Humes

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JACKING PIPES

ISSUE 6

TECHNICAL REFERENCE FOR JACKING PIPES

ISSUED BY HUMES

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Contents

Jacking Pipes

Humes leads the industry and develops world class jacking pipes ideally suited for use with modern, closed faced microtunnelling systems.

We provide a comprehensive range of steel reinforced concrete jacking pipes from DN300 to DN3600 in a variety of classes and joint types to suit various applications and installation methods.

Reinforced concrete pressure pipes are designed for the combined effects of the external load and internal (in service) pressure. Australian/New Zealand Standard AS/ NZS 4058:2007 Precast Concrete Pipes (Pressures and Non-Pressure) gives a minimum requirement for factory test pressure of 120% of working pressure in the pipeline.

The Jacking Technique (Microtunnelling)

Pipe jacking is a method of tunnel construction where hydraulic jacks are used to thrust specially made pipes through the ground behind a shield machine, from launch shaft to receival shaft.

The term microtunnelling is also often used to describe this method of pipe installation.

Pipe jacking is used to install conduits below ground for a variety of applications including:

- sewerage pipelines
- stormwater pipelines
- road and rail culverts
- pressure pipelines
- as a sleeve pipe for other utility pipelines (water, sewage, and electricity and communication cables)
- pipe replacement and relining.

Benefits of Pipe Jacking

Technical

- Inherent strength of lining.
- Smooth internal finish giving good flow characteristics.
- No requirement for secondary lining.
- Considerably less joints than a segmental tunnel.
- Prevention of ground water ingress by use of pipes with sealed flexible joints.
- Provision of invert channels in larger pipes to contain the dry weather flow of a sewer in a combined system.

Safety

Pipe jacking is an inherently safer method than open trench construction or when considering the risks associated with deep, large section, open excavations:

- Major reduction in man-hours, opportunities for accidents to occur are less with pipe jacking.
- In busy urban centres, trenchless operation will not interfere with pedestrian and motor traffic movements.
- There is significant reduction in the risk of injury as a result of utility strikes and interface with the public.
- Less risk of settlement.

Economic

- Less affected by weather condition
- Less risk of settlement
- Minimal surface disruption
- Minimal reinstatement
- Reduced requirement for utilities diversions in urban areas

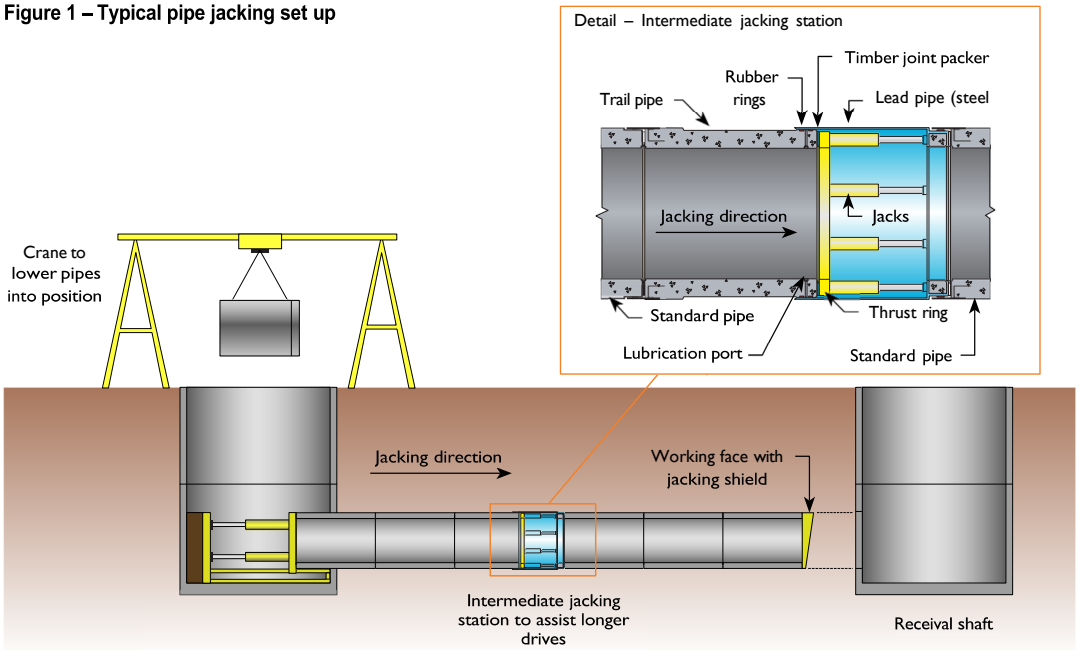
Environmental

There are substantial environmental benefits to be gained by the use of pipe jacking techniques when compared with the traditional open trench approach:

