Aug. 21, 1928. 1,681,709

A. L. NELSON

PISTON

Filed March 22, 1926 4 Sheets-Sheet 1

Fig. 1.

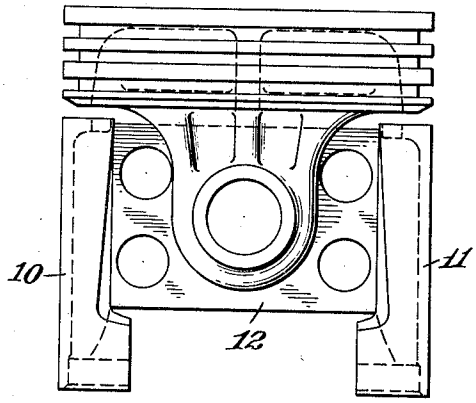
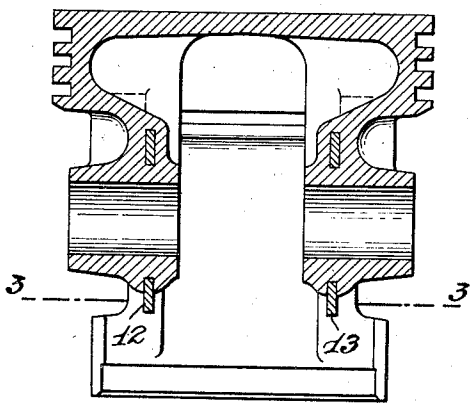


Fig. 2.



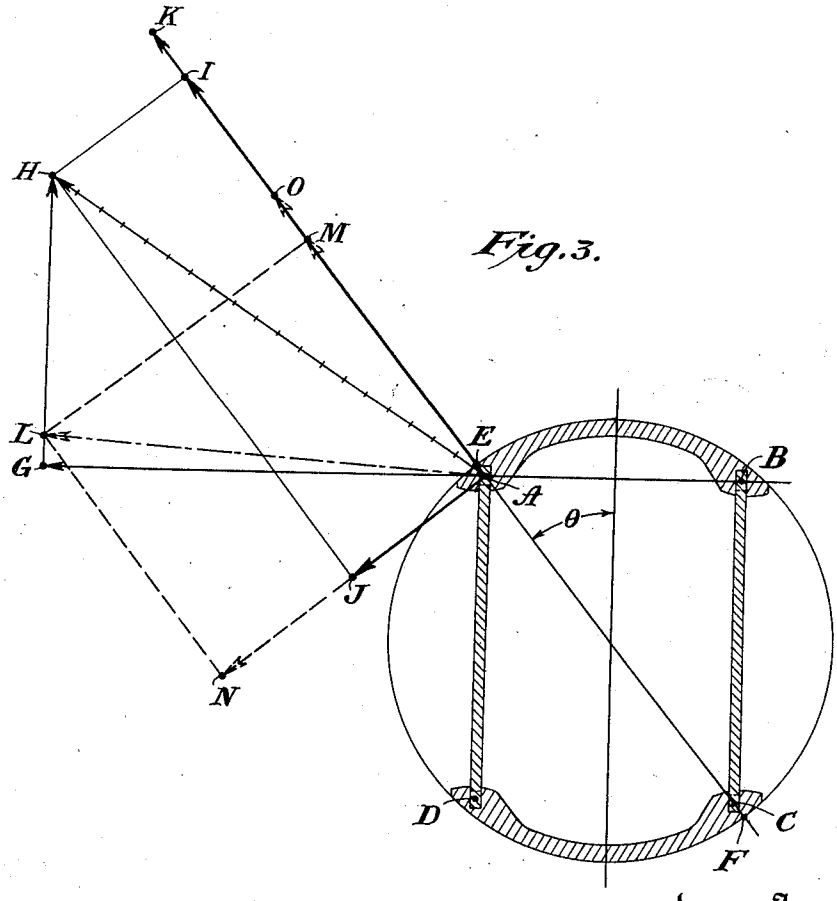


Fig. 3.

Inventor

Adolph L. Nelson

By his Attorney

Frank J. Hunt

Aug. 21, 1928. 1,681,709

A. L. NELSON

PISTON

Filed March 22, 1926 4 Sheets-Sheet 2

Fig. 4.

