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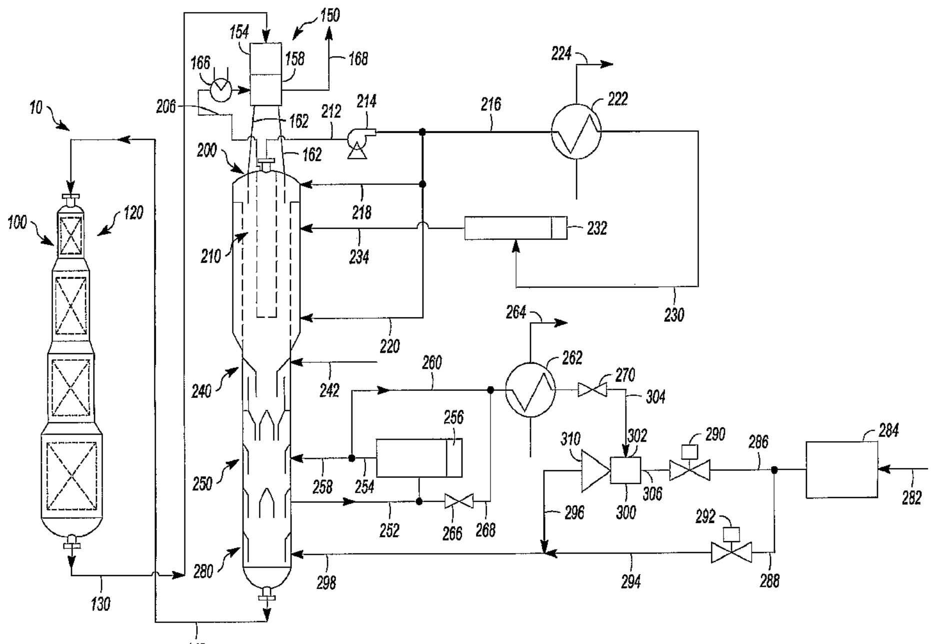
(54) Title: PROCESS FOR REGENERATING A CATALYST BY INTRODUCING A COOLING GAS WITH AN EJECTOR



(57) Abstract: A process for regenerating a catalyst, including passing a catalyst through a cooling zone (280) and introducing a cooling gas into the cooling zone (280) with an ejector (300).

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PROCESS FOR REGENERATING A CATALYST BY INTRODUCING A COOLING GAS WITH AN EJECTOR

[0001] Hydrocarbon conversion processes are often employed with multiple reaction zones. Usually, these hydrocarbon conversion processes utilize a moving bed reactor in conjunction with a regeneration vessel. An exemplary hydrocarbon conversion process that utilizes a moving bed reactor and a regeneration zone is catalytic reforming.

[0002] In some instances, it has been desirable to provide a regeneration unit that has an adsorbent section for removing compounds from a vent gas stream from a combustion zone and/or a vent gas stream from a drying and/or cooling zone. Particularly, these regeneration vessels are utilized to allow the recovery of halide, such as chloride, compounds before they are released to the atmosphere. The regeneration vessel usually provides combusting, halogenating, drying, and cooling. One such exemplary regeneration vessel is disclosed in US 5,837,636.

[0003] However, processing one or more vent gas streams to remove such compounds can create motivation to minimize the amount of the vent gas to be processed. One source of the vent gas stream from the drying and/or cooling zones is the use of excess drying and/or cooling gas, as disclosed in US 4,701,429, and therefore one minimization mechanism can be reducing or preferably eliminating the use of excess drying and/or cooling gas in the regeneration vessel. The drying and/or cooling gas is typically air or some other oxygen-containing gas. Generally, once the excess drying and/or cooling air is eliminated, the amount of oxygen-containing gas that enters the drying and/or cooling zone typically has a direct effect on the measured oxygen content of the combustion gas in the combustion zone because the oxygen-containing gas exiting the cooling and/or drying zones may be subsequently utilized, at least in part, by the combustion zone of the regeneration zone.

