Oct. 25, 1966 W. LEEMING ETAL 3,280,758

CYLINDER BLOCK OF A HYDRAULIC UNIT AND METHOD OF MAKING SAME

Filed Sept. 24, 1964

2 Sheets-Sheet 1

FIG. 1.

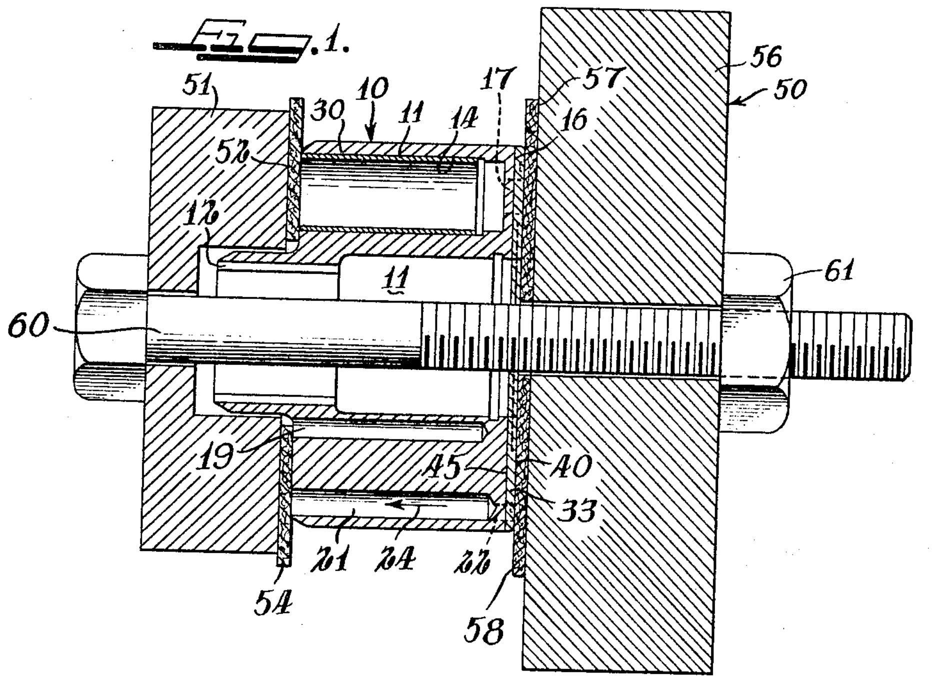


FIG. 2.

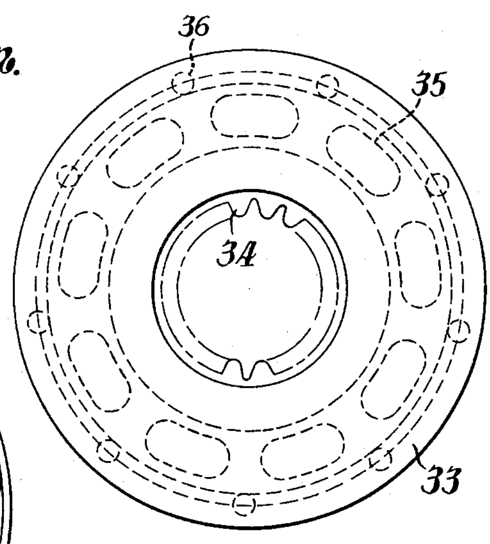
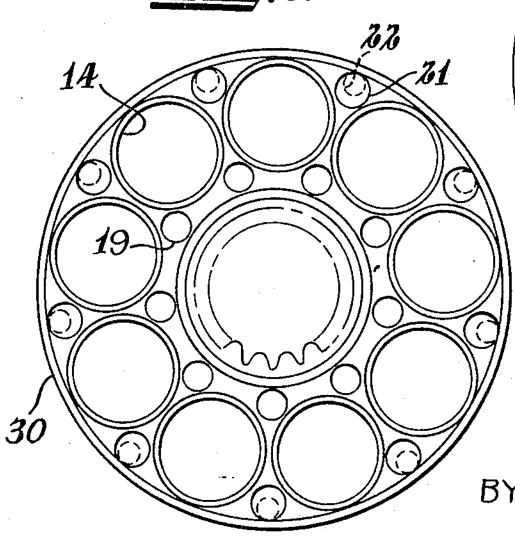


FIG. 3.



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CYLINDER BLOCK OF A HYDRAULIC UNIT AND METHOD OF MAKING SAME

Filed Sept. 24, 1964 2 Sheets-Sheet 2

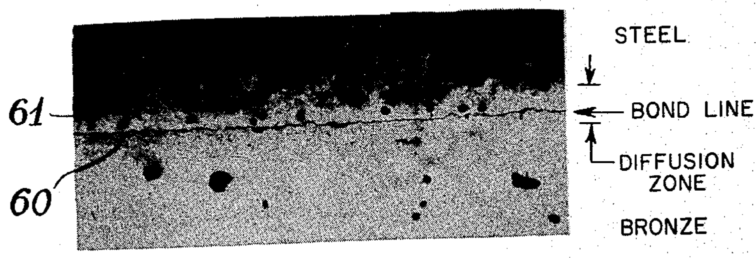

FIG. 4.

