ATSI
Applied Technology Specialists, Inc.
Environmental Technology Experts

A Process Gas Abatement System Eliminates Back Pressure Buildup And The Need for Bypasses

Background

In the late 1990s, several semiconductor manufacturing firms experienced property and product losses caused by process gas point of use (PoU) abatement equipment. The author of this paper has provided technical analysis to several law firms involved in litigation of cases where losses took place. Some modern operations require the use of process gases that produce significant quantities of solid reaction products when oxidized. Oxidization is the most frequent method used by process gas abatement systems. One example is the deposits of Tungsten trioxide (WO_3), the oxidization product of Tungsten hexafluoride (WF_6) that is frequently used to form Tungsten (W) deposits.

Because the WO_3 deposits tend to be "fluffy" agglomerates (See SEM to the left) that collect in the PoU equipment, back pressure to gas flow results. Several PoU equipment manufacturers build in an exhaust gas bypass to allow a process tool to complete a run by sending untreated exhaust gases to a central facility water scrubber or a separate abatement system, such as a dry scrub unit. This procedure is adequate for the occasional upset but is not acceptable for frequent use because of added expense or inadequate abatement of the gases used. A second danger is also present, and that is the formation of metastable compounds produced during cooling of some thermally cracked process gases such as Silane (SiH_4) and Phosphine (PH_3). This problem is minimized by placing the abatement tool as close as possible to the process equipment exhaust port. Diverting untreated exhaust streams to a secondary abatement system frequently increases the danger posed by these exhaust components. In May 2006, Applied Technology Specialists, Inc. (ATSI) embarked upon a development program to develop a new abatement technology to address these many exhaust problems. This technology was developed to dramatically reduce solids buildup on all surfaces in the gas train. In addition, the system was developed to minimize energy use by focusing energy only where it is needed. Two of the three coaxial oxidizer designs are complete, and allow the efficient destruction of a wide range of process gases.

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Development Program

In late 2006, the company was contacted by a large manufacturer of light emitting diodes (LEDs) in search of an abatement system that would process several reduced pressure reactor exhausts in a more reliable and efficient manner then was currently being used. Abatement has been done with vintage Guardian 8 abatement systems, followed by additional processing to remove entrained particles from the exhaust of the Guardians. While Guardians are quite reliable, in this application, they still require cleaning once per week. This necessitates the removal of four process reactors from service while the cleaning takes place. The reactor exhausts contain compounds that make abatement a very difficult operation. Large quantities of PH_3 and AsH_3 in a H_2 carrier produce heat, water, Phosphorus pentoxide (P_2O_5, really the double molecule P_4O_{10}) and the double molecule of Arsenic trioxide, As_2O_6 which are produced in the abatement exhaust streams. This mixture is a toxic, acidic wet paste that is difficult to contain or filter. The company began searching for integrated systems to replace the existing Guardians in order to reduce the burden placed on it with these outdated systems. The company evaluated two abatement systems, the BOC/Edwards Zenith III/V and Metron Marathon, both integrated abatement systems. After extensive testing and evaluation, neither of these systems proved to be acceptable for this application.

In late 2006, the company contacted ATSI with the challenge to come up with a new abatement system that would address as many of their exhaust abatement problems as possible. We evaluated their abatement needs and set out to configure a system with the following goals:

1. Little or no particle accumulation within the system

2. No bypass needed or allowed

3. Require lower facility air exhaust than the existing systems

4. Should be as simple as possible

5. Should be very easy to service if needed

6. Design should be rugged, inherently safe, and tolerant to unexpected upsets

7. Should be significantly lower in capital and operating costs than other available systems

In order to achieve these goals, we chose to integrate three of our technologies. These are:

1. A coaxial oxidizer module with transport conduit
2. A Residual Gas Reactor configured as a low pressure drop high energy water scrubber

3. A cyclone particle separator in place of a coalescing filter to eliminate the possibility of plugging the filter

These systems were then controlled by a PLC and touch screen operator interface.

