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The Development of Corrosion Control Document (CCD) in Refinery: Crude Distillation Unit (CDU) Process

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This study focuses on techniques of improving refinery reliability, profitability and availability. We studied corrosion control document (CCD) in the crude distillation unit (CDU) process. Recent studies show the Loss due to corrosion in the U.S.A. is 276 billion dollars per year. Therefore, both managers and engineers of refinery industry are always concerned about reliability of equipments related to corrosion. The CCD consists of numerous parts namely damage mechanisms (DM), design data, critical reliability variables (CRV), guidelines, etc. The first step in development of CCD is to draw material selection diagrams (MSD). It is needed to choose the DM of each process effecting equipments that are based on API (American Petroleum Institute) 571. The selected nine DM from API 571 (nineteen DM are exist) are (1) creep/stress rupture, (2) Fuel Ash Corrosion, (3) Oxidation, (4) High Temperature Sulfidation, (5) Naphthenic Acid Corrosion, (6) Hydrochloric Acid (HCL) Corrosion, (7) Ammonium Chloride (Salt) Corrosion, (8) Wet H2S Corrosion and (9) Ammonia Stress Corrosion Cracking. Each of DM related to corrosion of CDU process was selected by design data, P&ID, PFD, corrosion loop, flow of process, equipment's history and experience. Operating variables affecting severity of DM are selected in initial stage of CRV. After the CRV were set, we suggested the guidelines for reliability of equipments. The CCD we have been developed is the basis of the corrosion control in refinery industry. It also improves the safety of refinery process and reduces the cost of corrosion greatly.

1. Introduction

As an oil refinery has become bigger and accumulated recently, an accident of corrosion are more likely to be extended to serious accident. In fact, refinery process accidents have been happened continuously in the inside and outside of country. These accidents bring about many casualties and economic loss. Recently, an American report shows that corrosion cost was around $276 billion in 1998, and it was large sum accorded to 3.1 percent of American GDP of that year.
The principal case of corrosion accident in the refinery process was storage tank explosion in 2001.7.17 at Delaware. The storage tank exploded due to high-pressure gas release caused by the corrosion of connection pipe in tank. In consequence, one person who belong to repair works contractor died and eight people were wounded in this accident.

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In case of Korea, the accident which took place in 2003.10.20 was caused by high temperature sulfidation in HOU unicracking process. Corrosion made the tube thin. With thinned tube break caused by internal pressure, distilled crude oil in tube flew out, and then the fire broke out due to heater's high fever.
Like this, corrosion accidents occur frequently in the world, and corresponding men and money loss has been serious. Therefore, systematic system is required so as to reduce accidents caused by corrosion and to minimize corrosion cost. First of all, CCD (corrosion control document) development is necessary for development of systematic system. However, while most of internal oil companies state a few reasons such as lack of work force and time, they postpone the development of CCD.
In this study, our team developed CCD in oil refinery process and systemized development process. As following these, oil refining process as well as corrosion condition will be improved. Furthermore, on the basis of data from CCD DB, if this and currently used RBI (risk based inspection) apply to actual case together, economic effect can be achieved.

2. CCD Development

2.1 Background

In many cases, test and check of corrosion accident, in recent refined oil service as well as in petroleum chemistry equipment, was approximately recorded or it was not recorded at all. Also, information about process and arrangement which are apt to be corroded has been not well managed. Even though loss by corrosion is very small or negligible, it should be described exactly or managed well. As well, several things have to be determined, that is, which part is protected from record of loss caused by corrosion and which thing is prevented. Therefore, CCD development in refined oil and petrochemical process is needed firstly.
In this study, we developed CCD with an emphasis on CDU process in an oil refinery. Generally, Corrosion Control Document includes the following contents.

- Inclusive document about equipment efficiency decrease
- Unit process & Process State
- Shutdown & startup condition that is related to steady-state & corrosion.
- Process Flow Diagram, materials, corrosion diagram
  Corrosion control loops (Total system, Slurry system, Reflux System)
- Potential case of efficiency decrease in unit process & the spot where the accident took place.
- Efficiency decrease mechanism by corrosion
- Corrosion control procedures, injections, inhibitors inspection, corrosion monitoring, process alteration and advice of material replacement
- Integrity Operation Windows

The CCD is inclusive document that includes information about from principle design of equipment to corrosion reason, corrosion mechanism, past record, guide line on corrosion prevention. Hence, CCD development is requisite for equipments in an oil refinery as well as petrochemical plant. Also, it is fundamental document to improve reliability of equipment and to reduce loss by corrosion.

2.2 Process

The general order of CCD development is constituted of 4 steps like following Fig.1.

The first step is to classify the quality of material according to equipment in PFD process. After that, describe DM (damage mechanism) which gives effect on equipment with each process. On the basis of that, select CRV (critical reliability variables) which influence on inspection interval and equipment integrity. The last step is to make operation guidelines which propose proper extent of operation.

