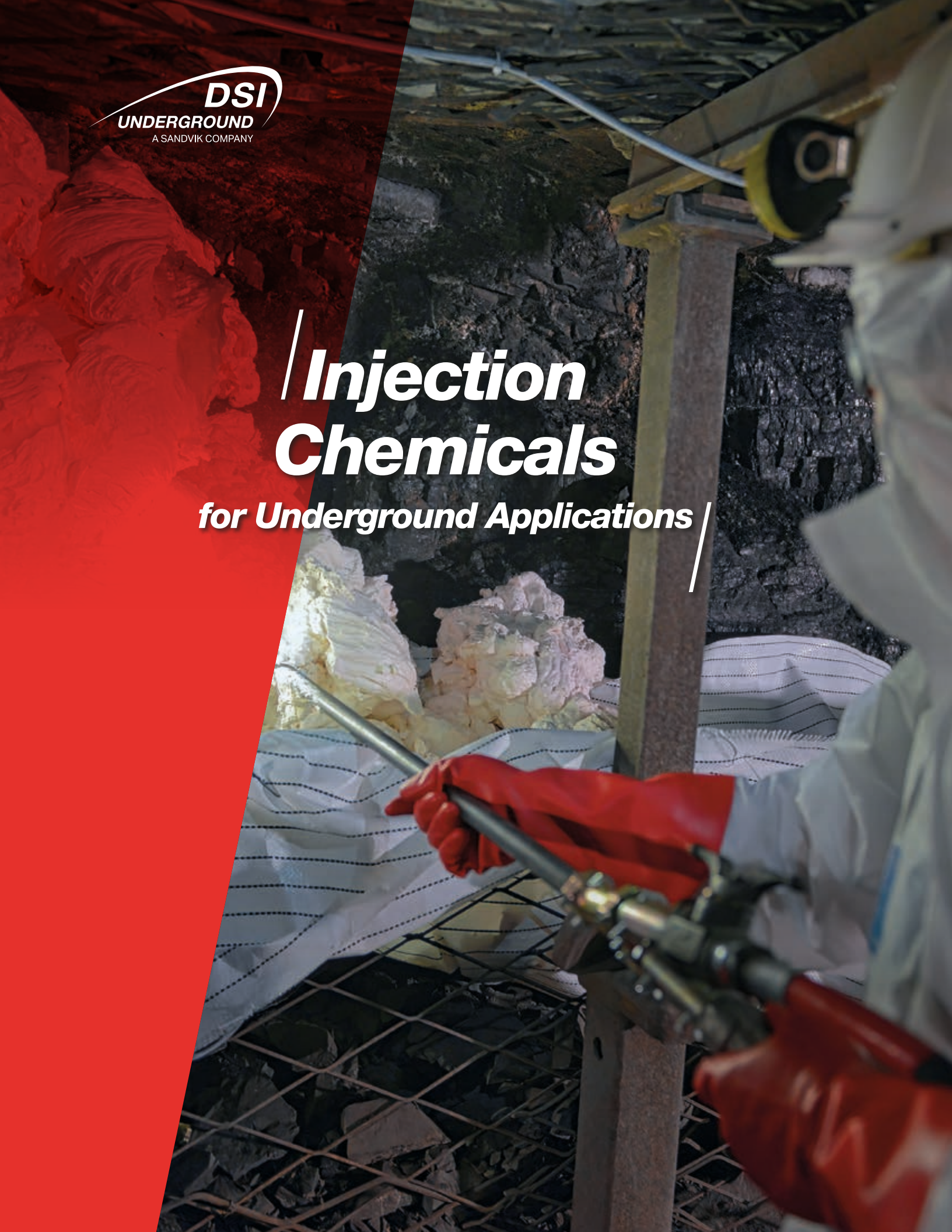
DSI UNDERGROUND
A SANDVIK COMPANY

Injection Chemicals

for Underground Applications



Contents

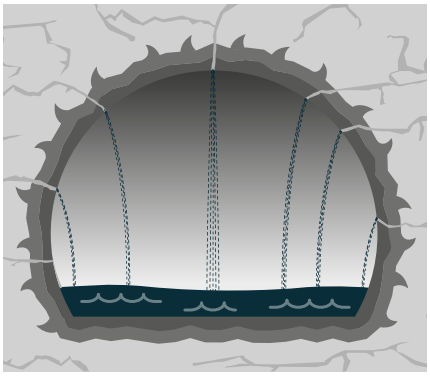
Introduction

The DSI Inject product line comprises injection resins used for underground and civil engineering applications. 2-component polyurethane systems (PUR) are the most versatile injection resin system and are mainly used for stopping water ingress and ground consolidation.

