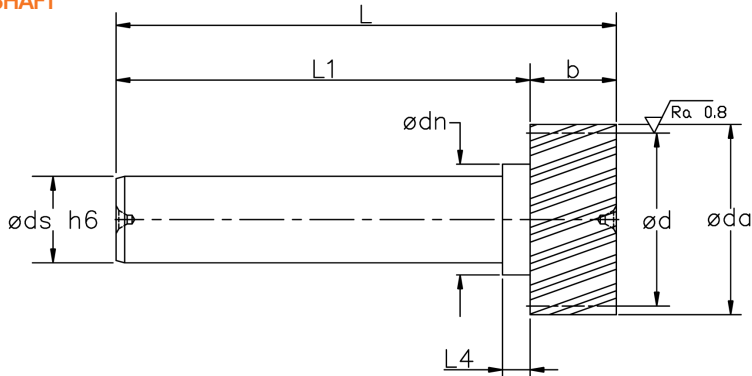


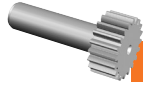
# MODULAR RACK & PINION SYSTEM

## PINIONS SHAFT



## MODULES 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 6.0, 8.0, 10.0

Helical Teeth, Left hand  
Helix Angle = 19° 31' 42"  
Pressure angle  $\phi=20^\circ$   
Material AISI 5115 (16MnCr5)  
Case Hardened, 60HRC, Ground & Crowned Teeth  
Quality 6F24 (~AGMA 11)



No. teeth	Module	d	da	ds	dn	L	L <sub>1</sub>	b	L <sub>4</sub>	Fits Servo	Part No.
16	1.5	26.36	29.36	12	16.0	90.0	70.0	20	4.5	HPG 030	211116
20	1.5	31.83	34.83	20	26.0	110.0	90.0	20	4.5	HPG 045	211120
16	2.0	35.15	39.15	20	26.0	110.0	90.0	20	8.0	HPG 045	211216
20	2.0	42.44	46.44	25	32.0	140.0	120.0	20	8.0	HPG 060	211220
20	2.5	53.05	58.05	25	32.0	145.0	120.0	25	8.0	HPG 060	211320
16	3.0	52.73	58.73	25	32.0	150.0	120.0	30	8.0	HPG 060	211416
20	3.0	63.66	69.66	40	50.0	190.0	160.0	30	12.5	HPG 090	211420
20	4.0	84.88	92.88	40	50.0	200.0	160.0	40	18.0	HPG 090	211520
20	4.0	84.88	92.9	60	74.0	310	270.0	40	14.5	HPG 120	211521
20	5.0	106.10	116.10	60	85.0	310.0	260.0	50	35.0	HPG 120	211620
20	6.0	127.32	139.30	90	105.0	350.0	290.0	60	20.0	HPG 180	211720
20	8.0	169.76	185.70	90	105.0	350.0	270.0	80	35.0	HPG 180	211820
15	10.0	165.16	185.20	90	105.0	410.0	310.0	100	40.0	HPG 180	211915

Dimensions are in mm and are subject to change - consult factory.

# MODULAR RACK & PINION SYSTEM

## RACK & PINION TORQUE RATINGS

The values shown in the tables below are given for a linear speed of 1.5 m/s, shock free operation, good lubrication (automatic electric lubricator, or manual lubrication once/day), and rigid cantilevered pinion support. Calculations are based on root stress bending fatigue and hertzian stress pit-

ting fatigue and provide a life of 20,000 hours. In all cases pinions are hardened & ground AISI 5115 (16MnCr5) with minimum quality of 7e25.

### Module 1.5 (19 mm Face Width)

# of Teeth z	Torque Capacity for Straight Nm(lb.ft.):					Torque Capacity for Helical Nm(lb.ft.):				
	d (mm)	Soft Rack A30	Quenched & Tempered Rack A20	Induction Hardened Rack A40	Hardened & Ground Rack A10	d (mm)	Soft Rack A31	Quenched & Tempered Rack A21	Induction Hardened Rack A41	Hardened & Ground Rack A11
15	22.5	2 (1)	3.2 (2)	7.9 (6)	-	-	-	-	-	-
16	24	6.4 (5)	-	-	35 (26)	25.46	-	-	-	41 (30)
20	30	10 (7)	-	32 (24)	55 (41)	31.83	-	-	-	67 (49)
25	37.5	20 (15)	30 (22)	60 (44)	70 (52)	-	-	-	-	-
30	-	-	-	-	-	47.75	-	-	-	-
32	48	38 (28)	53 (39)	75 (55)	82 (60)	-	-	-	-	-

