ALTRA MOTION

Universal Joints









Huco®
Altra Industrial Motion

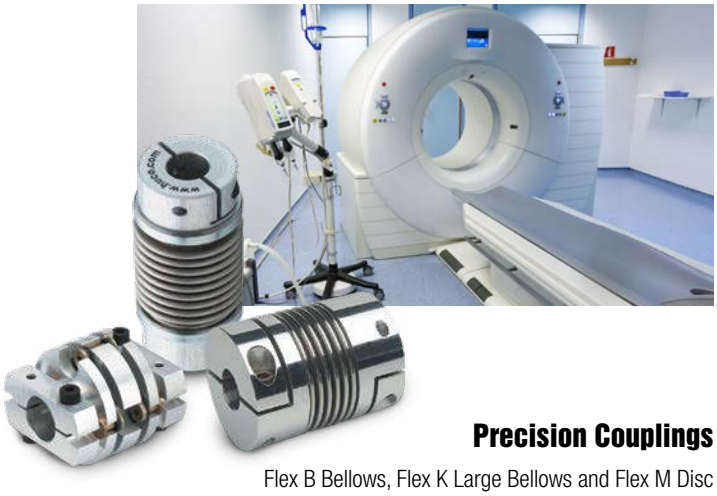
Huco offers a wide variety of couplings for precision industrial and commercial applications worldwide.

Selecting the right shaft coupling can be the difference between a drive system that provides the required dynamic response and one that is catastrophic. The application constraints lead engineers towards products that have different levels of torsional stiffness, vibration dampening, backlash, and low bearing loads. Huco can respond quickly with a wide variety of couplings such as general purpose, beam style, and precision couplings suitable for highly reliable applications.



Beam Couplings

Step Beam, Single Beam, Three Beam, and Six Beam couplings are available for use in stepper and servo drives, encoders, tachometers, small pumps, motors and drives and light-duty power transmission applications.



Precision Couplings

Flex B Bellows, Flex K Large Bellows and Flex M Disc type couplings are ideal for use in high-end servo drives, pulse generators, scanners, X-Y positioning slides, high speed dynamometers, measuring instruments, robots, and machine tools.



General Purpose Couplings

Oldham couplings are designed for use in stepper drives and most applications including positioning slides, pumps, actuators, etc. Uni-Lat models are ideal for encoder, resolver, tachometers, potentiometer drives, as well as small positioning slides, dosing pumps, and general light drives. Flex P units can be utilized in light power drives, pumps and small generators.



Friction Clutches

Vari-Tork™ friction clutches allow slippage when the torque being transmitted reaches a pre-determined threshold. Used in all types of small drives to help protect personnel and equipment.

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Universal Joints

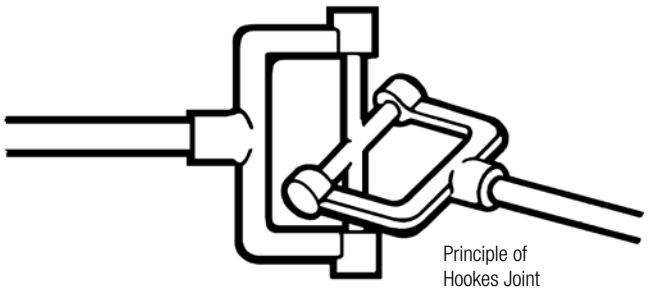
Basic Principles

Universal joints (U/J's) transmit rotation from one shaft placed end to end with another. They will operate at a much larger angle than is permissible with a misalignment coupler and are commonly used in pairs to take a drive train through laterally displaced axes. The ability to change angle while operating under load gives U/J's a further advantage and in these applications, a telescopic drive shaft is used to accommodate accompanying changes in length.



General purpose
telescopic drive shaft

Although constructional details can differ widely between one maker's product and the next, U/J's fall into two groups identified as constant velocity or non-constant velocity joints. Constant velocity types are most often seen on front wheel drive vehicles. They are relatively costly to produce and are generally purpose designed for the application. The joints featured in this catalogue work on the Hookes or Cardan principle and are of the non-constant velocity type.



Principle of
Hookes Joint

What this means is that for a given operating angle the output velocity fluctuates even though the input velocity is constant. These fluctuations result in the output gaining, then lagging with respect to the input, twice in each revolution to an extent governed by the operating angle. The fluctuation is predictable and varies between

$$\omega \cos \alpha$$

and $\omega \sec \alpha$

where ω = angular velocity (speed rev/min)

and α = operating angle

Thus at an operating angle of 5°, the fluctuation is ±0.4%, at 7° ±0.8% and at 10° ±1.5%. For example, a motor shaft turning at a constant 1000 rpm, driving through a single universal joint set at an operating angle of 5°, will produce an output that fluctuates between 996 and 1004 rpm twice every revolution. At low speed or on manual operation, the fluctuations will be of interest only in calibrated applications; at higher speeds, they will increasingly give rise to torsional vibration.

Constant velocity output can be restored by using a double joint or by connecting two single joints back to back. Two rules must be observed:

1. The operating angle must be the same at the input end as at the output end (Figs. 1 & 2).

2. When connecting two single joints, they must be orientated so that the inboard lugs are in line (Fig. 3).

Under these conditions the fluctuations in the first joint will for all practical purposes be cancelled out by the complementary fluctuations in the second.

