United States Patent [19]

Callahan et al.

[11] **3,850,741**

[45] **Nov. 26, 1974**

[54] **METHOD OF CLEANING HEAT EXCHANGERS**

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[22] Filed: **May 23, 1973**

[21] Appl. No.: **363,279**

[52] **U.S. Cl.** ..... **208/48 R,** 134/20, 134/39, 134/40

[51] **Int. Cl.** **C23g 5/02,** C10g 9/16

[58] **Field of Search** ..... 208/48 R; 134/2, 20, 34, 134/40

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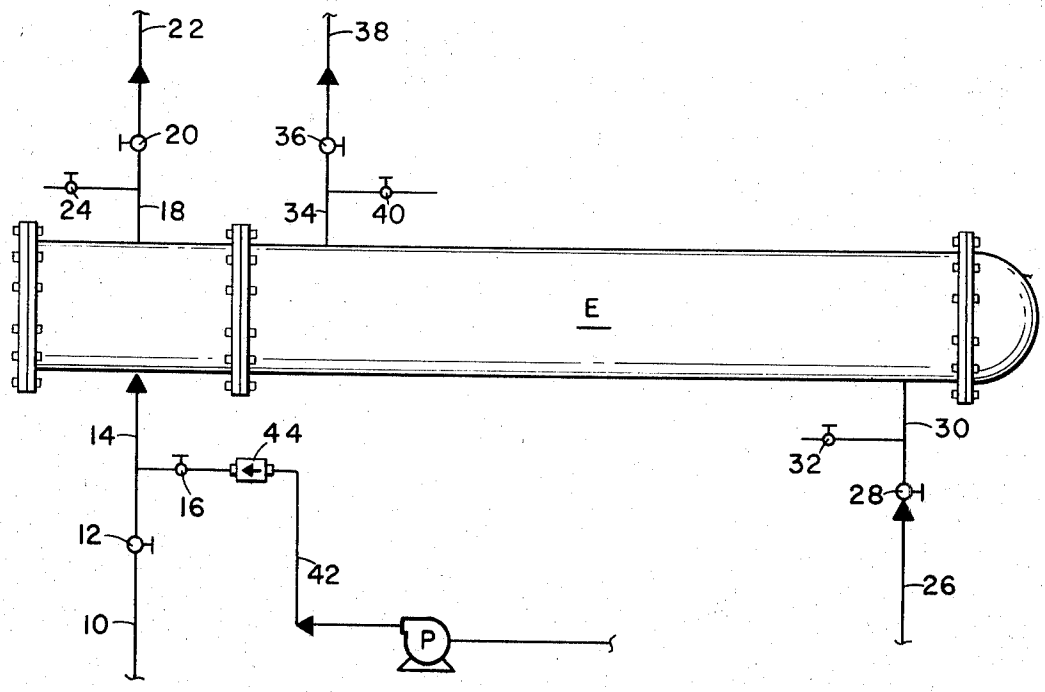
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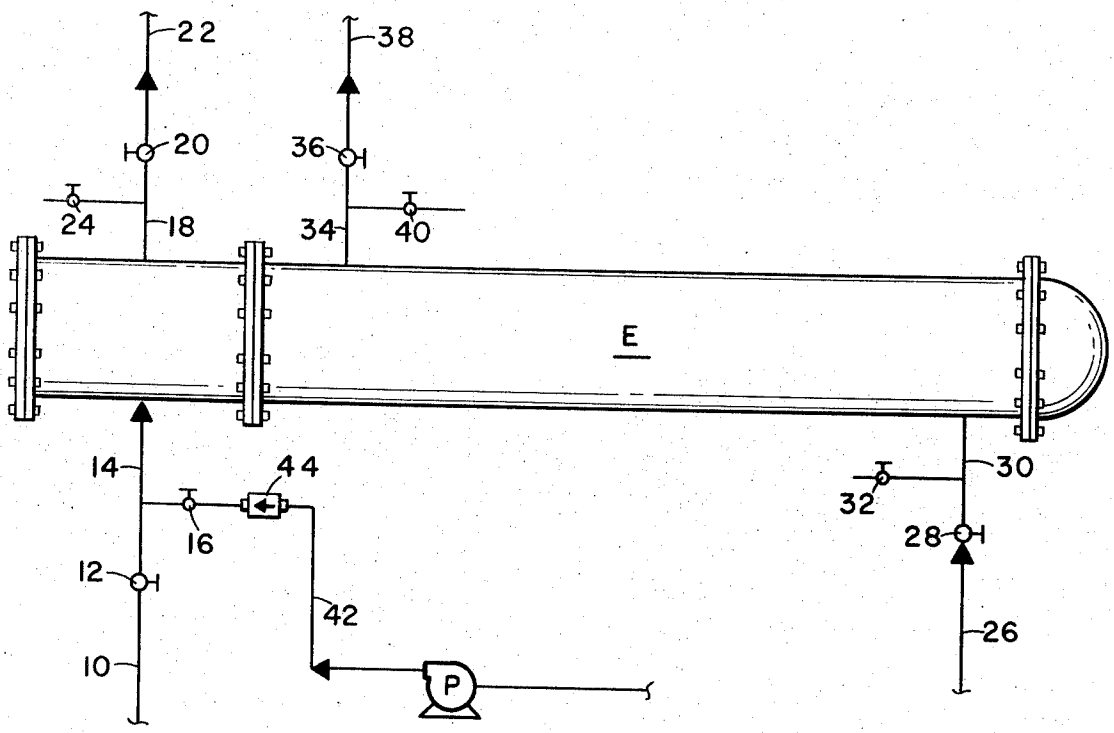
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[57] **ABSTRACT**

