# DUCTILE IRON PIPE SYSTEMS

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Sustainably superior – ductile iron pipe systems

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ductile iron pipe systems

Dear readers,

at the WASSER BERLIN INTERNATIONAL 2011 international trade fair, the Fachgemeinschaft Guss-Rohrsysteme (FGR®) e. V./ European Association for Ductile Iron Pipe Systems · EADIPS® and its member companies who were exhibiting at the fair, briefed the professionals attending about what ductile iron pipe systems are capable of doing for them in the various applications the systems have in the water industry.

These include not only the traditional fields of water supply and sewage disposal, but also more recent applications to high-pressure systems such as trunk mains for water, penstock pipelines and pipelines for snow-making systems. Some notable advances in trenchless installation using ductile iron pipe systems were given public recognition by the conferring of the German Society for Trenchless Technology's GSTT Award 2011. Prize-winners included the press-pull technique with soil removal (2nd prize) and an HDD installation operation in Berlin (3rd prize); you can find articles on these in this issue of the Journal.
Sustainability is one aspect of all the installation operations carried out. I have already reported on this subject in issue 45.

In making this assertion, the FGR®/EADIPS® substantiates its claim that, from the point of view of sustainability, ductile iron pipe systems are economically, environmentally and technically superior. The technical articles in this issue will confirm this claim.

Sustainably superior – ductile iron pipe systems

I hope you will find plenty to enjoy in the new 46th issue of **DUCTILE IRON PIPE SYSTEMS.**

Yours sincerely,
Raimund Moisa

## Ductile iron pipe systems: sustainably superior

*Ulrich Pässler* ........................................................ 8

A particularly important consideration for capital investments in supply infrastructure is the technical operating life of the items installed. No pipe material is a match for cast iron in this respect, because it has already been used in the supply of drinking water for several centuries. The sustainability of ductile cast iron pipe systems from the environmental and economic points of view is demonstrated; additionally it's increasing use in trenchless installation techniques and in high-pressure applications is considered.

## Ductile iron pipes across the river Main guarantee safety and security in the long term

*Stephan Hobohm and Heinz-Jörg Weimer* ......... 13

The sewage from a million people in the city of Frankfurt am Main is treated in two treatment plants. Because of the topography, pressure pipelines have to be used to transport the sewage. For increased reliability of operation, a pressure pipeline crossing the river Main needed another pipeline in parallel. The planning and selection of the material for the installation of the culvert pipeline required under the river Main, using ductile iron pipes installed in an open trench is described as: a good lesson in thorough planning as a prerequisite for a successful installation.

## Pile foundations for a pipeline of ductile iron pipes below the water table carrying uncontaminated wastewater

*Roger Saner* ........................................................ 19

Ground with hardly any bearing capacity yet still highly corrosive, a pipeline zone below the water table, and topography giving only a very slight gradient – hardly the conditions under which you would expect to install a non-pressurised wastewater pipeline able to operate successfully in the long term. Yet it has been done with vonRoll*geoecopur* ductile iron pipes! They had to have pile foundations so that the gradient, slight anyway at < 3‰, would not be jeopardised by settlement.

## The municipality of Kutzenhausen – New pipes for ducting the Schüttgraben, a DN 800 pipeline on pile foundations

*Simon Hähnlein and Manfred Schmied* ............. 24

Sometimes in a relatively small operation a number of individual and difficult problems may arise simultaneously, for example: when a stream is ducted into pipes which are dilapidated and have to be replaced; in ground with inadequate bearing capacity, below a road carrying heavy goods traffic. After a survey of the ground, it was possible to make a decision on an alternative route and that in turn provided the technical solution: the new pipeline of DN 800 ductile iron pipes for ducting the stream was given foundations formed by driven ductile iron piles.

## Installation of butterfly valves in plant equipment at the Bad Zwischenahn waterworks

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Butterfly valves, may be less spectacular than the pipes and are often not seen, but that is why it is all the more important for them to operate reliably. The waterworks has had a varied history, which began when it supplied drinking water to a military airfield during the Third Reich. Today it is a vital resource in what is now the peaceful and prosperous spa town of Bad Zwischenahn. Ductile iron butterfly valves are the guarantee for a safe and secure supply of drinking water.

## Which came first – the pipe or the seal?

*Felice Pavan* ........................................................ 30

It is amazing how materials as different as iron and rubber have developed; in the case of ductile iron pipelines the development has sometimes gone on in parallel. This is because pipelines for drinking water and sewage are important infrastructures, which all communities with flourishing economies need.

### The impact of the new EN 545 on practical planning and design for ductile iron drinking water pipelines

*Jürgen Rammelsberg* ......................................... 33

Having introduced pressure classes for pipes not subject to longitudinal forces, EN 545:2010, the new product standard for ductile iron drinking water pipes, still does not contain a practical solution for dealing with and marking the pipe system which has joints restrained against longitudinal forces. With such joints, the allowable operating pressure is generally appreciably lower than the pressure given by the pressure class. In an association standard of its own, the FGR®/EADIPS® will shortly be proposing a practicable procedure for dealing with and an unmistakable marking for these pipes, to cover the period until EN 545 is revised.

### Re-organization of the Wertheim water supply system – Feeder pipeline to the Eichel/Hofgarten district

*Erich Amrehn and Frieda Elenberger* ............... 38

Changes to official rules and regulations are sometimes the reason for an existing supply network being re-organized and for new and better quality water being distributed at a lower cost. This is what happened in Wertheim where, although the constraints were difficult, a further pressure zone was even added. The selection of the material was exemplary: in rocky ground, rugged ductile iron pipes and fittings are the ideal prerequisites for a viable long-term investment.

### Generating electricity by water power – An important contribution to the phasing out of atomic energy

*Andreas Schütz* ................................................ 42

Mountainous regions in Switzerland are often blessed by considerable differences in height between intake structures at springs and the drinking water reservoir serving a local community. What are referred to as drinking water power stations can kill two birds with one stone, the local water supply is combined with the local generation of green electricity. With guaranteed feed-in tariffs, the installation of the station soon pays for itself. Ductile iron pipes with restrained push-in joints are equal to the high operating pressures, are easy to install even in difficult terrain, and their robust material will withstand any external loads.

### Culvert pipeline under the river Traun near Linz High performance by ductile iron pipe systems

*Ingo Krieg* ......................................................... 45

Ductile iron pipes as problem solvers – that is how they are often seen, because they become a talking point in spectacular special cases. Often forgotten though are the many kilometres of ductile iron pipeline which go into the ground unnoticed under "bread and butter" contracts and quietly do their duty there for decades. But the real source of pride to those involved in the installation is of course problems successfully overcome, as here on the Traun where there were several types of river crossing – an instructive example of the universality of ductile iron pipe systems.

### Zweckverband Gruppenwasserwerk Dieburg supply utility – Southern trunk water main from Hergershausen to Gross-Zimmern

*Heinz-Jörg Weimer* ........................................... 48

Often there is not an easy solution for a technically demanding problem. Things are deferred and the problem becomes more urgent. Restricted and complicated routes for pipelines in which other construction and installation companies and agencies have a say, may be particularly critical in this case. Almost all the practical problems arising with pipelines can be solved with ductile iron pipes – easily, inexpensively and for the long term. Here is a project report which is typical of many similar cases.

### World premiere at WASSER BERLIN INTERNATIONAL 2011 – The press-pull technique with soil removal

*Stephan Hobohm and Franz Schaffarczyk* ........ 51

As so often in the past, Berlin has been the scene of an innovation in pipeline installation. The press-pull technique, a tried and trusted trenchless pipeline replacement technique, had to be modified because the soil displacement needed for the upsizing required for the new pressure pipeline was impossible with the given height of cover. The press-pull technique was therefore expanded to include soil removal, a reliable way of preventing a hump from being formed above the pipeline on the surface of the ground. The new technique made its debut on the Construction Site Day which formed part of the WASSER BERLIN INTERNATIONAL 2011 fair. On 07.12.2011, this project was awarded 2nd prize under the GSTT Award 2011.

A new record in Germany: on a strip of land on the banks of the river Havel where access was difficult, a 490 m long DN 700 pipeline for raw water has been installed using the horizontal direction drilling technique.
The 82 pipes with BLS® push-in joints were assembled and pulled in, on an enclosed assembly ramp, in 34 hours.
The onset of severe winter weather and high water levels interrupted the work for two months but the project was still completed within the time scheduled.
The project was awarded 3rd prize at the GSTT Awards 2011.



The encouragement to generate renewable energy which is provided by fixed feed-in tariffs, often results in existing small hydroelectric power stations looking at ways of increasing their capacity. Though it is only nine years old, this was achieved at the Tasser power station in South Tyrol, whose output has been boosted by 60 % by lengthening the existing penstock pipeline by 1,225 m and thus increasing the pressure in it from 15 bars to 28 bars. The installation of the extra length was extremely difficult, involving drilling through 174 m of rock, but it meant that the material for the penstock pipeline was easy to select: ductile iron pipe systems are equal to any challenge.



Ductile iron pipes for snow-making systems – this is an application which is showing satisfying levels of growth. The external conditions, steep runs of pipe, difficult ground, routes which are difficult to access, and high operating pressures: these are challenges which are just right for ductile iron pipe systems. This has once again been demonstrated on the Feldberg mountain in the Black Forest.



The 25 year success story of ductile iron driven piles – from their invention in a Swedish pipe foundry to today's 5 million metres of driven piles – is inconceivable without the properties of ductile cast iron, without the production of virtually monolithic foundation piles of all lengths from individual to mass-produced pieces, and without the minimal installation and site costs. Even very strict clients such as SBB (Swiss Federal Railways) use ductile iron driven piles as foundations for their network structures – sometimes while services continue running.

# Ductile iron pipe systems: sustainably superior

*by Ulrich Pässler*

## 1 Introduction – the development history

Around 150 years ago in Europe, the infrastructure for supplying towns and cities with gas and water was laid almost entirely in cast iron pipes. A large proportion of today's supply networks still date from that time. Over the years, the development of crucial aspects of the cast iron pipe system has continued: production processes have adapted to meet the increased requirements for dimensional accuracy, reductions in wall thickness and cost-effectiveness, and joints have become safer, more reliable and easier to connect. The triumphal progress of the cast iron pipe from the grey cast iron pipe of those days to the ductile iron pipe of modern times is a reflection of the story of industry itself and is an impressive demonstration of the qualities of ductile cast iron and of the many obvious advantages it has. There is no pipe material that can provide such clearly demonstrable proof of its durability as ductile cast iron.

Over the years, a series of other materials apart from ductile cast iron have been developed for pipes carrying drinking water and sewage but closer inspection shows none of them to have any major advantages over this traditional material. On the contrary, when it comes to reliability, durability, resistance to damage and sustainability, there is at the moment no pipe material which can offer higher standards of performance than ductile iron. This is just as true of pipes for pipelines for drinking water, where the very highest quality and purity has to be guaranteed, as it is of ones used in pipelines for sewage, which has to be transported safely to treatment and purification plants. And it is equally true of fittings and valves of ductile iron, whose reliability helps with the installation of pipelines and makes them sustainably safe.

## 2 Clear advantages in term of cost

Particularly in the very recent past, certain competing materials have tried to make out a case for themselves as having an advantage in terms of price. And in times when budgets are tight this supposed advantage has tempted municipalities and supply companies to make decisions that look only at the short term. However, on closer inspection the price-based argument proves to be deceptive because effects which only become apparent in the medium to long term are often ignored and the responsibility owed to future generations is thus often forgotten.

It has been shown by, for example, studies comparing the costs of plastic and ductile iron pipes over a period in use of 15 years that, as from a nominal size of DN 200, if not a smaller one, ductile iron pipes quite clearly have major advantages and that, as the sizes become larger, so do they become increasingly superior.
At a nominal size of DN 400, the advantage in terms of cost of using ductile iron pipes over using plastic ones can be calculated as more than 20% over the period mentioned [1]. This advantage is achieved by, amongst other things, more efficient installation.

**Ductile iron pipes, with their easily connected joints, can be installed quickly and easily regardless of the weather.** Polyethylene pipes on the other hand, whose joints have to be welded, involve considerably higher expenditure on, amongst other things, the skilled and certified personnel required for the welding. Also, dry weather is needed for the welding, and this means an increase in costs for the welding when the weather is bad and thus a decrease in the efficiency of installation.

**Fig. 1**
Ductile iron pipes do not require a sand bedding

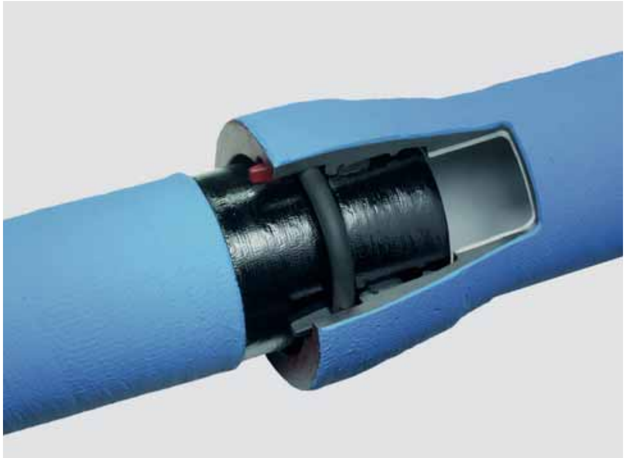

**Fig. 2**
A ductile iron pipe with a cement mortar coating and a restrained push-in joint

**The rugged ductile iron pipe system does not require a sand bedding (Fig. 1)**. Depending on the external protection, the material excavated from the trench can be re-used for installation, even at grain sizes up to 100 mm [2].
With plastic pipes, there is still some contention on this point: whereas under Appendix G to DVGW Arbeitsblatt W 400-2 [2] the grain size is limited to 40 mm (round grains) for polyethylene pipes > DN 200, according to [3] plastic pipes are installed in a bed of sand to protect them against external damage under the current rules. Without this bed of sand, some pipes would be very highly stressed by external loads or changes in pressure [3]. Hence, the nature of the material surrounding the pipe has to be such that the pressurised pipe carrying the medium is protected against external damage. This generates extra costs for the material and its transportation, extra costs which are unnecessary with ductile iron pipe systems.

**Under normal installation conditions and if restrained joints are used, ductile iron pipes manage without concrete thrust blocks** – another advantage which can impact on the costs of the pipeline **(Fig. 2)**.

**In the long term, as the studies mentioned above and also the damage statistics compiled by the DVGW (German Technical and Scientific Association for Gas and Water) have shown, ductile iron pipes also have considerably lower fault and damage rates.** The DVGW Damage Statistics for Water [4] (years surveyed 1997 to 2004, covering the whole of the Federal Republic of Germany) show a damage rate (number of damaged points per 100 km) of 4 for ductile iron pipes for 2004. For HDPE pipes the rate was 50 % higher, namely 6. With ductile iron pipes the proportion of damaged points caused by external effects was only about 5 % whereas it was approximately 18% with HDPE.

There could hardly be a clearer demonstration of the advantages of ductile iron pipes. A decision to use ductile iron pipelines therefore produces an investment whose advantages are sustainable, because there is also a saving on the cost of maintenance and repairs in the long term. Added to this are "incalculable" advantages from the environmental and hygienic points of view which make the ductile iron pipe a superior alternative investment even in very small nominal sizes.

## 3 Safety below ground. Responsibility for the environment

The raw material used for ductile cast iron is pre-sorted recycled steel scrap. In contrast to plastic pipes, virtually no primary or fossil raw materials have to be used for ductile cast iron, thus reducing $CO_2$ emissions and the demands made on natural resources. **Ductile iron pipes make a positive contribution to the environment.**
**An important factor in any environmental and hygienic consideration is ductile cast iron's impermeability to diffusion.** For the protection of drinking water and for sewage pipelines, this is an unbeatable argument. Where the diffusion of chlorinated hydrocarbons for example is possible, polyethylene pipes are around 1,000 times more permeable than ductile iron pipes [5].

What is more, ductile iron pipes have a guarantee of hygienic and environmentally friendly operation in the form of their linings (polyurethane to EN 15655 [6] and mortar based on blast furnace cement for the supply of drinking water [7] or mortar based on high-alumina cement for the disposal of sewage [8]).

## 4 Durability: Avoidance of future expenditure

There is no other pipe material which can provide such convincing practical proof of its durability, and therefore of the safety which it maintains for generations, as ductile iron. The technical operating life of ductile iron pipes is up to 140 years. If ductile iron pipes with their high-grade coatings as follows

- a cement mortar coating (ZM-U) to EN 15542 [9] and
- polyurethane (PUR) to EN 15189 [10]

are taken as a basis, they provide a particularly impressive and emphatic confirmation of this long operating life. A systematic study has been made in which the outer surfaces of pipes which had been in operation for periods of up to 32 years were examined and samples for examination under DIN 50929, part 3 [11] were taken of the native soils and of the bedding materials used in the respective cases. At all the test digs, it was found that, after being in use for from 25 to 32 years, pipes coated with cement mortar were in a virtually good as new state and were not showing any damage due to corrosion [12].

Similar studies to provide practical proof of the long-term resistance of the polyurethane coating are going on in Switzerland. Two runs of test pipeline, which are continuously monitored by the SGK (Swiss Society for Corrosion Protection), have been operating for more than 20 years in Zurich. The protective potentials of the polyurethane coated pipes and their contact resistances with the ground are measured in different soils. In all the beddings studied, these field studies show constant good performance on the part of ductile iron pipes coated with polyurethane [13].

**From all these studies, it can be concluded that these ductile iron pipe systems with high-grade coatings, will undoubtedly achieve a technical operating life of 100 to 140 years.**

A glance at the pre-industrial era reveals another impressive fact: In 1783, Clemens Wenceslaus, the Archbishop-Elector of Trier, gave instructions for a water pipeline to be laid to supply the public wells of the town of Koblenz. This pipeline, known as the Metternich water pipeline, consisted of socketed cast iron pipes of a laying length of 1.5 metres and a diameter of 80 millimetres. When, after more than 150 years, this pipeline was exposed in 1934, it was found that the material of the pipes was still in excellent condition after their long time in operation. The then Lord Mayor of Koblenz confirmed this in an official letter to the "Deutscher Gußrohr-Verband" [14], today's europäische Fachgemeinschaft Guss-Rohrsysteme (FGR®) e.V./European Association for Ductile Iron Pipe Systems · EADIPS®, www.eadips.org.

Polyethylene pipes are assumed to have an operating life of around 60 years. That is less than half the demonstrable working life of ductile iron pipes. This means that re-investment and rehabilitation budgets can be set at an appreciably lower level when ductile iron pipes are used.

## 5 Trenchless installation techniques and pipelines subject to high stresses

Trenchless installation techniques have now become very important all over Europe. To avoid site noise and obstacles to traffic in inner-city areas and to allow crossings to be made under obstructions such as roads or rivers, trenchless installation techniques are now indispensable when pressure pipelines have to be replaced. They are low-cost techniques which are kind to the environment. There was been a close connection between their development and the ductile iron pipe and its joints and types of external protection. Because of their ability to carry high mechanical loads, ductile iron pipes with restrained joints are very much superior to pipes of any other material for trenchless installation **(Fig. 3)**, a superiority which is also seen in the allowable tractive forces which can be used with them **(Fig. 4)**.

**Fig. 3**
A DN 125 push-in joint being connected on a burst lining project

**Fig. 5**
Ductile iron fittings and valves

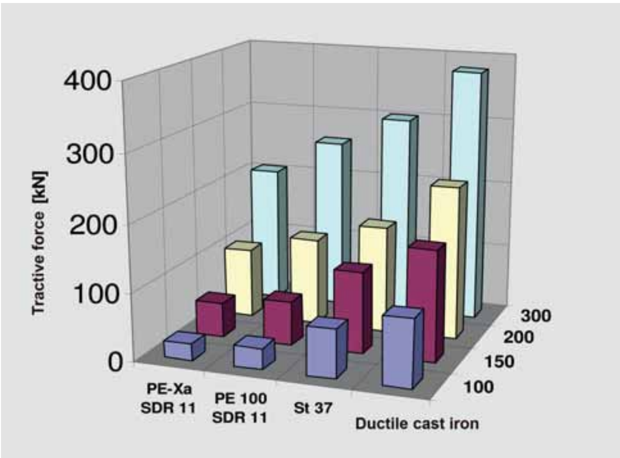


**Fig. 4**
Allowable tractive forces on pipelines in trenchless installation and replacement techniques

This superiority is also apparent in other heavy-duty applications. The strength of plastic pipes to resist pressure is limited and because of this they can be used to only a very limited extent, if at all, for turbine pipelines for example, which have to withstand high pressures and generally have to be installed in topographically difficult terrain.

Because of the properties of their material and the different types of external protection available, ductile iron pipes on the other hand can be installed without any problems even in rocky terrain and are even suitable for operating pressures of more than 100 bars. It is not only in the case of snow-making systems, which are generally located in mountainous terrain, and in the case of pipelines for fire extinguishing water, which call for a fireproof material for the pipes, that these advantages become clear. They also apply in principle to any ductile iron pressure pipeline used in municipal water supply, which needs good safety margins.

## 6 To sum up

Ductile iron is a material which can be used in any pipeline and water management applications and one which, due to its superior technical properties, the cost-saving technology used for its coatings and joints, and the full range of fittings and valves which is available **(Fig. 5)**, is able to guarantee long-term safety wherever it is used. Though a traditional material, cast iron is in fact more up to date than ever because it meets the demands of the future for the economical use of resources and for long-term cost advantages and therefore for true sustainability.

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# Ductile iron pipes across the river Main guarantee safety and security in the long term

*by Stephan Hobohm and Heinz-Jörg Weimer*

The experts at Frankfurt's drainage and sewage disposal utility Stadtentwässerung Frankfurt am Main (SEF) called it a special event such as happens only once a decade. On 10 March 2011 a new culvert pipeline for sewage was pulled through the bed of the river Main.
Since June 2011 the sewage from the town of Kelsterbach has been flowing through it to the sewage treatment plant at Frankfurt-Sindlingen. SEF is a Frankfurt-owned municipal utility and it has invested 3.3 million Euros in this new 267.5 metre long pipeline, including the connections to the existing pipelines on both sides of the Main.