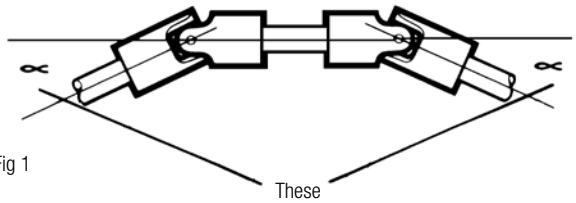


Fig 1

These
angles must
be equal

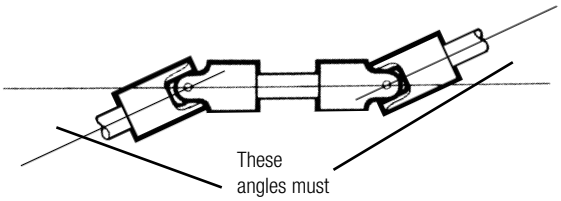


Fig 2

These
angles must
be equal

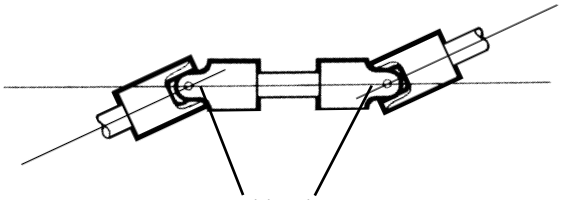
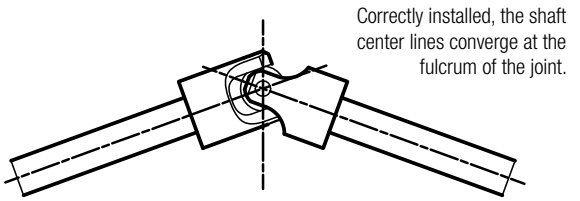


Fig 3

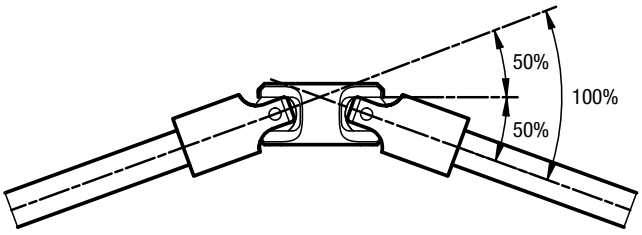
Inboard
lugs in line

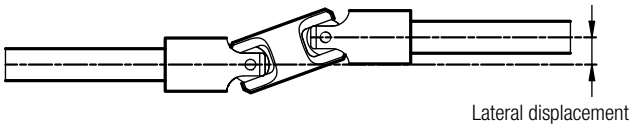
Application

Universal joints are typically used to transmit positive rotation through intentional offsets where the power source is some way from the load. It is important to note that a U/J is essentially a pivot and that it cannot accommodate any parallel displacement between shafts if used singly. Moreover, the installation must allow for some adjustment when mounting the joint so that the shaft centre lines can be made to converge at the fulcrum of the joint. This is essential if the joint is to function correctly and not impose excessive radial loads on adjacent bearings.



Most applications however, demand a pair of U/J's. This yields several advantages including constant velocity output, a less critical installation procedure, a shared operating angle (each joint works at 50% of the total), and the ability to drive through laterally displaced shafts. A pair of joints can comprise a drive shaft with a U/J at each end or a double U/J for close coupled applications. A double U/J offers greater misalignment compensation than a misalignment coupler and runs at higher efficiency. For a given torque rating however, it is usually significantly longer.





Selection

U/J's are selected for size on the basis of the torque to be transmitted, the speed of rotation and the operating angle. These variables give rise to a performance chart on which the values can be read off and a suitable joint selected. Factors relating to the nature of the power source or load are sometimes applied. A single cylinder internal combustion engine for example is more punishing to the transmission than an electric motor. An even load is less onerous than an intermittent one.

In principle, a U/J works harder as the operating angle increases. The larger the operating angle, the lower the torque or the speed at which it can be transmitted, or both.

In selecting the best type of universal joint for a given application, the intended duty and life requirement are the determining factors. High speeds and/or operating angles are best handled by U/J's fitted with roller bearings. These are lubricated for life but it is nevertheless a good plan to protect the moving surfaces with a gaiter which prevents the ingress of dust, moisture and other foreign matter. Roller bearing joints are generally specified where sustained rotational speeds exceed 1200/1500 rpm.



The most commonly specified joints are those fitted with plain bearings. These are better at withstanding shock loads and are adequate for speeds up to 1200/1500 rpm. Journals and bearings are usually heat treated then ground and honed respectively. On larger U/J's, the bearing may be manufactured separately and pressed into the parent.

Features

Huco universal joints feature a comprehensive range of sizes manufactured in good quality steels. Plain bearing and needle roller types are available and either can be supplied with square, hexagonal or keywayed bores to order. The joints are also manufactured with quick release collars and in telescopic form to order.

