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AdBlue: An Overview

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ABSTRACT

AdBlue is an ultra pure solution of urea in demineralised water, used in the latest generation of commercial diesel vehicles for the removal of Nitrous Oxide, an environmental pollutant. It consists of high purity urea dissolved and suspended within de-ionized water. The ratio of the mix is approximately 32.5% urea and 67.5% de-ionized water. It is used by modern diesel engines which are equipped with an SCR, AdBlue never comes into contact with the fuel, and it is a common misconception that it is an additive. AdBlue is carried onboard the vehicle in a separate vessel to the fuel storage tank. It is injected into the exhaust gases as a post combustion process through an SCR where it breaks harmful Nitrous Oxide emissions down into mostly Nitrogen and Oxygen. The use of AdBlue benefits everyone it helps the environment by reducing the number of harmful emissions created by diesel engines and it helps fleet operators and drivers reduce fuel costs. It is likely that further savings will be made in the future as governments are anticipated to introduce new carbon taxes and penalties for individuals who do not take necessary action to reduce damage impacted on the environment.

Keywords: AdBlue, Emission, Engines

1. Introduction

AdBlue is the international name given to a newly created additive for selective catalytic reduction. The name was created by joint agreement by the mineral oil industry, the chemical industry and the automobile industry and their suppliers. AdBlue is such an additive. They are stored as a concentration in a separate tank prior to mixing with the exhaust gases as they leave the engine. In order to maintain efficiency and to be sure that systems are not compromised, it is essential that the concentration is accurately maintained. Measuring devices such as refractometers and hydrometers may perform such checks and depending on the location and accuracy required. In an effort to reduce environmental pollution, has certain rules established about emissions from heavy and light goods vehicles. One method adopted by vehicle manufacturers to allow compliance is SCR (Selective Catalytic Reduction), which chemically reduces NOx emissions using a urea additive in the exhaust flow.

With the industry focus placed on selective catalytic reduction (SCR) systems that require urea dosing to reduce NOx, how urea is delivered and dosed has many system and engine manufacturers considering sealing, pumping and environmental resilience of dosing systems. Urea dosing systems require both a high dispense accuracy as well as low pressure. While a dosing system solution is predicated on these exacting parameters, the technology to address those needs is currently scarce. With ever-increasing emissions regulatory restrictions, precise and accurate dispensing in both infrastructure distribution as well as on-vehicle dosing remains a focus of concern, following attempts to address and allay some of these concerns.

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The guideline for this tightening of exhaust gas limits is the guideline for air quality which aims further reduction of air pollution by industrial plants and motor vehicles. Therefore new limits of euro 4 and euro 5 for exhaust gas emissions shall reduce the emission of pollutants. A requirement for reduction in NOx emissions by diesel engines is influenced by Euro 4 and Euro 5 legislation. Initial targets for emission reduction are Public Transport and the Commercial Sector. According to new standards, NOx emissions have to be reduced in two steps in 2005 (Euro 4) and 2008 (Euro 5), respectively, each time by 30 % vis-à-vis the current limits of Euro 3. Significantly tighter limits apply to the other pollutants, as well: for carbon monoxide (CO), unburned hydrocarbons (HC) and most importantly for particulate matter (PM) which is shown in table 1

Table 1: Exhaust Gas Limits

Pollutant	**Euro 3**	**Euro 4**	**Euro 5**
Nitrogen oxides (NOx)	5.0	3.5	2.0
Carbon monoxide (CO)	2.0	1.5	1.5
Unburned hydrocarbons (HC)	0.66	0.46	0.46
Particulate matter (PM)	1	0.02	0.02

2. Materials and Method

2.1 AdBlue

AdBlue is a 32.5 % by weight solution of technically pure urea in demineralised water manufactured to meet one of the stringent automotive standards: ISO 22241.This concentration was chosen, because at this urea content, the crystallization point reaches a minimum of minus 11 °C (eutectic mixing ratio). AdBlue must be kept free of any metal ions (e.g. Na, K, Mg, Ca, Al and especially heavy metals), because their salts can clog the pores of the ceramic carrier material or poison the active centers of the catalyst thereby rendering it ineffective. AdBlue is not inflammable, but can release ammonia under heat exposure. In such way that detail characteristics shown in table 1 and table 2