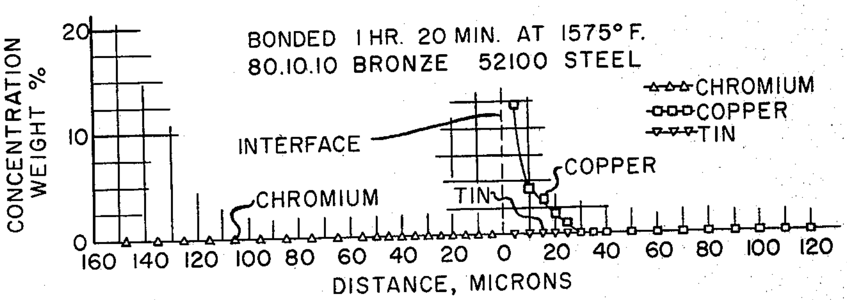

FIG. 5.

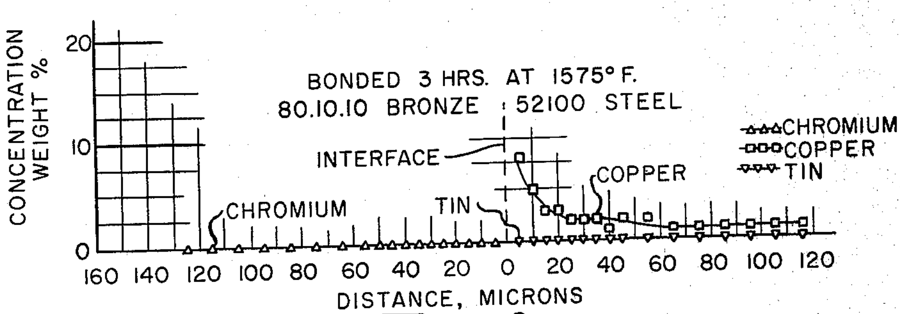

FIG. 6.

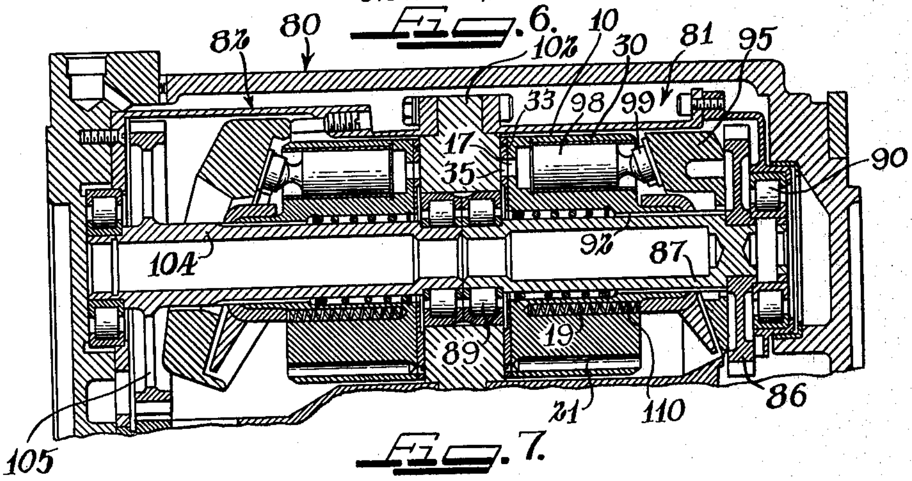

FIG. 7.

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CYLINDER BLOCK OF A HYDRAULIC UNIT AND METHOD OF MAKING SAME

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Filed Sept. 24, 1964, Ser. No. 399,046

17 Claims. (Cl. 103—162)

This invention relates to hydraulic pump and motor units and particularly to a new and improved cylinder block for a hydraulic unit and a method of making the cylinder block.

In one type of hydraulic unit, multiple pistons reciprocate in cylinders in a rotating cylinder block while fluid flows to and from the cylinders through ports such as arcuate ports in a stationary valve members against which the cylinder block rotates. The cylinder block may be of a radial piston type, in which the cylinders and pistons radiate from the axis of rotation of the cylinder block, or an axial piston type, in which the pistons and cylinders are formed in the cylinder block parallel to the axis of rotation of the block or the cylinders may be inclined radially and axially relative to the axis. A cam member stationary with respect to the cylinder block is conventionally employed to reciprocate the pistons and depending upon the position of the cam member and the direction of rotation of the cylinder block, the multiple piston hydraulic unit may be employed as either a pump for delivering hydraulic fluid under pressure or as a motor for driving a load.