### Module 2.0 (24 mm Face Width)

# of Teeth z	Torque Capacity for Straight Nm(lb.ft.):					Torque Capacity for Helical Nm(lb.ft.):				
	d (mm)	Soft Rack A30	Quenched & Tempered Rack A20	Induction Hardened Rack A40	Hardened & Ground Rack A10	d (mm)	Soft Rack A31	Quenched & Tempered Rack A21	Induction Hardened Rack A41	Hardened & Ground Rack A11
15	30	13.8 (10)	22 (16)	29 (21)	-	-	-	-	-	-
16	32	14 (10)	-	41 (30)	77 (57)	33.95	-	-	-	92 (68)
18	36	23 (17)	33 (24)	50 (37)	86 (63)	-	-	-	-	-
20	40	28 (21)	43 (32)	75 (55)	119 (88)	42.44	35 (26)	46 (34)	130 (96)	139 (103)
22	44	33 (24)	52 (38)	90 (66)	131 (97)	46.68	-	59 (44)	155 (114)	-
25	50	48 (35)	68 (50)	128 (94)	171 (126)	53.05	60 (44)	73 (54)	180 (133)	196 (145)
28	56	64 (47)	82 (60)	140 (103)	192 (142)	59.41	80 (59)	88 (65)	197 (145)	220 (162)
30	60	74 (55)	100 (74)	152 (112)	195 (144)	63.66	92 (68)	105 (77)	213 (157)	238 (176)
32	64	83 (61)	116 (86)	163 (120)	205 (151)	67.91	105 (77)	120 (89)	228 (168)	250 (184)
36	72	119 (88)	140 (103)	173 (128)	224 (165)	76.39	130 (96)	150 (111)	250 (184)	275 (203)
45	90	-	-	-	260 (192)	95.49	-	-	-	334 (246)

### Module 2.5 (24 mm Face Width)

# of Teeth z	Torque Capacity for Straight Nm(lb.ft.):					Torque Capacity for Helical Nm(lb.ft.):				
	d (mm)	Soft Rack A30	Quenched & Tempered Rack A20	Induction Hardened Rack A40	Hardened & Ground Rack A10	d (mm)	Soft Rack A31	Quenched & Tempered Rack A21	Induction Hardened Rack A41	Hardened & Ground Rack A11
15	37.5	15.6 (12)	-	60 (44)	-	-	-	-	-	-
20	50.0	45 (33)	-	150 (111)	225 (166)	53.05	-	-	-	275 (203)
22	55.0	60 (44)	-	180 (133)	251 (185)	-	-	-	-	-
25	62.5	95 (70)	-	256 (189)	-	66.31	-	-	-	343 (253)
28	70.0	115 (85)	-	280 (207)	311 (229)	-	-	-	-	-
36	90.0	215 (159)	-	350 (258)	389 (287)	-	-	-	-	-
40	100.0	245 (181)	-	400 (295)	-	-	-	-	-	-

