**We Need to Knock the NOx - extra credit challenge**

**Background:** There is a steel mill in Formosa that makes coarse wire. Coarse wire is an intermediate wire that has a diameter of 1.25 to 0.25 inches. The coarse wire began as a rod of metal which subsequently has had its diameter reduced and as a result it becomes longer. Coarse wire has the characteristic of being able to be coiled. The coarse wire is mild steel.

Part of its fabrication process is that in drawing the wire through a die, its diameter is reduced and it is work hardened. In order to further reduce its diameter, it needs to be annealed. Annealing consists of heating the wire to circa 1200 - 1400 degrees F for a specific length of time to allow the crystals to regrow and thereby creating a softer, more malleable material.

Because this annealing is performed in an open furnace, an oxide film is created on the surface of the wire. This iron oxide film must be removed so that the surface of the metal is clean when it is processed further.

The metal is cleaned using a 20 % nitric acid pickling bath. The nitric acid reacts with the iron oxide forming iron nitrate. Urea is added to the pickling bath to help stabilize the reaction rate. The reaction involves the generation of copious amounts of red nitrogen oxide gas. (I am purposely keeping the chemistry simple).

The government has passed new NOx regulations, and the nitrogen oxygen emissions need to be reduced and controlled. The replacement of the nitric acid is not an option, nor is it economically feasible to anneal using a reducing atmosphere which would not create an oxide film.

It is also not feasible to water scrub the NOx and recover nitric acid.

**Time:**  1998

**Challenge:** The firm has created a team of three PhD chemists to address this situation and to come up with a solution that will enable the plant to maintain compliance. They perform the theoretical chemistry, modeled the process, and determined that there should be no more than 40,000 pounds of coarse wire in each pickling load. Unlike the annealing process, the pickling process is a batch type process. 40,000 pounds of coarse wire would be lowered into the bath for circa 5 minutes, the reaction will take place with frothing to physically remove the oxide scale and then chemically consume it. The urea stabilizes the reaction rate. The tanks are at a nominal 80 degrees F. The cleaning reaction is exothermic, and the temperature of the metal when it is immersed is ambient - circa 70 degrees F.

For the most part everything is going well, however once or twice a week there is an uncontrolled episode. The tank goes up to 120 degrees F, and copious amounts of red gas exit the process - a non-compliance situation par excellence.

No matter what they do, they cannot eliminate the uncontrolled episodes.

Their consulting engineer called me to assist.

**Questions:**

1. What information was needed to solve the emissions problem/risk?
2. How can the uncontrolled episodes of emissions to the atmosphere be eliminated?

 **Conclusion:** The problem was solved after one telephone call and after the receipt of a three-page document.