Strength. Performance. Passion.

Tunnel and shaft solutions

Issue 7


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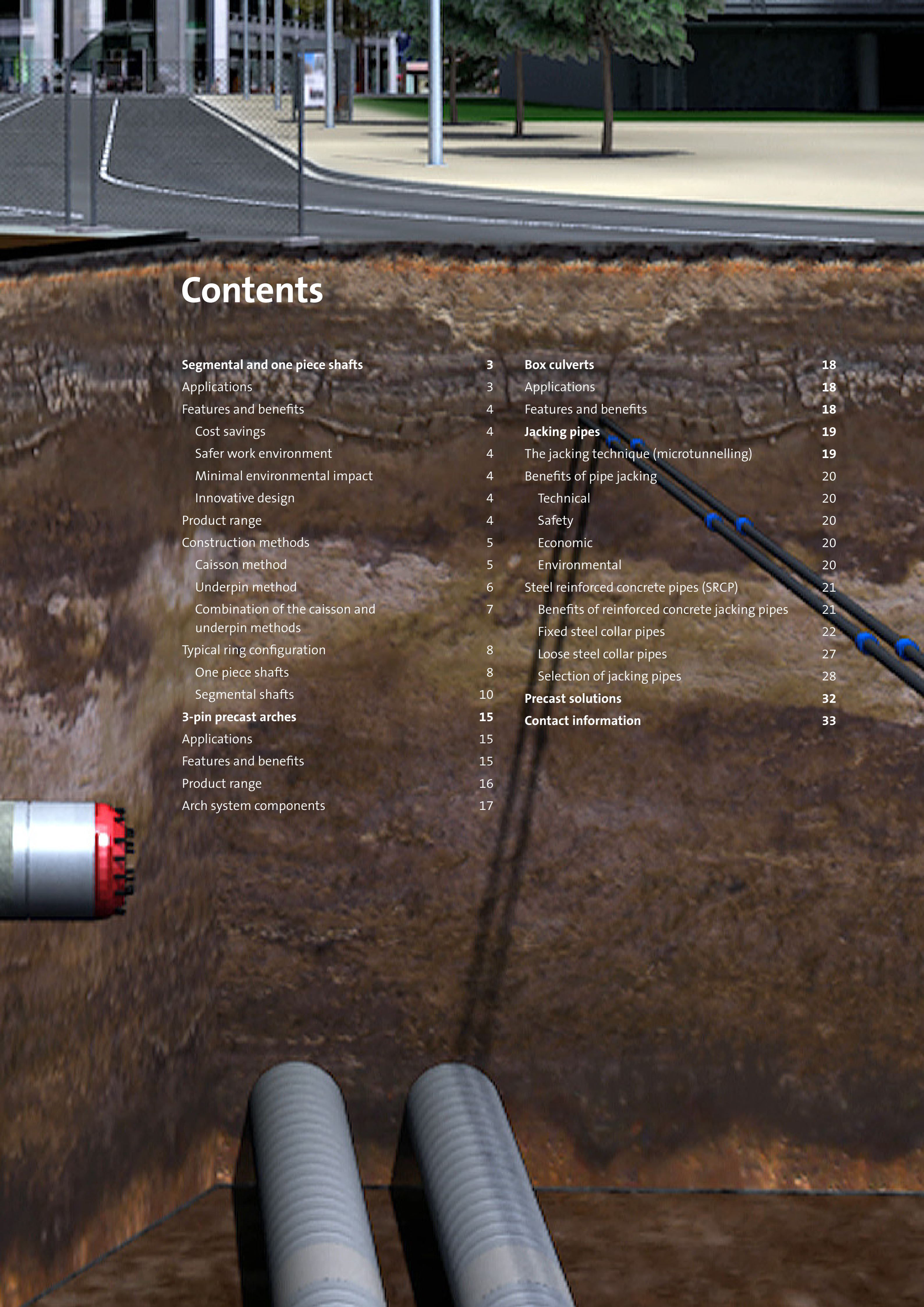


Contents

Segmental and one piece shafts

Applications

Humes' precast concrete shafts are an economical and safe solution for permanent and temporary underground structures. They are ideal for a variety of applications including:

- ventilation shafts
- escape shafts
- launch and receival shafts for pipe jacking applications
- storage overflow and pump stations (sewerage)
- water harvesting and reuse.

The shaft system suits a variety of soil conditions, and provides a soil and watertight solution.

Features and benefits

Precast shafts provide installation contractors with a number of significant benefits over traditional shaft construction methods; greater installation efficiencies, cost benefits, and a safer work environment. Humes' precast shafts also help to reduce the environmental impact of construction.

Cost savings

- Installation time is significantly reduced as excavation and ring placement can be on a continuous cycle.
- The precast concrete segments provide a one-pass finished shaft, so no further concrete work is required to finish the structure.
- There is no requirement for specialist labour and a small team should be capable of managing the entire installation process.

Safer work environment

Humes' precast shafts enable contractors to provide a safer environment for their workers:

- The majority of work can be carried out above ground (caisson method).
- Overhead services hazards are minimised as no large cranes are required.
- The system has a built-in safety barrier created by the installation of the top ring.

Minimal environmental impact

An efficient design means shafts have minimal impact on project sites and the surrounding environment:

- Noise and ground vibration are virtually eliminated as no hammering is required.
- The excavation and site storage areas are minimal, as the precast units are relatively compact at less than 2.5 m wide.
- Shaft installation does not require the use of water or wet concrete (except for the base and collar).

Innovative design

- The shaft can be installed accurately due to the high degree of control over the rate and direction of installation.
- No bracing is required due to its structurally efficient circular shape. The shaft gains structural stability from the surrounding soil so tie-backs or ring-beams are not required to support the segments.
- Suited to a variety of soil conditions.
- Extensive diameter range with full range of ancillary products.
- A soil and watertight solution.
- A unique external fixing is used to join the segments, eliminating the need for specialist trades, like welders, on site.

Product range

Humes is proud to announce the expansion of our range of precast concrete shafts; we now offer the following sizes in one piece and segmental shafts:

- 2.4 m one piece shaft
- 3 m one piece shaft
- 3.6 m one piece shaft
- 4.5 m segmental shaft
- 6 m segmental shaft
- 7.5 m segmental shaft
- 9 m segmental shaft

Construction methods

There are three techniques available to install a precast concrete segmental shaft. These are the caisson method, underpin method and the last method is a combination of the two. The design of caisson and underpin shafts requires specialist skills and should be executed by a designer experienced with these construction methods.

