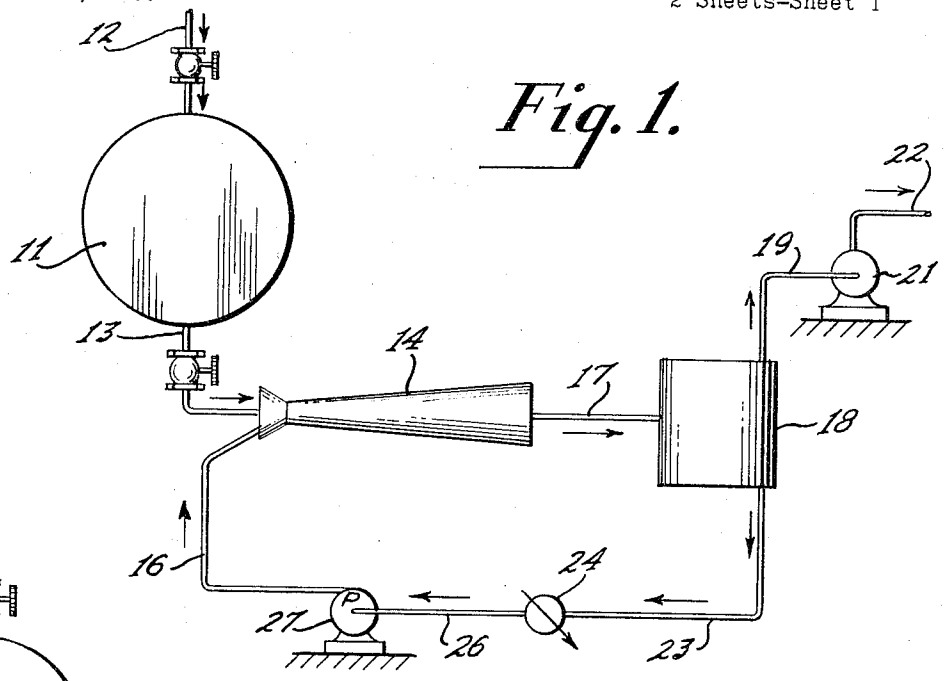
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QUENCH SYSTEM

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Fig. 1.