A method for removing carbonaceous fouling from shell and tube heat exchangers used in hydrocarbon processes which uses as the solvent a highly aromatic hydrocarbon and utilizes heat from the process itself to accomplish the removal of the carbonaceous fouling material is disclosed. This method is particularly useful to maintain the efficiency of heat exchangers between scheduled shutdown of particular units for extensive preventive maintenance.

11 Claims, 1 Drawing Figure




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METHOD OF CLEANING HEAT EXCHANGERS

BACKGROUND OF THE INVENTION

This invention relates to a method of cleaning shell and tube heat exchangers used in hydrocarbon processes where a cool stream flowing on one side of the heat exchanger is heated using the heat from another hotter process stream flowing on the other side of the heat exchanger in order to utilize all energy in the particular process to its best advantage. It is the usual practice in the hydrocarbon processing industry, whether it be the refining of petroleum crude oil to usable products or the conversion of such products in petrochemical plants to further useful materials, to periodically shut down units for inspection and preventive maintenance. The periodic planned shutdown best utilizes the maintenance force of the particular plant involved and is also used to plan production rates to compensate for the period of time when a particular operating unit or plant is shut down for maintenance. In the interim between these planned shutdowns, heat exchangers in the hydrocarbon processes become fouled and the efficiency of operating said exchangers decreases, causing a loss in energy which is either compensated for by consuming more energy through the use of heaters, and the like, or by suffering a decrease in production rate in the unit. In either case the overall efficiency is decreased and energy is being wasted.

This loss of efficiency normally occurs just with the passage of time due to the formation of deposits which, in the case of hydrocarbon processing in petroleum refineries and petrochemical plants, are generally carbonaceous and may be formed by deposition of suspended solid material or by the cracking and coking of the fluid streams.