Table 2: Chemical Characteristics

Content	**Limit**	**Content**	**Limit**
Urea	31.8 – 33.2 % w/w	Calcium	0.5 max. mg/kg
Alkalinity as NH_3	0.2 max. % w/w	Iron	0.5 max. mg/kg
Biuret	0.3 max. % w/w	Copper	0.2 max. mg/kg
Aldehydes	5 max. mg/kg	Zinc	0.2 max. mg/kg
Insolubles	20 max. mg/kg	Chromium	0.2 max. mg/kg
Phosphate	0.5 max. mg/kg	Nickel	0.2 max. mg/kg
Sodium	0.5 max. mg/kg	Aluminum	0.5 max. mg/kg
Potassium	0.5 max. mg/kg	Magnesium	0.5 max. mg/kg

Table 3: Physical Characteristics

Content	Limit
Density at 20°C	1.0870 - 1.0920 g/cm³
Refractive index at 20°C	1.3817 - 1.3840
Melting enthalpy	+270 J/g
Melting range (2 K/min)	(-20°C) to (-6°C)
Specific heat capacity Cp(T) at 25.04°C	3.51 J/g*K
Vapor pressure above liquid at 20.08°C	23.0 hPa
Thermal conductivity at 25°C	approx. 0.570 W/m·K
Viscosity at 25°C	approx. 1.4 mPa·s
Surface tension at 20 °C	min. 65 mN/m
pH	slightly alkaline, approx. 9.0

To further reduce pollution and Greenhouse gases, countries around the world are introducing ever more stringent exhaust emission regulations have developed different methods of exhaust treatment, these are:

1. Internal measures to the engine: shape of the cylinder, mixing of the fuel/ignition, valve timing
2. Catalytic converter for the reduction of CO, HC and NOx emissions while operating the gasoline engine in a stoichiometric proportion of $\lambda = 1$
3. Converter plus operation of the engine with excess air ($\lambda > 1$) for reduction of NOx emissions
4. Oxidation catalyst for decreasing CO, HC and also particulate matter emissions to a certain extent
5. Exhaust gas recycling (EGR) for the reduction of NOx emissions
6. Storage catalyst with separate control for reduction of NOx emissions
7. Selective catalytic reduction (SCR) to decrease NOx emissions (with an additive as a reducing agent)
8. Particle filter with continuous or discontinuous regeneration (with or without additive as a regeneration aid)

The above methods can also be used in various combinations. However, there is a dilemma when trying to reduce particle and NOx emissions simultaneously, because there is a correlation between the formation of NOx on one hand and of the remaining pollutants on the other: It is possible to reduce NOx emissions by internal measures, such as EGR, which lowers the temperature in the cylinder of the engine.

However, emissions of particles, unburnt hydrocarbons and carbon monoxide would then increase. In addition, efficiency and effectiveness of the diesel engine would be impaired and therefore fuel consumption and carbon dioxide emissions will increase. If, however, the combustion in the engine is optimized with regard to efficiency and performance, then formation of particulate matter and NOx will increase to such an extent that the imminent Euro standards cannot be met. Whereas the limit values of Euro 4 can still be met with various methods, such as exhaust gas recirculation in combination with a particle filter, the simultaneous reduction of NOx and particle emissions to the values of Euro 5 poses a technical problem, which, according to current knowledge, can only be solved with one specific method described such as selective catalytic reduction as follows.

2.2 Selective Catalytic Reduction Technology

An SCR system injects a product known as AdBlue into the hot exhaust gas where it decomposes into ammonia, which then reacts with the surface of catalyst to produce nitrogen and water vapor.

> Ammonia (NH_3) is used as a reducing agent; however, due to its aggressiveness and toxicity, it is not applied as such, but in the form of an innocuous substance, which releases NH_3 in the exhaust gas stream, the engine can be operated under optimal conditions, thus minimizing fuel consumption and therefore CO emissions as well as the discharge of all pollutants except NOx. After the combustion gases have left the engine, they first run through a pre-oxidation catalyst where hydrocarbons, carbon monoxide and particulate matter unburned are oxidized as completely as possible. NO is oxidized partly to NO, because the subsequent reduction proceeds fastest at a mixing ratio of NO: NO_2 of 1:1. Then a pump, which is controlled by a monitoring unit, injects AdBlue from a separate tank into the hot exhaust gas stream, where it hydrolyses to NH_3 and CO_2. In the actual selective reduction, NH_3 reacts with the NO/NO_2 mixture to form nitrogen and water (steam), which with 80 % constitutes the main natural component of the atmosphere. (Figure 1)

