BRAUER®

1.0 Specification For Standard Wheels & Castors

1. Plain bore tolerances are +0.05 / -0 mm.
2. Standard tolerances on width and diameter ±0.25 mm except tyred wheels which are ± 1.00mm.
3. Wheels are fitted with grease nipples, other than plain bore keywayed wheels, nylon, nylon centred wheels, or wheels of 75, 100 or 125 diameter. Wheels fitted with ball journal bearings up to 40 mm bore may be without grease nipples if fitted with double shielded bearings.
4. Wheels of 75, 100 or 125 diameter fitted with ball journal bearings have pre-lubricated shielded bearings.
5. All wheels supplied with ball journals, other than those of 75, 100 or 125 diameter, have bearings with a single shield fitted to the outer side unless otherwise stated. Wheels fitted with ball journal bearings up to 40 mm bore may be fitted with double shielded bearings.
6. All wheels with ball or roller bearings, other than those fitted with pre-lubricated double shielded ball journals, are supplied un-greased to avoid contamination during shipment.
7. All wheels fitted with ball journals have a central spacer between the bearings to allow them to be clamped to an axle abutment shoulder without pre-loading the bearings.
8. Taper roller bearings are supplied with the outer race (cup) press fitted, and the inner cone and roller assembly, together with metal shields, supplied loose.
9. All cast wheels are finished in one coat self-etching black primer paint.
10. Fully machined wheels or axles from billet, or barstock, are protected by a coat of air-drying oil.
11. Pressed steel castor brackets are finished in bright zinc electroplating to BS1706.
12. Fabricated castor brackets are finished in one coat of self-etching black primer paint.
13. Key ways are produced to Wheels in house standard tolerances.

2.0 Untyred Wheels

When less than the full tread width is used to carry the load, the allowable load can be determined as follows:-

$$\text{Allowable load} = \frac{\text{Load carrying width}}{\text{Full tread width (per catalogue)}} \times \text{'Maximum Load Rating' (per catalogue)}$$

3.0 Rubber Tyred Wheels

3.1 LOAD RATING.

The 'Maximum Load Rating' given for each rubber tyred wheel is the maximum load the wheel will carry in constant use under the following conditions:

a) the wheel is free-wheeling (not driving)
b) the ambient temperature is below 30 degrees C.
c) the surface speed does not exceed 6 kph
d) the surface on which the wheel runs is flat and smooth (i.e steel or smooth concrete)
e) that the wheel is not steering or subjected to axial loads
f) no chemical is present which will attack rubber (see 3.2)

For more severe conditions than those described above refer to Brauer for the allowable load, or consider polyurethane tyred wheels.

3.2 RESISTANCE TO CHEMICALS

A = little or no effect
B = moderate effect
C = severe effect

Acetic Acid 20%	C	Formaldehyde	C	Mineral oils	C
Acetone	C	Formic acid	B	Naphtha	C
Ammonium hydroxide	C	Fuel oil	C	Naphthalene	C
Barium hydroxide	B	Gasoline	C	Nitric acid	C
Benzene	C	Glue	B	Oil - lubricating	C
Borax	A	Hydraulic oils	C	Palmic acid	C
Boric Acid	A	Hydrochloric acid - cold	A	Perchlorethylene	C
Butane	C	Hydrochloric acid - 10%	A	Phenol	C
Calcium bisulphite	C	Hydrochloric acid - hot	C	Phosphoric acid 85%	A
Calcium chloride	A	Hydrochloric acid - 30% +	C	Sodium hydroxide	C
Calcium hydroxide	B	Hydrogen	B	Soybean oil	C
Carbon dioxide	A	Isopropyl ether	C	Sulphuric acid 10%	A
Carbon monoxide	C	JP- 3	C	Sulphuric acid 50%	C
Carbon tetrachloride	C	JP -4	C	Tannic acid	A
Castor oil	B	Kerosene	C	Toluene	C
Chlorine	C	Linseed oil	C	Trichloroethylene	C
Chromic acid	C	Magnesium chloride	A	Turpentine	C
Cottonseed oil	C	Magnesium hydroxide	A	Water	A
Cyclohexane	C	Methyl alcohol	A	Xylene	C
Ethyl acetate	C	Methyl ethyl ketone	C	Zinc sulphate	A
Ethyl alcohol	A	Mercury	A		

4.0 Cast Nylon Wheels

4.1 RESISTANCE TO CHEMICALS

A = Excellent
B = Good
C = Fair
D = Severe effect

Acetic Acid	D	Chromic Acid 10%	D	Naphtha	A
Acetone	A	Ethanol	A	Naphthalene	A
Acetyl Bromide	D	Ethyl Acetate	A	Nitric Acid (5-10%)	D
Alcohols:Butyl	D	Fluorine	D	Oils:Castor	A
Ammonium Hydroxide	A	Formaldehyde 100%	D	Oils:Creosote	D
Antifreeze	D	Formic Acid	D	Oils:Soybean	A
Asphalt	A	Fuel Oils	A	Ozone	D
Barium Hydroxide	A	Gasoline, leaded, ref.	A	Perchloroethylene	C
Beer	A	Glue, P.V.A.	A	Phenol (10%)	D
Benzene	A	Hydraulic Oil (Petro)	A	Sodium Hydroxide (50%)	A
Borax (Sodium Borate)	A	Hydrochloric Acid 20%	D	Sulfuric Acid (10-75%)	D
Boric Acid	B	Hydrogen Peroxide 10%	C	Tannic Acid	C
Butane	A	Jet Fuel (JP3, JP4, JP5)	C	Tetrachloroethylene	A
Calcium Chloride	A			Toluene (Toluol)	A
Calcium Hydroxide	A	Kerosene	A	Trichloroethylene	C
Calcium Sulfate	D	Lacquer Thinners	A	Water, Fresh	A
Carbon Dioxide (dry)	A	Magnesium Chloride	A	Water, Salt	A
Carbon Monoxide	A	Magnesium Hydroxide	B	Xylene	A
Chloric Acid	D	Methanol (Methyl Alcohol)	B	Zinc Sulfate	A
Chlorine Water	C	Motor oil	A		

