

Environmental Concerns Addressed in The Design of a New Ethylene Plant

Greg Dunnels - ABB Lummus
Chris Gaines - Westlake Group (Speaker)
Lytton Lai- ABB Lummus
Karl Kolmetz - Westlake Group

Submitted at the 1998 AIChE Spring Conference,
to the Ethylene Producers Conference,
Environmental Subcommittee.

Environmental Concerns Addressed in The Design of a New Ethylene Plant

1.0 Introduction

To convert an empty field to a commissioned Ethylene Plant has many challenges. The input from many engineering disciplines are needed. The unit must produce the designed rate of product within the limits of guaranteed conversion, utility consumption, and the current and anticipated environmental regulations.

In designing a new ethylene plant, many environmental considerations and concerns must be carefully evaluated, and value engineering must be added into the detail design to ensure that all relevant State and Federal environmental regulations will be met, and to ensure the plant is operationally and environmentally safe. The environmental issues start back at site selection and continue into operating concerns associated with air, water and waste regulations, both current and future.

The primary environmental issues to be considered are site location, attainment verses non attainment requirements, air, waste water, solid wastes, spill prevention and controls, hazardous and non hazardous waste disposal and permitting.

2.0 Air

The location of the plant site, whether it is located in an attainment or non attainment area has a great impact on the air quality regulatory requirements and the project schedule due to the differences in construction permit application procedures and requirements. Attainment versus non attainment of National Ambient Air Quality Standards (NAAQS) determines the air quality requirements for sulphur dioxide (SO₂), nitrogen oxides (NO_x), carbon monoxide (CO), particulate mater (PM) and volatile organic compounds (VOCs) emissions.

2.1 Attainment verses Non Attainment Areas

The primary concerns in the Gulf Coast areas are the emissions of NO_x and VOCs. If the plant is located in an attainment area the regulations require you to demonstrate that you are not a major source of air contaminants. If you are a major source, you must demonstrate that your facility does not cause significant deterioration to ambient air quality, and that the Best Available Control Technology (BACT) is utilized in the design of the facility.

Under Federal Prevention of Significant Deterioration (PSD) requirements, all major new or modified sources of air emissions regulated under the 1977 Clean Air Act Amendments and located in an attainment area must be reviewed and approved by the EPA or by the state agency if it has been granted PSD review authority.

If the plant is located in a non attainment area, and is a major source based on the non attainment areas regulations, New Source Review (NSR) and Lowest Achievable Emission Rates (LAER) must be met. In non attainment areas credits must be purchased or obtained to offset emissions, but the result must show an overall improvement to air quality. Often, the permitting schedule and the extra cost required to meet the additional air requirements for a non attainment area make the location infeasible and economically unjustified, forcing the consideration of an alternate site.

For a Gulf Coast non attainment area site, NO_x and VOCs are the primary concerns. For NO_x, a heater or boiler must meet the LAER for low NO_x burner technology of 0.06 to 0.08 lbs of NO_x per MM BTU heat input depending on hydrogen content in the process fuel gas. For an attainment area site, usually 0.1 lbs NO_x per MM BTU may be acceptable to meet BACT. Low NO_x burner technology will not meet the requirement of BACT in a non attainment area which could require additional NO_x control, such as Selective Catalytic Reduction (SCR).

For a new Olefins plant design, VOCs and Hazardous Air Pollutants (HAPs) emitted from fugitive emissions sources, such as leaks from valves, flanges, air compressor seals, pump seals, storage tanks, sample connections, sewers and process vents must be well managed, whether the site location is in attainment or non attainment areas.

In the non attainment areas, special requirements for additional emissions reductions are required. For example, the Texas 28 LAER requires a special maintenance program to achieve the VOC leak rate of 500 ppm for the fugitive emission sources. The LAER also dictates the requirements of using the best seals for valves, compressors, pumps and tanks for reducing VOC and HAPs emissions. All of the NO_x, VOC, and HAPs requirements now must become part of the equipment design criteria for a new plant.

2.2 Westlake Furnaces and Boilers

The plant is located in Calcasieu Parish, Louisiana which is classified as an attainment area for all criteria air pollutants. The furnaces and boilers were modeled for NO_x and CO emissions to show that the emissions do not cause or contribute to the degradation of air quality. The ABB Lummus furnaces will meet BACT requirements by utilizing John Zink low NO_x burners and a simplified predictive emission monitor system (PEMS) will be used to determine criteria pollutant emission levels.

A BACT evaluation was performed for the five ABB Lummus furnaces for the ethylene expansion project. Wall-mounted and flat-flame burners are used to optimize the flame pattern for greater efficiency and lower NO_x formation. In addition, PEMS based on excess oxygen and firing rates is utilized to predict NO_x and CO emissions.