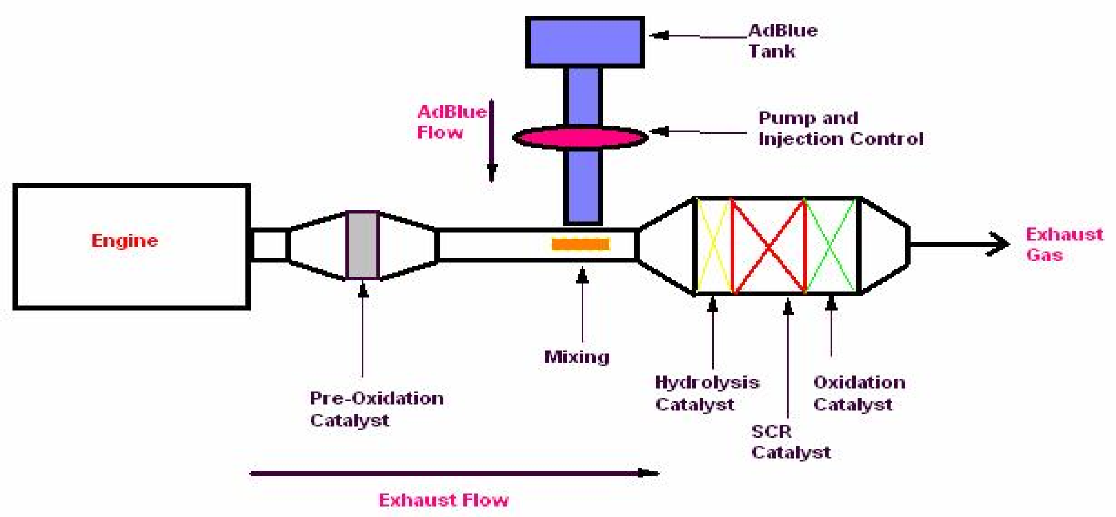

Figure 1: Scheme of a combined deNOx system for exhaust gas treatment on the basis of the SCR method

The chemical reaction in the exhaust gas stream behind the engine at the ceramic catalyst causes a reduction of the nitrogen oxides NO and NO by ammonia (NH_3), according to the following reactions

1. Partial oxidation:
   $2\ NO + O_2 \rightarrow 2\ NO_2$
   $2\ CO + O_2 \rightarrow 2\ CO_2$
   $4\ HC + 3O_2 \rightarrow 2\ CO_2 + 2H_2O$

2. Urea hydrolysis
   $(NH_2)_2CO + H_2O \rightarrow 2\ NH_2 + CO_2$

3. Selective catalytic reduction:
   $6NO_2 + 8\ NH_3 \rightarrow 7N_2 + 12\ H_2O$
   $4\ NO + O_2 + 4\ NH_3 \rightarrow 4\ N_2 + 6\ H_2O$
   $NO + NO_2 + 2NH_3 \rightarrow 2N_2 + 3H_2O$

4. Oxidation catalyst
   $3\ O_2 + 4\ NH_3 \rightarrow 2\ N_2 + 6\ H_2O$

3. Discussion

Consumption of AdBlue will be from 4 to 6% of the diesel consumption has been issued. To meet these standards the automotive industry has adopted several technologies; one such is Selective Catalytic Reduction (SCR), where harmful exhaust gases are converted to nitrogen and water by catalytic conversion. AdBlue is the trade name for a catalytic reduction agent used for this process. It stored at refueling sites and will become a common feature at filling stations for commercial diesel vehicles and private depots. Vehicles will have an AdBlue tank, from which it is injected into the engine exhaust stream immediately after the combustion chamber.

AdBlue is an aqueous solution of urea. If it is stored, handled and used according to manufacturer's instructions and guidelines, it poses a minimal risk to operators and a limited risk to the environment. However, urea solution is very polluting to groundwater and watercourses and has caused several serious pollution incidents from spillages at farms where it was stored and used as a fluid fertilizer. Because urea solution contains ammonia it is corrosive to some metals, such as copper and its alloys. If tanks and pipe work become corroded there is a higher risk of a spill that could cause pollution which is against the law.

