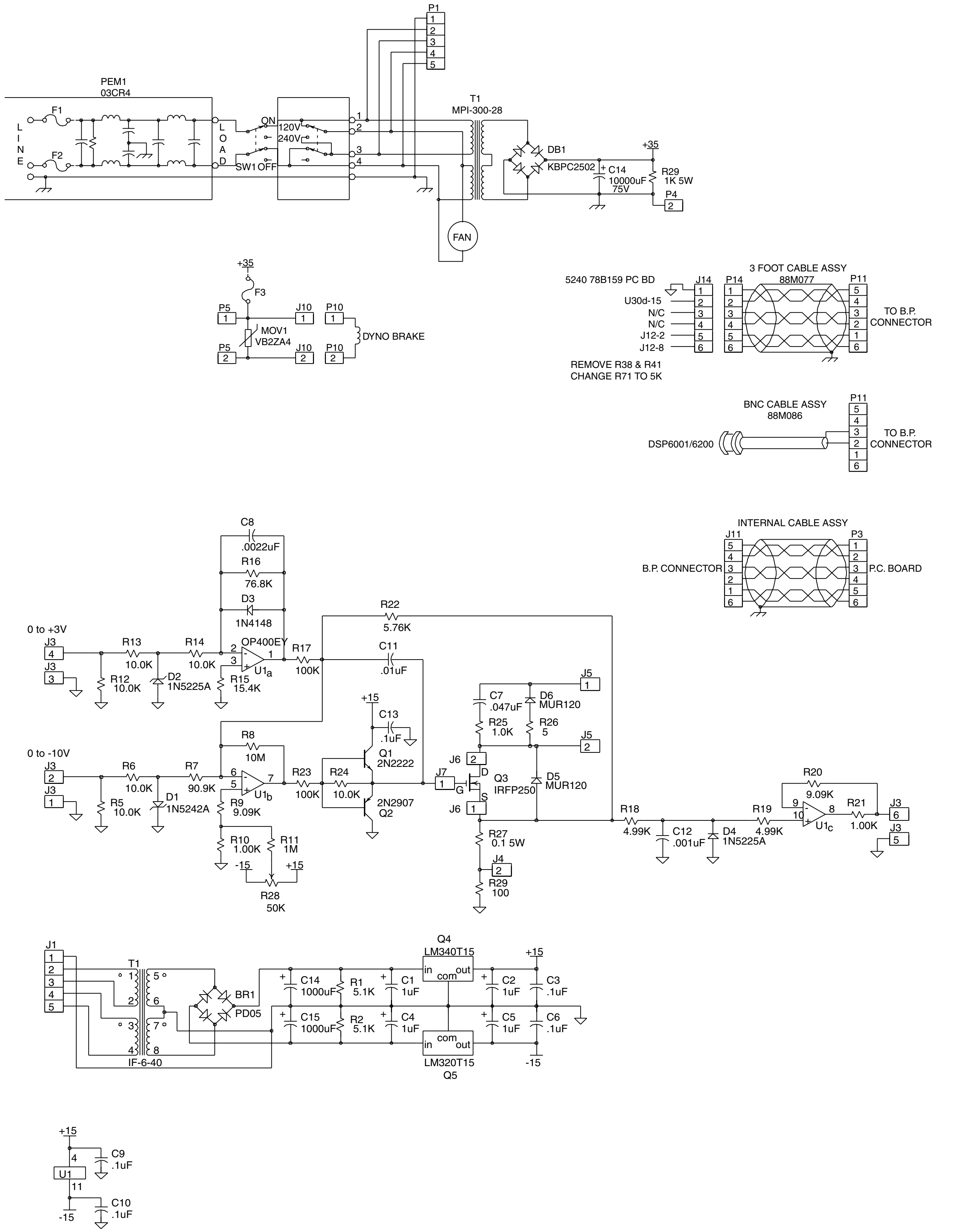
B.4 HD-800–815 BRAKE CONTROL SUPPLY



B.5 HD-825 BRAKE CONTROL SUPPLY



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Magtrol Limited Warranty

Magtrol, Inc. warrants its products to be free from defects in material and workmanship under normal use and service for a period of twenty-four (24) months from the date of shipment. Software is warranted to operate in accordance with its programmed instructions on appropriate Magtrol instruments. This warranty extends only to the original purchaser and shall not apply to fuses, computer media, or any other product which, in Magtrol's sole opinion, has been subject to misuse, alteration, abuse or abnormal conditions of operation or shipping.

