ONLINE CLEANING: A TOOL FOR IMPROVING OPERATIONAL EXCELLENCE

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ABSTRACT

ITW has developed and patented a technology for transforming sludge and coke-like deposits into a fully reusable/reprocessable product.

This technology has been successfully applied for online cleaning of refinery and petrochemical production units.

Different entire refinery and petrochemical units (no matter how big they are and the number of equipment) have been cleaned online in as low as 24 hours on a oil-to-oil basis.

Pro-active application of ITW Online Cleaning is a mind shift over current operating procedures.

With a downtime of 15-20 days it is of course much economical running the units under not optimized conditions rather than losing production.

The introduction of ITW Online Cleaning, by cleaning the unit in 24 hours, opens up a new scenario over current operations which will allow to recover losses and operate the units under improved and more reliable conditions.

Furthermore, turnarounds can be avoided or rescheduled under reduced downtime conditions.

INTRODUCTION

Petroleum plants suffer from fouling of equipment.

As used in the present paper the terms “petroleum plant” or “plant” refer to any industrial plant wherein there is processed a crude oil or any crude oil derivative, direct or indirect, that is derived from the processing of one or more derivative(s) of the crude oil.

It is to be considered, even crude oil just as extracted gives rise to fouling problems arising from heavy compounds precipitation inside production equipment.

For example, oil-gas separators, stabilization/distillation columns, heat exchangers, and filters are subject to such fouling.

Once the crude oil is processed in refining plants, these latter refining plants also experience heavy compounds’ fouling, generally of the asphaltenic and/or the paraffinic type.

Fouling generally increases by increasing process temperature and/or by having an heavier plant feed and/or a feed made up of residues of the preceding plants.

All of the Oil & Gas industry is experiencing this problem from oil/gas fields to refining and petrochemical plants, as well as fine chemicals production.

In the petrochemical plants, fouling from heavy compounds show up, besides from the heavy compounds themselves, also as polymeric compounds which plug equipment.

Such phenomenon is particularly evidenced in the plants which produce raw materials for the polymer/rubber industry or which directly produce polymer/rubber.

Fouling reduces plant performance and makes it necessary for equipment shutdown, placement out of service, decommissioning, cleaning and subsequent commissioning and then placement getting it back on-stream.

In any case, fouling associated costs imply: i) a energy costs, as it is more difficult to supply or exchange heat when the equipment is fouled, with related increase in fuel consumption; ii) production loss costs, as fouling limits throughput and/or plant yields or can lead to an anticipated shutdown; iii) maintenance costs, such as a specialized company mechanically cleaning the equipment; iv) environmental costs, as waste is generated, and needs to be disposed of, (with related waste disposal costs); environmental burdens, together with waste disposal, emissions of airborne pollutants are generated, included those related to increased fuel consumption.

The above costs are almost inevitable with current technologies.

THE CURRENT CLEANING APPROACH IN THE OIL & GAS INDUSTRY

Today’s technology for cleaning heat exchangers comprises essentially the following operations:

1. Flushing
2. Isolating the equipment from the process and blinding
3. Removing the hydrocarbons
4. Steaming out for gas removal
5. Scaffolding
6. Unbolting
7. Removing covers and distributor
8. Extracting the bundle
9. Transporting the bundle from plant to the washing area
10. Hydroblasting
11. Transporting the bundle from the washing area to plant
12. Inserting the bundle
13. Inserting new gaskets
14. Installing covers and distributor
15. Bolting

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16. Removing blinding
17. Removing scaffolding
18. Air removal and purging
19. Performing pressure tests
20. Inserting the apparatus in the process

All these operations have their related cost.

The above are very “normal” and “no brain” operations for the Oil & Gas Industry, but each of the at least 20 operations has a hazard.

To the operational costs (the bidding paid costs) are to be added the Customer’s organizational costs in terms of:

- ✓ Awarding (bid organization, evaluation and award)
- ✓ Planning
- ✓ Co-ordination
- ✓ Control during execution

Following equipment downtime, huge production loss costs are to be added to the above operational and organizational costs.

