June 7, 1960 M. WEBB 2,939,769

SULFUR RECOVERY APPARATUS

Filed May 28, 1956 7 Sheets-Sheet 1

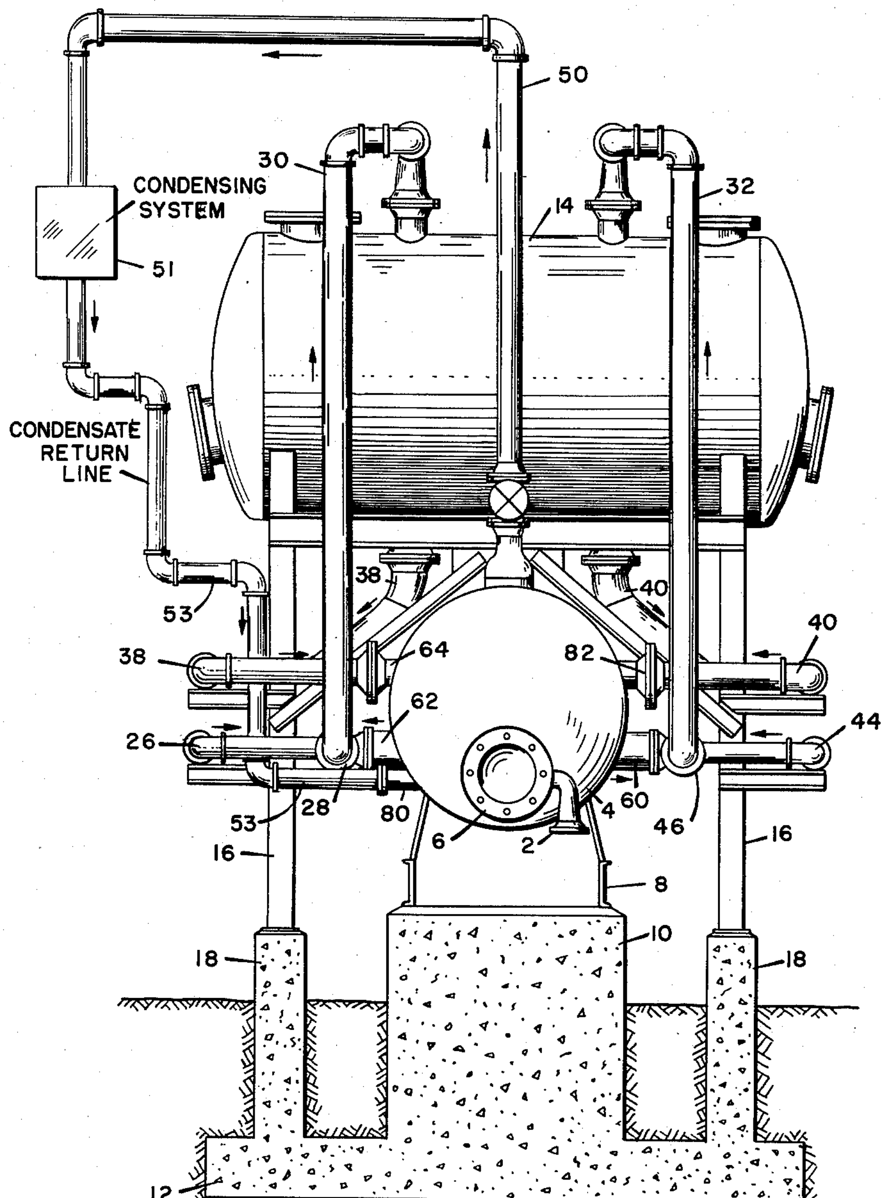

FIG. 1

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SULFUR RECOVERY APPARATUS

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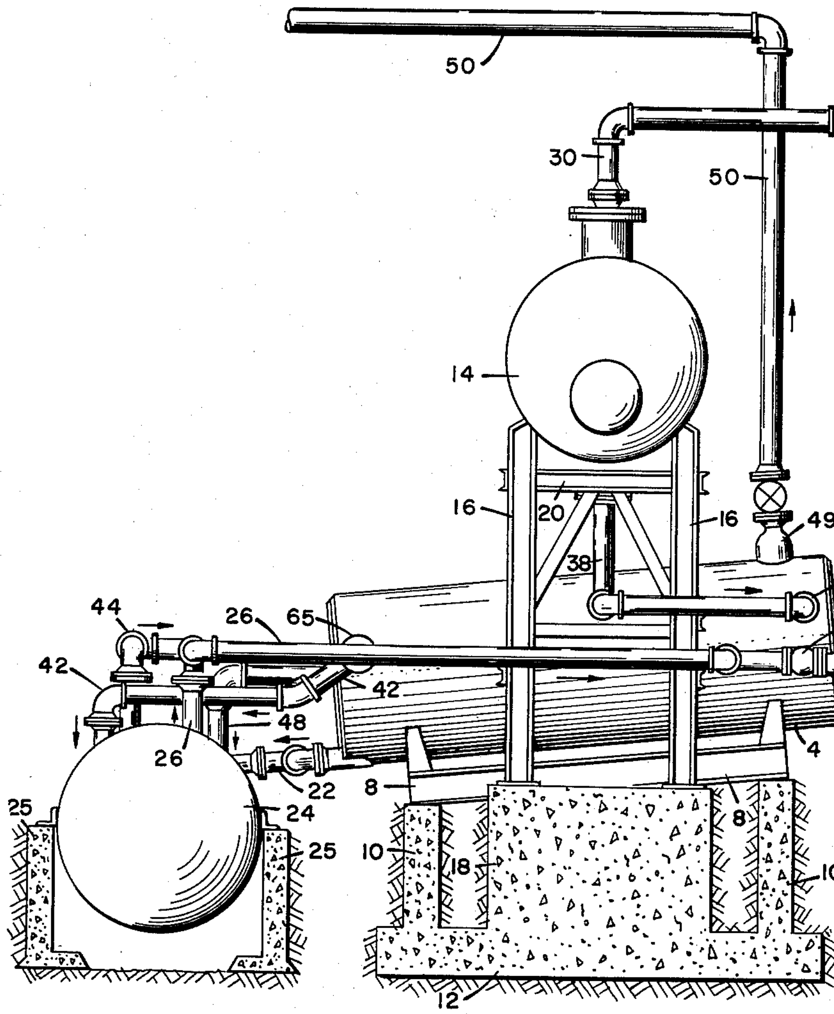

