Reducing exhaust emissions from stationary diesel engines in Greenwich

Background

Thames Water operate a pumping station in Greenwich, South-East London, which is used to pump sewage and rain water. For the majority of the time, electric pumps are used, but there are also two diesel engines which drive pumps directly, and these are used as back up in case of mains failure or extreme weather conditions.

The engines were made by Mirrlees Blackstone in the 1980s, and produce 800 kW at 1500 rpm. They were built before any emissions standards applied to diesel engines, and produced visible black smoke, especially on start up. This lead to complaints from residents living in newly-built luxury flats overlooking the site, and Thames Water was told by Greenwich Borough Council that it must eliminate this black smoke.

Thames Water made contact with Blackthorn, and Julian Hammond, Blackthorn's Managing Director, attended a meeting including staff from Thames Water and Greenwich Borough Council in July 2016. At this meeting it was decided to resolve the issue of black smoke but also to tackle the emissions of NOx to bring the engines into compliance with the forthcoming Medium Combustion Plant Directive.

Greenwich Pumping Station

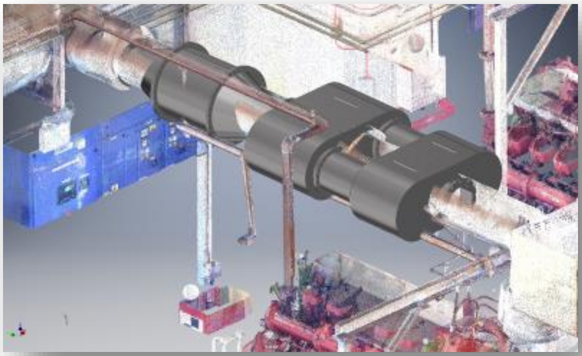
Medium Combustion Plant Directive

The Medium Combustion Plant Directive (MCPD) regulates toxic emissions from plants with a thermal input between 1 and 50 mW, which corresponds to an electrical output in the range 0.4 to 20 mW. In the case of plants fuelled by diesel only NOx emissions are regulated, and are required to be below 190mg/NM3 @ 15% oxygen. The MCPD applies to new plants with effect from 20 December 2018 and to existing plants from 1 January 2025 where the thermal input is over 5 megawatts or from 1 January 2030 where the thermal input is under 5 megawatts. Some generators which export power to the national grid may need to comply earlier.

Surveying

The engines are installed in a Victorian building which is listed, therefore no external changes to the building were permitted. This meant that all the emissions control components needed to be fitted inside the building, in place of existing exhaust pipework. Regulations on site also prohibited cutting and welding, therefore all fabrication needed to be done off-site, requiring great accuracy in measurement.

With this in mind, Blackthorn called in a firm of surveyors who used laser scanners to produce a three-dimensional model of the complete contents of the building. This enabled the dimensions of the emissions control system to be determined accurately so that the modules could be brought to site and simply bolted into place.



3D Modelling

Emissions targets

At the initial stage of the project, Blackthorn was given some approximate exhaust emissions data but it was clear that a more definitive emissions report would be required. Therefore an emissions testing company called ESG were commissioned to carry out testing on both engines in November 2016. Based on the results of this, it was clear that a 90% reduction in NOx would be required in order to comply with the MCPD. Blackthorn also guaranteed to reduce carbon monoxide by 90% and diesel particulate matter by 95%.

Blackthorn was not given a noise target, however they decided that the noise level should be no greater than before.

Diesel particulate filters

Blackthorn decided to use two wall-flow filters made from silicon carbide on each engine to filter out the diesel particulate matter. These filter elements were coated with platinum which acts as a catalyst to oxidise the accumulated diesel particulate and prevent the filters from becoming blocked. This catalytic oxidation of the particulate matter is dependent on the exhaust gas temperature and is often referred to as 'passive regeneration'. However whenever the engines were running they were driving a pump, and therefore the exhaust gas temperature was found to always be high enough for the catalytic oxidation to occur. As a precaution, Blackthorn supplied systems to log the exhaust temperature and pressure upstream of the DPFs, which will provide advance warning if the filters start to block up.

The catalytic coating on the DPFs is also very effective at oxidising carbon monoxide.

Selective Catalytic Reduction

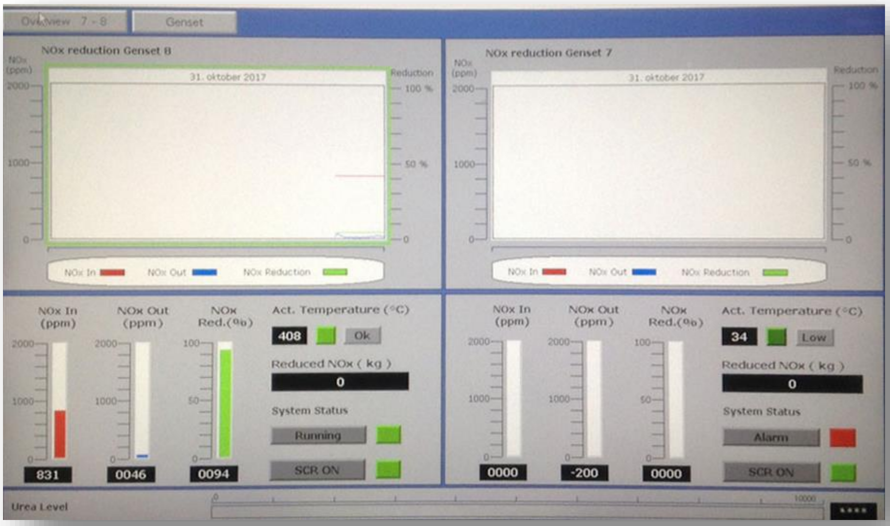
Selective Catalytic Reduction (SCR) is a technology for reducing NOx emissions in oxygen-rich environments such as diesel exhausts as well as various other combustion processes. It requires a ‘reductant’ to be mixed with the exhaust gas, and then the mixture to be passed through a special type of catalytic converter in which the oxygen atoms are extracted from the NOx and enticed to react with the reductant instead. In most cases the reductant used is ammonia. However, ammonia presents some problems in terms of safe handling, so a solution of urea is normally used, which only breaks down into ammonia after it has been mixed with the hot exhaust gases. The best-known type of urea solution is Adblue, which contains 32.5% urea.