## 1 The situation at the outset

The sewage from almost a million people in the Frankfurt urban area – which means, in dry weather, around 300,000 m³ a day or 15,000 tanker-lorry loads flows into the sewers and to the Niederrad/Griesheim and Sindlingen sewage treatment plants. There is another treatment plant in the town of Bad Vilbel, but the nature of the topography means that only the sewage from Nieder-Erlenbach flows to that. However, it is not just the sewage generated in the Frankfurt urban area; also connected to Frankfurt's sewer network are the Abwasserverband Main-Taunus and Westerbachverband sewage utilities and also five other towns (Offenbach, Kelsterbach, Neu Isenburg, Steinbach, and the Bischofsheim district of Maintal).
Previously, a pumping station on the left bank of the Main had pumped the sewage from Kelsterbach, a town on the south-western edge of Frankfurt, to the treatment plant in Sindlingen through a DN 500 size pressure pipeline. The maximum pumping rate was about 240 L/s. After about 450 m, this pressure pipeline crosses the Main at the point where the Bonnemühle mill belonging to the Okriftel district of Hattersheim is situated and on the right bank of the Main runs for another 2,250 m to where it opens into a gravity sewer at the treatment plant. Nowhere along the entire length of some 2,700 m are there any possibilities of a diversion or any retention facilities.

The pipeline was laid in 1981. At the last inspection carried out under the German Sewage Monitoring Regulations there was found to be slight damage and the SEF therefore felt itself compelled to act. Repairing the damage would necessarily have involved withdrawing the pressure pipeline from service for a time and this would not been possible without a replacement for the pipeline crossing the Main.
To ensure the reliability of the pressure pipeline and also to enable strategic action to be taken in the event of a fault, a new pressure pipeline had to be installed **(Fig. 1)**.

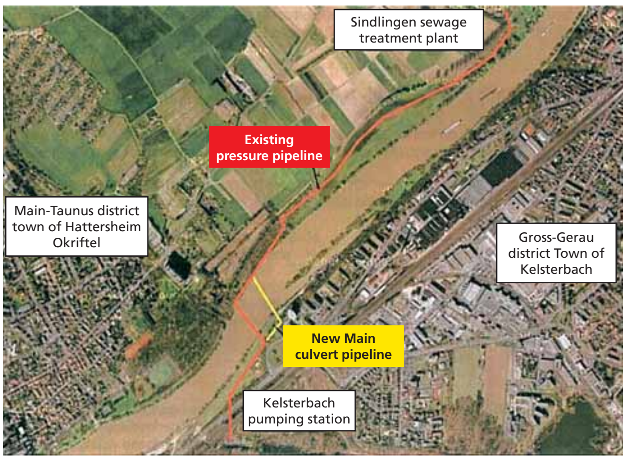


**Fig. 1:**
Path followed by the sewage pressure pipeline and position of the new culvert pipeline

## 2 The planning phase

As part of a feasibility study, a variety of options for the Main crossing were examined involving different routes and different laying techniques and materials. The comparison was therefore confined to the section of pipeline between the left and right banks of the Main and to the ascending sections on the two sides running to the connections to the existing pipeline. An open-trench crossing of the Main was found to be the simplest solution. It meant that only a trench, in which the pipeline would subsequently find a home, would have to be excavated in the bed of the river. This technique had the following advantages:

- very minor interference to nature and the environment,
- a route of comparatively short length,
- low installation costs,
- a technique which presented only minimal risks.

For the open-trench crossing of the Main, the trench for the culvert pipeline would be dug by the dry or dredging method of excavation, and the culvert pipeline would be installed and the trench refilled. It is true that major incursions would have to be made into the surface of the riverbed, but this is the technique where the laying soil poses the fewest risks. Even obstacles such as boulders, remnants of structures, etc. could be removed so to make sure that the culvert pipeline could be laid.

Once the laying technique had been decided on, the usual laborious business of obtaining all the consents and approvals followed. The districts, municipalities and other authorities having given the go-ahead, there was one more obstacle that had to be overcome: there are still bombs and shells from the Second World War lying on the bed of the Main. A check therefore had to be made to see whether there were still any dangerous leftovers that had to be removed. Areas of 4,500 m² in the Main and 500 m² on land and on the banks were searched. The divers came across all sorts of objects – bicycles and even mopeds – but luckily nothing of an explosive nature.

**Fig. 2:**
A ductile iron sewer pipe with a BLS®/VRS®-T push-in joint

In respect of the material, the client opted in the end for DN 500 ductile iron pipes to EN 598 [1] with BLS®/VRS®-T push-in joints and a cement mortar coating (ZM-U) to EN 15542 [2] **(Fig. 2)**. The reasons for this decision included:

- short delivery times for pipes and fittings,
- quick and easy assembly,
- assembly is possible in all weathers (including frost and snow)
- maximum corrosion protection provided by a zinc coating and the ZM-U
- being economically attractive
- durability,
- maximum safety margins to deal with unplanned loads,
- proximity to manufacturer's site (for technical support).

In the course of wide-ranging technical consultancy meetings held by the pipe supplier's Applications Engineering Division with Hülskens, the installing company from Wesel, all the details relating to the equipment specifications, the installation procedures and the leak testing were settled in full, in advance of the installation. In the light of the pipes to be used, the Hülskens company was then able to decide on and calculate the precise technical specifications for the design of the culvert pipeline. This showed the total weight of the culvert pipeline made up of the pipes, supporting structure and end sections to be some 82 t.

The calculation of buoyancy showed there to be a safety factor of just on 1.3 during the installation phase (pipeline empty, no cover of riverbed material). The maximum tractive force to be expected, given by the weight of the culvert pipeline structure and the installation technique, was determined as 15.22 t so the planning included two cable winches each providing a tractive force of 16 t. The maximum tractive force occurs shortly before the end (fully pulled-in) position and is calculated from the total buoyant weight of the culvert pipeline multiplied by a coefficient of friction $\mu = 0.65$. The overall tractive force was applied by the

**Fig. 3:**
Driving the sheet piling

**Fig. 5:**
The supporting structure on rollers

**Fig. 4:**
Dredging work

cable winches, via return pulleys, to a traction head which was connected to the structure supporting the culvert pipeline. This stopped any tractive forces from being transmitted to the pipeline itself.

Another point in the actual planning for the work was the fixing of the minimum radiuses. The BLS®/VRS®-T push-in joint of DN 500 ductile iron sewer pipes allows an angular deflection of 3°. This gives a minimum radius of 115 m. The Hülskens company's calculations showed the supporting structure to have a smallest allowable bending radius of 102 m. For safety's sake, a minimum radius of 150 m was decided on for the line followed by the pipeline and for the digging of the trench floor and the pull-in ramp.

## 3 The installation phase

### 3.1 Preparatory operations

After the quite long planning phase described above, the installation work got underway in October 2010.

Before the actual pulling-in, a trench some 2.5 to 3 m deep and just on 150 m long was excavated across the Main. A special dredger which kept exactly to the minimum radius of 150 m preset for the floor of the trench was used for this. The spoil excavated from the trench was taken away by barge and was later re-used as backfill material. This was possible because of the external protection on the pipes (a cement mortar coating applied in the factory). Under EN 545 [3], ductile iron pipes with a ZM-U coating can be installed in soil of any desired corrosiveness, i.e. even below the bed of a river.

The allowable maximum grain size of the backfill material is limited to 100 mm under DVGW-Arbeitsblatt W 400-2 [4] in this case. While the trench was being dredged, sheet piling was being driven on both sides of the Main and the launch and target pits and the pull-in ramp were being dug **(Figs. 3 and 4)**. A direction-changing frame was installed in the target pit, by means of which the traction cable was passed from the two cable winches through the trench to the traction head on the structure supporting the pipeline. At the same time as these operations, a start was made on building the supporting structure and assembling the pipes.

## 3.2 Assembly of the culvert pipeline

To minimise the pulling-in forces, the entire culvert pipeline including the supporting structure was assembled on rollers spaced 3 m apart **(Fig. 5)**. The load-bearing capacity of each individual roller was 13 t. The supporting structure was laid along the tops of the rollers. The structure mainly consisted of a 1,000 mm wide traction plate at the bottom, two 100 mm high angles forming the edging formwork, and the ballasting concrete (1,000 mm x 100 mm). The ascending supporting structures for the end sections of the pipeline were welded on at the beginning and end **(Fig. 6)**.

Winter set in early with temperatures well below freezing and snow, but in spite of this the next step, the assembling of the pipes, got started on time, not least because of the advantage of ductile iron pipes being able to be installed regardless of the weather. Using wooden saddles and steel straps, the DN 500 ductile iron pipes were fastened to the concrete-filled supporting structure together with two DN 100 ductworks **(Fig. 7)**. Ascending sections were formed at the two ends of the culvert pipeline because what would later be the connections to the on-shore pipelines were some 2.5 metres above its axis. The ends of the pipeline were closed off with fittings from the BLS®-/VRS®-T range **(Fig. 8)** and subsequent pressure testing could thus be carried out without any further shoring. The Vorwerk company of Halle/Saale, which has had plenty of experience with the laying of ductile iron pipes, was the contractor for the connection of the pipes. The actual assembly of the pipeline and its end sections took only three days. The severe frost and the high water level which followed **(Fig. 9)** stopped the pressure test from being carried out immediately but it did go off satisfactorily early in February.

**Fig. 6:**
Ascending section and supporting structure

**Fig. 8:**
Connecting a dead end

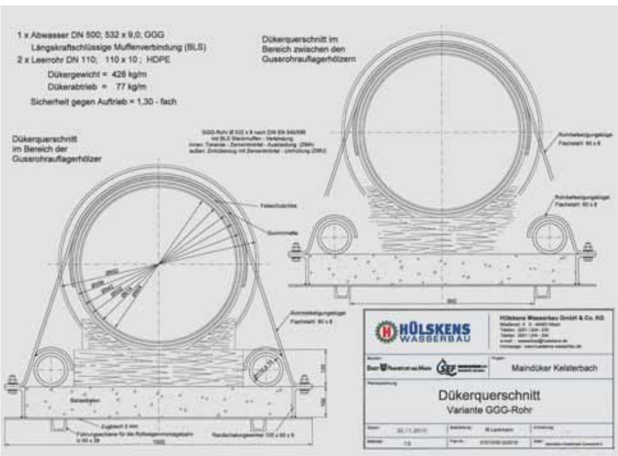


**Fig. 7:**
Cross-section of culvert pipeline

**Fig. 9:**
High water level

**Fig. 10:**
The traction head

**Fig. 11:**
Looking from the direction-changing frame over the cable winches to the left bank of the Main

### 3.3 Pulling-in of the culvert pipeline

As well as carrying the tractive forces, the supporting structure described not only ensured a stable position during the pulling-in but also gave added weight to stop the pipeline from floating up during the pulling-in. The traction head was fitted to the end of the supporting structure closer to the river **(Fig. 10)**. Fastened in the traction head was a return pulley for the traction cable and the latter ran across the Main and over a direction-changing structure to the two cable winches **(Fig. 11)**. Then, on 10 March 2011, the time had come and the pulling-in could start. The pulling-in operation began dead on 10 a.m., watched by 100 or so interested spectators.

The entire structure was pulled off the rollers towards the Main. The roller-equipped track ended about 20 m before the water line so the pipeline had to be pulled along the ground in this area. The front ascending section then began to slide into the water, to come to the surface again on the left bank of the Main some 2.5 hours later. The traction force measured during the pulling-in operation was a maximum of 14 t.

For safety reasons there was a ban on any navigation on the river on this day.

**Table 1:**
Technical data in brief

| | |
|---|---|
| **Standard depth of cover** | Standard depth of cover ≥ 1.2 m on land, ≥ 2.0 m under the Main |
| **Pipes** | DN 500 ductile iron pipes to EN 598 [1] with BLS®/VRS®-T push-in joints and NBR TYTON® gaskets to DIN 28603 [5] |
| **Coating** | Zinc coating (200 g/m²) plus cement mortar coating to EN 15542 [2] |
| **Lining** | Cement mortar lining based on high-alumina cement, to DIN 2880 [7] and EN 598 [1]<br>Thickness of layer ≥ 5.0 mm |
| **Protection for sockets** | ZM-U protecting sleeve |
| **Fittings** | DN 500 ductile iron fittings to EN 545 [3] with BLS®/VRS®-T push-in joints and NBR TYTON® gaskets to DIN 28603 [5] |
| **Internal and external coatings of fittings** | Epoxy powder coating (≥ 250 µm) to EN 14901 [6] |
| **Installation time** | October 2010 to May 2011 |
| **Cost of project** | 3.3 million Euros |

## 4 Concluding work

The pulling-in of the pipeline was still not the end of the operation. In addition to the pipeline itself, another 112 m of ductile iron pipes was installed on the left and right banks of the Main together with two manholes which included pig launcher/receivers. The pipeline can be cleaned in future from these. The connecting of the new pipeline to the existing one, and the backfilling of the pipeline trench, followed.

### 4.1 The data in brief

Extended, the length of the culvert pipeline across the Main is approximately 155.50 m. Pipelines around 112 m long are installed in addition in the land on the left and right banks of the Main. The overall length of the new pipeline is thus 267.50 m **(Table 1)**.

### 4.2 What is a culvert pipeline?

"Düker" (culvert) comes from Low German and means much the same as "diver" ("duiker" in Dutch). A culvert is a transverse drain or passage which passes below a road, dyke, tunnel or river and a culvert pipeline is a pipeline which passes below in the same way. The liquid carried is able to make its way past obstacles in this way without having to be pumped. Use is made in this case of the principle of communicating vessels, under which liquids in pipes which are connected together always settle to the same level. If fresh liquid is constantly flowing in on one side, it rises to the same level on the other side and can be passed on there with almost no loss in height. Even the Romans used various culvert pipelines of lead or clay pipes to allow drinking water pipelines to cross gorges without the need for an aqueduct.

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# Pile foundations for a pipeline of ductile iron pipes below the water table carrying uncontaminated wastewater

*by Roger Saner*

## 1 The "Grosses Moos" region in the Swiss Seeland

This region in the triangle of land between Lake Bienne, Lake Morat and Lake Neuchâtel is known as Swiss Seeland. Part of it is the "Grosses Moos" or Great Marsh, an area into which the Aare, the Rhine's largest tributary, would flood and it thus became trackless marshland. The floods repeatedly caused tremendous losses of crops and severe damage to buildings.

Following the first Jura waters correction from 1868 to 1891, one of Switzerland's biggest ever river engineering projects, the "Grosses Moos" was drained into the three Jura lakes via canals. Nevertheless, adverse ratios between the inflows to and outflows from the lakes and settlement of the existing peaty soil still caused repeated floods over large areas.
It was only after the second Jura waters correction (1962 to 1973), in which the three Jura lakes were combined into one communicating system by widening and deepening the canals, that widespread flooding could be prevented in the "Grosses Moos" and large areas of agricultural land could be permanently drained [1].

The top soil (humus) in the "Grosses Moos" consists of layers of black, fertile peat, some of which are covered by layers of overburden (man-made embankments, recent alluvial fans). Today, the Seeland and especially the "Grosses Moos" is Switzerland's most important vegetable growing region. More than 60 types of vegetable are grown there.
The ground below the top soil consists mainly of silty overburden and of lake marl and these, like the layers of peat, have very little bearing capacity and are very prone to settlement [2].

## 2 The situation at the outset: Development of the Rämismatte area of Ins

Situated in the middle of the "Grosses Moos" is the municipality of Ins, where the Rämismatte area was to be developed. Under Ins's statutory zoning plan for building, Rämismatte is in the urban enterprise zone intended for industrial, commercial and services companies.

### 2.1 The ground

Soil surveys made by means of excavated trenches confirmed the geological conditions known to exist in the region. The ground was found to have only limited bearing capacity. Below the top soil (covering layer) is a layer of peat between 1.20 m and 2.80 m thick which is very prone to settlement. Lower down there are silty and clay layers and the well-known lake marl. Only at a depth of about 10 m below the natural terrain is there a stratum of coarse gravel able to bear loads.

### 2.2 Groundwater conditions

As well as the adverse soil conditions, another characteristic of the Rämismatte area is a high water table. This is regulated by a canal system which was built at the time of the second Jura waters correction. In the lowest part of the area, the water table is about 1.50 m below the natural terrain.

### 2.3 The development plan

The construction project for developing the area was worked out by the firm of consulting engineers which had been engaged. As well as the usual below-ground infrastructure (for roads, combined sewerage, drinking and

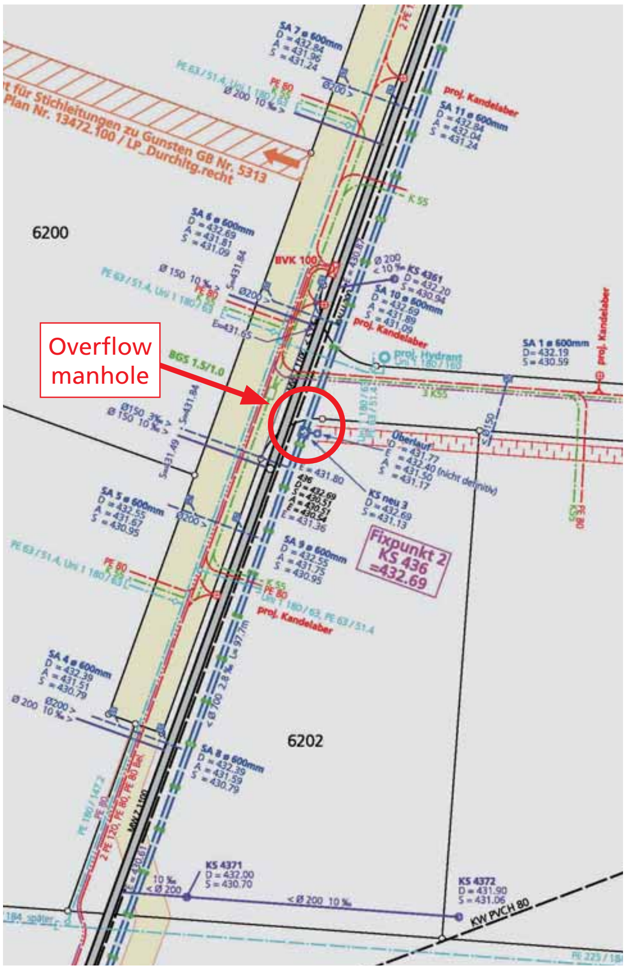


**Fig. 1:**
A detail from the drawing of site infrastructure

fire-extinguishing water, electricity, telephones and TV), the plans also had to include a pipeline for uncontaminated wastewater and provisions for the retention of water from precipitation **(Fig. 1)**. As well as taking away the clean and surface water from Rämismatte, the new pipeline for uncontaminated wastewater is also used to bring in this wastewater from two catchment areas lying to the north of the adjacent railway line. These catchment areas are drained by a system which drains the rainwater and dirty water separately.

The geometry of the development was very good as a result of the way in which it was divided into plots. The constraints affecting the construction project however were difficult, due above all to the flat topography of the terrain (problems with back-flow), the high water table and the poor soil conditions.

## 3 Planning of a new DN 700 pipeline for uncontaminated wastewater

Because of the flat terrain, the new DN 700 pipeline for uncontaminated wastewater could be planned and installed with a minimal gradient of only 3 ‰. For the pipeline to operate in accordance with the hydraulic calculations in ground highly prone to settlement and below the high water table, it had to be laid on piles.

To enable the trench to be dug for the new pipeline, the water table had to be lowered. This was done by a combined technique using firstly the existing system of canals in the “Grosses Moos” and secondly a technique for local vacuum dewatering known as wellpoint dewatering. This technique has the advantage that the trench can be dug with batter without the need for shoring. The wellpoint dewatering could be implemented section by section, each time with a short installation time, as the laying of the pipeline advanced **(Fig. 2)**, therefore allowing the laying to progress quickly.

An overflow manhole **(Fig. 1)**, which conveys the surface water (coming mainly from the road drains) into the pipeline for uncontaminated wastewater in the event of an overload, was also installed at the lowest point of the water retention channel in the verge of the road running through the development.

**Fig. 2:**
Lowering the water table by wellpoint dewatering

## 4 Advantages of ductile iron as a pipe material

The main consideration in selecting the right material for the pipes for the new pipeline was the existing soil conditions below the water table. It was vital for the following requirements to be met:

- absolutely leaktight socket joints, even against groundwater applying pressure from outside,
- an external coating resistant to acidic, highly corrosive soils,
- a flexible socket system to absorb ground movements,
- extremely high static strength properties,
- suitable for pile foundations, self-supporting,
- a hydraulically smooth internal coating for gradients ≤ 3 ‰,
- easy and quick assembly, including the lateral connections.

These demanding requirements themselves constituted a severe restriction in selecting the right pipe material, as there are only a few which have all these properties. Having considered the most significant criteria such as installation time, reliability in operation, sustainability and durability, the unanimous decision by the consulting engineers doing the planning and the client was to go for the vonRoll*geoecopur* DN 700 fully protected pipe of wall-thickness class K 9 under EN 598 [3]. The decision was also supported by the fact that a combined sewer pipeline of vonRoll*geoecopur* DN 400 ductile iron pipes had already been installed in the same area in 2008, with a gradient of < 5 ‰ and also on pile foundations.

With their high diametral stiffness, ductile iron pipes are very resistant to ovalisation by mechanical loads. Movements due to settlement of the ground are fully absorbed by the articulating push-in joints of the flexible ductile iron pipe systems. The K 9 wall-thickness class needed was found from the stress analyses under Swiss standard SIA 190 [4].

With ductile iron pipes, the leak tightness against positive external pressure is tested in the functional test under EN 598 [3] at 2 bars for two hours and in long-term operation the pipes have to withstand a positive external pressure of 1 bar (= 10 m water gauge).

In the case of the vonRoll*geoecopur* ductile iron pipe, corrosion protection is provided by an integrally applied polyurethane (PUR) coating which is applied to the internal and external surfaces of the pipe to standards EN 15655 [5] and EN 15189 [6]. Under these standards, the nominal thicknesses of the layers of polyurethane are 1.5 mm in the inside and 0.9 mm on the outside and the strength of adhesion called for to the cast iron is ≥ 8 MPa. The actual values measured were always more than 14 MPa. Also, under EN 598, Annex B.2.3 [3], the vonRoll*geoecopur* pipe is a fully protected pipe with a reinforced coating and can therefore be used in soils of all levels of corrosivity, including these existing acidic peaty soils.

## 5 The installation work

The first step was to lay the pile foundations for the new pipeline for uncontaminated wastewater and the inspection manholes. The locations of all the piles were plotted on the site by the surveyor from grid co-ordinates using GPS navigational data.
The pre-manufactured 220 mm Ø micro-piles had to be driven to a depth of 12 m to 14 m to reach the stratum of coarse gravel of good bearing capacity. The piles were produced in the factory to be slightly longer than required; as a result they projected from the ground for a short distance and could then be shortened to the exactly defined final length **(Fig. 3)**. To define the exact planned heights for the pipeline, steel plates were welded to steel tubes incorporated in the piles to millimetre accuracy. All the micro-piles are designed for a working load of 500 kN.

