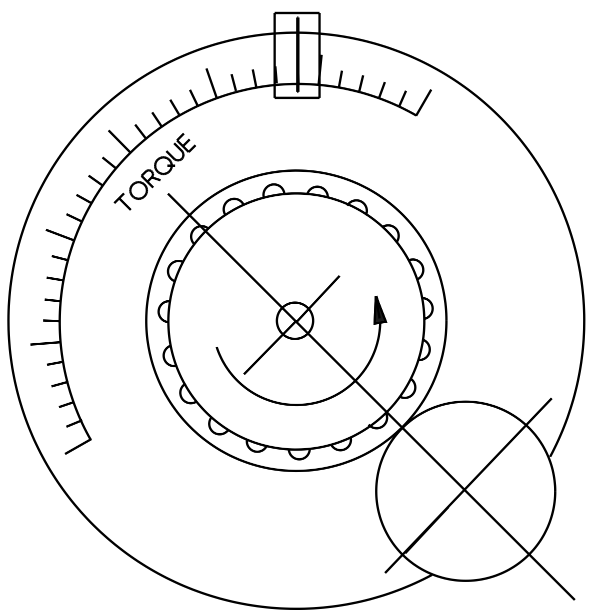
MAGTROL

Dial Weight Dynamometers



User's Manual

MAGTROL, INC.

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Manufacturers of:
Motor Test Equipment
◆
Hysteresis Brakes and Clutches

Table of Contents

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1 - Setting up the Dynamometer

UNPACKING

After unpacking the dynamometer, please check carefully through the *packing material ,* making certain that you have all dynamometer hardware, applicable power supplies and any other small items.

Retain the carton(s) until you are sure that there is no shipping damage. If there is evidence of damage, please notify the carrier and Magtrol Customer Service as soon as possible.

Install the dynamometer counter weights. They may be wrapped separately or installed on the brake. Remove any tape or packing material around the brake or weights. There should be as many weights, 2 or 3, as there are torque scales on the dynamometer dial - including the (minimum scale) weight permanently attached to the brake assembly. The dynamometer brake assembly should swing freely.

INTERCONNECTIONS

If an optional speed reading instrument, or Model 5400 Tachometer, is supplied with the dynamometer there will be two integral cord sets. These include a 14 Pin for the tachometer generator, and a 2 Pin for the brake control power supply. If there is no speed reading capability; the 14 Pin cable and internal tachometer generator are omitted. You may add these yourself at anytime - contact Magtrol Dynamometer Sales.

Connect all items together. The dynamometer controller and speed readout (if applicable) interconnections are straight forward using the cord sets.

Power supply options include the Model 5200 and the Model 5210. The 5200 operates in an "open loop" current control mode while the 5210 is a "closed loop" controller.

DYNAMOMETER LEVELING

Level the dynamometer base plate in all planes. The bubble level device on the base plate is convenient for front to back leveling. For side to side adjustment, it is more accurate to level the dynamometer by observing the torque dial for ZERO reading. It works best to use the most sensitive torque scale, by removing one, or both of the counter weights.

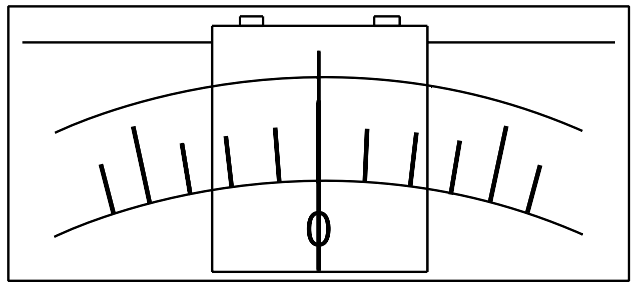


Figure 1. Torque Scale

Please note: There should be nothing connected to the dynamometer shaft.

INITIAL CHECKOUT

- Be sure the TORQUE control on the power supply is off (CCW).
- Turn on the speed readout device (if applicable) and the torque controller.
- Rotate the dynamometer shaft by hand while simultaneously adjusting the TORQUE CONTROL clockwise *very slowly*. You should feel resistance occurring on the shaft - stop at this point. If there is a speed reading instrument, RPM indication should be observed.
- Return the TORQUE CONTROL to zero.

You may notice slight torque pulsations on the shaft with the TORQUE CONTROL off. This is normal; for a further description of "salient poles" please refer to Chapter 3.

POWER DISSIPATION

All Magtrol Dynamometers are power absorption instruments. As a dynamometer loads a test motor, it is absorbing horsepower from the motor into the Hysteresis Brake. The brake converts this energy into heat.

There are finite limits to the operating temperature that any absorption brake can withstand. Rapidly rising temperature from excessive power input can cause severe mechanical distortion of the rotor assembly. This in turn may cause that rotating assembly to contact the stationary members that surround it. Once this happens, metal transfer and seizing of the brake may occur. At high shaft speeds the effect is usually memorable.

More moderate, but still excessive power over an extended period of time can result in more obscure damage; bearing lubricants break down, magnetic coil insulation degrades and/or plastic parts may warp out of shape.

