ACHE Axial Fan Drive Systems Engineering Manual

GOODYEAR.
ENGINEERED PRODUCTS

The performance of your axial fan air-cooled heat exchangers is critical to your operation's success. Optimizing the output of your current fans can offer real process improvement, giving you more for your energy dollar. We can help.

Whether your drive system needs the flex-fatigue resistance of Falcon Pd® or the self-tracking, reduced noise offered by Eagle Pd®, or the universal fit convenience of Hawk Pd®, Goodyear Engineered Products has the drive system solution to fit your needs.

Goodyear EP has the products to retro-fit your induced and forced draft axial fan drives.

Falcon Pd®

SYNCHRONOUS BELTS AND SPROCKETS

- **Drop-in replacement for Poly Chain® GT2* and Poly GT Carbon* belts.**
- Rubber construction for better resistance to flex fatigue.
- Full line of mating sprockets for a complete drive system.
- Easy part number cross-reference.
- Up to 4dB quieter than comparable Poly Chain® GT2 drives.
- Versatility in a wide-range of operating temperatures.
- Available in anti-static construction.+

Eagle Pd®

SYNCHRONOUS DRIVE SYSTEM

- **Patented, less noise H.O.T. tooth design.**
- Now available in ACHE longer lengths.
- Self-tracking, flange-less sprockets.
- Rubber construction for better resistance to flex fatigue.
- Exceptional tensile strength for lasting performance.
- Versatility in a wide range of operating temperatures.
- Available in anti-static construction.+

Hawk Pd®

SYNCHRONOUS BELTS AND SPROCKETS

- **Ideal for retro-fitting existing standard HTD curvilinear belt drives.**
- Available in ACHE specific lengths and widths.
- Industry compatible nomenclature.
- Compatibility with Gates® HTD, PowerGrip® GT and GT2, Carlisle® RPP and RPP Plus and TB Wood's Synchronous QD sprockets.**
- Refined construction for long-lasting performance.

* Poly Chain, GT2 and GT Carbon are registered trademarks of The Gates Corporation.
** Trademarks of Gates, Carlisle and TB Woods, respectively.

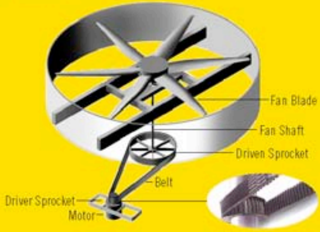
+ Drive conditions and service variables in combination with time in operation can result in a loss of static conductivity. It is recommended that a conductivity check be added to drive preventive maintenance programs where belt static conductivity is a requirement.

Create Your Optimal Drive System with Maximizer™.

MAXIMIZER™
Drive Selection Analysis Program

To make the switch to better performance, fill out the Maximizer form with the required drive data and fax to our Drive Change Team in Lincoln, NE or go to www.goodyearep.com/ptp.

As an added benefit, Maximizer's v. 5.2. or later premium analysis, including optimal component selection and tensioning data, is also available from your local Goodyear EP Authorized Distributor.



Use Maximizer to determine which Goodyear EP drive system solution is best for you.

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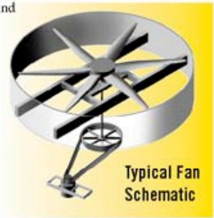
ACHEs and Synchronous Belts

Air Cooled Heat Exchangers (ACHEs) are used to condition process fluids. The fluid to be cooled is circulated through tubes (often finned) over which air is drawn by a ducted fan. The excess heat in the fluid is thereby transferred to the ambient air.

In most instances, the fan is a large-bladed unit, oriented in a horizontal plane and driven through a belt drive by an electric motor. Ambient air is typically drawn into the bottom of the unit and exhausted out the top. The tube array can be above the fan (forced-air system) or below the fan (induced-air system). The resultant drive arrangement must be both reliable and easy to maintain since the construction of these rather large units makes it difficult to access the drive.


Typical Fan Schematic

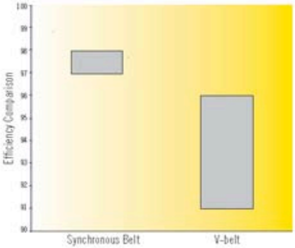
Belt drives provide flexibility in fan speed selection as well as allowing the motor to be located outside the air stream, a distinct advantage in high temperature or corrosive environments. Several types of belt drives are available with different cost and operating advantages associated with each type. V-belts are perhaps the most commonly used type. However, increased focus on operating efficiency and reduced maintenance is causing a shift to synchronous belts.

A V-belt transmits power through friction between the belt sidewall and the smooth side of the pulley groove. Belt slippage is inevitable, especially under high torque such as at start-up. Efficient operation is directly dependant upon proper belt tension meaning frequent adjustment is required. Synchronous belts have operational characteristics similar to a chain drive, a positive mesh between belt tooth and sprocket tooth which eliminates slippage. The stable tensile member in synchronous belts reduces or even eliminates the need for periodic retensioning of the drive.

Shaft alignment is more critical with the thin, wide synchronous belts, generally requiring components be aligned within +/- 1/16" per foot of shaft seperation. Equally important is the requirement for stability of the ACHE fan and motor supporting structure. Because the belts cannot slip, any shock load is transferred directly to the structure. During high-torque conditions such as at start-up, a synchronous belt system must be supported such that the belt teeth are not allowed to ratchet over the sprocket teeth due to flexing of the structure.

While synchronous belts eliminate any belt squeal associated with slippage such as often experienced with a V-belt system, there may be additional noise generated by a synchronous belt system through air expulsion as the belt and sprocket teeth engage and disengage. Tooth design such as Goodyear Engineered Products' revolutionary Helical Offset Tooth (H.O.T.) and belt material selection serve to minimize objectionable operating noise. Belt material selection can also counter many damaging effects resulting from operation in a corrosive environment.

Efficiency Comparison



Goodyear Engineered Products Synchronous Belts for ACHEs

Goodyear EP offers matched belts and sprockets in the following three configurations.

Eagle Pd® Synchronous Drive System

Your first look at an Eagle Pd® Belt and Sprocket will tell you that it's different than anything offered in the synchronous belt market today – it all starts with Eagle Pd®'s patented H.O.T. (Helical Offset Tooth) design.

Goodyear EP's exclusive Eagle Pd®:

- Patented drive system well suited for many high-end, high horsepower drive applications
- Available in lengths well-suited for cooling tower applications and other long-center applications
- Has the capacity to reduce noise by 17 – 19dB and lessen vibration when compared to other straight tooth synchronous belts
- Can reduce drive size and weight when replacing many traditional V-belt drives
- Wide range of operating temperatures for greater versatility
- Capable of improved efficiencies to optimize your energy dollar

Eagle Pd® Belt Construction Story:

Hibrex® rubber compound - for exceptional tooth rigidity and load carrying capacity - designed to be chemically stable to resist effects of oil, coolant heat, ozone and other chemicals.

Flexten® tensile members - for high impact strength - optimal resistance to flex fatigue, elongation and shock loads while operating in high torque conditions.

Hibrex® impregnated Plioguard® fabric tooth facing for reduced tooth engagement friction - provides excellent wear and abrasion protection in operation.

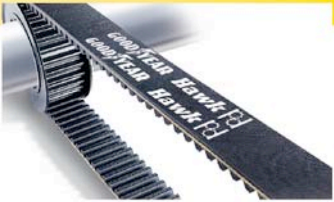
Eagle Pd® Color Spectrum System incorporates a color-coded part numbering system of belts and sprockets of the same size making it easier to select proper drive combinations.

Falcon Pd® Synchronous Belts & Sprockets

Exceptional tensile strength for premium performance.

- Rubber construction for better resistance to flex fatigue
- Backside idler compatible when needed
- Sprocket compatibility with Gates Poly Chain® GT2* and Poly Chain® GT Carbon*
- Tests show 1dB to 4dB quieter operation than comparable Poly Chain® GT2 belts
- Versatility in a wide range of operating temperatures
- Size-for-size "drop-in" convenience

Hawk Pd® Synchronous Belts



Axial Fan Hawk Pd® is now the premium choice for greater horsepower capacity and performance, all in a universal-tooth profile belt.

- Sprocket compatibility with the Gates HTD, PowerGrip® GT and GT2, Carlisle RPP and RPP Plus and TB Wood's Synchronous QD**
- Enhanced Wingprene™ compound affords greater flexibility, less flex fatigue and longer life
- Improved tooth facing for greater abrasion resistance than Hi-Performance Pd Plus
- Engineered Fiberglass cord for excellent resistance to shrinkage/elongation
- Special Axial Fan construction using single twist cord for tracking stability

* Poly Chain, GT2 and GT Carbon are trademarks of The Gates Corporation.

** Trademarks of Gates, Carlisle and TB Woods, respectively.

Goodyear Engineered Products ACHE sprockets

The tooth dimension and pitch tolerance of ACHE specific sprockets are identical to standard industrial designs. In fact, the smaller diameter driveR sprockets for ACHE systems for Eagle and Hawk belts use the standard industrial offerings. Only the Falcon line calls for special ACHE design driveR sprockets. The Falcon ACHE designs feature Quick Detachable bushings while the standard designs utilize Taper-Lock® bushings*. Even with Falcon, standard driveR sprockets can still be used if so desired.

Goodyear EP ACHE specific sprocket designs incorporate important features. Among these are; reduced mass, quick detachable bushings and corrosion control treatment.

Reduced Sprocket Mass

The drive ratios required by ACHE applications to keep the fan blades turning at optimal RPM dictate rather large driveN sprocket diameters. Standard sprockets are engineered to safely transmit the maximum torque that the matching belt can deliver. Thus sprocket features such as arm thickness and shaft diameter accommodation (i.e. bushing and hub sizes) must be correspondingly large.

ACHE fans do not generally involve inordinate amounts of torque and as a result, shaft diameters are relatively modest. Large, heavy standard industrial sprockets are not a good match for fan shafts. Goodyear EP's large diameter ACHE sprocket design incorporates small hubs and bushings to better match application requirements.