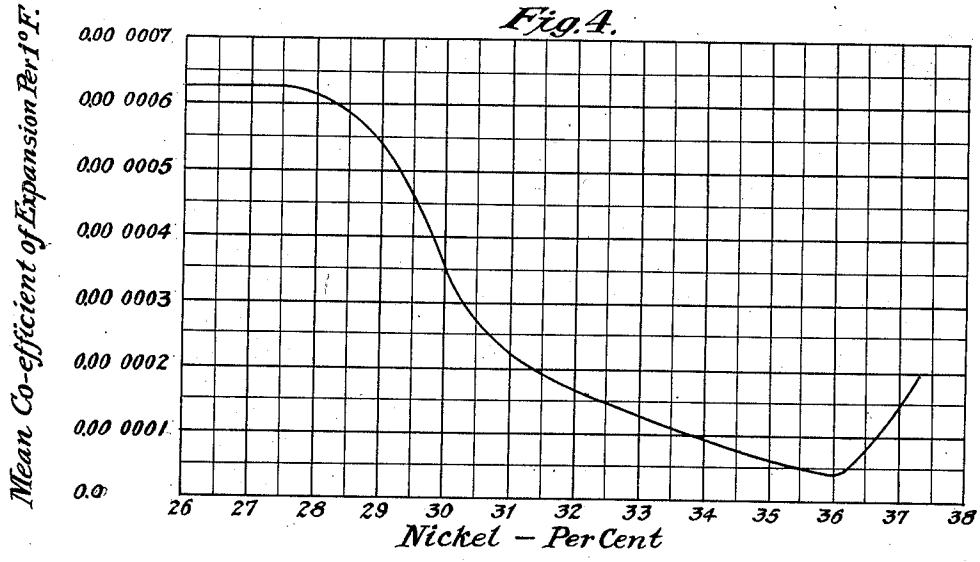


Fig. 6.

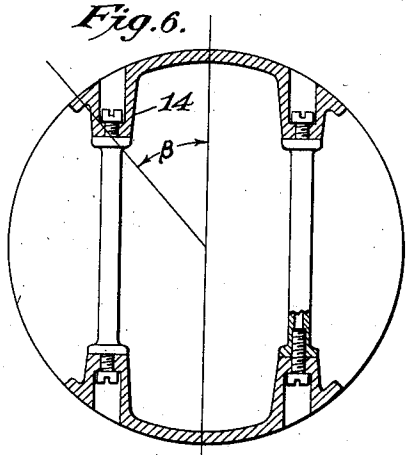


Fig. 7.

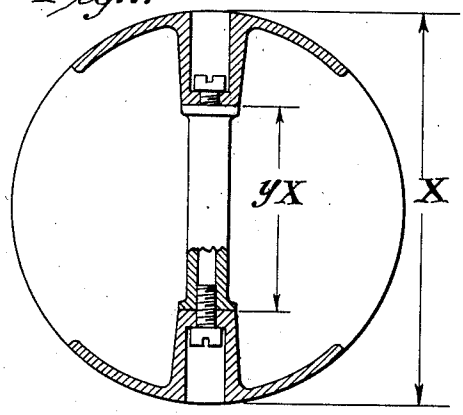


Fig. 9.

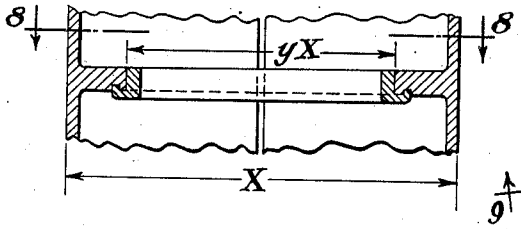
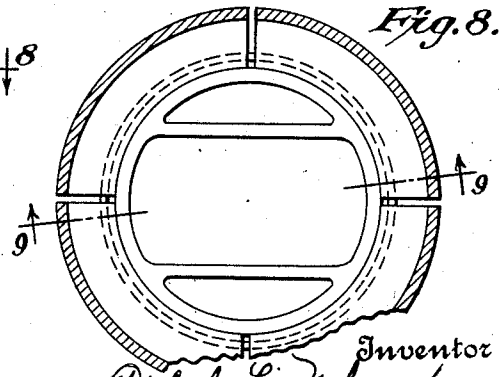


Fig. 8.