In the rotating cylinder block of hydraulic units of the character mentioned, there are generally two areas of critical bearing contact between the block and other portions of the hydraulic unit. One is the bearing surface between the pistons and the cylindrical bores in the block, and the other is the bearing surface between one end of the cylinder block and the stationary valving member against which the cylinder block rotates. It is extremely desirable to construct these areas of the cylinder block of a suitable bearing material to assure proper seating of the pistons and the valve member relative to the cylinder block. However, it is often impractical to construct the cylinder block entirely of a suitable bearing material as this reduces the over-all strength and temperature expansion characteristics of the cylinder block.

It is in this background that applicants have provided a hydraulic unit cylinder block constructed of high strength material with sleeves in the cylinder bores constructed of a bearing material to improve the sliding contact characteristics between the reciprocating pistons and the cylinder bores, and with a bearing plate constructed of a suitable bearing material on one end of the cylinder block adjacent and engaging the stationary valve member to improve the sliding contact characteristics between the block and the stationary valve member. Because of strenuous operating conditions normally encountered in the use of hydraulic units of the type described, it is necessary that the sleeves and the bearing plate be secured firmly to the cylinder block to prevent loosening or deformation of the members during use. By metallurgically bonding the sleeves and the valve plate to the cylinder block by a new and improved method, a durable and long-lasting cylinder block has been provided. The metallurgical bond is provided between the bearing material of the sleeves and the bearing plate, which may be bronze, and the high strength steel of the cylinder block, which may be a low alloy or carbon tool steel, by heating the metals while in intimate contact under a relatively low pressure to a temperature just within the melting range of the bearing material and in the austenitizing range of the steel

cylinder block so that a portion of the bearing material adjacent the interface diffuses across in the steel adjacent the interface.

It is, therefore, a primary object of the present invention to provide a method of joining dissimilar metals as by diffusing a portion of the lower melting range metal adjacent the interface into the higher melting range metal to form an intimate metallurgical bond.

Another object of the present invention is to provide a method of joining a bearing metal to carbon steel by heating the metals while in intimate contact under relatively low pressure into the austenitizing range of the steel and just within the melting range of the bearing metal for a sufficient time so that a portion of the bearing metal adjacent the metal interface diffuses into the steel. This method proceeds without the use of a flux or a tertiary bonding metal and results from the intimate contact of the two metal surfaces to be joined along with the application of heat at a temperature and time determined by the characteristics of the metals to be joined.

A further object of the present invention is to provide a new and improved method of bonding cylinder sleeves to a hydraulic unit cylinder block by press fitting the sleeves constructed of a suitable bearing material into the cylinder bores of a steel cylinder block and heating the block to a temperature and for a time sufficient for a portion of the sleeves adjacent the interface to expand and liquify and diffuse into the interstices of the steel cylinder block forming an intimate metallurgical bond.

Another object of the present invention is to provide a new and improved method of joining a bearing plate to one end of a cylinder block by clamping the bearing plate constructed of a suitable bearing material to a carbon steel cylinder block and then heating the cylinder block at a temperature and for a time sufficient for a portion of the bearing metal adjacent the interface to diffuse into the steel forming an intimate metallurgical bond.

A more specific object of the present invention is to provide a method of joining cylinder sleeves and a bearing plate both constructed of bronze to a carbon steel cylinder block by press fitting the bronze sleeves into the cylinder bores and clamping the bronze bearing plate to one end of the cylinder block and then heating the cylinder block into the austenitizing range of the carbon steel and just within the melting range of the bronze so that a portion of the copper in the bronze adjacent the interfaces crosses thereover and diffuses into the carbon steel adjacent the interfaces forming intimate metallurgical bonds.

Another object of the present invention is to provide a new and improved cylinder block having a bearing metal sleeve bonded within the cylinder bores to reduce the frictional contact and improve the sliding fit between the pistons and the cylinder block. The sleeves are bonded to the cylinder bores without the use of a flux or a third bonding material with the bond consisting purely of a diffused portion of the bearing metal interlaced in the material of the cylinder block.

A further object of the present invention is to provide a new and improved cylinder block for a hydraulic unit having a bearing plate adjacent one end thereof adapted to slide against a relatively stationary valving member in which the bearing plate is metallurgically bonded to the cylinder block and a portion of the valve plate adjacent the interface is diffused into the steel of the cylinder block.

A still more specific object of the present invention is to provide a new and improved cylinder block for a hydraulic unit with bronze sleeves bonded within the cylinder bores of a carbon steel cylinder block and a bronze bearing plate bonded to one end of the cylinder block with a portion of the bronze in the sleeves and in the plate diffused into the carbon steel.