Steel Universal Joints

Types TL & TS, Plain Bearings - 1200 rpm Max



These joints feature hardened journals of generous proportions. In joint sizes 13 – 60 (external diameter in mm) they are retained in the forks and pivot in holes provided in the central core. A large bearing surface is thus achieved which helps to reduce wear and tear and prolongs the operational life of the joint.

By virtue of the increased wall thickness available in the larger joints, pins fitted to sizes 70 – 100 are retained in the central core and pivot in treated bushes housed in the fork ends.

Type TR, Needle Roller Bearings - 6000 rpm Max



This series is intended for applications demanding high rotational speeds (up to 6000 rpm) and large working angles where operation is without benefit of periodic lubrication.

They are constructed with hardened and ground journals pivoting between caged needle roller bearings housed in the fork ends. Four bronze thrust rings interface between the central core and the inner surfaces of the forks. These help to achieve greater load capacities by minimising friction generated by side loads.

Although the joints are pre-lubricated, rubber gaiters are recommended as a protective measure in abrasive or damp environments and to prevent ingress of foreign matter. Note that good heat dissipation becomes important under conditions of high working angles and high rotational speeds.

Type TR joints are suitable for all high speed applications or where periodic lubrication is difficult, typically machine tools, textile machines, multi-spindle drilling and tapping machines, packaging machines, special purpose machines and mechanical applications generally.

Styles & Sizes

U/J's are produced in 17 sizes, identified by their outside diameter in mm. All sizes are available in single and double form.

Style	Outline	Sizes
Extended unbored series with plain bearings		13 to 60 with 10 intermediate sizes
Standard bored series with plain bearings		13 to 100 with 15 intermediate sizes
Standard bored series with needle roller bearings		20 to 50 with 3 intermediate sizes

Any of these can be manufactured as a telescopic drive shaft. The range of practical bore diameters corresponding with universal joints is 5.00-60.00mm.

Lubrication

Regular lubrication at intervals consistent with the duty cycle is essential in the interests of extending the life of the joint.

The joints should be adequately lubricated and the use of rubber gaiters loaded with grease is recommended. They protect against dust, damp and foreign matter and by ensuring permanent lubrication of the sliding surfaces, maintain optimum efficiency over a longer service life.

The gaiters are moulded in a special mix of synthetic rubber which permits their use in temperatures from –20°C to 100°C. They are resistant to oils, greases, many chemical agents, sea water and tropical climates.

The joints are suitable for use in machine tools, textile machines, agricultural equipment, multi-spindle drilling and tapping machines and mechanical engineering applications generally where the maximum speed of rotation does not exceed 1200 rpm.

Also Available to Special Order

The range also includes:

- Joints with quick-release collars
- Ball Joints

Any of these executions can be supplied as telescopic drive shafts. Please contact Technical Sales for further information.

Steel Universal Joints T-Series

Standard Bored Joints with Plain Bearings

A comprehensive range of good quality steel universals available in a range of standard sizes from stock. Alternative bores, round, keywayed or square, etc. can be produced to order. Also available in stainless steel. Please call Technical Sales for assistance with non-standard requirements.

Maximum working angle is 40° for single and 80° for double joint sizes 13 – 45. This reduces to 30° and 60° respectively for size 50 and upwards.

Maximum speed 1200 rpm, see performance charts on page 11.

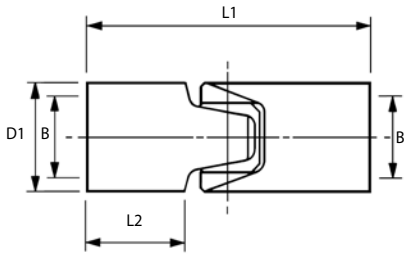
These plain bearing universal joints must be lubricated.
The use of gaiters is recommended.



Material

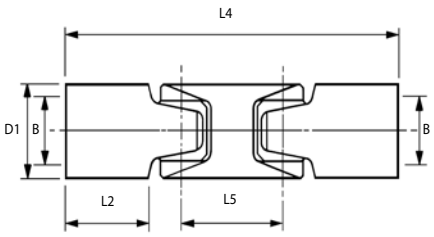
Forks: 36SMnPb14
Pins: 17NiCrMoS6-4
Balls: Size 13 to 35: 100 Cr6
Size 40 to 99: 17NiCrMoS6-4
Gaiters: Nitrile Rubber

Type TS Single Joint



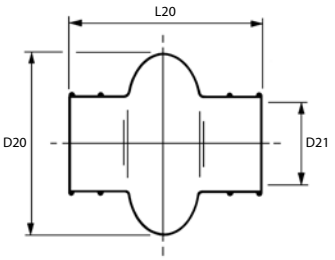
Order Code	H7 Bores B	D1	L1	L2	Static Torque at Break (Nm)
134.13.2222	6x6	13	34	11	65
134.17.2828	8x8	17	40	12	120
134.20.3232	10x10	20	45	13	150
134.23.3535	12x12	23	50	14	210
134.26.3838	14x14	26	56	16	290
134.29.4242	16x16	29	65	18	480
134.32.4545	18x18	32	72	20	850
134.35.4848	20x20	35	82	24	1000
134.40.4949	22x22	40	95	28	1350
134.45.5252	25x25	45	108	35	1750
134.50.5656	30x30	50	122	40	2500
134.55.6060	35x35	55	140	45	4000
134.60.6363	40x40	60	160	50	5000
134.70.0000	unbored	70	75	50	8000
134.80.0000	unbored	80	190	55	11500
134.90.0000	unbored	90	210	65	13500
134.99.0000	unbored	100	230	70	16000