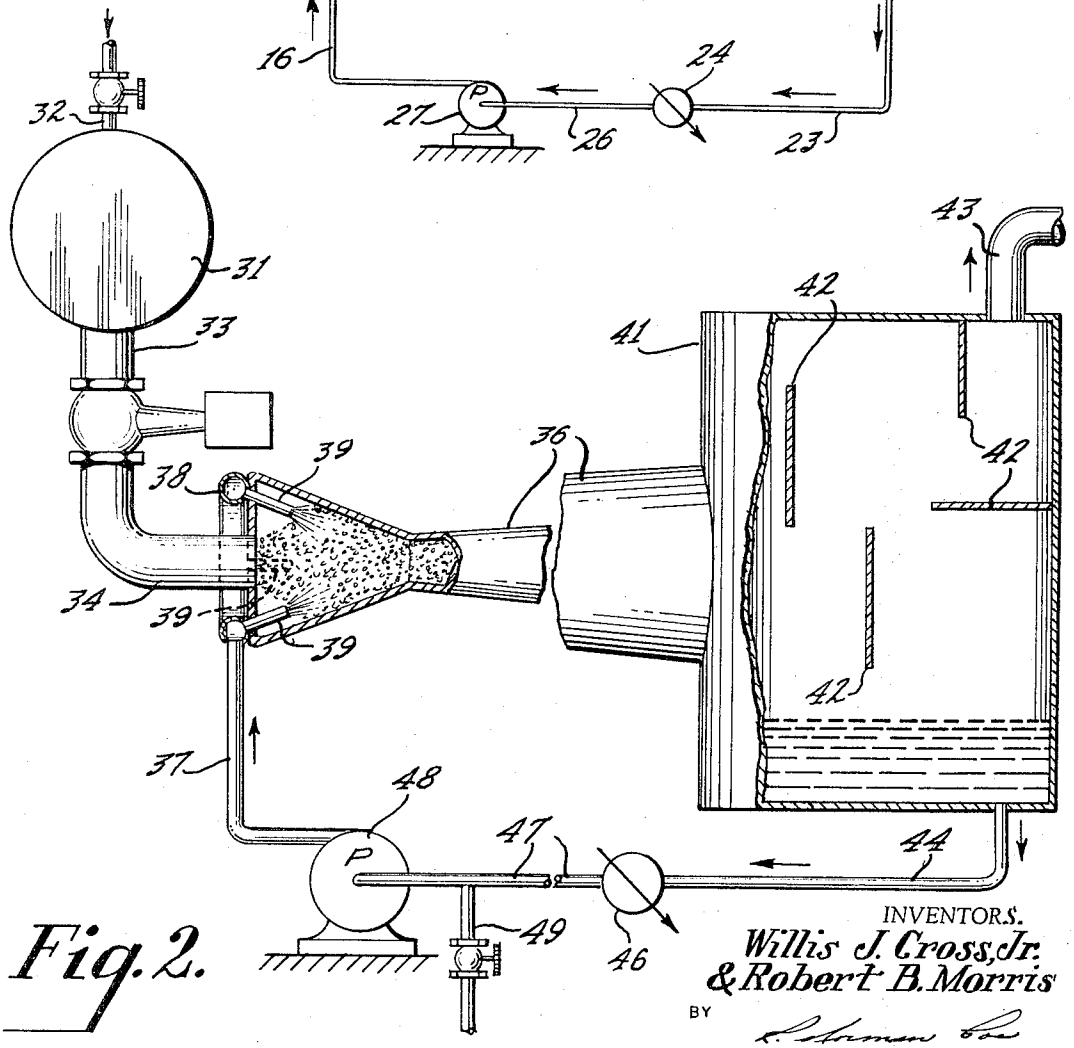


Fig. 2.

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Fig. 3.

