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SHELL-TUBE HEAT EXCHANGE APPARATUS FOR CONDENSATE SUBCOOLING

Filed March 18, 1957

2 Sheets-Sheet 1

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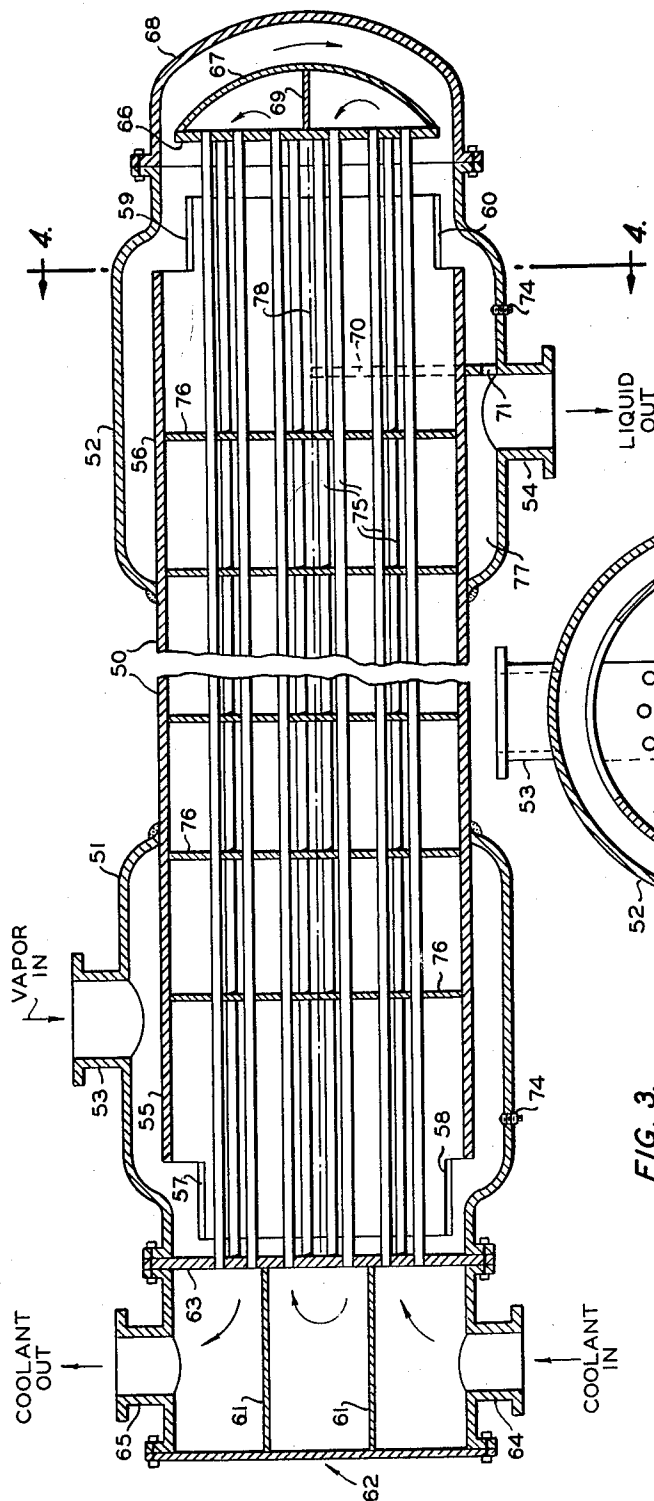


FIG. 3.

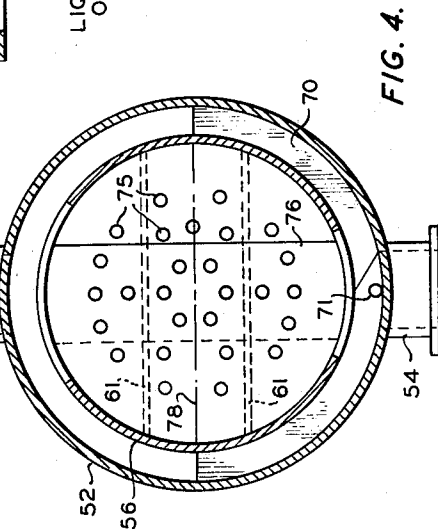


FIG. 4.