- Typically, the trenchless method will reduce the quantities of incoming and outgoing materials, with a consequent reduction in tipping of spoil and quarrying of imported stone fill. This in turn leads to reduced vehicle movements and subsequently less associated disruption.
- Minimal surface disruption and reinstatement.
- Trenchless will not harm existing vegetation.
- Noise, dirt and smell are minimised.

Source: An introduction to pipe jacking and microtunelling design – Pipe Jacking Association UK

Figure 1 – Typical pipe jacking set up



Steel Reinforced Concrete Pipes (SRCP)

Humes is Australia's leading manufacturer of SRCP. We have a wide range of diameters, lengths and strengths available. Our SRCP has a proven track record and can be custom designed for applications such as drainage, sewage, water supply and irrigation.

A milestone was achieved when Humes' DN2100, fixed steel collar pipes were jacked 1,030 m without any intermediate shafts on the Northern Pipeline Interconnector – Stage 2, SEQ (refer to our case study on this project for further details).

Benefits of Reinforced Concrete Jacking Pipes

Optimal Strength

Humes SRCP are manufactured and factory tested for quality to AS/NZS 4058:2007 "Precast concrete pipes (Pressure and Non-pressure)":

- A concrete pipe is a rigid pipe system that relies mostly on the strength of the pipe and is only slightly dependent on the strength derived from the soil envelope. The inherent strength of concrete pipe can compensate for site problems not designed for, such as construction shortcomings and higher fill heights and trench depths.
- Concrete pipes are less susceptible to damage during construction, and maintain their shape by not deflecting.
- All concrete pipe strengths are standardised by AS/NZS 4058 "Precast Concrete Pipes". Concrete pipes are strength-tested by the manufacturer to proof loads, or test loads, as nominated by the standard for particular diameter and class.
- Steel reinforcement in concrete pipes adds significantly to their inherent strength. The steel reinforcement is shaped into cages by automatic cage welding machines. The machines ensure that the reinforcement cages are dimensionally correct and have tight engineered tolerances.

Durable

Humes SRCP has a number of concrete properties that influence long service life. These properties are:

- Ultimate compressive strength: Humes SRCP compressive strength is usually in the range of up to 60 MPa and above. The strength of the pipe is a result of the materials used in the concrete mix, the mix design, manufacturing techniques and the curing process.
- Low water absorption, below 4%, due to the density and impermeability of the concrete used and manufacturing process. AS/NZS 4058-2007 specifies a maximum allowable absorption of 6% for all concrete pipes.
- A low water/cement (W/C) ratio of below 0.35. The W/C ratio is considered a trademark for durable concrete pipe, particularly as high compressive strength is related to this criterion.
- High alkalinity is controlled by cementitious content maintained by a proper mix design, material properties as well as the manufacturing and curing process.
- Concrete pipe aggregates, both coarse and fine, meet the requirements of AS 2758. Aggregates are a key element in producing quality concrete and in turn, quality pipe.

Source: Concrete Pipe Facts, Concrete Pipe Association of Australasia, www.cpaa.asn.au/concrete-pipe-facts.html

Fixed Steel Collar Pipes

A wide robust range is available from DN300 to DN3000 inclusive. They are a custom designed reinforced concrete jacking pipe incorporating a single wide jacking face including timber packers, a secure steel collar cast onto the pipe and a flexible watertight joint. All these being essential for longer pipe jacks and unstable ground conditions.

Applications

The fixed steel collar jacking pipes provides high axial load transfer capacity and a flexible watertight joint. This is the ideal jacking pipe for all stormwater, sewerage, sleeve pipe and jacked low pressure pipeline applications.