There is no reason that these ACHE designs cannot be used for other applications. The user must be aware that in some cases, the system rating may be truncated by bushing capacity and sprocket arm design. MAXIAMIZER™ will consider bushing limits for any selections the software may make from the ACHE sprocket list.

Quick Detachable Bushings

Most ACHE installations feature horizontal orientation of the fan. The combination of gravity and sprocket size can present installation and alignment challenges. Quick detachable bushings can be utilized to ease the installer's task.

Goodyear EP's ACHE sprockets are intended for installation such that the flanged end of the bushing is located to the bottom of the assembly. When oriented in this manner, the weight of the sprocket acting through the taper of the bushing causes the bushing to grip the shaft even prior to the bushing bolts being installed. Since the bolts are not yet tightened, small lateral adjustments to achieve alignment can be made by easing the sprocket up slightly, using the bolts in the jacking position, until the bushing can be moved on the shaft. While the sprocket will have to be supported at this stage, as soon as the jacking bolts are backed off the bushing will again grip the shaft and help support the sprocket. The installer will quickly learn to accurately estimate the small shift associated with final tightening of the bolts so that the "trial & error" process, usually associated with alignment efforts, is shortened.

Sprocket Corrosion Control

Certain ACHE installations are subject to corrosive environment. In addition to reduced service life due to fin root corrosion, detriment to belt drive components can also occur. Airborne contaminants that combine with rainwater and condensation promote decomposition or oxidation of component surfaces. While rust on the exposed surfaces of sprockets and bushings may be unsightly, its presence does little actual damage. However, rust and scale on the driving face of the sprockets may be cause for concern.

Generally there is no issue if the fan is in nearly continuous operation. The natural interaction between belt surface and sprocket surface will keep the interface neatly polished. There can be a corrosion issue with systems that sit idle for an appreciable time. The exposed sprocket driving face will rust lightly. The bigger problem occurs on that sprocket surface under belt wrap. A capillary effect draws contaminated moisture into the belt/sprocket interface where it is held in close contact with the sprocket material. The resulting decomposition can be severe enough to cause scale to develop, often most severe towards the outer edges of the belt wrap zone. If the fan is started with this scale in place, belt damage can result.

The driveN sprocket is located in the air stream in both forced draft or induction draft coolers. The driveR sprocket is generally in a more protected position. It is also smaller in diameter than the large driveN sprocket, thus presenting much less surface to potential corrosion. The driveR sprocket also polishes much more quickly due to its higher RPM.

Goodyear Engineered Products can address the sprocket corrosion issue by providing a salt bath nitride treatment on the sprockets at additional cost.

Goodyear EP does not recommend plating of sprockets. Plating is a surface buildup process and as such, alters the fit between belt and sprocket. In addition, an electrostatic plating process may leave sharp deposits at ridges and corners that can damage the belt during run-in of the system. Plating will soon erode from the driving face, leaving the area unprotected anyway. The nitride process penetrates the sprocket strata rather than building on the surface. The penetration is deep enough that by the time the nitride-treated material is worn away, the sprocket is worn beyond further use.

There is one exception to the general recommendation against plating of sprockets. That exception allows for a yellow zinc chromate treatment with plating thickness 0.001" or less. Plating trials including field testing of the resultant plated components indicate that any reduction in belt service life due to deposition of plating is well within acceptable range.

* Taper-Lock is a registered trademarks of Reliance Electric Corp.

ACHE design and drive selection procedure

1. Determine Design Horsepower	The American Petroleum Institute, in specification API 661, calls for a service factor of 1.8 to be used for ACHE belt drive systems. (Also see "CAUTION" statement below.) Design HP = motor nameplate HP x 1.8
2. Determine Drive Ratio	Drive Ratio = RPM of faster shaft / RPM of slower shaft Most applications involve a speed reduction so that the drive ratio determination is Drive Ratio = motor RPM / fan RPM
3. Define shaft center distance requirement (c-c)	For existing installations, c-c can best be determined by direct measurement. Center distance may also be deduced by reverse engineering based upon the existing belt and pulleys, if those components are fully defined.
4. Select Belt Type	Choose between Eagle, Falcon or Hawk based upon specific system attributes desired.
5. Use the appropriate Ratings and Center Distance Table to find the best match with criteria determined in steps 1, 2 & 3	Hint: It may not be possible to find an exact match. Best practice is to select a system with equal or greater HP rating than the target design HP. Informed compromise on c-c and ratio may also be required.
6. Evaluate the selected drive components for suitability	Physical dimensions effecting clearances and shaft mounting dimensions should be checked before committing to the selected system.

Goodyear Engineered Products' innovative MAXIMIZER™ Application Program, version 5.2 and later, includes all available components and supporting data for ACHE applications. Use of this program is a fast, easy and accurate alternative to the steps described above.

CAUTION

Most electric motors are capable of producing torque of up to 300% of the nameplate rating for a very short burst such as with across-the-line starting. ACHE installations where the fan can auto-rotate in the reverse direction due to prevailing air inflow can absorb this torque spike. If frequent starts under such conditions are anticipated, consider adding an anti-rotation device to the system.

If such a device will not be included, then increase the design HP of the belt drive by raising the service factor to 2.3. The support structure for the drive must also be stiffened accordingly.

Eagle Pd® ACHE Ratings & Center Distance

					870 RPM Motor		HP Rating		1160 RPM Motor	
Ratio	dR	Pitch F (in)	dN	Pitch F (in)	dN RPM	Speed (fpm)	Blue	Green	dN RPM	Speed (fpm)
4.500	40	7.018	180	31.580	193	1598	53.00	80.00	258	2131
4.737	38	6.667	180	31.580	184	1519	50.00	76.00	245	2025
5.000	36	6.316	180	31.580	174	1439	47.00	70.00	232	1918
5.000	40	7.018	200	35.089	174	1598	53.00	80.00	232	2131
5.263	38	6.667	200	35.089	165	1519	50.00	76.00	220	2025
5.294	34	5.965	180	31.580	164	1359	43.00	64.00	219	1811
5.556	36	6.316	200	35.089	157	1439	47.00	70.00	209	1918
5.600	40	7.018	224	39.300	155	1598	53.00	80.00	207	2131
5.625	32	5.614	180	31.580	155	1279	39.00	59.00	206	1705
5.882	34	5.965	200	35.089	148	1359	43.00	64.00	197	1811
5.895	38	6.667	224	39.300	148	1519	50.00	76.00	197	2025
6.000	30	5.263	180	31.580	145	1199	36.00	54.00	193	1598
6.222	36	6.316	224	39.300	140	1439	47.00	70.00	186	1918
6.250	32	5.614	200	35.089	139	1279	39.00	59.00	186	1705
6.429	28	4.912	180	31.580	135	1119	33.00	49.00	180	1492
6.588	34	5.965	224	39.300	132	1359	43.00	64.00	176	1811
6.667	30	5.263	200	35.089	131	1199	36.00	54.00	174	1598
7.000	32	5.614	224	39.300	124	1279	39.00	59.00	166	1705
7.143	28	4.912	200	35.089	122	1119	33.00	49.00	162	1492
7.467	30	5.263	224	39.300	117	1199	36.00	54.00	155	1598
8.000	28	4.912	224	39.300	109	1119	33.00	49.00	145	1492

Falcon Pd® ACHE Ratings & Center Distance

					870 RPM Motor		HP Rating		1160 RPM Motor	
Ratio	dR	Pitch F (in)	dN	Pitch F (in)	dN RPM	Speed (fpm)	20mm	37mm	dN RPM	Speed (fpm)
5.000	36	6.316	180	31.580	174	1439	39.00	55.23 #	232	1918
5.294	34	5.965	180	31.580	164	1359	37.00	52.04 #	219	1811
5.556	36	6.316	200	35.089	157	1439	39.00	49.82 #	209	1918
5.625	32	5.614	180	31.580	155	1279	34.00	49.19 #	206	1705
5.882	34	5.965	200	35.089	148	1359	37.00	46.97 #	197	1811
6.000	30	5.263	180	31.580	145	1199	32.00	46.01 #	193	1598
6.222	36	6.316	224	39.300	140	1439	39.00	44.43 #	186	1918
6.250	32	5.614	200	35.089	139	1279	34.00	44.11 #	186	1705
6.588	34	5.965	224	39.300	132	1359	37.00	41.89 #	176	1811
6.667	30	5.263	200	35.089	131	1199	32.00	41.57 #	174	1598
7.000	32	5.614	224	39.300	124	1279	34.00	39.35 #	166	1705
7.467	30	5.263	224	39.300	117	1199	32.00	57.13 #	155	1598

Hawk Pd® ACHE Ratings & Center Distance

					870 RPM Motor		HP Rating			1160 RPM Motor	
Ratio	dR	Pitch F (in)	dN	Pitch F (in)	dN RPM	Speed (fpm)	40mm	55mm	85mm	dN RPM	Speed (fpm)
4.200	40	7.018	168	29.475	207	1598	36.87	53.09	65.69 #	276	2131
4.421	38	6.667	168	29.475	197	1519	34.59	49.80	62.52 #	262	2025
4.667	36	6.316	168	29.475	186	1439	32.26	46.45	59.03 #	249	1918
4.800	40	7.018	192	33.686	181	1598	36.87	53.09	57.44 #	242	2131
4.941	34	5.965	168	29.475	176	1359	29.89	43.04	55.85 #	235	1811
5.053	38	6.667	192	33.686	172	1519	34.59	49.80	54.58 #	230	2025
5.250	32	5.614	168	29.475	166	1279	27.47	39.56	52.68 #	221	1705
5.333	36	6.316	192	33.686	163	1439	32.26	46.45	51.73 #	218	1918
5.400	40	7.018	216	37.896	161	1598	36.87	51.09 #	51.09 #	215	2131
5.600	30	5.263	168	29.475	155	1199	25.00	36.01	49.19 #	207	1598
5.647	34	5.965	192	33.686	154	1359	29.89	43.04	48.87 #	205	1811
5.684	38	6.667	216	37.896	153	1519	34.59	48.55 #	48.55 #	204	2025
5.793	29	5.088	168	29.475	150	1159	23.75	34.20	47.60 #	200	1545
6.000	28	4.912	168	29.475	145	1119	22.50	32.38	46.01 #	193	1492
6.000	32	5.614	192	33.686	145	1279	27.47	39.56	46.01 #	193	1705
6.000	36	6.316	216	37.896	145	1439	32.26	46.01 #	46.01 #	193	1918
6.353	34	5.965	216	37.896	137	1359	29.89	43.04	43.48 #	183	1811
6.400	30	5.263	192	33.686	136	1199	25.00	36.01	43.16 #	181	1598
6.621	29	5.088	192	33.686	131	1159	23.75	34.20	41.57 #	175	1545
6.750	32	5.614	216	37.896	129	1279	27.47	39.56	40.94 #	172	1705
6.857	28	4.912	192	33.686	127	1119	22.50	32.38	40.30 #	169	1492
7.200	30	5.263	216	37.896	121	1199	25.00	36.01	38.40 #	161	1598
7.448	29	5.088	216	37.896	117	1159	23.75	34.20	37.13 #	156	1545
7.714	28	4.912	216	37.896	113	1119	22.50	32.38	35.86 #	150	1492

