**Installing Piping Systems in Tunnels**

**Tunnels present designers and engineers with particular challenges when it comes to installing pipework. Grooved mechanical pipe-joining technology can help overcome these both during the design and construction phases, explains Dave Hudson, Senior Engineer with Victaulic.**

Tunnels occur in many construction projects: notably in major road and rail systems, as well as pedestrian subways, in mines, water and wastewater treatment plants, and even hospital buildings or medical campuses. Frequently long, seldom straight and commonly with access issues, tunnels pose a specific set of engineering challenges. These are chiefly accommodating curvature, directional changes and thermal movement but can also include limited installation time, lack of space to install pipework and a challenging environment.

Then there are the all-important health and safety considerations. The heightened risk of fire and increased difficulty in extinguishing a fire on a tunneling construction site, along with potential workforce exposure to noxious fumes with some joining methods, makes grooved piping the option of choice.

The grooved mechanical pipe-joining system is a safe, efficient alternative which takes up curvature and accommodates thermal expansion and contraction. As a flame-free method, it eliminates not only the dangers associated with hotworks but also the necessary fire watch together with time-consuming job-site preparation – all of which add time and labour costs to a tunneling project.

Grooved pipe-joining offers design flexibility, reduces stress on the piping and provides a more compact, easy-to-inspect and productive method of installation over other pipe-joining methods.

**Mechanical joining explained**

A grooved mechanical joint is comprised of four elements: grooved pipe, gasket, coupling housing, and nuts and bolts. The pipe groove is made by cold forming or machining a groove into the end of a pipe. The piping connection is secured by the coupling which houses a resilient, pressure-responsive elastomer gasket. The coupling housing fully encloses the gasket, reinforcing the seal and securing it in position as the coupling keys engage the pipe groove. The bolts and nuts are tightened with a socket wrench or impact wrench, which holds the housings together. In the installed state, the coupling housings encase the gasket and engage the groove around the circumference of the pipe to create a leak-tight seal in a self-restrained pipe joint. Once assembled, the mechanical coupling provides a union at every joint, allowing for ease in future system access and maintenance.

**Grooved mechanical piping systems in tunnels**

At the start of the construction, tunnel boring machinery will need to be supplied with pipework to provide clean water and compressed air and then to remove the earth in the form of a slurry. Using the grooved method can deliver a major advantage here. Its very flexibility means that piping can be readily modified as needed and extended quickly and easily as the tunnel progresses, enhancing the construction schedule.

Once built, a tunnel requires permanent services in the form of a fire main with hydrants located at intervals which the fire service will access in the event of fire – and maybe other services such as heating, air conditioning and domestic water. Thermal movement is an important consideration in the design and installation of piping systems in addition to following the tunnel curvature.

Designers, engineers and contractors have used grooved piping systems to address these issues in tunnels across the globe. They include the award-winning Tunnel de Fréjus between France and Italy; the Sydney Cross City Tunnel in Australia; the Fort Smith Lake Tunnel Pipeline in Arkansas, USA; the A6B tunnel in Paris; the Vielha Tunnel in Spain and the Metro Warszawskie and Vistula Tunnel in Poland.

Grooved technology is currently being used in the London Underground where Oxford Circus and Green Park stations are being retrofitted with air conditioning systems. Pipes required to transmit cooling water have to follow the curves of the existing tunnel and safety and speed of installation are vital. The need to keep the transport network operating as normal also means there is a very limited time overnight when work can be carried out. Grooved installation is helping to raise productivity and compress the schedule: with no cumbersome welding equipment to set up or remove from the job site, installing the pipework is much more time efficient and this flame free joining method does not require the removal of hazardous fumes.

**Angular deflection and linear movement**

Grooved mechanical couplings are available with two distinct performance features: rigid and flexible couplings. Rigid mechanical couplings are designed to ‘fix’ the joint in its installed position, permitting no linear or angular movement at the joints. Flexible grooved mechanical couplings on the other hand are designed to allow controlled linear and angular movement at each joint that can accommodate pipeline deflection and piping thermal movement.

The design of the components enables grooved mechanical flexible couplings to allow for controlled movement in the pipe joint. Because the dimensions of the coupling key are narrower than the groove in the pipe, the coupling key has room to move in the pipe groove. Additionally, the width of the coupling housings allows for pipe-end separation. This leaves room for controlled linear and angular movement at the joint. The mechanical coupling remains a self-restrained joint, and the unique pressure-responsive design provides sealing even under deflection and pipe movement.

***Figure A: linear movement Figure B: angular deflection***

**Thermal movement**

Based upon the type of tunnel, there are two causes of thermal piping movement that require consideration. The first is from ambient temperature fluctuations due to the change in seasons. The second is from internal fluid temperature changes such as in heating and cooling systems.

There are four common methods for accommodating this thermal pipe movement in a grooved system: utilizing the linear movement/deflection capabilities of flexible grooved couplings; providing an expansion joint utilizing grooved mechanical pipe components; providing an expansion loop utilizing grooved mechanical components; allowing the system to “free-float”. When constructing a tunnel, the selection of one or more of these methods is dependent on the system type, the scope of the project and the engineer's preference.