Steel Collar Types

Humes offer two different types of fixed steel collars: the S type which is fitted into pipes up to DN700 and the J type fitted into remaining sizes (mainly from DN800 to DN3000). The steel collar bands are fabricated to high tolerances to ensure optimum joint performance.

Both steel collars include a water stop hydro-seal to prevent ingress of water between the band and the concrete pipe wall.

Elastomeric Seal

The elastomeric seal is located with the corrugated steel collar in the S type collar band, factory secured internally to the steel socket band with adhesive. While, in the J type the seal is retained within the accurately formed recess on the pipe spigot.

Both unique designs will ensure that the elastomeric seal remains in place in compression even if joint deflection occurs. The joint integrity remains intact when subjected to either internal or external hydraulic pressure.

A muck ring is fitted within the J type joint; limiting the ingress of soil into the joint during jacking. The muck ring will be compressed by the end of the steel collar.

Watertight Joint – (External Pressure Testing)

Humes have undertaken external pressure testing of deflected joints with external hydrostatic pressures up to 400 kPa without visible leaks. On this basis, fixed steel collar jacking pipes are rated for 250 kPa external pressure for the joint deflections shown in Figures 4 and 5 on page 7. Humes can design pipes for higher external pressure ratings if required.

Bentonite or Grout Injection Fittings

Pipes can be supplied with or without threaded sockets and plugs, which are cast into the pipe wall in locations to meet the project specific requirements for grout and/ or lubrication injection.

Figure 2 – S type joint profile

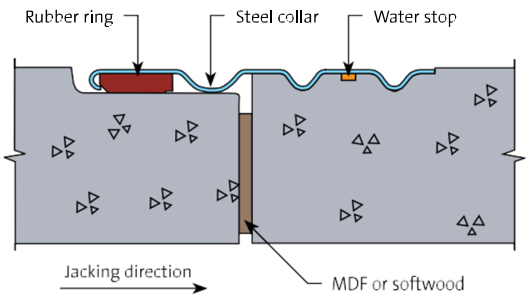
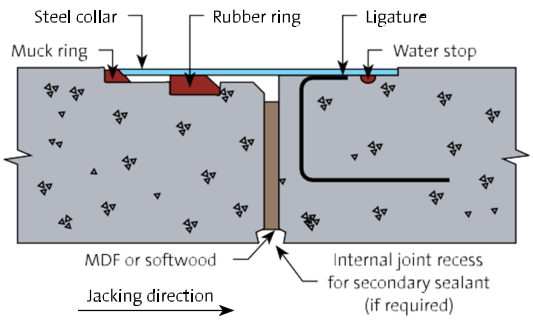


Figure 3 – J type joint profile



Secondary Sealing Recess

All J type steel collar jacking pipes are supplied with a recess on the internal pipe ends which allows for locating a flexible sealant, applied internally after installation,
if required by the project designer for isolation of the joint from the pipeline environment (see Figure 21 on page 26). The combination of mild steel collars with internal joint gap sealant can provide a cost effective solution in certain ground conditions.

Intermediate Jacking Stations

Humes have standard designs for intermediate jacking stations and these include trail and lead pipes for all diameters DN1000 to DN2000. The arrangement of these pipes at the intermediate jacking station is shown in Figure 1 on page 24.

