

**Technical training.**  
**Product information.**

## **SCR 2 (US)**



**BMW Service**

Edited for the U.S. market by:  
**BMW Group University**  
**Technical Training**

ST1307

4/1/2015

# General information

## Symbols used

The following symbol is used in this document to facilitate better comprehension or to draw attention to very important information:



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Contains important safety information and information that needs to be observed strictly in order to guarantee the smooth operation of the system.

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## Information status and national-market versions

BMW Group vehicles meet the requirements of the highest safety and quality standards. Changes in requirements for environmental protection, customer benefits and design render necessary continuous development of systems and components. Consequently, there may be discrepancies between the contents of this document and the vehicles available in the training course.

This document basically relates to the European version of left-hand drive vehicles. Some operating elements or components are arranged differently in right-hand drive vehicles than shown in the graphics in this document. Further differences may arise as a result of the equipment specification in specific markets or countries.

## Additional sources of information

Further information on the individual topics can be found in the following:

- Owner's Handbook
- Integrated Service Technical Application.

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The information contained in this document forms an integral part of the technical training of the BMW Group and is intended for the trainer and participants in the seminar. Refer to the latest relevant information systems of the BMW Group for any changes/additions to the technical data.

Information status: **February 2013**  
**BV-72/Technical Training**

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# SCR 2 (US)

## 1. Introduction

The abbreviation SCR stands for **Selective Catalytic Reduction**. This is currently the most effective system for the reduction of nitrogen oxides in the exhaust gas.

This system is model-specific and is now being used for all current BMW diesel engines in USA as well as in other markets. It is necessary to comply with the EURO 6 exhaust emission standards (in Europe) as well with the US EPA and CARB emission regulations. Although the new US market diesels are certified to the more stringent ULEVII (California) standard in some states the requirement is still Tier 2, Bin 5 (LEV II). Compliance with these regulations has been possible by combining SCR the already known emission systems such as NSC (NO<sub>x</sub> storage catalytic converter), EGR (low-pressure exhaust-gas recirculation) and DPF (diesel particulate filter) and the internal engine measures. Therefore the requirements of the CARB and EURO 6 exhaust emission standards are also fulfilled in the cold-start phase, when the SCR system is not yet operational.

BMW already has experience with the SCR system as it has been used in the BMW diesel fuel models in the US market since 2008.

The special feature of the SCR system is the additional used of the urea/water mixture (AdBlue<sup>®</sup>), a supply of which is stored and carried in the vehicle. This urea/water mixture is generally known under the brand name “**AdBlue<sup>®</sup>**” and also referred to as **Diesel Exhaust Fluid (DEF)**.

The system is managed at BMW under the marketing name “**BMW BluePerformance**”.

**This document discusses the second generation of the SCR system (SCR 2) with regard to the US market specifications. The system is based on the previous US SCR system as well on the EURO 6 and is installed in combination with the second generation diesel engines the N47TU and the N57TU.**

# SCR 2 (US)

## 1. Introduction

### 1.1. History

BMW models with SCR technology.



1 — BMW 335d (E90)



2 — BMW X5 xDrive35d (E70)

Model	335d Advanced Diesel with BluePerformance US	X5 xDrive35d Advanced Diesel with BluePerformance US
Series	E90	E70
Engine	M57D30T2	M57D30T2
Displacement in cm <sup>3</sup>	2993	2993
Stroke/Bore hole in mm	90/84	90/84
Power in kW/HP at rpm	200/265 – 4200	200/265 – 4200
Torque in Nm at	580/1750	580/1750
Market introduction	12/2008	12/2008

### 1.2. Introduction dates of SCR 2 to the US market

Model	Engine version	Introduction date
F30, F31	N47D20O1	07/2013
F10	N57D30O1	07/2013
F15	N57D30O1	09/2013

#### 1.2.1. Second generation diesel emission system

Although the second generation diesels are certified to the more stringent ULEVII (California) standard in some states the requirement is still Tier 2, Bin 5 (LEV II). The basic design of the exhaust emission system in the US market is very similar to the previous system. However, a more powerful system for exhaust gas treatment is required to meet increasingly stringent emissions regulations in spite of lower

# SCR 2 (US)

## 1. Introduction

exhaust temperatures and high efficiency diesel engines. These special measures and components apply exclusively to the US market models with the second generation diesel engines the N47TU and N57TU mentioned above (N47D20O1 and N57D30O1).

The most notable features of the second generation diesel exhaust after treatment system are listed below:

- Where the previous system used an oxidation catalyst there is now a NOx Storage Catalyst (NSC) installed. The NSC is a NOx adsorption (storage) catalyst which incorporates the precious metals Platinum, Palladium and Rhodium and is installed in the same housing as the Diesel Particulate Filter (DPF).
- There is also now an additional O<sub>2</sub> sensor (downstream of the DPF). It is used to monitor the function of the NSC and to determine whether it needs to be regenerated.
- The new system also incorporates the second generation SCR system (SCR 2) which is described in detail in this training material. The combination of a NOx Storage Catalyst (NSC) and SCR catalyst has significant advantages for the exhaust gas after-treatment due to the efficiency of the NSC especially under lean conditions.
- In addition, for the first time there is also a particulate matter sensor (located down stream of the SCR). This sensor is used to monitor and manage the efficiency of the diesel particulate filter (DPF) in order to maintain the soot emission levels well below the mandated guidelines.



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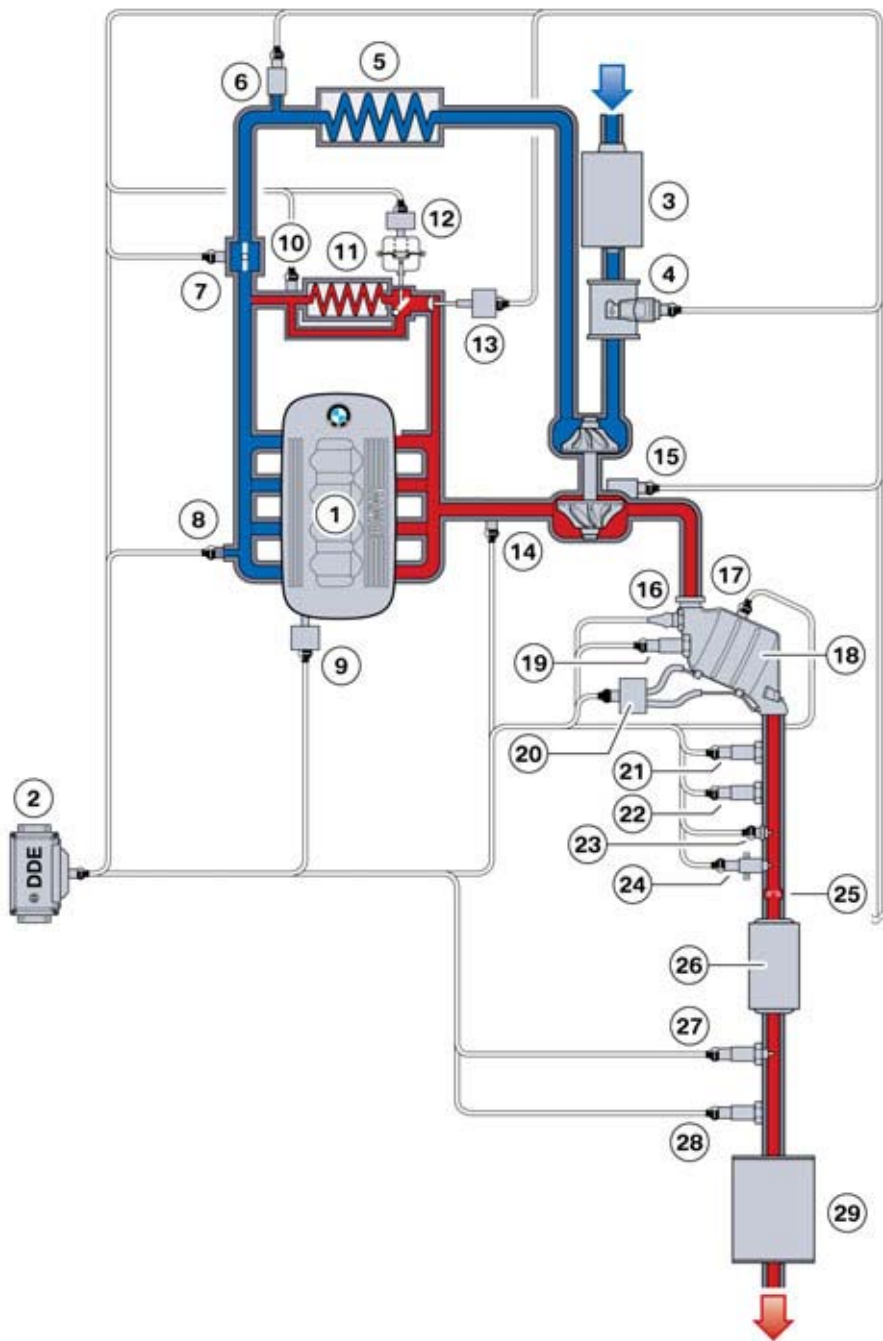
**This training manual only describes the SCR 2 system. See the “N47TU Engine” and “N57TU Engine” reference manuals (available on TIS and ICP), as well as, OL1310 “2nd Generation Diesel Technology” online training (available on ICP) for more information.**

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These components are illustrated in the graphic on the following page.

# SCR 2 (US)

## 1. Introduction



N47TU engine intake air and exhaust emission system (US)



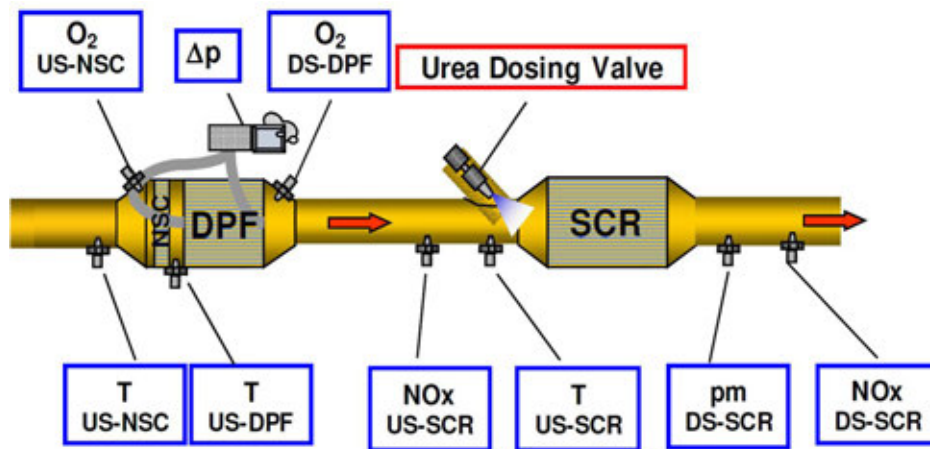
# SCR 2 (US)

## 1. Introduction

Index	Explanation
1	N47TU Engine
2	Digital Diesel Electronics (DDE)
3	Intake silencer
4	Hot film air mass meter
5	Charge air intercooler
6	Charge-air temperature sensor
7	Throttle valve
8	Boost pressure sensor
9	Swirl-flap actuator
10	Exhaust-gas recirculation temperature sensor
11	Exhaust-gas recirculation cooler
12	EGR cooler bypass plate
13	Exhaust-gas recirculation valve with position sensor
14	Exhaust back pressure sensor before the exhaust turbocharger
15	Boost pressure actuator
16	Exhaust-gas temperature sensor upstream NO <sub>x</sub> storage catalytic converter (NSC)
17	Exhaust-gas temperature sensor downstream NO <sub>x</sub> storage catalytic converter (NSC)
18	NO <sub>x</sub> storage catalytic converter and diesel particulate filter (NSC/DPF)
19	Oxygen sensor upstream the NO <sub>x</sub> storage catalytic converter (NSC)
20	Differential exhaust pressure sensor before and after the diesel particulate filter (DPF)
21	Oxygen sensor downstream diesel particulate filter (NSC/DPF)
22	NO <sub>x</sub> sensor upstream selective catalyst reduction (SCR)
23	Exhaust-gas temperature sensor upstream of the Selective Catalyst Reduction (SCR)
24	Dosing valve
25	Mixer for (SCR)
26	Selective Catalyst Reduction (SCR)
27	Particulate matter (soot) sensor
28	NO <sub>x</sub> sensor downstream Selective Catalyst Reduction (SCR)
29	Rear silencer

# SCR 2 (US)

## 1. Introduction



Second generation diesel exhaust after-treatment components for the US market.

Index	Explanation
T US-NSC	Temperature sensor up stream of the NOx Storage Catalyst
O <sub>2</sub> US-NSC	O <sub>2</sub> sensor up stream of the NOx Storage Catalyst
NSC	NOx Storage Catalyst
Δp	Differential pressure sensor
T US-DPF	Temperature sensor up stream of the Diesel Particulate Filter
O <sub>2</sub> DS-DPF	O <sub>2</sub> sensor down stream of the Diesel Particulate Filter
NOx US-SCR	NOx sensor up stream of the Selective Catalytic Reduction
UDV	Urea Dosing Valve
T US-SCR	Temperature sensor up stream of the Selective Catalytic Reduction
SCR	Selective Catalytic Reduction
NOx DS-SCR	NOx sensor down stream of the Selective Catalytic Reduction
pm DS-SCR	Particulate matter sensor down stream of the Selective Catalytic Reduction



The exhaust after-treatment systems and components of the N47TU and the N57TU have been especially design to comply with current (ULEV II) US market emission regulations and thus are different from those used with the previous US diesel (M57D30T2) engine.



This training manual only describes the SCR 2 system. See the “N47TU Engine” and “N57TU Engine” reference manuals (available on TIS and ICP), as well as, OL1310 “2nd Generation Diesel Technology” online training (available on ICP) for more information.

# SCR 2 (US)

## 1. Introduction



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For more information regarding the exhaust after-treatment refer to the “Second generation diesel engine emission controls” in the ST1210 Diesel Technology training material available on TIS and ICP.

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# SCR 2 (US)

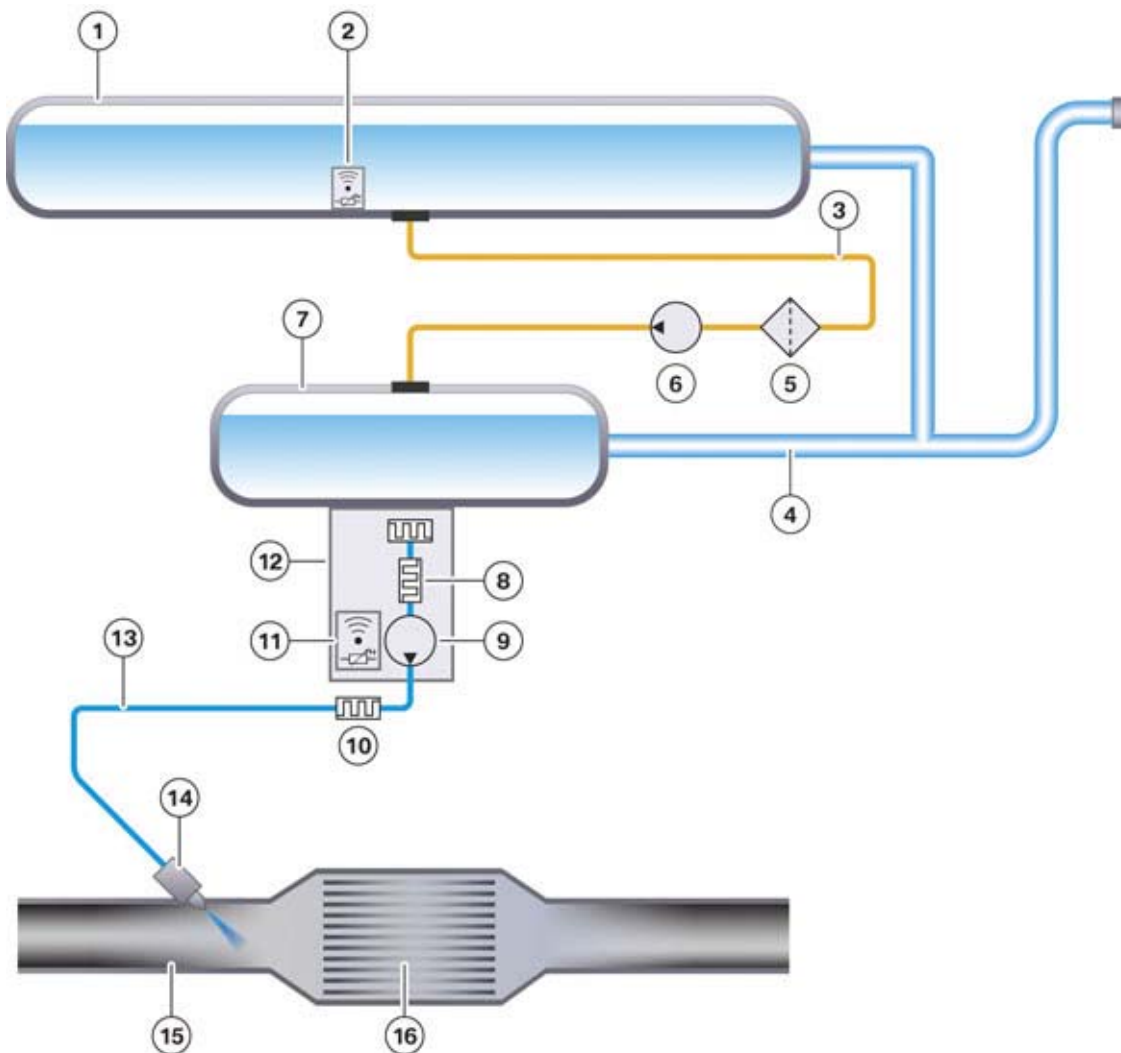
## 2. Summary

The Selective Catalytic Reduction (SCR) is a system for the reduction of nitrogen oxides  $\text{NO}_x$  (nitrogen monoxide  $\text{NO}$  and nitrogen dioxide  $\text{NO}_2$ ) in the exhaust gas. As with the previous system a reducer (urea/water mixture) (AdBlue<sup>®</sup>) is directly injected into the exhaust gas after the diesel particulate filter before the SCR catalytic converter.

The response to the nitrogen oxide reduction then takes place in the SCR catalytic converter.

The urea/water mixture (AdBlue<sup>®</sup>) is stored in the vehicle in one or two tanks. The volume is enough to guarantee a high range.

The following graphic shows a **simplified** schematic diagram of the system:



Simplified schematic diagram of the SCR system using the example of the F10

TD12-0942

# SCR 2 (US)

## 2. Summary

Index	Explanation
1	Passive tank
2	Tank flange with level sensor and temperature sensor — passive tank
3	Transfer line
4	Filler connection
5	Fine filter
6	Transfer pump unit
7	Active tank
8	Heating, active tank and SCR delivery module
9	SCR delivery module
10	Heating metering line
11	Level sensor and temperature sensor — active tank
12	Tank flange, active tank
13	Metering line
14	Metering valve
15	Exhaust system
16	SCR catalytic converter

The reason for using two tanks is that the urea/water mixture (AdBlue<sup>®</sup>) freezes at -11 °C (12.2 °F). The active tank is therefore heated. This prevents the entire volume of the urea/water mixture (AdBlue<sup>®</sup>) having to be heated, which saves energy. Also the stretching of the top-up intervals for covering longer distances between the tank processes for the urea/water mixture (AdBlue<sup>®</sup>) is a reason that two expansion tanks are installed (depending on the model).

The heated tank is called the active tank. From here the urea/water mixture (AdBlue<sup>®</sup>) is sent through the SCR delivery module to the metering module (this pipe is also heated).

The unheated tank is the passive tank. The transfer pump unit regularly ensures that the urea/water mixture (AdBlue<sup>®</sup>) is pumped from the passive tank to the active tank.

This documentation sometimes describes and shows the system with two tanks, the functions of the one tank version are generally the same, the additional components required for the second tank system can be omitted for the one-tank system.

The F10 535d for the US market only has one tank (active tank).

### 2.1. Differences between SCR 2 – SCR

The SCR 2 was introduced to save components in comparison to the first generation. The advantages are cost savings and reduction in the variants, such as no longer two different Digital Diesel Electronics (DDE) hardware components. The Digital Diesel Electronics (DDE) hardware can be used for all series. If the SCR system is installed, a SCR dosing control unit (DCU) is also installed.