Reductant injection system

Blackthorn discussed the requirements with a number of suppliers of reductant injection systems and selected one based in Europe. This supplier designed a system which encompassed both engines but only required a single control panel. Power requirements of this system are 230 V/ 50 Hz, and no compressed air is needed. The system injects a carefully-controlled dose of urea solution into the exhaust based on two parameters: exhaust gas temperature and engine load. However, it was found that the engines produced no load signal, therefore fuel-flow meters were installed and the fuel-flow was used as a proxy for load.

Reductant injection system, cont

The urea solution chosen is known as 'AUS40' and contains 40% urea. This product is available in 1000 litre IBCs but unfortunately there was no space for the IBC inside the building so a container for the IBC was installed adjacent to the building. This container was equipped with heating since AUS40 freezes at zero Centigrade. Blackthorn designed and supplied a double-skinned stainless steel day tank with a capacity of 300 litres which was installed inside the building.



Touch screen for reductant injection system

SCR catalytic converters

Catalytic converters comprise a ‘substrate’, which is a honeycomb-like structure the purpose of which is to provide a large surface area, and a catalytic coating. On large diesel engines it is traditional to use substrates intended for power stations which have large channels through them, meaning that they are resistant to blocking by soot and dust. However, these require a lot of space and there was insufficient space available inside the building. Also, since Blackthorn were going to install DPFs upstream of the SCR catalytic converters, the issue of blocking by soot and dust would not arise. Therefore Blackthorn opted to use substrates made from metal foil with relatively small channels, with the result that the required surface area could be provided in a more compact unit.

Blackthorn specified round substrates which made them easier to connect to the adjacent tubes (most suppliers use square substrates on large engines). The substrates were coated with vanadium pentoxide, in a formulation optimised for the exhaust gas temperatures which had been identified during the data-gathering stage.

SCR catalyst element

SCR catalytic converters cont

Five SCR catalytic converters in line were used on each engine, followed by a sixth which had an oxidation coating to get rid of any excess ammonia present in the exhaust.

Upstream of the SCR catalytic converters there was a section incorporating the nozzle through which the urea solution was injected and also an expansion chamber which provided the necessary dwell-time for the urea solution to evaporate and convert into ammonia.

Fabrication

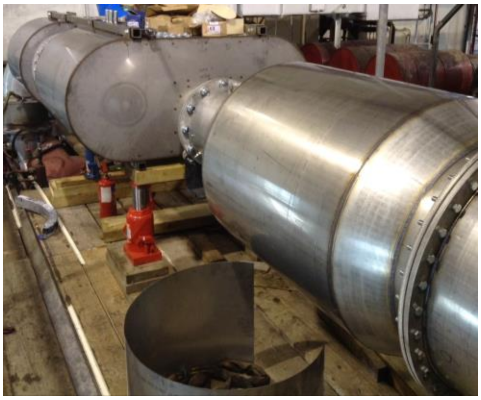
The fabrication of the exhaust components, brackets and day tanks was carried out by a sheet-metal company specialising in stainless steel, located near Portsmouth. Since they were only about two hours' drive from the site, it meant that any minor changes required could be accomplished quickly.

DPF Module

Installation

Removal of the old exhaust system and installation of the new one was carried out by a company which specialises in pump maintenance and is one of Thames Water's 'framework contractors'.

This company was ideally suited to the task since they were familiar with Thames Water's requirements in terms of site safety etc and had employees with a range of skills including electrical. In addition, they had sufficient manpower and equipment to move large and heavy items.



Exhaust During Installation'

Commissioning

When the exhaust systems had been installed, the supplier of the reductant injection system sent a technician to site to check that their system had been installed correctly, and then to calibrate the dosing of the reductant to achieve the maximum possible conversion of NOx whilst minimising any excess ammonia left over. This was a difficult task since it was impossible to maintain a fixed load condition, or to simulate extreme conditions which would only occur during periods of very heavy rainfall. The load on the engines was inversely proportional to the head of water on the inlet side of the pumps, however once the engines were started this declined and could only be built up again by stopping the pumps and waiting several hours. Because of the impossibility of simulating particular load conditions, or of repeating load conditions which had already been experienced, the relationship between the reductant dosing and the fuel flow had to be extrapolated.

Nevertheless, under the conditions present on the day of commissioning, a reduction in NOx of 94-96% was achieved which comfortably exceeded the design criteria, and there was no noticeable smell of ammonia outside the building.

Conclusions

Since the installation of the new exhaust systems at Greenwich there have been no more complaints from residents and the site is now compliant with the forthcoming MCPD.

There have been no operational problems with the pumps, no noticeable ammonia emissions, and the noise levels are no greater than before.

If Blackthorn carries out future projects involving pumps where different load conditions cannot be simulated, it would be preferable to base the dosing of the reductant on the signal from a NOx sensor, which would make it possible to set up the calibration for conditions which only occur very rarely.

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