Other objects and advantages will become readily apparent from the following detailed description taken in connection with the accompanying drawings, in which:

FIG. 1 is a longitudinal cross-sectional view of the cylinder block of the present invention with a valve plate clamp engaging both ends of the block in carrying out the method of the present invention;

FIG. 2 is an end elevation of the cylinder block of FIG. 1 showing the valve plate with annularly arrayed cylinder ports therein;

FIG. 3 is an opposite end elevation of the cylinder block shown in FIG. 1 showing the cylinder sleeves in place in the cylinder bores;

FIG. 4 is a photomicrograph of the metallurgical bond between the cylinder sleeves, the bearing plate and the cylinder block taken along the interface between the two metals;

FIG. 5 is a graph showing the diffusion of the metals adjacent the interface in the present invention employing exemplary metals;

FIG. 6 is a graph similar to FIG. 5 showing the diffusion of the metals adjacent the interface in the present metallurgical bond resulting from a longer bonding time than was employed in the bond exemplified by the graph of FIG. 5; and

FIG. 7 is a fragmentary cross-section of a transmission incorporating hydraulic units with cylinder blocks of the present invention.

While an illustrative embodiment of the invention is shown in the drawings and will be described in detail herein, the invention is susceptible of embodiment in many different forms and it should be understood that the present disclosure is to be considered as an exemplification of the principles of the invention and is not intended to limit the invention to the embodiment illustrated. The scope of the invention will be pointed out in the appended claims.

Referring to FIGS. 1, 2 and 3, a generally cylindrical cylinder block designated by the numeral **10** has a central bore **11** therein reduced at one end and internally splined as at **12** to receive and engage a splined drive shaft. As illustrated, nine cylinder bores **14** are formed in the cylinder block **10** in annular array with their axes parallel to the center line of bore **11**. The cylinder bores **14** communicate with an end surface **16** of the cylinder block through axially extending ports **17** shown in FIG. 1. Formed radially inwardly of bores **14** are closed end bores **19** in annular array about the center line of bore **11** as shown more clearly in FIG. 3. The bores **19** are adapted to receive compression springs which serve to urge the cylinder block **10** against a stationary valve member having arcuate ports adjacent the end surface **16** of the cylinder block **10**. Also in annular array about the center line of bore **11** are bores **21** which communicate with ports **22** opening to the end surface **16** of the cylinder block **10**. The passages **21** serve to permit the escape of leakage fluid from between the cylinder block and the valve member (not shown) and discharge of the fluid in the direction of arrow **24** in FIG. 1.

The cylinder block **10**, as described above, is of the type employed in an axial piston hydraulic motor, in which pistons reciprocate in cylinder bores **14** as fluid enters and leaves the cylinders through the right end of the cylinder block as viewed in FIG. 1. Conventionally, the pistons (not shown in FIGS. 1 to 3) extend from the left end of bores **14** and engage an inclined cam member or swashplate normally stationary with respect to the cylinder block and serving to reciprocate the pistons in the cylinder bores **14**. If the hydraulic unit is acting as a pump, an input engages the splines **12** in the bore **11** and rotates the cylinder block against a valve member having two arcuate ports which serially communicate with the bores **14**. As the cylinder block rotates, the pistons follow the swashplate or cam member on intake strokes as the cylinder bores pass over one of the arcuate ports in the stationary valve member and the cam pushes the pistons into the cylinders on discharge strokes as the cylinders pass over the other port to deliver fluid under pressure through the other port in the stationary valve member. When the hydraulic unit is acting as a motor rather than a pump, fluid under pressure admitted to the cylinders pushes the pistons which slide on the cam and cause rotation of the shaft splined to the block.

The cylinder block **10** is constructed of a high strength steel such as a carbon tool steel, a bearing steel, an air hardening steel or a low alloy steel. Cylinder sleeves **30** are bonded within each of the cylinder boves **14** to improve the sliding contact characteristics of the pistons and the cylinder block **10** by a method described in detail below. The cylinder sleeves **30** may be constructed of an alloy of the base metals such as one of the bronzes, AMS 4842, for example. A bearing plate **33** is bonded to end surface **16** of the cylinder block **10** and serves as a bearing surface between the cylinder block **10** and the stationary valve member. Viewing FIG. 2, the bearing plate **33** is annular in shape and has a central bore **34** concetric with through bore **11** in the cylinder block, and nine annularly arrayed arcuate ports **35** aligned with the axial ports **17** in the cylinder block **10**. Annularly arrayed ports **36** communicate with passages **21** and **22** in the cylinder block to discharge leakage fluid escaping between the surface **40**, FIG. 1, of the bearing plate and the valve member (not shown in FIG. 3) in the operation of the hydraulic unit. The bearing plate **33** is constructed of a suitable bearing material, such as bronze, and may be the same material as that employed in the cylinder sleeves **30**. It may be seen that the sliding contact between the cylinder block **10** and the stationary valve member is on the surface **40** of the bearing plate and not on the steel portions of the cylinder block so that an improved sliding contact is effected with reduced friction and improved sealing.