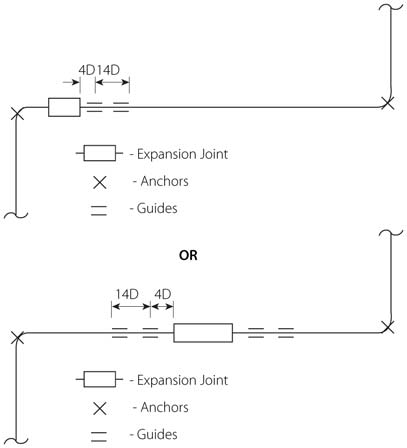
The simplest, most common and cost-effective option is to use the angular deflection and linear movement capabilities of flexible couplings as the natural choice. Grooved mechanical couplings are a good alternative to welded U-shaped expansion loops and welded offsets. These couplings are easier and faster to install and take up less space. .A system which is to be installed using grooved couplings can be designed to take care of both curvature and thermal movement within the flexible couplings’ free range of motion so system stresses are minimized and without any additional components or piping configuration.

For long straight runs it is common to use rigid couplings along the run and either the use flexible couplings on the perpendicular leg at each end or a grooved in-line expansion joint. In free floating systems, offsets of sufficient length must be used to accommodate movement within the design deflection capability of the flexible coupling.

**Expansion joints**

Expansion joints are in-line devices that can be compressed or expanded axially to accommodate thermal movement in a tunnel. Welded piping expansion joints are typically flanged into the system and, depending on the specific expansion joint design used, may require regular maintenance. Another cost-effective type of expansion joint utilizes flexible grooved mechanical couplings and specially-grooved, short pipe nipples. These expansion joints are preset to allow the desired amount of contraction and/or expansion. Axial movement can be adjusted by simply adding or removing couplings. When a series of flexible couplings are installed, the resulting grooved expansion joint will further protect equipment by reducing vibrations and stresses in the system. Grooved expansion joints are easy to install and are a useful solution, whether it be at the early design stages of a project or in retrofitting or extensions of piping projects.

Whether using specialty expansion joints or a grooved expansion joint, the adjacent piping must be properly guided to ensure the movement is directed into the device and no lateral movement is experienced.



***Figure C: anchoring and guiding piping***

**Expansion loops**

The flexible mechanical joint can be used in expansion loops utilizing a U-shaped pipe configuration while minimizing the stresses in the pipes, elbows or joints. A total of eight flexible grooved mechanical couplings, four grooved end 90-degree elbows and three pipe spools are required to complete each expansion loop. As system temperatures fall and the pipe run contracts, the loop expands and the deflection capability of the couplings accommodates this movement. As system temperatures increase, the opposite effect occurs as the pipe run expands and the loop contracts with the couplings accommodating the deflection in the opposite direction. The chief advantages of using grooved expansion loops over welded loops are significant reductions in both the size of the loop and the residual stresses in the piping system such as on anchor points to activate the loop.

**Efficient solution**

In summary, grooved mechanical systems offer a range of efficient solutions to pipework installation challenges in tunnels. Grooved pipe joining provides effective time proven methods for accommodating tunnel curvature and thermal pipe movement, while at the same time reducing stresses on the piping system and decreasing system maintenance needs. Additionally, the method helps to accelerate tunneling projects, reduce costs and minimize job-site health and safety risks. Tunnels throughout the world are fitted with grooved piping systems – a testament to the practical engineering and economic benefits of this technology.

**BOX-OUT 1**

**Tunnel and groove**

Contractors working on the 1300-metre tunnel under the Vistula River in Warsaw used grooved flexible couplings to accommodate curvature and thermal movement. The project was the first in Poland to benefit from tunnel boring technology when the tunnel was constructed in 2011 to transmit water from Warsaw’s left-bank districts to the Czajka waste water treatment plant on the right bank. Two 1.6 metre diameter pipelines run through the 4.5 metre diameter tunnel which also houses the track for a service railway car, ventilation systems, closed circuit television and other installations. The Victaulic pipe-joining system was selected to install the carbon steel lines for water, compressed air and slurry - safely, reliably and faster than if welding or flanging had been used. The method compressed the construction schedule and reduced the total installed cost. And because there were no hotworks or hazardous fumes associated with welding, jobsite health and safety was enhanced.

**BOX –OUT 2**

**Underground expansion**

The Ted Williams Tunnel is a 25-kilometre underground expressway in Boston Massachusetts. It includes a 12-kilometre stretch under Boston Harbour built using a dozen steel tube sections, each longer than a football field, that were sunk into a trench on the harbor floor and connected together. Allowing for movement of the interconnecting piping between the immersed tubes presented an engineering challenge. The solution was to use grooved expansion joints to provide the pipe movement necessary for the fire protection, water supply and drainage lines which ranged in size from 4 – 10” (100 – 250 mm).

**BOX-OUT 3**

**Durable joints**

The QueenswayMersey Tunnel near Liverpool in the United Kingdom opened in 1934 and was one of the earliest tunnels to use a Victaulic shouldered system on its original fire main installation. Remarkably, the couplings were still found to be intact when the system was recently refurbished, although pipe sections had disintegrated. This evidence of the durability of Victaulic products was the best possible reason for the contractor to specify its modern successor – the Victaulic grooved system – as a replacement. The fire main pipeline provides water to numerous fire hydrant stations along the entire length of the 3428 metre tunnel. Grooved pipe joining was chosen for its ability to cater for curvature of the tunnel and thermal pipe movement due to fluctuations in temperature. Since all work was required to be carried out at night, speed of installation was critical so the steel pipework was supplied in sections of 3, 6 and 12 meters, pre-grooved and painted with a protective coating to maximize the limited time available for fitting on site.

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