We create chemistry **Beaumont Site Procedure**	**Title**: Safety Fundamentals of Industrial Cleaning		
	Function: Health and Safety		
	No.: BMEHS-002.039		**Page:** 1 of 21
	Reviewed: 03/25	**Effective:** 12/20	**Supersedes:** Rev 02
Preparer: EH&S Team Member	**Owner: Health and Safety Manager**		**Approver: Site Manager**

Revision Number	Revision Description	Revised By	Revision Date
New	*Considered as starting document for revision change table*		
	Procedure Reviewed	G. Dawson	11/17
Rev. 02	Title Block updated, Reviewed. Corrections to related BMEHS documents numbers	C. Megas	12/20
Rev 03	Removed reference to “Total Petrochemicals” section 3 and 4.1	A Fischer	03/10/25

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1. PURPOSE

This procedure has been established to reduce injury and/or incident, standardize plant and contractor requirements and improve communications between plants and contractors for water cleaning, water cutting and Pressure Washing services for BASF Corporation personnel, Contractor Employees and Contracted Employees.

This Procedure will allow the user to make an informed decision on industrial cleaning processes considering advantages, disadvantages, and risks.

2. DEFINITIONS

2.1. **Anti-Withdrawal Device** – An indexing device that attaches to the equipment or piping being cleaned that allows the flex lance to pass through but prevents the withdrawal of the nozzle.

2.2. **Automation- Automatically controlled operation of an apparatus, process, or system by mechanical or electronic devices that take the place of human labor. Examples are automated feed, automated Indexing, automatic manipulation, or any of these combinations. Non-automated examples include Shot gunning and hand fed lance assemblies. Non-automated activities require a formal review and approval.**

2.3. **Back Thrust Force** – The force produced by a jetting gun and the amount of force the operator must withstand… Back Thrust (lbf)=0.052 x Flow Rate x Pressure

2.4. **Double Trigger Gun** – A high pressure water gun which requires the operator to activate two triggers, one with each hand, to generate a high pressure water jet.

2.5. **Dump System (Valve)–** A quick response valve that can be triggered by the Hydroblasting technician to cut off the high pressure water stream.

2.6. **Flexible Lance** – A flexible tube or hose section carrying water to the nozzle; normally located between the trigger or control valve and the nozzle.

2.7. **Foot-controlled Valves** – A valve that dumps the pressure of the system by the activation (release) of a foot pedal.

2.8. **High Pressure Hose –** a flexible hose that can be used to carry water and/or other fluids from one part of the high pressure water jet system to another.

High Pressure Water Cutting – The use of pressurized water (typically between 30,000 psi and 40,000 psi), usually with the addition of solid particles (abrasives), to penetrate into the surface of a material for the purpose of cutting that material.

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2.9. **Hydroblasting –** The process of cleaning surfaces with high pressure (at or above 5,000 psi) water with or without the addition of other liquids or solids.

2.10. **Hose Shroud** – A length of flexible material usually formed into a tube around a hose end coupling or across the connection to the jetting gun; the shroud provides some instantaneous protection to the operator holding the gun from high pressure water injury resulting from a hose or fitting failure.

2.11. **Hydrokinetics Cleaning-** A cleaning process based on the induction of “sonic resonance” into the cleaning water stream. This sonic resonance travels through the water stream and safely transfers to both the tube and the fouling material. Because of the different compositions of the tube and the fouling material, they resonate at different frequencies, breaking the bond between them and allowing the fouling to be expelled quite easily.

2.12. **Indexing –** The act of positioning or adjusting the cleaning nozzle into the device or equipment being cleaned.

2.13. **Lancing** – An application whereby a rigid or flexible lance and nozzle combination is inserted into and retracted from the interior of a pipe or tubular product.

2.14. **Moling** – An application whereby a hose fitted with a nozzle is inserted into, and retracted from, the interior of a tube and has a self-propelling nozzle for cleaning the internal surfaces of pipes or drains.

2.15. **Nozzle** – A device with one or more orifices through which the water discharges from the system. The nozzle restricts the area of flow of the fluid, accelerating the water to the required velocity and shaping it to the required flow pattern. Nozzles are also commonly referred to as bits, tips, or orifices.