FIG. 2

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SULFUR RECOVERY APPARATUS

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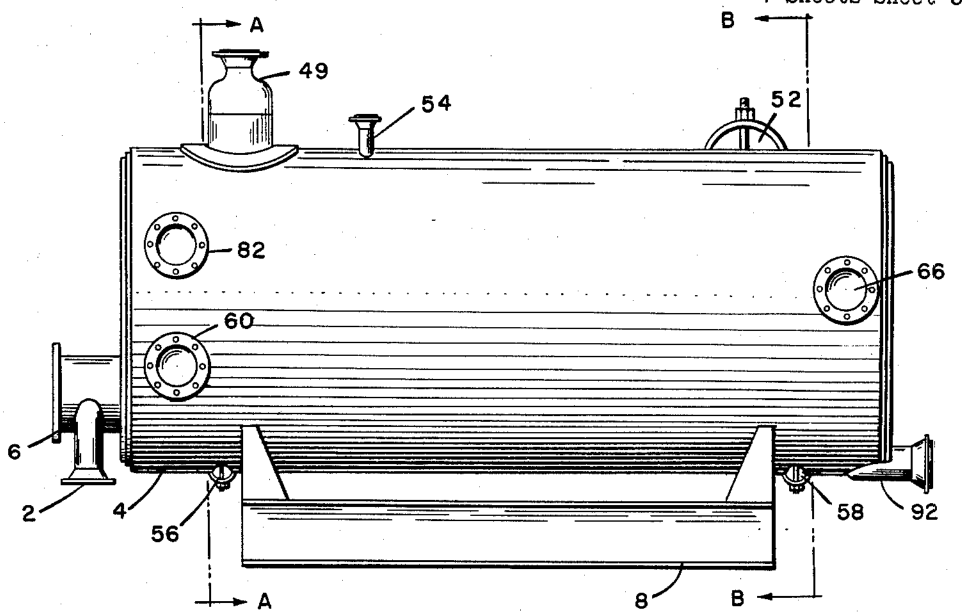

FIG. 3

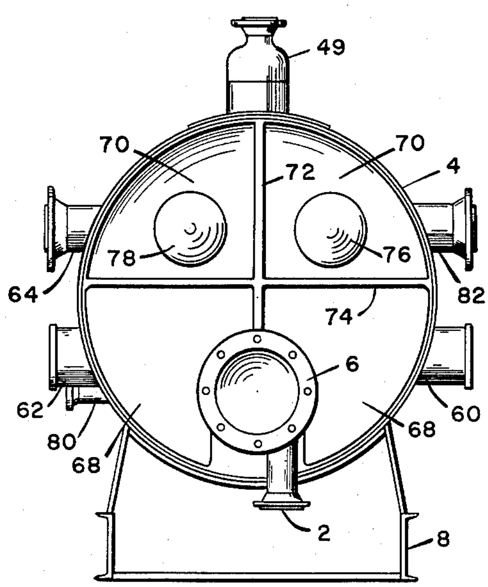

FIG. 4

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SULFUR RECOVERY APPARATUS

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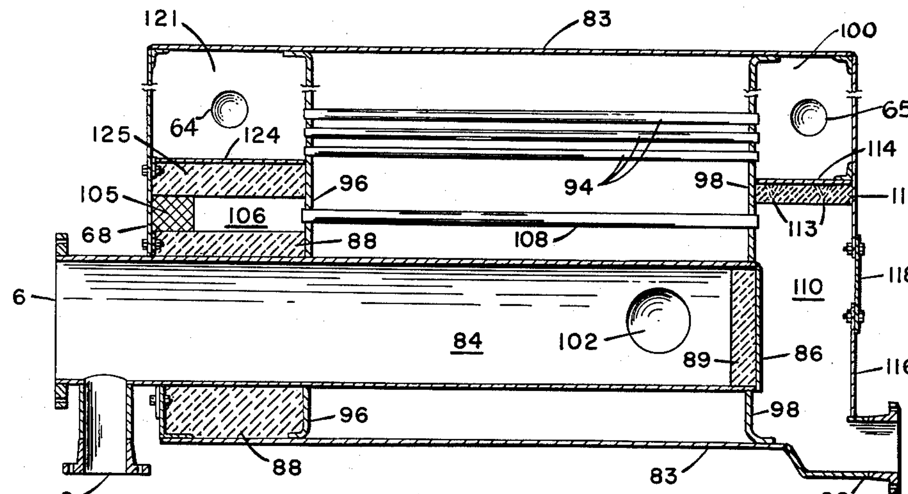

FIG. 5

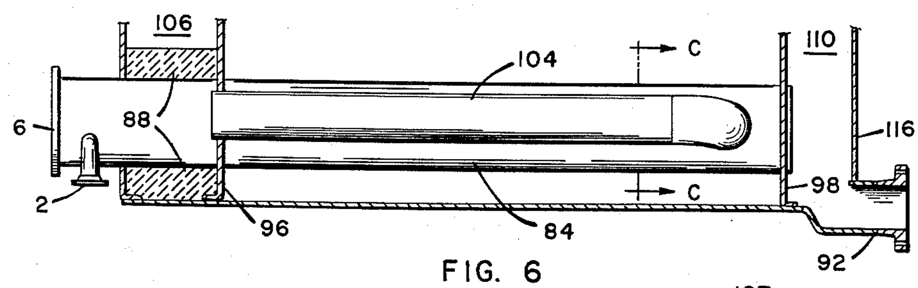

FIG. 6

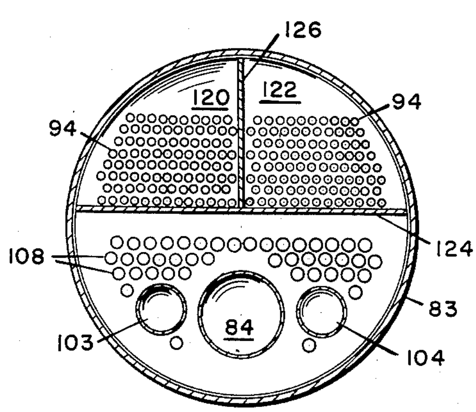

FIG. 8

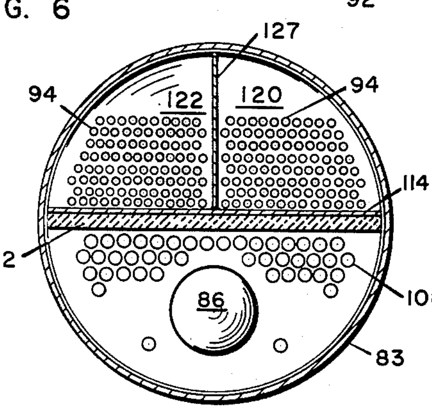

FIG. 9

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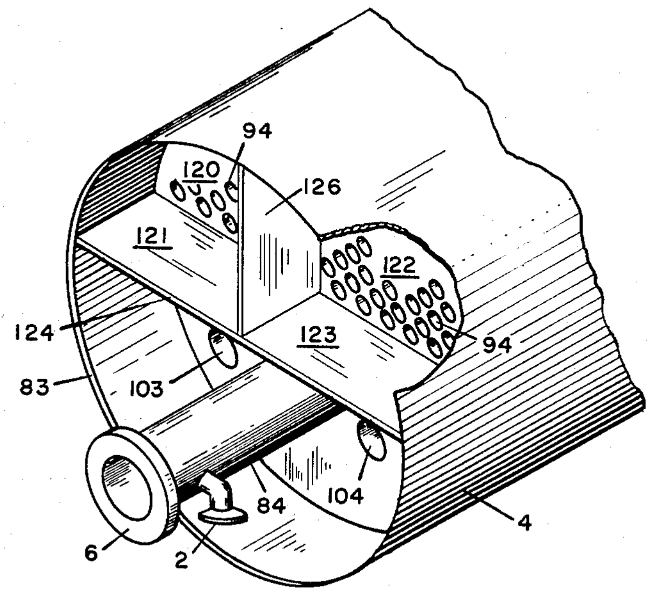

