

AMINE PLANT VAPOUR PHASE CLEANING (STEAM OUT)

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ABSTRACT

In preparation for major turnarounds or shorter term vessel inspections, gas processing facilities use various cleaning methodologies to prepare the system for safe vessel entry and inspection. Traditional cleaning in amine gas plants can be expensive and may not be as safe as more advanced technologies. Companies are looking for cleaning methods that reduce down time, reduce mechanical work, provide safer conditions, and reduce waste. In 1960, vapour phase cleaning was developed for cleaning large vessels.⁽¹⁾ Vapour phase cleaning provides shorter cleaning time, has the ability to contact and clean the majority of surfaces of the equipment being cleaned, allowing for less mechanical work, and allowing safer conditions when the equipment is opened while also cutting the waste volume.

Various technologies are currently being utilized across the industry and more are being developed. This paper reviews commercially available vapour phase technologies that use amine oxides as well as discusses alternative technologies that use solvent-based chemistries. Advantages and disadvantages, vapour phase technology limitations and economic analysis of each technology will be presented to aid with the selection process.

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Introduction

Traditional cleaning in amine gas plants can be expensive and unsafe. Companies are searching for cleaning methods that reduce time, mechanical work, waste and provide safer conditions. Vapour phase cleaning, developed in 1960, provides shorter cleaning time and could contact and clean most surfaces of the equipment. That process allows for less mechanical work and safer conditions when the equipment is open, all while cutting the waste volume.

Various technologies are currently being utilized across the planet with more currently under development. This paper reviews commercially available vapour phase technologies that use amine oxides as well as discusses alternative technologies that use a solvent base. The limitations, advantages, disadvantages and an economic analysis of vapour phase technology will be presented to aid the selection process.

Problems:



Figure 1 - Sludge/FeS/Hydrocarbon from separator carryover



Figure 2 - Plugged tubes



Figure 3 - Contaminated outer tubes



Figure 4 - Tray fouling

With the problems faced by amine plants as shown above, the oil and gas industry is demanding safer and more efficient cleaning methods. In gas plants and many contaminated systems, there is demand for safer cleaning methods for shutdowns, turnarounds, and emergency outages. Service companies have answered with traditional and new technologies. This paper will look at the traditional three stage cleaning that includes an alkaline wash, followed by an acid wash and then finish with a passivation stage. It will also explore the use of new technology through the usage of vapour phase cleaning using amine oxides as well as alternative technologies using a solvent base. Advantages and disadvantages, vapour phase technology limitations and economic analysis of each technology will be presented to aid the technology selection process.

Traditional Cleaning Technologies

There are two types of traditional cleaning: Mechanical and chemical⁽²⁾. Traditionally, amine towers, exchangers and vessels are chemically cleaned using 'fill-circulate' (entire process loop cleaned at once) or cascade cleaning (cleaning discrete process units within the whole process loop in a systematic manner) with chemical cleaning equipment using alkaline chemistry, acid chemistry and passivation chemistry.

Alkaline chemistry can vary depending on contaminants, levels of fouling, metallurgy, historic cleaning and other factors that need to be considered. A combination of the alkaline chemistry listed below can be used, depending on the contaminants and level of fouling.

- (a) Sodium Hydroxide
- (b) Sodium Metasilicate
- (c) Tri-sodium Phosphate
- (d) Solvent Base Chemistry
- (e) Asphaltene Removal Additive
- (f) Wax Removal Additive
- (g) Water Based Degreaser
- (h) Odor Controller
- (i) Amine Oxides

Acid chemistry can also vary depending on contaminants, levels of fouling, metallurgy, historic cleaning, toxic product being produced and other factors. All acid cleaning corrosion inhibitors are added depending on the type of acids. Mineral/inorganic acid potential acid chemistry:

- (a) Hydrochloric Acid
- (b) Sulphuric Acid
- (c) Sulfamic Acid
- (d) Phosphoric Acid
- (e) Citric Acid
- (f) Tergitol™ – surfactant
- (g) Ammonium Bifluoride (ABF) – silica removal

Passivation chemistry (prevents flash rust) can vary depending on metallurgy and client's request.

Option 1

- (a) Sodium Carbonate
- (b) Trisodium Phosphate
- (c) Sodium Gluconate

Option 2

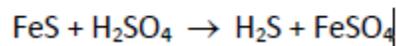
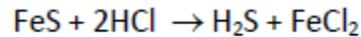
- (a) Sodium Nitrite

Water flushes are added in between stages to ensure residual chemistries are removed.

