ROPE BREAKING LOADS

Breaking Loads

Wire, Nylon, Terylene, Kevlar & Polypropylene Rope

	Stainless Steel Wire Rope BS970 Part 4-316516 MA 29 73			Galvanised Wire Rope BS302 180 kg 1/mm²					Synthetic Fibre Rope 3 & 8 Strand to BS 4928			Braided Yacht Ropes			
Dia	1×19″	7×7	7×19	6×19 (12/6+6F/1) Steel Core	6×36″ (14/7&7/7/1) Steel Core	6×19 (12/6&6F/1) Fibre Core	6×36″ (14/7&7/7/1) Fibre Core	7×7 (6/1) *BS 3530	Nylon	Terylene	Polypro Pylene	Kevlar	Gleistein Terylene Cup Sheet	Marina Terylene	Dia
2mm 5/64″	320kg 704lbs	242kg						276kg*							2mm 5/64″
2.5mm 3/32″	500kg 1100lbs	380kg	274kg												2.5mm 3/32″
3mm 1/8″	720kg 1584lbs	545kg	510kg	588kg		498kg		629kg*							3mm 1/8″
4mm 5/32″	1280kg 2816lbs	968kg	907kg	1040kg		885kg		1120kg*	320kg	295kg			475kg		4mm 5/32″
5mm 3/16″	2000kg 4400lbs	1510kg	1420kg	1630kg		1380kg		1750kg*	500kg	400kg		600kg			5mm 3/16″
5.5mm 7/16″	2400kg 5280lbs														5.5mm 7/32″
6mm 1/4″	2880kg 6336lbs	2180kg	2040kg	2350kg		1990kg		2520kg*	750kg	565kg	550kg	950kg	575kg	650kg	6mm 1/4″
7mm 9/32″	3550kg 7810lbs	2970kg	2780kg	3200kg		2710kg		3430kg*	1020kg	770kg					7mm 9/32″
8mm 5/16″	4640kg 10208lbs	3870kg	3630kg	4200kg	4100kg	3890kg	3800kg	4130kg	1350kg	1020kg	960kg	1750kg	1060kg	1175kg	8mm 5/16″
9mm 11/32″	5870kg 12914lbs	4900kg	4511kg	5310kg	5190kg	4920kg	4810kg	5220kg	1700kg	1270kg					9mm 11/32″
9.5mm 3/8″															9.5mm 3/8″
10mm 13/32″	7250kg 15950lbs	6050kg	5670kg	6570kg	6420kg	6080kg	5940kg	6460kg	2080kg	1590kg	1425kg	2600kg	2080kg	1800kg	10mm 13/32″
11mm 7/16″	9450kg 20790lbs	7300kg		7950kg	7770kg	7360kg	7190kg	7820kg	2500kg	1910kg					11mm 7/16″
12mm 15/32″	10400kg 22880lbs	8710kg	8160kg	9450kg	9230kg	8750kg	8550kg	9300kg	3000kg	2270kg	2030kg	3500kg	2770kg	2575kg	12mm 15/32″
13mm 1/2″	13200kg 29040lbs	10200kg		11100kg	10800kg	10300kg	10000kg	10810kg	3500kg	2720kg					13mm 1/2″
14mm 9/16″	14200kg 31240lbs	11900kg	11100kg	12900kg	12500kg	11900kg	11600kg	12630kg	4100kg	3180kg	2790kg	5700kg	4000kg	3650kg	14mm 9/16″
16mm 5/8″	18600kg 40920lbs	15500kg		16800kg	16400kg	15600kg	15200kg	16520kg	5300kg	4100kg	3500kg		5900kg	4525kg	16mm 5/8″
18mm 11/16″				21300kg	20700kg	19700kg	19200kg	20950kg	6700kg	5100kg	4450kg		7030kg	5675kg	18mm 11/16″
19mm 3/4″	23200kg 51040lbs			23700kg	23100kg	21900kg	21400kg								19mm 3/4″
20mm 25/32″				26200kg	25700kg	24300kg	23800kg	25800kg	8300kg	6300kg	5370kg		8300kg	7925kg	20mm 25/32″
20.5mm 13/16″															20.5mm 13/16″
22mm 7/8″	30825kg 67815lbs			31800kg	31000kg	29400kg	28700kg	31200kg	10000kg	7600kg	6500kg				22mm 7/8″
24mm 15/16″				37800kg	36900kg	35000kg	34200kg	36150kg	12000kg	9100kg	7600kg		11900kg	10200kg	24mm 15/16″
26mm 1″	41684kg 91704lbs			44000kg	43300kg	41100kg	40100kg	43630kg	13400kg	10100kg	8600kg				26mm 1″
28mm 1 3/32″				51500kg	50300kg	47700kg	46600kg	50650kg	15300kg	12200kg	10100kg				28mm 1 3/32″
28.5mm 1 1/8″															28.5mm 1 1/8″
30mm 1 3/16″							51500kg								30mm 1 3/16″
32mm 1 1/4″				67200kg	65700kg	62200kg	60800kg	65890kg	20000kg	15700kg	12800kg				32mm 1 1/4″
35mm 1 3/8″				80500kg	78500kg	74500kg	72700kg								35mm 1 3/8″
36mm 1 13/32″				85100kg	83200kg	78800kg	77000kg	83700kg	24800kg	19300kg	16100kg				36mm 1 13/32″
38mm 1 1/2″				94800kg	92600kg	87800kg	85700kg								38mm 1 1/2″
40mm 1 9/16″				105000kg	103000kg	97300kg	95000kg	103350kg	30000kg	23900kg	19400kg				40mm 1 9/16″
41mm 1 5/8″															41mm 1 5/8″
44mm 1 3/4″				127000kg	124000kg	118000kg	115000kg				23400kg				44mm 1 3/4″
48mm 1 1/8″				151000kg	148000kg	140000kg	137000kg		42000kg	33500kg	27200kg				48mm 1 1/8″
51mm 2″															51mm 2″
52mm 2 1/16″				177000kg	174000kg	164000kg	161000kg				31500kg				52mm 2 1/16″
54mm 2 1/8″				191000kg	187000kg	177000kg	173000kg								54mm 2 1/8″
56mm 2 3/16″				206000kg	201000kg	191000kg	186000kg		56000kg	44700kg	36000kg				56mm 2 3/16″
60mm 2 3/8″				237000kg	231000kg	219000kg	214000kg				41200kg				60mm 2 3/8″
64mm 2 1/2″				269000kg	262000kg	249000kg	243000kg		72000kg	57900kg	46600kg				64mm 2 1/2″
72mm 2 27/32″									90000kg	72100kg	58500kg				72mm 2 27/32″
80mm 3 5/32″									110000kg	88400kg	72000kg				80mm 3 5/32″