**Fig. 3:**
Heads of piles projecting from the ground

**Fig. 4:**
Cradle of in-situ concrete with
a neoprene supporting lining

**Fig. 7:**
Fitting vonRoll*geoecopur* ductile iron pipes to a
cradle of in-situ concrete at very low temperatures

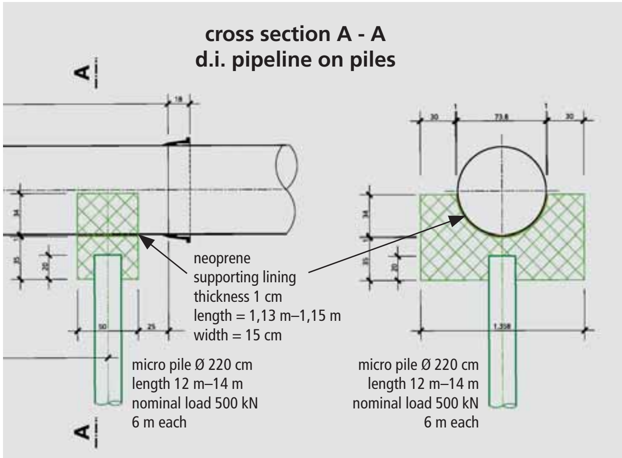


**Fig. 5:**
Detail view of head of pile and cradle of in-situ concrete

**Fig. 8:**
DN 700 ductile iron pipes – easy, time-saving assembly

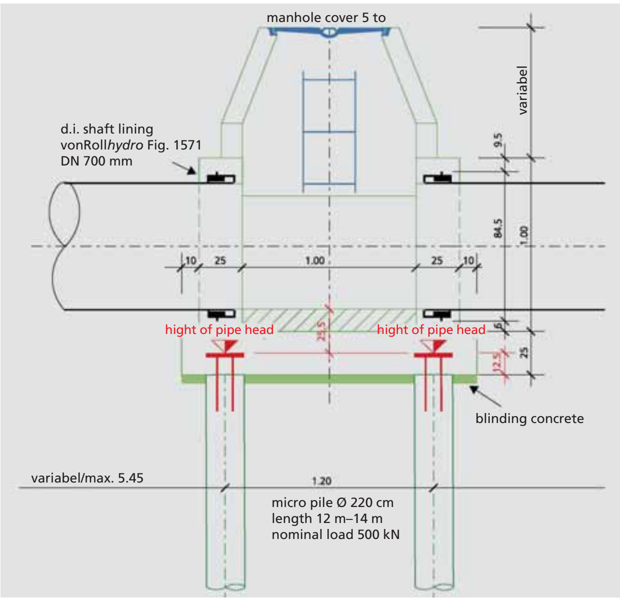


**Fig. 6:**
Detail view of pile foundation
for in-situ concrete manhole

**Fig. 9:**
Lateral connections are child's play to connect:
On left: bored hole coated with epoxy paint
On right: fully connected 90° tapping saddle

Immediately behind the socket, the 6 m long ductile iron pipes each require a pile-mounted support carrying a cradle of in-situ concrete. A 1 cm thick supporting neoprene lining was inset into the cradle to act as a sliding and protective layer for the vonRoll*geoecopur* pipes **(Figs. 4 and 5)**. Three piles also formed the foundations for each of the in-situ concrete inspection manholes **(Fig. 6)**.

The assembling of the DN 700 fully protected ductile iron pipes began at the lowest point of the new pipeline (at the "bottom" socket) to allow the pumped water to be fed straight into the new pipeline when the wellpoint equipment was changed over. Once again, there was a convincing demonstration to everyone involved of the ease of assembly of ductile iron pipes. Last winter, in 2011, the pipeline was laid without a break at very low temperatures of –10 °C **(Fig. 7)**.

The consulting engineers and the installing company were impressed to see how easily and quickly, and therefore how cost-effectively the work of assembling vonRoll*geoecopur* pipes is with the vonRoll*hydrotight* push-in joints **(Fig. 8)**. Using 90° tapping saddles, lateral inlets were very easy to connect in with no need for the PUR coating to be peeled off **(Fig. 9)**.

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# The municipality of Kutzenhausen – New pipes for ducting the Schüttgraben, a DN 800 pipeline on pile foundations

*by Simon Hähnlein and Manfred Schmied*

## 1 Introduction

In the Agawang district of the municipality of Kutzenhausen, in the Augsburg district of Swabia, a pipeline for ducting a stream, the Schüttgraben, was no longer serviceable and needed to be replaced **(Fig. 1)**.

A change of route was discussed by the bodies responsible in the municipality and there were two possible options: option 1 passed close to the adjoining buildings present on the neighbouring properties in an area of land parcel, and option 2 ran through the adjoining cemetery. On option 1, the low-deformation shoring required would have been very expensive, and damage to the buildings could still not have been ruled out, therefore the decision was made to go for option 2 **(Fig. 2)**. The length of the route was about 160 m.

**Fig. 1:**
The old concrete pipeline – the duct for the Schüttgraben stream

## 2 The planning

A feature of both the routes was difficult ground with no bearing capacity. The surveyors Baugrundinstitut Kling Consult (BIKC) were therefore asked to make soil surveys. BIKC made three small-core percussion tests along the route of option 2. The locations for the bores were found from the drawings of the existing pipeline made by Ingenieurbüro Endres.

Anthropogenic fill (fill containing proportions of foreign materials such as rubble, broken brick, etc.) was found in the specimens from the bores. Below this fill there was natural overburden and peat. None of the fill and overburden found had any bearing capacity or was suitable to carry structural loads **(Fig. 3)**.

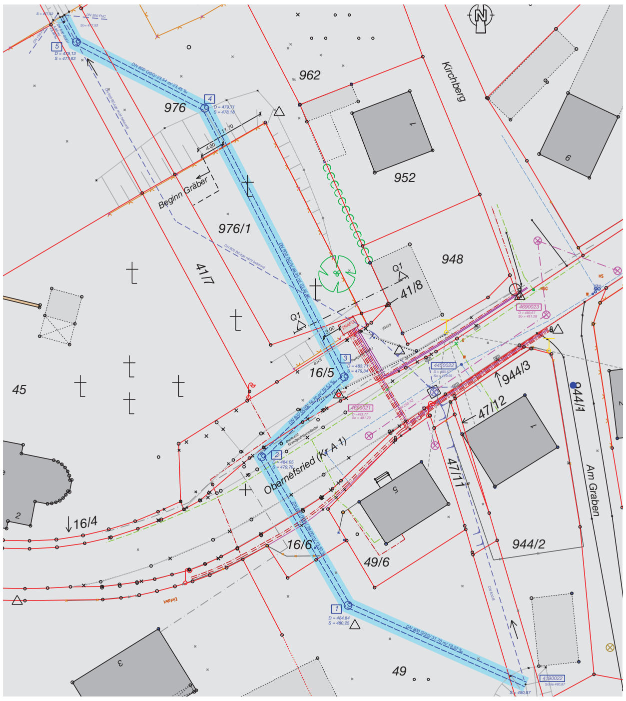


**Fig. 2:**
Layout plan – the route of the new DN 800 pipeline

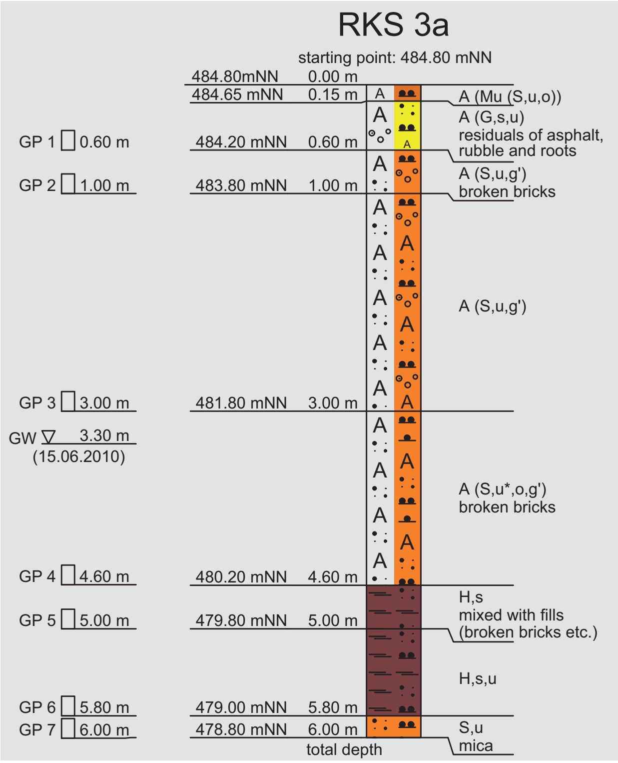


**Fig. 3:**
The Schüttgraben in Agawang –
Section diagram for window sample 3a

Because of the results of the soil surveys, the foundation selected for the pipes and manholes was driven piles of ductile iron.

The driven ductile iron piles, of 118 mm x 7.5 mm size, were designed as pressure grouted piles, but were sized as end-bearing piles. The alkaline mortar of 0–4 mm grain size which was fed in under pressure as the piles were being driven acts as corrosion protection in corrosive soils. The piles were driven into the soil present at the bearing level (the foundation soil) until the cut-off criterion for driving (< 10 mm/20 s) was reached. The average pile length required was 9 m. The possible presence of quite large thicknesses of undrained soil of too low a shear strength ($c_u \leq 15$ N/mm²) could not be ruled out, so the safety of the piles against buckling had to be verified.

The invitation to tender called for the pipes for the pipeline to be ductile iron pipes to EN 598 [1]. These pipes are able to carry high loads and they allowed the piles to be spaced 6 m apart. They are lined with the tried and tested cement mortar lining (ZM-A) based on high-alumina cement and their external protection is a zinc coating and an epoxy finishing layer. The depth of cover over the ductile iron pipes was 5 m.

**Fig. 4:**
Pre-manufactured concrete cradles to carry DN 800 ductile iron pipes

## 3 The installation work

The contract for the installation work was placed with the Carl Heuchel GmbH & Co. KG company of Nördlingen. The laying length of the ductile iron pipes was 6 m. The pipe manufacturer supplied a stress analysis for the pipes which showed that one driven pile (and pipe cradle) per pipe was adequate with no loss of the existing high safety margins. The cradle **(Fig. 4)** always needed to be positioned at a distance of 88 cm from the pipe joint.

The pipeline crosses below the A 1 district road, which has heavy goods traffic carrying castings weighing up to 80 t. During the installation phase, the district road had to be closed to heavy goods traffic for a week. Although the stress analysis indicated that one pile (and pipe cradle) per pipe would have been enough in the region of the crossing, two piles (and pipe cradles) were installed there. The pipe-carrying-cradles simply needed to provide support over a larger angle of 180° in the region of the crossing **(Fig. 5)**. In the areas of the route not subject to traffic loads, the angle was 140° **(Fig. 6)**.

The pipe-carrying-cradles used were ready-made reinforced concrete parts with built-in filling openings. The cradles are 36 cm wide in the areas not subject to traffic loads and 80 cm wide in the areas where there are traffic loads (heavy goods traffic). There is a layer of neoprene between the cradle (of concrete) and the ductile iron pipe **(Fig. 7)**.

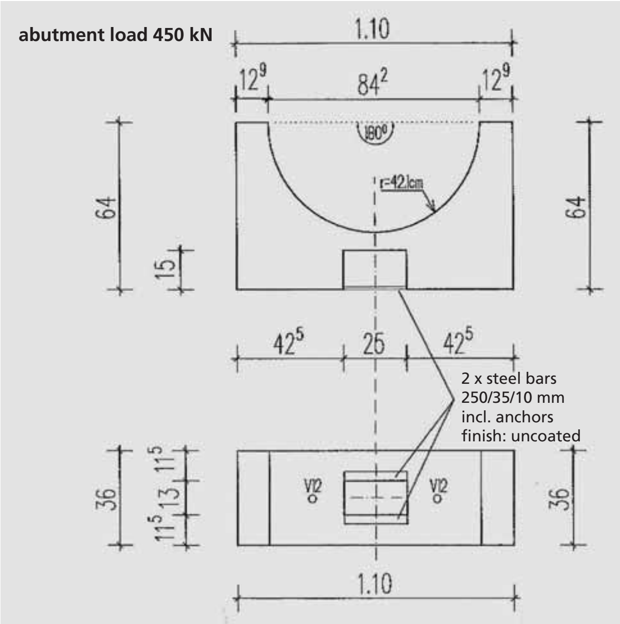


**Fig. 5:**
Production drawing for the concrete cradles providing support over an angle of 180° for DN 800 ductile iron pipes

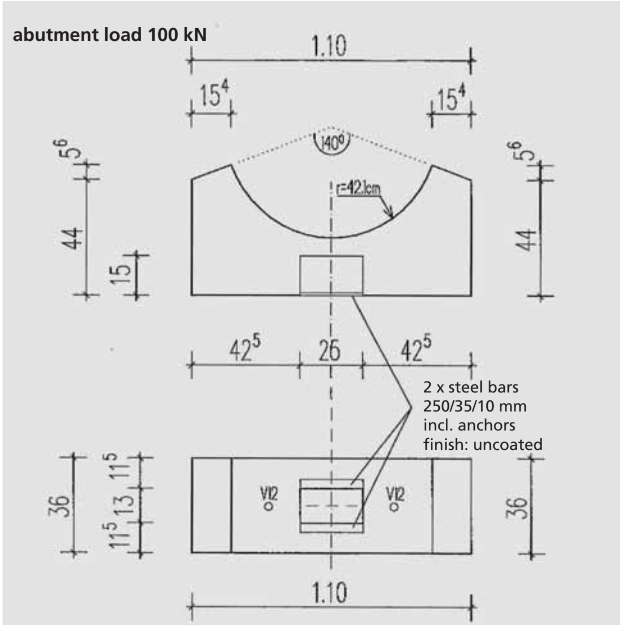


**Fig. 6:**
Production drawing for the concrete cradles providing support over an angle of 140° for DN 800 ductile iron pipes

The foundations for each of the manholes were three driven piles. The piles were driven with a rapid-stroke hammer **(Fig. 8)**.

The quick-change coupler system used by the Heuchel company meant that the entire sequence of operations – excavation, driving of the piles, installation of the pipeline and back-filling of the trench – could be carried out with a single excavator. Vacuum dewatering of the trench was necessary during the installation work.

## 4 To sum up

For the client and the planning engineers, the operation was convincing proof of the viability of the system of using driven ductile iron piles as foundations for ductile iron pipes because a relatively simple solution could be found to deal with the very difficult existing constraints (the ground). The excellent co-ordination between everyone involved made it possible for the entire operation to be carried out in only six weeks.

**Fig. 7:**
Installing the DN 800 ductile iron pipes – pipes supported on neoprene-lined concrete cradles

**Fig. 8:**
Driving the 118 mm x 7.5 mm ductile iron piles

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# Installation of butterfly valves in plant equipment at the Bad Zwischenahn waterworks

*by Tim Hobbiebrunken*

## 1 Introduction and past history

The Bad Zwischenahn waterworks went into operation in 1938; its main purpose was to supply drinking water to a Luftwaffe airfield. The municipality of Bad Zwischenahn had played a part in the planning at the time and had therefore ensured a secure supply of drinking water for the village of Bad Zwischenahn downstream of the airfield.

Because of the impending war and the armament and construction work which it involved, it was very difficult to obtain building materials at the time. The waterworks, with a water tower, was built in spite of all the difficulties and it went into operation on 1 August 1938. Over next few years, the demand for water increased due to the airfield and only two years later the waterworks had to be enlarged to include a further well. The airfield was bombed a number of times in 1944 and 1945 and destroyed, the new water tower was also damaged and holed; only the waterworks was not attacked. After the end of the war the airfield was used as an emergency landing area by the allied forces and in 1955 it was converted into a Bundeswehr military hospital, which was decommissioned in 2006.

## 2 Development of the demand for water

Because of the increase in the population of Bad Zwischenahn, the waterworks was enlarged in 1958 and the volume of water treated was increased by a third.

Consumption continued to increase and in 1979 a further section was built and went into operation to expand the waterworks. In this section, the water supply facilities were expanded to include a new aeration system, a new filtration building with open filters and a flocculation system. In 1990, a system for carbonic acid/calcium balancing was installed.

From 1990 onwards there was no further renovation or expansion of the waterworks. Water consumption has remained largely constant since then.

## 3 Renovation of the technical equipment of the Bad Zwischenahn waterworks

Every year, the Bad Zwischenahn waterworks treats approximately 800,000 $m^3$ of water extracted from four groundwater wells. Around 150 t of iron is removed from this water The waterworks uses three stages of treatment which can be divided into aeration, lime precipitation and the downstream gravel filters.

Because of its state of repair, the Bad Zwischenahn municipal utilities authority decided to renovate the technical equipment of the waterworks. The project was planned jointly with the consulting engineers Ingenieurbüro Lührs of Bremen and is currently in its third phase. Further renovation work is imminent.

As part of the various pieces of renovation work, which take place while operation continues and are usually done in the winter months, butterfly valves made by the Keulahütte GmbH company of Krauschwitz are being installed. The reason for this is the good experience the municipal utilities have had with the valves on the pipeline network which they also maintain. They are used mainly as shutoff valves upstream of the treatment systems.

**Fig. 1:**
Settling chamber outlet


**Fig. 2:**
Settling chamber outlet
with sampling equipment

Soft seated, double eccentric butterfly valves to EN 593 [1] (GR 14 face-to-face dimensions as in EN 558 [2]) of DN 200 and DN 250 nominal sizes and PN 16 pressure rating are being installed. All the valves have an epoxy powder coating to GSK (Quality Association for the Heavy Duty Corrosion Protection of Powder Coated Valves and Fittings) guidelines [3] (coating thickness ≥ 250 µm) and also have valve-disc bearings not exposed to the fluid carried. The gearboxes of the valves are intended for manual operation by handwheels **(Figs. 1 and 2)**.

Butterfly valves from the same manufacturer will also be installed in the remaining sections of the renovation work.

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2009 + A1:2011

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# Which came first – the pipe or the seal?

*by Felice Pavan*

## 1 Introduction

It may have been pipes which existed first but it was only with seals that they could be connected into pipelines. The story of the transporting of drinking water is therefore also the story of sealing. In 1724, in his textbook on hydraulic engineering, Leupold [1] described the problem of making a permanently watertight connection between pipes. In the early days the gap at the socket was sealed with a type of permanently elastic putty, but later on the gap was packed with hemp and lead **(Fig. 1)**. A further development was gaskets made of vulcanised natural rubber.

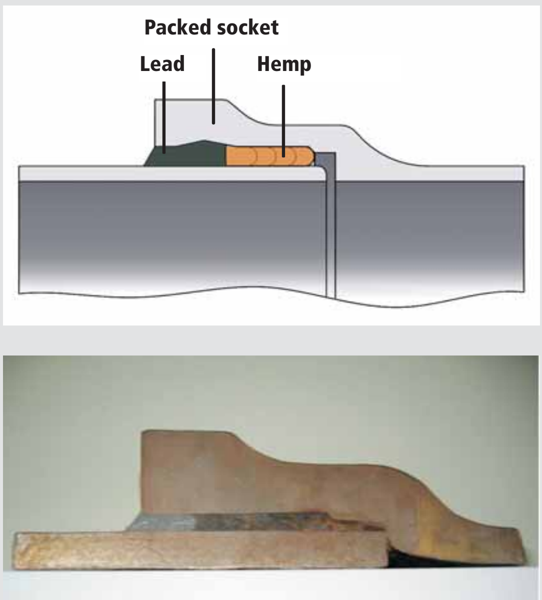


**Fig. 1:**
Section through a packed socket joint

Today, it is only gaskets made of synthetic rubber which are used. EPDM (ethylene propylene diene monomer) is used for drinking water and NBR (nitrile butadiene rubber) for sewage.

## 2 Requirement to be met by rubber gaskets

### 2.1 Mechanical and physical requirements

For its durability in operation, the most important characteristic of an elastomer gasket is its long-term elasticity. This characteristic is determined in what is known as compression set in accelerated tests.

In these tests, a rubber specimen is compressed by a fixed amount and is allowed to age in this state at various temperatures for 24 or 72 hours. When the compression is released, the thickness to which the specimen recovers is measured and the remaining loss in thickness is related to the original thickness.

The requirements given in EN 681-1 [2] for the compression set of gaskets of the hardness class of TYTON® joints in water pipelines (Fig. 2) are

- 72 h at 23 °C: compression set < 12 %
- 24 h at 70 °C: compression set < 20 %.

Further measures of resistance to ageing are the increase in hardness and reduction in tensile strength and elongation at break as compared with the original state, in a seven-day accelerated ageing test at 70 °C.

**Fig. 2:**
Double-socket tee with 45° plain-end branch for sewage TYTON® socket with inset TYTON® gasket (of NBR)

For the types of rubber used for the TYTON® joint, the requirements are:

- Ageing over seven days at 70°C, maximum change from original values:
  - hardness + 8/–5 IRHD
  - tensile strength –20 %
  - elongation at break +10 %/–30 %.

## 2.2 Drinking water hygiene requirements

Organic materials in contact with drinking water are subject to strict statutory regulations to ensure that no harmful substances migrate into the drinking water.

The requirements in the Elastomer Guideline issued by the German Federal Environmental Agency [3] are considered a prototype for a future European scheme of approval for rubber gaskets. Under this Guideline, these are the basic requirements, namely

- that the **external characteristics**
  - odour/taste,
  - clarity/colour/foaming

  of the "migration" water obtained in tests may not be changed, and
- that the **release of organic substances (TOC)** may not exceed certain limiting values.

Also, only materials which are entered on a positive list may be used to manufacture rubber gaskets.

What also has to be assessed for gaskets is their tendency to enhance microbial growth under DVGW Arbeitsblatt W 270 [4].

## 3 Gaskets performing an additional restraining function

It was about 40 or so years ago that a gasket into which metal "teeth" with hardened cutting edges had been vulcanised was first developed. At one end these teeth engage in the surface of the spigot end and at the other end they are supported against the locating collar of the socket of the other pipe and they therefore prevent any undesirable pulling apart of the pipe joint caused by the internal pressure (TYTON SIT PLUS® gasket). **Figures 3 and 4** show the TYTON SIT PLUS® gasket which is usually used.