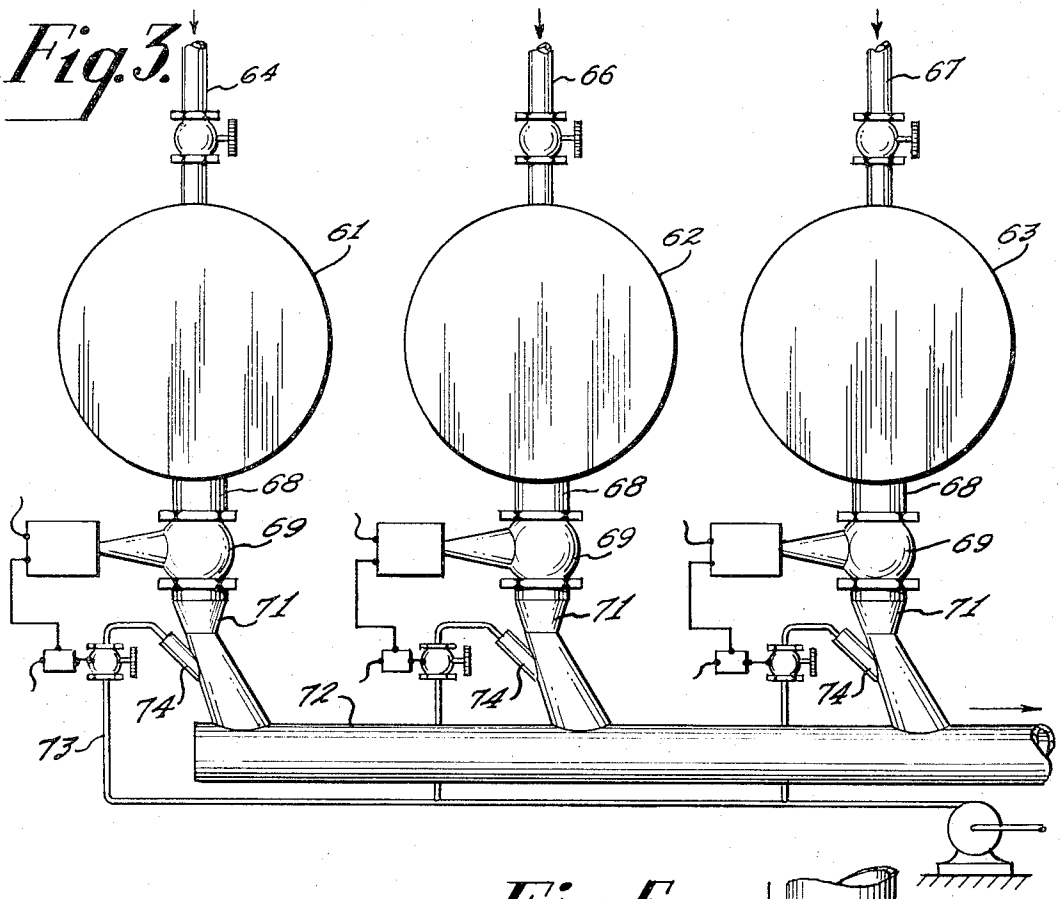


Fig. 4.

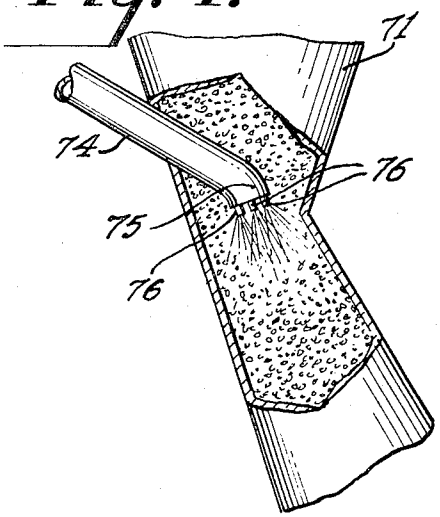
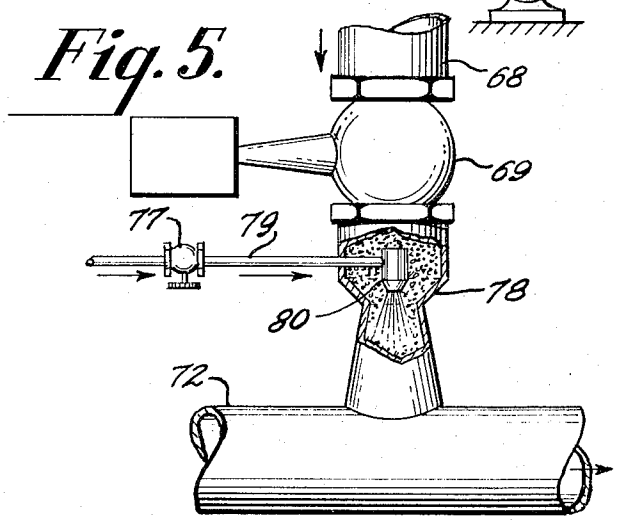


Fig. 5.



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QUENCH SYSTEM

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ABSTRACT OF THE DISCLOSURE

Quenching of the hot gaseous effluent obtained by the conversion of hydrocarbons at sub-atmospheric pressure, such as the dehydrogenation of normally gaseous hydrocarbon, in order to inhibit polymerization and coking reactions preparatory to pressuring for subsequent treatment, is effected in transit and with minimal pressure differential between the reactor outlet and the inlet to the pressuring zone by direct heat exchange between the gaseous effluent and a liquid coolant. Such direct heat exchange is effected by engaging the hot effluent with a high-velocity stream of the liquid coolant and passing the admixture through a venturi, using the velocity of the liquid as the sole motive force. The fluid discharging from the venturi is then separated into quenched effluent gas, which is conveyed to the pressuring zone, and liquid coolant which may be cooled and recirculated. The preferred liquid coolant is a quench oil, non-reactive with the gaseous effluent, and the pressuring of the quenched effluent is effected by a turbo-compressor whose inlet pressure is not substantially lower than the discharge pressure of the reactor effluent.

This invention is concerned with the quenching of high temperature fluids and is more particularly concerned with the quenching of high temperature reactor effluent fluids such as dehydrogenation products in which an early and substantial temperature reduction is necessary to arrest further reactions and avoid product losses.