Type TS Double Joint



Order Code	H7 Bores B	D1	L2	L4	L5	Static Torque at Break (Nm)
136.13.2222	6x6	13	11	57	23	65
136.17.2828	8x8	17	12	67	27	120
136.20.3232	10x10	20	13	75	30	150
136.23.3535	12x12	23	14	84	34	210
136.26.3838	14x14	26	16	92	36	290
136.29.4242	16x16	29	18	106	41	480
136.32.4545	18x18	32	20	119	47	850
136.35.4848	20x20	35	24	132	50	1000
136.40.4949	22x22	40	28	151	56	1350
136.45.5252	25x25	45	35	176	68	1750
136.50.5656	30x30	50	40	194	72	2500
136.55.6060	35x35	55	45	219	79	4000
136.60.6363	40x40	60	50	248	88	5000
136.70.0000	unbored	70	50	264	89	8000
136.80.0000	unbored	80	55	286	96	11500
136.90.0000	unbored	90	65	310	100	13500
136.99.0000	unbored	100	70	360	130	16000

Type T Gaiter



Order Code	D20	D21	L20
-	-	-	-
143.17	32	16.5	40
143.20	39	20.5	47
143.20	39	20.5	47
143.26	47	24.5	52
143.29	51	27.5	58
143.32	56	30.5	67
143.35	66	35.5	74
143.40	75	40.0	84
143.45	83	45.0	97
143.50	93	50.0	110
143.50	93	50.0	110
143.60	100	56.0	122
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-

Extended Unbored Joints with Plain Bearings

A series of good commercial quality joints manufactured to longer dimensions. They are stocked with solid ends for boring by the user.

Maximum working angle is 40° for single and 80° for double joint sizes 13 – 45. This reduces to 30° and 60° respectively for size 50 and upwards.

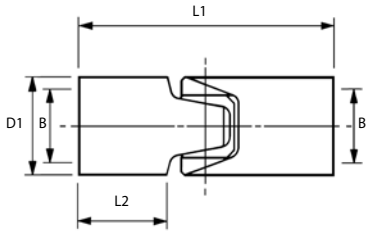
Maximum speed 1200 rpm, see performance charts on page 11. These plain bearing universal joints must be lubricated. The use of gaiters is recommended.



Material

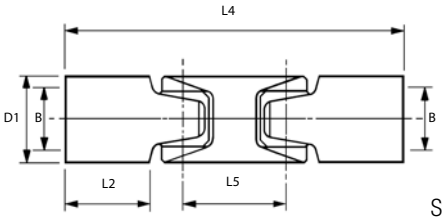
Forks: 36SMnPb14
Pins: 17NiCrMoS6-4
Balls: Size 13 to 35: 100 Cr6
Size 40 to 99: 17NiCrMoS6-4
Gaiters: Nitrile Rubber

Type TL Single Joint



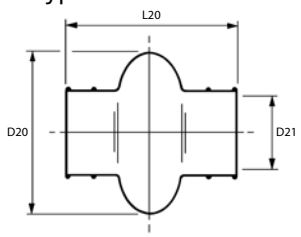
Order Code	B Bores	D1	L1	L2	Static Torque at Break (Nm)
135.13.0000	SOLID	13	50	19	65
135.17.0000	SOLID	17	58	21	120
135.20.0000	SOLID	20	64	22	150
135.23.0000	SOLID	23	76	27	210
135.26.0000	SOLID	26	86	31	290
135.29.0000	SOLID	29	90	30	480
135.32.0000	SOLID	32	95	31	850
135.40.0000	SOLID	40	108	34	1350
135.45.0000	SOLID	45	127	44	1750
135.50.0000	SOLID	50	140	49	2500
135.55.0000	SOLID	55	165	57	4000
135.60.0000	SOLID	60	178	59	5000

Type TL Double Joint



Order Code	B Bores	D1	L2	L4	L5	Static Torque at Break (Nm)
137.13.0000	SOLID	13	19	73	23	65
137.17.0000	SOLID	17	21	85	27	120
137.20.0000	SOLID	20	22	94	30	150
137.23.0000	SOLID	23	27	110	34	210
137.26.0000	SOLID	26	31	122	36	290
137.29.0000	SOLID	29	30	131	41	480
137.32.0000	SOLID	32	31	142	47	850
137.40.0000	SOLID	40	34	164	56	1350
137.45.0000	SOLID	45	44	195	68	1750
137.50.0000	SOLID	50	49	212	72	2500
137.55.0000	SOLID	55	57	244	79	4000
137.60.0000	SOLID	60	59	266	88	5000

