The Synchrotorque Variable Speed Drive operates on the principle of shearing an oil film to transmit torque. This hydroviscous (hydrodynamic shearing) effect transmits torque in proportion to a variable clamping force. For unrestrained loads, the higher the clamping force, the faster the output speed. The input drive plate functions as the driver. The output friction disc is faced with a suitably grooved resilient material. The material couple between input drive plates and output friction discs allows virtually infinite speed control right up to 100% of input speed. This simple phenomenon (based on established hydrodynamic bearing principles) is the basis of controlled torque transmission in the Synchrotorque Variable Speed Drive.

The Oil Film

**Oil Film:**
- Transmits Torque.
- Separates Input Drive Plates and Output Friction Discs.
- Carries away heat generated due to oil shearing.

How The Oil Film Is Established

The input member accelerates the oil particles tangentially and a hydrodynamic film is established through the action of the friction disc oil grooving. The oil particles also are acted upon by centrifugal force which accelerates them outwardly. This natural pumping action insures a uniform oil film across disc faces for controlled shearing. The oil film is continuously replenished by a circulating oil pump, which pumps oil from the reservoir through a cooler and back to the center of the rotating members where the cycle is repeated.

Lockup Capabilities

Eddy Current and Fluid Couplings exhibit fixed slip loss ranging from 2 to 5%. This means highest attainable efficiency is only 95-98% with corresponding maximum attainable output speed of 95-98% of input speed. Unlike Eddy Current and Fluid Couplings, the Synchrodrive® does transmit torque up to 100% of input speed. This savings of 2-5% compared to Eddy Current and Fluid Couplings means important power savings, additional capacity, and/or compensation for pump or fan wear.

How Torque Capacity Is Increased

The amount of torque that can be transmitted varies directly with the number of disc surfaces over which the shearing action occurs. To increase the number of working surfaces, a hydroviscous disc pack is built up by alternately stacking discs splined to the input member between discs splined to the output member. All discs are free to slide axially but must rotate with the member to which they are splined. The variable clamp force is applied to one end of the disc pack and is distributed to the remainder of the discs due to their freedom to slide axially. The working oil is introduced (orificed) to each set of surfaces by oil passages appropriately drilled in the output member.
How Torque Is Controlled

The variable clamping force is obtained by varying the pressure to a piston. This piston force is transmitted to the actuator which rotates with the output shaft. The actuator clamps the disc pack in proportion to the pressure applied to the piston. Piston pressure is controlled by the Synchrodrive control system which responds to the command signal. The Synchrodrive control system is a closed-loop system using output shaft speed as feedback. Any input command signal is automatically compared to output shaft speed. The Synchrodrive control system quickly and accurately regulates piston pressure (clamping force) to the proper value. Response is virtually instantaneous and the speed feedback feature insures linearity between input command and output shaft speed. The standard source of actuation pressure is hydraulic (electro-hydraulic control). For certain special applications, the source of actuation pressure may be pneumatic (electro-pneumatic control). The input command signal may come from a customer provided source (Automatic Control) or from within the controller (Manual Control).

The Result...

SYNCHRODRIVE®
A simple rugged, effective Variable Speed Drive!
SYNCHRODRIVE® for Horizontal Applications

Accessories

Synchrodrive® Controllers

Lubrication Package

Water/Oil Cooler

Air/Oil Cooler
SYNCHRODRIVE® for Vertical Applications

INPUT SHAFT

HYDROVISCOS DISK PACK

OIL INLET

RUGGED WELDED STEEL HOUSING

DRYWELL CONSTRUCTION AROUND OUTPUT SHAFT

BEARING LUBE INLET

ACTUATION PRESSURE INLET

THRUST BEARING

SPEED SENSOR

OIL OUTLET

VARIABLE SPEED OUTPUT SHAFT

Accessories

Hydraulic Actuation Package

Integral Sump/Base for mounting motor and/or driven equipment

Separate Lube Consoles
SYNCHRODRIVE®

Performance Characteristics

VARIABLE SLIP DRIVES
The most common drives of this type are:
1. SYNCHRODRIVES (HYDROVISCOUS)
2. FLUID COUPLINGS (HYDROKINETIC)
3. EDDY CURRENT COUPLINGS (MAGNETIC)

Figure 1 shows the power relationships which govern these drives—their performance depends on the type of load and speed range.

TYPES OF LOADS
Virtually, all loads can be categorized into one of three types.
1. VARIABLE TORQUE
2. CONSTANT TORQUE
3. CONSTANT HORSEPOWER

The above categories refer specifically to the torque demand of the load vs. speed. See page 7 for examples of these types of loads.