**Fig. 3:**
All-socket tee with 90° branch for drinking water, TYTON® socket with inset TYTON SIT PLUS® gasket (EPDM)

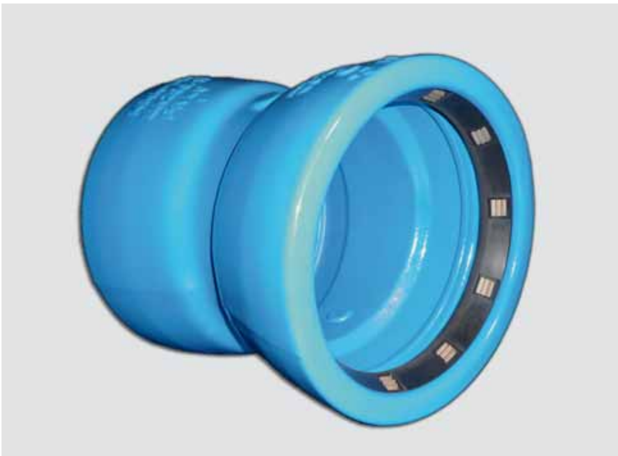

**Fig. 4:**
DN 200 11° double socket bend for drinking water with TYTON SIT PLUS® gasket (EPDM)

The vulcanising-in of the metal restraining members was a major challenge to gasket manufacturers because there were other requirements that the gasket also had to meet. The requirements for its operation and the test methods for the restraint provided are described in detail in product standards EN 545 [5] and EN 598 [6].

## 4 To sum up

All the requirements to be met by a modern gasket for ductile iron pipe systems can be summarised in the following list:

- **The mechanical and physical requirements must be met.**
  In conjunction with the design of the joint, these ensure that there is a permanent sealing function.
- **The drinking water hygiene requirements must be met.**
  These ensure that the quality of the drinking water transported in the pipeline is not adversely affected.
- **The requirements relating to operation must be met.**
  These ensure that a design of joint with the right rubber gasket remains sealed for decades even though there may be adverse conditions (movements of the ground, dimensional tolerances, etc.)
- **The requirements relating to the restraining function must be met.**
  These ensure that a pipeline is held stably in position when acted on by internal pressure, even at changes in direction, dead ends, etc.

Not the least of the requirements which belong in this list is that a rubber-sealed joint must be easy, quick and reliable to assemble and also tolerant of minor errors by the assembling personnel.

This list shows that all of the following three things need to work together in the optimum way to enable a permanently sealed and durable joint to be obtained between pipes

- the pipe and its joint,
- a correctly fitting gasket,
- a conscientious assembler.

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# The impact of the new EN 545 on practical planning and design for ductile iron drinking water pipelines

*by Jürgen Rammelsberg*

## 1 Introduction

The change made in the revised version of EN 545:2010 [1] which has the most serious consequences, is the general introduction of pressure classes and the dropping of the old K classes (wall-thickness classes). This was done under a recommendation in EN 14801 [2] aimed at simplifying the planning and design of buried pipelines. It was recommended not only that the operating pressure be laid down but also that three typical loading conditions, namely

- traffic load in a rural area,
- minor traffic load of an urban road, and
- heavy traffic load of a main road

be specified as representing various loads on the pipe crown to serve as criteria for selecting a suitable pipe.

Whereas there is a detailed discussion and appraisal in EN 14801 [2] of the usual parameters required to draw up a stress analysis for a pipeline, only a rather meagre amount of space is devoted to longitudinal forces in pipelines in informative Annex A. There is equally incomplete coverage of the rules for joints restrained against longitudinal forces in the new EN 545: 2010 [1].

## 2 Forces and stresses in pipelines

As shown in **Fig. 1**, the internal pressure in a pipeline or a pressurised container produces stresses in the wall of the pipe or container, namely circumferential or tangential stresses $\sigma_t$ and longitudinal or axial stresses $\sigma_a$.

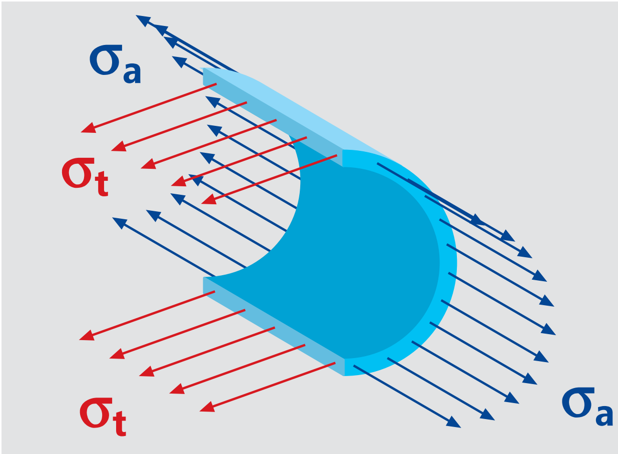


**Fig. 1:**
Stresses due to internal pressure in the wall of a pipe

The two types of stress can be calculated as follows:

$$\sigma_t = \frac{p \cdot D}{2 \cdot e} \left[ N / mm^2 \right] \quad (1)$$

$$\sigma_a = \frac{p \cdot D}{4 \cdot e} \left[ N / mm^2 \right] \quad (2)$$

where

| | |
|---|---|
| $p$ | Internal pressure [bar]<br>1 bar = 0.1 MPa = 0.1 N/mm² |
| $D$ | Central diameter [mm]<br>$D = (DE + D_i) / 2 = DE - e$ |
| $DE$ | Outside diameter [mm] |
| $D_i$ | Inside diameter [mm] |
| $e$ | Wall thickness [mm] |
| $\sigma_t$ | Tangential stress in the wall [N/mm²] |
| $\sigma_a$ | Axial stress (in the longitudinal direction) in the wall [N/mm²] |

The majority of ductile iron pipes to EN 545:2010 [1] are joined together into pipelines by push-in joints. A distinction has to be made in this case between
1. flexible push-in joints, and
2. flexible restrained push-in joints.

The flexible push-in joints shown as 1. above do not transit axial forces. Should the internal pressure of the water generate any axial forces, these have to be transmitted into the ground by some suitable means, e.g. by concrete thrust blocks at dead ends, branches, reductions or changes of direction.
Over the last six decades flexible push-in joints have played a major part in shaping the image of the ductile iron pipe; they are inexpensive and easy to push together and they relieve the pipe of loads precisely because they are not able to pass on any axial forces.

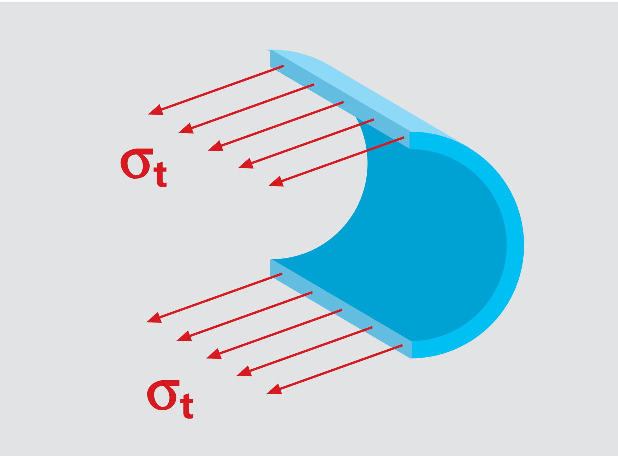


**Fig. 2:**
Circumferential stresses in a pipe with a flexible non-restrained push-in joint

A typical non-restrained socketed pipe absorbs only the circumferential or tangential stresses $\sigma_t$ arising from the internal pressure of the water **(Fig. 2)**. The following equation gives the level of these stresses:

$$\sigma_t = \frac{p \cdot D}{2 \cdot e} \left[ N / mm^2 \right] \qquad (1)$$

which, when converted for the internal pressure, gives:

$$p = \frac{2 \cdot e \cdot \sigma_t}{D} \left[ bar \right] \qquad (3)$$

where $D$ is the diameter at the centre of the wall of the pipe. With the wall thickness e and the outside diameter $DE$, from this is obtained the known equation which we have been using for decades in EN 545 [1] to obtain the wall thickness $e_{min}$ from the internal pressure:

$$p = \frac{2 \cdot e_{min} \cdot \sigma_t}{\left( DE - e_{min} \right)} \left[ bar \right] \qquad (4)$$

$e_{min}$ Minimum wall thickness [mm] of the selected type of pipe under EN 545 [1]

Ductile cast iron has a minimum tensile strength $R_m = 420$ MPa and the circumferential stress in the wall needs to differ from the minimum tensile strength by a safety factor of $S_F = 3$. With this stipulation we can obtain the internal pressure which is then referred to as the allowable operating pressure $PFA$:

$$PFA = \frac{2 \cdot e_{min} \cdot 420}{\left( DE - e_{min} \right) \cdot 3} = \frac{2800 \cdot e_{min}}{\left( DE - e_{min} \right)} \left[ bar \right] \qquad (5)$$

**Definition from EN 805 [3]**

Allowable operating pressure PFA [bar]:

*Maximum hydrostatic pressure that a component can withstand continuously in service*

This definition applies only when there are no pressure surges and only to non-restrained joints.

## 3 The previous method of deciding on wall thicknesses

As diameter increases, so too do the wall thicknesses for a given operating pressure. So that there was no need for a table to be incessantly consulted, wall-thickness classes were introduced. These characterise the level to which a pipe will perform by one whole number $K$ for all diameters or nominal sizes.

The value of $K$ can be freely selected, e.g. … 8, 9, 10 … and it connects nominal size DN and wall thickness e by the following equation:

$$e = K \cdot (0{,}5 + 0{,}001 \cdot DN)[mm] \qquad (6)$$

This nominal wall thickness also has a minus tolerance $\Delta e$, which then gives the minimum wall thickness $e_{min}$:

$$\Delta e = -(1{,}3 + 0{,}001 \cdot DN)[mm] \qquad (7)$$

So that it would in fact remain possible for the wall thicknesses to be produced at small nominal sizes, bottom limits were set

for the nominal wall thickness at
$e \geq 6$ mm

and for the minimum wall thickness at
$e_{min} \geq 4.7$ mm.

Taking the minimum wall thicknesses for K = 9, the allowable operating pressure *PFA* can be plotted as a function of the nominal size DN as shown below **(Fig. 3)**.

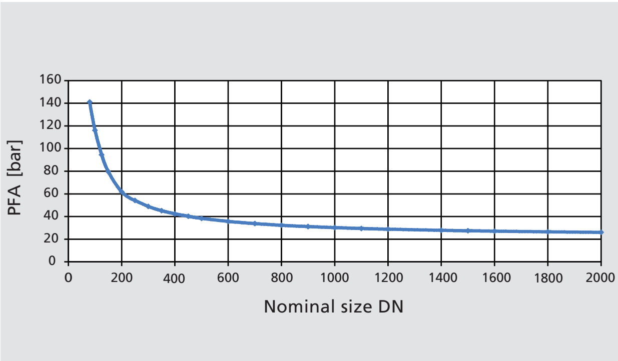


**Fig. 3:**
Allowable operating pressure PFA for non-restrained pipes of wall-thickness class K 9

Because of the bottom limit of 4.7 mm for minimum wall thickness, the graph shows that in the bottom part of the nominal size range, from DN 80 to DN 200, the pipes are somewhat oversized for the internal pressure, which is usually 10 bars in drinking water distribution networks.

This is particularly true when it is considered that the sizing equation already includes a safety factor of $S_F = 3$ relative to the minimum tensile strength.

This resulted in the bottom limit of 4.7 mm for minimum wall thickness being reduced to a value of 3.0 mm. It was in this phase that the call came in EN 14801 [2] for pipeline components to be classified by their pressure and, as it were, for their ability to withstand internal pressure to be shown as a performance feature in their name or designation. The pressure classes were therefore created. Hence, a non-restrained pipe of pressure class C 40 is designed for an internal pressure of *PFA* = 40 bars.

Up to DN 300, this is a serious change with regard to the sizing for internal pressure of non-restrained pipes, as the next graph shows **(Fig. 4)**. At DN 400 and above the differences are fairly negligible.

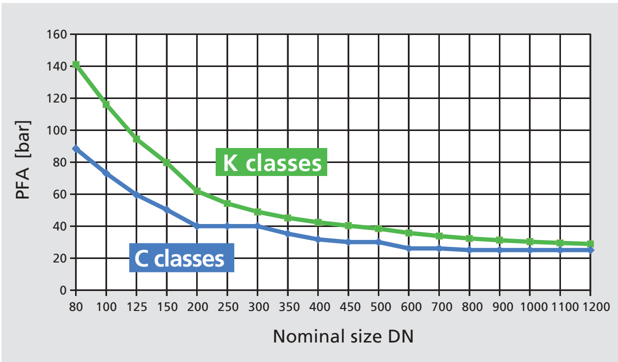


Fig. 4:
K classes (wall-thickness classes)
compared with C classes (pressure classes)

This effect is due solely to the fact that the limiting value for wall thickness was lowered (by about a third) from 4.7 mm to 3 mm. Equation (5) which applies to the calculation of wall thickness continues to apply.

When anyone has gained their experience of ductile iron pipes over years of professional activity as a planner, pipeline layer or network operator, the image of a pipe that will have been impressed on their mind is that of a pipe of wall-thickness class K 9.

This is because this pipe represents a good compromise between

- ability to withstand internal pressure,
- resistance to longitudinal bending (longitudinal bending strength)
- resistance to ovalisation (diametral stiffness).

If they now wish to define this tried and tested pipe (non-restrained, remember) as required by standards, what he needs is Table 2 in [4], which converts the old K class into the new pressure class for them for each nominal size. The wall thickness in millimetres is of course a value common to both these classes. In this table, the ranges of similar wall thicknesses and the ranges of the allowable operating pressure *PFA* which correspond to the pressure classes are shown in the same colours.

This gives the pipeline planner or designer an opportunity to bring his experience based on the K classes into line with the new way of looking at things in the form of the pressure classes and, in so doing, to always keep his eye on the **actual minimum wall thickness as a common reference value**.

## 4 Restrained joints

**Quotation from EN 545:2010 [1]:**

> **4. Technical requirements**
>
> **4.2 Pressure class**
>
> *In accordance with 3.21, the pressure class of a component is defined by a combination of its structural performance and the performance of its non-restrained flexible joint.*
>
> *Restrained joints may reduce the PFA; in this case the PFA shall be declared by the manufacturer.*

The structural performance means simply the minimum wall thickness which is calculated for the *PFA* from equation (5) by taking the tensile strength, safety factor and diameter.

The performance of the **non-restrained** flexible joint means nothing more than that the push-in joint will remain sealed at least up to this *PFA*.

When it refers to **restrained** joints, the second sentence is rather confusing because in fact the pipe already has a pressure-based designation, its C class.

If for example there is then not only the designation C 40 called for in the standard but also a *PFA* = 16, this may lead to misinterpretations, particularly when the pipe is one which has a flexible push-in joint which can if required be turned into a restrained joint by fitting a gasket having metal retaining claws.

### 4.1 Use of restrained push-in joints

Restrained flexible push-in joints are used in two different ways in the laying of pipelines:

1. For **securing in position** in the case of buried pipelines (DVGW-Arbeitsblatt GW 368 [5]).
   Forces due to the internal pressure are transmitted into the ground at changes in direction, dead ends, branches or reductions. The stress state in the barrel of the pipe is bi-axial. The stating of the *PFA* plus the pressure class is all that is needed. The pressure class is then merely a synonym for the minimum wall thickness and the crucial criterion for performance is the *PFA*.
2. When **pulling-in** takes place in trenchless installation techniques (DVGW-Arbeitsblatt GW 321 [6] ff.), empty, non-pressurised pipe strings are pulled in along preset routes. The stress state in the barrel of the pipes is uniaxial. It is not enough for the *PFA* (which once again is synonymous with the minimum wall thickness) plus the pressure class to be stated. The allowable tractive force has to be stated in addition. The crucial criteria for performance are the *PFA* and the allowable tractive force.

In the German-speaking part of the world, the proportion of restrained ductile iron pipelines is, after all, more than 75 %.

## 4.2 Marking

**Quotation from EN 545:2010 [1]:**

> **4.7 Marking of pipes, fittings and accessories**
>
> 4.7.1 Pipes and fittings
> *All pipes and fittings shall be legibly and durably marked and shall bear at least the following information:*
> - *the manufacturer's name or mark;*
> - *the identification of the year of manufacture;*
> - *the identification as ductile iron;*
> - *the DN;*
> - *the PN rating of flanges for flange components;*
> - *the reference to this European standard, i. e. EN 545;*
> - *the pressure class designation of centrifugally cast pipes.*
>
> *The first five markings given above shall be cast-on or cold stamped; the other markings can be applied by any method, e.g. painted on the casting.*

There is no clear and unequivocal stipulation in EN 545:2010 [1] relating to the marking of pipes which have restrained joints.

## 5 Conclusions

By introducing the pressure classes for non-restrained pipes, EN 545:2010 [1] has implemented a recommendation of EN 14801 [2].

What is said in the standard is not adequate for pipes which are equipped with restrained joints of the kind needed for trenchless installation techniques. There are no rules whatsoever for pipes which have friction-locking joints in a normal socket profile.

EN 545:2010 [1] needs urgent revision to meet the needs of practical users because it is misleading in its current state.

The FGR®/EADIPS®, the European Association representing the interests of the ductile iron pipe industry, will shortly be publishing an association standard in which the details which are unclear will be clarified and those which are missing will be added. Until the revised version of the product standard is published, the Association's recommendation to its members is that they continue using the well established K class marking for restrained pipes.

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# Re-organization of the Wertheim water supply system – Feeder pipeline to the Eichel/Hofgarten district

*by Erich Amrehn und Frieda Elenberger*

## 1 Introduction

Stadtwerke Wertheim GmbH is the company that operates the water supply systems of the town of Wertheim and the utility Zweckverband Wasserversorgung Main-Tauber. Zweckverband Wasserversorgung Main-Tauber was founded in 1971 as an entity under public law with its headquarters in Freudenberg am Main and it began operations in 1972. To obtain a secure water supply using only its own water, an ultra-modern new waterworks was built and put into operation in 2011 in the Aalbachtal valley. The raw water is pumped from six wells in the Aalbachtal valley and is treated in the waterworks to produce drinking water of outstandingly good quality.

The overriding aim of this first major joint project is to distribute drinking water of the same quality over the whole of the area supplied by the Zweckverband, comprising the town of Freudenberg and its associated villages and the town of Wertheim and its 18 districts and villages.

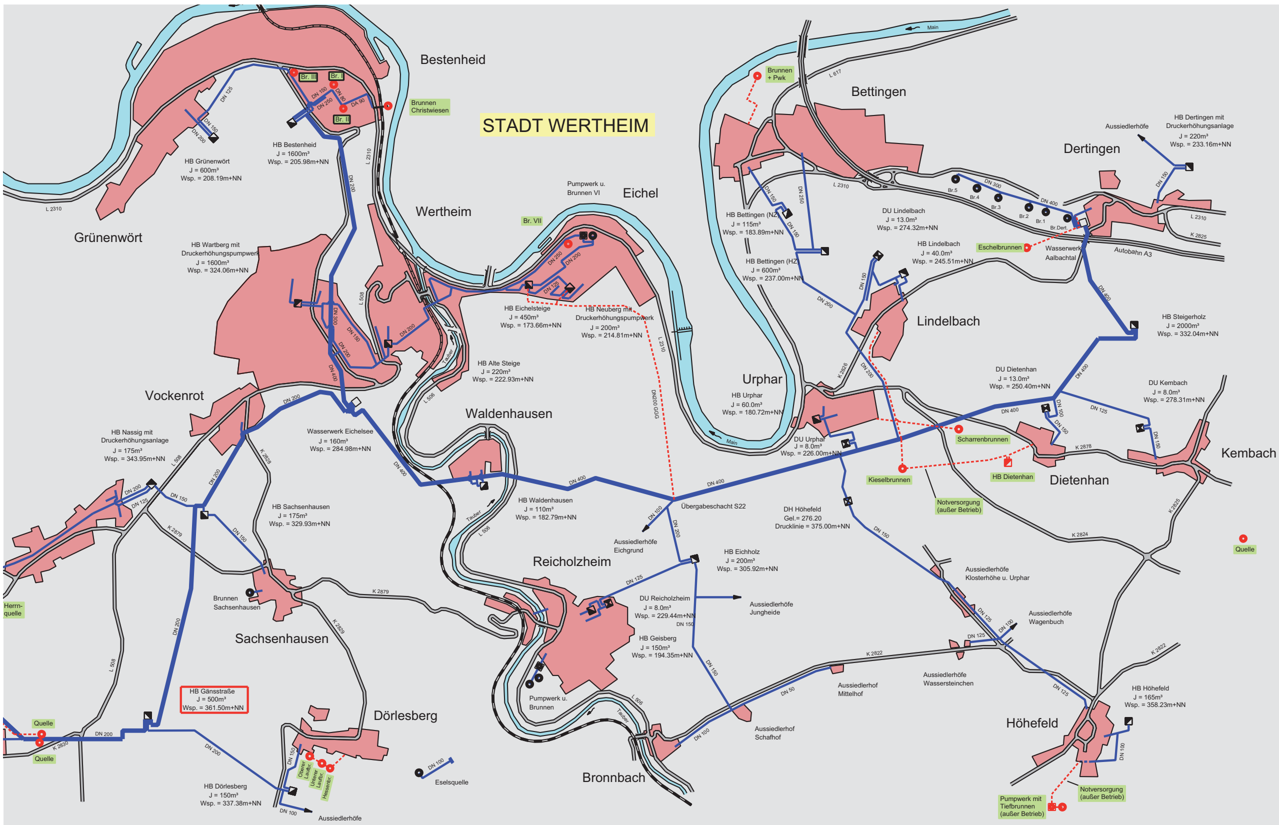


**Fig. 1:**
Wertheim's water supply network

**Table 1:**
List of the four pressure zones – Settings of the pressure-reducing valves

| Consumption zone | Valve | Altitudes of pressure regulating stations [m above sea level] | Inlet pressure [m above sea level/bar] | Outlet pressure [m above sea level/bar] | Altitudes of land in the area supplied | | Setting for safety valves |
|---|---|---|---|---|---|---|---|
| | | | | | [m above sea level/bar] | [m above sea level/bar] | |
| | Nr. | | | | max. | min. | |
| High zone HZ III Hofgarten | DR3 | 234 | 317/8.3 | 268/3.4 | 238/3.0 | 211/5.7 | About 0.8 bars higher than the outlet pressure set |
| High zone HZ II Hofgarten | DR2 | 234 | 317/8.3 | 250/1.6 | 225/2.5 | 181/6.9 | |
| High zone HZ I Hofgarten (= service reservoir CMS) (water level = 215.00) | DU | 211 | 215/– | 215/0.4 | 179/3.6 | 149/6.6 | |
| Low zone Hofgarten/ Old-town | DR1 | 170 | 317/14.7 | 185/1.5 | 155/3.0 | 137/4.8 | |

The Zweckverband's pipeline system is designed so that the water is pumped centrally by only three pumping stations which lift it to the various storage facilities. The increase in pressure required for this is 15 bars.