Type T Gaiter



Order Code	D20	D21	L20
-	-	-	-
143.17	32	16.5	40
143.20	39	20.5	47
143.20	39	20.5	47
143.26	47	24.5	52
143.29	51	27.5	58
143.32	56	30.5	67
143.40	75	40.0	84
143.45	83	45.0	97
143.50	93	50.0	110
143.50	93	50.0	110
143.60	100	56.0	122

Type TS Single Joint - Stainless Steel

Order Code	B Bores	D1	L1	L2
158.13.0000	SOLID	13	34	11
158.17.0000	SOLID	17	40	12
158.20.0000	SOLID	20	45	13
158.23.0000	SOLID	23	50	14
158.26.0000	SOLID	26	56	16
158.29.0000	SOLID	29	65	18
158.32.0000	SOLID	32	72	20
158.35.0000	SOLID	35	82	24
158.40.0000	SOLID	40	95	28
158.45.0000	SOLID	45	108	35
158.50.0000	SOLID	50	122	40
158.55.0000	SOLID	55	140	45
158.60.000	SOLID	60	160	50

Material

Forks: AISI 303
Pins: AISI 420
Balls: Size 13 to 35: AISI 420
Size 40 to 60: AISI 303

Performance values quoted on page 11 do not apply to stainless steel versions. Please contact Huco for application assistance.

Steel Universal Joints T-Series

Standard Bored Joints with Needle Roller Bearings

A series of good commercial quality universals with needle roller bearings. The round bores listed are stock sizes, other diameters or solid ends can be supplied to order. Please call Technical Sales for alternative sizes including keywayed and square bores.

Maximum working angle is 40° for single and 80° for double joints.

Maximum speed 6000 rpm, see performance charts on page 12.

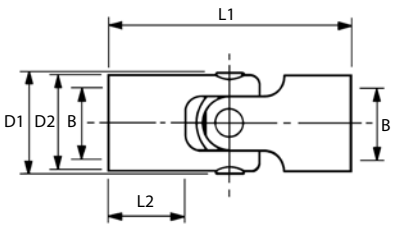
Bores listed under 'bores & order codes' are stock items. Other bores are supplied to order.



Material

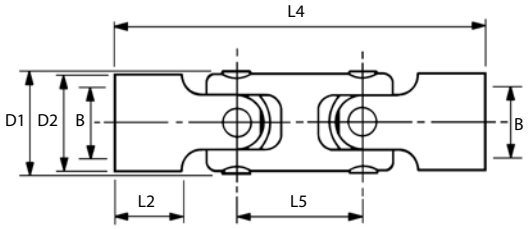
Forks: 36SMnPb14
Pins: 17NiCrMoS6-4
Balls: Size 13 to 35: 100 Cr6
Size 40 to 99: 17NiCrMoS6-4
Gaiters: Nitrile Rubber

Type TR Single Joint



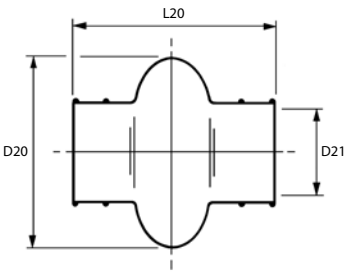
Order Code	H7 Bores B	D1	L1	L2	Static Torque at Break (Nm)
138.20.3232	10x10	21.5	62	19	40
138.26.3838	14x14	27.9	74	23	130
138.32.4242	16x16	35.6	86	25	300
138.40.4848	20x20	42.7	108	33	500
138.50.5252	25x25	53.0	132	38	1200

Type TR Double Joint



Order Code	H7 Bores B	D1	D2	L2	L4	L5	Static Torque at Break (Nm)
139.20.3232	10x10	21.5	20	19	92	30	40
139.26.3838	14x14	27.9	26	23	110	36	130
139.32.4242	16x16	35.6	32	25	133	47	300
139.40.4848	20x20	42.7	40	33	164	56	500
139.50.5252	25x25	53.0	50	38	204	72	1200

Type T Gaiter



Order Code	D20	D21	L20
143.20	39	20.5	47
143.26	47	24.5	52
143.32	56	30.5	67
143.40	75	40.0	84
143.50	93	50.0	110

Unbored Joints

Type TS and TR joints are available without bores. Order codes for unbored versions are as indicated with the last four digits replaced by zeros.
(e.g.138.20.0000)

Types TL & TS, Plain Bearings- 1200 rpm Max
- 200 rpm for Sizes 60-100

(Please note that the nomograms do not apply to joints assembled as telescopic drive shafts)

