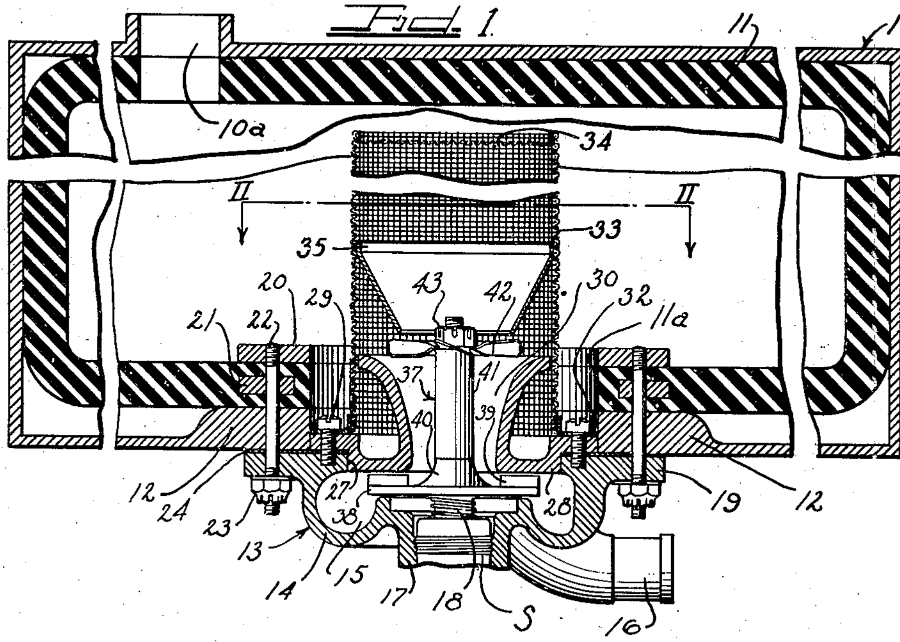
Feb. 5, 1946. W. H. CURTIS ET AL 2,394,154