Rating limited by bushing capacity

HP Rating		1750 RPM Motor		HP Rating		Belt Length				
					Belt Length Correction Factors	1.07	1.12	1.14	1.16	1.20
Blue	Green	dN RPM	Speed (fpm)	Blue	Green	2800mm c-c (in.)	3136mm c-c (in.)	3304mm c-c (in.)	3500mm c-c (in.)	3920mm c-c (in.)
67.00	100.00	389	3215	93.00	139.00	21.27	28.82	32.41	36.53	45.20
63.00	95.00	369	3054	88.00	132.00	21.48	29.04	32.64	36.76	45.43
59.00	88.00	350	2894	81.00	122.00	21.69	29.26	32.86	36.99	45.67
67.00	100.00	350	3215	93.00	139.00	No Fit	24.69	28.53	32.84	41.75
63.00	95.00	333	3054	88.00	132.00	No Fit	24.90	28.75	33.07	41.98
54.00	81.00	331	2733	75.00	113.00	21.90	29.48	33.09	37.22	45.91
59.00	88.00	315	2894	81.00	122.00	No Fit	25.11	28.96	33.29	42.21
67.00	100.00	313	3215	93.00	139.00	No Fit	No Fit	No Fit	27.86	37.31
50.00	74.00	311	2572	69.00	103.00	22.11	29.70	33.31	37.45	46.14
54.00	81.00	298	2733	75.00	113.00	No Fit	25.32	29.18	33.51	42.44
63.00	95.00	297	3054	88.00	132.00	No Fit	No Fit	No Fit	28.07	37.53
45.00	68.00	292	2411	63.00	94.00	22.32	29.92	33.54	37.68	46.38
59.00	88.00	281	2894	81.00	122.00	No Fit	No Fit	No Fit	28.28	37.75
50.00	74.00	280	2572	69.00	103.00	No Fit	25.53	29.39	33.73	42.67
41.00	62.00	272	2250	N.R.**	N.R.**	22.53	30.14	33.76	37.91	46.61
54.00	81.00	266	2733	75.00	113.00	No Fit	No Fit	23.63	28.49	37.97
45.00	68.00	263	2411	63.00	94.00	No Fit	25.74	29.61	33.95	42.90
50.00	74.00	250	2572	69.00	103.00	No Fit	No Fit	23.83	28.70	38.19
41.00	62.00	245	2250	N.R.**	N.R.**	No Fit	25.94	29.82	34.17	43.13
45.00	68.00	234	2411	63.00	94.00	No Fit	No Fit	24.03	28.91	38.41
41.00	62.00	219	2250	N.R.**	N.R.**	No Fit	No Fit	24.23	29.11	38.63

HP Rating		1750 RPM Motor		HP Rating		Belt Length					
					Belt Length Correction Factors	1.04	1.07	1.08	1.10	1.12	1.14
20mm	37mm	dN RPM	Speed (fpm)	20mm	37mm	2800mm c-c (in.)	3136mm c-c (in.)	3304mm c-c (in.)	3500mm c-c (in.)	3920mm c-c (in.)	4410mm c-c (in.)
51.00	73.62 #	350	2894	74.00	111.07 #	21.69	29.26	32.86	39.15	41.13	55.63
48.00	69.50 #	331	2733	70.00	105.04 #	21.90	29.48	33.09	39.42	41.36	55.87
51.00	66.32 #	315	2894	74.00	99.96 #	16.24	25.11	28.96	36.39	37.42	52.33
45.00	65.37 #	311	2572	65.00	98.69 #	22.11	29.70	33.31	39.70	41.58	56.11
48.00	62.52 #	298	2733	70.00	94.57 #	16.44	25.32	29.18	36.67	37.64	52.57
42.00	61.25 #	292	2411	61.00	92.66 #	22.32	29.92	33.54	39.98	41.81	56.35
51.00	59.03 #	281	2894	74.00	89.17 #	No Fit	18.62	23.43	33.09	32.41	48.18
45.00	59.03 #	280	2572	65.00	88.86 #	16.64	25.53	29.39	36.95	37.86	52.80
48.00	55.85 #	266	2733	70.00	84.41 #	No Fit	18.82	23.63	33.36	32.62	48.41
42.00	55.23 #	263	2411	61.00	83.46 #	16.84	25.74	29.61	37.22	38.08	53.04
45.00	52.68 #	250	2572	65.00	79.33 #	No Fit	19.02	23.83	33.64	32.83	48.64
42.00	49.19 #	234	2411	61.00	74.26 #	No Fit	19.21	24.03	33.92	33.04	48.87

HP Rating			1750 RPM Motor		HP Rating			Belt Length			
							Belt Length Correction Factors	1.05	1.10	1.10	1.10
40mm	55mm	85mm	dN RPM	Speed (fpm)	40mm	55mm	85mm	3150mm c-c (in.)	3360mm c-c (in.)	3500mm c-c (in.)	3850mm c-c (in.)
45.14	65.00	87.59 #	417	3215	60.25	86.76	132.33 #	31.35	35.73	38.62	45.76
42.40	61.06	83.14 #	396	3054	56.79	81.77	125.66 #	31.58	35.96	38.85	46.00
39.61	57.03	79.02 #	375	2894	53.24	76.66	119.00 #	31.80	36.19	39.09	46.24
45.14	65.00	76.80 #	365	3215	60.25	86.76	115.83 #	26.73	31.35	34.36	41.70
36.75	52.92	74.57 #	354	2733	49.59	71.41	112.34 #	32.03	36.42	39.32	46.48
42.40	61.06	72.99 #	346	3054	56.79	81.77	109.80 #	26.94	31.57	34.58	41.93
33.84	48.72	70.13 #	333	2572	46.59	66.02	105.67 #	32.26	36.66	39.55	46.72
39.61	57.03	69.18 #	328	2894	53.24	76.66	104.09 #	27.16	31.80	34.81	42.17
45.14	65.00	68.23 #	324	3215	60.25	86.76	102.82 #	21.10	26.36	29.62	37.34
31.63	44.42	65.69 #	313	2411	41.99	60.47	97.43	32.48	36.89	39.79	46.96
36.75	52.92	65.05 #	310	2733	49.59	71.41	98.38 #	27.37	32.02	35.03	42.40
42.40	61.06	64.74 #	308	3054	56.79	81.77	97.70 #	21.30	26.57	29.83	37.56
29.33	42.24	63.47 #	302	2331	N.R.**	N.R.**	N.R.**	32.60	37.00	39.90	47.08
27.79	40.02	61.25 #	292	2250	N.R.**	N.R.**	N.R.**	32.71	37.12	40.02	47.20
33.84	48.72	61.25 #	292	2572	46.59	66.02	92.66 #	27.59	32.24	35.25	42.63
39.61	57.03	61.25 #	292	2894	53.24	76.66	92.66 #	21.50	26.78	30.04	37.78
36.75	52.92	58.07 #	275	2733	49.59	71.41	87.26 #	21.71	26.99	30.25	38.00
31.63	44.42	57.44 #	273	2411	41.99	60.47	86.63 #	27.80	32.46	35.48	42.86
29.33	42.24	55.53 #	264	2331	N.R.**	N.R.**	N.R.**	27.91	32.56	35.59	42.97
33.84	48.72	54.58 #	259	2572	46.59	66.02	82.19 #	21.91	27.20	30.47	38.22
27.79	40.02	53.63 #	255	2250	N.R.**	N.R.**	N.R.**	28.01	32.67	35.70	43.09
31.63	44.42	51.09 #	243	2411	41.99	60.47	77.11 #	22.11	27.40	30.68	38.45
29.33	42.24	49.50 #	235	2331	N.R.**	N.R.**	N.R.**	22.21	27.51	30.78	38.56
27.79	40.02	47.06 #	227	2250	N.R.**	N.R.**	N.R.**	22.31	27.61	30.89	38.67

Rating limited by bushing capacity ** Not recommended due to high belt flexure (sprocket diameters below allowed minimums)

Eagle Pd® Belt Data

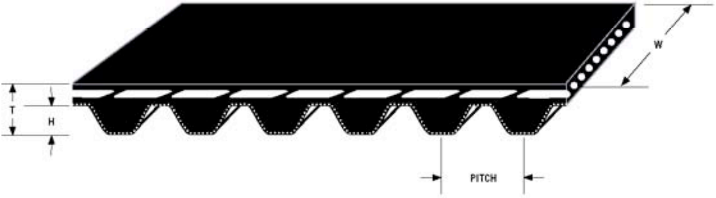
Dimensions

Part Number			Teeth	Length (in.)	Belt Weight (lbs.)	
B	G	-2800	200	110.24	1.29	1.93
B	G	-3136	224	122.46	1.45	2.16
B	G	-3304	236	130.08	1.52	2.28
B	G	-3500	250	137.80	1.61	2.41
B	G	-3920	280	154.33	1.81	2.70