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SHELL-TUBE HEAT EXCHANGE APPARATUS FOR CONDENSATE SUBCOOLING

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6 Claims. (Cl. 257—32)

This invention relates to shell-tube heat exchange apparatus for condensate subcooling. In one aspect it relates to shell-tube heat exchange apparatus for condensing vapor and subcooling the condensate so produced to a temperature below its condensation temperature.

In shell-tube type heat exchangers wherein the cooling fluid passes through the tubes in indirect heat exchange with vapor to be condensed, it is sometimes desired to withdraw condensate from the exchanger at a temperature below the temperature at which the vapor was condensed. By so operating such an apparatus as a condenser and as a subcooler, separate pieces of equipment to do these two services, are not required. The main object of subcooling a condensate is to prevent flashing from occurring when such a condensate is passed from the condensing heat exchanger at the heat exchange temperature to a point of lower pressure. Condensate formed at a given temperature and pressure might be considered approximately in equilibrium with the vapor phase from which it was produced. It is obvious, then, if the pressure of this condensate is reduced, as at the suction inlet of a transfer pump, while the condensate is maintained at approximately its condensation temperature, flash vaporizing may occur.

A main object of this invention is to provide an apparatus for subcooling condensate in the condenser in which the condensate is produced.

Another object of this invention is to provide a single apparatus for condensing vapor and for subcooling the condensate to a temperature below the condensation temperature.

Still another object of this invention is to provide a single apparatus in which the condensation and subcooling of the condensate is carried out, the apparatus being substantially no more expensive than a conventional condenser.

Still other objects and advantages of our invention will be realized upon reading the following description which, taken with the attached drawing, forms a part of this disclosure.

In the drawing,

Figure 1 illustrates in diagrammatic form an elevational view, partly in section, of one embodiment of our invention.

Figure 2 is a sectional view taken along the line 2—2 of Figure 1.

Figure 3 is an elevational view, partly in section, of another embodiment of our invention.

Figure 4 is a sectional view taken along the line 4—4 of Figure 3.

Applicants have specifically devised a condenser for condensing vapor and subcooling condensate formed therein comprising, in combination, a horizontally disposed shell, a bundle of condenser tubes in said shell, said condenser having a head end and a floating end, an inlet in the upper portion of said shell for inlet of vapor to be condensed, a conduit disposed around at least the lower portion of said shell adjacent one end thereof, an outlet

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for fluid in the lower portion of said conduit, a first passageway at least near said one end of said shell for passage of condensate to said conduit, a baffle in said conduit intermediate said outlet for condensate and said passageway, said baffle extending vertically in said conduit to a level intermediate the bottom and top of said bundle of tubes to maintain a body of condensate in contact with the lower tubes of said bundle, a second passageway within said conduit and over the top level of said baffle for overflow of condensate from said body of condensate to said outlet for condensate, and an inlet and an outlet for coolant to and from said condenser tubes.

Referring now to the drawing, and specifically to Figures 1 and 2, reference numeral 10 identifies a shell of the heat exchanger. Reference numeral 11 identifies a distributor member 11, one edge of which is attached to the outer surface of the shell 10 at welds 39 thereby forming an annular passageway or conduit 40 therebetween. The other edge of the annular member 11 is formed as a flange to which a coolant inlet and outlet member 21a is bolted by bolts 36. This coolant inlet and outlet end of the exchanger is herein termed the head end of the exchanger. The adjacent end of the shell 10 is likewise termed the head end of the shell. The opposite end of the shell, and of the exchanger is termed the floating end of the shell, and of the exchanger. An inlet 12 is disposed in the upper portion of the distributor member 11 for inlet of vapors to be condensed. Reference numeral 15 identifies a cut-out section in the upper head end portion of the shell for passage of vapors from the conduit 40 into the upper tube section 18 of the condenser. A connection 13 is provided in the lower portion of member 11 for outlet of condensate from the exchanger. The portion of the shell enclosed within member 11 is herein termed a sleeve and is identified by reference numeral 14. Reference numeral 16 identifies a cut-out portion in the lower head end portion of the sleeve 14. This cut-out section 16 provides a passage for outlet of condensate from the lower tube portion of the condenser to the lower portion of conduit 40. The condenser tubes, as a whole, are herein termed a bundle of tubes, which terminology is common in the condenser art. This bundle of condenser tubes is operatively complete in that it is assembled with a floating tube sheet 32 and a head end sheet 41 to support the tubes fluid tight. The tubes of this bundle are identified by reference numeral 31. Since the inlet and outlet to this exchanger are at the same end a baffle 17 is provided to make certain that fluid to be condensed and condensate travel the full lengths of the upper tube portion 18 and the lower tube portion 19.