Previously, the cleaning of these heat exchangers has required shutting down the unit or the heat exchanger, opening it and removing the tube bundle inside, and then cleaning the tube side by either drilling, water blast, and more recently, by oxidation of the material using an oxygen-containing gas with heat (see U.S. Pat. No. 3,054,700). The shell side of the tube bundles have been heretofore cleaned by water blasting, sand blasting, acid washing or flame treating while circulating coolant through the tubes (U.S. Pat. No. 3,060,064). All of the above-discussed treatments require excess amounts of down time and, hence; loss of energy and/or production during the period occurs. It has also been attempted to use certain solvents for cleaning heat exchanger surfaces, as described in U.S. Pat. No. 2,380,340, but the practice using solvents has generally been disappointing since either several solvents must be sequentially used, the time involved of interrupting the process use has been excessive, or the degree of cleaning has not been effective.

SUMMARY OF THE INVENTION

In accordance with this invention, therefore, an improved method for removing carbonaceous fouling from shell and tube heat exchangers used in hydrocarbon processes is described whereby the process stream on one side of the shell and tube heat exchanger is displaced with a high-boiling hydrocarbon solvent having at least 50 wt. percent aromatic content, a Kauributanol value of at least about 90 and a minimum boiling point of at least about 350°F and a maximum boiling point of at least about 500°F. Regardless of the side

of the heat exchanger to cleaned, whether it be the tube side or shell exchanger cleaned, whether it be the tube side or shell stand while the other side operates normally with the process stream flowing therethrough providing the heat which advantageously accelerates the cleaning process on the side of the exchanger being cleaned. In the practice of this invention, it is found that it is only necessary to continue the cleaning while holding the solvent solution in the shell and tube exchanger for a period of about **8** to about **24** hours to materially increase the heat transfer of the particular piece of equipment and to return it to an efficient operating range. After the cleaning time is finished, the solvent which is itself a hydrocarbon can be either bled out of the heat exchanger by allowing the normal material to displace the solvent or it can be, in the case of where the process stream is a crude stream or a waste stream, pushed by said process stream into the process itself. This avoids any messy disposal problems for the solvent containing the removed carbonaceous fouling materials. Once the solvent and removed fouling material have been displaced from the side of the heat exchanger being cleaned, it is then returned to service in the process. The method of this invention is particularly well adaptable to cleaning the shell and tube heat exchangers in hydrocarbon processes such as the refining of petroleum products and the production of petrochemical materials. One particularly advantageous application of this invention is to clean the heat exchangers used to preheat crude oil prior to its being charged to fractionation towers. The crude is also further heated in an oven and delivered to fractionation towers with certain products from the fractionation tower being passed on the other side of the aforementioned heat exchanger to provide the heat for the incoming crude and also to cool the product from the tower. These crude preheat trains may be only a few heat exchangers or a bank of sometimes as many as fifty such heat exchangers, depending upon the size of the refinery. As the operation of the heat exchanger continues, whether the crude is passed on the shell side or the tube side of the heat exchanger, the exchanger begins to foul through the deposition of carbonaceous materials on the heat exchange surfaces. The heat transfer is then lowered and, to compensate for this inefficiency, the crude oven must consume more fuel to bring the crude stream to adequate temperature for efficient fractionation. This could lead to damage to the oven and, in any case, represents a waste of energy which could otherwise be conserved.

Another instance where the practice of this invention is particularly applicable is with respect to the preheat train to a catalytic reformer unit wherein the incoming feed is heated on one side of the exchanger by the passage of the hot reformate on the other side. While the reformate is very clean and does not cause fouling problems, the bottoms from the unit which are also used to heat the feed, can cause fouling problems. When the side containing a bottoms stream that is a waste stream is being cleaned, the BTU value in such a stream is lost. However, this loss is minimized by the fact that the heat exchanger is off stream only a minimum amount of time.

Those skilled in the art would readily recognize, from the above-described applications of heat exchangers which may be cleaned through the method of this invention, other such applications of the invention.