As shown in U.S. 3,080,153, it is well established in the art to take reactor effluent from dehydrogenation reaction zones and effect quenching thereof in one or more successive stages. In the dehydrogenation of normally gaseous hydrocarbons, of which the dehydrogenation of more saturated C_4 hydrocarbons to less saturated C_4 hydrocarbons is a large scale practical embodiment, efficient and rapid quenching of the reactor effluent is highly desirable for preventing the loss of olefinic product through polymerization and/or coking reactions. It is known that reaction conditions are generally improved when the operating pressures are less than atmospheric. In fact, the production of butadiene is materially improved in such systems when the operating pressure is 7" Hg and preferably lower.

The apparatus and equipment in which the dehydrogenation of the hydrocarbons is effected is of such magnitude that materials of construction as well as actual construction and operating matters constitute a sizable problem in commercial scale operation. The efficient and effective handling of extremely large volumes of gases, particularly at subatmospheric conditions, is one of the major problems. Reactor conditions in the order of 7" or even 5" Hg, while obtainable in commercial operation between the inlet to the reactor and a downstream turbo-compressor, begin to approach the lower pressure limit of apparatus and hardware currently employed. The turbo-compressor which, in effect, acts as a vacuum pump usually takes the quenched effluent gas at a temperature of approximately 300° F. and at a pressure as low as 2–3" Hg and eventually transfers the compressed material at a pressure of approximately 10–15 atmospheres for subsequent processing.

Because of the extremely low molecular weight of the gaseous product, lower operating pressures to the inlet of the turbo-compressor are impractical in that "pumping" in the turbo-compressor is apt to occur. "Pumping" merely means that the turbo-compressor refuses to accept and compress the effluent gases except in fits and starts, i.e., spasmodically. In fact, in operation of this equipment it is not unusual to add additional quantities of some vapor to the critical area within the turbo-compressor system to augment the volume and molecular weight state of the gases to be compressed.

The limitation thus imposed by the lowest pressure region of the gas flow pattern through the reactor and subsequent equipment has a direct bearing on the practical operating pressure obtainable within the reactor itself in commercial systems. Substantially all of the pressure differential existing between the approximately 7"–5" Hg pressure in the reactor itself and the lower pressure at the inlet to the turbo-compressor is attributable to the pressure drop within the various portions of the plant system interposed between the reactor outlet and the turbo-compressor inlet. The major proportion of pressure drop for the flowing gases occurs within the quench system, which may easily account for more than an inch of mercury pressure drop and is more likely to account for several inches, thus making it substantially impractical for plants to operate within the reaction zone at less than about 7" Hg. It has now been found that a substantial amount of this pressure drop can be eliminated by effecting the quenching of the effluent gases in accordance with the system of the present invention.

The benefits accruing from a reduction in the pressure drop between the outlet of the dehydrogenation reactors and the product compressor are many. These benefits include increased yields at lower reactor pressures, the possibility of using smaller product compressors for a given throughput and, in existing equipment, the ability to increase throughput. Inasmuch as the quench system presently is the major contributor to the pressure drop, replacement thereof and improved operation is practically and economically attractive.

In accordance with this invention reactor effluent is passed for quenching into and through at least one venturi ejector whose motive force is the normally liquid quench oil; thereafter the quench oil is separated and removed from the quenched reactor effluent, which then passes more or less directly to the product compressor for subsequent treatment in standard fashion or as may otherwise be desired. Such a system gives improved quenching action over and above that obtained in currently employed equipment in that it has little or no pressure drop and may even develop some negative pressure drop. Quench fluid separated from the quenched reactor effluent is collected and withdrawn from the separation zone, cooled as may be desired and recycled to the quench operation. It is to be understood, of course, that all of the usual and useful hardware in these operations is contemplated for use where required without necessarily defining its nature and operation.