## 2 Planning of the Eichel/Hofgarten feeder pipeline

The Eichel/Hofgarten district and parts of the old-town of Wertheim were previously supplied with drinking water from two wells on the Main-Aue river system. Following the amendment of the drinking water regulations, various parameters exceeded their limiting values, these water extraction facilities therefore had to be shut down. In future the supply of water will be taken from the set of wells in the Aalbachtal valley via the newly built Eichel waterworks with its central treatment facilities **(Fig. 1)**.
Because of the wide variations in its altitude, the expanded area supplied, comprising the old-town of Wertheim and the Eichel district, is being re-organised to have four different pressure zones (rather than the previous three) **(Table 1)**.
To cope with this task, the following pipelines have had to be laid:

1. A feeder pipeline to the Eichel/Hofgarten district running from manhole S 22 (on the Eichgrund housing estate) to the pressure reduction station on the Oberer Neuberg hill. DN 200, pressure rating PN 16, length 2,740 m.

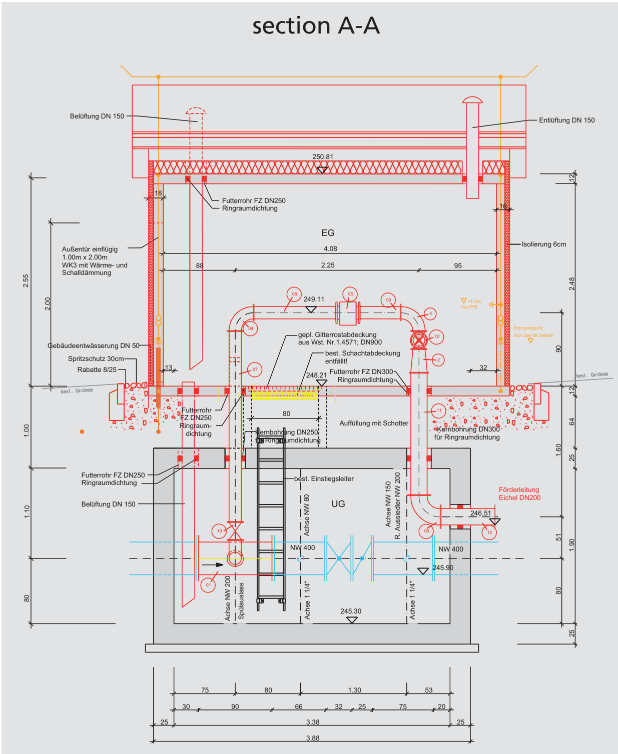


**Fig. 2:**
Enlargement of the S 22 manhole structure to allow the new feeder pipeline to the Eichel/Hofgarten district to be controlled

2. A connecting pipeline from the planned pressure reduction station to the existing Eichelsteige high-level service reservoir. DN 200, pressure rating PN 16, length 425 m.
3. Connecting pipelines for zone isolation for the new pressure zones set up in the Hofgarten district. DN 100 and DN 150, pressure ratings PN 10 and PN 16, length 385 m.

Thanks to the good experience which the client has had with them in the past, the invitation to tender called for ductile iron pipes to EN 545 [1] for all the pipelines. The ductile iron pipes have a cement mortar lining (ZM-A) and an external zinc/aluminium (Zn/Al) coating with an epoxy finishing layer. There were certain structures which had to be converted in connection with the operation, such as manhole structure S 22 **(Fig. 2)**, the gate-valve chamber at the Caspar-Merionstrasse service reservoir and the Eichelsteige pumping station. A new operations building was also built at the Oberer Neuberg pressure reducing station.

## 3 The installation work

The route followed by the pipeline starts above the existing Eichelsteige high-level service reservoir and runs, via the Eichelsteige approach road, along the municipality connecting road to the Eichgrund housing estate in the Reichholzheim district. An added problem along the route was the presence of **(Fig. 3)**
- telecommunication cables
- high and low-voltage electricity cables
- water supply pipelines
- sewer pipes, and
- gas pipelines.

All the entrances to residential and other properties had to remain accessible throughout the installation phase. The biotopes found along the route had to be given special protection.

The ground encountered along 2/3 of the route was rock and along the remainder of the route it was non-cohesive soil **(Fig. 4)**. The pipeline, of ductile iron pipes of a laying length of 6 m, was installed in the conventional way in open trenches. The pipes were bedded in sand in accordance with DVGW-Arbeitsblatt W 400-2 [2] to provide additional corrosion protection **(Fig. 5)**. To avoid the need for excavated cuts (excess depths) at high points, it was necessary for four additional air-release and admission valves to be fitted. The pipeline generally has a height of cover of 1.2 m to 1.5 m.

**Fig. 3:**
A third-party pipeline along the route of the new pipeline

**Fig. 4:**
Non-cohesive soil in the pipeline zone

**Fig. 5:**
Additional corrosion protection by a sand bedding

To ensure that the pipeline remains in a secure and robustly maintained position in steep stretches, the ductile iron pipes and fittings were installed using the BLS®/VRS®-T restrained push-in joint at these points. Along the rest of the route, pipes and fittings with the friction-locking BRS® push-in joint with a TYTON SIT PLUS® gasket were used. Concrete thrust blocks could therefore be dispensed with everywhere along the route.

In the installation and subsequent pressure testing of the pipeline, the requirements of EN 805 [3] and DVGW-Arbeitsblatt W 400-2 [2] were followed and complied with.

## 4 To sum up

Ductile iron pipes were used for the operation described. Under the sometimes difficult constraints which existed, such as
- the ground,
- intersecting third-party pipelines,
- the need to maintain access,
- the biotopes requiring protection, and
- the steep stretches,

these pipes provide very high levels of safety and security and a long operating life. They are rugged and insensitive to point support and, by virtue of their laying length and the ability of the joints to deflect, they allow problems to be solved in a flexible way.

All those involved worked together well and this, together with the good weather during the installation phase, meant that the installation time was shorter than planned.

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[2] DVGW Arbeitsblatt W 400-2
Technical rules of water distribution systems
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Water supply. Requirements for systems and components outside buildings
2000


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# Generating electricity by water power – An important contribution to the phasing out of atomic energy

*by Andreas Schütz*

## 1 Introduction

Thanks to the topographical conditions in Switzerland, there is still a vast potential for the environmentally-friendly generation of electricity by hydroelectric power, especially in the mountainous regions. What is more, this form of electricity generation has for many years now, been actively encouraged by the federal government by the provision of financial support.
The decision in May 2011 by the Swiss Federal Council to completely phase out atomic energy by 2034 is now creating an entirely new situation. In releases to the media, the federal government has stated that it is planning to make the development of water power its first priority. Other important elements of its future energy policy are the saving of electricity, improved efficiency and above all efforts relating to renewable energy sources.

## 2 The promotion of water power

A revision of the Swiss Energy Law is expected as a result of the Federal Council's decision. Even before this decision, the Energy Law laid down an increase of at least 5,400 GWh in the generation of electricity from renewable energy sources by 2030. There is now expected to be a substantial upward adjustment of this figure.
The existing Energy Law already includes a raft of measures for promoting renewable energies and for increasing efficiency in the electricity sector. The main measure in this case has been the cost-covering remuneration for feed-in to the grid (CRF) for electricity from renewable energy sources. Around 247 million Swiss francs per annum has been made available to offset the difference between the remuneration and the market price. To date, the cost-covering remuneration is provided for the following energy sources:

- water (i.e. hydroelectric) power
- photovoltaic energy
- wind power
- geothermal energy
- biomass and waste from biomass.

Depending on the energy source, the remuneration is payable for 20 to 25 years.

## 3 Green electricity from drinking water power stations

A principal aim of the federal government's new energy strategy is to increase energy efficiency. In this respect, electricity generated by drinking water power stations is particularly energy efficiency because, as well as serving their main purpose of supplying drinking water, the drinking water pipelines also generate environmentally-friendly electricity. The advantages to the operator are obvious. The electricity generated by drinking water power stations is produced locally, and the environment and the water cycle remain virtually unaffected. What is more, an important contribution can be made to achieving the government's aims at a relatively low cost **(Fig. 1)**.

The production of electricity does not impair the quality of the drinking water. Also, in the assessment of the VUE (Swiss Association for Environmentally Sound Energy), the environmental pollution caused by drinking water power stations can hardly be measured. The energy produced therefore ranks as green electricity and can be sold as such.

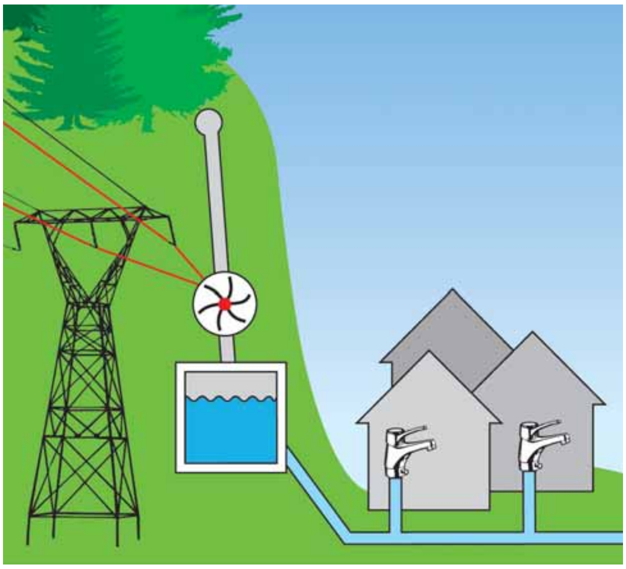

**Fig. 1**
Diagrammatic representation of a hydroelectric power station (a combination of drinking water and power station pipelines)

**Fig. 2:**
Installing a vonRoll*ecopur* DN 200, PFA 40, wall-thickness class K 9 pipe

## 4 The Herber small power station project in Hergiswil

The Herber small power station in Hergiswil (in the canton of Obwalden) was built as a new station and was incorporated into an existing 1,270 m long pressure pipeline for drinking water.
The 160 mm diameter of the existing pipeline was not large enough so a diameter of 200 mm was decided on for the new pressure pipeline.

The pipes used were vonRoll*ecopur* DN 200, K 9 class (wall-thickness class) ductile iron pipes of PFA 40 with restrained push-in joints and a reinforced coating to EN 545 [1] and with an integral polyurethane coating and lining. These are referred to as fully protected pipes. Thanks to the flexibility of the tried and tested vonRoll*hydrotight* push-in socket system, the pipes could be assembled easily and very efficiently **(Figs. 2 to 4)**.

## 5 Performance features

The net head of the Herber small power station is 290 m. This gives an operating pressure of about 29 bars. The flow-rate of the water is 72 L/s. The turbine spins at a speed of 1000 rpm and the output of the generator is 150 kW.

**Fig. 3:**
A vonRoll*ecopur* ductile iron pipe with a polyurethane lining

**Fig. 4:**
The vonRoll*hydrotight* Fig. 2807 A internal thrust resistance system

## 6 Very high energy efficiency

The polyurethane-lined vonRoll*ecopur* fully protected pipe has a wall roughness of k < 0.01 mm and can therefore be considered hydraulically smooth. This is a prerequisite for minimal head losses. This pipe is therefore made-to-measure for hydroelectric power stations, where high energy efficiency is of crucial importance.

The push-in joints can be deflected by up to 3°. The pipeline therefore adjusts to slight curves without the need for additional fittings, which further optimises the energy properties of a network; for the operator, lower head losses mean a higher output from the turbine and consequently strikingly greater efficiency from the system as a whole, something which it was possible to achieve in the present case.

## 7 Demanding requirements for the pressure pipeline

The requirements which the client had for the lining of the pipes were demanding ones. The lining had to meet the requirements for drinking water hygiene, to withstand soft water and at the same time to be extremely strong mechanically. The polyurethane lining to EN 15655 [2] meets these requirements.

For the laying of a power station pipeline carrying high pressures, crucial factors governing the choice of a sustainable material for the pipeline are also high safety and reliability, economical operation, easy laying of the pipeline in steep terrain and a long working life.

The vonRoll*ecopur* fully protected pipe with the proven vonRoll*hydrotight* thrust resistance system meets these demanding requirements and is therefore ideal for use at hydroelectric power stations.

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Ductile iron pipes, fittings, accessories and their joints for water pipelines –
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[2] EN 15655
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2009


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# Culvert pipeline under the river Traun near Linz
# High performance by ductile iron pipe systems

*by Ingo Krieg*

## 1 Introduction

Ductile iron pipe systems are known to be successful in particularly difficult applications. When a pipeline for transporting water was laid from Linz to Ansfelden, the ductile iron pipe system once again attracted attention because there were many challenges which had to be overcome in a distance of 1.4 kilometres. Ductile iron pipe systems had to show the full range of their talents.

## 2 Planning and installation work

Hardly any water management project this year in Upper Austria has made such great demands on the underground installation engineers and the material of the pipes as the installation of this pipeline for transporting water. Not only did a culvert pipeline 92 m long have to be run under the river Traun, but crossings were also needed over the river Krems (a tributary of the Traun), the Mühlkanal and the Mühlbach. Even a canal serving a power station had to be crossed by a pipe bridge.
LINZ AG, Linz's city-owned supply company, did all the planning and installation work.
DN 400 ductile iron pressure pipes to EN 545 [1], with BLS®/VRS®-T push-in joints and a PUR TOP coating, were used for this work, which lasted from 6 February to mid-April 2011. The water-transporting pipeline, which supplies the Wasserverband Grossraum Ansfelden utility and the southern part of Linz, was successfully put into operation in June 2011.

What made the project necessary was a bridge pipeline (700 m of steel pipes and 700 m of asbestos-cement ones), which was laid in 1960 when Linz's A 7 urban autobahn was built, which had become unserviceable. Renovation would have cost 350,000 Euros more so LINZ AG opted for a new, buried, pipeline.

## 3 The route

The new route runs along the A 7 towards Ansfelden. The planning made allowance for the prospective widening of the A7 to three lanes. But that was not all the planners had to cope with; there were also many stipulations made by the authorities to be complied with.

In the words of Wilhelm Riedlbauer, operations manager of LINZ AG's water department, who saw to the planning and implementation of the special project: "The major part of the pipeline is situated in the Natura 2000 nature reserve. For this sensitive area there were therefore special legal stipulations relating to nature and fishing which had to be allowed for. But there were also water rights to be observed, not to mention consents to be obtained for ground clearance and stipulations by ASFINAG – AUTOBAHNEN- UND SCHNELLSTRASSEN-FINANZIERUNGS-AKTIENGESELLSCHAFT of Vienna, the Austrian motorways operator, and by the electricity supplier VERBUND AG of Vienna."

## 4 Installation of the culvert pipeline

The major challenge from the laying point of view was the 92 m long crossing below the Traun by a culvert pipeline following a curve measuring 80 m in radius. This was done without using a pre-drained trench. Excavators dredged a trench two metres deep in the river, and the DN 400 ductile iron pipeline, which

**Fig. 1 (on the left):**
The DN 400 culvert pipeline before being pulled in – ductile iron pipes encased in concrete

**Fig. 2 (on the right):**
A concrete casing was needed to stop the pipeline from buoying up

was encased in concrete **(Fig. 1)**, was pulled in by a cable winch able to exert a tractive load of 80 t. The concrete casing was insisted on by the authorities to stop the 76 t weight of the pipeline from buoying up, given the high speed of flow of the Traun **(Fig. 2)**.

Because the ductile iron pipes were mounted on a sledge of steel plate, the tractive forces acted on the sledge and not on the culvert pipeline. At the time of installation, an ascending end section was pulled in as well **(Fig. 3)** to stop any river water from getting into the pipeline. Two divers kept watch on the pulling-in.

When the other, smaller, waterways were crossed, a heavy crane lifted the culvert pipelines, pre-assembled and suspended from a spreader beam, into their final position **(Fig. 4)**. In some cases the ductile iron pipes were pre-assembled in a steel supporting cradle **(Figs. 5 and 6)** and lifted into the water.

Special plain-ended pipes to the manufacturer's standard, with welded beads for restrained BLS®/VRS®-T push-in joints, were used for these sections of the pipeline.
Pressure tests were carried out before and after the pulling-in and lifting-in work done in the respective cases.


**Fig. 3:**
The fully assembled culvert pipeline end section

**Fig. 4:**
A fully assembled culvert pipeline being lifted in – done under floodlights

**Fig. 5:**
A culvert pipeline combination comprising ductile iron pipes and a cradle of steel plate

**Fig. 6:**
The culvert pipelines were lowered into place by heavy cranes to cross some smaller waterways

## 5 Concluding remarks

The demanding work of laying ductile iron pipes on the Traun was possible without any problems, due not least to the professionalism of the companies involved – GLS Bau und Montage GmbH of Perg, Hitthaller of Linz and LINZ AG – but also to the reliability of the BLS®/VRS®-T push-in joint and to the ruggedness of the pipes and their cement mortar coating (ZM-U).

## References


[1] EN 545
Ductile iron pipes, fittings, accessories and their joints for water pipelines – Requirements and test methods
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# Zweckverband Gruppenwasserwerk Dieburg supply utility – Southern trunk water main from Hergershausen to Gross-Zimmern

*by Heinz-Jörg Weimer*

## 1 Introduction

The Zweckverband Gruppenwasserwerk Dieburg utility supplies water to more than 120,000 people in the region. The water is distributed to customers through its pipeline network of around 1,000 km via trunk mains, local mains and house connection pipes. Of this total of around 1,000 km, the Zweckverband replaces about 2 % a year with the latest generation of ductile iron pipes.

## 2 Planning

In the southern part of its distribution network, the renovation of a difficult section had been put off in the past because of the demanding technical requirements. Along a very short stretch, the pipeline crossing below an important section of German Federal Railways (DB) track and a federal highway similar to an autobahn needed to be replaced. The existing protective casing tubes could not be used because the supply of drinking water had to be maintained throughout the whole of the replacement phase.

## 3 Description of the route

The site of the replacement operation was on the south-eastern edge of the Dieburg group of municipalities. At this point, the route runs along the Altheimer Strasse for about 385 m in a north-south direction between the Darmstadt-Aschaffenburg railway line and a valve-equipped manhole containing a needle valve which is situated on district road K 128.
The route to be followed by the new pipeline due for installation began on the northern side of the Darmstadt-Aschaffenburg railway line

**Fig. 1:**
Path followed by the route

and crossed below it. It then continued for a length of 30 m along the foot of the embankment carrying federal highway B 45 and then crossed below it **(Fig. 1)**. Where it continued, there was a DN 1500 overflow sewer below which a crossing had to be made by culvert.

## 4 Crossings below

DN 900 protective casing tubes were installed by steered pipe jacking for the crossings below the railway embankment and federal highway B 45 **(Fig. 2)**. The lengths of the stretches of casing tube were 20 m (to cross the railway embankment) and 65 m (to cross the federal highway).

Retained seepage water and an intersecting gas pipeline allowed only slight variations in height **(Fig. 3)**. The jacking of the tubes having been completed, the ductile iron pipes were pulled in **(Figs. 4 and 5)**.

**Fig. 2:**
Removing the soil from an installed DN 900 protective casing tube with a feed auger

**Fig. 5:**
A DN 500 ductile iron pipe pulled into the DN 900 steel protective casing tube

**Fig. 3:**
Installation above an existing pipeline

**Fig. 6:**
DN 500 restrained ductile iron pipes with a cement mortar coating and shrink sleeves plus protective cones at the socket joints

**Fig. 4:**
Fitting the skids for sliding to a DN 500 ductile iron pipe – in preparation for the pulling-in

**Fig. 7:**
The annular gap sealed off at the end of the steel protective casing tube – the annular gap was not filled.

The pipes used were DN 500 ductile iron pipes to EN 545 [1] with restrained BLS® push-in joints and a cement mortar coating (ZM-U) to EN 15542 [2] serving as external protection. The annular gap between the medium-carrying pipes and the protective tube was not filled **(Fig. 7)**.

## 5 Installation variants

For the three installation techniques employed, namely

- open trench installation,
- pulling-in (trenchless installation)
- culverting,

the use of BLS®/ZM-U pipes allowed the installation of concrete thrust blocks to be dispensed with given the very short distances involved, even though there were frequent changes in direction and height.

## 6 Concluding remarks

Further unforeseeable problems occurred during the operation. One of these was old bridge foundations which were encountered and which made it necessary to re-plan the original route.

**Fig. 8:**
Ductile iron fittings and a butterfly valve which were installed

The collaboration between the client and the pipe supplier was ideal and allowed the fittings required **(Fig. 8)** to be supplied and installed at short notice without the site being shut down. The new pipeline went into operation within the schedule that had been laid down for installation.

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Ductile iron pipes, fittings, accessories and their joints for water pipelines – Requirements and test methods
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# World premiere at WASSER BERLIN INTERNATIONAL 2011 – The press-pull technique with soil removal

*by Stephan Hobohm und Franz Schaffarczyk*

**Fig. 1:**
The GSTT Award 2011 trophy

## 1 Introduction

On the Construction Site Day which Berlin's water supply company Berliner Wasserbetriebe (BWB) organised on 4 May as part of WASSER BERLIN INTERNATIONAL 2011, the Berlin branch of the Josef Pfaffinger Bauunternehmung GmbH company presented a new development in the field of trenchless water pipeline replacement to an interested trade audience. A modification of the press-pull technique usually used in Berlin to replace water pipelines was employed to replace a DN 300 pressure sewage pipeline with a new pipeline of DN 500 ductile iron sewer pipes, following the same route. New machinery for this operation had been developed in close collaboration with the TRACTO-TECHNIK GmbH & Co. KG company of Lennestadt **(Fig. 2)**.


**Fig. 2:**
The DN 300/DN 500 press-pull technique with soil removal

## 2 The situation at the outset

Berlin is divided into drainage regions which are designed to follow the courses of rivers and navigational canals. The sewers convey sewage to 150 sewage pumping stations and from there it is pumped to the treatment plants through a network of pressure pipes around 1,200 km long. Though parts dated from 1962, most of the section of pipeline intended for replacement on the Walchenseestrasse dated from 1944.

The main reason for replacing the pipeline was its hydraulic performance, which was not good enough for today's conditions. By increasing its diameter from DN 300 to DN 500, it will be possible for its paired operation with a further pressure sewage pipeline and for intermediate pumping stations to be dispensed with in future.

The majority of the pipeline is situated in public areas. The Walchenseestrasse (in Berlin Köpenick, the Grünau district) is a residential street carrying little traffic, with only a thin layer of surfacing. Nor are there any trees or other obstructions to pipe-laying. In this section the height of cover is only 1.40 m to 1.50 m.
These would have been ideal conditions for replacing the pipeline in conventional open trenches, except that it would have needed to cross below a privately owned piece of land. In the interests of the owner of the land, Berliner Wasserbetriebe decided to make a trenchless crossing below the land affected, with no change of route, and therefore minimise any claims the owner might be entitled to make.