Moreover, all these operations may have different problems, such as:

a) Long time for isolating/inserting the equipment
b) Waste generation
c) Hydrocarbon emissions
d) Bundle damage
e) Difficulties in bundle extraction due to the position of the apparatus (e.g. elevated from the floor)
f) Difficulties in unbolting
g) Hazard to workers performing mechanical operations
h) Hazard from scaffolding
i) Hazard from spills of carcinogenic products
j) Hazard to people working nearby due to lifting means/heavy vehicles
k) Hazard from bundle transportation/cleaning apparatus/cranes inside the plant
l) Hazard from bundle transportation/cleaning apparatus/cranes outside the plant
m) Hazard from high pressure water jetting

Because of continuous improvements in process safety and environmental performances, these problems are now only acceptable when there is no other choice.

Think about the continuous technical effort and investment the Oil & Gas Industry is making for limiting airborne emissions.

Think about investments and revamps for the purpose of limiting VOC (e.g. valves substitution, flanges insulation, double seals on pumps, double seals on tanks, etc.) and then think (and watch) what happens during hydroblasting.

Finally think about continuous efforts in the Oil & Gas Industry for improving safety in operations and for reducing waste generation.

It is also understood, mechanical cleaning was until now the only available technology for cleaning heat exchangers and process equipment: that’s why the myth has been created and operators give it for granted and unavoidable.

Consider the Value

The average perception over the mechanical cleaning is simply the cleaning cost or, worse, the cost of hydroblasting only.

In reality the mechanical cleaning cost is more than 30 times the cost paid to the mechanical cleaning company.

Just consider the preheat train cleaning in a major turnaround. Nobody of course will argue anything about the cost of spare parts.

It is mandatory to replace gaskets and bolts after bundles extraction and cleaning, but the cost can be very significant.

By considering a 40 heat exchanger preheat train, this can be very easily more than 200,000 USD: this would be “easy money” to recover.

Think differently: what if this cost can be saved by not opening the bundles?

Let’s put it simple: at current refining margins an average 100,000 bbl refinery can make profits in the range of 2 MMUSD/day.

Saving 7 days of downtime can have a minimum value of 14 MMUSD: is it worth to think how to debunk some myths?

THE ONLINE CLEANING APPROACH

ITW Online Cleaning patented technology is based on cleaning heat exchangers and process equipment in a closed loop, in the hydrocarbon phase.

ITW Online Cleaning is a patented cleaning technology which includes <u>ALL</u> of:

- ➢ Patented method and process steps
- ➢ Patented chemicals
- ➢ Patented monitoring system

For avoidance of misunderstandings, ITW Online Cleaning patent does not only cover the chemicals but also includes the cleaning method, the process steps and the monitoring system.

ITW Online Cleaning cleans an entire production Unit in as low as 24 hours on a feed-out/feed-in basis.

The very short time needed to clean the Unit makes ITW Online Cleaning an ideal tool to:

- ✓ Reduce downtime during turnaround, as well as improving turnaround operations
- ✓ Improve Operational Excellence, by resuming production within 24 hours after the Unit is handed over for Online Cleaning

In a turnaround application the process steps can be summarized as follows:

i. Reducing the temperature and feeding out the Unit
ii. Displacing the feed with a hydrocarbon carrier
iii. Implementing ITW Online Cleaning
iv. Pumping out the washing fluids for reuse/reprocessing
v. Deinventoring the Unit
vi. Leave the cleaned equipment in situ, without opening the same (in case no inspection/repair is required), or
vii. Perform ITW Improved Degassing/Decontamination (in case inspection/repair is required)

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In an Opex application the process steps can be summarized as follows:

i. Reducing the temperature and feeding out the Unit
ii. Displacing the feed with a hydrocarbon carrier
iii. Implementing ITW Online Cleaning
iv. Pumping out the washing fluids for reuse/reprocessing
v. Feeding back the Unit and resuming production

The washing fluids arising from ITW Online Cleaning are fully reusable/reprocessable, which means no waste will be generated by the cleaning operations.