5.0 Polyurethane (Vulkollan) Tyred Wheels

5.1 LOAD RATING AND FACTORS

The 'Maximum Load Rating' given for each polyurethane tyred wheel is the maximum load the wheel will carry in intermittent use (a maximum of 1 hour running followed by a minimum of 1 hour at rest) under the following conditions:

a) the wheel is free-wheeling (not driving)
b) the ambient temperature is below 45 degrees C
c) the surface speed does not exceed 6 k.p.h.
d) the surface on which the wheel runs is flat and smooth (i.e steel or smooth concrete)
e) that the wheel is not steering or subjected to axial loads
f) no chemical is present which will attack polyurethane (see 5.2)

For more severe conditions the 'Maximum Load Rating' must be multiplied by the 'Load factor' as follows:

Condition	Load Factor
Continuous running	0.75
Surface Speed 6-10 kph	0.8
Surface Speed 10-16 kph	0.7
Driving wheels	0.7

For speeds over 16 kph, for operating temperatures over 45 degrees C and below 20 degrees C, for humid conditions, and for curved running surfaces (i.e. in supporting rotating drums) refer to HMC-Brauer for the allowable load.

Load factors must cumulate, for example:
A wheel with a 'maximum load rating' of 1000kg is to be subjected to continuous running at 8kph in a driving application,

allowable load = 1000kg x 0.75 (continuous running factor) x 0.8 (speed factor) x 0.7 (driving factor)
= 420kg.

DESIGN DATA

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5.2 **RESISTANCE TO CHEMICALS**

A = little or no effect
B = moderate effect
C = severe effect

Acetic Acid 20% max	B	Formic acid	C	Palmitic acid	A
Acetone	C	Fuel oil	B	Perchlorethylene	C
Ammonia hydroxide	A	Gasoline	B	Phenol	C
Barium hydroxide	A	Glue	A	Phosphoric acid 70%	A
Benzene	C	Hydraulic oils	B	Phosphoric acid 80%+	C
Borax	A	Hydrochloric acid - 20% max.	B	Potassium hydroxide	B
Boric Acid	A	Hydrochloric acid - 30%+	C	SAE No. 10 Oil (70˚C)	A
Butane	A	Hydrogen	A	Sea water	A
Calcium bisulphite	A	Isopropyl ether	B	Soap solutions	A
Calcium chloride	A	JP- 4	B	Sodium hydroxide - 20% max.	A
Calcium hydroxide	A	JP -5	C	Sodium hydroxide - 45% max.	B
Carbon dioxide	A	JP - 6	C	Sodium hypochlorite	C
Carbon monoxide	A	Kerosene	B	Soybean oil	B
Carbon tetrachloride	C	Ketone	C	Stearic acid	C
Castor oil	A	Linseed oil	B	Sulphuric acid 10% max.	A
Chlorine	C	Magnesium chloride	A	Sulphuric acid 10%+	B
Chromic acid	C	Magnesium hydroxide	A	Sulphuric acid 50%	C
Copper Chloride	A	Mercury	A	Tannic acid	A
Copper Sulphate	A	Methyl alcohol	C	Toluene	C
Cottonseed oil	A	Methyl ethyl	C	Trichloroethylene	C
Cyclohexane	A	Mineral oils	A	Turpentine	C
Ethyl acetate	C	Naphtha	B	Water (45˚C)	A
Ethyl alcohol	C	Naphthalene	B	Water (100˚C)	C
Ethylene glycol	B	Nitric acid	C	Xylene	C
Formaldehyde	C	Oils - lubricating	B		

6.0 Rail Wheels

6.1 **APPROXIMATION OF ALLOWABLE LOAD FOR CATALOGUE ITEMS**

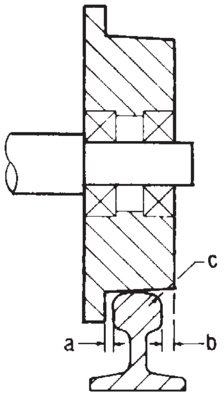
The ‘maximum Load Rating’ given for each rail wheel (types CSF, SSF,CDF,CFT and SFT) is the maximum load the wheel can carry without permanent deformation and to give an acceptable service life when the full tread width is in contact with the rail.

In practice full contact with the rail across the tread width is rarely achieved due to

a) Flange to rail clearance.
b) Wheel overhang
c) Rail corner radii

Allowable load capacities of catalogue items used on a given rail can be determined as follows:-

$$\text{Allowable Load} = \frac{\text{useable Rail width (per 6.2.4)}}{\text{full tread width (per catalogue)}} \times \text{maximum load rating (per catalogue)}$$



Note:

i) The ‘useable rail width’ (per para 6.2.4) takes into account the profile of the rail head, whether convex or flat.
ii) The above applies to wheels with very light axial (flange) loads when fitted with bearings. Heavy axial loads will severely limit the radial load carrying capacity of the bearings – see 7.1
iii) ‘Maximum Load Ratings’ of catalogue items are based on P_L = 0.52, C_1=1.1, C_2 = 0.9 for steel wheels, and P_L = 0.15, C2 = 0.8 for cast iron wheels - refer to 6.2 & 6.3 for relevant equations.