[0004] Generally, the oxygen content of the combustion gas is very accurately controlled, and thus, in units without excess drying and/or cooling air, the amount of drying and/or cooling air is also accurately controlled. Unfortunately, sometimes the gas required for cooling and drying exceeds that required for combusting. Too much oxygen in the combustion gas can overheat and damage the catalyst while too little oxygen can allow too much coke to remain on the catalyst exiting the combustion zone. Although it is desirable to control the oxygen content of the combustion gas, independently controlling the amount of oxygen-containing gas passing through the cooling zone for providing sufficient catalyst cooling would also be beneficial.

[0005] The catalyst removed from a cooling zone of a regeneration vessel is generally required to be cooled below about 150° C. (about 300° F.) to prevent uncontrolled catalyst reduction. Insufficient cooling gas may not properly cool catalyst. Improperly cooled catalyst can create difficulties reducing the catalyst in a valveless lock hopper and/or a seal drum before sending the catalyst back to the reforming zone to convert a hydrocarbon stream. Although the catalyst can be cooled by indirect cooling with water via panel coils or by recirculating a counter-current cool gas to the downward flowing catalyst, these solutions may, respectively, require additional maintenance and capital equipment expense, such as a blower and/or cause the diameter of the nitrogen seal drum to increase.

[0006] Although the reduction of excess gas helps reduce the amount of vent gas requiring treatment from the combustion zone, this reduction can influence the effectiveness of the drying and cooling zones if their gas requirements exceed that of the combustion zone. Consequently, there is a desire to remedy these shortcomings without providing excess gas to the drying and/or cooling zones.

SUMMARY OF THE INVENTION

[0007] One exemplary embodiment is a process for regenerating a catalyst, including passing a catalyst through a cooling zone, and introducing a cooling gas into the cooling zone with an ejector.

[0008] The present embodiment as disclosed herein can provide sufficient cooling gas for a catalyst in a regeneration zone while avoiding sending excess gas to a combustion zone. Particularly, the embodiments herein can divert a portion of a gas being sent to a drying zone to a cooling zone. Specifically, the gas from the drying zone can be cooled before being received in an ejector. Recycling gas with an ejector is significantly less expensive than utilizing other equipment such as a blower or panel coils. Moreover, the flow scheme is economical to implement, and flexible enough to meet design and turndown conditions, thereby fulfilling low coke burning and cooling requirements simultaneously.

[0009] FIG. 1 depicts a reforming unit according to one exemplary embodiment.

DEFINITIONS

[0010] As used herein, the term “zone” can refer to an area including one or more equipment items and/or one or more sub-zones. Additionally, an equipment item, such as a reactor or vessel, can further include one or more zones or sub-zones.

[0011] As used herein, the term “halogen-containing material” can include a halogen, such as chlorine or fluorine, and a compound containing one or more halogen radicals.

DETAILED DESCRIPTION OF THE INVENTION

[0012] The embodiments discussed hereinafter can be utilized with a regeneration vessel used in conjunction with a moving bed reactor arranged with a plurality of stacked reaction zones or sub-zones. Processes having multiple reaction zones may include a wide variety of hydrocarbon conversion processes such as reforming, alkylating, dealkylating, hydrogenating, hydrotreating, dehydrogenating, isomerizing, dehydroisomerizing, dehydrocyclizing, cracking, or hydrocracking. Catalytic reforming often utilizes multiple reaction zones and may be referenced hereinafter. Desirably, the regeneration vessel is one that minimizes the use of excess air in its drying and/or cooling zones.

[0013] Referring to FIG. 1, a reforming unit 10 can include a moving bed reactor 100 including at least one reaction zone 120 and a regeneration vessel 200. Desirably, the moving bed reactor 100 includes a plurality of stacked reaction zones for converting a hydrocarbon stream into, for example, a reformate. Alternatively, one or more of the reaction zones can be conducted in a separate vessel. The moving bed reactor 100 receives catalyst from the regeneration vessel 200. Generally, the catalyst travels through the reaction zone of the moving bed reactor 100 and exits through a lift conduit 130 to the disengaging vessel 150. The disengaging vessel 150 can include a disengaging zone 154 where spent catalyst is deposited. Afterwards, the catalyst can pass to the adsorption zone 150, as hereinafter described. Afterwards, the catalyst can pass from the disengaging vessel 150 through the lines 162 to the regeneration vessel 200 to be regenerated. The regenerated catalyst may return from the regeneration vessel 200 through a lift conduit 140 to the moving bed reactor 100. Exemplary moving bed reactors are disclosed in US 4,119,526 and US 4,409,095.

