Chemistry - PI 24

CHEMICAL CLEANING OF FOULED EQUIPMENT

Objectives:

1. Define in one or two sentences "fouling" as applied to equipment that requires chemical cleaning.

2. List four criteria of a chemical cleaning job for a system. ie, What must happen to a system during a chemical clean.

3. List four criteria for a chemical cleaning agent (eg, acid) used in a cleaning job.

4. State five differences (advantages or disadvantages) between chemical and mechanical cleaning.

5. State which chemical agents are recommended for:

   Carbon Steel; Stainless Steel, Monel; Aluminum; Brass.

   State also which agents should be avoided (if any) for the above list.

Pumps, compressors, and station machinery with many moving parts may be affected most by wear-and-tear and erosion - but for most other equipment, corrosion and fouling are the biggest contributors to deterioration. Fouling not only hampers operations, but, by obstructing normal heat transfer and providing a site for unwanted chemical reactions, it can lead to very undesirable changes in the micro-structure of materials.

While any deterioration process that involves a chemical reaction can be called corrosion, we usually associate the term specifically with metals and alloys.

Most metals and alloys that we use are in a state that we can say is thermodynamically unstable. It should be remembered that most metals and alloys are attempting to become stable by trying to revert from a higher energy to lower energy state. Iron pipe in corroding reverts to iron ore. Once corrosion occurs it often becomes a fouling problem in process equipment.

Fouling of Process Systems

Fouling may be defined as the accumulation of solid or non-fluid phases in a manner that hampers the operation of and may contribute to the deterioration of station equipment. The solid phases can contain the following:

1. Products of corrosion reactions as discussed above.

2. Particles torn loose by wear and abrasion and subsequently redeposited in the system.

3. Solid phases originating entirely in the environment.

These may be solids disposed in the environment when the steam enters the system, eg, resins carried into the system through strainers or filters. They may form as a result of physical changes that allow something to condense. They may be the result of chemical changes taking place in the environment that yeilds insoluble solid products, or there may be biological fouling such as algae growth.

Here's What To Do:

Gather a group of four or five colleagues. Consider the following as a group project, then compare your groups work with the data on the following pages.

Group Project

Your group has been assigned to deal with a contractor who is an expert in chemical cleaning. The reason we need the contractor is that somewhere in our plant there is a system (non-radioactive) which is fouled to the point where there is definite loss of heat transfer and some small amount of flow restriction.

Your group is to hold a meeting prior to your first meeting with the contractor. The items which are to be discussed and documented at the meeting are:

(1) Develop a list of items which are the parameters that will constitute a satisfactory cleaning job as far as the system is concerned. (You might think of this as a list of "musts" and "wants" for those of you who have PI-14).

(2) Develop a list of parameters which will apply to the agent. (Agent means the chemical, not the contractor).

(3) Develop a list of "other items" which you will have to consider for this job.

For these first three statements, try to list at least six items in each category.

(4) Suppose the systems were to contain:

(a) carbon steel,
(b) stainless steel,
(c) monel,
(d) aluminum,
(e) zircalloy.

What cleaning agent would you prefer? Similarly, which would you avoid?

(5) There has been considerable discussion as to whether a chemical or a mechanical method of cleaning should be employed. Try to outline some of the advantages of chemical over mechanical cleaning and vice versa.

After your group has discussed the above four agenda items, compare your results to the lists and comments on the following pages. It is not intended that your lists will match exactly those provided, but there should be significant agreement in principle.

If your group finds itself dead stuck for a starting place, ask the Course Manager for a few helpful hints rather than depriving yourself of the opportunity of discussion by consulting the given list too early.

Parameters For The System

1. The foulant must be removed to restore heat transfer and flow to specification or as installed values.

2. The parent metal of the system must not be damaged during the process. Damage may occur by attack from the agent used or by abrasion from particles of foulant broken off during the cleaning process and then being circulated with the cleaning solution.