### Module 3.0 (29 mm Face Width)

# of Teeth z	Torque Capacity for Straight Nm(lb.ft.):					Torque Capacity for Helical Nm(lb.ft.):				
	d (mm)	Soft Rack A30	Quenched & Tempered Rack A20	Induction Hardened Rack A40	Hardened & Ground Rack A10	d (mm)	Soft Rack A31	Quenched & Tempered Rack A21	Induction Hardened Rack A41	Hardened & Ground Rack A11
15	45	40.8 (30)	63 (46)	87 (64)	218 (161)	-	-	-	-	294 (217)
16	49.8	-	-	-	302 (223)	50.93	-	-	200 (148)	346 (255)
18	54	81 (60)	121 (89)	197 (145)	324 (239)	57.30	-	-	-	434 (320)
19	57	-	-	-	390 (288)	-	-	-	-	-
20	60	92 (68)	138 (102)	215 (159)	411 (303)	63.66	102 (75)	145 (107)	410 (302)	467 (344)
22	66	115 (85)	170 (125)	305 (225)	434 (320)	70.03	128 (94)	182 (134)	430 (317)	511 (374)
25	75	168 (124)	235 (173)	440 (325)	500 (369)	79.57	188 (139)	245 (181)	490 (361)	605 (446)
28	84	205 (151)	285 (210)	485 (358)	564 (416)	-	-	295 (218)	555 (409)	-
32	96	290 (214)	-	510 (376)	641 (473)	-	-	415 (306)	563 (415)	-
35	105	-	-	-	670 (494)	111.41	-	-	-	750 (553)
36	108	386 (271)	512 (378)	642 (474)	692 (510)	-	-	525 (387)	700 (516)	-
40	120	450 (332)	620 (457)	780 (575)	850 (627)	127.32	-	640 (472)	820 (605)	940 (693)
52	156	-	-	-	1133 (836)	165.52	-	-	-	1255 (926)

## RACK & PINION TORQUE RATINGS

### Module 4.0 (39 mm Face Width)

# of Teeth z	Torque Capacity for Straight Nm(lb.ft.):					Torque Capacity for Helical Nm(lb.ft.):				
	d (mm)	Soft Rack A30	Quenched & Tempered Rack A20	Induction Hardened Rack A40	Hardened & Ground Rack A10	d (mm)	Soft Rack A31	Quenched & Tempered Rack A21	Induction Hardened Rack A41	Hardened & Ground Rack A11
15	60	130 (96)	190 (140)	220 (162)	-	63.66	145 (107)	205 (151)	670 (494)	700 (516)
18	72	200 (148)	290 (214)	450 (332)	-	76.39	224 (165)	305 (225)	900 (664)	1085 (800)
19	76	-	-	-	915 (675)	-	-	-	-	-
20	80	250 (184)	355 (262)	640 (472)	963 (710)	84.88	280 (207)	370 (273)	975 (719)	1205 (889)
22	88	300 (221)	430 (317)	890 (656)	1081 (797)	93.37	335 (247)	445 (328)	1100 (811)	1335 (985)
25	100	415 (306)	575 (424)	1070 (789)	1257 (927)	106.10	465 (343)	590 (435)	1200 (885)	1520 (1121)
28	112	505 (372)	720 (531)	1220 (900)	1427 (1053)	118.84	-	735 (542)	1350 (996)	1560 (1151)
32	128	700 (516)	962 (710)	1400 (1033)	1608 (1186)	135.81	-	985 (727)	1550 (1143)	-
40	160	1100 (811)	1550 (1143)	1710 (1261)	1885 (1390)	169.77	-	1650 (1217)	1970 (1453)	2200 (1623)
45	-	-	-	-	-	190.99	-	-	-	2700 (1992)

### Module 5.0 (49 mm Face Width)

# of Teeth z	Torque Capacity for Straight Nm(lb.ft.):					Torque Capacity for Helical Nm(lb.ft.):				
	d (mm)	Soft Rack A30	Quenched & Tempered Rack A20	Induction Hardened Rack A40	Hardened & Ground Rack A10	d (mm)	Soft Rack A31	Quenched & Tempered Rack A21	Induction Hardened Rack A41	Hardened & Ground Rack A11
12	60	150 (111)	190 (140)	280 (207)	-	63.66	-	-	-	1050 (774)
15	75	260 (192)	320 (236)	450 (332)	1100 (811)	79.58	300 (221)	-	-	1330 (981)
18	90	400 (295)	460 (339)	905 (668)	-	95.49	-	-	-	2147 (1584)
19	95	450 (332)	520 (384)	1070 (789)	1773 (1308)	-	-	-	-	-
20	100	499 (368)	590 (435)	1150 (848)	1866 (1376)	106.10	560 (413)	-	-	2385 (1759)
25	125	800 (590)	920 (679)	1660 (1224)	2433 (1795)	-	900 (664)	-	-	2950 (2176)
36	180	-	-	-	2800 (2065)	190.98	1030 (760)	-	-	3300 (2434)
42	210	-	-	-	-	222.82	-	-	-	3700 (2729)