# SCR 2 (US)

## 2. Summary

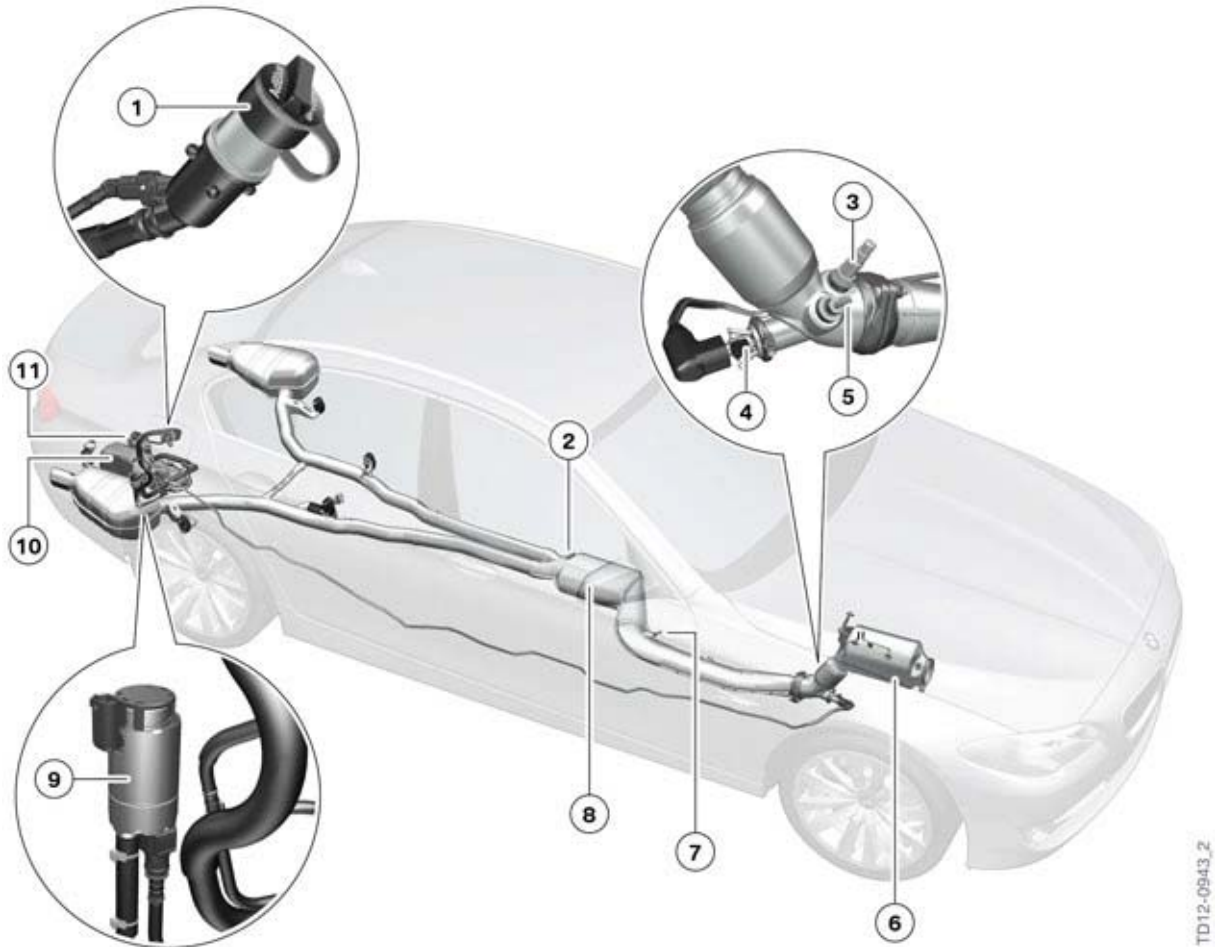
The SCR 2 differs to the SCR with regard to the following characteristics:

- SCR 2 control is housed in its own SCR control unit (Dosing Control Unit, DCU).
- SCR 2 strategy is in the Digital Diesel Electronics (DDE).
- Elimination of the reversing valve; two pumps are used instead.
- Level sensors are contactless and operate on ultrasonic basis.
- Pressure determination based on calculated pressure module, therefore the pressure sensor is no longer required.
- Draining connections were eliminated (these became redundant due to the level sensor).
- Metering module is now cooled by the engine cooling system.
- Only one filler connection of the SCR system for active tank and passive tank. (except F15 which still has 2 different filling ports like E70).
- Encapsulated components without direct contact to the medium (avoids components damage due to contact with the corrosive DEF).

# SCR 2 (US)

## 2. Summary

### 2.2. Installation locations



Installation locations of SCR 2 system using the example of the F10

Index	Explanation
1	Urea/water mixture (AdBlue <sup>®</sup> ), filler connection with fluid filler cap
2	NO <sub>x</sub> sensor after SCR catalytic converter
3	Oxygen sensor
4	Metering module
5	NO <sub>x</sub> sensor before the SCR catalytic converter
6	NO <sub>x</sub> storage catalytic converter and diesel particulate filter
7	Exhaust-gas temperature sensor after diesel particulate filter
8	SCR catalytic converter
9	Transfer pump unit
10	Active tank (Passive tank is Not installed in US F10 models)
11	SCR dosing control unit (DCU)

# SCR 2 (US)

## 2. Summary

In the F10 with the N57D30O1 a 15 liter capacity active tank is installed, which is located in the vehicle underbody at the rear right. A passive tank is not installed in the US market F10. The filler connection for the urea/water mixture (AdBlue<sup>®</sup>) is located in the fuel filler flap beside the (diesel) fuel filler neck at the rear right of the vehicle.

In the F30 with the N47D20O1 an 8,7 liter capacity active tank is used, which is located in the vehicle underbody in front of the right rear wheel. The F30 passive tank is located behind the right rear wheel and has 9,4 liters. The filler connection for the urea/water mixture (AdBlue<sup>®</sup>) is located in the fuel filler flap beside the (diesel) fuel filler neck at the rear right of the vehicle.

The F31 has the same SCR system as F30 therefore the tanks have the same capacity and are installed in the same general locations.

In the F15 the active tank has a max volume of 13,7 liters and the passive tank has a 15,3 liter capacity. The active tank is located on the right side of the vehicle directly behind the front bumper cover. And the passive tank is located in the vehicle underbody in the area under the front seats. The filler connections for the urea/water mixture (AdBlue<sup>®</sup>) are located in the engine compartment. The passive tank filler point is at the same position as E70 (on the left side of the engine compartment).

The different tank sizes result from the available installation areas in the different series.

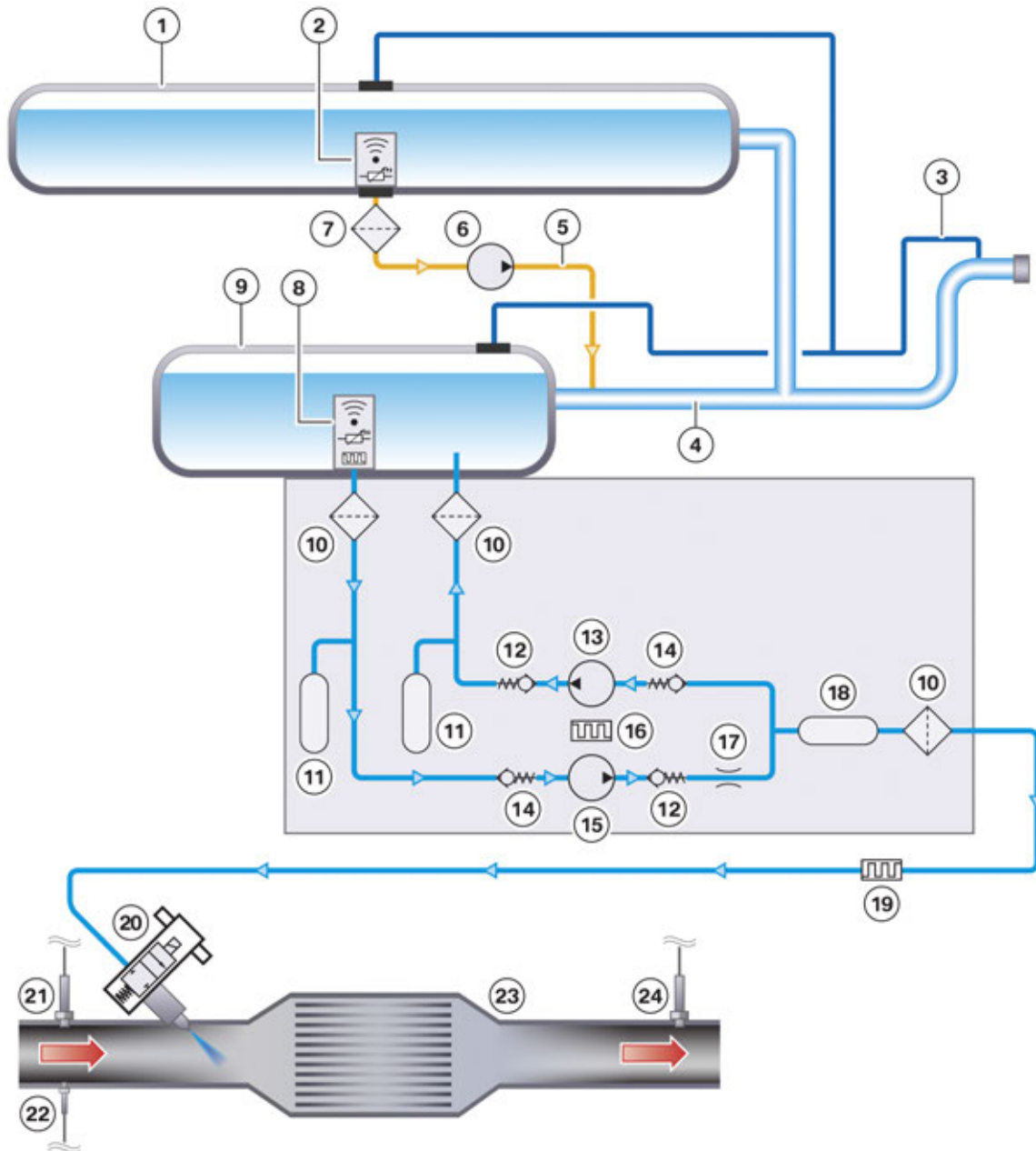
The installation location of the SCR dosing control unit (DCU) varies from series to series. The SCR control is housed in the DCU while the strategy is still integrated in the Digital Diesel Electronics.



# SCR 2 (US)

## 2. Summary

### 2.3. System overview in detail



SCR system overview

TD12-0944

Index	Explanation
1	Passive tank
2	Tank flange, passive tank with level sensor and temperature sensor
3	Tank ventilation line
4	Fluid filler neck breather pipe

# SCR 2 (US)

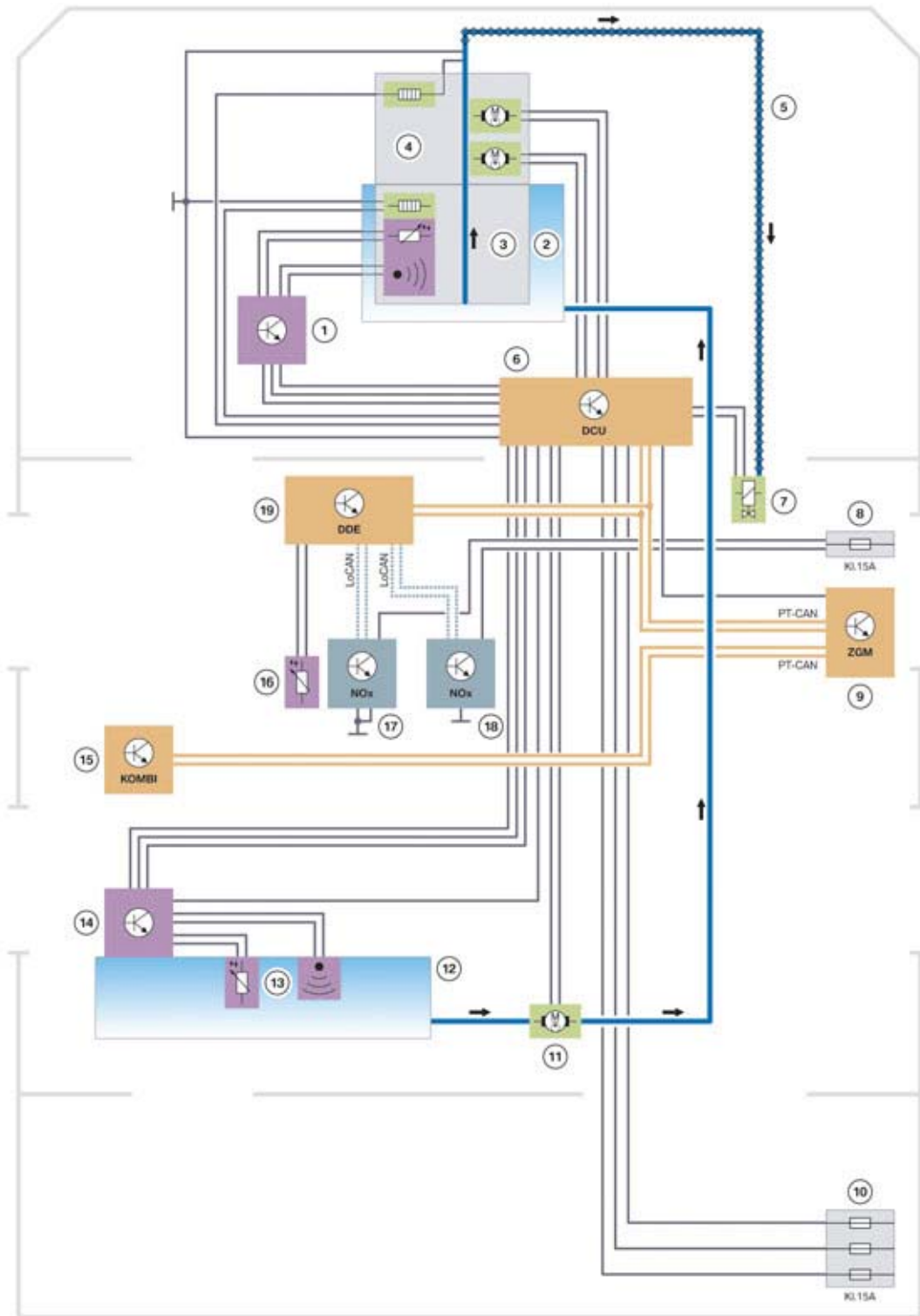
## 2. Summary

Index	Explanation
5	Transfer line
6	Transfer pump unit
7	Filter
8	Tank flange, active tank with SCR delivery module, level sensor, heating and temperature sensor
9	Active tank
10	Filter
11	Ice pressure damper
12	Fluid pressure control valve
13	Back-flow pump
14	Intake valve
15	Supply pump
16	Heating
17	Restrictor
18	Pulsation damper
19	Heating metering line
20	Metering valve
21	NO <sub>x</sub> sensor before the SCR catalytic converter
22	Exhaust-gas temperature sensor after diesel particulate filter
23	SCR catalytic converter
24	NO <sub>x</sub> sensor after SCR catalytic converter

## SCR 2 (US)

### 2. Summary

## 2.4. System wiring diagram



System wiring diagram of the European F10 for example only (No passive tank is installed in the US model F10)

# SCR 2 (US)

## 2. Summary

Index	Explanation
1	Evaluation unit, active tank
2	Active tank
3	Level sensor, temperature sensor and heating, active tank
4	SCR delivery module with supply pump, return pump and heating
5	Heating metering line
6	SCR dosing control unit (DCU)
7	Metering module
8	Fuse, supply of NOx sensors
9	Central gateway module (ZGM)
10	Fuses, supply of SCR control unit
11	Transfer pump unit
12	Passive tank
13	Level sensor and temperature sensor, passive tank
14	Evaluation unit, passive tank
15	KOMBI (instrument cluster)
16	Exhaust-gas temperature sensor
17	NO <sub>x</sub> sensor before the SCR catalytic converter
18	NO <sub>x</sub> sensor after SCR catalytic converter
19	Digital Diesel Electronics (DDE)



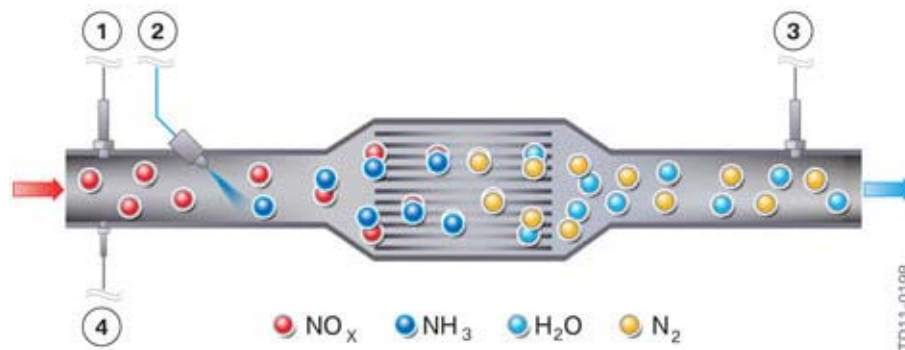
**Note:** There is no passive tank (and related components 11, 12, 13, 14) installed in the US market specific F10.

# SCR 2 (US)

## 3. Functions

The Selective Catalytic Reduction (SCR) is currently the most effective system for the reduction of nitrogen oxides ( $\text{NO}_x$ ). During its operation the system achieves an efficiency of almost 100 % and over the entire vehicle operation about 90%. The difference can be found in the time that the system requires to be operational after a cold start.

A urea/water mixture (AdBlue<sup>®</sup>) is used as a reducer agent and is stored and carried in the vehicle.



Functions of the SCR

Index	Explanation
1	$\text{NO}_x$ sensor before the SCR catalytic converter
2	Metering module
3	$\text{NO}_x$ sensor after the SCR catalytic converter
4	Temperature sensor after the diesel particulate filter

The urea/water mixture (AdBlue<sup>®</sup>) is injected into the exhaust pipe via the metering module before the SCR catalytic converter. The Digital Engine Electronics (DDE) calculates how much has to be injected. The nitrogen oxide content in the exhaust gas is calculated via the  $\text{NO}_x$  sensor before the SCR catalytic converter. Using this value the exact required amount of urea/water mixture (AdBlue<sup>®</sup>) is injected in order to completely reduce the nitrogen oxides.

The urea/water mixture (AdBlue<sup>®</sup>) transforms into ammonia in the exhaust pipe. The ammonia reacts in the SCR catalytic converter with the nitrogen oxides and nitrogen ( $\text{N}_2$ ) and water ( $\text{H}_2\text{O}$ ) are created.

Behind the SCR catalytic converter there is a second  $\text{NO}_x$  sensor which monitors the function. (see 3.2.1)

A temperature sensor located in the exhaust pipe behind the diesel particulate filter (before the SCR catalytic converter and the metering module) also influences the function because the injection of the urea/water mixture (AdBlue<sup>®</sup>) begins only once 170 °C (338 °F) is reached.

# SCR 2 (US)

## 3. Functions

### 3.1. Chemical reaction

The SCR system significantly reduces the nitrogen oxides ( $\text{NO}_x$ ) in the exhaust gas.

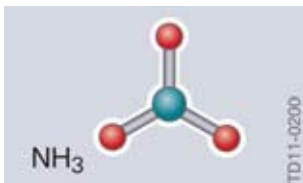
The nitrogen oxides occur in two different forms:

- Nitrogen monoxide ( $\text{NO}$ )
- Nitrogen dioxide ( $\text{NO}_2$ ).



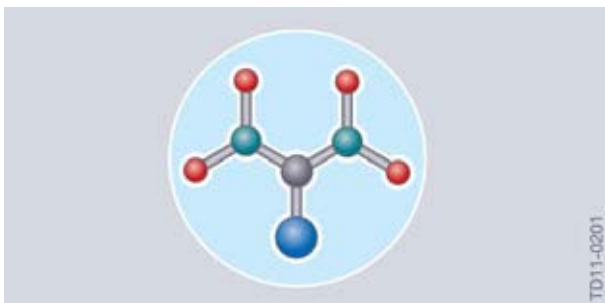
Nitrogen oxides

Ammonia ( $\text{NH}_3$ ) is used for the reduction of the nitrogen oxides in a special catalytic converter.



Ammonia

The ammonia is delivered via a urea/water mixture (AdBlue<sup>®</sup>).



Urea/water mixture (AdBlue<sup>®</sup>)

The urea/water mixture (AdBlue<sup>®</sup>) is injected via the metering module into the exhaust system downstream of the diesel particulate filter. The required quantity must be exactly metered as otherwise nitrogen oxides or ammonia would escape. The following description of the chemical processes should explain why this is the case.