2-component silicate systems (SIL) have a broad application range with excellent bonding capabilities. Single-component resins (SCR) are widely used for smaller-scale repair works, and acrylic resins (ACR) have been successfully used for ground consolidation and grout curtain applications.

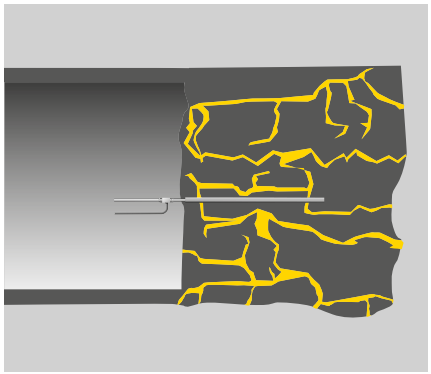
All DSI Inject Systems are processed with 2-component or 1-component high pressure pumps, tailored for each project and application. Mixed and cured DSI Inject Systems are ecologically approved, solid (CFC and halogen free), and suitable for application in ground water areas.

Fields of Application



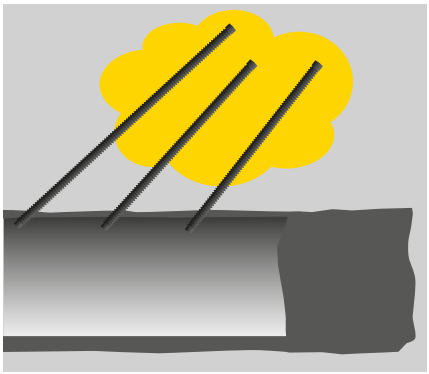
Sealing

- Water ingress
  - Temporary or permanent
  - Amount of water
- Pressing water
  - Temporary or permanent
  - Pressure range
  - Amount of water
- Leaking gas
  - Gas type
  - Amount of gas
  - Escape ways
- Product range
  - PUR fast-setting
  - PUR foam
  - SCR
  - SIL foam



Consolidation and Stabilization

- Consolidation
  - Geology
  - Required grade of improvement
- Stabilization
  - Geology
  - Temporary or permanent
- Product range
  - PUR med-slow setting
  - PUR foam
  - SCR
  - SIL
  - SIL foam
  - ACR



Filling

- Filling of cavities
  - Cavity size
  - Required grade of improvement
- Backfilling
  - Gap width
  - Presence of water
- Product range
  - SIL foam

Full Portfolio of Solutions

Type	Product Designation	Application							
		Water Ingress	High Pressure Water Ingress	Sealing (Gas & Water)	Ground Stabilization	Ground Consolidation	Cavity Filling	Backfilling	Bolt Bonding
Two-Component Resins									
PUR (2C)	Fast setting polyurethane resins	+++	+++	+	++	+	-----	-----	++
	Medium and slow setting polyurethane resins	-----	-----	++	+++	+++	-----	-----	+
	Fast setting polyurethane foam resins	+++	+++	+	++	-----	-----	-----	-----
SIL (2C)	Organo-mineral (silicate) resins	-----	-----	++	+++	+++	-----	-----	+
	Organo-mineral (silicate) bolting resins	-----	-----	+	++	-----	-----	-----	+++
	Organo-mineral (silicate) foam resins	++	-----	+	+++	+++	+++	+++	-----
Single-Component Resins									
SCR (1C)	Fast and medium setting polyurethane resins	+	-----	+++	++	+	-----	-----	-----
	Slow setting polyurethane resins	-----	-----	+	++	++	-----	-----	-----
Acrylic Resins									
ACR	Acrylic resins	-----	-----	-----	+++	+++	-----	-----	-----
	Acrylic gel resins	-----	-----	+++	++	+	-----	-----	-----

"+" Recommended, "-" Not recommended.

