THERMAL CLEANING OF HEAT EXCHANGERS, NO ALTERNATIVE BUT A BETTER WAY TO CLEAN

R. A. Mol*
*CEO Thermo-Clean Group, Dellestraat 45, B-3550 Heusden-Zolder,
heatexchangercleaning@thermoclean.com

ABSTRACT

Thermal cleaning of heat exchangers is not a new technology. However, to this day it is still not commonly used due to the varied experiences with this cleaning method, ranging from irreparable damage to superb cleaning quality. The Thermo-Clean Group has developed an improved way to remove fouling from heat exchangers using thermal cleaning. This provides a safe and highly effective cleaning technology with astonishing results in terms of operational lifespan and energy savings. The advantages of this method are significant! Controlled heat cleans very thoroughly, even in places where typical high-pressure cleaning cannot reach. After thermal cleaning, heat exchangers are practically returned to their original specifications. The result is perfect heat transfer, a longer production lifespan and no residue mixing with your products. Thermal cleaning is also fast, making short delivery times possible during shutdowns. After all, better cleaning means less cleaning, which means the interval between expensive shutdowns for cleaning can be extended. Other advantages are no wear or roughening of the surface, fixed duration of the cleaning, stable cleaning costs, cleaning of duplex material is possible and no wastewater problems.

INTRODUCTION

The Thermo-Clean Group has been very active in the thermal cleaning of heat exchangers for more than 20 years now. In the early years, only heat exchangers with specific fouling could be cleaned properly. Any type of fouling that would create an exothermic reaction during the thermal process made it difficult to guarantee safe and controlled cleaning. Heat exchangers could be deformed during the gasification process due to inadequate temperature control.

Together with our sister company Strunz Anlagentechnik GmbH (Germany) - a global player in thermal cleaning installations - Thermo-Clean developed a completely new thermal cleaning system as well as special software and tooling. This now enables Thermo-Clean to completely remove all kinds of organic fouling, and even combinations of organic and inorganic fouling, in a safe and environmentally friendly way with no hazardous waste or huge amounts of wastewater.

In comparison to other cleaning methods, our unique thermal cleaning process delivers superior benefits. Thanks to the controlled heat, the cleaning process is extremely thorough. This means we are able to remove fouling from inside the tubes, around the tubes, between the tubes and shell (even fixed shells), and inside tubes with static mixers, all at the same time.

WHAT IS THERMAL CLEANING?

Introduction to the thermal cleaning technique

The pyrolysis process. Pyrolysis is the thermal decomposition of organic materials in an oxygen-poor environment (Fig. 1).

At a temperature below 450°C (842°F), organic materials are converted into a homogeneous residue ready for further controlled processing.

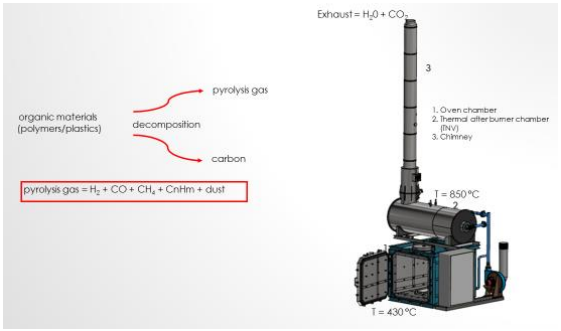

Fig. 1. The pyrolysis process.

At such high temperatures, higher hydrocarbons are decomposed into components with a much lower molecular mass, resulting in pyrolysis gases (ethane, ethene, propane, propylene), pyrolysis oil (which contains aromatic components), and a carbon-rich residue.

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The pyrolysis gas and oil are transformed into carbon dioxide and vapour due to partial oxidation. This phase is exothermic, and 40% of the energy released is reused to decompose the organic material.

Aside from steady heating and cooling, a very important factor in the process is maintaining a constant temperature to prevent damage to the parts being cleaned.

Advantages of the thermal cleaning technique.