Magtrol's obligation under this warranty is limited to repair or replacement of a product which is returned to the factory within the warranty period and is determined, upon examination by Magtrol, to be defective. If Magtrol determines that the defect or malfunction has been caused by misuse, alteration, abuse or abnormal conditions of operation or shipping, Magtrol will repair the product and bill the purchaser for the reasonable cost of repair. If the product is not covered by this warranty, Magtrol will, if requested by purchaser, submit an estimate of the repair costs before work is started.

To obtain repair service under this warranty, purchaser must forward the product (transportation prepaid) and a description of the malfunction to the factory. The instrument shall be repaired at the factory and returned to purchaser, transportation prepaid. **MAGTROL ASSUMES NO RISK FOR IN-TRANSIT DAMAGE.**

THE FOREGOING WARRANTY IS PURCHASER'S SOLE AND EXCLUSIVE REMEDY AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTY OF MERCHANTABILITY, OR FITNESS FOR ANY PARTICULAR PURPOSE OR USE. MAGTROL SHALL NOT BE LIABLE FOR ANY SPECIAL, INDIRECT, INCIDENTAL, OR CONSEQUENTIAL DAMAGES OR LOSS WHETHER IN CONTRACT, TORT, OR OTHERWISE.

CLAIMS

Immediately upon arrival, purchaser shall check the packing container against the enclosed packing list and shall, within thirty (30) days of arrival, give Magtrol notice of shortages or any nonconformity with the terms of the order. If purchaser fails to give notice, the delivery shall be deemed to conform with the terms of the order.

The purchaser assumes all risk of loss or damage to products upon delivery by Magtrol to the carrier. If a product is damaged in transit, PURCHASER MUST FILE ALL CLAIMS FOR DAMAGE WITH THE CARRIER to obtain compensation. Upon request by purchaser, Magtrol will submit an estimate of the cost to repair shipment damage.

Service Information

RETURNING MAGTROL EQUIPMENT FOR REPAIR AND/OR CALIBRATION

Before returning equipment to Magtrol for repair and/or calibration, please visit Magtrol's Web site at http://www.magtrol.com/support/rma.htm to begin the Return Material Authorization (RMA) process. Depending on where the equipment is located and which unit(s) will be returned, you will be directed to either ship your equipment back to Magtrol, Inc. in the United States or Magtrol SA in Switzerland.

Returning Equipment to Magtrol, Inc. (United States)

When returning equipment to Magtrol, Inc.'s factory in the United States for repair and/or calibration, a completed Return Material Authorization (RMA) form is required.

1. Visit Magtrol's Web site at http://www.magtrol.com/support/rma.htm to begin the RMA process.
2. Complete the RMA form online and submit.
3. An RMA number will be issued to you via e-mail. Include this number on all return documentation.
4. Ship your equipment to: MAGTROL, INC.
70 Gardenville Parkway
Buffalo, NY 14224
Attn: Repair Department
5. After Magtrol's Repair Department receives and analyzes your equipment, a quotation listing all the necessary parts and labor costs, if any, will be faxed or e-mailed to you.
6. After receiving your repair estimate, provide Magtrol with a P.O. number as soon as possible. A purchase order confirming the cost quoted is required before your equipment can be returned.

Returning Equipment to Magtrol SA (Switzerland)

If you are directed to ship your equipment to Switzerland, no RMA form/number is required. Just send your equipment directly to Magtrol SA in Switzerland and follow these shipment instructions:

1. Ship your equipment to: MAGTROL SA
After Sales Service
Centre technologique Montena
1728 Rossens / Fribourg
Switzerland
VAT No: 485 572
2. Please use our forwarder : TNT • 1-800-558-5555 • Account No 154033
Only ship ECONOMIC way (3 days max. within Europe)
3. Include the following documents with your equipment:
   - Delivery note with Magtrol SA's address (as listed above)
   - Three pro forma invoices with:
     - Your VAT number
     - Description of returned goods
     - Noticed failures
     - Value - for customs purposes only
     - Origin of the goods (in general, Switzerland)
4. A cost estimate for repair will be sent to you as soon as the goods have been analyzed. If the repair charges do not exceed 25% the price of a new unit, the repair or calibration will be completed without requiring prior customer authorization.

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