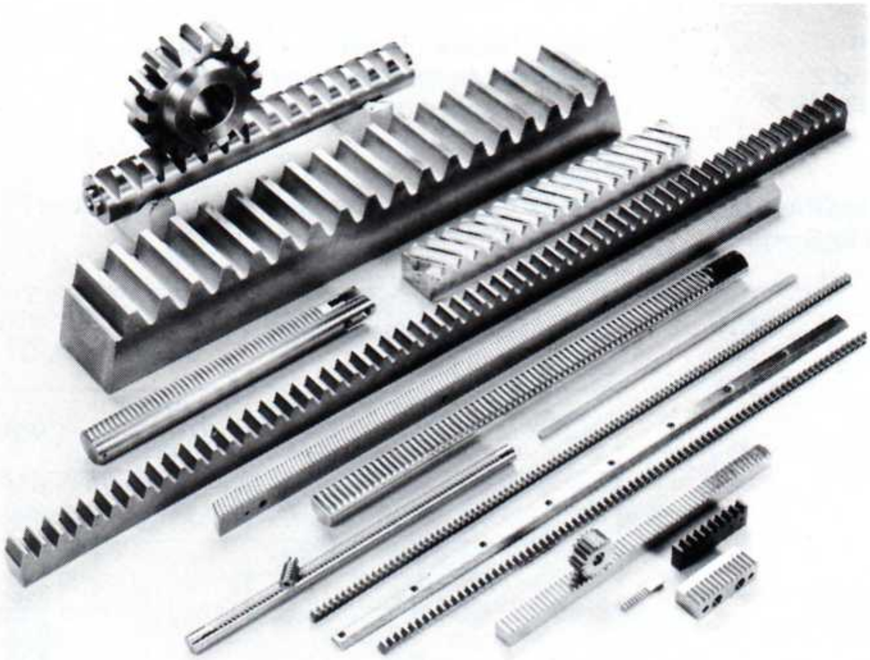
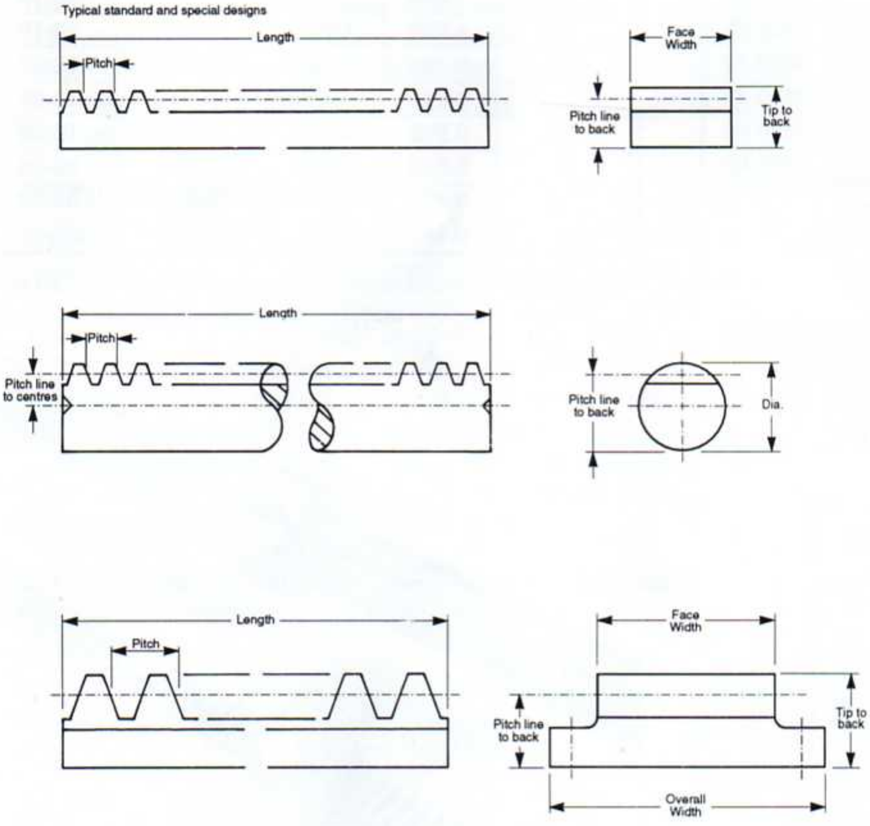
GEAR RACK PRODUCT RANGE