A sketch of the system can be seen as Figure 1.

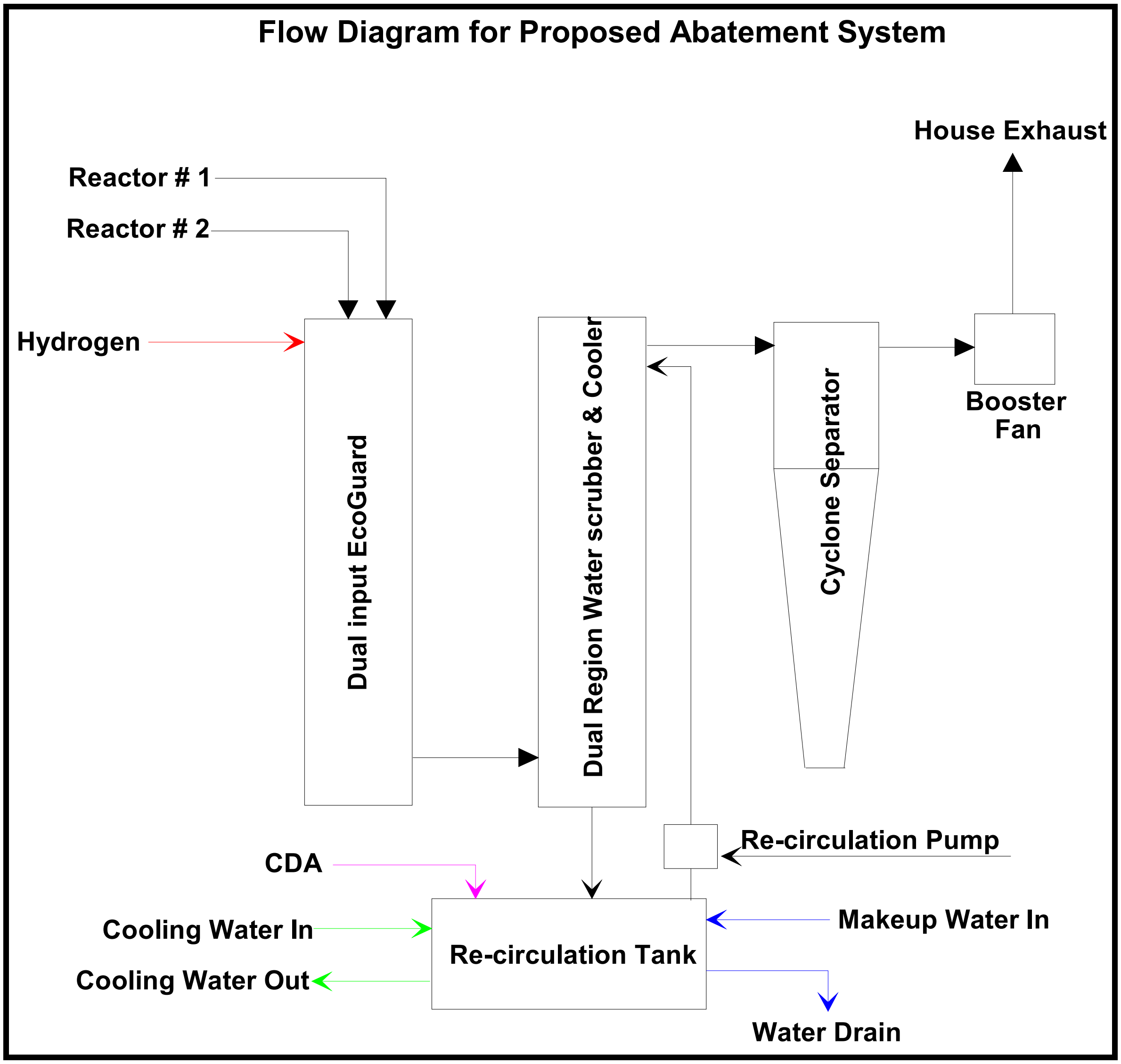

Figure 1

Since this system was built for evaluation of the technology (proof of concept), as it applied to their particular application, we did not concern ourselves with packaging and appearance. We wanted an open system for easy inspections and access to all components, therefore, it was built as such and on a skid that doubles as secondary containment.