Inventor
Adolph L. Nelson,
By his Attorney
Frank J. Kent

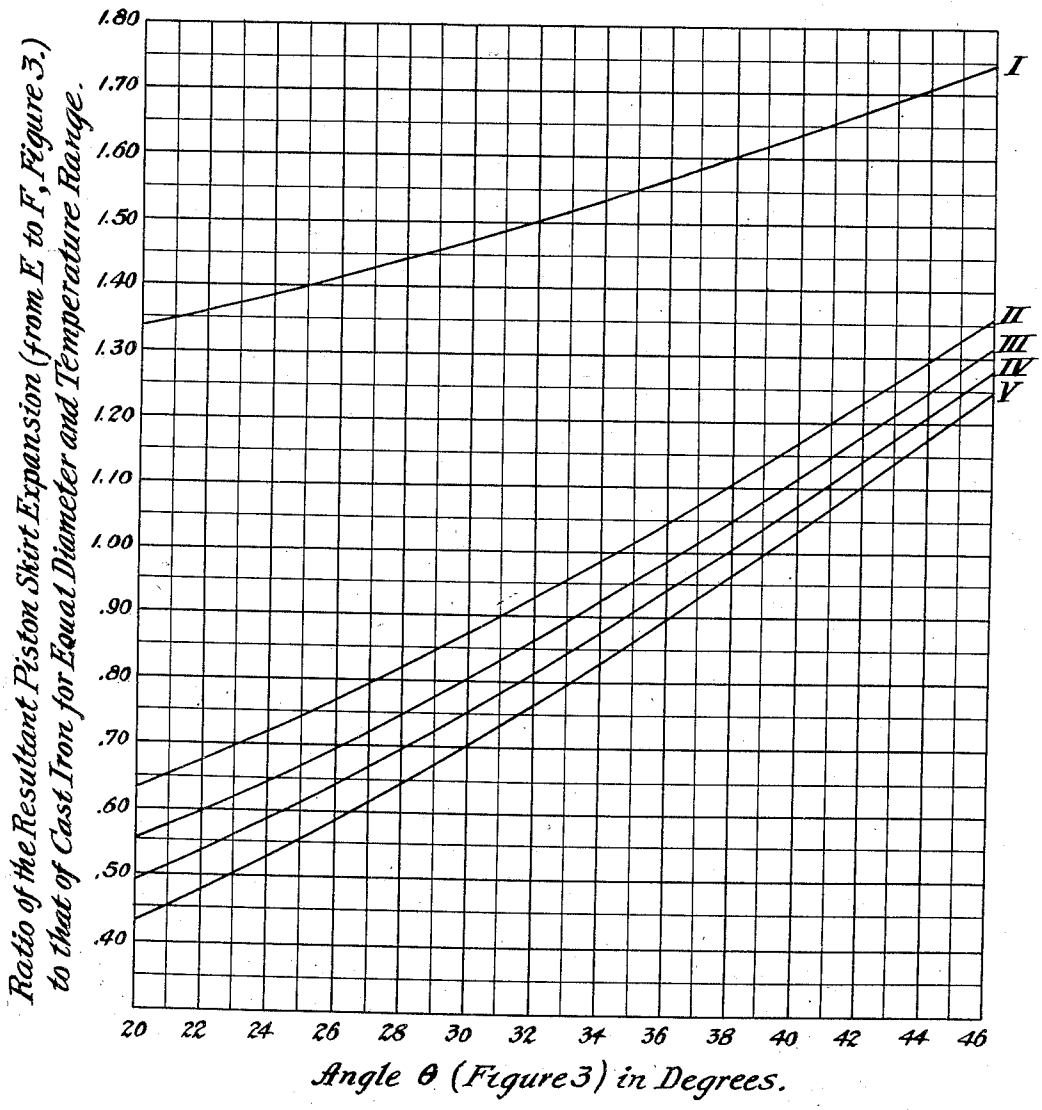
Aug. 21, 1928. 1,681,709

A. L. NELSON

PISTON

Filed March 22, 1926 4 Sheets-Sheet 3

Fig. 5.



Inventor
Adolph L. Nelson

By his Attorney
Frank H. Kent

Aug. 21, 1928.