Thermal cleaning reduces 1 kilogram of fouling to only 50 grams of dust, which is easy to remove. Moreover - and this is one of the biggest advantages of this cleaning method - the controlled heat reaches all areas of the contaminated component, meaning that pyrolysis occurs everywhere in the component being cleaned.

This makes it possible to clean inside the tubes (even with static mixers) as well as around and between the tubes and any fixed housing. Even if the bundle is mechanically stuck in the housing, thermal cleaning will remove the fouling to enable the two parts to be separated.

Because the heat can reach everywhere, thermal cleaning is extremely well-suited to heat exchangers. It causes fouling in extremely inaccessible places to decompose into dust, which can then be removed easily using simple techniques[i]. This is impossible if for example only high-pressure cleaning is used.

After thermal cleaning, your heat exchanger will be returned close to its original performance level. This results in perfect heat transfer, longer production life and no residue mixing with your products. In short: better performance at a lower cost.

General functioning of a pyrolysis oven. A pyrolysis oven (Fig. 2) consists of an operating chamber 1m³ to 100m³ in size, depending on the type. The standard maximum dimensions of today's ovens are 10m x 3m x 2.5m, but even larger dimensions are also possible.

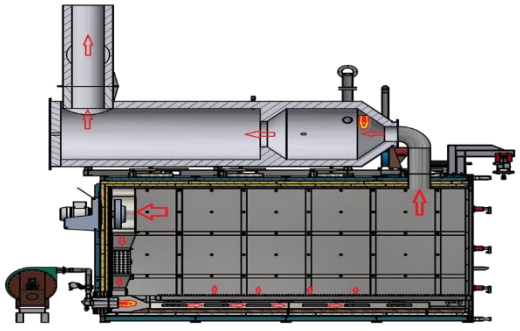

Fig. 2. Working principle of a pyrolysis oven.

The parts to be cleaned are put on a loading cart that is brought into the oven chamber. After closing, the oven chamber is made inert by lowering the oxygen level to 8%. The temperature is then slowly increased to as high as 450°C (842°F), depending on the character of the objects and the nature and amount of fouling.

When the temperature required for gasification is reached, slight positive pressure causes the gases released to flow to the afterburner chamber. Here, they are processed at high temperature (>850°C/1562°F) for at least 2 seconds, after which they are removed[ii]. This air current is sometimes used for heat recycling to recover part of the energy.

Because all organic components are gasified, only a residue consisting of pigments and inorganic fillers remains. This is generally 1-5% of the original fouling volume and can easily be removed by various techniques.

SAVE CLEANING TECHNIQUE

Special developments for the safe thermal cleaning of heat exchangers

Thermal cleaning installations have been built all over the world. They vary widely, ranging from very cheap, uncontrolled burning ovens to highly sophisticated installations with very good temperature and oxygen control.

Although the latter category is excellent for stripping paint or removing plastics from extruder parts, these installations are not suitable for cleaning heat exchangers because they cannot control the exothermic reactions that occur when removing fouling from the petrochemical and refinery industries. These exothermic reactions cannot be stopped and cause the temperature of the parts being cleaned to rise above 500°C (932°F) or even much higher. This inevitably results in deformed, and even unusable, heat exchangers.

Oven operators very often try to prevent this excessive temperature by injecting water into the oven chamber. The harsh cooling of the hot surface makes it even worse and results in heavily deformed tubes, cracked welds and bent heat exchangers. We can conclude that thermal cleaning in conventional thermal cleaning systems is not the best option.

What makes Thermo-Clean safer?

Thorough preparation. A number of essential points need to be respected to ensure that the heat exchanger gets the best and safest thermal treatment. To prepare the cleaning process, it is necessary to draw up a proper temperature protocol. This cleaning program describes important temperatures that have to be considered during the process such as melting phase, gasification phase, the maximum temperature allowed due to the metal(s) used, etc.

It is therefore very important to know the exact composition of the heat exchanger material and that of the fouling itself. In case of doubt, a reliable laboratory analysis can give a decisive answer. The weight of the exchanger, the type of metal(s) used,

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the geometry and the type of fouling all determine the heating and cooling curves, which can give a good indication of the total time needed in the oven.

