

5 TITLE: CLOSED CAVITY PISTON FOR HYDROSTATIC POWER  
UNITS AND METHOD OF MANUFACTURING THE SAME

#### BACKGROUND OF THE INVENTION

This invention relates to a closed cavity piston for a  
10 hydrostatic power unit. More specifically and without  
limitation, this invention relates to a new method of  
manufacturing a closed cavity piston by using metal  
injection molding techniques to form the body of the closed  
cavity piston and then sinterbonding an end cap on the  
15 piston body.

A closed cavity piston is a piston that includes one or  
more sealed hollow compartments within the piston. The  
reduced piston weight provided by the hollow compartments  
allow for greater hydrostatic shaft speeds, whereas the  
20 closed piston end reduces the amount of compressed oil  
volume in the hydrostatic unit and improves volumetric  
efficiency and control of swash plate moments. The piston  
includes a central tube for lubrication and an internal  
sphere that contacts an external sphere of a mating slipper.  
25 The piston also has either a deformable region near the  
piston sphere for joining the piston onto the slipper, or a  
deformable region near the slipper sphere for retaining the  
slipper to the piston depending on whether the piston is  
male or female.

30 There are several methods for manufacturing closed  
cavity pistons for hydrostatic units, but these methods have  
several cost and technical disadvantages. One method  
consists of positioning a hollow tube within a hollow piston  
body and attaching the tube to the piston body with one or  
35 more washers that extend radially between the outer wall of  
the tube and the inner wall of the piston body. The steps  
of this method include machining bar stock to create a one-

5 piece hollow piston with integral stem, and then securing  
the stem with a washer. Next, a welder inertia welds a  
round slug onto the end of the piston. Finally one drills a  
hole through the stem over the length of the piston. This  
manufacturing method is very expensive and not practical for  
10 pistons with small diameters.

Another method is described in U.S. Patent No.  
6,314,864 and it consists of joining a piston cap to a  
piston body by welding or brazing. Compared to the method  
previously described, this method is less expensive and can  
15 be applied to small diameter pistons. Still, the  
manufacturing equipment required to join the cap and body is  
relatively expensive and the joining process requires an  
additional manufacturing step subsequent to the metal  
injection molding process. Furthermore, the joining method  
20 introduces additional radial alignment between the piston  
socket center and the piston body center that could  
interfere with methods used to join the piston onto the  
mating slipper.

Because of recent improvements in metal injection  
25 molding techniques, making hydraulic components with these  
techniques has become feasible. The basic process of metal  
injection molding is that a desired shape may be created by  
carving the shape into two blocks of mold. This forms the  
outer surface of the product that is to be produced.  
30 Metallic mold inserts that may be repeatedly used form the  
interior of the product. Metal powder and non-metallic  
binding material are then injected into the mold and heated  
to form the shape dictated by the mold and the insert.  
After removing the product from the mold, debinding of the  
35 product occurs. The debinding process separates the  
metallic particles from the non-metal particles. After

5 debinding, the product is sintered. Sintering is a process  
by which the metallic powder may be formed into a coherent  
mass without melting the material. The same sintering  
process may be used to join together two or more components  
in contact with each other. This joining method, or  
10 "sinterbonding" process, is superior to conventional methods  
for combining metal injection molded components because  
other methods result in poor bond strength. The present  
invention uses metal injection molded components that are  
sinterbonded to produce a new closed cavity piston.

15 Thus, it is a primary object of the present invention  
to provide a new closed cavity piston that improves upon the  
state of the art.

Another object of the present invention is to minimize  
the amount of hydraulic fluid that flows through a closed  
20 cavity piston body.

Yet another object of the present invention is to  
optimize surface geometries between the closed cavity body  
and end cap to aid sinterbonding the two together.

Another object of the present invention is to provide a  
25 magnetic end cap that can capture magnetic particles present  
in a hydrostatic unit.

Yet another object of the present invention is to use a  
metal injection molding process and sintering to improve  
upon the state of the art.

30 Another object of the present invention is to provide a  
method of manufacturing a closed cavity piston that is  
inexpensive.

Yet another object of the present invention is to  
provide a method of manufacturing a closed cavity piston  
35 that can be made with great speed and efficiency.

5           Another object of the present invention is to provide a method of manufacturing a closed cavity piston using metal injecting molding to form all of the components.

          Yet another object of the present invention is to provide a method for sinterbonding metal injected molding  
10   objects together to form a closed cavity piston.

          Another object of the present invention is to provide a method for manufacturing a closed-cavity female piston that minimizes radial misalignment between the piston socket center and the center of the main piston body.

15           Yet another object of the present invention is to provide a joining technique that requires, at most, modification of the processes already employed in the metal injection molding process.

          These and other objects, features, or advantages of the  
20   present invention will become apparent from the specification and claims.

#### BRIEF SUMMARY OF THE INVENTION

          The present invention is a closed cavity piston design  
25   that can be manufactured inexpensively. The new design consists of a piston body and an end cap. Both components are manufactured using metal injection molding techniques. The piston body includes a central hollow stem and spherical socket that are integral to the rest of the piston body.  
30   The end cap is joined to the piston body using a sinterbonding process that metallurgically bonds the piston body and end cap contacting surfaces.

          The sinterbonding process may take place during the normal sintering operation used in the processing of the  
35   metal injection molding components, requiring little, if any, additional processing time. Special fixturing and

5 loading may be required during the debinding and/or sintering process to bring the cap and body into contact and to ensure a complete bonding between the end cap and the body.

