Jan. 3, 1967 W. R. STELLING, JR., ET AL 3,295,842

WEB TEMPERATURE CONTROL APPARATUS

Original Filed March 15, 1961 2 Sheets-Sheet 1

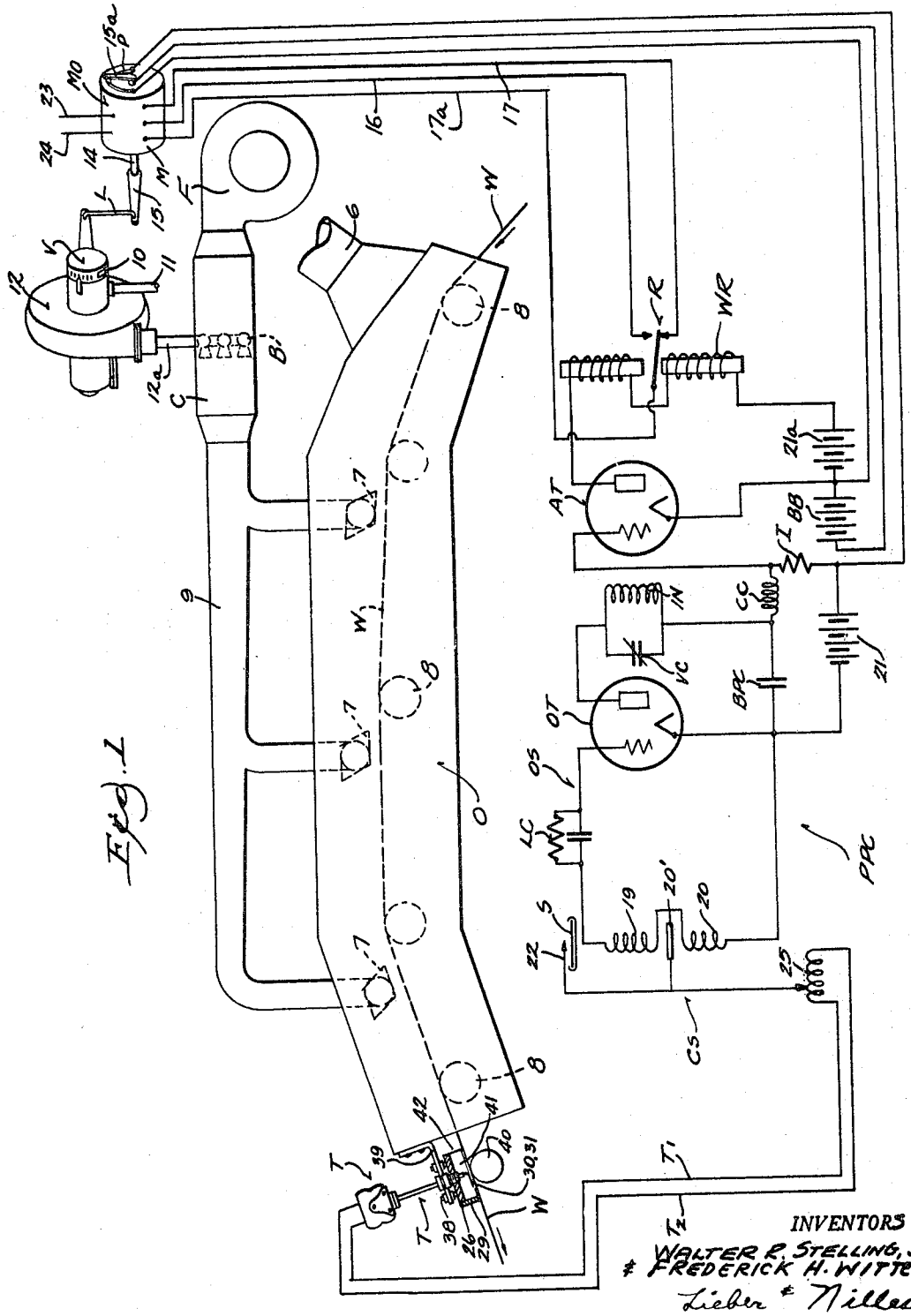


Fig. 1

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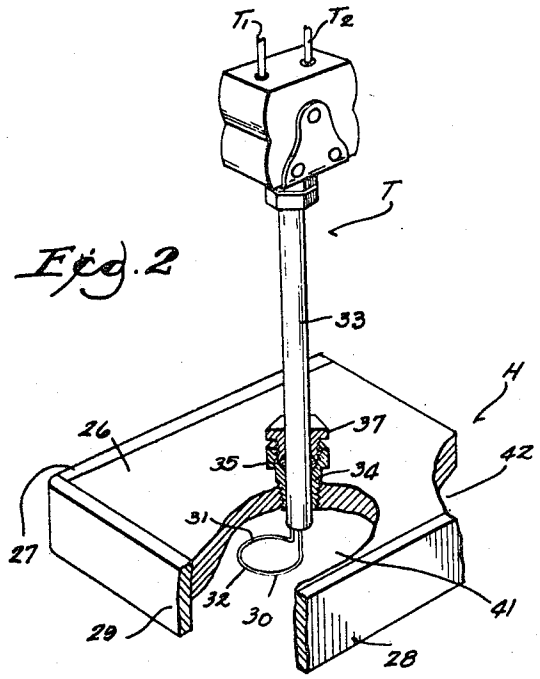


Fig. 2

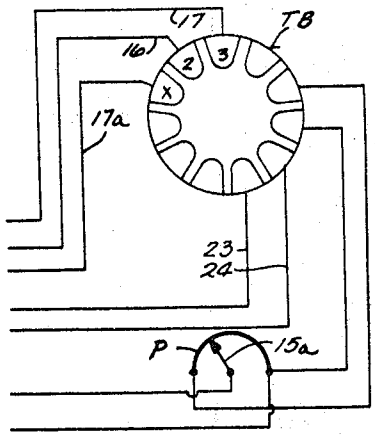


Fig. 6

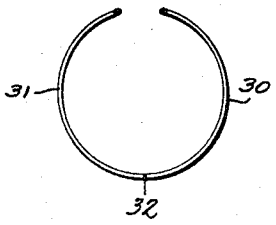


Fig. 5

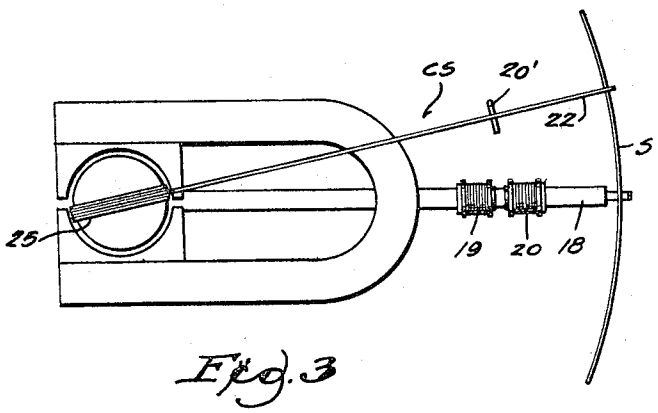


Fig. 3

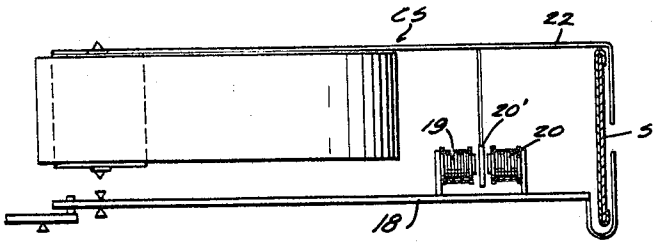


Fig. 4

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WEB TEMPERATURE CONTROL APPARATUS

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Original application Mar. 15, 1961, Ser. No. 96,026, now Patent No. 3,163,406, dated Dec. 29, 1964. Divided and this application Aug. 8, 1963, Ser. No. 300,878

1 Claim. (Cl. 263—3)

This invention relates generally to drying ovens for webs and relates more particularly to temperature control systems for such webs.

This application is a divisional application of U.S. Serial No. 96,026 filed March 15, 1961 which issued as Patent No. 3,163,406 on December 29, 1964.

In equipment of the type to which the present invention relates, it is important to be able to accurately control the temperature of the web to prevent web damage by temperatures which are too high, and on the other hand, to insure sufficient heat to properly dry the web.

Many factors affect the drying effect of the web for any setting of the oven, for example, varying moisture content or different web speeds. It is imperative to be able to immediately change the heat input to the rapidly moving web so as to provide the proper drying effect without delay and without casing the control mechanism to "hunt."

