

PATENT SPECIFICATION

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DRAWINGS ATTACHED

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(54) IMPROVEMENTS IN OR RELATING TO SULFUR TRIOXIDE

(71) We, THE RALPH M. PARSONS COMPANY, a corporation organised and existing under the laws of the state of Nevada, United States of America, residing at 617 West Seventh Street, Los Angeles, California, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to the art of sulfur trioxide production and particularly but not exclusively sulfuric acid production.

It is an object of the invention to provide an improved process for converting sulfur dioxide, produced for example by the combustion of elemental sulfur in air, by multiple pass catalysis into sulfur trioxide and ultimately to sulfuric acid.

One method for producing sulfuric acid begins by burning molten sulfur in dry air to form sulfur dioxide ($S + O_2 = SO_2$) which, after being properly cooled, is catalytically converted to sulfur trioxide. A considerable amount of heat is generated by this combustion of sulphur. The hot combustion products are forced through a waste heat boiler which generates high pressure steam and cools the sulfur dioxide containing gas to the required temperature for catalytic conversion. If desired, the steam generated in the boiler may be used elsewhere in the plant to operate equipment. Catalytic conversion of the cooled sulfur dioxide gas takes place in a multistage converter in the presence of a suitable catalyst such as vanadium pentoxide. This reaction is exothermic and therefore liberates a considerable amount of heat with a majority of the heat being released in the first conversion stage. The catalytic reaction also tends to reverse when the reaction temperature becomes excessive. Therefore, the reaction product stream from the first stage reintroduced into the converter for further catalytic conversion. The next stage of conversion occurs

before any absorption stage and produces another increase in temperature of the reaction stream and a low oxygen to sulfur dioxide ratio. The low oxygen to sulfur dioxide ratio decreases the catalysis reaction. The stream is therefore normally cooled in heat exchangers or diluted or quenched by the addition of dry air or gas.

The sulfur trioxide produced in the converter is cooled and then introduced into an absorber system. In the absorber system the sulfur trioxide is absorbed by a counter-current flow of strong sulfuric acid. After removal of the sulfur trioxide, the stream eventually is exited as stack gas.

This process begins with sulfur dioxide at a temperature in excess of a required conversion temperature. Some processes begin with a sulfur dioxide stream at a temperature lower than the required conversion temperature. Of these, one of the most common begins by roasting iron pyrites or other sulfur bearing materials with air to produce sulfur dioxide, which is cooled, purified, and dried before being preheated for the catalysis reaction.

One roasting process also employs multi-pass or multistage catalytic conversion with heat exchange between each stage to cool the reaction product stream. This process employs an intermediate absorption stage to remove sulfur trioxide before catalytic conversion is completed. The absorber exit gas, containing sulfur dioxide, is returned to the converter.

The intermediate absorber exit gas is at a relatively low temperature. The low temperature intermediate absorber exit gas is used to cool the hot reaction product stream passing to the intermediate absorber. The heat energy produced during conversion is used to heat the first stage converter inlet gas to its required conversion temperature. The heat exchange with the first stage converter inlet gas cools the reaction product stream between stages. This process is reputed to produce about 99.5 per cent conversion of

sulfur dioxide into sulfur trioxide and is described in U.S. Patent No. 3,142,536 of Guth et al.

5 The present commercial practice of conversion of sulphur dioxide to sulphur trioxide and then to sulfuric acid, using multiple pass catalysis and only one stage of absorption, results in stack effluents containing two per-
10 cent to four per cent of the initial sulfur dioxide of the catalysis feed. Sulfur dioxide is an atmospheric pollutant and it is therefore required to minimise the discharge of sulfur dioxide to the atmosphere.

15 Thus, there is a present need to effect maximum conversion of sulfur dioxide to sulfur trioxide in sulfuric acid production plants in an economical manner.

20 We have found for example, that in a process for producing sulfuric acid from sulfur dioxide formed by burning sulfur in air, in which sulfur dioxide is converted to sulfur trioxide by catalytic oxidation in a multiple pass catalytic converter, a cool return gas stream leaving an intermediate
25 sulfur trioxide absorber or extractor may be employed to cool a converter inlet stream emanating from the sulfur combustion furnace to a required conversion temperature before the inlet stream enters the converter; and
30 the cool return gas stream is also used to cool the reaction product stream between successive passes of catalytic conversion.