Caisson method

The caisson method is generally used in softer soils with or without the presence of ground water. Caisson are either installed as a 'wet caisson' where the water level inside the caisson is slightly higher than the external ground water level, or as a 'dry caisson' where the inside of the caisson is open to the atmosphere. In the caisson method, the precast concrete elements are erected at the surface and are then lowered into the ground whilst excavation progresses.

There are a number of common features unique to Humes' caisson shaft systems which facilitate installation. These are:

- **In-situ cast concrete collars**
  These collars act as a guide ring to keep the caisson shaft vertical and, in larger diameter shafts, resist the force from the hydraulic jacks.
- **Hydraulic jacks (gallows)**
  These are installed to both steer the shaft and to add to the vertical force in addition to the self weight of the shaft lining (generally not required for one piece rings).
- **Excavation should be slightly larger in diameter than the precast concrete shaft**
  The annulus between the shaft and the excavated ground should be filled with suitable fluid (usually bentonite with additives as required to suit the ground conditions) which acts both as a lubricant but also supports the ground during installation.
- **The bottom/choker ring is wider than the standard ring and the same diameter as the excavation**
  The choker ring is designed to provide a seal diameter between the shaft and excavated ground so that the fluid in the annulus above the ring is retained. The choker segments are also designed to bolt the steel cutting edge to the shaft and connect the underpin segment. Refer to combination method on page 11.
- **A steel cutting edge underneath the bottom/choker ring**
  The steel cutting edge literally cuts through the ground. An additional function is that it acts as a stiffener.
- **All caisson units are provided with grout sockets**
  This allows the exterior annulus to be filled with a cementitious grout at completion of the installation.

Top:
Caisson method of shaft installation showing hydraulic jacks (gallows)

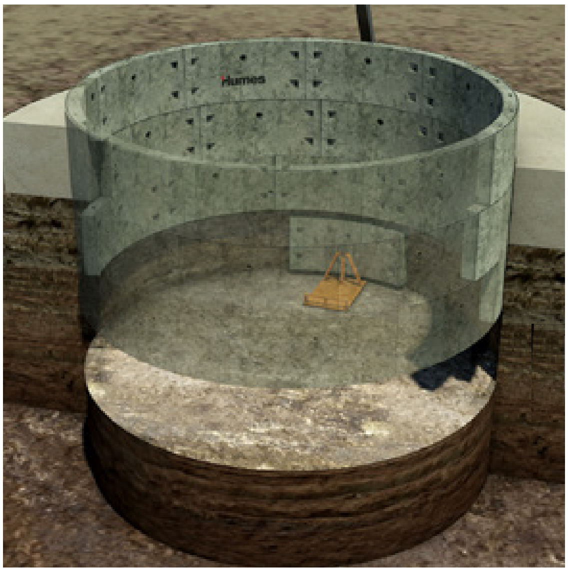
Bottom:
Bottom/choker ring with steel cutting edge

Underpin method

The underpin method can be used in self supported soil where caisson installation is not possible. In this method, the precast concrete elements are progressively installed at the base of the excavation. Segmental rings are built and the annulus between their outside perimeter and the excavated ground is immediately grouted.

The recommended installation procedure is as follows:

- Secure the first installed ring by casting a concrete collar around it prior to excavating underneath to construct the next ring. Shear connection may be required.
- Always excavate, install and grout one ring at a time. This reduces the risk of overloading the upper rings which could pull down the whole ring build, due to lack of ground friction.
- Excavation of the next ring below can commence once the grout reaches it recommended strength.
- The underpin segments are designed to be installed using a specialised handling/lifting frame. The segment will be secured into the frame via the plastic grout socket assembly.



Top:
Underpin method of shaft installation

Bottom:
Segment lifting frame for underpin method

Combination of the caisson and underpin methods

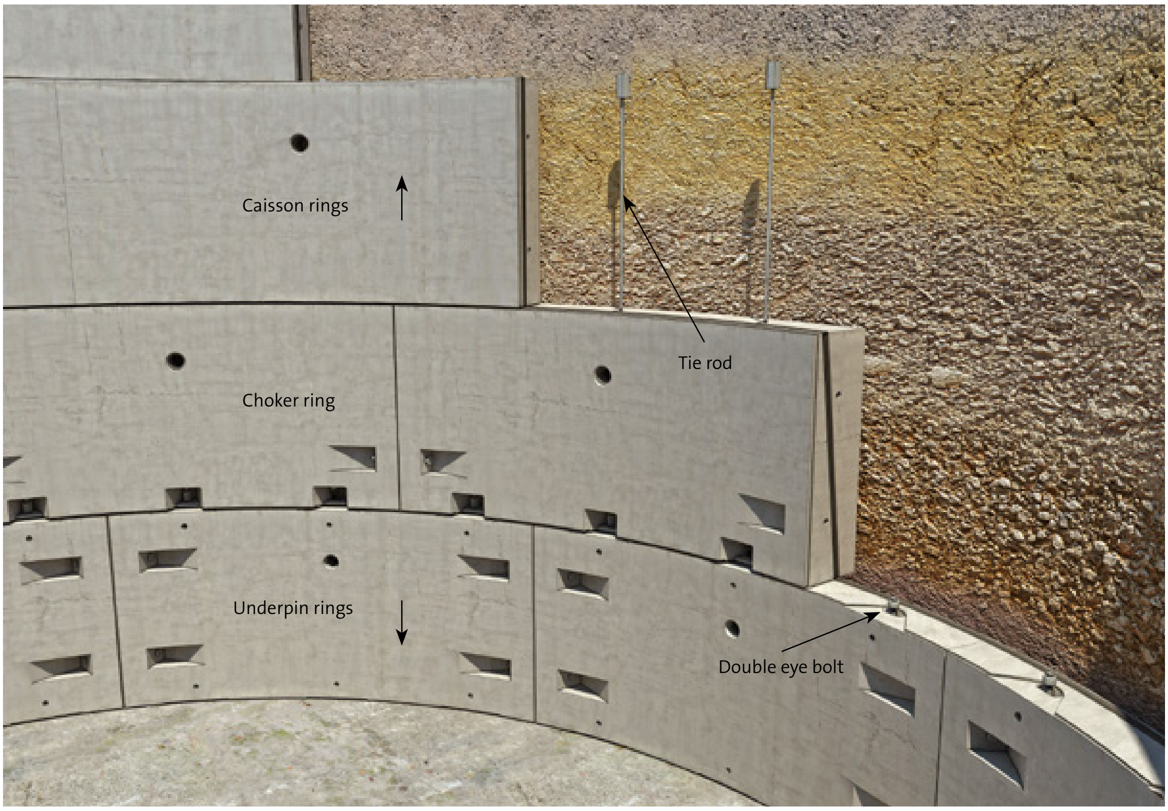
A combination of both methods can be used if the soil condition varies. Installation commences with the caisson method (using a special choker ring) and then shifts to the underpin method when the hard soil ground is reached.