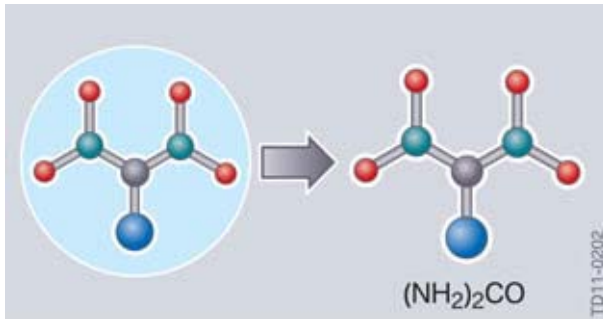
# SCR 2 (US)

## 3. Functions

### 3.1.1. Transformation of the urea/water mixture (AdBlue®)

The equal distribution of the urea/water mixture (AdBlue®) in the exhaust gas and the transformation into ammonia takes place in the exhaust pipe before the SCR catalytic converter.

First, the urea dissolved in the urea/water mixture (AdBlue®) ( $(\text{NH}_2)_2\text{CO}$ ) is released.

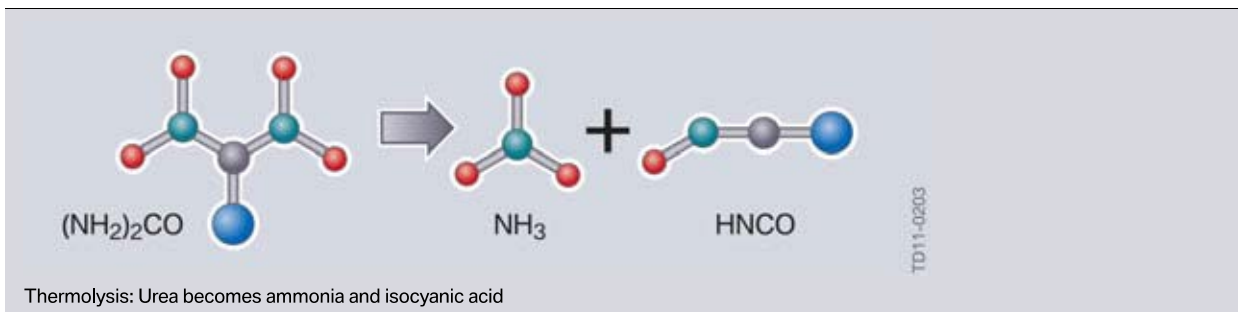


Releasing the urea from the urea/water mixture (AdBlue®)

The transformation of the urea into ammonia takes place in two stages.

#### Thermolysis

Explanation	In the thermolysis the urea/water mixture (AdBlue®) is split into two products by heating.
Starting products	Urea ( $(\text{NH}_2)_2\text{CO}$ )
Result	Ammonia ( $\text{NH}_3$ ) Isocyanic acid ( $\text{HNCO}$ )
Chemical formula	$(\text{NH}_2)_2\text{CO} \rightarrow \text{NH}_3 + \text{HNCO}$



In the thermolysis only a part of the urea/water mixture (AdBlue®) is transformed into ammonia. The rest is isocyanic acid and is transformed in a second step.

# SCR 2 (US)

## 3. Functions

### Hydrolysis

Explanation	The isocyanic acid, that was created during the thermolysis, is also transformed into ammonia and carbon dioxide (CO <sub>2</sub> ) during the hydrolysis through the addition of water.
-------------	--

Starting products	Isocyanic acid (HNCO) Water (H <sub>2</sub> O)
-------------------	---

Result	Ammonia (NH <sub>3</sub> ) Carbon dioxide (CO <sub>2</sub> )
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Chemical formula:	$\text{HNCO} + \text{H}_2\text{O} \rightarrow \text{NH}_3 + \text{CO}_2$
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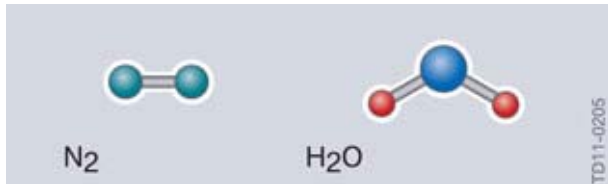
Hydrolysis: Isocyanic acid reacts with water and becomes ammonia and carbon dioxide

The required water is also delivered via the urea/water mixture (AdBlue®).

Therefore, after the hydrolysis the entire urea is transformed into ammonia and carbon dioxide.

### 3.1.2. NO<sub>x</sub> reduction

In the SCR catalytic converter the nitrogen oxides are transformed into harmless nitrogen and water.



Nitrogen and water



# SCR 2 (US)

## 3. Functions

Reduction	
Explanation	The catalytic converter enables a "docking" of the ammonia molecules. The nitrogen oxide molecules meet the ammonia molecules and the reaction begins. This releases energy and is valid both for NO as well as NO <sub>2</sub> .
Starting products	Ammonia (NH <sub>3</sub> ) Nitrogen monoxide (NO) Nitrogen dioxide (NO <sub>2</sub> ) Oxygen (O <sub>2</sub> )
Result	Nitrogen (N <sub>2</sub> ) Water (H <sub>2</sub> O)
Chemical formula	$\text{NO} + \text{NO}_2 + 2\text{NH}_3 \rightarrow 2\text{N}_2 + 3\text{H}_2\text{O}$ $4\text{NO} + \text{O}_2 + 4\text{NH}_3 \rightarrow 4\text{N}_2 + 6\text{H}_2\text{O}$ $6\text{NO}_2 + 8\text{NH}_3 \rightarrow 7\text{N}_2 + 12\text{H}_2\text{O}$

NO<sub>x</sub> reduction: Nitrogen oxides react with ammonia and become nitrogen and water

It is possible to recognize that at the end each individual atom has found its place again. So, there are the exact same amount of elements on the left side as on the right. This only happens if the ratio of urea/water mixture (AdBlue<sup>®</sup>) to nitrogen oxides is correct.

If too little urea/water mixture (AdBlue<sup>®</sup>) is injected then nitrogen oxides escape. If too much urea/water mixture (AdBlue<sup>®</sup>) is injected then ammonia escapes, which could lead to unpleasant odors and environmental damage (ammonia slip).

### 3.2. SCR control

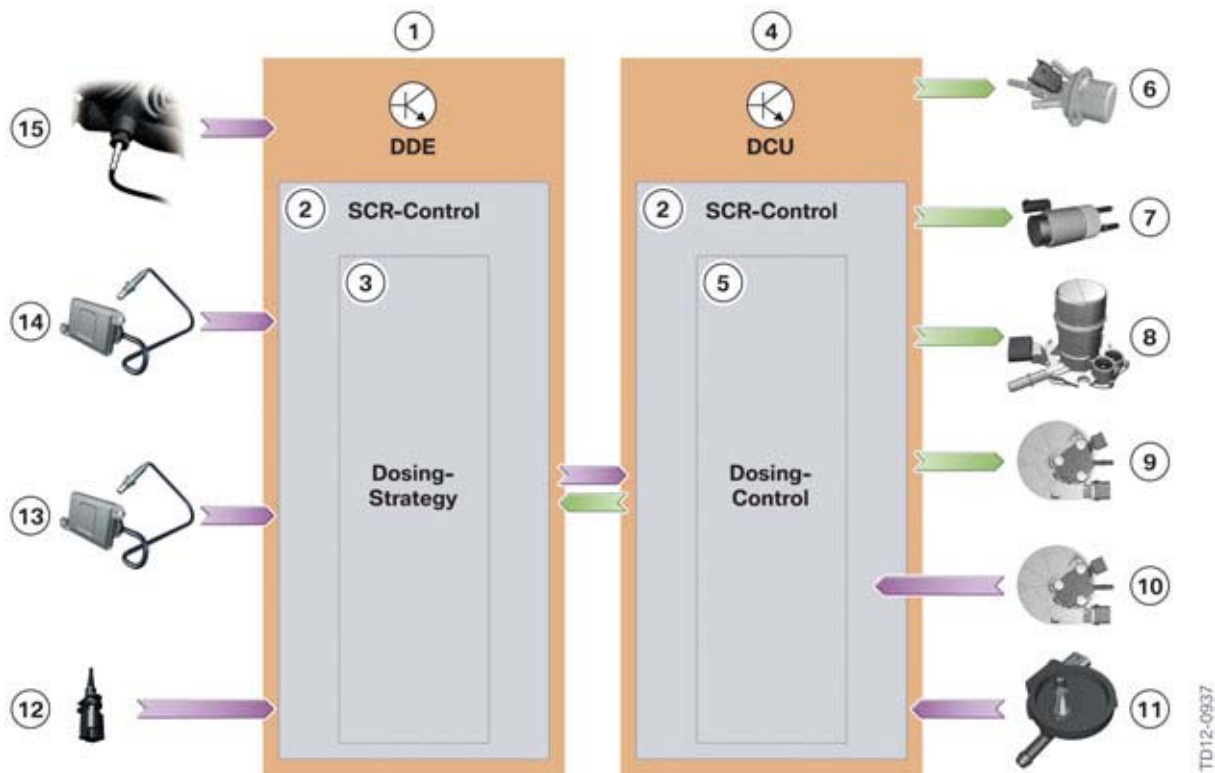
The SCR control is divided into the dosing system control, which is implemented by the SCR dosing control unit (DCU), and the metering strategy, which is defined by the Digital Diesel Electronics (DDE).

# SCR 2 (US)

## 3. Functions

The SCR dosing control unit (DCU) assumes the following functions:

- System functions CAN communication and network management.
- Control of the urea/water mixture (AdBlue<sup>®</sup>) pumps, metering line filling/emptying and pressure build-up/pressure reduction.
- Control of the urea/water mixture (AdBlue<sup>®</sup>) metering module, implementation of the metering amount specification of the Digital Diesel Electronics (DDE).
- Control of the urea/water mixture (AdBlue<sup>®</sup>) heating.
- Evaluation of the level sensors and temperature sensors.
- Monitoring functions.
- On-board diagnosis (OBD) monitoring.
- Control of the heating in active tank, pump and metering line.
- Control of the pumping function from passive tank (if installed) to active tank.



SCR control

Index	Explanation
1	Digital Diesel Electronics (DDE)
2	SCR control
3	Metering strategy
4	SCR dosing control unit (DCU)

# SCR 2 (US)

## 3. Functions

Index	Explanation
5	Dosing system control
6	Metering module
7	Transfer pump unit
8	SCR delivery module
9	Tank flange, active tank with heating
10	Level sensor and temperature sensor in tank flange, active tank
11	Level sensor and temperature sensor in tank flange, passive tank
12	Outside temperature sensor
13	NO <sub>x</sub> sensor before the SCR catalytic converter
14	NO <sub>x</sub> sensor after SCR catalytic converter
15	Exhaust-gas temperature sensor

The Digital Diesel Electronics (DDE) assumes the following functions:

- Evaluation of the nitrogen oxide sensor
- Evaluation of the exhaust-gas temperature sensor
- Calculation of the urea/water mixture (AdBlue<sup>®</sup>) amount and transmission to the SCR dosing control unit (DCU) via PT-CAN
- Control of the engine shut down scenario.

### 3.2.1. Metering strategy

The metering strategy in the Digital Diesel Electronics (DDE) is the part of the SCR control that calculates how much urea/water mixture (AdBlue<sup>®</sup>) is injected at which time.

The signal of the NO<sub>x</sub> sensor before the SCR catalytic converter is used for the calculation of the quantity in normal operation. This calculates the amount of nitrogen oxide in the exhaust gas and transmits the value to the Digital Diesel Electronics (DDE).

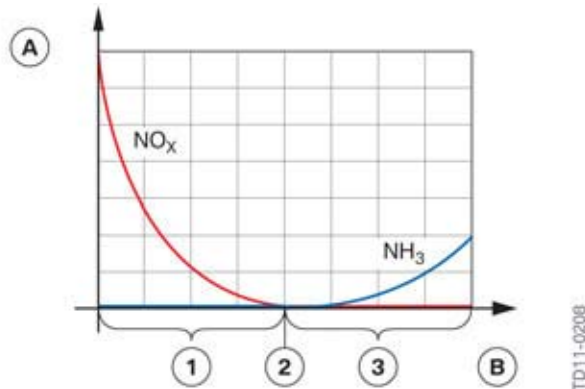
However, the NO<sub>x</sub> sensor must reach its operating temperature in order to begin measuring. Depending on the ambient temperature this can take up to 15 min. Until this point a substitute value from the Digital Diesel Electronics (DDE) is calculated for the determination of the nitrogen oxide quantity in the exhaust gas.

In order to monitor the system there is a second NO<sub>x</sub> sensor downstream of the SCR catalytic converter. It measures whether there are still nitrogen oxides in the exhaust gas. If this is the case, then the fluid injection rate of the urea/water mixture (AdBlue<sup>®</sup>) is adapted. The NO<sub>x</sub> sensor not only measures the nitrogen oxides, but also ammonia, but is unable to make a distinction between the two.

If too much urea/water mixture (AdBlue<sup>®</sup>) is injected, then the nitrogen oxides are fully reduced, however, there is an increased risk of a so-called "ammonia slip", i.e. ammonia escapes from the SCR catalytic converter. The value is increased as the NO<sub>x</sub> sensor measures again. Therefore, the target is to reach a minimum of the sensor value.

# SCR 2 (US)

## 3. Functions



Nitrogen oxide and ammonia emissions diagram

Index	Explanation
A	Calculated value of the NO <sub>x</sub> sensor
B	Injected quantity of urea/water mixture (AdBlue <sup>®</sup> )
1	Too small quantity of urea/water mixture (AdBlue <sup>®</sup> ) injected
2	Correct quantity of urea/water mixture (AdBlue <sup>®</sup> ) injected
3	Too large quantity of urea/water mixture (AdBlue <sup>®</sup> ) injected ("ammonia slip")

However, this is a long-term adaptation and not a short-term control as the SCR catalytic converter has a memory function for ammonia.

### 3.2.2. Metering system control

The metering system control in the SCR dosing control unit (DCU) is the part which performs the metering functions. It implements the requirements set by the metering strategy in the DDE. This includes both the metering and the injection of the urea/water mixture (AdBlue<sup>®</sup>) as well as the supply of the urea/water mixture (AdBlue<sup>®</sup>).

The tasks of the metering system control (in normal operation) are listed below:

Metering of the urea/water mixture (AdBlue<sup>®</sup>):

- Implementation of the required target amount of urea/water mixture (AdBlue<sup>®</sup>)
- Return of the required urea/water mixture actual quantity (AdBlue<sup>®</sup>).

Supply of the urea/water mixture (AdBlue<sup>®</sup>):

- Provision of the metering ability (fill lines and pressure build-up) under certain ambient conditions (temperature)
- Empty lines at after-run
- Activation of the heating.

# SCR 2 (US)

## 3. Functions

### 3.3. Supply of the urea/water mixture (AdBlue®)

An adequate supply of urea/water mixture (AdBlue®) is required for the proper operation of the Selective Catalytic Reduction (SCR) system. Furthermore, this medium must be stored in the vehicle and made available as quickly as it is necessary under all ambient conditions. In this case making available means that the urea/water mixture (AdBlue®) should be under a required pressure at the metering valve.

### 3.4. Metering of the urea/water mixture (AdBlue®)

The metering strategy establishes the quantity of the urea/water mixture (AdBlue®) that should be injected. The metering system control now ensures the implementation of this requirement. The metering activation is a part of the function from which the actual opening of the metering valve is determined.

Depending on engine load level and vehicle speed, the metering valve injects with a frequency of 0.3 Hz to 1.0 Hz.

**The dosing valve is actuated with 0,3 Hz in Idle condition for acoustic reasons and at 0,9 Hz when a high dosing amount is requested.**

In order to inject the right amount the metering control calculates following:

- the duty cycle for the actuator of the metering valve in order to ascertain the injection period
- the activation delay for the compensation of the metering valve inertia.

The metering system control also calculates the actual metered amount and sends this back to the metering strategy.

The metering amount is also calculated over a longer period of time. This long period calculation is reset upon refilling.

In order to fulfill these tasks various functions are necessary that are described in the following section.

#### 3.4.1. Heating

The SCR system must also be heated as the urea/water mixture (AdBlue®) freezes at a temperature of -11 °C (12.2 °F).

The heating function has the following tasks:

- Monitoring of the temperatures in the active tank and its surrounding area.
- Thawing of a sufficient amount of urea/water mixture (AdBlue®) and the components required for metering at system start.
- Prevention of freezing of the relevant components during operation.
- Monitoring of the components of the heating system.

# SCR 2 (US)

## 3. Functions

Following components are heated:

- Active tank.
- Metering line (from the active tank to the metering module).
- SCR delivery module via the coils of the supply pump and return pump.

The heating of the active tank is adjusted depending on the temperature in the active tank and the ambient temperature. The required control of the heating for the metering line and the heating for the SCR delivery module are based on the current ambient temperature values.

Each heater circuit is supplied with power by a semiconductor switch (driver). These power semiconductors are designed as high side switches, which are switched directly by the control unit. With help of the shunt measuring principle, the SCR dosing control unit (DCU) calculates the actual current, which flows over the heating elements. The DCU can also perform a function check of the heater circuits and thus detect any faults which are stored in the fault memory.

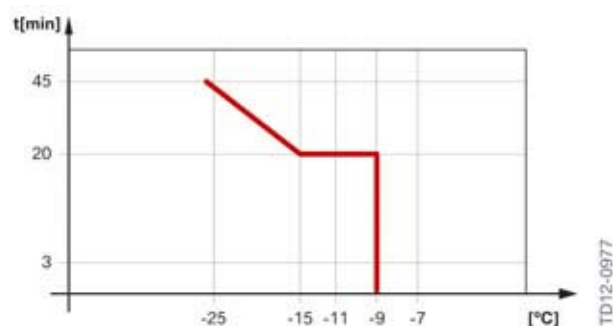
A temperature model is used for the heating of the components in order to establish the metering readiness.

With the temperature model, the following three basic parameters are set so that metering readiness can be reached.

The following values are defined by law and must be observed:

- at  $-25^{\circ}\text{C}$  ( $-13^{\circ}\text{F}$ ) the metering readiness is reached after 45 minutes
- at  $-15^{\circ}\text{C}$  ( $5^{\circ}\text{F}$ ) the metering readiness is reached after 20 minutes
- at  $-9^{\circ}\text{C}$  ( $15.8^{\circ}\text{F}$ ) the metering readiness is reached after 3 minutes.

The following table shows the metering readiness in relation to the temperature:



Metering readiness temperature

Index	Explanation
t [min]	Time in minutes
$^{\circ}\text{C}$	Temperature in degree Celsius

At a temperature under  $-9^{\circ}\text{C}$  ( $15.8^{\circ}\text{F}$ ) in the active tank the metering readiness is delayed, i.e. a defined time is waited until a pressure build-up begins. This time is constant from  $-9^{\circ}\text{C}$  to  $-15^{\circ}\text{C}$  ( $15.8^{\circ}\text{F}$  to  $5^{\circ}\text{F}$ ) as it cannot be ascertained at which degree the urea/water mixture (AdBlue<sup>®</sup>) is frozen. Under  $-15^{\circ}\text{C}$  ( $5^{\circ}\text{F}$ ) the heating period extends until a pressure build-up attempt.

# SCR 2 (US)

## 3. Functions

Generally heating up the metering line is significantly faster which is why the temperature in the active tank is decisive for the period until a pressure build-up attempt has been undertaken. If there is significantly lower ambient temperature than the temperature in the active tank the warm-up phase of the metering line becomes longer. Then the ambient temperature is used for the delay of the metering readiness.

### 3.4.2. Transfer pumping

As the storage of the urea/water mixture (AdBlue<sup>®</sup>) generally requires two tanks (depending on the model) a transfer pumping system is required.