35 The invention provides a process for producing sulfur trioxide wherein sulfur dioxide in a sulfur dioxide containing converter inlet stream is converted to sulfur trioxide by multiple steps of catalytic oxidation with an intermediate sulfur trioxide extraction
40 stage a sulfur trioxide containing reaction product stream emanating from each said catalytic conversion step, the converter inlet stream emanating from a source at a higher temperature than a required catalytic con-
45 version temperature and the intermediate sulfur trioxide extraction stage producing a cool return gas stream containing unconverted sulfur dioxide which returning stream is heated to a required catalytic conversion tem-
50 perature prior to passing to the appropriate said conversion step, the process comprising the steps of (a) cooling the converter inlet stream to a required catalytic conversion tem-
55 perature by indirect heat exchange with the return gas stream said cooled stream being introduced into a first said catalytic conversion step; and (b) cooling to a required conversion temperature the reaction product stream pass-
60 ing to a said catalytic conversion step which is subsequent to said first step and is prior to the intermediate extraction stage by indirect heat exchange with the return gas stream, the reaction product stream from the last said conversion step prior to the inter-
65 mediate extraction stage passing thereto without heat exchange with the return gas stream.

The invention also provides a process for producing sulfuric acid wherein sulfur tri-
oxide is absorbed in an aqueous liquor to produce said sulfur acid and sulfur dioxide
70 in a sulfur dioxide containing converter inlet stream is converted to produce said sulfur trioxide by multiple steps of catalytic oxidation with an intermediate sulfur trioxide ex-
75 traction stage a sulfur trioxide containing reaction product stream emanating from each said catalytic conversion step, the converter inlet stream emanating from a sulfur combustion source at a higher temperature than a required catalytic conversion temperature, and the intermediate sulfur trioxide extraction
80 stage producing a cool return gas stream containing unconverted sulfur dioxide which return stream is heated to a required catalytic conversion temperature prior to passing to the appropriate said conversion step, the process
85 comprising the steps of (a) cooling the converter inlet stream to a required catalytic conversion temperature by indirect heat exchange with the return gas stream said cooled stream being introduced into a first said
90 catalytic conversion step and (b) cooling to a required conversion temperature the reaction product stream passing to a said catalytic conversion step which is subsequent to said first step and is prior to the intermediate ex-
95 traction stage by direct heat exchange with the return gas stream, the reaction product stream from the last said conversion step prior to the intermediate extraction stage passing thereto without heat exchange with
100 the return gas stream.

It is another object of the invention to provide plant adapted for use in carrying out a process according to the invention.

105 The invention also provides sulfur trioxide when produced using a process according to the invention.

110 The invention also provides sulfuric acid when produced from sulfur trioxide using a process according to the invention.

One embodiment of the present invention employs for example, the use of at least two stages of catalytic oxidation with a plurality of passes in at least the first stage to convert the sulfur dioxide in a converter
115 inlet stream from a sulfur combustion furnace and boiler into sulfur trioxide. An intermediate sulfur trioxide absorption stage removes the sulfur trioxide formed in the first stage of catalytic conversion. The sulfur di-
120 oxide in a return gas stream from the intermediate absorption stage ultimately undergoes a second stage of catalytic conversion. The return gas stream from the intermediate absorber is at a low temperature. This stream
125 is passed in heat exchange relationship with the converter inlet stream coming from the sulfur combustion furnace and boiler to cool the stream to a required conversion tem-
130 perature. The return gas stream is also used

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in the cooling of the reaction product stream between successive first stage passes through the converter which is upstream from the absorption stage. The cooling between successive conversion passes lowers the temperature of the reaction product stream to approximately the required conversion temperature before a pass is made. After the last conversion pass before the intermediate sulfur trioxide absorption stage, the reaction product stream passes to the intermediate absorption stage without heat exchange with the return gas stream and is cooled to a required absorption temperature by heat exchange with, for example, water used in a waste heat boiler or an economiser. After the intermediate sulfur trioxide absorption stage, the return gas stream, still containing sulfur dioxide and oxygen, is heated by the converter inlet stream and the reaction product stream between successive first stage passes to approximately the required conversion temperature to form an inlet stream for secondary catalysis. The heated return gas stream passes into the catalytic converter for the second stage of catalytic conversion.