BRAKE HORSEPOWER VS. SPEED
Torque multiplied by speed is equal to horsepower. If, for example, torque is proportional to speed squared, brake horsepower will be proportional to speed cubed.

\[
\text{IF } T \propto N^2 \text{ THEN } BHP \propto (TN) \propto (N^2 N) \propto N^3
\]

WHERE 
- \( T \) = Torque
- \( N \) = Speed
- \( BHP \) = Brake Horsepower

INPUT POWER VS. LOAD SPEED
Input power to the Synchrodrive vs. load speed must equal the torque demanded by the load times the full load prime mover speed. Since the prime mover's speed (Synchrodrive input speed) is constant, the relationship of input power vs. load speed is directly proportional to load torque. For a variable torque, load where \( T_{\text{load}} \propto N_{\text{load}}^2 \):

\[
\text{HP}_{\text{in}} \propto (T_{\text{load}} N_{\text{load}}) \propto T_{\text{load}} \propto N_{\text{load}}^2
\]

In every case, the input power vs. the speed of the load will follow the torque vs. speed curve except for the slight bearing and windage loss which also must be provided by the prime mover.

SLIP LOSS
The difference between input and output power is defined as slip loss.

\[
\begin{align*}
\text{HP}_{\text{in}} &= (T_{\text{load}}) (N_{\text{in}}) \\
\text{HP}_{\text{out}} &= (T_{\text{load}}) (N_{\text{load}}) \\
\text{HP}_{\text{loss}} &= \text{HP}_{\text{in}} - \text{HP}_{\text{out}} = T_{\text{load}} (N_{\text{in}} - N_{\text{load}}) \\
&= T_{\text{load}} (N_{\text{slip speed}}) = T_{\text{load}} (\Delta N)
\end{align*}
\]

The magnitude of the slip loss is dependent upon two parameters.
1. LOAD TORQUE
2. SPEED RANGE (DEFINES SLIP SPEED)

This is the same for all variable slip drives, regardless of type.

EFFICIENCY
Efficiency is the ratio of output horsepower to input horsepower. The above equations will simplify to show efficiency is a straightline relationship with speed.

\[
\text{EFFICIENCY} = \frac{\text{HP}_{\text{out}}}{\text{HP}_{\text{in}}} = \frac{N_{\text{out}}}{N_{\text{in}}}
\]

This does not take into account fixed slip losses found in all types of variable slip drives (except Synchrodrives) and bearing and windage loss common to all rotating equipment. Synchrodrives exhibit the highest attainable efficiency of any variable slip drive.

While efficiency considerations are important, when analyzing performance of a variable slip drive, the actual magnitude of the loss is the most important factor. This is dependent on the type of load and speed range.

PERFORMANCE AND ADVANTAGES
Figures 2, 3, and 4 are graphical representations of the above information. Figure 5 summarizes the performance equations for each type of load.

The figures can be used to estimate performance. Refer to page 3 for advantages. For exact performance characteristics, refer to factory since miscellaneous losses contribute to overall performance.
**FIGURE 1** Schematic Representation of Variable Slip Drive

\[
\text{Variable Slip Drive} \\
\text{Power In: } \frac{\text{Torque in in-lbs}}{\text{in rpm}} = \frac{\text{Torque in in-lbs}}{63025} = \frac{\text{Power In}}{63025} \] \\
\text{Power Out: } \frac{\text{Torque in in-lbs}}{\text{in rpm}} = \frac{\text{Torque in in-lbs}}{63025} = \frac{\text{Power Out}}{63025} \]

**NOTE:** Torque in in-lbs, N in rpm

**FIGURE 2** Variable Torque

**FIGURE 3** Constant Torque Load

**FIGURE 4** Constant HP Load

**FIGURE 5** Performance Equations for Various Types of Loads

<table>
<thead>
<tr>
<th>Type of Load</th>
<th>Torque vs. Speed</th>
<th>BHP vs. Speed</th>
<th>*HP Prime Mover vs. Speed</th>
<th>HP Slip Loss at Any Point</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable Torque</td>
<td>( T \propto N^2 )</td>
<td>( \text{BHP} \propto N^1 )</td>
<td>( \text{HP}_{\text{pm}} \propto N^2 )</td>
<td>( \text{HP}_{\text{slip}} \propto T \Delta N )</td>
<td>( \frac{\text{N}<em>{\text{out}}}{\text{N}</em>{\text{in}}} )</td>
</tr>
<tr>
<td>Constant Torque</td>
<td>( T = K )</td>
<td>( \text{BHP} \propto N )</td>
<td>( \text{HP}_{\text{pm}} = K )</td>
<td>( \text{HP}_{\text{slip}} \propto T \Delta N )</td>
<td>( \frac{\text{N}<em>{\text{out}}}{\text{N}</em>{\text{in}}} )</td>
</tr>
<tr>
<td>Constant HP</td>
<td>( T \propto \frac{1}{N} )</td>
<td>( \text{BHP} = K )</td>
<td>( \text{HP}_{\text{pm}} \propto \frac{1}{N} )</td>
<td>( \text{HP}_{\text{slip}} \propto T \Delta N )</td>
<td>( \frac{\text{N}<em>{\text{out}}}{\text{N}</em>{\text{in}}} )</td>
</tr>
</tbody>
</table>

* Does not take into account bearing and windage loss.

