TECHNICAL BULLETIN

DESIGN GUIDELINES

MODEL FEA

SPRING-APPLIED ELECTRIC MULTIPLE DISC CLUTCHES and BRAKES

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Model FEA Spring-Applied Electric Multiple Disc Clutches and Brakes

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1 Introduction

1.1 About Carlyle Johnson

Carlyle Johnson manufactures clutches, brakes, torque limiters, overload release clutches, fail-safe brakes, and power take-off packages for many applications. Electric, mechanical, pneumatic, and hydraulic powered clutches and brakes are available. From submarines to the Space Shuttle; military armored vehicles to commercial aircraft; machine tools to medical devices; packaging machines to printing presses; oil drilling equipment to rocket launchers; and hundreds of other applications where power-transmission equipment is installed, Carlyle Johnson Maxitorq® clutches and brakes provide long-life and trouble-free service. Original Equipment Manufacturers have known for almost 100 years that their products will perform better and more reliably if Carlyle Johnson Maxitorq® power transmission products are specified.

This bulletin deals with the model FEA electric spring-applied clutches and brakes - sometimes referred to as "fail-safe" because they engage when power is *removed* - a family of devices which can handle torque from 12 lb-ft to 240 lb-ft. Five standard models cover this range. Many special designs have also been created, running in both dry and oil-bathed applications, to solve specific problems outside the performance range of our catalog standards.

Maximum life of FEA clutches and brakes can be achieved with careful attention to size, installation, and application. This publication details the technical characteristics of the Maxitorq® model FEA devices. Engineering and applications personnel at Carlyle Johnson are always available to provide additional data, assist in applications, and suggest solutions to unique or difficult power transmission design problems. You may contact the factory toll-free at 1-888-MAXITORQ (1-888-629-4867) between 8:00 A.M. and 5:00 P.M. Eastern Time, during normal workdays, for technical assistance, pricing, and delivery information.

1.2 Related Publications

Clutch Dimensions, etc. Brochure *"Maxitorq® Fail-Safe Electric Clutches and Brakes"* available from Carlyle Johnson or your authorized Representative / Distributor

Clutch Maintenance and Repair Booklet *"Maxitorq® Model FEA Electric Multiple Disc Clutches and Brakes – Maintenance / Repair / Troubleshooting Manual"* available from Carlyle Johnson

1.3 How to contact Carlyle Johnson

Carlyle Johnson may be reached from 8:00 A.M. to 5:00 P.M. in the Eastern Time Zone of the United States, during normal workdays.

Telephone: 1 - (860) 643-1531 Option "3" SALES then select from the following:
- Option "1" for Spare Parts
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Internet: http://www.cjmco.com

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2 Application - Theory of Operation

2.1 Application

Carlyle Johnson Model FEA spring-applied clutches and brakes are appropriate in applications which have the following characteristics:

As a clutch, where the clutch will be normally engaged and only occasionally disengaged. By allowing the springs to mechanically maintain engagement, no power is present at the coil, reducing power consumption and eliminating the necessity of considering heat buildup over long periods of engagement;

As a brake, where it is necessary to engage the brake immediately on loss of power or when the voltage to the coil is removed when a jam or safety fault occurs;

Or where an electric clutch/brake is needed, but special nonmagnetic disc material is desired for its friction characteristics - since the FEA series does not utilize 'through the disc' magnetic flux paths.

2.2 Theory of Operation

Maxitorq® Model FEA Fail-Safe clutches and brakes are spring-set. When power is applied to the coil, the armature plate is disengaged, separating the multiple discs and allowing free rotation (see Figure 1 for an exploded parts diagram). The device is then in its "disengaged" position.

If power to the coil is interrupted, de-energizing the coil allows the springs to compress the multiple friction discs, thereby "engaging" the device.

When used as a brake, removing the power source allows the springs to compress the discs, engaging the brake and bringing the rotating device to a stop.

When used as a clutch, removing the power source allows the spring to compress the discs, engaging the device and coupling the driving and driven elements of the rotating equipment.

Model FEA units are sometimes referred to as "fail-safe" when used in brake applications, because they require power to keep them disengaged; when power is interrupted the springs automatically engage the unit.

Torque capability of the FEA clutches and brakes is fixed. An adjustable end plate is supplied to compensate for wear over the life of the unit. By turning the adjusting ring, the air gap can be set precisely to allow for full disengagement. This setting can be held by tightening a locking screw, and reset when necessary by loosening the screw and turning the End Plate adjusting ring. Adjustment is seldom required.

2.3 Related Products

Carlyle Johnson also manufactures a line of spring-set brakes with torque ratings from 1,200 lb-ft. to below 180 lb-in. Please contact the factory and request information on Model SAB and FEB Spring-Set Brakes.

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3 Design Guidelines – Mechanical

3.1 Mounting

Model FEA clutches and brakes are normally mounted on a finished shaft with a key to transmit torque.

Used as a brake, the unit engages a stationary cup which is usually secured to a fixed frame member. When the coil is energized, the armature plate is disengaged allowing the multiple discs to separate. The brake is then in a disengaged state and free to rotate.