The use of the return gas stream emanating from the intermediate sulfur trioxide absorption stage to cool the converter inlet stream from the sulfur combustion furnace and boiler and to cool the reaction product stream between conversion passes may be accomplished in a number of ways. The return gas stream may be split with a first branch cooling the converter inlet stream from the combustion furnace and boiler and with a second branch cooling the reaction product stream between successive conversion passes. Alternatively, the return gas stream may be passed initially into heat exchange relationship with the reaction product stream between conversion passes and then passed into heat exchange relationship with the converter inlet stream. It is also possible to employ the return gas stream to initially cool the converter inlet stream and then to cool the reaction product streams between successive passes through the catalytic converter.

Sulfur dioxide in the heated return gas stream is catalytically converted in the second stage of the converter for the purpose of extracting further sulfur trioxide. Therefore, the return gas stream is heated to a required conversion temperature prior to the catalytic conversion of its sulfur dioxide. After the second stage of catalytic conversion, the reaction product stream is cooled and passes into a second stage of sulphur trioxide absorption for the removal of the sulfur trioxide formed.

Sulfur trioxide is extracted by two stages of absorption in aqueous sulfuric acid. Adsorption may be effected in absorption towers where sulfur trioxide gas is absorbed in a countercurrent flow of sulfuric acid to produce a higher strength acid. The inter-

mediate absorption stage produces sulfuric acid containing sulfur dioxide dissolved from the reaction product stream. This dissolved sulfur dioxide may be stripped with air from the sulfuric acid in a drying tower or special stripping tower and returned to the combustion furnace and the converter inlet stream. This increases the amount of product acid and reduces the amount of sulfur dioxide in the stack gases; it also reduces the dissolved content of sulfur dioxide in the product acid.

The cooling of the secondary reaction product stream leaving the converter is accomplished by passing the stream in heat exchange relationship with a fluid which must be heated. Boilers, economisers, superheaters and gas coolers are used in sulfuric acid production plants and may be used to cool the secondary reaction product stream. The heat contained in the secondary reaction product stream can be used to heat purified water which may be passed into a waste heat boiler where it is used to cool the sulfur dioxide bearing stream leaving the sulfur combustion furnace. The same cooling media may be used to cool the primary reaction product stream passing to the intermediate sulfur trioxide absorption stage.

A process embodying the present invention offers enhanced sulfuric acid plant economies. The process reduces the cost in terms of capital expenditure, maintenance and upkeep of the heat exchangers required in the conversion of sulfur dioxide to sulfur trioxide. After the intermediate sulfur trioxide absorption stage, the return gas stream is at a relatively low temperature and has not suffered a great loss in its mass flow rate. This low temperature in conjunction with the high temperature of the converter inlet stream reduces the heat exchange surface necessary to lower the converter inlet stream to the required temperature of conversion and to raise the return gas stream to a required conversion temperature. Moreover, the temperature differential and mass flow rates are such that the return gas stream may also be used in cooling the reaction product stream between successive passes through the converter. These economies are effected while reducing the amount of sulfur dioxide discharged to atmosphere, thereby reducing pollution problems. High conversion is possible because of the intermediate sulfur trioxide absorption stage and further by recycling sulfur dioxide dissolved in the sulfuric acid associated with the intermediate stage absorber.

There now follows a description to be read with reference to the accompanying drawings of certain embodiments of the invention. This description, which is illustrative of both plant and process aspects of the invention, is given by way of example and

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not by way of limitation of the invention.

In the drawings:—

Fig. 1 is a flow depicting one embodiment of the present invention;

5 Fig. 2 is another flow sheet depicting an alternative form of the embodiment shown in Fig. 1; and

Fig. 3 is a flow sheet showing a further alternative form.

10 Fig. 1 is a flow sheet of a sulfuric acid production plant. The plant burns sulfur in air to form sulfur dioxide which is converted into sulfur trioxide. The sulfur trioxide gas produced is absorbed to produce sulfuric acid.

15 Elemental sulfur is burned in a combustion furnace 10 with previously dried air to produce sulfur dioxide. A high temperature stream 11 containing this sulfur dioxide leaves furnace 10 and is introduced into a waste heat boiler 12. Stream 11 is cooled in the waste heat boiler but leaves at a temperature higher than required for the converter inlet. The stream leaving boiler 12 may merge with a bypass stream of sulfur dioxide and air to form a converter inlet stream 14. The bypass stream is denominated by reference numeral 16.

30 Converter inlet stream 14 contains the sulfur dioxide which will be converted to sulfur trioxide. The sulfur dioxide is converted to sulfur trioxide by a catalytic process. Sulfuric acid is formed by absorption of the resultant sulfur trioxide in sulfuric acid and subsequent dilution with water.