Why traditional cleaning is starting to be left behind

1) *Toxic gases exposure / release*

Deposits containing iron sulfide (FeS) foul many types of refineries, petrochemical and gas treating equipment. When a mineral acid, such as hydrochloric acid (HCl) or sulfuric acid (H₂SO₄), is used to dissolve the iron sulfide deposit, a large amount of hydrogen sulfide (H₂S) gas is evolved.



H₂S gas poses three serious problems during a chemical cleaning: H₂S is extremely toxic, H₂S is very corrosive to metals, and the large volumes of gas generated can cause pump cavitation and equipment failure. The need for expensive scrubbers are typically required to prevent H₂S exposure and environmental release.

2) *Larger equipment footprint*

Equipment required typically for traditional chemical cleaning:

- Chemical Unit
- Vacuum Truck
- Exchanger
- Scrubbers
- Water Truck – if water is not available
- Boiler – if heating source not available
- Hoses/Pipes

3) *Other factors*

- a. Larger waste generated
- b. Longer execution duration
- c. Potentially more mechanical work & cleaning
- d. Confined Space Entry

Vapour Phase Technologies

Technologies available for vapour phase cleaning

1. Amine Oxides
 - a. Mild oxidizing agents
 - b. Oxidizing agent
2. Solvent Type Vapour Phase

Mild Oxidizing Agents

Mild oxidizing agents are a blend of low toxicity surfactants in water intended to help in the removal of hydrocarbon contaminants from process equipment. This agent can assist in degassing, in the removal of hydrogen sulfide and pyrophoric iron compounds. It water-wets metal surfaces and loosely emulsifies hydrocarbons, improving their removal by hot water or steam from process equipment and tanks.

Mild oxidizing agents can help with reducing Lower Explosive Limits [LEL] (benzene), hydrogen sulfide (if any), ammonia and other types of vapour within acceptable working levels while degassing the metal contaminants by de-oiling and breaking down pyrophoric and other iron sulfides deposits. That process allows for personnel entry to a safe environment. The process induces the hydrocarbon liquid phase to be emulsified in the steam condensate allowing for decontamination and degassing at a much faster rate than normal steam-out. Sulfide deposits are reacted with and broken down into fine particulate and transported out in the condensate and, preferably, a subsequent water wash.

Features and Advantages

- High Temperature Performance
- Low Toxicity
- Non Flammable
- Water Soluble
- High Performance
- Acts as scavenger for H₂S and pyrophoric Iron compounds

Typical Physical Properties

Appearance	Clear Liquid
Specific Gravity	1.01
Flash Point	>95° C
pH	8 – 8.5
Freeze Point	0°C
Ionic Character	Nonionic

Methods of application

Mild oxidizing agents can be added to hot water or steam at various concentrations. The amount used depends on the composition and amount of hydrocarbon needed to be removed. When added to steam it should be first diluted in water and added to the flowing steam as a mist. It is compatible with alkaline additives such as trisodium phosphate and sodium hydroxide. These should be added in strongly sour systems to improve the removal of hydrogen sulfide.

Mild oxidizing agents are also compatible with some mineral and organic acid solutions such as hydrochloric acid, acetic and formic acid.

Mild oxidizing agents can also be combined with H₂S scavengers to substantially improve the removal of hydrogen sulphide.

Safety and Handling

Mild oxidizing agents are non-flammable but will cause irritation to the eyes and skin. Refer to the material safety data sheet for more detailed information when using these chemicals.

Equipment

Positive – Less footprint than conventional cleaning

Negative – Need saturated LP/MP steam (most plants do not have easy access), and the cost of a boiler can be high

Hazards

High temperature chemical piping and/or hoses, steam hoses and steam condensate lines at the temporary exchanger. High temperature steam and condensate drain lines.

Waste

All of the chemical cleaning solutions, waste steam condensate and water flushes containing chemical residue are to be collected into temporary storage tanks for later disposal to an approved disposal well. Clients dictate where the waste must be collected and be disposed of due to their site requirements and environmental requirements.

The advantages of this technology is that the quantity of waste is typically less compared to traditional chemical cleaning and other methods.

Execution/Procedure snap shot

Experience from previous vapor phase cleaning projects suggests that the key target to achieve during the vapor phase cleaning is a system temperature in the range of 106 - 135°C (223 - 275°F) as per the vessel temperature indicators, at a system pressure of 34 – 207 kPa (5 - 30 psi) as per the vessel pressure indicators, indicative of the steam being saturated. A temperature cooler than the target range will result in the mild oxidizing chemical (Chemical) not being suspended in the steam, thus decreasing the effectiveness of the cleaning. A temperature warmer than the target range may cause the Chemical to decompose or flash off and lead to the possibility of the steam baking the contaminants to the internal surfaces of the process vessels, exchangers and piping.