A special choker/transition ring must be used to enable the shift to the underpin construction method. Once the caisson rings have been completely grouted and the steel cutting edge removed. The underpin method can commence as previously described

With some ground conditions it may be necessary or cost effective to stop the caisson at a certain depth. After grouting the exterior annulus, it may be possible to remove the cutting edge and then continue the shaft construction using the underpin method.

Left: Combination method of shaft installation

Figure 7 – Combination method details



Typical ring configuration

One piece shafts

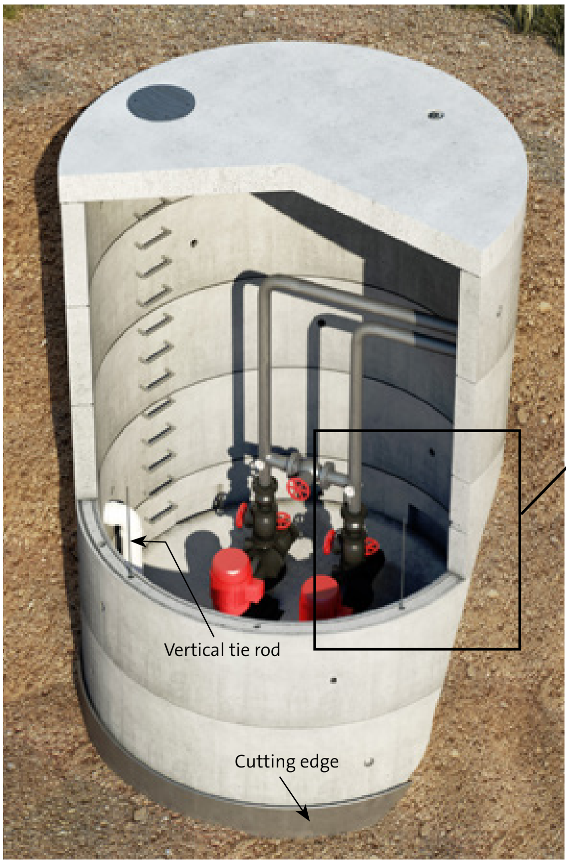
One piece caisson units are ideally suited for construction of sewage pump station wet wells, access chambers for large diameter pipelines and jacking launch or receival shafts for small diameter microtunnelling. One piece shafts can be supplied in a range of diameters but standard sizes are as detailed in Table 2 below.

Table 2 – Standard one piece caisson units*

Nominal diameter (DN)	Internal diameter (mm)	External diameter (mm)	Height of standard units (mm)*	Mass of standard units (tonnes)	Number of tie rod couplers
2,400	2,374	2,782	1,000	4.3	6
3,000	3,060	3,460	1,000	5.2	8
3,600	3,600	4,000	1,000	6.0	9

Note:
* Dimensions are subject to change. Contact Humes for confirmation.

Figure 8 – One piece shaft used in a pump station application



Detail – Panelled ring with recesses

Joint and connection details

Horizontal joints between one piece caisson units are sealed with both a hydrophilic rubber seal near the external surface and a butyl mastic rubber seal near the internal surface. For temporary installations, a single butyl mastic seal is likely to be sufficient. In addition, units come complete with a groove on the inside face which allows caulking of the internal surface.

Horizontal joints between one piece caisson rings are connected with vertical tie rods that are mainly provided for temporary loads during installation. These rods are normally made from galvanised steel. For permanent installations, it is recommended that approximately half of these rods and couplers be replaced with stainless steel so that the hydrophilic seal is confined during the life of the structure.

Special units

Special units include the following:

- Panelled rings which include recesses, are designed to provide a shear connection between the precast concrete shaft and an in-situ cast concrete plug, installed to prevent flotation. Either single or multiple panelled rings are particularly effective for wet caissons where the connection plug will be cast prior to de-watering.
- Rings with corrosion protection linings (either High Density Polyethylene (HDPE) or Plastiline® - Polyvinyl Chloride (PVC)) for added corrosion resistance.
- Soft eye rings are applied to small diameter (DN600 or less) microtunnelling applications. Rings can be provided with either reduced or no steel reinforcement at pipe penetrations.
- Cover slabs incorporating openings and/or lids as required. The joint and connection details for the standard rings are included with these cover slabs.

Left:
One piece shaft

Right:
Cover slab

Segmental shafts

Where shaft diameters exceed the size of the one piece ring '3.60 m ID', the segmental shaft system comes into its own so that shafts of almost any diameter can be constructed.

A ring consists of a series of ordinary segments which have four edges that are perpendicular to each other and two tapered segments (left and right) which have one tapered end which allows for closing of the ring by simply lowering the last (tapered right) segment into position.

Number of segments per ring varies depending on the shaft diameter (refer to Table 3 below).

Figure 9 – Installing tapered segments to close the ring

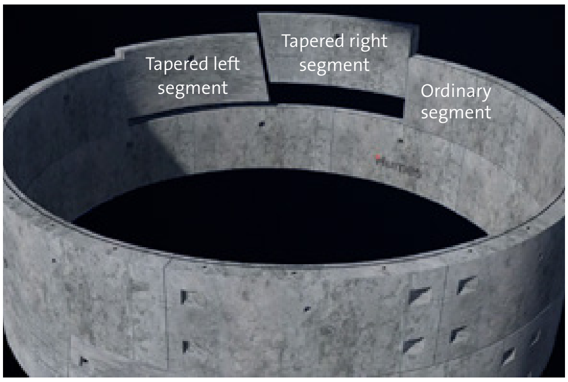


Table 3 – Standard segmental shaft details

Internal diameter (m)	External diameter (m)	Height (m)	Segments per ring		Mass per ring (tonnes)	Mass per segment (kg)
			Ordinary	Tapered		
4.50	4.90	1.00	5	2	7.36	1,050
6.00	6.45	1.00	7	2	10.78	1,200
7.50	7.95	1.00	8	2	13.37	1,340
9.00	9.50	1.00	12	2	17.80	1,270

Joint and connection details

A unique external fixing is used to join the smooth segmental shaft. The strong connection bolts together the segments to form a ring. Subsequently, the rings come together to form a shaft. The system retains all the benefits of strength, flexibility and speed of erection whilst providing the client with a safer shaft construction system.