35 Catalytic conversion is accomplished in a two-stage multipass converter 18. An intermediate absorption or extraction stage is accomplished in an absorber 20. The intermediate absorption stage separates the conversion stages into primary and secondary stages. A return gas stream 22 containing some sulfur dioxide and oxygen leaves absorber 20. Stream 22 contains the sulfur dioxide which remains after the primary stage of catalytic conversion in converter 18. This stream leaves absorber 20 at a much lower temperature than the required conversion temperature. Stream 14 is passed in indirect heat exchange relationship with a branch of return gas stream 22, denoted by reference numeral 24, in a heat exchanger 26. Stream 14 is reduced in temperature in this heat exchanger to a required conversion temperature of about 800°F. After the stream 14 reaches a required conversion temperature, it passes into converter 18 for the primary stage of catalytic conversion.

50 The sulfur dioxide contained in converter inlet stream 14 undergoes a primary catalytic conversion in converter 18. A primary reaction product stream 28 containing sulfur dioxide and sulfur trioxide is produced in this primary conversion stage or step. The primary reaction product stream passes from

the converter for cooling in heat exchanger 30. The cooling of stream 28 to a suitable required conversion temperature prior to the second pass through converter 18 is necessary to effect a maximum amount of sulfur dioxide conversion by preventing reversal of the conversion reaction.

70 The second branch of return gas stream 22, stream 32 is used as the heat exchange medium for cooling reaction product stream 28. Stream 32 is, therefore, passed in indirect heat exchange relationship with stream 28 in heat exchanger 30 where the temperature of the stream 28 is lowered to a required conversion temperature. After leaving heat exchanger 30, stream 32 merges with stream 24 coming from heat exchanger 26. The two streams, 24 and 32, form stream 34 when they leave heat exchangers 26 and 30. Stream 34 is now at a required conversion temperature.

85 The merged stream, indicated by reference numeral 34, becomes the inlet steam for the secondary catalysis. This inlet stream passes into converter 18 for the second or final stage of catalytic conversion of its contained sulfur dioxide into sulfur trioxide. After this last stage of conversion, the secondary reaction product stream leaves the converter at an elevated temperature as a stream 36.

90 Primary reaction product stream 28, after its cooling in heat exchanger 30, is reintroduced into converter 18 for a second or more passes of catalytic conversion in the primary stage of the converter. After the second or several passes through the converter a reaction product stream 38, containing significant amounts of sulfur trioxide, leaves the converter. Stream 38 is slightly hotter than stream 36 but both streams are cooled for subsequent processing.

105 Stream 38 is cooled in a boiler, economiser or superheater 39 to a required extraction temperature for introduction into absorber 20. The heat exchange medium for this cooling is a treated water or steam stream 41. The sulfur trioxide contained in stream 38 is absorbed by sulfuric acid circulating from a pump tank 40 through a line 42. The resulting higher concentrate sulfuric acid leaves absorber 20 as an acid stream 44 and is cooled in a heat exchanger 46 before entrance into pump tank 40. The return stronger sulfuric acid stream is then diluted to the strength of the acid in tank 40 by the addition of water as indicated. Return gas stream 22 leaving absorber 20, therefore, has had a considerable amount of sulfur trioxide removed from it before its continued processing in converter 18. The last stage of conversion results in stream 36 as previously described.

120 Stream 36 leaves converter 18 and passes for cooling into boiler, superheater or economiser 39 to reduce its temperature for a second stage of absorption in an absorber 48.

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Again the cooling medium is stream or water stream 41. A main pump tank 50 contains sulfuric acid which is circulated through absorber 48 via line 51 for the absorption of the final sulfur trioxide in stream 36. A stream of relatively concentrated sulfuric acid 52 leaves absorber for reintroduction into main pump tank 50 or for diversion to a product cooler. The concentration of the acid in tank 50 may be controlled by the addition of water as indicated.