DESIGN DATA

6.2 CALCULATION OF ALLOWABLE LOAD - STEEL OR S.G IRON RAIL WHEELS

The following equations can be used for wheels of up to 1.25m diameter of cast, rolled or forged steel, or S.G cast iron, to determine the relationship between:

i) wheel diameter
ii) ultimate strength of wheel material
iii) load capacity
iv) service life
v) the useable width of the rail
vi) speed of rotation of the wheel.

a) for the wheel to withstand the maximum static load to which it is subjected:

$$P_L \geq \frac{P_S \text{ mean}}{b \times D \times C_{1\,max.} \times C_{2\,max.}} = \frac{P_S \text{ mean}}{b \times D \times 1.38}$$

and

b) For the wheel to perform its specified duty without abnormal wear:

$$P_L \geq \frac{P_d \text{ mean}}{b \times D \times C_1 \times C_2}$$

Where:
- D = wheel diameter (mm)
- b = useable rail width (mm) – see 6.2.4
- P_L = limiting pressure (kgf/mm^2) – see 6.2.1
- C_1 = a coefficient determined by r.p.m. – see 6.2.2
- $C_{1\,max.}$ = 1.2
- C_2 = a coefficient determined by ‘machine life and utilisation’ – see 6.2.3
- $C_{2\,max.}$ = 1.15
- $P_{S\,mean}$ = the mean static load to be withstood by the wheel (kg) $= \dfrac{2P_{s\,max.} + P_{s\,min.}}{3}$
- $P_{d\,mean}$ = the mean dynamic load to be withstood by the wheel (kg) $= \dfrac{2P_{d\,max.} + P_{d\,min.}}{3}$

6.2.1 Determining the limited pressure P_L

(as a function of the ultimate strength of the metal of which the rail wheel is made)

Notes:

I) in the case of wheels heat treated to increase the surface hardness, the value of P_L is limited to that of the steel prior to surface treatment.

ii) The ‘Limiting Pressure’ P_L is a notional pressure determined by supposing that the contact between wheel and rail takes place over a surface whose length is a diameter of the wheel, and width is the ‘useable rail width’ b.

P_L Kgf/mm^2	ULTIMATE STRENGTH OF METAL USED FOR RAIL WHEEL N/MM^2 (SEE NOTE I)
0.50	500
0.56	600
0.65	700
0.72	800

6.2.2 Determining coefficient C_1

WHEEL ROTATIONAL SPEED, R.P.M.	C_1	WHEEL ROTATIONAL SPEED, R.P.M.	C_1	WHEEL ROTATIONAL SPEED, R.P.M.	C_1
5.0	1.17	20.0	1.06	63	0.91
5.6	1.16	22.4	1.04	71	0.89
6.3	1.15	25.0	1.03	80	0.87
8.0	1.14	28.0	1.02	90	0.84
10.0	1.13	31.5	1.00	100	0.82
11.2	1.12	35.5	0.99	112	0.79
12.5	1.11	40.0	0.97	125	0.77
14.0	1.10	45.0	0.96	160	0.72
16.0	1.09	50.0	0.94	200	0.66
18.0	1.07	56.0	0.92		

Design Data

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6.2.3 Determining coefficient C_2
(machine life and utilisation)

Should a longer service life be required for a given material whose load/life properties have been determined per paragraph 6.2 refer to paragraph 6.4 'Surface Hardening'.

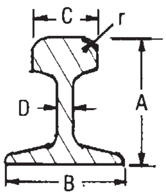
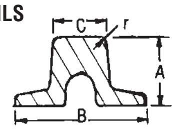
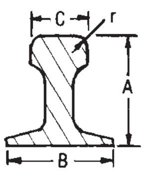
UTILISATION	SERVICE LIFE – HOURS							
	400	800	1600	3200	6300	12000	25000	50000
Mechanisms subjected very rarely to their maximum load and, normally, to very light loads	1.12	1.12	1.12	1.12	1.12	1.00	0.90	0.80
Mechanisms occasionally subjected to their maximum load, but, normally, to rather lighter loads	1.12	1.12	1.12	1.12	1.00	0.90	0.80	0.80
Mechanisms frequently subjected to their maximum load and, normally, to loads of medium magnitude	1.12	1.12	1.12	1.00	0.90	0.80	0.80	0.80
Mechanisms frequently or constantly subjected to their maximum load	1.12	1.12	1.00	0.90	0.80	0.80	0.80	0.80

6.2.4 Determining the useable rail width, b
The useable rail width is determined by the following equations:

i) for convex topped rails $b\ (mm) = C - \frac{4}{3}\ r$
(these are generally flat bottom rails)

ii) for flat topped rails $b\ (mm) = C - 2r$
(these are generally bridge, crane and barstock rails)

Dimensions and Useable Widths of a selection of rails are given below. These are for illustration only and details may deviate. Brauer recommend consulting the rail supplier for detailed cross section of rail selected before finalising the design of the wheel tread.