FIG. 7

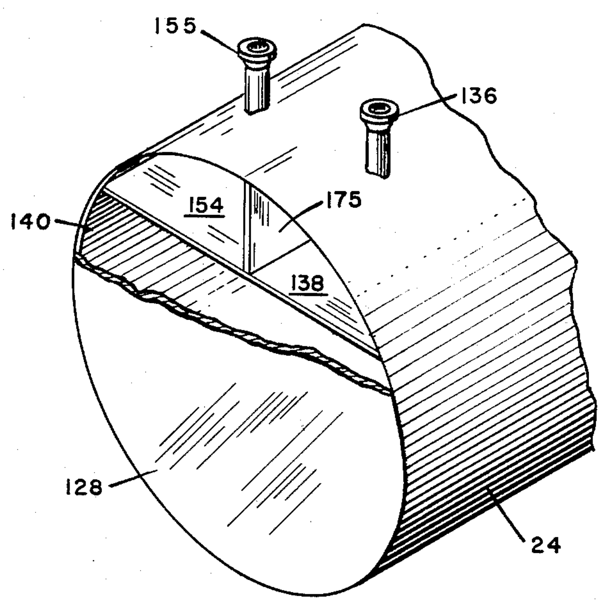

FIG. 13

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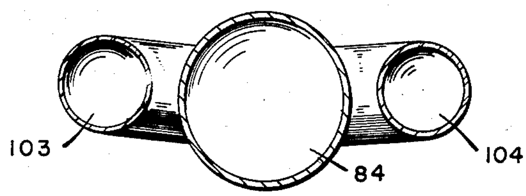

FIG. 10

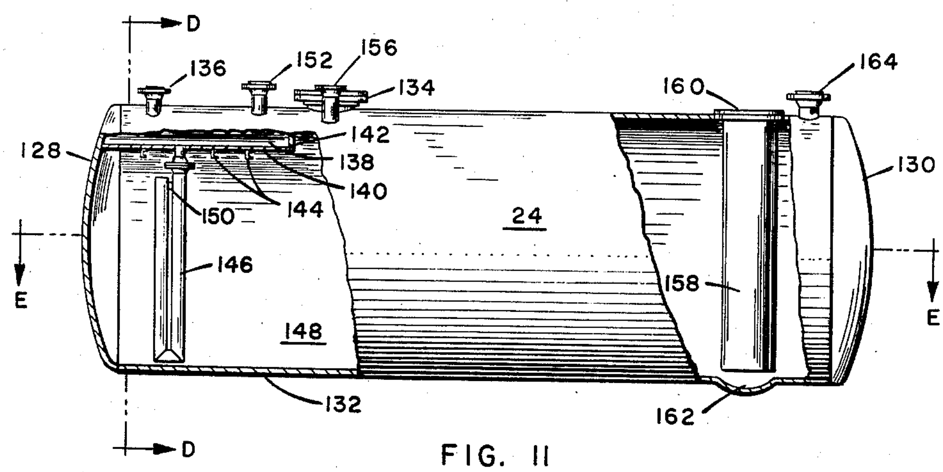

FIG. 11

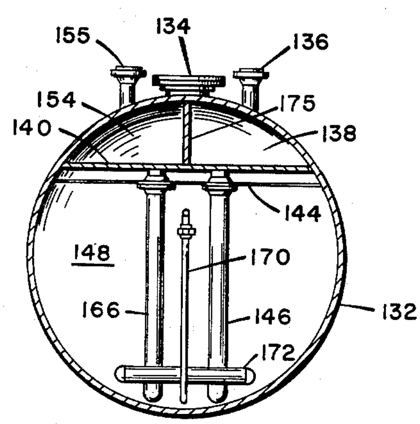

FIG. 12

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SULFUR RECOVERY APPARATUS

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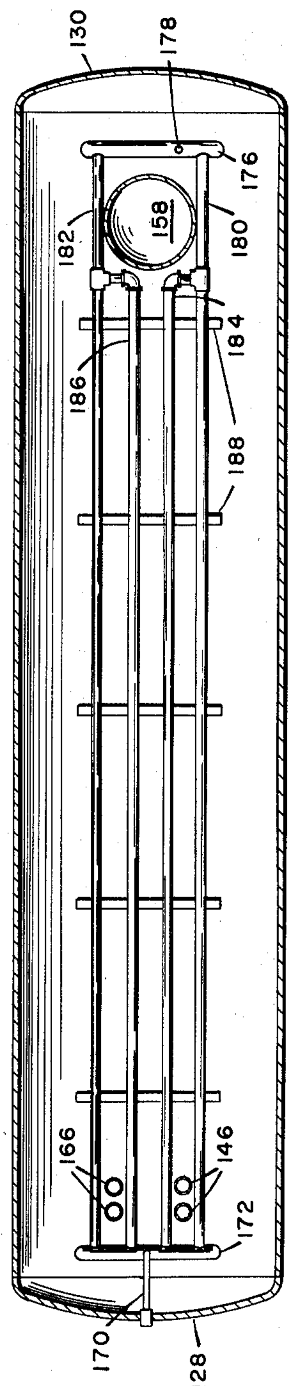

FIG. 14

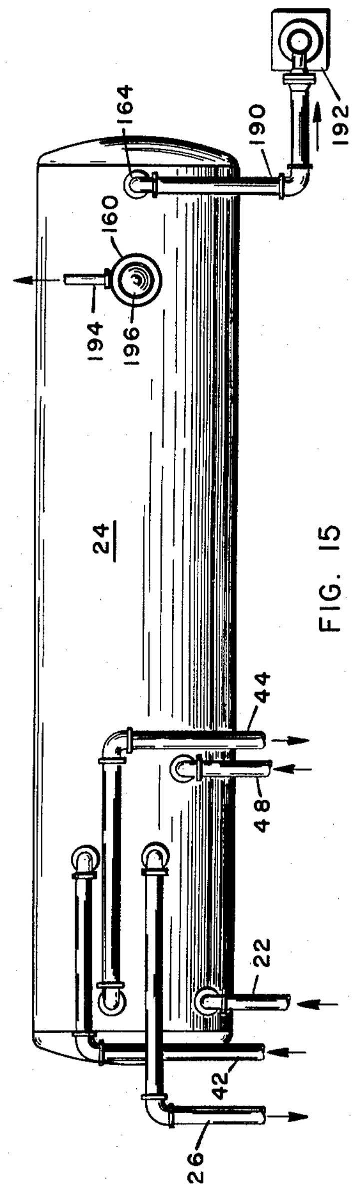

FIG. 15

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United States Patent Office

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Patented June 7, 1960

2,939,769

SULFUR RECOVERY APPARATUS

Maurice Webb, Tulsa, Okla., assignor to Pan American Petroleum Corporation, a corporation of Delaware

Filed May 28, 1956, Ser. No. 587,738

11 Claims. (Cl. 23—262)

The present invention relates to the recovery of sulfur from hydrogen sulfide containing gases. More particularly, it is concerned with novel equipment design which makes possible the construction of a highly efficient and compact sulfur recovery plant.

At present two procedures are employed commercially for the recovery of free sulfur from sour gas streams. In one type of operation all of the feed is introduced into a boiler together with sufficient air or other source of free oxygen to oxidize one-third of the hydrogen sulfide in the feed to sulfur dioxide. As the mixture of hot gases is cooled in the furnace boiler which has a pressure tight case, some sulfur is produced and is recovered. The gaseous effluent from the boiler is then adjusted to a temperature of from about 400 to 450° F. The resulting reaction mixture is then injected into a reaction zone filled with a suitable catalyst, a substantial conversion, e.g. 75 percent, of hydrogen sulfide to free sulfur obtained, the gaseous products then usually sent through an economizer or condenser and thereafter introduced into a liquid sulfur scrubbing unit. The unreacted gases taken off the scrubber overhead line are then adjusted to a temperature of from about 400 to 450° F. and sent to a second reaction zone. The products from this reactor are then led to a second scrubber to recover free sulfur therefrom.