Belt Part Number

G - 3304

- G — Width & Pitch Color
- 3304 — Pitch Length in mm



W is the belt top width

T is the total belt thickness

Pitch is the spacing of the teeth

H is the tooth height

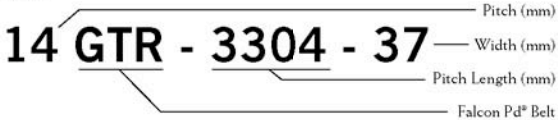
Color	Width		Pitch	T	H	Belt Mass
	Inch	mm.		in.	in.	kg/m
Blue	1.38	35	14mm	0.34	0.21	0.241
Green	2.07	52.5	14mm	0.34	0.21	0.363

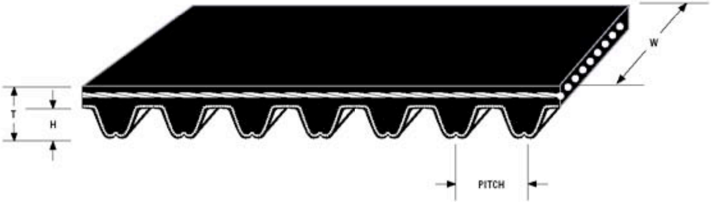
Falcon® Pd Belt Data

Dimensions

Width (mm)		Length (mm)	Teeth	Length (in.)	Belt Weight (lbs.)	
					20mm	37mm
20	37	2800	200	110.24	0.95	1.71
20	37	3136	224	122.46	1.06	1.91
20	37	3304	236	130.08	1.11	2.01
20	37	3500	250	137.8	1.18	2.13
20	37	3920	280	154.33	1.32	2.38
20	37	4410	315	173.62	1.48	2.68

Belt Part Number





W is the belt top width

T is the total belt thickness

Pitch is the spacing of the teeth

H is the tooth height

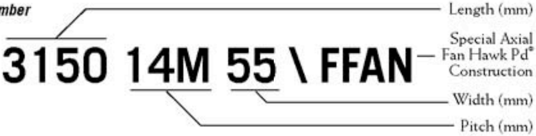
Width Suffix	Width		Pitch	T	H	Belt Mass
	Inch	mm		in.	in.	kg/m
20	0.79	20	14mm	0.39	0.24	0.154
37	1.46	37	14mm	0.39	0.24	0.277

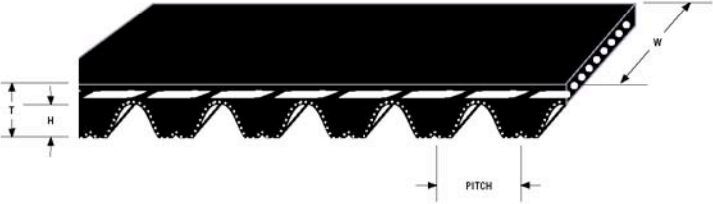
Axial Fan Hawk Pd® Belt Data

Dimensions

Width (mm)			Length (mm)	Teeth	Length (in.)	Belt Weight (lbs.)		
						40mm	55mm	85mm
40	55	85	3150	225	124.02	2.88	3.96	6.10
40	55	85	3360	240	132.28	3.07	4.22	6.50
40	55	85	3500	250	137.80	3.19	4.40	6.77
40	55	85	3850	275	151.57	3.51	4.83	7.44

Belt Part Number





W is the belt top width

T is the total belt thickness

Pitch is the spacing of the teeth

H is the tooth height

Width Suffix	Width		Pitch	T	H	Belt Mass
	Inch	mm		in.	in.	kg/m
40	0.79	40	14mm	0.39	0.24	0.412
55		55	14mm	0.39	0.24	0.570
85	1.46	85	14mm	0.39	0.24	0.877

Eagle Pd® ACHE Sprocket Data

For Blue belts (35mm wide)

# of teeth	Product #	Bushing	Bore Min. (in.)	Bore Max. (in.)	Pitch F (in.)	O.D. (in.)	Material	Weight* lbs.	WR^2** lb-ft^2
28	B-28S-SK	SK	1/2	2 5/8	4.912	4.802	Ductile iron	3.7	0.1077
30	B-30S-SK	SK	1/2	2 5/8	5.263	5.153	Ductile iron	4.9	0.1481
32	B-32S-SK	SK	1/2	2 5/8	5.614	5.504	Ductile iron	6.0	0.2009
34	B-34S-SK	SK	1/2	2 5/8	5.965	5.855	Ductile iron	7.2	0.2648
36	B-36S-SF	SF	1/2	2 15/16	6.316	6.206	Ductile iron	7.6	0.3269
38	B-38S-SF	SF	1/2	2 15/16	6.667	6.557	Ductile iron	8.9	0.4075
40	B-40S-SF	SF	1/2	2 15/16	7.018	6.908	Ductile iron	10.3	0.5139
180	B-180S-F	F	1	3 15/16	31.580	29.365	Cast iron	62.0	79.5
200	B-200S-F	F	1	3 15/16	35.089	33.576	Cast iron	69.0	119.7

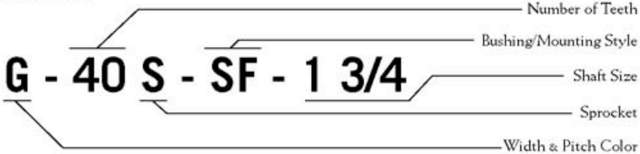
* Weights are approximate and include the bushing.
** WR^2 calculations do not include the bushing.

For Green belts (52.5mm wide)

# of teeth	Product #	Bushing	Bore Min. (in.)	Bore Max. (in.)	Pitch F (in.)	O.D. (in.)	Material	Weight* lbs.	WR^2** lb-ft^2
28	G-28S-MPB	n.a.	1	2.688	4.912	4.802	Ductile iron	11.8	0.2397
30	G-30S-MPB	n.a.	1	2.750	5.263	5.153	Ductile iron	13.7	0.3201
32	G-32S-MPB	n.a.	1	3.000	5.614	5.504	Ductile iron	15.8	0.4167
34	G-34S-MPB	n.a.	1	3.250	5.965	5.855	Ductile iron	18.0	0.5368
36	G-36S-SF	SF	1/2	2 15/16	6.316	6.206	Ductile iron	8.7	0.4325
38	G-38S-SF	SF	1/2	2 15/16	6.667	6.557	Ductile iron	10.7	0.5506
40	G-40S-SF	SF	1/2	2 15/16	7.018	6.908	Ductile iron	12.7	0.6713
180	G-180S-F	F	1	3 15/16	31.580	29.365	Cast iron	98.0	91.1
200	G-200S-F	F	1	3 15/16	35.089	33.576	Cast iron	108.0	135.8

* Weights are approximate and include the bushing.
** WR^2 calculations do not include the bushing.

Sprocket Part Number



Falcon Pd® ACHE Sprocket Data

For 20mm wide belts

# of teeth	Product #	Bushing	Bore Min. (in.)	Bore Max. (in.)	Pitch F (in.)	O.D. Sprocket (in.)	O.D. Flange (in.)	Material	Weight* lbs.	WR²** lb-ft²
30	GTR-30G-14M-20-SK	SK	1/2	2 5/8	5.263	5.153	5.59	Cast iron	5.06	0.071
32	GTR-32G-14M-20-SK	SK	1/2	2 5/8	5.614	5.504	5.91	Cast iron	6.16	0.094
34	GTR-34G-14M-20-SK	SK	1/2	2 5/8	5.965	5.855	6.22	Cast iron	7.04	0.122
36	GTR-36G-14M-20-SF	SF	1/2	2 15/16	6.316	6.206	6.54	Cast iron	5.58	0.153
180	GTR-180G-14M-20-E	E	7/8	3 1/2	31.580	29.365	n.a.	Cast iron	72.60	77.6
200	GTR-200G-14M-20-E	E	7/8	3 1/2	35.089	33.576	n.a.	Cast iron	79.20	117.2
224	GTR-224G-14M-20-E	E	7/8	3 1/2	39.300	37.786	n.a.	Cast iron	88.00	182.6

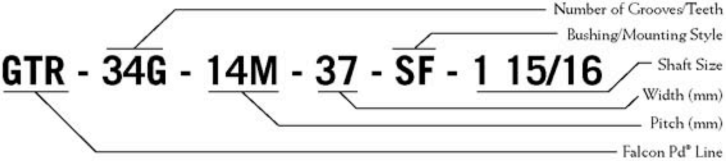
* Weights are approximate and include the bushing.
** WR² calculations do not include the bushing.

For 37mm wide belts

# of teeth	Product #	Bushing	Bore Min. (in.)	Bore Max. (in.)	Pitch F (in.)	O.D. Sprocket (in.)	O.D. Flange (in.)	Material	Weight* lbs.	WR²** lb-ft²
30	GTR-30G-14M-20-SK	SK	1/2	2 5/8	5.263	5.153	5.59	Cast iron	7.92	0.107
32	GTR-32G-14M-20-SK	SK	1/2	2 5/8	5.614	5.504	5.91	Cast iron	9.24	0.146
34	GTR-34G-14M-20-SK	SK	1/2	2 5/8	5.965	5.855	6.22	Cast iron	11.88	0.185
36	GTR-36G-14M-20-SF	SF	1/2	2 15/16	6.316	6.206	6.54	Cast iron	13.20	0.218
180	GTR-180G-14M-20-E	E	7/8	3 1/2	31.580	29.365	n.a.	Cast iron	81.00	89.3
200	GTR-200G-14M-20-E	E	7/8	3 1/2	35.089	33.576	n.a.	Cast iron	90.00	133.4
224	GTR-224G-14M-20-E	E	7/8	3 1/2	39.300	37.786	n.a.	Cast iron	101.20	240.7

* Weights are approximate and include the bushing.
** WR² calculations do not include the bushing.