### Module 6.0 (59 mm Face Width)

# of Teeth z	Torque Capacity for Straight Nm(lb.ft.):					Torque Capacity for Helical Nm(lb.ft.):				
	d (mm)	Soft Rack A30	Quenched & Tempered Rack A20	Induction Hardened Rack A40	Hardened & Ground Rack A10	d (mm)	Soft Rack A31	Quenched & Tempered Rack A21	Induction Hardened Rack A41	Hardened & Ground Rack A11
15	90	470 (347)	-	795 (586)	-	95.49	-	-	-	2250 (1660)
18	-	-	-	-	-	114.59	-	-	-	3724 (2747)
19	114	625 (461)	-	1850 (1365)	3014 (2223)	-	-	-	-	-
20	120	810.3 (598)	-	2200 (1623)	3173 (2340)	127.32	910 (671)	-	-	4137 (3051)
25	150	1400 (1033)	-	2950 (2176)	4135 (3050)	-	1570 (1158)	-	-	5285 (3898)
35	-	-	-	-	-	222.82	-	-	-	5570 (4108)

### Module 8.0 (79 mm Face Width)

# of Teeth z	Torque Capacity for Straight Nm(lb.ft.):					Torque Capacity for Helical Nm(lb.ft.):				
	d (mm)	Soft Rack A30	Quenched & Tempered Rack A20	Induction Hardened Rack A40	Hardened & Ground Rack A10	d (mm)	Soft Rack A31	Quenched & Tempered Rack A21	Induction Hardened Rack A41	Hardened & Ground Rack A11
15	120	1149.5 (848)	-	1898 (1400)	-	127.32	-	-	-	7281 (5370)
16	128	-	-	-	5838 (4306)	-	-	-	-	-
20	160	2101 (1550)	-	4502 (3321)	7298 (5383)	169.77	-	-	-	9709 (7161)
25	200	3398 (2506)	-	7500 (5532)	-	-	-	-	-	-

### Module 10.0 (99 mm Face Width)

# of Teeth z	Torque Capacity for Straight Nm(lb.ft.):					Torque Capacity for Helical Nm(lb.ft.):				
	d (mm)	Soft Rack A30	Quenched & Tempered Rack A20	Induction Hardened Rack A40	Hardened & Ground Rack A10	d (mm)	Soft Rack A31	Quenched & Tempered Rack A21	Induction Hardened Rack A41	Hardened & Ground Rack A11
14	-	-	-	-	-	148.54	-	-	-	11920 (8792)
15	150	-	-	-	10286 (7587)	165.16	-	-	-	12773 (9421)
16	160	-	-	-	10972 (8093)	-	-	-	-	-
20	200	4000 (2950)	-	9900 (7302)	13864 (10226)	213.21	-	-	-	18569 (13696)

## RACK & PINION TORQUE RATINGS

### CIRCULAR METRIC PITCH

# of Teeth z	d (mm)	Torque Capacity for Straight Nm(lb.ft.):		
		Soft Rack A70	Induction Hardened Rack A60	Hardened & Ground Rack A50
<b>Circular metric pitch 2.0 (9.5 mm Face Width)</b>				
25	15.91	1.5 (1.1)	-	2.7 (2)
30	19.10	2.1 (1.6)	-	4 (3)
<b>Circular metric pitch 5.0 (14.5 mm Face Width)</b>				
20	31.83	15 (11)	-	49 (36)
<b>Circular metric pitch 7.5 (19.5 mm Face Width)</b>				
20	47.75	47 (35)	-	166 (123)
<b>Circular metric pitch 10.0 (29.5 mm Face Width)</b>				
20	63.66	138 (102)	250 (185)	470 (347)
<b>Circular metric pitch 12.5 (40.0 mm Face Width)</b>				
14	58.09	90 (67)	315 (233)	-
20	79.58	203 (150)	563 (416)	-
<b>Circular metric pitch 16.0 (50.0 mm Face Width)</b>				
20	101.86	-	1378 (1018)	-
<b>Circular metric pitch 20.0 (60.0 mm Face Width)</b>				
20	127.32	-	2720 (2010)	-
<b>Circular metric pitch 25.0 (80.0 mm Face Width)</b>				
20	159.15	-	6092 (4502)	-

## SELECTION & CALCULATIONS

### Rack & Pinion Calculations & Selection

Follow this method to select the correct size rack and pinion:

Start with the type of application: HORIZONTAL translation or VERTICAL lifting

Determine the units: Metric or Imperial

Follow the table below for the calculation procedure:

Application	HORIZONTAL translation		VERTICAL lifting	
	APPLICATION PARAMETERS			
Units	Metric	Imperial	Metric	Imperial
Mass to move, M	Kg	W/gc, Lb * s2 / ft.	Kg	W/gc, Lb * s2 / ft.
Linear Speed, V	M/s	Ft/s	M/s	Ft/s
Acceleration time, ta	s	s	s	s
Acceleration due to gravity, g	9.8 M/s2	32.2 Ft/s2	9.8 M/s2	32.2 Ft/s2
Coefficient of friction, $\mu$	-	-	-	-
Pitch circle dia. of pinion, d	mm	in.	mm	in.
External Force, F	N	Lbs.	N	Lbs.
Service Factor, S.F. *	-	-	-	-
	CALCULATED DATA			
Acceleration, a	$a = V/ta$ M/s2	$a = V/ta$ Ft/s2	$a = V/ta$ M/s2	$a = V/ta$ Ft/s2
Application force at rack, Fr	$Fr = \mu M^*g + M^*a + F$ N	$Fr = \mu M^*g + M^*a + F$ Lbs.	$Fr = M^*g + M^*a + F$ N	$Fr = M^*g + M^*a + F$ Lbs.
Application Torque at Pinion, Tp	$Tp = (Fr * d)/2000$ NM	$Tp = (Fr * d)/24$ Lb.Ft.	$Tp = (Fr * d)/2000$ NM	$Tp = (Fr * d)/24$ Lb.Ft.
Design Torque, Td	$Td = Tp * S.F.$ NM	$Td = Tp * S.F.$ Lb.Ft.	$Td = Tp * S.F.$ NM	$Td = Tp * S.F.$ Lb.Ft.
Max. Rotational speed of pinion, Np	$Np = (V * 19,100)/d$ RPM	$Np = (V * 229.2)/d$ RPM	$Np = (V * 19,100)/d$ RPM	$Np = (V * 229.2)/d$ RPM

\* The service factor, S.F. is selected based on experience with the application. The service factor takes into account shock loading, assembly tolerances, pinion mounting and life required. Service factors range between 1.0 and 4.0.

### Rack & Pinion Selection:

- Select the pinion number of teeth
- Select the module and quality level based on the torque ratings, (Trating) in the preceding tables. Insure that: **Trating > Td**
- Check that the quality level selected is suitable for the application requirements by evaluating the cumulative pitch error, Fp for the quality level selected.

## SELECTION & CALCULATIONS

### Rack & Pinion Properties:

**Pinion Description**

**Metric:**

$M = \text{ød}/Z$  (mm)

$\text{ødth} = Z \cdot M / \cos\beta$  (mm)

$\text{ød}w = Z \cdot M / \cos\beta + 2 \cdot x \cdot M$  (mm)

$\text{ød} = \text{Pitch Diameter}$

$Z = \text{Number of teeth}$

**Imperial:**

$P = Z / \text{ød}$  (1/in.)

$\text{ødth} = Z / P \cdot \cos\beta$  (in.)

$\text{ød}w = Z / P \cdot \cos\beta + 2 \cdot x / P$  (in.)

**Rack Description**

**Metric:**

$M$

$p = \pi \cdot M$  (mm)

$1.25 M$

**Imperial:**

$p = \pi / P$  (in.)