Table 1 – Features and benefits

Features	Benefit to asset owner	Benefit to contractor
Elastomeric seal	**Watertight joint** Prevents ingress or egress of water and soil surrounding the pipes and allows pressure grouting of the excavated annulus at the completion of jacking (if required).	**Flexibility** Allows joint rotation without damage to the pipe joint. **Watertight joint** Lubrication fluids are retained in the excavated annulus without loss of fluid or pressure.
Steel collar fixed to pipe with in-built water stop	**Collar material** The designer has many options for the grade of steel to suit the intended design life in the installed environment of the pipe. Generally, mild steel is considered suitable for in-ground conditions and a non-aggressive environment.	**Secure system** Steel collar will remain watertight and secured in place during jacking, even in variable ground conditions. **Efficient jointing** Rapid pipe jointing ensures operational efficiency in the jacking pit.
Corrugated collar recess (S type) Deep spigot groove (J type)	**Permanent seal location** The seal remains in place throughout the design life of the pipeline providing a long-term watertight structure under external groundwater pressures or ground movement.	**Restrained seal** Ensures that the seal remains in place during jointing and jacking with external pressure from groundwater or lubrication injection.
Single wide jacking face	**Efficient construction** Long drives, lower construction costs and less disturbance to above-ground activities.	**Long drives** The wide face on the pipe end enables transfer of high jacking forces through the centerline of the pipe wall enabling accurate steering and long drives.
Muck ring (J type)	**Maintain watertight joint** After installation the muck ring protects the rubber ring and the steel collar to maintain watertightness.	**Maintain watertight joint** Prevents ingress of soil into joint during jacking.
Internal joint recess	**Additional sealing options** The recess is shaped to allow retention of a flexible sealant if secondary joint sealing is required.	**No spalling** Prevents spalling of inside concrete face if the packer is displaced during jacking.

Optimal strength

Humes fixed collar jacking pipes, both with S and J type collar, are designed with steel reinforcement placed for optimal strength, which combined with the strength and durability of Humes concrete pipes, provides an excellent jacking pipe. Steel reinforced concrete jacking pipes are capable of withstanding higher jacking loads.

The jacking load capacity of standard pipes for a range of joint deflections is illustrated in Figures 4 and 5 on the following page. Pipes with higher jacking loads and/or joint deflections can be designed for specific projects.

Jacking Design and Forces

The Concrete Pipe Association of Australasia (CPAA) publication, *Jacking Design Guidelines* is a recommended guide to calculate and define jacking forces. The guide can be downloaded by visiting;
www.cpaa.asn.au/CPAA-Online-Shop.html

Jacking forces and lateral displacement off line and level have to be recorded at regular intervals of jacking distance (not exceeding 200 mm or every 90 seconds).

Ensure that jacking forces are maintained within the limits specified in Figures 4 and 5 on the following page. If circumstances cause a jacking force/deflection combination outside of these limits, hold the jacking operation and contact Humes for assistance.