The vapor phase cleaning temperature should be monitored (via heat gun/temperature indicators) at several locations throughout the system on a frequent basis to ensure that it is maintained within the target values. If the temperature is not within the target values, the amount of steam injected into the process equipment or the pressure in the unit may need to be adjusted in order to return the temperature to the acceptable value.

It is essential to maintain the system pressure in the range of 103 – 207 kPa (15 – 30 psi), as allowed by the process equipment design, by controlling the venting to flare to assist the movement of the resulting condensate from the system low point drains through the temporary piping header and cooler into the storage tanks. If sufficient pressure isn't maintained throughout the cleaning process, the condensate draining may stop flowing to the storage tank.

Testing & meeting KPIs

H₂S sampling of the condensate sample head space using industry standard testing equipment like Draeger or lead acetate paper, indicates that the H₂S concentration in the process equipment meets the Key Performance Indicators (KPIs).

The Chemical concentration has stabilized in the condensate.

- No adjustments made to the chemical injection rate and constant steam flow maintained.

Once the Chemical concentration appears to be stabilized, continue to collect samples to test for Amine Oxide concentration, pH and appearance.

- Three consecutive samples with consistent Amine Oxide concentration and clarity deem the cleaning is complete.

Oxidizing Agents

An *oxidizing agent* is an oxidizer and can be used as a process chemical in every decontamination job. It is designed to change characteristics during the job and promote physical removal. Certain Oxidizing Agents are not a commodity chemical.

In a very basic description of the technology, oxidizing agents contain an amine oxide. In the oxide form, this amine oxide is very water soluble. During every oxidizing agent application, the oxide form of this compound is reduced and the oxygen is used to oxidize sulfides, oils, and other compounds in the decontamination system. When the oxygen is removed from the amine oxide, the residual amine is then poorly soluble in water but is soluble in oil. This change in physical characteristics allows the amine oxide to perform numerous functions while in the water phase, and then easily separate to the oil phase when the decontamination effort is complete.

For the reason above, it is easy to start with high concentrations of oxidizing agent at the beginning of the job, add more during the job, and still have very low oxidizing agent concentrations at the end of the job.

This is why enough oxidizing agent must be used for each job—the oxidation requirements for the job are fixed by the contamination in the system. However, it is also easy to use enough oxidizing agent for the job and not more. If too much oxidizing agent is used, then several methods can be used to destroy the remaining oxidizing agent. Choices for destroying remaining oxidizing agent include allowing additional time for the circulation or decontamination effort (1-4 hours is often enough) or putting the wastewater into crude or other tankage. Exposure to sulfides, metals, and other contamination will destroy the oxidizing agent quickly. Some customers prefer to put all oxidizing agent solutions into crude or other tankage to oxidize sulfides in the tanks. This also helps break emulsions and lowers the sludge level in many tanks.

The residual oxidizing agent that separates into the oil phase will not harm the oil for normal crude processing. The wastewater/condensate from the decontamination process typically has low level oxidizing agent residuals that most waste facilities can accept for disposal. In practice, 400 ppmv of oxidizing agent is used as the final concentration.