1,681,709

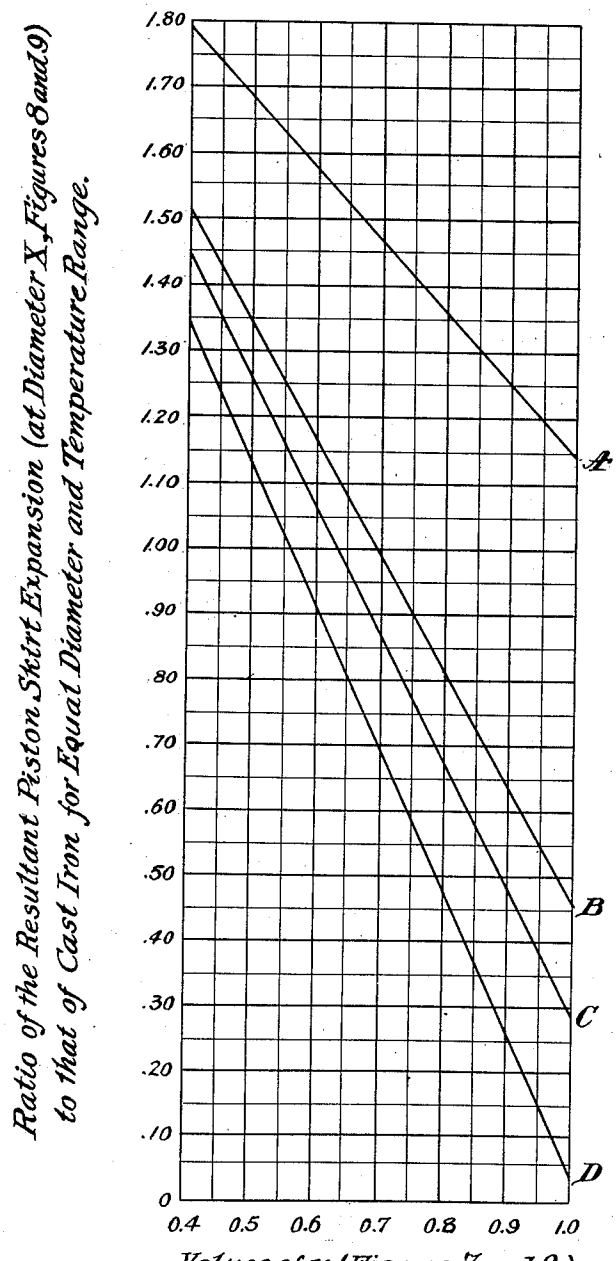
A. L. NELSON

PISTON

Filed March 22, 1926

4 Sheets-Sheet 4

Fig. 10.



Inventor

Adolph L. Nelson

By his Attorney

Frank H. Curr

Patented Aug. 21, 1928. 1,681,709

UNITED STATES PATENT OFFICE.

ADOLPH L. NELSON, OF DETROIT, MICHIGAN, ASSIGNOR TO BOHN ALUMINUM & BRASS CORPORATION, OF DETROIT, MICHIGAN.

PISTON.

Application filed March 22, 1926. Serial No. 96,379.

This invention relates to pistons, particularly to pistons for internal combustion engines, and aims to provide means for accurately controlling the rate of expansion of the piston skirt.

In the past the piston skirt expansion has generally been expressed in terms of the cylinder and the clearance between the cylinder and the piston. This is not a reliable standard of reference since it is very generally recognized by the engineering fraternity that the cylinder expansion is a variable quantity and that the temperature range of the cylinder has no fixed relation to that of the piston skirt. In setting forth the present invention the rate of expansion of the piston skirt will be defined in terms of a suitable comparison that will give an exact unit of measure.

Various types of pistons have been proposed in which auxiliary members are relied upon to control the expansion of the piston skirt. It is often assumed that the skirt will have a resultant expansion similar to that of the material of the controlling member, but this assumption usually involves a very large percentage of error that should not be overlooked in accurate piston engineering.

It is an object of this invention to provide a piston in which the arrangement of parts and materials may be changed to give any selected rate of expansion of the piston skirt. The fact that the piston skirt must work in a cylinder to which it is rather closely fitted and which has a temperature range different from that of the skirt makes it desirable to select and use a rate of expansion to suit the difference in temperature ranges. For the most practical results it is desirable not only to compensate the expansion rate of the skirt to suit the temperature conditions, but at the same time to select a rate by experimental determination which will also increase or decrease the working clearance between the piston skirt and the cylinder as may be found desirable. The rate of skirt expansion found most suitable under the circumstances may be such that it could not be obtained by combining any of the commercially available materials in a structure relying solely on the expansion rate of the materials to control the skirt expansion rate. But in the present invention any desired rate of expansion may be accurately obtained by choosing a suitable commercial material and selecting a proper arrangement of parts.

