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17 September 2003

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QUENCHING APPARATUS

The invention is generally directed to an apparatus for quenching a hot gaseous stream. The invention is more specifically directed to a process for quenching the pyrolysis product from a pyrolysis furnace.

5 In one of Applicant's gas oil steam cracker plants for producing olefins it was recognized that wetting of the quench tube wall is essential in order to keep the quench tube from fouling because of coke deposits. The use of a spray nozzle to introduce the quench oil for
10 cooling the hot pyrolysis gas exiting the radiant section, was found not to work because of the difficulties in keeping the walls completely wetted. Previous nozzle configurations included an external quench ring encircling the quench tube for distributing
15 quench oil between three nozzles arranged 120 degrees apart around the quench tube. This design created excessive thermal stress on the quench ring. Later, it was modified into three separate quench nozzles, all sharing one quench oil supply line, which required a flow
20 restriction in each nozzle to ensure good distribution of quench oil.

25 The restriction orifices and smaller sized nozzles in the prior multi-nozzle oil injection quench tubes were frequently plugged by coke particles present in the quench oil. When this occurred, the quench oil flow wetting the quench tube wall was interrupted and this led to incomplete wetting of the quench tube wall. Coke would form and grow on the dry spot of the quench tube wall and would eventually plug the quench tube. When this
30 occurred, the entire furnace had to be shutdown for cleaning. Even without problems with the injection

17 September 2003

nozzles, the quench tube was subject to coke formation and plugging at the moving boundary between wetted and dry walls near the oil inlets.

5 The present invention aims to provide a nozzle configuration wherein the problems outlined hereinbefore can be avoided. This was achieved by using a quench nozzle configuration, wherein the nozzle introduces quench oil tangentially into the quench tube and cools the hot gaseous pyrolysis products coming out of the hot radiant
10 tubes in a pyrolysis furnace (e.g., in ethylene manufacture), while at the same time keeping the inner wall of the quench tube wetted by the quench oil, which is necessary to prevent coke deposition on the quench tube.

15 Accordingly, the present invention relates to an apparatus for quenching a hot gas stream comprising:

(i) first conduit means for conveying said hot gas from an upstream source to a downstream location;

(ii) flow obstruction means located within said conduit means for creating a low-pressure zone in said hot gas

20 stream immediately downstream of said obstruction means;

(iii) second conduit means located downstream from said flow obstruction means, said second conduit means intersecting said first conduit means on a tangent thereof and at an angle thereto, said second conduit means adapted to
25 inject a quenching fluid tangentially into said hot gas stream at a pressure sufficient to cause said quenching fluid to flow circumferentially around the inside surface of said first conduit means and to fill said low-pressure zone of said hot gas stream and to contact the downstream
30 face of said flow obstruction means; and

(iv) interface means on said downstream face of said flow obstruction means for providing a sharp interface between said hot gas stream and said quenching fluid. Preferred embodiments of this apparatus are

17 September 2003

Preferably, the second conduit means intersects said first conduit means on a tangent thereof and perpendicular thereto.

5 Preferably, said flow obstruction means is an insertion ring adapted to be placed in said first conduit means on a diameter thereof.

10 Preferably, said first conduit is a cylinder and said insertion ring is located circumferentially on an inside diameter thereof, said insertion ring having a ramp which increases in height in the direction of said gas flow, said ramp terminating in a flat portion, said flat portion terminating in a sharp interface with the downstream side of said flow obstruction means.

15 Preferably, the ramp has a convex or a concave curvature.

Preferably, said flow obstruction means is formed by two or more concentric conduits.

20 Preferably, the distance between the outside surface of said second conduit and the downstream face of said flow obstruction means is between 20% and 100% of the inside diameter of said second conduit.

25 One specific embodiment of the present invention is a process for cooling a hot gas stream of a pyrolysis furnace which process comprises a quench zone associated with the hot gas stream of the pyrolysis furnace, which quench zone comprises

30 (a) a quench tube through which the hot gas is flowing and into which the quench oil is injected for cooling this hot gas, said quench tube comprising an insertion ring, located circumferentially on an inside diameter of said quench tube, said insertion ring having a ramp which increases in height in the direction of gas flow, said ramp terminating in a flat portion, said flat portion terminating in a sharp interface; and

17 September 2003

(b) at least one nozzle located downstream from said sharp interface, said nozzle being positioned at an angle to said quench tube and tangential thereto for the introduction of quench oil into said quench tube.

5 Preferably, the nozzle is positioned perpendicular and tangential to said quench tube.

Preferably, the distance between the outside surface of the nozzle and the sharp interface is between 20% and 100% of the inside diameter of said nozzle.