***PUR:** Two-Component Polyurethane Resins*

***SIL:** Two-Component Organo-Mineral Silicate Resins*

***SCR:** Medium and Fast Setting Single-Component Resins*

***ACR:** Acrylic Injection Resins*

Grouting Fundamentals

Step 1: Identify the Application

- Sealing
- Consolidation and stabilization
- Filling

Step 2: Determine the Grouting Material

Three Commonly used Types of Grouting Material

- Suspension
  - Water + cement (e.g. micro-cements, ultra-fine cements, etc.)
  - Water + cement + fillers (e.g. sand, fly ash, etc.)
- Solution
  - Chemicals diluted in water (e.g. water glass + hardeners)
  - Polyurethanes (e.g. 1C one component, 2C two components)
  - Acrylates
- Emulsion
  - Silicates

Limitations in the Application of Cementitious Grouts

- Dilution in general
- Partial penetration
- Large openings
- Permeability range below 10^{-6} [m/s]
- Low temperatures

Application Window for Injection Resins

Polymer resins must be used if at least one of the following criteria applies:

- Discontinuities
  - Large-size joints or caverns
- Permeability and hydraulic conductivity
  - Lugeon < 15 - 20
  - Permeability < 10^{-6} [m/s]
- Groundwater
  - Velocity > 20 [mm/s]
- Water and ground temperature
  - Below 3 - 5 [°C]

Step 3: Method Statement

- Qualified and experienced expert(s)
- Clear identification of the on-site situation
- Type of injection resin
- Material properties with reaction profile
- Application team
- Equipment

Step 4: Application and Verification

- Implementation according to the method statement
- Continuous data monitoring
- Attention to predefined stop criteria
- Qualitative and quantitative evaluation of injection results
- Determination of further steps, if required

Competence in Application

Permeability in Soil and Jointed Rock Mass

Method Statement

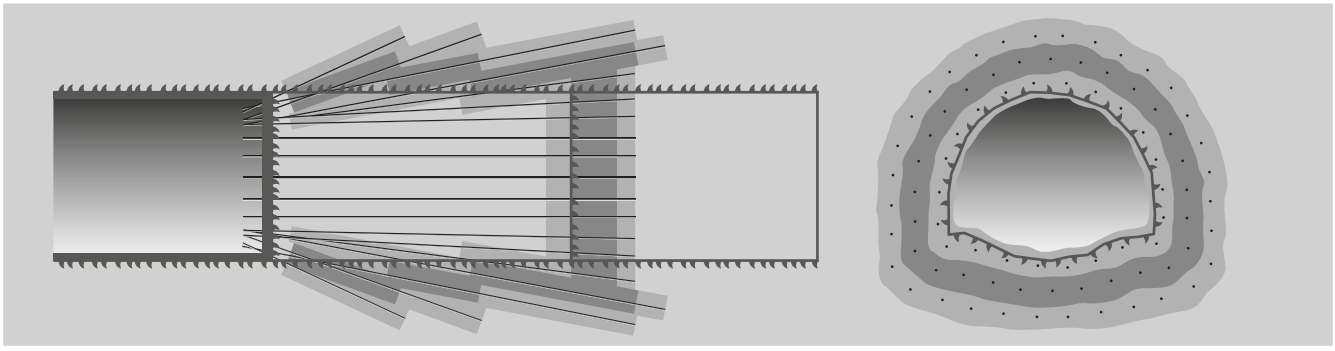
Contrary to the design of ground support elements, the application of injection chemicals can rarely be planned in advance.

Certain default applications where access to the future application site, excavation dimensions, and other influencing factors are known – such as filling of identified cavities or sealing of segmental linings – can be scheduled and prepared in advance.

The unknown part in each underground construction are unpredictable ground and groundwater conditions, which might lead to a so-called emergency application situation. For an emergency application, project-specific method statements for mastery of challenging conditions must be prepared.

Influencing factors of the design include the magnitude (size) of application area, underlying ground conditions, temperature, water flow rate, and pressure.

Data acquisition and a sound probing approach are key to gain further information for the preparation of an emergency method statement.



Technology

Over the past decades, injection chemicals for underground and civil engineering applications have undergone major development and improvement.

One key aspect was the diversification of the portfolio through the development of new products and systems with optimized adaptation to specific injection applications.

The toolbox of today's injection resins also shows enhanced performance characteristics, thanks to the advancement of chemical raw materials and compounds.

Besides an enhancement in the mode of action, state-of-the-art injection resins feature a significant reduction of the environmental impact, for example in terms of groundwater compatibility.