Sprocket Part Number



Hawk Pd® ACHE Sprocket Data

For 40mm wide belts

# of teeth	Product #	Bushing	Bore Min. (in.)	Bore Max. (in.)	Pitch Dia. (in.)	O.D. Sprocket (in.)	O.D. Flange (in.)	Material	Weight* lbs.	WR²** lb-ft²
28	P2814M40	SK	1/2	2 5/8	4.912	4.802	5.56	Cast Iron	7.4	0.13
29	P2914M40	SK	1/2	2 5/8	5.088	4.978	5.56	Cast Iron	7.5	0.14
30	P3014M40	SK	1/2	2 5/8	5.263	5.153	5.56	Cast Iron	7.6	0.16
32	P3214M40	SK	1/2	2 5/8	5.614	5.504	6.09	Cast Iron	9.2	0.23
34	P3414M40	SK	1/2	2 5/8	5.965	5.855	6.50	Cast Iron	10.6	0.30
36	P3614M40	SF	1/2	2 15/16	6.316	6.206	6.87	Cast Iron	11.9	0.32
38	P3814M40	SF	1/2	2 15/16	6.667	6.557	7.22	Cast Iron	13.3	0.47
40	P4014M40	SF	1/2	2 15/16	7.018	6.908	7.50	Cast Iron	15.1	0.61
168	F16814M40	E	7/8	3 1/2	29.475	29.365	n.a.	Cast Iron	95.0	79.00
192	F19214M40	E	7/8	3 1/2	33.686	33.576	n.a.	Cast Iron	109.0	124.00
216	F21614M40	E	7/8	3 1/2	37.896	37.786	n.a.	Cast Iron	143.0	210.00

* Weights are approximate and include the bushing.
** WR² calculations do not include the bushing.

For 55mm wide belts

# of teeth	Product #	Bushing	Bore Min. (in.)	Bore Max. (in.)	Pitch Dia. (in.)	O.D. Sprocket (in.)	O.D. Flange (in.)	Material	Weight* lbs.	WR²** lb-ft²
28	P2814M55	SK	1/2	2 5/8	4.912	4.802	5.56	Cast Iron	9.3	0.17
29	P2914M55	SK	1/2	2 5/8	5.088	4.978	5.56	Cast Iron	10.2	0.20
30	P3014M55	SK	1/2	2 5/8	5.263	5.153	5.56	Cast Iron	8.7	0.20
32	P3214M55	SK	1/2	2 5/8	5.614	5.504	6.09	Cast Iron	10.7	0.29
34	P3414M55	SK	1/2	2 5/8	5.965	5.855	6.50	Cast Iron	12.5	0.31
36	P3614M55	SF	1/2	2 15/16	6.316	6.206	6.87	Cast Iron	13.6	0.45
38	P3814M55	SF	1/2	2 15/16	6.667	6.557	7.22	Cast Iron	15.2	0.58
40	P4014M55	SF	1/2	2 15/16	7.018	6.908	7.50	Cast Iron	17.4	0.75
168	F16814M55	E	7/8	3 1/2	29.475	29.365	n.a.	Cast Iron	100.0	88.00
192	F19214M55	E	7/8	3 1/2	33.686	33.576	n.a.	Cast Iron	117.0	138.00
216	F21614M55	E	7/8	3 1/2	37.896	37.786	n.a.	Cast Iron	152.0	230.00

* Weights are approximate and include the bushing.
** WR² calculations do not include the bushing

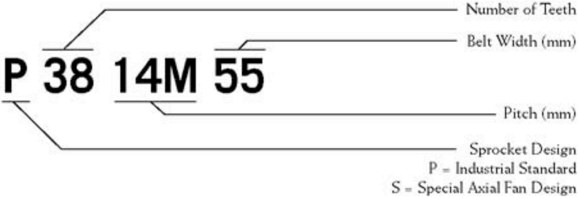
Hawk Pd® ACHE Sprocket Data *continued*

For 85mm wide belts

# of teeth	Product #	Bushing	Bore Min. (in.)	Bore Max. (in.)	Pitch F (in.)	O.D. Sprocket (in.)	O.D. Flange (in.)	Material	Weight* lbs.	WR²** lb-ft2
28	P2814M85	SFL	1/2	2 3/8	4.912	4.802	5.56	Ductile Iron	10.4	0.21
29	P2914M85	SFL	1/2	2 3/8	5.088	4.978	5.56	Ductile Iron	11.7	0.25
30	P3014M85	EL	7/8	2 7/8	5.263	5.153	5.56	Ductile Iron	11.1	0.23
32	P3214M85	EL	7/8	2 7/8	5.614	5.504	6.09	Ductile Iron	14.1	0.35
34	P3414M85	EL	7/8	2 7/8	5.965	5.855	6.50	Ductile Iron	17.0	0.50
36	P3614M85	SF	1/2	2 15/16	6.316	6.206	6.87	Cast Iron	16.9	0.62
38	P3814M85	SF	1/2	2 15/16	6.667	6.557	7.22	Cast Iron	19.1	0.79
40	P4014M85	SF	1/2	2 15/16	7.018	6.908	7.50	Cast Iron	22.1	1.03
168	F16814M85	E	7/8	3 1/2	29.475	29.365	n.a.	Cast Iron	108.0	107.00
192	F19214M85	E	7/8	3 1/2	33.686	33.576	n.a.	Cast Iron	130.0	171.00
216	F21614M85	E	7/8	3 1/2	37.896	37.786	n.a.	Cast Iron	161.0	270.00

* Weights are approximate and include the bushing.
** WR² calculations do not include the bushing.

Sprocket Part Number



Quick Detachable Bushing Data

Quick Detachable Bushings, ACHE

Bushing	** Torque Capacity (in-lb)	Bore Range (in.)		Cap Screws		
		Min. (in.)	Max (w/full key)	No.	Size	** Wrench Torque (in-lb)
SK	7,000	1/2	2 1/8	3	5/16 x 2	180
SF	11,000	1/2	2 3/16	3	3/8 x 2	360
SFL*	11,000	1/2	1 15/16	4	1/4 x 1 1/2	180
E	20,000	7/8	2 7/8	3	1/2 x 2 3/4	720
EL*	20,000	7/8	3 1/8	4	5/16 x 1 3/4	360
F	30,000	1	3 1/4	3	9/16 x 3 5/8	900

*Flangeless style

**Use of anti-seize or any other lubicant at the bushing/sprocket interface as well as to the screw threads invalidates these ratings and subjects the assembly to potentially hazardous damage.

Shaft and Key Data

Key Size Versus Shaft Diameter ANSI B17.1-1967 (R1998)

Nominal Shaft Diameter		Nominal Key Size	Set Screw Diameter
Over	To (Incl.)		
7/16	9/16	1/8	#10
9/16	7/8	3/16	1/4
7/8	1 1/4	1/4	5/16
1 1/4	1 3/8	5/16	3/8
1 3/8	1 3/4	3/8	3/8
1 3/4	2 1/4	1/2	1/2
2 1/4	2 3/4	5/8	1/2
2 3/4	3 1/4	3/4	5/8

Two Set Screws are recommended.
One located over the key
with an additional one at 90°.

British Standard Metric Shaft & Keys BS 4235:Part 1:1972(1986)

Nominal Shaft Diameter		Nominal Key Size w x h	Set Screw Diameter*
Over	To (Including)		
12	17	5 x 5	M6
17	22	6 x 6	M6
22	30	8 x 7	M8
30	38	10 x 8	M10
38	44	12 x 8	M10
44	50	14 x 9	M12
50	58	16 x 10	M12
58	65	18 x 11	M16
65	75	20 x 12	M16
75	85	22 x 14	M20

Two Set Screws are recommended.
One located over the key
with an additional one at 90°.

*Set Screw Diameter recommendations not part of BS Standard.

Center Distance Allowances

In addition to the calculated or tabulated center distance, sufficient system collapse must be provided to allow belt installation while avoiding belt damage. Conversely, there must be allowance to increase center distance to provide proper belt tensioning.

Falcon Pd® and Hawk Pd® *(installed on sprockets with flanges)*

If the belt is to be installed over one flanged sprocket and one unflanged sprocket with the sprockets already in place, allow the following decrease in center distance for installation and increase in center distance for tensioning. All allowances are from nominal center distance.

Pitch Length Range (mm)	Allowance (Collapse) for Installation (mm/in)	Allowance (Increase) for Tensioning (mm/in)
1525 - 3050	39.0 / 1.5	5.0 / 0.2
Greater than 3050	41.5 / 1.6	7.5 / 0.3

If the belt is to be installed over two flanged sprockets with the sprockets already in place, allow the following decrease in center distance for installation and increase in center distance for tensioning. All allowances are from nominal center distance.

Pitch Length Range (mm)	Allowance (Collapse) for Installation (mm/in)	Allowance (Increase) for Tensioning (mm/in)
1525 - 3050	62.0 / 2.4	5.0 / 0.2
Greater than 3050	64.5 / 2.5	7.5 / 0.3

Eagle Pd® *(sprockets do not feature flanges)*

Pitch Length Range (mm)	Allowance (Collapse) for Installation (mm/in)	Allowance (Increase) for Tensioning (mm/in)
1525 - 2800	17.8 / 0.7	5.0 / 0.2
Greater than 2800	20.3 / 0.8	7.5 / 0.3

Engineering Considerations

Static Conductivity

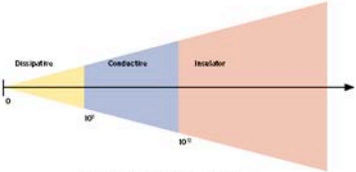
When two surfaces in close contact are moved relative to one another, a static charge is generated. A belted ACHE system is a classic example. In operation, the belt is continually entering and leaving the pulley/sprocket surface thereby generating static electricity. Additional charge is generated by action of the air against the fan blades. Varying the types of surfaces can affect the amount of static electricity generated or determine the polarity of the charge.

The generation of static electricity cannot be stopped. However, the accumulation and storage of static electricity can be controlled. There are several techniques to neutralize the electrostatic charge in a belt drive system. The first variable to consider is the ambient conditions in which the belt drive system operates. Static electricity is continuously being bled from the system by the surrounding atmosphere. Over 5 times as much static electricity will be dissipated by a 65% relative humidity environment than by a 15% relative humidity atmosphere.