All of the pyrolysis furnaces and boilers at the Ethylene Expansion Project will meet BACT for CO by monitoring excess oxygen at or above 3 percent. In turn, an operating window is established which is used to predict emission rates of criteria pollutants. The boilers at the ethylene expansion project will utilize low NO_x burners and flue gas recirculation to meet BACT guidelines and New Source Performance Standards.

2.3 Flare Design

The flare system design is also a major environmental and safety design issue for a new olefins plant. In order to provide the ultimate protection to the environment and reduce the HAPs exposure of workers, all hydrocarbon relief valves are vented to the flare system. All hydrocarbons are deinventoried through a closed drain system and the drain tanks are vented to the flare system and the inventories are recycled back to the process. All light and cold hydrocarbon blowdowns are collected in the cold flare drum and vaporized and disposed of via the flare system. The flare is an acceptable combustion process by the EPA to dispose of the waste gases from a petrochemical plant.

In order not to over design the flare system and yet to provide the ultimate plant safety, the design team chose using instrument shut downs to reduce the flare load. By implementing the triple instrument concept and the multiple interlock shut down philosophy, the flare relieves were evaluated for all failure modes; cooling water, power failure, equipment trips and fire cases. Flare load was reduced by deactivating some of the sources of over pressure. A flare transient analysis and HAZOP was performed to insure that they will never be relieved simultaneously.

The team designed the interlock system to be of a fault tolerant design, allowing the failure of any single system component without the loss of system functionality. With this type of design, it should be possible to reduce the probability of interlock system failure to less than or equal to a relief valve.

The interlock system was designed to immediately detect the failure of any system component so that proper repair or maintenance may be taken to correct the fault. The system was designed to provide "fail-safe" protection but also designed to avoid false trips. Experience is that false trips may cause operations to bypass interlocks resulting in a loss of safety protection. Interlock Logic was performed in a state-of-the-art fault-tolerant controller based on Triple-Modular Redundant architecture with 2 out of 3 voting.

Three separate pressure transmitters were used to input analog signals to the interlock system. These signals were shared with the DCS controller/indicator inputs by hard wired connection. High-high pressure detection was used in the interlock system using 2 out of 3 voting. Bad input signals from pressure transmitters were interpreted by the interlock system as high-high pressure. The interlock system was designed to monitor the deviation between the three pressure transmitters providing an alarm if the deviation is greater than a set limit.

Regardless of the level of redundancy, system reliability cannot be achieved unless appropriate inspection, testing and maintenance procedures are established and rigorously followed. It is vital that the plant owner make a commitment to maintain the integrity of the critical safety instrumentation. The failure to do so will expose plant equipment and personnel to unacceptable risk. Inspection, testing and maintenance procedures need to be developed and followed.

2.4. VOC Control

In an ethylene plant the VOC standard requirements are that the fugitive emissions be below 10,000 ppmv on valves and pumps. Westlake voluntarily uses a guideline of 1,000 ppmv and for new construction uses a guideline of 500 ppmv for both pumps and valves. All pumps and valves are monitored quarterly and if any are found to be above the guideline they are repaired, and the monitored monthly for the next three months. Flanges are monitored on a quarterly schedule.

Westlake prevents from having any open ended valves or lines by using caps, blind flanges, plugs, or second valves. Sampling connections will be purged or vented to a closed system. On some small control valves bellow seal valves were installed which are considered zero emitters.

2.5. Storage of Volatile Organic Compounds

Per Louisiana regulations, all tanks larger than 250 gallons but not more than 40,000 gallons that contain a VOCs with a true vapor pressure of 1.5 psia were designed to have a submerged fill pipe. Per Federal regulations, Tanks larger than 40,000 gallons and containing a VOCs with a true vapor pressure of 1.5 psia were designed to have an emission control with a minimum of 95% removal efficiency.

There are four (4) tanks in the Westlake Ethylene Manufacturing Complex that have capacities greater than 40,000 gallons and contain VOC liquids with a true vapor pressure greater than 1.5 psia but less than 11.1 psia. These tanks are equipped with internal floating roofs that meet all state and federal requirements. Monitoring, inspection and record keeping are performed in accordance with all requirements.

2.6. Pump Seal Selection

Depending on the type of process fluid to be handled, the selection of pump seals can contribute a large portion of capital investment in a pumping system. Under the current EPA and States VOC and HAP regulations, many pumps in the petrochemical industries are required to meet the allowable leakage rates regulated under the National Emission Standards for Hazardous Air Pollutants(NESHAP) from manufacturing processes producing synthetic organic chemicals(SOCMI). The rule is also referenced as the hazardous organic NESHAP or HON.