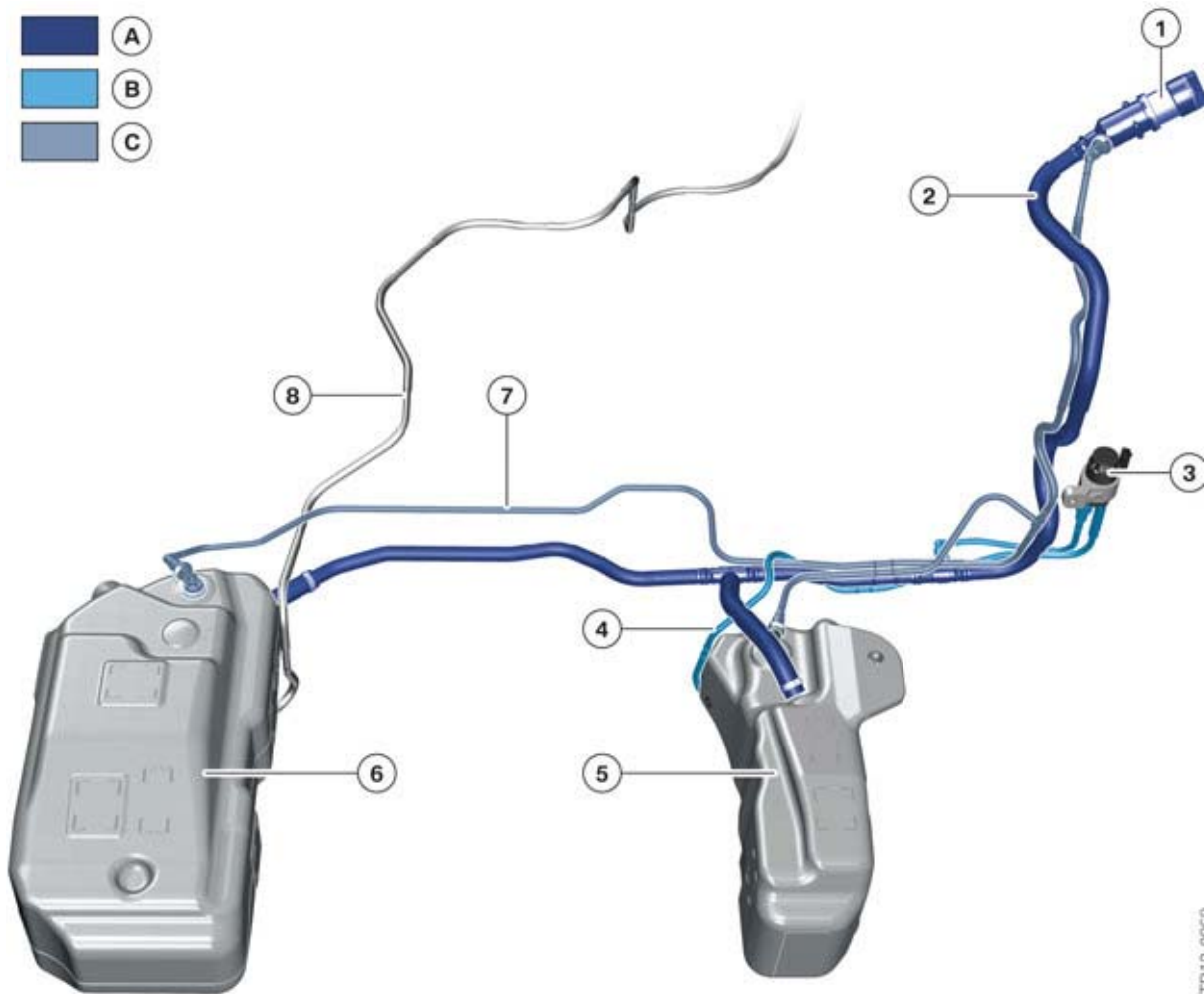
The delivery of urea/water mixture (AdBlue<sup>®</sup>) from the passive to the active tank is described as transfer pumping.

During transfer pumping the transfer pump unit pumps the urea/water mixture (AdBlue<sup>®</sup>) from the passive tank to the filling pipe. The filling pipe in the active tank is located below the filling pipe of the passive tank, therefore the urea/water mixture (AdBlue<sup>®</sup>) does not return to the passive tank, but always flows to the active tank.

The following (ECE model F10) image shows the installation locations of the filling and storage components. Although the image is not US model specific it is used here purely as an example for better understanding the DEF supply system:

# SCR 2 (US)

## 3. Functions



TD12-0959

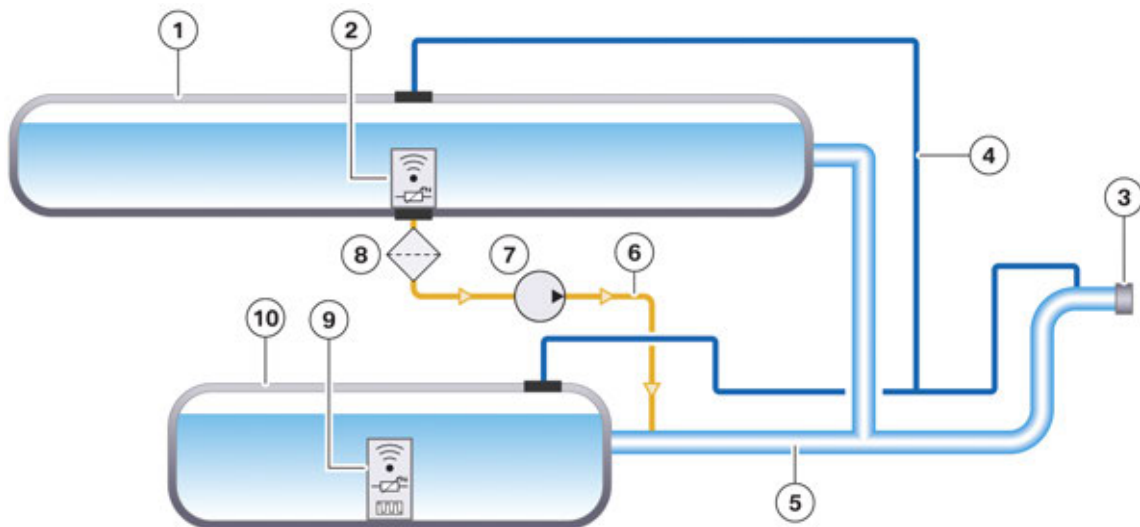
Pipes of SCR 2 tank system using the European F10 for example **(NOT US)**

Index	Explanation
A	Fluid filler neck breather pipes
B	Transfer lines
C	Tank ventilation lines
1	Urea/water mixture (AdBlue®), fluid filler cap
2	Fluid filler neck breather pipe, active tank and passive tank
3	Transfer pump unit
4	Transfer line
5	Passive tank
6	Active tank
7	Tank ventilation line
8	Metering line



# SCR 2 (US)

## 3. Functions



Transfer pumping

Index	Explanation
1	Passive tank
2	Temperature level sensor, passive tank
3	Fluid filler cap
4	Tank ventilation line
5	Fluid filler neck breather pipe, active tank — passive tank
6	Transfer line
7	Transfer pump unit
8	Filter
9	Heating temperature sensor, level sensor, active tank
10	Active tank

The following preconditions must be met for transfer pumping:

- Urea/water mixture (AdBlue®) is present in the passive tank.
- The ambient temperature is at least ten degrees above a minimum value of -7 °C (19.4 °F) in the case of a longer engine switch-off time.
- The ambient temperature is at least ten degrees above a minimum value of -0 °C (32 °F) in the case of a shorter engine switch-off time.
- 300 grams of volume is available in the active tank (300 grams of available capacity must be present in the active tank in order to not overfill the active tank).
- Active tank and passive tank contain a liquid urea/water mixture (AdBlue®) (tank temperature below -5 °C (23 °F) ).

Then enough time is spent re-pumping until the active tank is full again. If the level "full" is reached before this the transfer pumping is stopped.

# SCR 2 (US)

## 3. Functions

If there is a fault in the fluid level sensor then there is no pumping.

### 3.4.3. Delivery

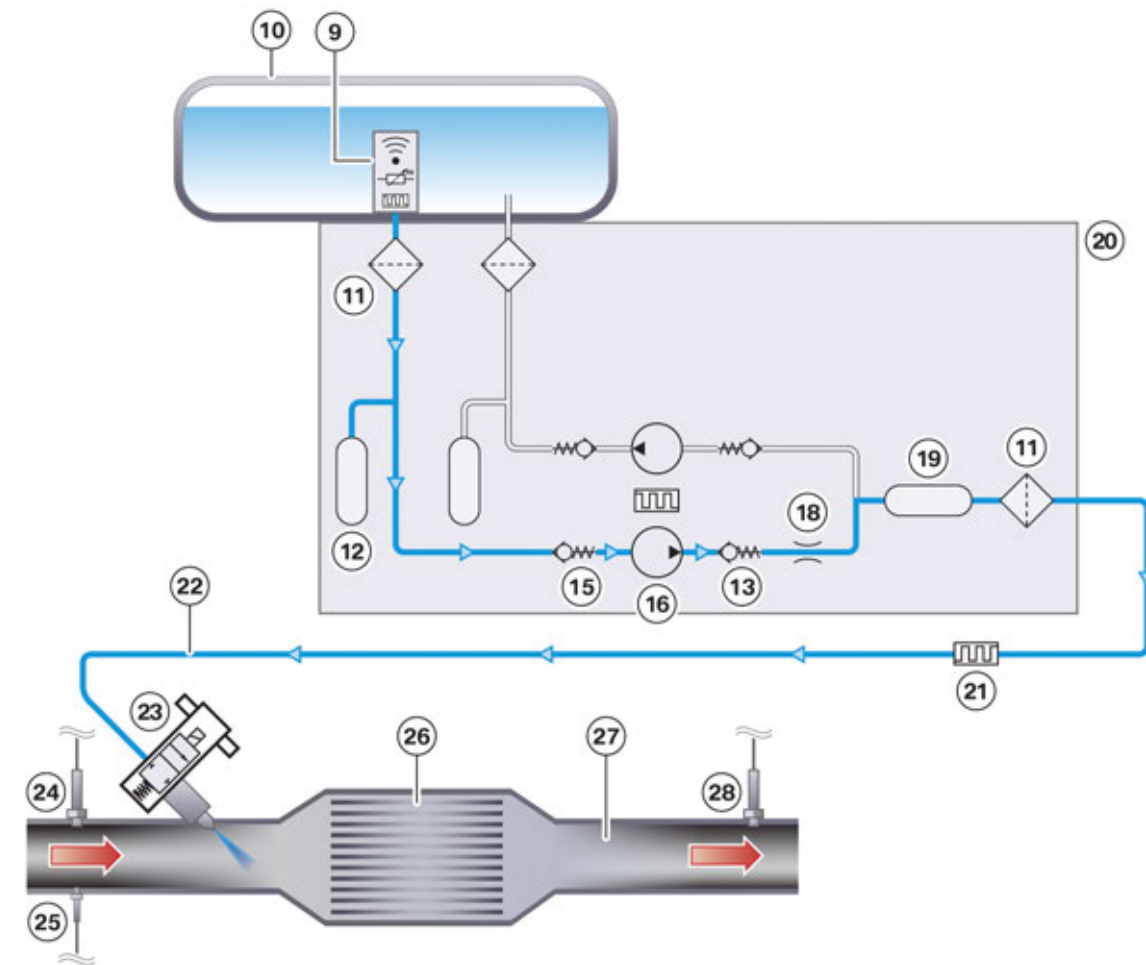
The supply pump is located in the SCR delivery module and is used to deliver the urea/water mixture (AdBlue<sup>®</sup>) from the active tank to the metering module.

The SCR delivery module incorporates the following components:

- Filter
- Intake valve
- Supply pump
- Fluid pressure control valve
- Restrictor
- Pulsation damper
- Filter
- Metering line
- Heating, metering line, if required
- Metering valve

# SCR 2 (US)

## 3. Functions



Delivery

TD12-0963

Index	Explanation
9	Heating temperature sensor, level sensor
10	Active tank
11	Filter
12	Ice pressure damper
13	Fluid pressure control valve
15	Intake valve
16	Supply pump
18	Restrictor
19	Pulsation damper
20	SCR delivery module
21	Heating metering line
22	Metering line

# SCR 2 (US)

## 3. Functions

Index	Explanation
23	Metering module
24	NO <sub>x</sub> sensor before the SCR catalytic converter
25	Exhaust-gas temperature sensor after diesel particulate filter
26	SCR catalytic converter
27	Exhaust system
28	NO <sub>x</sub> sensor after SCR catalytic converter

When heating with the pump coil, the supply pump is activated via a pulse-width modulated signal (PWM) by the SCR dosing control unit (DCU). This is done to limit the current for the DCU and the heat for the coil. The PWM is adjusted according to the actual voltage at the DCU.

PWM is not used for normal pump operation. The activation of the pump is for a defined time in order to make a full stroke. This defined time depends on the actual voltage and the pressure in the system.

The new system does not use a pressure sensor. The pressure is modeled by the characteristic profile of the measured current of the supply pump. The current profile has 2 characteristic points: These are the **“Beginning of Movement of Pump”** (BMP) and the **“End of Movement of the Pump”** (MSP -mechanical stop of pump). These points are derived from the changing inductivity of the coil (when the plunger starts moving and stops at the end). New pressure values are only available if the pump is activated therefore there are no new pressure values without pumping.

The PWM operating method is therefore only used for heating. When pumping the pump is always fully actuated to make a full stroke or fill the line. The supply line is filled until the metering module, then the pressure build-up mode takes place. Only then does the pressure regulation take place.

When filling the metering line a small amount of the urea/water mixture (AdBlue<sup>®</sup>) is injected into the exhaust system as the metering valve is open.

The SCR 2 operates with volumetric delivery/dosing. The dosed amount is determined by the high accuracy of the supply pump. The injector must always dose the amount that is pumped into the line. Under normal conditions the system should run at about 6.5 bar but because the system is installed in various vehicles this pressure may vary between 5 and 8 bar depending on the model.

For example: In case of a weak pump with a big injector the pressure will be about 5 bar. And with a strong pump and a small injector it will be about 8 bar. These are all acceptable pressures for these system. A fault will be set only if the pressure drops below 4,5 bar or exceeds the 9 bar limit.

The quantity delivered is determined by the opening period and opening stroke of the metering valve. However, this is so short that there is virtually no pressure drop in the metering line.

### 3.4.4. Evacuating

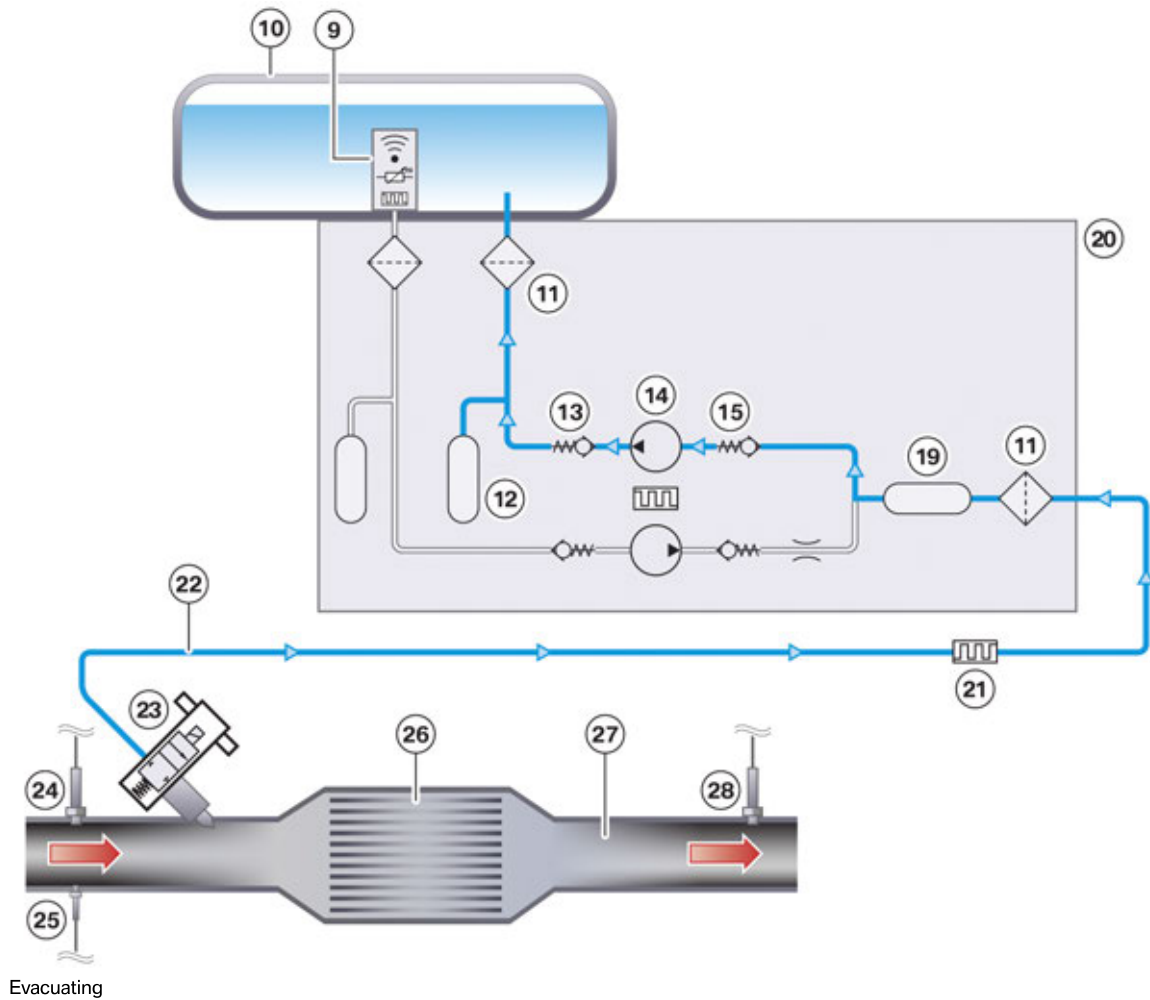
After the engine is stopped, the return pump of the SCR delivery module is activated and the metering line and the metering module are evacuated (drawn off).

## SCR 2 (US)

### 3. Functions

The SCR delivery module incorporates the following components:

- Metering valve
- Heating, metering line, if required
- Metering line
- Filter
- Pulsation damper
- Intake valve
- Back-flow pump
- fluid pressure control valve
- Filter



# SCR 2 (US)

## 3. Functions

Index	Explanation
9	Heating temperature sensor, level sensor, active tank
10	Active tank
11	Filter
12	Ice pressure damper
13	Fluid pressure control valve
14	Back-flow pump
15	Intake valve
19	Pulsation damper
20	SCR delivery module
21	Heating metering line
22	Metering line
23	Metering module
24	NO <sub>x</sub> sensor before the SCR catalytic converter
25	Exhaust-gas temperature sensor after diesel particulate filter
26	SCR catalytic converter
27	Exhaust system
28	NO <sub>x</sub> sensor after SCR catalytic converter

Even if the system has to be switched off due to a fault or, for example, if the minimum temperature in the active tank can no longer be maintained, it is drawn off.

**Due to acoustic reasons the draining of the system is reduced to a minimum. Only the metering valve (injector) is drained. The line and the delivery module are ice resistant and are maintained filled.**

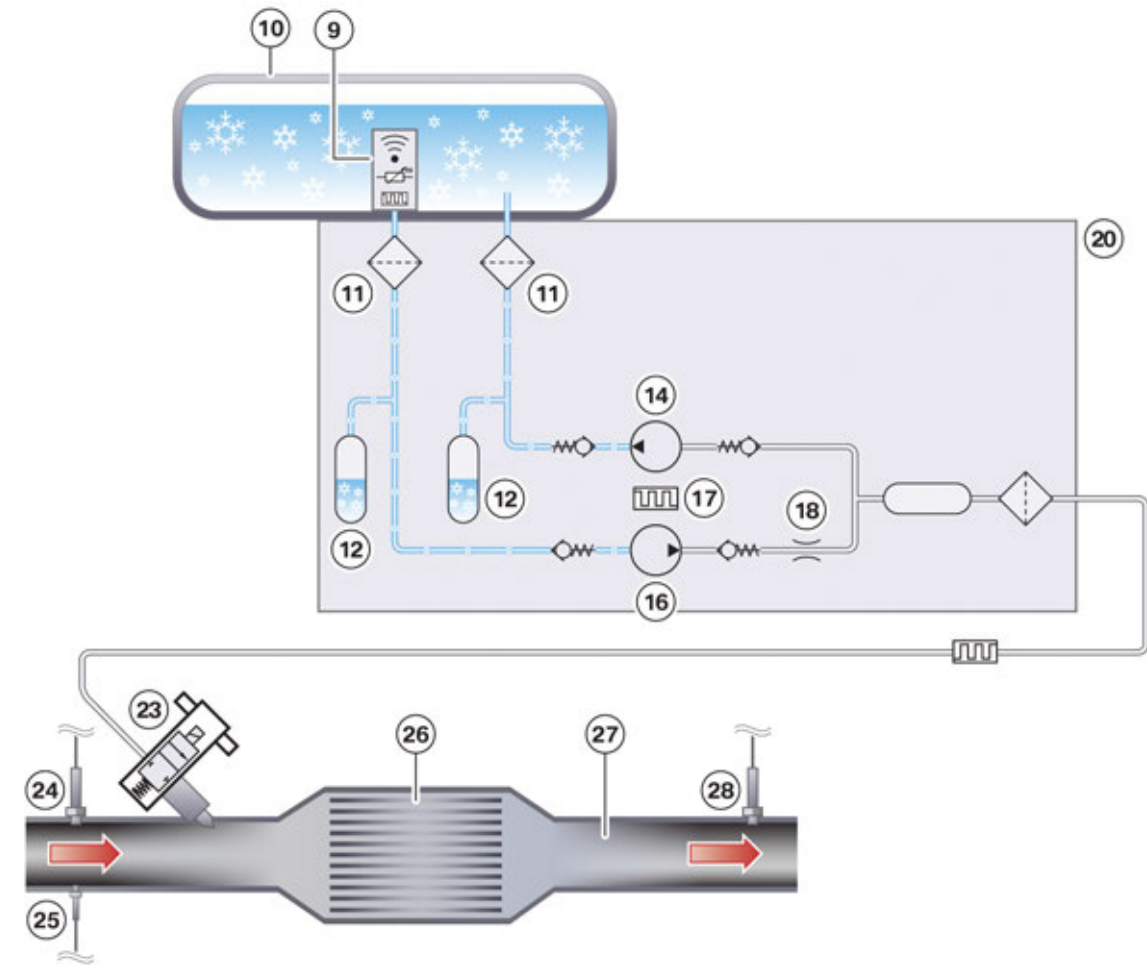
When evacuating the metering valve (injector) is open.