2.16. **Pressure Pump** – Pumps that will increase the pressure of water delivered to it and deliver it into a common manifold to which either flexible hoses or rigid tubing connecting to lances and nozzles is attached. These pumps can be either mobile or permanently mounted and are most often of a positive displacement plunger style that will provide a constant flow of water at a given speed of rotation.

2.17. **Pressure Washing –** The process of cleaning surfaces with high pressure (below 5,000 psi) water with or without the addition of other liquids or solids.

2.18. **Rigid Lance** – A rigid tube carrying water to the nozzle or nozzle manifold. Commonly known as stiff lance.

2.19. **Roto jet –** A Hydroblasting nozzle that projects a 2 or 3 dimension high pressure water stream.

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2.20. **Shotgunning** – A hand-held application whereby an assembly of a lance and a nozzle can be manually manipulated in virtually all planes of operation.

2.21. **Stinger** - A short section of rigid tubing used on the nozzle end of the flex lance that is primarily used to prevent the lance from reversing directions inside of the piping or equipment.

2.22. **Water jet** – A rapidly moving stream of water of different shapes and types exiting from a nozzle orifice. The speed of the jet depends on the pressure drop across nozzle orifice.

2.23. **Whip Hose** – the short piece of hose that attaches directly to the shotgun.

2.24. **Whip Lock / Whip Check** – Restrainer attached at any point where two hoses are joined; used to control the movement of a pressurized hose if it becomes uncoupled.

2.25. **Working Pressure** – The maximum pressure, recommended by the manufacturer, at which a component is to be used.

3. SCOPE

This procedure applies to BASF ~~TOTAL Petrochemicals~~ Beaumont, Texas Site and is intended to define the minimum standards required at the site for Industrial Cleaning.

4. PROCEDURE

4.1. General Statement

BASF Beaumont has committed to automating all water cleaning and cutting services and to phase out Hydroblasting Shotgun cleaning activities. Because of this commitment to automation, sites must implement a formal review and approval each and every time a non-automated cleaning operation occurs. Document the formal review and approval in the Change Management database. See procedure BMEHS003.002 Beaumont Site Management of Change Procedure.

4.2. General Safe Work Practices

4.2.1. When all other measures have been exhausted and Automation is not feasible, a formal review shall be performed for Hydroblasting Shotgunning and hand-fed lancing in accordance with section 4.8 of this procedure.

During and at the completion of the job, it is the responsibility of the Hydroblasting crew to control debris/waste and maintain good housekeeping practices on the job site. This includes, but is not limited to, the elimination of slip, trip and fall hazards including proper hose placement; proper disposal of trash, contaminated PPE and chemical/product wastes generated from the cleaning service.

4.2. General Safe Work Practices cont'd.

4.2.2. The Hydroblasting Company shall comply with all plant environmental policies and procedures.

4.2.3. Barricading of the pump/s and job site hazards is required on every job and should be placed accordingly to restrict unauthorized people from entering the work area. Barricading should also include the end point of the operation. The barricade system should indicate "Danger Hydroblasting". When working above ground level, barricades will be required below.

4.2.4. At least one wheel on staged mobile equipment must be double chocked against accidental movement, when parked on location.

4.2.5. Whip Locks shall be used on all pressured hose connections to prevent the hose from whipping in the event the coupling breaks or becomes disconnected.

4.2.6. A trained crew member is required to be in attendance of all operating equipment all times. This crew member must be close enough to shut the equipment down in an emergency.

4.2.7. All jobs require a line-of-sight between the equipment attendant and the hose end equipment operator. If direct line-of-sight cannot be achieved, radio communication or use of an additional person for line-of-sight must be utilized to assist in quickly de-energizing the equipment.

4.2.8. All hoses shall be routed and protected in a manner that prevents vehicular damage and personnel exposure to the hoses. When possible, roadways should be barricaded for vehicular and pedestrian traffic where hoses cross roadways.

4.2.9. All personnel, when the system is under pressure, shall not be within six (6) feet of pressurized connections unless the equipment is shielded or guarded in some manner (including weep holes).

4.2.10. To help prevent injury from a lance or line mole hose reversing under hydraulic pressure it is required to clean the tube sheet and the first 6" (inches) of the tubes or the first 24" (inches) of the piping with a shotgun or similar automated device so that proper engagement with the lance or line mole can be achieved before high pressure is applied.