Pump tank 40 contains sulfuric acid and a considerable amount of dissolved sulfur dioxide gas. This sulfur dioxide is stripped in a drying tower 60 and enters stream 16. For this purpose, the sulfuric acid and dissolved sulfur dioxide are removed from pump tank 40 as a stream 52 and introduced into the top of drying tower 60. Air is also introduced into drying tower by a blower 54. The sulfuric acid stripped of its dissolved sulfur dioxide leaves drying tower 60 as a stream 56 and passes into main pump tank 50. The sulfuric acid also dries the combustion air in stream 16 which is used in furnace 10 the stream 16 passing through the tower 60. Sulfuric acid is taken from main pump tank 50 as a stream 58 and introduced into drying tower 60 to augment the stripping and air drying process. Stream 58 is cooled in heat exchanger 62 prior to its introduction into drying tower 60.

Figure 2 depicts an alternate method of cooling a converter inlet stream to a required, optimum conversion temperature and for cooling the reaction product stream between successive passes in the primary converter stage.

A converter inlet stream 70 from a sulfur combustion furnace (not shown) passes through a heat exchanger 72 where it is lowered in temperature to a required, optimum conversion temperature. Cooling is effected in heat exchanger 72 by heat exchange with a return gas stream 74 coming from an intermediate absorber (not shown). At the required conversion temperature, converter inlet stream 70 enters a catalytic converter 76 where a pass through a first stage bed converts some of the sulfur dioxide to sulfur trioxide. The primary reaction product stream denominated by reference numeral 78 leaves converter 76 at an elevated temperature and passes into a heat exchanger 80. In heat exchanger 80, stream 78 is cooled to a required conversion temperature by heat exchange with return gas stream 74. After leaving heat exchanger 80, stream 78 enters converter 76 for a second catalytic conversion pass. After this pass, the reaction product stream shown by reference numeral 81 undergoes cooling and an intermediate stage of absorption of its sulfur trioxide to form return gas stream 74. This cooling and absorption takes place in a

manner identical to that described with reference to Figure 1.

After being heated in heat exchangers 72 and 80 to a required, optimum conversion temperature, return gas stream 74 passes into catalytic converter 76 for the last stage of conversion. A fully converted stream 82 leaves converter 76 for cooling and the final stage of absorption in the manner previously described.

Figure 3 illustrates another embodiment of the present invention wherein the sequence of cooling by the return gas stream is reversed over that described with reference to Figure 2.

As previously, a return gas stream 90 from an intermediate absorber (not shown) and at a relatively low temperature passes in indirect heat exchange relationship with a stream 92 from a sulfur combustion furnace (not shown). This heat exchange is accomplished in a heat exchanger 94 and is the first heat exchange for stream 90. The temperature of converter inlet stream 92 leaving heat exchanger 94 is within a range of temperatures suitable for the initiation of catalytic conversion. The converter inlet stream enters a converter 96 where a first stage sulfur dioxide to sulfur trioxide conversion takes place by catalytic oxidation. After the first pass of the first stage conversion, the reaction product stream denominated by reference numeral 98 leaves the converter and passes into heat exchanger 100. In heat exchanger 100, reaction product stream 90 passes in indirect heat exchange relationship with return gas stream 90 and is cooled to a required conversion temperature. Stream 98 is then reintroduced into converter 96 for a second or more passes through the beds of the converter. After the second pass of the first stage of catalytic conversion a reaction product stream 102 leaves converter 96. Stream 102 is cooled and its entrained sulfur trioxide extracted to form return gas stream 90 as in the embodiment described with reference to Figure 1.

Stream 90 leaves heat exchange 100 at a required optimum conversion temperature and passes into converter 96 for the last stage of conversion. After this last stage of conversion, a resultant stream 104 leaves converter 96 for subsequent cooling and sulfur trioxide extraction as in the previously described embodiments.

The following example illustrates specifically by way of example various parameters experienced in the process of the present invention. The example is with reference to Figure 1.

EXAMPLE

Sulfur is burned with air dried in drying tower 60 in combustion furnace 10. Sulfur dioxide stripped in drying tower 60 from the

sulfuric acid introduced from tank 40 is also introduced into the furnace. A portion of the dried air and this stripped sulfur dioxide from the tower is bypassed into converter inlet stream 14 downstream from boiler 12. The conversion of the molten sulfur to sulfur dioxide takes place at a reaction temperature of approximately 1750°F. The sulfur dioxide leaves the furnace at this temperature in stream 11. Stream 11, containing approximately eleven per cent by volume sulfur dioxide, passes into waste heat boiler 12 where its temperature is reduced. Stream 11 then combines with bypass stream 16 of air and sulfur dioxide to form converter inlet stream 14; this combined stream enters heat exchanger 26 at about 1080°F. and contains approximately ten per cent by volume sulfur dioxide and eleven per cent oxygen by volume.