Beside the improvement of injection chemicals, the entire application chain has been improved continuously. Hoses, fittings, and valves have been enhanced; tailored mixing elements ensure a sound interaction of single components. Standardized handling procedures ensure a safe and reliable working process.

Equipment and Accessories

- Case-specific design and dimensioning
- Supply of package solutions
- Wide range of toolbox accessories

Selection and Design Criteria

Product Properties

Introduction

There are several parameters used for describing the properties and assessing the suitability of injection resins in terms of their proper application.
These parameters include reactivity, viscosity, reaction time, mechanical properties, adhesion, foamability, and water miscibility – just to mention the most important ones. They determine the scope of use of a certain resin system and, even more importantly, the success of the application.

Undoubtedly, a detailed parameter analysis has to be an integral part of each case study in order to achieve the intended purpose of the application, i.e. sealing, consolidation, filling, or bonding.

Setting Time

Setting time is the system parameter which shows the reactivity of the material, e.g. the point when the reacting liquid stops to flow. After that time the material starts to set, i.e. the hardening process begins to develop.

Setting time can vary from seconds to hours. Practically, the systems are divided into fast, medium, and slow. Setting time mainly affects the penetrability of the ground and the ability to stop water inflow or outflow.

Another term commonly used is tack free time, which defines the point when the surface of the reacting resin is becoming non-sticky.

Viscosity

Viscosity is one of the physical parameters which characterizes both single components and reacting mixture.
The higher the viscosity of the components the higher is the flow resistance, thus this factor is important for the correct selection of pumps and pumping accessories regarding the pumping pressure.

Viscosity is also an important parameter considering the relationship between the crack size, pumping pressure, and penetration distance.

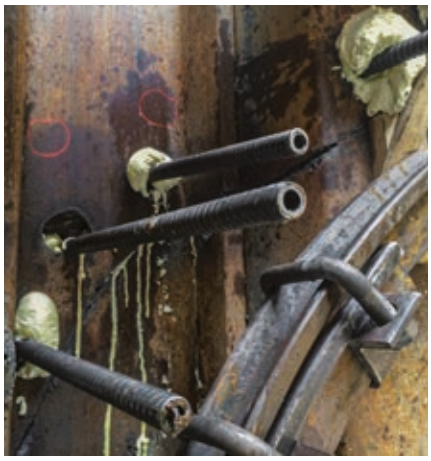
There is a direct correlation between viscosity, pumping pressure, and pumping volume.

Thixotropy

Thixotropy describes a fluid which can be thick or viscous under static conditions and flows, or become less viscous when sheared or mixed. The pseudo-plastic behavior is a specific case of thixotropy, where the liquid regains high viscosity nearly immediately as the shear force is reduced.

A pseudo-thixotropic behaviour of the liquid material can also be featured by the specific reaction control when the gelling is well separated from the solidification process.
Thixotropic behavior is necessary in any overhead application to stop outflow of the material during and after grouting.

Another important role of thixotropy is surface spraying in terms of coatings and membranes.



Foaming Properties

For polyurethane and silicate resins, the ability to foam is the characteristic feature of the injection system.

Specific formulations allow to control the foaming factor and the foam cell structure – to receive an open or closed cell foam. The following rules of thumb apply: the higher the foaming factor, the lower the mechanical properties and cost of unit volume filling.

The higher the content of the closed cells, the better the water tightness of the foam.

Open cell foams are mainly used for temporary applications.

Water Reactivity

The presence of water in the area of application always affects the effectiveness. Water presence must be considered in a range of aspects during the material selection process:

- Chemical reactivity with the components
- Physical modification of the material
- Water temperature
- Water inflow or outflow
- Water pressure

Mixing of Components

The majority of commonly used materials are two component systems. To obtain the final product, the components have to be pumped to the application zone, where separated components have to be mixed. The effectiveness of the component's mixing determines final material properties and reaction parameters.

The mixing process takes place during the flow through a static mixing element. Design of static mixers may differ for various resin components.

Therefore, this item is carefully selected and checked by the material developer – the end user should respect indications of the injection chemical manufacturer.

Mechanical Properties

Mechanical properties are distinct features of injection materials, e.g. compressive, flexural, or tensile strength. Compact or limited foaming materials are notable stronger compared to foamed materials. With an increasing foaming factor, the compressive strength will decrease consequently.