The method of bonding the bearing plate **33** and the cylinder sleeves **30** to the cylinder block **10** will be described with a specific reference to several dissimilar metals, it should be understood that the principles are applicable to other metals having similar characteristics. It is necessary that the surfaces to be joined be smooth and have the proper surface finish. For this purpose, the outer diameter of the bushings must be finished with the discontinuities and irregularities removed preferably to a roughness on the order of 16 R.M.S. and the bushing may be sized in the range of .0003 inch loose fit or clearance in the cylinder bore to a .0010 inch interference fit in the bore in order to secure intimate contact between the outer diameter of the bushing and surface of the cylindrical bore **14** in the cylinder block. The valve plate **33** should be machined with both faces thereof parallel within .005 inch with bonding surface **45** flat within .0002 inch with discontinuities and irregularities removed to a roughness on the order of 10 R.M.S. The cylinder block **10** is machined so that the cylinder bores **14** have a smooth surface finish with a roughness on the order of 32 R.M.S. and the end surface **16** is flat and straight within .0002 inch with a surface roughness on the order of 4 R.M.S.

A clamp **50** is employed in the process to secure intimate contact between the bearing plate **33** and the cylinder block **10** during bonding. The clamp **50** consists of a first plate **51** having a clamping surface **52** engaging the rear end of the block through asbestos sheet **54**, and a second clamping member **56** having a clamping surface **57** engaging the bearing plate surface **40** through asbestos sheet **58**. The clamping members **51** and **56** are urged together by bolt **60** and nut **61**. Suitable vents (not shown) are provided in the clamping members **51** and **56** and the asbestos sheets to permit gas to escape from the cylinders **14** and the bore **11** during bonding.

In preparing the parts for the bonding operation, it should be understood that the bores 14 and 21 in the cylinder block are left blind prior to the bonding operation, and subsequent to bonding the ports 17 and 22 in the end of the cylinder block and the registering ports in the bearing plate are suitably machined, as well as any grooving in the surface 40 of the bearing member. It should also be understood that if desired, the bearing plate may initially have an outer diameter greater than the diameter of the cylinder block and be suitably machined down to the diameter of the cylinder block after bonding.

After the bonding surfaces are suitably smooth, the surface oxides are removed from the cylinder bores 14, the outer surface of the sleeves 30, the end surface 16 of the cylinder block and the bonding surface 45 of the bearing plate 33 by any suitable method such as hand scrubbing with a suitable abrasive cleaning agent (such as household cleanser) or cleaning solution. The cylinder block 10, bushings 30 and valve plate 33 are then sonic cleaned to remove all foreign matter. These members are then placed in an acetone bath to assure that the parts are clean until the heating process. The clamping fixture 56 should also be cleaned in accordance with the above cleaning operation.

The bushings 30 are then pressed into the cylinder 14 by a suitable press. The resulting assembly is then returned to an acetone bath preparatory to the next operation. The bearing plate is then placed on asbestos sheet 58 on the second clamping member 56 and thereafter the cylinder block 10 is stacked on bonding surface 45 of the bearing plate 33. After the clamping member 51 and the asbestor sheet 54 are placed on the left end of the cylinder block, bolt 60 is threaded through nut 61 to clamp the parts together as a unitary assembly.

The pressure between the bearing plate 33 and the cylinder block is initially on the order of 2,000 p.s.i., within a range of ±200 p.s.i. for example, when clamped in the bonding fixture at room temperature, and is dependent upon the torque applied to nut 61. The criterion is a good intimate contact between the surfaces to be bonded. Such initial pressure reduces as a function of time in the bonding temperature through loss of strength and creep under load of the steel bolting element which ties the pieces together. By the end of the bonding cycle, the pressure at the interface may be zero or very close to it.

The pressure at the interface of the bushing and bore is a function of the fit of the bushing in the bore initially, the modulus of elasticity of the block and the bushing material, and the diameter, and may vary depending upon the tightness of the fit in the range referred to above. The criterion is a good, snug fit with the pressures ranging from zero to the yield strength of the bushing which may be on the order of 18,000 p.s.i. Of significance is the higher coefficient of expansion of the bearing inserts which assures a greater expansion of the inserts in order to maintain pressure between the bearing insert and the wall of the cylinder bore during bonding.

While three bonding cycles are described below in detail, with different bronze bearing metals and steel cylinder blocks, it should be noted that the principles of the bonding operation are applicable to the joining of other dissimilar metals having similar characteristics. However, the specific steels and bronzes have been found to produce a preferable bond. The bonding cycle is effected by raising the temperature of the bearing metal, i.e., in the sleeves and the valve plate 33, to a temperature just within the melting range of the bearing metal so that a portion of the bearing metal is in the liquid phase. This temperature corresponds to the austenitizing temperature range of the cylinder block, which of course is still a solid phase. No fluxing material or bonding agent or other intermediate materials are employed in the bonding cycle. The bonding temperatures and times are adjusted and determined so that bonding proceeds just within the melting range of the bearing metal by maintaining a compatible temperature for austenitizing the cylinder block and perhaps subsequent direct hardening so that overheating or coarsening thereof is avoided. By producing a partial liquid phase of the bearing metal, diffusion of the bearing metal adjacent the interface occurs.

