

[54] **INDUCTION CONDENSER**

[76] Inventor: **George H. Cash**, 8 Holly Lane, Londonderry, N.H. 03053

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[58] Field of Search....**55/80, 83, 261, 264, 468, 466; 110/119, 147, 148; 201/126; 417/155-157; 98/66, 80**

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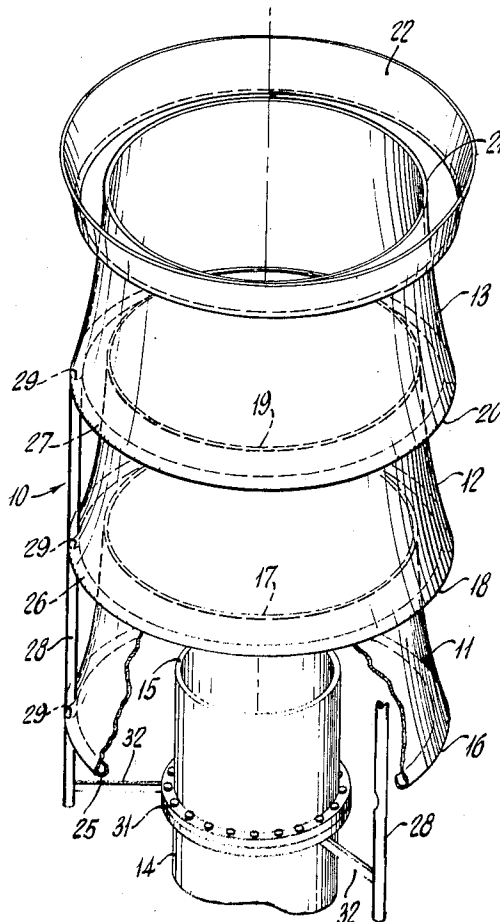
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Primary Examiner—Bernard Nozick
Attorney—Lorimer P. Brooks et al.

[57] **ABSTRACT**

A plurality of low pressure venturis mounted at the top of a stack draw in ambient air to condense vapors in the stack effluents, thus eliminating or minimizing offensive opaque smoke and vapor plumes. Water soluble gases and heavy particulates are also condensed and removed.