Stream 14 then passes through heat exchanger 26 where its temperature is reduced to a converter inlet temperature of about 800°F. Branch 24 of return gas stream 22 is heated from about 180°F. to a required conversion temperature of about 830°F. The return gas stream contains about one per cent by volume sulfur dioxide.

Branch 32 of return gas stream 22 is heated in heat exchanger 30 from about 180°F. to about 830°F. Branch 32 is then combined with heater stream 24 to form stream 34 which is introduced into converter 18 where the final stage of conversion occurs and converter exit stream 36 formed. Stream 36 leaves converter 18 at a temperature in excess of about 850°F. The downstream processing of stream 36 will be described subsequently.

During the first pass in the primary converter stage, reaction product stream 28 is formed. This stream leaves converter 18 at a temperature of about 1140°F. and is cooled by branch 32 of return gas stream 22 to a required conversion temperature of about 810°F. After two or more passes through the beds of converter 18, stream 38 is formed which leaves the converter at a temperature of about 937°F. Stream 38 has about nine per cent by volume sulfur trioxide to about one per cent by volume sulfur dioxide; the sulfur dioxide is then about 90 per cent converted to sulfur trioxide.

Stream 38 is cooled in economiser 39 to a temperature of about 450°F. At this temperature, stream 38 is introduced into intermediate absorber 20 where stream 22 is formed. As was previously stated, stream 22 is at a temperature of about 180°F. and contains about one per cent by volume sulfur dioxide.

Absorption in absorber 20 is accomplished with recycled sulfuric acid from tank 40. The temperature of the contents of the tank is about 180°F. The temperature of return acid

stream 44, before cooling in heat exchange 46 and dilution by water, is about 240°F.

Gas stream 36 leaves converter 18 and passes through economiser 39 where it is cooled to about 450°F. by boiler feed water steam stream 41.

After the final stage of absorption in absorber 48, the remaining sulfur dioxide is vented to atmosphere. This stream contains about 0.05 per cent by volume sulfur dioxide by volume.

The sulfur dioxide dissolved in the sulfuric acid used to absorb the sulfur trioxide in absorber 20 is stripped in tower 60 and recycled in gas stream 16, which is predominantly air, for conversion to sulfur trioxide.

To summarise, beginning with a gas stream 14 containing about ten per cent by volume sulfur dioxide through the multiple catalysis and multiple absorption process described, results in but 0.05 per cent by volume sulfur dioxide leaving absorber 48. This represents in excess of 99.5 per cent conversion of sulfur dioxide to sulfur trioxide and, ultimately, to sulfuric acid.

If desired, known methods may be employed to convert the sulfur trioxide in stream 38 to either fuming sulfuric acid (oleum) or liquid sulfur trioxide.

WHAT WE CLAIM IS:—

1. A process for producing sulfur trioxide wherein sulfur dioxide in a sulfur dioxide containing converter inlet stream is converted to sulfur trioxide by multiple steps of catalytic oxidation with an intermediate sulfur trioxide extraction stage a sulfur trioxide containing reaction product stream emanating from each said catalytic conversion step, the converter inlet stream emanating from a source at a higher temperature than a required catalytic conversion temperature, and the intermediate sulfur trioxide extraction stage producing a cool return gas stream containing unconverted sulfur dioxide which returning stream is heated to a required catalytic conversion temperature prior to passing to the appropriate said conversion step, the process comprising the steps of (a) cooling the converter inlet stream to a required catalytic conversion temperature by indirect heat exchange with the return gas stream said cooled stream being introduced into a first said catalytic conversion step; and (b) cooling to a required conversion temperature the reaction product stream passing to a said catalytic conversion step which is subsequent to said first step and is prior to the intermediate extraction stage by indirect heat exchange with the return gas stream, the reaction product stream from the last said conversion step prior to the intermediate extraction stage passing thereto without heat exchange with the return gas stream.
2. A process according to claim 1, wherein there are a plurality of said catalytic con-



sulfuric acid introduced from tank 40 is also introduced into the furnace. A portion of the dried air and this stripped sulfur dioxide from the tower is bypassed into converter inlet stream 14 downstream from boiler 12. The conversion of the molten sulfur to sulfur dioxide takes place at a reaction temperature of approximately 1750°F. The sulfur dioxide leaves the furnace at this temperature in stream 11. Stream 11, containing approximately eleven per cent by volume sulfur dioxide, passes into waste heat boiler 12 where its temperature is reduced. Stream 11 then combines with bypass stream 16 of air and sulfur dioxide to form converter inlet stream 14; this combined stream enters heat exchanger 26 at about 1080°F. and contains approximately ten per cent by volume sulfur dioxide and eleven per cent oxygen by volume.

