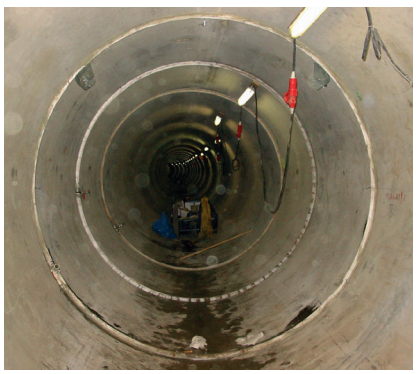
APPLICATORS' MANUAL

RASCOflex PU309 polyurethane injection resins



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1 Information on use

1.1 GENERAL

Polyurethane (PU) synthetic resins are used, among other things, to consolidate friable rock masses and soft ground by means of injection. Special systems are deployed to provide a barrier against standing water, strong hydrostatic pressure and gases in cracks, joints and fissures.

1.2 COMPOSITION AND PROPERTIES

1.2.1 COMPONENTS

RASCOR's two-component (2C) injection resins essentially comprise a polyol component (e.g. RASCOflex PU A-Comp) and a polyisocyanate component (e.g. RASCOflex PU B-Comp).

All RASCOflex PU components are supplied in metal canisters/barrels. The various RASCOflex PU309 A-Comp types are distinguishable not only by the labelling, but also by the different lid colours (for full details on the features/properties of the individual systems, please consult RASCOR's technical data sheets, available at www.rascor.com).

The RASCOflex PU B-Comp, a dark-brown liquid, comprises isocyanates and is hygroscopic. This means that it absorbs moisture from the air and may react to form crystalline solids. The RASCOflex PU B-Comp containers are supplied in black metal canisters and, for the PU309 and PU112 systems, are additionally fitted with a black lid. Opened containers that are to be stored must be carefully protected from water and moisture.

1.2.2 POLYURETHANE REACTION

Thorough mixing of RASCOflex PU A-Comp and B-Comp produces a synthetic resin whose properties – depending on formulation – range from rigid tough-elastic to force-transmitting or limited ductile. The type of reaction that forms polyurethanes is so-called polyaddition. For this, each A-Comp molecule needs a B-Comp molecule to the right and left. Triggering of the reaction creates molecule chains with alternate polyol and isocyanate units. The result is a cross-linked synthetic resin.

Thorough blending of the components with a suitable static mixer is essential. The RASCOR polyurethanes are designed for a mixing ratio of 1:1 by volume. Any surplus of one component will bring about a change in the properties:

- A surplus of RASCOflex PU A-Comp (polyol) results in a soft, sticky product.
- A surplus of RASCOflex PU B-Comp (isocyanate) results in a soft substance that cures over time to form a brittle end product.

The presence of water in the ground leads to foaming during injection due to the formation of carbon dioxide. Depending on the system, this foaming may be moderate to heavy/high-volume.

The pH value of the water in the ground also influences the reaction. Water with a low pH value slows down and water with a high pH value speeds up the reaction.
Oils form a barrier on the surface of cracks and joints, thereby impairing adhesion.

1.2.3 FOAMING REACTION

The foaming action of the resins is triggered by the reaction with either water or the relevant RASCOflex PU-FO additive. This reaction produces carbon dioxide in the still-liquid resin mix. Once the resin mix is enclosed by the grout body, with no possibility of expansion or of the carbon dioxide escaping, the cross-linking reaction comes to a standstill. The two-component systems cure without foaming and the carbon dioxide remains bound in the system.

The quantity of water present during polyaddition (2% is already quite a lot) and the volume of space available for expansion dictate how heavily the resin foams (see technical data sheets).
The RASCOflex PU-FO additive may be added to the two-component RASCOflex PU309 systems to guarantee foaming with or without water contact. This is required, in particular, for filling large voids.

1.2.4 VISCOSITY AND PERMEATION BEHAVIOUR

Permeation of the RASCOflex PU into the ground or a building element is achieved by virtue of the resin's low viscosity. Low outdoor temperatures necessitate temperature-controlled storage or gentle warming up of the canisters.
The resin mix initially exhibits a similar viscosity to that of the individual components. Once injected into the ground or building fabric, it immediately assumes the ambient temperature, which then alters its viscosity. The viscosity of the resin mix essentially remains low for a long time during injection, then rapidly increases shortly before curing.

This low viscosity may also allow the resin mix to be washed out of the ground by water or permit its uncontrolled escape from wide cracks. In such cases, RASCOR recommends use of the RASCOflex PU309 THIX additive or the ready-to-use RASCOflex PU309V product. With this resin mix, the viscosity increases immediately after mixing, thus considerably reducing or even preventing the premature escape of material from cracks, joints or problem areas.