Other methods of sulfur recovery involve dividing the feed stream and separately burning one-third thereof to sulfur dioxide, after which the latter is combined with the remaining two-thirds of the original feed gas to give a mixture roughly equivalent to that produced when all of the gas is passed through the boiler in the manner generally described above. With a process of this sort using two converters, the method of processing the stream through the system and recovering free sulfur is substantially the same as is involved when the reaction mixture is prepared by introducing all of the feed gas into a furnace and burning one-third of said gas to sulfur dioxide. Both methods require essentially the same items of equipment, i.e. a boiler, two converters, two condensers, a gas-liquid separator for each of said condensers, two reheaters or inline burners, and a liquid sulfur storage pit. In addition to being quite costly, plants of this type require steam jacketed lines and considerable space which frequently is an important factor, particularly in crowded refinery areas.

Accordingly, it is an object of my invention to provide a compact sulfur recovery plant involving the use of a specially designed boiler structure which provides in the upper portion thereof separate means for condensing the product streams from the converters. It is another object of my invention to eliminate reheaters or inline burners frequently used for purposes of controlling the feed gas temperature to the converters. It is a further object of my invention to construct the overall plant such that all process lines are self-draining, and thus eliminate the need for steam jacketed drain lines. It is another object of my invention to provide a novel separator and storage

tank design, the use of which eliminates the necessity for a gas-liquid separator, or equivalent thereof, for each condenser utilized. Still another object of my invention is to provide an overall plant layout based primarily on the aforesaid novel boiler design whereby it is possible to eliminate all boiler feed water preparation facilities. For example, this latter object can be accomplished by using the produced steam in an elevated amine reboiler of the type employed in Girbotol sour gas sweetening units.

For a better understanding of my invention there is shown in the accompanying drawings a series of embodiments where:

Figure 1 is a front end elevational view of a sulfur recovery plant embodying my invention illustrating a particular arrangement of piping and equipment.

Figure 2 is a side elevational view of the arrangement shown in Figure 1.

Figure 3 is a side elevational view of the novel boiler design.

Figure 4 is an end view of the boiler shown in Figure 3, illustrating in further detail the position of the two principal sections of the furnace, i.e. the boiler section and the condensing sections.

Figure 5 is a sectional view of the boiler shown in Figure 3.

Figure 6 is a detailed drawing of the fire tube section shown in Figure 5.

Figure 7 is a fragmentary isometric end view principally in section of the boiler of my invention having the front cover removed.

Figure 8 is a front end view of the boiler tube sheet shown in Figure 3 taken along line A—A.

Figure 9 is a rear view of the boiler tube sheet shown in Figure 3 taken along line B—B.

Figure 10 is a sectional view of Figure 6 taken along line C—C.

Figure 11 is an elevational view partly in section of a novel liquid sulfur separator and storage tank.

Figure 12 is a sectional view of Figure 10 taken along line D—D.

Figure 13 is a fragmentary end view partly in section of the combination separator and storage tank of my invention.

Figure 14 is a plan view in section taken along line E—E of Figure 11.

Figure 15 is a plan view of the liquid sulfur separator and storage tank showing in detail a piping arrangement employed for handling gaseous and liquid product flowing to the separator and for gaseous effluent coming from the separator.

Similar reference characters refer to similar parts throughout the several views of the drawings and the description.

Broadly, my invention contemplates use of a specially designed boiler in which substantially the lower half thereof comprises a main fire tube and steam tubes. In the fire tube section hydrogen sulfide is burned producing temperatures in the neighborhood of 2200 to about 2500° F., by employing sufficient air to produce a final mixture of hydrogen sulfide to sulfur dioxide in a mol ratio of about 2:1. A gas tight metal plate at each end of the boiler divides the upper and lower interior portions of the structure on the gas side thereof only, i.e. steam tubes in the upper half of the unit are in contact with the same water that contacts the steam tubes in the lower half thereof. The gas side in the upper half of the structure at each end of the boiler is preferably divided in half by means of a gas tight metal plate or partition. This provides separate entrance areas or compartments for the product gas from each of the two converters employed. Hot gaseous reactants are removed from the boiler section, some produced sulfur recovered therefrom in a section of the liquid separator and storage tank and the remainder of said reactants sent to the first converter in accordance with the more detailed description appearing below. After reaction in the first converter the product gas is sent to that portion of the boiler designed as the condenser section to handle said product gas from the first converter. The resulting condensate, together with uncondensed gases, is next sent to a separator. After separation of sulfur in a section of the liquid separator and storage tank to be described in greater detail later, the uncondensed reactants are sent to the second converter and the general procedure of condensation, sulfur separation, etc., repeated with the condensation step, this time occurring in a different and separate portion of the boiler from that in which product sulfur from the first converter was condensed. Steam generated during the simultaneous oxidation of about one-third of the hydrogen sulfide to sulfur dioxide and the condensation of converter product gas as generally outlined above is withdrawn from the boiler, and, if desired, it may be sent to a unit in which steam is used as a heating medium or to a suitable elevated condenser after which the resulting condensate is returned to the water or liquid side of the boiler by gravity. In this manner boiler feed water is continuously supplied to the unit without further treatment.

My invention may be further illustrated by reference to the accompanying drawings wherein Figures 1 and 2 are front end and side elevational views, respectively, of a preferred arrangement of piping and equipment embodying my invention in which air is brought in through line **2** and mixed with acid (H_2S) gas entering furnace **4** through line **6**. The furnace is supported by means of I beams **8** which in turn rest on concrete footings **10** set in concrete pad **12**. A second supporting structure holding vessel **14** comprises vertical I beams **16** resting on footings **18** also supported by concrete pad **12**. Vessel **14** has two gas-tight compartments each of which contains a catalyst bed. Cross-beam **20** makes the supporting structure more rigid and transmits the weight of vessel **14** to the supporting column **16**. Boiler **4** is inclined at an angle of about 5° so that free sulfur condensed therein or produced as a result of the oxidation of one-third of the hydrogen sulfide to sulfur dioxide is removed along with the process streams from the rear portion of said boiler, as hereinafter described in detail, by means of line **22** and sent to partially submerged gas-liquid separator and storage tank **24** set in a concrete support **25**. Usually tank **24** is maintained at a temperature in the neighborhood of from about 250° to about 300° F. by the produced sulfur and by the hot process gas streams in order that the liquid product sulfur is kept in a pumpable and free flowing condition. The exposed portion of tank **24** may be covered with insulation which in turn may, if desired, be protected by means of a metal jacket not shown. Along with the product sulfur passing through line **22** is a portion of the hydrogen sulfide remaining after the oxidation or burning step in the boiler. This gas comes out of the first separator section in tank **24** through line **26** and is mixed with hot bypass gas coming from furnace **4** into a three-way valve **28**. The bypass gas is so proportioned with respect to the reactants in line **26** that the temperature of the resulting mixture in line **30** subsequently going into the first catalyst chamber in vessel **14** is at the desired initial temperature of about 450° F. Product gas from the first catalyst chamber in vessel **14** is withdrawn through line **38** and sent to the first condensing section of boiler **4** via entrance port **64**. Condensed product sulfur, together with unreacted product gas, is withdrawn through exit port **65** and line **42** and sent to the second separating section in tank **24**. Uncondensed reactants issue from the second separating section through line **44** and are mixed with hot bypass gas passing from furnace **4** through three-way valve **46**. The resulting mixture comprises the feed gas to the second catalyst chamber and is transmitted thereto through line **32**. Hot product gas is taken from the base of the second catalyst chamber in vessel **14** through line **40** and enters the second condensing section of the boiler **4** through inlet port **82**. In the upper portion of the boiler product sulfur vapors are condensed to liquid sulfur and the latter together with uncondensed gases are sent through exit port **66** (Figure 3), directly opposite exit port **65**, and line **48** to storage tank **24** where said gases are separated from product liquid sulfur and vented through a stack not shown.