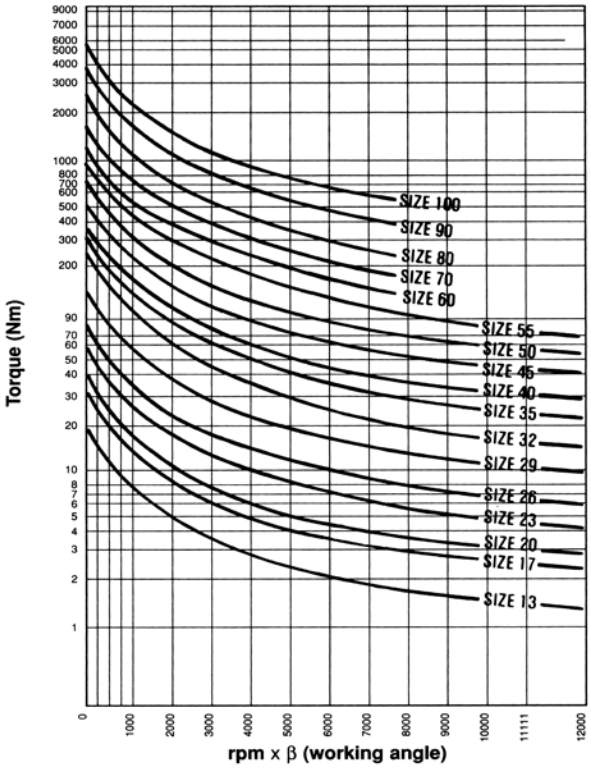


Table	A			B		
rpm x β	250 or less			more than 250		
Operating conditions						
hrs per day	< 3	8	> 8	< 3	8	> 8
Uniform Load SF	2.5	3.0	3.5	3.0	3.6	4.0
Intermittent Load SF	3.0	3.5	4.0	3.6	4.0	5.0
Severe Intermittent Load SF	3.5	4.0	4.5	4.0	5.0	6.0

Using the Nomogram

The nomogram charts the maximum dynamic moment for each size of joint. The curves represent the limit of performance and must not be exceeded, however momentarily, by peak impulse loads.

The product of speed of rotation x working angle is given for values from 250–12000. The upper speed limit for this series is 1200 rpm and this corresponds to a maximum working angle of 10° at this speed.

Working angles up to 45° are practicable provided the corresponding speeds are held within the limits of the nomogram. A double joint working at 90° is considered the equivalent of two singles working at 45°.

Selection

1. Determine the driving torque of the application in Newton meters (Nm) and the speed of rotation in revolutions per minute (rpm). If converting from other units:

   1 lbf ft = 1.36 Nm
   1 kpm = 9.81 Nm

   The relationship between driving torque, speed of rotation and power transmitted is expressed by the formula:

   $$\text{torque (Nm)} = \frac{7120 \times \text{HP}}{\text{rpm}} \quad \text{or} \quad \frac{9550 \times \text{kW}}{\text{rpm}}$$

2. Find the product of rpm × working angle (β) and select the appropriate service factor (SF) from table A or B after identifying the nature of the loading on the transmission.

   'Uniform' loads – typically electric motors driving fans, centrifugal pumps or conveyors under constant load conditions.

   'Intermittent' loads – presses, shears, radial displacement pumps or compressors, all driven by electric motors.

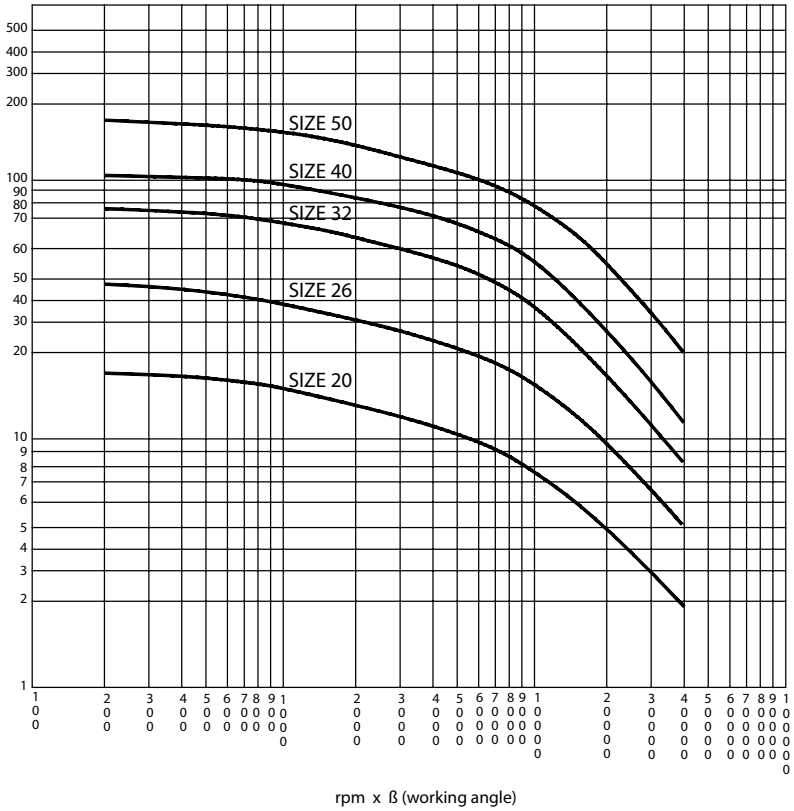
   'Severe Intermittent' loads – typically rolling mills or crushers or 'intermittent' type loads driven by I.C. motors with less than 4 cylinders.

3. If table A is relevant, multiply Nm × SF and select a joint with a static torque figure in excess of this value.

   If table B is relevant, apply the products of Nm × SF and rpm × β to the nomogram and select the joint with the performance curve immediately above the point of intersection.