- **Cross joints**
  Segments are connected across this joint using curved bolts (refer to Figure 10 below) which are installed from the outside for caisson installation and from the inside for underpin installation (see photos).

Top:
Curved bolt fitting - caisson installation

Bottom:
Curved bolt fitting - underpin installation

Figure 10 – Curved bolts used for cross joints

- **Circle joints**

  Caisson segmental rings are connected using vertical tie rods that extend through the full length of the segments (refer to Figure 11 and 12).

  Underpin segmental rings are connected using a double eye bolt arrangement that allows the joint to be tightened from inside the shaft (refer to Figure 13 below).

  All bolts used with segmental shaft construction are made from galvanised steel and are only necessary to support the shaft during the installation. Once segmental shafts have been grouted into position the bolts are redundant.

Figure 11 – Jointing details (caisson segment)

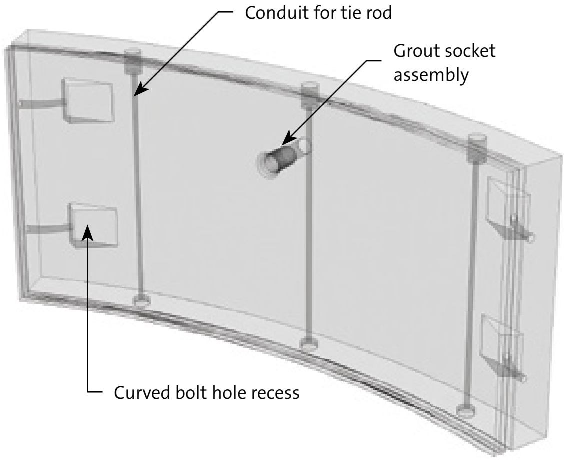


Figure 12 – Tie rod connection used for caisson installations

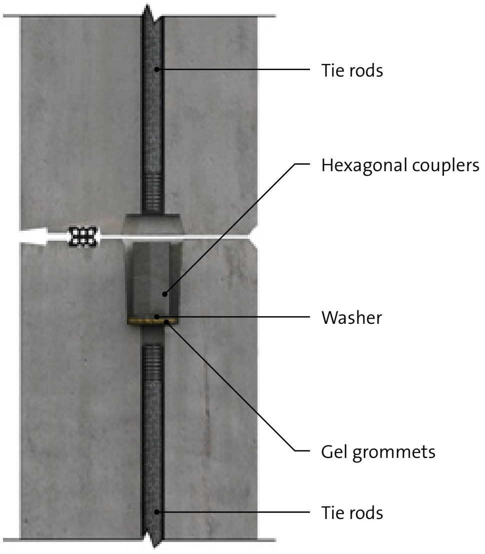
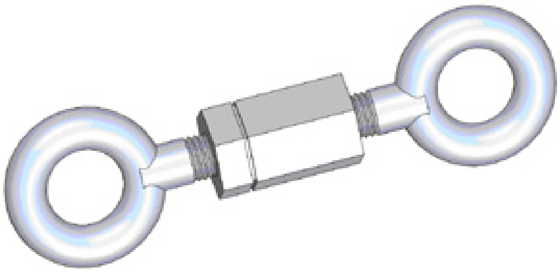


Figure 13 – Double eye bolt used for underpin installations



Top:
Tie rod

Bottom:
Adjusting the double eye bolt - underpin installation

Special units

Special rings and/or segments can also be supplied in addition to the standard segmental shaft caisson rings:

- **Panelled rings**
  Recesses can be included in both standard rings and choker rings as required. As with the one piece caisson rings these are intended to provide a shear connection between an in-situ cast plug or base slab and the segmental shaft. It is recommended that complete panelled ring(s) are installed.
- **Soft eye rings**
  Standard segments are reinforced with steel reinforcing bars. It is possible to provide rings with some segments manufactured using fibre reinforcement located at pipes penetrations for microtunnelling applications. For the caisson method, a complete ring of fibre reinforced segments is not recommended.

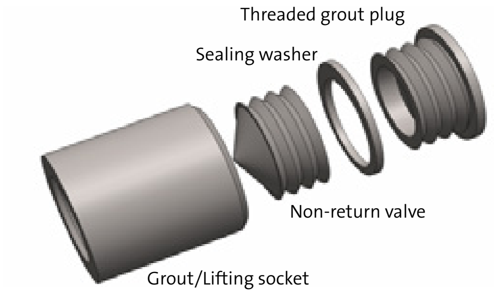
Innovative features

- **Grout socket assembly**
  Each segment and ring is fitted with a plastic grout socket assembly which includes a non-return valve. The assembly is used to introduce bentonite slurry between the caisson ring and the soil, to lubricate and reduce friction force while jacking rings into the ground. The same socket is used to inject grout to permanently secure the rings. For underpin installations the socket is also used to secure the segment into the underpin lifting frame (refer to page 10).
- **Packing**
  Bituminous felt packing of 3 mm nominal thickness is used on all longitudinal joints. The packing is designed to prevent direct contact between concrete surfaces as a result from compressed forces imposed by the surrounding soil.