### 3.4.5. Freezing conditions

If the ambient conditions cause the urea/water mixture (AdBlue<sup>®</sup>) to freeze, the SCR delivery module is protected by the ice pressure damper.

## SCR 2 (US)

### 3. Functions



Frozen

TD12-0989

Index	Explanation
9	Heating temperature sensor, level sensor, active tank
10	Active tank
11	Filter
12	Ice pressure damper
14	Back-flow pump
16	Fluid pre-supply pump
17	Heating, pump
18	Restrictor
20	SCR delivery module
23	Metering module
24	NO <sub>x</sub> sensor before the SCR catalytic converter

# SCR 2 (US)

## 3. Functions

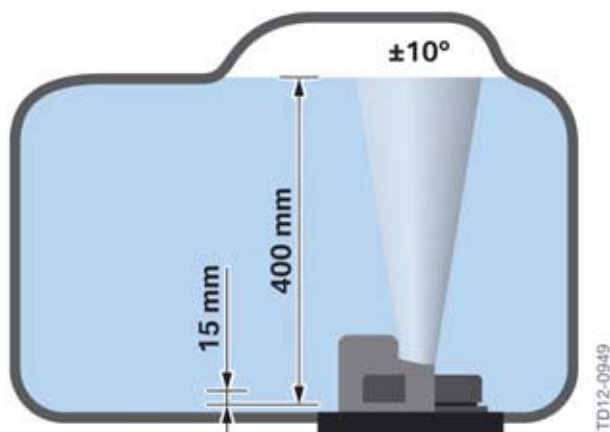
Index	Explanation
25	Exhaust-gas temperature sensor after diesel particulate filter
26	SCR catalytic converter
27	Exhaust system
28	NO <sub>x</sub> sensor after SCR catalytic converter

If the urea/water mixture (AdBlue<sup>®</sup>) freezes (below –11 °C (12.2 °F), the SCR delivery module and its components are protected by the ice pressure damper.

The ice pressure dampers allow an increased volume in the internal lines of the SCR delivery module thanks to their diaphragm, which is designed for the residual amount containing urea/water mixture (AdBlue<sup>®</sup>) in the SCR delivery module. The resulting increase in volume in the ice pressure dampers protects the internal components of the SCR delivery module by the ice formation.

### 3.4.6. Level measurement and temperature measurement

There are level sensors and temperature sensors in the active tank and passive tank (if installed). The ultrasonic level sensors can capture level readings in the range from 15 mm to 400 mm. The temperature sensors are embedded in the tank flange of the active tank and passive tank and work according to the negative temperature coefficient (NTC) principle. The signals of the level sensors and temperature sensors do not go directly to the SCR dosing control unit (DCU), but to an evaluation unit in the respective tank flange, as the SCR dosing control unit (DCU) cannot process the results of the ultrasonic sensors and temperature sensors directly. In the evaluation unit the ultrasonic values and measured values of the temperature sensors are converted to a pulse-width modulated signal (PWM signal), which can be processed by the SCR dosing control unit (DCU).



Level measurement range of ultrasonic sensor

Four pulse-width modulated signals are sent to the SCR dosing control unit (DCU): 2 level signals with a timeshift of 480ms, one for the temperature and one for the sensor status.

These pulse-width modulated signals (PWM) of level, temperature and status are transmitted in 120 ms units to the SCR dosing control unit (DCU).

The signal is implausible between 0 – 20 ms and 100 – 120 ms.

Only one of the T1 –T5 signals is not used.



# SCR 2 (US)

## 3. Functions

The PWM signal is broken down as follows:

### **T1: Temperature**

For the temperature measurement a PWM signal (pulse-width modulated signal) of 0 % clock ratio = 20 ms of a temperature corresponds to urea/water mixture (AdBlue<sup>®</sup>) of -40° Celsius (-40 °F).

For the temperature measurement a PWM signal (pulse-width modulated signal) of 50 % clock ratio = 60 ms of a temperature corresponds to urea/water mixture (AdBlue<sup>®</sup>) of 20° Celsius (68 °F).

For the temperature measurement a PWM signal of 100 % clock ratio = 100 ms of a temperature corresponds to urea/water mixture (AdBlue<sup>®</sup>) of 80° Celsius (176 °F).

### **T2: 1st level measurement**

For the first level measurement a PWM signal of 0 % clock ratio = 20 ms corresponds to a level of urea/water mixture (AdBlue<sup>®</sup>) of 0 %

For the first level measurement a PWM signal of 100 % clock ratio = 100 ms corresponds to a level of urea/water mixture (AdBlue<sup>®</sup>) of 100 %

The level range of 15 mm to 400 mm is transmitted in a total of 771 stages with a solution of 0.5 mm.

### **T3: currently not used**

### **T4: 2nd level measurement**

Similar to T2, for the second level measurement a level is only recorded every 480 ms. The transmission is effected via the PWM signal (pulse-width modulated signal) in the 960 ms grid. Therefore, two levels are transmitted per PWM signal.

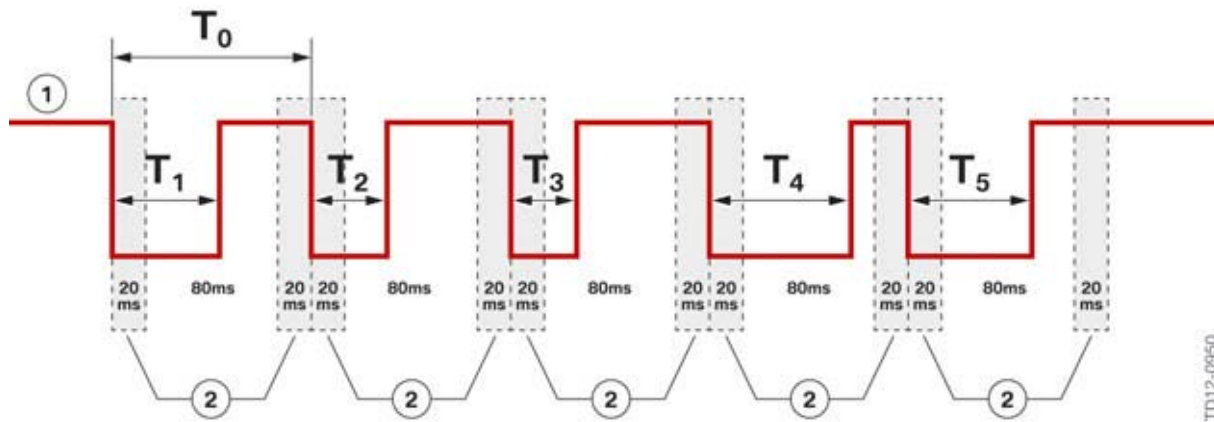
### **T5: Sensor status**

Is used for monitoring the five set-point values (T1 – T5) and checks whether all five power output stages have led to a measurement which can be evaluated.

The sensor status is used to transmit the quality of the echoes. The level evaluation is only done if the status gives a good quality of the level signal. Out of Status 3, 4 or 5 the status 5 means that 5 equal measurements of the level were done.

# SCR 2 (US)

## 3. Functions



Example of PWM measured value blocks

Index	Explanation
$T_0$	Pulse width
1	Idling
2	Implausible range
$T_1 - T_5$	Pulse-width modulated signal — clock ratio

### 3.5. SCR system conditions

If the ignition is switched on then the SCR control in the SCR control unit (DCU) runs through a logical sequence of conditions. However, there are preconditions that set off the change from one condition to the other. The following graphic shows the procedure of the modes/conditions that are then described in the following.

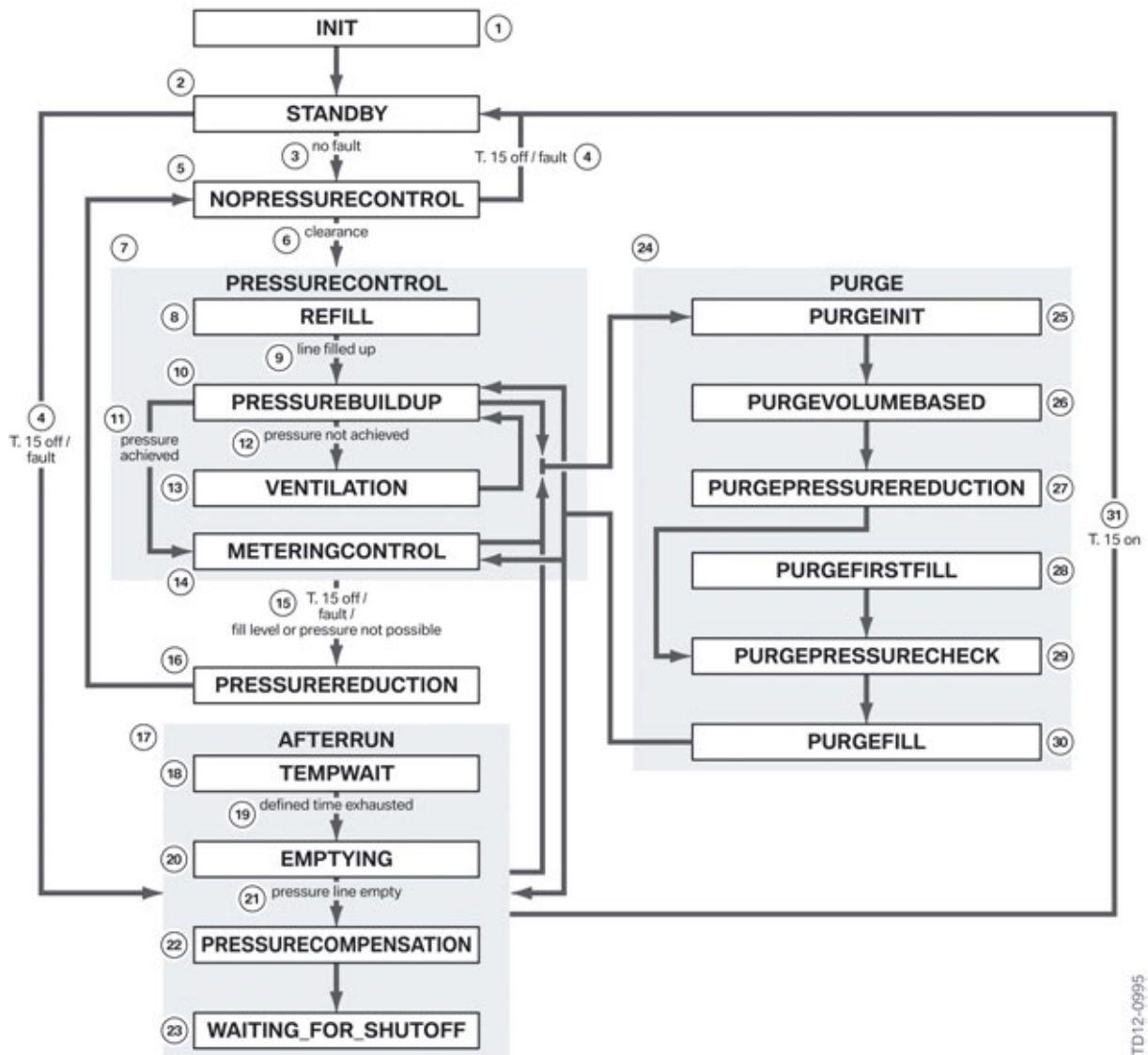
In comparison to the first generation SCR, there is an additional mode/condition for the SCR 2:

- PURGE

For the sake of clarification, all modes are described again in this training manual.

# SCR 2 (US)

## 3. Functions



Conditions of the SCR system

Index	Explanation
1	Initialization
2	Standstill
3	No fault
4	Terminal 15 Off/Fault
5	No pressure regulation/Wait on approval
6	Approval
7	Pressure regulation/SCR system running
8	Filling
9	Line filled

# SCR 2 (US)

## 3. Functions

Index	Explanation
10	Pressure build-up
11	Pressure reached
12	Pressure not reached
13	Ventilation
14	Metering control/Metering
15	Terminal 15 Off/Fault/Filling or pressure build-up not possible
16	Pressure reduction
17	After-run
18	Wait on temperature
19	Time frame lapsed
20	Drain
21	Pressure line drained
22	Pressure compensation
23	Switch off
24	Purge
25	Initialize purging
26	Purging, volume-based
27	Purging, pressure reduction
28	Purging, initial filling
29	Purging, pressure test
30	Purging, filling
31	Terminal 15 ON

### 3.5.1. “INIT’ (SCR initialization)

The control unit is switched on (terminal 15 ON) and the SCR system is initialized.

### 3.5.2. “STANDBY” (SCR standstill)

The STANDBY condition is assumed either after initialization or if there are faults.

If terminal 15 is switched off in this condition or if a fault occurs, it is switched to the AFTERRUN condition.

### 3.5.3. “NOPRESSURECONTROL” (wait for approval for pressure regulation)

The NOPRESSURECONTROL condition is reached if there are no faults in the system. In this condition there is a wait for the approval of the pressure regulation which takes place via the following sensor signals:

# SCR 2 (US)

## 3. Functions

- Temperature in the catalytic converter
- Temperature in active tank
- Ambient temperature
- Engine status (engine running).

In addition, the system pauses for a minimum time in the NOPRESSURECONTROL condition so that a plausibility check of the pressure model can be carried out.

If the approval is then given it is switched to the PRESSURECONTROL condition.

If terminal 15 is switched off in the condition NOPPRESSURECONTROL or a fault occurs, or the system should be reset (e.g. to improve metering accuracy or the pressure regulation), a switch is made to STANDBY condition.

### 3.5.4. “PRESSURECONTROL” (SCR system running)

The PRESSURECONTROL condition is the normal operating condition of the SCR system and has three sub-conditions.

The PRESSURECONTROL condition remains as long as terminal 15 is switched off. Subsequently it is switched to the PRESSUREREDUCTION condition.

If a fault occurs in the system it is also switched to the PRESSUREREDUCTION condition.

In the following the sub-conditions of the PRESSURECONTROL condition are described:

- **“PRESSUREBUILDUP” (pressure build-up)**  
In this condition the pressure is built-up to a certain value. Also, the supply pump is activated while the metering valve is closed.  
If the required pressure is built up within a certain time it is switched to the next condition: METERINGCONTROL. If the required pressure build-up is not reached after a certain amount of time or the condition unit goes into a slip, then it is switched to the VENTILATION condition. If the pressure cannot be built up after a certain defined number of attempts then the system indicates a fault and switches to the PRESSUREREDUCTION condition.  
It also switches to the PRESSUREREDUCTION condition if terminal 15 is switched off or if a different fault occurs in the system.
- **“VENTILATION” (ventilation)**  
VENTILATION is used for the ventilation of the pressure line and is performed for each PRESSUREBUILDUP.  
From a certain pressure threshold in the PRESSUREBUILDUP condition, the metering valve is first activated for a certain time at a defined opening width. The pressure is compared before and after the valve opening. If the pressure drop is over a certain threshold value, the value is activated again (this process can be repeated up to three or four times).  
If the pressure drop is less than the threshold value, or the metering value was activated four times, the VENTILATION condition is terminated and the system switches back to the PRESSUREBUILDUP condition.  
The system can build up normal pressure without or with insufficient VENTILATION and switch to the METERINGCONTROL condition. It may then transpire that upon the start of metering the system pressure collapses by the escape of air. In this case the system changes to the PURGE condition and then to PRESSUREBUILDUP.

# SCR 2 (US)

## 3. Functions

If terminal 15 is switched off during this time or if a fault occurs in the system a change in the PRESSUREREDUCTION condition takes place.

- **“METERINGCONTROL” (metering)**  
In the METERINGCONTROL condition the system has metering release. It is the actual condition in normal operation. Here the urea/water mixture (AdBlue<sup>®</sup>) is injected.  
If terminal 15 is switched off or if a fault occurs in the system, the condition also switches to PRESSUREREDUCTION.

### 3.5.5. “PRESSUREREDUCTION” (pressure reduction in the SCR system)

Upon entering PRESSUREREDUCTION the metering release is withdrawn.

This condition ensures a pressure reduction in the SCR delivery module, the metering line and the metering module after the PRESSURECONTROL condition. In addition, the return pump is activated while the metering valve is closed.

The end of the PRESSUREREDUCTION condition is reached by dropping below a certain pressure.

### 3.5.6. “PURGE”

In the PURGE state/mode the system is purged. This state has six sub-conditions.

The system switches to PURGE state, if no pressure build-up is possible or there is a vacuum in the system. This condition may occur if, for example, air or a foreign body are in the system or valves are sticking.

The purge state is used to remove air that might be in the supply pump. Both pumps are activated and the air can be purged into the tank again. Purge is activated if the pressure build up has failed or if the MSP/BMP cannot be found.

After defrosting we purge the system to stabilize the conditions inside the delivery module. Purge can be activated with the ICID tester to remove the air out of the system for a new tank.

If the PURGE state is exited, there is a switch to the initial condition before purging. This affects both the possible faults and the successful completion of the purging function. A reaction to the faults then takes place, if necessary, in the initial condition.

- **“PURGE INIT” (initialization of purging function)**  
Based on the status of the initialization the transition to the required purging mode).
- **“PURGE VOLUMEBASED” (volume-based purging)**  
In the condition PURGE VOLUMEBASED a defined volume of the urea/water mixture (AdBlue<sup>®</sup>) is pumped by the SCR delivery module.
- **“PURGE PRESSUREREDUCTION” (pressure reduction during purging)**  
In the condition PURGE PRESSUREREDUCTION the pressure is reduced.
- **“PURGE FIRSTFILL” (initial filling during purging)**  
In the condition PURGE FIRSTFILL the initial filling takes place. This condition can also be activated via the service functions in the diagnosis system (ISTA) and must be performed if components in the SCR system are replaced during servicing or upon the initial operation.
- **“PURGE PRESSURECHECK” (pressure build-up check during purging)**

# SCR 2 (US)

## 3. Functions

In the condition PURGE PRESSURECHECK a pressure build-up attempt is performed to check the initial filling. If this is unsuccessful, the condition PURGE FILL is exited for further filling (watch out for external leaks). This condition can also be activated via the service functions in the diagnosis system (ISTA) and must be performed if components in the SCR system are replaced during servicing or upon the initial operation.

- **“PURGE FILL” (filling during purging)**  
In the condition PURGE FILL the system is refilled. If the condition is exited successfully, a change to PURGE PRESSURECHECK takes place for further checking.

### 3.5.7. “AFTERRUN” (after-run)

In the AFTERRUN condition the system is shut down.

If terminal 15 is switched on again before the after-run has come to an end the after-run is considered interrupted and the condition switches to STANDBY. If this is not the case, the sub-conditions of the AFTERRUN condition are run through.

- **“EMPTYING” (draining of the pressure line)**  
After the cooling-down period it is switched to the sub-condition AFTERRUN EMPTYING. In this sub-condition the pressure line and the SCR delivery module are emptied. The urea/water mixture (AdBlue<sup>®</sup>) is suctioned by the return pump and the opening of the metering valve back to the active tank. This should prevent the freezing of the urea/water mixture (AdBlue<sup>®</sup>) in the metering line or in the metering module.  
If the pressure line is empty, a change to the condition AFTERRUN PRESSURECOMPENSATION takes place.  
It is also switched to the AFTERRUN PRESSURECOMPENSATION condition if there is a fault in the system. If terminal 15 is switched on it is switched to the STANDBY condition.
- **“WAITING FOR SHUTOFF” (switching off SCR)**  
The control unit is shut down and switched off.

### 3.5.8. Automatic engine start-stop function

Under certain operating conditions an engine shutdown of the MSA may be influenced by the SCR control.

