

[54] METHOD OF MAKING DISHED ION THRUSTER GRIDS

High-Voltage Electron-Bombardment Ion Thruster," Jan. 1969, J. Electrochem Soc. pp. 9-17.

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[57] ABSTRACT

[52] U.S. Cl. .... 29/25.18, 72/63  
[51] Int. Cl. .... H01j 9/02  
[58] Field of Search..... 29/25.18, 25.14, 25.17; 72/63

A pair of flat grid blanks are clamped together at their edges with an impervious metal sheet on top. All of the blanks and sheets are dished simultaneously by forcing fluid to inflate an elastic sheet which contacts the bottom grid blank. A second impervious metal sheet is inserted between the two grid blanks if the grids have high percentage open areas. The dished grids are stress relieved simultaneously.

[56] References Cited

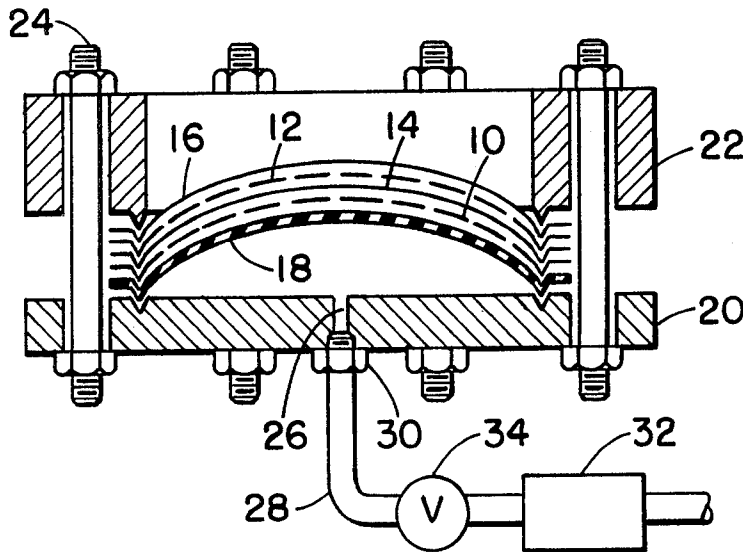
UNITED STATES PATENTS

1,329,969 2/1920 Harrison ..... 72/63

OTHER PUBLICATIONS

David C. Byers, "An Experimental Investigation of a

8 Claims, 3 Drawing Figures



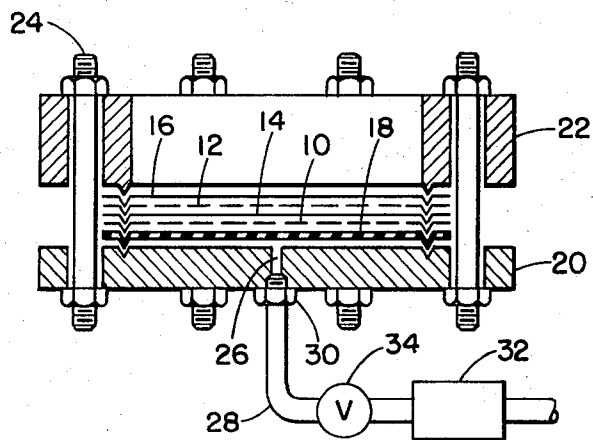


FIG. 1

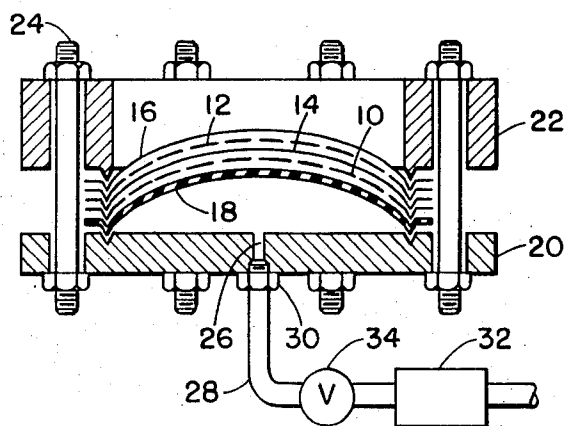


FIG. 2

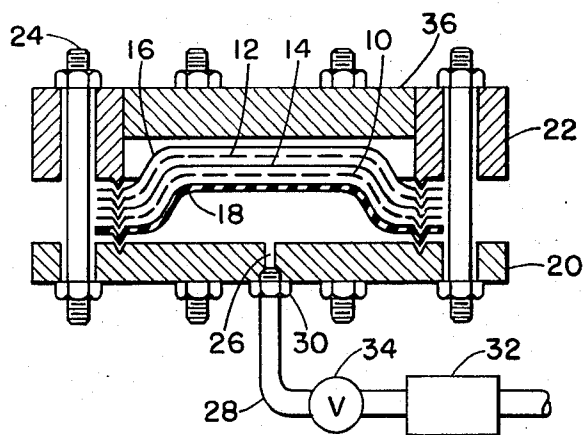


FIG. 3

## METHOD OF MAKING DISHED ION THRUSTER GRIDS

### ORIGIN OF THE INVENTION

The invention described herein was made by an employee of the United States Government and may be manufactured or used by or for the Government without the payment of any royalties thereon or therefor.

### BACKGROUND OF THE INVENTION

This invention is concerned with forming curved grids for an ion thruster accelerator system. The invention is particularly directed to the fabrication of matched pairs of dished grids having high percentage open areas.

Electron bombardment ion thrusters are being considered for a variety of space missions for which the optimum specific impulse is between 2000 and 3000 seconds. Achievement of this optimum specific impulse with a thruster having a double grid accelerator system at the desired thrust density and thruster efficiency requires a screen grid that is less than 0.5 mm thick and has a high open area fraction, preferably in excess of 0.7. A grid-to-grid spacing of about 0.25 to 0.75 mm must be maintained over the entire grid system. The ion extraction system must also survive both the launch environment and repeated thermal cycling in space.

These factors combine to impose a difficult mechanical problem on the ion thruster accelerator system. Techniques such as holding the grids in tension, supporting the screen grid from the mercury vapor distributor manifold, adding stiffener ribs, and using inter-electrode supports have been proposed for the ion extraction systems of thrusters utilized in these missions. However, individual problems have been encountered with each of these techniques.