There is no provision within the brake itself to secure it to the shaft. Typically, the end is set against either a shoulder in the shaft, a spacer, a retaining ring, a shaft collar or clamping screw.

The cup is mounted on a stationary frame member (if used as a brake) or some type of power transmission component (if used as a clutch) such as a pulley, sheave, sprocket, gear, or a coupling hub. As a clutch, the power transmission component must be separated from the shaft with an anti-friction bearing suitable to the application.

When used as a clutch, the drive cup may be either the driving or driven element. Normally the cup is driven; however inertia considerations may require the driving element to be the cup.

The proper distance between the clutch and the drive cup must be maintained. See Figure 2 for a typical clutch and brake application.

3.2 Alignment

The drive cup and the clutch body must be held concentric within .005 TIR. One design approach which will assure this concentricity when applied as a clutch, is the use of an alignment bearing as shown in Figure 2. The bearing and drive cup adapter are supplied by the customer or are available from Carlyle Johnson as an optional accessory; they are not included in the standard catalog clutch configuration.

See Table 1 and Figure 2 for tolerance on axial position by clutch model.

If an alignment bearing is not used, care must be taken during design to maintain both the cup-to-housing dimension, as well as their concentricity and angular displacement.

3.3 Anti-rotation Strap

The stationary coil housing assembly contains an NPT nipple which is to be used both as an attachment for electrical conduit, and an anti-rotation strap. All models have 1/2” NPT straight threads. See Figure 2 for a typical installation.

Even though the clutch housing is mounted on ball bearings, some bearing torque may be transmitted into the housing assembly due to rotation, particularly at low temperatures. The electrical lead wires are not capable of serving as an anti-rotation device.

Depending on rigid conduit to act as an anti-rotation device is not recommended. Additional care must be taken during design and installation to prevent rigid conduit from loading the clutch bearings, which will lead to accelerated wear of the device, as well as interference with operation, particularly neutral drag.

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3.4 Dry vs. Oil Bath

Maxitorq® Model FEA devices can be run either dry or in an oil bath. If the clutch is run in oil, the oil must not contain any extreme pressure additives. Extreme pressure additives will degrade the clutch's ability to transmit torque.

The use of ATF oils such as Dextron II are recommended for oil-bathed applications.

Table 1 "Mechanical Characteristics" shows the RPM limits for dry clutch applications. Contact the factory for RPM limitations when clutches are run in oil.

3.5 Constant-slip Applications

Maxitorq® clutches and brakes are not designed to be run in constant-slip applications, whether run dry or in oil. Voltage must always be sufficient to permit full disengagement of the multiple discs. See Section 4 for further information.

3.6 Neutral Drag

A small amount of torque is transmitted in the neutral or "disengaged" position. This is normal for multi-disc clutches and brakes.

At very low speeds, up to 2% of the rated static torque may be transmitted in dry applications. This value will fall to 1% or less at high speeds.

3.7 Drive Cups

Carlyle Johnson can supply internal or external flange drive cups. See Figure 2 for typical illustrations. Special design drive cups can also be engineered and produced.

Wherever possible, ball bearings are recommended to support drive cups and assure good clutch/drive cup alignment. If oil impregnated bronze bearings are used, ample flange area on the bearing must be provided to take any end thrust between the drive cup and clutch body which may be transmitted by the power transmission components.

3.8 Clutch to Drive Cup Relationship

Torque is transmitted from the lugs on the Outer Discs to the clutch cup. Care should be taken to make certain that the cup engages all of the Outer Discs uniformly.

In addition, the clutch cup "fingers" must not contact the Buttress Plate. Figure 2 shows the typical clearance between the cup fingers and the Buttress Plate.

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4 Design Guidelines – Electrical

4.1 Power Supply

Performance data in Table 2 “Electrical Data” were derived using a standard Carlyle Johnson Model CEC Power Supply. Other power supply sources may yield less favorable clutch performance figures.

Switching should be done on the DC positive (+) leg of the circuit. Suitable suppression is incorporated into the circuit of the Carlyle Johnson CEC Power Supply to provide acceptable switch life.

Carlyle Johnson has special power supply designs to enhance the performance of the clutch. Soft start power supplies, and over-energizing power supplies can be used for slower or quicker clutch engagement. For power savings, reduced holding voltage power supplies are available, as are special power supplies to meet your specific needs. Contact the factory for information.

Caution is advised when cycling the clutch directly from a PLC output or other electrically sensitive device. The inductance of the clutch coil is extremely high, as are inrush and outrush currents. Contact the factory for assistance in power supply selection when over-energizing the clutch or using a PLC for clutch power.

Table 2 shows the power draw for FEA clutches.

4.2 Voltage / Power Requirements

Standard FEA Maxitorq® clutches are provided with either 24 or 100 volt DC coils. Other voltages are available - Carlyle Johnson stocks coils with voltages ranging between 12 and 240 volts DC. Please contact the factory for information.

Voltage supplied to the clutch must be within 10% of the coil rating to achieve full disengagement.

Full power must be applied for at least one second. Thereafter, power may be reduced by 50% once the clutch is fully disengaged. This will allow the clutch/brake to achieve faster engagement time when power is removed, as well as reducing power consumption during long periods of disengagement.