Accumulation and storage of electrostatic charges can be controlled by making the entire system sufficiently conductive by insuring that it is contiguously and properly grounded. In systems sensitive to electrostatic charge, the driveR and driveN units, the pulley/sprockets, shafts, bearings and supporting structure must all be connected electrically to a common ground. Also, conductive grease is essential in the bearings. Static conductive belts should also be used. Under no circumstances should a belt be considered the electrical connection or conductor between the driveR and driveN units.

Rubber belts can made marginally conductive by addition of static conducting fillers such as acetylene carbon black or by applying a relatively thin layer of conductive film to the driving surfaces of the belt when manufactured. RMA IP-3-3, 1995 defines a procedure for determining the relative static conductive characteristics of a belt at the time of manufacture. Values so determined can be considered valid for the first three months of operation barring any adverse operating conditions.

MATERIAL CLASSIFICATION



Surface Resistivity (Ohms/surface square unit)

Since static electricity is strictly a surface effect, conductive properties can change dramatically during belt storage and use. Dust and contamination from both storage and/or the operating environment can collect on and become embedded in the belt surface, greatly altering the surface resistivity of the belt. For example: a surprisingly small amount of silica dust can turn a static conducting belt into an insulator. This reinforces the principle of never relying upon the belt as a grounding conductor of the system.

ACHE STATIC CONDUCTING RATINGS

Belt Design	Resistivity	Rating (RMA IP-3-3)
Eagle Pd®	$r > 10^{12}$	non-conductive
Eagle Pd® Special Order	$10^5 < r < 10^{12}$	conductive
Falcon Pd®	$10^5 < r < 10^{11}$	conductive
Axial Fan Hawk Pd®	$10^5 < r < 10^{11}$	conductive

Eagle Pd® belts can be special ordered as static conductive per RMA IP-3-3. All regular production Falcon Pd® and Axial Fan Hawk Pd® belts are rated as static conductive to that same specification. Other manufacturers must be consulted concerning their specific product designs.

Fan Performance

You have selected your belt drive based upon maximum efficiency at parameters for ideal fan operating condition (i.e. RPM, blade pitch). Information on this ideal operating condition should have come from the original specification sheet (fan curve) supplied by the cooler manufacturer at time of purchase. It now becomes tempting to use the VFD (Variable Frequency Drive motor controller) to attenuate airflow for seasonal adjustment. This rarely results in the fan running in its "sweet spot". There is a complex relationship between static pressure, fan speed and blade pitch. Adjusting only one parameter can throw this relationship out of whack. You may inadvertently place the fan in a near-stall condition, guaranteeing a most energy inefficient operation.

Windmilling

Sometimes a fan will auto-rotate, often backward to its intended direction of rotation. This is especially prevalent in a system where more than one fan shares a housing and one of the fans is not energized. A very heavy load is then placed on the drive when the fan is switched on. A VDF can help by providing a soft start.

Another solution is a mechanical accessory known as an Anti-Rotation Device. It is a simple, self-contained attachment that bolts onto the large fan sprocket. Your fan supplier should be able to offer further information on this device

Vibration

Blade pass frequency (fan speed times the number of blades) should be the dominant system frequency. If vibration analysis shows a dominant frequency that is some multiple of the motor speed then the investigation should focus on the motor or the belt drive. Belt tension, bearing condition, mounting bolts and/or drive alignment are some possible avenues of investigation before the experts are called in.

Alignment

Parallel Misalignment

Angular Misalignment

Misalignment causes uneven loading across the width of the belt. Uneven loading across the width of the belt means that some tensile members are carrying more load than are others. This can damage the tensile member of the belt as well as changing the overhung load to the shafts and bearings.

Misalignment can cause tracking aberrations. This leads to increased friction which in turn generates both unnecessary heat and excessive component wear. Unnecessary heat adversely affects the service life of drive components such as bearings, belts and motors. Abrasive wear shortens the service life of belt, pulleys and sprockets.

No high performance flat belt of any configuration can operate satisfactorily with very much misalignment. The general industry standard for synchronous belt systems is that misalignment should not exceed 1/4 ° (or 1/16" per foot of center distance). The more severe the drive, the more important alignment becomes.

Drive serviceability is directly dependant on the installer's craftsmanship. In addition to shaft orientation, improper assembly of the bushing can lead to a cocked sprocket causing angular misalignment. It is recommended to always recheck alignment immediately after final belt tensioning is completed. On most ACHE Drives, angular misalignment is corrected by using shims at the motor bracket. There are several methods and tools available, including a laser alignment device, to aid the process.

Belt Tracking

On some long center distance systems' belt tracking may remain a problem even after sprocket/shaft alignment has been carefully set. In the worst case the belt will contact a flange on the driveR sprocket while tracking off the opposite edge of the driveN sprocket. When this tracking condition is observed, sprocket location may need to be adjusted. Although then technically out of parallel alignment, optimum system performance is achieved when one sprocket is offset such that the belt runs lightly against one flange of the driveR sprocket while running nearly centered on the driveN sprocket.

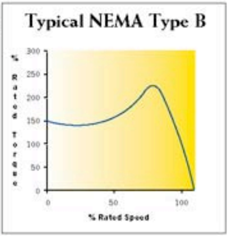
RoHS Compliance

Goodyear Engineered Products' ACHE belts are manufactured in compliance with Directive 2002/95/EC of the European Parliament and the Council of 27 January 2003, commonly referred to as RoHS. Regarding specific material requirements Goodyear EP stipulates the following:

Lead is < 0.01% and Cadmium is < 0.001%. Both lead and cadmium are "Not Intentionally Added" to the homogeneous elastomeric material and concentrations are below the maximum accepted limits for these metals.

Hard Starts

Because of the positive engagement between belt and sprocket, a synchronous ACHE belt drive system will not slip to alleviate the over-torque condition resulting from hard starts. A typical induction motor can produce start-up torque of 150% to 300% of the nameplate rating during an across-the-line starting event. The belt selection process must consider the actual load to be expected. Component selection as well as tensioning parameters must be based accordingly.



The integrity of the supporting structure must also be considered. When the line contacts close, the sudden application of torque can cause flexing of the structure. This has the same effect as running with insufficient installation tension. In many cases the result will be a ratcheting of the teeth at the small sprocket. Teeth can even be machined off the belt as a "spin burn".

Hard-start drive systems generally end up being a magnitude larger than similar systems that feature a soft start. Utilizing a soft start device such as a variable frequency drive should be considered. A controlled start operation not only allows reduction of the total size of the drive, it also conserves energy. An additional benefit gained by a controlled-start system is a reduction in the peak loads on the bearings, shaft and structure.

Belt Tension

A synchronous belt drive is a precision gear train. Pitching (tooth mesh) between belt and sprocket is critical to proper function and acceptable service life. Manufacturing tolerances of belt and sprockets are beyond control of the end user. However, belt tension is the prime determinant of proper tooth mesh and is within direct control of the user. Belt tension is important for two prime reasons: tension defines final belt dimensions and also prevents the belt tooth from climbing up the flank of the sprocket tooth.

Materials used in current generation synchronous belts yield a very stable belt carcass able to absorb the stresses of the application. However, there is a limit to how stout a belt can be since the belt must remain flexible in order to function. Because of the residual elasticity required, a belt is slightly short in the just-out-of-the-box condition. It must be given a metered preload in order to assume the dimensions required for proper pitching with the sprockets. This is the first function of installation tensioning: to bring the system into proper pitch.

In order to promote smooth engagement/disengagement between sprocket and belt, the design of the tooth form incorporates a draft angle. Under certain load conditions the belt and sprocket will dislocate slightly with respect to each other with the belt trying to rise or climb up the included draft angle. In addition, there is a centrifugal force generated by operation at speed which also promotes the belt rising out of mesh. This defines the second function of installation tensioning: to keep the system operating within the proper pitch tolerance range.

Proper belt tension is a function of the specific belt design, the load to be transmitted and the operating speed. Manufacturer-supplied charts or use of the MAXIMIZER™ Drive Selection Program will define the target tension settings for an application. The installer must then set the tension using one of a selection of tension measuring tools such as the TensionRite® Belt Frequency Meter. The drive supporting structure must be sufficiently stable to maintain tensioning and alignment settings during drive operation.

Tensioning with Idlers

For simplicity's sake, a moveable motor base is the preferred method of belt tensioning. This is not always possible. However, Goodyear Engineered Products ACHE belts may be satisfactorily used with idlers. Idlers may be used to apply tension for those systems where the center distance is not adjustable. Backside idlers may also be used to increase sprocket wrap (teeth in mesh or TIM) at the small sprocket. Idlers do impose an additional bending stress on the belt. Because of that, the RMA suggests that the horsepower rating for a system utilizing one idler be reduced by a correction factor of 0.91.

Here are some guidelines to observe when designing a synchronous belt system incorporating either a backside idler or an inside idler.

- Locate the idler on the slack span of the belt.
- Idlers should be rigidly mounted and sufficiently stout to support the load imposed by operating conditions.
- Spring-loaded idlers are not recommended for any synchronous belt system.
- Idlers must be aligned with the other system components. Both parallel and angular alignment requirements must be observed.
- Inside idlers must be provided with the same tooth profile as the belt.
- Backside idlers should be flat (uncrowned) only.
- The belt span between the idler and the entry to the next sprocket should be a minimum of 5 x the belt width.
- Backside idlers for a 14mm pitch belt system should be a minimum of 4-1/2" diameter for 55mm and under belt width and a minimum of 6" diameter for belts greater than 55mm wide.
- Inside idlers should generally be as large as the smallest load-carrying sprocket in the system. (This rule may be violated where the idler wrap is less than 45°.
- Backside idler wrap greater than 90° is not recommended.
- Backside idlers on long-span systems (where the span length is greater than 5 x the idler diameter) should be furnished with guide flanges. The flange spacing should be approximately 115% of the belt width while the flange height should be approximately 130% of the belt thickness. Flanges should have a slight flare and exhibit no sharp edges.
- Inside idlers and unflanged backside idlers should have a face width of 125% of the belt width except for idlers with an Eagle Pd™ tooth pattern which should have a width equal to that of the driveR and driveN sprockets.
- Belt length selection should keep idler arc of contact (idler wrap) to a minimum. However, idler collapse must be sufficient to allow installation of the belt (see "Center Distance Allowance" information).
- Idlers should be located such that adequate clearance between the opposing belt strand is maintained. Expect some belt vibration or flop. A prediction of the clearance to be provided can be based upon the length of the belt span by the following relationship: Minimum recommended clearance = belt span length / 20.