HALIFAX RACK & SCREW



The photograph shows a small sample from a wide range of standard and special gear racks including both spur and helical tooth forms that are manufactured within the following capacity

Typical standard and special designs



Gear Rack Capacity Table

	Metric	Imperial
Min. pitch	0.5 mod	64 DP
Max. (full depth)	28 mod	1 DP
Max. face width	450mm	$17\frac{3}{4}$"
Max. overall width	580mm	23"
Max. tip to back	450mm	$17\frac{3}{4}$"
Max. length	5 tonne wt.	
Tooth forms	$14\frac{1}{2}$°, 20° and 25° PA. Full depth and stub Spur or Helical to 45° HA.	

The above maximum capacities may not be used in total combination - refer to H.R.S. Rack lengths can be accurately 'ended' to provide an air gap for 'continuous' runs.

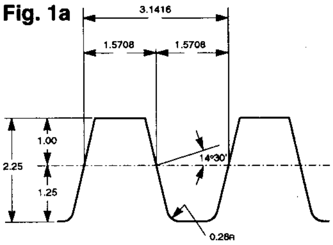
Drilling, tapping to suit customer's assembly.

NOTE: The level of accuracy grade may restrict the achievable length, etc.
Mating spur or helical pinions are supplied to customer's requirements.
Comprehensive ancillary machining facilities for all bespoke special requirements

GEAR RACKS

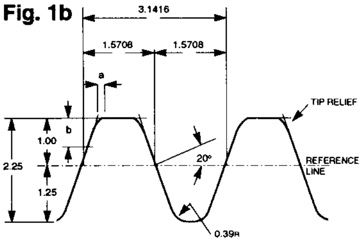
BASIC RACK TOOTH PROFILES

Fig. 1a



14½° Coarse pitch Full depth involute AGMA 201.02
(Not recommended for new designs i.e. replacements)

Fig. 1b



BS 436 20° Coarse pitch involute ≥ 20 DP ≥ 1 mod
Limits of any tip relief a - 0.02 b - 0.6 max

TOOTH FORMS

Whilst no longer recommended for new designs, the 14½° pressure angle full depth involute from Fig 1a) is still in much demand for spares and replacements. The most widely national and international tooth form is the 20° pressure angle, full depth involute Fig 1b) Note, for fine pitches i.e. < 20 DP, < 1 mod. the full depth is 2.4, and dedendum 1.4 Other forms include the 25° coarse pitch, full depth involute to AGMA 201.02 designed for increased strength, also various stub forms i.e. American Standard 20° Involute Stub, Fellow Stub and Nuttall Stub Tooth System. Stub forms have shallow addendums and dedendums and have mainly been used where design restrictions on gear diameters prevented the use of full depth gears. Halifax Rack & Screw are able to cut all of the above tooth forms in both spur and helical configurations up to 45° helix.

ACCURACY AND GRADES

Existing European standards (i.e BS.and DIN) refer to 'cylindrical' gears though DIN 3960 - Aug '60 regarded "a gear rack as an infinitely large externally - toothed gear in which the pitch circle has become a pitch line. The definitions and terminology laid down for spur gears are therefore applicable analogously to racks also". Applying this definition to BS436 accuracy grades then unless agreed or specified otherwise, the tolerance on cumulative pitch accuracies applied by Halifax Rack & Screw is as follows:-

PREFERRED DIAMETRAL PITCHES AND METRIC MODULES.