Top:
Panelled ring

Bottom:
Segment packing

Figure 14 – Grout socket assembly



Watertightness

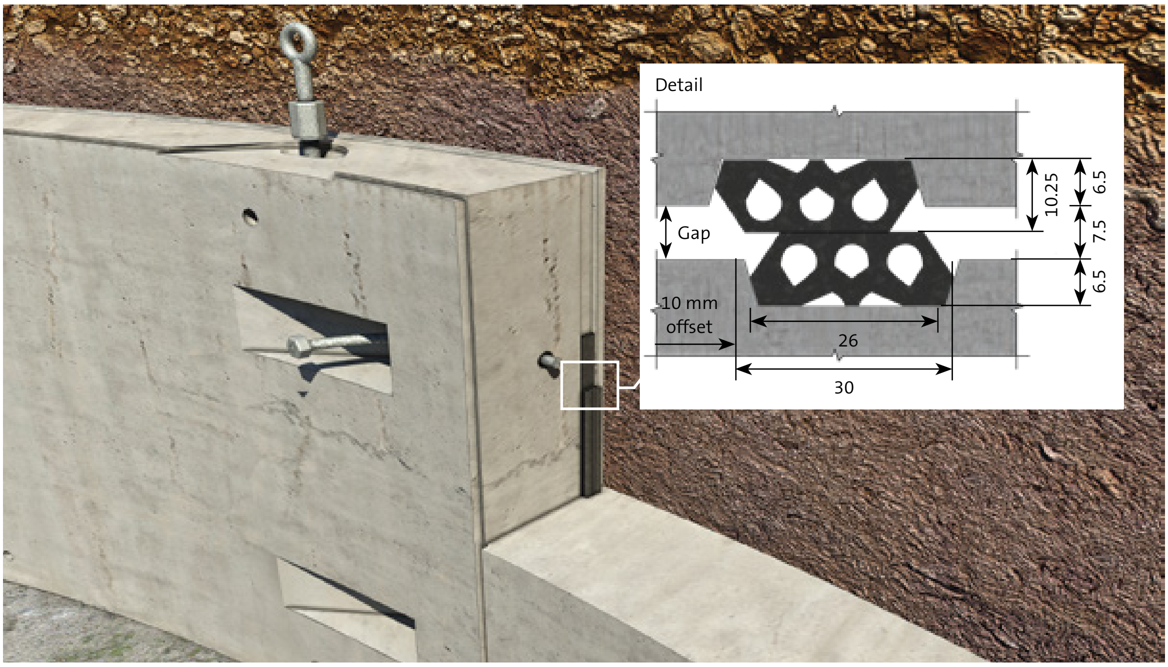
Top and middle: Watertightness testing

Bottom: EPDM gasket placement and detail

All Humes shaft segments are supplied with Ethylene Propylene Diene Manomer (EPDM) gaskets fitted into purpose designed grooves cast around the full circumference of each segment. In addition, each segment is cast with caulking grooves on the internal circumferential and longitudinal sides to meet the specific requirements of the sealing system.

Humes conducted experiments to determine the watertightness of our segmental shafts to water infiltration. The experiments concluded that the EPDM gasket seals were successful up to 350 kPa (the testing apparatus pressure limit). This demonstrated that the seals are capable of withstanding the effects of pore water pressure to a depth in excess of 12m depending on soil conditions. This is in standing with laboratory testing which indicates the seals are capable of withstanding pressures in excess of 600 kPa.

In the event that assembly tolerances can't be achieved during construction, there is a rectification solution that has been researched and successfully implemented. This method involves removing the concrete in the location of the gap using a masonry drill and injecting a mastic sealant such as SikaFlex 11-FC into the area.



3-pin precast arches

Humes' precast arch system is a high performance and cost effective tunnel solution. A large range of custom designed 3-pin arches have been developed which are ideal for a variety of complex heavy loading criteria and internal envelopes.

A wide range of 3-pin arches have been used for reclaim tunnels in mining applications. They are designed to suit coal and other mineral stockpiles up to 45 metres.

The 3-pin arch is a soil-structure interaction system where the backfill of the specified zone contributes to the load carrying capacity of the arch and becomes part of the structure. Its optimised geometry and the unique pinned joint allows it to bear and pass heavy load to the foundation.

Applications

- Reclaim tunnels
- Conveyor tunnels
- Escape tunnels
- Underpasses

Features and benefits

- Designed to meet the mine's designated design life and can exceed 100 years.
- Delivered in segments to suit light cranes.
- Require minimal maintenance since:
  - the combination of backfill and overfill protects the arch element
  - it has no exposed metal nor bolting system.
- Openings for ventilation, escape accesses and intake valves can be easily accommodated.
- Grades and curved tunnels can be achieved using the same type arch profile.
- A unique jointing system without any overlapping, staggering, bolting or cast in-situ joints.
- Self supported during installation, does not require scaffolding or support of backfill.
- Easy to clean and maintain as conveyor belts can be attached to the internal soffit of the arch allowing sufficient clearance for service vehicles to pass beneath.
- Fewer units are required for installation as most arch units are 1.8 m to 2.5 m wide.
- Arches can be installed with minimum disruption to conveyor operation.

Product range

Humes 3-pin arches are custom-made to suit specific project requirements. They are designed to accommodate the defined envelope, where the function of the tunnel and loads are applied.

Humes in-house design team can assist in choosing the most economical 3-pin arch profile (some standard profiles are shown in Figure 17 below). We will conduct both linear and non-linear 3D analysis to define structure suitability, an example of this is shown in Figure 18 below.

Figure 17 – 3-pin arch profiles

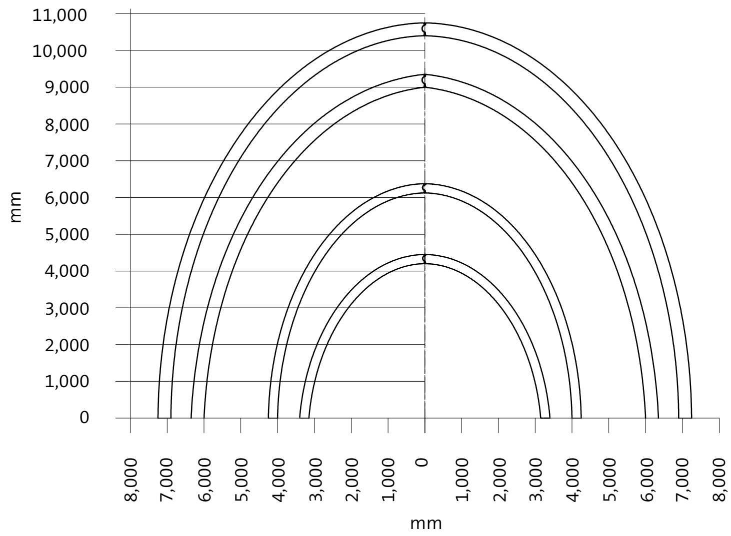
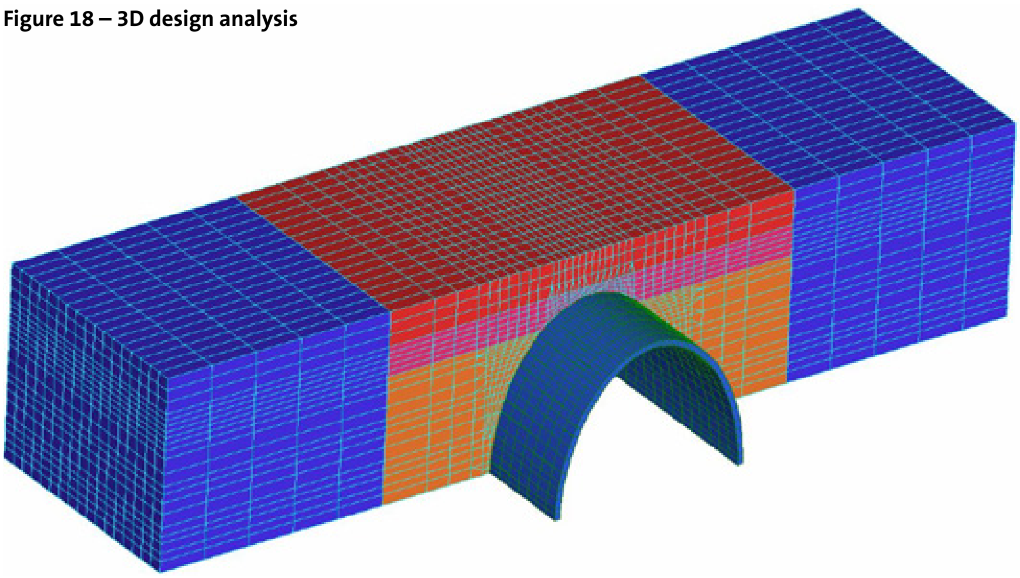