10 Claims, 4 Drawing Figures



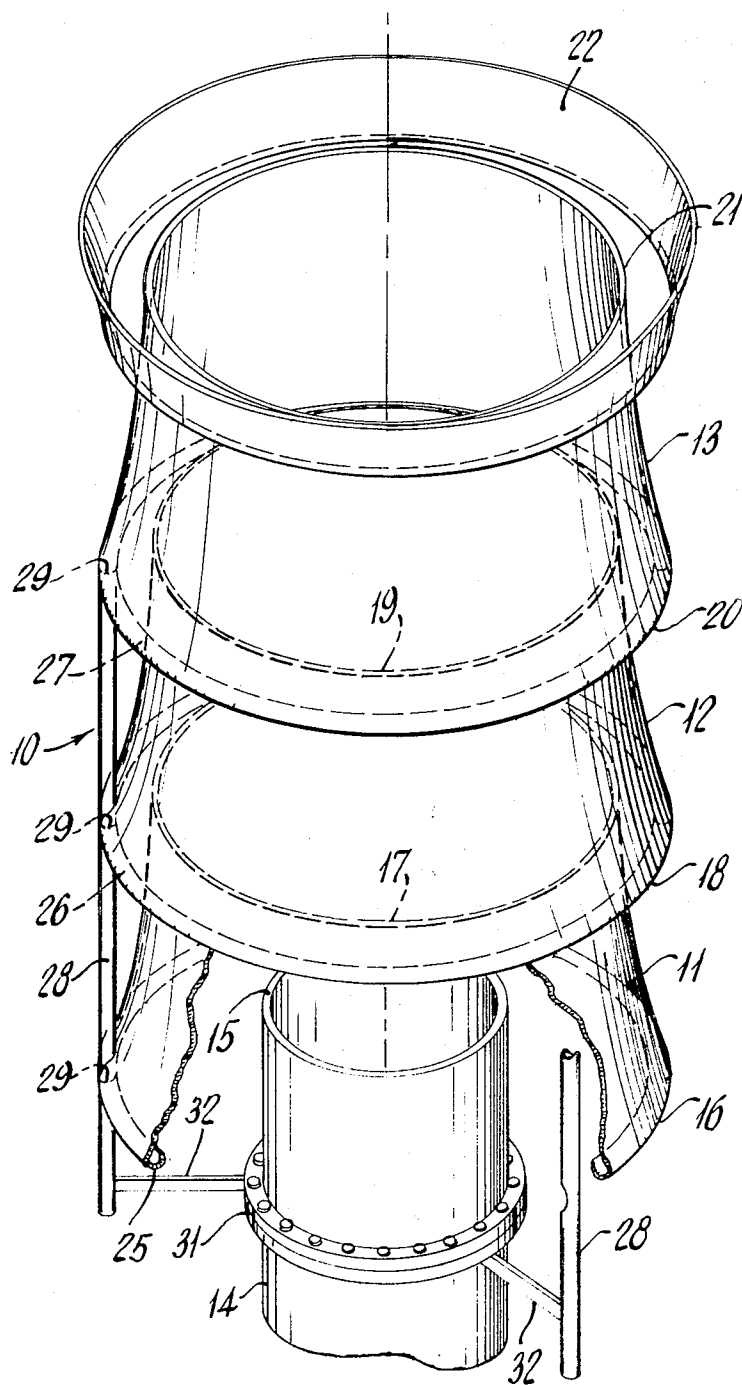
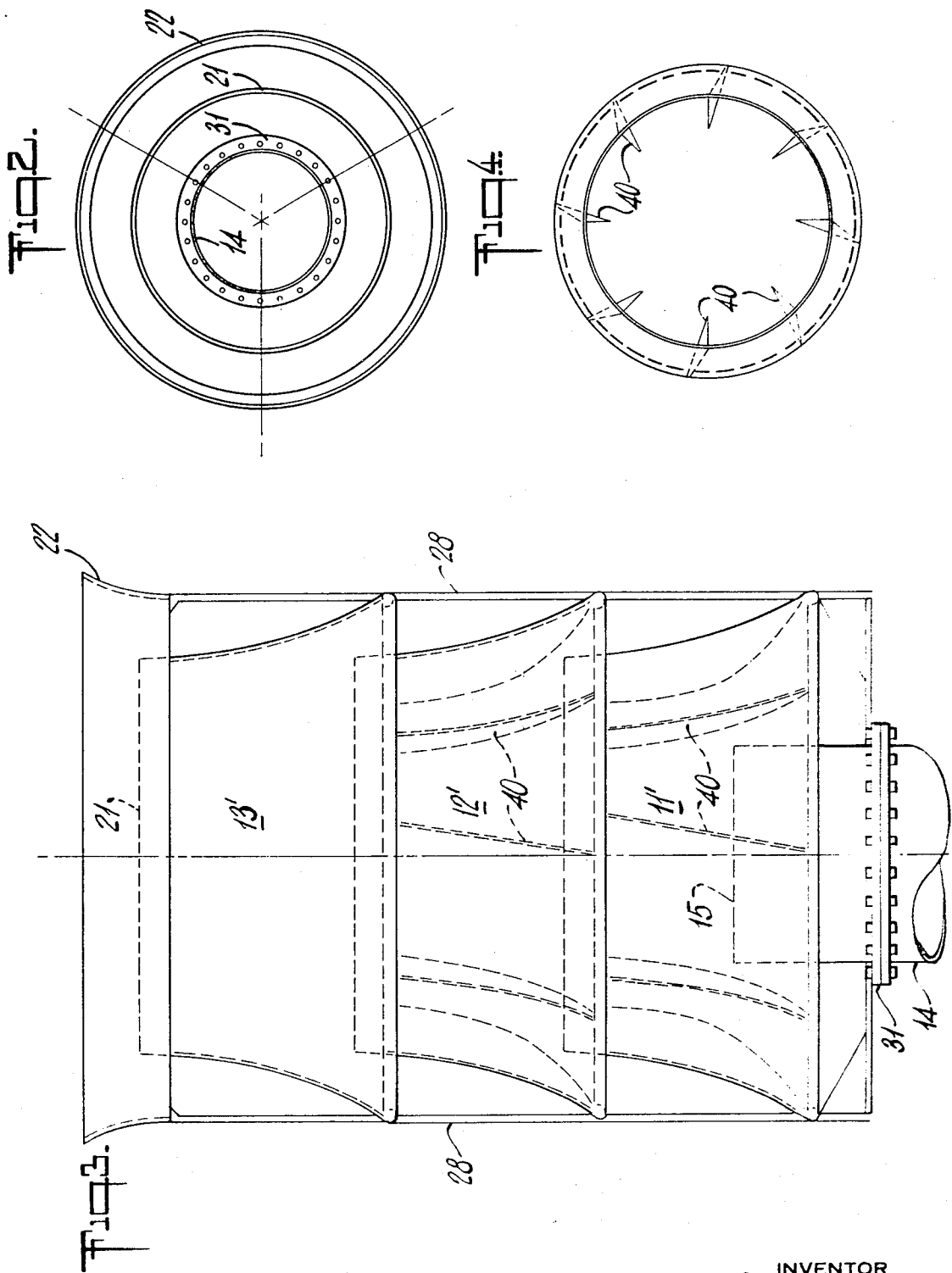


Fig. 1.