D P	C.P. mm.	Mod	Thickness on Pitch Line mm.	Addendum mm.	Full Depth B S. mm.
64	1.2468		0.623	0.397	0.953
	1.5708	0.5	0.785	0.500	1.200
48	1 6624		0.831	0.529	1.270
	1.8850	0.6	0.942	0.600	1.440
40	1.9949		0.997	0.635	1.524
	2.1991	0.7	1.099	0.700	1.680
36	2.2166		1.108	0.706	1.693
32	2.4936		1.247	0.794	1.905
	2.5133	0.8	1.257	0.800	1.920
28	2.8499		1.425	0.907	2.177
	3.1416	1.0	1.571	1.058	2.250
24	3.3249		1.667	1.058	2.540
	3.9270	1.25	1.964	1.250	2.813
20	3.9898		1.995	1.270	2.858
	4.7124	1.5	2.356	1.500	3.375
I6	4.9873		2.494	1.588	3.572
	6.2832	2	3.142	2.000	4.500
12	6.6497		3.325	2.117	4.763
	7.8540	2.5	3.927	2.500	5.625
10	7.9796		3.990	2 540	5.715
	9.4248	3	4.712	3.000	6.750
8	9.9746		4.987	3.175	7.144
	12.5664	4	6.283	4.000	9.000
6	13.2994		6.650	4.233	9.525
	15.7080	5	7.854	5.000	11.250
5	15.9593		7.980	5.080	11.430
	18.8496	6	9.425	6.000	13.500
4	19.9491		9.975	6.350	14.288
	25.1327	8	12.566	8.000	18.000
3	26.5988		13.299	8.467	19.050
	31.4159	10	15.708	10.000	22.500
2.5	31.9186		15.959	10.160	22.860
	37.6991	12	18.850	12.000	27.000
2	39.8982		19.949	12.700	28.575
	50.2655	16	25.133	16.000	36.000
1.5	53.1976		26.599	16.933	38.100
	62.8319	20	31.416	20.000	45.000
1.25	63.8372		31.919	20.320	45.720
	78.5398	25	39.270	25.000	56.250
1	79.7965		39.898	25.400	57.150

An individual rack having z number of continuous teeth i.e. $z.p_t$ overall tooth length L, is equivalent to a cylindrical gear of pitch diameter $d = z.\ p_t / \pi$

HRS GRADE	BS 436 COARSE PITCH	BS FINE PITCH	Tolerance on 300mm	12"	* AGMA QUALITY	* DIN QUALITY
PRECISION	5	B	0.032	0.0013	11	6/7
STANDARD PRECISION	6	C	0.050	0.0020	10	7/8
	7		0.070	0.0028	9	8/9
COMMERCIAL	8	D	0.10	0.0040	8	9/10
	9		0.14	0.0056	7	10/11
	10		0.20	0.0079	6	11/12

Notes: * Refer to actual standards for exact comparisons. This table compares cumulative pitch tolerances of 300mm and 12" spans only and does not necessarily relate to other elements i.e. run-out, lead, etc.

The B.S tolerance on cumulative pitch accuracy for any grade can be applied up to a maximum span of $\pi d/2$ i.e L/2. The limits of tolerance on cumulative pitch accuracy for the overall tooth length L is then the arithmetic total of that for the span L/2 i.e a rack having 600 mm of continuous teeth to HR & S Standard Precision (BS 436 Grade 6 - see table) cumulative pitch tolerance over 300mm span is 0.050mm, cumulative pitch tolerance over 600mm is 0.10mm.

AGMA 390.03 section 4 tabulates individual tooth element, composite action and tooth thickness tolerances for each AGMA Quality Number of coarse and fine pitch spur and helical racks.

An approximate comparison of international standard classification with HR & S capabilities for pitch variation is shown above.

STOCK & STANDARD SERIES - GEAR RACKS (Commercial & Precision Quality)

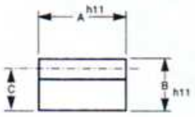
STANDARD MATERIAL: 40 Carbon 080M40Pb (En 8) † **Low Carbon 080M15Pb (En 32c)**

COARSE PITCHES (≥20 D.P., ≥ 1 mod)
Basic rack to BS 436 : 1967 Parts 1 and 2
Pressure angle 20°

Pitch accuracies:
Stock Commercial Quality racks cut to Grade 8
Standard Precision Quality racks cut to Grade 6

FINE PITCHES (< 20 D.P., < 1 mod)
Basic rack to BS 978 : 1968 Parts 1
Pressure angle 20°

Pitch accuracy:
Standard Precision Quality racks cut to Class C



METRIC MODULE SERIES
Dimensions in Millimetres

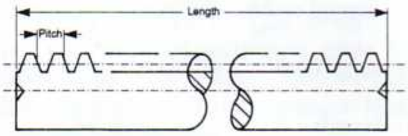
MODULE	FACE WIDTH A h11	TIP TO BACK B h11	PITCH LINE TO BACK C	CODE
† 1	15	15	14.00	M10-15
1.5	18	18	16.50	M15-18
2	20	20	18.00	M20-20
2.5	25	25	22.50	M25-25
3	30	30	27.00	M30-30
4	40	40	36.00	M40-40
5	50	50	45.00	M50-50
6	60	40	34.00	M60-60

