EGR operated engines process water equipment operational safety procedure

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Abstract: *In this publication the wash water subsystem features of an exhaust gas recirculation (EGR) system of marine diesel engine are considered. In regard with the safety of the operation, a procedure for handling the wash water system of the EGR is proposed. The chemical reactions between the flue gas and the process water are observed. The wash water system components and their specifics related to the chemical reactivity are presented. The problems with the water impurities, pH value and the operation of the EGR system are highlighted. The engineering crew special precautions on safety on using caustic soda on board is considered. Recommendations are proposed.*
Keywords*: EGR WASH WATER, CAUSTIC SODA, MARINE ENGINE EGR, EGR WASH WATER SAFETY PROCEDURE*

1. Introduction

There are unusual circumstances for the engine operation with additional EGR. Chemical reactions force aggressive chemical impact on the metal surfaces in the EGR scrubber. Routine maintenances must be carried with special precautions from the operators view. The engineers used to the daily routines are not familiar with the new challenges of the aggressive chemicals as it is the caustic soda.

The aim in this publication is to be determined the weak points of the EGR process water system form operational point of view. The tasks related to the aim are concluded in a review of the specifics of the wash water system particulars and to suggest a safety procedure for the companies operating EGR systems concerning a safe and efficient operation of the EGR wash water system.

In this publication the intention is to underline the specifics of the physical and chemical properties of the caustic soda related to the personal safety of the personal on board. From other side it is important to be known the delicate behavior of the washing water chemical stability and ability to keep the system operational without to build up large deposits through the system.

Considering the specifics of the above stated a procedure with explanations of the importance of the described steps in it is proposed to be incorporated in the ship management companies SMS to obtain a reasonable and practical guide for the engineering department to safely handle the EGR wash water system.

2. *The EGR wash water system components*

The EGR wash water system has the following main components: scrubber unit with water spraying nozzles to the gas stack, process tank, circulation pump as main unit and water treatment system for the water quality conditioning shown on figure (1). The water treatment system contains a filtering unit and additional buffer tank not shown in the figure (1).

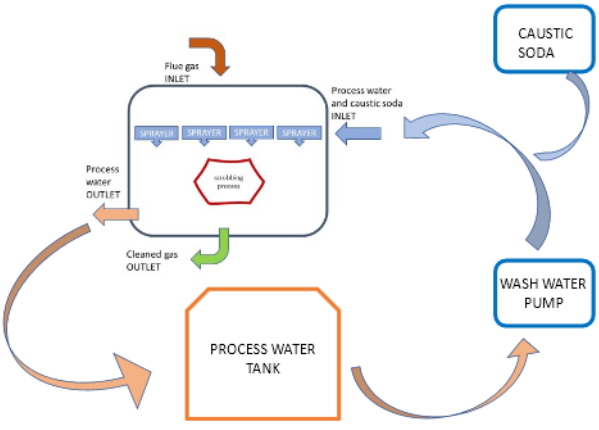

Fig. 1 *EGR water washing system.*

The EGR water washing system has basic function to neutralize the acidity of the flue gases returned to the engine scavenge system and to reduce the sulfur content, black carbon and particular matters. Proper operation of the cleaning system is a must for normal operation of the engine without contamination. Improper cleaning of the gases returned to the scavenge system will lead to contamination and probable failure of the engine.

EGR system operation failure means in most cases not compliant operation of the engine to the environmental requirements in force. There are several critical points which may lead the EGR system to shut down for short or long term, depending on the circumstances. Mode fluctuations and controller misalignment may lead to short stoppages of the system, but severe contamination and system components failure seems to lead to long term shut down. Further this condition may lead to extensive repair works, delays in the engine operation and profit losses. Material strength and durability is important for the reliability of the volume where the chemical neutralization is performed. The proper operation and maintenance of the EGR components are critical for increasing of the probability the system to fail. Related to the latter the operator's knowledge determines the safe operation.

3. *The chemical reaction of the sulfur oxides and the salinity/alkalinity ingredients of the wash water*

The wash water chemical composition changes with the process of the EGR operation due to the combustion products contamination. Not only the visible particles of ash and black carbon are inserted, but also the pH value is reduced as the interaction between the exhaust gas stack and the water continues. The sulfur oxides SO2 and SO3 reacts with the water and the injected caustic soda in the following manner [1]:

$$SO_2 + H_2O \rightarrow H_2SO_3 \text{ and/or } SO_3 + H_2O \rightarrow H_2SO_4 \quad (1)$$
$$Na^+ + OH^- + H_2SO_3 \rightarrow Na^+ + HSO_3^- + H_2O \text{ and/or} \quad (2)$$
$$Na^+ + OH^- + H_2SO_4 \rightarrow Na^+ + HSO_4^- + H_2O \quad (3).$$

With the pH value varying and the reaction products build up in the system it can be reached level of the sulfites and sulfates to dissolve from the process water and to soft plug the pipelines and the process tanks [2]. The water cleaning system must be kept with special precautions in fit condition so to keep the ability of the water to be sprayed through the scrubber nozzles. If closed loop water system is used, the proper cleaning of the water is on vital importance for the system operation.

Depending on the approach, if sea water is used the process water must be refreshed to keep the salinity at reasonable range to keep the sulfates and sulfites solved. In case of fresh water, the chemical composition must be kept by proper dosing of caustic soda and freshwater addition, so to not to reach the saturation of the sulfates and sulfites and latter to precipitate and to plug the system lines. Meanwhile the reaction of the CO2 with the water changes

the pH value thus changing the tendency of the water to change its dilution properties to the sulfites and sulfates produced [3]. It is very important to keep continuously the pH at an optimum value to not to overlap the lower limit and to start soft contamination build up in the process water system.

The set-up of the pH control system must be fast reacting to changes in the process. The unreasonable addition of process water to restore the quality may become problematic in case of closed loop operation by filling up the process tank and the overflow tanks (if any). This process must be controlled carefully especially in case of long-term operation without to be possible the wash water to be discharged.

Depending on the fuel type and its sulfur content there may be divided two basic differences. The new fuels with low sulfur content up to 0,5% have lower impact on the required capacity of the EGR unit compared to the fuels with sulfur content up to 3,5%. This old fuels with high sulfur content have greater capacities of the scrubbers and higher demand on their performance due to the larger amount of sulfur oxides present. With the new low sulfur fuels and with the gaseous fuels with virtually no sulfur content, the scrubbing process is facilitated but still there is a need of special attention to be paid to the system performance.

4. Caustic soda application on EGR gas cooling/cleaning system

The application of the caustic soda in the marine engineering practice is not widely known. The recent requirements of the new EGR technology and the general sulfur oxides (SOx) scrubbing applications have forced the need to use caustic soda in the everyday routines in the engine room. For safety reasons there must be underlined the hazard potential of the caustic soda to the human health and its aggressive nature to the surfaces which it gets in contact. Main milestones to be considered are the health hazards and its incompatibility with color metals as aluminum, magnesium, tin, and zinc with which the caustic soda forms flammable hydrogen [4, 5] The chemical reaction of the caustic soda with the metal is done as:

$$2Al + 6\ NaOH \rightarrow 3\ H_2 + 2\ Na_3AlO_3 \quad (4).$$

The physical properties of the caustic soda tend to be problematic with its appearance – clear colorless and odorless liquid just like the water. In case of spillage, it may be not recognized from first impression. Any spilled water looking liquid must be investigated with care. Mixing caustic soda and water in relatively comparable quantities is related with exothermal reaction. Diluting caustic soda with water may become problematic. Before any mixing of caustic soda and water all the precautions must be taken to face the potential hazards of the heat release.

Depending on the solution percentage, the commonly commercially used 50% solution with water has freezing temperature at 12 ºC. This temperature is relatively high and in the range of the temperatures seen in the engine room, especially in winter conditions. For that reason, proper heating arrangements must be used to keep the tanks and pipelines for the caustic soda at warm condition and in no case, they may be left non-operational.

In case of caustic soda leakage, it can be very dangerous given its toxicity and corrosive nature. Once exposed to air the chemical will begin to crystalize forming into a white scale. When pumping caustic soda its primary leak paths are flange gaskets and mechanical seals. When caustic crystalizes on a mechanical seal its abrasive crystals and corrosive properties damage the seal face increasing the potential for increased leakage. This leads to frequent mechanical seal maintenance [7]. Gasket materials for general use are not suitable to handle caustic soda. Acceptable performance with sealing this liquid has the Teflon material. In no circumstances the Teflon may be replaced by general purpose gasket material.

5. Construction materials for pipelines and scrubber unit

Conventional materials as carbon steel or color metals are not suitable when handling aggressive chemicals as the caustic soda. Known from the chemical industry the stainless steels are suitable to be used for construction material of the wash water system.

Usually, the pipeline material is stainless steel but for the scrubber body it must be used more specific material as it is the duplex stainless steel. Duplex stainless steel gets their name from the fact that they contain both a ferritic and austenitic microstructure. They have a relatively high chromium content of between 18 and 28%. Nickel content is moderate at 4.5 to 8%. At this level, the nickel content is too low to generate a fully austenitic structure. This results in a duplex microstructure containing both ferritic and austenitic phases. Duplex stainless steel also tends to contain 2.54% molybdenum [8]. The prime advantage of duplex stainless steel is the combination of properties derived from both austenitic and ferritic stainless steel.

Duplex stainless steel has: Excellent corrosion resistance; Increased resistance to chloride attack; Good resistance to stress corrosion cracking; Tensile and yield strength higher than austenitic or ferritic grades; Good weldability; Good formability [8, 9]. Fabrication and repair works of all stainless steel should be done only with tools dedicated to stainless steel materials. Tooling and work surfaces must be thoroughly cleaned before use. These precautions are necessary to avoid cross contamination of stainless steel by easily corroded metals that may discolor the surface of the fabricated product [10]. Further it may result in intensive corrosion process. Proper washing of the surfaces from residual caustic soda is critical to be done before maintenance to be carried out.

6. Safety procedure proposal to the ship management companies

Respecting the problems considered in this publication, related to the chemical reactivity it may be stated a basic instruction for proper actions when handling the EGR wash water system as follows:

- Strictly follow the chemical composition of the wash water content. If marginal condition of frequent sediment builds up in the system occurs, consider readjustment of the process controlling the wash water refreshment or caustic soda addition.

- Handle with care the system for caustic soda storage and transfer. Avoid use of colored metals in the system pipelines and gasket material different than Teflon, especially during repairs.

- Metal surfaces of the scrubber/cooler keep with great care to avoid metal contamination and rapid corrosion.

- Use proper PPE when handling the caustic soda. Especially when working within the units flush the surfaces thoroughly before any action to be carried out.

- Keep caustic soda heated up above freezing temperature (relatively high). If for prolonged period the system to be out of operation, flush the system pipelines with water.

Conclusions:

The task in this publication was accomplished in respect to be created general safety procedure while handling EGR wash water systems, related to the subjects investigated in the present study. The background of the simple tasks to be performed was detailed with the nature of the problems which may occur, while working with the EGR wash water system. The following features remain due to be considered by the ship operators:

- The wash water system of the EGR requires additional special attention related to the safety of the crew.

- There are specifics in the chemical reactivity of the caustic soda which are to be considered by the engineering crew while handling the EGR system.

- System repairs with exchange of different components must be done only with respect of the proper material intended to use.

- Metal contamination of the stainless-steel material may lead to fast corrosion process and component failure.

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