The scope and practicability of this invention will become apparent from a study of the diagrams and curves herein set forth representing the fundamental principles controlling the resultant rate of expansion of the piston skirt.

In the drawings:

Fig. 1 is an elevation of a piston embodying the invention;

Fig. 2 is a longitudinal section through the piston shown in Fig. 1;

Fig. 3 is a cross section on line 3—3 of Fig. 2 including a diagram representing the analysis of the expansion rate of the piston skirt;

Fig. 4 is a curve chart showing how the linear coefficient of expansion of nickel-iron alloy varies with the nickel content;

Fig. 5 is a curve chart showing how the piston skirt expansion rate varies with angles θ of Fig. 3;

Fig. 6 is a modification showing how the length of the strut can be varied;

Figure 7 is a modification showing a single diametral strut;

Fig. 8 is a further modification showing a strutted ring;

Fig. 9 is a section on line 9—9 of Fig. 8.

Fig. 10 is a chart representing a certain phase of the invention.

This application is in part a continuation of my copending application Serial No. 643,499 filed June 5, 1923, and Figs. 1 and 2 illustrate a piston of the type set forth in said copending application. The piston skirt includes two slipper sections 10 and 11 which are held in spaced-apart relation by the struts 12 and 13.

Fig. 3 includes a diagram representing the analysis of the expansion rate of the piston skirt. In this figure the points A, B, C and D represent the neutral points (regarding relative movement) in the joints between the struts and the slipper sections. A diameter through point A makes an angle θ with the diameter parallel to the struts. Points E and F are opposite peripheral points in the diameter through A. For the examples given the material of the skirt is taken as an aluminum alloy having a coefficient of linear expansion of 0.00001234 per degree Fahrenheit. The examples will show the results obtained by using strut materials having various expansion rates.

To make an analysis of the resultant expan-

sion of the skirt we will first find the expansion between points E and F, Fig. 3, then divide this expansion by that of a solid cylindrical block of cast iron of equal diameter. That is, we will use a cylindrical block of cast iron, which has a coefficient of expansion of 0.00000556 per 1° F., as a standard reference or unit of measure for comparing the actual skirt expansion for equal diameters and temperature ranges. The ratio of the expansions thus defined we will call the piston skirt expansion rate.

To lay out the diagram of expansion components as given in Fig. 3 we first calculate the expansion between points A and B. Using A as a pole we lay off A G (on line A B extended) to represent this expansion. (For convenience a piston having a diameter of 3.375 in. was used and the temperature range was taken from 70° to 212° F. On the vectors one inch on the original drawing represents .001 inch expansion, and it will be apparent that in the printed patent this scale will be reduced ⅔.) Next we calculate the expansion from D to A, using ordinary steel in the struts, and represent this by G H. Drawing A H we have a line representing the combined expansive movement of point A in reference to point C. We will next resolve A H into two components, one, A I, normal to the skirt wall at E and the other, A J, parallel to the tangent at E. Then A I represents the diametral expansion between C and A, while A J is the expansion component parallel to the tangent and represents the peripheral movement of point A, or the distance it creeps along the cylinder wall. To obtain the total resultant expansion of the skirt we must add the expansion from A to E and from C to F, and we lay off I K to represent this expansion, taking distance A E as 3.555 per cent of the piston diameter. Then A K represents the total expansion from E to F on the diameter of the piston through point A.

On this same figure we have superimposed a diagram for a strut material having a coefficient of expansion of 0.000000636 per 1° F., or $\frac{1}{10}$ that of ordinary steel. Since the expansion between points A and B is the same in this case, line A G remains the same, but the strut expansion between A and D will be only $\frac{1}{10}$ of G H, or G L, and line A L represents the combined expansive movement of point A in reference to point C. Resolving A L into two components we get A M and A N. Laying off M O, equal to I K, we get A O representing the resultant diametral expansion for the skirt when the coefficient of expansion of the strut material is $\frac{1}{10}$ that of ordinary steel. Line A N is the expansion component parallel to the tangent.