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4.2. General Safe Work Practices cont'd.

4.2.11. All equipment being cleaned shall be shielded to prevent flying debris/chemicals that could pose a potential injury or exposure to someone. Examples include but are not limited to plywood, metal sheeting or water blast curtains.

4.2.12. Hydroblasting equipment shall be grounded per site and or Hydroblasting company requirements.

4.2.13. An Anti-Withdrawal Device must be used on all flex lance, rigid lance and line moling jobs. The anti- withdrawal devices must be securely attached to the equipment being cleaned.

4.2.14. When flex lancing or line moling, the lance/hose must have a hard stop for the maximum length of travel.

4.2.15. All non-rotating equipment high pressure hose assemblies must include whip checks to protect personnel from excessive movement of hoses in case of a hose rupture or blown end fitting.

4.2.16. Hose Shrouds shall be designed so that they can withstand the full rated service pressure of the system for maximum personnel protection and are not intended to only perform water management duties in the event of a hose rupture.

4.2.17. The Back Thrust Force for a Hydroblasting operator shall not be greater than 1/3 of their body weight. Rotating operators in and out is also recommended due to the physical demand of the job duration.

4.2.18. The Dump System shall be manually controlled only by the Nozzle Operator. When a foot valve is used, it must be placed within a frame that will guard the valve from being accidentally operated and that is sturdy enough so that it will not be accidentally moved or knocked over when it is used. Where the water dumped through a dump system is not immediately released to the open air, but passed into a dump line, the dump line must be secured so that it does not whip when active. Also ensure that the Dump System is clear of obstructions.

4.2.19. Indexing is not allowed while the lance is energized

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4.3. Hydroblasting Equipment Requirements

4.3.1. All high pressure pumps provided by Hydroblasting companies must be equipped with a rupture disc assembly or PSV rated at minimum of 1.2 times the maximum allowable working pressure (MAWP) of the system's weakest component.

4.3.2. All rigid lance assemblies shall include use of a minimum 3' (feet) Shroud to protect the employee handling the end of the rigid or stiff lance. The construction of the Shroud (e.g. double stainless steel braided) shall be sufficient enough to help ensure the safety of the employee against serious injury from the potential of a high-pressure hose rupture. The hose Shroud must be inspected for inner and outer integrity (e.g. excessive wear and breakdown of reinforcement wire braiding) at a minimum on a quarterly basis.

4.3.3. Anti-withdrawal devices used on tube sheets when flex lancing or rigid lancing must include use of a snorkel that does not exceed 1'' (inch) clearance from the tube sheet. In vertical tube sheet applications, to prevent the potential of a water-cut to the foot, that gap (between snorkel and tube sheet) must be protected from the lance operator by utilizing some type of physical barrier e.g. 4"x4"x12" (inches) piece of angle iron or a 2"x4"x12" (inches) board. *This shielding is not required if indexing is automated.*

4.3.4. In addition to use of anti-withdrawal devices when line moling, a Stinger must be attached to the end of the nozzle, that is at least 1½ times the I.D. of the piping being cleaned. The rigidity of the compression fitting and nozzle length can be included in the overall stinger length requirement. Special consideration shall be given to tees in the line being cleaned when the tee in the line is larger than the main line being cleaned. Additional length of Stingers may be required to prevent accidental reversal of the line mole assembly in the piping.

4.3.5. All high pressure hoses and flex lances used for line moling must be marked at a minimum 24" (inches) from the end compression fitting. This visual marking will minimize the potential for a serious water-cut when the line mole on the hose end is exiting toward the end of the pipe. *Not applicable with automated processes.*

4.3.6. All shotgun whip hoses must be shrouded to protect the shot-gunner against accidental rupture of the whip hose. Shotgun Shrouds must be constructed (e.g. double S.S. braided) in a manner that protects the shot-gunner against a serious water-cut. The protective Shroud must be a minimum of 6' (feet) in length. The whip hose shroud must be inspected for inner and outer integrity (e.g. excessive wear and breakdown of reinforcement wire braiding) at a minimum on a quarterly basis.