3. The parent metal should be left passivated. (Not anxious to react.) eg, If we are removing iron oxide from mild steel; before exposing the metal to atmospheric oxygen a step which promotes formation of a protective, passive magnetite layer on the surface of the metal is employed. This is known as passivation (compare this to the procedure for chemical conditioning of the Primary Heat Transport System in Module PI 24.23-2).

4. No debris is left in the system. If the foulant breaks up under the influence of the cleaning agent then the chunks of foulant must be thoroughly flushed out of the system.

5. All traces of the chemical cleaning agent should be thoroughly rinsed from the system.

6. System passes inspection at end of job.

Parameters For The Cleaning Agent

1. The chemical agent or solvent must react with, or otherwise dissolve, the solid foulant.

2. The agent must be compatible with the parent metal or some "inhibitor" must be used. An example of an inhibitor is the use of an organic compound (which is usually sold as a proprietary product) to allow HCl to be used to clean mill scale from mild steel but not attack (violently) the base Fe^0 metal.

Several years ago, arsenic compounds were used to inhibit HCl. Because of toxicity hazard, this practice was stopped. Present inhibitors are organic compounds with polar groups, containing nitrogen, sulfur or oxygen atoms attached to hydrocarbon chains.

The polar group (an electrically unsymmetrical cluster of atoms) may be attracted to metal surfaces to be "adsorbed" there while hydrocarbon chain fends off marauding H^+ ions that seek to reach and corrode the metal surface.

3. Ideally, the agent should be easily rinsed so that we can be sure that there is none left in the system.

4. At the end of the cleaning job it is usual to dump the cleaning solution into a pond for evaporation on site. These ponds are usually lined to prevent seepage but all the same, the agent should be environmentally acceptable in case of accidental release.

5. During the process, some cleaning agents react with the foulant or base metal to generate toxic or explosive gases. We would like to keep these to a minimum. (To say the least!)

6. The agent should be easy to transport to the site and easy to inject into the system. A low toxicity would be favourable as personnel will be handling the agent or near to it during the process.

7. Low cost!

Other Considerations

1. What isolation of the system from the rest of the plant is required? What is available?

2. What outage time is required - Do we have a spare system?

3. How will we monitor the progress of the job?

4. Are there any pressure or temperature requirements for the agent, or limitations?

5. What are the manpower requirements for the job?

6. When is the contractor available to come to our site?

System Material Considerations

For mild steel systems, most conventional cleaning agents are satisfactory. The agent of choice is inhibited Hydrochloric Acid as it is cheap and effective. Where systems contain stainless steels, HCl must be avoided due to the phenomenon of "chloride-stress corrosion cracking". This is a type of brittle failure that occurs with little or no metal loss. The agents most popular for stainless systems are then the organic acids, especially citric and formic. (For those of you who wish to delve further into cleaning by organic acids, see the Course Manager for articles).

Nitric Acid could be used on stainless steel but copper alloys are usually present as well which in combination with nitric acid would form toxic nitrogen oxides. As stated above, systems containing copper alloys (eg, Brass: Cu-Zn and Monel: Ni-Cu) should not be exposed to nitric acid for safety reasons.

Aluminum is quite a problem; it is badly affected by both acids and bases. Therefore only weak acids (eg, H_3PO_4) or bases should be used.

Chemical/Mechanical Advantages and Disadvantages

1. Outage time is usually shorter for a chemical cleaning job as no dismantling is required.

2. Results are visible at all times during a mechanical cleaning.

3. A chemical cleaning agent will get behind corners where mechanical methods may miss.

4. Depending on the chemical used or the method of mechanical cleaning one or other may pose a threat to the parent metal.

5. Chemical cleaning jobs tend to be more uniform.

6. Mechanical jobs require more man-hours of labour.

Here's What To Do:

1. If your list of items was better than mine, congratulations and would you let the Course Manager know of any serious omissions.

2. If you felt your group was not on the right track; have a short group session with the Course Manager.

3. Carry on to Module 61-1 to read about some actual jobs done in NGD by chemical cleaning.

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