In the lower portion of the conduit 40 is provided an annular submergence dam 26. This annular submergence dam 26 is composed of two sections, section 26a and section 26b, as shown in Figure 2. One of these sections, for example section 26b in Figure 2, extends upward from the condensate outlet 13 to a level at which it is desired to maintain liquid in the lower tube section 19. The section 26a of the annular dam extends up the other side of the conduit 40 to the same level. As illustrated in Figure 2, the annular submergence dam 26 is illustrated as being composed of the two sections for purposes of installation. Reference numeral 42 identifies the line of juncture of these two sections. At still a higher level in the conduit 40 are provided separate baffles 29. These baffles 29 are intended to provide a fluid tight separation between the upper portion of conduit 40, referred to herein as the vapor inlet portion, and the lower portion of the conduit, referred to as the liquid or fluid outlet portion. Reference numeral 28 identifies the condensate level in the lower tube portion 19 of the condenser. As mentioned,

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this condensate level is intended to be substantially the same level as the upper ends of the submergence dam 26. If it is desired to operate such an apparatus with a higher liquid level in the lower tube section 19, it is merely necessary to construct the apparatus so that the annular submergence dam rises to a higher level in the lower conduit 40. An opening 27 is provided in the bottom of the annular submergence dam 26 for drainage of liquid from the condenser at such a time as it is desired to disconnect a pipe from outlet 13. Cross baffles 30 are provided in the upper tube portion 18 and lower tube portion 19 so that the vapor being condensed and the condensate follow tortuous paths for efficient heat exchange.

Reference numeral 33 identifies a floating head cover 33 which covers the open ends of the tube at the floating head end of the exchanger while a shell cover 34 covers the floating end of the condenser and is attached to the shell by bolts 35.

The coolant inlet and outlet at the head end of the condenser, are provided with the coolant inlet and outlet member 21a. A baffle 20 is disposed at about a midpoint of this member to provide separate inlet and outlet coolant sections 22 and 21, respectively. Reference numerals 23 and 24 identify a coolant inlet and a coolant outlet connection to this section.

A drainage plug 33 is provided in case it is desired to drain the liquid from the exchanger without disassembling the liquid outlet connection 13.

In the operation of the embodiment of our exchanger illustrated in Figures 1 and 2, coolant enters the apparatus by way of coolant inlet section 22 and flows to the right through the tubes of the lower tube section 19 and enters the tubes of the upper tube section at the floating head end of the exchanger. The coolant leaves the apparatus by way of the coolant outlet section 21.

Vapors to be condensed enter the apparatus through the vapor inlet connection 12 and pass through cut-out section 15 and contact the exterior surfaces of the tubes of this upper tube section 18. The vapors and condensate as produced therefrom follow a tortuous path formed by crossbaffles 30 on passage through tube section 18. At the floating head end fluid passes downward beyond the end of the long baffle 17 and again follows a tortuous path formed by crossbaffles 30 from the floating head end to the fixed head end of the lower tube section. At the fixed head end of the lower tube section 19 liquid is held at the level indicated by reference numeral 28 by the positioning of the annular submergence dam 26. The condensate at this end of the condenser flows through the cut-out section 16 and over the submergence dam 26 in the lower conduit 40 and thence passes from the exchanger through the liquid outlet 13.