BOOSTER PUMP

Filed May 27, 1942 2 Sheets-Sheet 1



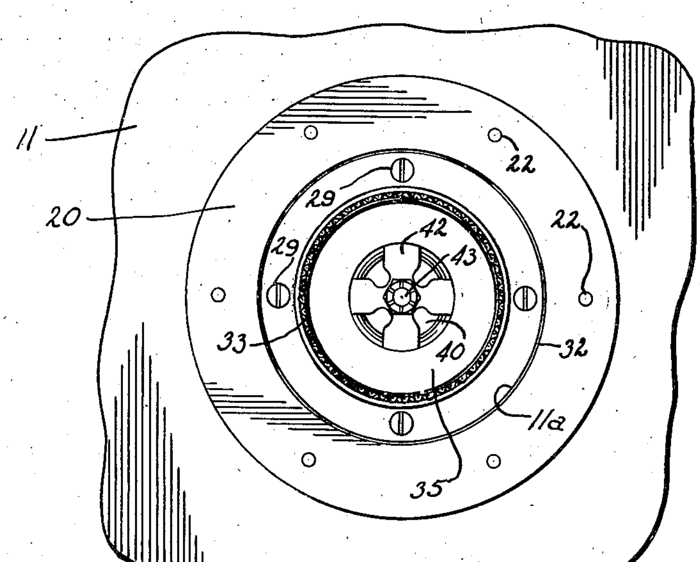


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Fig. 3

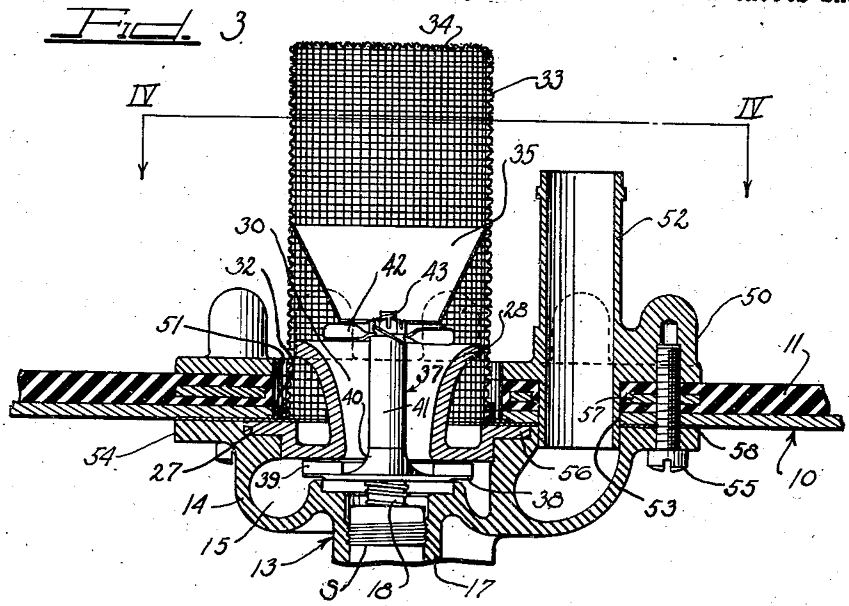
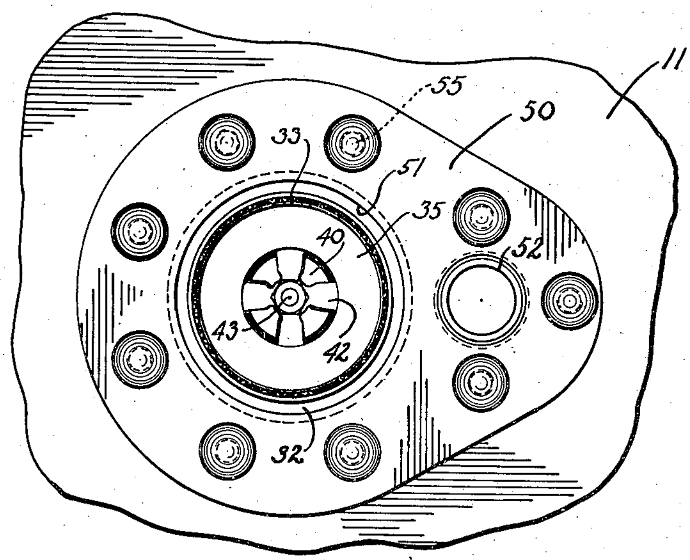


Fig. 4



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2,394,154

BOOSTER PUMP

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Application May 27, 1942, Serial No. 444,644

4 Claims. (Cl. 222—383)

This invention relates to centrifugal booster pump assemblies having bubble generating and separating means for acting on liquid material ahead of the pumping vanes of the pump. More particularly, the invention pertains to booster pump assemblies of the type indicated that are particularly adapted for use in fuel tanks for military aircraft provided with self-sealing fuel tank wall linings as a protection against leakage from perforations such as bullet holes.

The copending application of Russell R. Curtis, Serial No. 409,647, filed September 5, 1941, entitled "Booster pump," describes and claims a centrifugal pump, now Patent No. 2,306,298, granted December 22, 1942, assembly including a pump having a volute chamber and an outwardly flared throat converging to form a central inlet for the chamber which is in full communication with the liquid to be pumped. The impeller assembly spans the inlet and the pumping vanes of the assembly underlie the throat to form therewith open ended pumping channels communicating with the inlet at their inner ends and opening into the volute chamber at their outer ends. The copending application further provides an impeller assembly including auxiliary propeller means in or ahead of the mouth of the outwardly flaring throat for agitating and beating the liquid to be pumped and thereby liberating bubbles of gases and vapors from the liquid. These bubbles rise through the liquid along an outwardly flaring path and burst at the surface of the liquid to release the gases and vapors. The auxiliary propeller means not only beats out entrained gases and vapors from the liquid but also serves to liberate fixed or dissolved gases by generating the same in bubble form.

Thus by the time the liquid has moved along a central downward path into the pumping channels of the pump it is in a stabilized or fully liquid condition so that only fully bubble freed liquid material is pressured into the volute chamber of the pump because the previously separated gas bubbles have risen outside of the central path of the liquid flowing into the mouth of the flared throat.