In the first exemplary method, the cylinder block is AISI E52100 and the cylinder sleeves 30 and the bearing plate 33 are sand, centrifugal, or investment cast AMS 4842. The completed cylinder block assembly, removed from the bag, is placed in a furnace and preheated at 1300 ±25° F. for a minimum of one-half hour. Then the assembly is heated at 1575 ±15° F. for approximately two to two and one-half hours for cylinder blocks under three and one-half inches in diameter and three to three and one-half hours for cylinder blocks over three and one-half inches in diameter. An endothermic atmosphere controlled to a carbon potential neutral to the base steel is maintained in the furnace during the heating and cooling steps. An exemplary dew point is between 30 and 35 for the atmosphere. Cooling is then begun by reducing the assembly temperature to 1300 ±15° F. for two to two and one-half hours. Cooling is continued to room temperature while maintaining a protective atmosphere as by transferring the assembly to a zone over an oil quench tank heated to 300–350° F. for example where it is atmosphere cooled for a minimum of thirty minutes. Thereafter, the layup may be removed from the furnace and cooling continued at room temperature. The steel cylinder block then has a Rockwell C hardness between ten and twenty-five.

The furnace atmosphere is important in that no flux or other third material is used in the bonding operation so that clean surfaces and nonoxidizing conditions must be maintained. Best results are obtained when a dry, inert atmosphere is used. Because of availability, a standard endothermic furnace has been generally used and has worked well enough for production purposes. The endothermic gas atmosphere in such furnaces is reducing in nature and is maintained with a carbon potential neutral to the ferrous member of the assembly being bonded. The pressure need only be slightly above atmospheric in order to insure against leakage into the furnace.

A second exemplary bonding cycle is employed for AISI A–6 steel cylinder blocks and cast AMS 4842 bearing plates and cylinder sleeves. After removal from the bag, the cylinder block assembly is preheated at 1300 ±25° F. for a minimum of one hour. Then the assembly is heated at 1575 ±15° F. for approximately two to two and one-half hours or three to three and one-half hours depending upon the block sizes noted above. A similar atmosphere as employed in the first method described above is provided. This completes the bonding and the assembly is then rapidly cooled to produce transformation and a hardened structure. Tempering of the block may then proceed at 500 ±10° F. for two to two and one-half hours with a resulting block hardness of between 50 and 60 Rockwell C. The furnace may be similar to that referred to above.

A third method employs AISI E52100 for the cylinder block the same as the first method noted above, with cast AMS 4842 bronze cylinder sleeves and bearing plates. Initially, in a vacuum furnace the completed cylinder block assembly is degassed to less than three microns of mercury at 600 ±10° F. The bonding furnace is then back filled with dry argon to produce a non-oxidizing atmosphere at a pressure only slightly above atmosphere. Any inert gas may be used such as neon, nitrogen and helium. The pressure should be above the vapor pressure of the most volatile constituent such as the lead in the leaded bronze. Then the cylinder block assembly is preheated at 1300 ±25° F. for at least one-half hour. The assembly is then heated to 1600 ±15° F. for two to two and one-half hours or three to three and one-half hours depending upon the size of the cylinder block as noted above, and then cooled to 1300 ±25° F. for about two to two and one-half hours. Cooling is continued by stepping the temperature of the assembly from 1300° F. to 1000° F. in 100° hourly increments for four hours. Thereafter, the assembly is cooled at room temperature after which it is removed from the argon atmosphere of the furnace.

Other steels for the cylinder block have been tested satisfactorily using the above methods. These steels include AISI 4340 and AISI 4140.

The specific examples of the methods above are adapted to the type of steel and bearing metal employed and the bonding temperature ranges are controlled by the physical properties of the bearing material in the sleeves and plate and the steel in the cylinder block. To accomplish the broad aspects of the present method, the dissimilar metals must be paired so that a partial, but not complete, melting of the bearing alloy is accomplished while providing an acceptable austenitizing temperature range for the steel cylinder block. Somewhat lower temperatures may be employed if it is not desired that the steel in the cylinder block be hardened or if it is to be later hardened by another method, such as the induction hardening of specific areas of the block.

Referring now to FIG. 4 wherein a photomicrograph of the resulting bond is shown under a 500× magnification. The metal below interface **60** is primarily the bronze in the bearing plate or cylinder sleeves and the metal above the interface **60** is primarily the steel in the cylinder block. The photomicrograph is of the interface between an AISI 52100 steel cylinder block and an AMS 4842 bronze bearing plate or cylinder bushing, but it should be understood that similar photomicrographs will result from the use of the other similar metals noted above. It may be seen that a portion of the bronze is diffused above the interface **60** as shown by the light area **61**. During bonding, the bronze including that adjacent the interface **60** partially liquifies, whereby the bronze is then metallurgically in an alpha plus liquid state, while the steel is in an austenitic state, and the liquified copper in the bronze crosses the interface **60** and flows into the steel crystalline structure taking a substitutional position in the iron lattice, producing an intimate metallurgical bond. Some of the iron may diffuse into the bronze but this is not illustrated. The bond line shown in FIG. 4 is continuous and contains no foreign material.