The following graphs of Horsepower Vs. Time provide a reference for allowable power dissipation. Please take a moment to familiarize yourself with any limitations that may apply to your dynamometer and motor testing requirements. The Power-Time specifications assume the following conditions:

Maximum desired brake temperature = 100°C.
Ambient Temperature = 25 +/- 5°C.

The following Torque-Speed to Horsepower conversion formulas are provided for your convenience. They are sufficiently accurate (within 1%) to establish HP for use in heat rise determination curves.

$HP = Oz.In. \times RPM \times 10^{-6}$
$HP = Lb.Ft \times RPM \times 1.9 \times 10^{-4}$
$HP = Oz.Ft. \times RPM \times 1.19 \times 10^{-5}$
$HP = Lb.In. \times RPM \times 1.59 \times 10^{-5}$
$HP = G.Cm. \times RPM \times 1.38 \times 10^{-8}$
$HP = N.m. \times RPM\ 1.4 \times 10^{-4}$

The following sketch shows the identifications for shaft height "H" and diameter "D" used in the following specifications.

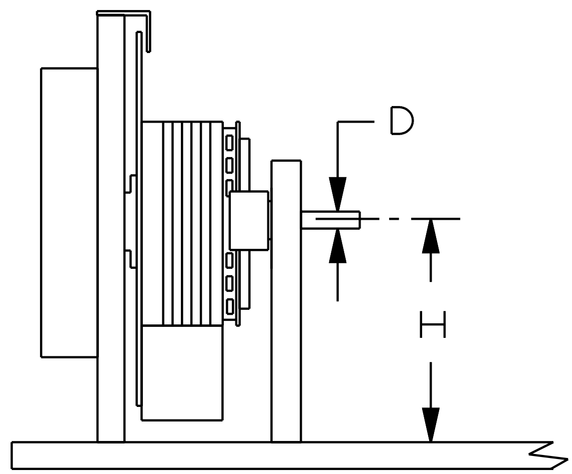
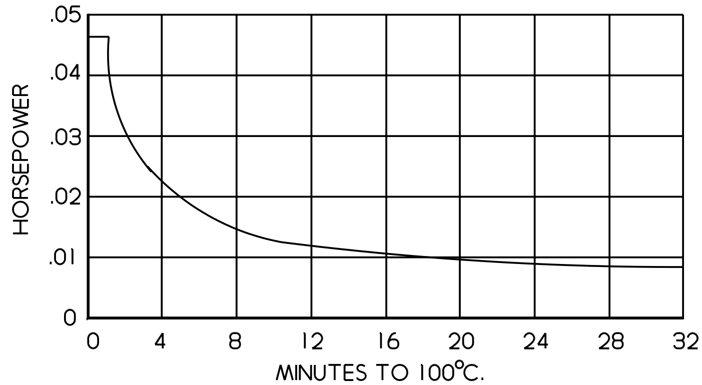


Figure 2. Dynamometer Side View

POWER ABSORPTION CURVES

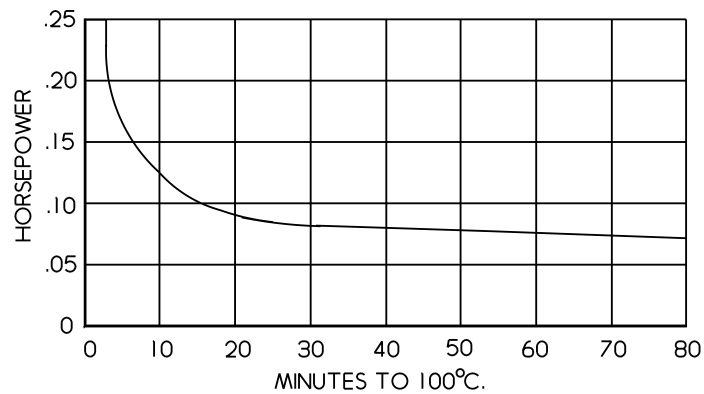
Model HD-106-1

D .1245/.1250
H 3.50
Torque Ranges 0.5 - 1.0 - 2.0 oz.in.
Input Inertia 7.04 Slug Ft² x 10^{-7}
Maximum Speed 30,000 RPM
Maximum Input Power 40 Watts



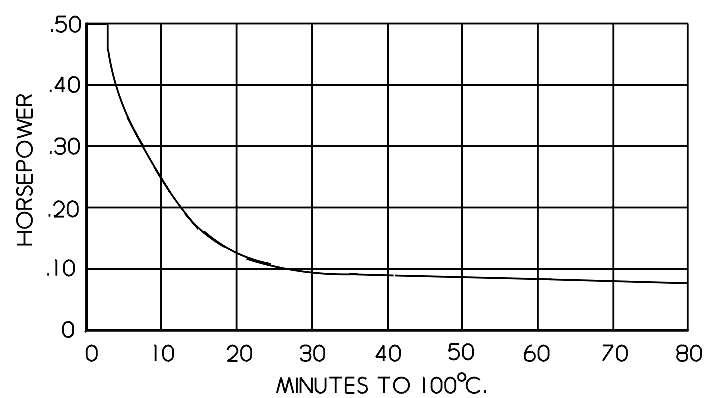
Model HD-400-1/2

D .2495/.2500
H 3.50
Torque Range (-1) 2 - 8 - 16 oz.in.
Torque Range (-2) 8 - 16 - 32 oz.in.
Input Inertia 15.5 Slug Ft² x 10^{-6}
Maximum Speed 25,000 RPM
Maximum Input Power 190 Watts