Steam generated in both the lower and upper sections of boiler **4** is led off through steam outlet nozzle **49** and line **50** at a pressure of about 50 pounds (absolute). This steam may be used for process heating or for a number of other purposes. For example, such steam may be conducted to a suitable condensing unit, shown diagrammatically as **51** and the resulting condensate returned to the boiler via line **53** and entrance port **80**.

The overall plant structure as shown in Figures 1 and 2 with the particular equipment sizes given stands approximately 20 feet high and covers an area of about 330 square feet. The furnace itself may be 15 to 20 feet in length by 5 to 8 feet in diameter. The separator and storage tank may be 25 to 30 feet long by 6 to 8 feet in diameter. The overall length of the vessel serving as the two reactors may be from 12 to 15 feet with a diameter range of 6 to 8 feet. The capacity of a plant of this size may range from about 10 to about 25 tons of sulfur per day.

Figures 3 and 4 are detailed elevational side and front end views, respectively, of boiler **4**. Thus, in Figure 3 a manway **52** is provided for access to the steam section of the boiler. Nozzle **54** serves as a fitting for the boiler pressure relief valve. Hand holes **56** and **58** are provided at both ends of the base of the boiler for occasional cleaning. An exit port **60** leading from a point near the front end of the lower half of the boiler carries hot bypass gas from the furnace fire tube for purposes previously explained. An exit port **62** appears on the opposite side of furnace **4** and also handles hot bypass gas from the fire tube as previously explained. Entrance port **82** receives product gas coming from the second catalyst chamber and supplies said gas to the second condensing section of the furnace. After condensation occurs the mixture of uncondensed gases plus liquid product sulfur is withdrawn from the condensing section through exit port **66**.

Figure 4 shows the front end of the furnace consisting principally of face plates **68** and **70**. These plates may be secured to the boiler by bolting them to a flanged support member integral with the shell portion of said boiler. They may also be bolted to vertical steel support **72** and horizontal member **74**. Hand holes **76** and **78** serve as a means of access into the separate condensing sections of the furnace. Inlet port **80** receives condensate water and supplies it to the steam section of the boiler. Entrance ports **64** and **82** receive product gas from the first and second catalyst chambers, respectively, in accordance with the procedure generally set forth above and which will be described in greater detail below.

Figure 5 is a sectional view of the novel boiler design of my invention comprising a cylindrical shell **83** containing fire tube **84** into which acid gas and air flow through entrance ports **6** and **2**, respectively. Surrounding the front portion of fire tube **84** is a castable refractory material **88**. Fire tube **84** has a rear metal cover plate **86** protected from the hot combustion products by means of castable refractory **89**. Combustion occurs in fire tube **84**. Hot process gases produced in said tube then pass through outlets near the end of fire tube **84**, one of said outlets **102** being shown herein. Thereafter, said gases enter tubes **108** where the final cooling in the boiler section is accomplished. Portions of fire tube **84** not water cooled by the steam side of the boiler as well as other portions of said boiler, such as chamber **106**, which are exposed to temperatures in excess of 800° F., are protected by castable refractory **88** and **125**. Return tubes **103** and **104** (shown in Figures 6 and 8) should be so sized that the hot gases emerging therefrom will be at a temperature of the order of about 1000° to 2000° F. If these gases are too hot they cannot be handled in a conventional three-way valve such as those indicated in Figure 1, at **28** and **46**. If these gases are too cold an excessive quantity will be bypassed to maintain desirable temperatures in the feed gas to the catalyst chambers. Tubes **94** secured to tube sheet **96** and **98** receive hot product gases from the catalyst chambers, said gases entering the boiler through entrance ports **64** and **82** as shown in Figure 4, and are conducted into separately confined condensing sections **120** and **122**, the latter being shown in detail in Figures 7 and 8. The sulfur vapors along with unreacted gases pass through tubes **94** where the sulfur is transformed into a liquid product. The boiler being inclined at an angle of about 5° from rear to front causes the condensed sulfur in tubes **94** as well as that in tubes **108** to flow to the rear of the boiler into chambers **100** and **110**, respectively, where it is withdrawn along with unreacted process gases through exit port **92** and lines **42** and **48**, as shown in Figure 2.

The relationship of return bend tubes **103** and **104** to fire tube **84** is shown in greater detail in Figure 6 in which one of said tubes, **104**, is indicated to run from a point near the end of fire tube **84** and extend back to tube sheet **96**. Tubes **103** and **104** are in communication with zone **106** which in turn leads into tubes **108** and to the three-way valve ports **60** and **62** shown in Figures 1 and 4.

Fire brick refractory **105** protects cover plate **68** from hot combustion gases in zone **106**. In tubes **108** additional liquid sulfur may be formed and drains into chamber **110** along with unreacted gases which eventually flow out of the boiler through exit port **92** as previously explained. Castable refractory **112**, secured by means of tack welded anchors **113**, is also placed on the underneath side of steel plate **114** forming the base of chamber **100** thereby protecting the latter from the high temperatures prevailing in lower chamber **110**. The furnace is closed at the rear, lower end thereof by means of a steel wall plate **116** equipped with hand hole cover **118** so that access may be had to interior portions of the structure communicating with chamber **110**. The entire interior of the boiler coming in contact with hot acidic gases is preferably coated with a suitable protective material such as, for example, sodium silicate. These areas consist of the interiors of chambers **100**, **106**, and **110**, as well as the two chambers communicating with condensing sections **120** and **122** (see Figure 7), one of said two chambers being shown as **121** and communicating with condensing section **120**.

Figure 7 is a fragmentary isometric end view of boiler **4** with the cover plate removed. This view indicates clearly the structure of the gas tight sections at the front end of the boiler. The gas tight sections at the rear of the boiler are formed in an identical fashion. In this view vertical plate **126** is shown to project from tubes **94** to the front edge of horizontal divider plate **124** thereby making possible a gas tight barrier between condensing sections **120** and **122** and forming chambers **121** and **123** which communicate with said sections **120** and **122**, respectively.

Figure 8 is a front end view of the boiler shown in Figure 3 taken along line A—A with the cover plates **68** and **70** removed. The upper and lower front portions of the boiler are divided on the gas side only by means of horizontal steel plate **124** and the upper half thereof is further divided into condensing sections or compartments **120** and **122** by means of gas tight vertical steel plate **126**. Plate **124** serves to prevent passage of gas between groups of tubes **94** and **108**. The relative position of return bend tubes **103** and **104** to fire tube **84** and to tubes **108** is also shown.