4.3.7. The length of the shotgun shall be a minimum of 66" (inches) in overall length from the butt stock of the gun to the end of the nozzle when used in a manual application.

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4.3.8. High pressure hose end fittings, connection fittings and couplings shall be manufactured to be compatible with the hose. Only fittings marked with the Maximum Allowable Working Pressure (MAWP) shall be used. Fittings designed for pressure less than the service pressure of the pump shall never be used in a higher pressure application. NPT or Pipe Thread connections shall not be used at pressures greater than 15,000 p.s.i.g.

4.3.9. Hydroblasting shotguns require double triggers.

4.3.10. When Roto Jet nozzles are in operation inside a vessel, the entry point where the hose enters the vessel must be securely covered to prevent the jet from coming out of the vessel.

4.3.11. A pressure gauge with the full range of system capability must be verified operable and must be visible to the equipment operator.

4.4. Chemical Cleaning Specific Requirement

4.4.1. In the decision to clean chemically and the selection of the cleaning method, the following factors should be considered:

a) the type of design, amount of flow, operating temperature, and pressure of the steam generator
b) The surface finish required in/on the unit or component.
c) the characteristics and quantity of deposit
d) the compatibility of the cleaning solvent with system metallurgy
e) Extent of material loss which car be permitted by exposure to acids if applicable.
f) Deposit Solubility in the cleaning fluid
g) the method of spent solvent disposal
h) the availability of demineralized water or condensate
i) personnel safety
j) cost

4.4.2. A written cleaning procedure and schedule should be drawn up and made available for reference by all personnel participating in the operations.

4.4.3. If the release of a hazardous vapor, mist, gas, or dust is possible, perform the work using the appropriate engineering control, such as a chemical fume hood, glove box, or vented biosafety cabinet. Take the time to label temporary containers and inspect manufacturers' labels for thoroughness and accuracy.

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4.4.4. When planning your work, consider the following possibilities:

1. Substituting less hazardous chemicals;
2. Using less;
3. Ordering only what is needed; and
4. Sharing chemicals when possible.

4.4.5. Review the hazards of the chemicals before using them. Review the Material Safety Data Sheet for safe handling procedures and PPE recommendations. Be prepared for a spill or an exposure involving the hazardous chemical. Know the location of the nearest eyewash and emergency shower.

4.5. High Pressure Water Cutting Requirements

4.5.1. Job plans must be established and approved by BASF for all high pressure cutting activities before work execution. At a minimum this shall include basic job steps, parameters, and safeguards.

4.5.2. All high pressure water cutting will be through the use of an automated track system.

4.5.3. Manual held cutting devices are not permitted.

4.5.4. Track cutting systems will be firmly attached to include a secondary method of attachment.

4.5.5. Personnel must remain 10 feet from the cutting head.

4.5.6. Prior to starting the cut, ensure that the customer has supported the portion of the structure to be cut so that it will remain suspended when the cut is finished. If the portion of the structure to be cut is not rigged, determine with the customer contact how much of the structure to leave uncut until the support is in place.

4.5.7. The largest orifice to be used for hydro cutting is .022 inches.

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4.6. Pressure Washing (below 5000 psi)

4.6.1. While Pressure Washing is typically performed at lower service pressures, the below special precautions shall be followed.

- Pressure Washing shall follow the requirements of the Safe Work Permitting process.
- Pressure Washing does not include line moling, or lancing type activities.
- Pressure Washing units shall be inspected prior to use and operated per the manufacture's recommendations. Periodic system inspections shall follow manufacturer's recommendations or site/company procedures. Alterations or modifications are not permitted.

4.6.2. Personnel utilizing Pressure Washing equipment shall be trained in the operation and use of the Pressure Washing equipment.

4.6.3. PPE shall address the hazards associated with Pressure Washing which could include but is not limited to water cuts, chemical contact, noise, respiratory consideration for legionnaires' disease and chemicals, and any other recognized hazards for the task.

4.6.4. Job plans must be established for all Pressure Washing activities before work execution. At a minimum this shall include basic job steps, equipment, parameters, and safeguards.