Aside from the cleaning program, it is also essential to position the heat exchanger correctly in the pyrolysis oven. Proper support of the item to be cleaned will prevent deformation during the thermal process. The exchanger must be placed in a way that ensures good airflow inside the installation to avoid blind spots during the gasification process. Protocols are written to guarantee safe and thorough thermal cleaning.

Safer Thermo-Clean technology. Aside from good preparation of the thermal cleaning, the installation itself (Fig. 3) is the second, and by far the most important, factor.

Fig. 3. Inside of a pyrolysis oven.

Strunz Anlagentechnik and Thermo-Clean drew on years of research and expertise to come up with the Strunz "heat exchanger line". These installations combine a thermal cleaning oven with special features and highly sophisticated software specifically designed for the thermal cleaning of high value, heavily fouled parts such as heat exchangers.

One of the special features is a very new type of oxygen control. It is no longer measured in the afterburner, as in most high-level ovens, but effectively inside the cleaning chamber itself. Controlling the oxygen in this area makes it possible to determine exactly what is happening during the cleaning process regarding the gasification of organic fouling.

Another important technical aspect is the presence of an excellent internal circulation unit, which provides proper circulation in the oven chamber. This results in a homogeneous temperature on all sides, which is essential to avoid temperature differences inside the object(s) being cleaned.

To control the temperature with air instead of water, the installations are also equipped with an internal heat exchanger. This has increased temperature control considerably, which is now accurate almost to 1°C (33,8°F). Moreover, not having to inject water into the chamber reduces problems with volatile rust on the parts to be cleaned, and inherently avoids sudden cooling of hot surfaces.

To monitor the heat exchanger itself, the "heat exchanger line" installations are equipped with thermocouples. It is important to use object temperatures instead of room temperatures to be able to track the process in the oven correctly. During the thermal cleaning program, the installation will use special software to monitor all the different temperatures and to ensure that the maximum delta T determined in the protocol is respected at all times. The process can control highly exothermic reactions perfectly.

Other features include high capacity afterburners to remove the huge amounts of fouling often found in heat exchangers coming from the petrochemical and refinery industries. In addition, special high range modular burners are installed to control the temperature very precisely.

In comparison with the traditional familiar brands on the market, the dimensions of these ovens are in another league. They are also equipped with special seals and a sealed, one-piece door to prevent outside air entering the thermal cleaning compartment.

All these features combined with the right temperature protocol and years of expertise enable us to clean almost any heat exchanger fouled with oil, plastics, carbon and all other kinds of organic fouling without the problem of very high heat damaging the parts. This is a completely safe way to clean heavily fouled equipment!

A COMPARISON

Traditional vs. thermal cleaning

The level of cleanliness achieved by traditional cleaning methods for heat exchangers is often only visual. It may look clean enough to the operator and be used for many years, but after the cleaned heat exchanger is started up, the original performance is never gained back. But because there was no viable alternative, this has always been how fouled heat exchangers were cleaned.

Nevertheless, there are a number of very specific problems that everyone recognizes. High-pressure cleaning causes deterioration of the surface and cannot reach all the fouling.

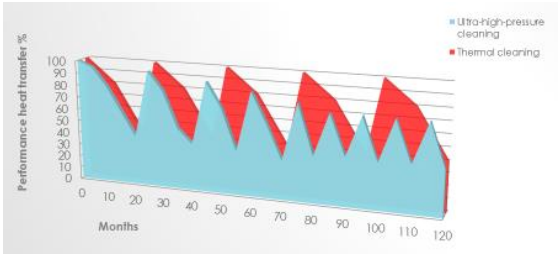

Fig. 4. Comparison of frequency of ultra-high-pressure cleaning vs. thermal cleaning.

The remnants left behind mean that your exchanger has to be taken out of production to be

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cleaned again sooner and aside from the bill for high-pressure cleaning, there is the secondary and often hidden cost of the high volumes of wastewater produced. (Table 1, Table 2, Fig. 4).