- **Remaining capacity undershot**  
If the remaining capacity falls below 0 km/mls and there is no more urea/water mixture (AdBlue<sup>®</sup>) available, an automatic engine shutdown is prevented by the MSA. In the event that the urea/water mixture (AdBlue<sup>®</sup>) is not available and switch off scenario has initiated, an engine start is prevented (no engine operation is allowed without urea/water mixture (AdBlue<sup>®</sup>)).

## 3.6. Warning and switch off scenario

The SCR system is required to meet the mandated exhaust-emission regulations. If the system fails, the approval is void and the vehicle can no longer be operated. A very plausible case which leads to a system failure is that the supply of the urea/water mixture (AdBlue<sup>®</sup>) runs out.

# SCR 2 (US)

## 3. Functions

Without urea/water mixture (AdBlue<sup>®</sup>) further operation of the vehicle is not allowed, therefore the engine can no longer be started.

**The control of the switch off scenario is done by the Digital Diesel Electronics (DDE).**

So that it does not come as a surprise to the driver, there is a warning and switch off scenario that begins long enough before the disabling of the vehicle so that the customers can comfortably either refill the urea/water mixture (AdBlue<sup>®</sup>) themselves or have someone else refill it for them. According to legal regulations **(in the US)** the first warning must have a range of 1000 mls based on a linear counter (as E70 and E90).

### 3.6.1. Warning scenario

#### Warning level 1

At the start of the inducement (engine shut off scenario) a residual amount of DEF **(about 3 liters in (F30) active tank, 3,2 liters for F10 and 3,5 liters in F15)** should in any case be enough for a range of **1000mls**. The “linear counter” is started from this point irrespective of the actual DEF consumption. The driver receives a priority 1 Check Control message (white), **with** a check control message showing the remaining range.

A range of **999 mls** is actually displayed to provide a safety reserve margin.

Check Control display: **“Refill Exhaust Fluid Reserve/AdBlue, range: 999 mls”**



Check Control message in the instrument cluster at warning level 1

At the same time, an instruction is also output via the central information display (CID):

**"Exhaust Fluid /AdBlue Reserve. Exhaust Fluid /AdBlue must be refilled. Have vehicle checked by your BMW Service Department."**

From this point onwards, the available range is counted downwards linearly, irrespective of actual urea/water mixture (AdBlue<sup>®</sup>) consumption.

#### Warning level 2

If the fluid level sensor has dropped below “empty” then the driver receives a priority 2 Check Control message (yellow). "Refill DEF" and the remaining range is displayed in mls. Although there is still a DEF reserve in the active tank (which would normally allow a range greater than 200 mls) a range of **199 mls** is actually displayed to provide a safety reserve margin.

Check Control display: **“Refill Exhaust Fluid Reserve/AdBlue, range: 199 mls”**



# SCR 2 (US)

## 3. Functions



Check Control message in the instrument cluster at warning level 2

At the same time, an instruction is also output via the central information display (CID):

**“Refill Exhaust Fluid /AdBlue”**

**“Note range. Exhaust Fluid /AdBlue must be refilled, otherwise an engine start is no longer possible. Drive to the nearest BMW Service.”**

### Warning level 3

If the range falls to 0 km/ml three lines are displayed instead of the range – next to the fluid range.



Check Control message in the instrument cluster range = 0 km

Check Control display: **“Refill Exhaust Fluid /AdBlue, range: — — —”**

At the same time, an instruction is also output via the central information display (CID):

**“Refill Exhaust Fluid /AdBlue”**

**“Engine start without Exhaust Fluid /AdBlue no longer possible. Exhaust Fluid /AdBlue must be refilled. Drive to the nearest BMW Service Department.”**

### 3.6.2. Switch off scenario

When the range of 0 km/ml has been met the next engine start is prevented, **but only if the engine was switched off for more than three minutes**. This ensures being able to escape any dangerous situations.

There is normally a remaining 0.8 l in the system which is used as a safety reserve for the following scenario:

- The vehicle is filled up with fluid and is started with a very low urea/water mixture (AdBlue®) range (e.g. 1 km). The urea/water mixture (AdBlue®) range reaches 0 km/ml but the vehicle can still be driven until the next engine shutdown. Here it is ensured that the vehicle is still operated with a functioning SCR system, even in this case.

### 3.6.3. Incorrect refilling

There are 2 ways of monitoring wrong medium. A big amount was refilled and the NOx efficiency drops suddenly (increasing nitrogen oxide values in the exhaust gas despite the sufficient injection of the supposed urea/water mixture). Or if only small amounts are refilled several times (e.g. passive tank

# SCR 2 (US)

## 3. Functions

filled with water) the adaptation will increase the dosing quantity. In this case the car keeps emission compliant and the wrong medium detection will react a certain adaptation factor. From this point this is displayed by a Check Control display (display of range or a reduction of range is not displayed).



Check Control message in the instrument cluster in the event the wrong medium is detected

Check Control display: **“Exhaust Fluid/AdBlue wrong medium”**

At the same time, an instruction is also output via the central information display (CID):

**“Exhaust Fluid/AdBlue wrong fluid”**

**“Have vehicle checked by your BMW Service authorized workshop.”**

### 3.6.4. System fault

Faults, which prevent the metering of the urea/water mixture (AdBlue®) don't always lead to the implementation of the inducement (engine shut down) process.

Pressure regulation error or disconnected components will only set a malfunction indicator light (MIL). This is why we have special (tamper proof) screws for the cover of the dosing valve (injector).

In the event of a communication failure between the Digital Diesel Electronics (DDE) and the SCR control unit (DCU) this will be indicated by a Check Control Message and the display of the **199 mls** range along with the **“Exhaust Fluid/AdBlue System Fault”** warning.

The engine shut down scenario will only initiate in the following cases:

- If the tank is empty, the system will display the **999 mls** CCM
- If the wrong medium is detected, the system will display the **199 mls** CCM
- If no communication is detected between the DCU and DDE, the system will display the 199 mls CCM

**A disconnected DCU or a removed/blown fuse for the DCU will lead to the inducement (engine shut off) process. VERIFY**



Check Control message in the instrument cluster in the event of system fault

Check Control display: **“Exhaust Fluid/AdBlue System Fault”**

At the same time, an instruction is also output via the central information display (CID):






**“Exhaust Fluid/AdBlue System Fault.”**

**"Have system checked by your BMW Service Department."**

# SCR 2 (US)

## 3. Functions

The following chart explains the possible system warnings and fault scenarios for the US market.

Stages	Cause	Symbol	Check Control Message	Description
Stage 1	Reserve < 1000mls		Exhaust Fluid/ AdBlue Reserve	Exhaust Fluid/AdBlue Reserve. Pay attention to left over range. Driving on is still possible. Add Exhaust Fluid/AdBlue soon. See owners manual.
Stage 2	Exhaust Fluid/ AdBlue Total Range < 200 mls		Add Exhaust Fluid/AdBlue	Exhaust Fluid/AdBlue at Minimum. Pay attention to range left. Fill Exhaust Fluid/AdBlue immediately or engine will not start.
Stage 3	Exhaust Fluid/ AdBlue Range < 0 mls		Refill Exhaust Fluid/AdBlue	Refill Exhaust Fluid/AdBlue. Engine restart may not be possible. Refill Exhaust Fluid/AdBlue asap. See owners manual.
Stage 4	Exhaust Fluid/ AdBlue Wrong Medium		Exhaust Fluid/ AdBlue Wrong Medium Filled	Exhaust Fluid/AdBlue Wrong Medium. Exhaust Fluid/AdBlue wrong fluid filled. Pay attention to range left. At 0 miles range engine restart may be impossible. Get system checked by BMW Service Department.
Stage 5	Exhaust Fluid/ AdBlue System Fault		Exhaust Fluid/ AdBlue System No Start in 0 Miles	Exhaust Fluid/AdBlue System. Exhaust fluid system fault Engine start impossible. Get system checked by BMW Service Department.

### 3.7. On-board diagnosis functions

The Digital Diesel Electronics (DDE) additionally has the task of monitoring all exhaust-relevant systems for their problem-free function. This task is described as an On-Board Diagnosis (OBD). If a fault is registered by the On-Board Diagnosis then the emissions warning light is activated.

In the following the most important SCR specific results are explained that lead to the lighting up of the emissions warning light.

#### 3.7.1. SCR catalytic converter

The effectiveness of the SCR catalytic converter is monitored by the two nitrogen oxide sensors.

# SCR 2 (US)

## 3. Functions

The nitrogen oxide mass is measured before and after the SCR catalytic converter and a sum is formed over a certain period. The actual reduction is compared to a calculated value which is stored in the Digital Diesel Electronics (DDE).

For this the following preconditions must be met:

- NO<sub>x</sub> sensors plausible.
- Metering active
- Ambient temperature in the defined area.
- Ambient pressure in the defined area.
- Diesel particulate filter regeneration not active.
- SCR catalytic converter temperature in the defined area (is calculated using exhaust-gas temperature sensor before the SCR catalytic converter amongst others).
- Exhaust flow in the defined area.

Monitoring includes four measuring cycles. If the actual value is lower than the one calculated a reversible fault is created. If the fault is determined in two consecutive driving cycles then an irreversible fault is stored and the emissions warning light is activated.

In order to guarantee the SCR catalytic converter over a long period there is a long-term adaptation in which the metered amount is adjusted to the urea/water mixture (AdBlue<sup>®</sup>). In order to undertake the adaptation the signal of the NO<sub>x</sub> sensor after the SCR catalytic converter is compared with a calculated value. If deviations occur here then the metering amount is adjusted in the short-term. The systematics of the adaptations is evaluated and a correction factor is applied to the metering amount.

The operating range for the long-term adaptation is the same as for the effectiveness monitoring.

If the correction factor exceeds a certain threshold a reversible fault is created. If the fault is determined in three consecutive driving cycles then an irreversible fault is stored and the emissions warning light is activated.

### 3.7.2. Supply of urea/water mixture (AdBlue<sup>®</sup>)

The supply of urea/water mixture (AdBlue<sup>®</sup>) is necessary for a problem-free operation of the SCR catalytic converter.

After the SCR catalytic converter reaches a certain temperature (calculated by the exhaust-gas temperature sensor in front of the SCR catalytic converter, amongst other things) the metering control tries a pressure build-up in the metering line. For this the metering module must be closed and the supply pump must be activated with a certain number of pump strokes for a certain amount of time.

If the pressure threshold cannot be reached within a certain amount of time then the metering module injector is opened in order to bleed the metering line. Subsequently a renewed pressure build-up is attempted.

If a set number of pressure build-up attempts take place unsuccessfully then a reversible fault is created. If the fault is determined in two consecutive driving cycles then an irreversible fault is stored and the emissions warning light is activated.

# SCR 2 (US)

## 3. Functions

**This monitoring only runs once per driving cycle before the metering begins. If this monitoring is "passed" then the continuous pressure monitoring begins.**

For the Selective Catalytic Reduction (SCR) a constant pressure of the urea/water mixture (AdBlue<sup>®</sup>) is necessary (6 bar). The actual pressure and the resulting pressure module are determined and monitored by the SCR dosing control unit (DCU) using an available parameter. The available parameter is the power consumption in a defined period of the supply pump in the SCR delivery module.

The following values are checked:

- High pressure
- Vacuum
- Implausible pressure readings

If these limits are exceeded for a certain amount of time a reversible fault is created. If the fault is determined in three consecutive driving cycles then an irreversible fault is stored and the emissions warning light is activated, the pressure in the SCR system is reduced fully and the SCR system shut down.

**This monitoring takes place in active metering.**

### 3.7.3. Level measurement of active tank

A level sensor with ultrasonic technology is used for the active tank. The plausibility of the sensor takes place in the evaluation unit in which it is checked if the signals are logical.

The Level/Temperature Sensor has new faults compared to the previous system. The "no echo error" fault is set if no valid echo can be detected on a certain distance of driving. This could happen if something blocks the sensor signal or the tank is overfilled and the echo from the tank wall doesn't hit the sensor.

Slosh plausibility: After breaking a certain amount of slosh (moving signal) is expected.

### 3.7.4. Suitable urea/water mixture (AdBlue<sup>®</sup>)

The SCR system is monitored for wrong medium in terms of refilling. This monitoring begins when refilling is identified. The refilling identification is described in the previous SCR system training material.

In order to recognize a wrong medium the monitoring of the effectiveness of the SCR catalytic converter is used. A wrong medium is identified if the effectiveness falls below a certain value within a set time after an identified refilling event. In this case a reversible fault is created. If the fault is determined in two consecutive driving cycles then an irreversible fault is stored and the emissions warning light is activated.

### 3.7.5. NO<sub>x</sub> sensors

For the operation and therefore also the monitoring of the NO<sub>x</sub> sensor a so-called dew point must be reached. This ensures that no more water is in the exhaust that could otherwise damage the NO<sub>x</sub> sensors.

# SCR 2 (US)

## 3. Functions

If a fault is identified by the following monitoring of the NO<sub>x</sub> sensor then; A reversible fault is created. If the fault is determined in three consecutive driving cycles then an irreversible fault is stored and the emissions warning light is activated.

The following faults are identified:

- Identification signal or correction factor is wrong
- Interrupted or short circuit between measuring probe and control unit of the NO<sub>x</sub> sensor
- Measured value outside of the defined area for a certain time
- Operating temperature is not reached after a defined heating period
- In coasting (overrun) mode (no nitrogen oxide expected) too great a distance from the measured value to zero is identified
- In the transfer from the load in coasting (overrun) mode the signal of the NO<sub>x</sub> sensor does not fall from 80% to 50% quickly enough (only NO<sub>x</sub> sensor before the SCR catalytic converter)
- If, despite a spike in the signal of the NO<sub>x</sub> sensor before the SCR catalytic converter there is not at least one defined change in the signal of the NO<sub>x</sub> sensor after the SCR catalytic converter, then this counts as implausible.

### 3.7.6. Display and driver information

The SCR dosing control unit (DCU) delivers the combined data from the level sensor in the active tank and passive tank, if installed, to the Digital Diesel Electronics (DDE), which makes the data accessible to other bus users via the PT-CAN and central gateway module (ZGM) or the Body Domain Controller (BDC).

# SCR 2 (US)

## 4. System Components

### 4.1. Components of the Selective Catalytic Reduction (SCR)

#### 4.1.1. Urea/water mixture (AdBlue®)

The diesel exhaust fluid (DEF) is a urea-water solution which acts as a the carrier for the ammonia that is used to reduce the nitrogen oxides (NOx) in the exhaust gas. In order to protect people and the environment against ammonia and in order to make it more manageable for transportation and tank processes it is available in a liquid urea form for use in the SCR system.

The recommended urea/water mixture is AdBlue®. The naming rights of AdBlue® are owned by VDA (German Association of the Automotive Industry). AdBlue® is a high-purity, water-clear, synthetically manufactured solution consisting of 32.5% urea with the balance (67.5%) being water. The urea-water solution used must correspond to this standard.

The recommended urea-water solution must meet certain standards for quality which are set forth in accordance with the DIN 70070/AUS32.



AdBlue® trademark

The urea/water mixture used (AdBlue®) must in any case be of this standard.

#### **Hazard and health**

The urea/water mixture (AdBlue®) is not poisonous. It is an aqueous solution which poses no special risks. It is not a hazardous substance and it is not a dangerous medium which is readily apparent after reviewing the Material Safety Data (MSDS) sheets.

The urea-water solution is not toxic. If small amounts of the product come in contact with the skin while handling the urea-water solution it is sufficient to simply rinse it off with ample water. In this way, the possibility of any ill effects on human health are ruled out.

The urea-water solution can be broken down by microbes and is therefore easily degradable. The urea-water solution poses a minimum risk to water and soil. Refer to local laws regarding handling and disposal requirements.

If, when handling the urea/water mixture (AdBlue®), traces of the product come into contact with the skin, it is sufficient to wash it off with lots of water. An impairment of human health in this way is practically impossible.

# SCR 2 (US)

## 4. System Components

### Decomposability and disposal

The urea/water mixture (AdBlue<sup>®</sup>) can be used by microbes and is therefore very easily decomposable. From the urea/water mixture (AdBlue<sup>®</sup>) there is a very small danger for water and soil. In Germany the urea/water mixture (AdBlue<sup>®</sup>) is in the lowest water danger class (WGK 1). Thanks to its outstanding decomposability, small amounts of spilled urea/water mixture (AdBlue<sup>®</sup>) can be washed into the sewage system with lots of water without any problems.

### Storage and durability

In order to prevent quality impairments due to impurities and a high inspection effort the urea/water mixture (AdBlue<sup>®</sup>) can only be stored in designated storage and container systems.

As the urea/water mixture (AdBlue<sup>®</sup>) becomes solid at -11 °C/12.2 °F (frozen) and decomposes more quickly at temperatures above 25 °C (77 °F) storage and container systems are to be setup in such a way that a temperature range of 30 °C to -11 °C (86 °F to 12.2 °F) can be guaranteed.

If the recommended storage temperature of maximum 25 °C (77 °F) is kept then the urea/water mixture (AdBlue<sup>®</sup>) fulfills the requirements of the DIN 70070 standard for at least 12 months after its manufacture. If its recommended storage temperature is exceeded then this period is reduced. If the urea/water mixture (AdBlue<sup>®</sup>) cools to under -11 °C (12.2 °F) it becomes solid. Upon heating the frozen urea/water mixture (AdBlue<sup>®</sup>) becomes liquid again and can be used again as normal without any loss of quality.

The urea/water mixture (AdBlue<sup>®</sup>) is normally odorless. If an unpleasant odor (strong smell of ammonia) occurs then this suggests old medium.

Direct ultraviolet radiation is to be avoided.

### Material tolerance

The contact of urea/water mixture (AdBlue<sup>®</sup>) with copper and zinc as well as their alloys and aluminium is to be urgently avoided as it leads to corrosion. Stainless steels and most plastics are no problem whatsoever.



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For further information in relation to handling, first aid, storage and disposal, please consult the safety data sheet of the manufacturer.

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# SCR 2 (US)

## 4. System Components

### 4.1.2. Passive tank

Vehicle	Volume	Installation location
F10 with N57D3001	No passive tank is installed on F10 for US market	NA
F15 with N57D3001	15.3 liters	Below the floor, under front seat area
F30 with N47D2001	9.4 liters	Right rear under the trunk, to the right of muffler
F31 with N47D2001	9.4 liters	Right rear under the trunk, to the right of muffler
F02 with N57D3001	No passive tank is installed on F02 for US market	NA

The name passive tank means that it is not heated.

The following components belong to the passive tank:

- Tank flange with level sensor and temperature sensor
- Filling port
- Service vent line, fluid filler neck breather

Depending on the series, it is possible that the passive tank is insulated. The insulation comprises foam material and prevents quick freezing at low temperatures. As its installation location may also be near the exhaust system depending on the vehicle, it would also lead to a high introduction of heat to the urea/water mixture (AdBlue®).

If there are very low temperatures over a long period of time there is a possibility that the urea/water mixture (AdBlue®) might completely freeze in the passive tank. No transfer pumping can then take place. In this case the active tank must be refilled more often.

The passive tank cannot be filled separately as it is filled via the active tank.

The F30 has only one filling position. The DEF will flow to the active tank until this is full. Then the liquid will rise in the filler pipe and the passive tank will be filled.

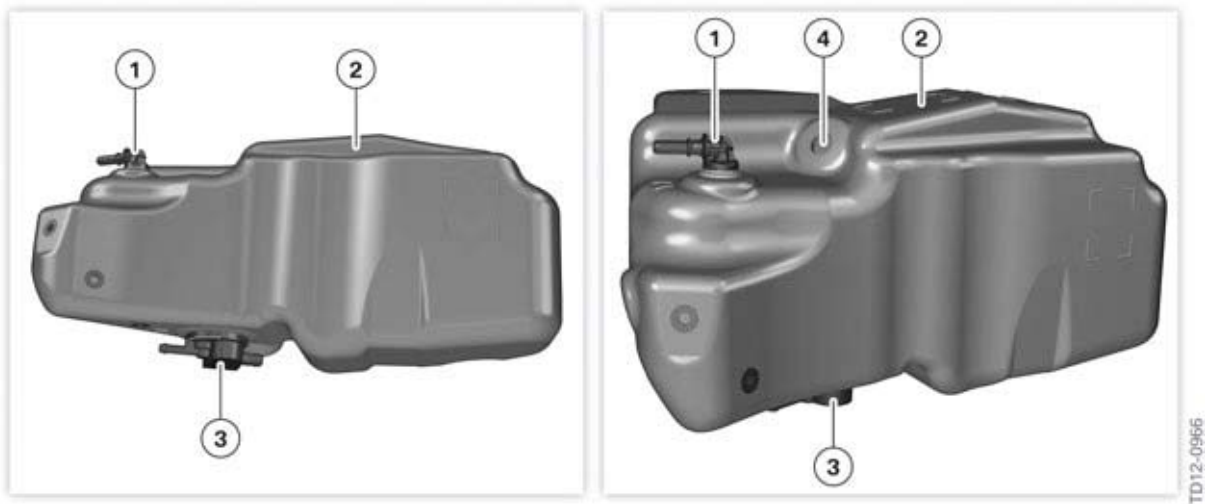
F15 has a separate filler pipe for the passive tank.