INVENTOR
 GEORGE H. CASH
 BY
 Brooks Haight & Haffner
 ATTORNEYS



INVENTOR
GEORGE H. CASH
BY
Brooks Haidt & Hoffman
ATTORNEYS

INDUCTION CONDENSER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to the elimination of visible air pollution by condensing vapors and reducing the opacity of emissions. More particularly, the invention relates to a system using the venturi effect to condense vapors discharged from a stack by drawing ambient air into the stream of effluents.

2. Description of the Prior Art

The effluents from such processes as combustion, evaporation, drying and gas scrubbing contain water vapor, which vapor condenses upon discharge into a colder atmosphere, producing an opaque plume.

Attempts at eliminating condensed vapor plumes from stack exhausts have resulted in schemes for superheating the effluents, systems for surrounding the effluent with a curtain of high velocity clear air, and in various other complex and expensive proposals, none of which have gained acceptance by industry.

SUMMARY OF THE INVENTION

Current anti-pollution regulations and the increasing public awareness of the dangers of air pollution make the elimination of smoke and vapor plumes from stacks highly desirable. The opaque plume from a stack may indicate that the effluents contain noxious gases and particles or may just be the result of condensation of water vapor in a cooler atmosphere. In accordance with the present invention, the moisture content of discharged gases is reduced to substantially the prevailing ambient level, and most of the water soluble gases and heavy particles are removed with the liquid resulting from condensation.

Millions of tons of vapor are ejected into the atmosphere every day from industrial processes. The amount of discharged vapor is such that in low-lying areas and in urban areas the absolute humidity is raised. Recent studies have indicated that smog results from the action of the sun's actinic rays upon a highly humid or supersaturated atmosphere. By condensing the vapor at the stack or chimney, the present invention avoids any contribution to this public nuisance and health hazard.

The vapor condensing arrangement of the present invention includes a plurality of registering low pressure venturis in series, which may be mounted directly on an existing stack or chimney. The effluent carrying vapors entering the first of the venturis induces a flow of air from the surrounding area into the stream in a volume ratio proportionate to the ratio of densities of the effluent to the surrounding air and the velocity of the gas stream. The mixture of gases drops below its dew point temperature and condensation occurs on the inner walls of the venturi. The successive venturis each induce flow of more of the surrounding air into the discharge stream, condensing more of the vapor down to the wet bulb temperature of the ambient air.

The final mixture is dispersed by means of a dispersing ring and enters the atmosphere at a dry bulb temperature close to the wet bulb temperature of the ambient air. Means are provided for carrying off the liquid condensate with entrained particles and soluble gases. The condensable gases such as SO_2 , H_2S and NH_3 are substantially removed during the condensing process.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is an overall perspective view of a preferred embodiment of the condensing system of the invention, with parts broken away to show internal structure.

FIG. 2 is a view from above of the embodiment shown in FIG. 1.

FIG. 3 is a side view of a modified embodiment of the system of the invention, with internal structure shown by dashed lines.

FIG. 4 is a view in horizontal section through one of the venturis of the embodiment of FIG. 3.

DESCRIPTION OF PREFERRED EMBODIMENTS

An illustrative embodiment of the vapor condensing arrangement according to the invention is generally designated by the reference numeral 10 in FIG. 1. As shown in the drawing three similar venturis 11, 12 and 13 are mounted in series on a stack 14, concentrically with the axis of the stack. The upper end or mouth 15 of the stack 14 is received centrally within the widened lower end 16 of the lowest venturi 11. The upper end 17 of the venturi 11 is received centrally within the lower end 18 of the middle venturi 12. The upper end 19 of the middle venturi 12 is itself centrally received within the lower end 20 of the topmost venturi 13, the upper end 21 of which is surrounded by a dispersing ring 22. A venturi is a tube that has a flaring end and a constricted section forming a throat, that depends for operation on the fact that as velocity of flow of fluid increases in the throat the pressure decreases. The venturis 11, 12 and 13 according to the invention have gently curving walls as shown in the drawing for most effective operation and smooth flow. The characteristics of the venturi are well-known.