As described above, the viscosity of the resin mix is influenced by the ambient temperature. As a general rule, a 9-11°C drop in temperature is likely to bring about a doubling of the viscosity. The flow properties of a resin mix depend heavily on its viscosity.

1.2.5 INJECTION PRESSURE

The pressure with which the injection resin is injected into the ground is not identical to that shown on the manometer. As long as the resin mix is flowing, the manometer will display the pressure of the overall hydraulic system. The pressure steadily increases due to friction resistance. The flow path of the resin mix through tubes, hoses and mixer unit, on the one hand, and through cracks, pores and fissures, on the other, reduces the resin pressure until, at the farthest point of grouting, this falls to zero.

As a basic rule, the pressure loss from the pump to the injection point is proportional to the

- Delivery capacity (quantity)
- Length of delivery path (hose system)
- Viscosity of liquid

though inversely proportional to the fourth power of the tube diameter. A 10 mm hose, for example, will experience 16 times the pressure loss of a 20 mm hose!

Prior to the actual injection works, a control measurement should always be taken in order to determine the effective pressure loss. In other words, it is important to know how much pressure is required on the cylinders to achieve the required, predefined material pressure at the injection point.

1.2.6 MECHANICAL PROPERTIES

Mechanical strength is most commonly expressed in terms of (uniaxial) compressive strength. Standard concretes and cements achieve values of 25-50 N/mm².
The value for non-foamed RASCOflex PU systems runs to around 60-80 N/mm². As a result of foaming, however, the strength falls disproportionately, at a rate roughly proportional to the square of density.

Yet, unlike mineral materials, (two-component) RASCOflex PU does not fracture upon reaching its strength limit, but first undergoes plastic deformation while retaining adhesion. PU injection resins are generally classed as elastic waterproofing materials (RASCOflex PU110X). The more rigid RASCOflex PU309 (2C) and RASCOflex PU112 (2C) resins offer an additional consolidating effect. Even when exposed to vibrations or similar action (earthquakes!), polyurethane is capable of preventing the destruction of ground and built structures.

1.2.7 ENVIRONMENTAL HYGIENE

Emergency situations, e.g. bearing/soil shear failure, damage or risks to other building fabric, are subject to different assessment guidelines from planned large-scale injection works. Emergency injections tend to involve only relatively small quantities of injection grout. Moreover, any potentially contaminated water runs off into the excavation pit and, from there, into the surface water or sewage system. Similarly, injections into rock or building fabric generally entail little contact with the groundwater. In this regard, RASCOR has obtained expert reports, e.g. a hygiene investigation for groundwater prepared by the Institute of Environmental Hygiene and Environmental Medicine, Gelsenkirchen, based on the DIBt (German Institute for Construction Technology) guidelines for assessing impacts on soil and groundwater.

Once cured, the RASCOflex PU resin is eco-neutral. With two-component products, it is vital to ensure that neither component is separately injected into the ground or building fabric, but only as part of the resin mix prepared in the ratio 1:1 (A:B) by volume.

The RASCOflex PU A-Comp (polyol components) are generally classed as only "slightly hazardous to water". They undergo slow ecological degradation in the ground through contact with oxygen.

The RASCOflex PU B-Comp (isocyanate component) is similarly classed as "slightly hazardous to water", though reacts with natural moisture in the ground to produce a harmless, non-degradable polyurea.

Any spillages of resin components must be covered e.g. with sand or soil and the saturated solids properly disposed of (see Sections 4.1 and 4.2). The safety data sheet for the relevant product (permanently available from the download area at www.rascor.com) must in all cases be consulted. Under no circumstances shall the ground be contaminated.

Nowadays, the contaminating impact of injection products is laboratory tested under realistic conditions. This involves the injection of material into water-saturated sand columns (the Institute of Environmental Hygiene and Environmental Medicine, Gelsenkirchen, is widely known for this type of investigation). All

ground injections must be based on the hygiene investigation prepared in accordance with the DIBt guidelines for assessing impacts on soil and groundwater.

2 Handling

2.1 TRANSPORT AND STORAGE

The polyurethanes are supplied in approx. 20 ltr metal canisters. All canisters are clearly labelled to provide users with details of the content, manufacturer, batch number and material properties.

In the winter months,
it is essential to avoid lengthy storage of RASCOflex PU components at temperatures below +10°C. The crucial factor here is that the viscosity of the components increases at temperatures below around +12°C, which may lead to difficulties during proportioning. Minimum storage temperatures for the relevant products are specified in the relevant technical data sheets.