If the purpose of the injection is the strengthening of the injection area (roof, ribs, slabs, concrete, or masonry structure), mechanical parameters are the most crucial ones.

Adhesion to the Substrate

Adhesion is also an important factor in case of ground consolidation/stabilization and surface application. It can remarkably improve the target result of the application. Ground improvement, consolidation, and anchoring are good examples.

In all cases adhesion increases the technical properties.

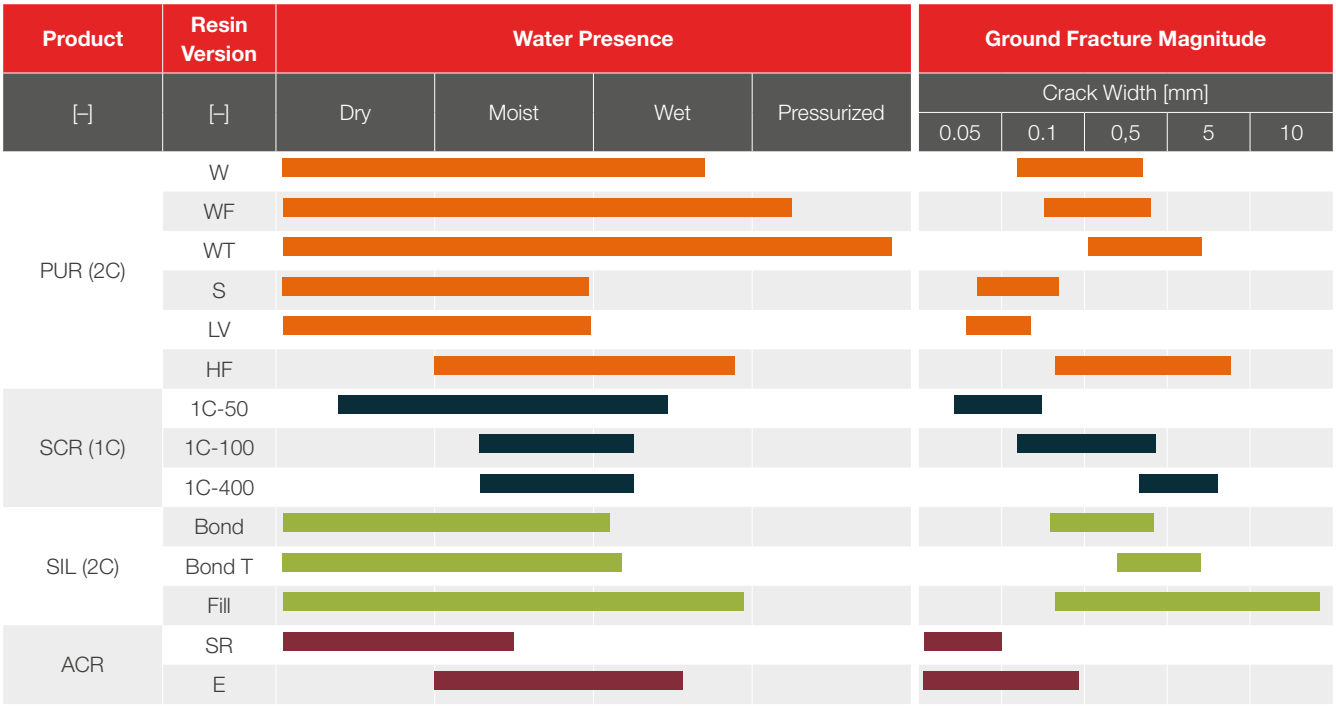
Application Range

Once the application (or multiple applications) for an injection project is defined, selection of proper resin type(s) for a given application is the key. SCR resins are used for small-scale grouting works under manageable conditions. 2-component PUR and SIL injection resins can be used for a variety of applications. DSI Underground offers various different product characteristics to ensure an optimum injection result.

In mechanized Tunneling, SIL or ACR type injection resins may be the preferred selection due to their characteristics during mechanical removal or temporary excavations.

An initial estimation of a suitable product range can be accomplished based on water pressure conditions and ground fracture magnitude.