Before Decontamination

After Decontamination

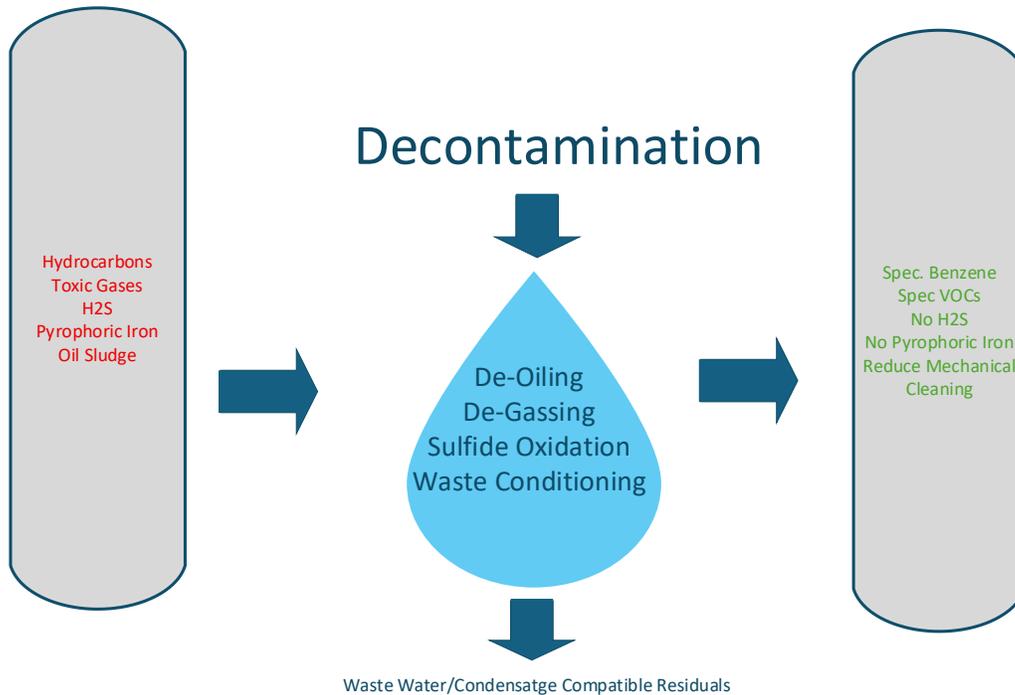


Figure 5 – Oxidizing Agent Decontamination Process Diagram

Targets for Gas Plants

- Amine Units: polymers, oil, FeS scale, H₂S, VOCs
- Glycol Units: polymers, VOCs
- Exchangers: polymer/heavy oil fouling
- Benzene, H₂S anywhere
- Time savings
- Increased safety

Common Gas Plant Concerns

- H₂S, Pyrophoric Iron Sulfide
- Mercaptans
- LEL / VOC gases
- Polymer / heavy oil
- Water Volumes
- Waste Disposal

Oxidation

- H₂S, FeS oxidized by reaction to sulfates
- Safe with light hydrocarbons
- Cannot perform “runaway” exothermic reactions

- Can be combined with other products for multiple targets at the same time

Mercaptans and VOC

- Mercaptans may be oxidized or will be removed as VOC
- VOC / LEL gases (including benzene) removed by distillation to flare during decontamination job
- Oxidizing agent provides faster distillation than just steaming as it breaks up sludge and oxidizes FeS deposits.

Polymer and heavy oil

- Common in amine and glycol systems
- Common in debutanizers (if present)
- Can be liquefied or mobilized with solvents combined with oxidizing agent in circulations for heavy deposits
- Many light deposits in amine and glycol units easily removed with oxidizing agent in vapour phase applications.

Water and wastewater

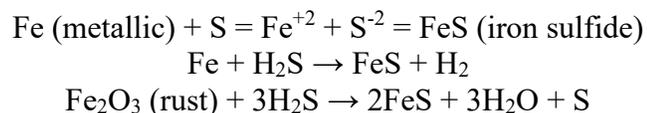
- Multiple targets at one time allow single chemical application for all targets
- Many vessels can be treated only with vapour phase applications—reducing water consumption dramatically
- Waste water will be minimized, but may contain amine and glycol in addition to liquefied polymers—commonly disposed of in deep wells

Designing Decontamination

- Identify scope of work
- Identify limitations of application
- Devise best-fit application method
- Proposal to client
- Client accepts proposal
- Client operations staff & technology provider work together to develop procedure
- Client and technology provider review procedure
- Acceptance / revision of procedure
- Job performed

Iron sulfide formation

As per the previously presented LRGCC (2006) paper from Ben Spooner and Mike Sheilan titled “Iron Sulfides – Friend or Foe?”, iron sulfide can be formed through the following reactions⁽³⁾:



The paper further discusses the different types of iron sulfides: Mackinawite, Pyrrhotite, Pyrite, Greigite, Troilite.

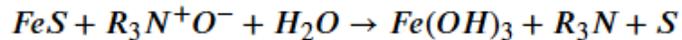
Iron sulfides may have advantages in an amine system like corrosion protection; however, it has disadvantages. One of the disadvantages is the safety concerns when it comes to fire, when iron

sulfide is exposed to air after a unit is opened to atmosphere. Also, iron sulfides will simply add to the suspended solids content of the system and can cause several problems, primarily foaming, plugging and flow distribution issues⁽³⁾.

Amine oxide reaction with iron sulfide during vapour phase cleaning

Vapour phase with amine oxide – the amine oxide reacts with the iron sulfide creating a “flake” that needs to be washed off by a water flush (steam only rinse or water rinse through cascade). This will prevent the exothermic reaction causing fire and could remove the suspended solids.

Possible Overall Reaction



Note: This is a simplified representation. The exact products and stoichiometry would depend on the specific amine oxide and reaction conditions.

Factors Affecting the Reaction

The feasibility and outcome of the reaction are heavily influenced by several factors:

- **Amine oxide strength:** Stronger oxidizing amine oxides will react more readily.
- **Stoichiometry:** The molar ratio of the reactants will affect the degree of oxidation of both iron and sulfide.
- **Physical state:** The reactivity of iron sulfide varies greatly based on its physical form. Freshly precipitated (pyrophoric) iron sulfide, with its high surface area, is much more reactive than a passive crystalline form.
- **Reaction medium and temperature:** The reaction conditions, such as temperature and solvent, play a significant role. Higher temperatures can accelerate the reaction but may also cause the amine oxide to decompose.
- **pH:** The reaction is likely sensitive to pH, which will affect the speciation of both the iron and sulfide ions.