The flared throat of the pump assembly of the copending application is not particularly deep or extended and the auxiliary agitating means are not disposed at a level much higher than the bottom of a conventional fuel tank fitted with the pump assembly in question.

Many military aircraft are provided with fuel tanks having a fairly thick layer of self-sealing material disposed inside the walls of the fuel tanks. Even if not spaced from the bottom of the fuel tank, such a lining of self-sealing material raises the effective bottom level of the tank above the level of the inlet throat and the auxiliary propeller means of the copending application. Since the pump cannot be fixedly mounted on the deformable lining of a bullet proof tank, the inlet throat and propeller assembly of the pump disclosed in the referred to copending application would be disposed below the top of a well having sides formed by the self-sealing lining when the pump is mounted on the rigid outer wall of such a bullet proof tank. Such walls of self-sealing material rising about the auxiliary propeller means to a higher level will interfere with the free outward movement of gas bubbles away from the path of liquid entering the pump, unless, of course, the self-sealing material is not brought into close proximity to the pump assembly. But this latter arrangement will leave a wide unprotected zone around the pump assembly, which is highly undesirable.

The present invention provides a pump assembly including an extended or deep flared throat and an auxiliary propeller means at the level of the mouth of the extended or deep flared throat. This extension or deepening of the throat and this positioning of the propeller means are arranged to dispose the auxiliary propeller means and the throat mouth at least level with the inner face of the self-sealing material, so that this material will not interfere with the separation and escape of gas bubbles from liquid entering the pump. In pump assemblies according to the present invention, the self-sealing material can be brought into close proximity or contact with the pump assembly so that no unprotected zone is left thereabout.

The self-sealing material conventionally used as a fuel tank lining to protect the tank against leakage due to perforating bullet holes has but little rigidity and ability to support the weight of fuel contained in the tank. This weight is carried, as a rule, by outer metal walls similar to the walls of conventional fuel tanks. Where, as in the pump assemblies of the present invention, the self-sealing lining covers the inside of the fuel tank continuously without leaving any interspace between the lining and the fuel pump assembly, the problem arises of providing a tight joint or connection between the tank and the pump assembly so as to prevent leaks therebetween and at the same time to hold the lining in place around the pump assembly.

For this purpose the pump assemblies according to the present invention are formed with casings having outturned flanges covering a portion of the fuel tank wall. A relatively rigid annular member is laid upon the inner surface of the tank lining about the pump assembly and clamping bolts extend between the annular member and the pump flange to mount the pump on the tank wall. An annular rigidifying ring may also be inserted in the self-sealing lining portion thus clamped between the tank wall and the annular member disposed on the inner face of the lining to rigidify the well defining wall of the lining which receives the pump throat.

It is, therefore, an important object of the present invention to provide a centrifugal booster pump assembly particularly adapted for use in fuel tanks of military aircraft having self-sealing fuel tank linings.

A more specific object of this invention is to provide a pump assembly of the type indicated including impeller means and auxiliary propeller means ahead of the impeller means together with a flared throat defining a liquid path from the propeller to the impeller, and having a mouth extended at least to the level of the inside of the fuel tank lining.

Another specific object of the invention is to provide a pump assembly of the type indicated for seating in an aperture through a self-sealing tank lining and provided with appropriate flanges and annular members for effecting a tight connection between the pump assembly and the tank.

Other and further objects and features of this invention will be apparent to those skilled in the art by the following detailed description of the annexed sheets of drawings which by way of preferred examples show several embodiments of the invention.

On the drawings:

Figure 1 is a fragmentary vertical cross-section, with parts in elevation, of a fuel tank lined with self-sealing material and provided with a pump assembly according to the present invention;

Figure 2 is a transverse cross-sectional view with parts in plan view, taken along the lines II—II of Figure 1;

Figure 3 is a vertical cross-section, with parts in elevation, of another pump assembly according to the present invention including a discharge fitting mounted on the inner face of a self-sealing material;

Figure 4 is a transverse cross-sectional view with parts shown in plan view, taken along the line IV—IV of Figure 3.

Like parts are designated with the same reference numerals in all the figures.