Accelerator systems having closely spaced grids that have been dished to a hemispheroidal configuration are used without grid supports to satisfy the requirements imposed by near term missions. To obtain uniform small grid spacing between 0.25 and 0.75 mm requires that the contours of the adjacent surfaces of the screen and accelerator grids be nearly identical. Any local irregularity must occur at the same location and to the same degree in both grids.

Fabrication techniques which dish both grids simultaneously tend to minimize grid spacing variations. Numerous methods have been employed in attempts to fabricate dished accelerator grid systems. These include spinning, hot and cold pressing, and hammering. However, irregularities in the resulting grid contours have been so severe that the grids could not be successfully used in a closely spaced system.

A hydroforming process has also been proposed for fabricating the grids. This process consists of inflating grids individually into a female cavity. In this process each grid is dished separately, and irregularities in thickness result in nonmatching contours in the screen grid and accelerator grid. This produces uneven spacing between the grids which is undesirable because of ion focusing and electrical breakdown problems.

Hydroforming into a female die results in dished grid contours which are different from the female die because of the spring back in the grid material. Such hydroforming is done with a minimal amount of edge clamping of the grid to be dished. This produces a ran-

dom edge slippage which causes wrinkles to be produced in the dished grids.

Dishing can also be achieved by simply hydroforming a single grid with no backing sheet. However, this reduces the amount of dish depth possible because catastrophic rupture failure occurs. This further prevents the hydroforming of dished accelerator grids having high open areas.

### SUMMARY OF THE INVENTION

These problems have been solved by the present invention wherein no female die is utilized. An assembly of grid blanks separated and covered by impervious metal sheets is placed on top of an elastic sheet. The assembled sheets are clamped at their edges to prevent random slippage. The blanks are then dished by forcing fluid to inflate the elastic sheet which, in turn, forces the impervious sheets and grid blanks to dish to their natural contour which is approximately hemispheroidal. The impervious sheet between the grid blanks prevents distortion caused by slight misalignment of the holes in the screen and accelerator grids. The dished grids are stress relieved simultaneously in matched dies.