Referring to FIGS. 5 and 6, the diffusion of portions of the metals across the interface as determined by an electron microprobe analysis is illustrated in graphic form. FIG. 5 represents a bonding time of one hour and twenty minutes at 1575° F. while FIG. 6 represents the resulting diffusion after three hours of bonding time at 1575° F. both employing AMS 4842 bronze and 52100 AISI steel. In FIG. 5, it can be seen that for a one hour and twenty minute bonding cycle, the copper in the bronze has diffused across the interface between the metals into the steel to a depth of thirty microns from the interface. In FIG. 6, when the three hour bonding cycle is employed, the liquified copper is diffused as far as 60 microns, or even further, from the metal interface into the steel.

Illustrated in FIG. 7 is a hydraulic transmission with axial piston hydraulic units incorporating the bonded bearing plates **33** and bonded cylinder sleeves **30** on the cylinder block **10** as described with reference to FIGURES 1 to 3. Like reference numerals in FIG. 7 designate the identical parts shown in FIGS. 1 to 3. The hydraulic transmission generally indicated by the numeral **80** consists of an axial piston pump **81** in back-to-back coaxial relation with an axial piston motor **82**. As the pump and motor are similar, the components thereof will be described with reference to the pump **81**. A gear **86** driven by a suitable prime mover is fixed to and drives an input shaft **87** rotatably mounted in bearings **89** and **90**. The input shaft **87** is splined at **92** to drive the rotating cylinder block **10**. A stationary cam member **95** has an inclined surface **96** which reciprocates the pistons **98** within the bonded cylindrical sleeves **30**. The pistons **98** are connected to the cam member **95** through the ball and socket connections **99**.

As the input shaft rotates, driving the cylinders and pistons in rotation, the cam member **95** reciprocates the pistons **98** and fluid is admitted during piston intake strokes through ports **17** in the steel portion of the cylinder block and ports **35** in the bonded bearing plate from an arcuate inlet port in a valve member **102** which supports both the pump **81** and the motor **82**. During piston discharge strokes, high pressure fluid passes through an outlet port in the valve member **102** and drives the pistons in the motor **82** which effects rotation of the cylinder block of the motor **82** and thereby the output shaft **104** and output gear **105**. Hydraulic fluid returning from the motor **82** passes through the arcuate inlet port in the valve member **102** diametrically opposite the outlet port and returns to the cylinders in the pump motor block **10** as the pistons move to the right in FIG. 7. Springs **110** seated in bore **19** urge the pistons toward the cam member and a spring **111** urges the cylinder block and the bearing plate **33** against the valve member **102**.

We claim:

1. A reciprocating piston hydraulic unit, comprising, a stationary valve member having inlet and outlet ports therein, a steel cylinder block rotatably mounted and having one end thereof adjacent said valve member, said cylinder block having cylindrical bores therein, bronze sleeves bonded within said bores, said cylinder block having a bronze bearing plate bonded on said one end thereof and slidably engaging said valve plate, said bonds consisting of a portion of the bronze substitutionally diffused in the steel cylinder block, ports in said plate communicating with said cylindrical bores, pistons slidably mounted in said sleeves, and an inclined cam member for reciprocating said pistons on rotation of the cylinder block.

2. A method of bonding bronze bearing sleeves to a low alloy carbon steel cylinder block having plural cylinders therein comprising the steps of; smoothing the surfaces to be joined, cleaning the surfaces to be joined, press fitting the bronze sleeves into the cylinders, and heating the block between 1550 and 1650 degrees Fahrenheit for a time sufficient to cause substitutional diffusion of the copper in the bronze into the carbon steel.

3. A method of bonding bronze bearing sleeves to a low alloy carbon steel cylinder block having plural cylinders therein as defined in claim **2**, wherein the time is sufficient to cause approximately a 20 micron diffusion of the copper into the steel.

4. A method of bonding bronze bearing sleeves to a carbon steel hydraulic unit cylinder block having plural cylinders therein, comprising the steps of; smoothing the surfaces to be joined, cleaning the surfaces to be joined, press fitting the bronze sleeves into the cylinders, preheating the metals between 1250 and 1350 degrees Fahrenheit in a nonoxidizing atmosphere, heating the metals between 1550 and 1650 degrees Fahrenheit for at least one and one-half hours, cooling the metals at approximately 1300 degrees Fahrenheit for at least one and one-half hours, and then further cooling the metals whereby the copper in the bronze substitutionally diffuses across the interface into the carbon steel and forms an intimate metallurgical bond.