DESCRIPTION OF THE DRAWING

The drawing attached hereto is a schematic diagram to aid in the explanation of applying the method of this invention to a shell and tube heat exchanger in service to conserve energy in hydrocarbon processing plants.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The heat exchangers in hydrocarbon processing plants, i.e., petroleum refineries and petrochemical plants, for reasons of economy, perform double duty. That is to say, a hot stream which needs to be cooled is used to supply heat in a shell and tube heat exchanger to a cooler stream which needs to be heated. In most cases, the shell and tube heat exchangers will be found to be employed in series or parallel, such that one or more of the exchangers may be taken out of service for one reason or another without causing the entire unit to become shut down. Often it would be found that several heat exchangers would be operated in series where the whole series would be in parallel with other similarly disposed and aligned heat exchangers. It is one of the particular advantages of the method of this invention that any down time of heat exchangers is minimized, thus effecting a significant savings in not only energy, but also in production of the hydrocarbon processing unit which is involved, since unit operation is disturbed when an exchanger is out of service.

As the heat exchangers are operated, carbonaceous material becomes attached to the heating surface and fouling occurs reducing the effectiveness of the heat transfer between the heating side and the cooling side, thus reducing the efficiency of the heat transfer. This heat transfer efficiency, generally designated as the heat transfer coefficient, U, BTU/(hour)(ft.^{2})(°F), can deteriorate to such a point that the overall efficiency of the unit is jeopardized. It is at this point that the invention described herein is especially important, since it allows the minimum of down time and the continuation of operation of the side of the heat exchanger not being cleaned.

In the operation of the method of this invention, the process stream utilizing the side of the exchanger being cleaned is displaced with the solvent used in the practice of the invention. Of course, the intake feed valve would be closed to stop the flow of material through the side being cleaned and the solvent would be retained in the heat exchanger in contact with the carbonaceous fouling material and "cook" under the influence of the material passing through the other side of the heat exchanger. This can be accomplished through either shutting down the heat exchanger and allowing it to cool before filling with the solvent used in the practice of this invention and reintroducing the process stream to the other side of the heat exchanger, or it can be accomplished by simply closing the feed valve to the side to be cleaned and pumping the solvent into the exchanger against the pressure of the outlet side of the exchanger to displace the feed material in the exchanger. Once the exchanger is full, then pumping is ceased and the action of the solvent on the carbonaceous fouling takes place. During this time, the outlet valve remains open and the exchanger "floats" against the pressure in the exit line. To put the exchanger back on stream, the inlet feed valve is merely opened and the solvent flushed from the exchanger into the process stream. Of course, if the solvent involved were detrimental to the purity of the stream going through the side of the exchanger being cleaned, then the outlet valve of the exchanger would be closed and the solvent removed through a bleed valve to prevent the contamination of the feed stream. However, in the case of cleaning the exchangers for the crude preheat train or the bottoms coolers of certain refinery columns, the process of this invention has particular application since the solvent can usually be flushed into the stream without causing any adverse results.

The solvent used in the practice of this invention is a high boiling hydrocarbon having a high aromatic content. The solvent, to operate satisfactorily, contains at least about 50 wt. percent aromatics and has a minimum initial boiling point at atmospheric pressure of about 350°F, and preferably about 400°F, and a minimum upper limit of the boiling range (end point temperature) of at least about 500°F, preferably 600°F minimum. The solvent will have a Kauri-butanol value of at least about **90** and preferably from about 100 to about 110. The Kauri-butanol test is a well-known standard test for solvents. The preferred solvents falling within the above specifications, are the heavy aromatic naphthas containing from about 75 to about 98 wt. percent aromatic constituents. If desired, or if necessary for thorough cleaning, a minor amount of chlorinated benzenes, particularly ortho-dichlorobenzene, can be used conjointly with the above described solvents to clean the heat exchanger. Generally, the chlorinated benzene will be used in an amount of about 10 percent by volume of the entire solvent, but the amount may vary within the preferable range of from about 5 to about 25 percent by volume. However, it is necessary when using a chlorinated hydrocarbon solvent in combination with the high aromatic solvent in the practice of this invention to carefully determine whether or not such chlorinated hydrocarbons can be allowed to contaminate the stream which passes through the side of the heat exchanger being cleaned, since chlorinated hydrocarbons are known to contaminate certain catalysts.