\( K = \text{Constant} \)
**SYNCHRODRIVE®
Selection Procedure, Horizontal and Vertical**

1. Determine prime mover horsepower required, RPM, speed ratio, and type of load.

**TYPICAL TYPES OF LOADS:**
- **Variable Torque:** Centrifugal fans, blowers, pumps, compressors, some fluid mixers, and axial flow compressors.
- **Constant HP:** Wire drawing machinery, grinders, some mixers, let-off and wind-up reels.
- **Constant Torque:** Extruders, ball and rod mills, tension stands, reciprocating and lobe type compressors, conveyors, most drum type mixers.

*PRELIMINARY PRIME MOVER SIZING:

**VARIABLE TORQUE LOADS:**
To determine prime mover horsepower (HP<sub>pm</sub>) it is necessary to know the brake horsepower (BHP<sub>α</sub>) required by the load at a particular load speed (N<sub>α</sub>).

\[ HP_{pm} = BHP_{α} \left( \frac{N}{N_{α}} \right)^3 \]

Where  
- HP<sub>pm</sub> = nominal prime mover HP  
- BHP<sub>α</sub> = brake horsepower at speed N<sub>α</sub>  
- N = maximum speed of load

**EXAMPLE—find HP<sub>pm</sub> if load requires 200 HP at 875 RPM, maximum load RPM is 1750, HP<sub>pm</sub> = 200 x (1750/875)<sup>3</sup> = 200 x 8 = 1600 HP

**NOTE:** Since the SYNCHRODRIVE'S input and output shaft may be completely synchronized, maximum speed of load will be prime mover full load RPM times the speed ratio between prime mover and load.

**CONSTANT TORQUE LOADS:**

\[ HP_{pm} = BHP_{α} \left( \frac{N_{max}}{N_{min}} \right) \]

**CONSTANT HP LOADS:**

\[ HP_{pm} = BHP \left( \frac{N_{max}}{N_{min}} \right) = BHP \text{ (Speed Ratio)} \]

2. Size Synchrodrive to match prime mover horsepower found in Step 1. Ample service factors have been incorporated for continuous service.

3A. Look up the column with correct SYNCHRODRIVE input RPM in Table 3. Select a basic model size using horsepower noted in Step 2.

3B. If SYNCHRODRIVE input RPM is not shown in Table 3, calculate required load torque using RPM and horsepower (HP<sub>pm</sub>) from Step 2. Choose from Table 1 unit with a rated torque equal to or higher than the calculated value.

\[ \text{Torque} = \frac{63,000 \cdot \text{HP}}{\text{RPM}} \text{ (in. lb.)} \]

4. THERMAL HORSEPOWER—Refer to Table 2 for thermal horsepower calculations. Compare calculated Thermal Horsepower to maximum Thermal Horsepower capacity listed in Table 1 for Drive size selected in step 3A or 3B. If calculated Thermal Horsepower exceeds maximum capacity listed, select the next largest size drive, which has a thermal horsepower capacity larger than the required value.

5. MODEL DESIGNATION is basic Synchrodrive size found in step 3A or 3B, followed by thermal horsepower found in step 4.

**EXAMPLE:**

**HORIZONTAL SYNCHRODRIVES**

<table>
<thead>
<tr>
<th>Model</th>
<th>Rated Torque</th>
<th>Maximum Thermal Horsepower Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-60</td>
<td>400</td>
<td>400</td>
</tr>
</tbody>
</table>

**VERTICAL SYNCHRODRIVES**

<table>
<thead>
<tr>
<th>Model</th>
<th>Rated Torque</th>
<th>Maximum Thermal Horsepower Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>HV-60</td>
<td>400</td>
<td>400</td>
</tr>
</tbody>
</table>

Basic model size with 400 thermal horsepower rating

GEAR PAK (see pages 12 and 13)

<table>
<thead>
<tr>
<th>Model</th>
<th>Rated Torque</th>
<th>Maximum Thermal Horsepower Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>HQ-60</td>
<td>400</td>
<td>400</td>
</tr>
</tbody>
</table>

Basic model size with 400 thermal horsepower rating

Included as standard are actuation servo system and electronic speed control.

The above is intended to aid the user in making preliminary selections. Refer all final selections to factory for approval and to be sure the optimum selection has been made.