Shortcomings of conventional drying systems include their tendency to "hunt" in attempting to establish the proper web temperature—a slight blast of heat causing excessive web temperature rise. Other conventional systems use web temperature sensing devices which in themselves give false or inaccurate temperature readings, due in some cases, to the heat of friction developed by the moving web in contact with the sensing device.

Accordingly, the present invention provides a web temperature sensing device which will accurately measure the temperature of the web as the latter leaves the drying oven and without contacting the web.

More specifically, the invention provides an improved thermocouple and holder therefor by means of which the sensing end of the thermocouple accurately senses the web temperature and can be precisely adjusted relative to and protected from the rapidly moving web.

These and other objects and advantages will appear herein as this disclosure progresses, reference being had to the accompanying drawings, in which:

FIGURE 1 is a schematic diagram of a web drying oven assembly and a circuit diagram of the web temperature control system in accordance with the present invention;

FIGURE 2 is a perspective view of the thermocouple unit shown in FIGURE 1, but on an enlarged scale and with parts broken away and in section for clarity in the drawings;

FIGURES 3 and 4 are plan and side elevational views of the contactless sensitive instrument means for use in the circuit shown in FIGURE 1;

FIGURE 5 is an enlarged detail view of the loop end of the thermocouple made in accordance with the present invention; and

FIGURE 6 is a schematic external wiring diagram of the motor operator.

Oven

Referring in greater detail to the drawings, the drying oven O is of the enclosed tunnel type having an exhaust conduit **6** extending from adjacent the entry end of the tunnel. A series of blast tubes **7** extend inside the tunnel and across its width and act to produce a direct and localized blast of air on the web W as it moves rapidly

through the tunnel on the idler rolls **8** and in the direction indicated by the arrow in FIGURE 1. The supply conduit **9** furnishes heated air to one end of each of the tubes from the heating chamber C in which is located the burner B, to be described. If a more complete description of the structure and function of the blast tubes or oven is deemed necessary or desirable, reference may be had to the co-pending United States patent application, Serial No. 52,117, filed August 6, 1960, and entitled, "Web Dryer," which issued on January 22, 1963, as U.S. Patent No. 3,074,179.

Air supply

A fan F is provided for forcing air past the burner B, through conduit **9**, out of the tubes **7** and over the surface of the web. In the illustration shown, the burner is located on the pressure side of the fan F but of course the burner could also be located on the suction side of the fan. The air supplied by the fan is preferably filtered and may consist of fresh air mixed with some of the air which has been exhausted from the oven O. In other words, the system may be of the recirculating or non-recirculating type, with the burner located on the suction or pressure side of the circulating fan.

Fuel Valve

Means are provided for furnishing a properly proportioned mixture of air and fuel to the burner. This means consists of a conventional mixing or ratio valve mechanism V having an air inlet opening **10** and a fuel supply conduit **11** for supplying fuel such as gas to the valve mechanism. The valve mechanism is located on the inlet side of the blower **12**, and the gas and air are intimately mixed and then delivered by blower **12** through its outlet conduit **12***a* to the burner. These ratio valves are conventional and may be of the type shown in United States Patent No. 2,286,173, issued June 9, 1942, and further description of them is not believed to be necessary except to say that the valve mechanism serves to vary the volume of air as received from a supply source at any pressure, and to vary the volume of fuel as received from a supply source at any pressure, and to modify the proportioning so obtained, and to establish such modification for different stages of the feed flow of the proportioned air and fuel; by such facility, the combustible mixture ultimately resultant from said proportioning, being of consistency which is dictated by the conditions under which the burner is operated. In short, the valve mechanism is opened or closed to vary the amount of fuel by a linkage L to thereby vary the heat delivered by the burner.

Fuel valve adjusting means

Means are also provided for actuating the linkage L and this means may take the form of a motor operator MO which includes an electric shaded coil motor M having a rotatable shaft **14**. A link **15** is secured to one end of the shaft **14** and is connected with linkage L for operation thereof. An adjustable resistor or potentiometer carried by the motor has a wiper or slider **15***a* secured to the other end of shaft **14**. The motor M of the operator is driven in either direction, and is connected by wires **16**, **17**, and **17***a* to a relay R of the proportional position control PPC, as will more fully appear. The direction of rotation of the motor shaft **14** is determined by the relay R of the control apparatus to be described, and the shaft is caused to rotate in one direction to thereby open the valve mechanism V the desired amount for more heat; and in the opposite direction to close the valve mechanism V the desired amount through the linkage L. The motor operator MO is also of conventional design may be of the type manufactured by Barber-Colman Company of Rockford, Illinois.