As shown on the drawings:

In Figure 1 the reference numeral 10 designates generally a fuel tank vented as at 10*a*, and lined internally with self-sealing material 11 which may have a laminated structure. The bottom wall of the tank and the bottom tank lining are pierced by registering circular apertures defining a well 11*a*. The tank bottom margins 12 around this well or passage are thickened considerably relative to the walls of the tank 10.

A booster pump 13 of the centrifugal type is mounted on the tank to extend into the well or passage 11*a* and includes a casing 14 defining a volute chamber 15, a discharge outlet 16 for the volute chamber and a shaft housing 17. The casing 14 is connected to the casing of an electric motor (not shown) which drives a shaft 18 in the shaft housing 17. A seal S may be associated with the shaft 18 within the housing 17. This seal may be of any conventional construction and will not be described in detail since the seal forms no part of the present invention.

The pump casing 14 has an outturned annular flange 19 underlying the tank bottom margins 12. A metal mounting ring 20 overlies the lining margin about the well 11*a* with the inside of the ring flush with the well sides. Within the body of self-lining material included between the ring 20 and the tank bottom margin 12 may be embedded a metal ring 21 serving to rigidify the lining margin about the well 11*a*. The rings 20 and 21, the lining margin about the well 11*a*, the tank bottom margin 12 and the casing flange 19 are all apertured to receive studs 22 therethrough at spaced intervals. The studs are threaded into the ring 20 at their inner ends and receive nuts 23 on their outer ends. When these nuts are tightened, a tight seal is formed between the pump, the fuel tank bottom and the lining. For added sealing effect, an annular gasket 24 may be interposed between the fuel tank bottom margin 12 and the top face of the casing to extend over flange 19.

The top face of the pump casing 14 has a circular opening 27 therein. A throat ring 28 is mounted on the top face of the casing and is secured to the casing by means such as screws 29. The periphery of the throat ring projects above the top face of the casing 14 and forms a pilot portion snugly fitting in the aperture in the bottom wall of the tank. The throat ring 28 also seats in the opening 27 of the casing and extends upwardly beyond the level of the lining 11 and has an aperture 30 therethrough for joining the interior of the tank 10 with the volute chamber 15. The aperture 30 flares outwardly to provide a converging inlet for the pump 13 having a wide mouth with horizontally outturned lips.

The throat ring 28 receives the flange 32 of a cylindrical screen 33 having a screened top wall 34 spaced materially above the bottom of the lining 11. The flange 32 may suitably be interposed between the throat ring 28 and the heads of the screws 29 for being secured by the latter. The screen 33 carries an inverted frusto-conical hollow shield 35 in spaced relation above the throat ring. As shown in Figure 1, the throat ring 28 extends upwardly into the inner screen space.

The booster pump 13 has an impeller-propeller assembly indicated generally at 37. This assembly includes a disk or flange portion 38 spanning the inlet or aperture of the throat ring and communicating freely around the periphery thereof with the inner rim of the volute chamber 15. Curved pumping vanes 39 are mounted on the flange 38 around the periphery thereof to underlie the throat ring 28. These pumping vanes define with the throat ring 28 and the flange 38 open ended pumping channels communicating at their outer ends with the volute chamber 15 and at their inner ends with the inlet of the throat ring.

The impeller flange 38 is integral with an impeller hub 40 slidingly embracing the shaft 18 and keyed thereto in driven relationship. The impeller assembly 37 further includes an impeller sleeve 41 embracing the shaft 18 and abutting against the top of the hub 40. A propeller 42 slidingly fitting the shaft 18 abuts the top face of the impeller sleeve 41 in driven relationship therewith. The impeller-impeller sleeve-propeller assembly may be held against a shoulder or other abutment means (not shown) on the shaft 18 by a nut 43 threaded over the threaded free end of the shaft 18. The impeller hub 40 and sleeve 41 are keyed (not shown) to the shaft 18 and the propeller 42 is locked to the sleeve (not shown) so that both the impeller and propeller are driven by the shaft.

The free end of the shaft 18 extends through and beyond the throat ring 28. The impeller sleeve 41 is so proportioned and so positioned on the shaft that the blades of the propeller 42 are disposed above the throat ring 28 with the lower propeller blade edges on a level with the top of the throat ring and below the shield 35.