10 The second conduit of the apparatus or nozzle has one quench oil entry, thus eliminating the need for any restriction orifice which would be required to evenly distribute quench oil flows between several nozzles. Also, the one-nozzle oil introduction has a larger diameter than
15 that required if more than one nozzle were employed in this service. The replacement of multiple nozzles (and restriction orifices) with a single larger diameter nozzle eliminates plugging problems caused by coke particles present in the quench oil. The inner walls of the first

20 ~~conduit means or quench tube are maintained wetted by the~~ use of internal flow obstruction means, suitably in the form of a ring with a specially-tapered leading edge and an abrupt terminal end which serves to prevent the quench oil/gas interface from moving axially back and forth in
25 the quench tube, and thereby eliminating coke formation.

17 September 2003

The invention is illustrated by Figures 1 to 10:

FIGURE 1 is a cross section view of the quench tube and nozzle of the instant invention.

FIGURE 2 is a cross section view taken along the line 2-2 of Figure 1.

FIGURES 3-10 show various embodiments of several permutations of the insertion ring.

One possible environment of the present invention is a pyrolysis furnace as disclosed in Figure 1 of U.S. Patent No. 3,907,661. Applicants' invention is an improvement in the design of the quench zone 13 of that patent or in other similar apparatus.

Referring now to Figure 1 of the instant application, quench tube 10 is shown in cross section and having a quench oil inlet tube or nozzle 12 which forms an entry into quench tube 10 on a tangent thereto. Figure 1 is taken on a diameter of nozzle 12 and of quench tube 10 where the two conduits intersect and the combination as described herein comprises an improvement to the quench zone 13 of the aforesaid U.S. Patent No. 3,907,661.

Figure 2 shows a cross section of quench tube 10 taken along the longitudinal axis thereof and looking back into the nozzle 12. Within quench tube 10 and upstream of nozzle 12 (relative to gas flow and corresponding to the input to the quench zone 13 in Figure 1 of the '661 patent) is an insertion ring 14 having a ramp portion 14a terminating in a flat section 14b, the latter having a sharp interface with face 14c. That is, flat section 14b and face 14c of insertion ring 14 intersect at a right angle to form a sharp edge 14d. The function of the insertion ring 14 and variations thereof is to form a low-pressure zone 16 at the downstream face 14c.

Nozzle 12, in its simplest form, may be a constant-diameter pipe which enters quench tube 10, preferably at a

right angle and with one of its walls on a tangent to the quench tube 10. An insertion ring 14 is located a short distance upstream of nozzle 12 and creates a low-pressure zone 16 at face 14c. The optimum distance between face 14c and nozzle 12 is the distance that results in no liquid flowing over the sharp edge 14d but which completely wets face 14c. The quench oil injected by nozzle 12 flows circumferentially around the inner surface of quench tube 10 (because of the tangential injection at sufficient pressure) filling the low-pressure zone 16 at the face 14c. In order for the invention to function properly, it is necessary that the liquid being injected tangentially through nozzle 12 have sufficient velocity so that the applied centrifugal force acting on this incoming stream for the duration of the fluid's first revolution within quench tube 10 exceeds that acting on the incoming stream which is due to the gravitational field in effect in this region of the apparatus. In other words, this velocity must be such that

$$U^2/(Rg) > 1 \text{ where:} \quad (1)$$

U^2 is the square of the inlet velocity,

R is the inside radius of quench tube 10, and

g is the acceleration of gravity,

all expressed in a consistent set of dimensional

units. Typical values of $U^2/(Rg)$ range between 3 and 20. The quench oil is then spread along the inner wall of the quench tube 10 as a result of fluid drag forces acting on the oil by the gas phase. This interaction between the gas and oil phases also results in some transfer of momentum in the downstream direction from the gas to the quench oil. In this manner, face 14c and the inner wall of the quench tube 10 downstream thereof, are maintained in a "wet" condition, thereby creating a two-phase annular flow regime which inhibits the formation of coke. The portion of quench tube 10 upstream of face 14c, including

surfaces 14a and 14b of insertion ring 14, remain "dry" and are, therefore, not subject to coke formation. The sharp edge, 14d of insertion ring 14, forms the abrupt interface between "wet" and "dry" sections.

5 Insertion ring 14 has been described herein as having flat sections (14a, 14b and 14c) but could also be constructed with curved, extended or shortened sections. The critical features required to be maintained are the sharp interface 14d and the low-pressure zone 16.

