NOx Emissions, Marine Steam Boilers and the LNG Re-gasification Ship

Introduction

With the advent of LNG carriers having onboard re-gasification facilities, either as FSRU's (Floating Storage and Regasification Units) or RV's (Regasification Vessels), the emissions from the ship's steam boilers have come under new scrutiny. This is also the case for many of the proposed LNG FPSO projects where large steam boilers are under consideration for power generation purposes.

To date, the dual-fuel steam propulsion plant of conventional LNG carriers have no exhaust emission limits imposed on them, such as NO_x (nitrous oxides) and CO (carbon monoxide), unlike the heavy fuel burning engines of other ships which must comply with IMO MARPOL Annex VI. However, with some ships now re-gasifying the LNG, and hence having prolonged or even permanent station just offshore, the local land environmental regulations for air borne emissions are being imposed, as they would be for new land power plant and alike.

To re-gasify the LNG, a significant amount of heat is required. Such heating systems are either open loop, where vast quantities of sea water are used, closed loop where the LNG carriers has it's own heating plant, or a combination of both open and closed loop. For the various FSRU and SRV projects undertaken so far, closed loop or a combination of closed loop and open loop systems have shown to be preferred.

The steam LNG FSRU, whether new or converted to have re-gasification ability, benefits from having a large steam plant for propulsion. This is idle when the ship is moored and can therefore be used for cargo re-gasification purposes. Hence, the steam plant has a dual function to also provide the heat for re-gasification of the LNG cargo.

In some cases, like the FSRU *Golar Spirit* (below), the size of the existing steam plant is sufficient for the required maximum re-gasification rate. However in other cases, including Golar's other FSRU project, *Golar Winter*, additional boilers are installed.

Marine boilers, and in particular the existing propulsion boilers on LNG carriers, do not lend themselves well to reducing NOx. This has become an issue to shipowners, and in some cases an unexpected problem, as their thinking was that only a change of burners was required.

NOx Formation & Considerations

The formation of NOx from fuel gas firing is related to the peak flame temperature in the boiler furnace. In simple terms, the higher the peak flame temperature, the higher the NOx, as more nitrogen from the air is oxidised as part of the combustion process.

Combustion techniques to reduce NOx have been around for many years, and companies like Hamworthy Combustion invest heavily in R & D programs in search of the "holy grail" of zero ppm NOx, for all types of boilers and fired heaters. The combustion techniques include low excess air operation, staged fuel injection, staged air mixing, flue gas re-circulation, over-fired air and steam injection. All these reduce the peak flame temperature.

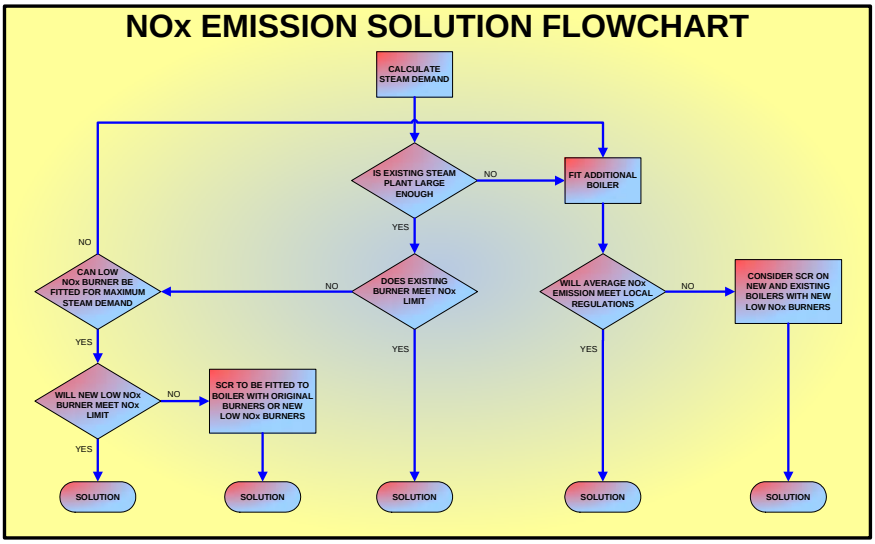
These combustion techniques result in less intense and therefore large flames which require boilers with large combustion chambers (furnaces). However over the years, marine boilers have been reduced in size to make engine rooms as small as practical, to maximise the cargo space. Furnaces of the marine boilers have been reduced which has resulted in furnace heat release rates of typically 1.1 MW/m^3, and in some cases as high as 1.4 MW/m^3. This being in comparison to land power boilers where ratings circa 0.5 to 0.7 MW/m^3 are more typical.

The NOx reducing techniques all have the effect of "de-stabilising" the flame. Thus the target is to maintain a stable flame with minimum NOx.

A low NOx flame is therefore one that is often on the edge of in-stability. On land applications this is acceptable as atmospheric variations are small and regular, and boiler loads are relatively steady. On ships however the operation and conditions on the burners is far more complex. Burners on multiple-burner boilers are regularly lit and extinguished, steam demand variations are wider ranging, and factors such as ambient temperature, ship's movement and even engine room pressure more changeable.

With planning and evaluation the shipowner can achieve the required NOx emission levels from the boiler plant for his FSRU or SRV / RV. The final configuration needs to be thoroughly assessed and optimised on a case-by-case basis. A full understanding of the applicable regulations and consultation with the appropriate environmental protection agencies is also important.

A flowchart of how the thought process might be for an existing steam LNG carrier that is to be converted to an FSRU is given below:



You will see from the above that in some instances combustion techniques alone will not achieve the low level of NOx necessary. Sub-30ppm NOx is regularly achieved by combustion techniques alone on land power plant, however such boilers are very large compared to their output and hence not well suited for offshore installations and ships where available space is restricted.

An option for the shipowner is to fit NOx removal systems to the boiler exhaust. These systems, termed SCR for Selective Catalytic Reduction, are very efficient, removing in excess of 80% of the total NOx. They come at a premium though as they are expensive, large, and incur operational costs as they continually consume ammonia (in the form of urea). They also require additional electrical power due to increase flow resistance that must be catered for by the boiler's forced draft fan.

A combination of low NOx combustion and SCR can give very low single ppm NOx levels for the ship. If the NOx and CO_2 emissions associated with producing the SCR catalyst and urea consumable were also to be taken into account, the overall environmental benefit may be questionable. It may therefore be more environmentally beneficial to fit the best possible low NOx combustion system only such that the global emissions are less than if an SCR system was also fitted.

Conclusion

In conclusion, the combustion techniques certainly exist to satisfy the imposed emission levels when LNG carriers are stationed for long periods just offshore. However the boilers of existing ships however do not have furnaces large enough to enable these techniques to be applied. Hence future projects will most likely see new boilers fitted that are designed to suit, or partial NOx reduction by combustion techniques with exhaust gas SCR systems.

To date Hamworthy Combustion have only needed to apply their first generation of low NOx register burners on ships and offshore, such as the DFL burner (right). When the time comes that ultra-low NOx levels are required, Hamworthy Combustion's leading edge proven power burners such as LNOG and Eco*Jet* ® are already available.