Figure 9 is a sectional rear view of Figure 3 taken along line B—B. This view indicates the similarity in structure of the gas side at the rear of the boiler to that in the front end thereof shown in Figure 8. The lower portion of the boiler containing the steam tubes **108** is shown to be insulated from the condensing sections **120** and **122** by means of castable refractory **112**. The rear upper and lower portions of the boiler are likewise divided on the gas sides only by means of horizontal plate **114** and the upper half thereof is further divided by means of vertical plate **127** to form the rear portions of condensing sections **120** and **122** in a manner similar to the structure in the front of the boiler as shown in Figures 7 and 8.

Figure 10 is a sectional view of Figure 6 taken along line C—C showing in further detail the relative position of return bend tubes **103** and **104** to fire tube **84**.

Figure 11 is an elevational view, partly in section, of a novel tank design comprising a combination gas-liquid separator and storage tank with end covers **128** and **130** welded to the cylindrical shell or body portion thereof **132**, having on the top side a manhole **135**. Inlet port **136** communicates with compartment **138** defined by steel baffle plates **140**, **142** and **175** (Figure 12) welded, respectively, to end cover **128** and the top side of cylindrical vessel **132**. Plate **140** is made rigid by means of horizontal channel support members **144**. Product gases along with product liquid sulfur enter compartment **138** through port **136** where the liquid sulfur flows down through U seal pipe **146**. The temperature within the entire tank is maintained generally within the range of about 250° F. to about 300° F. by means of the process gases thereby assuring free flow of liquid sulfur down through seal tube **146** and out the opposite end thereof into storage zone **148** of the tank which actually serves as a third separating section. The discharge end of tube **146** is held rigid by means of a welded spacer **150** fixed to said discharge end and to a point directly opposite said end on the inlet side of said tube. Uncondensed gases are withdrawn from compartment **138** through exit port **152** and returned to the reactor for further conversion of hydrogen sulfide as previously described. An identical separator compartment **154** not shown in Figure 11, but illustrated more in detail in Figure 12 described below, is opposite compartment **138** and has inlet and outlet ports (not shown) similar to ports **136** and **152**. After reactant gases have passed through the second catalyst chamber, the resulting product gas together with liquid sulfur are introduced into main storage zone **148** through port **156**. The opposite end of the tank is equipped with a pump well **158**, which is suspended from a collar **160** at the top of the storage tank, and extends to a level generally 2 to 4 inches above the base of the tank. Directly below the base of the pump well is a dished head sump **162**. Any gases which have not condensed at this stage of the process are withdrawn from the tank through exit port **164** and delivered to a suitable stack not shown. Through the use of a tank of the design just mentioned above, I am able to eliminate steam jacketed lines and costly separator and scrubbing equipment employed in plants of conventional design.

Figure 12 is a sectional view of the vessel shown in Figure 11 taken along line D—D illustrating in greater detail the structure of separator compartments **138** and **154** and the relationship of said compartments to U bend seal tubes **148** and **168**. Between said U bend tubes is a riser **170** through which condensate is withdrawn from steam header **172**. Channel support member **144** spot welded to the sides of said cylindrical shell **132** and to base plate **140** serves as a stiffener for the latter. Partition **175** extends from plate **142** to end cover **128** to define gas tight compartments **138** and **154**, having inlet port **136** and exit port **155**, respectively.

Figure 13 is a fragmentary isometric view, partly in section, of combination separator and storage tank **24**. This view illustrates the manner in which vertical plate **175** is affixed to horizontal plate **140** to form separating compartments **138** and **154**. This figure indicates particularly the manner in which a gas tight closure may be effected between end cover plate **128**, which is shown partly broken away, and the front edges of plates **140** and **175**.

Figure 14 is a sectional plan view of Figure 11 taken along line E—E illustrating in detail the steam heating coil located at the base of the storage tank which may be used to maintain proper temperature during periods when the plant is not operating and process gases are not entering the tank to supply heat. In this system, header **176**, provided with steam inlet line **178**, is affixed to lines **180** and **182** which in turn divide their flow of steam into lines **184** and **186**, respectively, all of said lines **180** to **186**, inclusive, terminating in header **172**. These lines are supported and held free from the base of the tank by means of U rails **188**. The entire steam line assembly is slanted so that the included angle defined by the base of the tank and the steam lines themselves terminating in header **172** is about 5 to 10° thus allowing condensate to flow into header **172** and permitting subsequent withdrawal thereof through line **170**.

Figure 15 is a plan view of separator and storage tank **24** showing the piping arrangement to and away from tank **24** when the latter is employed in combination with the boiler and reactors shown in Figures 1 and 2. At the end opposite that into which the product gases discharge a conduit **190** attached to exit or exhaust port **164** leads to stack **192** where unreacted product gases are vented to the atmosphere. Liquid product sulfur is removed from the tank through conduit **194** by means of pump **196**.

Utilization of the apparatus of my invention in the recovery of free sulfur by the partial oxidation of hydrogen sulfide in a known manner and under the conditions set out below will be further illustrated by the following example when interpreted in light of the foregoing drawings.

Table

Composition	Acid Gas	Air	Sulfur Removed, #1 Separator Compartment	Feed to 1st Converter	1st Converter Effluent	1st Condenser Effluent	Sulfur Removed, #2 Separator Compartment
H_2S	36.10	-----	-----	7.89	2.61	2.61	-----
COS	-----	-----	-----	.14	.004	.004	-----
SO_2	-----	-----	-----	4.01	1.30	1.30	-----
CO_2	18.35	-----	-----	15.80	15.97	15.97	-----
H_2O	5.02	1.60	-----	28.78	33.92	33.92	-----
CH_4	.11	-----	-----	-----	-----	-----	-----
C_2H_6	.06	-----	-----	-----	-----	-----	-----
C_3H_8	.06	-----	-----	-----	-----	-----	-----
C_4H_{10}	.06	-----	-----	-----	-----	-----	-----
N_2	-----	72.55	-----	60.94	60.94	60.94	-----
O_2	-----	19.17	-----	-----	-----	-----	-----
S_2	-----	-----	-----	-----	.021	-----	-----
S_6	-----	-----	-----	.14	.360	.0029	-----
S_8	-----	-----	-----	.366	1.214	.00963	-----
S_n	-----	-----	14.52	-----	-----	(11.815)	11.815
Total Mols/Hr	59.76	93.32	14.52	118.066	116.34	114.76	11.815
Mol. Wt	35.77	28.8	32.06	30.6	30.8	28.0	32.06
M s.c.f.d	543	848.8	-----	1,073.9	1,058.2	1,043.8	-----
Temp., ° F	120	177	300	425	600	300	300
Press., p.s.i.a	18.1	18.1	17.1	17.1	16.6	16.1	16.1

Composition	Feed to 2nd Converter	2nd Converter Effluent	2nd Condenser Effluent	Sulfur Removed by #3 Separator Compartment	Stack Gas
H_2S	4.12	1.48	1.48	-----	1.48
COS	.024	.001	.001	-----	.001
SO_2	2.06	.74	.74	-----	.74
CO_2	18.98	19.00	19.00	-----	19.00
H_2O	39.40	42.02	42.02	-----	42.02
CH_4	-----	-----	-----	-----	-----
C_2H_6	-----	-----	-----	-----	-----
C_3H_6	-----	-----	-----	-----	-----
C_3H_8	-----	-----	-----	-----	-----
C_4H_{10}	-----	-----	-----	-----	-----
N_2	72.55	72.55	72.55	-----	72.55
O_2	-----	-----	-----	-----	-----
S_2	.49	.002	-----	-----	-----
S_6	.343	.070	.004	-----	.004
S_8	.0646	.890	.013	-----	.013
S_n	-----	-----	(7.420)	7.42	-----
Total Mols/Hr	138.032	136.75	135.81	7.42	135.81
Mol. Wt	28.8	29.1	27.6	32.06	27.6
M s.c.f.d	1,255.5	1,243.9	1,235.3	-----	1,235.3
Temp., ° F	450	500	300	300	300
Press., p.s.i.a	15.6	15.1	14.6	14.6	14.6

By operation of the plant designed in accordance with the present invention and under the conditions set forth in the above table, 33.75 mols per hour or 11.6 long tons of sulfur per day were obtained for a recovery of 93.5 percent.