4.6.5. Work areas shall be adequately barricaded and tagged with the hazards.

4.6.6. Pressure Washing equipment shall be grounded per site and or contract company requirements.

4.6.7. Whip Checks are required at all hose to hose connection.

4.6.8. All component parts and fittings shall be checked for correct size and rating for the unit.

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4.6.9. Hose Assemblies – Do not bend or pinch pressure hose as this may cause internal damage that is not visible to the naked eye and lead to hose failure. Do not use tools (pliers, wrenches, vise grips) directly on the hose portion as they may also cause internal damage. All hose assemblies shall be inspected prior to use as follows:

- Assemblies shall be free from external damage such as broken wires or excessive braids showing.
- All end fittings and couplings are in good order and satisfy pressure rating for the unit operating pressure
- Only threaded hose connections are to be used at the pump.

4.6.10. Hoses shall be pressure tested quarterly at a minimum. Hoses must have tags/bands etc. to reflect current testing period.

4.6.11. Any electrical equipment in the immediate area of the Pressure Washing activity that presents a hazard to the operator or could damage equipment will be de-energized, shielded or otherwise made safe.

4.6.12. Pressure Washing on process piping and/ or equipment that contains a hazardous energy source shall require a safe work permit.

4.6.13. Pressure Washing wands shall not be pointed at personnel.

4.6.14. The Pressure Washing wand trigger assembly shall not be locked in position and if equipped with a locking mechanism, the mechanism shall be removed or disabled.

4.6.15. The system shall be completely flushed with sufficient water to remove any contaminants before installing the nozzle.

4.6.16. Objects to be cleaned must not be held by personnel and must be secured.

4.6.17. Equipment shall not be left unattended when in operation nor left under pressure.

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4.7. Periodic, Before Use Inspection, and Preventive Maintenance

4.7.1. Hydroblasting companies shall have an equipment inspection program that ensures equipment is ready for service prior to job identification or notification. Before job notification, the inspection of high pressure hoses and flex lances must include the visual inspection for hose deficiencies (bulges, cracks, etc.), integrity of the compression fittings, outer cover, and no evidence of broken wire braids. If one or more broken wire braids exist, the hose must be taken out of service and discarded.

4.7.2. Once equipment is staged, all hose assemblies shall be inspected for leaks and/ or damage.

4.7.3. High pressure hose assemblies shall be pressure tested quarterly at a minimum. Hoses must have tags/bands etc. to reflect current testing period.

4.7.4. All high pressure hoses with outer rubber or plastic covering construction and assemblies, including shotgun whip hoses/assemblies, must be tested to the working pressure (WP) of those hoses at a minimum. Hoses must have tags/ bands, etc. to reflect the current testing period.

4.7.5. Documentation of the hose tests must be recorded to indicate testing occurred at least quarterly. The hose test documentation should include the type (e.g. 10K, 20K, and 40K), size, and identifying markings (e.g. serial # or special numbering system) on the hoses to ensure testing of all hoses.

4.7.6. All pressure relief devices must be; at a minimum, visually inspected or tested for correct pressure rating and over all condition on a quarterly basis. Visual evidence of the inspection frequency is required.

4.8. Hydroblasting Companies shall have the following elements in their company programs

4.8.1. A documented training program that includes but is not limited to energy isolation of equipment, confined space entry, correct body positioning for tasks (Ergonomics), using shotguns, flex lancing, rigid lancing, line moling, and use and installation of anti-withdrawal safety devices as a minimum.

4.8.2. A written energy isolation procedure in place to effectively de-energize and isolate water cleaning and cutting equipment when it is being serviced, repaired, installed, relocated, or any time anyone could be exposed to the high pressure water stream.

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4.8.3. Training of all employees to the National Center for Construction Education and Research (NCCER), Hydroblasting Technicians Level.

4.8.4. A documented heat stress policy and shall have provided training on their policy and work/ rest schedule for all employees.

4.8.5. Job plans must be established for all Hydroblasting activities before work execution. At a minimum, this should include basic job steps, parameters, and safeguards.

4.8.6. Use a pre-job check list/ job safety analysis (JSA) to help identify all job hazards and ensure the safe execution of the job with the crew. The pre- job check list/ JSA shall be initiated and reviewed with the crew initially and any any time there is a change in job scope, an instance of an unsafe condition, additional personnel added to the job, or at each and every personnel shift change.