This entire apparatus is so arranged as to provide countercurrent flow and indirect heat exchange with coolant. The coolant of lowest temperature contacts the condensate in the lower portion of the lower tube section 19 while the coolant, somewhat warmed, passes through the tubes of the upper tube section for condensation of the vapors. In this manner liquid in the lower tube section 19 is cooled to a temperature below the condensation temperature of the vapors when the coolant enters the system at a temperature below the desired vapor condensation temperature. For example, if it is desired to condense vapors at, for example, a temperature of 100° F. at a pressure of, for example, 40 pounds per square inch gauge, the temperature of the inlet coolant is about 80° F. At the time the coolant issues from the tubes of the lower tube section 19 and enters the tubes of the upper tube section 18 its temperature is very near the desired condensation temperature of 100° F. In this manner condensation is achieved at a desired temperature while the condensate is sub-cooled to a temperature below the condensation temper-

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ature. Liquid so cooled when transferred by a pump will not flash or form vapor at the inlet of the pump under reduced pressure conditions ordinarily existing at the suction side of the pump.

In Figure 3, reference numeral 50 identifies a shell of a second embodiment of exchanger of our invention. Shell 50 is provided with a distributor member 51 at the vapor inlet end and an outlet member 52 at the floating end of the exchanger. Attached to the distributor member 51 at the upper portion thereof is a vapor inlet connection 53 and a fluid outlet 54 is provided in communication with the lower portion of the outlet member 52. This shell is approximately like shell 10 described hereinabove relative to Figures 1 and 2 and is thus provided with a sleeve 55 at the head end and a sleeve 56 at the floating end. The floating end of the exchanger of Figures 3 and 4 is the condensate and uncondensed vapor outlet end. The main difference between the hereindescribed embodiments of exchanger is that in Figure 1 the vapor inlet and fluid outlet are adjacent the head end of the exchanger while in Figures 3 and 4 the vapor inlet is at the head end and the condensate and uncondensed vapor outlet is at the floating end. Sleeve 55 is provided with an upper cutaway section 57 and a lower cutaway section 58 while sleeve 56 is also provided with an upper cutaway section 59 and a lower cutaway section 60. The head end of the exchanger is provided with a coolant inlet and outlet assembly 62. This assembly is provided with a coolant inlet 64 and outlet 65. It also is provided with a pair of baffles 61 for directing flow of coolant through tubes 75. A baffle 69 is provided at the floating head end of the exchanger for directing flow of coolant at this point. Fixed tube sheet 63 and floating tube sheet 66 are provided as illustrated. At the floating head end of the exchanger are provided a floating head cover 67 for assisting in directing flow of coolant in cooperation with the aforementioned floating head baffle 69. Shell cover 68 covers the entire floating head end of the apparatus.

To maintain a level 78 of condensate in the condenser in order to be subcooled, i.e., cooled to a temperature below the actual condensation temperature, an annular submergence dam 70 is provided in the lower portion of the space 77 between outlet member 52 and the corresponding sleeve 55. This submergence dam 70 is, if desired, constructed of two portions similar to those described relative to the submergence dam 26 of Figures 1 and 2. The upper ends of this submergence dam are disposed relatively high in space 77 in order to maintain an appreciable depth of liquid in the condenser for sub-cooling purposes. Liquid condensate leaves the floating head end of the condenser through cutaway space 60 and around the right-hand end of the sleeve 56 and enters space 77 on the side of submergence dam 70 adjacent the floating end of the condenser. When the level of the condensate reaches the top of the submergence dam 70, liquid overflows and passes from the condenser through fluid outlet 54. Uncondensed vapor, of course, remains in the upper portion of the condenser and is collected in the portion of space 77 not occupied by liquid and under the influence of throughput pressure uncondensed vapor issues from the condenser along with liquid through the fluid outlet 54. A drain hole 71 is provided in the bottom portion of the annular submergence dam 70 for drainage of condensate from the condenser in case it is desired to do maintenance work thereon. A drain plug 74 in the lower portion of each annular member 51 and 52 is also provided for drainage purposes.

Crossbaffles 76 are provided as illustrated in Figures 3 and 4 for forming a tortuous path through which fluid entering the condenser must travel prior to its exit therefrom to make certain that there has been efficient con-

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tact between vapor to be condensed and liquid condensate with the tubes.