The propeller 42 acts as a low pressure liquid pump urging several times as much liquid toward the impeller 39 as may pass through the latter. For instance, the propeller may, at normal low pressure operating speeds, deliver approximately 7200 pounds of fuel per hour to the impeller, if operating at an assumed slippage factor of 0.60. This delivery to the impeller is to be compared with a probable maximum output of 1800 pounds per hour from the impeller to the volute. The excess of liquid fuel amounting to about 5400 pounds per hour must escape in a direction other than through the impeller. There is no other avenue of escape than the lateral path afforded by the space outside of the propeller tips, above the contoured throat and below the sloping outsides of the shield 35.

The high slippage factor stated herein above is indicated by the severe beating action of the propeller that has been observed. This beating action is accomplished by cavitation, which effects evolution of bubbles of dissolved gases and also vapors from lighter fuel fractions. The bubbles thus generated tend to rise and are therefore preferentially carried along by the fuel streaming radially outwardly between the contoured throat and the shield rather than by the fuel flowing downward into the impeller space.

Thus the propeller 42 creates a whirlpool in the liquid in the tank with the liquid flowing down through the shield 35 and with the bubbles rising outside of the shield to the surface of the liquid.

The position of the flared or belled lip of the throat ring 28 at least level with the inner face of the lining and the position of the propeller 42 above or beyond the inner face level of the lining, will eliminate interference with the outward course of bubbles effected by the propeller.

Improved flow of liquid and improved bubble separation are obtained by the bell shape of the throat ring lip, the disposal of the propeller blades with their lower edges flush with the top of the belled lip, the provision of propeller blades terminating short of the belled lip but outside of the shield 35, and the provision of a relatively deep shield with steeply sloping walls. For example, the bell shaped lip gathers liquid over a large area and the throat then converges at a rate that will not require increased head pressure for high capacity liquid flow. The bubbles are directed outwardly from the incoming liquid over the lip and the shield prevents entrainment of the bubbles in the incoming liquid. As any bubbles rise in the screen, they must pass around the outer face of the shield in isolated relation from the incoming liquid passing through the shield. Most of the bubbles, however, are carried by the laterally streaming fuel outwardly through the screen and as they rise outside of the screen they become larger so that they can not re-enter the screen.

The pump assembly of Figures 3 and 4 includes a pear shaped mounting member 50 having two apertures therethrough. The mounting member 50 overlies the inner face of the lining with the larger aperture of the member in registry with a well 51 defined by an aperture through the lining 11 and the tank bottom wherein the pump is seated. The second and smaller mounting member aperture forms a discharge outlet for the pump, being formed as a pipe 52 extending transversely to the plane of the mounting member up through the fuel tank and down into the volute chamber 15 through an aperture 53 in the tank lining and tank bottom. The pipe 52 can receive a tube extending through the tank to deliver pressured fuel out of the tank. The pump casing 14 has an outturned flange 54 about the volute chamber 15 with edges co-extensive with the edges of the mounting member 50 for mounting on the bottom wall of the tank 10. The flange 54 receives screws 55 at spaced intervals therearound which are threaded into blind tapped wells in the mounting member 50. The mounting member overlaps an outturned flange 56 on the throat ring to hold the throat ring in place when the screws 55 are threaded home.

A rigidifying member 57 having apertures larger than the well 51 and the aperture 53 may be embedded in the lining 11 about the well 51 and the aperture 53. A gasket 58 having holes adapted to register with the well 51 and the aperture 53 may be interposed between the outside tank bottom and the flanges 54 and 56.

Apart from the facts that the discharge line of the pump of Figures 3 and 4 extends upwardly through the fuel tank and that the connections between the fuel tank bottom and the pump have been modified accordingly, the construction and functioning of the pump of Figures 3 and 4 are essentially similar to those of the pump of Figures 1 and 2.