4.9. Approval Process for Non-automated Hydroblasting Activities

4.9.1. The MOC database will be utilized to document the approval. The MOC “Change Title” shall be entered as “Non-Automated Hydroblasting Approval”.

4.9.2. An assessment must be conducted to verify that Automation cannot be accomplished and to include the additional safe guards that must be implemented. The assessment shall contain the following information:

4.9.3. Why Automated services cannot be performed. (MOC form, Tab 1 - Technical basis).

4.9.4. What actions will be taken to manage the risk and protect workers during Hydroblasting activities. (MOC form, Tab 3 – Risk, “Mode of Failure”).

4.9.5. What steps or actions will be put in place to prevent future non-automated Hydroblasting. (MOC form, Tab 4 – After Start Up, enter an Ad-hoc action item).

4.9.6. The assessment shall be authorized by Site management, Unit management and EHS Site Team leader.(MOC form, Tab 7 – Start up Approval).

4.9.7. Complete other sections of MOC form as needed.

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5. Personal Protective Equipment

5.1. Assessment: The appropriate type of personal protective equipment (PPE) used during a given situation will vary with the hazards associated with the material, equipment, location, and ability to verify that the equipment/ line is clear. The specific PPE must be consistent with the Safety and Health Procedure BMEHS-002.022 – Personal Protective Equipment.

5.2. The minimum PPE in any industrial cleaning operation shall be:

- Hard Hat
- Eye Protection (ANSI Z87.1 glasses with side shields as a minimum)
- Face Shield and Mono Goggles as required by hazards such as chemical exposure, base or acidic pH, flying debris, etc… Mono Goggles are required to be carried on your person at all times while in the operating portions of the plant site.
- Appropriate work gloves
- Appropriate hearing protection up to and including double hearing protection as required by Site or Contractors Safety Policies and Procedures.
- Flame Retardant Clothing
- Safety Toed boots up to and including metatarsal protection as required by Site or Contractors Safety Policies and Procedures

5.3. PPE requirements can be down-graded when utilizing certain automated equipment and the PPE down grade meets the approval of BASF.

6. Training

6.1. BASF and Contracted Employees involved in Industrial Cleaning Activities:

- Owning and/ or Service Personnel shall receive training to recognize the applicability of the situations and the necessary means to safeguard against the hazards posed during these activities.
- Training shall be conducted during employee orientation and periodically thereafter, at least every third year.
- Retraining of employees is required whenever deviations or inadequacies in any procedure are identified.

6.2. Personnel Not Directly Involved in Industrial Cleaning Activities:

- Personnel not directly involved in Industrial Cleaning activities will receive instruction concerning their role in the procedure and how it may affect their specific work operation.
- Training will be conducted during employee orientation and periodically thereafter, at least every third year.

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6.3. Contractor Employees:
Contractor Employees will receive their Industrial Cleaning training during their orientation prior to working at the Beaumont Site, and with additional training by their employer at the site.

Note: All Contract Companies are subject to having their policies and training programs audited for plant entry compliance on these minimum safety requirements.

7. RESPONSIBILITIES

7.1. Beaumont Site Leadership Team
Has responsibility for implementation, administration and/ or interpretation of this procedure

7.2. Environmental, Health, and Safety
Has responsibility for the administration and/ or interpretation of this procedure.

7.3. TES Administration
Has primary responsibility for the initiation, re-issuance, administration and/ or interpretation of this procedure.

7.4. Beaumont Site Employees and Contractors
Have primary responsibility for adherence to this procedure including identifying deficiencies in the procedure, and identifying , reporting and correcting activities not in compliance with the procedure.

8. RELATED DOCUMENTS

BMEHS-002.005 Control of Hazardous Energy

BMEHS-002.026 Safe Work Permits

BMEHS-002.022 Personal Protective Equipment

BMEHS-002.032 Respiratory Protection

BMEHS-002.045 Procedure Deviation

BMEHS-003.002 Beaumont Site Management of Change Procedure

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APPENDIX A

HEAT EXCHANGER CLEANLINESS LEVELS

Scope:

This document serves as a guideline for describing cleanliness levels for heat exchanger tubes and is intended to provide a standardized description for communicating to a hydroblast contractor.