Solvent Base Vapour Phase Cleaning

Solvent base vapour phase is a chemical cleaning method based upon a solubility mechanism and not a chemical reaction. The chemistry never gets consumed (or spent) and therefore does not need to be monitored during injection for deactivation. This chemical cleaning approach is fundamentally different than most water-based cleaning chemistry that must be constantly monitored for effectiveness.

The amount of solvent chemistry required to clean a piece of process equipment is calculated based on vessel dimensions, type of service, and length of run. This cleaning method relies on experiences of cleaning thousands of vessels to determine the amount of chemistry required with predictable results.

The cleaning process occurs in two-steps. First, the vendor executes the solvent base vapour phase cleaning process. Next, they apply a rinse step. Depending on the equipment type the rinse is either a steam dwell (process where only steam is injected until condensate samples do not have any more residual chemicals) or a batch cascade rinse with water. Both the cleaning and the rinse steps are critical to ensure that all hydrocarbon and residual chemistry is removed from the system. During the cleaning steps, all light end materials (benzene, H₂S, LEL, etc.) are carried overhead to a closed system (flare, pump out, etc.) while the heavier hydrocarbons are dissolved and drained out through low points. Once the cleaning is completed, the net result is a vessel or system free of grease, oil, LEL, H₂S, and benzene. This can be determined using all standardized tests for gas measurements in the field.

In some process applications, pyrophoric treatment is a requirement. If a client determines the need, and pyrophoric treatment is in the scope of the project, liquid phase solvent and/or another vapor phase solvent chemistry application will be a part of the process. It is important to note that this cleaning process will not remove solids (coke, corrosion by-products, scale, etc.) but will remove heavy hydrocarbon from the remaining solids.

Methods of Application

1. Planning - 1 Lead Planner per project
 - Initial planning kickoff meeting
 - Initial preliminary plan development
 - Initial Mechanical needs review and walkdown
 - Client procedure reviews
 - Client timeline reviews
 - Final Chemical Cleaning Plan Review
 - Final review of Mechanical needs installation
 - Operations training
2. Execution – Operations managers and Operations technicians
 - On site Safety Training & Orientation
 - Pre-execution field verification of Mechanical needs installation
 - Pre-execution walkdowns
 - Execution
 - Demobilization

Project planning

Once a purchase order (PO) is received, lead operations planner(s) will contact the client to begin the regimented planning process. This process utilizes best practices gained by planning more than 300 projects/year and is led by experienced planners. The planning process sets the foundation for a timely and predictable project. The vendor will partner with you to produce the following planning deliverables:

1. Kickoff meeting
 - a. Introduction of team members: Operations, TA Team, Environmental, Engineering, etc.
 - b. Verify the scope of work and critical path.

- c. Discuss decontamination strategy – limitations, vents, drains, utilities, cleaning sequences, effluent requirements, etc.
 - d. Commit to deliverable milestones.
 - e. Review proposal, facility requirements and expectations.
2. Initial preliminary plan
 - a. A list of suggested chemical injection points; Client has final responsibility and authorization regarding the use of 's suggested injection points.
 - b. High level drawings to illustrate suggested injection points, spools and other necessary fittings.
 - c. Review of Client's shutdown procedures with recommended improvements.
 - d. Step-by-step procedures for chemical cleaning coordination. Final procedure approvals and MOC items will be coordinated and supervised by Client.
 - e. A mechanical needs list of Client-supplied hardware requirements.
 - f. Appropriate quantities of vendor's proprietary chemistry.
 - g. An estimate of the amount of chemical cleaning effluent to be generated by each system and a description of this cleaning effluent composition.
 3. Mechanical needs/temporary facilities proposal
 - a. Accurate and scope-inclusive proposal of mechanical needs identified by the preliminary plan.
 - b. Identify if vapor control or total condensation is required based on Client restraints.
 4. Client timeline and procedure review
 5. Final Plan development and review
 - a. Implemented feedback from Client after preliminary plan review.
 - b. Final plan review with Client.
 - c. Final plan issued.
 6. Classroom operator training given to the Client Operations Team by planners

Execution support

Execution support is critical to the success of the project. The team that plans the work will be the team in the field ensuring that the procedure is followed. It will provide:

1. Prior to oil-out the field verification of Mechanical needs and any exceptions that need to be highlighted and communicated to Client.
2. Experienced operations personnel to collaborate with Client Operations/TA team in the field and implement the procedure developed during the planning phase.
3. Technicians to assist in staging the chemistry and operate rented injection pumps.
4. Assurance of KPI compliance during the process.
5. Real time communication of any procedure deviations and implications via documented deviation form.