Injection Resin Application Range



Abbreviations

W Water
SCR / 1C Single-Component
LV Low Viscosity

F Fast
S Slow
T Thixotropy

HA High Adhesion
HF High Foaming
HS High Strength

SR Semi-Rigid
E Elastic

Pumps and Accessories

Pumps

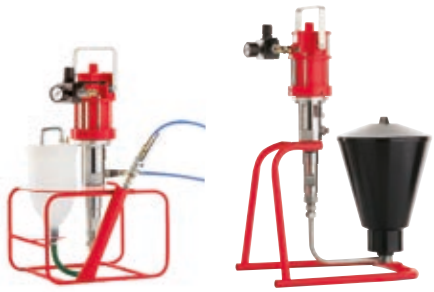
Selection of a suitable high-pressure pump depends on the type of application, available infrastructure, and ground conditions. Availability of existing equipment may also influence equipment selection. DSI Underground offers a wide range of high-pressure pumps for underground and civil engineering applications. Further details are described in separate technical data sheets.

DSI Inject 2-Component High-Pressure Piston Pump

- Brace operated, pneumatically driven piston pump
- 1:1 mixing ratio for processing DSI Inject PUR and SIL Systems
- Independent intake of both components
- Robust design and little susceptibility for damages
- Easy operation and handling
- Spare parts and starter set available
- Technical data sheet and operation manual available upon request

DSI Inject 1-Component High-Pressure Pump

- Small and light-weight aggregate
- Electric or pneumatic versions available
- Different versions for lower and higher injection pressure ranges
- Easy to clean and maintain



DSI Inject 2-Component High-Pressure GEL Pump

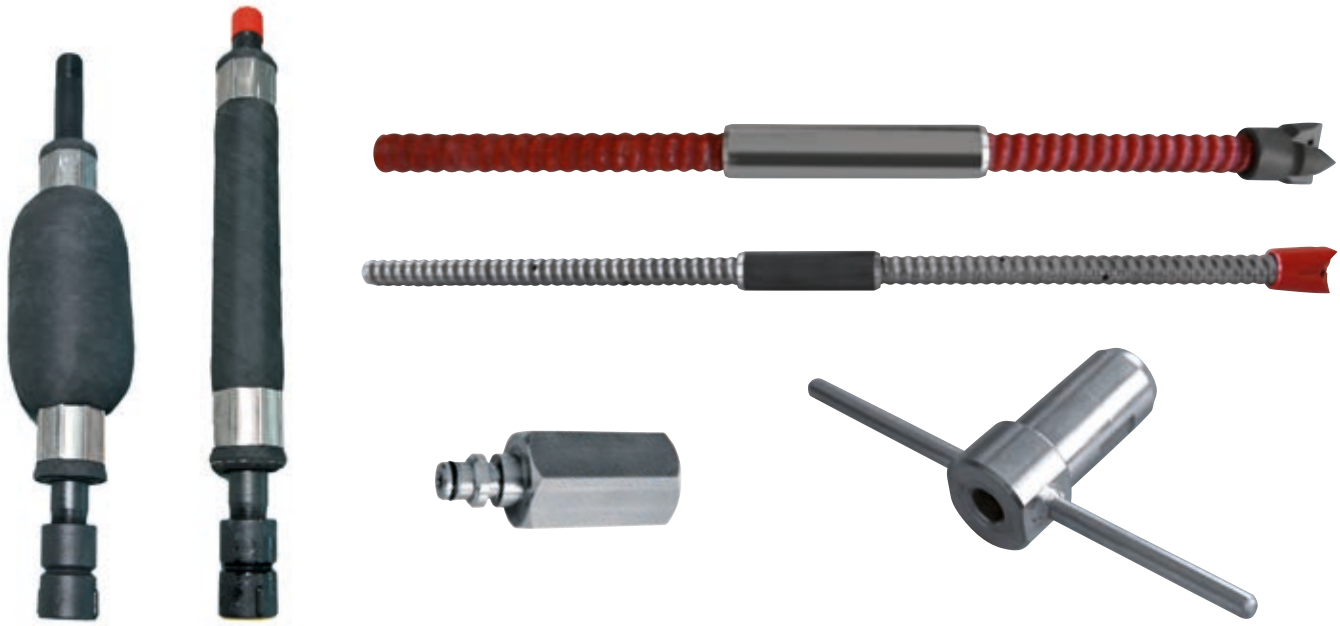
- Robust design and little susceptibility for damages
- Additional flushing pump for easy cleaning
- High performance
- Stainless steel pump featuring supreme corrosion resistance
- Double piston pump, pneumatically driven
- Independent intake of both components