For purposes of illustration of the practice of this invention, reference is hereby made to the accompanying drawing wherein the heat exchanger E represents a shell and tube heat exchanger typical of those which are advantageously used in hydrocarbon processing plants and, therefore, are particularly adaptable to the use of practice of this invention. For purposes of this illustration, the tube side of the exchanger will be cleaned without interrupting the flow of the process stream through the shell side. From the following description, one of ordinary skill in the art will readily be able to accomplish the cleaning of the shell side of the exchanger by merely applying the stated procedure to the shell side process stream. During operation on the tube side, the process stream flows through line **10,** valve **12** and thence through line **14** into the heat exchanger E. A bleed valve **16** is connected to line **14** between valve **12** and the heat exchanger E. On the exit side of the heat exchanger E, the material flowing through the tube side, whether it be heated or cooled, exits the exchanger through line **18,** valve **20** and back to the process through line **22.** Connected to line **18** is a bleeder valve **24.** On the shell side of the heat exchanger E the process flow enters through line **26,**

valve **28** and line **30** to which is attached a bleeder valve **32.** The material exiting the shell side of the heat exchanger E exits through line **34,** valve **36** and returns to the process through line **38.** To line **34** is attached a bleeder valve **40.** When cleaning the tube side of the heat exchanger, a line **42** is connected to bleeder valve **16** through an optional check valve **44.** The inlet valve **12** is closed, the bleeder valve **16** opened and the solvent pumped by pump P through line **42,** the optional check valve **44** and thence through the bleeder valve **16,** line **14** and into the exchanger E to replace the process material which is within the exchanger. The amount of solvent pumped is sufficient to fill the exchanger and force all of the process material out through the exit valve **20** which remains open during the cleaning process of this invention. Once the exchanger is filled, the process material flowing through the shell side of the heat exchanger E heats the solvent in contact with the carbonaceous fouling material and causes said material to be removed from the heat exchange surfaces. This cooking process is allowed to continue for at least about 8 and preferably at least about 18 hours with the time generally ranging from about 8 to about 24 hours, preferably from about 18 to about 24 hours, depending upon the nature of the carbonaceous fouling. Longer times can be used but as a practical matter are rarely necessary and generally considered wasteful.

Once the cleaning has been completed, to return the tube side of the heat exchanger to on-stream operation, assuming, for example, the heat exchanger E is a part of the crude preheat stream where the heavy aromatic solvent would not contaminate or harm the feed stream; it is only necessary to open the inlet valve **12** with the bleed valve **16** being closed to allow the process fluid, crude in this case, to push the heavy aromatic solvent out through the exit valve **20** and thence into the process stream. Thus, it is seen from the foregoing description that the heat exchanger has been off line only a very short period of time, as compared with prior art processes for such heat exchanger cleaning. It has not even been necessary to discontinue the flow of the material on the shell side of the exchanger.

If it is desired to avoid pushing the solvent into the process stream, once cleaning is completed, exit valve **20** can be closed and bleed valve **24** opened, along with inlet valve **12** and the solvent piped away to a remote location in the plant using proper safety precautions in view of the high temperatures generally involved and the danger of fire which inheres in the handling of hydrocarbon materials at high temperatures and pressures.

The use of the method of this invention is adaptable to process parameters involved in operating the particular shell and tube heat exchanger involved and such process parameters are not critical to the practice of this invention, but should be kept in mind by the skilled engineer in order that proper safety precautions be followed at all times.