The task was therefore to replace a DN 300 pressure sewage pipeline of grey cast iron with a new ductile iron pipeline of DN 500 nominal size, trenchlessly and along the same route, and in so doing remove all the material of the old pipe from the ground without in any way affecting the piece of privately owned land. The complete removal of the material of the old pipe is an essential requirement whenever pipes are replaced in Berlin. At Berliner Wasserbetriebe the decision was made to leave the method of replacing the pipeline to the contractor. Its proposal to replace the pipeline by the press-pull technique with additional soil removal landed the contract for the Berlin branch of the Josef Pfaffinger Bauunternehmung GmbH company.

The press-pull technique has a long tradition in Berlin. Every year around 10,000 m of water pipelines of nominal sizes from DN 80 to DN 400 are replaced by this technique. Berliner Wasserbetriebe has created a set of rules of its own for this, in the form of company standard WN 322. These rules are closely related to DVGW-Arbeitsblatt GW 322-1 [1], but allow higher tractive forces for ductile iron pipes with positive locking joints.

The problems with this installation project were, above all, the very large amount of upsizing called for by the change of dimension through two nominal size increments, and the relatively small height of cover.

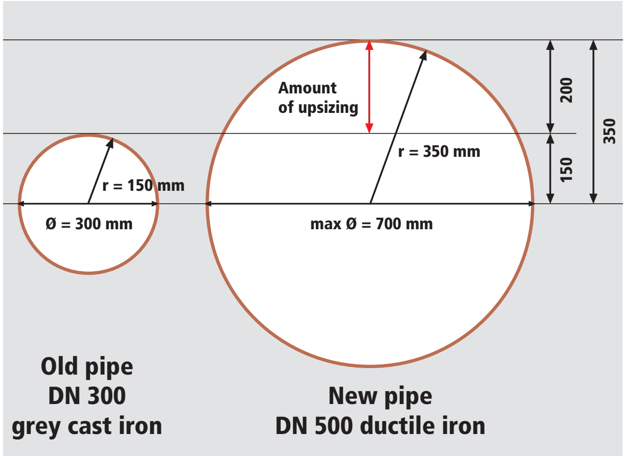


**Fig. 3:**
Determining the amount of upsizing

Under DVGW-Merkblatt GW 323 [2], the amount of upsizing is the difference between the inside radius of the old pipe and the radius of the enlarged passage required **(Fig. 3)**. In this case the diameter of the enlarged passage was about 700 mm so the radius was 350 mm. This value was obtained from the outside diameter of 636 mm of the socket of the DN 500 BLS®/VRS®-T push-in joint plus the 5 mm thickness of the cement mortar coating (ZM-U) plus the oversize required. The amount of upsizing was therefore 200 mm. This amount of upsizing was the criterion for the cover required for the pipes and for the minimum distances from neighbouring pipelines. The cover for the pipes may not be less than 10 times the amount of upsizing if damage is to be avoided to surfaced ground. For the present operation, this figure would have been at least 200 cm. However, because the cover available was only 1.40 m to 1.50 m, the normal press-pull technique was not an option.

The solution therefore lay not in displacing the excess soil but in removing it – a totally new procedure when combined with the familiar press-pull technique.

Consequently, the Josef Pfaffinger Bauunternehmung GmbH company had to collaborate with the TRACTO-TECHNIK GmbH & Co. KG company to develop new machinery to cater for this ambitious project. The pipe supplier assisted with this.

## 3 The machinery and pipes

As the installation work progressed, the use of a Groundoburst 2500 G **(Fig. 4)** proved to be the right decision. This machine has a maximum tractive force of around 250 t and therefore meets the basic requirements for bursting pipes of nominal sizes up to DN 1000 or for pressing pipes of a nominal diameter of DN 300 (or more) out of the ground.

This massive tractive force is transmitted by the QuickLock bursting string, which measures 140 mm in diameter and weighs some 200 kg per section.

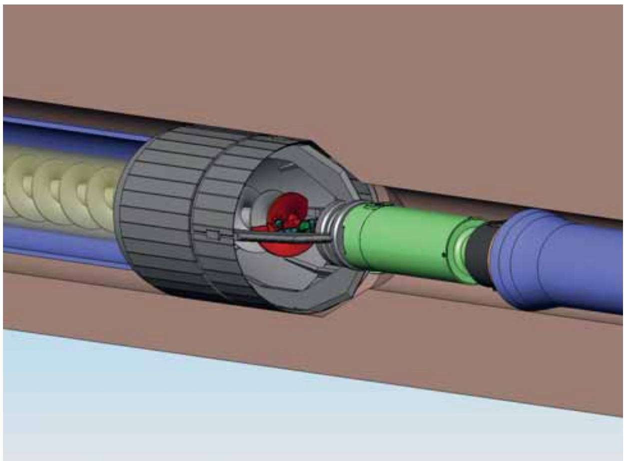

**Fig. 5:**
Schematic representation of the soil removal process

**Fig. 4:**
Groundoburst 2500 G with a front frame

A press-pull head was coupled to the QuickLock string in the usual way. The job of the head was to push the old pipe ahead of it and out of the soil onto a bursting mandrel. The press-pull head was followed by a system for measuring tractive force. This in turn was followed by the real innovation, the system for removing the soil (a reamer) **(Fig. 5)**. The reamer consisted in essence of a head fitted with cutting edges, within which opened a tube containing a feed auger to take away the soil reamed out. The soil was transported away towards the pipe-assembly pit by means of the string of auger sections and the feed tube. The reamer also had incorporated in it the coupling for connecting on the new pipe to be installed. In the case of the Walchenseestrasse, a modified PN 40 flanged socket with a BLS®/VRS®-T push-in joint was used as a coupling.

Because the new pipeline being installed was a pressure sewage pipeline, ductile iron sewer pipes to EN 598 [3] were later coupled to the coupling and pulled in. In accordance with the stipulations of GW 322-1 [1] and Berliner Wasserbetriebe's rules, the pipes to be pulled in had to be connected together by positive locking joints.

This was why the tried and tested BLS®/VRS®-T push-in joint was used. This joint has been in use in Berlin for the trenchless replacement of drinking water pipelines for decades now. Its chief characteristics are that it is quick, easy and safe to assemble and also has very high safety margins when being pulled in. The allowable tractive force on the DN 500 BLS®/VRS®-T push-in joint in this case was 860 kN, at a maximum angular deflection of 3°. Its wall thickness complied with wall-thickness class K 9 under EN 545 [4]. The maximum operating pressure (PFA) was 30 bars, which was more than enough for the operating pressure expected of 4 bars to 6 bars. In principle, the ductile iron pipes used for all trenchless installation techniques should only be ones which have restrained push-in joints operating on a positive locking basis.

**Fig. 6:**
A ZMU-Plus pipe with a BLS®/VRS®-T push-in joint and an internal feed auger

Ductile iron sewer pipes are lined with high-alumina cement mortar. As is usual for trenchless installation, a cement mortar coating (ZM-U) to EN 15542 [5] was selected as the external protection. This however was specially modified in the light of the geological conditions and to minimise any risk of subsequent settlement.

The usual layer thickness of 5 mm was increased to around 60 mm on the barrel of the pipe. This made the pipe entirely cylindrical from the spigot end to the socket – what is referred to as a ZMU-Plus pipe **(Fig. 6)**. As well as providing excellent mechanical protection, the cement mortar coating also has very good protective properties against chemicals. Under EN 598 [3] ductile iron pipes with a ZM-U coating can be installed in soils of any type of corrosivity.
The laying length is 6 m with a total weight of approximately 2,000 kg.

## 4 The installation phase

Because this new installation technique was to be presented in the course of the Construction Site Day during WASSER BERLIN INTERNATIONAL 2011, neither the installing company nor the client wanted to leave anything to chance.

The first section had been installed, and the technique had therefore been tested, even before the Construction Site Day. Even the section which was presented on 4 May 2011 was not the one for which the technique had in the end been developed for. It merely served as a demonstration for the trade visitors and of course as a further test for the third section which followed. It was this section which was then to be installed under the piece of privately owned land described above. The length of run for all the sections was 40 m to 50 m.

**The installation work itself was divided into the following six stages:**

1. digging of the launch and target pits,
2. inspection of the old pipeline and determination of its state,
3. preparation of the old pipeline,
4. installation of the machinery,
5. pulling in of the new pipeline,
6. connecting together of the sections and backfilling of the pits.

### 4.1 Digging of the launch and target pits

A launch and a target pit were needed for each section, the target pit of the previous section being used wherever possible as the launch pit for the next section. Given the six metre length of the pipes plus the space needed for assembly and working and the size of equipment, i.e. the machine used (the Groundoburst 2500 G and the front frame), the dimensions of the launch pit were approximately 10 m x 2 m x 2 m.

A Berlin type pit lining with double-layer timber shoring was used. In certain areas the pits had to be pre-drained. As well as this, various intersecting supply pipes and cables had to be re-laid. The last stage was the concreting of the previously calculated thrust block in the machinery pit. Because of the high tractive forces expected, this block proved to be correspondingly large at 5 m³ **(Fig. 7)**.

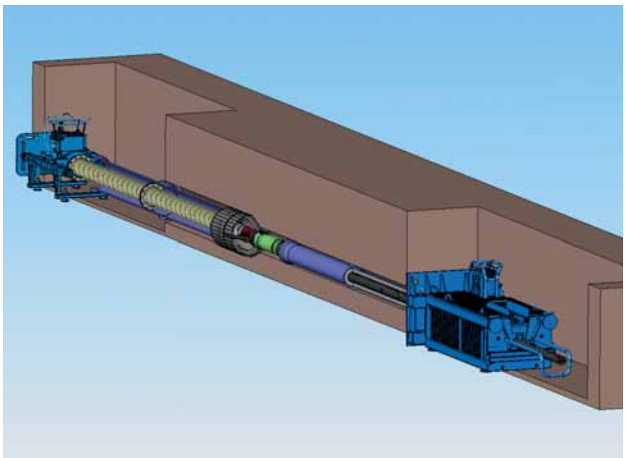

**Fig. 7:**
Schematic general arrangement view

### 4.2 Inspection of the old pipeline and determination of its state

As in any trenchless replacement operation, the pipeline to be replaced was subjected to a thorough examination.
Even while the pits were being dug, the sections of pipeline which were cut out in the course of this were examined for their degree of fouling, the properties of their material and their residual load-bearing capacity. This latter one was particularly significant for the subsequent procedure. Whether the pipeline needed further strengthening before the replacement depended on it. The pipeline which had been cut open was also subjected to a visual inspection, the path followed by it was documented and the positions of valves and other installed items were established from drawings. All these had to be removed as otherwise there would have been an uncontrolled rise in the tractive force.

### 4.3 Preparation of the old pipeline

It was found that the load-bearing capacity was not in fact high enough for the intended replacement technique. It was very likely that the walls of the pipes would collapse as the pipeline was being pressed out and would therefore make continued pressing impossible. The installing company therefore decided to undertake retrospective strengthening.

For this purpose, a DN 150 PVC pipe for connecting to sewers was slid concentrically into the old pipe on spacers. The annular gap around 7 cm wide which was created in this way was then grouted with a special mortar. This mortar was notable for its good flowability, and its high capacity for swelling and resistance to compression. The curing time of the mortar was five days. The nominal size of the PVC pipe was firstly intended to produce as large an annular gap as possible and hence as large as possible a cross-section for the concrete. Secondly the 140 mm diameter traction string had to fit into it.

### 4.4 Installation of the machinery

After the preparatory work on the old pipeline, the installation of the machinery could begin. A rail-type supporting structure on which the soil removal equipment would slide freely and the new pipes could be assembled was installed in the launch pit **(Fig. 8)**.


**Fig. 8:**
The launch or assembly pit

The traction machine and its front frame were lowered into the target pit. They were both braced against the shoring formed by the concrete thrust block already cast. The front frame served more than one purpose. Firstly the bursting mandrel for splitting open the old pipeline could be accommodated there and secondly the space was needed for pulling the new pipeline into the target pit. The traction string was slid into the old pipeline, i.e. into the PVC pipe. The press-pull head, followed by the system for

**Fig. 9:**
Assembly of the first pipe to the reamer

measuring tractive force and the reamer, was coupled to the traction string. Because of the outside diameter of just on 650 mm of the ductile iron sewer pipes which would follow, the soil removal process was designed for a diameter of 690 mm. This was equal to an oversize of 20 mm or 5.7 %. To reduce the skin friction between the pipeline and the ground, the reamer also had provision for bentonite lubrication built into it. As the installation operation advanced, this very much reduced the tractive forces.

The assembly of the new pipeline and its internal feeding system, and the pulling-in, could then begin **(Fig. 9)**.

### 4.5 Pulling in of the new pipeline

The actual pulling-in of the new pipeline went off smoothly. The pulling-in of a 40 m long run needed only a day. The assembly and pulling-in of one six metre long pipe plus the feeding system took about an hour. How this hour broke down can be seen from Table 1.

**Table 1:**
Breakdown of one assembly and pulling-in cycle

| Process | Time taken [min] |
|---|---|
| Coupling of feed tube with internal auger string | 20–25 |
| Assembly of ductile iron sewer pipe with BLS®/VRS®-T push-in joint | 5 |
| Protection of the push-in joint | 5 |
| Pulling-in of new pipe, removal of soil and pressing-out/removal of old pipe | 30 |

For the initial start-up, i.e. the freeing of the old DN 300 pipe from the surrounding soil, a tractive or thrust force of 160 t had to be applied. This was no problem given the 250 t tractive force of the traction machine employed.

As the pulling-in continued, the tractive force went down to 40 t to 60 t. The traction forces were logged by means of a data logger. This was positioned between the press-pull head and the reamer. The pipe and the BLS®/VRS®-T push-in joint (allowable tractive force 860 kN under GW 322-1 [1]) were subjected to appreciably lower loads because it was only low skin friction which had to be overcome in their case.

**Fig. 10:**
Extraction by suction of the fed spoil

The soil reamed out was fed through the feed tube situated in the new pipeline to the launch pit and removed there by a suction excavator **(Fig. 10)**.

In the target pit/machinery pit, the old pipe and the PVC pipe and concrete reinforcement were pressed onto a bursting mandrel and then burst and broken into fragments. The broken fragments were then removed from the pit **(Fig. 11)**.

**Fig. 11:**
Bursting mandrel and removal of the fragments of old pipe

### 4.6 Connecting together of the sections and backfilling of the pits

The sections which had been pulled in were connected by PN 16 restrained flanged sockets and flanged spigots from the BLS®/VRS®-T range. The final steps were the dismantling of the shoring, the backfilling of the pits and the restoration of the ground surfaces.

## 5 Summing up and future outlook

The press-pull technique with soil removal is a new development, so there is of course still potential for further development and refinement of the technique. For example, the Josef Pfaffinger Bauunternehmung GmbH company decided, as from the next section, to dispense with the feed augers and to extract the soil cut away by vacuum. This does away with the complicated and laborious assembling of the feed augers and at the same time reduces the amount of troublesome mechanical components which tend to cause blockages.

To date, sections 40 m to 50 m long have been produced. Lengths of run of up to 100 m seem perfectly possible, as do diameters of up to 1,000 mm for the new pipes.

Because of their high load-bearing capacity for tractive force and high abrasion resistance, the ductile iron sewer pipes with BLS®/VRS®-T push-in joints and a ZM-coating which were used, they were installed with no damage whatever. The small oversize of just 20 mm all round stopped any visible humps, and any subsequent settlement, from occurring on the surface.

With its maximum traction force of 250 t, which was needed in this case, the sophisticated machinery made by the TRACTO-TECHNIK GmbH & Co. KG company of Lennestadt ensured that the old pipe string could be freed and the new pipeline pulled in.

Particular thanks are due to Berliner Wasserbetriebe, which has once again shown itself to be a pioneer in and promoter of trenchless installation techniques.


**Fig. 12:**
The certificate for 2nd prize under the GSTT Award 2011

## 6 GSTT Award 2011 for the press-pull technique with soil removal

On 7 December 2011, Berliner Wasserbetriebe AöR's "Berlin-Walchenseestrasse" project was awarded the 2nd prize under the GSTT Award 2011 **(Figs. 1 and 12)**. By awarding these prizes to special trenchless installation projects, the German Society for Trenchless Technology e.V. (GSTT) wishes to show what a wide range

**Fig. 13:**
The winners of the 2nd prize under the GSTT Award 2011

of opportunities there are for this technology, what financial savings can be made compared with open-trench installation, and what vast resources it offers for dealing sensitively with the environment. The prize was awarded to Berliner Wasserbetriebe AöR, Josef Pfaffinger Bauunternehmung GmbH and Duktus Rohrsysteme Wetzlar GmbH **(Fig. 13)**.
The FGR®/EADIPS® offers its sincere congratulations to all those involved.

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[1] DVGW Arbeitsblatt GW 322-1
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# Germany's biggest HDD project, using DN 700 ductile iron pipes

*by Lutz Rau*

**Fig. 1:**
The GSTT Award 2011 trophy

## 1 Background and context

In Berlin Charlottenburg, the river Havel is more than a kilometre wide. From the banks of the river, Berlin's water supply company, Berliner Wasserbetriebe, pumps raw water from the "Schildhorn" set of wells and treats it in the "Tiefwerder" waterworks to produce drinking water **(Fig. 2)**. For three years now renovation on the set of wells has been ongoing, with open trench replacement work on a 2 km long section of the pipeline for raw water, using ductile iron pipes.

The Berlin water authority, the Berlin Senate Department for Health, Environment and Consumer Protection (Sen GUV), and Nature Protection have stringent requirements which have to be observed for this work. There are also special requirements applying to laying work within the sensitive drinking water protection zone as well.

The DN 700 collecting main for raw water had to be installed in a narrow strip of land between the Havelchaussee road and the river bank **(Fig. 3)**.

This meant that in a sloping region 486 m long the pipeline had to run below the 17 m or so high river bank **(Fig. 4)**.
There were other problems:

- a high water table,
- the river bank was accessible from only one side
- the access route was not surfaced.

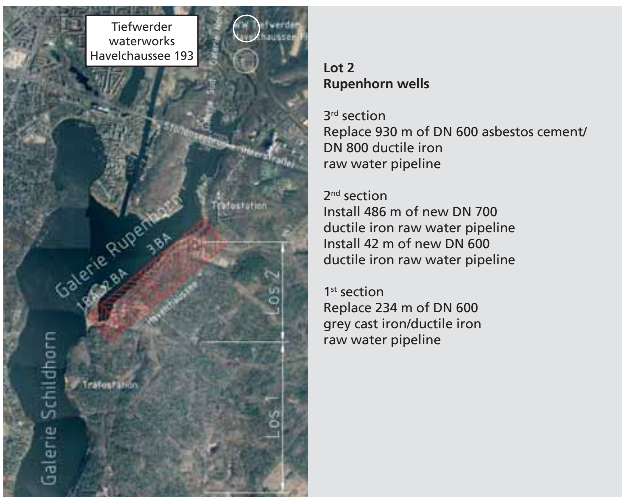


**Fig. 2:**
Locations of the sets of wells on the bank of the Havel

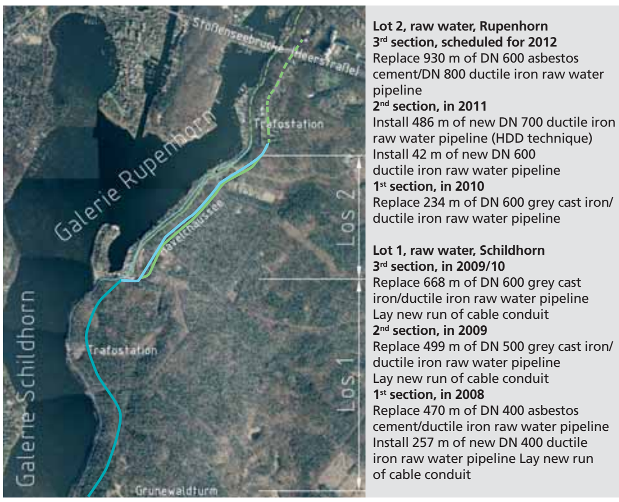


**Fig. 3:**
Route of the pipeline along the Havel

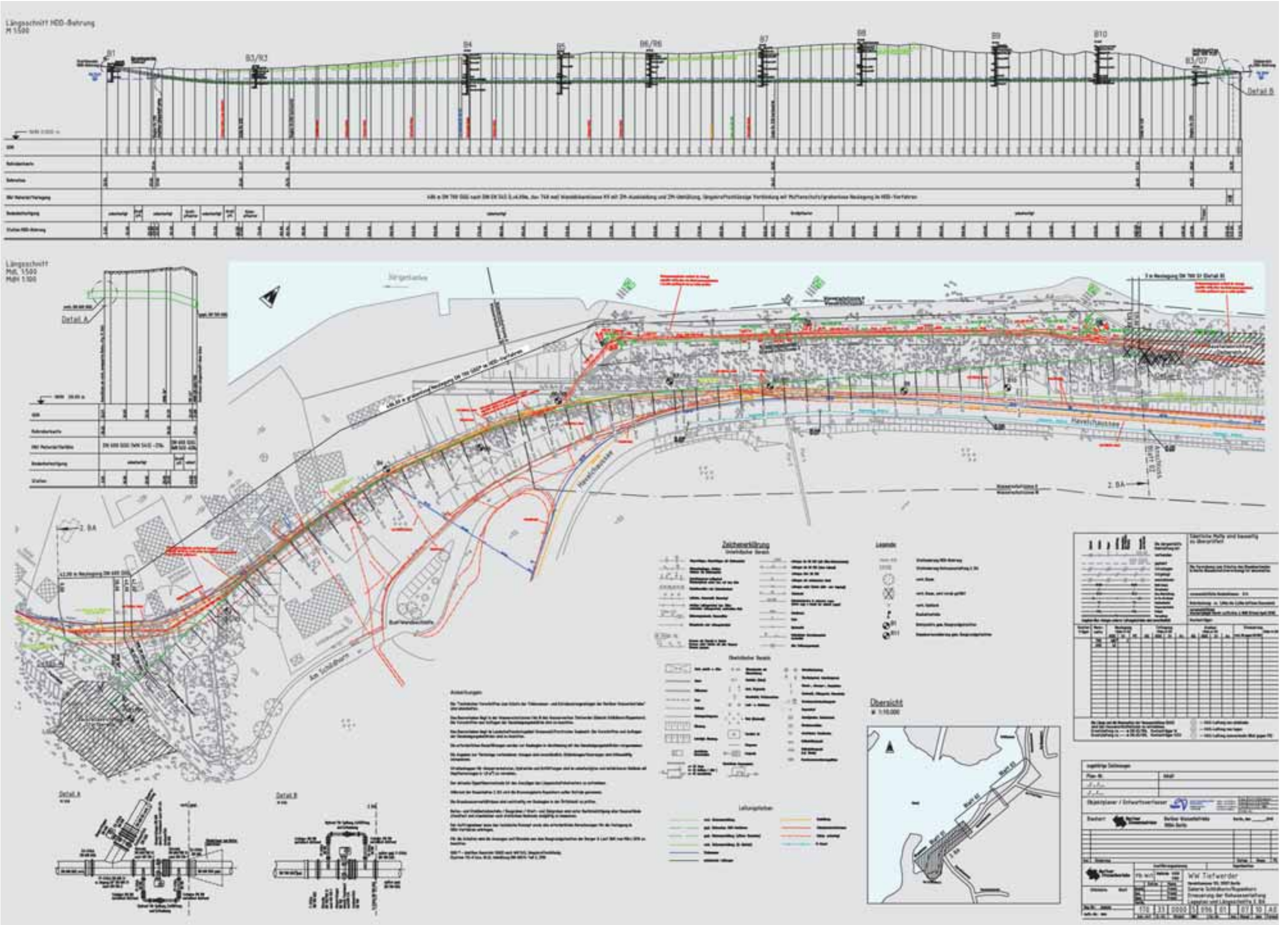

**Fig. 4:**
DN 700 HDD – Plan of locations and heights

## 2 The problems and how they were solved

With all the requirements and constraints described, installation in open trenches could be dismissed straightaway. The old pipeline could not be replaced during operation, but operation needed to be maintained. Because of the restricted access routes, pipes of any great length were not an option and short assembly times were wanted. Laying out a string of pipes would have hampered access and consent had not been given for the pipeline to be floated out on the river.