Sprocket Flanges

Most ACHE installations feature vertical shaft layouts. Gravity has increased influence on belt tracking in such systems. The unique helical offset tooth pattern of the Eagle Pd® belts makes an Eagle Pd® system self-tracking and thus immune to such effects. Straight-tooth designs are another matter. It is desirable to utilize flanges on the sprockets of such systems.

For vertical shaft drives, the smaller driveR sprocket should be furnished flanges on both sides. The larger driveN sprocket, because of size and resulting cost, is generally used without flanges. If a flange is absolutely required (as an added cost feature), the most cost effective solution is to provide a flange to the bottom side only. Flanges must be securely fastened, as tracking forces can be considerable. Appropriately spaced mechanical fasteners or welding are recommended methods. Flanges should have a slight flare and exhibit no sharp edges.

Sprocket Wear

Sprockets are consumable items and as such, should be expected to eventually wear out. Erosion of the sprocket affects the mesh between belt and sprocket. Increasingly poor fit then accelerates the erosion such that component wear becomes self perpetuating. Because of the great size difference between driveR and driveN sprockets of the typical ACHE application, the smaller motor sprocket experiences a much faster wear rate than does the fan sprocket.

Sprockets should be carefully inspected every time belts are changed. Sprockets should be given special attention at the third belt installation (or sooner if operating under severe conditions) since the need for replacement is likely eminent.

Inspect sprockets for:

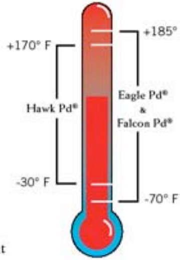
- Pockets or undercut in the driving flanks
- Shelf or step on all surfaces (loss of tooth volume)
- Reduced O.D.
- Damage such as nicks or dings (foreign body damage)
- Loose or missing flanges

Continued operation with worn sprockets will drastically reduce the service life of the replacement belt.

Environmental Factors

Oil Environments: Contact with oil (or any liquid, for that matter) should be avoided with any belt drive. When an oily environment does exist, the Hibrex® compound used in Eagle Pd® and Falcon Pd® will provide improved performance over competitive neoprene belts. The premium neoprene-based compound used in Hawk Pd® belts gives oil resistance equal to or better than seen with competitive neoprene belts.

Beyond actual attack to the belt, the presence of oil will alter the frictional properties of the belt/sprocket interface. This will promote the tendency of the belt teeth to rise on the sprocket teeth when the system is under load, leading to a ratcheting event. Belt tension will have to be increased to counter this effect. Increasing belt tension of course results in increased bearing and structure loading. Best preventative action is to protect the belt drive from oil contamination.



Temperature: Goodyear Engineered Products' ACHE Synchronous Belts will successfully function over a wide range of ambient temperatures. Although the backing rubber is designed to handle intermittent temperatures of +275°F, the recommended upper limit is +185°F ambient. This then allows for the normal heat rise associated with high speed flexing without degrading belt performance.

Falcon Pd® and Eagle Pd® have improved cold flex properties compared to premium neoprene belts.

Temperature degradation generally results in increased brittleness of the belt carcass. This can then lead to premature cracking of the belt carcass (although not all such cracks are attributed to heat embrittlement). The resulting cracks then expose the tensile cord to damage resulting in ultimate belt failure.

Noise: Drive noise is generated by all rotating drive components and is often magnified by the resonating properties of the supporting structure as well as by the acoustical properties of the enclosure. Increased noise can result from a misaligned drive system. Improper belt tension (both too loose and too tight) is known to increase noise generation. Loose fasteners and vibrating structural elements are also known culprits as are damaged or eroded sprockets or rough bearings.

Belt type and profile can affect drive noise. The unique tooth design of the Eagle Pd® belt is universally recognized for reducing belt noise by as much as 3 to 20 dB(A) compared to similarly sized straight-tooth drives.
Belt noise is definitely a function of belt speed and belt width. The faster the belt is traveling when it engages the sprocket, the louder the belt noise. The wider the belt, the louder the belt noise. Based upon the operating parameters for a specific drive, the MAXIMIZER™ Drive Selection Analysis Program can calculate a noise prediction.

Chemical Environments: Both Hibrex® and neoprene rubber are chemically stable and will not degrade when exposed to many chemicals. However, exposure to certain chemicals can have a pronounced effect leading to catastrophic failure. There is no universal belt construction that will resist the effects of any and all chemicals. Exposure to chemicals can have a variety of effects, ranging from softening and swelling to embrittlement. The universal effect is a reduction in belt service life.

The following chart summarizes the expected tolerance of Goodyear Engineered Products' ACHE Synchronous Belt tooth material to non-emersion (vapor and incidental splash) exposure by several selected chemicals.

Chemical Resistance Chart

Chemical	Rating	
	Hibrex•	Neoprene
Steam	B	C
Acetic Acid	B	B
Hydrochloric Acid	A	B
Phosphoric Acid	A	B
Nitric Acid	B	U
Sodium Hydroxide	A	A
Aqueous Ammonia (28%)	A	B
Sodium Chloride (30%)	A	A
Sodium Carbonate (10%)	A	A
Hydrogen Peroxide (3%)	B	C
Sodium Hypochlorite (5%)	B	C
Chlorine	U	U
Iso Octane	A	B
Toluene	C	U
Trichloroethylene	C	U
Methyl Alcohol	A	A
Ethyl Alcohol	A	A
Ethyl Ether	C	U
Ethyl Acetate	U	U
Methyl Ethyl Ketone	U	U
Furfural	B	C
Triethanol Amine	A	A
Carbon Disulfide	C	U
5% Diluted Chlorine	B	U

Rating: A=little or minor effect, B=Minor to moderate effect, C=Moderate to severe effect, U=Not recommended

The above ratings are for the chemical resistance of the tooth compound only and should be used solely for reference. Concentration, temperature and duration of exposure will play a major role in actual belt life and performance. The chemical resistance of the tensile cord and the tooth facing should also be a consideration when considering the best application. Consult the Goodyear EP ACHE Synchronous Belt experts for additional information.

Belt Storage

Proper storage conditions and practices will help retain belt quality while unfavorable storage conditions will have an adverse effect thereby shortening belt service life. Belt performance will not degrade significantly over seven years of proper storage as outlined in the Rubber Manufacturers Association (RMA) Technical Bulletin IP-3-4. Service life is expected to decrease 10% per year for each year of storage beyond seven years.

A proper storage environment as defined by the RMA consists of an ambient temperature of less than +85°F and relative humidity of less than 70%. The seven year stability limit decreases by 50% for each +18°F increase in storage temperature above +85°F. In no case should storage temperatures exceed +115°F.

In addition to time, temperature and humidity, the following recommendations constitute "best practice" for successful belt storage.

- Store belts in a cool, dry environment
- Avoid floor storage and surfaces that promote condensation
- Do not store belts near radiators and heaters
- Avoid high ozone environments
- Store belts away from direct sunlight
- Avoid sharp bends or crimping of belt
- Store belts in a nested configuration if possible
- Avoid distortion or excess weight on stored belts

Remember, proper storage will help maintain belt quality thus insuring that your belt investment will deliver the maximum intended service life.

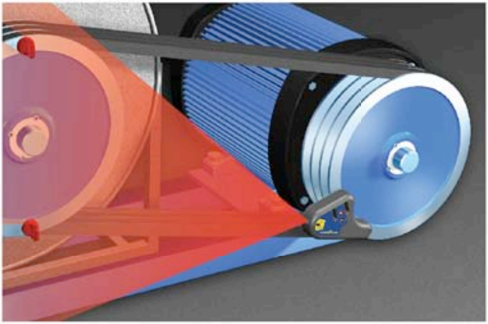
V-belt Conversions

Since fan air flow and power usage are very sensitive to speed, one advantage of synchronous belts for these drives is that the driven speed is consistent, predictable and doesn't change with belt wear or tension. For retrofits, a common error is to simply use the ratio of the V-belt pulley diameters to calculate the synchronous ratio. Selecting the synchronous system based on such a parameter results in higher than desired fan speed, increased amp draw, and possible motor overload. A better method is to measure driver and driven speeds during operation and then calculate the ratio as: drive ratio = driver rpm/driven rpm.

Tools

Laser Alignment Tool

There are three major economic benefits ascribed to maintaining proper belt alignment: improved energy efficiency, increased drive component life and reduced labor cost by allowing longer service/replacement intervals.



Misalignment causes increased friction which in turn generates both unnecessary heat and excessive component wear. Unnecessary heat adversely affects the service life of drive components such as bearings, belts and motors. Abrasive wear shortens the service life of belt, pulleys and sprockets. Uneven loading across the width of the belt can damage the tensile member of the belt as well as changing the overhung load to the shafts and bearings.

Our Laser Alignment Tool improves both accuracy and efficiency of operation, whether installing new belt drives or maintaining existing ones. Increased efficiency also means energy cost savings. This tool can pay for itself within months.

- Shows the axial and radial misalignment
- Much faster than measuring with earlier, conventional methods
- Alignment can be made by one operator

Tools

TensionRite®
OPTICAL BELT FREQUENCY METER

- Displays the natural vibration frequency of a belt strand
- Calculates the corresponding belt tension in either English or SI units

Quartz crystal based solid-state circuitry

- Will not drift or go out of calibration
- No gain adjustment, filters or alternate sensor heads required

Direct rather than indirect measurement of vibration frequency

- Senses movement of the belt not the disturbances of the air adjacent to the belt
- Unaffected by ambient noise level or air currents

Meter range matches "real life" belt installation parameters

- The fundamental vibration frequency of most commonly used power transmission belts trends to the low end of the scale (< 400Hz). Any higher frequency capability is wasted money.
- Meter can be used with all type belts

Tools

MAXIMIZER™
Drive Selection Analysis Program from Goodyear Engineered Products

MAXIMIZER™ is an exciting program which allows the user to have Goodyear EP belt specifications and information right at their fingertips. It is easy to install and easy to use, making inquiries a snap.