Figure 18 – 3D design analysis



Arch system components

A range of precast concrete products are usually provided as part of the arch structure along with a selection of retaining wall structures including:

- precast concrete feeder chambers to fit intake valves
- spandrel walls which run parallel to the arch, retaining the backfill at each end of the tunnel. They are designed to match the arch profile.
- wing walls which are placed at each end of the spandrel wall to retain the backfill and support the spandrel walls.

Top:
Arch system with spandrel wall and wing walls

Middle:
Spandrel wall

Bottom:
Wing walls

Box culverts

Top and bottom: Construction of a box culvert mine portal

Opposite page: Jacking pipe

Humes manufactures extra large span box culverts with spans and leg heights up to 6 metres. For additional strength, prestressed units and post-tensioning are also available.

A complete precast base and crown unit can be supplied for fast and easy installation. This will minimise the need for cast in-situ concrete, especially for remote mining sites.

Box culverts can also be jacked underneath railways and roads or slid into a pre-excavated tunnel.

Applications

- Portal entries - provide safe ingress and egress for mine and construction sites
- Conveyer tunnels
- Escape tunnels
- Railways and roads
- Drainage for haul roads

Features and benefits

- Designed to withstand explosion loads and impact from rock that may fall from a cut face.
- Designed to take heavy mining vehicle loads.
- Blast doors can be fitted into units as required.
- Custom made to suit project specific envelopes.
- Easy to install, no backfilling or jointing of units is required for structure stability.
- Can be installed to meet site grade condition.
- Conveyor belts are easily attached to the internal surface of the crown.

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

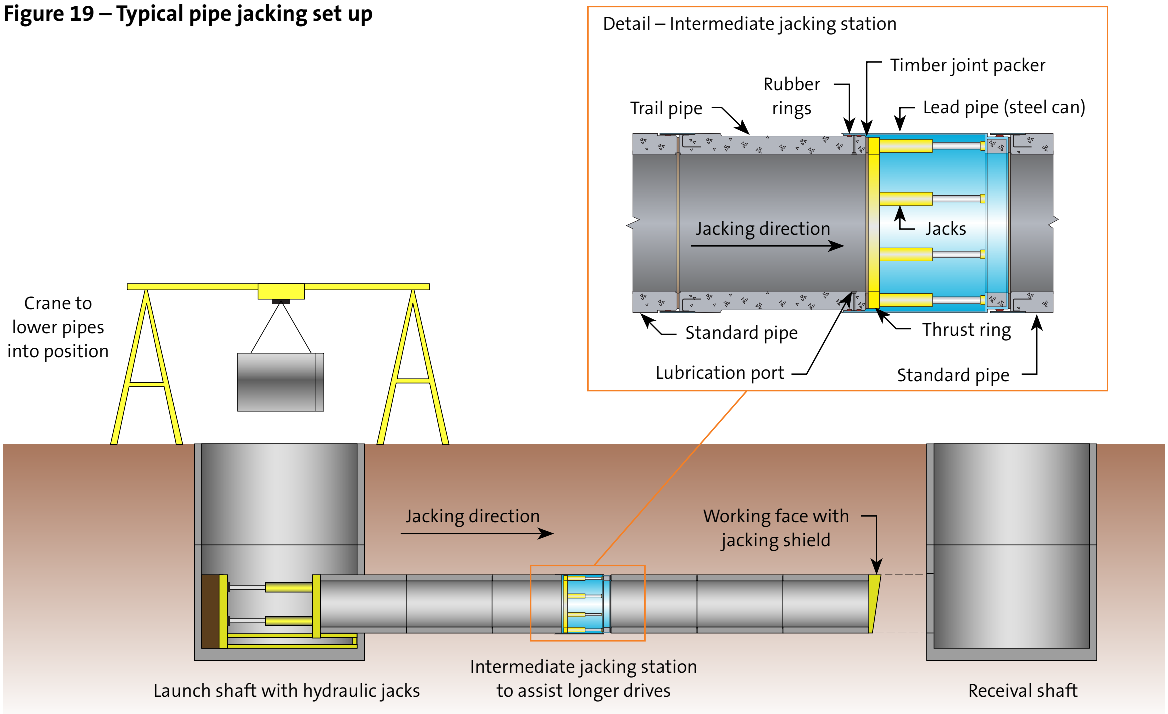
Environmental

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 19 – 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 collar: the S series which is fitted into pipes up to DN700 and the J series 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 series, factory secured internally to the steel socket band with adhesive. While, in the J series 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 series 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 22 and 23 on page 29. 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 20 – S series joint profile

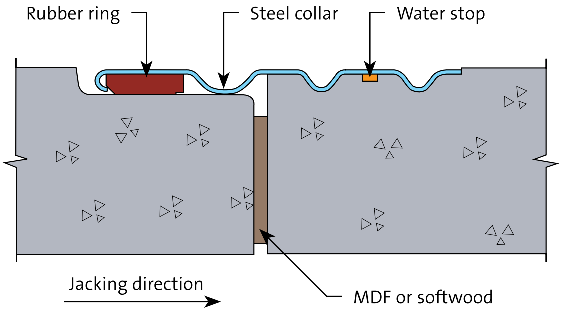
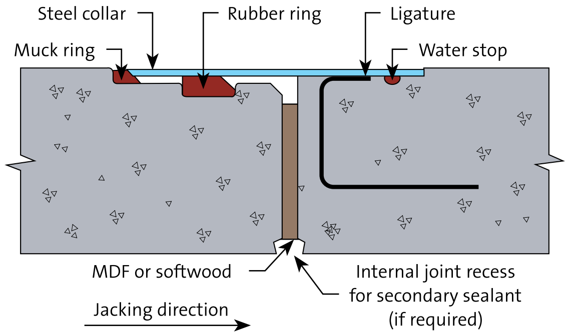


Figure 21 – J series joint profile



Secondary sealing recess

All J series steel 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 19 on page 24.