4.3 Electrical Leads

Clutches are supplied with lead wires which protrude through the coil housing in a fitting that has a standard NPT straight thread. The typical length of these leads is 30”. There is no polarity to the leads – either one may be considered positive (+).

When making electrical connections, follow NEC standards and/or other governing electrical codes.

4.4 Fuses

Fuses must be capable of tolerating 135% of the nominal clutch power draw. Fuse recommendations are contained in Table 2 – Electrical Data. These values represent normal application of Model FEA clutches. Buss AGC series fuses will provide the proper inrush/outrush current protection.

The fuse protects upstream equipment – such as the power supply – not the clutch. Design considerations must include the effect of a potential coil short circuit, should one occur.

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4.5 Arc Suppression

The clutch coil acts as a large inductor in the control circuit. When the coil is de-energized (engaging the clutch/brake), a reverse voltage spike is generated by the clutch coil and transmitted back through the clutch circuit. This reverse voltage spike can be very high, and unless suppressed, can cause damage to the switch and/or coil.

There are three types of arc suppression commonly used. Their application and effect on disengagement speed are as follows:

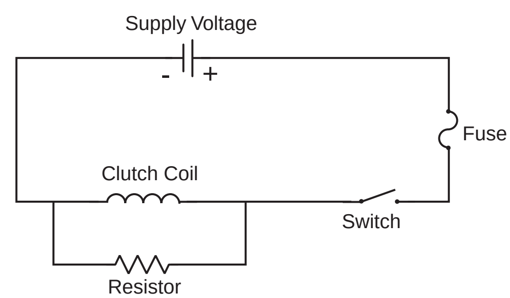
Resistor or Varistor - used for normal disengagement speed

Capacitor or Zener Diode - used for fast disengagement speed

Diode - Used for slow disengagement speed, and when arcing is to be completely eliminated.

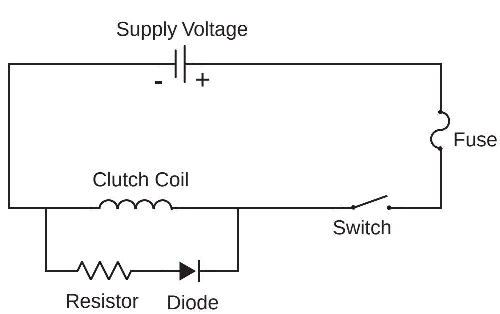
Using a Resistor for Arc Suppression

For most applications, a simple resistor connected in parallel with the clutch coil will suffice (see Schematic 1 below). The value of the resistor should be five to six times the coil resistance (see Table 2 at the back of this Bulletin for coil resistance values). The resistor should be rated for wattage equal to about 25% of the coil's power rating (see Table 2).

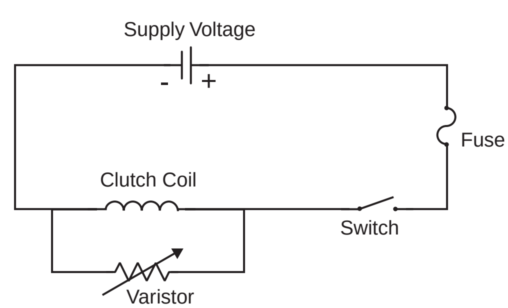


SCHEMATIC 1

To eliminate the power dissipated by the resistor while the clutch is energized, a varistor alone or a diode in series with the resistor may be used (See Schematics 2 and 3). For a 100-volt coil, use a 1N5402 diode with a 200 PIV rating, and for a 24-volt circuit, use a 1N5401 diode with a 100 PIV rating. The varistor should be equivalent to a Siemens S14K35 (24-volt coil) or equivalent to a Siemens S14K275 (100-volt coil).



SCHEMATIC 2

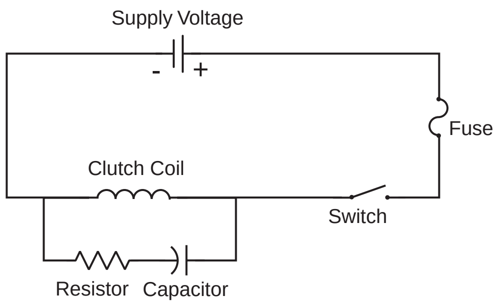


SCHEMATIC 3

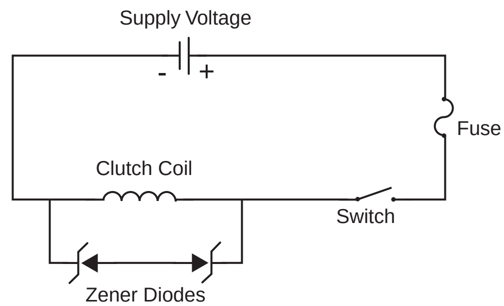
DESIGN GUIDELINES

Using a Capacitor or Zener Diode for Arc Suppression

For applications that require a fast clutch or brake engagement, a capacitor in series, or transient suppressor zener diodes should be connected in parallel with the clutch coil (See Schematics 4 and 5).