RAIL TYPE		RAIL SECTION IDENTITY	SECTION WEIGHT		PRINCIPAL DIMENSIONS (mm)					USABLE WIDTH b (mm)
			kg/m	lb/yd	HEIGHT A	BASE B	HEAD WIDTH C	WEB D	RADIUS r	
FLAT BOTTOM RAILS	British	**X BS 20 'M'**	9.881	20	65.09	55.56	30.96	6.76	6.35	22.49
		X BS 30 'M'	14.785	30	75.41	69.85	38.10	9.13	7.92	27.54
		BS 35 'M'	17.387	35	80.96	76.20	42.86	9.13	7.92	32.30
		BS 35 'R'	17.360	35	85.73	82.55	44.45	8.33	7.92	33.89
		X BSC 40	19.890	40	88.11	80.57	45.64	12.30	9.13	33.47
		ACSE 40	20.09	40.5	88.9	88.9	42.60	9.9	7.94	32.02
		X BS 50 'O'	24.833	50	100.01	100.01	52.39	10.32	8.73	40.75
		BS 60 'R'	29.822	60	114.30	109.54	57.15	11.11	9.53	44.44
		X BS 60 'A'	30.618	60	114.30	109.54	57.15	11.11	9.53	44.44
		BS 70 'A'	34.807	70	123.82	111.12	60.32	12.30	9.53	47.61
		BS 75'R'	37.041	75	128.59	122.24	61.91	13.10	11.11	47.10
		BS 75'A'	37.455	75	128.59	114.30	61.91	12.70	11.11	47.10
		**BS 80 'O'**	39.781	80	127.00	127.00	63.50	13.89	9.53	50.79
		BS 80 'R'	39.674	80	133.35	127.00	63.50	13.49	11.11	48.69
		BS 80 'A'	39.761	80	133.35	117.47	63.50	13.10	11.11	48.69
		BS 90 'R'	44.506	90	142.88	136.53	66.67	13.89	12.70	49.74
		BS 90 'A'	45.099	90	142.88	127.00	66.67	13.89	12.70	49.74
		BS 95 'A'	47.142	95	147.64	141.29	68.26	14.29	12.70	51.33
		BS 95 'N'	46.951	95	147.64	139.70	69.85	13.89	12.70	52.92
		BS 113 'A'	56.398	113	158.75	139.70	69.85	20.00	12.70	52.92
	European	**S10**	10	–	70	58	32.00	6	6.00	24.00
		S14	14	–	80	70	38.00	9	8.00	27.33
		S18	18.3	–	93	82	43.00	10	8.00	32.33
		S20	19.8	–	100	82	44.00	10	9.00	32.00
		S30	30.03	–	108	108	60.30	12.3	8.00	49.63
		S41-10	41.38	–	138	125	67.00	12.00	–	–
		S49	49.3	–	149	125	67.00	14	13.00	52.67
		UIC 54	54.43	–	159	140	70.00	16	13.00	54.67
		UIC 60	60.34	–	172	150	72.00	16.5	–	–
BRIDGE RAILS 	British	**X BSC 13**	13.306	26.77	48.0	92.0	36.00	–	11.00	14.00
		X BSC 16	16.029	32.25	54.0	108.0	44.50	–	10.50	23.50
		X BSC 20	19.861	39.95	55.5	127.0	50.00	–	9.53	30.94
		X BSC 28	28.624	57.58	67.0	152.0	50.00	–	9.00	32.00
		X BSC 35	35.375	71.16	76.0	160.0	58.00	–	10.00	38.00
		X BSC 50	50.179	100.00	76.0	165.0	58.50	–	10.00	38.50
CRANE RAILS	British	**X BSC 56**	58.806	114.27	101.5	171.0	76.00	–	9.53	56.94
		X BSC 89	89.81	180.67	114.0	178.0	102.00	–	10.00	82.00
		**X BSC 101**	100.383	201.94	155.0	165.0	100.00	–	10.00	80.00
		X BSC 164	166.83	335.61	150.0	230.0	140.00	–	10.00	120.00
	European	**A45**	22.1	–	55	125	45.00	24	4.00	37.00
		A55	31.8	–	65	150	55.00	31	5.00	45.00
		A65	43.1	–	75	175	65	38	6	53.00
		A75	56.2	–	85	200	75	45	8	59.00
		A100	74.3	–	95	200	100	60	10	80.00
		A120	100	–	105	220	120	72	10	100.00
		A150	150.3	–	150	220	150	80	–	–

ITEMS SHOWN IN BOLD ARE NORMALLY AVAILABLE FOR NEW BUILD

NOTE: Items with X are not manufactured by steel mills now.
Items in bold are at time of printing still currently manufactured.

DESIGN DATA

6.3 **CALCULATION OF ALLOWABLE LOAD - CAST IRON RAIL WHEELS**

While grey cast iron wheels are the most economic for light to medium duty, they are not suitable for high rotational speeds or where substantial shock loadings are to be withstood. Their performance is not as predictable as that of steel or S.G. iron wheels due principally to the presence of flake graphite which encourages ‘spalling’ of the surface.

6.3.1 **Allowable Load - grey iron as cast**

The relationship between:

i) Wheel diameter
ii) Load capacity
iii) Useable rail width

but **not** service life, can be approximated by the equation $P_L = \dfrac{P_{max}}{b \times D \times C_{2\,max}}$

Where:-
D = wheel diameter (mm)
b = useable rail width (mm) – see 6.2.4
P_L = 0.15 (a conservative value to provide an acceptable service life)
$C_{2\,max}$ = 0.8
P_{max} = maximum load to be withstood by the wheel (kg)

6.3.2 **Allowable Load - chilled cast iron or surface hardened cast iron**

Chilling or surface hardening of cast iron refines and hardens the surface to give an economic wheel capable of carrying moderate loads, with a service life similar to that of comparable steel wheels. For cast iron wheels having a hardened surface, the equation for steels wheels applies (para 6.2) with a value $P_L = 0.50$

6.4 **SURFACE HARDENING**

Surface hardening can extend service life beyond that given in para 6.2.3. a guide to the relationship between surface hardness and service life being:

Note: The surface hardness of the wheel must be taken into account when selecting the rail.