Terminology:

Deposits: Tar, sludge, product, etc.
Scale: Mill scale, corrosion scale, oxides

Level 1:

Tubes are open for flow, or unplugged. Tube surface may still be covered with scale or deposits. Large chunks of deposits are removed. Tube surface is still largely covered by deposits. Scales may still be present.

Level 2:

Most of the tube surface is visible. Up to 1/3 of the equipment surface may be still covered by deposits. Scales may still be present. Total material remaining is greater than 50%

Level 3:

Isolated areas of deposits remain. Scales are greater than 50% removed. There may be flash rust on steel. Total material remaining is less than 50%.

Level 4:

The tube surface is 100% visible. There are no isolated deposits. Scales are 99% removed. There may be flash rust on steel. This is typically the minimum level for tube mechanical integrity inspections (Eddy Current Testing, Visual Testing, IRIS)

Level 5:

The equipment surface is 100% visible. There are no isolated deposits or scales. Steel surfaces have been passivated or otherwise protected to prevent flash rusting.

Level 6:

Pharmaceutically clean. The equipment surface is 100% clean, with no deposits or scale. There is no flash rust, and there are no residual films or deposits after drying.

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APPENDIX B

Decision Basis Matrix for Cleaning Method Selection

CLEANING METHOD	Application Pros and Cons
Manual Hydroblasting Processes- Usually Require Deviation	
Shotgunning	1. Used for Pre-cleaning of exchanger tubesheets and tube-ends prior to the final cleaning process, cleaning exchanger components, general equipment cleaning and piping prior to final cleaning process 2. Used to clean exterior of u-tube bundles removed from shell 3. Can be used for general cleaning in low priority cleaning applications 4. General interior cleaning of large I.D. equipment
Flex lancing	1. Most general cleaning applications with light to moderate scale, polymers, or hydrocarbon residues readily removable by water impingement. 2. Applications with restricted space and limited access to tubesheets
Flex lancing with Spin tip	1. General cleaning applications where some limited scale or residues remain after completion of a single, stiff lancing pass 2. Applications where residues remain in a streaking pattern after flex lancing due to lanes of fixed orifice impingement 3. Applications with restricted space and limited access to tubesheets 4. Spin tip is mainly for polishing and has limited cutting capabilities due to nozzle orientation but can be combined with a forward projecting tip to improve cutting ability.
Stiff lancing	1. More severe cleaning applications involving tightly adhered deposits, or deposits forming some restrictions to the tube ID requiring a greater number of forward impinging jets for removal 2. Applications where flex lancing has been proven ineffective for single pass cleaning
Stiff lancing with Spinnig lance and/ or Spin tip	1. General cleaning applications where some limited scale or residues remain after completion of a single, stiff lancing pass 2. Applications where residues remain in a streaking pattern after stiff lancing due to lanes of fixed orifice impingement 3. Spin tip is mainly for polishing and has limited cutting capabilities due to nozzle orientation but can be combined with a forward projecting tip to improve cutting ability.
Abrasive grit blasting	1. Severe applications with thin, tightly adhered films requiring more additional erosion for removal i.e. paints, thin film polymers, thermal degradation compounds 2. Aggressive nature with some blasting agents requires judicial use to prevent damage to equipement

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	3. Applications where residues remain after completion of single pass stiff or flex lancing methods
Sodium Bicarbonate (Bio) Blasting	1. Applications with thin, tightly adhered films requiring more additional erosion for removal 2. Used dry in applications sensitive to moisture 3. Applications where residues remain after completion of single pass stiff or flex lancing methods
CO2/ Cryo Blasting	1. Applications with thin, tightly adhered films requiring more additional erosion for removal 2. Used in applications sensitive to moisture 3. Used where limiting water usage is a concern- minimal residual materials 4. Generally safer to use due to the lower pressures used to apply the abrasive. 5. Somewhat limited in ability to effectively clean longer, small diameter tubes
Tube brushing (rotating or static)	1. Severe applications with thin, tightly adhered films requiring additional erosion for removal i.e. paints, thin film polymers, thermal degradation compounds 2. Generally safer than hydroblasting 3. Progress can be quite slow at times as compared to hydroblasting 4. Aggressive nature with some attachments requires judicial use to prevent damage to equipement 5. Can be used in applications where there is a benefit to reduced water generation during cleaning
Hand Fed Rotating Nozzle Line Moling	1. Application used for general cleaning of piping systems 2. More complete cleaning of larger I.D. pipes and tubes than using a flex lance or other static cleaning device 3. Limited in the total run- length of piping that can be cleaned
Hand Fed Rotating Hose/ Nozzle Line Moling	1. Application used for general cleaning of piping systems. 2. More efficient than Rotating Nozzle Line Moling in total coverage and effective cleaning. 3. Limited in the total run- length of piping that can be cleaned 4. More complete cleaning of larger I.D. pipes and tubes than using a flex lance or other static cleaning device