2.2 INJECTION EQUIPMENT

RASCOR's polyurethanes can be injected with various types of two-component pump with a range of different capacities. The key criterion, however, is that the two components (A + B) are delivered in the ratio 1:1 by volume.

2.3 INSTRUCTIONS ON USE OF TWO-COMPONENT PUMPS

2.3.1 START-UP

First and foremost, the guidance provided by the relevant pump manufacturer must be observed.

The RASCOflex PU309 metal canisters are provided with an opening that allows them to serve as pump containers. To eliminate the risk of air entering the system, the containers into which the suction hoses are inserted must be refilled and not exchanged when their contents are used up. In such cases, it is essential to ensure that the A-container is refilled with A-Comp and the B-container with B-Comp. Care must also be taken to ensure that the suction strainers remain permanently covered by material as air in the system may distort the mixing ratio!

Here some key points for successful injections:

- Prior to injection, run the pump with resin until all rinsing oil has been displaced and only fresh material escapes (rinsing oil to be collected separately). Then switch off the pump.
- Hold the rinsing hoses in the containers. Switch on the pump and keep running until bubble-free material escapes. At the same time, visually check that the material is delivered in the mixing ratio 1:1 by volume. The use of two identical measuring beakers is recommended. Should any discrepancies arise, then eliminate the fault or replace the pump. Then switch off the pump.

2.3.2. COMPLETION OF INJECTION PROCESS

First and foremost, the guidance provided by the relevant pump manufacturer must be observed.

▪ Where two-component injection pumps are used, a circulation system (for diversion of the individual components back to their respective containers) must be incorporated to reduce the pressure in the hose system when the injection is stopped.
  This allows simple and hazard-free decoupling from the injection tubes/packers transporting the mixed grout.
▪ The decoupled mixing tube is then either fitted to the packer in the next drill hole – the pump then being restarted before the resin in the mixing unit can thicken – or the end of the mixing tube is held in a waste container and rinsed clean with A-component.

Please note: Care must be taken to ensure that the individual components from the two canisters are uniformly delivered. Any proportioning errors by a pump require a prompt interruption of the injection process followed by immediate determination and elimination of the cause.

The injection must be stopped at the latest when:

▪ the specified pressure limit is reached
▪ any movement is observed in the rock mass for consolidation
▪ resin mix escapes from the rock mass or the water ingress is stopped
▪ there is no detectable increase in pump pressure after injection of a large quantity of resin

Should the injection equipment or hoses be damaged – even where only small amounts of material escape – the injection works must be stopped immediately, the hoses replaced and the injection equipment properly repaired.

2.3.3 PACKER LAYOUT

The layout of the packers varies according to the particular job specification and the waterproofing objectives to be achieved.
The key parameters are:
▪ Wide-area injections
▪ Crack/joint injections
▪ Occurrence of voids in problem area (flow behaviour)
▪ Viscosity of material (ambient temperature)
▪ Injections against water pressure

2.4 INJECTION WITH FAST-REACTING MIXES

Standard two-component injection equipment and hoses can be used to inject fast-reacting resin mixes, e.g. RASCOflex PU309S and PU309N systems and the like. Should the resin mix prematurely escape from the rock mass (without reaching the problem area), then the pumping rate must be reduced or the pump briefly switched off to allow the resin to react at the point of escape and thereby plug the escape path. The pump is then restarted – before any reaction can begin in the packer system.

2.5 CONSOLIDATING WATERPROOFING INJECTIONS

Flowing water may influence the injection works as follows:

- It may wash out injection resin from the problem area before a reaction can take place
- It may absorb and dissipate the heat generated by the reaction and thereby slow down the reaction
- It may dilute the injection resin to such an extent that it can no longer fully react

The chances of a successful waterproofing operation therefore increase when:

- A hydraulic equilibrium exists in which the water flow speed is counterbalanced and the flow stopped.
- The water pressure and volume can be diverted, thereby allowing a reduction in the flow speed in the problem area to be waterproofed. This normally involves the performance of relief drillings.
- The surface of the problem area is mechanically plugged.

The various options available for this purpose include:

- Textile rags/wood wool/textile hoses for holes
- Wooden wedges or battens for very wide crack/joint openings
- Sand bags, excavated soil

The length of the drill hole must be specified so as to optimize injection of the grout and position the discharge point of the grout such that the resin mix cures before it can be carried out of the ground by the flowing water. These criteria are essential for effective injections.

During the injection process, the injection resin meets the water in the ground and foams heavily. This foam already shields the upstream injection resin against the infiltrating water such that the foaming action of the injection resin is gradually reduced. Ultimately, the curing process produces a dense, completely foam-free material structure capable of durably consolidating the ground or building fabric.