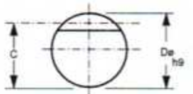
*** LENGTHS:** Suffix Code 600, 1200, 1800mm

DIAMETRAL PITCH SERIES
Dimensions in Inches

D.P.	FACE WIDTH A h11	TIP TO BACK B h11	PITCH LINE TO BACK C	CODE
3	3.000	1.500	1.167	3-30
4	3.500	2.000	1.750	4-35
5	2.500	1.500	1.300	5-25
6	2.000	1.500	1.333	6-20
6	1.500	1.000	0.833	6-10
8	1.500	1.500	1.375	8-15
8	1.250	1.250	1.125	8-12
10	1.250	1.250	1.150	10-12
10	1.000	1.000	0.900	10-10
12	1.000	1.000	0.917	12-10
12	0.750	0.750	0.667	12-07
16	0.750	0.750	0.688	16-07
16	0.500	0.500	0.438	16-05
20	0.500	0.500	0.450	20-05
† 24	0.250	0.250	0.208	24-02
† 32	0.187	0.187	0.156	32-01

*** LENGTHS:** Sections down to ½" sq. Suffix code 48 or 72 in.
Sections below ½" sq. Suffix code 24 or 48 in.





Dimensions in Millimetres

MODULE	DIA D h9	PITCH LINE TO BACK C	CODE
1	12	11.00	M10-15
1.5	18	16.50	M15-18
2	22	20.00	M20-20
2.5	25	22.50	M25-25
3	30	27.00	M30-30
4	40	36.00	M40-40
5	50	45.00	M50-50
6	60	54.00	M60-60

*** LENGTHS:** Suffix Code 600, 1200, 1800mm

* Racks are supplied slightly longer than indicated to allow for cutting or matching.
Racks can be supplied faced to exact lengths on request.

- **We carry extensive stocks of normalised material in sections other than those listed (Imperial and Metric)**
- **Cutters for 1 to 64 Diametral Pitch range also alternative Module and Circular Pitches, 14½°, 20° P.A. or 25° (To BSS, DIN and AGMA standards, etc.) and special tooth forms.**
- **Bespoke racks (complete supply or cutting only customer's free issue material) cut to individual pitch accuracy requirements up to Grade 5, BS 436 : 1967 and Class B, BS 978 : 1968.**
- **Forging, casting, planing and drilling capacity available.**
- **Our special purpose machines produce both straight and helical teeth.**
- **Long and short batches are our speciality.**
- **Mating pinions supplied to customer's requirements.**

GEAR RACK DESIGN

The majority of racks and pinions are the final machine elements of a power transmission drive that converts rotary motion to linear motion. There should be a balance in the design and selection of every element of the transmission drive from the prime mover to the final element - the rack. The design of each element may also require adherence to any bespoke industries or national 'code of design practice' and the application of appropriate shock and fatigue factors.

Methods of calculation of gear tooth root bending strength and tooth contact wear limitations are the subject of various national standards i.e BS 436. The norm of such standards primarily relate to cylindrical gear combinations, operating continuously for a given design life and require many tentative assumptions including the tooth number combinations etc. In applying such standards to a rack in contact with a pinion, account must be made of the variable duty i.e. cycle travel, reversing, inching etc associated with a rack traverse motion

HR & S pride their expertise in the specialised manufacturing facilities of gear racks to customers own design requirements. Industries as diverse as nuclear, passenger / goods hoists, medical, machine tool etc are supplied, where necessary with Certificates of Conformance to customer's specifications. Each of these industries applies their knowledge of 'code of design practice'. However, a simple resort to a tentative design only, is to revert to the initial Lewis bending stress formula which considers a gear rack in isolation from the pinion, and vice versa. Any such tentative selection of rack and pinion must then be checked to the ruling national standard.

LEWIS FORMULA

Introduced in 1892, the extensively used Lewis Formula determines the beam strength capacity of Gears. Subsequent national and international research continues to be documented for determining the power transmitting capacity of gears. The progressive aim being the achievement of optimum gear tooth loading design procedures. This research shows that the Lewis calculated strength capacity is usually much less than that which could be transmitted safely.

GEAR RACK DESIGN

NOTATION

DP	DIAMETRAL PITCH
f	FACE WIDTH mm (inch)
F_t	SAFE TANGENTIAL LOAD N (lbs)
hp	HORSEPOWER
K	RATIO OF f / p_t - normal between 3 and 5
kw	KILOWATTS
m	MODULE
p_t	TRANSVERSE PITCH = $m \pi$ mm $\left(\frac{\pi}{DP}\text{ in.}\right)$
V	PITCH LINE VELOCITY m/min (ft/min)
Y	TOOTH FORM FACTOR
σ	ALLOWABLE UNIT STRESS FOR MATERIAL AT VELOCITY V N / mm² (lbf/in²)
* σ_s	ALLOWABLE UNIT STATIC STRESS FOR MATERIAL N / mm² (lbf/in²)
z	NUMBER OF TEETH IN GEAR (infinity for rack)

* Note, in general, σ_s may be taken as approximately one third of the ultimate strength of the material.

FORMULA DESIGN

Y $14\frac{1}{2}°$ full depth $0.390 - \frac{2.149}{z} = 0.39$ for rack

$20°$ full depth $0.484 - \frac{2.865}{z} = 0.484$ for rack

$20°$ stub $0.55 - \frac{2.827}{z} = 0.55$ for rack

σ Allowable unit stress for material at velocity V

$$= \sigma_s \left(\frac{183}{183 + V}\right) \text{ N/mm}^2 \qquad = \sigma_s \left(\frac{600}{600 + V}\right) \text{ lbf/in}^2$$

F_t Safe tangential load at pitch line

$$= f.Y.\sigma.\,m \quad \text{N}, \qquad = f.Y.\sigma / DP \quad \text{lbf.}$$

Allowable transmitted power

$$= \frac{f.Y.m.V.\sigma_s}{60{,}000}\left(\frac{183}{183+V}\right) \text{ kW}, \quad = \frac{f.Y.V.\,\sigma_s}{33000\text{ DP}}\left(\frac{600}{600+V}\right) \text{ hp}$$

Pitch required to transmit given power

$$m = \sqrt{\frac{\text{kW} \times 60000}{Y.\,V.\,k.\;\pi.\,\sigma_s}\left(\frac{183 + V}{183}\right)}$$

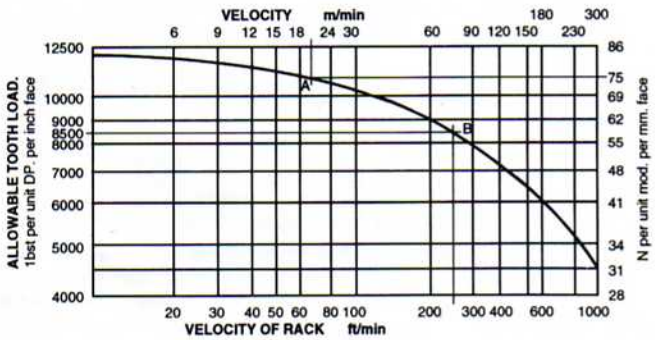
$$DP = \sqrt{\frac{Y.\,V.\,k.\;\pi.\,\sigma_s}{\text{hp} \times 33000}\left(\frac{600}{600 + V}\right)}$$

Based on Lewis and 40 carbon steel 080m40 Pb(EN8) normalised 540N/mm² (35 tonf/in²) min tensile, 152/207 HB and an allowable static stress of 172.25 N/mm² (25,000 lbf/in²). The graph below gives a quick approximation of the allowable tooth load in Newtons per unit module per mm. face (pounds per unit DP per inch face).

Hence a 5 mod, 50 mm face at 20m/min velocity has an allowable tangential tooth load of approximately 75 N/mod/mm x 5mod x 50 = 18750 N. *(shown at A)*

A rack 8 DP, $1\frac{1}{2}$" face at 250ft/min velocity has an allowable tangential load of approximately

$$\frac{8500 \text{ lbf/DP/in} \times 1\frac{1}{2}}{8} = 1594 \text{ lbf.}$$ *(shown at B)*



The above procedure is given only as a first approximation to determining gear rack sizes. Gear racks so designed should be ultimately rated to BS436 (or the ruling National Standard).