July 23, 1929. C. F. KETTERING 1,721,808

HEAT EXCHANGE APPARATUS

Filed Nov. 9, 1921 5 Sheets-Sheet 1

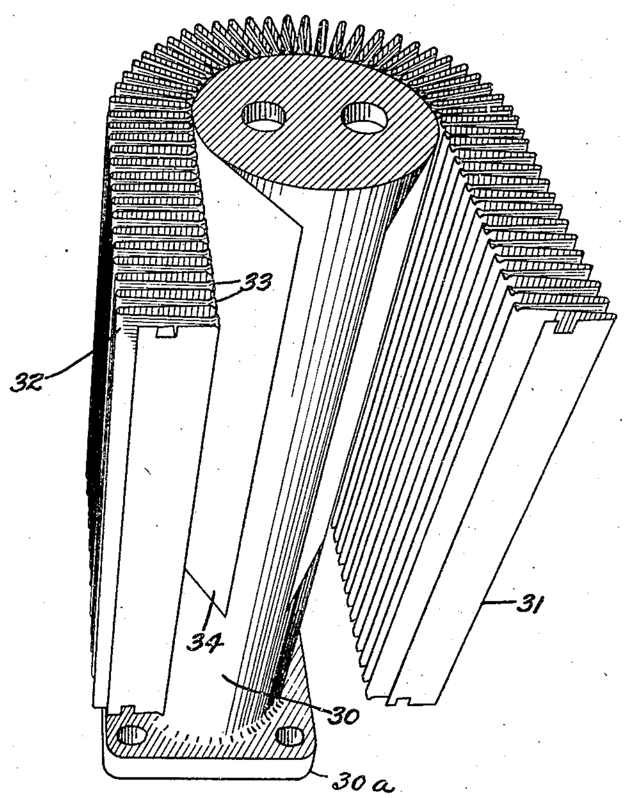

Fig. 1.

Witnesses
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HEAT EXCHANGE APPARATUS

Filed Nov. 9, 1921 5 Sheets-Sheet 2

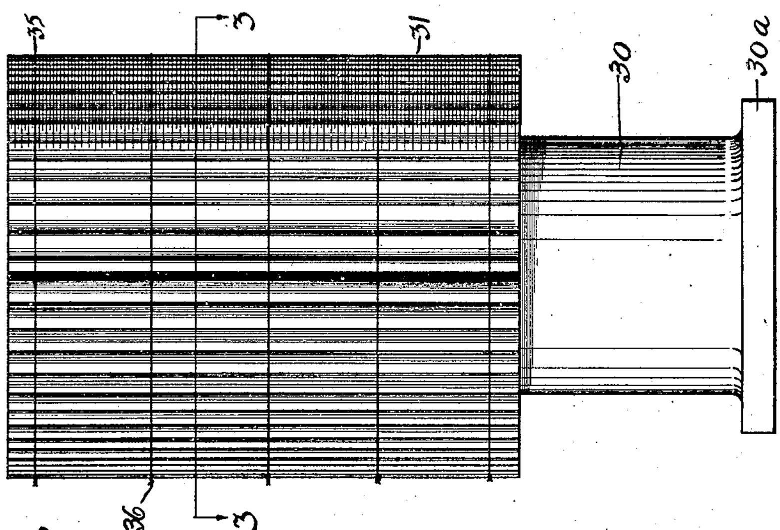

Fig. 2.

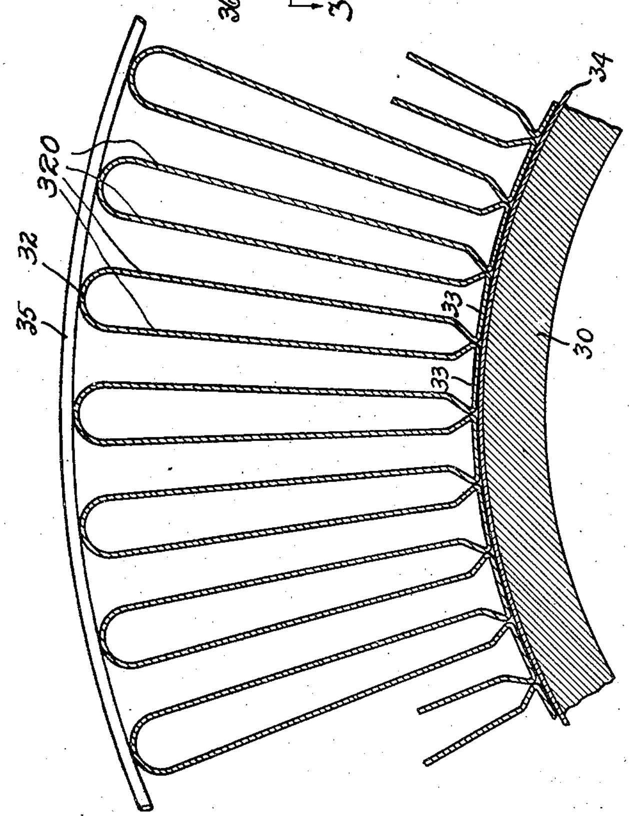

Fig. 3.