[0014] The regeneration vessel 200 can include a combustion zone 210, a halogenation zone 240, a drying zone 250, and a cooling zone 280. Exemplary regeneration vessels are disclosed in US 5,277,880 and US 5,824,619. The spent catalyst enters at the top of the regeneration vessel 200 and enters the combustion zone 210. Subsequently, the catalyst proceeds through the halogenation zone 240 to redisperse the metals on the catalyst, and then to the drying zone 250 and the cooling zone 280 before being returned to the moving bed reactor 100.

[0015] Gas is supplied to the regeneration vessel 200 through a line 282. This gas can be an oxygen-containing gas, such as air. The gas can contain an inert gas component, such as nitrogen. Typically, the gas enters a dryer 284 and proceeds to the cooling zone 280 as hereinafter described. The gas is then retrieved from the cooling zone and subsequently returns to the drying zone where it rises to eventually be utilized in the combustion zone 210. As such, the amount of gas supplied through the line 282 is determined by the requirements, such as an oxygen requirement, of the combustion zone 210.

[0016] In the combustion zone 210, a recycle gas is removed through a line 212 and passed through a compressor 214. As used herein, a compressor can be other devices for transferring fluids, such as a blower or a fan. A portion of the gas is recycled through the line 218 to a location above the catalyst bed in combustion zone 210 and also through the line 220. Generally, another portion passes through the line 216 and is cooled in a heat exchanger or cooler 222. The cooling medium can be air or water and be supplied by a line 224. Subsequently, the recycle gas passes through a line 230 to a heater 232, which can be utilized during start-up, and returned to the combustion zone 210 through a line 234. Usually, the cooler 222 helps control the temperature, and hence the rate of combustion, in the combustion zone 210.

[0017] A vent or flue gas can be withdrawn from the combustion zone 210 through a line 206. The vent gas can be cooled in the exchanger or cooler 166 before being passed into an adsorption zone 158 of the disengaging vessel 150. The adsorption zone 158 can utilize spent catalyst to remove a halogen-containing material from the vent or flue gas. An exemplary adsorption zone utilizing spent catalyst as adsorbent is disclosed in US 6,034,018. Alternatively, the vent or flue gas from the combustion zone 210, or even from the drying zone 250 and/or cooling zone 280 can be routed to an adsorber, such as a swing bed adsorber, containing an adsorbent as disclosed in US 6,881,391 B1. Next, the vent gas can be passed through a line 168 to be discharged to the atmosphere or undergo further treatment to remove undesirable compounds.

[0018] The halogenation zone 240 can receive a halide agent, such as a chloride agent, through a line 242. In the halogenation zone 240, the halide agent can aid in redispersing the active metals on the catalyst.

[0019] As briefly mentioned above, the cooling zone 280 receives an oxygen-containing gas, such as air, through a line 282. The oxygen-containing gas is dried in the dryer 284. The cooling oxygen-containing gas can be passed through a line 286 and a valve 290 to be received in an ejector 300. Generally, the ejector 300 utilizes the kinetic energy of one fluid (primary fluid, such as a primary gas) to pump another fluid (secondary fluid, such as a secondary gas). Preferably, the ejector 300 is a thermocompressor. The gas in the line 286 can be the motive force (primary fluid or gas) for powering the thermocompressor 300, as described in more detail hereinafter. Subsequently, the gas is passed from the thermocompressor 300 through a line 296, and optionally combines with gas bypassed through a line 288, a valve 292, and a line 294 to enter through a line 298 into the cooling zone 280. The gas or effluent from the cooling zone 280 can be withdrawn through a line 252 and be heated in a heater 256. The heated gas is discharged through a line 254 and can be passed to the drying zone through a line 258. A portion of this gas can be withdrawn through a line 260 and cooled in a cooler 262, such as a double pipe exchanger. The cooler 262 can be cooled with any suitable medium, such as air or water in a line 264. The recycled oxygen-containing gas from the cooling zone 280 can pass through a valve 270 to supply the thermocompressor 300 as a secondary fluid or gas through a line 304.