By operating on a closed loop basis, no airborne emissions will be generated during the cleaning.

In both cases of ITW Online Cleaning application, namely Turnaround or Opex improvement, the polar star is the VALUE achieved vs the previous conditions.

This is easy to do in a Opex application by measuring the KPI before/after the Online Cleaning and putting in a spreadsheet ALL of the cost items which would have impacted the run by continuing the same under the conventional conditions.

By considering an easy example, if 1°C furnace inlet temperature (FIT) loss in a 100,000 bbl/day Crude Distillation Unit is costing, say 1,000,000 USD/year the recovery of 10°C FIT will have a value of 10,000,000 USD/year.

If fouling is impacting the capacity of the unit (e.g. by increased delta P) then the value is given by the production recovery.

To put it simple, if the above CDU has reduced the capacity by 5% and the Unit is making 8 USD/bbl the margin recovery (over losses) will be 40,000 USD/day.

In the case of delta P also the pumping cost reduction should be taken into consideration, just to mention one of the items which is much often "given for granted" or overlooked.

Of course the capacity increase adds to the energy consumption reduction.

Needless to say, the real value will be determined by the Company: the important is putting on the table ALL of the items which make up the loss, which are often under the control of different departments.

For a turnaround application, the main value lies in downtime reduction and margin recovery as well as loss of opportunity avoidance.

Anyway many others items should be considered, like e.g. the overall cost of mechanical cleaning (e.g., scaffolding, mechanical operations, transportation, lifting means, hydroblasting, cost of spare parts, damaging of bundles following extraction, waste disposal, waste water treatment, etc.).

In both cases, one additional item to be evaluated is the HS&E improvement.

Besides the already mentioned no waste and no emission generation, one key element to be considered is ease of operations.

ITW Online Cleaning is very easy to implement and requires only negligible manpower and equipment.

By considering the conventional mechanical cleaning operations which implies hundreds of personnel operating inside the Unit, cranes, extractors, scaffolding, forklifts, drums, hoses, means for transportation of bundles, extracting the bundles at elevated position, temporary lines, etc. the HS&E improvement is easy to figure out.

In particular the reduction of operating personnel inside the Unit is of utmost importance to any Operator in order to reduce the risk of any accident.

The value is not only the HS&E improvement and the elimination of the above operational costs.

Much more important, the elimination of the many different activities which do occur simultaneously or in a sequence during conventional mechanical cleaning operations, eliminates the interferences among both these activities and the ones which are in the "critical path" of the turnaround.

For example, if the revamp of a tower is in the critical path of the turnaround, ITW technologies can help reducing the downtime e.g. in the following manners:

a) By quicker handing over the tower for revamp
b) By eliminating interferential activities around the tower

In this connection indeed, ITW Online Cleaning will clean the tower together with the rest of the Unit, e.g. the entire preheat train, in 24 hours only and thereafter ITW Improved Degassing/Decontamination will achieve safe entry conditions in a couple of hours.

By using the conventional approach, upon opening manways, the tower needs to be mechanically cleaned before any maintenance/repair/revamp can be accomplished, which impacts downtime.

Additionally think that "by magic" the area around the tower will be totally clear with no scaffoldings, cranes , people, hoses, temporary lines, extractors, transportation means: don't you think that the activities inside the tower will benefit from this ?

Just think of all the Company personnel whom has to co-ordinate and control all of the above activities: don't you think that they could be more focused on the real critical path and released from other activities?

The Operators will surely envisage many optimizations in the turnaround schedule, which will lead to a significant downtime reduction out of the use of ITW technologies.

ONLINE CLEANING OF REFINING PLANTS

In the refining industry, mostly of the fouling is related to the precipitation of asphaltene.

Asphaltene precipitation occurs due to destabilization of the asphaltenic micelles, which can be driven by chemical or thermal factors.

Among the chemical destabilization, the most common cause is the incompatibility of different feedstocks.