The above table is a guide only-refer to the manufacturer for individual specification.

COURTESY OF SPENCER RIGGING

WORKING LOADS

SAFE WORKING LOADS ON BLOCKS AND FOOT BLOCKS

The safe working load is the maximum load at which a block or foot block should be operated. It is important to look at each block individually because if it is part of a system it might not relate directly to the actual load being pulled.

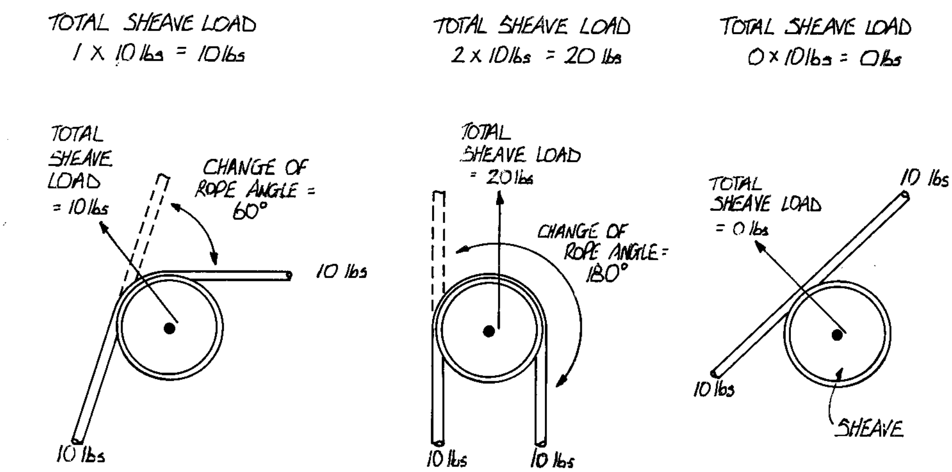
There is another factor involved in block loading. This is the change of angle the rope turns through – the angle between the line of entry and the lines departing direction after passing around the sheave.