With MAXIMIZER™, available belts, sprockets, pulleys and bushings are matched with requirements specified by the user.

The MAXIMIZER™ screen allows the user to select the most efficient drive. With other pertinent information such as relative price index, belt tensioning information and engineering drawings included, the benefits of MAXIMIZER™ are quickly realized.

Appendix

English/SI Conversion Factors

Force Equivalents

SI to English

Newtons(N) x 3.5969 = Ounces$_f$
Newtons(N) x 0.2248 = Pounds$_f$
Kilograms$_f$(kg$_f$) x 2.2046 = Pounds$_f$

English to SI

Ounces$_f$ x 0.2780 = Newtons(N)
Pounds$_f$ x 4.4482 = Newtons(N)
Pounds$_f$ x 0.4536 = Kilograms$_f$(kg$_f$)

SI to SI

Kilograms$_f$(kg$_f$) x 9.8067 = Newtons(N)
Newtons(N) x 0.1020 = Kilograms$_f$(kg$_f$)

Torque Equivalents

SI to English

Newton-Meters(N-M) x 141.6119 = Ounce-inches
Newton-Meters(N-M) x 8.8508 = Pound-inches
Newton-Meters(N-M) x 0.7376 = Pound-feet

English to SI

Ounce-inches x 0.0071 = Newton-Meters(N-M)
Pound-inches x 0.1130 = Newton-Meters(N-M)
Pound-feet x 1.3558 = Newton-Meters(N-M)

SI to SI

Newton-Meters(N-M) x 10.1972 = Kilogram-Centimeters
Kilogram-Centimeters x 0.0981 = Newton-Meters(N-M)
Newton-Meters(N-M) x 0.1020 = Kilogram-Meters
Kilogram-Meters x 9.8067 = Newton-Meters(N-M)

Common Term Interchange

Pound$_f$-inches = Inch-pounds = in-lb
Pound$_f$-feet = Foot-pounds = ft-lb

Power Equivalents

SI to English

Kilowatt(kW) x 1.3410 = Horsepower(hp)
Watt(W) x 0.0013 = Horsepower(hp)

English to SI

Horsepower(hp) x 745.6999 = Watt (W)
Horsepower(hp) x 0.7457 = Kilowatt(kW)

Speed Equivalents

SI to English

Meters per second(m/s) x 196.8504 = Feet per minute(fpm)

English to SI

Feet per minute(fpm) x 0.00508 = Meters per second(m/s)

English to English

fps x 60 = fpm
fpm x 0.0167 = fps

Length Equivalents

SI to English

Millimeters(mm) x 0.0394 = Inches(in)
Meters(m) x 39.3701 = Inches(in)
Meters(m) x 3.2808 = Feet(ft)
Meters(m) x 1.0936 = Yards(yd)

English to SI

Inches(in) x 25.4 = Millimeters(mm)
Inches(in) x 0.0254 = Meters(m)
Feet(ft) x 0.3048 = Meters(m)
Yards(yd) x 0.9144 = Meters(m)

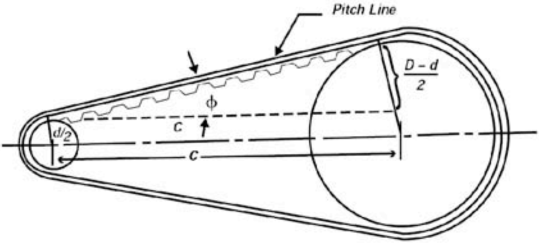
Appendix

Power Transmission Formulas

Required	Given	Formula
Speed Ratio (R)	Shaft Speeds (rpm) rpm1 = faster shaft rpm2 = slower shaft	$R = \text{rpm1}/\text{rpm2}$
	Sprocket Diameter D = large sprocket d = small sprocket	$R = D/d$
	Sprocket tooth count N = large sprocket n = small sprocket	$R = N/n$
Horsepower (hp)	Torque (T) in in-lb Shaft speed (rpm)	$hp = T \; x \; rpm / 63{,}025$
	Effective Belt Tension (Te) in lbs Belt Speed (S) in fpm	$hp = Te \; x \; S / 33{,}000$
Design Horsepower (Dhp)	Rated Horsepower (hp) Service Factor (SF)	$Dhp = hp \times SF$
Power (kW)	Horsepower (hp)	$kW = 0.7457 \, x \, hp$
Torque (T) in in-lb	Shaft Horsepower (hp) Shaft Speed (rpm)	$T = 63{,}025 x \; hp / rpm$
	Effective Belt Tension (Te) in lbs Sprocket Radius R in inches	$T = Te \times R$
Belt Speed (S) in fpm	Sprocket Pitch Diameter (PD) in inches Shaft Speed in rpm	$S = PD \; x \; rpm / 3.82$
Belt Speed (S) in m/s	Sprocket Pitch Diameter (PD) in mm Sprocket speed in rpm	$S = 0.0000524 x \; PD \times rpm$
Belt Pitch Length (PL) in inches (approximate)	Center Distance (C) in inches Sprocket Diameters in inches D = large sprocket d = small sprocket	$PL = 2C + [1.57x(D+d)] + \frac{(D-d)^2}{4C}$
Arc of Contact (AC°) on smaller sprocket	Sprocket diameters in inches D = large sprocket d = small sprocket Center Distance (C) in inches	$AC = 180 - \left[\frac{(D-d)x60}{4C}\right]$

Appendix

Calculations to find Center Distance and Belt Length



If the center distance is known, belt pitch length may be calculated as follows:

$$L_p = 2C\,\text{Cos}\phi + \frac{\pi(D+d)}{2} + \frac{\pi\phi(D-d)}{180} \quad \text{or} \quad L_p = 2C + 1.57(D+d) + \frac{(D-d)^2}{4C}$$

where

L_p = Belt Pitch length in inches
C = Center Distance in inches
D = Pitch Diameter of large sprocket in inches
d = Pitch Diameter of small sprocket in inches

$$\phi = \text{Sin}^{-1}\left(\frac{D-d}{2C}\right)$$

Calculated belt pitch length will have to be adjusted to the nearest full tooth dimension (14mm increments for ACHE belts). Further accommodation will then need to be made to match belt availability since not all tooth counts are manufactured or stocked.

If the belt pitch length is known, center distance may be approximated by:

$$C = \frac{K + \sqrt{K^2 - 32(D-d)^2}}{16}$$

where

$K = 4L_p - 6.28(D+d)$
D = Pitch Diameter of large sprocket in inches
d = Pitch Diameter of small sprocket in inches

Appendix

Fan Law Equations

Fan laws define the interrelationships within the operating system. They are particularly useful in identifying the effects on elements of the system when making charges to one or more operating parameters.

IMPORTANT NOTE: When changing the rpm of a bladed fan it is important to make sure that the new rpm does not exceed the maximum allowable speed for that fan. Information on maximum allowable speed can be obtained by contacting the fan supplier.

$$CFM_2 = \frac{rpm_2}{rpm_1} \times CFM_1 \longrightarrow \frac{CFM_2}{CFM_1} = \frac{rpm_2}{rpm_1}$$

$$SP_2 = \left(\frac{rpm_2}{rpm_1}\right)^2 \times SP_1 \longrightarrow \frac{SP_2}{SP_1} = \left(\frac{rpm_2}{rpm_1}\right)^2$$

$$bhp_2 = \left(\frac{rpm_2}{rpm_1}\right)^3 \times bhp_1 \longrightarrow \frac{bhp_2}{bhp_1} = \left(\frac{rpm_2}{rpm_1}\right)^3$$

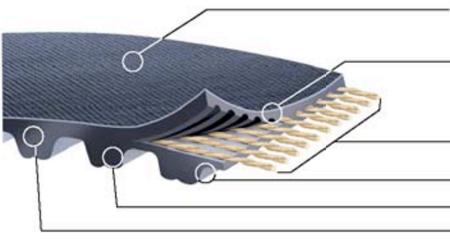
Subscript 1 = existing conditions
Subscript 2 = new conditions

where

- CFM = Cubic feet per minute, the volume of air moved per minute.
- rpm = The number of rotations the fan shaft makes per minute.
- SP = Static pressure in inches of H_2O, a measure of the potential energy of the airstream. SP acts equally in all directions within the duct.
- bhp = Brake Horsepower, the fan's power consumption.

Appendix

Manufacturing Tolerances, ACHE Synchronous Belts



Width Tolerances per RMA IP-27(2003)	Belt Width (mm)	Tolerance
	Up to 38	+0.8 -1.2
	38.1 to 50.8	+1.2 -1.6
	50.9 to 63.5	+1.6 -1.6
	63.6 to 76.5	+1.6 -2.0
	76.6 to 101.6	+2.0 -2.0

Thickness Tolerances	Belt Pitch & Type	Nominal Overall Gauge (mm)	Overall Gauge Tolerance (mm)	Overall Gauge Variation within Single Belt (mm)
	14mm Eagle Pd®	8.6	± 0.45	0.45
	14mm Falcon Pd®	10.0	± 0.50	0.50
	14mm Hawk Pd®	10.0	± 0.50	0.50

Appendix

Physical Properties, ACHE Synchronous Belts

Belt Type	Pitch & Width (mm)	Ultimate Tensile (lb per belt strand)	Belt Modulus (per belt strand)	Allowable Working Tension (lb per belt strand)
Eagle Pd®	Blue	9,050	257,000	1,467
	Green	13,575	384,000	2,200
Falcon Pd®	14M-20	6,063	220,472	1,332
	14M-37	11,217	407,874	2,465
Hawk Pd®	14M-40	10,551	274,016	2,340
	14M-55	14,508	376,772	3,218
	14M-85	22,421	582,283	4,973

Belt Modulus Definition

$$M = \Delta T / E = \Delta T / (\Delta L / L) = (\Delta T / \Delta L) \times L$$

where:

M = belt modulus (lbs per 100% elongation)
L = belt length (original belt length)
L = change in belt length
E = elongation per length (L/L)
T = strand tension
T = change in strand tension

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