**TABLE 1 Torque and Maximum Thermal Horsepower Ratings**

<table>
<thead>
<tr>
<th>Model</th>
<th>Rated Torque lb. in.</th>
<th>Maximum Thermal Horsepower Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-8</td>
<td>5,400</td>
<td>110</td>
</tr>
<tr>
<td>H-12</td>
<td>9,900</td>
<td>240</td>
</tr>
<tr>
<td>H-20</td>
<td>14,400</td>
<td>325</td>
</tr>
<tr>
<td>H-29</td>
<td>21,884</td>
<td>450</td>
</tr>
<tr>
<td>H-40</td>
<td>27,000</td>
<td>550</td>
</tr>
<tr>
<td>H-50</td>
<td>36,000</td>
<td>725</td>
</tr>
<tr>
<td>H-60</td>
<td>45,000</td>
<td>780</td>
</tr>
<tr>
<td>H-80</td>
<td>56,000</td>
<td>920</td>
</tr>
<tr>
<td>H-100</td>
<td>72,000</td>
<td>1,160</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model</th>
<th>Rated Torque lb. in.</th>
<th>Maximum Thermal Horsepower Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-125</td>
<td>90,000</td>
<td>1,300</td>
</tr>
<tr>
<td>H-165</td>
<td>117,000</td>
<td>1,340</td>
</tr>
<tr>
<td>H-200</td>
<td>144,000</td>
<td>1,350</td>
</tr>
<tr>
<td>H-250</td>
<td>180,000</td>
<td>1,925</td>
</tr>
<tr>
<td>H-300</td>
<td>216,000</td>
<td>1,900</td>
</tr>
<tr>
<td>H-400</td>
<td>288,000</td>
<td>2,100</td>
</tr>
<tr>
<td>H-530</td>
<td>360,000</td>
<td>2,400</td>
</tr>
<tr>
<td>H-700</td>
<td>594,000</td>
<td>3,300</td>
</tr>
<tr>
<td>H-1000</td>
<td>720,000</td>
<td>4,000</td>
</tr>
</tbody>
</table>

8
### TABLE 2  Thermal Horsepower

<table>
<thead>
<tr>
<th>TYPE OF LOAD</th>
<th>Variable Torque</th>
<th>Constant HP</th>
<th>Constant Torque</th>
</tr>
</thead>
<tbody>
<tr>
<td>REQUIRED THERMAL</td>
<td>15%-30% of Prime Mover HP</td>
<td>( \text{HP}_{\text{load}} ) ( \text{Speed ratio} - 1 )</td>
<td>( \text{HP}_{\text{prime mover}} \left( \frac{1}{1 \cdot \text{speed ratio}} \right) )</td>
</tr>
</tbody>
</table>

### TABLE 3  Synchrodrive Selection

![Performance Curves Diagram](image-url)
SYNCHRODRIVE® Dimensions

Horizontal Models H8-H50

<table>
<thead>
<tr>
<th>MODEL</th>
<th>A†</th>
<th>B</th>
<th>C†</th>
<th>D</th>
<th>E†</th>
<th>G</th>
<th>H†</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>EST. UNIT WT. (LBS.)</th>
<th>SUMP CAP GALS, †</th>
<th>K.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-8</td>
<td>24</td>
<td>17.12</td>
<td>26.31</td>
<td>32.56</td>
<td>2.9</td>
<td>19.23</td>
<td>2.0</td>
<td>11.0</td>
<td>15.0</td>
<td>11.61</td>
<td>.88</td>
<td>850</td>
<td>12</td>
</tr>
<tr>
<td>H-12</td>
<td>30.5</td>
<td>22</td>
<td>31</td>
<td>42.88</td>
<td>3.56</td>
<td>20</td>
<td>2.5</td>
<td>14.25</td>
<td>20.25</td>
<td>9.62</td>
<td>.88</td>
<td>1,400</td>
<td>22</td>
</tr>
<tr>
<td>H-20</td>
<td>30.5</td>
<td>22</td>
<td>35</td>
<td>42.88</td>
<td>3.56</td>
<td>24</td>
<td>2.5</td>
<td>14.25</td>
<td>20.25</td>
<td>9.62</td>
<td>.88</td>
<td>1,600</td>
<td>32</td>
</tr>
<tr>
<td>H-29</td>
<td>30.5</td>
<td>25</td>
<td>43</td>
<td>45.88</td>
<td>3.56</td>
<td>32</td>
<td>2.5</td>
<td>14.25</td>
<td>23.25</td>
<td>9.62</td>
<td>.88</td>
<td>2,200</td>
<td>50</td>
</tr>
<tr>
<td>H-40</td>
<td>33</td>
<td>32</td>
<td>44</td>
<td>52.25</td>
<td>4.38</td>
<td>32</td>
<td>3.25</td>
<td>15.50</td>
<td>28</td>
<td>11.50</td>
<td>.88</td>
<td>2,500</td>
<td>65</td>
</tr>
<tr>
<td>H-50</td>
<td>40.5</td>
<td>32</td>
<td>44</td>
<td>52.25</td>
<td>4.38</td>
<td>32</td>
<td>3.25</td>
<td>19.25</td>
<td>28</td>
<td>11.50</td>
<td>.88</td>
<td>3,000</td>
<td>85</td>
</tr>
</tbody>
</table>

† Values shown are maximum and are dependent on thermal horsepower requirements.
FOR INSTALLATION PURPOSES USE CERTIFIED DIMENSIONS ONLY. ALL DIMENSIONS SHOWN ARE IN INCHES.