DSI Inject 2-Component High-Pressure Gear Pump

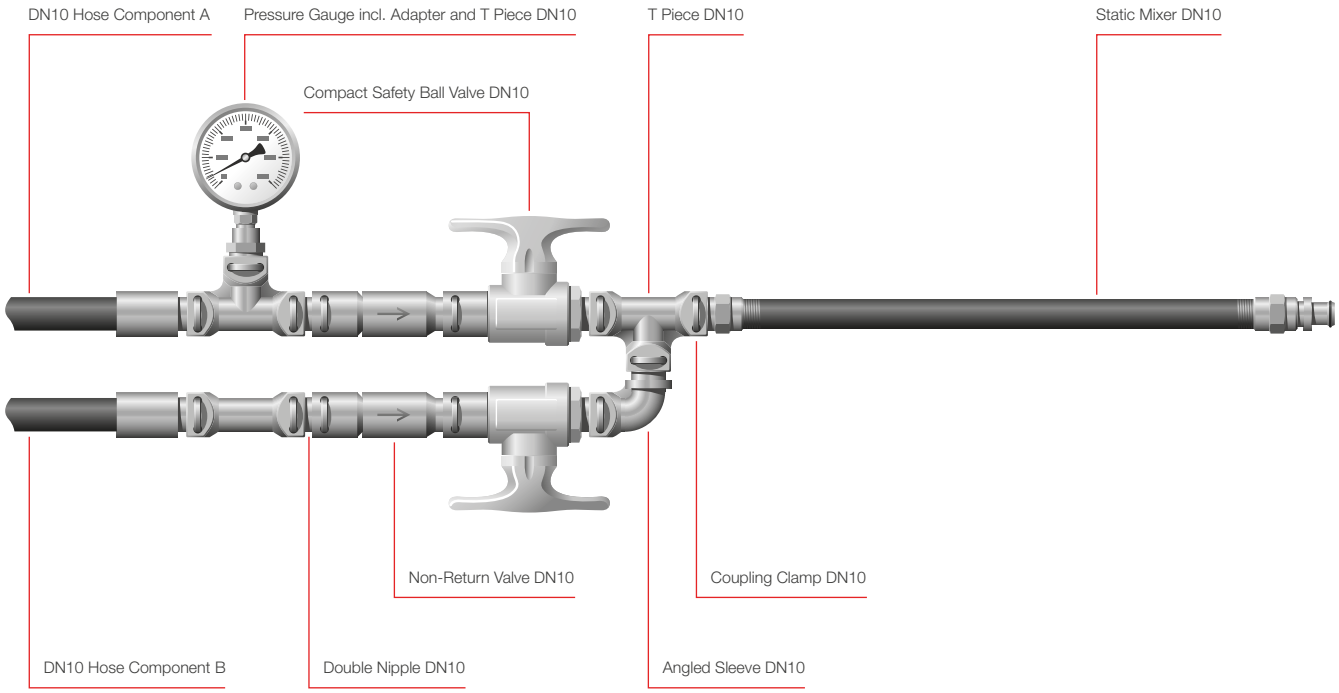
- Adjustable mixing ratio
- High output
- Reliable, long-lasting aggregate for long-term application
- Electrically driven

Accessories

- Mixing tubes and static mixers
- Connectors
  - Injection adapters for DSI Hollow Bar System and GRP hollow bars
  - Quick connectors (cable bolts)
- Screw-on nipples
- DSI Hollow Bar System and GRP hollow bar injection lances
- Steel and plastic injection lances
- Injection deep packers



Mixing Assembly 1:1 (Example)



Emergency Kit

Types of Emergency Kits

- Prepared in advance for standard applications
- Just-in-time system solution: ensures no loss of valuable construction time

DSI Underground as Problem Solver

- One-stop shop: all material from one source
- Quick reaction: contingency material stock and experience in global logistics
- Support throughout all project phases: from initial evaluation to method statement to material supply to on site application

Customized Emergency Kits for Conventional and Mechanized Tunneling

- 10 [ft] or 20 [ft] GP container
- Material: steel and chemical consumables
- Equipment: injection pumps etc.
- Worldwide support by DSI Underground competence centers

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