Once the line starts to bend around the sheave, the total load on the sheave starts to increase until at 180 degrees the maximum sheave loading is reached, i.e. see from the chart below if a rope turns 180 degrees around the sheave and the rope has a tension of 10lbs (4.5kg) the total sheave load is increased by a factor of 2 = 2 × 10lbs (9kg) total sheave load.

The diagrams below show load deflection due to change in rope angles.

Change of Angle	Load Factor	Change of Angle	Load Factor	Change of Angle	Load Factor
180°	2.00	120°	1.73	50°	0.84
170°	1.99	110°	1.64	45°	0.76
160°	1.97	100°	1.53	40°	0.68
150°	1.93	90°	1.41	30°	0.52
140°	1.87	80°	1.29	20°	0.35
135°	1.84	70°	1.15	10°	0.17
130°	1.81	60°	1.00	0°	0.00

DEFLECTION LOADS



BLOCK LOADINGS

All the various sail control systems on board a boat have a common problem, they are powered by human muscles (with the exception of the latest electric or hydraulic push button winches).

For example a small boat of 20ft (6.0m) jib could be easily trimmed, whereas a 70ft (21m) cruising yacht may require 5,000lbs (2250kg) of trimming force in a blow, but regardless of boat size the trimming engine is the same: a human being.

Today small crews often operate large yachts therefore efficient use of manpower for sail trimming is imperative.

The average forces a man can exert are as follows:–

i) Pull directly downwards from above a force directly equivalent to his bodyweight.

ii) Pull horizontally standing up with feet braced, approx. 75lbs (34kg) with both hands and 50lbs (23kg) with one hand.

iii) If pulling control lines such as the mainsheet traveller he can comfortably handle loads of 25 to 35lbs (11 to 16kg).

And so, since human force is limited to a small pulling power, and the loadings sails create can be enormous, a mechanical advantage must be applied through Block Systems and Winches, to allow a sailor to correctly control sail trim.

PURCHASE RATIOS

PURCHASE SYSTEMS

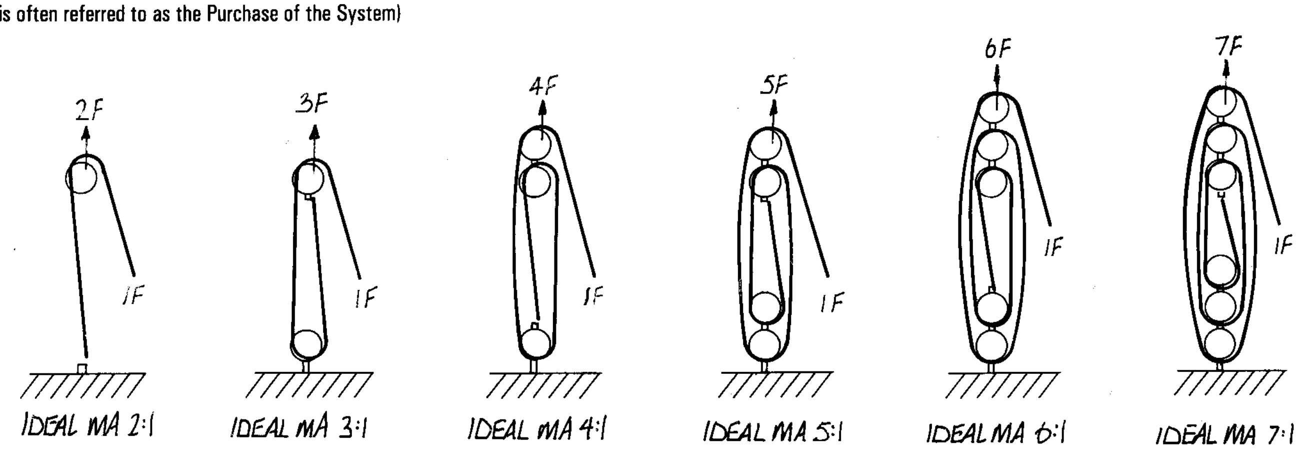
Mechanical advantage can be achieved by using a purchase systems as seen in diagrams below –