It will be apparent from these diagrams that when a strut material having a lower coefficient of expansion is used the resultant normal to the skirt wall is materially decreased, while the resultant parallel to the tangent is greatly increased.

It will further be observed from Fig. 3 that increasing angle θ decreases the length of the strut, A D, and increases the distance A B of the skirt, thereby changing the resultant expansion of the skirt.

To illustrate how changes of strut material and or angle θ affect the resultant skirt expansion, a series of diagrams similar to Fig. 3 were drawn accurately and to scale for the following examples of material:

Material 1—Having a coefficient of expan. of 0.00000636 (ordinary steel).
Material 2—Having a coefficient of expan. of 0.00000159 (¼ that of ordinary steel).
Material 3—Having a coefficient of expan. of 0.00000109 (⅙ that of ordinary steel).
Material 4—Having a coefficient of expan. of 0.000000636 ($\frac{1}{10}$ that of ordinary steel).
Material 5—Having a coefficient of expan. of 0.000000226 (invar).

Any suitable materials having the above coefficients of expansion would produce the desired results in the illustrations given, but it is to be noted that materials having these coefficients are available in commercial nickel-iron alloys. The curve chart of Fig. 4 shows how the coefficient of linear expansion of such an alloy varies with the nickel content. Plotted values of the coefficient between 31 and 36 per cent nickel as given by different authorities agree very well and since this is the flatter part of the curve commercial products can be kept within reasonable distance of the curve. On the other hand the change is quite rapid between 26 and 31 per cent nickel and this part of the curve is not so reliable. The material used for the struts must have a consistent coefficient of expansion within commercial limits and hence materials lying between 31 to 36 per cent of nickel should be used. Finding the location of materials 2, 3, 4 and 5 on this chart we find they fall within this flatter part of the curve, as follows:

2—Nickel-iron alloy having 32.2 per cent nickel.
3—Nickel-iron alloy having 33.6 per cent nickel.
4—Nickel-iron alloy having 35.1 per cent nickel.
5—Nickel-iron alloy having 36 per cent nickel.

In drawing the diagrams to obtain the actual skirt expansion for the above materials for different values of angle θ, the angle θ was varied from 20 to 46 degrees in increments of 2 degrees. (That is, five diagrams were made for each angle, one for each of the five materials.) The skirt expansion found from each diagram was divided by the expansion of a cylindrical block of cast iron of equal diameter and temperature range to find the piston skirt expansion rate. These rates or ratios are plotted in Fig. 5 as ordinates against the angles of θ as abscissas.

The chart of Fig. 5 shows quite clearly the cooperative relation between the strut material and the value of angle θ. A few examples will demonstrate how a proper combination of these two factors will produce any desired piston skirt expansion rate.

Curves I to V represent materials 1 to 5, respectively.

For an angle θ of 20°, curve I gives us a rate of skirt expansion of 1.34, i. e., a skirt expansion rate 34 per cent greater than that of a cast iron cylinder of equal diameter and temperature range. Curve V for the same angle gives us a rate of 0.43, i. e., 43 per cent of the expansion of cast iron. For an angle of 46° the expansion rates from curves I and V are 1.74 and 1.25, i. e., we have 74 per cent greater expansion than cast iron with the struts of ordinary steel and 25 per cent greater expansion with the invar struts.

Attention is called to the fact that for $\theta=20°$ the strut of ordinary steel gave a skirt expansion rate greater than cast iron, while Invar gave far less. For $\theta=46°$ the expansion rate for struts of ordinary steel is still greater, while even the invar strut gives an expansion rate greater than that for cast iron. This illustrates clearly that the rate of expansion cannot be controlled within the desired limits by relying solely on a selection of materials, while the combination of proper strut material and the proper angle θ will give any desired piston skirt expansion rate.

Suppose that we wanted a skirt expansion rate identical with that of cast iron, i. e., a rate of 1.00. If invar is to be used as the strut material we run from 1.00 on the ordinates across to curve V and find we must use an angle θ of 39°. This would give us a rate approximately suitable for an automobile engine piston.