It should be realized that, in case local conditions dictate, the vapor inlet could, with a minimum of alteration, be provided at the floating end of the assembly while the condensate and uncondensed vapor outlet and annular submergence dam 70 could be provided at the fixed head end of the condenser. However, it is preferred to construct and operate the condenser in the form illustrated in Figures 3 and 4.

One of the important advantages of the several embodiments of our invention is that full and complete use is made of the entire length of our condenser tubes in the exchangers. That point is important because condenser tubes are very expensive and are ordinarily designed to make full use of the tubes, and in such cases where full use of the tubes is not achieved, condenser efficiency is less than the desired efficiency.

Materials of construction can, in general, be selected from among those available in commerce, taking into account the corrosive nature of materials being condensed as well as the coolant. In case the exchangers are required to operate under pressure, account should be taken to design the condensers to withstand required pressures.

Stressing the point mentioned above relative to making use of the entire heat exchange surfaces available, it should be pointed out that that is particularly the case in the subcooling in the liquid containing section of the condensers. By placing the submergence dams in the condensate outlet we are able to maintain a body of condensate in the entire tube section of the lower portion of the condensers. If the submergence dams were placed in the shell 50 with the tubes extending through openings in the dams, those portions of the tubes between the submergence dams and the condensate outlet would not be in effective heat exchange with the condensate and thus condensate subcooling would not be the maximum.

While certain embodiments of the invention have been described for illustrative purposes, the invention obviously is not limited thereto.

We claim:

1. A condenser for condensing vapor and subcooling condensate formed therein comprising, in combination, a horizontally disposed shell, a bundle of condenser tubes in said shell, said condenser having a head end and a floating end, an inlet in the upper portion of said shell for inlet of vapor to be condensed, an annular conduit disposed circumferentially around at least the lower portion of said shell adjacent one end thereof, an outlet for fluid in the lower portion of said conduit, a first passageway at least near said one end of said shell for passage of condensate to said conduit, an annular baffle within and fitting the inner walls of said conduit intermediate said outlet for condensate and said passageway, said baffle extending vertically in said conduit to a level intermediate the levels of the bottom and top of said bundle of tubes to maintain a body of condensate in contact with the entire lengths of the lower tubes of said bundle, a second passageway within said conduit and over the top level of said baffle for overflow of condensate from said body of condensate to said outlet for condensate, and an inlet and an outlet for coolant to and from said condenser tubes.

2. A condenser for condensing vapor and subcooling condensate formed therein comprising, in combination, a horizontally disposed shell, a bundle of condenser tubes in said shell, said condenser having a head end and a floating end, an inlet in the upper portion of said shell near said head end for inlet of vapor to be condensed, an annular conduit disposed circumferentially around at least the lower portion of said shell adjacent one end thereof, an outlet for fluid in the lower portion of said conduit, a first passageway at least near said one end of said shell for passage of condensate to said conduit,

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an annular baffle within and fitting the inner walls of said conduit intermediate said outlet for condensate and said passageway, said baffle extending vertically in said conduit to a level intermediate the levels of the bottom and top of said bundle of tubes to maintain a body of condensate in contact with the entire lengths of the lower tubes of said bundle, a second passageway within said conduit and over the top level of said baffle for overflow of condensate from said body of condensate to said outlet for condensate, and an inlet and an outlet for coolant to and from said condenser tubes.

3. A condenser for condensing vapor and subcooling condensate formed therein comprising, in combination, a horizontally disposed shell, a bundle of condenser tubes in said shell, said condenser having a head end and a floating end, an inlet and an outlet for coolant at said head end of said condenser, an inlet in the upper portion of said shell near said head end for inlet of vapor to be condensed, a horizontal first baffle extending from the head end of said bundle of tubes toward the floating end dividing said shell into upper and lower sections, an annular conduit disposed circumferentially around at least the lower portion of said shell adjacent said head end, an outlet for fluid in the lower portion of said conduit, a first passageway at least near said head end of said condenser for passage of condensate to said conduit, a vertically disposed annular second baffle within and fitting the inner walls of said conduit intermediate said outlet for condensate and said passageway, said second baffle extending vertically in said conduit to a level intermediate the level of said first baffle and the level of the bottom of said bundle of tubes to maintain a body of condensate in contact with the entire length of the lower tubes of said bundle, a second passageway within said conduit and over the top level of said second baffle for overflow of condensate from said body of condensate to said outlet for condensate.