$$\text{Mechanical advantage (MA)} = \frac{\text{Load}}{\text{Effort.}}$$

$$\text{The velocity ratio of the system (VR)} = \frac{\text{Distance moved by effort}}{\text{Distance moved by load}}$$

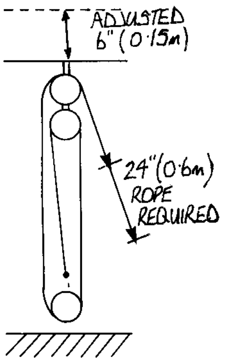
(this is often referred to as the Purchase of the System)

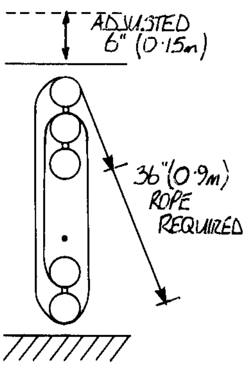
The mechanical advantage of the system is always slightly less than the velocity ratio or purchase due to friction losses. In an ideal system (100% efficiency) the mechanical advantage = velocity ratio.



RELATIVE MOVEMENT

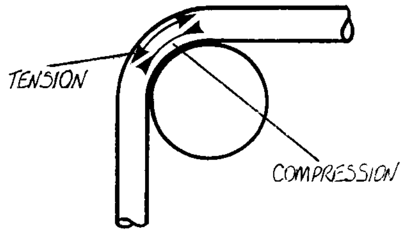
If a downhaul with a 4:1 purchase system has to be adjusted 6 inches (0.15m), then the input line must be moved 4 × 6 inches (0.15m) = 24 inches (0.6m). Or if a downhaul with a 6:1 purchase system has to adjusted 6 inches (0.15m), then the input line must be moved 6 × 6 inches (0.15m) = 36inches(0.9m). This situation is particularly relevant to mainsheet systems which require long lengths of rope to let the boom right out down wind, the larger the purchase system employed the greater amount of rope is required, this makes the system slow to operate and when sailing up wind leaves a great mass of rope in the cockpit.



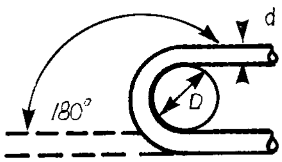


'IDEAL' BLOCK DIAMETER

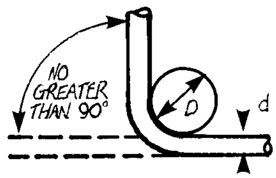
The smaller the sheave the greater will be the internal loads in the sheet (compression closest to the sheave, tension on outer radius) hence causing faster fatigue and reduced life of the sheet.
The relationship between the rope diameter and sheave diameter is dependent on the angle over which the rope is bent.



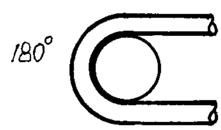
Polyester and Nylon rope
Recommended sheave diameter D = 5 × d where D = overall sheave diameter d = rope diameter.