Each of the venturis 11, 12 and 13 is of similar size and shape, the proportions of the venturi being determined in accordance with the exhaust velocity and temperatures of the stack gases as well as prevailing ambient atmospheric conditions in a manner to be described. The venturis 11-13 and the dispersing ring 22 are preferably formed of strong, yet light weight, corrosion resistant material such as material produced from glass fibers and marketed under the trademark "Fiberglas." Stainless steel or some other metal might also suitably be used.

The widened lower ends 16, 18 and 20 of the venturis 11-13 are formed with similar inner circumferential troughs or gutters 25-27 respectively. As shown in FIG. 1 the gutters 25-27 may be suitably formed as returned upward and inward bent lips integral with the material of the respective venturis. When liquid condenses on the inner surfaces of the upstanding venturi walls, it runs down the venturi walls to be collected in the gutters 25-27. Three equally radially spaced hollow pipes 28 serve to support the assembly of venturis and the dispersing ring. As shown in FIG. 1 the pipes 28 have openings 29 registering with the gutters 25-27 at the points where the pipes 28 meet the gutters 25-27 so that condensate collected by the gutters will be drained through the openings 29 and carried off down the pipes 28.

Generally, the support pipes 28 may be secured firmly to the stack 14 as by a mounting ring 31 and radially extending struts 32 as shown in FIG. 1. Of course other suitable mounting arrangements could be

substituted for that illustrated in FIG. 1. The pipes 28 may extend all the way down to the base of the stack 14 or some other suitable arrangement for carrying off condensate can be utilized where the particular conditions make another arrangement desirable. Since it is contemplated that the vapor condensing system of the invention will be used on existing stacks and chimneys, this flexibility of the arrangements for drainage is a valuable advantage of the invention.

In order to achieve effective operation of the system according to the invention, the size of the venturis 11, 12 and 13 is determined as follows:

The maximum pressure drop available for the induction of ambient air through the system may be computed by using a well known engineering rule of thumb.

$$\text{Pressure drop} = (\text{exhaust velocity})^2 / 4000$$

where the pressure drop is in inches of water and the exhaust velocity is the velocity of gases leaving the stack measured in feet per minute. Thus in a typical example where the velocity of the exiting gases is 2,000 ft/min the pressure drop is 0.25 inches of water.

An aspiration curve characteristic of the venturi units of the invention gives the ratio of the volume of induced air to the volume of emission gases as a function of the temperature of the emission gases. Thus in a typical example the volume of induced air is determined as follows:

EXAMPLE

A stack 14 emits gases at 150°F. The volume rate of emission is 50,000 cubic feet per minute. Then the volume rate B of induction of ambient air follows the formula

$$B = A/R$$

where R is a function of the temperature of the exhaust gases characteristic of the low pressure venturi system of the invention and A is the volume rate of the exhaust gases entering the venturi. It has been found that the parameter R varies as follows with stack temperature

Temperature of emitted gases in degrees F	R
70	1.00
80	1.04
90	1.06
100	1.10
110	1.12
120	1.14
130	1.16
140	1.20
150	1.25
160	1.32
170	1.39
180	1.48
190	1.60
200	1.75
212	1.94

So at 150°F : $B = A/1.25 = 50,000/1.25 = 40,000$ ft.³/min.

Thus the volume of gases leaving the first venturi 11 is 90,000 cubic feet per minute. The temperature of the gas mixture leaving the first venturi of course depends on the temperature of the ambient air which was in-

duced into the stream. If the ambient air is at a temperature of 75° the mixture has a temperature of 115°F.

The volume rate of induction of air by the second venturi 12 is calculated in the same way as for the venturi 11. At 110°F, R is 1.12, so the volume of induced gases is about 80,000 cubic feet per minute. The ratio R is higher because the cooler, denser gas mixture can draw more of the ambient air into the system than can the less dense hotter gas. Therefore the third venturi 13 receives a stream of 170,000 cubic feet per minute of mixed gases at a temperature of about 93°F.

The volume of air induced by the venturi 13 can be readily calculated in the manner indicated for the venturis 11 and 12.

It will be obvious from the foregoing that each successive venturi must handle a larger flow of gases at a lower temperature. It would seem that the venturi 12 would necessarily need to have a larger throat diameter than the venturi 11 and that the venturi 13 would need to be still larger. Surprisingly it has been found that the venturis 11, 12 and 13 may all be the same size with little loss of efficiency and a small deviation from the predicted results. Thus the system of the invention can be made much more economically than if venturis of three different diameters were used. Of course, somewhat better results can be obtained with venturis sized according to the amount of gases they must handle, but that is not necessary.