If desired, the above described cleaning process could be carried out by first taking the heat exchanger E out of service by closing valves **12, 20, 28** and **36** to stop flow of process material in the exchanger and open bleeder valves **24** and **16** on the tube side and **40** and **32** on the shell side and, using proper safety precautions for the material and temperatures and pressures involved, drain the exchanger. The exchanger can then be properly cooled by circulating nitrogen through both sides of the heat exchanger. Again for purposes of illustration, the tube side is used and the high aromatic solvent is pumped through the bleed valve **16** into the exchanger E with venting through the outlet bleed valve **24.** Once the exchanger is full of solvent, the bleed valves are closed and the outlet valve **20** opened to allow the tube side of the heat exchanger to again "float" on the open outlet valve. The process stream, normally flowing through the shell side, will then be allowed to enter the shell side by opening valve **28** using the normal safety precautions for starting up a shell and tube heat exchanger where differential pressures are involved. These procedures are well-known to those skilled in the art. The process stream will then flow through the shell side of the heat exchanger E with valve **36** having been opened, the bleeder valves, of course, have been closed.

To return the heat exchanger E to normal process operation, the procedure discussed above is to be followed.

Those of ordinary skill in the art, after having read the above discussion of the process of this invention, will have no trouble applying it to other situations wherein shell and tube heat exchangers are used in hydrocarbon processing.

The following Examples are offered by way of illustration of the practice of this invention and should not be construed as limiting the scope thereof. Many modifications and variations thereof will be obvious to one of ordinary skill in the art after studying the foregoing discussion and considering the following Examples.

EXAMPLES 1-4

In the following Examples, the heat exchangers cleaned were in the crude preheat train of a refinery with incoming crude on one side and hot product from the crude fractionation tower on the other supplying the heat to cook the solvent. The solvent used was a heavy aromatic naphtha containing 98 wt. percent aromatics and having a boiling range of 405°F to 690°F and a Kauri-butanol value of 105. The inlet crude valve was closed and the crude was displaced from the heat exchanger by solvent pumped with a positive displacement pump through the inlet bleed valve on the side of the exchanger being cleaned. After a volume sufficient to fill the side of the exchanger being cleaned had been pumped, the positive displacement pump was cut off and the inlet bleed valve was closed. The exit valve on the side of the exchanger being cleaned was left open and the heat exchanger was allowed to "float" on the open valve during the time of the cleaning. After the cleaning was complete, the inlet crude valve was opened and the solvent, with removed carbonaceous material, entered the crude stream through the exit valve of the exchanger. The pertinent information concerning the cleaning and the results thereof are set forth on Table 1 below.

TABLE 1

Ex.	Side Cleaned	Volume[1] Gals.	Temp.[2] °F	Time, hr.	Heat Transfer* Coefficient Before	After	Design	Pressure Drop,[1] psi Before	After	Increased[1] Throughput bbl/day
1	Tube	500	780	18	12.5	24.4	33	140	56	2,500

TABLE 1–Continued

Ex.	Side Cleaned	Volume[1] Gals.	Temp.[2] °F	Time, hr.	Heat Transfer* Coefficient Before	After	Design	Pressure Drop,[1] psi Before	After	Increased[1] Throughput bbl/day
2	Shell	1,000	550	24	28.0	101	79	N/A	N/A	6,000
3	Tube	750	350	18	25.5	63.6	75	N/A	N/A	4,000
4	Shell	1,200	785	18	21.0	61.0	33	102	41	6,000

* — U_o = BTU/(hr)(ft.²)(°F) for side cleaned
(1) — for side cleaned
(2) — process side

It was estimated that as a result of the cleaning described in Example 1 a savings of $10,000.00 per month resulted from reduced fuel consumption in the crude oil furnace in the system.

EXAMPLE 5

Two exchangers in series in a crude preheat train with hot product from the crude fractionation tower on the tube side and incoming crude on the shell side were cleaned with a solvent having 28 to 30 wt. percent aromatic content, although it fit the proper boiling range. The shell side of the exchangers were cleaned using the procedure described in Examples 1–4 for 24 hours. The first exchanger had a shell side heat exchange coefficient, U_o, of 16.5 before cleaning and 18.6 after cleaning. The second exchanger had a U_o of 24.5 before cleaning and a U_o of 26.0 after cleaning. Tube side temperature was 476°F. The amount of cleaning was unsatisfactory.