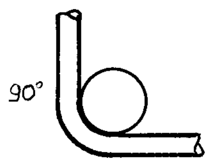
Recommended sheave diameter D = 3¾ × d



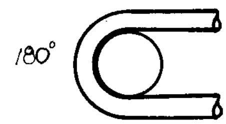
Kevlar rope
Recommended sheave diameter D = 12 × d



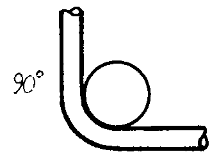
Recommended sheave diameter D = 9 × d



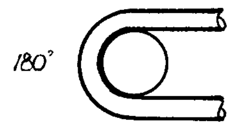
Wire rope 1 × 19
Recommended sheave diameter D = 50 × d



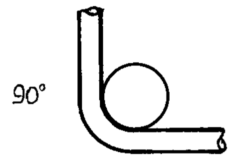
Recommended sheave diameter D = 37½ × d



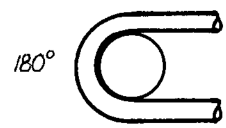
Wire rope 7 × 7
Recommended sheave diameter D = 26 × d



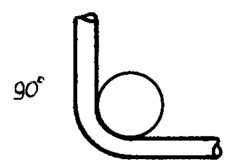
Recommended sheave diameter D = 19½ × d



Wire rope 7 × 19
Recommended sheave diameter D = 16 × d



Recommended sheave diameter D = 12 × d



Note: If there are restrictions on the size of sheaves i.e. in a mast etc. an alternative way may be to fit 2 or 3 small sheaves in tandem.

In the case of Kevlar and Wire rope using these ideal diameters may produce over large/heavy blocks for the job. Hence a compromise is often taken thus reducing the life of the rope slightly.

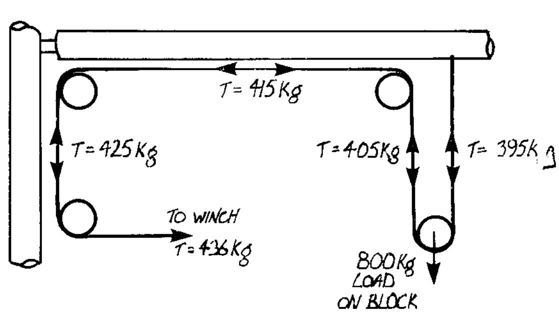
ALIGNMENT OF BLOCKS

Special care must always be taken that the block is allowed to lie in the same plane as the sheet otherwise wear/chaff will occur or even an overloading of the block due to the imposed torque.

FRICTION

Mainsheet System showing losses due to friction
(assuming an allowance per block of 2.5%, using roller bearings)

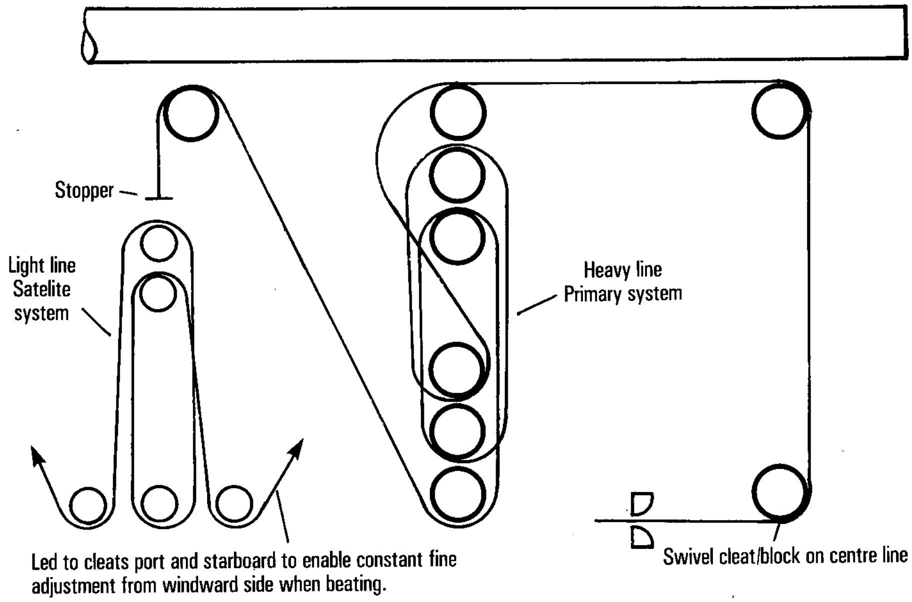
Whilst pulling the mainsheet in friction requires more input and increases the load on the input blocks. Once the pulling is over and the mainsheet is secured the friction will contribute to the holding power hence reduce the loading in the mainsheet. It is this principle that is utilized for ratchet blocks.