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HEAT EXCHANGE APPARATUS

Filed Nov. 9, 1921 5 Sheets-Sheet 3

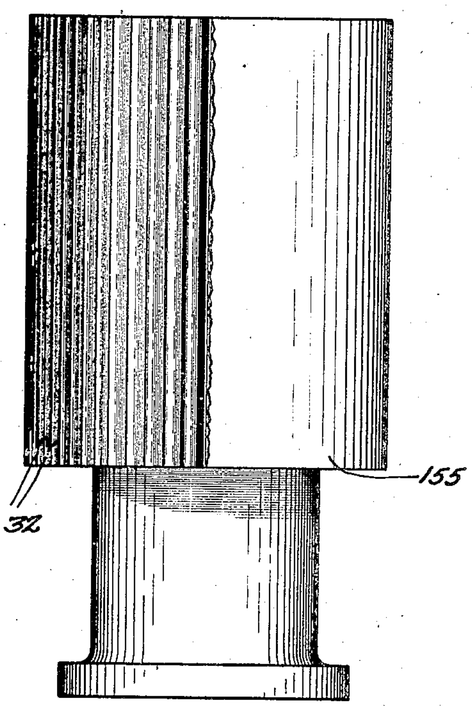

Fig. 5.

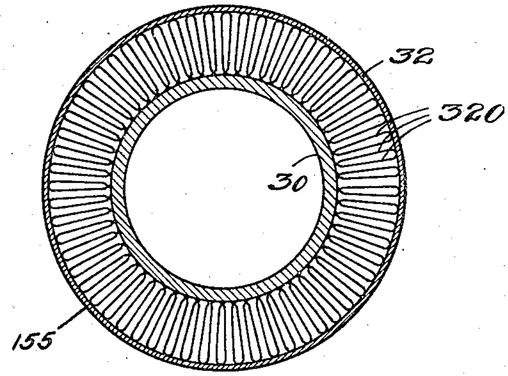

Fig. 4

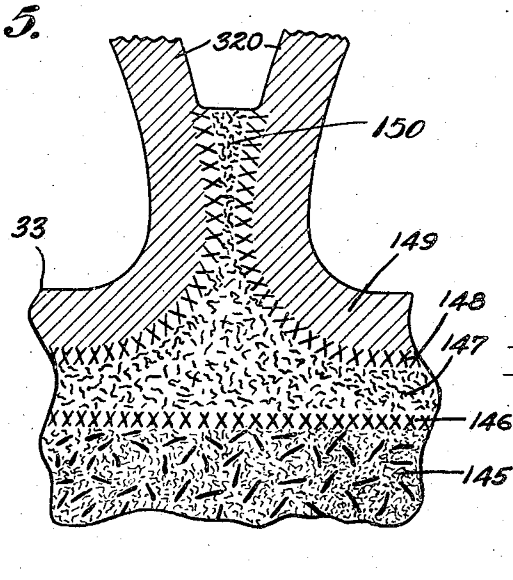

Fig. 6.