The following embodiment of an installation designed in accordance with the present invention demonstrates the magnitude of quench systems. Reactor effluent, at the rate of 91,000 lbs. per hour having a molecular weight of 43.4, a specific heat of 0.68 B.t.u. per lb. per degree Fahrenheit at a temperature of approximately 1000 to 1200° F. and at a pressure of 2.5 p.s.i.a., passes through a 48" diameter line to the quench ejector. The quench ejector has an inlet opening approximately 96" in diameter and a typical venturi configuration which extends horizontally approximately 50'. The ejector quench liquid, having a gravity of about 15° API, a specific heat of approximately 0.44 B.t.u./lb./° F. and an inlet temperature of 175°

F., is fed through a 10" line at the rate of 90,000 gallons per hour, i.e., about 686,000 lbs. per hour. This quench liquid has an initial pressure of approximately 65 p.s.i.g. Under these circumstances, the material emerging from the quenching area is at a temperature in the order of 300° F. and a pressure of approximately 2.0 p.s.i.a.

It is to be understood that instead of the single ejector described immediately above, it is possible to employ parallel units of somewhat smaller individual size which have substantially the same total operating capacity. For example, in the above described system it would be possible to substitute twin parallel units of approximately 35 ft. long with 72" inlet dimensions each of which is operated with a quench oil motive fluid usage somewhat higher than one-half of the amount employed in the above described single unit. Likewise, it should be realized that the discharge pressure from the quench area may be at or above the suction pressure by as much as up to 0.3 p.s.i. higher while still obtaining substantially all of the described benefits including a substantial reduction of pressure drop in the system over and above that heretofore existing in commercial units.

A better understanding of the invention can be obtained by reference to the schematic drawings in which FIGURE 1 is a diagrammatic representation of the flow pattern in the area affected by inclusion of the quench system of the present invention. FIGURE 2 is a representation of an embodiment employing a single venturi quench ejector. FIGURE 3 represents a modification in which a venturi prequench ejector is added. FIGURE 4 is an enlarged cross sectional view of the prequench ejector system of FIGURE 3. FIGURE 5 is a modification of the prequench ejector system shown in FIGURE 4.

Referring particularly to FIGURE 1, reactor **11** is fed reactants from a source, not shown, through valved line **12**. Reactor effluent is removed from the reaction zone through valved line **13** and passes to the venturi quench system **14** which is operated by quench fluid introduced through line **16**.

The quenched effluent vapor and quench liquid thereafter pass through line **17** into separator vessel **18** wherein the gaseous materials are removed through line **19** for introduction to product compressor **21** from which they are passed through line **22** to further downstream processing in equipment, not shown. Quench oil collected in separator **18** is withdrawn through line **23** and passes through heat exchange element **24** wherein temperature is adjusted and thence through line **26**, through pump **27** and into line **16** for reuse in the venturi quench system **14**.

In FIGURE 2 the particularly important quench area is shown in somewhat greater detail. Reactants are introduced to reactor **31** through valved line **32**. Effluent product is withdrawn from reactor **31** through valved line **33** into line **34** for introduction into the quench venturi section **36**. The quench fluid is introduced through line **37** to manifold **38** from which it is discharged through nozzle elements **39** as the motive cooling quench within venturi section **36**.

The mixed quench vapors and liquid enter separator **41** having suitable baffles **42** which act to interrupt the direction of the gas and liquid flow only to the extent needed to obtain a reasonably complete separation of the gaseous materials from the liquid materials. The separated gases are withdrawn from separator **41** through line **43** for passage to the product compressor, not shown. Quench liquid collected in the bottom of vessel **41** is is withdrawn through line **44** for passage through heat exchanger **46** where it is cooled. The quench liquid then passes through line **47** and pump **48** into line **37** for return to the quench ejector system. Make-up quench oil or excess quench oil may be introduced or withdrawn through line **49**, as required.

In FIGURE 3 reactors **61**, **62** and **63** operate in timed sequence with introduction of the charge through valved lines **64**, **66** and **67** in accordance with conventional sequence programming. Limiting consideration at the moment to operation of reactor **61** as a typical embodiment, reactor effluent passes through line **68** and open valve **69** through venturi throat **71** and is prequenched before entering line **72** for passage subsequently into the main quench system, not shown. Quench liquid is introduced through valved line **73** and inlet line **74** into the venturi quench throat **71** area for effecting prequenching of the effluent gas and assisting in its movement to line **72** as indicated. Use of the prequench permits an initial temperature reduction of the reactor effluent at a desirably early time after emergence from the reactor. Additional advantage resides in the increased cooling capacity of the quench system such that temperature of the effluent may be reduced to as low as 100° F. if desired.