Table 1. Comparison ultra-high-pressure cleaning vs. thermal cleaning

	Ultra-high-pressure	Thermal + high-pressure after-cleaning
Typical cleaning results	65-95%	95-100%
Water consumption	50,000-500,000 L	Max. 10,000 L
Risk level	High risk of injury (manual)	Very low risk of injury
Time	4-16 hours, sometimes 1-2 weeks	12-100 hours
Capacity	1 piece	Possible to clean several pieces simultaneously
Effective for all types of fouling	Not effective for many contaminants (e.g., calcium, hardened plastics are difficult)	Yes. Almost all (organic) contaminants can be removed
Waste (water & original fouling)	100% of water used + 100% fouling = chemical waste	1% Is collected.

Chemical cleaning can sometimes take a long time to dissolve the fouling, which delays the availability of the tube bundle. On the other hand, thermal cleaning is very effective and reaches every spot. The results prove that a degree of cleanliness of almost 100% can be reached, which results in longer operating times between cleanings and therefore cost savings (Table 1, Table 2, Fig. 4).

Cost comparison

Table 2. Cost comparison

	HP cleaning	Thermal + HP after-cleaning
Hourly rate	€€€	€€€€
Water	€€€	€
Wastewater	€€€€€	€
Location	€€	-
Safety engin. client	€	-
Lifting costs	€€	€
Transportation costs	€	€€€

THERMAL CLEANING OF DIFFERENT TYPES OF HEAT EXCHANGERS

A definitely-incomplete overview of different types of heat exchangers is given below, together with the typical advantages and disadvantages of thermal cleaning for each.

Straight bundles

The contamination can be in and/or around the tubes. The problem with high-pressure cleaning is that the water jet can barely reach the very inside of the exchanger to remove the fouling around the tubes. This means that some remnants are left behind and because of this, the exchanger will become contaminated more quickly during production, resulting in a shorter operating time.

Thermal cleaning destroys the fouling everywhere (Fig. 5) and therefore gives a much better level of cleanliness, resulting in a longer operating time. In case of extreme contamination, high-pressure pre-cleaning is often done first, after which thermal cleaning can take place.

For hairpin bundles, thermal cleaning can easily remove fouling inside the bends of the tubes, which is usually where problems occur.

Fig. 5. Different types of straight bundles.

Bundles with fixed shell

The problem with classic high-pressure cleaning is that there is practically no access to clean around the tubes. Chemical cleaning by flushing is often used to clean the fouled interior, but the effectiveness of this is often very poor. Very good results have been seen when using thermal cleaning (Fig. 6) to remove the fouling around the tubes.

Aside from the heat, a small amount of oxygen is needed to obtain good oxidation of the fouling. Otherwise the fouling will carbonize, making it difficult to remove.

Fig. 6. Different types of bundles with fixed housing.

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Organic constituents are reduced to ashes. However, in this case it is better to use air to remove most of this dust. Water will cause the dust to stick, so the part is only rinsed with water after cleaning with compressed air. Even so, dust particles from remaining ash may disturb your process for the first few running hours. This normally disappears quickly. In some cases, an endoscope is used to verify the cleaning result on the inside.

Bundles with (fixed) static mixers

High-pressure water cleaning is useless here as the degree of penetration is zero. Chemical treatment can give reasonable results depending on how well the chemical used to dissolve the fouling can flow inside. However, both traditional methods often give very poor results, which immediately shows the need for the thermal cleaning method.

First the thermal treatment destroys the organic fouling on the inside of the static mixers. A combination of water and air is then used to remove the dust particles from inside the mixers. This is repeated until the water is clear, which indicates that most of the ash is gone (Fig. 7).

It is difficult to guarantee that the tubes with the mixers are 100% clean because there is no control method to inspect inside the tubes of fixed static mixers. The only control is to check that the water runs through normally, indicating that the tube is not blocked.

After the cleaning procedure, your flow may contain dust particles for the first few running hours. This is not the case with removable static mixers because they can be cleaned separately after the thermal treatment.

Fig. 7. Cleaning of a heat exchanger with fixed static mixers.