SCHEMATIC 4

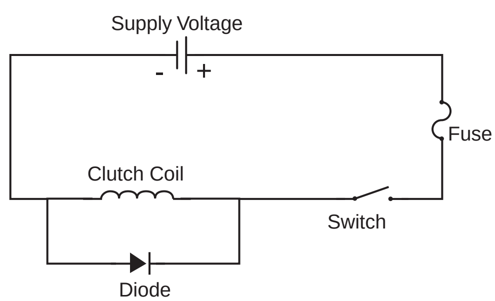


SCHEMATIC 5

The capacitor used must be bipolar such as a motor starter capacitor. When a capacitor larger than 50 mfd. in is used for arc suppression, a resistor should be connected in series with it. This is required in order to limit the capacitor charging current, so that the switch or power supply will not be overloaded. The resistor should be approximately 15 ohms for both a 100-volt coil and a 24-volt coil.

Using a Diode for Arc Suppression

If it is desirable to delay the engagement time, a diode should be used (see Schematic 6). For a 100-volt circuit, use a 1N5402 diode with 200 PIV rating, and for a 24-volt circuit, use a 1N5401 diode with a 100 PIV rating.



SCHEMATIC 6

DESIGN GUIDELINES

5 Operating Parameters

5.1 Torque Ratings

Table 1 reflects the static torque handling capability of the FEA clutches. Dynamic torque varies with speed but as a rule of thumb at 1800 RPM it is approximately 50% of static torque. Table 1 shows the full static and dynamic torque at rated voltage and 1800 RPM.

To calculate actual torque required for your application, refer to the formula in Appendix 1

5.2 Engagement / Disengagement Times

When disengaging clutch, full voltage (± 10%) is required to overcome the spring forces. After one second at full voltage, ‘holding voltage’ equal to 50% of the coil rating will keep the clutch disengaged and spinning freely. This will reduce the engagement time, as well as reduce power consumption.

5.3 Cycle Rate

The maximum cycle rate is limited by the ability of the clutch to dissipate heat. Table 1 shows the heat dissipation of the family of FEA Maxitorq® clutches running dry.

Heat dissipation is influenced by the inertia of the rotating components; the rotation speed of the clutch; and the cycle rate. Refer to the appropriate formula in Appendix 1, which can be used to calculate the heat generated from clutch cycling.

Once a clutch size has been selected by determining the torque capability of the drive components, it is recommended that the heat dissipation capability of the specified clutch be checked. Even though the model selected may have the appropriate torque rating for a device, frequently designers must move up to a larger model to accommodate the heat dissipation requirements of the application.

5.4 Rotation / Speed

Maxitorq® clutches can rotate in either direction; in addition the driving member can be either the clutch drive cup or the clutch body. Inertia considerations may dictate which element is driven, and which is the driving element.

Maximum RPM for standard conditions are shown in Table 1. Contact the factory for additional information about higher speed applications. Carlyle Johnson has experience with rotating components at speeds up to 40,000 RPM.

5.5 Inertia

The data in Table 1 details the inertia of the clutch components. When sizing a clutch for dynamic engagement, inertia of the driving and driven components must be considered. The formulas in Appendix 1 show how to utilize the inertia values of the system to determine the clutch size. If assistance is required to determine system inertia, please contact the factory.

When calculating inertia of the clutch/brake and its components, the drive cup and outer discs must be included, unless the device is applied as a brake and the cup is the stationary element. In the examples given in Appendix 2, the inertia figures used include the clutch (from Table 1), the outer discs, and an internal flange drive cup. As a brake, the inertia of the stationary elements should not be included in the calculation.

MODEL FEA ELECTRIC SPRING-APPLIED MULTI-DISC CLUTCH
MECHANICAL DATA

CLUTCH MODEL	TORQUE (LB-FT)		STANDARD BORE SIZE[2] (in)		AXIAL POSITION (min in ± .005)	MAX RPM[3]	TEMP LIMITS (° F)		HEAT DISSIPATION[1] (BTU / MIN)	INERTIA (WK^2) ($LB\text{-}FT^2$)				THEORETICAL BACKLASH	
	DYNAMIC	STATIC	MIN	MAX		DRY	COIL	BEARINGS		CLUTCH	OUTER DISCS	INTERNAL FLANGE CUP	EXTERNAL FLANGE CUP	ANGULAR MAXIMUM	RADIAL@ CUP O.D,
FEA0375	6	12	3/4	7/8	0.3750	5,000	500°	300°	5.5	0.043	0.010	0.020	0.040	2° 36'	.095”
FEA0425	12	25	1	1 1/8	0.3125	5,000	500°	300°	9.5	0.070	0.015	0.030	0.060	2° 22'	.094”
FEA0475	25	50	1 1/4	1 3/8	0.4375	3,600	500°	300°	13.5	0.110	0.020	0.050	0.100	2° 03'	.093”
FEA0625	50	100	1 3/4	1 7/8	0.5000	3,600	500°	300°	20.5	0.659	0.070	0.160	0.230	1° 34'	.092”
FEA0800	120	240	2	2 1/4	0.5000	3,600	500°	300°	30.0	1.334	0.230	0.430	0.620	1° 16'	.094”