Performance Data T-Series

Types TR, Needle Roller Bearings- 6000 rpm Max
- 3000 rpm for Sizes 40 and 50



Using the Nomogram

The nomogram charts the maximum dynamic moment for each size of joint. The curves represent the limit of performance and must not be exceeded, however momentarily, by peak impulse loads.

The product of speed of rotation ×working angle is given for values from 200–40000. The upper speed limit for this series is 6000 rpm and this corresponds to a maximum working angle of 6° 30' at this speed.

Working angles up to 45° are practicable provided the corresponding speeds are held within the limits of the nomogram. A double joint working at 90° is considered the equivalent of two singles working at 45°.

Selection

1. Determine the driving torque of the application in Newton metres (Nm) and the speed of rotation in revolutions per minute (rpm)

2. Find the product of rpm × working angle (β) and check that the result is within the limits of the nomogram.

3. Apply the values obtained in 1) and 2) to the nomogram and select the joint with the performance curve immediately above the point of intersection. Normal safety factors are built into the nomogram which is based on tests conducted with joints operating under arduous conditions.

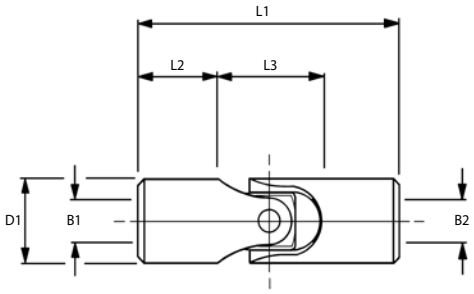
Miniature Standard Bored Joints with Plain Bearings



The A range of good quality miniature universal joints suitable for motorised applications up to 500 rpm.

Also available in stainless steel to special order.

Type SM/M



Type SM

Sub-Miniature Steel Universal Joints | Material Steel S45C

Order Code	Bores B1x B2	D1	L1	L2	L3	Weight G	Max Torque Nm	Max Angle	Max Speed rpm
178.03.V203	1.5 x 1.5	3.0	12.0	4.0	4.0	0.6	0.05	30º	500
178.04.V204	2.0 x 2.0	4.0	14.0	4.5	5.0	1.0	0.13	30º	500
178.05.V205	2.5 x 2.5	5.0	15.0	4.5	6.0	1.7	0.20	30º	500

Type M

Miniature Standard Bored Joints with Plain Bearings | Material Steel S45C

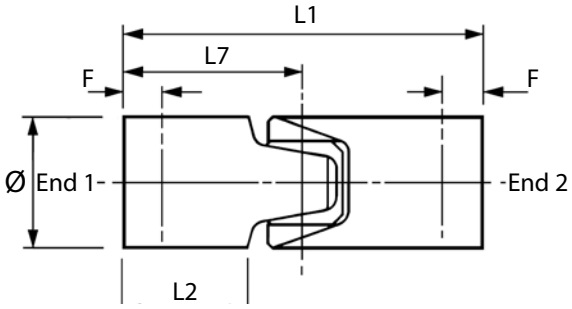
Order Code	Bores B1x B2	D1	L1	L2	L3	Weight G	Max Torque Nm	Max Angle	Max Speed rpm
177.06.1414	3.00 x 3.00	6.0	18.0	5.5	7.0	3.0	0.39	30º	500
177.08.1818	4.00 x 4.00	8.0	24.0	7.2	9.6	7.1	1.07	30º	500
177.10.2020	5.00 x 5.00	10.0	30.0	9.0	12.0	12.5	2.35	30º	500

Special Joints & Telescopes

The universal joints featured in this catalogue can be specified with non-stock bores and to special dimensions. Any of the listed joint sizes can be built as telescopic drive shafts. *See next page.*

Please enter all relevant details on a photocopy of this page and attach your company letterhead with your name, title and extension number for a quotation. Please use a separate photocopy for each component.

Please Quote _____ pcs single joint TYPE _____ SIZE Ø _____ *Needle Roller / Plain Bearing



☑ for standard. Specify dimensions only if absolutely necessary.

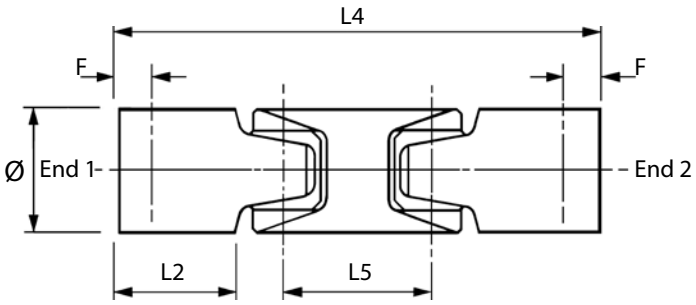
Overall Length L1 _____ ☐

Half Length L7 _____ ☐

Where specified, keyways will be spaced at 90º.

*Delete where appropriate

Please Quote _____ pcs single joint TYPE _____ SIZE Ø _____ *Needle Roller / Plain



☑ for standard. Specify dimensions only if absolutely necessary.

Overall Length L4 _____ ☐

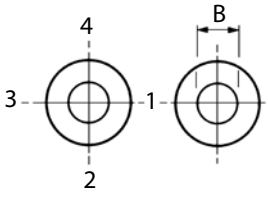
Half Length L5 _____ ☐

Where specified, keyways will be spaced in line unless requested, otherwise at 180º.