Suppose we found from actual production that a slightly higher rate of expansion would be desirable to give a minimum amount of trouble from piston slaps, and we decided to try a production run of pistons having a rate of 1.10, or a 10 per cent increase in expansion. If we are using invar, curve V shows that we must use a θ of 42°.

Suppose again that experience with the finished automobiles shows that this last rate of skirt expansion is satisfactory but we desire to save in cost of materials by reducing the nickel content of the strut steel. Curve II corresponds to a lower nickel content and shows that with material 2 an angle θ of 38° will produce the desired skirt expansion rate of 1.10. If a new and cheaper material suitable for struts should be brought out we would plot a curve corresponding to its coefficient of expansion and then obtain the angle θ which would have to be used in order to keep the piston skirt expansion rate identical with that already found to be desirable. In other words, having once determined the most suitable skirt expansion rate we can easily determine the angle θ required to produce that rate with any given strut material.

The above examples illustrate the results obtainable by having an exact unit of comparison for measuring skirt expansion and by intelligently selecting a strut material and arrangement of parts to produce a rate of skirt expansion found to be satisfactory in actual use.

In the examples given so far it has been assumed that the distance A E remained a constant ratio to diameter E F. Fig. 6 shows a modification in which the distances A E and C F may be increased or decreased by varying the height of pedestal 14, resulting in a proportionate increase or decrease in vector I K (Fig. 3). In this case angle β may be varied without changing the height of pedestal 14.

Fig. 7 shows a strut across the central diameter of the skirt, while Fig. 8 shows a strutted ring for controlling the skirt expansion. An unsupported ring is a spring member, and while it would have a controlling influence upon the skirt expansion, it would not positively hold the skirt round and to size within the small variations permissible in a working piston. A ring heavy enough to give the requisite rigidity would have prohibitive weight. A strut is a bar member, and is the most efficient type of member to space the skirt portions positively and keep the spacing constant under working conditions for long periods of time. It is therefore necessary, in order to obtain accurate results, to brace the ring by struts. It is to be understood that the principles herein disclosed will apply to an unbraced ring, although such a ring will not give the positive results produced by rigid strut members.

In Fig. 7 the strut length may be varied from the extremes of $y=0$ to $y=1$. The same is true of Fig. 9.

In the case of Fig. 3 we gave a graphical presentation of the analysis of the expansion rate of the skirt. For Figs. 7 and 9 we will give an analytical derivation.

From Figs. 7 and 9 it will be seen that y is the ratio of the strut length yX to the diameter of the skirt X. Thus for $y=0.5$ the strut is half as long as diameter X.

Now let

γ = the coefficient of expansion for cast iron per 1° F.
T = Temperature range in degrees F. (e. g., 212° − 70° = 142°).

Then the expansion for cast iron for diameter X would be

$$= \gamma XT \quad (1)$$

Also let

α = coefficient of expansion of the skirt material.

and

β = coefficient of expansion of the strut material.

Then the resultant expansion of the skirt along dia. X is

$$= \alpha TX\,(1-y) + \beta TXy$$
$$= TX\,[\alpha - y(\alpha-\beta)] \quad (2)$$

Dividing equation (2) by equation (1) we get the ratio of the resultant skirt expansion to that of cast iron for equal diameter and

temperature range. Let us call this ratio R, then,

$$R=\frac{\alpha}{\gamma}-y\left(\frac{\alpha-\beta}{\gamma}\right) \quad (3)$$

Using equation (3) the values of R were calculated to plot the curves given in Fig. 10. In this figure curves A, C and D, respectively, are for materials 1, 2 and 5, previously mentioned. Curve B is for a material (No. 6) having a coefficient of expansion 0.4 that of ordinary steel, a material corresponding to a nickel-iron alloy contaning 30.7 per cent of nickel. The skirt material for all curves is aluminum alloy. ($\alpha=0.00001234$). The coefficient of cast iron was taken as $\gamma=0.00000556$.

Fig. 10 gives at a glance the various skirt expansion rates that can be elected at will by choosing suitable strut materials and values of y. Some examples will illustrate the use of the curves and emphasize the advantages of the possible combinations.