Figure 4 – S type jacking pipes deflection curves

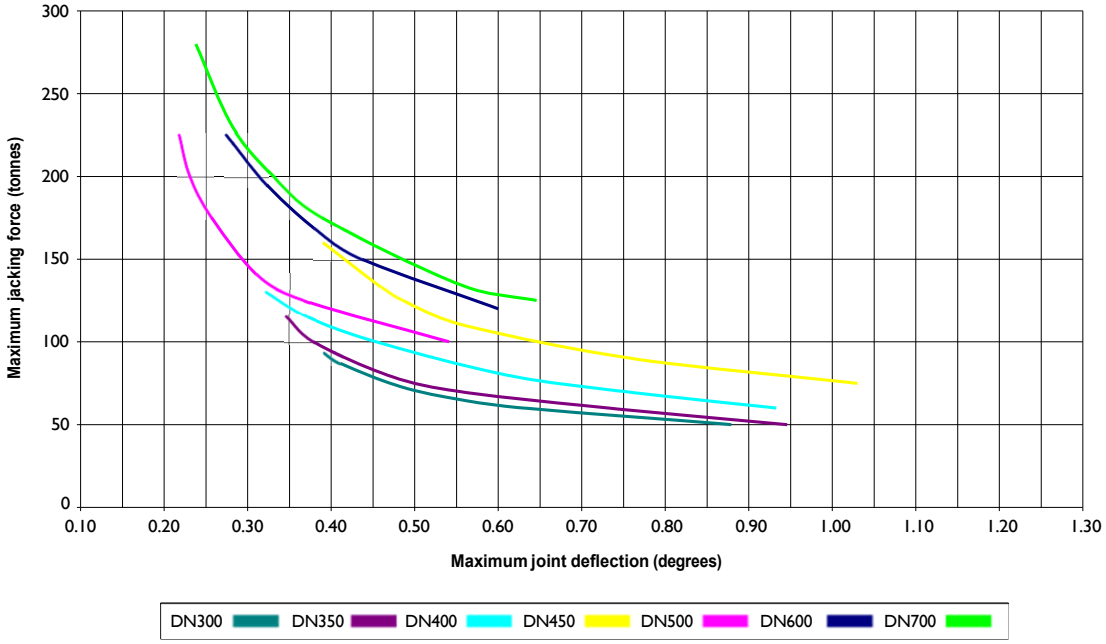


Figure 5 – J type jacking pipes deflection curves

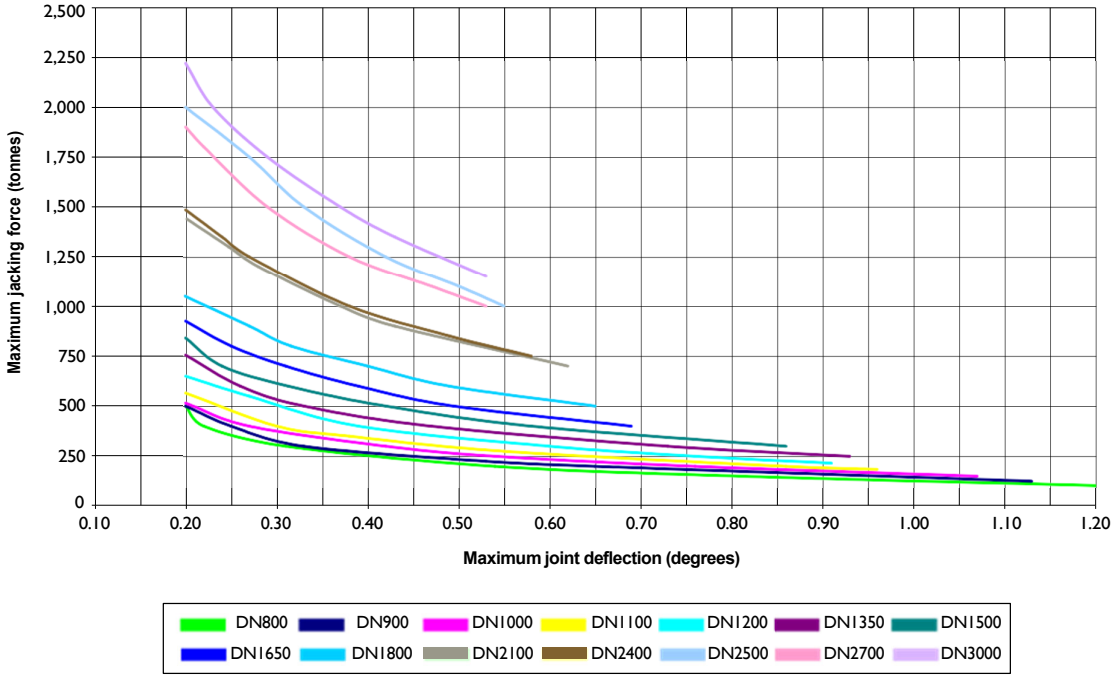
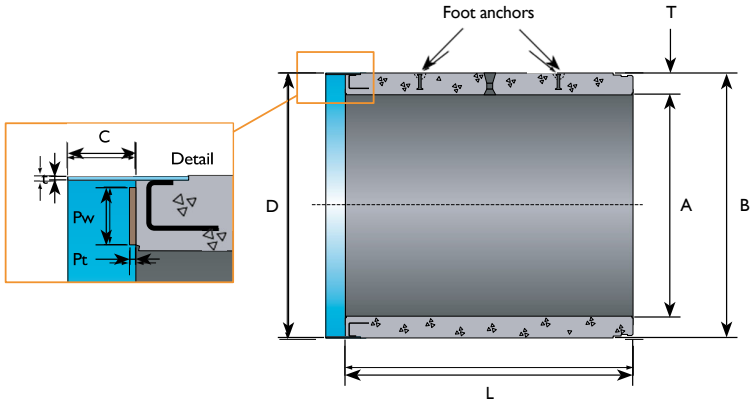


Table 2 – Fixed steel collar pipes dimensions, mass, jacking loads and deflections