From the temperatures in the above illustrative example it will be seen that multiple stages are necessary to take advantage of the temperature difference between the exhaust A and the ambient air B and to obtain maximum heat transfer. For every pound of vapor condensed about 1,000 BTU's of heat are absorbed as latent heat, this reducing temperature rapidly and providing a thermodynamic advantage.

In some cases a system of two or of four venturis may be preferable to the three venturis 11, 12 and 13 shown, as will be obvious to those of ordinary skill in the art.

It has been found in several experimental installations of the vapor condensing system of the invention that the dry bulb temperature of the mixture of gases finally dispersed by the dispersing ring 22 is close to the wet bulb temperature of the ambient air, so that no opaque plume appears above a stack. This has been found to be true for a wide range of ambient air temperatures and conditions of relative humidity.

In a modified embodiment of the invention shown in FIGS. 3 and 4, the venturis 11', 12' and 13' are similar to the venturis 11, 12 and 13 of FIGS. 1 and 2 except that the venturis 11' and 12' are equipped with a plurality of internal spiral vanes 40 for imparting a degree of swirling motion to the induced air. This swirling motion enhances the mixing of the induced cooler air with the exhaust gases. The vanes 40 are preferably formed of the same material as the venturis 11' and 12'.

Other variations and modifications within the spirit and scope of the present invention may include providing an internal baffle centrally disposed in the stream of gases through the condensing system to force the gases into contact with the interior of the venturis and the provision of throttling means on the stack itself to increase the speed of flow of exhaust gases. Numerous other obvious modifications will suggest themselves to

those of ordinary skill in the art. What is disclosed is a new and advantageous arrangement for condensing exhaust gases and eliminating opaque plumes resulting from industrial processes.

What is claimed is:

1. In combination with a stack a system for condensing vapors in gases emitted from the stack comprising a plurality of vertical registering low-pressure venturi units defining annular spaces between each of said units, said units being mounted in series for receiving air and a stream of emitted gases, each venturi unit of said system having a wide lower end, and a gently curved wall terminating in an upper end narrower than said lower end operating to induce a flow of ambient air into the system in a volume ratio proportionate to the ratio of the density of effluents entering the venturi to the density of the surrounding atmosphere, and means defining a gutter within and extending from the lower end of each venturi unit and including means for draining off condensate resulting from the condensing of gases within the venturi walls.
2. The system of claim 1 wherein the venturi units all have substantially the same throat diameter at their narrow upper ends.
3. The system of claim 1 and including a dispersing ring mounted above the last venturi unit in the system for dispersing gases passed through the system.
4. The system of claim 1 wherein at least one of said venturi units has a plurality of spiral vanes mounted therein for enhancing the mixing of induced air with the emitted gases.
5. A vapor condensing system adapted to be mounted above conduit means for condensing vapors in gases emitted from such conduit means, comprising a plurality of vertically registering low pressure venturi units defining annular spaces between each of said units, said units being mutually secured in series for receiving air and a stream of emitted gases, means for

mounting the units above conduit means, a narrowed upper end of each but the uppermost of said venturi units being coaxially received within a widened lower end of a next higher venturi unit, all of said venturi units being of circular horizontal cross section and having a gently inwardly and upwardly curving wall for smooth gas flow therethrough, the uppermost of said venturi units having a dispersing ring mounted at its upper end, each of said venturi units having an intumed lower end edge defining a peripheral gutter within and extending from the lower end of the venturi unit, the gutters of all of the venturi units communicating with vertical common drainage means for receiving and discharging condensate formed within the venturi units.

6. The system of claim 5 wherein the drainage means comprises a plurality of vertical tubes having openings communicating with said gutters, said vertical tubes also constituting supports for the venturi units and dispersing ring.

7. The system of claim 5 wherein at least one of said venturi units has a plurality of spiral vanes mounted therewithin for imparting swirling motion to air induced into the system to enhance condensation by mixing the gases within the venturi unit with entrained air, said spiral vanes extending only from the lower end of the venturi unit to the upper end of the venturi unit and having their radially inner edges spaced from any registering unit.

8. The system of claim 5 wherein all said venturi units have the same throat diameter at their narrowed upper ends.

9. The system of claim 5 wherein the venturi units are formed of strong light weight material produced from glass fibers.

10. The system of claim 5 wherein there are three mutually similar venturi units.

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