A second cleaning of these two exchangers using the same process for the same length of time was carried out using the solvent described in Examples 1–4. This cleaning increased the U_o on the first exchanger to 32.8 and the second exchanger to 34.4. Design U_o on the first exchanger is 42.0 and on the second 44.0. The crude throughput increase was estimated at 8,000 bbl/day.

EXAMPLE 6

In a crude preheat train of a refinery a heat exchanger with the incoming crude on the shell side was cleaned in the manner described in Examples 1–4. The solvent used was 10 percent by volume orthodichlorobenzene and 90 percent by volume of the heavy aromatic naphtha of Example 1. The cleaning took place for a period of 18 hours with a process side temperature of 450°F. The volume of the shell side was 1,200 gallons and the flow through said shell side was increased by 2,500 barrels per day after cleaning. The heat transfer coefficient, U_o, for the shell side before cleaning was **24** and after cleaning **67** with a design heat transfer coefficient of **72.**

In view of the foregoing description, drawing and Examples, one of ordinary skill in the art may make many modifications and variations of the above-described invention without departing from the scope of the claims attached hereto.

We claim:

1. A method for removing carbonaceous fouling from shell and tube heat exchangers used in hydrocarbon processes which comprise the steps of:

a. displacing a process stream on one side of the heat exchanger with a hydrocarbon solvent having at least about 50 wt. percent aromatic content, a Kauri-butanol value of at least about 90 and a minimum initial boiling point of at least about 350°F and an end point temperature of at least about 500°F, and retaining said solvent in said one side of the heat exchanger;

b. heating the solvent being retained in one side of the exchanger by passing a process stream through the other side of the heat exchanger as in normal operation of the heat exchanger for a period of at least about 8 hours to remove the carbonaceous fouling; and

c. displacing the solvent and removed fouling with the process stream.

2. The method of claim **1** wherein the solvent and removed fouling are displaced into the process stream itself.

3. The method of claim **1** wherein the flow of the process stream on the side not being cleaned remains uninterrupted during step (a).

4. The method of claim **1** wherein the heat exchanger is taken out of service and cooled prior to step (a).

5. The method of claim **1** wherein the solvent includes about 10 volume percent of a chlorinated benzene.

6. The method of claim **5** wherein the solvent and removed fouling displaced by the process stream is removed from the process.

7. The method of claim **1** wherein the solvent is a heavy aromatic naphtha.

8. The method of claim **7** wherein the solvent has an aromatic content of from about 75 wt. percent to 98 wt. percent and a boiling range of from about 400°F minimum initial boiling point to about 600°F minimum end point and a Kauri-butanol value of from about 100 to about 110.

9. The method of claim **8** wherein the cleaning was continued for a period of from about 18 to about 24 hours.

10. A method for removing carbonaceous fouling on the side of a shell and tube heat exchanger carrying crude oil in the crude preheat train of a petroleum refinery which comprises the steps of:

a. displacing the crude in the heat exchanger with a heavy aromatic naphtha solvent having an aromatic content of from about 75 wt. percent to 98 wt. percent a Kauri-butanol value of about 105 and a boiling range of from about 405°F to about 690°F without interrupting process flow on the other side of said heat exchanger;

b. heating the heavy aromatic naphtha being retained on the crude oil side of the exchanger by passing the hot process stream through the other side of said exchanger as in normal operation of the heat exchanger for a period of from about 18 to about 24 hours to remove the carbonaceous fouling; and

c. displacing the solvent and removed fouling by flushing the solvent and removed fouling into the crude stream flow with said crude oil.

11. The method of claim **10** wherein the exit valve of the crude oil side remains open during heating of the solvent being retained therein.

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