Pump seal leak definitions for HON are specified at 10,000 ppmv in Phase I (beginning on the compliance date), 5000 ppmv in Phase II (beginning no later than 1 year after the compliance date), and 1000 ppmv in Phase III (beginning no later than 2 1/2 years after the compliance date). So eventually all SOCOMI plants will have to meet the 1000 ppmv and below for all pumps that handle VOC and HAPs.

Olefins plants are currently not regulated under SOCOMI, however, future regulations are expected to be similar to that of SOCOMI. In most of the recent applications, whether they are located in attainment or non attainment areas, similar requirements have already been applied and used by the States during new or modified plant permit evaluation if required to reduce VOC and VHAPs. Therefore for a new Olefins plant or modifications, the current regulations for SOCOMI are recommended to be used as guides for equipment design to avoid future implications.

To meet the required VOC and VHAP leak definitions, and depending on the fluid specific gravity and vapor pressure, single mechanical seal and dual (double or tandem) seals can be used. Double seals is with barrier fluid pressure exceeds process pressure. Tandem seal is also a dual seal which has a non-pressurized buffer fluid system. Both dual seal buffer fluid systems are vented to a “closed-vent system” or is purged into a process stream with no atmospheric emissions.

For seals selection, the Society of Tribologists and Lubrication Engineers (STLE) has provided a special Publication, SP-30 “Guidelines for Meeting Emission Regulations for Rotating Machinery with Mechanical Seals”. The article has provided a convenient reference for selection of basic seal configurations for service in applications covered by the EPA HON, or other VOC regulations. Basically the seal selection chart is divided into Three (3) general areas and are as follows:

Area I - For products with specific gravities above 0.4 and the target leak control levels of 1000 ppmv or greater. In this area, general purpose single seals, or dual seals(double and tandem), are all acceptable sealing mechanism.

Area II - For products with specific gravities from 0.5 to 0.7 and the target leak control levels from 50 to 500 ppmv, and specific gravities above 0.7 and the target leak control levels above 50 ppmv. In these areas, special purpose single seals, or dual seals (double and tandem), are acceptable sealing mechanism.

Area III - For products with a low specific gravity and below 0.4, or the target leak control levels of below 50 ppmv, only dual pressurized (double) seals are recommended. This area generally applies to the cold hydrocarbon services in an Olefins plant.

For most of the Olefins plant design and applications, even though single mechanical seals sometimes are sufficiently and technically meeting the leakage rate definitions, however, due to the BACT and LAER requirements, dual seals are generally required for all hydrocarbon (VOC and VHAP) services by the air permits and the owners.

3.0 Water

3.1 Waste Water Collection Philosophy

For a modern ethylene plant waste water collection and treatment design, the latest EPA waste water related regulations must be considered. Due to the benzene and other HAPs in the waste waters, the design will use Benzene National Emission Standards for Hazardous Air Pollutants (NESHAPs), Synthetic Organic Chemical Manufacturing Industry (SOCMI), Hazardous Organic NESHAPs (HON) and Hazardous Waste Management System, like TCLP Rules as design criteria to ensure that both the environment and health concerns are protected.

During the course of detailed engineering, the primary concerns are the VOC and HAP leaks from sewers and control equipment, and potential ground water and soil contamination by chemicals in the waste waters.

3.2 Waste Minimization

The minimization of waste effluent is carefully considered in the plant to reduce waste design capacity and thus reduce capital investments. As a result, the following special designs were considered and implemented to minimize the environmental and safety concerns.

- All low pressure condensate is collected and recovered.
- All continuous boiler and steam drum blow downs are recovered and reused as make up to the caustic tower.
- All intermittent boiler and steam blow downs are recovered as cooling tower make up.
- Through many recycles, the process technology has reduced the continuous process organic waste effluent streams to only two small continuous streams, the saturator blow down, and the spent caustic wash water.
- All cooling water, including sample cooler usage, is returned to the cooling tower.
- The cooling tower make up water is clarified and filtered to increase the tower operating cycles and thus reduce cooling tower blowdown.
- Hydrocarbons are recovered by oil removal and steam stripping processes.
- Hydrocarbons are recycled through the collection drain tanks.

3.3 Above vs. Below Ground Process Sewers

During the initial design stage the team studied what kind of oily water sewers should be designed for the new plant. Major concerns are the potential soil and underground contamination and hazardous waste clean up for leaks of potential under ground sewer systems. The team decided that no under ground oily water sewers would be installed in the new plant. All deinventorying maintenance drains are hard piped to the above ground drain tank systems.