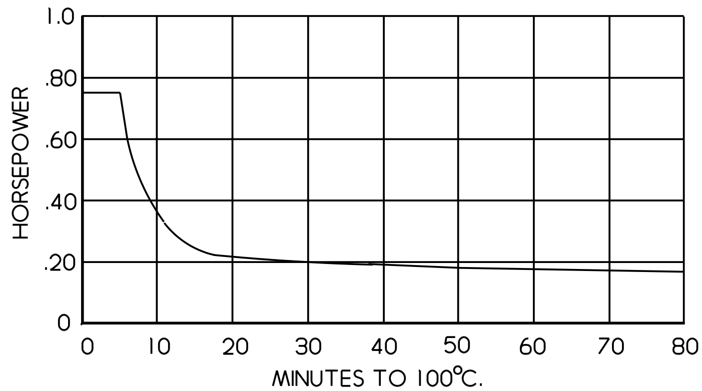
Model HD-500-1

D .3745/.3750
H 4.00
Torque Ranges 25 - 50 - 100 oz.in.
Input Inertia 80.5 Slug Ft² x 10^{-6}
Maximum Speed 20,000 RPM
Maximum Input Power 375 Watts



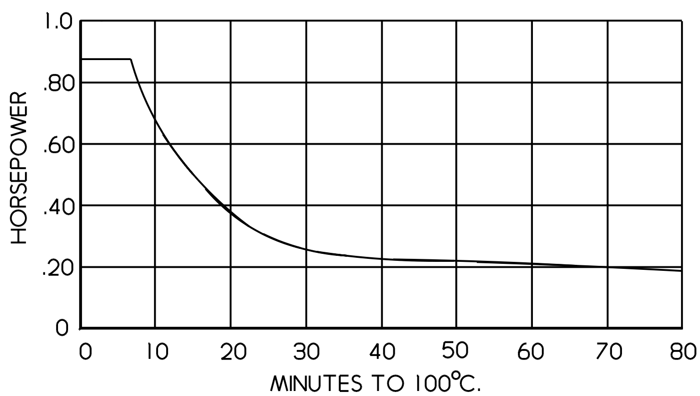
Model HD-600-1

D .4995/.5000
H 4.812
Torque Ranges 50 - 100 - 200 oz.in.
Input Inertia 233.6 Slug Ft^2 x 10^{-7}
Maximum Speed 20,000 RPM
Maximum Input Power 550 Watts



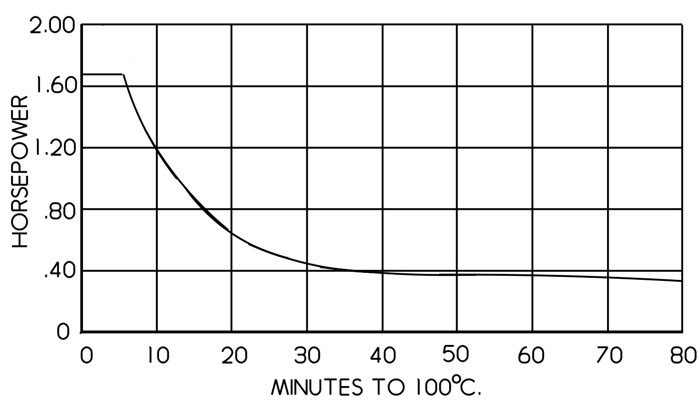
Model HD-700-1

D .4995/.5000
H 5.875
Torque Ranges 100 - 200 - 400 oz.in.
Input Inertia 551 Slug Ft^2 x 10^{-6}
Maximum Speed 15,000 RPM
Maximum Input Power 650 Watts



Model HD-705-1

D .4995/.5000
H 5.875
Torque Ranges 200 - 400 - 800 oz.in.
Input Inertia 1.100 Slug Ft^2 x 10^{-3}
Maximum Speed 10,000 RPM
Maximum Input Power 1400 Watts



ACCURACY

All Dial-Weight systems, on all ranges of each dynamometer model are calibrated to an accuracy of +/- 1% of the torque reading, with the following exceptions:

HD-106-1, .5 oz. in. scale HD-106-1, 1.0 oz. in. scale HD-400-1, 2.0 oz. in. scale HD-400-1, 8.0 oz. in. scale HD-400-2, 8.0 oz. in. scale HD-500-1, 25.0 oz. in. scale	± 2% of Full Scale

Other factors that affect accuracy are coupling losses and dynamic windage effects.

- Coupling losses: After a period of running, depending on the size of the motor-dynamometer, if the coupling becomes hot to the touch, or if the dynamometer/motor vibrate badly, coupling loss error can be in the order of several percent. Please see Chapter 3.

- Windage: This effect is described more extensively below. At speeds up to 6000 RPM it is negligible.