Table 4 – 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 series) Deep spigot groove (J series)	**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 series)	**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 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 22 and 23 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 22 and 23 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 22 – S series jacking pipes deflection curves

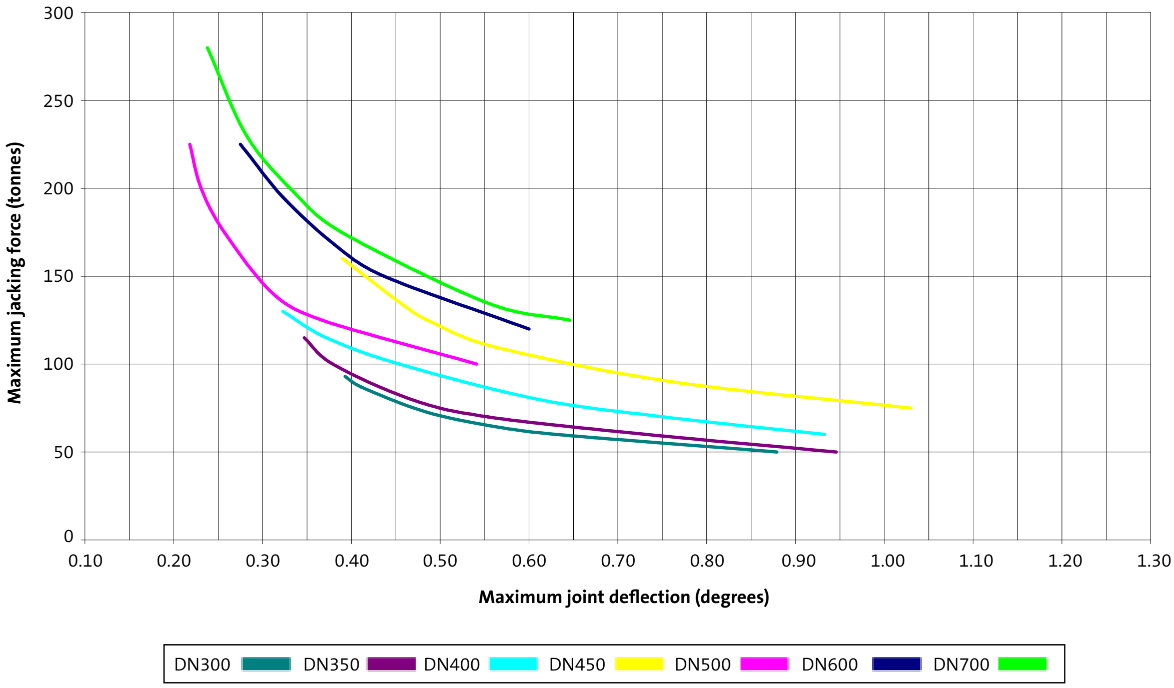


Figure 23 – J series jacking pipes deflection curves

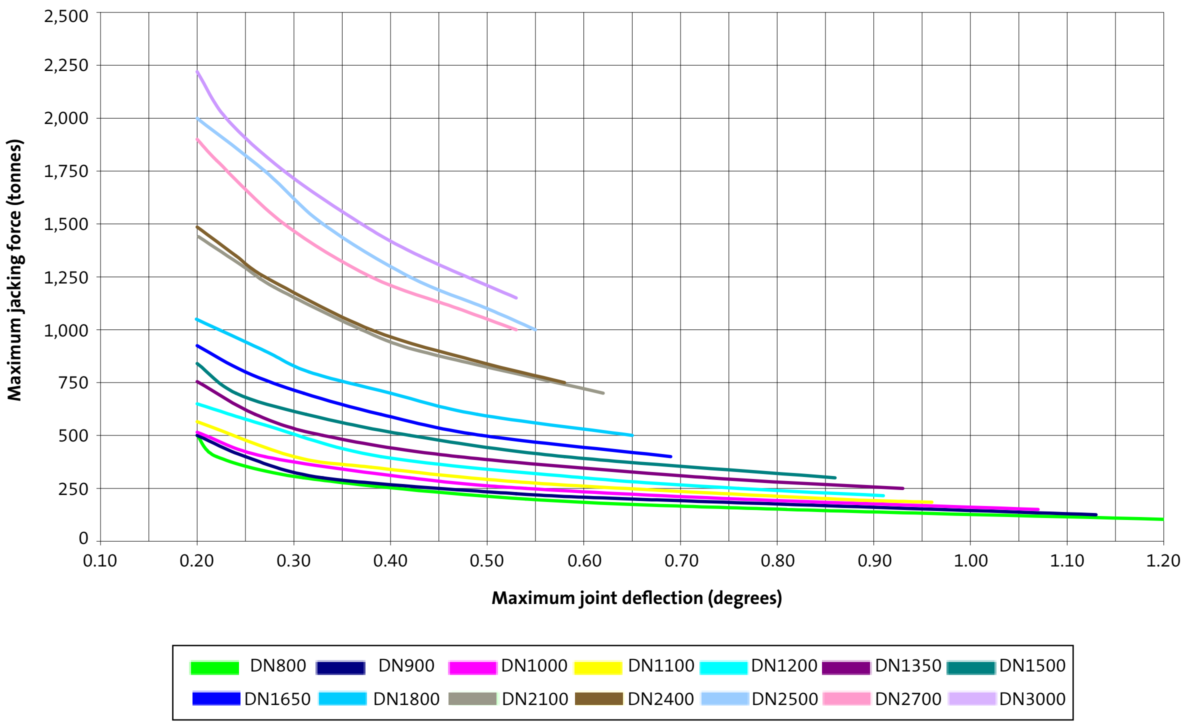
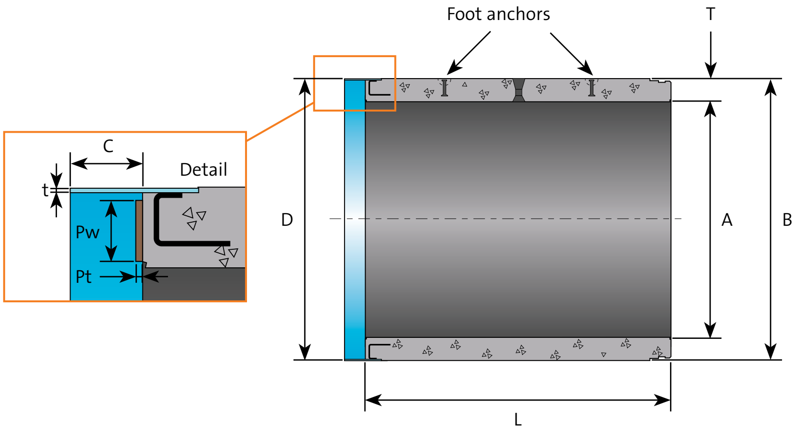