Horizontal Models H60-H1000

<table>
<thead>
<tr>
<th>MODEL</th>
<th>A</th>
<th>B</th>
<th>C†</th>
<th>D</th>
<th>E†</th>
<th>G</th>
<th>H†</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>L</th>
<th>EST. UNIT WT. (LBS.)*</th>
<th>OIL CAP. GAL. †</th>
<th>K.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-60</td>
<td>43.5</td>
<td>45.25</td>
<td>41.25</td>
<td>59.0</td>
<td>5</td>
<td>30.75</td>
<td>3.75</td>
<td>19.25</td>
<td>35.5</td>
<td>6.75</td>
<td>20.25</td>
<td>(8): .06</td>
<td>4,000</td>
<td>100</td>
</tr>
<tr>
<td>H-80</td>
<td>43.5</td>
<td>46</td>
<td>50</td>
<td>64.5</td>
<td>6</td>
<td>36</td>
<td>3.75</td>
<td>22</td>
<td>35.5</td>
<td>8.25</td>
<td>20.25</td>
<td>(8): .12</td>
<td>4,800</td>
<td>120</td>
</tr>
<tr>
<td>H-100</td>
<td>43.5</td>
<td>46</td>
<td>56</td>
<td>64.5</td>
<td>6</td>
<td>42</td>
<td>3.75</td>
<td>28</td>
<td>35.5</td>
<td>8.25</td>
<td>20.25</td>
<td>(8): .12</td>
<td>5,400</td>
<td>160</td>
</tr>
<tr>
<td>H-125</td>
<td>56</td>
<td>45.5</td>
<td>73.5</td>
<td>78.75</td>
<td>7</td>
<td>40</td>
<td>5.0</td>
<td>20</td>
<td>46</td>
<td>12.12</td>
<td>25.5</td>
<td>(8): .56</td>
<td>8,500</td>
<td>200</td>
</tr>
<tr>
<td>H-155</td>
<td>56</td>
<td>45.5</td>
<td>85.5</td>
<td>68.75</td>
<td>7</td>
<td>48</td>
<td>5.0</td>
<td>28</td>
<td>46</td>
<td>12.12</td>
<td>25.5</td>
<td>(8): .56</td>
<td>9,000</td>
<td>265</td>
</tr>
<tr>
<td>H-200</td>
<td>59</td>
<td>45.5</td>
<td>73.5</td>
<td>78.62</td>
<td>8</td>
<td>55</td>
<td>5.0</td>
<td>32</td>
<td>46</td>
<td>13.25</td>
<td>26.5</td>
<td>(8): .56</td>
<td>9,500</td>
<td>320</td>
</tr>
<tr>
<td>H-250</td>
<td>59</td>
<td>47.5</td>
<td>82.5</td>
<td>80.62</td>
<td>8</td>
<td>64</td>
<td>5.5</td>
<td>41</td>
<td>48</td>
<td>13.25</td>
<td>26.5</td>
<td>(8): .56</td>
<td>12,000</td>
<td>400</td>
</tr>
<tr>
<td>H-300</td>
<td>59</td>
<td>47.5</td>
<td>90.5</td>
<td>80.62</td>
<td>8</td>
<td>72</td>
<td>5.5</td>
<td>49</td>
<td>48</td>
<td>13.25</td>
<td>26.5</td>
<td>(8): .56</td>
<td>13,500</td>
<td>480</td>
</tr>
<tr>
<td>H-400</td>
<td>60</td>
<td>64</td>
<td>100.5</td>
<td>9</td>
<td>48</td>
<td>6.5</td>
<td>27</td>
<td>50</td>
<td>15.56</td>
<td>26</td>
<td>(8): .62</td>
<td>19,500</td>
<td>320</td>
<td>1½ x ¾</td>
</tr>
<tr>
<td>H-530</td>
<td>66</td>
<td>73.75</td>
<td>76.5</td>
<td>115.75</td>
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† Values shown are maximum and are dependent on thermal horsepower requirements.
* Does not include cooling package.
NOTES: 1. Units shown less cooling package. May be mounted integral or separate.
2. Controls and actuation package are mounted separately. See pages 4 and 5.
FOR INSTALLATION PURPOSES USE CERTIFIED DIMENSIONS ONLY. ALL DIMENSIONS SHOWN ARE IN INCHES.
Dimensions SYNCHRODRIVE®
Vertical Models HV8-HV1000

NOTES:
1. All models contain provisions for absorbing normal up or down pump thrust.
2. Ratings for vertical Synchrodrives same as horizontal units—See pages 8 and 9.
3. Unit shown less sump.
4. Controls and lubrication and actuation packages are mounted separately. See pages 4 and 5.