4. A condenser for condensing vapor and subcooling condensate formed therein comprising, in combination, a horizontally disposed shell, a bundle of condenser tubes in said shell, said condenser having a head end and a floating end, an inlet and an outlet for coolant at the head end of said condenser, an inlet in the upper portion of said shell near said head end for inlet of vapor to be condensed, an annular conduit disposed circumferentially around at least the lower portion of said shell adjacent said floating end, an outlet for fluid in the lower portion of said conduit, a first passageway in the lower portion of said shell at least near said floating end of said condenser for passage of condensate to said conduit, a vertically disposed annular baffle within and fitting the inner walls of said conduit intermediate said outlet for condensate and said passageway, said baffle extending vertically in said conduit to a level approximately midway from the bottom to top of said bundle of tubes to maintain a body of condensate in contact with the entire lengths of the lower tubes of said bundle, and a second passageway within said conduit and over the top level of said baffle for overflow of condensate from said body of condensate to said outlet for condensate.

5. A condenser for condensing vapor and subcooling condensate formed therein comprising, in combination, a horizontally disposed shell, a bundle of condenser tubes in said shell, said condenser having a head end and a floating end, an inlet and an outlet for coolant at said head end, an annular conduit disposed circumferentially around said shell adjacent said head end, first and second baffles disposed in opposite sides of said conduit separating said conduit into upper and lower portions, an outlet for fluid in the lower portion of said conduit, an inlet for vapor to be condensed in the upper portion of said conduit, a horizontal third baffle extending from the head end of said tubes toward the floating end dividing said shell into upper and lower sections, a first passageway adjacent the head end of said shell for passage of

vapor to be condensed from the upper portion of said conduit to the upper section of said shell, a second passageway adjacent the head end of said shell for passage of condensate from the lower section of said shell to said lower portion of said conduit, a vertically disposed annular fourth baffle within and fitting the inner walls of the lower portion of said conduit intermediate said outlet for condensate and said second passageway, said fourth baffle extending vertically in the sides of the lower portion of said conduit to a level intermediate the level of said third baffle and the bottom of said bundle of tubes so as to provide a body of condensate in contact with the entire lengths of the lower tubes of said bundle, a third passage within the lower portion of said conduit intermediate the top level of the fourth baffle in one side of said lower portion of said conduit and the corresponding baffle separating said upper and lower portions of said conduit for overflow of condensate from said body of condensate to said outlet for condensate.

6. A condenser for condensing vapor and subcooling condensate formed therein comprising, in combination, a horizontally disposed shell, a bundle of condenser tubes in said shell, said condenser having a head end and a floating end, an inlet and an outlet for coolant at said head end, a first annular conduit disposed circumferentially around said shell adjacent said head end, an inlet in the upper portion of said first conduit for inlet of

vapor to be condensed, a first passageway in said shell adjacent said head end for passage of vapor from said first conduit into said shell, a second annular conduit disposed circumferentially around said shell adjacent said floating end, an outlet for fluid in the lower portion of said second conduit, a second passageway in the lower portion of said shell adjacent said floating end for passage of condensate to said second conduit, a third passageway in the upper portion of said shell adjacent said floating end of said condenser for passage of uncondensed vapors in said second conduit, a vertically disposed annular baffle within and fitting the inner walls of the lower portion of said second conduit intermediate said outlet for fluid and said second passageway, said baffle extending vertically in both sides of said second conduit to a level approximately midway from the bottom to the top of said bundle of tubes to maintain a body of condensate in contact with the entire lengths of the lower tubes of said bundle, and said third passageway being at a level above the top level of both sides of said baffle.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

January 5, 1960

Patent No. 2,919,903

Lucien H. Vautrain, et al.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 6, line 33, for "length" read -- lengths --; column 8, line 11, for "in" read -- into --.

Signed and sealed this 9th day of August 1960.

(SEAL)

Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents