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Banks

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[54] **APPARATUS FOR FORMING DISHED ION THRUSTER GRIDS**

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Related U.S. Application Data

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[52] **U.S. Cl.** **72/63;** 72/363; 29/421; 72/54

[51] **Int. Cl.²** **B21D 22/12;** B21D 26/04

[58] **Field of Search** 72/54, 63, 363; 29/421

[56] **References Cited**

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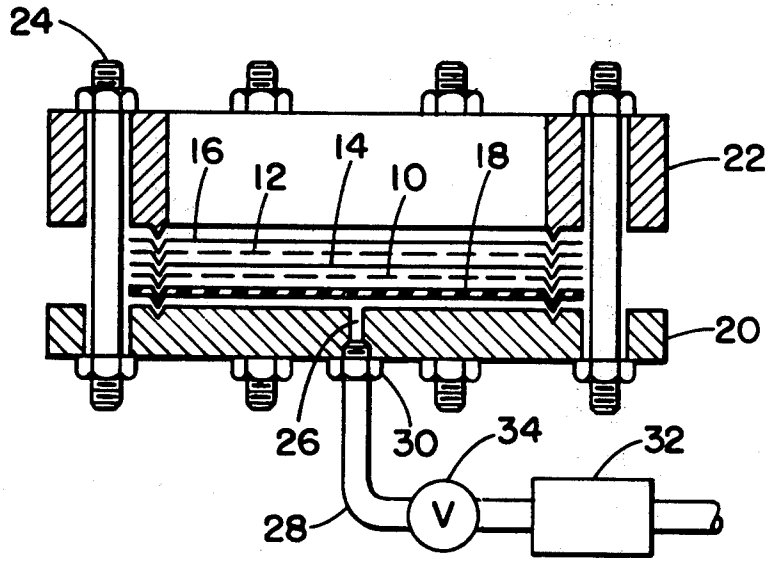
Primary Examiner—Milton S. Mehr
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[57] **ABSTRACT**

An impervious metal sheet is placed on top of a pair of flat grid blanks which are clamped together at their edges. An elastic sheet contacts the bottom grid blank, and a second impervious metal sheet is inserted between the two grid blanks if the grids have high percentage open areas.

All of the blanks and sheets are dished simultaneously by forcing fluid to inflate the elastic sheet. The dished grids are also stress relieved simultaneously.