Proportionate position control

A proportional position control PPC serves to position the shaft **14** of the motor M in proportion to a temperature change as sensed by a thermocouple T connected by conductors T1 and T2 to the control PPC. The proportional position control PPC may be of the type manufactured by Wheelco Division of Barber-Colman Company and as shown in Patent 2,228,163, issued January 7, 1941, and enables a vacuum tube oscillator to control a relay without requiring the engagement of contacts for controlling the oscillator. This control may utilize a relay such as shown in Patent 2,443,784, issued June 22, 1948, and a brief description of the control PPC will follow which is believed sufficient for purposes of this disclosure.

The apparatus and circuit shown in FIGURE 1 comprises; an oscillator circuit OS including an electron discharge gun in the form of a vacuum or oscillator tube OT, a grid leak and condenser LC in the input or grid circuit of tube OT, tuning or pick-up coils **19** and **20**, and the output circuit of tube OT may be supplied from a battery **21**; contactless sensitive instrument means CS to be presently described for affecting the oscillator circuit; and an electro-responsive device such as a relay apparatus R controlled by the oscillator output change for controlling the temperature to which the contactless sensitive means CS is responsive. In order to effect operation of the polarized relay R in response to changes in the plate current of the oscillator circuit OS, a repeater or amplifier tube AT is provided. The load impedance I is common to both the output circuit of the oscillator tube and the input circuit of the repeater tube, the latter circuit extending through the potentiometer P which is connected across a suitable bias battery BB. Also included in the circuit are a radio frequency choke coil CC, an inductance IN, and a variable condenser VC. A by-pass condenser BPC is located in the by-pass circuit which together with the choke coil CC prevents the flow of high frequency oscillatory currents through the load impedance I and the battery **21**, only the non pulsating component of the plate current flowing through the load impedance and the battery.

The output circuit of the tube AT is energized from a suitable battery **21***a* and extends to the winding WR of the relay R. Energization of the winding operates the moveable contact of the relay.

The motor M of the motor operator MO is connected to a source of energy through conductors **23**, **24**. The motor is also connected to the proportionate position control by wires **16**, **17**, and **17***a*. More specifically, wires **16** and **17** are connected to the contacts of relay R, and wire **17***a* is the ground. As shown in FIGURE 6, the ground line **17***a* is connected to the terminal X of the terminal block TB of the motor, and lines **16** and **17** to terminals **2** and **3** respectively. The direction of motor rotation depends, of course, on the position of the relay switch, and when a circuit is formed between points X and **2** of the block, the motor rotates in one direction; when the circuit is through points X and **3**, motor rotation in the opposite direction occurs. Thus, operation of the relay effects corresponding operation of the motor M and the motor operator to control the fuel valve V, previously described.

The contactless sensitive means CS includes a setting pointer **18** which is manually set along a temperature scale S at the pre-determined temperature at which it is desired to hold the web. Secured to the setting point **18** are the pair of oscillator pick-up coils **19** and **20** between which flows an oscillating current. The frequency of this oscillating current is changed when a metal flag **20'** mounted on a temperature indicating pointer arm **22** is moved between the coils by the slightest temperature change as sensed by the thermocouple T. That is to say, the sensing thermocouple T develops a millivoltage and

causes the indicator flag to swing between the pre-positioned oscillator pick-up coils. More specifically, fluctuations of web temperature affect the thermocouple T so as to vary the energization of the winding **25**, whereby fluctuations in temperature are converted into corresponding movements of the arm **22**, pivoted at **22***a* and its flag **20'**, movement of the flag being effective through the circuit shown cause the relay winding to open or close the contacts of relay R, and thus actuate the motor M to control the heat input of the burner B. Stated otherwise, the output of the oscillator circuit varies depending on the position of the flag in the coils and is fed to the polarized relay R.

As previously mentioned, the relay R causes the motor M to be driven in one direction or the other. An adjustable resistor or slider **15***a* fixed on the end of the motor shaft **14** is thus driven to match the oscillator output to the polarized relay. Stated otherwise, the resistor **15***a* is rotated until it picks off the same voltage as the output of the proportionate position control PPC.