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FOR INSTALLATION PURPOSES USE CERTIFIED DIMENSIONS ONLY. ALL DIMENSIONS SHOWN ARE IN INCHES.
GEAR-PAK®
Mates SYNCHRODRIVE® with Precision Gear Set

The disc pack in the Gear-Pak and the Synchrodrive units are identical and have the same functional characteristics. The description of the Synchrodrive, its performance characteristics, and selection procedures are applicable to the Gear-Pak.

By mating the Synchrodrive to a precision set of gears, Philadelphia Gear Corporation can offer a variable speed drive system with unique advantages without sacrificing any of the advantages and proven performance of the individual components. See Figures 6 through 8.

Performance Characteristics

The Gear-Pak consists of a set of precision gears, in a parallel shaft or right angle configuration, located within a rugged welded steel housing, connected to a Synchrodrive disc pack.

The gears may be single, double, or triple reduction, or step-up. The disc pack is usually located on the input shaft. The driving shaft is attached to the input members of the disc pack. The output members of the disc pack are attached to the gear or pinion. All components are located in the same housing. Also, a large inspection plate is located on top of the gearcase to provide a means of inspection.

Unlike other variable slip drives (Eddy Current and Fluid Couplings) the disc pack in the Gear-Pak can be run locked up. The absence of slip at top speed leads to a significant advantage. The gear ratio can be reduced by the amount of fixed slip loss found in other variable slip drives, which amounts to 2% to 5%. The decrease in gear ratio means that the slip losses are commensurately less throughout the entire range of operation (see Figure 8) and results in significant savings in operating cost. For example, in a 4500 HP centrifugal pump drive (or any variable torque load) a 2.5% power savings is 112 HP or 84 KW and adds up to 725,000 KWHR savings a year, based on 360 day per year, 24 hour per day operation. A saving of $29,000 each year with power costs at 4¢ per Kilowatt Hour!

Another Synchrodrive benefit is soft start capability. The prime mover, whether induction or synchronous motor, can be started across the line and still draw less current for a shorter duration than a full load start. The load can be brought up to speed under torque or acceleration control by the Gear-Pak control system. The least expensive and more reliable low starting torque motor can be utilized. After startup is complete, the Gear-Pak transmits full motor speed with zero fixed slip loss, again contributing to reduced operating costs.

Space & Foundation Costs Reduced Up to 50 Percent

TYPICAL SYNCHRODRIVE INSTALLATION VS. GEAR-PAK INSTALLATION

FIGURE 6

Motor

Synchrodrive variable speed drive

Oil cooler

Gearbox

Oil sump

*Patents applied for

- 50% space and foundation savings
- Simplified alignment

FIGURE 7

Motor

Contains hydroviscous disc pack from Synchrodrive

Gear-Pak*

Oil cooler

Oil sump

- Major drive components eliminated
- Maximum drive train efficiency

Simplified Alignment • Major Drive Components Eliminated • Maximum Efficiency
GEAR-PAK® CONSTRUCTION
Horizontal, Vertical, From 100 HP to 20,000 HP

- Provides vibration free, infinitely variable speed.
- Not affected by the most adverse environment.
- Complete range of sizes for all mounting configurations.
- The most efficient drive of its type, with no fixed slip losses. Output speed equals input speed upon command.
- Mark Series electronic controller accepts any standard process control signal.
- Easily adaptable for parallel operation.
- Provides instantaneous response upon command.
- Transmits torque in either direction.
- Ideal for conveyors, extruders, kilns, rod or ball mills, and boiler feed pumps.
- Allows prime mover to be started under no load. Eliminates the need for reduced voltage starting and expensive electrical accessories when using synchronous motors.
- Allows prime mover to remain running while disconnected from load.
- Provides controlled acceleration for even the largest of inertia loads.
- Protects drive train from excessive loads with automatic torque limiting feature.
- Most economical solution for variable speed operation of fans, pumps, blowers, and compressors—rather than wasteful throttling for those processes with variable flow demands.
- Extends fan blade liner life when running in abrasive atmospheres by varying fan speed rather than throttling flow.

- May be paired (master/slave mode) or used to share load—two or more Gear-Packs connected to same load.

Efficiency of GEAR-PAK® Vs. Other Combined Geared And Variable Speed Drive Combinations

Slip losses are less throughout entire range providing significant savings in operating costs!
Synchrotorque test equipment is used on the more than one dozen test stands that are in continuous use at Philadelphia Gear Corporation’s manufacturing plants. These test stands have virtually been in daily use since 1969 with no more than routine maintenance. Beginning in 1974, the Synchrotorque Division began selling test stands to others, and since then has furnished everything from individual load absorbers and variable speed drives to complete test stands (drivers, absorbers, gearing, torque actuators, and instrumentation), all using the hydroviscous torque transmission principle. Outstanding features are torque adjustability independent of speed (unlike water brakes and eddy current dynamometers) and ability to lockup drivers (transmit at zero slip) when desired.