Stream 14 then passes through heat exchange 26 where its temperature is reduced to a converter inlet temperature of about 800°F. Branch 24 of return gas stream 22 is heated from about 180°F. to a required conversion temperature of about 830°F. The return gas stream contains about one per cent by volume sulfur dioxide.

Branch 32 of return gas stream 22 is heated in heat exchanger 30 from about 180°F. to about 830°F. Branch 32 is then combined with heater stream 24 to form stream 34 which is introduced into converter 18 where the final stage of conversion occurs and converter exit stream 36 formed. Stream 36 leaves converter 18 at a temperature in excess of about 850°F. The downstream processing of stream 36 will be described subsequently.

During the first pass in the primary converter stage, reaction product stream 28 is formed. This stream leaves converter 18 at a temperature of about 1140°F. and is cooled by branch 32 of return gas stream 22 to a required conversion temperature of about 810°F. After two or more passes through the beds of converter 18, stream 38 is formed which leaves the converter at a temperature of about 937°F. Stream 38 has about nine per cent by volume sulfur trioxide to about one per cent by volume sulfur dioxide; the sulfur dioxide is then about 90 per cent converted to sulfur trioxide.

Stream 38 is cooled in economiser 39 to a temperature of about 450°F. At this temperature, stream 38 is introduced into intermediate absorber 20 where stream 22 is formed. As was previously stated, stream 22 is at a temperature of about 180°F. and contains about one per cent by volume sulfur dioxide.

Absorption in absorber 20 is accomplished with recycled sulfuric acid from tank 40. The temperature of the contents of the tank is about 180°F. The temperature of return acid

stream 44, before cooling in heat exchange 46 and dilution by water, is about 240°F.

Gas stream 36 leaves converter 18 and passes through economiser 39 where it is cooled to about 450°F. by boiler feed water stream 41.

After the final stage of absorption in absorber 48, the remaining sulfur dioxide is vented to atmosphere. This stream contains about 0.05 per cent by volume sulfur dioxide by volume.

The sulfur dioxide dissolved in the sulfuric acid used to absorb the sulfur trioxide in absorber 20 is stripped in tower 60 and recycled in gas stream 16, which is predominantly air, for conversion to sulfur trioxide.

To summarise, beginning with a gas stream 14 containing about ten per cent by volume sulfur dioxide through the multiple catalysis and multiple absorption process described, results in but 0.05 per cent by volume sulfur dioxide leaving absorber 48. This represents in excess of 99.5 per cent conversion of sulfur dioxide to sulfur trioxide and, ultimately, to sulfuric acid.

If desired, known methods may be employed to convert the sulfur trioxide in stream 38 to either fuming sulfuric acid (oleum) or liquid sulfur trioxide.

WHAT WE CLAIM IS:—

1. A process for producing sulfur trioxide wherein sulfur dioxide in a sulfur dioxide containing converter inlet stream is converted to sulfur trioxide by multiple steps of catalytic oxidation with an intermediate sulfur trioxide extraction stage a sulfur trioxide containing reaction product stream emanating from each said catalytic conversion step, the converter inlet stream emanating from a source at a higher temperature than a required catalytic conversion temperature, and the intermediate sulfur trioxide extraction stage producing a cool return gas stream containing unconverted sulfur dioxide which returning stream is heated to a required catalytic conversion temperature prior to passing to the appropriate said conversion step, the process comprising the steps of (a) cooling the converter inlet stream to a required catalytic conversion temperature by indirect heat exchange with the return gas stream said cooled stream being introduced into a first said catalytic conversion step; and (b) cooling to a required conversion temperature the reaction product stream passing to a said catalytic conversion step which is subsequent to said first step and is prior to the intermediate extraction stage by indirect heat exchange with the return gas stream, the reaction product stream from the last said conversion step prior to the intermediate extraction stage passing thereto without heat exchange with the return gas stream.