The equipment to be deinventoried, when possible, will first be pumped or pressured forward to the next process system. Then the residual will be emptied by pressurizing nitrogen to the above ground process sewer, which will then gravity drain to the above ground drain tanks. For the equipment that cannot be pressured to the process sewer, they will be collected manually by gravity or pumped to a portable collection wagon which is equipped with a pump and collecting funnel.

Operations and maintenance crews will inspect the plant frequently and regularly for drips and drains and quickly fix any leaks as necessary. This should minimize waste hydrocarbons and maintenance water that would otherwise normally enter the under ground oily water sewer systems that need treatment. Any spill will be cleaned up immediately to avoid contamination if possible.

3.4 Segregation of Waste Water Systems

An ethylene plant generally consists of the following waste water categories that need to be segregated, collected, and pretreated before the final treatment and disposal. The segregation is required to reduce contamination by the hydrocarbons streams from the mostly water streams to reduce possible hazardous waste production.

3.4.1. Process waste water contaminated only by hydrocarbons;

- Saturator blowdown
- DOX backwash (Quench Tower water clean up system)
- Equipment and maintenance drains
- TLE hydrojetting water

3.4.2. Process waste water containing chemicals and hydrocarbons;

- Caustic washwater
- Spent Caustic
- Equipment and maintenance drains containing caustic

3.4.3. Inorganic wastewater;

- Cooling tower blowdown
- Demin regeneration waste

- Clarifier blowdown
- Waste treatment system backwash
- Boiler blowdown
- Waste condensate and leaks
- Waste cooling tower and exchanger leaks
- Acid and caustic waste and washdown

3.4.4. Runoff;

- Contaminated stormwater runoff
- Paved area washdown
- Potential firewater runoff
- Clean stormwater

To handle all of the above wastes is a challenge. All waste must be carefully evaluated and minimized when possible. Their environmental concerns and impact were considered in the design phase. Their segregation, collection, treatment, and disposal of must be environmentally sound and shall meet all the relevant regulations. Spent caustic will be oxidized, caustic contaminated waste are neutralized. All benzene wastes are removed in a steam stripper. Hydrocarbon oily wastes are equalized, oil decanted, steam stripped in a complete enclosed and above ground system before being sent to a biological treatment system for BOD5, COD and other contaminants reduction.

4.0 Solid Waste

4.1. Solid Waste Identification

An ethylene plant generally consists of the following solid waste categories that need to be segregated, collected, and pretreated before the final treatment and disposal.

4.1.1 Solid Wastes

- Coke from TLE hydrojetting
- Quench tars from Quench Tower and Quench Settler
- Tar and heavy oils from DOX backwash
- Slop oil and oily sludge form Oil and Grease removal systems
- Solids and dirt from runoff
- Yellow oils from caustic system
- Sludge from inlet raw water clarification and filtration systems
- Bio sludge for biological treatment system
- Spent catalysts
- Heat exchanger oily residue

5.0 Other Environmental Concerns and Considerations

5.1 Spill Prevention

To minimize spills exposure, all process equipment areas are paved. All paved areas which may contact acid or caustic are coated with epoxy to protect the pavement. Any loss of containment within the paved area are to be intercepted by the stormwater sumps, and removed via a vacuum truck and pumped to the contaminated stormwater tank for temporary storage and then recycled to the process as conditions allow.

5.2 Tank Primary and Secondary Containment with Leak Detection

All chemical storage tanks and waste water storage tanks are located in dikes. A spill within the dike will be contained. A spillage wash down will be processed through the waste water treatment system.

In addition to diking, all API type hydrocarbon and wastewater storage tanks are equipped with double bottom to provide secondary containment to prevent soil contamination. Should a leak develop in the first tank bottom it would be noticeable from regular inspection of the drainage opening located in the second tank bottom.

5.3 Contaminated Run Off Storage and Diversion

Normally the process paved areas will be maintained by good house keeping practices and washdown. During storms the “first flush” run off is assumed contaminated and will be collected and diverted into a contaminated above ground storage tank and will be treated along with the other process waste streams. The stormwater diversion sumps were designed that the first flush runoff will be contained, any free oils if present will be trapped and subsequently removed by skimming. The stormwater diversion sumps are normally pumped down during the dry seasons, thus no wastewater or hydrocarbons can accumulate in the sumps.

6.0. Conclusion

The responsibility of environmental design considerations are never actually concluded. The goal should be to continually improve environmental conditions by the evaluation of past designs and utilizing lessons learned to improve the present and future operations and designs. The environmental issues that start back at the proposal stage, continued through site selection and into design and operating concerns, both current and future, are to enhance the conservation of our natural resources by reducing and eliminating, when possible, wastes and emissions.