[0020] The thermocompressor 300 has a suction 302, an inlet nozzle 306, and an outlet nozzle 310. The thermocompressor 306 operates within a relatively narrow range of operating conditions. Consequently, if the combustion zone 210 requires additional gas from the line 282, a portion can be bypassed around the thermocompressor 300 via the line 288 and the valve 292 to operate the thermocompressor 300 at the desired conditions. Particularly, the valves 290 and 292 can be equipped with controls, and a sensor can detect excess gas flow from the line 282 to bypass a portion of that gas through the lines 288 and 294, and the valve 292. The ejector or thermocompressor 300 is generally preferred over a compressor or other type of equipment due to its relatively inexpensive cost.

[0021] The heaters 232 and 256 can use any suitable medium as a heat source. As an example, if at least one of the heaters 232 and 256 is a heat exchanger, a suitable heat source can be steam or another process stream. Alternatively, at least one of the heaters 232 and 256 can be a gas-fired furnace or a section thereof, or be an electric heater.

[0022] With respect to the gas withdrawn from the cooling zone 280, at least a portion of this gas can be bypassed around the heater 256 by opening a valve 266 to allow gas to flow through a line 268 to the cooler 262. Typically, it is desirable not to bypass the gas around the heater 256, particularly if electric, due to the minimum gas flow requirements.

[0023] Generally, the present embodiments are suited for a regeneration vessel 200 operating at, for example, low coke conditions. As a consequence, the oxygen-containing gas coming through the line 282 is at a relatively low mass flow.

[0024] In an example, the gas in the line 282 can enter at a flow rate of about 540 – about 580 kg/hr (about 1,200 – about 1,500 lb/hr) and at a temperature of about 38° C. (about 100° F.) The gas can travel to the cooling zone 280 at a pressure of about 241 - about 260 kPa(g) (about 35 – about 37 psig). Generally, the cooling zone 280 operates at a temperature below about 150° C. (about 300° F.) The gas exiting the heater 256 in the line 254 is typically at a temperature of about 482° C. (900° F.) at a mass flow rate of about 1,100 kg/hr (about 2,400 lb/hr). The gas sent through the line 260 to the cooler 262 for recycling to the cooling zone 280 is generally at the same temperature as the gas discharged from the heater 256, but has a mass flow of about 540 kg/hr (about 1,200 lb/hr). After passing through the cooler 262, the gas is cooled to a temperature above the dew point of the gas in the line 304. Generally, the temperature is above about 5 – about 10° C. (about 40 – about 50° F.), desirably about 38 - about 66° C. (about 100 – about 150° F.).

[0025] Typically, the present embodiment recirculates cooling oxygen-containing gas, such as air, in the cooling zone 280 to maintain a gas/catalyst thermal mass ratio above 1.0 (about 1 – about 1.2). The thermal mass ratio is defined at column 9 of US 6,703,479 B1. Generally, the ejector can operate at the desired throughput to maintain the oxygen requirements of the combustion zone, which can depend, e.g., on the catalyst recirculation rate and coking levels. Typically, the circulation of air to net air flow will be a maximum of about a 1/1 ratio. With a small recirculation pressure drop of about 21 – about 34 kPa (about 3 – about 5 psi) and a large motive delta pressure ranging from about 100 – 1400 kPa (about 15 – about 200 psi) or more depending on the pressure of the entering gas and the pressure of the regenerator, there will typically be enough energy to recirculate the cooling oxygen-containing gas without the use of a blower.

CLAIMS:

1. A process for regenerating a catalyst, comprising:
   (a) passing a catalyst through a cooling zone (280); and
   (b) introducing a cooling gas into the cooling zone (280) with an ejector (300).

2. A process according to claim 1, further characterized by passing the catalyst through a drying zone (250) before the cooling zone (280); and heating an effluent from the cooling zone (280) with a heater (256).

3. A process according to claim 2, further characterized by discharging a gas from the heater (256) characterized in that the discharged gas comprises a first portion entering the drying zone (250) and a second portion received by a suction (302) of the ejector (300).

4. A process according to claim 3, further characterized by cooling the second portion of the gas discharged from the heater (256) before being received by a suction (302) of the ejector (300).