#### 10 BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective view of the closed cavity piston and end cap.

Fig. 2 is a sectional view of a closed cavity piston and slipper taken along line 2 in figure 1.

15 Fig. 3 is a perspective view of a metal injection molding mold.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention relates to a closed cavity piston  
20 10 for reciprocation in the rotating cylinder block of a hydrostatic unit, such as a pump or a motor. Fig. 1 shows a closed cavity piston 10 having an end cap 12. Closed cavity piston 10 has an elongated body 14 that receives end cap 12 at open end 15. The piston body 14 may include tapered  
25 surface 16 at the open end 15, an end with a spherical cavity 18, and a hollow stem 20. The tapered surface 16 is used to align the end cap 12 and the body 14 together and to maximize the contact area between the two parts during the sinterbonding process, resulting in a more robust joint.  
30 The tapered surface 16 and tapered lip portion 22 of end cap 12 may differ slightly to ensure that complete contact is made as the two components are integrated. The tapered lip 22 and tapered surface 16 may be integrated either by mechanical means external to the parts, or through the  
35 formation of the parts during the sintering process. End cap 12 also has an opening 23 that aligns with hollow stem

5 20 forming a lubrication path through the piston. Opening  
23 and stem 20 have corresponding tapered mating surfaces.

The end cap 12 may consist of a magnetic material to capture contaminants within the hydrostatic unit. The magnetic properties of the end cap 12 may also be used for  
10 other purposes, i.e., sensing the position and motion of the piston. Use of a magnetic end cap requires a reduction in the end cap 12 diameter to ensure that contaminants do not come between the piston outside diameter and the block bore.

It should also be appreciated that in an alternative  
15 embodiment the end cap 12 can have a non-tapered lip that optimizes the geometries between the end cap 12 and the body 14 to create a matingly fit to enhance the sinterbonding process.

Fig. 2 shows a cross section of a closed cavity piston  
20 10 that can be manufactured using metal injection molding and sinterbonding an end cap 12 to the body 14. The piston 10 has a slipper 26 pivotably attached to the piston. The slipper 26 can include a portion of a spherical ball that engages a ball socket recess in the piston body 14, or one  
25 skilled in the art will appreciate that the slipper 26 could be equipped with a ball socket recess and the mating surface would be formed as a portion of a spherical ball in the piston. Fig. 2 shows a piston that has a ball socket recess 28 that mates with a ball socket 30 that is on the slipper  
30 26. Slipper 26 also has a fluid passageway 32 that fluidly connects with hollow stem 20.

The hollow stem 20 extends longitudinally throughout the entire body 14. Closed cavity piston 10 also has one or more hollow compartments 34 within its body 14.

35 Fig. 3 shows a typical metal injection mold 60. The mold 60 shapes the outer surface of the piston body 14 while

5 an insert core (not shown) is used to shape the interior of the piston body 14. The end cap 12 is created in a similar mold 60 that shapes the end cap 12.

In the manufacturing process the body 14 and the end cap 12 of the closed cavity piston 10 are separately  
10 manufactured using a metal injection molding process. Next the body 14 is sintered to form the proper metallic bonding. During this process an end cap 12 is sinterbonded to the open end 15 of the piston body 14. Therefore, the only fluid outlet the piston 10 has is through the opening 23,  
15 insuring the rest of the piston 10 is plugged. It should also be appreciated that because of the use of metal injection molding techniques little if any machining of the sintered piston assembly is required. The metal injection molding and sinterbonding processes allow for a more  
20 efficient and cost effective process for creating a closed cavity piston. Thus all of the objects of the present invention have been accomplished.

It will be appreciated by those skilled in the art that other various modifications could be made to the device  
25 without departing from the spirit and scope of this invention. All such modifications and changes fall within the scope of the claims are intended to be covered thereby.

What is claimed is:

1. A closed cavity piston comprising:  
an elongated cylindrical body having a first end adapted to  
receive a slipper, a second end, and at least one  
5 longitudinally elongated hollow compartment;  
a bore longitudinally disposed through the elongated  
cylindrical body;  
an end cap secured to the second end of the elongated  
cylindrical body and having a central opening that  
10 aligns with the bore; and  
wherein the end cap is made of magnetic material.

2. The closed cavity piston of claim 1 wherein the  
elongated cylindrical body is created using a metal  
15 injection molding process.

3. The closed cavity piston of claim 1 wherein the end cap  
is secured to the elongated cylindrical body by  
sinterbonding the end cap to the body.

4. The closed cavity piston of claim 1 wherein the opening  
of the end cap is circular.

5. The closed cavity piston of claim 4 wherein the  
25 perimeter of the circular opening corresponds to the  
perimeter of the bore.

6. The closed cavity piston of claim 1 wherein the end cap  
is a washer.

7. The closed cavity piston of claim 1 wherein the closed cavity piston is a female piston.

8. A method of manufacturing a closed cavity piston steps  
5 comprising:  
metal injection molding an elongated cylindrical body having  
a first end adapted to receive a slipper, a second end,  
and at least one longitudinally elongated hollow  
compartment;  
10 metal injection molding an end cap having a central opening;  
sinterbonding the end cap to the elongated cylindrical body.

9. The method of claim 8 wherein the end cap has a tapered  
surface that matingly engages the second end of the elongated  
15 cylindrical body to aid in the sinterbonding of the end cap  
to the elongated cylindrical body.

10. The method of claim 8 wherein the end cap has a lip that  
matingly engages the second end of the elongated cylindrical  
20 body to aid in the sinterbonding of the end cap to the  
elongated cylindrical body.