GENERAL STATEMENT OF ACCURACY

Much of the above is dependant upon motor horsepower, fixturing and other circumstances beyond the control of Magtrol. As a general rule, if reasonable care in taking readings is exercised, motor test data accuracy better than 1.5% of a torque-speed value can be expected.

Some torque scale graduations are more difficult to read (rapidly) than others. What usually works well for most people, is to record torque data points from the easiest reading scale; then correct all your data to correspond to the particular range (counterweight) selected, by multiplying - or dividing - by 2 or 4.

WINDAGE

Although a smooth surface, the dynamometer rotor will drag air around with it. Most of this air movement 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. This becomes error, since it is produced by the test motor - but not part of the dynamometer reading.

Windage effect on accuracy has been conducted on all Magtrol Dynamometers. Pumping loss is between the range of .025% and .20%, of maximum (full scale) torque, at the maximum rated RPM. The larger figure tending toward the smallest capacity (HD-106) dynamometer. Since pumping loss increases by the square of an increase in speed, above maximum rated RPM the error magnifies rapidly; conversely, at speeds below rated RPM the effect quickly becomes immeasurably small.

FRICTION

Some friction exists in the carrier bearings. Correctly loaded and lubricated, it is negligible. The level may be quantitatively established by doing the following.

- Remove all attachments to the dynamometer shaft.

- Swing the brake assembly up to full scale - by hand.

- Carefully allow the assembly to return to zero without swinging back and forth.

- Repeat the above in the other direction, if necessary, and observe the amount the reading is off zero.

Any difference should be within the accuracy specifications outlined above. During actual motor testing there is usually enough system vibration to maintain the carrier bearings "settled," negating frictional effects.

If you should determine there is an excessive drag or "stickiness," mechanical realignment (axial preloading) may be necessary. Please contact Magtrol Customer Service for assistance.

MOTOR FIXTURING

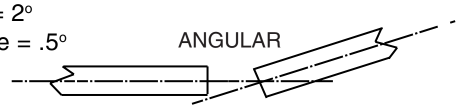
Because of the wide variety of motor shapes and sizes, Magtrol cannot provide standard motor mounting fixtures. We will be pleased to quote the fabrication of special fixturing for you. Contact Magtrol Customer Service.

When mounting your test motor, please consider the following:

- Construct precise fixturing that provides good shaft alignment.
- Secure the test motor torsionally in the fixture, 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 motors may be similarly affected.
- The dynamometer base plate material is 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.

The following is a general recommendation of allowable shaft misalignment as a guide. The tolerances specified assume the use of high quality double flexure couplings. This type of coupling - two flexing elements separated by a solid link - inherently tolerate greater parallel offset. If you would like specific coupling recommendations contact Magtrol Customer Service.

1 Lb.In. range = 2°
300 Lb.In. range = .5°



1 Lb.In. range = .015
300 Lb.In. range = .030

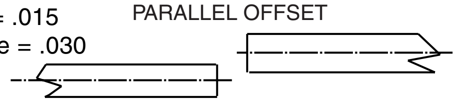


Figure 3. Typical Allowable Misalignment

SAFETY

For general safety considerations, when shaft speeds exceed a few hundred RPM, or motor horsepower attains significant levels, 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.
- *Always* wear safety glasses when working around dynamometer test equipment.
- Never allow anyone to stand close to the side of, or lean over, a shaft coupling.
- *Insulate* electrical (internal and external) motor connections well. A power line short into the dynamometer base could pass a transient surge through all interconnected instruments - and *you too* if you're not careful! Always connect the motor frame to a high current capacity (water pipe) earth ground.
- Be sure the motor control circuit breakers cannot be confused or tripped by accident, at the wrong time. Variable autotransformers are especially hazardous: Someone plugs something in - thinking that the transformer is set to zero, but - *zap - it's not*!

VIBRATION

All dynamometer rotating component assemblies are precision balanced. However, the dynamometer shaft has some overhang. Overhang makes any assembly less stiff and more vulnerable to radial forces.

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

Shaft couplings operating at speeds above their design limits, are the worst hazard. Many couplings contain somewhat loosely supported flexure elements. When overdriven, excessive centrifugal force may displace these out of axial alignment. As this happens they immediately begin to absorb energy; instantaneous, severe vibration ensues, and the various coupling elements may disconnect from each other - go their separate ways - spectacularly.

SALIENT POLE EFFECT (COGGING)

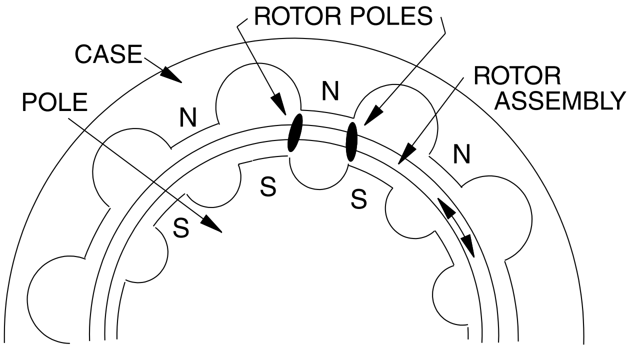


Figure 4. Hysteresis Brake Cross-section

The cross section sketch 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 magnetic rotor of the hysteresis 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, in that, first it tries to resist rotation - 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 torque onto the dynamometer. Then - decrease the torque control *while* the shaft is rotating.

