Reducing NOx SCR vs FGR

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1) **Q: Interested in Flue Gas Recirculation vs Catalytic for NOx Reduction in diesel generation (plus steam and HW boilers)**

   A: Flue Gas Recirculation is commonly used for diesel generation (assuming you are talking about diesel engines coupled to a generator). In these types of applications, it is called EGR (vs FGR) and it stands for Exhaust Gas Recirculation, but we are talking about the same principle. SCR can be used on diesel engines using low sulfur oil to reduce NOx as well.

2) **Q: Does Flue Gas Recirculation reductions meet the CA air quality requirements?**

   A: I am not familiar with all the different local air quality requirement for California. An ultra-low NOx burner with about 20-25% FGR can achieve single digit NOx level (down to about 8 PPM). If regulations limit the amount of FGR to anything lower than that, or if a lower NOx limit is required, an SCR will be required.

3) **Q: How to determine the ratio of air and the FGR?**

   A: On large system, the FGR flow will be metered and controlled. For smaller unit, the amount of FGR is determined by measuring the stack O2 and wind box (downstream of the FGR point of injection) O2. These two values allow us to determine the amount of FGR.

4) **Q: When utilizing FGR, how does one verify the amount of FGR actually being utilized (in %)?**

   A: See question 3 above

5) **Q: Capital cost pf ammonia setup?**

   A: The CAPEX cost of adding ammonia (SCR) was given for 2 different scenarios. For smaller 80,000 lb/hr unit, it was 33% higher compared to FGR. For larger 400,000 lb/hr unit, it was 5% higher, which was close and prompted a closer look at OPEX.

6) **Q: Does that include chemicals such ammonia?**

   A: Initial CAPEX costs presented did not include first fills of ammonia, or any other consumables. OPEX analysis added cost of ammonia consumption, and assumed all other consumables like water chemicals and plant air were equal.

7) **Q: Can you review the con of pressure drop for SCR?**

   A: Adding extra pressure drop in the system requires more FD fan HP, but so does more flow due to FGR. You also need to make sure the furnace and breaching are designed for the additional static pressure.

8) **Q: Can you explain which SCR system DEF is?**

   A: DEF stands for diesel exhaust fluid, and is a form of urea commonly used on diesel engines.

9) **Q: What happens if you run an SCR with expired catalyst? How much does it cost to replace catalyst?**

   A: There is no danger in running a boiler with “expired” catalyst. NOx will increase and ammonia slip will increase. This being said, catalyst effectiveness decrease is a very slow process, which is easy to track. The cost will be proportional to the amount of catalyst used.

10) **Q: In the OPEX table, the operating cost of replacing the catalyst every few years is not included. Any idea of the catalyst cost?**

    A: The cost of replacing the catalyst varies on a case-by-case basis depending on the amount used for a given application. For smaller boilers, it could be as little as $10,000 US, for larger industrial-scale units, it could be in the range of a few hundred thousand.

11) **Q: Do you see the need to use all the means to lower NOx at the same time (e.g. low NOx burners with SCR)?**

    A: It obviously depends on the NOx level we want to achieve. Being a supplier of both, low NOx burner and SCR, we look at the most effective combination of strategies to optimize the NOx reduction with the lowest capital and operational cost possible. It is not uncommon to combine technologies to achieve the desired emissions regulations while preserving efficiency and performance.

12) **Q: The NOx PPM you mentioned are all at 3% Oxygen I assume. Is this correct? (in Gas Turbine applications we use 15% O2)**

    A: This is correct. These are just reference numbers and can be converted from one another.

13) **Q: Can you give us an idea of NOx limits for different areas of the USA?**

    A: For natural gas firing, most of the USA are allowing 30-80 ppm NOx.

14) **Q: What is the catalyst material?**

    A: It can vary depending on the application, but generally it is a mixture of vanadium and tungsten oxides.

15) **Q: In your examples, I noticed you included an increase in natural gas cost associated with adding FGR. How do I evaluate this increase in natural gas costs associated with FGR vs non-FGR?**

A: Simple. When comparing FGR to SCR, there is no increase in natural gas cost for SCR.