Nominal diameter	Internal diameter 'A' (mm)	External diameter 'B' (mm)	Wall thickness 'T' (mm)	Effective length 'L' (mm)	Min. joint packer 'Pt/Pw' (mm)	Steel collar			Pipe mass (kg)	Max. jacking load (tonnes)	Collar type
						Length 'C' (mm)	ID 'D' (mm)	Thickness 't' (mm)			
300	300	430	65	2,400	3/40	50	412	1.5	500	100	S
350	350	480	65	2,400	3/40	50	462	1.5	550	115	S
400	400	540	70	2,400	3/40	50	522	1.5	660	135	S
450	450	606	78	2,400	3/40	50	588	1.5	725	165	S
500	500	672	86	2,400	3/40	50	654	1.5	1,000	225	S
600	600	774	87	2,400	6/60	80	752	2	1,190	240	S
700	700	876	88	2,400	6/60	80	854	2	1,380	280	S
800	800	1,000	100	2,360	12/65	120	989	4	1,800	500	J
900	900	1,110	105	2,360	12/70	120	1,099	4	2,100	500	J
1,000	1,000	1,220	110	2,360	12/75	120	1,209	4	2,400	515	J
1,100	1,100	1,332	116	2,360	12/80	120	1,321	4	2,800	565	J
1,200	1,200	1,450	125	2,360	12/90	120	1,439	4	3,300	650	J
1,350	1,350	1,626	138	2,320	16/90	160	1,611	6	4,000	755	J
1,500	1,500	1,800	150	2,320	16/100	160	1,785	6	4,800	840	J
1,600	1,600	1,940	170	2,985	16/110	160	1,911	8	7,500	1,020	J
1,650	1,650	1,974	162	2,320	16/110	160	1,959	6	5,700	925	J
1,800	1,800	2,150	175	2,320	16/125	160	2,135	6	6,700	1,050	J
2,100	2,100	2,500	200	2,985	16/160	160	2,481	8	12,050	1,440	J
2,400	2,374	2,783	204	2,985	16/175	175	2,759	10	12,950	1,485	J
2,500	2,500	3,000	250	2,985	16/195	175	2,977	10	16,650	2,000	J
2,700	2,636	3,096	230	2,985	16/175	175	3,073	10	16,150	1,900	J
3,000	2,972	3,472	250	2,985	16/195	175	3,449	10	19,700	2,220	J

Loose Steel Collar Pipes

Humes offer two types of loose steel collar SRCP jacking pipes, butt joint and in-wall joint. They are available from DN300 to DN3000 (standard range DN300 to DN2100).

The steel collar is not attached to the pipe (cast with) but rather is fitted onto the pipe before installation. The collars can be supplied by either Humes or the contractor.

Butt Joint Pipes

Butt joint jacking pipes incorporate a single wide jacking face. External recesses at each end of the pipe allow for a rolled steel collar to be located between adjacent pipes, providing the necessary shear connection (see Figure 6).

- **Applications**
  Butt joint jacking pipes can provide a cost effective solution for typically short length applications where only limited flexibility is required and a soil or watertight joint is not required. This pipe is also suited to sleeve pipe applications for road and rail crossings where the annulus between the utility pipeline and conduit is to be filled with grout after installation.

  Refer to Table 4 – Selection of jacking pipes (page 11), which provides a summary of capabilities for each of the different types of jacking pipes for different requirements and applications.

In-Wall Joint Pipes

In-wall joint jacking pipes are available from DN1200 to DN3600 (standard range DN1200 to DN2100). In-wall joint jacking pipes incorporate a concrete socket formed in the wall of the pipe, a rubber ring located on the pipe spigot and timber packers on one or both joint faces (see Figure 7).

- **Applications**
  In-wall joint jacking pipes are an economical viable alternative for typically short length applications where a flexible watertight joint is required, however, this type of joint can have limitations in jacking load transfer. A J type pipe should be specified in these situations.