2. A process according to claim 1, wherein there are a plurality of said catalytic con-



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version steps subsequent to said first step and prior to said intermediate extracting stage and the reaction product stream passing to each said catalytic conversion step subsequent to said first step and prior to the intermediate extraction stage is cooled to a required conversion temperature by indirect heat exchange with the return gas stream the return gas stream being heated to its required conversion temperature by said heat exchange and by its heat exchange with the converter inlet stream.

3. A process for producing sulfuric acid wherein sulfur trioxide is absorbed in an aqueous liquor to produce said sulfuric acid and sulfur dioxide in a sulfur dioxide containing converter inlet stream is converted to produce said sulfur trioxide by multiple steps of catalytic oxidation with an intermediate sulfur trioxide extraction stage a sulfur trioxide containing reaction product stream emanating from each said catalytic conversion step, the converter inlet stream emanating from a sulfur combustion source at a higher temperature than a required catalytic conversion temperature, and the intermediate sulfur trioxide extraction stage producing a cool return gas stream containing unconverted sulfur dioxide which return stream is heated to a required catalytic conversion temperature prior to passing to the appropriate said conversion step, the process comprising the steps of (a) cooling the converter inlet stream to a required catalytic conversion temperature by indirect heat exchange with the return gas stream said cooled stream being introduced into a first said catalytic conversion step and (b) cooling to a required conversion temperature the reaction product stream passing to a said catalytic conversion step which is subsequent to said first step and is prior to the intermediate extraction stage by indirect heat exchange with the return gas stream the reaction product stream from the last said conversion step prior to the intermediate extraction stage passing thereto without heat exchange with the return gas stream.

4. A process according to claim 3, wherein there are a plurality of said catalytic conversion steps subsequently to said first step and prior to said intermediate extraction stage and the reaction product stream passing to each said catalytic conversion step subsequent to said first step and prior to the intermediate extraction stage is cooled to a required conversion temperature by indirect heat exchange with the return gas stream the return gas stream being heated to its required conversion temperature by said heat exchange and by its heat exchange with the converter inlet stream.

5. A process according to claim 3 or claim 4 wherein the sulfur trioxide extracted in the intermediate extraction stage is extracted by absorption in sulfuric acid and the sulfur dioxide absorbed with the sulfur trioxide is

tripped from the sulfuric acid and recycled into the converter inlet stream.

6. A process according to any one of claims 3, 4 and 5 comprising the additional step of cooling the reaction product stream from the last catalytic conversion step prior to the intermediate extraction stage to a required extraction temperature by indirect heat exchange.

7. A process according to any one of claims 3 to 5 wherein the return gas stream is split into a first and a second cooling stream, the first cooling stream being used for said converter inlet stream cooling, and the second cooling stream cooling being used for said reaction product stream cooling.

8. A process according to any one of claims 3 to 5, wherein the return gas stream passes successively to be used first for said reaction product stream cooling and then for said converter inlet stream cooling.

9. A process according to any one of claims 3 to 5 wherein the return gas stream passes successively to be used first for said converter inlet stream cooling and then for said reaction product stream cooling.

10. A process for the production of sulfuric acid substantially as hereinbefore described with reference to Figure 1, Figure 2 or Figure 3 of the accompanying drawings.

11. A process for the production of sulfuric acid substantially as hereinbefore described with reference to the Example.

12. Plant adapted for use in carrying out a process according to claim 1 comprising (a) multiple step catalytic oxidation means for converting sulfur dioxide to sulfur trioxide with intermediate means for extracting sulfur trioxide and producing a cool return gas stream containing unconverted sulfur dioxide; (b) means for producing sulfur dioxide at a higher temperature than a required catalytic conversion temperature; (c) means for cooling the converter inlet stream to a required catalytic conversion temperature by indirect heat exchange with the return gas stream prior to introduction of the inlet stream into a first catalytic conversion step; and (d) means for cooling to a required conversion temperature the reaction product stream passing to a said catalytic conversion step which is subsequent to the first conversion step and prior to the intermediate extraction means by indirect heat exchange with the return gas stream; the arrangement being such that in the operation of the plant the reaction product stream from the last said conversion step prior to the intermediate extraction means passes thereto without heat exchange with the return gas stream.

13. Plant adapted for use in producing sulfuric acid constructed, arranged and adapted to operate substantially as hereinbefore described with reference to the Figure

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1, Figure 2 or Figure 3 of the accompanying drawings.

14. Sulfur trioxide when produced using a process according to claim 1.

5 15. Sulfuric acid when produced from sulfur trioxide using a process according to claim 1.

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