AdBlue is stored in containers that are specifically designed and manufactured from materials that are suitable for use with urea. The same applies to all storage ancillary equipment, such as valves, dispensing nozzles and pipe work. AdBlue is soluble in water and should be kept out of surface water drainage systems discharging to the environment. It will not be removed in an oil separator so it's important to isolate dispensing area drainage from the surface water system to reduce the possibility of spills and drips causing pollution. AdBlue poses no serious risk to humans, animals or the environment. However, it should be stored separately from nitrates and nitrites. Thus these are following factors discussed in brief:

3.1 Handling and Storage of AdBlue

1. AdBlue is a colorless, transparent, and harmless chemical liquid. Therefore it is a safe substance even if spilt onto the body or clothes. AdBlue has a slight ammonia odour.
2. While AdBlue is a safe liquid; it may cause slight skin irritation for some people. If spilt onto the body, clothes, or ground, flush the area with water. If ingested, drink 1 to 2 cups of water or milk. For larger spills, first dilute with large amounts of water and refer to local regulations for disposal (due to Nitrogen content).
3. Diluted AdBlue can be used as a fertilizer.

4. AdBlue is non-flammable, but it should be moved to a safe location if there is a fire, as intense heat may cause the sealed storage container to pressurize and possibly rupture.
5. AdBlue should be stored in the manufacturer's original container and kept in a cool, covered area with good ventilation and out of direct sunlight. This will prevent water loss due to evaporation and ensure 1 – 2 years product life.
6. AdBlue freezes at -11.5 deg C. When it thaws, the product will return to its initial quality.
7. No qualifications, permits or licenses are required for the handling or storage of AdBlue

3.2 Testing of AdBlue

Stability tests

1. Storage stability
2. Thermal stability

Field tests

1. Handling: filler nozzle/spills/ drippings/cleaning
2. Winter operation (temperatures between –4 and –8 °C)
3. Summer operation (temperatures up to 32 °C)

Compatibility with other materials

1. Concrete
2. Metals and plastic material
3. Seals

Emulsion test

1. Separation of fuel/AdBlue mixtures

3.3 National and international activities

A number of committees of the automobile and mineral oil industry as well as their associations, scientific societies, accessories industry, urea manufacturers, shipping agencies, environmental authorities and universities are engaged on a national or international level in the issue of reducing NOx emissions from diesel engines and more specifically in the SCR/urea technology. The activities of the main committees are described

1. Standardization of the urea solution, quality requirements
2. Tanking systems for urea solution
3. Interface filling nozzle/filling neck
4. Anti-freeze measures

5. Urea: production and demand estimate; costs
6. Establishment of a balanced distribution network for urea throughout Europe
7. Symbol and trade name for the urea solution
8. Alternative usage of ammonia as a reducing agent
9. Exhaust gas regulations
10. Systems of self-supervision
11. Application in different vehicle categories from HD to light duty commercial vehicles and passenger cars
12. Programs for the assistance and introduction of the SCR technique in combination with urea

4. Conclusion

. 4.1 Environmental compatibility of AdBlue

1. Due to its excellent solubility in water (1,080 g/l) urea will tend to stay in the aqueous phase in an oil separator, and from there it will get into the public sewage system and eventually into the public waste water treatment plants. There it will be completely catabolized within a few days. However, the question of permits for release of urea solutions into the public sewage systems still needs to be investigated.
2. As SCR is a chemical process, the exhaust gas can smell different to a conventional diesel vehicle. In addition, some “white smoke” might be seen from the exhaust pipe when the engine is started, this is only water vapor. Do not touch this vapor as it may be slightly acidic. If it makes contact with skin, or clothes, flush the area well with water.

4.2 Advantages of SCR technology

1. Cleaner Emissions
2. The engine can be operated at optimal conditions
3. The optimal engine adjustment results in a better efficiency (about 5 % less fuel consumption) and therefore in less CO_2 emissions.
4. The discharge of all pollutants (NOx, PM, CO and CH) is minimized, thereby complying with the stringent requirements of Euro 4 and 5.
5. The SCR/urea technology is applicable to all types of engines and functions with diesel fuels of varying qualities.
6. The SCR method is maintenance-free and designed for the entire lifespan of the vehicle.
7. SCR has no influence on service and oil change intervals of the vehicles.

4.3 Necessary developments

1. Standardization and maintaining quality of AdBlue
2. Delivery and Storage of AdBlue to the filling station

3. Constructive and technical arrangement of AdBlue and diesel filling pumps
4. Temperature effects (crystallization, hydrolysis)
5. Material compatibility
6. Endangering of surface waters/oil separator
7. Optimal access to the AdBlue filling pump
8. Interface filler nozzle/filler neck for AdBlue tanking
9. Durability of concrete pavement on driveways against AdBlue dripping losses
10. Accounting with the customer at the service station
11. Calibrated instrument for volume measuring with official permission

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