COARSE AND FINE TUNE PURCHASE MAINSHEET SYSTEMS

These systems are only usually used on racing boat mainsheet systems. The system comprises of: –
'Primary' mainsheet tackle. This is used for hauling in the mainsail, especially after a gybe when mark rounding. This coarse purchase system say 5:1 can cater for such large adjustments.

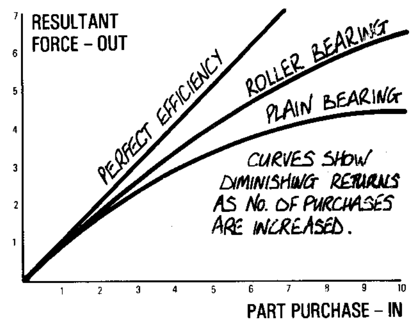
The 'Satelite' mainsheet tackle. This system is used for the constant final adjustment of the mainsail when sailing to windward, especially in gusty conditions. This fine tune system has a higher purchase say 20:1



CHOICE OF BEARING

For lines requiring rapid adjustment whilst under high load i.e. mainsheet, headsail halyards, traveller systems, use should be made of roller or ball bearings in order to keep friction losses to a minimum. Applications where plain bearings are adequate include spinnaker pole uphauls/downhauls, main halyards.

See graph below comparing efficiency of roller bearings and plain bearings.

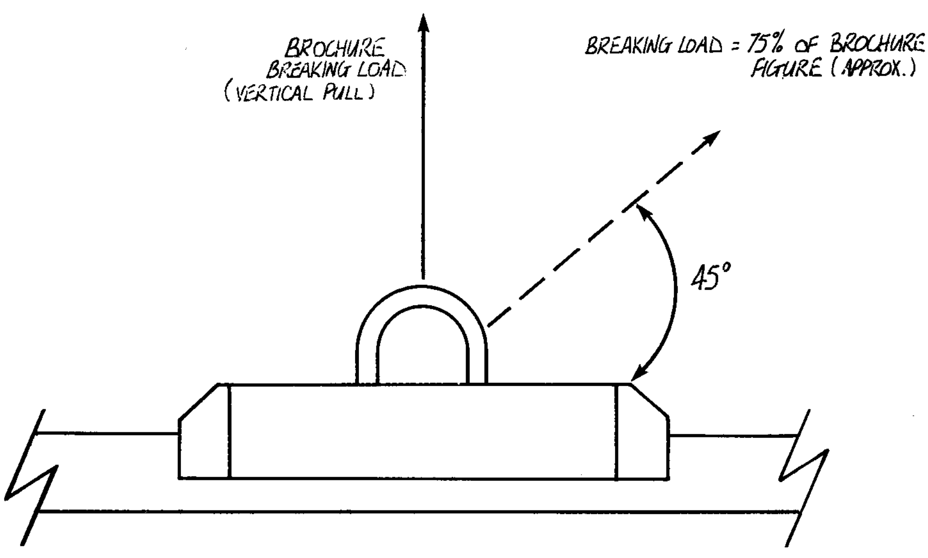


OFFSET LOADS ON MAINSHEET CARS

Typical reduction in breaking load, hence safe working load for car with shackle type attachment.

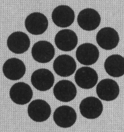
This applies to all Lewmar – Frederiksen mainsheet cars with Shackle/eye attachments.

If you are in any doubt as to the suitability of selection contact your Lewmar subsidiary.

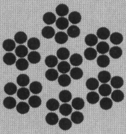


TYPES OF WIRE USED

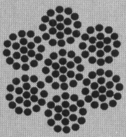
1×19
Very strong, little stretch. Difficult to splice. Used for shrouds, forestay and other high load standing rigging.



7×7
Not as strong as 1×19 but more flexible. Used for standing rigging where some degree of flexibility is required. Easy to work, splice etc.



7×19
The best choice for running rigging that will be subjected to severe bending such as halyards.



Rod rigging
Used for standing rigging on racing yachts. Lowest stretch and highest strength to diameter ratio but expensive