The system is needed, which can feedback the result to related team after monitoring selected CRV from online or offline, and make a report. This is called IOW (integrity operating window) system. The concept of IOW system is representing certain limit to operation guidelines of measurable operation variables. (Fig. 2) With IOW system, perception of process change can assure equipment reliability by getting feedback and report earlier than condition change is recognized.

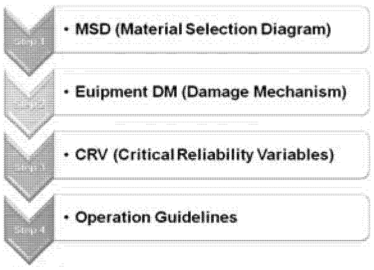

Fig. 1 - Steps of Development of Corrosion Control Document (CCD)

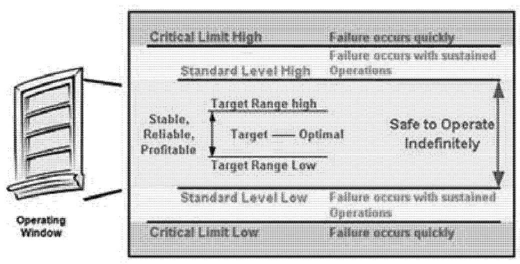

Fig. 2 - Concept of IOW system ("Establishing Integrity Operating Windows (IOW's)", John Reynolds

If it runs out of fixed value, it can make problem like devolution or corrosion of material. We developed CCD as 4 steps. Important content of each step is following.

2.2.1. Step 1: Building a MSD (material selection diagram)

Considering corrosion and economic efficiency, each equipment of oil refinery and petrochemical plant is made from different material. For instance, carbon is used in upper portion of A-column in CDU process, but lower portion is made from Hastelloy alloy that hardly ever corrode. Compared to upper portion, such corrosion materials as asphalt and coke in lower portion are comparatively less pure, and these flow more through lower portion than through upper portion. Therefore, using existing materials, carbon, may cause several problems.

At first, we drew the Process Flow Diagram of each process. Generally, one PFD includes following information.

- Process Piping
- Major equipment items
- Control valves and other major valves
- Connection with other systems
- Major bypass and recirculation streams
- Operational data (temperature, pressure, mass flow rate, density, etc.), often by stream references to a mass balance.

- Process stream names

On completed PFD, We make MSD which reflect all the past histories of material use. Based on design data of corresponding process and the past history, we indicate such the qualities of material as Cr, Duplex, 400SS, Hastelloy, and 300ss on PFD. While making MSD, we marked the spots where the probes have already been installed and where we need to install other probes.

Following Fig. 3 shows MSD in front of A-column in CDU process.

2.2.2. Step 2: Equipment Damage Mechanism Selection

After building a MSD, there’s a need to select a Damage Mechanism. The corrosion materials and the mechanism should be found during this step.

First of all, the design and the operation data should be collected, and then check up the temperature, the pressure and heat treatment conditions from collected data. Once finishing collection data, it’s necessary to collect the corrosion material data of each steam. What should be collected is sulfur, chloride ion, hydrogen sulfide, ammonia and so on. The followed step is selecting a DM related to an equipment or each part of equipment refer to API(American Petroleum Institute) 571.

We selected 9 DM(data mechanisms) out of 19 DM on API regarding to possibility of occurrence at current processes, Creep/Stress rupture, Fuel ash corrosion, Oxidation, High temperature sulfidation, Naphthenic acid corrosion, Hydrochloric acid(HCL) corrosion, Ammonium chloride(salt) corrosion, Wet H2S corrosion and Ammonia stress corrosion cracking.

There are the specific explanation of selected 9 DM, affected materials, main factors, the methods of prevention & alleviation and the ways of inspect & monitoring.

Fig. 4 shows the DM of equipment.

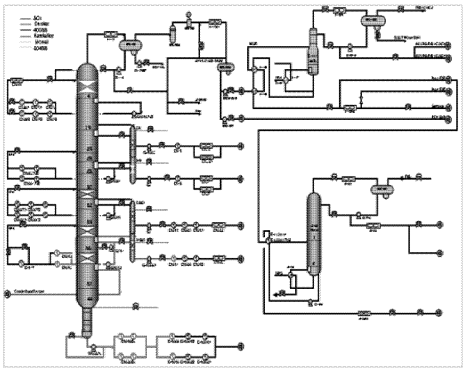

Fig. 3 - MSD of CDU process

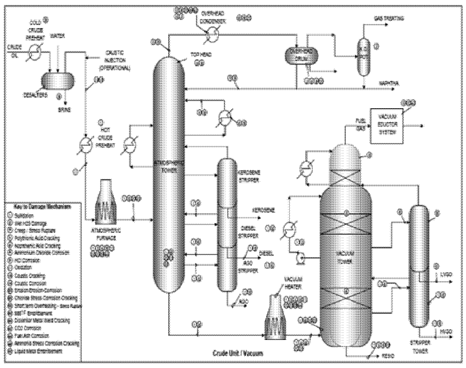

Fig. 4 - DM of Equipment (API 571)

We describe the DM according to equipments and more focuses on parts of equipment. For example, the upper part of A-column has HCL corrosion and Salt corrosion. So are that the middle part has Salt corrosion as well as the lower part has Naphthenic acid corrosion and High temperature sulfidation.