SPEED

If your dynamometer contains a speed pickup, there will be two cords; one terminating with a two pin plug for the brake power, the other is a 14 pin plug servicing an optical encoder.

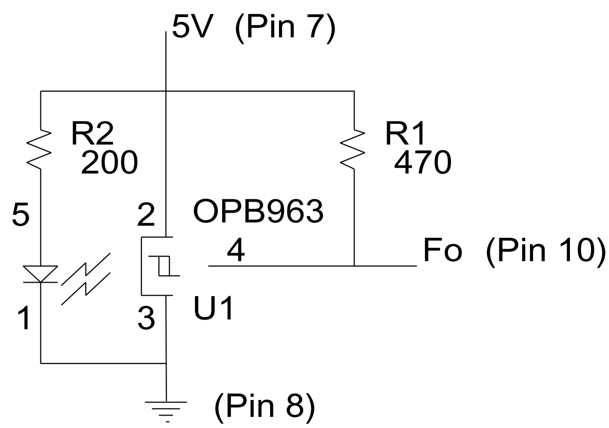


Figure 5. Optical Encoder Circuit

This encoder consists of an infrared transmitter/ receiver pair. On the end of the dynamometer shaft, positioned between the LED and detector, is an optical disc with opaque and clear segments. Rotation of the disc results in the detector generating a frequency of 60 pulses per shaft revolution.

TORQUE

Torsional force, acting upon the hysteresis brake, is produced by the test motor, and applied to the brake's rotor-shaft assembly. Whatever torque exists on the rotor-shaft, must be reacted upon equally by the suspended brake-dial-weight assembly. Sir Isaac Newton defined this effect some time ago.

Since the brake assembly is imbalanced by the suspended weight attached to it, torsional force will lift the weight. The graduated dial provides a readout value equal to this torque. Once the weights are calibrated to match the dial graduations, the system accuracy becomes permanently fixed.

When torque is defined by a point on the radius of a weight, lifted in a circular motion, the scale derivation is inherently a cosine function - thus, the nonlinear scale graduations.

TORQUE CALIBRATION

If you wish to check the torque calibration accuracy, it will be necessary to apply a precisely known torque value. The most accurate method to apply a known torque is with the use of a *beam and weight* system.

Figure 7 shows the calibration set up using a beam with pins installed at a precise distance from the shaft centerline. There are various sizes of these torque beams available from Magtrol. Contact Magtrol Dynamometer Sales.

- First, apply full torque onto the dynamometer to restrain the shaft from rotating.
- Attach a calibrated and balanced beam onto the dynamometer shaft. Lock the beam with the locking screw against the flat on the shaft.
- Suspend a known weight, at a known distance, on the beam.
- By restraining the beam from rotation, and maintaining it in a level position, lift the weight-dial assembly until a balance is attained between the assembly and the beam. Observe the deviation, if any, and you have established the system accuracy.

Please note: The calibration beam must be maintained exactly level at all times. Also, to attach a weight onto a pin , fashion a *loop* of light, but strong line - or thread, on the weight. Do not use a wire hook. Hooks apply the force slightly off the centerline of a pin, thereby creating an albeit small; but measurable error.

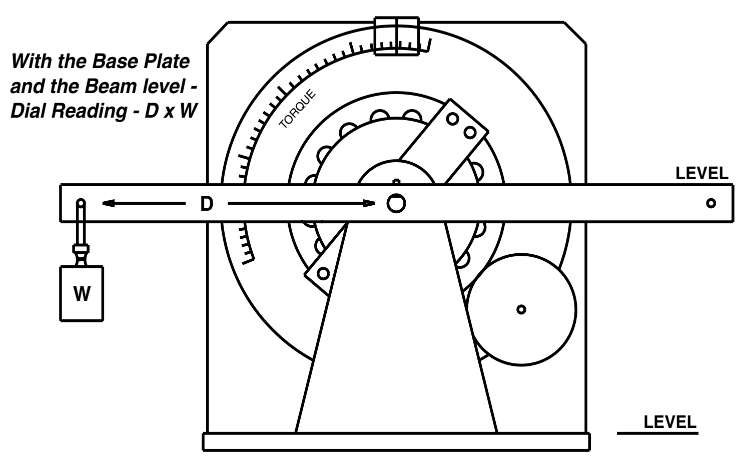


Figure 6. Calibration Set-up

HYSTERESIS BRAKE CONTROL POWER

Hysteresis brakes require direct current for torque control. They will not respond to alternating current above a few Hz. The nominal voltage rating for all Magtrol Hysteresis Brakes is 28 VDC. The following is a listing of the resistance and current, for each brake, by Dynamometer Model.

Model	Res. Ohms	F.S.Current
HD-106	171	.164
HD-100	180	.155
HD-400	80	.350
HD-500	120	.233
HD-700	80	.350
HD-705	40	.700

TORQUE STABILITY

A major advantage in using a hysteresis brake as a loading means, is the ability to produce torque essentially independent of speed. This permits very low speed and locked rotor torque testing.