Figure 2 is a photo of the actual system. The customer asked us to equip it with two inputs so they could add a second reactor exhaust, if needed.

Figure 2

Figure 3 is a photograph showing the coaxial oxidizer modules and transport conduit.

Figure 3

The system was installed and ducting, piping, drains, power, and any other connections were made. When the system was turned on, we made the necessary adjustments in limit switches and gas flows. The customer then spent about three weeks learning how to operate the system and began trial testing. The fan motor suddenly failed and was replaced under warranty. Following the trial testing period that lasted four weeks, the system was released to testing on an actual reactor exhaust. It soon became apparent that the flame front coaxial oxidizer was accumulating deposits of solids therefore; we removed the module and replaced it with a coaxial flame wall oxidizer module. This module showed no tendency to accumulate any deposits. Because the system is designed to be modular, changing the oxidization module can be done in just a few minutes.

Several weeks into operation, the re-circulation pump developed a leak. The customer replaced it with a pump that they stock for other equipment and we changed the nozzles to more closely match the performance curve of the new pump. The scrubber and cooling functions work very well with these changes.

In October 2007, we updated the software to include monitoring of several sensors, such as gas pressures, that the customer installed on gas lines leading to the abatement equipment. We also added a status page to the display so the maintenance personnel can look at the status of every switch, making faults easy to locate, should they occur.

The system ran for a period of fifteen months before a quick clean was done by simply pushing a brush through the transport conduit to push the “fluffy” deposits from the conduit into the water scrubber.

Since the entire system was constructed for easy access to all components as well as the interior of each element, frequent inspections have been done anytime the reactor was not in use. These inspections showed that there was no sign of any deposits in the water scrubber, ductwork, or cyclone. We decided to add a conventional coalescing filter in the top region of the water scrubber just above the top spray nozzle. The scrubber is working very well and no back pressure or any signs of particle accumulation on the filter have occurred. We are confident therefore, that no cyclone is needed in place of a coalescing filter and future systems will not include these elements. This will reduce the size, weight, power consumption, and initial cost even further.

Since the system has performed so well, the customer had us design a “piggyback” unit to be placed on the back of each reactor right at the exhaust of the process pump. The oxidizer module is fully enclosed and oxidization air is drawn in through a four-inch duct from outside of the fab area. Metastable deposits forming in the exhaust lines leading to a remote abatement device will be eliminated, along with all process gases, and reaction products. The customer feels that this type of system will reduce operating costs significantly over present abatement techniques.

This is a review of how well this system met the goals we set forth.

Goal 1 Little or no particle accumulation within the system
  Result Goal 1 has been met and exceeded our expectations by a wide margin.

Goal 2 No bypass needed or allowed
  Result No bypass needed or considered

Goal 3 Require lower facility air exhaust than the existing systems
  Result Only 40% exhaust air requirements compared to the same capacity Guardian

Goal 4 System should be as simple as possible
  Result System started as a simple design and became even simpler with the removal of the cyclone, booster pump, and interconnects ducting.

Goal 5 System should be very easy to service, if needed
  Result Modular design has made any service very easy to perform.

Goal 6 System design should be rugged, inherently safe, and tolerant to unexpected upsets
  Result With only one moving part being the re-circulating pump, and with enough air to dilute Hydrogen gas below its LEL, the system is rugged and inherently safe.

Goal 7 Should be significantly lower in capital and operating costs than other available systems

Result This system has fewer parts than most, and with modular design it can be produced with costs significantly lower than other systems with the same capabilities. Lower exhaust air and fuel requirements than other systems, along with very little maintenance requires somewhat lower capital and operating expenses than other available systems.

Conclusion It appears that our goals were met and, in some cases, by a wide margin.

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