NOTES
1 - For clutches run dry
2 - Special bore sizes are available - contact factory.
3 - Standard applications - see factory for higher speed applications

Table 1

MODEL FEA ELECTRIC SPRING-APPLIED MULTI-DISC CLUTCH
ELECTRICAL DATA

CLUTCH MODEL	24 VOLT DC COIL[3]					100 VOLT DC COIL[3]				
	POWER (WATTS)[4]	CURRENT (AMPS)	RESISTANCE (Ω)	RECOMMENDED FUSE (AMPS)[1]	COIL INDUCTANCE (mH)	POWER (WATTS)	CURRENT (AMPS)	RESISTANCE (Ω)	RECOMMENDED FUSE (AMPS)[1]	COIL INDUCTANCE (mH)
FEA0375	40	1.7	14	2 1/2	50	40	0.4	250	1	750
FEA0425	40	1.7	14	2 1/2	60	40	0.4	250	1	850
FEA0475	50	2.1	12	3	65	50	0.5	200	1	950
FEA0625	50	2.1	12	3	75	50	0.5	200	1	1,000
FEA0800	80	3.3	7	4	85	80	0.8	125	1 1/4	1,200

NOTES

1 - Fuses must be able to tolerate an inrush current equal to 135% of their rated value for a minimum of 1 second

2 - Times obtained using standard Carlyle Johnson Model CEC Power Supply

3 - at 65º F

4 - Approximate

Table 2

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Model FEA Spring-Applied Electric Multiple Disc Clutches and Brakes