Today the Synchrotorque Division of Philadelphia Gear Corporation offers variable speed drives, load absorbers, torque actuators and gearing of all types and configurations including associated transducers and instrumentation covering the following ranges:

- **Speeds zero to 30,000 + rpm**
- **Torques to ten million inch pounds**
- **Powers to 50,000 HP continuous**
- **Torque modulation to 25 Hz**

If you have a need to test equipment for commercial or military applications with special quality or safety assurance program requirements, consider Synchrotorque.
The Synchror torque hydroviscous variable speed drive for pumping applications can provide 100 percent synchronous output speed without the usual 3% to 5% slip loss common to eddy current or hydrodynamic drives. Reliability has been confirmed through the years by tens of thousands of hours of troublefree service. In addition, Synchrodrive units sharply reduce hydraulic pulsations and cavitation, thereby extending the service life of pumps, seals, and piping.

The range of horizontal and vertical Synchrodrive types, plus Gear-Pak—the variable speed drive with integral gear reducer, provides the versatility required to meet the diverse needs of industry. The range of pumping applications includes: boiler feed pumps, condensate pumps and slurry pumps in power plants; oil and gas pipeline and booster pumps for the petroleum industry; reciprocating pumps drives and centrifugal pumps for diverse applications in both the public and industrial sectors around the world.

If you have a pumping requirement that demands close control, reliable day-in-day-out performance, and economy of operation, Synchrodrive and Gear-Pak variable speed pumping drives designed for 100 to 20,000 horsepower, can provide the most economical solution.
Synchrotorque's Gear-Pak—the hydroviscous drive with integral gear reducer—is used on the most demanding belt conveyors around the world. Current installations include: coal, iron, copper mines and coal-fired powerplants all over North America, Mexico, South America, China and India.

The unique capabilities of the hydroviscous drive for conveyors include:

- Soft starts, adjustable from a few seconds to several minutes.
- Soft stops, adjustable from seconds to minutes.
- "Same Time" starts and stops.
- Fail-safe stops, using spring loaded hydroviscous brakes, built into the Gear-Pak housing.
- Load sharing among two or more drives, located miles apart, if necessary.
- Creep speed operation using either the main motor or a pony motor.
- Jogging using the same hydroviscous drive.
- Electronic controls are standard.
- Battery backup option for safe controlled deceleration in the event of a power outage.
- Flywheel powered lube system option for safe slowdown and stops when power fails.
- Wide selection of gear arrangements—parallel shaft, right angle, multiple input or output shafts.
- Multiple speed ranges using on-the-fly "HiLo" shifting.

Gear-Pak housing are rugged steel weldments designed to withstand the punishment from falling rocks, crane hooks and construction debris. Drive elements are alloy steel forgings, heat treated for strength and to resist overloads. Gears are precision finished, case hardened and ground where applications warrant. Philadelphia Gear can also supply baseplates, backstops, couplings, externally mounted brakes, and customer specified accessories.

Philadelphia Gear can supply the complete conveyor drive system, from motor to baseplate, regardless of system complexity.
SYNCHRONOUS CONDENSER DRIVES

The application of Philadelphia Gear Corporation's Synchrotorque hydroviscous drive to convert steam-powered alternators to synchronous condensers has saved utilities many times their cost; in fact, the conversion can pay for itself in six months.

Philadelphia Gear Corporation's synchronous condenser starter drive provides an alternate method of:

- bringing the alternator from rest up to synchronous speed in a reasonable time period (usually within 15 minutes).
- closely controlling the alternator speed near synchronism (including higher than synchronous speeds).
- allowing the starter drive (by means of a disconnect device) to come to rest after the alternator floats on line.
- starting multiple alternator systems by simply uncoupling the portable sync-start drive from a rotating alternator and moving it to the next alternator to be placed on line.
- electrically isolating the starter drive from the alternator and power grid.

Existing steam turbine powered alternators that have been declared surplus can now be economically converted to synchronous condensers using this starter drive technology. Philadelphia Gear Corporation's synchronous condenser starter drives are based on well proven industrial gearing, hydroviscous drive components and standard induction motors. The result is a reliable and easily maintainable system.

Forced-synchronizing clutches, Model 51009, rated 60,000 HP at 3600 rpm, for a gas-turbine driven generating plant in Brazil. Clutches allow generators to be used as synchronous condensers during off-peak season.