The experience which Berliner Wasserbetriebe had already had with ductile iron pipes on previous sections had been good. The relatively short laying lengths of 6 m were found to be an advantage on these. Angular deflections of the restrained joints would allow flexible adjustments to be made to cater for fixed points along the route.

The horizontal direction drilling (HDD) technique was an elegant way of meeting these different requirements. After a critical check on the costs, the consulting engineers doing the planning, Hyder Consulting GmbH Deutschland, also considered it the preferred technique. Experience with projects of a similar size abroad meant that there was even less of a risk.

## 3 Preparations for installation

Berliner Wasserbetriebe's project management department did the planning and took conscientious account of the interests and demands of all the parties involved and affected. A restricted invitation to tender with an open competitive pre-qualification procedure then selected the consortium to do the installation work and a further invitation to tender decided the pipe and fittings supplier.

An order was placed for 504 m of ductile iron pipes to EN 545 [1] of wall-thickness class K 9 with TYTON® push-in sockets and the BLS®-/VRS®-T restraint system and for the fittings required. The pipes are lined with cement mortar and on the outside are zinc coated with a rugged outer cement mortar coating to

EN 15542 [2]. This coating withstands very high mechanical and chemical stresses. The joint regions are protected by heat-shrinkable tapes and sheet-metal cones.

## 4 The installation work – Part 1

Under the lead management of the Berlin branch of the Stehmeyer + Bischoff GmbH & Co. KG company, the preparatory work got under way:

- drawing up and agreeing a timetable for installation,
- setting up of the site,
- digging of the launch pit lined with timber shoring,
- surfacing/securing the site areas
- dismantling/relaying a number of pipelines in the launch pits and target pits.

The pilot bore and the following enlargement stages were the work of consortium member BLK-Bohrteam GmbH. The client required the allowable curve radius of 230.00 m (max. angular deflection at sockets 1.5°) to be kept to with absolute accuracy and to be documented by means of a cable-guided measuring system. While the drilling specialists were enlarging the diameter of the drilled bore, the target pit was dug and the line for the back-flushing fluid was set up. Work began early in November 2010.

By the end of November, the bore had been enlarged first to 500 mm and then to 850 mm. The pipes were ferried from the storage point to the assembly pit on smaller vehicles.

## 5 Problems with the installation work

Early in December 2010, the onset of winter forced the work to be suspended. Because of the frost there could be no guarantee of thorough back-flushing and the launch pits and target pits were also iced up. Another surprise was a historically high water level on the Havel, which meant that the track along the bank to the assembly pit was flooded **(Fig. 5)**. The water even threatened to run into the assembly pit, which needed an extra safeguard in the form of sandbags.

## 6 The installation work – Part 2

Work resumed from mid-January 2011. The enlargement to 850 mm was repeated and the bore then bored out to 1,100 mm. The final clearing was done by a "cleaning pass" by a 6 m long DN 850 trial pipe and the bore was checked for free passage. The requirements for river bank protection prevented a pre-assembled pipe string from being pulled in. This was why pipe-by-pipe assembly **(Fig. 6)** with a fairly steep angle of entry at the assembly pit was adopted. A 12 m long inclined steel assembly ramp, which was enclosed in scaffolding and tarpaulins because of possible bad weather, was constructed for this purpose **(Figs. 7 and 8)**. Following instruction by the pipe supplier's applications engineering department **(Fig. 9)** and joint fitting of the traction head **(Fig. 10)**, the actual pulling-in could begin **(Fig. 11)**.
The crew from the installing company soon got into a routine and the 486 m long pipeline was assembled and pulled in in just 34 hours, including the protection of the joints (60 hours had

**Fig. 5:**
High water on the Havel –
Work in the flooded site area

**Fig. 6:**
Pipe-by-pipe assembly – the first DN 700 ductile iron pipe on the assembly ramp

**Fig. 7:**
The steel assembly ramp – A shrink-on sleeve and protective cone being fitted


**Fig. 8:**
The enclosure in the assembly area

**Fig. 9:**
Instruction by the pipe supplier's applications engineering department

**Fig. 10:**
Fitting the traction head

**Fig. 11:**
The DN 700 ductile iron pipeline dipping into the drilling fluid


**Fig. 12:**
Three-shift work – Work on the night shift

been planned). All in all, an average of 14 workers per shift worked on the three-shift system **(Fig. 12)**. To control its buoyancy, the DN 700 was filled with water at all times. Three small filler pipelines were also pulled in in parallel. The tractive force for pulling-in was below the allowable 165 t.

## 7 Remaining work and resumé

The remaining drilling fluid between the ductile iron pipeline and the tunnel wall was replaced by a hydraulically curing cement-based suspension with a final strength of 2.0 $N/mm^2$. A camera was passed through the pipeline to inspect it and it was pigged, flushed out, disinfected and pressure tested. The ends of the pipeline were connected into the existing system.

Despite the bad weather the operation was successfully completed by late February 2011. With the easily assembled BLS®-/VRS®-T system, pipe-by-pipe assembly proved to be an advantage in this case and even in cramped conditions the angle of entry required was easy to set and still allowed high installation rates to be achieved. This was a convincing demonstration

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3. Preis

GSTT - Award 2011

innovatives und bedeutendes Projekt
des grabenlosen Bauens

Berliner Wasserbetriebe AöR

Projekt „HDD DN 700 Berlin – Havelchaussee"

Beteiligte Unternehmen:
Duktus Rohrsysteme Wetzlar GmbH
ARGE Stehmeyer & Bischoff GmbH & Co. KG /
BLK Bohrteam GmbH

Prof. Hölterhoff
Vorstandsvorsitzender

Dr. Beyer
Geschäftsführer

GSTT
GERMAN SOCIETY FOR TRENCHLESS TECHNOLOGY e.V.

**Fig. 13:**
The certificate for $3^{nd}$ prize at the GSTT Awards 2011

**Fig. 14:**
The prize being presented by Prof. Jens Hölterhoff to the representative of Berliner Wasserbetriebe, Herr Torsten von Trotha

of the allowable tractive forces and provided an assurance of high levels of safety for user and client, even on angled routes.

Pipes of ductile iron with a cement mortar lining and the rugged cement mortar coating are a guarantee of a long life and decades of trouble-free operation.

## 8 Prize awarded to the project at the GSST Awards 2011

With its GSTT Awards, the German Society for Trenchless Technology (GSTT) honours special, outstanding projects in the field of trenchless installation.

On 7 December 2011 at the Dortmunder Sanierungstage conference, Berliner Wasserbetriebe AöR was awarded $3^{rd}$ prize **(Figs. 1 and 13)** at the GSTT Awards 2011 for its "DN 700 HDD Berlin-Havelchaussee" project. The companies involved in the project were the Stehmeyer + Bischoff GmbH & Co. KG/ BLK-Bohrteam GmbH consortium and Duktus Rohrsysteme Wetzlar GmbH.

The accolade was bestowed on the project, and the GSTT Award 2011 was presented, by the chairman of the board of GSTT, Prof. Jens Hölterhoff **(Fig. 14)**.

The FGR®/EADIPS® offers its congratulations to the companies involved for winning the 3rd prize at the GSTT Awards 2011.

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Ductile iron pipes, fittings, accessories and their joints for water pipelines – Requirements and test methods
2007

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Ductile iron pipes, fittings and accessories – External cement mortar coating for pipes – Requirements and test methods
2008



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# A DN 500 penstock pipeline pulled in straight through a mountain

*by Andreas Moser*

## 1 Extension of the penstock pipeline

Under a new licence granted under water law, the "E-Werk Tasser" small hydroelectric power station has been completely replaced except for the water intake structure and the existing penstock pipeline. The existing penstock pipeline was 1,840 m long and travelled through a difference in height of 147 m. It was laid in 2002. For the new "E-Werk Tasser" project which had been submitted, the existing pipeline was to be lengthened by 1,225 m, which would give it an increase in operating pressure from 15 bars to 28 bars. The additional head of 128 m would produce a rise of approximately 60 % in annual electricity generation.

**Fig. 1:**
The turbine pipeline was installed straight through the mountain at the point indicated by the red circle

## 2 Selecting the material of the pipes

Ductile iron pipes as shown below were selected for the installation of the penstock pipeline extension:

- nominal size: DN 500,
- socket joints:
  BLS®/VRS®-T restrained push-in joints,
- wall-thickness classes: K 9 and K 11,
- lining:
  high-alumina cement mortar due to the driving water's very low pH (pH = 5)
- coating:
  active: thermally sprayed zinc
  passive: polyurethane

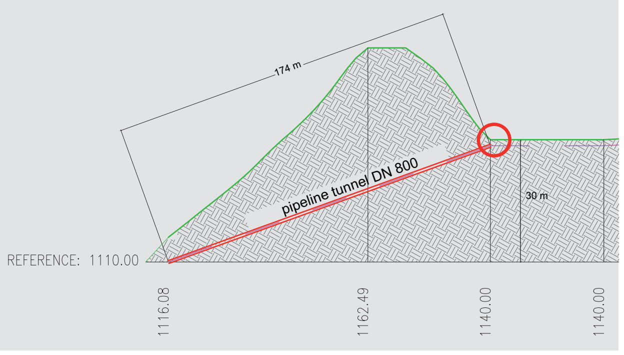


**Fig. 2:**
Height profile of the pipeline tunnel – difference in height 30 m

## 3 Planning

The planning of the new route to be followed by the turbine pipeline extension was a major challenge for everyone involved. This was not because of high operating pressures, but because of the cramped space available between the stream carrying the water and the steep slopes surrounding it. **Fig. 1** shows how the valley narrows at the start of the planned pipeline tunnel. It was impossible for a safe route for the pipeline to be excavated on the right or left of

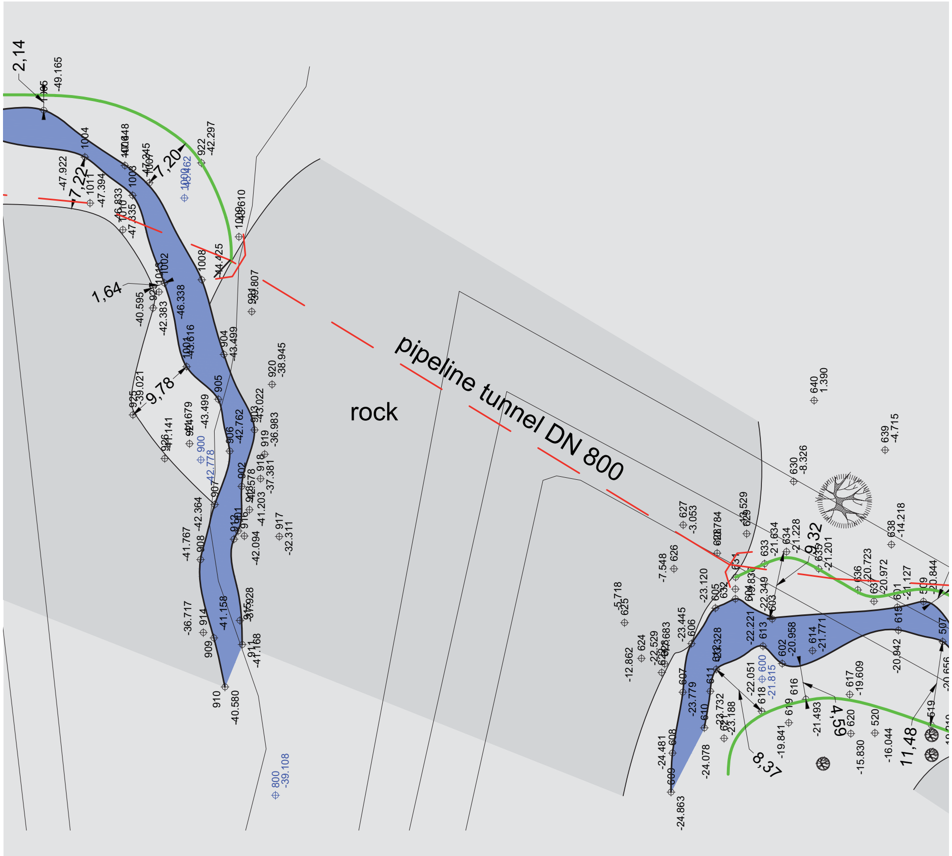


**Fig. 3:**
Layout plan of the route selected – Length of pipeline tunnel 174 m

the stream. Doing this would have created a risk of the pipeline floating out at high water and of its being damaged by the bed load of the stream (large stones and sand).

The plan envisaged part of the pipeline having to be installed through a mountain ridge of solid dolomite rock.

**Fig. 2** shows the difference in height between the launch pit and the exit of the new pipeline tunnel to be produced.

It is 30 m; this corresponds to a difference in operating pressure of $\Delta PFA = 3$ bars.

**Fig. 3** shows the route followed by the new penstock pipeline.

**Table 1** is an overview of the technical details of the project.

**Table 1:**
Technical details

| | |
|---|---|
| Length of the new run of penstock pipeline | 1,225 m |
| Length of the extended penstock pipeline | 3,065 m |
| Length of the pipeline tunnel crossing through the mountain | 174 m |
| Diameter of the pipeline tunnel | 800 mm |
| Nominal size of the penstock pipeline | DN 500 |
| Operating pressure in the region of the pipeline tunnel | 20 bar |
| Material of the penstock pipeline pipes – in the region of the tunnel | |
| Ductile iron pressure pipes with BLS®/VRS®-T push-in joints, wall-thickness class K 11<br>– coating:<br>active corrosion protection: 200 g/m² of thermally sprayed zinc<br>passive corrosion protection: fibre-reinforced cement mortar coating with a layer thickness of 6 mm<br>- lining:<br>high-alumina cement due to the very soft, acid, water (pH = 5) | |
| Material of the penstock pipeline pipes – remainder of the new penstock pipeline | |
| Ductile iron pressure pipes with BLS®/VRS®-T push-in joints, wall-thickness class K 9<br>– coating:<br>active corrosion protection: 200 g/m² of thermally sprayed zinc<br>passive corrosion protection: polyurethane with a layer thickness of ≥ 150 µm<br>– lining:<br>high-alumina cement due to the very soft, acid, water (pH = 5) | |

## 4 The installation work

For the quite short distance of 174 m, the boring of the DN 800 tunnel was protracted and took six months. The reason for this was that the dolomite rock which often occurs in the region concerned (the Gadertal in South Tyrol) is very difficult to work on and presented considerable difficulties for the boring of the tunnel.

The cutting wheels of the boring head had to be replaced a number of times **(Fig. 4)**. The bored tunnel was lined with steel tubes, chiefly to protect the empty polyethylene pipes (for control cables, etc.) which were also installed in the tunnel against any pieces of rock breaking loose. What was also needed was a smooth surface for pulling in the ductile iron pipes **(Figs. 5 and 6)**. The ductile iron pipes with BLS®/VRS®-T restrained push-in joints were pulled into the previously inserted steel tubes downhill by a diesel-hydraulic traction system **(Fig. 7)**.

To keep the friction generated as low as possible, a commercially available lubricant was used at the points of contact between the steel tubes and ductile iron pipes. A traction head supplied by the pipe manufacturer was used as a connector between the positively locked ductile iron pipeline and the traction unit **(Fig. 8)**.
The 174 m long ductile iron pipeline with a dead weight of 26,380 kg was pulled into the tunnel all in one run.

The allowable tractive force on the BLS®/VRS®-T restrained push-in joint is 860 kN. The tractive force which actually occurred was determined to be 49 kN.

**Fig. 4:**
DN 800 boring head,
showing replaced cutting wheels

**Fig. 6:**
The launch pit – an inserted steel tube with ductile iron pipes pulled in

**Fig. 5:**
The pipeline tunnel when bored, showing the sometimes friable rock

**Fig. 7:**
The diesel-hydraulic traction unit at the tunnel exit.
It was also converted to act as the boring unit

**Fig. 8:**
At the tunnel exit: the traction head with ductile iron pipes hitched on with four empty pipes riding on them

**Table 2** is an overview of the operating pressure, the allowable tractive force, and the angular deflection and therefore the radius of curves, for the selected nominal size of DN 500. It also gives details relating to assembly.

**Table 2:**
DN 500 penstock pipeline – Application and installation information and assembly times

| | |
|---|---|
| Nominal size | DN 500 |
| Operating pressure PFA | 30 bar |
| Allowable tractive force $F_{all}$<br>DVGW-Arbeitsblatt GW 320-1<br>Duktus Manual on Trenchless Installation of Ductile Iron Pipes | <br>860 kN<br>860 kN |
| Possible angular deflection at sockets | 3° |
| Minimum radius of curves | 115 m |
| Number of assemblers | 2 |
| Assembly time not including joint protection | 12 min |
| Assembly time when using a rubber sleeve | 14 min |
| Assembly time when using a shrink-on sleeve | 28 min |

## 3 To sum up

In the region of the Untermojerbach stream (municipality of Enneberg in the province of Bozen in South Tyrol, Italy), the new section of the DN 500 penstock pipeline for the "E-Werk Tasser" small hydroelectric power station has been run through a pipeline tunnel. All the fresh installation work to increase the capacity of the small hydroelectric power station was carried out from June 2010 to November 2011.


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# The operators' association Liftverbund Feldberg makes sure of snow

*by Stefan Wirbser, Christian Weiler and Alexander Bauer*

## 1 About the ski resort

The operators' association Liftverbund Feldberg GbR was founded in the 1970's and consists of the tourist services departments of the towns of Todtnau and St. Blasien and the municipality of Feldberg. The association operates three cable cars and twelve surface lifts on 40 km of ski runs of all levels of difficulty.
The Feldberg mountain is the third largest skiing region in Germany. The 2 km long World Cup downhill course on the Rothausbahn has been the venue for the Alpine Ski World Cup three times. Each time, only the best in the world at the time were able to emerge victorious on it, they were Ingemar Stenmark, Pirmin Zurbriggen and, in 2000, Hermann Maier.

An average of 130 operating days each winter bears witness to the high reliability of snow. 400,000 to 480,000 skiers visit the resorts every winter **(Fig. 1)**. Turnover varies between 6 million and 8.5 million Euros. Over the past few years about 30 million Euros has been invested on piste grooming and snow-making systems and in modernising the lifts and cable cars. Around 120 seasonal jobs and another 350 at skiing schools and in restaurants provide the population of this high area of the Black Forest with employment in the winter months.

On the Feldberg mountain there are a number of cable car companies which belong to the Liftverbund Feldberg **(Fig. 2)**. The Feldberg is the highest mountain in the federal state of Baden-Württemberg and with the general conditions which exist there, it is one of the regions in the European low mountain ranges where snow can be relied on. 16 uphill transport systems provide access to the ski runs. Artificial snow is available on about 1/3 of the ski runs.
The showpiece of the skiing region is the World Cup ski run. The last time it was the venue for the Alpine Ski World Cup was in 2000. The German Snowboard Championships were last held on the Feldberg in 2007.

**Fig. 1:**
Skiers at the top station


**Fig. 2:**
The Liftverbund Feldberg

**Fig. 3:**
The reservoir lake

**Fig. 4:**
Leisure-friendly landscaping for around the reservoir lake

## 2 The snow-making plan

In 2008, Liftverbund Feldberg decided to place a contract with the well known consulting engineers Klenkhart & Partner Consulting ZT GmbH, whose head office is in Absam in Tirol, to draw up a basic plan for snow-making. Klenkhart & Partner counts some 250 cable car companies all over the world among its regular customers and a flagship project for it was the drawing up of the overall technical plan for the FIS Alpine World Ski Championships 2011. It developed a forward-looking snow-making plan for the enormous skiing region on the Feldberg. In its fully developed form, this will guarantee reliable snow on all the main downhill runs on at least 110 days of operation a year.

At the heart of the snow-making plan was the setting up of a central reservoir lake with a capacity of around 250,000 m$^3$ **(Fig. 3)**. This lake is an environmentally acceptable way of ensuring a supply of water for the snow-making systems. Environmentally acceptable means that the reservoir lake will be filled at the times when the surrounding flowing watercourses are carrying high levels of water (i.e. during the melting of snow or during and immediately after heavy rainfall), and the withdrawal of water from these flowing watercourses is therefore not a problem for freshwater ecology. Water does not need to be withdrawn from flowing watercourses at times when flow is low, whereas there is no objection from the point of view of freshwater ecology to large volumes of water being withdrawn from the big reservoir lake for short periods.

What is more, the reservoir lake was to be laid out in such a way as to look like a natural mountain lake. Habitats for amphibians, reptiles and insects in the form of small untended pools of a wide variety of types are also to be created in the area immediately surrounding the reservoir lake.

These operations are enriching the appearance of the landscape, are creating new and attractive habitats and are widening the range of what is on offer to summertime guests and local residents looking for recreation **(Fig. 4)**.

## 3 The reservoir lake

In drawing up the basic plan for snow-making, a main concern was finding a solution which was as energy-efficient as possible. Because of the high altitude of the reservoir lake in the skiing region, full use can be made of the natural pressure produced by the geodetic difference in height. There are also enough springs and flowing watercourses on the same level as the reservoir lake, making it energy efficient to fill it.

The altitude of the reservoir lake combined with the use of the geodetic difference in height also allows the pumps used to be only medium-pressure ones (high-pressure pumps are not required); as well as reducing the capital costs, this fact also means a considerable reduction in the use of energy and, as a result, in the operating costs.

In their fully developed form, the central reservoir lake and the central pumping station, whose projected pumping capacity is 600 L/s, will be supplying the skiing regions of Feldberg-Seebuck, Todtnau-Fahl and St. Blasien-Grafenmatt through a 15 km long network of snow pipelines.

## 4 The use of ductile iron pipes

Because of the sometimes difficult geology of the ground (a constant alternation between soil class 2, shifting soils, and soil class 7, rock), the material selected for the pressure pipelines was ductile iron. The pipes used were ductile iron pipes **(Fig. 5)** with restrained push-in joints to EN 545 [1].

Even with the difficult ground conditions which existed here, ductile iron pipes were a guarantee of fast and easy installation, with little likelihood of mistakes regardless of the temperature and weather.

This was tremendously important given the short installation period each year on the Feldberg (in order not to interfere with summer tourism, installation work close to the main hiking trails is only possible outside the high season in summer) **(Fig. 6)**.

Since 2010, and building on the findings made under the basic snow-making plan, extensions are now being made, year on year, to the existing

**Fig. 6:**
The Feldberg with snow-covered ski runs

snow-making systems to allow the planned fully developed stage to be reached in about ten years. In the past two years, the pipes used have been only ductile iron pipes of the DN 80 to DN 250 nominal sizes with BLS®/VRS®-T push-in joints. The length of run is 4 km. The installation work was put out to open tender.

The difficulties in doing the installation work lay mainly in the difficult terrain and the very short time period for the installation. These two factors and the high operating pressures of up to 63 bars imposed severe requirements for the material of the pipes to be installed. The ductile iron pipes have met the requirements laid down for them in every respect.

**Fig. 6:**
Ductile iron pipes with restrained push-in joints

## 5 Future prospects

For the future, the movers and shakers around Feldberg's lord mayor Stefan Wirbser (the chairman of the Liftverbund) are planning further investments in snow-making.

The aim here is for snow to be made on all the ski runs. Also, the surface lifts are to be successively replaced by coupleable chair lifts. As well as this there are also plans for the construction of a multi-storey car park containing 1,300 parking spaces. Work is currently being done on financing this.

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# 25 years of driven ductile iron piles

*by Jérôme Coulon and Erich Steinlechner*

## 1 Five million metres installed

When they invented the ductile iron pile in the early 80's at the AB Gustavsberg company, this was a figure the Swedes Bertil Schmidt and Pentti Kosonen would not have dreamed of. Ductile iron was completely unknown in special geotechnical engineering, nor did people see it as a very likely candidate. Initially, they underestimated the "G-Påle" and it was only felt to be justified for underpinning inside buildings. It was as a result of the technology being transferred (a licence agreement) in 1986 between the Tiroler Röhren- und Metallwerke AG and AB Gustavsberg companies that the ductile iron pile reached Austria and therefore Central Europe. As a result, it became known as a versatile idea for foundations which meant reliability and speed. The success story began. In 25 years, five million metres have been produced and have been used all over the world on the most varied projects.

Whereas in the early days of the story, the system met with scepticism and misunderstanding among pile-driving engineers, today Austria could not do without it. Spheroidal graphite cast iron **(Fig. 1)**, also known as ductile iron, was and is the key to this success.

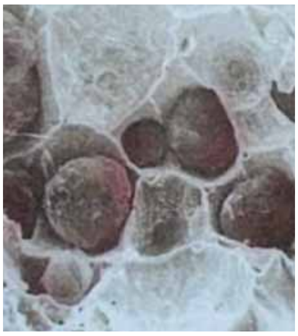

**Fig. 1:**
Ductile iron under the scanning electron microscope: spheroidal graphite gives the iron high levels of strength, including for example impact resistance

**Fig. 2:**
Driven ductile iron piles are preformed industrially under very strict quality controls during the process. Together with the barrel of the pile pipe, the conical plug-in joint is produced in a single cast.

**Fig. 3:**
5 m long driven ductile iron piles stored ready for delivery

The material was industrialised in the early 50's and provides a simultaneous combination of everything a driven pile system needs:

- ductility,
- impact strength, and
- corrosion resistance.

Added to this, there is excellent castability. The conical plug-in joint is the most important means of connection and is produced, together with the barrel of the pile pipe, in a single cast **(Fig. 2)**; this makes things very much easier on site. The piles are produced in 5 m long sections **(Fig. 3)**, which makes for easy handling, and can be connected directly on site without any welding or special tools. This also allows the piles to be varied in length.

Bored piles of diameters ≥ 500 mm or bored micropiles [1] of diameters ≤ 300 mm are economically replaced in Austria by ductile iron piles because ductile iron gives the best possible combination of high loads with slender design. Its modern material even allows the driven ductile iron pile to score points over other preformed driven piles in many respects.

## 2 Advantages of preformed driven piles

In special geotechnical engineering, there have always been two means of support, bored piles and driven piles. The advantages of bored piles come to the fore when high loads and high bending moments have to be withstood, e.g. in multi-storey buildings and bridge abutments. The disadvantage is the heavy and expensive equipment needed for them. Where the use of heavy equipment is not possible, e.g. on gap sites or where the headroom or access is restricted, large sets of conventionally bored micropiles are therefore employed. However, both systems, bored piles and bored micropiles, have a low installation rate per day and the boring spoil fed out has to be disposed of. Over the past few years, dumping costs have soared. With contaminated soils, disposing of the spoil costs several times more than the actual foundation. Because of this, it is more and more frequently being asked why the soil cannot be left where it is.

High productivity is always wanted. With bored piles, new techniques such as the SOB pile (augered cast-in-place pile) have been developed for this purpose. However, this system shows little response to the actual foundation soil present. Variations in load-bearing capacity due to load-bearing soil layers of varying thickness and compactness are a problem. Concreting below the water table, the exposure of concrete reinforcement, constrictions of the column of fresh concrete due to expanding soil, these are all added difficulties which have to be factored into the design.

Given all these difficulties, reliance in special geotechnical engineering is placed, wherever possible, on precast driven piles. The precast driven pile is usually manufactured industrially, is subject to thorough quality control and, due to the high degree of production by machine, there is a reduction in human error on site.

As a representative of the precast driven pile, the driven ductile iron pile has the advantage that, due to its good strength-to-mass ratio, high load-bearing capacities can be obtained using only small and light-weight equipment. The pile heads do not have to be trimmed and integrity tests can be dispensed with.

## 3 The superiority of ductile iron

The most important materials for precast driven piles are reinforced concrete, steel, wood and cast iron, though the wooden pile is taking very much of a back seat nowadays firstly due to its limited length, but above all because problems may be caused by the only limited consistency in quality. It is true that wood does not rust but it is subject to uncontrollable rot due to oxygen in areas where the water table varies. In terms of quantity, reinforced concrete and steel are the leaders in precast driven piles, but as the loads rise and the driven items become larger, the equipment which has to be used very soon becomes very big and the advantages over the equipment for bored piles no longer exist. Both materials impose high labour costs for cutting off the projecting piece of pile if the criterion for ceasing to drive is reached prematurely. Lengthening the individual pile sections also imposes additional labour costs.

As well as all the advantages which the precast driven pile has over the bored pile, driven ductile iron piles have an additional advantage in the form of their DUKTEC material. DUKTEC is a specially modulated cast iron produced by Duktus S.A. which optimises the ductility, impact strength and corrosion resistance of the driven ductile iron pile. Ductile iron is also the only material which allows the plug-in joint to be produced directly with the barrel when the pile is being produced in the factory. The PLUG AND DRIVE joint is stiff in bending and locked by friction. No additional work has to be done on site to connect the individual sections of the pile. In terms of stress analysis, a driven ductile iron pile is the same as a continuous monolithic pile. Pile lengths of 50 m or more are not a problem and can be driven with the same small equipment.

The most important features of the materials used in the technology of precast driven piles can be identified by considering the following criteria:

- **Environmental compatibility**
  Raw materials from the recycling industry, local resources, low pollution from fossil fuels and $CO_2$ emissions,
- **Drivability**
  Equipment required, high impact strength and low risk of fracture
- **Handling/transport**
  Modular make-up, individual lengths, economical transport and storage, potential hazards when being unloaded, response of material to over-stressing
- **Adjustment of length**
  Time spent on assembling joints (plug-in joints, welded joints and bolted joints), trimming of pile heads,
- **Long life**
  Fitness for purpose, corrosion,
- **Vibration/noise**
  Frequency in the ground, effects on man and nature.

**Table 1** shows the criteria for the use of different materials in the field of precast driven piles. Ductile iron shows up convincingly under all the criteria, and the idea of recycling should be particularly emphasised. In a society which considers the sorting of waste important, the idea of recycling must also apply to the materials used in foundation engineering. To sum up, it can be said that ductile iron meets all the above criteria and therefore makes a significant contribution to sustainability.

## 3 Lowering of level of the Lucerne Zentralbahn

An enormous increase in traffic can be expected on Switzerland's A 2 autobahn in the Lucerne area over the next few years. By expanding the urban railway services, the intention is to get the proportion of commuters to change over to suburban public transport. This shifting of traffic, combined with the moving of the Zentralbahn (central railway) to a lower level in the area of the town, will result in a significant reduction in noise emission in the town of Lucerne **(Figs. 4 and 5)**.

The Zentralbahn Development Project is a key project in the programme for the Lucerne conurbation. Work is underway on the stretch of the Zentralbahn network between the Lucerne-Engelberg and Lucerne-Interlaken sections. In 2006, the Federal Council included the project

**Table 1:**
Criteria for the use of different materials in the field of precast drive piles

| Criteria for use | Ductile iron | Wood | Steel | Reinforced concrete |
|---|---|---|---|---|
| Environmental compatibility | ++ | +++ | + | + |
| Drivability | +++ | – | ++ | – |
| Handling/transport | +++ | + | + | – |
| Adjustment of length | +++ | – – | – | – |
| Long life | ++ | – – | + | ++ |
| Vibration/noise | + | – | – | – – – |

**Fig. 4:**
Aerial photo of the area of the "Lowering of level of the Lucerne Zentralbahn" site, where ductile iron piles were used for the first phase of the work

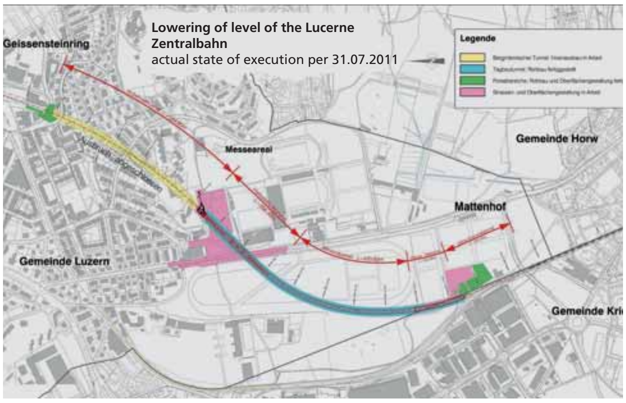


**Fig. 5:**
Layout plan of the "Lowering of level of the Lucerne Zentralbahn" site

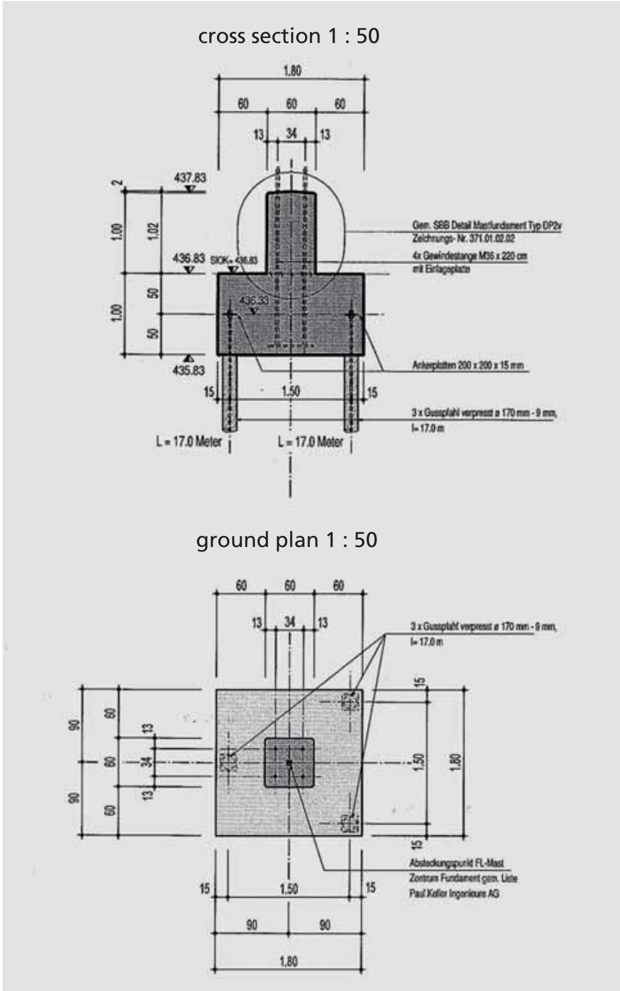


**Fig. 6:**
Design drawings of a mast and anchorage footing for the overhead lines

on the list of urgent projects to be implemented under the National Infrastructure Fund. The capital investment costs amount to 250 million CHF. The Zentralbahn Development Project consists of a number of sub-projects.

The key element is a widening to two tracks, with the tracks moved to a lower level, in Lucerne (the moving to a lower level will allow four changes of levels to be done away with in the inner city). There is also provision for other adjustments on the rest of the Zentralbahn network to increase speeds on the sections of track and performance generally. The first trains will be travelling through the Allmend and Hubelmatt tunnels to Lucerne on the new twin tracks after the timetable change in December 2012. Conversion work on the railway infrastructure has been necessary for the lowering of the level in Lucerne. The below-ground work on the tracks, including the deep foundations for the footings carrying the posts for the overhead lines, has been done quickly and promptly by the C. Vanoli AG company of Immensee **(Figs. 6, 7, 8 and 9)**.

The mast and anchorage footings for the overhead lines of Swiss Federal Railways (SBB) and the Zentralbahn (zb) are stressed in compression and tension (vertical forces) and the horizontal forces are coupled to the moments and are applied to the head of the footing. Depending on the type of footing, two to three piles per footing are being installed. The compressive loads are transmitted to the soil by 170/9.0 mm grouted driven ductile iron piles – outside diameter 250 mm – and the tensile loads are transmitted by additional 28 mm Ø pre-injected anchor rods fixed into the piles **(Fig. 10)**.

The ground at the site of the project consists of mushy to soft lacustrine deposits, sometimes permeated with unstable lenticles of clay, and below the lacustrine deposits, a stiff to hard, i.e. dense to very dense, ground moraine. The ground is saturated with water to a point close to the surface (water table about 1.0 m below the terrain surface). The lacustrine deposits are susceptible to settlement and are not suitable for the transmission of loads by shallow foundations. Also, the level of the top of the ground moraine varies widely and a pile system of variable length is needed.

All these requirements can be met with the driven ductile iron pile and the first sections of the work have been completed to the client's satisfaction **(Figs. 11, 12 and 13)**. The load-bearing capacity was confirmed by a tensile test, which showed a safety factor of 3.5.

**Fig. 7:**
The driven ductile iron piles being driven

**Fig. 8:**
Thanks to the light and compact driving equipment, the ductile iron piles were installed directly by the existing tracks and overhead lines, with restricted headroom, while normal railway services continued.

**Fig. 9:**
New masts erected for overhead lines

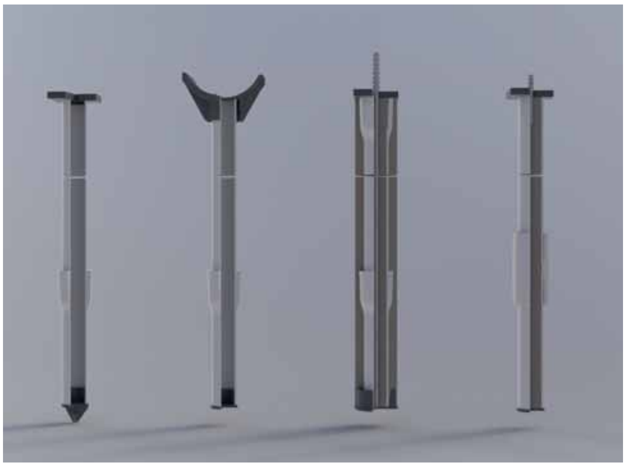

**Fig. 10:**
Types of driven ductile iron piles – tension and compression piles: depending on the nature of the soil and the loads, ductile iron piles with suitable top and bottom accessories are installed with or without grouting.

**Fig. 11:**
A tension pile being tested: in the tensile test, the test pile operating by skin friction achieved the requisite load-bearing capacity with a safety factor of 3.5.

**Fig. 12:**
Laying overhead line and anchorage footings

**Fig. 13:**
New Swiss Federal Railways overhead lines: the piles for the mast and anchorage footings are loaded in tension and compression and the horizontal forces are coupled with the moments and are applied to the top of the footings.

## 5 To sum up

After 25 years of positive experiences with driven ductile iron piles and a wide range of projects carried out all over the world, it has to be said that ductile iron, with all its advantages, is today an established part of special geotechnical engineering. The centrifugal casting process allows the plug-in socket joint to be produced in one piece with the tubular barrel and, in this way, allows the time spent and the quality achieved to be improved on site. The properties of the material in the areas of processing and corrosion characteristics, the easy processing technique, and the high load-bearing capacities are the success factors which will ensure that there is a place for the driven ductile iron pile in special geotechnical engineering not just now but in the future too.

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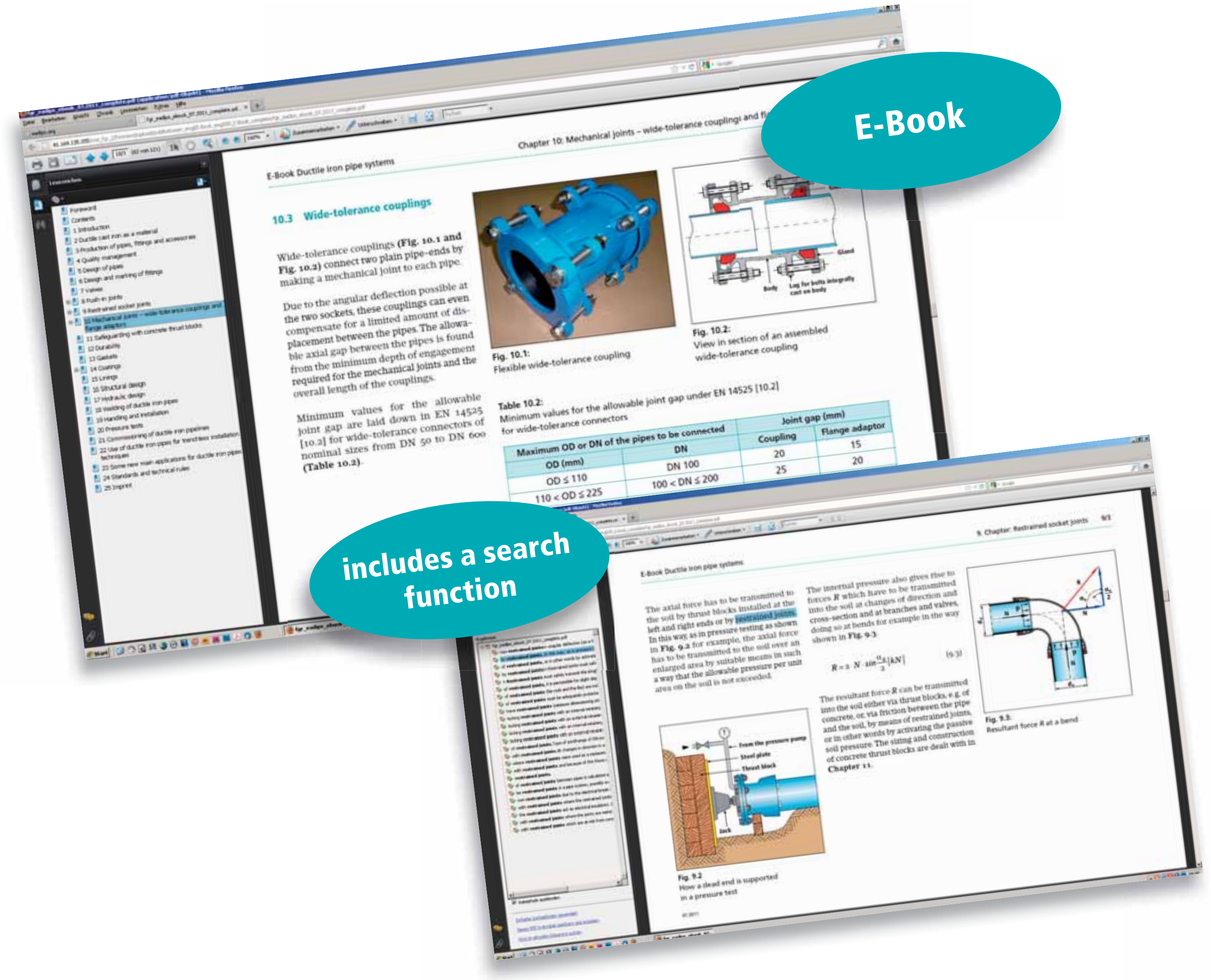


# Welcome to the FGR®/EADIPS®

On our web-site, **www.eadips.org**, you can find everything you want to know on the subject of ductile iron pipe systems:

- pipes,
- fittings, and
- valves.

Under the **Publications** button you will find an **E-Book** button. The chapters of the German FGR®/EADIPS® E-Book Guss-Rohrsysteme are constantly being updated. Chapters 9 (Restrained socket joints), 10 (Mechanical joints) and 14 (Coatings) were updated in 2011.

In Chapter 24 (standards, directives and technical rules), there is a link to the FGR®/EADIPS®'s standards database **www.eadips.org/normen-datenbank**. This standards database is currently under construction and in the future will contain all the standards and other normative documents which have to be followed in connection with ductile iron pipe systems. The most recent German version of the E-Book is the 07.2011 version.

In 2011, the FGR®/EADIPS® E-Book also began to be made available in English. You can also access the English E-Book **Ductile iron pipe systems** on our web-site. Only updated chapters have been taken over from the German version to the English one. Chapters 8 (Push-in joints), 9 (Restrained socket joints), 10 (Mechanical joints) and 14 (Coatings) were added in 2011. The most recent English version of the E-Book is the 07.2011 version.

The FGR®/EADIPS® will endeavour to continue updating chapters of the E-Book and in this way to document the current state of knowledge on ductile iron pipe systems.

# Notes

## Notes


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