2.2.3. Step 3: CRV(Critical Reliability variables) Selection

After selection the DM, the next step is choosing key parameters that influence DM severity as Critical Reliability Variables.

Main variables are PH, Chloride ion, Hydrogen sulfide, ammonia, TAN and etc refer to Chevron Best Practice, API 571 and API 580 & 581. As it's already mentioned, the upper part of A-column has HCL corrosion and Salt corrosion. The influencing factors on HCL corrosion are Water PH, Water CI-, Water Fe, Water H2S, Water NH3 and Temperature. In addition, measuring temperature have to be always done, whereas the others could be inspected 3times a week.

2.2.4. Step4: Operating guideline proposal

The last step is to introduce a CRV operation guideline which has no influence on the reliability of the equipment. (references : Chevron Best Practice, API 571 and API 580 & 581, Chemical Vendor Guideline)

Fig.5 illustrates the final developed CCD. It is essential to set the boundary of main variables which affects each equipments so as not to damage reliability.

For instance, PH level should be 6~7 at CRV of HCL corrosion, CI- must be lower than 30ppm, so is that Fe is lower than 1ppm. This guideline is the basic data of an IOW(Integrity Operating Window system). The IOW system automatically makes a report every time each variable goes beyond their upper and lower bound. To keep the reliability of the equipment, it's required to pay special attention to the variables which goes beyond their limits too many times.

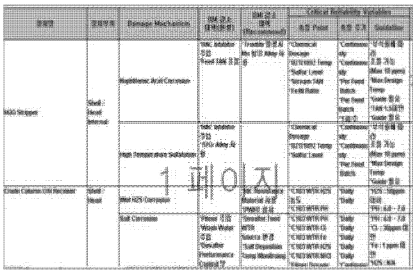

Fig. 5 - Corrosion Control Document

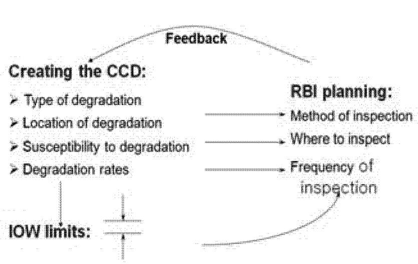

Fig. 6 - Relationship among CCD, IOW, RBI

3. Result and Application

3.1 Application to RBI

CCD development becomes a basic data for RBI(Risk Based Inspection) which deals with the priority orders, methods of equipment examination as well as cycle by conducting quantitative analysis about equipment troubles and accidents caused by corrosion.

Unless there's enough data of corrosion factor, it is not possible to make full use of RBI which aims control obsolete equipment. Therefore, there's a need to apply CCD DB to RBI.(Fig.6)

That would be able to figure out quantitative risk due to corrosion. Moreover, it could not only improve profit where companies have the methods of risk inspection to reduce the risk through minimum costs and endeavor, but also enhance the safety of process equipment through developing decision-making guideline based on RBI system which has different inspecting cycle and methods refer to the priority order of equipment risk.

3.2 Risk Monitoring and Process Simulation

We could achieve some side effects such as prevention against fatal accident which causes casualties and poverty damage by development of risk monitoring and analysis algorithm. If we hope to development this system, we should define the important factors which bring about a lowering efficiency such as the continuous flames on pumps, valves, generators, ventilators or heat exchangers.

It's possible to control equipments with significant effects through process simulation. For example, the development of a corrosion scenario and simulating make an accurate estimate of risk linked with probability of accident. Furthermore, it makes reducing unexpected interruption of plant. On top of that, as we've pointed out, the optimal operation guideline with estimation of high risk brings a number of advantages such as reducing unexpected shutdown and downtime, boost output, improvement in quality, executing the optimum equipment and innovation in safety management system.

4. Conclusion

This study focuses on the development of CCD(Corrosion Control Document) to enhance reliability of the whole process equipment as well as to operate smoothly in chemical corrosion. The CCD is developed by building a MSD, selecting DM, CRV and operation guideline proposal. We sincerely believe that CCD could improve the reliability and the safety of the whole refinery industry, and so is sharing information with each department of company. The further step is IOW system could be coupled with RBI system. Besides RBI, we could reduce the risk through simulating process and risk monitoring.

Especially, building CCD is terribly important as the first step for the reliability of an equipment and the safety of a plant. And IOW, RBI and Risk Monitoring become the fundamental data of subsequent research.

Finally, we could improve the reliability of the whole refinery, petroleum industry by applying developed CCD to FCC(Fluid Cracking Catalysys), HOU(Heavy Oil Upgrade), LPG and aromatics process due to CCD based on CDU process.

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