Chemical Cleaning Equipment Package:

1. Injection hoses
2. Injection pumps
3. Exchangers
4. Miscellaneous tooling and equipment

Commercial Summary

Cost Advantage:

1. Reduced downtime – can help quantify this by providing estimated timelines, procedure reviews and economic justification.
2. Predictability – Gaining predictable access to the equipment allows for cost effective planning of maintenance activities.
3. Quality planning and support – will provide exceptional support that delivers on required documents and planning milestones.
4. Cleanliness – this technology claims it allows for the very best hydrocarbon removal in the industry. This allows maintenance personnel to work in a hydrocarbon free environment.

Criteria for success

The objective of solvent base vapour phase cleaning project is to reduce hydrocarbon contaminants and various gasses to allowable levels for rapid permitted entry. Disturbance of inorganic sludge that may exist in the vessel after cleaning may liberate LEL, H₂S or other hydrocarbon vapors trapped beneath the sludge layer. The chemistries and the process will not dissolve/remove inorganic scale deposits, rust, heavy/hardened coke, sludge or organic polymers that are insoluble in other organic solvents. The facility maintains ownership and responsibility for writing all entry permits and the initial and ongoing use of all gas detection meters associated with determining the air quality required to allow for vessel entry. Gas readings include but are not limited to CO, LEL, H₂S, Benzene and other noxious or hazardous gasses. Process units may contain large amounts of solids, coke and scale. These contaminants may plug drains and result in liquid hold-up during the de-inventorying and cleaning processes. Systems that cannot be properly drained will likely remain filled with hydrocarbons and sludge.

The technology provider will develop contingencies for the facility in the planning phase to address these challenges, but if it is still not possible to drain the system prior to or during cleaning, then criteria for success is jeopardized and the guarantee to meet a hydrocarbon-free environment does not apply. The technology provider cannot ensure success of the project without the entire system being properly drained free of liquid hydrocarbon during the cleaning process.

If the facility chooses to fabricate, rent, or use their own drain header equipment, the technology provider must approve this equipment (hard pipe or drain hoses) and confirm it is rated for the process conditions required for the cleaning. If there are safety concerns with this equipment, then it will not be utilized until process conditions warrant a safe atmosphere for that equipment, which may affect the project results.

It is typically agreed that the success of the application is contingent upon the facility following the mutually agreed upon cleaning procedure and key performance indicators (temperature, pressure, flow rates, etc.) and the facility properly isolating this equipment prior to the start of this application, as well as after the chemical injection, de-pressure and rinse phase (where applicable).

Recontamination may result from:

- Improperly prepared equipment and associated piping.
- Light hydrocarbons / vapors, H₂S, or other contaminants from leaking block valves, etc.

Cleaned System:

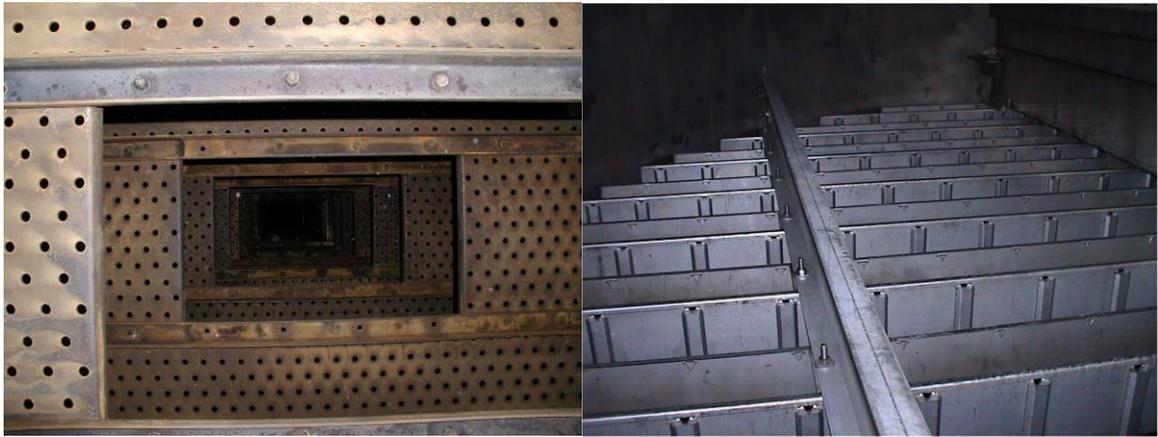


Figure 6 – Clean Trays

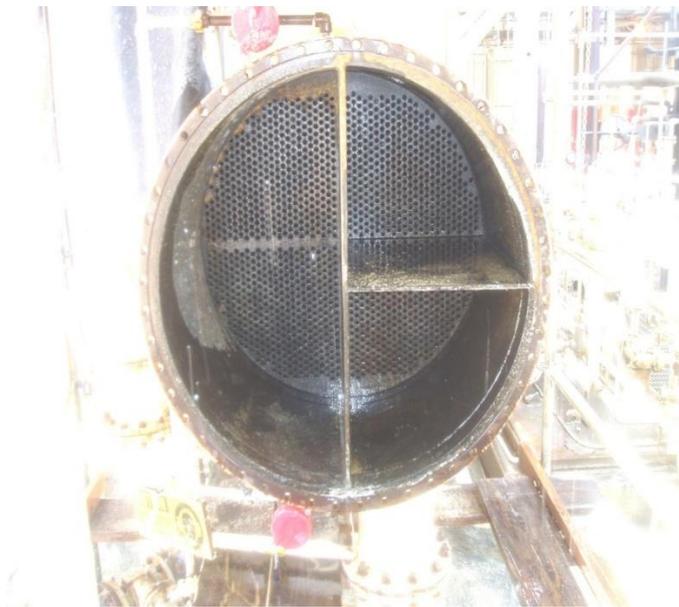


Figure 7 - Unplugged Tubes



Figure 8 - Cleaned Outer Tubes

Technology Selection Process

Three aids are provided for the technology selection process. Figure 6 shows a road map to help with the selection process. Table 1 lists the advantages and disadvantages of each technology based on experience in the field. Table 2 provides the snapshot of the economic/cost breakdown base in the Western Canada Region. Vendors will have comparable costing profiles for other geographical locations in North America.

Another major factor to consider is waste. Tables 1 and 2 provide technology feasibility and use based on waste and disposal. Disposal costs can vary due to location, availability, transport, permits, types of waste etc. It is best to work with your local environmental team, contractor and other stakeholders to determine the best option.