SURFACE HARDNESS (Hv)	LIFE FACTOR (240 HV = 1)
240	1.0
280	1.7
320	2.0
360	2.2
400	2.3

6.5. **FLANGE STRENGTH**

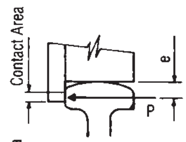
An approximation of rail wheel flange strength sufficient for most purposes can be determined as follows:

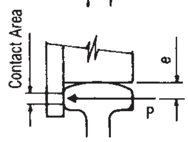
Allowable flange bending moment M (Nmm) $= \dfrac{\sigma_{tu} \times 1.5 \times t_f^3}{6 \times N \times K_m \times K_c}$

Allowable flange load due to bending P (kg) $= \dfrac{M}{9.81 \times e}$

Note: Moments about bearings and axial loads on bearings due to flange loads must be taken into account when selecting bearings and axle/bearing arrangements -see 7.1

Where:
σ_{tu} = tensile strength of the wheel material (N/mm²)
t_f = Flange thickness (mm)
N = Flange safety factor (2.0 minimum recommended)
K_m = load factor = 1.0 for gradually applied loads
= 1.5 for suddenly applied loads
K_c = casting factor (for cast wheels only) = 1.5
e = dimension (mm) from tread to point of application of load P as shown;





7.0 Bearing and Seal Arrangements – Non Standard Wheels

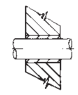
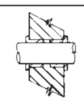
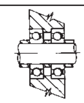
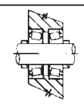
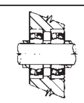
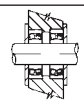
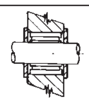
7.1 **SELECTION OF BEARINGS**

The main considerations in the selection of bearings are:

i) radial load
ii) axial load
iii) speed of rotation
iv) bearing friction

In selecting ball or roller bearings it is important that the static and/or dynamic radial load rating requirement for each bearing should be determined taking into account a) the radial load. b) the radial equivalent or any axial load (as given in the bearing manufacturer’s catalogue), and c) the radial load resulting from the moment of the axial load acting about the bearings.

It should be noted that in most bearing arrangements axial loads are taken by only one bearing , and that loads caused by condition c) above usually act positively on one bearing (being added to the radial load) and negatively on the other bearing (being deducted from the radial load).

DESCRIPTION	GENERAL ARRANGEMENT	RADIAL LOAD	AXIAL LOAD	SPEED OF ROTATION	BEARING FRICTION
1. Plain bronze or self-lubricating bushing		Very High	Very Light	Low	Moderate/ High
2. Flanged bronze or self-lubricating bushing		Very High	High	Low	Moderate/ High
3. Ball bearings		Light/ Moderate	Light	High	Low
4. Opposed taper roller bearings		Moderate	Moderate	High	Low
5. Spherical roller bearings		High	Light/ Moderate	High	Low
6. Spherical roller or cylindrical roller bearings and thrust washers or thrust bearings		High	Very High	High	Low
7. Needle roller bearings and thrust washers or thrust bearings		Very High	Very High	High	Low

DESIGN DATA

7.2 BEARING SEALS

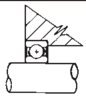
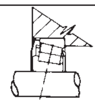
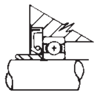
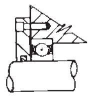
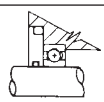
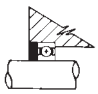
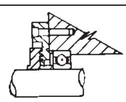
Bearing seals perform two main functions:

I) To prevent the ingress of material which will affect the life of performance of the bearing,

and/or

ii) To retain lubricant, particularly in hot or hostile environment.

Some typical sealing arrangements are illustrated:

DESCRIPTION	GENERAL ARRANGEMENT	APPLICATION NOTES
1. Bearings with seals and/or metal shields		Seals can be on one (outer) side only for lubrication via a grease nipple, or sealed both sides in 'sealed for life' applications. Seals of this type are not generally available for roller bearings.
2. Metal external shields		The simplest way of shielding roller or taper roller bearings, but without providing a complete seal.
3. Spring loaded lip seals		Provides excellent sealing. Spring should face outwards for grease renewal via a nipple and to prevent ingress of material, and inwards to retain lubricant in 'sealed for life' applications. Normal temperature range -40˚C to +100˚C.
4. Felt seals		Useful in high temperature applications in conjunction with suitable lubricants. Provide effective sealing of split housings.
5. 'O' ring seals		Can provide complete sealing, particularly against external pressure such as in underwater applications. Suitable only for circumferential surface speeds of less than 30m/min and temperatures of -40˚C to +110˚C.
6. Pressed steel labyrinth		Suitable only for 'sealed for life' applications as regreasing via a nipple tends to force the labyrinth out of its housing. Extra sealing can be obtained by inserting greased felt washers within the labyrinth during assembly.
7. Machined labyrinth		Can be used in conjunction with spring-loaded lip seals to provide the most effective seal in hostile environments.

8.0 Inertial and Rolling Resistance

The main forces resisting initial movement and acceleration of a wheeled vehicle are :

i) the rolling friction between the wheel and the surface on which it rests and, in the case of tyed wheels, the rolling resistance of the flat area of tread caused by static loading.
ii) the friction within the wheel or axle bearings.
iii) the inertial resistance of vehicle and load.

The main forces resisting the maintenance of movement after acceleration from rest are i) and ii) above (excluding the effect of a tyre 'flat')

8.1 ROLLING FRICTION

8.1.1 Polyurethane tyred wheels

Guide figures for rolling resistance per wheel as a percentage of load per wheel.

i) from rest , when the period of rest is 8 hours maximum = 5% of load.
ii) from rest, when the period of rest is greater than 8 hours = 8% of load.
iii) to maintain a constant speed = 3% of load.

Note: these figures are approximations as they are influenced by such factors as ambient temperatures, the track surface, the load/rest cycle timing, wheel diameter etc.

8.1.2 Rail wheels

When a body rolls on a surface, the force resisting the motion is termed rolling friction.

The force required to overcome rolling friction of a rail wheel in constant motion is determined by the equation: $F = \lambda \times P$

Where: F = Force required to overcome rolling friction(kgf) per wheel.
λ = Lambda, the coefficient of rolling friction.
P = Load per wheel (kg).