Exploded Parts Diagram - Model FEA

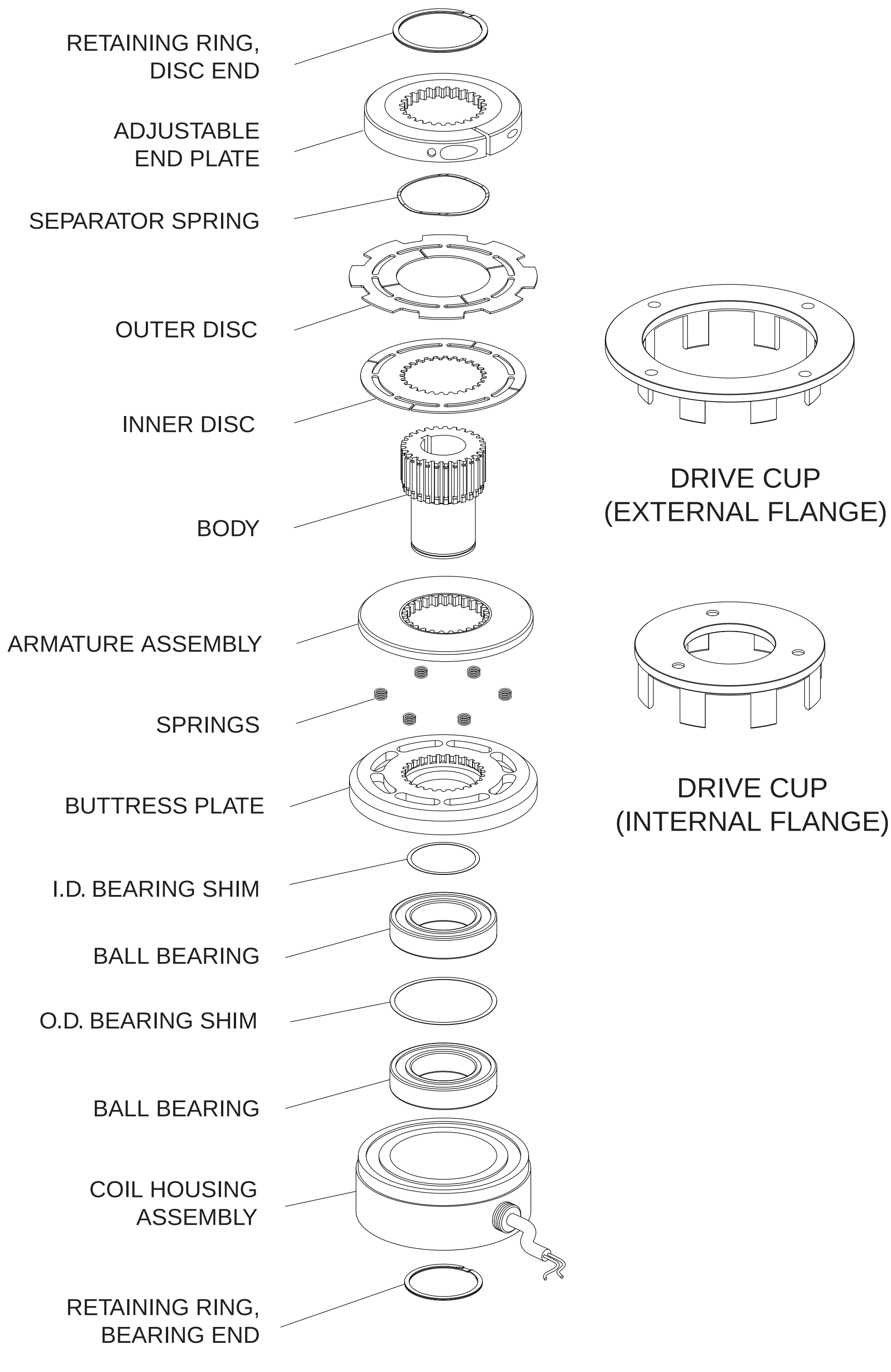


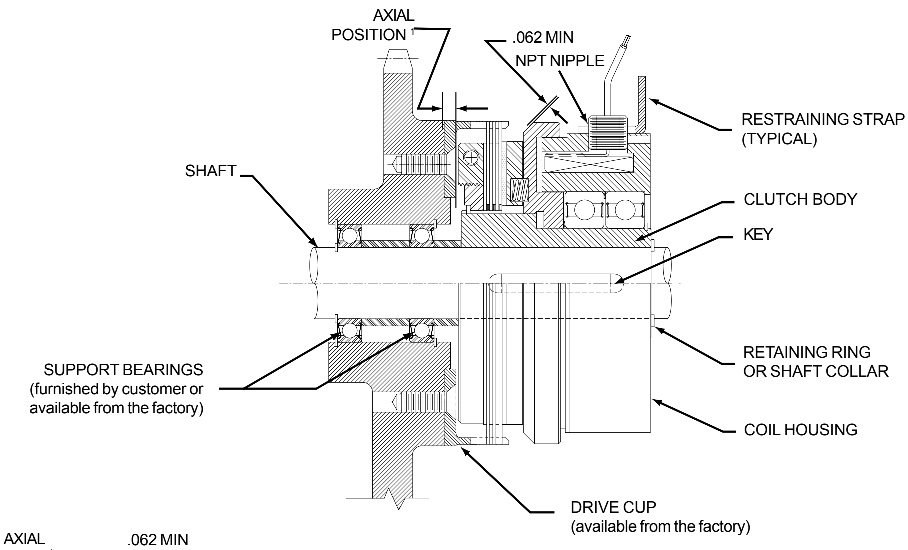
Figure 1

The Carlyle Johnson Machine Company, LLC

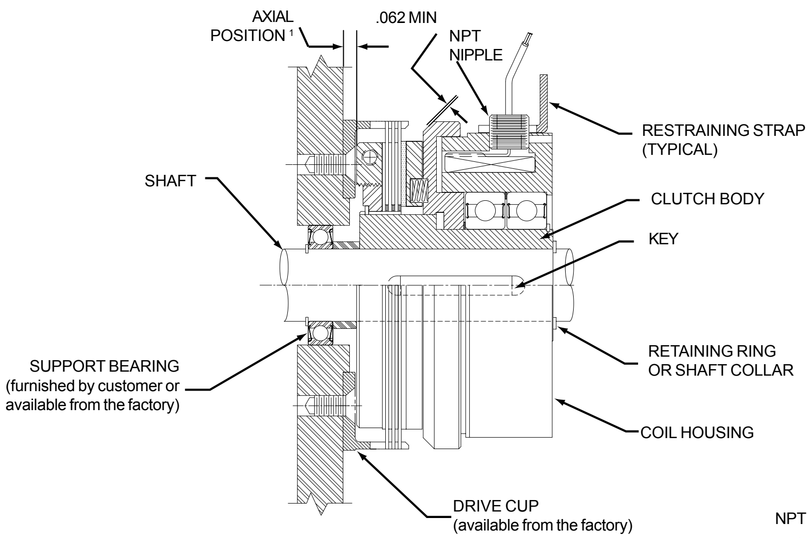
Model FEA Spring-Applied Electric Multiple Disc Clutches and Brakes

Typical Applications

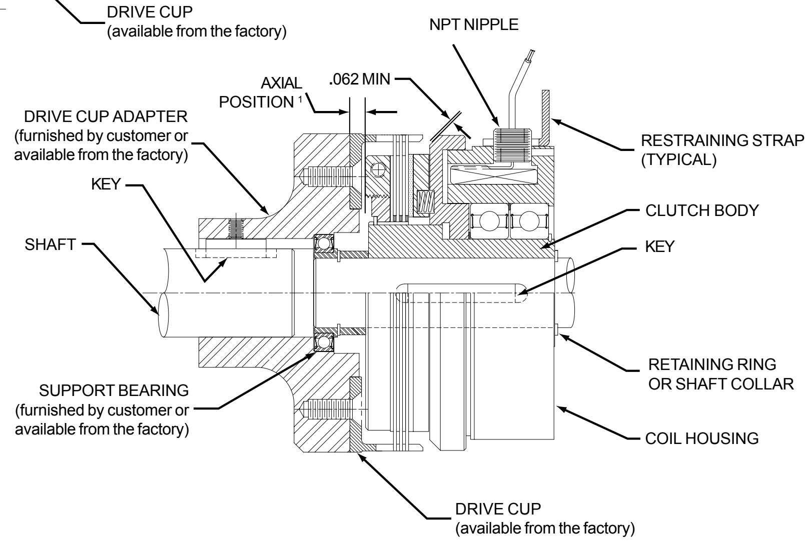
Clutch



Brake



Cut-off Coupling



NOTE 1 - See Table 1 for dimensions by clutch model

Figure 2

FORMULAS

Formula 1 - Torque based on Inertia and Time

$$\text{Dynamic Torque}_{ave} = \frac{(WK^2)(\Delta N)}{308(t)}$$

Dynamic Torque is expressed in (lb ft)
N = Speed (RPM)
$(\Delta N) = N_i - N_o$ where N_i = Input speed; N_o = Output speed
(WK^2) = Inertia (lb ft^2) of the clutch and system
$(WK^2) = (WK^2_{system}) + (WK^2_{clutch\ components})$
t = time (sec)