5. A method of bonding a bronze bearing plate to a carbon steel plural cylinder block of a reciprocating piston hydraulic unit having a relatively stationary valve member against which the cylinder block rotates, comprising the steps of; clamping the bearing plate to the end of the cylinder block to be adjacent the valve member; and heating the plate and the block while clamped to the austenitizing range of the carbon steel and just within the melting range of the bronze for a sufficient time for the copper in the bronze to substitutionally diffuse across the interface into the steel and form a metallurgical bond.

6. A method of bonding a bronze valve plate to the working end of a carbon steel plural cylinder block in a reciprocating piston hydraulic unit having a relatively stationary valve member against which the block rotates, comprising the steps of; smoothing the surfaces of the block and the plate to be joined, cleaning the surfaces to be joined, clamping the bearing plate to the cylinder block, preheating the block and plate while clamped in a non-oxydizing atmosphere between 1250 and 1350 degrees Fahrenheit, heating the block and the plate between 1550 and 1650 degrees Fahrenheit for at least one and one-half hours to substitutionally diffuse the bronze in the steel, and cooling the block and the plate at approximately 1300 degrees Fahrenheit.

7. A method of bonding bronze bearing sleeves and a bronze bearing plate to a carbon steel plural cylinder block of a reciprocating piston hydraulic unit having a relatively stationary valve member against which the cylinder block rotates, comprising the steps of; smoothing the surfaces to be joined, cleaning the surfaces to be joined, press fitting the sleeves into the cylinder block, clamping the bearing plate against one end of the cylinder block under a pressure of approximately 2,000 pounds per square inch, heating the cylinder block with the sleeves and plate in intimate contact therewith to the austenitizing range of the cylinder block and just within the melting range of the valve plate, and maintaining that temperature until the copper in the bronze substitutionally diffuses across the interface into the carbon steel cylinder block thereby forming an intimate metallurgical bond.

8. A cylinder block for a reciprocating piston hydraulic unit, comprising; a block member constructed of carbon steel and having a plurality of cylindrical bores therein adapted to receive the reciprocating pistons, sleeves constructed of a base metal alloy bonded within said bores, said bond consisting of a metallurgical substitutional diffusion of a portion of the base metal in the steel block.

9. A cylinder block as defined in claim 8, wherein the diffusion of the base metal extends in the steel from the interface approximately thirty microns.

10. A cylinder block as defined in claim 8, wherein the base metal is bronze, and the diffused portion of the said base metal is copper.

11. A cylinder block for a reciprocating piston hydraulic unit, comprising; a carbon steel block member having cylindrical bores therein opening to a substantially flat valving surface, and a base metal bearing plate metallurgically bonded to said bock surface, said bond consisting of a portion of said base metal being substitutionally diffused across the interface in the carbon steel cylinder block.

12. A cylinder block for a reciprocating piston hydraulic unit, comprising; a steel block member having cylindrical bores therein, and said block member having a valve surface on one end thereof communicating with said bores, a bronze bearing plate bonded on said valve surface, said bond consisting of a portion of the copper in the bearing plate substitutionally diffused across the interface in the steel block member.

13. A cylinder block as defined in claim 12 wherein said copper is diffused on the order of 30 microns in the steel.

14. A cylinder block for a reciprocating piston hydraulic unit, comprising; a carbon steel block member having cylindrical bores therein, and said block member having a valve surface on one end thereof; bronze sleeves bonded within said bores, and a bronze bearing plate bonded to said valve surface, said bonds each consisting of a portion of the copper in the bronze being substitutionally diffused in the steel block across the interface.

15. A cylinder block as defined in claim 14, wherein the substitutionally diffused portion of the copper extends from the interface into the steel a distance in the range of 30–60 microns.

16. A method of bonding base metal bearing sleeves to a carbon steel cylinder block having plural cylinders therein, comprising the step of: smoothing the surfaces of the sleeves and the cylinders to be joined, pressfitting the sleeves into the cylinders heating the metals to the austenitic temperature range of the carbon steel cylinder block and just within the melting range of the base metal sleeves whereby the base metal is in a partial liquid state, and maintaining that temperature for a time sufficient to cause substitutional diffusion of a portion of the liquified base metal across the interface into the carbon steel.

17. A method of bonding a flat base metal bearing plate to a carbon steel plural cylinder block of a reciprocating hydraulic unit having a stationary valving member against which the cylinder block rotates, comprising the steps of: clamping the base metal bearing plate to the end of the cylinder block to be adjacent the stationary valving member, and heating the plate and the block while clamped until a substitution diffusion of the base metal across the interface in the steel produces a metallurgical bond.

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Disclaimer

3,280,758.—*Wilson Leeming*, *James E. Knabe*, and *Richard C. Britton*, Rockford, Ill. CYLINDER BLOCK OF A HYDRAULIC UNIT AND METHOD OF MAKING SAME. Patent dated Oct. 25, 1966. Disclaimer filed Feb. 25, 1977, by the assignee, *Sundstrand Corporation*.

Hereby enters this disclaimer to claims 1, 5, 8, 10 to 12, 14 and 17 of said patent.

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