Spiral heat exchangers

High-pressure cleaning does not give an optimal result here. Chemical cleaning generates a lot of waste. With these classic methods, deposits are always left on the walls that cause the exchangers to foul again quickly during production. Thermal cleaning (Fig. 8) is the most effective solution here.

Fig. 8. PE removal from a spiral heat exchanger.

Compablocs

Depending on the fouling, traditional water cleaning can be very difficult or even impossible in some cases.

As with all other heat exchangers, thermal cleaning is a good option to restore your compabloc to almost new condition using controlled heat followed by a good rinsing (Fig. 9).

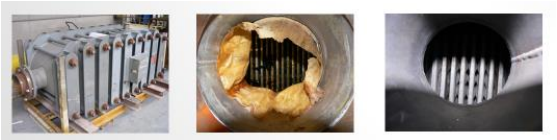

Fig. 9. Cleaning of a compabloc (e.g. polyacryl removal).

Twisted tube heat exchangers

Because of the twist in the tubes, accessibility is very poor for proper cleaning by water. It is only possible to clean the outside using water.

Thermal cleaning produces very good results because of its technical characteristics. All fouling is removed (Fig. 10), including from deep inside.

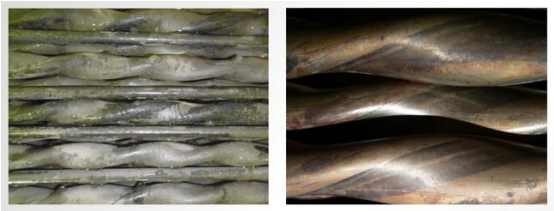

Fig. 10. Different types of bundles with twisted tubes[iii].

Plate heat exchangers

In most cases, a chemical treatment is used and has been proven very effective to clean fouled plates. High-pressure cleaning is sometimes done, but the risk of damage is very high.

Thermal cleaning can be used to remove all kinds of fouling from the plates, including glue and polymerized or carbonized fouling which are difficult to remove with chemicals.

However, thermal cleaning cannot remove scale, which is inorganic.

POSSIBILITIES

What dimensions are possible?

We can currently clean heat exchangers up to 100 metric tonnes with a maximum length of 18 metres at our plant in the Netherlands, another of our

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plants can handle up to 10 meters, and all other Thermo-Clean plants go up to 8 meters.

However, this does not mean that the method itself is limited to these dimensions. Bigger is definitely possible, but the existing installations would need to be modified or new ones would need to be built. It may seem extravagant to build a thermal cleaning installation just to clean one heat exchanger with exceptional dimensions, but it has already been proven in practice that this is often an economically sound solution. A new pyrolysis oven is much cheaper and faster to build than many heat exchangers. It can definitely pay off to consider thermal cleaning for "the real big boys", or to discuss it with your industrial cleaner!

What can be cleaned?

The thermal cleaning method can certainly be used to clean other types of products such as large vessels, pumps, extruder parts, filters, pipelines, reaction vessels, and many more. All kinds of organic fouling including PP, PE, PS, PC, SAN, PET, PA (also reinforced), PBT, PU, carbonized material, coke, etc. can also be removed, which shows that the thermal cleaning method has excellent potential as a substitute, or even improvement, to today's cleaning techniques. In fact, the thermal cleaning technique often offers you the possibility of making your fouled heat exchangers or other parts like new again. This is a major advantage that cannot be ignored.

What about inorganic fouling?

When the fouling consists of organic and inorganic components, the organic component will acts as a kind of glue in which the inorganic components attach themselves. Thermal cleaning converts the organic components into dust, causing the glue to disappear and consequently release the inorganic components. These can easily be removed with high pressure cleaning.

If only inorganic components are present in the fouling, thermal cleaning has only a little effect. However, we have noticed while testing that, for example, lime deposits after thermal cleaning become brittle and easier to rinse off with high pressure.