It is well known indeed that when a paraffinic stock is blended with an asphaltenic one, the asphaltene will precipitate out of the blend and will deposit into the equipment.

The current trend in the refining industry of processing *opportunity* crudes (which are normally heavy crudes), makes this problem even more evident,

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in that refineries cannot have enough storage capacity for segregating the many crudes which are processed on a daily basis.

Another type of fouling occurs when processing *tight oils*, which are basically very light oils, mostly of paraffinic nature.

In this case heavy paraffins may separate out and precipitate, eventually together with the very few asphaltene which are present in the oil.

The Online Cleaning technology can effectively address both types of fouling.

Some case histories will better illustrate the results achievable by ITW Online Cleaning.

Case History: Run Length Improvement of VBU Case 1

ITW Technology has been applied on the Vacuum Section of a Visbreaker Unit. The Refinery layout features a CDU, VDU, VBU, a Vacuum Section of the VBU, the storage of the Visbroken Residue and a IGCC.

The Refinery problem was related to the increase in Vacuum Section bottom train outlet temperature (tag TI1826).

The Refinery procedure was to clean the exchangers when the outlet temperature was going to approach 280°C.

During the run, the refinery normally used to mechanically clean 2 exchangers in order to reach the targeted run length.

Before the application of ITW Technology, mechanical cleaning did not help in recovering temperature, so there was a steady increase of TI1826 values, reaching the shutdown limit 6 months before the scheduled turnaround.

The Visbreaker Unit was facing therefore an unscheduled shutdown for mechanically cleaning all the Vacuum Section bottom.

To solve the problem ITW Online Cleaning was applied in Vacuum Section, then VBU resumed production immediately after.

ITW temperature recovery on TI1826 was on average 45°C, which was stable during the time as reported in Figure 1.

The Unit could easily target the scheduled turnaround and run 5 more months without any issues.

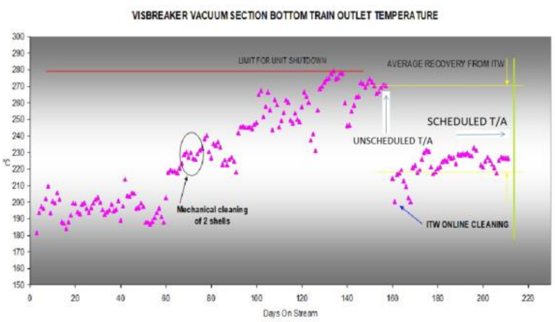

Fig. 1. Avoiding an Unscheduled Shutdown and Increasing Run Length of a VBU

Case History: Run Length Improvement of VBU Case 2

A refinery wanted to validate our patented ITW Online Cleaning to strategically use it for avoiding cleaning turnarounds of VBU and for improving Opex of the other refinery Units.

The scope of work was avoiding the scheduled turnaround, which is performed on a regular basis every 6-7 months in order to target the mechanical cleaning of the preheat train.

In particular, the most critical items are 2 huge spiral exchangers, very effective indeed, but difficult to clean mechanically.

In the current run, the VBU started up with only one spiral exchanger on stream. Thereafter, when the performance decreased (which occurred after about 2 months from start-of-run) the other clean spiral exchanger was lined-up in series with the running one.

ITW Online Cleaning occurred when the two spiral exchangers were lined up and the Unit was about to shut down for mechanical cleaning of the preheat train.

ITW Online Cleaning has been performed on the entire VBU and lasted 24 about hours on a feed-out/feed-in basis.

Washing fluids have been routed to fuel oil tank (IFO 380) and fully reused as a blending component, with no detrimental effects on fuel characteristics.

The VBU resumed production immediately after ITW Online Cleaning, with no mechanical cleaning whatsoever.

Upon VBU resuming production, the results of ITW Online Cleaning were the following:

- ✓ Average Furnace Inlet Temperature increased by 10°C
- ✓ Normalized FIT increased by 32°C
- ✓ Feed rate increased by 10%
- ✓ Steam production increased by 11%

The above, notwithstanding a decrease of about 7.3°C in the Furnace Outlet Temperature

The cleaning resulted in having the same furnace duty (even slightly lower) for processing about 10% more feed. This can clearly and effectively summarize the performance of the cleaning.