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HEAT EXCHANGE APPARATUS

Filed Nov. 9, 1921 5 Sheets-Sheet 4

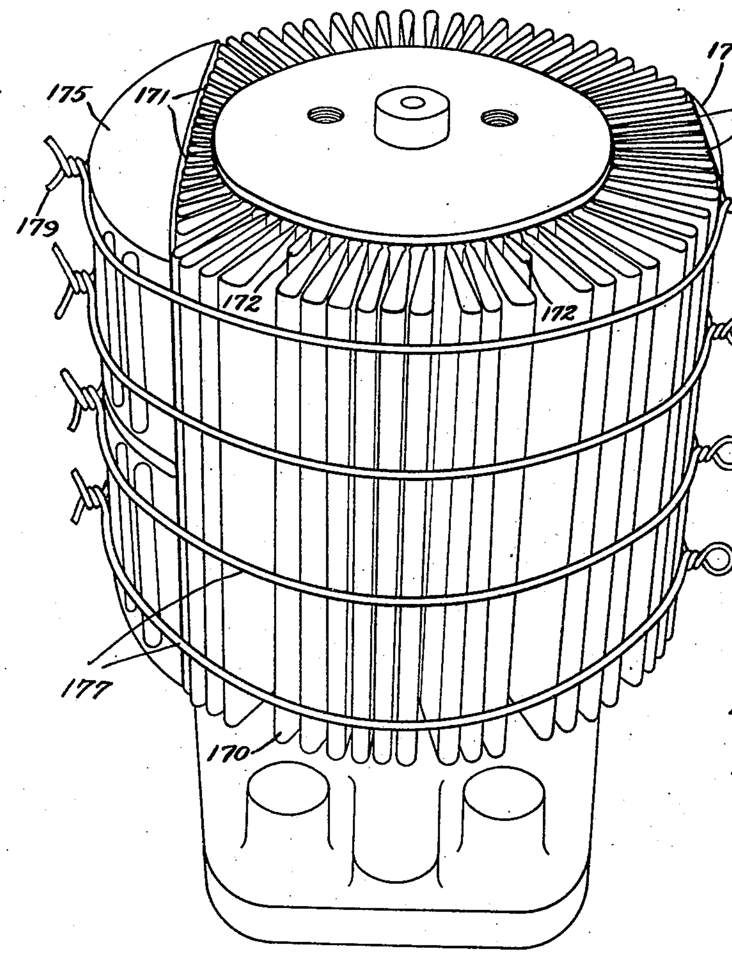

Fig. 8.

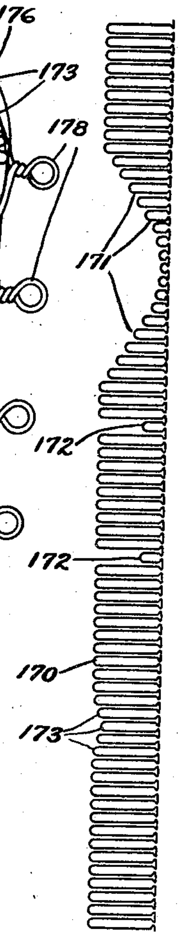

Fig. 7.

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HEAT EXCHANGE APPARATUS

Filed Nov. 9, 1921 5 Sheets-Sheet 5

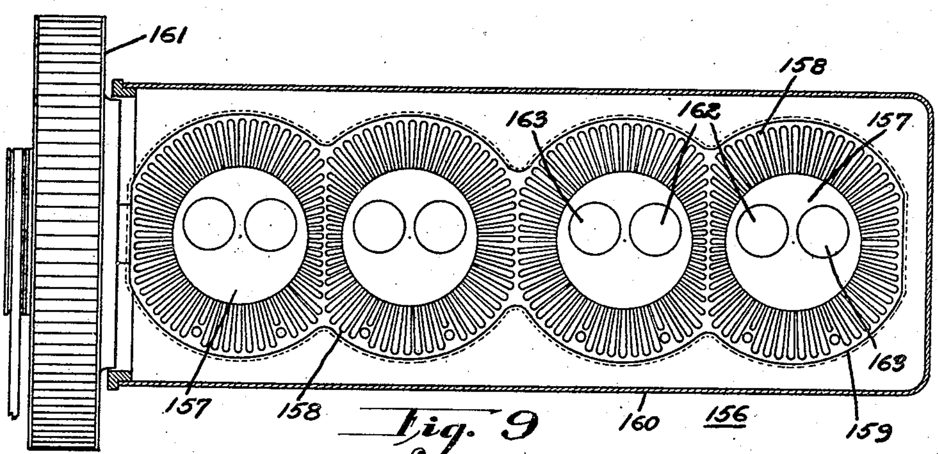

Fig. 9

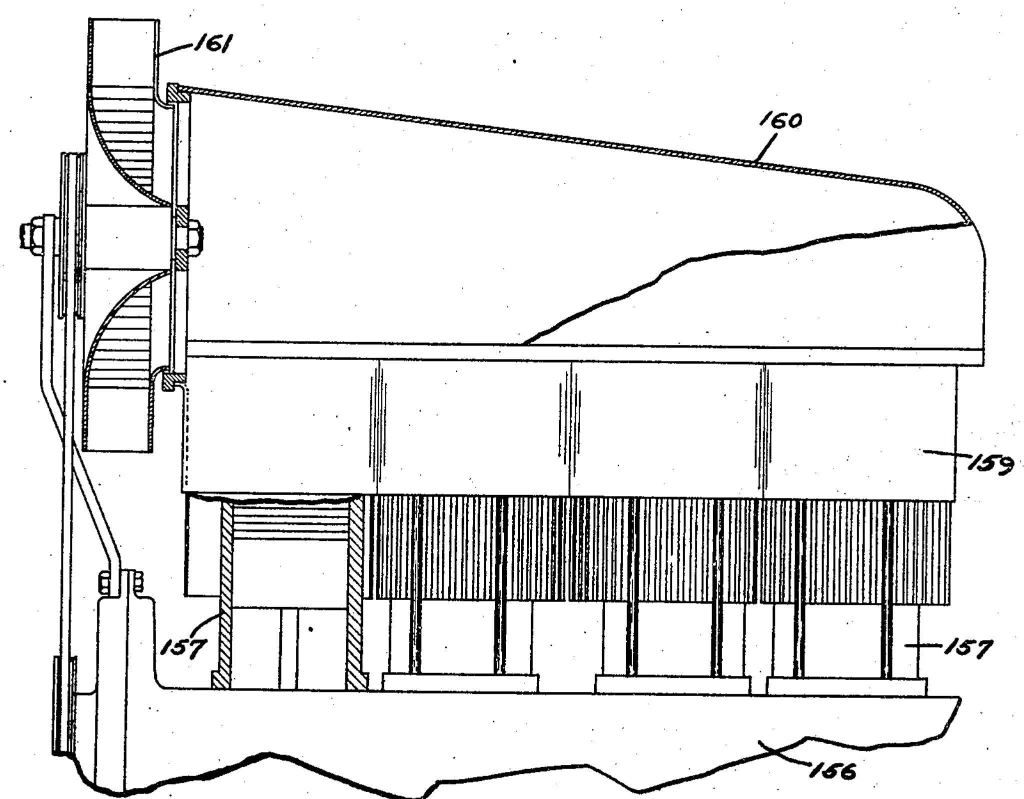

Fig. 10

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Patented July 23, 1929. **1,721,808**

UNITED STATES PATENT OFFICE.

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HEAT-EXCHANGE APPARATUS.

Application filed November 9, 1921, Serial No. 514,014, and in Canada August 23, 1920.

This invention relates primarily to improvements in internal combustion engines and more particularly to improvements in cylinders for internal combustion engines of the air cooled type.

This application is, in part, a continuation of my application, Serial No. 392,646, filed June 29, 1920.

Among the objects of the present invention is to provide an engine, the cylinder of which has attached thereto a number of radiating fins of a metal of relatively high conductivity, the attachment of said fins being such that the heat generated in the engine cylinder can readily flow into the fins, the heat dissipating faces of which are preferably located in the path of a stream of cooling air. In the preferred embodiment of the invention hereinafter described I make the heat dissipating fins of copper, and I provide means for attaching the said fins to the cylinder, whether it be of steel or of cast iron, or of any suitable metal, in such manner that the fins will unite strongly to the cylinder, will remain permanently in position on the cylinder without coming loose, and will be in substantially true thermal contact with the cylinder, that is, there will be no substantial obstruction to the flow of heat from the ferrous metal of the cylinder to the copper fins such as would exist were the fins attached to the cylinder by ordinary riveting, screwing or other analogous mechanical means. A still further object of the invention is to attach the aforesaid fins to the cylinder by an intermingling, alloying union or penetration of metals between the cylinder and the fins such that there will be a merging of the metals at the points where the fins unite to the cylinder. This merging of the metals presents the advantage that the heat from the cylinder can flow readily and without substantial obstruction to the copper fins. The attachment of the fins to the cylinder, in the preferred form of the invention, involves the employment of bonding means, such as metallic brass or silver solder, which forms part of the means for causing the fins to unite to the cylinder. It is, therefore, a further object of the invention to provide a cylinder of cast iron or steel with copper fins brazed or soldered thereon in such manner that the fins will be permanently attached, and will not come off during use and will cohere to the cylinder and form with the cylinder an integral body.

Another object of the invention is to provide a cylinder with a large number of thin copper fins made of a continuous pleated strip of copper, and to provide an engine cylinder in which each of a number of fins is attached to the engine cylinder by a union which is substantially uniform with the union of the other fins with the engine cylinder.

A still further object of the invention is to provide a cylinder with a large number of thin longitudinal fins of a continuous pleated strip of thin copper, the fins being formed to provide a substantial area at their base for attachment to the cylinder by means of brazing or soldering along a longitudinal line.

In order to illustrate more clearly the products of the present invention, the same will be described with reference to an engine cylinder having copper fins or cooling elements which cylinder is of ordinary gray cast iron, the walls of which are relatively thin.

In the accompanying drawing which illustrates some preferred forms of cylinders in accordance with the present invention:

Fig. 1 is a perspective view illustrating a stage in the assembling of a strip of finning material and the brazing material around a cast iron or steel cylinder.

Fig. 2 is a side view showing a cylinder with the finning structure assembled and ready for the furnace.

Fig. 3 is an enlarged cross section on the line 3—3 of Fig. 2.

Fig. 4 is a cross-sectional view taken through a cylinder made in accordance with the invention.

Fig. 5 shows the completed cylinder having a tube surrounding the finning structure in contact with the fin loops.

Fig. 6 is an enlarged view of a diagrammatic and exaggerated nature, showing in cross-section the bond between the finning structure and the cylinder wall.

Fig. 7 shows a modified form of copper finning structure developed, before attachment to a cylinder.

Fig. 8 shows the assembly of a cylinder

with said modified form of finning structure before bonding.

Fig. 9 is a plan view partly in section of an engine embodying the invention.

Fig. 10 is a side view of the engine shown in Fig. 9, partly in section.

The construction of engine and engine cylinder will best be understood by first describing the structure of the fins and cylinder shell and then the method of attaching the fins to the cylinder shell, and for the purpose of comprehending more clearly the description which follows, reference should be had to Figs. 1, 2 and 3 of the drawing which show the finning structure 31 and the shell 30, to which the said fins are to be attached. The flange 30^a serves as a means by which the cylinder may be attached to a crankcase or base.

In order to facilitate the attachment of the fins to the cylinder shell, to insure uniformity of contact, to save labor in attaching the fins and secure other advantages, I prefer to form some or all of the fins of a strip of copper bent or crimped to the shape of the fins, and in the embodimend here illustrated I have shown all the fins made from a continuous thin strip of copper so that there will be a large number of fins which will be attached to the cylinder simultaneously and under uniform treatment; that is, each fin is subjected to substantially the same condition as all the other fins in the process of attaching the fins to the shell. These fins are preferably made of substantially pure metallic copper which is preferably of uniform gauge, and while the thickness of the copper depends upon the type of engine upon which it is employed and other factors, I prefer, for an engine to be installed in an ordinary passenger car, to use a thin sheet of copper. In actual practice, copper strips ranging from thirteen to eighteen thousandths of an inch have given good results in such automobile engines.

The finning structure illustrated in Figs. 1, 2, 3, 4 and 5 provides a number of uniform radial fins spaced substantially equidistant and arranged concentrically around the periphery of the cylinder shell; for convenience, this type of finning structure will be referred to hereinafter as concentric finning. The fins need not be uniform, however, and in another form of the invention which is illustrated in Figs. 7, 8, 9 and 10, the cylinder is provided with fins of varying height in order that cylinders of an engine may be placed more closely together and to accomodate certain of the working members such as valve push rods which would otherwise be obstructed by the fins; the finning structure, when assembled on the cylinder, may present an external configuration which is eccentric with respect to the periphery of the shell, notwithstanding the fact that the bases of the fins are concentric with and attached to the shell. The invention will first be described with reference to the attachment to the exterior of a cylinder of a finning structure the exterior of which is concentric with the cylinder, and thereafter with reference to the attachment of a finning structure the exterior of which is not concentric with the cylinder.

Referring first to Figs. 1, 2, 3, 4 and 5, it will be seen that the finning structure consists of a plurality of fin loops, 32 each loop including two fin portions 320 exposed on both sides to cooling air, and of base portions 33 connecting the loops 32. The distance from the base of a fin to the outer end of the fin measured radially of the cylinder shell, is herein after referred to as the height of the fin, and the distance from the top edge of the fin to the bottom edge of the fin measured in a longitudinal direction or parallel with the axis of the cylinder shell being referred to as the length of the fin. By referring to Fig. 2, it will be noticed that the fins are shorter than the length of the cylinder and it is desired to have them embrace the cylinder more particularly around the upper zone of the cylinder which becomes hottest in the operation of the engine. By curving the finning structure circumferentially around the cylinder in the manner illustrated in Fig. 1, it will be noticed with reference to Fig. 3, that the bases of successive fins are contiguous to each other, thus forming approximately a circle, and the flexibility of the metal sheet is such that the base portions 33 can follow the periphery of the iron cylinder when the finning structure is pressed against the shell in the manner more particularly hereinafter described. It will thus be obvious that the bases 33 of the fins, edge to edge, at this stage in the process of manufacture, form a substantially circular cylindrical surface broken along lines lengthwise of the fins where the fin portions 320 of loops 32 are in contact and whence the loops extend outwardly from the bases thereof. The provision of these bases of relatively large area is important because it insures good face contact between the base of the fin and the bonding metal as hereinafter described, thus providing a maximum surface for attachment and insuring both mechanical strength and efficient heat-conducting capacity.

The finning structure may be formed by crimping, in a suitable machine designed for the purpose, copper sheets in long lengths. A proper length of this finning structure may be cut off and wrapped around a cylinder. The length will be determined accurately, so that the bases connecting the fin loops will lie in contact when the finning structure is wrapped around the cylinder. The finning structure may be cleaned by dipping in caustic soda, or any suitable bath, then in commercial nitric acid. It may be afterwards washed, dipped in a cyanide solution to neutralize the acid, then again washed with a brush and afterwards dipped in hot water. Flux may be applied to the under surfaces of bases 33 of the fins, as by a brush. A suitable flux is a mixture of borax and boric acid, applied in a heated condition.

The iron cylinders to which the finning structure is to be attached, should be given a smooth, clean outer surface. They may be electroplated with a light coating of copper if desired, although this is not at all necessary. The iron cylinders may be coated with a flux, preferably borax and boric acid, applied with a brush and allowed to dry. A sheet of brass bonding material should then be wrapped snugly around the cylinder. This bonding material should consist preferably of about 62% copper. The sheet of brass referred to, constitutes the brazing material by which the finning structure is bonded to the iron cylinder. This brazing material has a lower melting point than that of the copper used for the finning structure. The finning structure may be temporarily bound to the cylinder mechanically, as by iron wires 35, the ends of which may be twisted together, as at 36, for the purpose of tightening the wires around the finning structure. The assembly thus formed should be dipped in a bath of relatively thick fluxing material, thus coating all exposed surfaces of the copper finning material. This protects the copper from the action of heat during the subsequent brazing operations. The assembly may be then brazed in a furnace.

The brazing operation should take place preferably out of contact with products of combustion and preferably by the radiant heat of an electric furnace. In the furnace the assembly is heated to a temperature at which the brazing material fuses and will flow into all spaces between the elements of the finning structure and the iron cylinder. The heat is not so high as to melt the copper. After the brazing operation is completed, the assembly is thoroughly cleaned, any distorted fin loops trued up, and treated otherwise to put the product in finished condition.

It will be appreciated from the above description of the brazing operation that the temperature conditions must be such that the brass is brought into the best condition for forming a bond with the cast iron and the copper fins, and that care is taken that this bond shall be as uniform as possible, and shall extend over substantially the entire area of the under surface of the finning structure. By conducting the heat operation in the manner described, sufficient heat is applied to bring the assembly up to the desired temperature, and sufficient time is given to enable the metals to become uniformly heated and bonded. The molten brazing solder unites with and coheres to the copper of the fins, and the iron is united with the contiguous metals which cohere to it.

Attempts have been made to shear off the metals of the union from a cylinder made in accordance with the process, and it has been found that the contiguous metals are bonded to the iron with a strength greater than the breaking strength of the contiguous brass and copper, indicating the presence of a zone of cohesion intermediate the iron and the contigous metals where the iron is combined or alloyed with the contiguous metals.

A magnified cross section of the union between the cylinder and a fin is illustrated in Fig. 6, in which 145 represents the cast iron cylinder and 146 represents the zone of intermixture, alloying or cohesion between the iron and the brazing solder, 147 represents the zone of solder, 148 represents the zone of intermingling, alloying or cohesion between the solder and the copper of the finning structure, and 149 represents the substantially pure copper. The zones 146 and 148, are represented diagrammatically by the symbol *xxxx* and may not be as thick, relatively, as the drawing indicates. So far as I am able to ascertain I believe that these zones are present in the completed structure. But the dimensions and thicknesses are exaggerated for the sake of clearness, and are not intended to be accurately proportional. Microphotographs of sections of bonds produced by the hereindescribed process seem to indicate that there is a progressive merging metallic path for the conduction of heat from the iron to the copper, and tests tend to show that true thermal connection exists between the fins and the iron. At least this union offers considerably less resistance to the passage of heat than would be the case in a junction where the copper fins are merely in contact with the iron.

It will be noted from examination of Fig. 6 that the brazing solder has flowed up between the edges of adjacent fins during the brazing operation as indicated at 150, bonding these fins together, thus strengthening the roots of adjacent fins. The bases of adjacent fins are thus each interconnected by the brazing solder alloyed therewith so that there is formed a continuous "skin" of heat conducting metal around the outside of the cylinder from which the roots of the fins project and merge into the fins proper, the roots of these fins being preferably of greater thickness than double the thickness of the fins beyond the roots.

While it is desirable to have a continuous skin on the outside of the cylinder, as described above, as it permits of equalizing the distribution of heat in the outer surface of the cylinder, the invention is not limited to a bond between the fin and the engine cylinder which results in the formation of a "skin", as each fin might be affixed by a bond of the type described above without contacting with the adjacent fins. Moreover the contact between each fin and the engine cylinder may be and preferably is continuous; it may also be a series of short contacts. It will be noticed that the flow of heat takes place very readily from the inside of the cylinder shell to the fins; a relatively thin iron cylinder shell is preferably used, and the heat passes rapidly to the bond and passes relatively unimpeded over the zones 146, 147 and 148 into the copper 149 of the fins which are usually subjected to cooling air as hereinbefore described. The melting point of the brazing metal being higher than that attained in the normal operation of the engine, there will be no tendency for the fins to come off the cylinder in the operation of the engine due to the heat of engine operation, and tests extending over a considerable period indicate that no deteriorating action tending to weaken the bond takes place after rapid running of the engine for a considerable length of time, so that the attachment of the fins to the cylinder may be termed a permanent one. It will be found that the union between the fins and the engine cylinder is continuous not only circumferentially between adjacent fins, but also longitudinally between the shell and the fin. The mechanical strength of this union is such that if it is attempted to pull the fins off the cylinder of the dimensions heretofore described, they will break elsewhere than in the area of junction.

Nowithstanding the fact that the cast iron is raised up to a high temperature, it is not injured by the brazing operation. It will further be noticed that a large number of copper fins are employed, and that these fins are made of relatively thin copper; each fin is permanently attached to the cast iron cylinder by the intermediary of a heat conducting union which covers an extensive area of the cylinder compared with the cross sectional area of the fin.

Good results have been obtained by the use of a fin in which the height of the fin is in the neighborhood of about 70 times the thickness of the metal of the fin; the total number of fins employed and their height and length and distance apart are also preferably predetermined with the view to providing a very extensive heat dissipating surface. This extensive heat dissipating surface is obtained by employing a large number of thin copper fins separated by relatively small air spaces. In the embodiment of the invention shown in Fig. 4, sixty fin loops 32, providing in all one hundred and twenty fins 320 are shown. In practice it has been found advantageous to use about 12 fins per peripheral inch.

While the union of metals in accordance with the invention may be employed with any thickness of copper fins, I prefer nevertheless to use it with a thin fin such as described herein, and having the advantages referred to.

It will be noted by examination of the strip of finning illustrated in Figs. 1 and 3 that the fins are equidistantly separated and are folded so as to have the inner edges provided with a flat base produced by "flaring" the inner portions of the several folds or crimps as clearly shown. This form of fin, which may be termed a "flare edge" or "base-formed" fin, has been found to have decided advantages. It assists in uniformly spacing the fins apart, and it provides for more equal distribution of the air between the fins.

The preferred form of finning structure comprises a plurality of folds or fin loops of sheet metal each constituting a flattened tube having one edge attached to the cylinder wall. This tube is open at both ends and allows the passage therethrough of a draft of air, while the finning structure may be protected and strengthened and an additional draft of air caused to pass along the outside of the several loops by surrounding the entire fin structure with a sleeve indicated at 155. (Figs. 4 and 5.)

Referring to Figs. 9 and 10 which show a portion of a complete engine 156, it will be noticed that the cylinders 157 and finning 158 are surrounded by a draft tube 159 which merges into a head portion 160 leading into the inlet side of a fan 161 driven by the engine. Because of the large area of the heat dissipating fins, an efficient cooling of the engine takes place with the utilization of a fan which takes only a small proportion of power from the engine in order to provide a flow of cooling air sufficient to keep the cylinder efficiently cooled. As a result of this efficient cooling, due to the use of a large number of thin copper ribs or fins attached to the cylinder in the manner herein described, and dividing the draft tube into a large number of air passages, it is possible to get a higher horse-power and more economical engine.

The invention has been described above with reference to fins the outer edges of which are arranged concentrically around the engine cylinder, each fin being of the same dimensions as its neighbor. In constructing an engine utilizing cylinders in accordance with the present invention, it is found possible to reduce the length of the engine by arranging the cylinders in pairs with the inlet sides of the cylinders closer together than the outlet sides. Such an arrangement is shown in Fig. 9, wherein the inlet ports of the cylinder 157 are indicated at 162 and the exhaust ports at 163. The valve structure is omitted in Fig. 9 for sake of clearness.

It has been found that the fins at the inlet sides of the cylinder need not provide so large a conducting area and so large a heat dissipating area as the fins on the outlet side of the cylinder, inasmuch as the inlet side of the cylinder is cooled by the incoming fuel mixture while the exhaust side of the cylinder is heated by the outgoing products of combustion. It thus becomes desirable to provide fins of varying contour, which contour may be that indicated in Figs. 7, 8 and 9, Fig. 7 shows an end elevation of the so-called eccentric finning structure 170 in condition ready to be wrapped about a cylinder, there being provided a series of short fins 171 to permit the cylinders to come close together, which short fins are located on the inlet side of the cylinder. The short fins 172 provide passage for the push rods for the valves. The fins 173 are shortened to reduce the distance between the adjacent pairs of cylinders. When this form of finning structure is assembled on a cylinder it has the shape shown in Fig. 8. The method of assembling and heat treating is substantially the same as already described in connection with the fins of the same radial height hereinbefore described, but in assembling the aforementioned fins of varied height spacing blocks 175 and 176 shown in Fig. 8 are employed. In assembling a fin structure of uneven contour, difficulty is encountered in providing for the proper even pressure applied to all the fins. This results from the fact that if an iron wire is passed circumferentially around the fins of uneven contour, it is difficult to produce even pressure and even contacts. This difficulty is overcome by employing a pair of spacing means, these being respectively, the large spacing block 175 and the small spacing block 176 which fill up the spaces between the short fins and the circle which would include the full size fins. These blocks are preferably made of copper, and are adapted to bear against the outer faces of the fins so that when the assemblage is completed on the assembling fixture, it is possible to bind the iron wire circumferentially around the assemblage as shown in Fig. 8, and to insure that the radial pressure exerted by the wires shall be substantially evenly distributed through both the short and long fins. In tying the assemblage together by means of wires, it has been found desirable to use a number of short pieces of wire which are provided with loops 178 in a median portion thereof, and these wires fit into grooves (not shown) in the outer face of the small copper block 176. The operator first twists the free ends of the wires together as shown at 179 and thereafter tightens the median loops 178 until he is satisfied that the pressure is distributed evenly over the entire surface of the fin structure.

While there have been described specifically copper fins of particular forms united to a cast iron or steel cylinder, it is to be understood that the invention is not limited to these specific forms herein, which are the preferred ones and have given satisfactory results in practice. The examples of particular forms and dimensions herein referred to, are by way of preference or examples, and not by way of limitation, as I believe it is novel in this art to attach a fin of copper to a cast iron, steel or other type of cylinder by a metallic union which is permanent, gives excellent thermal contact, is mechanically strong, and does not deteriorate substantially under running temperatures and running conditions of an internal combustion engine. The heat from the cylinder passes through the union from the iron to the copper without substantial obstruction, and the fin, being made of copper (which is almost nine times as good a conductor as iron), rapidly draws the heat out of the cylinder. This heat is withdrawn from the copper fins by the cooling air stream, and, owing to the large number of copper fins and their relatively large dimensions, the engine cylinder has a very large heat dissipating surface which increases its cooling efficiency to a marked degree as compared with the iron or steel fins common in this art.

The invention may also be found useful in connection with the brazing of copper and any heat exchange vessels which are subjected to conditions similar to those obtained in the interior of an engine. The term brazing metal as used in certain of the appended claims is intended to mean not only brass of a specific composition such as herein given, but any alloy or metal which can act in the same way as brass in effecting a union between the shell and the fins, which fins are not necessarily made of copper as any metal of high heat conductivity might be employed in place of copper.

While the invention has been described herein with reference to attaching copper fins, it is to be understood that it may apply to, and be employed equally advantageously in attaching fins of other suitable high conductive metals to the engine cylinder, and that while the engine cylinder is here described as being made of cast iron or steel, it may be made of other suitable metal without departing from the bounds of my invention, or the scope of the annexed claims.

The structures herein shown and described constitute preferred embodiments of the invention, but it is to be understood that other forms might be adopted and changes made, all coming within the scope of the claims which follow.

What I claim is as follows:

1. In heat exchange apparatus, means for dissipating heat comprising a metallic body, sheet metal heat-dissipating elements thereon projecting from said body, said heat-dissipating elements having base flanges ar-

ranged side by side, so that said base flanges substantially cover the surface of said body from which said heat-dissipating elements project, and an uninterrupted layer of bonding metal cohering to said body and to said elements and providing an uninterrupted molecular path for conducting heat from said body to said elements.

2. In heat exchange apparatus, means for dissipating heat comprising a metallic body, heat-dissipating elements bonded thereto, said heat-dissipating elements comprising a series of radiating fins forming parts of a continuous sheet of metal, said fins being joined by portions of said sheet constituting base flanges in contact with said body, said base flanges lying in substantial contact with each other.

3. In heat exchange apparatus, means for dissipating heat comprising a metallic body, heat-dissipating elements bonded thereto, said heat-dissipating elements comprising a series of radiating loops forming parts of a continuous sheet of metal, said loops being joined by portions of said sheet constituting base flanges in contact with said body, said base flanges lying in substantial contact with each other.

4. In heat exchange apparatus, means for dissipating heat comprising a metallic body, heat-dissipating elements bonded thereto, said heat-dissipating elements comprising a series of radiating fins forming portion of a continuous sheet of metal, said fins being joined by portions of said sheet constituting base flanges in contact with said body, said base flanges lying in substantial contact with each other and being integrally connected by an interposed layer of metal cohering to said flanges and providing an uninterrupted molecular path for conducting heat from one flange to the other.

5. In heat exchange apparatus, means for dissipating heat comprising a ferrous body, copper heat-dissipating elements bonded thereto, said heat-dissipating elements comprising a series of radiating fins forming parts of a continuous sheet of copper, said fins being joined by portions of said sheet constituting base flanges in contact with said body, said flanges being integrally connected by an interposed layer of metal cohering to said flanges and providing an uninterrupted molecular path for conducting heat from one flange to the other.

6. In heat exchange apparatus, means for dissipating heat comprising a cylindrical metallic body and a plurality of heat-dissipating loops bonded thereto, said loops extending parallel with the axis of said body and being connected together by a plurality of bases, the combined area of said bases being substantially equal to the peripheral area of that portion of the cylindrical body to which the heat-dissipating loops are bonded.

7. In heat exchange apparatus, means for dissipating heat comprising a ferrous cylinder, radiating heat-dissipating elements uniformly spaced on the outer surface of the cylinder, said heat-dissipating elements being made of non-ferrous metal having a heat conductivity substantially greater than that of the ferrous cylinder, said heat-dissipating elements being formed of a thin sheet bent to form the heat-dissipating elements and of sufficient conducting capacity and surface to dissipate heat absorbed by the cylinder from fuel combustion, said sheet being bonded to the cylinder by a progressive alloying with an intermediate metal of high conductivity so as to provide a progressive alloying of the cylinder with the bond and of the bond with the heat-dissipating elements, thereby providing an uninterrupted molecular path for the conduction of heat from the cylinder to the heat-dissipating elements.

In testimony whereof I hereto affix my signature.

CHARLES F. KETTERING.