Table 5 – Fixed steel collar pipes dimensions, mass, jacking loads and deflections



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 Length 'C' (mm)	Steel collar ID 'D' (mm)	Steel collar Thickness 't' (mm)	Pipe mass (kg)	Max. jacking load (tonnes)	Collar type
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 24).

- **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 7 – Selection of jacking pipes (page 33), 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 25).

- **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 series pipe should be specified in these situations.

Figure 24 – Butt joint profile

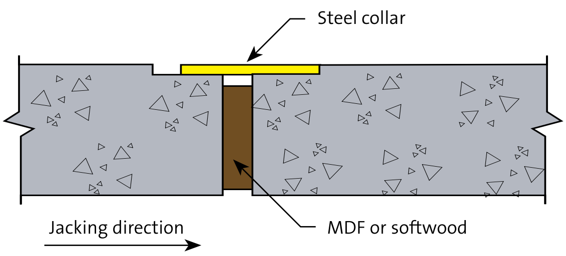


Figure 25 – In-wall joint profile

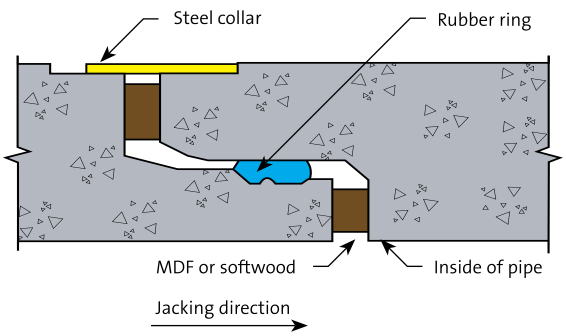


Table 6 – Loose steel collar pipe range

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 7 opposite provides a summary of the capabilities of each of our types of jacking pipes for different requirements and applications.

Table 7 – Selection of jacking pipes

Stakeholder	Jacking pipe requirements or application	Fixed steel collar		Loose steel collar	
		S series	J series	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	150§	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.

Figure 27 – Joint profiles for DN200 to DN300 pipe with Type 1 coupling

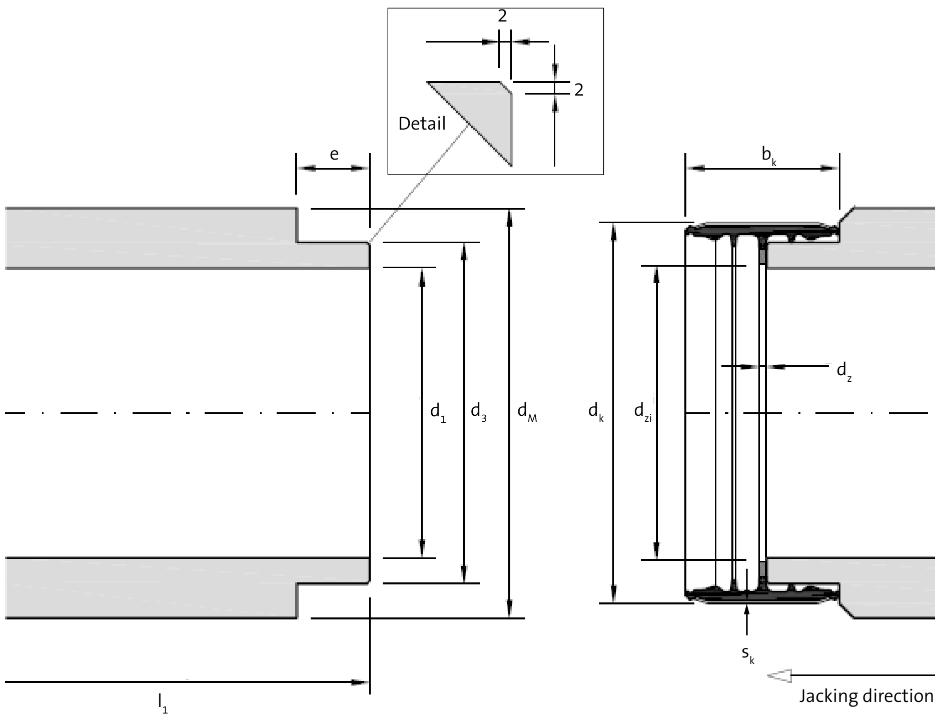


Table 8 – Dimensions for DN200 to DN300 pipe with Type 1 coupling (refer Figure 27 above)

DN	Pipe dimensions					Coupling			Pressure transfer ring			Max. jacking force*	Min. crushing load	Average weight
	Internal	Pipe end	Pipe body	Length	e	d_k ± 1	s_k ± 0.2	b_k ± 1.5	d_z ± 1	d_{za} ± 0.5	d_{zi} ± 0.5	kN	kN/m	kg/m
	d_1 ± 5	d_3	d_M	l_1 ± 1										
mm														
200	199	244^{+2}_{-2}	276^{+0}_{-6}	990	49^{+3}_{-1}	267.8	1.5	103	10	241	205	350	80	60
250	250	322^{+0}_{-1}	360^{+0}_{-6}	990 1,990	48^{+3}_{-0}	342.8	1.5	106	10	320	257	810	110	105
300	299	374^{+0}_{-1}	406^{+0}_{-10}	990 1,990	48^{+3}_{-0}	395.8	2.0	106	10	372	309	1,000	120	125

Notes:
1. * Permissible jacking force for automatic recording and control, safety factors 2 and 1.6.
2. Compressive strength = 100 N/mm².
3. Bending tensile strength = 14 N/mm².
4. Supplied with wooden pressure transfer ring according to EN 312 P5.
5. The ground spigot ends (d_3) are trimmed ca. 2 x 2 mm.

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