### OBJECTS OF THE INVENTION

It is, therefore, an object of the present invention to provide well matched pairs of dished screen and accelerator grids having high percentage open areas that are suitable for use as grid systems for ion thrusters.

Another object of the invention is to provide an improved process for producing well matched molybdenum grids having space variations of less than 0.1 mm.

Another object of the invention is to provide a pair of grids that are uniformly dished to a spherical configuration.

These and other objects of the invention will be apparent from the specification which follows and from the drawing wherein like numerals are used throughout to identify like parts.

### DESCRIPTION OF THE DRAWING

FIG. 1 is a vertical section view of apparatus constructed in accordance with the invention showing an assembly of grid blanks and metal sheets prior to dishing;

FIG. 2 is a vertical section view similar to FIG. 1 showing the assembled grid blanks and metal sheets after dishing; and

FIG. 3 is a vertical section view of an alternate embodiment of the apparatus shown in FIGS. 1 and 2.

### DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawing, there is shown in FIG. 1 a screen grid 10 and an accelerator grid 12 in the form of perforated sheets that are substantially flat prior to dishing. The two perforated sheets are molybdenum.

The screen grid 10 preferably has a thickness of less than about 0.5 mm. This screen grid has a high open area fraction, preferably in excess of 0.7.

The accelerator grid 12 is usually thicker than the screen grid 10. Accelerator grids having thicknesses up to about 0.75 mm have been satisfactory. The accelerator grid 12 has less open area than the screen grid 10.

The percentage open area may be as low as 50% in some accelerator grids.

The grid blanks 10 and 12 may be separated by a metal sheet 14 that is impervious. A stainless steel sheet 14 having a thickness of about 0.4 mm has been satisfactory.

A second impervious metal sheet 16 covers the accelerator grid 12 to prevent catastrophic rupture. The assembly of grid blanks and metal sheets is placed on an elastic sheet 18 which covers a rigid base plate 20. The elastic sheet 18 may be either rubber or plastic.

A metal clamping ring 22 is placed on top of the solid metal sheet 16 so that the ring 22 is in engagement with a marginal peripheral surface portion of the metal sheet 16. A plurality of clamping bolts 24 engage both the metal ring 22 and the base plate 20 to maintain the clamping ring in engagement with the marginal peripheral surface portion of a top metal sheet 16. A protuberance on the ring 22 mates with an aligned depression in the base plate 20. This clamps the peripheral edges of the grids and metal sheets to prevent random slippage during dishing.

A centrally disposed passage 26 is placed in communication with a fluid line 28 by a fitting 30. The end of the line 28 opposite the fitting 30 is connected to a source 32 of high pressure fluid through a valve 34. The source 32 is pressurized by a pump which is not shown. The fluid is preferably a liquid, and satisfactory results have been obtained when the source 32 contains water under high pressure.

When the valve 34 is opened, high pressure hydraulic liquid from the source 32 passes through the line 28 and passage 26 to the bottom surface of the elastic sheet 18. This pressurized liquid inflates the sheet 18 against the bottom grid blank 10. The inflation of the sheet 18 forces the sheets 14 and 16 and grid blanks 10 and 12 above it to dish to their natural contour as shown in FIG. 2. This configuration is approximately hemispheroidal.

During this dishing the solid metal sheet 14 between the grids 10 and 12 prevents distortion caused by slight misalignment of the holes in the screen and accelerator grids. Such distortion occurs when the grids have high percentage open areas because the metal between the apertures in the screen grid 10 is forced into the openings in the accelerator grid 12.

After the grids and sheets have been dished to the configuration shown in FIG. 2 the fluid is removed from the space between the deformable sheet 18 and the base plate 20. The clamping 24 bolts are then removed to release the metal ring 22. The sheets and grids can then be removed from the base plate 20 and stress relieved.