10 Figures 3 through 10 illustrate a portion of other combinations for insertion ring 14. Figure 3 utilizes a zero length flat section 14b, i.e., a ramp 14a terminating in a sharp interface 14d with face 14c. Figure 4 shows a curvature in the section 14b that is generally parallel

15 with the axis of the quench tube. Figure 5 utilizes a concave section 14c to contain the low-pressure zone and alter the angle of the sharp edge, 14d. Figure 6 illustrates an altered shape of the ramp portion, 14a. Figure 7 shows one embodiment of combinations of

20 modifications that maintain the "wet/dry" interface and the low-pressure zone. Figure 8 is another combination utilizing an "infinite" ramp length, i.e., no internal insertion ring 14a. It is, essentially, a demonstration of how two quench tubes of different diameters may perform

25 the function of insertion ring 14. Figure 9 shows an insertion ring 14 having 90-degree faces 14a and 14c. This configuration causes excessive leading edge (of insertion ring) turbulence and resultant pressure drop, but could be used in some applications. Figure 10 is an embodiment of

30 Figure 8 that may be easier to fabricate. It is shown with a concave face 14c, although convex or flat surfaces may also be utilized.

35 Although the nozzle 12 is described herein in terms of a tube or conduit (cylindrical) element, it could be of other shapes in cross section, i.e., elliptical, square,

rectangular, etc. The critical features of the design are the utilization of a tangential, or approximately tangential, inlet tube to impart a velocity to the oil of sufficient momentum to cause the oil to flow around the circumference of the quench tube 10 while completely wetting the face 14c. Likewise, although only one nozzle is described, plural nozzles could be used, e.g., two nozzles diametrically opposed on quench tube 10 so as to aid each other in circumferentially flowing the quench oil. Also, the tangential entry is preferably at a right angle to the quench tube 10 whereas any angle may be employed as long as the oil will fill the low-pressure zone 16 around the circumference of the quench tube 10 next to the face 14c. Similarly, the distance of the outside surface of nozzle 12 from face 14c is determined by the need to have the oil pulled and spread into the low-pressure zone 16 without overflowing the sharp edge 14d. In the preferred embodiment of the invention, this distance should lie between about 20% and 100% of the inside diameter of nozzle 12.

Insertion ring 14 may be fabricated as a ring that is welded inside quench tube 10, or it may be fabricated as an integral portion of the quench tube. Insertion ring 14, as illustrated in Figure 1, includes a ramp portion 14a that is preferably about 7½ degrees but may be inclined to 90 degrees, or more, maximum grade. The ramp, 14a, may be as little as zero degrees in the case of two separate quench tube diameters (Figure 8). The ramp portion 14a terminates in a flat or curved portion 14b which, in turn, terminates in a sharp edge, or interface 14d, with face 14c. Under gas flow conditions, the insertion ring 14 restricts the flow area causing the gas velocity to increase as it flows through the insertion ring. A low-pressure zone 16 is created by this increased velocity which tends to pull the tangentially injected quench oil

from nozzle 12 into the low-pressure zone 16 thereby wetting the quench tube inner wall and insertion ring surface 14c in this area. The quench oil from nozzle 12 is then conveyed downstream by the furnace gas flow and is maintained against (thereby wetting) the quench tube 10 wall. The length of the ramp 14a is preferably as long as possible so as to cause the least turbulence; however, manufacturing (machining) limitations control the physical dimensions which are possible.

Although the orientation of the quench tube 10 is shown as being horizontal, as long as the combined momentum of the quench oil and gas flow can maintain the quench wall wetted, the orientation of the quench tube 10 can be vertical or at an angle to the horizontal position, upflow or downflow. The lines should be sized and oriented, and the gas and liquid flow rates should be such as to produce and maintain two-phase annular flow within the quench tube 10 downstream of face 14c in order to accomplish the wall wetting function.

Although the invention has been described herein with reference to a specific application in pyrolysis furnaces, other applications are possible such as:

1. The injection of a "wash-water" stream into a pipe carrying a gaseous stream in order to wet the downstream piping walls to prevent or remove salt deposits in process water-wash operations (e.g., hydrocracker water-wash operations).

2. The injection of a water or hydrocarbon-based corrosion inhibitor into a pipe bearing a gaseous stream in order to uniformly wet the downstream piping walls for corrosion control. (e.g., the injection of a filming amine into the overhead line of an absorption or distillation column).

3. The injection of a hydrocarbon or water-based liquid into a pipe bearing a gaseous stream in order to prevent

the downstream pipe walls from becoming excessively hot (e.g., injection of "spray" or quench water into catalytic cracking or fluid coking overhead lines in order to keep pipe temperatures below their metallurgical operating limits).