Besides control current, there are two other factors that have a minor secondary influence on hysteresis brake torque. Please note that the torque changes in the following explanations are always part of the actual torque measured - as applied to a test motor - and *not errors.*

EDDY CURRENTS EFFECTS

Magnetically induced currents within the brake rotor cause an increase in brake torque proportional to an increase in speed. These are referred to as *Eddy Currents*.

As hysteresis brakes become larger, both the rotor surface velocity, and the rotor cross sectional area increases. These factors compound, such that eddy current generation is much more significant on larger size dynamometers. On the smaller dynamometer sizes, the eddy current torque component *adds* approximately 2% to 4% per thousand RPM to a static (fixed current) torque value.

TEMPERATURE RISE EFFECTS

Temperature rise has a more complex effect on hysteresis brake load torque - and is difficult to quantify.

As the brake heats, differential expansions cause dimensional changes, that tend to *increase* torque. Conversely, the rotor's electrical resistivity increases with torque-speed load, resulting in decreased eddy current generation - tending to *decrease* torque. The time frame for these opposing factors is unmatched and variable. Now, toss in a few other things like thinning bearing lubricants, Curie effects on magnetic materials, and a precise evaluation of "change in torque-Vs.-temperature", becomes very complex to define.

From torque (stability) Vs. time (at various HP levels) tests, we have found that where brake current and RPM remain fixed, you may expect a gradual torque increase over a period of several minutes. This increase will generally stabilize at approximately 0.5% per unit of torque per thousand RPM - on smaller (up to HD-500) dynamometers, up to 1.5% per unit of torque per thousand RPM on the larger sizes.

MODEL 5200-2

Torque is controlled by adjusting a ten turn ADJUST control that is located on the front panel of the 5200-2 power supply. This control adjusts the output voltage to the dynamometer coil from 0 to about 34 volts DC. Since this voltage is unregulated, the dynamometer coil current will vary as a function of coil temperature (resistance changes) and line voltage. As the dynamometer torque is proportional to power supply current, the torque variation will also be a function of both coil temperature and line voltage. If these fluctuations are undesirable for your application, you should order the current regulated power supply, MAGTROL Model 5210-2.

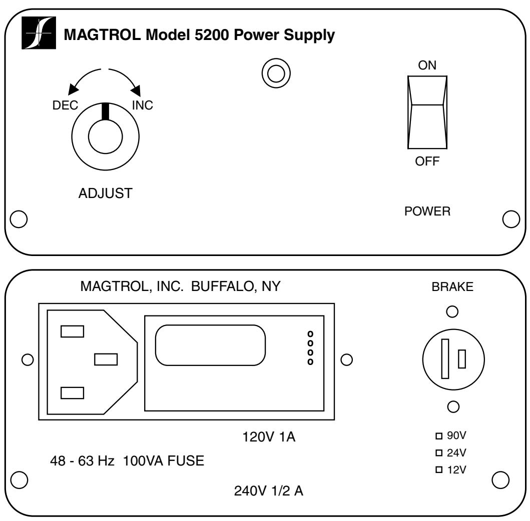


Figure 7. Model 5200 Front and Rear Panels

MODEL 5200-2 CIRCUIT DESCRIPTION

Hysteresis brake control power must be in the form of direct current. The transformer, bridge rectifier and filter capacitor provide a source of DC power from the AC line voltage. Transistor Q1 is a PNP Darlington power device connected as an emitter follower to amplify the control potentiometer voltage setting. CR2 is a transient suppression diode connected in parallel with the brake coil to absorb negative inductive surges.

The 5200-2 was shipped set for 120 Vrms power. This can be verified by observing the location of the round white tab in the fuse holder of the power line filter module that is located on the rear panel - it should show through the 120 V hole. Line power can be set for 240 Vrms by removing the fuse holder to access the inner module. Then, remove the small circuit board with the white tab. The white tab is rotated and repositioned so that when the board and the fuse holder are reinserted, the round point of the white tab now inserts into the small round hole on the fuse holder that is opposite the 240 V position.

NOTE: Of the four (4) voltage positions shown on the fuse holder, only the 120 V and the 240 V positions are active. Selecting either the 100 V or the 220 V position will not apply line power to the power supply. Therefore, use only the 120 V or 240 V positions.

NOTE: The line cord must be removed before removing the fuse holder.

Fuse replacement:
Pry out the fuse holder with the blade of a small screwdriver, remove and replace the fuse. For 120 Vrms power, use a 1 Amp fuse. For 240 Vrms power, use a 1/2 Amp fuse.