$1/P$

$1.25/P$

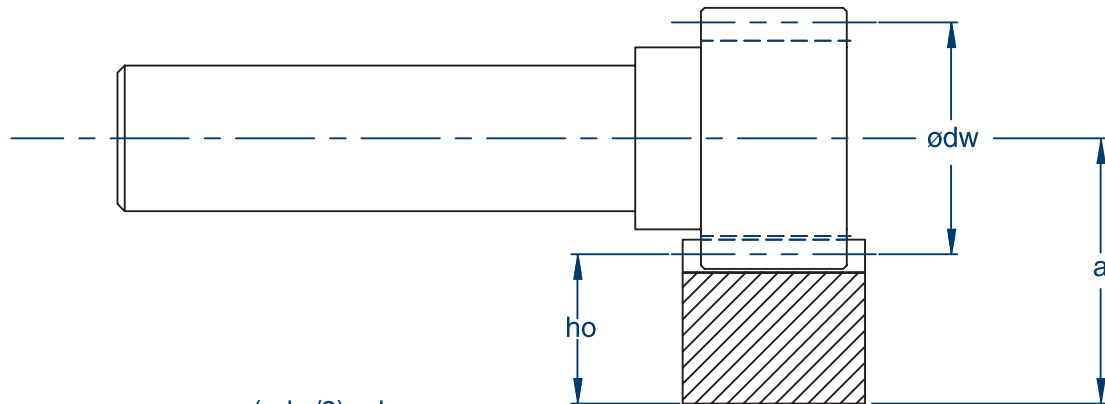
$P = 25.4/M$

**Module 2.0**  $P = 12.70$

**Module 6.0**  $P = 4.23$

## SELECTION & CALCULATIONS

### Theoretical Center Distance Between Pinion and Rack:



- $a = (\text{ødw}/2) + h_o$
- $Z =$  Number of teeth
- $\text{ødw} =$  Working Pitch Diameter
- $h_o =$  distance from back face to pitch line of rack

### Nomenclature:

#### Application Data:

$W =$  Weight, Lbs.

$g_c =$  Gravitational Constant = 32.2 Ft/s<sup>2</sup>

#### Pinion Data:

$M =$  Module, mm

$P =$  Diametral Pitch, 1/in.

$\text{Ødth} =$  Theoretical Pitch diameter, (mm or in.)

$\text{Ød} = \text{Ødth} =$  Pitch diameter when  $x = 0$  (mm or in.)

$\text{Ødw} =$  Working Pitch diameter, (mm or in.)

$x =$  Addendum correction factor

#### Rack Data:

$p =$  Circular pitch (mm or in.)

## RACK & PINION DRIVE SYSTEM APPLICATION SHEET

COMPANY: \_\_\_\_\_ CONTACT: \_\_\_\_\_  
 ADDRESS: \_\_\_\_\_ PHONE: (     ) \_\_\_\_\_ - \_\_\_\_\_  
 \_\_\_\_\_ FAX: (     ) \_\_\_\_\_ - \_\_\_\_\_  
 \_\_\_\_\_ EMAIL: \_\_\_\_\_

### APPLICATION DESCRIPTION:

Machine Type:  Traveling Gantry/Bridge (driven on both sides)  
 Traveling Column (driven on one side only)  
 Material Being Machined (if any):  Steel  Aluminum  Other: \_\_\_\_\_  
 Operations Being Performed:  Contouring  Milling  Boring  
 Machine Description:  
 Axis Orientation:  Horizontal  Vertical

### APPLICATION SPECIFICATIONS:

Axis Travel Length: \_\_\_\_\_ feet or: \_\_\_\_\_ meters  
 Total Weight Being Moved: \_\_\_\_\_ lb.  
 Maximum Axis Speed: \_\_\_\_\_ inches/minute or: \_\_\_\_\_ meters/minute  
 Maximum Acceleration Rate: \_\_\_\_\_ in/sec<sup>2</sup>  
 Acceleration Time: \_\_\_\_\_ seconds  
 Axis Friction Factor ( ): \_\_\_\_\_  
 Additional Cutting Force (if any): \_\_\_\_\_ lb.  
 Axis Duty Cycle: \_\_\_\_\_ cycles per hour \_\_\_\_\_ hours per day  
 Desired Axis Accuracy: \_\_\_\_\_  
 Drive Motor Mfg./Model (if known): \_\_\_\_\_ (Send flange & shaft dimensions)  
 Drive Motor Base Speed: \_\_\_\_\_ rpm  
 Drive Motor Continuous Torque: \_\_\_\_\_ in.lb.  
 Machine Sales Potential: \_\_\_\_\_ machines per year

### REDUCER SPECIFICATIONS:

Reducer Style:  In-line  Right-Angle  
 Rack preload required:  Yes  No  
 Preload Style:  Split-Pinion  Dual-Drive  Electrical (Twin-Drive)  
 Unit Mounting Orientation:  Output Horizontal  Output Vertically Down