Figure 6 – Butt joint profile

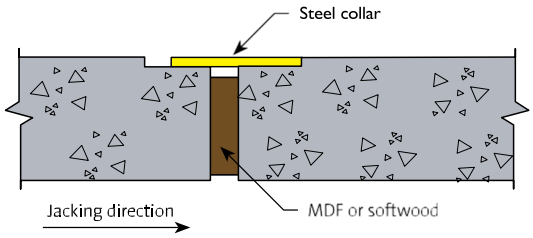


Figure 7 – In-wall joint profile

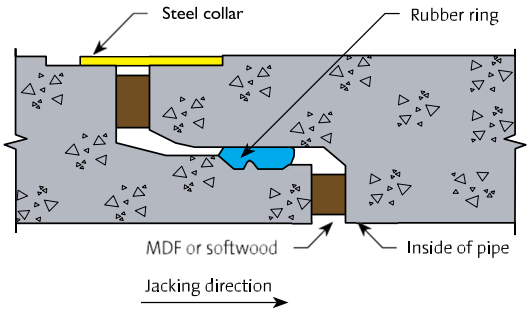


Table 3 – Loose steel collar pipe range

Nominal diameter	In-wall joint		Butt joint	
	Internal diameter	External diameter	Internal diameter	External diameter
	mm			
DN300			280	362
DN375			363	445
DN475			438	534
DN525			518	616
DN600			586	698
DN675			653	781
DN750			730	864
DN825			790	946
DN900			875	1029
DN975			951	1,111
DN1050			1,026	1,194
DN1200	1,200	1,500	1,163	1,359
DN1350			1,324	1,524
DN1500			1,452	1,676
DN1650			1,596	1,842
DN1800			1,756	2,006
DN1950	1,920	2,220	1,930	2,198
DN2100	2,088	2,388	2,096	2,388

Notes:

1. Alternative internal diameters (and external diameters) may be available to suit project specific requirements, contact Humes for assistance.
2. Standard range is equivalent to load class 4 pipes.
3. Contact Humes for in-wall joint pipes in this range.

Selection of Jacking Pipes

The most basic requirements for all jacking pipes is that they must be capable of supporting the excavation (earth and traffic loads), transferring axial load, providing a shear connection between adjacent pipes and joint flexibility that allows for each pipe to follow the path excavated in front of the shield.

In addition, jacking pipes may need to prevent ingress of surrounding soil, groundwater, lubricants or grouts and provide a joint capable of withstanding internal pressure in sewerage or pressure pipeline applications.

Jacking pipes must meet both the needs of the contractor and asset owner who is usually represented by the pipeline designer. Table 4 opposite provides a summary of the capabilities of each of our types of jacking pipes for different requirements and applications.

Table 4 – Selection of jacking pipes

Stakeholder	Jacking pipe requirements or application	Fixed steel collar		Loose steel collar	
		S type	J type	Butt joint	In-wall joint
Asset owner	Standard size class	DN300 – DN700	DN800 – DN3000	DN300 – D2100	DN1200 – DN2100
	Extended diameter range*	DN800	Up to DN3600	DN2250 – DN3000	DN2250 – DN3600
	Incorporation of inert thermoplastic lining	N/A	Available	DN900 >	Available
	External grouting	Suitable for short lengths	Ideally suited	Not suitable	Limited suitability†
	Internal pressure test capability (kPa)‡	90	90§	N/A	90
	Application of internal secondary sealants	N/A	Suitable	Not suitable	Limited suitability
	Sewerage pipelines	Limited suitability‖	Ideally suited	Not suitable	Suitable
	Stormwater pipelines	Ideally suited	Ideally suited	Limited suitability	Suitable
	Road and rail culverts	Ideally suited	Ideally suited	Limited suitability	Suitable
	Sleeve pipe applications	Ideally suited	Ideally suited	Limited suitability#	Suitable
Asset owners and contractors	Length of jacked pipeline (m)	0 – 50††	< DN1000: 0 – 150 DN1000 – DN3000: no limit‡‡	0 – 50**	0 – 50
	External pressure test capability§§	90	250	N/A	90
	Jacking force transfer	Excellent	Excellent	Good	Moderate
	Intermediate jacking stations pipes	N/A	Available DN900 – DN3000	To be provided by contractor	To be provided by contractor
Contractors	Open face shields	Suitable	Suitable	Suitable	Suitable
	Closed face pressure shields	Ideally suited	Ideally suited	Not suitable	Limited suitability
	Lubrication along length of pipeline	N/A	Ideally suited	Not suitable‖‖	Limited suitability

Notes:

* Refer to Humes for availability.