5. A process according to claims 1, 2, 3, or 4, further characterized by controlling an amount of the cooling gas introduced into the cooling zone (280) by an amount of oxygen required by a combustion zone (210).

6. A process according to claims 2, 3 or 4, further characterized by controlling an amount of the cooling gas introduced into the cooling zone (280) by an amount of oxygen required by a combustion zone (210) and characterized in that the amount of cooling gas introduced into the cooling zone (280) is substantially equal to an amount of the effluent exiting the cooling zone (280).

7. A process according to claims 1, 2, 3, or 4 further characterized by passing the catalyst through a disengaging vessel (150) comprising an adsorption zone (158) and passing a vent gas stream from a combustion zone (210) through the adsorption zone (158) to adsorb a halogen-containing material.

8. A process according to claims 1, 2, 3, 4, 5, 6, or 7, characterized in that a primary gas entering an inlet nozzle (306) of the ejector (300) optionally has at least a portion of the primary gas bypassing the ejector (300).

9. A process according to claims 1, 2, 3, 4, 5, 6, 7, or 8, characterized in that the cooling gas comprises air.

10. A process according to claims 1, 2, 3, 4, 5, 6, 7, 8, or 9, characterized in that the ejector (300) is a thermocompressor (300).

AMENDED CLAIMS
RECEIVED AT THE INTERNATIONAL BUREAU
ON 27 NOVEMBER 2007 (27.11.07)

1. A process for regenerating a catalyst, comprising:

(a) passing a catalyst through a cooling zone (280); and

(b) introducing a cooling gas into the cooling zone (280) with an ejector (300) wherein at least a part of the cooling gas comprises at least a part of an effluent recycled from the cooling zone (280).

2. A process according to claim 1, further characterized by passing the catalyst through a drying zone (250) before the cooling zone (280); and heating the effluent from the cooling zone (280) with a heater (256).

3. A process according to claim 2, further characterized by discharging a gas from the heater (256) characterized in that the discharged gas comprises a first portion entering the drying zone (250) and a second portion received by a suction (302) of the ejector (300).

4. A process according to claim 3, further characterized by cooling the second portion of the gas discharged from the heater (256) before being received by a suction (302) of the ejector (300).

5. A process according to claims 1, 2, 3, or 4, further characterized by controlling an amount of the cooling gas introduced into the cooling zone (280) by an amount of oxygen required by a combustion zone (210).

6. A process according to claims 2, 3 or 4, further characterized by controlling an amount of the cooling gas introduced into the cooling zone (280) by an amount of oxygen required by a combustion zone (210) and characterized in that the amount of cooling gas introduced into the cooling zone (280) is substantially equal to an amount of the effluent exiting the cooling zone (280).

7. A process according to claims 1, 2, 3, or 4 further characterized by passing the catalyst through a disengaging vessel (150) comprising an adsorption zone (158) and passing a vent gas stream from a combustion zone (210) through the adsorption zone (158) to adsorb a halogen-containing material.

STATEMENT UNDER ARTICLE 19(1)

Applicant has amended claim 1 to add the words, "wherein at least a part of the cooling gas comprises at least a part of an effluent recycled from the cooling zone (280)" to further define the cooling gas. Support for this amendment can be found at paragraphs 19 and 20 and the drawing figure. Applicant has also amended claim 2 to provide antecedent basis by replacing the word "an" with "the".

Accordingly, Applicant respectfully requests reconsideration and issuance of a favorable opinion regarding novelty and inventive step with respect to claims 1-7. Regarding claims 8-10, Rule 6.4 provides that failure to use the manner of claiming of the national law of the national Office acting as the International Searching Authority shall have no effect in a designated State if the manner of claiming actually used satisfies the national law of that State.