4. The wetted-wall tangential quench tube configuration can be applied to the individual tube in the Transfer Line Exchanger (TLE) at the outlet of pyrolysis furnaces. TLE's are shell-and-tube heat exchangers where the hot pyrolysis gaseous products exiting the radiant tube are indirectly cooled or quenched on the tube side while generating high-pressure steam on the shell side. Coke will deposit on the tube side, thereby reducing heat transfer, increasing pressure drop across the TLE and requiring periodic decoking and furnace downtime. By applying the wetted wall quench technology (method) disclosed herein to completely wet the inside of these TLE tubes, coking can be prevented, thus reducing the attendant downtime and production loss.

The invention is further illustrated by the following example without limiting the scope of the invention to this particular embodiment.

EXAMPLE

Furnaces in one of Applicant's plants utilizing the old quench nozzle design typically have to be shut down every fifteen days due to quench nozzle plugging in one or more of the ten quench passes in each furnace. In Applicant's test installation to prove the concept of the invention disclosed herein, the quench pass (with the old nozzle design) that was most prone to a plugging problem in the most frequently plugged furnace was selected for replacement. That nozzle was replaced by a quench tube which utilized a Schedule 40 pipe having a nominal 8-inch (20.3 cm) diameter and was intersected by a nozzle having an internal diameter bore of 4.3 cm (1½ inch). The

quench liquid was injected at a flow rate of about
4.0 m/sec (13 ft/sec or 74 gal/min) into the hot gas
stream flowing at about 61-76 m/sec (200-250 ft/sec). The
test quench pass nozzle system was operated for about one
5 year with no downtime or plugging even though other
nozzles (with the old design), including those adjacent to
the test nozzle in the same test furnace, did plug due to
coking, thus requiring shutdown of the whole test furnace.
This demonstrated the resistance of the new nozzle design
10 to plugging in a plugging-prone environment as shown by
the continuing plugging problems experienced by the other
"old design" nozzles in the same furnace.

C L A I M S

1. Apparatus for quenching a hot gas stream comprising:

(i) first conduit means for conveying said hot gas from an upstream source to a downstream location;

5 (ii) flow obstruction means located within said conduit means for creating a low-pressure zone in said hot gas stream immediately downstream of said obstruction means;

10 (iii) second conduit means located downstream from said flow obstruction means, said second conduit means intersecting said first conduit means on a tangent thereof and at an angle thereto, said second conduit means adapted to inject a quenching fluid tangentially into said hot gas stream at a pressure sufficient to cause said quenching fluid to flow circumferentially around the inside surface of said first conduit means and to fill said low-pressure zone of said hot gas stream and to contact the downstream face of said flow obstruction means; and

15 (iv) interface means on said downstream face of said flow obstruction means for providing a sharp interface between said hot gas stream and said quenching fluid.

20 2. Apparatus as claimed in claim 1, wherein the second conduit means intersects said first conduit means on a tangent thereof and perpendicular thereto.

25 3. Apparatus as claimed in claim 1 or 2, wherein said flow obstruction means is an insertion ring adapted to be placed in said first conduit means on a diameter thereof.

30 4. Apparatus as claimed in any one of claims 1-3, wherein said first conduit is a cylinder and said insertion ring is located circumferentially on an inside diameter thereof, said insertion ring having a ramp which increases in height in the direction of said gas flow, said ramp terminating in a flat portion, said flat portion

17 September 2003

terminating in a sharp interface with the downstream side of said flow obstruction means.

5. Apparatus as claimed in claim 4, wherein the ramp has a convex or a concave curvature.

5 6. Apparatus as claimed in any one of claims 1-5, wherein said flow obstruction means is formed by two or more concentric conduits.

10 7. Apparatus as claimed in any one of claims 1-6, wherein the distance between the outside surface of said second conduit and the downstream face of said flow obstruction means is between 20% and 100% of the inside diameter of said second conduit.

15 8. Process for cooling a hot gas stream of a pyrolysis furnace, which process comprises a quench zone associated with the hot gas stream of the pyrolysis furnace, which quench zone comprises

20 (a) a quench tube through which the hot gas is flowing and into which the quench oil is injected for cooling this hot gas, said quench tube comprising an insertion ring, located circumferentially on an inside diameter of said quench tube, said insertion ring having a ramp which increases in height in the direction of gas flow, said ramp terminating in a flat portion, said flat portion terminating in a sharp interface; and

25 (b) at least one nozzle located downstream from said sharp interface, said nozzle being positioned at an angle to said quench tube and tangential thereto for the introduction of quench oil into said quench tube.

30 9. Process as claimed in claim 7, wherein the nozzle is positioned perpendicular and tangential to said quench tube.

35 10. Process as claimed in claim 8 or 9, wherein the distance between the outside surface of the nozzle and the sharp interface is between 20% and 100% of the inside diameter of said nozzle.

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