See Appendix 2 for sample calculations.

Formula 2 - Torque based on Drive Components

$$\text{Torque}_{ave} = \frac{(5250)(HP)(K_f)}{N_R}$$

Torque is expressed in (lb ft)
HP = Horsepower
(K_f) = Safety factor
N_R = Running speed (RPM)

See Appendix 2 for sample calculations.

Formula 3 - Formula for determining Heat Load

$$E = BTU/_{min} = \frac{1.7\,(WK^2)\,(RPM / 100)^2\,(\text{Engagements per Minute})}{780}$$

$E = BTU/_{min}$ = Heat load
(WK^2) = Inertia

See Appendix 2 for sample calculations.

SAMPLE CALCULATIONS

Formula 1 - Torque based on Inertia and Time

Example 1: Torque required to accelerate an inertia load of 3 lb ft^2 from rest to 1,800 RPM in 0.5 seconds:

Start with a rough approximation of the dynamic torque using the formula: ((3.00 * 1800) / (308 * .5)) = 35.06 lb ft dynamic torque, requiring an FEA0625, based on the table "Mechanical Data"

(ΔN) = 1800 (accelerate from 0 to 1,800 RPM)
$(WK^2) = (WK^2_{system}) + (WK^2_{clutch\ components}) = 3\ lb\ ft^2 + .889\ lb\ ft^2$ (Model FEA0625) = 3.889 lb ft^2
t = .5 sec

$$\text{Dynamic Torque}_{ave} = \frac{(WK^2)(\Delta N)}{308(t)} = \frac{(3.889)\ (1800)}{308(.5)} = \frac{7000}{154} = 45.45 \text{ lb ft}$$

Model FEA0625 with a dynamic torque rating of 50 lb ft is the appropriate selection.

Formula 2 - Torque based on Drive Components

Example 2: Torque output of a 5 HP motor at 1,800 RPM with a clutch attached directly to the motor shaft:

HP = 5.0
(K_f) = 1.0 (for electric motors. Use 2.0 for internal combustion engines)
N_R = 1,800 RPM

$$\text{Torque}_{ave} = \frac{(5250)\ (HP)\ (K_f)}{N_R} = \frac{(5250)\ (5.0)\ (1.0)}{1800} = 14.58 \text{ lb ft}$$

Model FEA0475 with a dynamic torque rating of 25 lb ft is the appropriate selection.

Formula 3 - Formula for determining Heat Load

Example 3: Using the data from Example 1, determine the heat load with a cycle rate of 4 engagements per minute:

$$E = BTU/_{min} = \frac{1.7\ (WK^2)\ (RPM\ /\ 100)^2\ (\text{Engagements per Minute})}{780} = \frac{1.7\ (3.889)\ (1800\ /\ 100)^2\ (4)}{780}$$

$$= \frac{8568.24}{780} = 10.98\ BTU/_{min}$$

Model FEA0475 has the necessary heat dissipation rate to handle this application, even though Model FEA0625 is required to handle the torque. The larger clutch - either determined by torque requirement or heat load - should be specified for the application.

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INERTIA OF STEEL BARS, SHAFTS, OR DISCS
(per inch of length or thickness)