6 Claims, 3 Drawing Figures



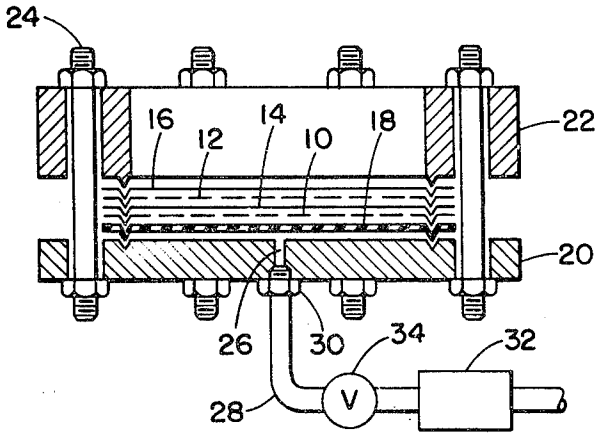


FIG. 1

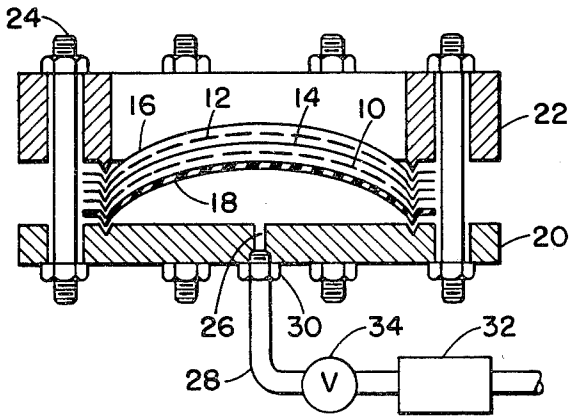


FIG. 2

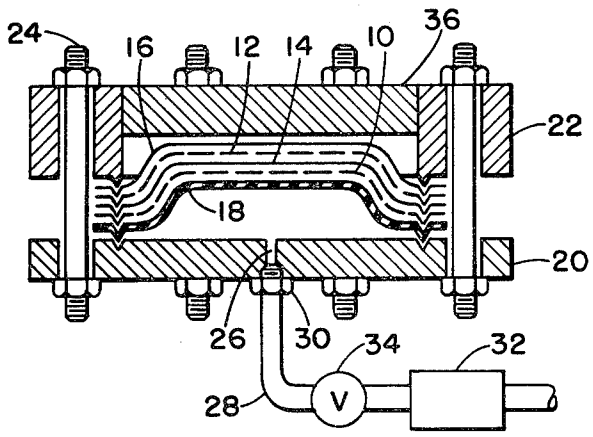


FIG. 3

APPARATUS FOR FORMING 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.

RELATED APPLICATION

This application is a division of copending application Ser. No. 352,381 which was filed Apr. 18, 1973, now U.S. Pat. No. 3,864,797.

BACKGROUND OF THE INVENTION

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

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 interelectrode 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 apparatus which dish both grids simultaneously tend to minimize grid spacing variations. Numerous devices have been employed in attempts to fabricate dished accelerator grid systems. These include machines for 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 press has also been proposed for fabricating the grids. This machine inflates the grids individually into a female cavity. With this machine 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 random 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 apparatus constructed in accordance with the present invention wherein an assembly of grid blanks is separated and covered by impervious metal sheets. This assembly is placed on top of an elastic sheet, and the assembled sheets are clamped at their edges. This prevents random slippage and forms an expansible fluid chamber. Pressurized fluid in this chamber inflates 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 apparatus 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 hemispheroidal 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 sh-ets 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 pretuberance on the ring **22** mates with an aligned depression in the base plate **20.** This clamps the p-ripheral 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 controur 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 1750° F in matched dies. The grids are maintained at this temperature in the matched dies for about one 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 opening 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 **36.** 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.

What is claim is:

1. Apparatus for forming matched pairs of dished grids having high open areas to substantially hemispheroidal configurations for ion thruster accelerator systems from substantially flat grid blanks comprising

a base member for supporting a pair of said grid blanks to substantial alignment,

a first substantially flat sheet of impervious metal engaging a surface of one of said grid blanks remote from said base member,

a sheet of elastic material covering a surface of said base member, said sheet of elastic material contacting the other of said grid blanks not engaging said impervious metal sheet,

a second substantially flat sheet of impervious metal interposed between said grid blanks to prevent portions of one of said pair of grids from being forced into the openings of the other of said pair of grids,

a ring contacting said first substantially flat sheet,

means for securing said ring to said base member thereby clamping the marginal peripheral portions of said assembled grid blanks and impervious sheets to hold said assembled blanks and sheets in contact with each other to prevent slippage thereof and forming an expansible fluid chamber within said ring between said elastic material and said base member, and

means for applying fluid pressure between said elastic material and said base member thereby inflating said elastic material into said ring whereby said assembled blanks and sheets are dished to the curvature of said inflated elastic material.

2. Apparatus for forming matched pairs of dished grids as claimed in claim **1** wherein the base member has at least one passage therethrough terminating at an aperture in the surface of said base member covered by the elastic material, and

a supply of hydraulic fluid under pressure selectively connected to said passage for introducing fluid under pressure to said elastic sheet.

3. Apparatus for forming matched pairs of dished grids as claimed in claim **1** wherein the ring has a protuberance thereon for engaging said first impervious metal sheet and deforming a portion of the assembled grid blanks into a mating depression in said base member thereby clamping the peripheral edges of the grids and metal sheets to prevent random slippage during dishing.

4. Apparatus for forming matched pairs of dished grids as claimed in claim **3** wherein the base member has a passage therein for placing the expansible chamber in communication with a source of high pressure fluid.

5. Apparatus for forming matched pairs of dished grids as claimed in claim **4** wherein the source contains hydraulic liquid.

6. Apparatus for forming matched pairs of dished grids as claimed in claim **5** including an intermediate female die in the ring for distributing the elongation of the grids during dishing.

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