The two above pictures are large generator soft-start drive systems. Designed and built by Philadelphia Gear as ready-to-install packages, they allow generators to be brought to synchronous speed, connected to line, and act as synchronous condensers. Portability allows one drive to start any number of generators.
MARINE APPLICATIONS

The Synchrotorque Division of Philadelphia Gear Corporation manufactures a complete line of marine clutch, brake and variable speed drive units. We've been doing it since 1971. The marine units share the same basic components as their industrial counterparts, but are normally offered as a subassembly, to be integrated into the marine drive, whether the end use is in main reduction gearboxes or auxiliary drives. Hydroviscous discs can range from four to 44 inches in diameter; horsepower from 15 to 250,000 HP; torques, from 1,000 to ten million inch pounds.

Synchrotorque marine clutches and brakes for main propulsion duty are now in service on major combatant ships and many commercial vessels including: destroyers, guided missile cruisers, frigates, surface effect ships, hovercraft, and ferryboats. In addition, Synchrotorque clutches, brakes and hydroviscous drives are being used to improve operating efficiencies of auxiliary machinery on assault ships, helicopter carriers and commercial transports.

Philadelphia Gear Corporation's Synchrotorque Division can custom design a marine clutch, brake or special hydroviscous drive to meet your specific requirements for diesel, gas turbine or combined powerplants. Other applications include:

- High or low speed shaft brakes
- Reverse gear clutches and brakes
- Cross connect clutches
- Dredge pump clutches and variable speed drives
- Slip clutches and brakes for low speed maneuvering
- Clutches for "Z" drives (On/Off or variable speed types)
- Clutch/brake units for marine conveyors, including fully submersible types
- Ultra lightweight clutches and brakes for surface effect and full air cushion craft
- Variable speed drives for constant speed generator drive systems
- Clutches and variable speed drives for bow thrusters

Each of the (4) 22,000 HP gas turbines powering the Ticonderoga class Aegis cruisers drives through Synchrotorque quills with, equipped with Mode: BS150 hydroviscous shaft brakes.
For almost a century, Philadelphia Gear Corporation has continuously devoted itself to the design and manufacture of precision gearing and power transmission equipment...much of it custom-designed to accommodate the demands of the specific task identified. The reputation for excellence we enjoy today was earned through decades of experience, intense research in metallurgy, and the practical application of power transmission technology.

We are continuously expanding and improving our capabilities for producing extremely high capacity gears, enclosed gear drives, fluid mixers and variable speed drives. Many of the production machines in our plants, especially those for gear cutting, shaving and grinding, are the only ones of their size and precision in the United States. Most of this equipment has been custom made for us by the leading machine tool manufacturers of this country and Europe.

Through the years, Philadelphia Gear Corporation has assembled and nurtured a corps of craftsmen and technicians with the specialized skills and engineering expertise to translate your power transmission needs. Advanced computer programs have been developed to analyze gear selection and sizing, gear tooth stresses, tooth proportioning, load distribution, scoring factors and critical speeds. Our metallurgical laboratory is staffed with skilled metallurgists who continually test and evaluate the results of the company’s heat treating production as well as develop new and improved hardening techniques for making ever more durable gearing. The entire organization is dedicated to serving your needs.

As the leader in power transmission technology, Philadelphia Gear Corporation continues to explore new levels of research, more precise manufacturing techniques, and the sophistication of computer assisted design, manufacture and operation of its equipment. We are the compatriot of designers searching beyond the present state of the art for solutions to difficult and advanced projects.
Other Philadelphia Gear products

N-LINE SPEED REDUCERS—Single, double, triple, and quadruple reductions. Can be direct coupled or driven indirectly. Refer to catalog M-19.

"M" SERIES PARALLEL SHAFT SPEED REDUCERS—Available in single, double, triple and quadruple reductions with ratios ranging from 1:221 to 995:1. Refer to catalog M-19.

HI-SPEED REDUCERS AND INCREASES—Designed and built to operate at speeds up to 20,000 RPM and at ratios up to 1:1 ranging from 100 HP to 300,000 HP. Refer to catalog HS-1.

BASIC OXYGEN FURNACE DRIVES—These shaft mounted drives eliminate costly mounting platforms and many alignment problems. Refer to bulletin No. 490.

CHANGE SPEED GEAR UNITS—Available with 2, 3 or 4 gear combinations for increase or reduction of output speed. Refer to catalog CSU-2.

SYNCRODRIVE—Sizes from 100 to 20,000 HP offers a reliable, field proven unit for all types of variable speed and soft start applications. Does not require oil to produce torque. Write for catalog S30-2.

PHILADELPHIA APPLICATION ENGINEERED GEARINGS—Over 80 years of gear manufacturing experience goes into producing these major gear types: spur, helical, double helical, herringbone, bevel, hypoid, zero, and worm.

PHILADELPHIA PTE MIXER—Extremely versatile, unusually reliable. Standard speeds from 20 to 280 RPM. Refer to catalog PTE-3.

FLEXIBLE COUPLINGS—Long experience has proven that a Philadelphia designed and manufactured flexible coupling is the ultimate in service and reliability. Refer to catalog C-79.

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