**Note: The F10 and the F02 do not use a passive tank in the US market.**

# SCR 2 (US)

## 4. System Components



Passive tank, two-tank system

Index	Explanation
1	Service vent line and fluid filler neck breather
2	Passive tank
3	Tank flange with level sensor and temperature sensor
4	Filling port

### Level sensor

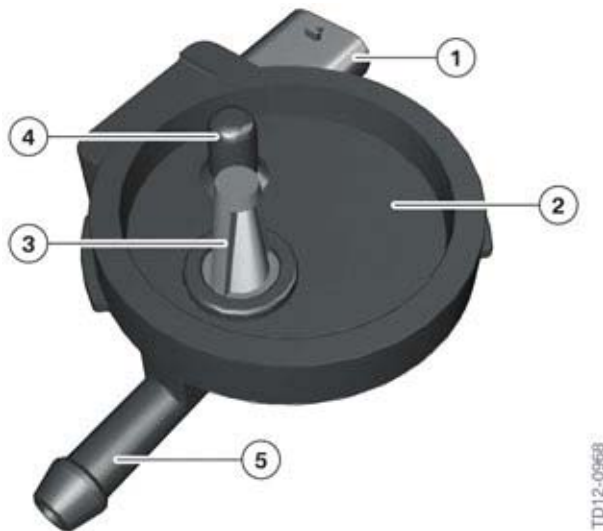
A level sensor is located in the tank flange of the passive tank.

The sensor works with ultrasound.

On extreme sloping positions or if the tank is frozen, the signal is at 15 mm. This corresponds to the signal of an empty tank. A level sensor is installed (as described) in the active tank and in the passive tank.

# SCR 2 (US)

## 4. System Components



Tank flange in the passive tank

Index	Explanation
1	Electrical connection
2	Position of the ultrasonic transducer (fluid level sensor)
3	Strainer
4	Integrated temperature sensor
5	Transfer line connection

The tank flange of the passive tank cannot be replaced separately in Service as it is welded to the passive tank.

### Temperature sensor

The temperature sensor is integrated in the tank flange and cannot be replaced separately. The temperature sensor integrated in the tank flange is installed in the active tank and the passive tank.

The fuel level sensor is connected via a 3-pin plug connection. A temperature sensor is integrated as part of the fill level sensor. A temperature-dependent electrical resistor is used for temperature sensing. The circuit contains a voltage divider where the resistance can be measured depending on the temperature. A temperature is converted using a characteristic curve specific to the sensor. The measuring range is from -40 °C to 80 °C (-40 °F to 176 °F).

### Ventilation

The passive tank has a service vent line and a fluid filler neck breather.

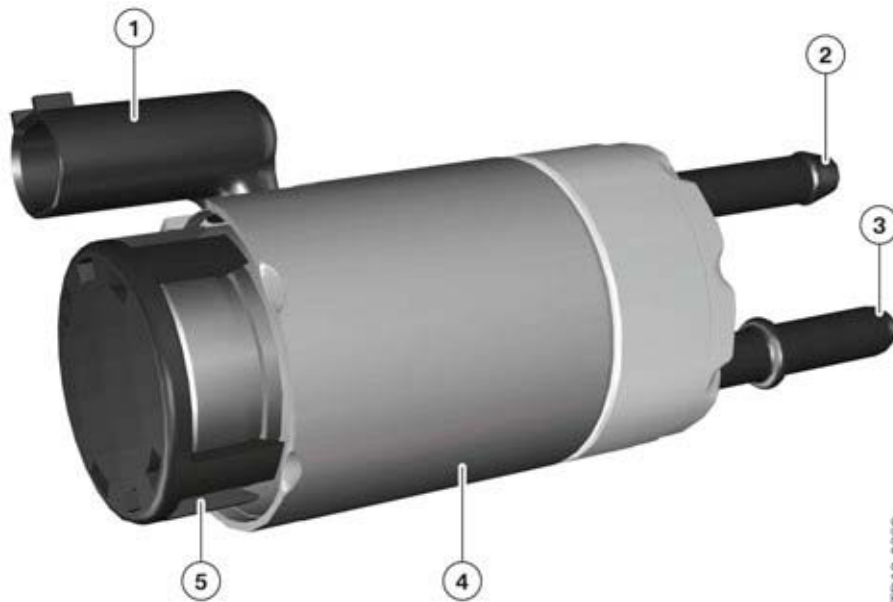
The service vent line and fluid filler neck breather lead to the filling pipe for the urea/water mixture (AdBlue®) at the fluid filler cap.

# SCR 2 (US)

## 4. System Components

### 4.1.3. Transfer pump unit

The transfer pump unit assumes the delivery of the urea/water mixture (AdBlue<sup>®</sup>) from the passive tank to the active tank. The transfer pump unit is only present if a two-tank system, i.e. passive tank and active tank, is installed.



Transfer pump unit

Index	Explanation
1	Electrical connection
2	Intake side from transfer line passive tank
3	Pressure side to transfer line fluid filler neck breather pipe active tank
4	Pump body
5	Pump motor

The transfer pump unit is a membrane pump. It functions similarly to a piston pump, only that the pump element is separated from the medium via a diaphragm. This means there are no problems concerning corrosion.

# SCR 2 (US)

## 4. System Components

### 4.1.4. Active tank

The active tank is so-called because it is heated.

The following components belong to the active tank:

- Level sensor
- Temperature sensor
- Service vent line, fluid filler neck breather
- Tank flange module with SCR delivery module and heating.

Depending on the series, it is possible that the active tank is insulated. The insulation comprises foam material and prevents quick freezing at low temperatures. As its installation location may also be near the exhaust system depending on the vehicle, it would also lead to a high introduction of heat to the urea/water mixture (AdBlue®).

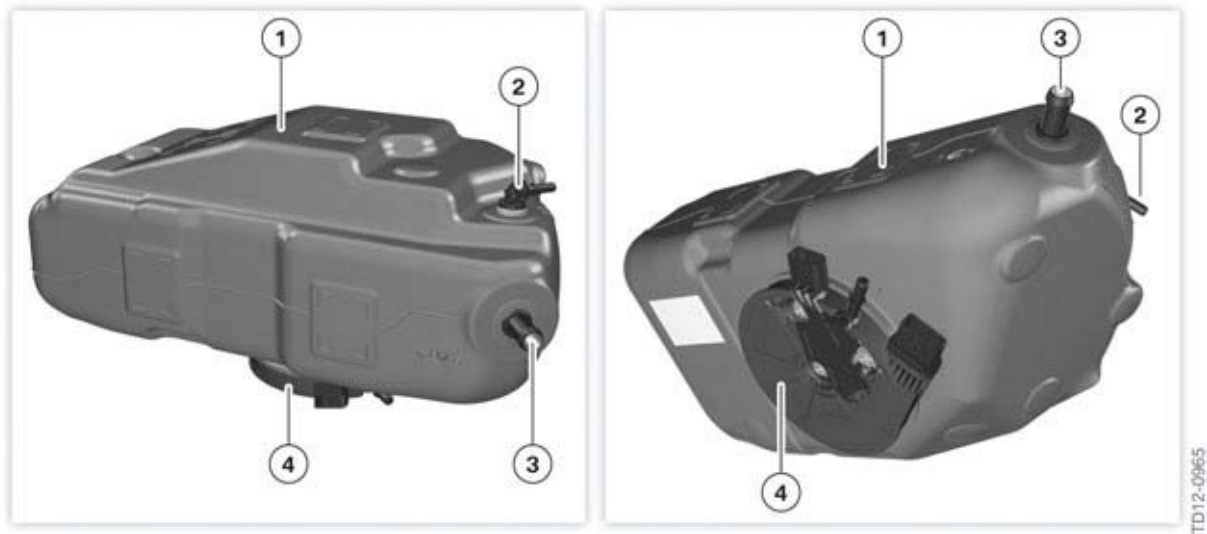
Vehicle	Volume	Installation location	Fluid filler neck position
F10 with N57D3001	15 liters	Rear right between wheel arch and bumper	Beside fuel filler necks, (rear right side of the vehicle) in fuel filler flap
F02 with N57D3001	15 liters	Rear right between wheel arch and bumper	On the right side of the rear bumper under the truck lid.
F15 with N57D3001	13.7 liters	Front right between wheel arch and bumper	In the engine compartment, on the right side
F30 with N47D2001	8.7 liters	Rear right of the fuel tank, area below the right rear seat	Beside fuel filler necks (rear right side of the vehicle) in fuel filler flap
F31 with N47D2001	8.7 liters	Rear right of the fuel tank, area below the right rear seat	Beside fuel filler necks (rear right side of the vehicle) in fuel filler flap



Possible danger as a result of incorrect refilling! Urea/water mixture (AdBlue®) filler necks are clearly marked as such. Nevertheless, there is a danger of incorrect refilling by third parties. Incorrectly refilled urea/water mixture (AdBlue®) systems (in particular with materials containing mineral oil) may be destroyed (gaskets).

# SCR 2 (US)

## 4. System Components



Active tank

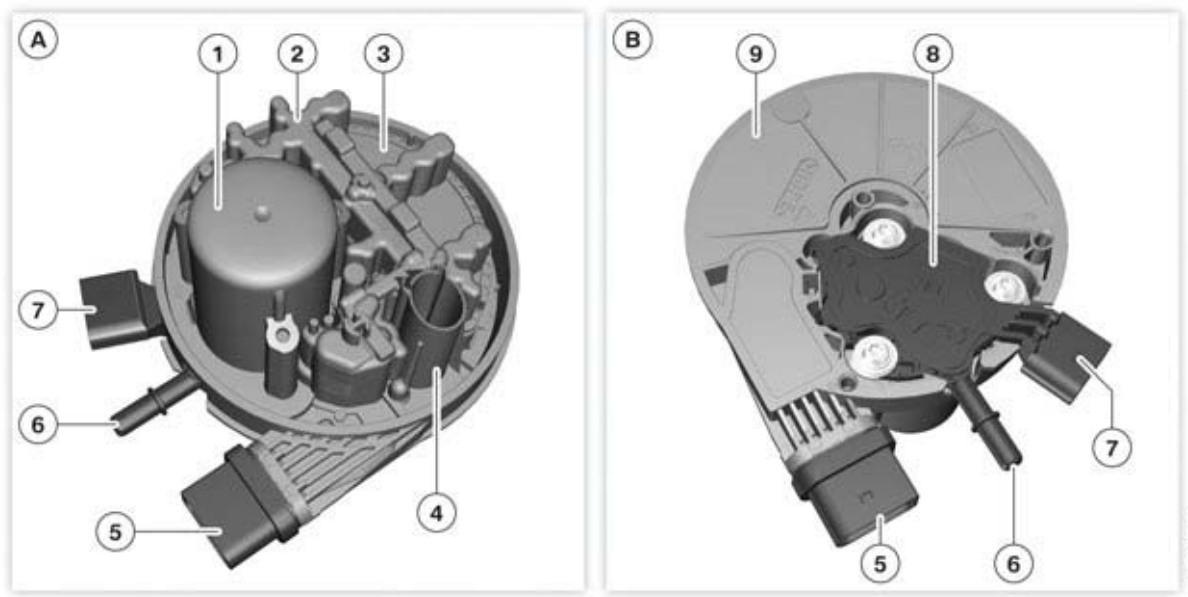
Index	Explanation
1	Active tank
2	Service vent line and fluid filler neck breather
3	Filling port
4	Tank flange module

### Tank flange module

The tank flange module is located in the active tank and holds the heating element, a filter, a temperature sensor and a level sensor. The tank flange module also holds the SCR delivery module. The tank flange module cannot be replaced individually in Service.

# SCR 2 (US)

## 4. System Components



Tank flange module

Index	Explanation
A	Top side
B	Bottom side
1	Housing for SCR delivery module
2	Heating element
3	Filter
4	Housing for level sensor with integrated temperature sensor
5	Electrical connection for tank heating and evaluation unit for level and temperature
6	Metering line connection
7	Electrical connection for SCR delivery module
8	SCR delivery module
9	Carrier plate

An electric auxiliary heater (positive temperature coefficient) is located in the tank flange module, so that at minimum temperatures liquid urea/water mixture (AdBlue<sup>®</sup>) is available for the journey. The positive temperature coefficient elements can be regulated or switched off independently upon reaching a certain limit temperature. Intrinsic safety is thus guaranteed which prevents damage and destruction in the event of a fault with the continuous power supply.

The heating element in the tank flange module is supplied with electricity by a power semiconductor. The power semiconductor is controlled by the SCR dosing control unit (DCU). The SCR dosing control unit (DCU) can give out the electricity that flows via the heating elements and therefore monitor their function.

# SCR 2 (US)

## 4. System Components

The temperature sensor delivers the signal for the control of the heating. It is an NTC sensor (negative temperature coefficient). The temperature sensor is integrated in the level sensor.

The level sensor in the tank flange module delivers the value of the level for the entire active tank.

The level sensor in the active tank works according to the same principle as the level sensor in the passive tank.

### 4.1.5. SCR delivery module

The SCR delivery module is integrated in the tank flange module (bolted on), which is located below at the active tank.

The SCR delivery module contains a supply pump and a return pump, maintenance-free filter, a Restrictor and two intake valves and two fluid pressure control valves for the supply pump and the return pump.

The delivery pump sends the AdBlue to the SCR metering module. The delivery pump operates at a **system pressure of between 4.5 and 8.5 bar**. The return pump drains the pressure line. Partial draining of the pressure line is needed to avoid ice damaging the SCR metering module in freezing conditions. Although this is kept to a minimum due to acoustic reasons related to the refilling of the metering line.

In addition, the ice pressure dampers are housed in the supply lines (supply and return) for the active tank. These prevent damage to the SCR delivery module and its supply pump and return pump in the event of frozen and therefore enlarging urea/water mixture (AdBlue®).

A pulsation damper and a strainer at the output for the metering line are also integrated in the SCR delivery module and prevent excessive pulsations in the metering line when the metering valve is open and penetration of dirt particles in the SCR delivery module (e.g. combustion residue, which could enter the SCR delivery module upon return of the urea/water mixture (AdBlue®) via the open metering valve.

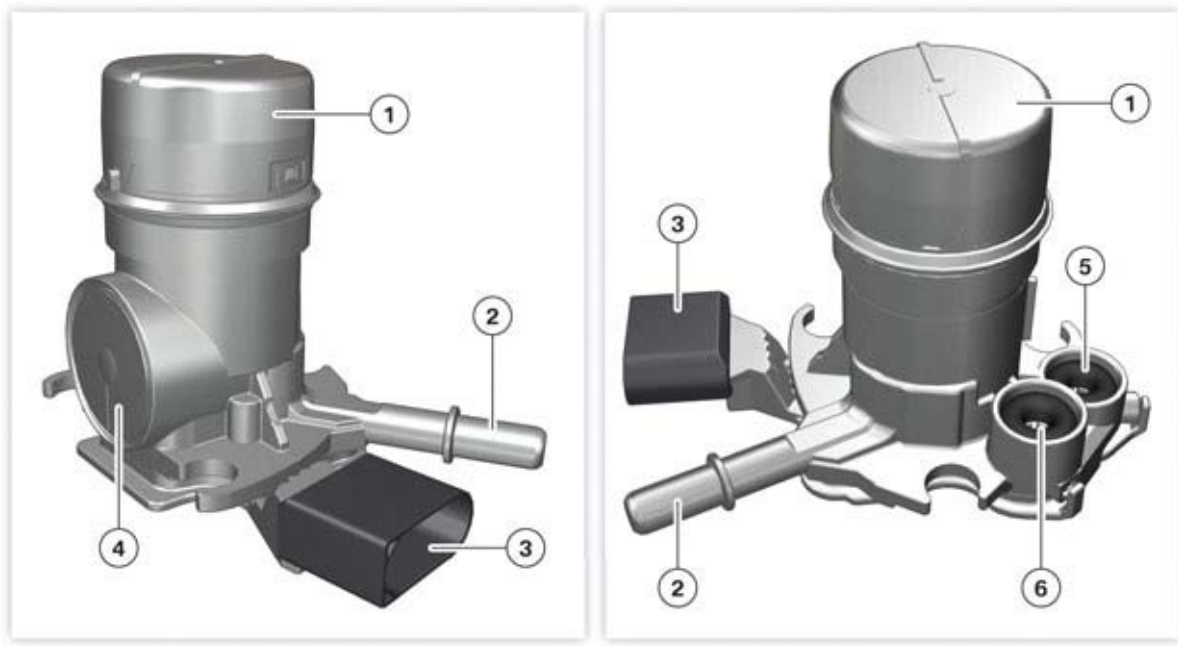
The SCR delivery module also contains a heating element. The SCR delivery module heating comprises the copper conductor of the coils from supply pump and return pump.

The SCR delivery module can be replaced individually in Service.



# SCR 2 (US)

## 4. System Components



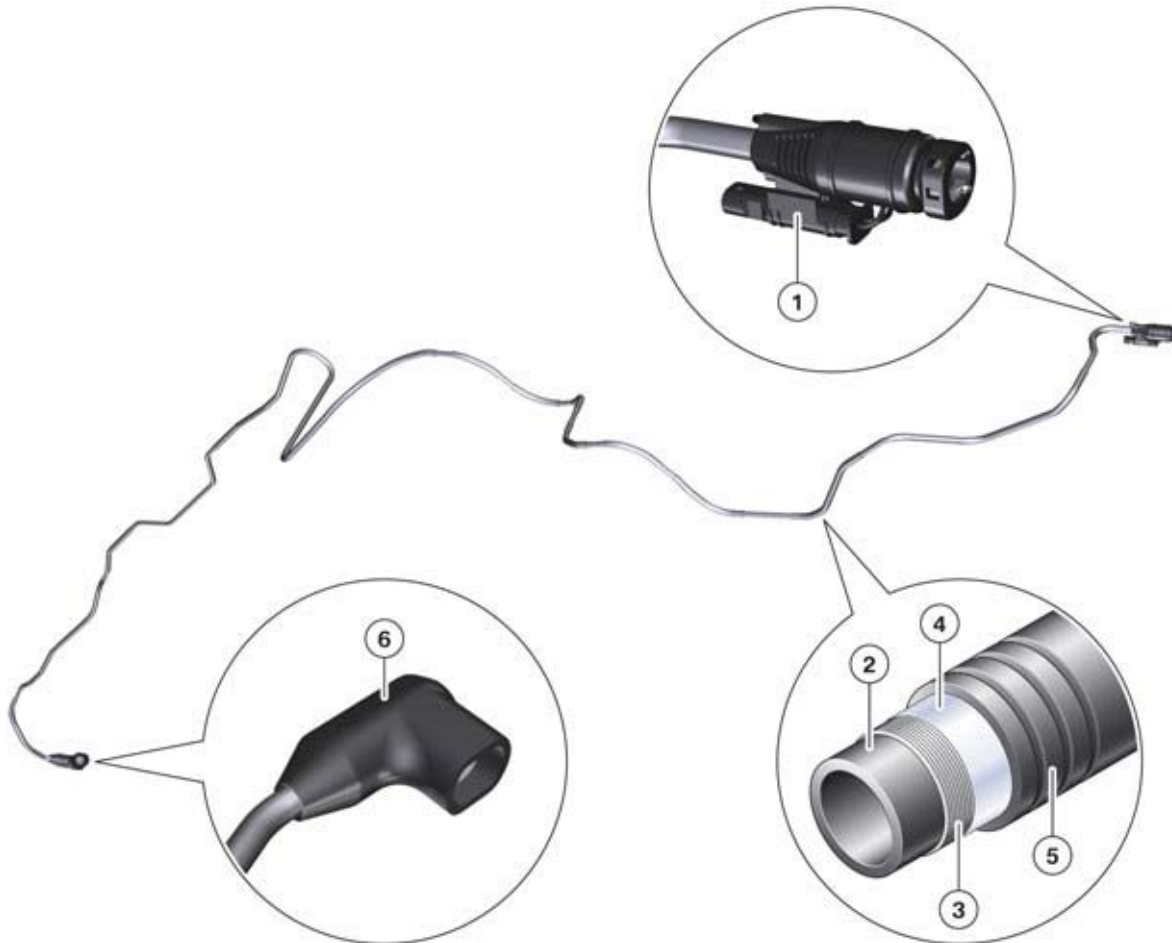
SCR delivery module

Index	Explanation
1	Supply pump
2	Metering line connection
3	Electrical connection
4	Back-flow (return) pump
5	Pre-supply connection
6	Return connection

# SCR 2 (US)

## 4. System Components

### 4.1.6. Heated metering line



TD12-0967

Metering line

Index	Explanation
1	Connection for tank flange module (hydraulic connection of metering line — electrical connection of metering line heating)
2	Line, urea/water mixture (AdBlue®)
3	Heating coils
4	Insulator
5	Protective sleeve
6	Hydraulic connection for metering module

Similar to the heating in the tank flange module for the active tank or the pump in the SCR delivery module, the metering line is heated electrically, if required, in order to prevent the urea/water mixture (AdBlue®) freezing.