One of the outstanding features of sulfur recovery plants designed in accordance with my invention is their compactness and relatively low initial cost. As previously mentioned, conventionally designed sulfur plants employing a two converter system require 10 major pieces of equipment. My design on the other hand, requires only three separate major items of equipment for a two converter plant. Thus, with plants producing less than 25 tons of sulfur per day I am able to construct a sulfur recovery unit in accordance with my design costing from about 25 to about 50 percent of the expenditure required for conventional plants of the same capacity.

A further factor of importance affording substantial economy in sulfur recovery plants of the type contemplated by my invention is the fact that all process lines are self-draining. In plants of conventional design it is necessary to steam jacket all drain lines in order to prevent undesirable accumulation and subsequent solidification of sulfur. Such lines are expensive to install and, of course, are subject to plugging. The use of self-draining process lines together with an ordinary steel storage tank having adequate external insulation and being so constructed to function as a final separator of liquid sulfur from product gases serves to reduce materially initial plant investment.

Also, in operation of a furnace of the type generally used in sulfur recovery plants, feed water preparation facilities such as surge tanks, feed pumps, level controllers, etc., add considerably to the expense. By using an elevated condenser or elevated process unit, such as amine reboilers, that require heating steam that is self-draining back to the steam section of the boiler, the usual feed water purification facilities can be eliminated to provide a simple inexpensive and serviceable unit.

While my design is particularly applicable to sour gas sources which provide from about 5 to 25 tons of sulfur per day, it obviously may be used for the recovery of much higher tonnages of sulfur with equally good results. Likewise, while I have described my invention with particular reference to its use in a two converter type sulfur plant, it is equally applicable to plants in which only a single converter is employed. Adaptation to the latter type of plant is readily effected merely by making the top half of the boiler a single condensing section rather than two such sections or compartments, said single condensing section having only one inlet port and one exit port.

I claim:

1. In an apparatus for producing elemental sulfur from a gas containing hydrogen sulfide, the combination which comprises an elongated enclosed metal vessel having a combustion chamber therein, means for injection of air and said gas into said chamber, conduits (1) near said opposite end of said chamber communicating with the interior thereof running exteriorly of said chamber and back toward the inlet end thereof, a first tube sheet extending from wall to wall of said vessel holding the open ends of conduits (1) and a portion of said chamber near the inlet end thereof, a second tube sheet holding said opposite end of said chamber extending from wall to wall of said vessel and parallel to said first tube sheet, conduits in said vessel substantially surrounding said combustion chamber and connecting said tube sheets, a first gas tight partition extending from said first tube sheet to the end of said vessel adjacent said first tube sheet and from wall to wall of said vessel thereby defining a first and a second gas tight chamber, each of said chambers thus defined being in communication with separate groups of said connecting conduits held by said first tube sheet, the open ends of conduits (1) being in communication with said second chamber, two outlet ports in said second chamber, a gas tight wall extending from said first partition to the vessel wall facing said partition and from said first tube sheet to the end of said vessel adjacent thereto to divide said first chamber into two compartments, an inlet port in each of said compartments, a second gas tight partition extending from said second tube sheet to the end of said vessel adjacent thereto and from wall to wall of said vessel thereby defining a third and fourth gas tight chamber, each of said chambers thus defining being in communication with separate groups of said connecting conduits adjacent said second tube sheet, an outlet port in said fourth chamber, a gas tight wall extending from said second partition to the vessel wall facing said partition and from said second tube sheet to the end of said vessel adjacent said second tube sheet to divide said third chamber into two compartments, and an outlet port in each of said last mentioned compartments.

2. In an apparatus for producing elemental sulfur from a gas containing hydrogen sulfide, the combination which comprises an elongated enclosed metal vessel having a combustion chamber therein, separate means for injection of air and said gas into said chamber, conduits (1) near the opposite end of said chamber communicating with the interior thereof running exteriorly of said chamber and back to the inlet end thereof, a first tube sheet extending from wall to wall of said vessel holding the open ends of conduits (1) and a portion of said chamber near the inlet end thereof, a second tube sheet holding said opposite end of said chamber extending from wall to wall of said vessel and parallel to said first tube sheet, conduits in said vessel substantially surrounding said combustion chamber and connecting said tube sheets, a first gas tight partition extending from said first tube sheet to the end of said vessel adjacent said first tube sheet and from wall to wall of said vessel thereby defining a first and second gas tight chamber, each of said chambers thus defined being in communication with separate groups of said connecting conduits held by said first tube sheet, the open ends of conduits (1) being in communication with said second chamber, two outlet ports in said second chamber, a gas tight wall at about the center of said first partition and at substantially right angles therewith extending from said first partition to the vessel wall facing said partition and from said first tube sheet to the end of said vessel adjacent thereto to divide said first chamber into two compartments, an inlet port in each of said compartments, a second gas tight partition extending from said second tube sheet to the end of said vessel adjacent thereto and from wall to wall of said vessel thereby defining a third and a fourth gas tight chamber, each of said third and fourth chambers being in communication with separate groups of said connecting conduits adjacent said second tube sheet, an outlet port in said fourth chamber, a gas tight wall at about the center of said second partition and at substantially right angles therewith extending from said second partition to the vessel wall facing said partition and from said second tube sheet to the end of said vessel adjacent said second tube sheet to divide said third chamber into two compartments, and an outlet port in each of said last mentioned compartments.

3. In an apparatus for producing elemental sulfur from a gas containing hydrogen sulfide, the combination which comprises an elongated enclosed metal vessel having a combustion chamber therein, means for injection of air and said gas into said chamber, conduits (1) near the opposite end of said chamber communicating with the interior thereof running exteriorly of said chamber and back toward the inlet end thereof, a first tube sheet extending from wall to wall of said vessel holding the open ends of conduits (1) and a portion of said chamber near the inlet end thereof, a second tube sheet holding said opposite end of said chamber extending from wall to wall of said vessel and parallel to said first tube sheet, conduits in said vessel substantially surrounding said combustion chamber and connecting said tube sheets, a first gas tight partition extending from said first tube sheet to the end of said vessel adjacent said first tube sheet and from wall to wall of said vessel thereby defining a first and a second gas tight chamber, each of said chambers thus defined being in communication with separate groups of said connecting conduits, the open end of conduits (1) being in communication with said second chamber, an outlet port in said second chamber, an inlet port in said first chamber, a second gas tight

partition extending from said second tube sheet to the end of said vessel adjacent thereto and from wall to wall of said vessel thereby defining a third and a fourth gas tight chamber, each of said third and fourth chambers being in communication with separate groups of said connecting conduits adjacent said second tube sheet, and an outlet port in each of said third and fourth chambers.