In case of planned (i.e. non-emergency) waterproofing works, the drilling of further holes is recommended to check the progress of the injections. On the one hand, this facilitates monitoring of the spread of the injection resin up to its escape from the control drill hole (communication between drill holes). On the other hand, it allows some of the water to be diverted and/or extracted during the injection works.

The inevitable consequence of waterproofing a problem area is an accumulation of the infiltrating water and thus an increase in water pressure. The growing pressure from such an accumulation may open up new water paths. This eventuality must therefore be addressed in the design and planning of the waterproofing solution. Otherwise, the implemented solution may not prove effective in the long term. The sudden occurrence of leakages in other areas that were still dry at the commencement of works is also likely. This may arise where the primary leakage was effectively acting as a “valve” that relieved other weak zones. As soon as this valve is closed, the pressure rises and these weak zones can no longer withstand the greater pressure.

With extremely heavy water ingress, the resin mix may be washed out into the excavation pit before it has chance to fully cure. Even relocating the grout discharge point deeper into the rock mass or slowing down the water flow by surface plugging will often fail to improve such situations. The use of RASCOflex PU309V (2C) is recommended in this case. The viscosity of RASCOR PU injection resins generally remains low after the components are mixed together, before

rapidly increasing shortly before curing. RASCOflex PU309V (2C), by contrast, thickens immediately after mixing to form a paste that is not so easily washed out by flowing water. This allows the primary water infiltration to be quickly and effectively halted. The remaining leakages can then be waterproofed through injection of the RASCOflex PU309S, PU309N or PU309L systems.

2.6 INJECTIONS INTO SOFT GROUND

Non-cohesive soft soil formations can be consolidated in a similar way to fissured rock masses. While substantial voids, fissures, fractures and sizeable cracks are "only" filled with grout, non-cohesive soils need to be saturated with the injected material. This involves the consumption of several times the amount of material. Even in relatively compact soils, the pore volume may already reach around 5% – equivalent to 50 ltr for one cubic metre. Pore volumes between 20-50 % are no rarity. Geological surveys are thus needed to calculate the theoretical material requirement.

Apart from the pore volume, the main factor governing grout consumption is the absorbency of the soil. The finer the soil particles, the greater the resistance to flow and the lower the foam factor. In gravel without sand particles, RASCOflex PU309N (2C) or RASCOflex PU309S (2C) can easily achieve a foam factor of 5-10 when injected. Sand offers much greater resistance to permeation of the resin mix into the voids between the sand particles. As a general rule, the greater the proportion of fines, the smaller the voids/pores. From d30 < 0.063 mm, only polymethacrylate gels – such as the RASCOflex AY range of grouts with viscosities of 4-12 mPas – can be used.

Sharp-tipped ram injection lances are suitable for grouting. These serve to create localized spherical grout bodies in the area of the discharge point. Where elongated grout bodies are required, ram injection lances with side-perforated tubes offer a suitable solution. These allow grout to escape at the side and fill the entire area around the lance.

Controlled injections are possible for a radius of up to 50 cm and proper filling of this zone is relatively easy to ensure. However, given that injected materials always follow the path of least resistance, full grouting of areas over 50 cm from the escape point is no longer controllable.

2.7 SHUTDOWN OF TWO-COMPONENT PUMPS

The manufacturer's guidance must be observed. No material must be allowed to remain in the pump system due to the risk of blockages caused by thickening of the remaining resin! In case of longer interruptions (over one week), suction hoses must be drained and placed in a container with water-free rinsing oil, preferably biodegradable oil. Use this to rinse pump and hoses.

3 Guidance on safety at work

Suitable protective clothing, gloves and goggles must be worn for the application of RASCOflex PU injection resins. An eyewash bottle, a first-aid kit and, if possible, a fire extinguisher must be kept at hand at the work location.

For detailed additional guidance on the handling and use of RASCOflex PU injection products, please consult the relevant safety data sheets. Up-to-date versions are permanently available for download from the Internet (at www.rascor.com).

3.1 FIRE BEHAVIOUR

Polyurethanes are combustible, their combustibility increasing in function of their surface area. Foamed polyurethanes are therefore more combustible than non-foamed types.

Due to the heat emitted by polyurethanes during polyaddition (exothermic reaction), spontaneous combustion is possible in extreme cases. The temperature of a curing polyurethane may reach up to 150°C. The following factors influence fire behaviour and the risk of spontaneous combustion:

- The shorter the gel time, the more heat is emitted
- The building fabric, soil or rock mass for injection acts as a heat dissipator
- With injections against water pressure, the water acts as a cooling medium
- The larger the void to be filled (in terms of volume), the less heat can be rejected via the contact area.
- Foamed polyurethanes heat up less strongly because the heat is rejected more rapidly to the outside by the pore structure.