It will be apparent from the foregoing that the present invention provides a fuel tank-booster pump assembly including a fuel tank lined with self-sealing material and a pump seated in a well formed by apertures through the tank lining and the tank bottom. The pump includes an impeller underlying the tank bottom wall and a propeller having a larger pumping capacity than the impeller overlying the tank lining as well as a throat member extending through said well and defining a liquid path from the propeller to the impeller and permitting unobstructed outward movement of excess fuel moved by the propeller toward the impeller. This laterally and outwardly streaming fuel carries with it the bubbles generated by the cavitating action of the propeller. Specifically, the pump impeller and the pump propeller are aligned but are separated by appropriate spacing means dimensioned in proportion to the thickness of the tank lining, as is also the throat member of the pump, and the propeller is disposed at a level immediately above the top of the throat member, which is flared to define horizontal lips thereabout extending beyond the ends of the propeller blades. Further, the pump has an outturned flange underlying the margins of the tank bottom about the pump well, and a separate mounting member is disposed on top of the lining margin for connection with the flange. Rigidifying members may be embedded in the lining margins included between the mounting member and the casing flange.

This correlation between the structure of the fuel tank and the construction of the fuel pump makes for efficient removal of bubbles and fixed gases from liquid fuel handled by the pump while affording protection against leakage due to perforating bullet holes from the whole tank wall, wherein the pump is securely and tightly mounted.

Many details of construction may be varied within a wide range without departing from the principles of this invention and it is therefore not our purpose to limit the patent granted on this invention otherwise than necessitated by the scope of the appended claims.

What we claim is:

1. In a fuel system, a fuel tank, a bag of self-sealing material lining said tank, aligned apertures through the bottom of said bag and the bottom wall of said tank providing an open-ended passage, a rigidifying ring embedded in said self-sealing material around said aperture therein, a pump casing closing the bottom end of said passage and having a portion underlying the bottom wall of the tank, a rigid mounting ring in said tank overlying the bottom wall of the liner bag around the aperture therein, and bolt means extending through said ring embedded in the liner bag and clampingly connecting said mounting ring and said portion of the pump casing underlying the tank wall to suspend the pump casing on the bottom wall of the tank.

2. In a fuel system, a fuel tank, relatively thick self-sealing material lining said tank, said tank and lining having aligned apertures therethrough forming first and second passageways, a mounting member in said tank overlying the lining having an aperture aligned with the first passageway, an upstanding discharge nipple integral with said mounting member having a depending portion projecting through said second passageway and extending beyond the tank, a pump casing having a first aperture, a second aperture, and a mounting flange therearound, a throat member on said pump casing defining an inlet for said first aperture thereof and extending through said first passageway into said tank in spaced relation from the lining, said second aperture of the pump casing snugly receiving said extending portion of the discharge nipple and centrally aligning said throat ring in said first passageway, and connection means extending through said mounting flange, said tank and said lining into said mounting member for securing the pump casing to the tank and for sealingly clamping the lining against the tank.

3. In a fuel system, a fuel tank, a liner bag in said tank composed of self-sealing material, aligned apertures through the bottom of the liner bag and tank forming an open-ended passage, a centrifugal pump closing the outer end of said passage and having a mounting flange underlying the tank around the aperture thereof, mounting means in said bag overlying the portion of the bag immediately surrounding the aperture therethrough, a throat ring on said pump having an inlet mouth-defining portion projecting through said passageway into the interior of said bag in spaced relation from the bag together with a pilot portion surrounding said inlet mouth-defining portion in snug seating engagement with the aperture-defining wall of the tank, and clamping bolts extending through the mounting flange, the tank and the bag into the mounting means for clamping the pump and liner respectively to the outer and inner faces of the tank whereby the snug-fitting relationship of the pilot portion and the tank will hold the pump casing against cocking relative to the tank.

4. In combination a tank, a bag of relatively soft self-sealing material lining said tank, aligned apertures through said bag and tank providing an open-ended passage, a rigidifying ring embedded in said bag around the aperture thereof, a pump casing closing the outer end of said passage and having a portion overlying the tank, a rigid mounting ring in said bag around the aperture thereof, and bolt means extending through said ring embedded in the bag and clampingly connecting said mounting ring and said portion of the pump overlying the tank to suspend the pump casing on the tank and to seal the interior of the bag from the interior of the tank by sealingly drawing the bag against the tank around the aperture in the bag.

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