4. In an apparatus for producing elemental sulfur from a gas containing hydrogen sulfide, the combination which comprises an elongated enclosed metal vessel having a combustion chamber therein, means for injection of air and said gas into said chamber, conduits (1) near the opposite end of said chamber communicating with the interior thereof running exteriorly of said chamber and back toward the inlet end thereof, a first tube sheet extending from wall to wall of said vessel holding the open ends of conduits (1) and a portion of said chamber near the inlet end thereof, a second tube sheet holding said opposite end of said chamber extending from wall to wall of said vessel and parallel to said first tube sheet, conduits in said vessel substantially surrounding said combustion chamber and connecting said tube sheets, a first gas tight partition extending from said first tube sheet to the end of said vessel adjacent said first tube sheet and from wall to wall of said vessel thereby defining a first and a second gas tight chamber, each of said chambers thus defined being in communication with separate groups of said connecting conduits held by said first tube sheet, the open ends of conduits (1) being in communication with said second chamber, two outlet ports in said second chamber, a gas tight wall extending from said first partition to the vessel wall facing said partition and from said first tube sheet to the end of said vessel adjacent thereto to divide said first chamber into two compartments, an inlet port in each of said compartments, a second gas tight partition extending from said second tube sheet to the end of said vessel adjacent thereto and from wall to wall of said vessel thereby defining a third and a fourth gas tight chamber, each of said chambers thus defined being in communication with separate groups of said connecting conduits adjacent said second tube sheet, an outlet port in said fourth chamber, a gas tight wall extending from said second partition to the vessel wall facing said partition and from said second tube sheet to the end of said vessel adjacent said second tube sheet to divide said third chamber into two compartments, an outlet port in each of said last mentioned compartments, a separator and storage vessel connected to said outlet port in said fourth chamber, said separator and storage vessel comprising an elongated enclosed shell having a portion thereof divided into a plurality of fluid tight compartments, an inlet and outlet port in each of said last mentioned compartments, a conduit leading from each of the latter into a common portion of said separator and storage vessel, an inlet port and an outlet port in said common portion, and means for withdrawing product liquid sulfur from said shell.

5. In an apparatus for producing elemental sulfur from a gas containing hydrogen sulfide, the combination which comprises an elongated enclosed metal vessel having a combustion chamber therein, means for injection of air and said gas into said chamber, conduits (1) near the opposite end of said chamber communicating with the interior thereof running exteriorly of said chamber and back toward the inlet end thereof, a first tube sheet extending from wall to wall of said vessel holding the open ends of conduits (1) and a portion of said chamber near the inlet end thereof, a second tube sheet holding said opposite end of said chamber extending from wall to wall of said vessel and parallel to said first tube sheet, conduits in said vessel substantially surrounding said combustion chamber and connecting said tube sheets, a first gas tight partition extending from said first tube sheet to the end of said vessel adjacent said first tube sheet and from wall to wall of said vessel thereby defining a first and a second gas tight chamber, each of said chambers thus defined being in communication with separate groups of said connecting conduits held by said first tube sheet, the open ends of conduits (1) being in communication with said second chamber, two outlet ports in said second chamber, a gas tight wall extending from said first partition to the vessel wall facing said partition and from said first tube sheet to the end of said vessel adjacent thereto to divide said first chamber into two compartments, an inlet port in each of said compartments, a second gas tight partition extending from said second tube sheet to the end of said vessel adjacent thereto and from wall to wall of said vessel thereby defining a third and a fourth gas tight chamber, each of said chambers thus defined being in communication with separate groups of said connecting conduits adjacent said second tube sheet, an outlet port in said fourth chamber, a gas tight wall extending from said second partition to the vessel wall facing said partition and from said second tube sheet to the end of said vessel adjacent said second tube sheet to divide said third chamber into two compartments, an outlet port in each of said last mentioned compartments, a separator and storage vessel connected to said outlet port in said fourth chamber, a separate reaction chamber connected to the inlet port in each of said compartments in said first chamber and to the outlet ports in said second chamber, and separate conduits leading from said fourth chamber and from said compartments in said third chamber to said separator and storage vessel.

6. In a separator and storage vessel for recovering elemental sulfur from a gaseous mixture containing sulfur vapors, the combination comprising an elongated enclosed shell having a plurality of contiguous fluid tight gas separation chambers within a portion of said shell for handling liquids and vapors containing free sulfur, the length and diameter of each of said chambers being less than the respective dimensions of said shell, an individual inlet and outlet port in each of said chambers communicating directly with the exterior of said vessel, and a separate conduit leading from each of said chambers into a common portion of said shell, each of said conduits lying within said shell.

7. In a separator and storage vessel for recovering elemental sulfur from a gaseous mixture containing sulfur vapors, the combination comprising an elongated enclosed shell having a fluid tight gas separation chamber within a portion of said shell for handling liquids and vapors containing free sulfur, the length and diameter of said chamber being less than the respective dimensions of said shell, an individual inlet and outlet port in said chamber communicating directly with the exterior of said vessel, and a separate conduit leading from said chamber into a common portion of said shell, said conduit lying within said shell.

8. In a separator and storage vessel for recovering elemental sulfur from a gaseous mixture containing sulfur vapors, the combination comprising an elongated enclosed shell having two fluid tight gas separation chambers within a portion of said shell for handling liquids and vapors containing free sulfur, the length and diameter of each of said chambers being less than the respective dimensions of said shell, an individual inlet and outlet port in each of said chambers communicating directly with the exterior of said vessel, and a separate conduit leading from each of said chambers into a common portion of said shell, each of said conduits lying within said shell.

9. In an apparatus for producing elemental sulfur from a gas containing hydrogen sulfide, the combination which comprises an enclosed metal vessel having a combustion chamber therein, means for injection of air and said gas into said chamber, an exit port in said chamber opposite said injection means, a first heat exchange means communicating with both said exit port and the

exterior of said vessel, and a second heat exchange means within said vessel superimposed on and spaced apart from said first heat exchange means and said combustion chamber, said second heat exchange means having individual inlet and outlet means communicating with the exterior of said vessel and in non-communicating relationship with said combustion chamber and said first heat exchange means, said combustion chamber and said first and second heat exchange means all being enclosed in a common heat exchange section.

10. In an apparatus for producing elemental sulfur from a gas containing hydrogen sulfide, the combination which comprises an enclosed metal vessel having a combustion chamber therein, means for injection of air and said gas into said chamber, an exit port in said chamber opposite said injection means, a first heat exchange means communicating with both said exit port and the exterior of said vessel, and a second heat exchange means within said vessel and spaced apart from said first heat exchange means and said combustion chamber, said second heat exchange means having individual inlet and outlet means communicating with the exterior of said vessel and in non-communicating relationship with said combustion chamber and said first heat exchange means, said combustion chamber and said first and second heat exchange means all being enclosed in a common heat exchange section.

11. In an apparatus for producing elemental sulfur from a gas containing hydrogen sulfide, the combination which comprises an enclosed metal vessel, said vessel having a first series of tubes arranged therein to define a boiler section, a second series of tubes in said vessel defining a separate condensing section therein having individual inlet and outlet means communicating with the exterior of said vessel but not communicating within said vessel with said first series of tubes, said condensing and boiler sections being enclosed in a common heat exchange section.

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