Technology Selection Process

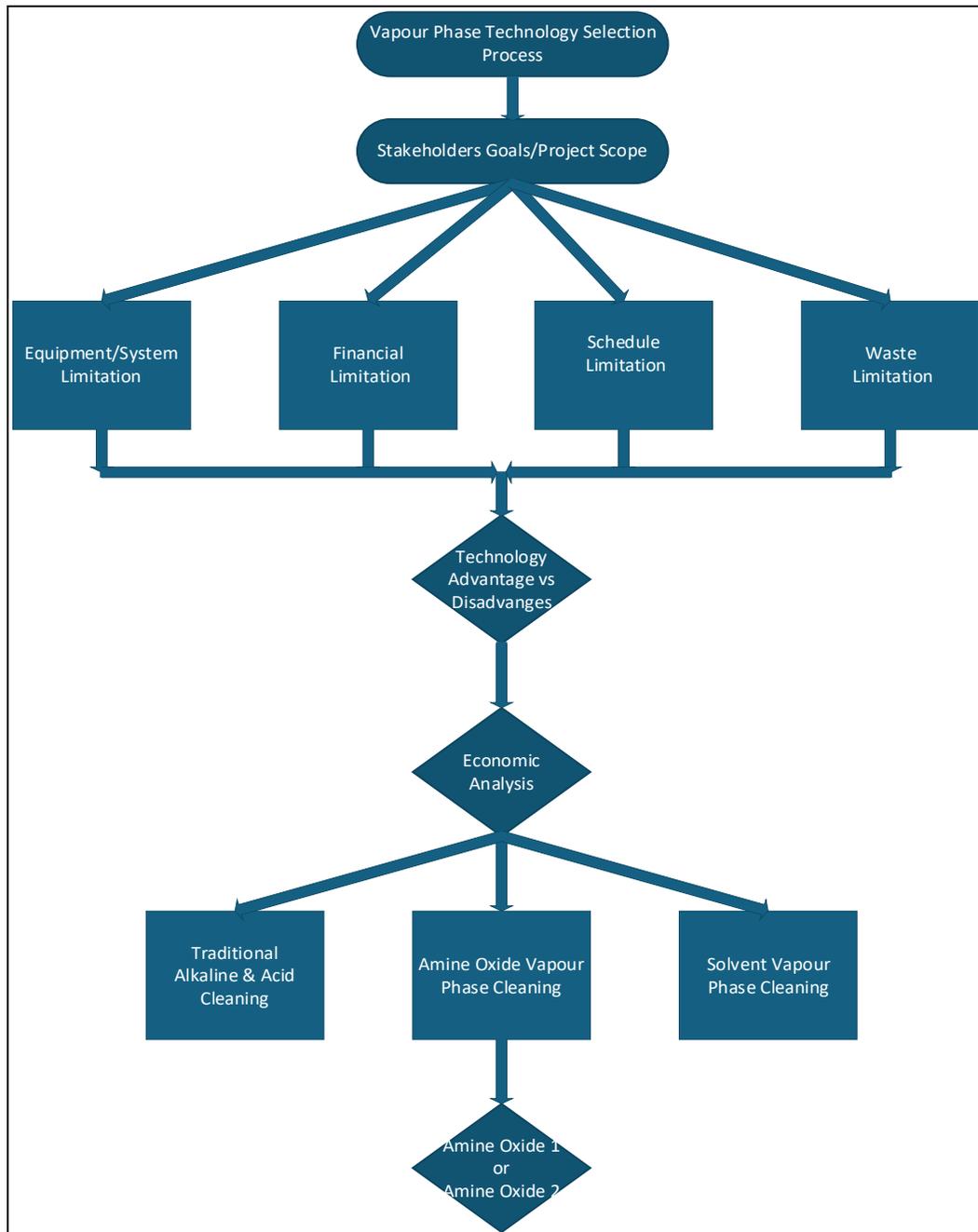


Figure 9 – System Cleaning Decision Tree

Table 1 - Cleaning Technology Advantages and Disadvantages / Limitations

Technology	Advantages	Disadvantages/Limitations
Traditional Cleaning Alkaline/Acid	<ul style="list-style-type: none"> - known/familiar technology - does not need steam - waste can be neutralized for safer transport and less limitations in terms of disposal locations - rig-up is typically not complex if tie-in points are available. 	<ul style="list-style-type: none"> - larger equipment footprint - large waste generated - longer execution duration - potential for more mechanical work
Amine Oxide Vapor Phase Cleaning	<ul style="list-style-type: none"> - smaller equipment foot print - shorter execution duration - cleans most of the surfaces being cleaned - one cleaning solution - sulfide oxidation (no pyrophoric potential) - oxidation of sulfides creates a product that can be washed off with the water flush. - waste is approximately 40% less than conventional cleaning - rig-up is low/medium complexity 	<ul style="list-style-type: none"> - known to be toxic to fish, special containment is needed, waste cannot enter sewage and water collection - condensate cooling - onsite waste collection/storage required - require steam (expensive boilers) - residual can cause foaming - cannot be used in vessels with coatings - flare is needed - disposal location/availability can be challenging and cost more - high temperature chemical piping and/or hoses, steam hoses and steam condensate lines at the temporary exchanger. High temperature steam and condensate drain lines.
Solvent Vapor Phase Cleaning	<ul style="list-style-type: none"> - personnel are knowledgeable to the process system - cleans most of the surfaces being cleaned 	<ul style="list-style-type: none"> - larger equipment footprint - rig-up is very complex - specialized equipment - multi-step & multiple chemical solutions - known to be toxic to fish, special containment is needed, waste cannot enter sewage and water collection

		<ul style="list-style-type: none"> - onsite waste collection/storage required - condensate cooling - medium/large waste generated - disposal location/availability can be challenging and cost more - solvent solutions needs special neutralizations - require steam/boilers - will require third party set-up - cannot be used in vessels with coatings - High temperature chemical piping and/or hoses, steam hoses and steam condensate lines at the temporary exchanger. High temperature steam and condensate drain lines. - flare is needed
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Economic Analysis

Table 2 – Cost Comparisons of Cleaning Technologies

Conventional Cleaning Alkaline & Acid	Amine Oxide Vapour Phase	Solvent Vapour Phase
Execution Cost per tower ~\$30,000 CAD	Execution Cost per tower ~\$12,000 CAD	Execution Cost per tower ~\$15000 - \$20,000 CAD
Disposal \$50 CAD/m ³	Disposal \$60-80 CAD/m ³	Disposal \$80-100CAD/m ³
24-hr duration	12-15 hr duration	20-48 hr duration
Easy Set-up	Easy-Medium Set-up	Complex Set-up

Recommendation

Stakeholders' input will help evaluate and determine the technology being selected. The equipment limitations/cost analysis/schedules/safety will be considered. If no equipment limitations and utilities are available, vapour phase with mild oxidizer will be recommended. For facilities with system limitations and a lack of utilities like steam, traditional cleaning might be the only option.

Conclusion

Vapour Phase Summary

- Reduces turnaround time
- Reduces turnaround expenses
- Fast vessel entry with elimination of H₂S, VOC, mercaptans, benzene
- Reduced hydroblasting
- Expert applications personnel

Acknowledgments

Mike Sheilan – SGS Amine Experts – Sponsor and for reviewing the paper

Reference:

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- (2) Canfield, Carlton (2004 LRGCC) "Amine System Cleaning Best Practice"
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