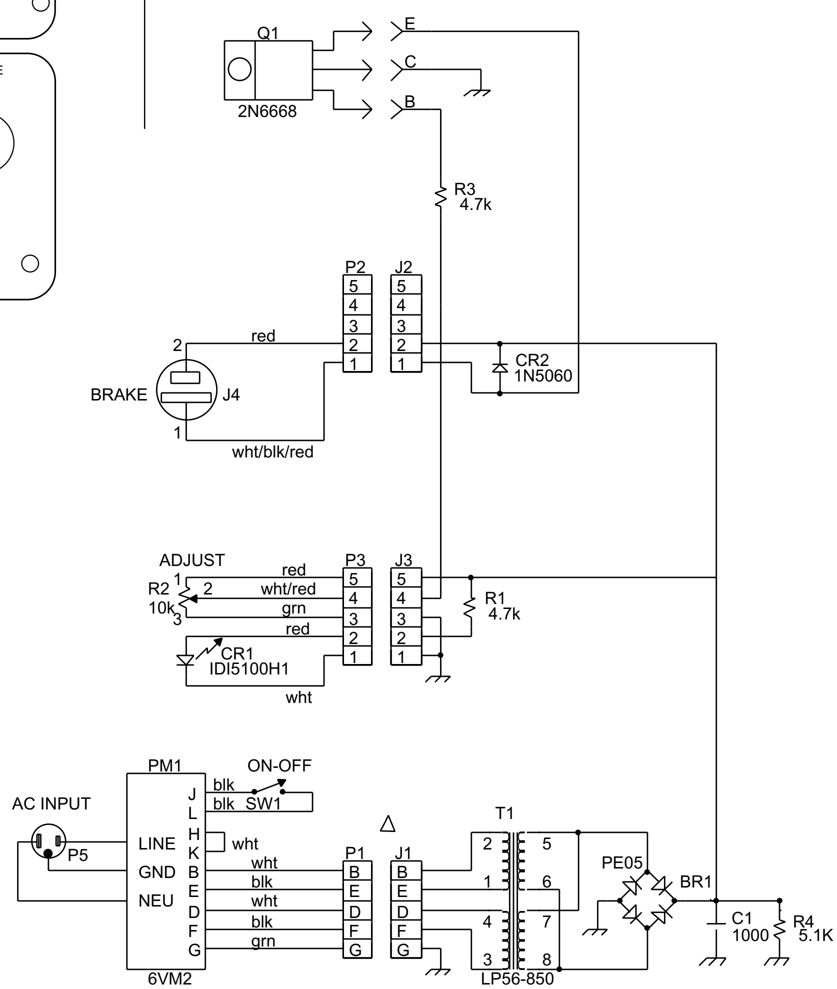


Figure 8. Model 5200-2 Schematic

MODEL 5210-2

This power supply is similar in application to the Model 5200-2, except that the 5210-2 is current regulated. This means that the brake operating current is maintained constant at the set level. The torque variations resulting from fluctuations in either the AC line voltage or resistance changes within the dynamometer coil are greatly reduced. Other secondary factors that affect torque stability, described on page 21, will still apply.

The 5210-2 is universal for all Magtrol Dynamometers. However, because of the wide range of full scale current requirements; 0 to .164 amps (HD-106) to 0 to .700 amps (HD-705), a three position current range control provides improved torque resolution control. The three settings, HIGH, MED and LOW determine the full scale current level of the power supply. Full scale for the HIGH, MED and LOW ranges are 1.0, 0.5 and 0.2 Amps, respectively. The digital panel meter indicates the current output level to within plus or minus 1% .

Starting on the LOW current range, with the ADJUST knob set fully counter clockwise (zero current), increase (INC) current until the desired torque is obtained. Select the next higher RANGE as necessary to obtain this torque.

There are three dash-number variations of the 5210 series of power supplies, each with a different maximum voltage output. The 5210-1 is 90 volts, 5210-2 is 24 volts, and the 5210-3 is 12 volts. All dynamometers are designed with a 24 volt coil, therefore, the 5210-2 is the only power supply you should use with a dynamometer. The 5210-1 and 5210-3 are for use with MAGTROL brakes and should not be used with a dynamometer.

The 5210-2 is shipped wired for 120 Vrms power. Line voltage can be set for 240 Vrms, as is done for the model 5200-2. Refer to page 23 of the MODEL 5200-2 Circuit Description for instructions.

An EXTERNAL CONTROL input is provided at the rear of the 5210-2 to adjust the dynamometer current from an external 0 to + 5.0 Vdc input. This input is scaled for 5.0 Vdc equals the full scale output current of each current range (0.2, 0.5 and 1.0 Amp). The EXTERNAL CONTROL input plug is a MAGTROL p/n 85M034 (Switchcraft 750). When this connector is plugged in, the front panel ADJUST control is nonfunctional.

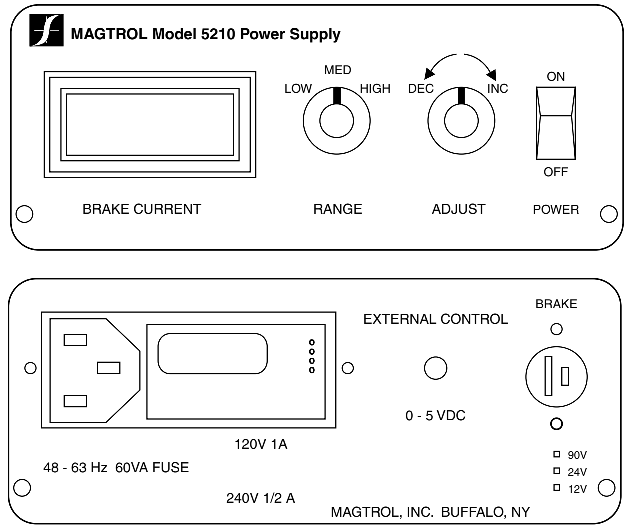


Figure 9. Model 5210 Front and Rear Panels

MODEL 5210-2 CIRCUIT DESCRIPTION

Functionally, the circuit is a closed loop, current feedback amplifier regulating the output current at the value set by the front panel controls.