DIA (in)	R^2	Weight per inch	WR^2 (lb ft^2)
3/4	0.00049	0.1252	0.00006
1	0.00087	0.2225	0.0002
1 1/4	0.00136	0.3477	0.000
1 1/2	0.0020	0.5006	0.001
1 3/4	0.0027	0.6814	0.002
2	0.0035	0.8900	0.003
2 1/4	0.0044	1.1264	0.005
2 1/2	0.0054	1.3906	0.008
2 3/4	0.0066	1.6827	0.011
3	0.0078	2.0025	0.016
3 1/4	0.0092	2.3502	0.022
3 1/2	0.0106	2.7256	0.029
3 3/4	0.0122	3.1289	0.038
4	0.0139	3.5600	0.049
4 1/4	0.0157	4.0189	0.063
4 1/2	0.0176	4.5056	0.079
4 3/4	0.0196	5.0202	0.098
5	0.0217	5.5625	0.121
5 1/2	0.0263	6.7306	0.177
6	0.0313	8.0100	0.250
6 1/2	0.0367	9.4006	0.345
7	0.0425	10.9025	0.464
7 1/2	0.0488	12.5156	0.611
8	0.0556	14.2400	0.791
8 1/2	0.0627	16.0756	1.008
9	0.0703	18.0225	1.267
9 1/2	0.0783	20.0806	1.573
10	0.0868	22.2500	1.931
11	0.1050	26.9225	2.828
12	0.1250	32.0400	4.005
13	0.1467	37.6025	5.516
14	0.1701	43.6100	7.420
15	0.1953	50.0625	9.778
16	0.2222	56.9600	12.658
17	0.2509	64.3025	16.131
18	0.2813	72.0900	20.275
19	0.3134	80.3225	25.171
20	0.3472	89.0000	30.903
21	0.3828	98.1225	37.563
22	0.42014	107.6900	45.245
23	0.45920	117.7025	54.049
24	0.50000	128.1600	64.080
25	0.5425	139.0625	75.446
26	0.5868	150.4100	88.261
27	0.6328	162.2025	102.644
28	0.6806	174.4400	118.716
29	0.7300	187.1225	136.606
30	0.7813	200.2500	156.445
31	0.8342	213.8225	178.371
32	0.8889	227.8400	202.524
33	0.9453	242.3025	229.052
34	1.0035	257.2100	258.103
35	1.0634	272.5625	289.834
36	1.1250	288.3600	324.405
37	1.1884	304.6025	361.980
38	1.2535	321.2900	402.728
39	1.3203	338.4225	446.823
40	1.3889	356.0000	494.444
41	1.4592	374.0225	545.774
42	1.5313	392.4900	601.000
43	1.6050	411.4025	660.315
44	1.6806	430.7600	723.916
45	1.7578	450.5625	792.004
46	1.8368	470.8100	864.786
47	1.9175	491.5025	942.473
48	2.0000	512.6400	1025.280
49	2.0842	534.2225	1113.427
50	2.1701	556.2500	1207.140
51	2.2578	578.7225	1306.647
52	2.3472	601.6400	1412.183
53	2.4384	625.0025	1523.986
54	2.5313	648.8100	1642.300
55	2.6259	673.0625	1767.373
56	2.7222	697.7600	1899.458
57	2.8203	722.9025	2038.811
58	2.9201	748.4900	2185.695
59	3.0217	774.5225	2340.376
60	3.1250	801.0000	2503.125

For calculating sizes not shown, and for other common materials, see formulas in Appendix 4

OTHER USEFUL FORMULAS - TORQUE and INERTIA

Torque Calculation for Electric Motors

Torque (lb-in) based on HP and RPM: $T = \dfrac{HP \times 63025}{\text{Motor RPM}}$

Torque (lb-ft) based on HP and RPM: $T = \dfrac{HP \times 5250}{\text{Motor RPM}}$

Horsepower of Rotating Objects

$$HP = \frac{\text{Torque (lb ft)} \times \text{Shaft Speed (RPM)}}{5250}$$

Horsepower of Objects in Linear Motion

$$HP = \frac{\text{Force (lb)} \times \text{Velocity (fpm)}}{33000}$$

Inertia of Bars, Shafts, or Discs

Weight of bar/shaft/disc (in pounds): $wt = f \times r^2$ — r = radius (inches); f = factor (see below)

Radius of gyration for a cylinder: $R^2 = (1/2) \times (r/12)^2$ — r = radius (inches)

Inertia per inch of length: $WR^2 = (wt) \times (R^2)$

Weight Factor per Inch of Various Materials (lbs)

Steel	f = .890
Rubber	f = .108
Nylon	f = .161
Aluminum	f = .310
Bronze	f = 1.010
Cast Iron	f = .821

To Calculate the Inertia per inch of length for a Hollow Cylinder:

Subtract the WR^2 of the I.D. from the WR^2 of the O.D.

DESIGN GUIDELINES

OTHER USEFUL FORMULAS - TORQUE and INERTIA

Reflected Inertia (Rotating devices)

Inertia calculations used to determine the proper size for a clutch or brake must take into account the ratio of the speed (in RPM) of the clutch and the speed (in RPM) of the other elements in the system. While horsepower is essentially unchanged throughout the system, inertia scales up or down proportionally in relation to rotating speed.

Inertia at Clutch: $$WR^2_{\text{at clutch}} = WR^2_{\text{at source}} \times \frac{RPM_{\text{at source}}}{RPM_{\text{at clutch}}}$$

Reflected Inertia (Linear devices)

Inertia calculations used to determine the proper size for a clutch or brake must take into account the load presented to the clutch from any linear devices being driven (such as a conveyor). This load can be reduced to an equivalent inertia value using the formula below. The critical information which must be determined is (1) the weight of the load; and (2) the diameter of the driving pulley, sprocket, gear, or drum.

Inertia of Load: $$WR^2_{\text{load}} = \text{Weight (lbs)}_{\text{load}} \times \left(\frac{DIA_{\text{ft}}}{2}\right)^2$$

Using the rotating device formula above, the inertia at the clutch can be calculated:

Inertia at Clutch: $$WR^2_{\text{at clutch}} = WR^2_{\text{load}} \times \frac{RPM_{\text{driving device}}}{RPM_{\text{at clutch}}}$$

NOTES