Stress relieving is achieved by heating the matched pair of dished grids to a temperature of about 1,750° F in matched dies. The grids maintained at this temperature in the matched dies for about 1 hour. During this stress relieving an inert gas, such as helium or argon, is provided to the space around the grids to prevent oxidation.

It is pertinent to note that the impervious metal sheet 14 is only required when the grid blanks 10 and 12 have high percentage open areas to prevent the metal of the grid 10 from being forced into the openings in the grid 12. When the open area fraction is less than about 0.7 the separating sheet 14 need not be used. Also, if the upper grid 12 is of a much lower open area than the

lower grid 10 the metal sheet 14 between the grids can be omitted. Omission of the metal sheet 14 facilitates the aligning of the holes in the two grids.

When the metal separating sheet 14 is used grid alignment is achieved by first matching the holes in the grids. The two grid sheets with holes aligned are then placed on the metal sheet 14. A plurality of holes are then drilled through all three assembled sheets. The impervious metal sheet 14 is then inserted between the grid sheets 10 and 12 with suitable fasteners being passed through the match drilled holes to maintain the alignment of the grid apertures.

#### DESCRIPTION OF AN ALTERNATE EMBODIMENT

It is contemplated that an intermediate step can be added by hydroforming with the two grids and metal sheets into an intermediate female die 56. This die has a geometry which more uniformly distributes the elongation as shown in FIG. 3.

After the intermediate step illustrated in FIG. 3 the hydroforming is completed in the manner shown in FIGS. 1 and 2. Stress relieving is performed after the intermediate step shown in FIG. 3 without any matched dies. After the final dishing step shown in FIG. 2 stress relieving is achieved with matched dies.

While several embodiments of the invention have been illustrated and described it will be appreciated that other modifications may be made without departing from the spirit of the invention or the scope of the subjoined claims. By way of example, a photoresist can be deposited on impervious grid blanks which are then hydroformed in accordance with the invention. The resulting dished blanks then have the holes chemically etched followed by simultaneous stress relieving. When the grids are dished in this manner prior to forming the holes both metal sheets 14 and 16 can be omitted. This embodiment is used when the spring back variation due to differences in open areas must be eliminated. This embodiment is also used where discontinuities in the open areas might cause tearing of the grids during hydroforming because of stress concentrations.

I claim:

1. A method of forming matched pairs of dished grids to a substantially hemispheroidal configuration for ion thruster accelerator systems comprising the steps of placing an elastic sheet on a rigid base member, aligning a pair of substantially flat grid blanks to form an assembly with said elastic sheet, clamping the marginal peripheral portions of said assembly with a ring to prevent slippage of said assembly and to form an expansible fluid chamber between said elastic sheet and said rigid base member, applying a fluid pressure to said elastic material thereby inflating the same whereby said blanks are dished to the curvature of said inflated elastic material, removing the dished grids from said assembly, and stress relieving said dished grids simultaneously.
2. A method of forming matched pairs of dished grids as claimed in claim 1 including the step of covering the aligned grid blanks with a substantially flat sheet of impervious metal so that said impervious metal is in engagement with the other of said grid blanks opposite the elastic material to prevent catastrophic rupture during dishing.

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3. A method of forming matched pairs of dished grids as claimed in claim 2 including the step of interposing a second substantially flat sheet of impervious metal between the grid metal blanks to prevent distortion caused by slight misalignment of apertures in the grids during dishing.

4. A method of forming matched pairs of dished grids as claimed in claim 1 wherein at least one of the grid blanks has a thickness less than 0.5 millimeter.

5. A method of forming matched pairs of dished grids as claimed in claim 4 wherein the grid blank is molybdenum.

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6. A method of forming matched pairs of grids as claimed in claim 1 including stress relieving the grids after dishing by heating the same to a temperature of about 1,750° F for about 1 hour.

7. A method of forming matched pairs of grids as claimed in claim 1 including the step of forming holes in the grid blanks after dishing.

8. A method of forming matched pairs of grids as claimed in claim 7 wherein the holes are formed by chemical etching.

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