The scheduled mechanical cleaning turnaround has been avoided and the VBU could run other 7 months with no mechanical cleaning.

Figure 2 reports the period of: a) Start-Of-Run (after T/A and mechanical cleaning—with one spiral exchanger on stream); b) Before ITW Online Cleaning at about End-Of-Run (with the two spiral exchangers in series); c) After ITW Online Cleaning (with the same layout as “Before”).

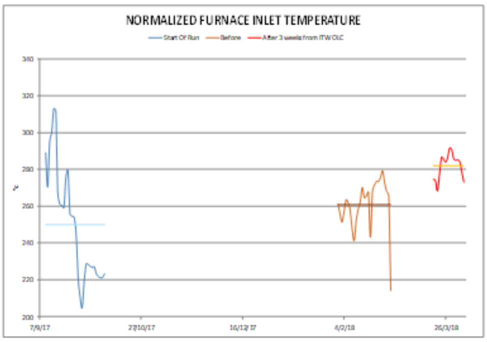

Fig. 2. Normalized Furnace Inlet Temperature of VBU Before/After ITW Online Cleaning

Case History: Furnace Inlet Temperature Improvement of CDU/VDU

A 325,000 bbl/day CDU/VDU was running under not optimal conditions and the owner wanted to recover its performance.

Poor performance was related to fouling issues which were costing the Refinery a significant lost profit opportunity in terms of production loss, as the capacity had to be reduced by 5%.

The scheduled turnaround was in a 9 months period of time, but current performance called for an unscheduled turnaround no later than 6 months.

The Refinery chose ITW Online Cleaning in order to avoid opening the equipment and performing mechanical cleaning, which would have resulted in a downtime of at least 20 days.

The CDU/VDU normally processes heavy crudes and opportunity high TAN crudes with a very complex crude slate.

ITW Online Cleaning was utilized specifically to recover Unit's performance, thereby improving the operational excellence of the refinery.

ITW Online Cleaning duration has been about 24 hours, excluding filling/emptying operations of the carrier.

Washing fluids have been sent to a crude storage tank and fully reprocessed with no issues at Unit start-up and hence in any downstream Unit.

After ITW Online Cleaning, the CDU/VDU immediately resumed production and unit performance was evaluated. In particular the Furnace Inlet Temperature increased by 12 °C (24.4 °F).

Following ITW Online Cleaning the CDU/VDU could also extend the run length by 6 months and postpone the scheduled turnaround.

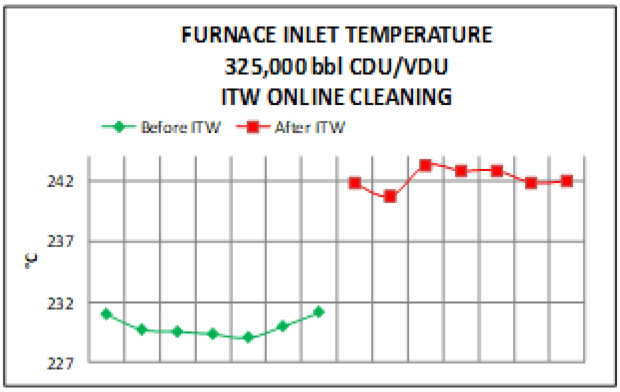

Fig. 3. Furnace Inlet Temperature Increase on a CDU/VDU

Case History: Heat Exchangers Cleaning of MEA Unit

A refinery was challenged with the need to perform a quick shutdown of its MEA unit to make needed repairs in parts of the system.

They chose ITW's patented cleaning and decontamination solution because it does not require the tube bundles to be removed for cleaning.

The lean/rich heat exchangers are in a tight space and removing the bundles for cleaning is very difficult and dangerous for maintenance and contractor personnel.

Management decided to clean the regenerator simultaneously with the lean/rich exchanger to improve unit efficiency upon restart.