Thus, as the motor shaft **14** rotates, the process input will be proportioned depending on the relative position of the setting pointer **18** and the indicator arm **22**. Thereby, in this modified bridge type control circuit, a change in web temperature causes an electrical unbalance of the polarized relay, and this unbalance causes the motor M of operator MO to rotate in one direction or the other and correspondingly to move the valve mechanism V in a direction to restore the web temperature toward the pre-determined value and bring the electrical bridge into balance.

Thermocouple and holder

The novel thermocouple will now be described in detail as well as the novel means for mounting it and sensing the temperature of the web.

The web moves through the oven at high rates of speed, for example, speeds of 200 to 600 feet per minute are not uncommon. An air stream or air curtain is developed along the surfaces of the web and moves along with it. This curtain is in the nature of one-eighth of an inch in thickness and "clings" tightly to the web surface. In other words, there is a stratification of air adjacent the surface of the web which hangs on to the web and moves along with it. It is this curtain of air that provides a good medium for sensing the temperature of the web because when the web leaves the oven after traveling a considerable distance through it, the air curtain is at the same temperature as the web itself.

The thermocouple T is positioned accurately and closely adjacent to the surface of the web within the air curtain, and adjacent the discharge end of the oven. By positioning the end or hot juncture of the thermocouple at a distance of approximately one-thirty second of an inch from the web surface, accurate temperature readings of the web itself can be made.

A holder H is provided for precisely locating the thermocouple in adjustable relationship to the web surface to thereby pick up the web "air-skin" temperature. This holder consists of a fiber block base member **26** having two opposite sides **27** and **28** secured thereto and which have their free edges positioned closely adjacent the web surface. A rear wall **29** also extends from the base member **26** to closely adjacent the web surface. The extreme end of the thermocouple is formed as a loop, one portion of the loop being constituted of a metal such as constantan **30** and another portion of the loop being constituted of a metal such as iron **31**. Both of these metals are joined together to form a hot junction **32** where the temperature is actually sensed. By forming these two wires to define a loop, a much more accurate sensing of the web is obtained. In other words, by forming a flat loop and having it positioned parallel to the web, the wires cover a greater portion of the width of the web and a more accurate reading is obtained at the hot juncture **32**.

The loop is also positioned so that it extends in a direction in which the web is traveling so that it will not be bent, twisted or otherwise damaged if it is accidentally touched by the rapidly moving web.

As indicated, it is also necessary to precisely locate this loop relative to and closely adjacent the web, and for this purpose a coarse adjustment and a fine adjustment are provided as follows. A threaded fitting **34** is securely engaged in the base member **26** and a tube **33** extends through the fitting and contains the wires T1 and T2 of the thermocouple. An adjustable nut **37** in threaded engagement with fitting **34** acts to compress a double beveled ferrule **35** located on the tube. Thus, a pressure fitting is formed for the tube and allows the tube to be adjusted relative to the fitting **34** to provide the coarse adjustment. The fine adjustment for locating the thermocouple precisely relative to the web is provided by the set screw thread connection **38** between the holder H and the bracket **39** by means of which the holder is mounted on the oven.

It is necessary to prevent the web from fluttering and for this purpose a roller **40** is positioned under the web and immediately under the thermocouple. It will be noted the extreme end of the thermocouple is located within the substantially enclosed chamber **41** formed by the base member and the three sides **27**, **28**, and **29**. The air curtain rushing along with the web enters the chamber **41** via the opening **42** in the front side of the holder H. With this particular holder and thermocouple arrangement, and the shape of and proximity of the thermocouple loop end to the web, the thermocouple is very accurate in sensing the temperature of the web. The fiber block is a poor heat conductor which minimizes heat dissipation from the holder.

Various modes of carrying out the invention are contemplated as being within the scope of the following claim particularly pointing out and distinctly claiming the subject matter which is regarded as the invention:

In a web dryer oven having a discharge end from which the rapidly moving and dried web emerges, a thermocouple holder secured on the outside of said oven and adjacent said end, said holder comprising, a base member adapted to be rigidly positioned adjacent a surface of said web, at least two opposite side walls extending generally in the direction of web movement and also a rear wall, all walls extending downwardly from said base member and towards said web and having free edges positioned closely adjacent said web, said base member and said walls together with said web defining a substantially enclosed chamber having a front side, unobstructed opening for an air curtain moving along with said web, said front side opening facing in the direction from which the web approaches said holder, a thermocouple secured on said holder and having a free end comprised of a flat loop and located in said chamber and closely adjacent to and parallel with said web, means for adjusting said holder relative to said web, and means for adjusting said thermocouple relative to said holder and web.

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