† Grout pressures need to be carefully monitored.

‡ Test to AS/NZS 4058: 2007.

§ Higher pressures are possible with certain diameters – refer to Humes for advice if higher pressures are required.

The butt joint jacking pipe is suitable for short length drives in certain soil conditions if the annulus between the concrete sleeve pipe and the product pipe is grouted. This grout should also flow into the annulus between the sleeve pipe and the excavated ground.

†† Intermediate jacking stations are not available and length is mainly limited by installation equipment. Some pipe jacking contractors may be able to achieve longer lengths of individual drives in certain soil conditions. Refer to jacking pipe contractor for advice for longer drives.

‡‡ The maximum length will be controlled by installation equipment rather than pipe capability.

** Lack of joint flexibility largely controls maximum length. This could be extended in certain soil conditions.

§§ There is no published test method for external joint testing of reinforced concrete pipes. External pressures due to lubrication or grouting can be well in excess of ground water pressures.

|||| For lubrication to be effective, the annulus between the external diameter of the pipe and the excavated soil needs to be filled. The butt joint pipe may not provide an effective sealed joint.

Load Class

Jacking pipes, as opposed to pipes laid in open excavations, are subjected to both jacking forces, external earth loads and life loads (permanent loads) and all of these have to be considered when specifying the pipes.

The effect of the jacking force on the pipe barrel is small on account of the high compressive strength of the concrete. The joint, however, must be considered because the joint cross-section is smaller, as a rule, than that of the barrel and the jacking force is transferred eccentrically across the joint.

The external earth load on the barrel is equal to or smaller than the trench load on a pipe bedded in a trench of same width as the excavation (i.e. the outside diameter of the pipe plus a margin for over-excavation). The jacking method of installation, therefore, is very efficient from an external load point of view since the external earth load is smaller than both trench and embankment load on pipes of the same diameter under the same height of fill.

As such a minimum Class 4 pipe is usually recommended although in some short length drives a Class 3 may be suitable. The Class 4 pipe to Australian Standard AS/NZS 4058: 2007 has very similar strength requirements to load classes specified for jacking pipes in European and Japanese Standards.

AS/NZS 4058: 2007 outlines the technique for determining the permanent vertical loads acting on pipes installed using pipe jacking. The jacking pipe is installed underground into undisturbed natural ground where the soil's natural cohesion contributes to arching over the pipe. Where the calculation includes the effects of arching due to soil cohesion extensive soil investigations should be carried out to determine the appropriate design soil properties.

The jacking installation results in a recommended bedding factor between two and three that is used to determine the minimum suitable pipe class required due to permanent loads.

The higher value is recommended when the annulus between the pipe and ground is grouted. Grouting of this annulus with a suitable cementitious grout is recommended in most installations as any voids could create a drainage path external to the pipeline which in turn could lead to soil erosion, lowering of ground water tables and, in aggressive soil conditions, an increased risk of corrosion of pipe materials.

The axial loading from the pipe jacking is not directly included in the selection of the pipe load class. Timber packers are placed between the jacking faces of the concrete pipes to avoid high stresses that could result from direct concrete to concrete contact. The axial load capacity of the concrete pipe is determined based on the minimum pipe wall thickness, concrete strength, properties of the timber packers and the deflections that can be expected at pipe joints during installation.

The allowable jacking forces and associated maximum joint deflections are calculated in accordance with the Concrete Pipe Association of Australasia (CPAA) publication, *Jacking Design Guidelines.*

Source: Jacking Design Guidelines, Concrete Pipe Association of Australasia.

Jacking Design and Forces

The CPAA publication, *Jacking Design Guidelines,* is a recommended guide to calculate and define jacking forces. The guide can be downloaded by visiting; www.cpaa.asn.au/CPAA-Online-Shop.html

Jacking force and lateral displacement off line and level have to be recorded at regular intervals of jacking distance (not exceeding 200 mm or every 90 seconds).

Ensure that jacking forces are maintained within the specified limits. If circumstances cause a jacking force/ deflection combination outside of these limits, hold the jacking operation and contact Humes for assistance.

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