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CLEANING METHOD	Application Pros and Cons
Automated Hydroblasting Processes- Should always be prefered over a manual method	
Automated Shotgunning	1. Pre-cleaning of exchanger tubesheets, channels and tube ends prior to final cleaning process 2. Useful for cleaning valves, pumps, etc… 3. Exterior of u-tube bundles removed from shell 4. Low priority cleaning applications
Automatic Feed and/ or Index Stiff Lance	1. Severe applications with plugged or heavily fouled tubes that require additional forward thrusting action for cleaning and for higher pressure applications up to 40,000 psi.. 2. Applications involving a large number of tubes where the additional setup time and cost of the automated equipment can be recovered. 3. Applications where the addition of the rotating element provides the required polishing finish
Automatic Feed and/ or Index Flex Lance	1. Severe applications with plugged or heavily fouled tubes that require additional forward thrusting action for cleaning and for higher pressure applications up to 40,000 psi.. 2. Applications involving a large number of tubes where the additional setup time and cost of the automated equipment can be recovered. 3. Applications where the addition of the rotating element provides the required polishing finish
Bundle Lancing Machine (Inside Bundle Cleaning)	1. Severe applications with plugged or heavily fouled tubes that require additional forward thrusting action for cleaning. 2. Applications involving a large number of tubes where the additional setup time and cost of the automated equipment can be recovered. 3. Requires large area so bundles must be typically removed from the unit and transported to the cleaning machine.
Shell Side Machine (Outside Bundle Cleaning)	1. Severe applications with plugged or heavily fouled tubes that require additional forward thrusting action for cleaning. 2. Applications involving a large number of tubes where the additional setup time and cost of the automated equipment can be recovered. 3. Requires large area so bundles must be typically removed from the unit and transported to the cleaning machine.
Automated Feed/ Index Power Rotating lancing	1. Severe applications with plugged or heavily fouled tubes that require additional forward thrusting action for cleaning and for higher pressure applications up to 40,000 psi. 2. Applications involving a large number of tubes where the additional setup time and cost of the automated equipment can be recovered.
Automated Line Moling	1. More severe applications with heavily fouled tubes due to the forward cutting action versus polishing action

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	2. Applications involving a large number of tubes where the additional setup time and cost of the automated equipment can be recovered. 3. Applications where lack of access to the tubesheets limits the use of ATL or Power Lancing 4. Consistent coverage over hand fed systems- no gaps or voids.
2D/ 3D Nozzles	1. Applications where limited access or large size are a concern 2. Applications where deposits have a known history of responding well to cleaning solutions

CLEANING METHOD	**Application Pros and Cons**
Other Cleaning Processes- Generally Preferred over Manual Methods	
Hydrokinetics	1. Applications with plugged or heavily fouled tubes where the previous use of manual or automated hydroblasting techniques has not proven to be cost efficient. 2. Applications involving tube bundles that are heavily plugged with polymeric materials. 3. Applications where tube ID is < 1/2” limiting use of normal hydroblasting techniques
Hydrodrilling	1. Applications with plugged or heavily fouled tubes where the previous use of manual or automated hydroblasting techniques has not proven to be cost efficient. 2. Aggressive nature with the mechanical cutter on the tip requires judicial use to prevent damage to equipement 3. Applications involving tube bundles that are heavily plugged with polymeric materials.
Chemical Cleaning	1. Applications where limited access or large size make it more cost effective to perform simultaneous cleaning of the entire tube bundle 2. Applications where deposits have a known history of responding well to cleaning solutions
Bake out Process	1. Applications where bundles are plugged or heavily fouled with polymers 2. Applications where bundles or exchanger is readily removable from process areas

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