In FIGURE 4 the venturi system of FIGURE 3 is shown in cross section. Motive quench fluid is supplied through inlet line **74** to manifold **75** and nozzles **76**.

The modified venturi throat system shown in FIGURE 5 simplifies the construction in this area without particularly affecting the efficiency of operation. Motorized valve **69**, operating in timed sequence with valve **77**, allows passage of reactor effluent through line **68** into venturi **78** where it is contacted with prequench liquid from line **79** which is injected through nozzle **80**. The prequench liquid and prequenched reactor effluent thereafter pass directly into line **72** for passage to the main quench system, not shown.

It is to be understood that standard operating techniques and associated equipment, except as modified and improved by use of the present invention, are contemplated and as such form no particular part of the invention. Likewise, the system is readily adaptable to provide effective quench-transfer of reactor effluent from one or more reactor zones whether they are operated in batch operation or in the more customary timed sequence operation in which one or more of the reactor zones may be on stream at a given time.

Obviously, many modifications and variations of the invention as hereinbefore set forth may be made without departing from the spirit and scope thereof, and therefore only such limitations should be imposed as are indicated in the appended claims.

What is claimed is:

1. Apparatus for quenching the gaseous effluent from a hydrocarbon conversion reactor operating at subatmospheric pressure, by direct heat exchange with a liquid coolant, and for transporting the quenched effluent, free of said liquid coolant, to turbo-compressing means having low suction pressure not substantially different from the effluent discharge pressure of said reactor preparatory to further processing, which comprises:

(a) at least one venturi ejector having a convergent inlet end portion, a constricted intermediate portion and a divergent outlet end portion;

(b) conduit means for conducting the hot effluent from said reactor to the inlet end of said venturi ejector;

(c) means for introducing liquid coolant at said inlet end of the venturi ejector in such amount and at such velocity as to intimately admix with the incoming effluent gas, for rapid and direct heat exchange therewith, and provide the motive force for transfer of the effluent to the turbo-compressing means;

(d) separator means arranged to receive the mixture of quenched effluent gas and coolant liquid from said venturi ejector and to separate the same;

(e) conduit means for conducting the quenched effluent gas from said separator means to said turbo-compressing means; and

(f) recirculation means for returning the separated liquid coolant to said venturi ejector including heat-exchanger means for cooling and pump means for pressuring the liquid.

2. Apparatus as in claim **1** including additional quenching means between said venturi ejector and said separator

means for effecting a further reduction in the temperature of the gaseous effluent.

3. Apparatus as in claim 2, in which multiple reactors and individual venturi ejectors are provided, and including individual timed sequence control means for introducing gaseous effluent and liquid coolant into said ejectors; manifold means for receiving pre-quenched effluent from said ejectors and conveying the same to said separator means; and second manifold means for distributing the recycle liquid coolant to said ejectors.

4. The method of transferring and quenching in transit the hot gaseous reactor effluent from a hydrocarbon conversion zone operating at subatmospheric pressure to a turbo-compression zone operating at suction pressure not substantially different from the effluent discharge pressure of said reaction zone, which comprises the steps of:

(a) passing the effluent gas to a venturi zone;

(b) introducing liquid coolant into the inlet of said venturi zone in such amount and at such high velocity as to effect rapid intermixing with and quenching of said effluent gas and as to provide the motive force for educting the effluent gas from said reaction zone and transporting the same to said turbo-compression zone;

(c) separating the mixture of effluent gas and coolant liquid discharging from said venturi zone;

(d) passing the cooled and separated effluent gas to said turbo-compressing zone;

(e) recooling the separated liquid coolant;

(f) pressuring the recooled liquid coolant;

(g) and recycling the liquid coolant to said venturi zone.

5. The method of claim 4 in which said quenching operation is effected with minimal pressure differential between the streams of gaseous material entering and leaving the quenching system, in the range of a little positive to some negative pressure drop in the direction of flow.

6. The method of claim 5 in which the gaseous reaction effluent is introduced to the venturi zone at a pressure of about 2.5 p.s.i.a. and is discharged from the quenching area at a pressure of about 2.0 p.s.i.a.

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