16) **Q: Did the SCR OPEX analysis include replacing the catalyst?**

A: See question 10.

17) **Q: Do SCR systems discharge ammonia in flue?**

A: Yes it does. This is what we referred to as the "ammonia slip". Typically between 5 and 10 PPMvd, @ 3% O2 reference.

18) **Q: Is there a size/$ difference of FGR vs ULNB boilers... under 100 mmBtu/hr Industrial Boiler?**

A: FGR is used to achieve "low-NOx" (LNB) levels down to approx. 20-30 ppm. FGR + Excess Air is used to achieve "ultra-low-NOx (ULNB) down to approx. 8-9 ppm. ULNB burners are always more costly, but the size/$ is a function of many variables. There is no rule of thumb and it must be evaluated on a case-by-case basis.

19) **Q: What happens if you run an SCR with expired catalyst? How much does it cost to replace catalyst?**

A: See question 9.

20) **Q: Would you put the SCR upstream or downstream of the FW economizer?**

A: Because the SCR efficiency increases as the temperature increases (within limits), it needs to be installed upstream for the economizer.

21) **Q: What residence time is needed for SCR?**

A: The reaction is quite rapid, but the residence time will be dependent on many factors, like temperature and reduction efficiency required. Sizing of the catalyst will take all these factors into account.

22) **Q: What is the catalyst material for the ammonia/NOx?**

A: See question 14.

23) **Q: We talked about O2 Trim control at one time. With FGR factors into the equation, how do these two control systems work hand-in-hand?**

A: Very good question. If there is a price for the best question, this is the winner. One must remember that combustion is a mass based reaction, while the way we control it is volume based. The role of the O2 trim is to compensate for varying

conditions (most of the time air density variation) to make sure that the amount of oxygen in the reaction is always sufficient, but never too much. So the O2 trim will always make sure that you have enough mass of air for the combustion to occur cleanly and efficiently. The amount of FGR is expressed as % of mass, so O2 trim and FGR do work hand in hand. The FGR amount is varying as a function of the firing rate, or mass flow of fuel. Since O2 trim always make sure the mass flow of air is proportional to the mass flow of gas, FGR and O2 trim work hand in hand.

24) Q: Is low NOx burner needed for FGR or SCR to achieve lower NOx?

A: There are basically three ways to achieve lower NOx:

- Add FGR
- Use Low NOx burner, alone or in conjunction with FGR
- Use SCR, alone, or in conjunction with low NOx burner (itself with or without FGR)

This being said, adding FGR to an existing burner is not always possible. Burners will have a different design if they are used with FGR (to optimize the stability), so adding FGR to an existing burner could lead to instability problem. Always check with the manufacturer to determine the maximum amount of FGR that can be used with the burner.

25) Q: How the NH3 injection is controlled as per the load variation in SCR case and also SNCR case? How the NH3 Slip is controlled?

A: There are different methods. If a CEMS is present, the amount of NH3 injection will be modulated to maintain the target NOx level. If no CEMS is present, the amount is defined at commissioning based on the firing rate. NH3 slip is typically controlled with a sensor and an alarm linked to the control system.

SNCR is not applicable to packaged boilers, which were the basis for our webinar.

26) Q: Where does digester gas fall regarding fuel bound NOx and are any additional measures required for the 3 reduction strategies?

A: Digester gas is by itself a “low NOx fuel”, because of its typically low flame temperature. Although digester gas analysis can vary a lot, it typically does not have any fuel bound nitrogen (the one creating fuel NOx). The nitrogen present in digester gas is diatomic nitrogen, like the one contained in combustion air.

This being said, digester gas typically has lower limits of flammability vs natural gas, so using large amount of FGR to further reduce NOx could be challenging. Use of an SCR can also be problematic if the digester gas contains poisons that could attack the material of the catalyst. These jobs need to be looked at on a case by case basis.

27) Q: Can an SCR be installed in a horizontal run of the exhaust stack?

A: Yes

28) Q: Does Cleaver-Brooks and other boiler makers also design and make the SCR and FGR or need separate vendor?

A: Cleaver Brooks designs and makes all components of the boiler room, including low NOx burners, FGR systems and SCR. This is our single source responsibility approach. We cannot comment about other boiler makers.

29) Q: What about SNCR for NOx control?

A: SNCR is used on large field erected boiler, typically with limited operational flexibility. It is currently not used on package boilers. Reason is that SNCR has a very narrow temperature window to be effective. Package boilers with their large turndown capability makes it nearly impossible to inject the urea at a location where temperature remains within that window for all different operation loads.

30) Q: Do these NOx regulations apply to all fired heaters or just boilers?

A: We can only comment on the regulations we see as a boiler OEM, which are those presented during the webinar.

31) Q: Are we worried about how caustic the ammonia is?

A: Obviously. Use, and specially storage, of ammonia is heavily ruled. Special permits are required. This is the reason why aqueous ammonia is preferred on large systems.

32) Q: Do you see the need to use all the means to lower NOx at the same time (e.g. low NOx burners with SCR)?

A: Depending on the NOx level required, and the operating requirements of the boiler, it might be necessary to use all NOx reduction methods simultaneously.

33) Q: What about Operating cost diff between the two options?

A: For the larger 400,000 lb/hr scenario, OPEX was analyzed given the nearly identical CAPEX cost. For the smaller 80,000 lb/hr scenario, OPEX was not analyzed during the webinar given the 33% premium for SCR and also due to time constraints. However, we strongly encourage all potential buyers to evaluate both CAPEX and OPEX.

34) Q: What happens if you run an SCR with expired catalyst? How much does it cost to replace catalyst?

A: See question 9.

35) **Q: In the OPEX table, the operating cost of replacing the catalyst every few years is not included. Any idea of the catalyst cost?**

A: See question 10.

36) **Q: What happens if you run an SCR with expired catalyst? How much does it cost to replace catalyst?**

A: See question 9.

37) **Q: when you replace the catalyst on a SCR, is it considered hazardous waste?**

A: I am not sure. I don't think it can be put with the household waste, but I think that most of the time it is recycled by the manufacturer.

38) **Q: How the NH3 injection is controlled as per the load variation in SCR case and also SNCR case?**

A: See question 25.

39) **Q: Is there any risk of NOx levels drifting in time with either technology?**

A: No more, but no less, than other parameters in combustion. Annual maintenance is recommended.

40) **Q: Are you involved in the permit process from start to finish or do we start it after the bid process?**

A: As an OEM, we do not get involved in actually obtaining the permits, but we are happy to assist ahead of the bid process as the allowable level needs to be defined to allow manufacturers to propose the appropriate system.

41) **Q: Why didn't you consider for the smaller size boilers the operations cost? Is that insignificant, or?**

A: See question 33.

42) **Q: When permit is given how long is it good? Does it cover the life of the boiler?**

A: Regulations can vary at any time. We are aware of many units being "grandfathered", meaning they are allowed to operate above the latest regulations.

43) **Q: Was the catalyst replacement every 3-5yrs included in the FGR SCR cost comparison for larger boilers?**

A: See question 10.

44) **Q: when permit is given how long is it good? Does it cover the life of the boiler?**

A: See question 42.

45) Q: How the NH3 Slip is controlled?

A: See question 25.

46) Q: Can FGR use reduce or eliminate the air preheater?

A: Not really. In fact, FGR will slightly increase the boiler outlet temperature (everything else being equal). For gas combustion, since the main NOx mechanism is thermal, which is highly dependent of temperature, removing the air preheater will have a dramatic effect on NOx emission.

47) Q: What is the best NOx (ppm?) reduction using only low NOx burner without using FGR and SCR?

A: It is dependent on the boiler, but levels of 50 PPM, and sometimes even lower, have been achieved.

48) Q: Is there any risk of the residual ammonia damaging the economizer if it is upstream? Do you need stainless tubes?

A: No, carbon steel is acceptable for contact with ammonia.