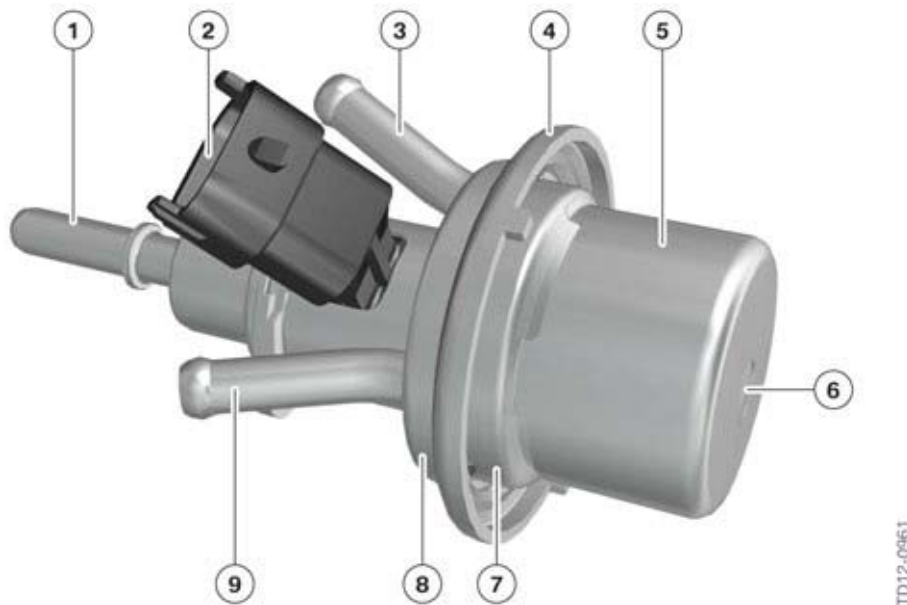
# SCR 2 (US)

## 4. System Components

The metering line is a 4 x 1 pipe, i.e. a pipe with an outer diameter of 4 mm and an inner diameter of 2 mm with a wall thickness of 1 mm in which the urea/water mixture (AdBlue®) is transported to the delivery module.

The heating element (in the form of ohmic heating wires) is attached from the outside to this 4 x 1 pipe, insulated and then physically protected by a corrugated plastic coating.

### 4.1.7. Metering module and mixer



Metering module

Index	Explanation
1	Metering line connection
2	Electrical connection, metering valve
3	Coolant inlet
4	Mounting flange
5	Thermal protection
6	Metering port
7	Sealing ring groove
8	Heat sink
9	Coolant return

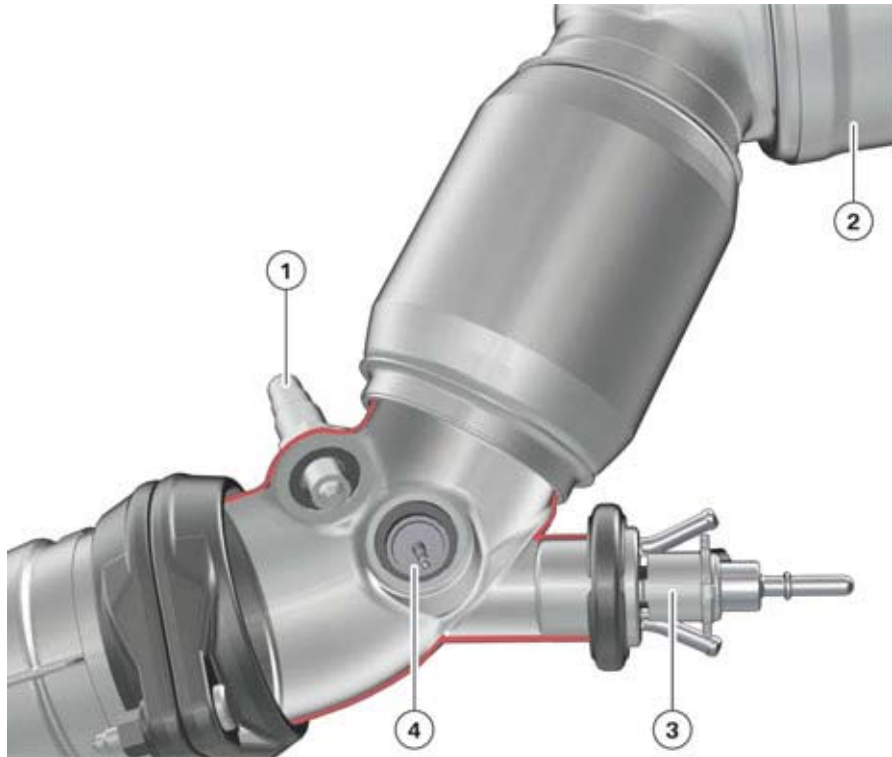
The metering module ensures the injection of the urea/water mixture (AdBlue®) into the exhaust pipe. It includes a solenoid valve that is similar to the fuel injector of a gasoline engine.

The metering module is not heated, but is heated up by the exhaust system therefore it has to be cooled using coolant from the engine cooling system.

# SCR 2 (US)

## 4. System Components

The metering module is activated by a pulse-width-modulated (PWM) signal from the SCR dosing control unit (DCU) in which the duty cycle determines the opening duration of the valve.



Metering module with built-in condition

Index	Explanation
1	Oxygen sensor
2	Diesel particulate filter
3	Metering module
4	NO <sub>x</sub> sensor before the SCR catalytic converter

A cone-shaped insert is attached at the metering module. This prevents the residue of the urea/water mixture (AdBlue®) drying up and the valve clogging. The shape creates a flow that prevents the urea/water mixture (AdBlue®) from sticking to the walls of the exhaust system. Deposits of urea on the insert are burnt off as it is heated by the exhaust flow.

### Mixer

The mixer is located directly behind the metering module in the exhaust system. It is inserted in the flange joint of the exhaust pipe. It swirls the exhaust flow in order to achieve a better mix of the urea/water mixture (AdBlue®) and the exhaust gas. This is necessary so that the urea is fully transformed into ammonia. The mixer can be replaced individually in Service.

# SCR 2 (US)

## 4. System Components



Mixer

Index	Explanation
1	Mixer
2	Mounting hole
3	Sealing in the flange
4	Centring pin

### 4.1.8. Urea/water mixture (AdBlue®) fluid filler cap

The urea/water mixture (AdBlue®) fluid filler cap includes ventilation. This ventilation is necessary as both the filling of the SCR system and the ventilation are realized via a common fluid filler neck breather pipe and tank ventilation line.

The ventilation is achieved via a defined hole in the urea/water mixture (AdBlue®) fluid filler cap. Therefore, only fluid filler caps which are approved for the respective vehicle are used.

A replacement or use of other fluid filler caps may cause a malfunction of the SCR system.



Urea/water mixture (AdBlue®) fluid filler cap

# SCR 2 (US)

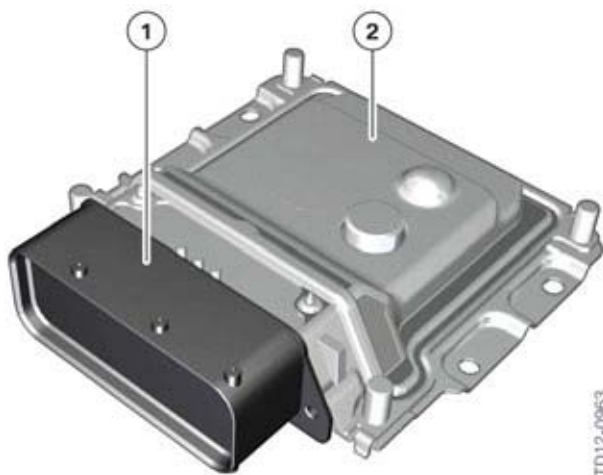
## 4. System Components

Index	Explanation
1	Urea/water mixture (AdBlue <sup>®</sup> ) fluid filler cap
2	Handle
3	Ventilation

### 4.1.9. SCR dosing control unit (DCU)

The SCR dosing control unit (DCU) must ensure that the input variables for the metering specification of the Digital Diesel Electronics (DDE) are in the permissible range. The fluid levels of the urea/water mixture (AdBlue<sup>®</sup>) passive tank (no vehicle operation without reducer), the medium temperatures in the urea/water mixture (AdBlue<sup>®</sup>) passive tank and the metering line (AdBlue<sup>®</sup>, freezing point at -11 °C/12.2 °F) and the pressure build-up metering line (ensures fluid injection rate) are relevant here.

The SCR dosing control unit (DCU) ensures that all available information is also available for other applications, for example the fluid level indicator and the remaining range (999 mls and 199 mls) display warning in the central information display (CID).



SCR dosing control unit (DCU)

Index	Explanation
1	Connector
2	Control unit

SCR dosing control unit (DCU) installation locations:

Series	Installation location
F15	Engine support, front right above SCR active tank
F10	Spare wheel well area
F30	On the right side in the trunk, near the manual emergency release of the fuel door

# SCR 2 (US)

## 4. System Components



**Note:** Please consult the respective repair information in ISTA for the most current component installation locations of the SCR dosing control unit.

### 4.2. NO<sub>x</sub> sensors



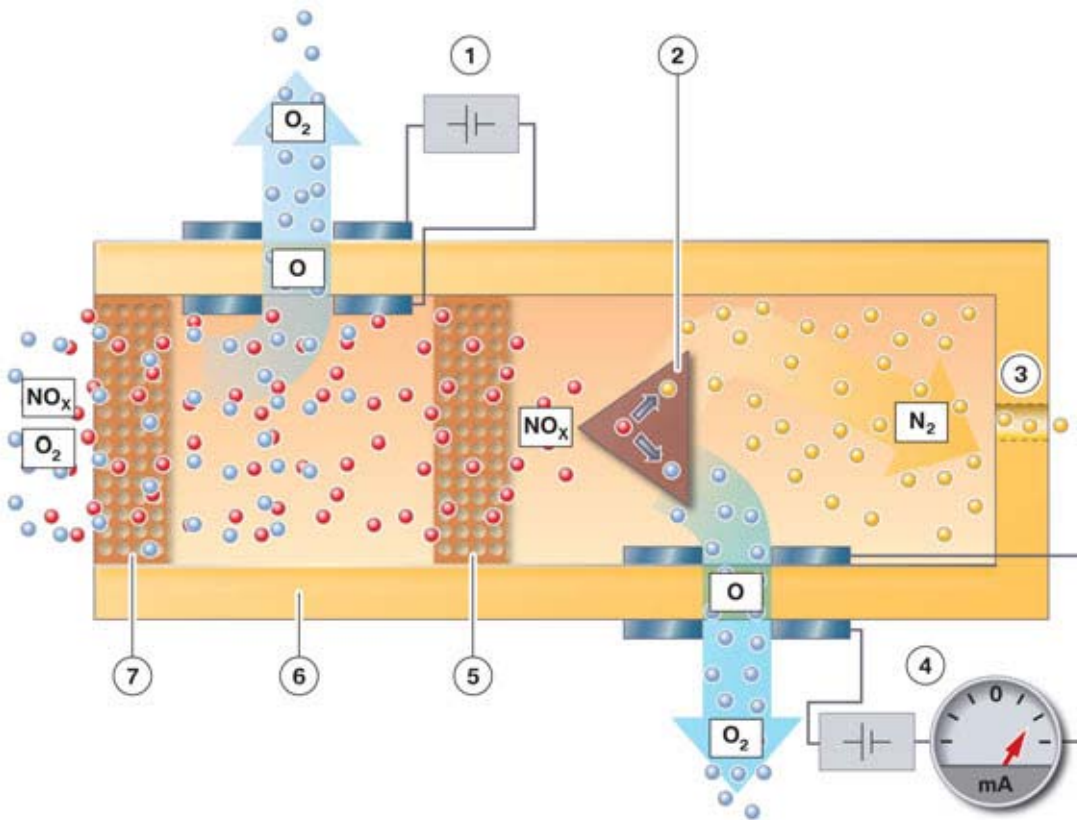
NO<sub>x</sub> sensor

As with the previous SCR system SCR 2 also incorporates two NO<sub>x</sub> sensors (one upstream and one downstream of the SCR catalyst) The nitrogen oxide sensor consists of the actual measuring probe and its own corresponding control unit. The control unit communicates via the Lo-CAN with the Digital Diesel Electronics (DDE). In terms of its operating principle, the nitrogen oxide sensor can be compared with a broadband oxygen sensor. The measuring principle is based on the idea of basing the nitrogen oxide measurement on oxygen measurement.

The operating principle of this measurement procedure is shown in the graphic on the following page.

# SCR 2 (US)

## 4. System Components



TD11-0239

NO<sub>x</sub> sensor function

Index	Explanation
1	1st chamber pumping electricity
2	Catalytic element
3	Nitrate outlet
4	2nd chamber pumping electricity
5	Barrier 2
6	Solid electrolyte zirconium dioxide (ZrO <sub>2</sub> )
7	Barrier 1

Functional description: The sensor system of the nitrogen oxide sensor consists of a solid electrolyte made of ceramic based on zirconium dioxide. Above a temperature of approximately 300 °C (572 °F), this material becomes conductive for oxygen ions. The internal heating element provides for the necessary operating temperature. The mixture of O<sub>2</sub> and nitrogen oxide in the exhaust gas reaches the nitrogen oxide sensor after the nitrogen oxide catalyst storage. The nitrogen oxide sensor consists of two chambers. A pump cell regulates the oxygen concentration to a specific value by pumping oxygen out of or into the first chamber. Through the application of a voltage, the oxygen molecules are split into ions and diverted through the solid electrolyte. The remaining nitrogen oxide then goes onto the second chamber. The oxygen concentration is then further reduced with a second pump cell



# SCR 2 (US)

## 4. System Components

in the second chamber. The remaining nitrogen oxide is split into oxygen and nitrogen at a catalytic element at the third pump cell. The released oxygen leads to a pump current which is proportional to the concentration of nitrogen oxide in the exhaust gas. The evaluation electronics generate the output signals based on the physical measured values. The control unit communicates via the Lo-CAN with the Digital Diesel Electronics (DDE).

# SCR 2 (US)

## 5. Information for Service

### 5.1. Refilling

The SCR system is generally maintenance-free. The service requirements are solely limited to refilling the urea/water mixture (AdBlue®).

The refilling of active and passive tanks with urea/water mixture (AdBlue®) can either be carried out in Service or by the customer themselves.

Refilling on an incline of up to 5° in any direction is no problem. 90% of the maximum possible refilling is still achieved.

The volume of the urea/water mixture (AdBlue®) tank is set out in such a way that a large range is possible. This means that the "normal" refilling takes place in a relatively long cycle so that the refilling can ideally take place in a second Service.

Should the urea/water mixture (AdBlue®) reserve not last until the next workshop visit a certain amount can also be refilled. A special bottle can be used for this that is screwed onto the fluid filler neck. The special bottle, also known as the "KRUSE bottle", guarantees filling without the danger of overfilling, overflowing or spraying in the engine compartment or on the paint surface.

Refilling using the KRUSE bottle is also possible via the urea/water mixture (AdBlue®) filler connection in the fuel filler flap as this bottle also runs dry at an angle of about 30°.

KRUSE refill bottles with a content of 0.5 US gallons can be ordered from the Electronic Parts Catalog (the current part numbers are set out in the Electronic Parts Catalog ).

# SCR 2 (US)

## 5. Information for Service



Special KRUSE bottles for urea/water mixture (AdBlue®)

Should the starting of the engine already be prevented by the switch off scenario (inducement with "no start in ---"), two bottles should be used to stop the switch off scenario from occurring again straight away.



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**In the case of a inducement with "no start in ---" a minimum of 2 bottles (approx. 4 Liters) is required to get a refill detection and reset the countdown. At the beginning of the inducement (999 mls left) one bottle is enough to get a refill detection.**

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### 5.2. Refilling in Service

For refilling in Service 10 liter canisters are available, which are used in conjunction with a special tool (the current special tool part numbers are set out in the Aftersales Assistance Portal).

The filling hose that was used for SCR 1 is still usable for SCR 2. **(This filling hose (next picture) is sold at Daimler in Europe) VERIFY use in US**

# SCR 2 (US)

## 5. Information for Service



TD12-1076

Filling hose

Once the system is fully drained two canisters are required. Via the workshop system ISTA it can be checked whether both tanks, active tank and passive tank, were filled completely.

Refill canisters with a content of 10 liters can be ordered from the Electronic Parts Catalog (the current part numbers are set out in the Electronic Parts Catalog ).



TD11-0705

10 liter canister for urea/water mixture (AdBlue®)

# SCR 2 (US)

## 5. Information for Service



Never refill the system from the canister without the special tools! Damage to components may occur due to overfilling and spillage (especially in the engine compartment) where various materials are very sensitive to the corrosive properties of the urea/water mixture AdBlue<sup>®</sup>).

### 5.3. Checking the urea/water mixture (AdBlue<sup>®</sup>) concentrate

The quality check of the urea/water mixture (AdBlue<sup>®</sup>) is performed using a refractometer, which determines the urea concentration (the current special tool part numbers are set out in the Aftersales Assistance Portal). Using the enclosed pipette a drop of the medium to be tested is placed on the prism and the lid closed. The values are shown on the relevant scale using the light/dark boundary in the eyepiece.



Refractometer

Index	Explanation
A	Refractometer
B	Scales (battery acid density/coolant frost protection/urea/water mixture (AdBlue <sup>®</sup> ))

#### Evaluation of the urea/water mixture (AdBlue<sup>®</sup>) concentrate:

- At values lower than 31.8 percent by weight, proper functioning of the urea/water mixture (AdBlue<sup>®</sup>) can no longer be guaranteed. Therefore, this must be replaced (for example, urea/water mixture (AdBlue<sup>®</sup>) aged by UV irradiation).
- The values are within the tolerance for values displayed between 31.8 and 33.3 percent in weight.
- Values higher than 33.3 percent in weight indicate a leak in the SCR system (for example if a proportion of water in the urea/water mixture (AdBlue<sup>®</sup>) has evaporated).

# SCR 2 (US)

## 5. Information for Service



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Urea/water mixture (AdBlue<sup>®</sup>) which has been drawn off cannot be reused without a check. Long storage times and the influence of high temperatures and UV light have a subtle effect on the decomposition of the urea/water mixture (AdBlue<sup>®</sup>).

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### 5.4. Evacuating the urea/water mixture (AdBlue<sup>®</sup>)

If it is necessary to draw off the urea/water mixture (AdBlue<sup>®</sup>) within the framework of maintenance measures or repair measures or in the case of a excessive ageing, this must be done using suitable tools. **It is not possible to drain the system as draining ports are not provided.**



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**It is not possible to drain the system!!!**

**The new systems do not have a draining provision as E70. In order to drain the new system it is necessary to remove the filler pipe and drain through the filler nipple on the active tank. The passive tank can be drained through the transfer connection.**

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**The drained urea/water mixture (AdBlue<sup>®</sup>) must be collected in a suitable plastic tank. The pump must be purged with water after each use and cleaned.**

**The safety data sheet must be observed for handling and disposal.**

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### 5.5. Urea/water mixture (AdBlue<sup>®</sup>) — Compatibility with other materials

Components of the SCR system are incompatible with materials with a mineral oil base. It therefore must be assured that the components of the SCR system do not come into contact with these. In the event of uncertainties whether SCR system components came into contact with materials with a mineral oil base or SCR system components were filled with materials with a mineral oil base, there are test strips available to check the rest of the materials with a mineral oil base in the urea/water mixture (AdBlue<sup>®</sup>).



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**In the event that these materials have been verified and components of the SCR system were damaged as a result, the SCR system must be completely replaced.**

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# SCR 2 (US)

## 5. Information for Service



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Special tools and other tools used in Service must be kept far away from materials containing a mineral oil base when handling the urea/water mixture (AdBlue<sup>®</sup>). This applies, in particular, for special tools and tools which are used for filling and draining the urea/water mixture (AdBlue<sup>®</sup>).

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