DC current from the internal 35 volt power supply passes through the dynamometer coil connected at the BRAKE connector J6, through the insulated gate field effect transistor Q1 (HEXFET), and through a current sense resistor R13, R14 or R15 (selected by the RANGE control). The voltage drop across the current sense resistor is amplified by Operational Amplifier U1b and applied to the non-inverting differential input of Operational Amplifier U1a. Amplifier U1a amplifies the difference between the conditioned current signal from the sense resistor and the voltage from the front panel current ADJUST potentiometer, R6. This amplified error voltage is applied to the gate of transistor Q1 to control its channel resistance and thereby regulates the output current at the value set by the ADJUST control.

Current is displayed by a 3 1/2 digit liquid crystal panel meter.

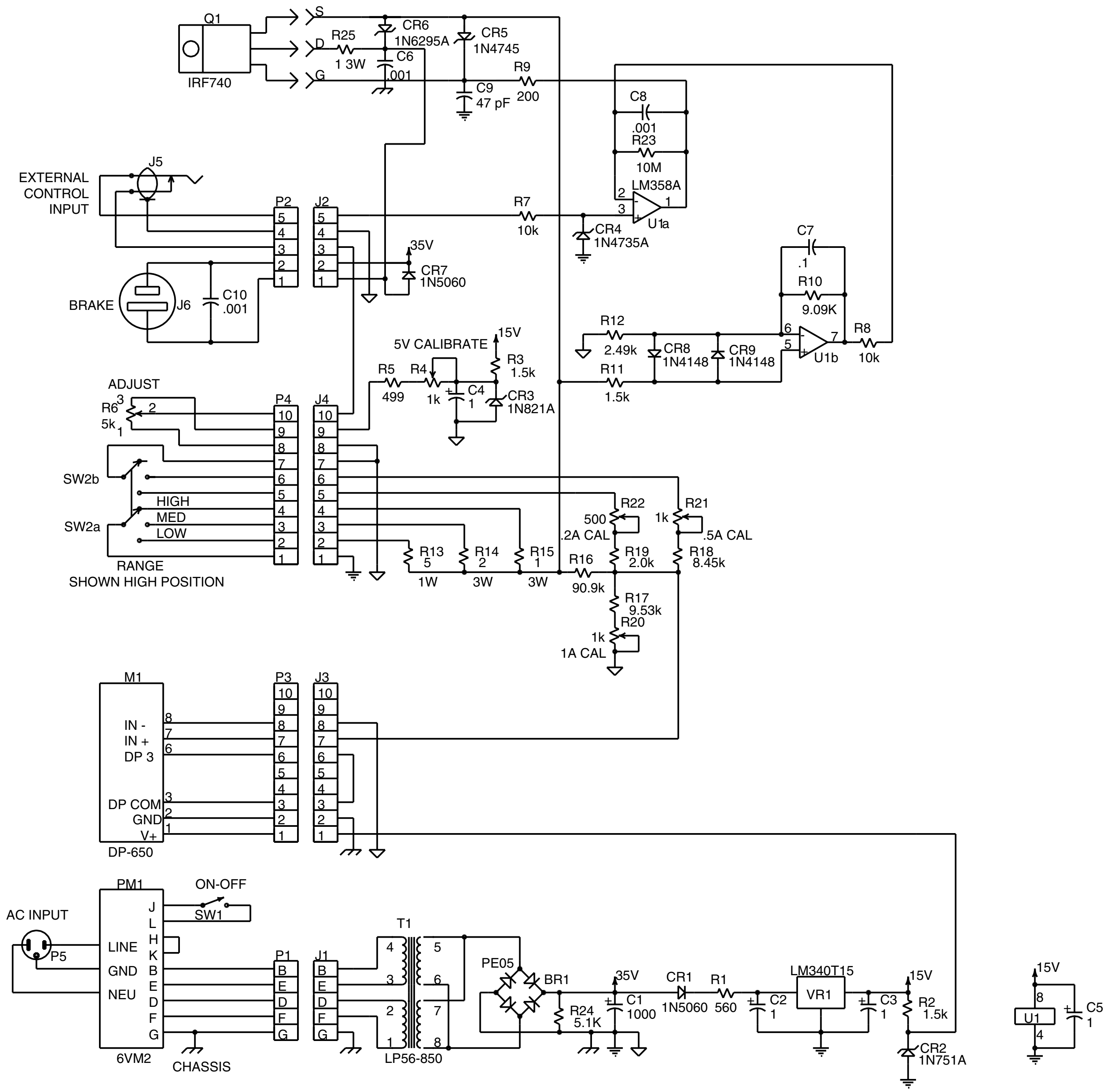


Figure 10. Model 5200-2 Schematic

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