*Delete where appropriate

Bore Details End 1





Cross hole positions

Plain Bore	B	_____	dia
Keywayed Bore	K	_____	dia
Key Width	W	_____ ☐	(standard is to BS 4235 Part 1)
Square Bore	S	_____	A/F
Hex Bore	H	_____	A/F
Bore Depth	L2	_____ ☐	

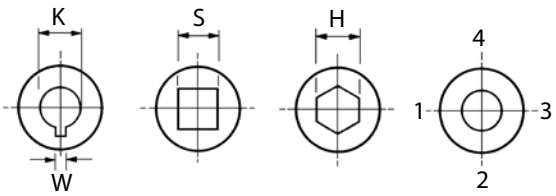
Tapped Hole at Posn _____ & posn _____ Tapped _____

Cross Hole at Posn _____ & posn _____ dia _____

Cross Hole datum F _____

Bore Details End 2





Cross hole positions

Plain Bore	B	_____	dia
Keywayed Bore	K	_____	dia
Key Width	W	_____ ☐	(standard is to BS 4235 Part 1)
Square Bore	S	_____	A/F
Hex Bore	H	_____	A/F
Bore Depth	L2	_____ ☐	

Tapped Hole at Posn _____ & posn _____ Tapped _____

Cross Hole at Posn _____ & posn _____ dia _____

Cross Hole datum F _____

Entire dimension required or ☑ if standard

The universal joints featured in this catalogue can be specified with non-stock bores and to special dimensions and be built as telescopic drive shafts.

Please enter all relevant details on a photocopy of this page and attach your company letterhead with your name, title and extension number for a quotation. Please use a separate photocopy for each component.

Please Quote _____ pcs telescope based on joint

TYPE _____ SIZE Ø _____

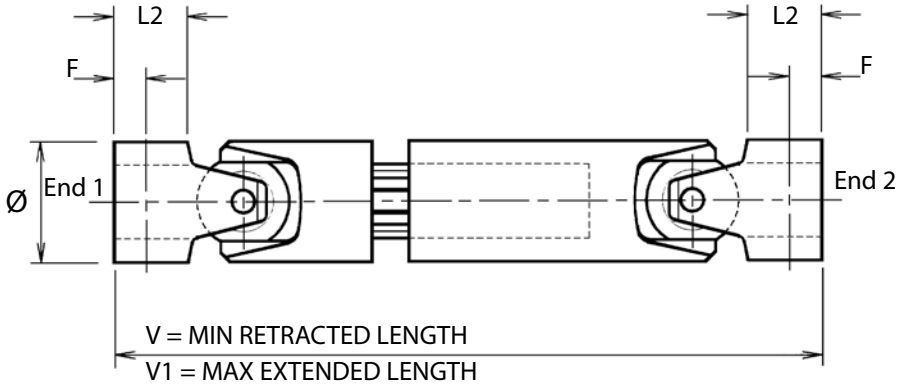
*Needle Roller Joint / Plain

MIN Retracted Length V _____ ☐

MAX Extended Length V1 _____ ☐

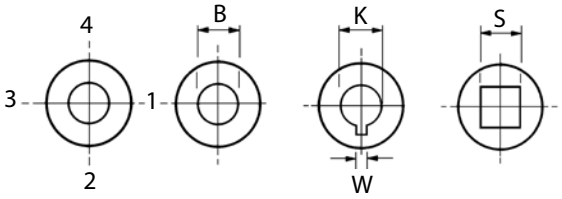
*Delete where appropriate

Where specified, keyways will be spaced in line unless requested, otherwise at 180º



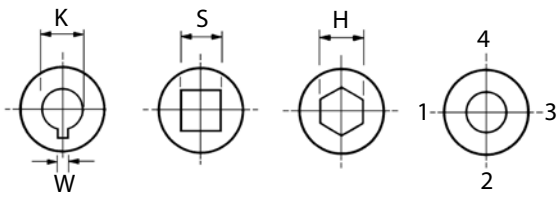
Splines/Spline Shaft Material Ref.
Steel: C40
Stainless Steel AISI 304 or 316 (depending on length)

Bore Details End 1



Cross hole positions

Bore Details End 2



Entire dimension required or ☑ if standard

Plain Bore	B _____	dia	
Keywayed Bore	K _____	dia	
Key Width	W _____	☐	(standard is to BS 4235 Part 1)
Square Bore	S _____	A/F	
Hex Bore	H _____	A/F	
Bore Depth	L2 _____	☐	

Tapped Hole at Posn _____ & posn _____ Tapped _____
Cross Hole at Posn _____ & posn _____ dia _____
Cross Hole datum F _____

Plain Bore	B _____	dia	
Keywayed Bore	K _____	dia	
Key Width	W _____	☐	(standard is to BS 4235 Part 1)
Square Bore	S _____	A/F	
Hex Bore	H _____	A/F	
Bore Depth	L2 _____	☐	

Tapped Hole at Posn _____ & posn _____ Tapped _____
Cross Hole at Posn _____ & posn _____ dia _____
Cross Hole datum F _____

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