REFERENCES

BASF, Borealis, Covestro (Bayer), Trinseo (Dow), DuPont, ExxonMobil, Rhodia, Arkema, BP, Esso, Lanxess, Mineraloelraffinerie Oberrhein, Q8, Raffinerie Heide, Sabic, Shell, Total Polymers, Total Additifs Carburants, Total Petrochemicals…

CASE STUDIES

Some examples of results achieved in the chemical industry are given below:

Case study 1

A good example is the heat exchangers from a naphtha cracker with "popcorn fouling" (Fig. 11) that our client cleaned with high-pressure every two months.

Fig. 11. Popcorn pollution before thermal cleaning.

After the first thermal cleaning (Fig. 12), they could be used without problems for 2 years: a huge improvement.

Fig. 12. Popcorn pollution thermal cleaning (before HP cleaning).

Case study 2

An oil refinery was eager to compare the effect of thermal cleaning with their traditional high-pressure cleaning method. To do this, they used two trains of four connected heat exchangers operating side-by-side. One train was cleaned thermally, the other with high pressure.

The test revealed that the thermally-cleaned heat exchangers produced such good results that the next cleaning could be postponed. According to the customer, this resulted in a saving of € 14,000,000. A successful test with a proven result!

Case study 3

Our third example is the case of a customer with historical hydrocarbon contamination between the tubes and the fixed housing (Fig. 13, Fig. 14).

This fouling had built up for years because good results could not be achieved with traditional cleaning techniques.

Fig. 13. Cleaning of bundles with fixed housing; shell side cleaning.

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Fig. 14. Inside of the heat exchanger before and after thermal cleaning (before rinsing).

The thermal treatment was able to reduce the fouling everywhere in this 23-metric-tonne heat exchanger to dust, which could be removed easily.

After thermal cleaning, the heat exchanger was found to weigh 3,000 kilograms less than before.

After the customer put the exchanger back into service, they found that the heat exchanger was practically returned to its original performance level, resulting in huge savings on steam costs.

Case study 4

For our fourth example, we present the case of a customer who had previously cleaned their exchanger using the conventional method (Fig. 15). After this conventional cleaning, the exchanger weighed 15,645 kilograms. But because it was not actually clean yet, we performed a thermal cleaning. After thermal cleaning, the weight was 14,505 kilograms, meaning that we were able to remove another 1,140 kilograms of fouling.

Fig. 15. Thermal cleaning after HP cleaning.

Case study 5

The fifth and final example we would like to cite is the low-temperature cleaning of a duplex bundle with a fixed housing and POM fouling. The fouling cracked at 270°C (518°F), which allowed us to extract (Fig. 16.) the bundle from the shell. This made it possible to remove the cracked POM from the heat exchanger.

In many cases, we can offer a solution for bundles with temperature restrictions through a combination of techniques.

Fig. 16. Extraction of a bundle from its shell.

CONCLUSION

We use controlled heat in our specially designed installations to destroy organic contamination and convert it into easy-to-remove dust.

This method is appropriate for almost every type of heat exchanger as long as it can withstand the temperature needed for the fouling to gasify.

The advantages are significant: Perfect cleaning quality (up to 100%), even on the inside; Benefit → performance levels like new; No wear or roughening of the surface; Fixed duration of the cleaning → stable cleaning costs; Cleaning of duplex material is possible; No wastewater problems; Thermal cleaning makes it possible to clean everywhere! (inside tubes, around tubes, between tubes & shell, inside tubes with static mixers).

NOMENCLATURE

C	Celsius scale, centigrade scale, temperature scale, °C
F	Fahrenheit scale, temperature scale, °F
L	Litre, unit of volume, L, l
m	Meter, unit of length in metric system, m
mm	Millimeter, unit of length in metric system, mm
m^3	cubic meter, unit of volume, m^3

[i] The remaining dust can easily be removed using various techniques (e.g. high-pressure or ultrasonic cleaning) and results in only 1,000-2,000 litres of water contaminated with dust that is easy to filter and reuse.

[ii] If the fouling contains sulphur and/or halogens, the gases need to be scrubbed before entering the atmosphere. The permitted emissions are regulated by local authorities and can vary between countries.

[iii] The right-hand picture shows a colour change of the stainless steel due to the thermal treatment. This is only a visual change; the thermal cleaning has no effect on the characteristics of the material.

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