The combustion of polyurethanes produces the same gases as with other organic substances containing nitrogen (carbon dioxide and water) together with unstable and toxic gases, such as carbon monoxide, nitrogen oxides and hydrogen cyanide (prussic acid). Consequently, where grout is injected behind sheet metal components, for example, these should be worked with cutting discs and not with a welding torch. When drilling into rigid, cured polyurethane, the use of bits with a "peeling" action (e.g. wood bits) in conjunction with cooling is recommended to prevent the bit from sticking.

Although the liquid polyurethane resin components are combustible, they are not subject to the German Combustible Liquids Ordinance (VbF) due to their high flash point. Nonetheless, they must not be exposed to excessive heat. During the cold season, the components may need to be warmed up for technical reasons. However, this must not be performed by a naked flame, immersion heater or the like due to the risk of localized overheating. Particularly with the B-component, this may cause the MAK (maximum workplace concentration) to be exceeded and ultimately the sensitization to isocyanate or, in extreme cases, even acute poisoning. The individual components should therefore be heated up slowly over a longer period by warm air, e.g. compressor exhaust, or using a water bath with a maximum temperature of 30°C.
Die flüssigen Polyurethanharz-Komponenten sind zwar brennbar, unterliegen aber wegen ihres hohen Flammpunktes nicht der Verordnung brennbare Flüssigkeiten (VbF). Dennoch darf man sie nicht zu stark erwärmen. Trotzdem sollten die Kompontenten, wenn dies in der kalten Jahreszeit aus technischen Gründen erforderlich sein sollte, nicht mit offener Flamme, Tauchsieder o.ä. aufwärmen. Es könnte dadurch sonst zu lokalen Überhitzungen kommen. Vor allem bei der B-Komponente kann es dann zum Überschreiten des MAK-Wertes und schlussendlich zur Sensibilisierung gegenüber Isocyanat kommen – im Extremfall sogar akute Vergiftungen. Deshalb sollten die einzelnen Komponenten langsam und über längere Zeit mit warmer Luft, z.B. Kompressorabluft, oder mittels Wasserbad von maximal 30°C erwärmt werden.

4 Disposal of metal containers

RASCOR has signed contracts with recycling companies for the disposal of RASCOflex injection resin canisters. Customers thus benefit from free disposal of fully emptied metal canisters via the Kreislaufsystem Blechverpackungen Stahl (KBS) GmbH recycling system. To ensure acceptance of the empty containers at the collection points, compliance is required with the following criteria:

- The metal containers to be handed over must be fully emptied of all residue, i.e. in drip-free condition.
- The containers must bear the KBS logo.
- Proof of RASCOR's participation in the KBS recycling system must be presented at the collection point.

4.1 DISPOSAL OF CURED POLYURETHANE RESIN RESIDUE

Cured polyurethane resin may be disposed of in a similar way to domestic waste and handed over for incineration. EWC waste code: 120105 (plastics shavings and turnings).

4.2 DISPOSAL OF LIQUID POLYURETHANE RESIN RESIDUE

Uncured polyurethane resin may be disposed of as special waste, subject to compliance with the relevant statutory provisions, or mixed with the other component in the ratio 1:1. In the latter case, mixing will trigger a reaction causing the material to cure. The procedure under Section 4.1 may then be adopted.
EWC waste code: 070208 (other still bottoms and reaction residues).

4.3 DISPOSAL OF OIL-CONTAMINATED LIQUID POLYURETHANE RESIN RESIDUE

Oil-contaminated uncured polyurethane resin residue must be handed over to disposal companies, which will then treat the waste or dispose of it as special waste, e.g. in a waste incineration plant.
EWC waste code: 130601 ("other" oil mixtures)

4.4 DISPOSAL OF EXCAVATED SOIL WITH UNCURED POLYURETHANE RESIN

Excavated soil/spoil and waste from soil treatment plants with harmful contamination must be handed over to the disposal company.

EWC waste code: 170599

LEGAL NOTICE: The information provided on the use and application of our products in this technical data sheet is based on the present state of our knowledge. The customer shall bear sole responsibility for the proper specification, application and use of the products in line with the intended purpose, project-specific conditions and external actions. The most recent technical data sheet shall apply. The current technical data sheets are available at www.rascor.com. Our General Terms of Business shall form an integral part of this technical data sheet.

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