ITW's online/in-situ cleaning and decontamination was successfully completed in less than 24 hours, with minimum waste generated, and significantly faster than the usual mechanical cleaning.

Upon resuming production, the following immediate benefits were observed:

· Reduced steam consumption at regenerator reboiler of about 500 Kg/h

· Increased delta T of the lean/rich exchangers of about 10 °C

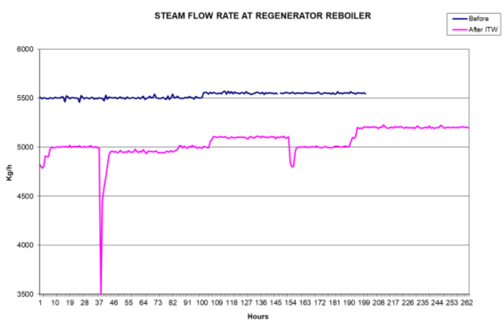

Fig. 4. Steam Consumption at Regenerator Reboiler

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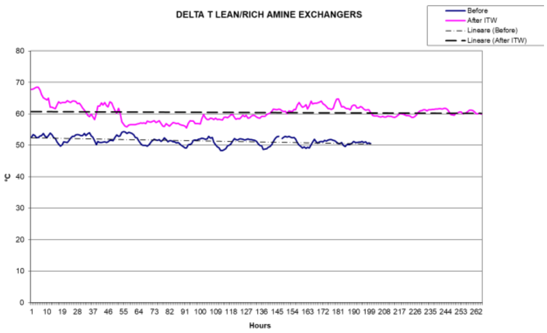

Fig. 5. Lean/Rich Exchangers Delta T

ONLINE CLEANING OF PETROCHEMICAL PLANTS

By its nature, the petrochemical industry is much prone to polymeric fouling formation, simply because many of the feed/products are unsaturated.

An Ethylene unit can experience butadiene polymer fouling generally in the deethanizer, depropanizer and debutanizer columns; this is usually referred as *popcorn polymer*. Polymer formation is strictly dependent on temperature, which should be kept below 200°F to reduce polymer formation (which cannot be avoided though).

In an Ethylene unit polymeric fouling is also commonly found in the Quench Water Loop, in the Interstage Coolers and in the Compressors it selves.

When co-cracking heavy olefinic feeds (e.g. Butadiene bottoms), severe fouling is also experienced in the feed preheaters and in the furnaces.

All the units which process butadiene experience severe polymeric fouling issues. Besides Butadiene itself, Styrene-Butadiene-Rubber (SBR) and Nitrile-Butadiene-Rubber (NBR) are the most popular ones.

The polymerization reaction of 1,3 butadiene monomers is extremely exothermic and could provide enough heat to expand and overpressure pipes and equipment, causing their failure.

Oligomerization units (e.g. Cyclopentadiene Dimerization) are an additional example of polymeric fouling formation in the petrochemical industry but, again, the list covers the entire industry.

Operating problems

The growth rate of popcorn polymer is tremendously high, for this reason this type of fouling is one of the toughest deposits found in the oil industry.

Popcorn polymer fouling is thought to be exclusive to Butadiene plants, but as a matter of facts, there a number of cases wherein popcorn polymer fouling has been found in the Light Ends section of Ethylene plants and also in the Green Oil Tower (GOT) and related circuits.

Popcorn has also been found in the Safety Relieve Valves lines, thereby seriously impairing plant safety. Surprisingly, many of these cases have occurred in areas wherein butadiene concentration is lower than 70%.

Case of popcorn formation have been reported in equipment wherein butadiene concentration is lower than 30%.

Historically, popcorn polymer do clog heat exchnagers, pipelines, storage tanks, distillation columns and even condensers and bent pipes.

Additional concerns from polymeric fouling arise during turnaround, e.g. :

- ✓ Difficulties in extracting/opening equipment
- ✓ Danger of pyrophoric fires
- ✓ Difficulties in mechanical cleaning

which all turn to increased downtime.

Additionally, polymeric fouling is difficult to remove even by high pressure water jetting, and quite often some polymer is left (especially when the fouling is from the shell side of an heat exchanger).

The left polymer will work as seed for new polymer to form and deposit.

Besides that, popcorn polymer growth leads to irreparable equipment damage (see Fig.6).

Fig.6. Exchanger damage due to popcorn polymer – bundle as extracted, with no cleaning

As a consequence, in many services, e.g. reboilers, the plant owners have to replace the bundles every 3-4 years; which is a budgeted cost.

Needless to say, this increases operational costs.

It is easy to suppose, if plant owners are obliged to replace the bundle due to fouling, unit throughput will be steadily reduced, up to a point wherein this is not sustainable anymore.

Besides that, energy consumption is dramatically affected by polymeric fouling.

By considering an average reboiler, steam consumption increase can seriously impact economics.

Let's suppose the following:

- Cleaning time: 1 year
- Steam consumption @ SOR : 16 T/h
- Steam consumption @ EOR : 20 T/h
- Average delta steam in 1 year : 4 T/h
- Cost of steam : 35 €/T
- Cost of fouling (energy loss only) : 1,226,400 €

This operational cost is commonly deemed as "normal" by the operators, as it belongs to plant "tradition" and it is already included in the budget and in the production costs.

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Case History : Debutanizer-Ethylene

The Debutanizer of an Ethylene Unit was suffering of severe fouling.

The feed to the Splitter is a C4+ mixture typical for Naphtha Crackers.

The turnaround standard procedure was to separate the tower from the process and to then degass it with steam and nitrogen for about 3 days.

Then, by entering the tower with breathing apparatus, the trays were removed, cleaned (scratched) at ground level and reassembled in the tower.

The original goal of ITW cleaning was to enter the tower without the need of breathing apparatus and heavy protection for benzene (as known in the industry, pygas has a high benzene content) and without the risk of ignition of residues.

ITW approached the problem by proposing its patented Online Cleaning and Improved Degassing/Decontamination technologies.

In particular for the Online Cleaning, we used a patented Polymer Modification technology.

A patented chemical has been introduced into the system and circulated.

Circulation lasted 24 hours; after that, washing fluids have been pumped out and the system deinventoried.

Washing fluids have been subsequently fully reprocessed with no problems.

After the Online Cleaning step, a patented decontamination chemical has been introduced together with steam.

This second step lasted about 16 hours.

The condensate did not have any emulsion, so it has been allowed to go the WWTP, after having checked all the specifications.

Safe entry conditions were immediately met upon checking the first time.

In particular, LEL = 0% and benzene = 0.1 ppm.

Maintenance personnel was allowed to enter without breathing apparatus and benzene protection.

This is a great achievement by taking into account that the tower feed has a high benzene content.

Upon inspection of the tower, the trays have been found clean .

Figures 7-9 report a tray before and after ITW online cleaning and tower bottom.

Fig. 7. Tray removed to be mechanically cleaned—Previous turnaround

Fig. 8. Clean tray in place no need for removal — after ITW

Fig. 9. Tower bottom—Deposits have been dissolved by ITW.

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ONSTREAM CLEANING OF OIL & GAS PLANTS

A new patent has been granted for cleaning the Oil & Gas plants during their run.

The technology uses the patented chemicals which have proven very effective for Online Cleaning.

The chemicals are completely safe for any equipment and/or for any catalyst, and therefore can be injected while the Unit is running.

Under ITW patent (US 9328300) some minor plant modifications need to be implemented to apply the technology.

CONCLUSION

Current methods for mechanical cleaning heat exchangers in the Oil & Gas industry create lots of concerns, including HSE and high overall costs.

ITW Online Cleaning technology can help overcoming the above concerns by cleaning the equipment in 24 hours on a feed-out/feed-in basis.

This creates a new paradigm in the industry, in that the cleaning can be *value driven* rather than performing the same after *running to death*, with related losses and inefficiencies.

A new patent has also been granted for cleaning the equipment while the Unit is running.

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