Let us first consider curve A, which is for material 1, having the same coefficient of expansion as ordinary steel. For a value of $y=0.4$ we get a skirt expansion rate of 1.79, i. e., 79 per cent greater than that of a cast iron cylinder of equal diameter and temperature range. Now let us take $y=1.0$, which is the extreme theoretical limit for the length of the strut. Then we would have an expansion rate of 1.14, or 14 per cent more than for cast iron. Let us consider a skirt 3 inches in diameter with 0.1 in. of skirt metal between the end of the strut and the outer end of the skirt diameter which gives the greatest practicable length for the strut. In this case $y=0.933$. Referring this value of y to the chart we get a rate of 1.21. In other words, with a strut as shown in Figs. 8 or 9 formed of ordinary steel the closest we can come theoretically to a cast iron rate is 14 per cent above the cast iron rate, while the closest we can come in actual practice is 21 per cent above cast iron. This example shows that it is an error to assume that a strut or rigid ring of ordinary steel will control the skirt expansion in such a way as to give the skirt a rate of expansion the same as that of a cast iron cylinder, thereby keeping the clearance between the cylinder and the piston constant. In the first place the rate of expansion of the skirt when controlled by a strut of ordinary steel is not the same as that of the cast iron cylinder, as explained above; and in the second place the temperature ranges of the piston and the cylinder are practically never the same. The actual expansion for the cylinder and the piston could be equal only for the one condition of temperature ranges in which the difference in temperature ranges would exactly offset the difference in the expansion rates of the cylinder and piston skirt. It would be an extremely unusual coincidence for such a condition to occur in any engine.

Again referring to Fig. 10 let us assume that we want a piston skirt having a rate of 1.05. If we wish to use material No. 6 we find from curve B that we must use a value of $y=0.66$, i. e., by making the strut length 66 per cent of the piston diameter we obtain the desired expansion rate.

It will be clear from the above that the structures of Figs. 6, 7 and 8 can be used to produce any desired skirt expansion rate just as accurately as the structure of Fig. 3. It will also be evident that the controlling members may be located at any desired point longitudinally of the skirt.

The above disclosure makes it clear that by a proper combination of commercial materials and skirt structure a piston skirt having any selected rate of expansion can be produced. The selected rate may be one that cannot possibly be obtained by relying on choice of materials alone since the rate may not correspond to the expansion rate of any known material. Obviously the principles herein set forth can be applied to modified structures and to any materials without departure from the true spirit and scope of the invention.

I claim:—

1. The method of making a piston having opposite bearing surfaces and struts of a material different from the bearing surfaces and with a predetermined rate of expansion, which comprises spacing the struts such a distance apart and spacing their end such a distance inwardly from the piston circumference that the spacing of the struts together with the coefficients of expansion of the materials of the skirt and struts cooperate to produce a predetermined rate of expansion diametrically of the bearing portions.

2. The method of designing a piston of the type wherein two opposite thrust bearing surfaces are provided, which consists in connecting said bearing surfaces to each other by two substantially parallel struts located on opposite sides of an axis extending horizontally between the centers of the bearing surfaces, the struts being formed of material having a coefficient of expansion lower than that of the material of the bearing surfaces, the spacing of said struts with respect to said axis and the spacing of the ends of the struts inwardly from the piston circumference being so chosen that taken in connection with the coefficient of expansion of the material of the bearing surfaces and the struts, a predetermined rate of expansion between diametrically opposite points of strut connection may be obtained.

3. A piston comprising a head, opposite bearing surfaces separated from the head, and a pair of struts extending between the bearing surfaces, said struts being formed of material having a coefficient of expansion lower than that of the material of the bear-

ing surfaces, the struts being spaced apart such a distance and the ends of the struts being spaced inwardly from the piston circumference such a distance that the spacing of the struts together with the coefficients of expansion of the materials of the skirt and struts cooperate to produce a predetermined rate of expansion diametrically of the bearing portions.

4. A piston comprising a head, opposite bearing surfaces separated from the head, and a pair of struts extending between the bearing surfaces, said struts being formed of material having a coefficient of expansion lower than that of the material of the bearing surfaces, the struts being located on opposite sides of an axis extending horizontally between the centers of the bearing surfaces, the struts being substantially parallel to the axis and spaced such a distance from the axis and the ends of the struts being spaced inwardly from the piston circumference such a distance that the spacing of the struts together with the coefficients of expansion of the materials of the skirt and struts cooperate to produce a predetermined rate of expansion diametrically of the bearing portions.

In testimony whereof I affix my signature.

ADOLPH L. NELSON.