8.1.2.1 Determining the coefficient of rolling friction λ

Contact Pressure (Hertz) Between Wheel and Rail (Kgf/mm²)	Coefficient of Rolling Friction λ
30	0.005
40	0.007
50	0.008
60	0.010
70	0.012
80	0.013

The contact pressure (Hertz) between wheel and rail being determined by the equation

$$P_a = \frac{2 \times P}{\pi \times a \times b}$$

Where: P_a = Contact pressure (Hertz) in Kgf/mm²
P = Load on wheel (kg)
b = Useable rail width (mm) – see 6.2.4
a = half the width of the 'plane contact zone' between wheel and rail

$$a = \sqrt{\frac{4 \times P \times R}{\pi \times E^1 \times b}}$$

Where: P = Load on wheel (kg)
R = Radius of wheel (mm)
b = Useable rail width (mm)
E^1 = Effective Youngs Modulus of elasticity
= 7470 Kg/mm2 for an iron wheel on a steel rail
= 11200 Kg/mm2 for a steel wheel on a steel rail

8.2 BEARING FRICTION

For the purpose of determining the force required to start or maintain a wheel in motion the frictional resistance of ball or roller bearings, with their coefficient in the region of 0.002, can be disregarded.

The force required to overcome bearing friction for plain bearings is determined by the equation: $F = \frac{\mu \times P \times d}{D}$

Where:
- F = force required to overcome bearing friction(kg)
- μ = The coefficient of friction
- P = load on wheel (kg)
- d = diameter of axle (mm)
- D = diameter of wheel (mm)

The table gives guide figures for the coefficient of friction μ for rolling bearings and for various plain bearing materials running on a smooth steel axle.

The lubricated coefficient should be used for wheels in motion, and the unlubricated coefficient for wheels starting from a period of rest under static load (which assumes the worst condition)

Bearing Material	Coefficient of Friction μ	
	Lubricated	Unlubricated
Cast iron	0.21	0.40
Bronze	0.16	0.35
Thin wall PTFE/Lead wrapped bushes	0.02 - 0.20	0.02 - 0.20

8.3 INERTIAL RESISTANCE

To calculate the force required to accelerate the mass of the vehicle and its load from rest with a uniform rate of acceleration on a level track:

i) when the time taken to achieve the final velocity is known $F = \frac{M \times V_f}{t \times g}$

or, ii) when the distance taken to achieve the final velocity is known $F = \frac{M \times V_f^2}{2 \times s \times g}$

Where:
- F = force required to overcome inertia (kg)
- M = total mass of vehicle and load (kg)
- V_f = final velocity (m/sec)
- t = time taken to achieve final velocity from rest (secs)
- s = distance taken to achieve final velocity from rest (m)
- g = force of gravity = 9.81 m/sec^2

9.0 Traction – Coefficient of Friction

The traction of a driving wheel = $\mu \times P$

Where:
- μ = the coefficient of friction for a given wheel material and track surface.
- p = the load of the wheel.

Guides values for coefficients of friction μ, for wheel and tyre materials in contact with various surfaces are given:

Surface	Wheel or Tyre Material				
	Rubber	Polyurethane	Steel	Cast Iron	Nylon
Dry Steel	0.8	0.7	0.6	0.4	0.4
Wet Steel	0.5	0.4	0.4	0.3	0.15
Dry Smooth Concrete	0.8	0.7	–	–	–
Wet Smooth Concrete	0.5	0.6	–	–	–
Dry Rough Concrete	1.0	0.8	–	–	–
Wet Rough Concrete	0.9	0.6	–	–	–
Ice	0.1	0.1	0.02	0.02	–

10.0 Load Calculations For Wheels Supporting and/or Driving Rotating Drums.

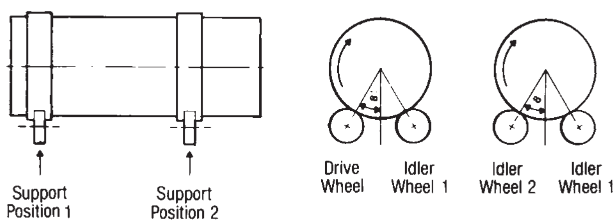
In installations where support wheels drive the drum we recommend that the driving wheels be positioned on the upwardly rotating side of the drum (as shown below) which is the more heavily laden side.

To determine the required 'Maximum Load Rating' for wheels at each support position for the purpose of wheel selection:

Maximum Load Rating – Drive Wheel $= \frac{(0.5P_1) + P_2}{\text{Cos} \propto \times L \times L_S \times L_C}$

Maximum Load Rating – Idler Wheel 1 $= \frac{0.5\,(P_1 + P_2)}{\text{Cos} \propto L_S \times L_C}$

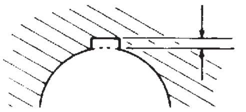
Maximum Load Rating – Idler Wheel 2 $= \frac{(0.5P_1) + P_2}{\text{Cos} \propto \times L_S \times L_C}$



Where:
- P_1 = weight of the drum at the support position under consideration (kg)
- P_2 = weight of the contents at the support position under consideration (kg)
- L = 0.7 = Load factor for driving wheels (polyurethane tyred wheels only)
- L_S = Load factor according to drum surface speed – see 5.1 (polyurethane tyred wheels only)
- L_c = 0.75 = Load factor for continuous running - see 5.1 (polyurethane tyred wheels only)

11.0 Keyway Dimensions – Parallel Key

Generally - (to commercial tolerances – keyways to BS46: part 1: 1958 and BS4235: part 1: 1972 available to order)



METRIC				INCH			
BORE Ø -0.00 +0.05	KEY SECTION		Keyway depth 'd' -0.0 +0.2	BORE Ø -0.000 +0.002	KEY SECTION		KEYWAY DEPTH 'd' -0.00 +0.006
	WIDTH	HEIGHT			WIDTH	HEIGHT	
12	4	4	1.8	0.5	0.125	0.125	0.060
20	6	6	2.8	0.75	0.188	0.188	0.088
25	8	7	3.3	1.00	0.250	0.250	0.115
30	8	7	3.3	1.25	0.312	0.250	0.112
35	10	8	3.3	1.50	0.375	0.250	0.108
40	12	8	3.3	2.00	0.500	0.312	0.131
50	14	9	3.8	2.50	0.625	0.438	0.185
60	18	11	4.4	3.00	0.750	0.500	0.209
75	20	12	4.9	3.50	0.875	0.625	0.264
100	28	16	6.4	4.00	1.00	0.750	0.318
150	36	20	8.4				

12.0 Reference Tables and Conversion Factors

12.1 HARDNESS CONVERSIONS AND EQUIVALENT TENSILE STRENGTH

VICKERS HARDNESS NUMBER HV	BRINELL HARDNESS NUMBER BHN	ROCKWELL C HRC	EQUIVALENT ULTIMATE TENSILE STRENGTH	
			N/mm²	tons/in2
500		49.7	1599	103
490		49.0	1568	101
480		48.2	1536	99
470	446.5	47.5	1504	97
460	437.0	46.7	1472	95
450	427.5	45.9	1441	93
440	418.0	45.1	1409	91
430	408.5	44.3	1377	89
420	399.0	43.5	1345	87
410	389.5	42.6	1314	85
400	380.0	41.7	1282	83
390	370.5	40.8	1250	81
380	361.0	39.8	1219	79
370	351.5	38.8	1188	77
360	342.0	37.8	1155	75
350	332.5	36.8	1124	73
340	323.0	35.7	1092	71
330	313.5	34.5	1059	69
320	304.0	33.5	1029	67
310	294.5	32.2	997	65
300	285.0	30.9	965	62
290	275.5	29.6	934	60
280	266.0	28.2	902	58
270	256.5	26.7	870	56
260	247.0	25.1	838	54
250	237.5	23.5	807	52
240	228.0	21.8	774	50
230	218.5	20.0	743	48
220	209.0		712	46
210	199.5		680	44
200	190.0		648	42
190	180.5		617	40
180	171.0		584	38
170	161.5		553	36
160	152.0		522	34
150	142.5		490	32
140	133.0		458	30
130	123.5		427	28

12.2 TENSILE STRENGTHS OF HEAT TREATED STEELS

HEAT TREATMENT CONDITION	TENSILE STRENGTH RANGE	
	N/mm2	Tons/in2
P	550 – 700	35 – 45
Q	625 – 775	40 – 50
R	700 – 850	45 – 55
S	775 – 925	50 – 60
T	850 –1000	55 – 65
U	925 – 1075	60 – 70
V	1000 – 1150	65 – 75
W	1075 – 1225	70 – 80

12.3 USEFUL CONVERSION FACTORS

TO CONVERT			TO		MULTIPLY BY
Length:	inch	(in)	metre	(m)	0.0254
	foot	(ft)	metre	(m)	0.3048
Area:	square inch	(in^2)	square millimetre	(mm^2)	645.16
Volume:	cubic inch	(in^3)	cubic metre	(m^3)	16.39×10^{-6}
	cubic foot	(ft^3)	cubic metre	(m^3)	0.02832
Mass:	kilogramme	(kg)	newton	(N)	9.807
	pound	(lb)	newton	(N)	4.448
	pound	(lb)	kilogramme	(kg)	0.4536
Torque:	pound force inch	(lbf.in)	kilogramme force metre	(kgf.m)	0.0115
	pound force inch	(lbf.in)	newton millimetre	(Nmm)	113.0
Pressure/	pound per square inch	(lb/in^2)	newton per square millimetre	(N/mm^2)	0.006895
Stress:	ton per square inch	(ton/in^2)	newton per square millimetre	(N/mm^2)	15.445

DESIGN DATA

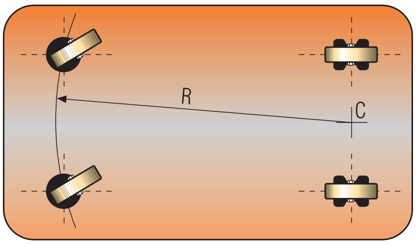
13.0 Castors

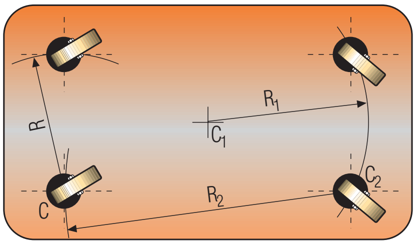
13.1 EXAMPLES OF POSSIBLE CASTOR ARRANGEMENTS

2 Swivel Castors and 2 Fixed Castors

Providing good load capacity and manoeuvrability, this arrangement ensures accurate steering, even on long straight runs, making it the most practical arrangement for industrial use.
Any trolley with this castor arrangement should be pushed with the fixed castors leading.

Maximum loading for each castor = $\frac{\text{Gross load}}{3}$





4 Swivel Castors

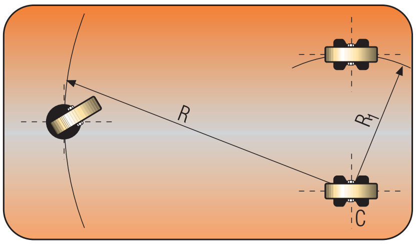
As this arrangement gives good load capacity with exceptional manoeuvrability, it is suitable for winding runs and where sideways action is required. It is not recommended for straight runs or ramps, as it may be hard to guide, especially over bumpy terrain and when heavily loaded. **However, equipping two castors with directional locks makes this arrangement very versatile and suitable for long straight runs.**

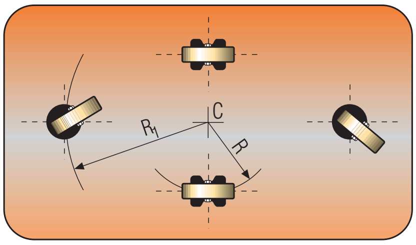
Maximum loading for each castor = $\frac{\text{Gross load}}{3}$

1 Swivel Castor and 2 Fixed Castors

This arrangement provides an economical solution for lightly loaded trolleys requiring good manoeuvrability. The trolley must be reasonably small in size and any load must be evenly distributed to ensure stability.

Maximum loading for each castor = $\frac{\text{Gross load}}{2.5}$





2 Swivel Castors and 2 Fixed Castors centrally pivoting

Ideal for confined spaces, this arrangement provides good load capacity with excellent manoeuvrability. The fixed castors can be replaced by an ‘A’ series axle assembly (see page 91) and wheels which pivot the trolley centrally. In this case, 25mm of packing is necessary above the two fixed castors (wheels) to give alternating load support. However if the trolley is tipped or the load is not evenly distributed, the swivel castors are subjected to shock loads.

The entire load rests on the two central, fixed castors/wheels.

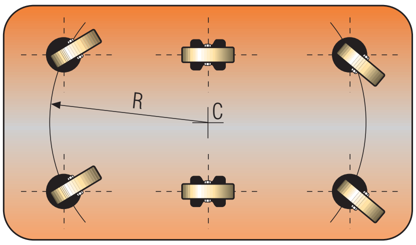
Maximum loading for each wheel/castor = $\frac{\text{Gross load}}{2}$

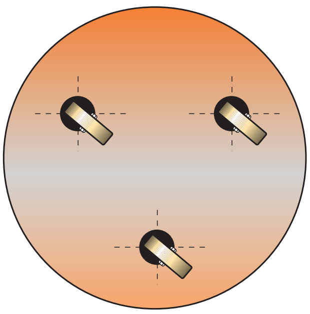
4 Swivel Castors and 2 Fixed Castors centrally pivoting

This arrangement provides an extremely high load capacity, with great manoeuvrability and stability. This is ideal for very long trolleys designed to carry heavy loads’ – the fixed castors can be replaced by wheels mounted onto a central ‘A’ series axle (see page 90). The unit’s base must be robust and the swivel castors are mounted to allow the trolley to pivot on the central wheels. Therefore, 25mm of packaging is required above the two fixed castors (wheels) to give alternating load support, depending on which pair of wheels is in contact with the floor. The entire load rests on 2 central, fixed castors/wheels.

Please note that the swivel castors are subjected to shock loads if the trolley is tipped or the load is not evenly distributed.

Maximum loading for each wheel/castor = $\frac{\text{Gross load}}{2}$





3 Swivel Castors

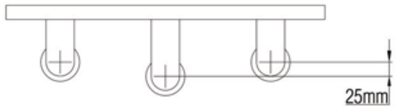
This provides good load capacity with excellent manoeuvrability. However, equipment with this arrangement will be difficult to guide on straight runs particularly over uneven ground.

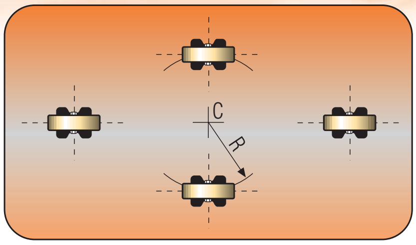
This arrangement is ideal for barrel dollies and small portable machines.

Maximum loading for each wheel = $\frac{\text{Gross load}}{2.5}$

2 Fixed Castors and 2 Fixed Castors centrally pivoting.

Suitable for moderate loads and long, straight runs with occasional changes in direction. The two central fixed castors can be replaced by wheels mounted onto a central 'A' series axle (see page 90). The two end castors are mounted as to pivot the trolley centrally.





25mm of packing is necessary above the two central castors (wheels) to give alternating load support. However if the trolley is tipped or the load is not evenly distributed, the end castors are subject to shock loads. The entire load rests on the 2 central, fixed castors/wheels.

Maximum loading for each wheel/castor $= \dfrac{\text{Gross load}}{2}$

13.1.2 Correct alignment of castors

i) Fixed and directional lock swivel castors - the mounting holes in the top plates are clearance holes and it is essential to align the castors correctly before the bolts are finally tightened.

ii) Swivel castors - it is essential they are mounted with the swivel axis vertical

13.1.3 Important Note The formulae above for the maximum loading for each castor is for an equally distributed load.

13.2 LOAD RATING

13.2.1 Limitations to stated maximum load rating for each model number:-

a) Untyred wheels - refer to design data para 2.0

b) rubber tyred wheels - refer to design data para 3.0

c) Polyurethane tyred wheels - refer to design data para 5.0

13.2.2 Floor conditions

The stated maximum load rating for each model assumes that the floor is reasonably level and free from cracks, obstructions, guide rails , gullies etc.

If any of the above are present in the operating environment then a castor with a load rating several times grater than calculated must be used. In addition the wheel diameter must be large enough to easily pass over any cracks, ridges and other obstructions.

13.3 MANUAL PROPULSION

The generally accepted effort an average human is capable of exerting is:-

a) 18 Kgf for moving from a standing start

b) 12 Kgf for a short distance once in motion

c) 6 Kgf for longer distances on travel

For inertial and rolling resistance, refer to design data para 8.0 and for traction design data para 9.0

13.4 POWER TOWING

Obstructions such as kerbs and gullies and even relatively small steps, can exert enormous impact loads which can damage a castor. Steps such as lift sills, drains covers and joints in concrete slabs, present a particular problem if they are not approached squarely and at low speeds. Approaching such obstacles obliquely makes the castor turn at right angles to the obstruction instead of turning in such a way that it can climb over it, this damages the castor.

Towing trailers in train increases the problem as only one castor may have to withstand the force generated by the mass of the whole train including the tractor.

When towing trailers in train the diagram below illustrates the position of the pin couplings relative to the rear fixed castors to ensure the weight of the trailer and its contents are evenly distributed between the front swivel castors and rear fixed castors as well as ensuring good tracking.