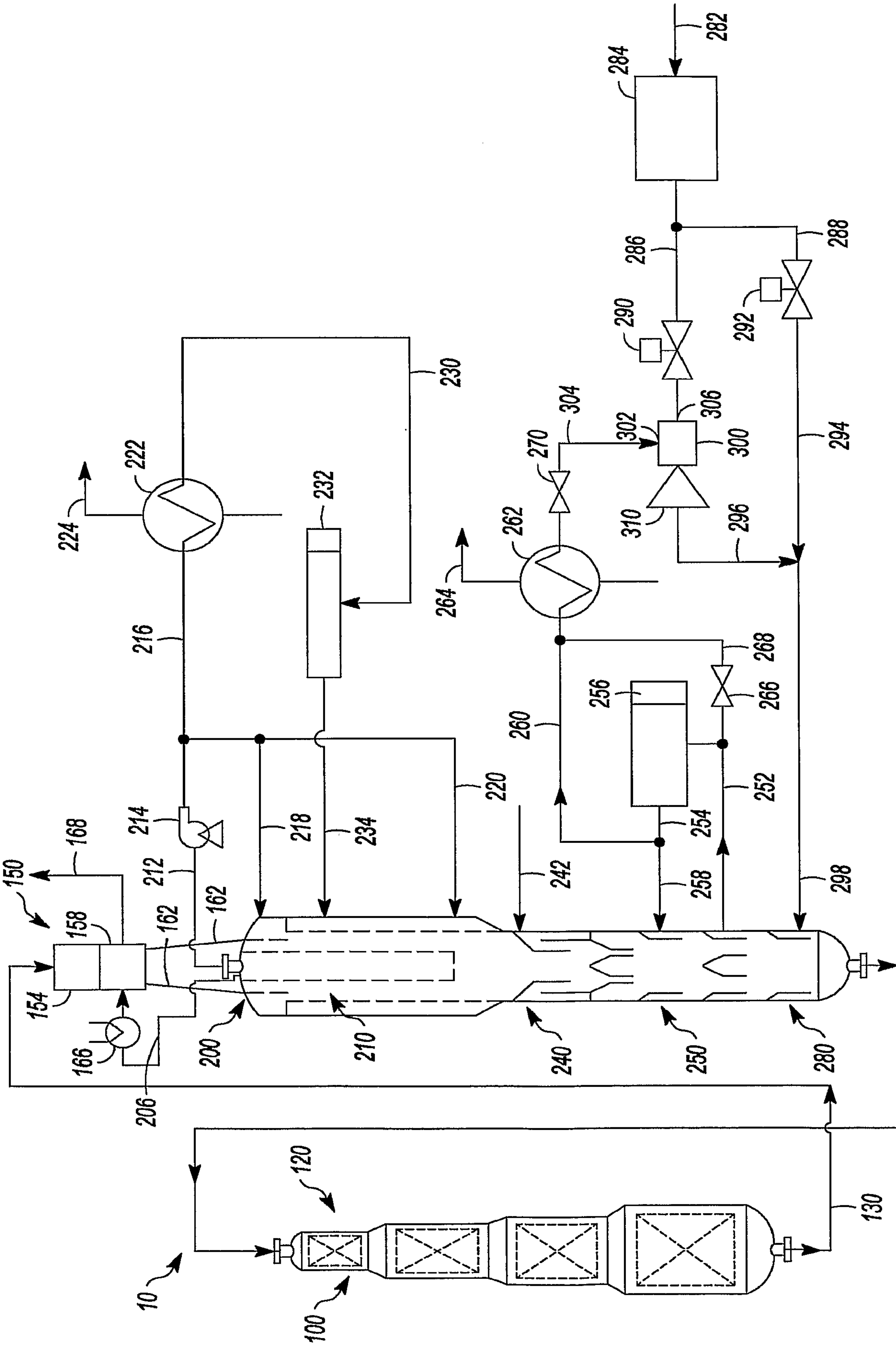
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FIG. 1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 06/62647

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - B01J 20/34 (2007.01)
USPC - 502/35, 502/34
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
USPC: 502/35, 502/34

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Electronic Databases Searched: USPTO WEST (PGPUB, EPAB, JPAB, USPT), Google, Thomson dialog.
Search Terms Used: cooling gas. cooling zone, regeneration, catalyst, ejector,

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,397,458 A (Micklich et al.) 14 March 1995 (14.03.1995); entire document especially col 9, ln 51 to col 10, ln 04; figure 1; col 7, ln 66 to col 8, ln 09; col 9, ln 13-20;	1-7
Y	US 2002/0197194 A1 (Machado et al.) 26 December 2002 (26.12.2002) para [0025]-[0028]; [0032]	1-7

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
03 August 2007 (03.08.2007)	02 OCT 2007

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 06/62647

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 8-10
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.