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A DUAL OUTPUT PRESSURE, HIGH RELIABILITY, LONG STORAGE LIFE GAS DELIVERY VESSEL ASSEMBLY

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ABSTRACT

A Gas Vessel Assembly has been developed that delivers purified, very low moisture content gas at two different output pressures. High pressure gas is delivered at up to 6,700 psi, and low pressure gas regulated to 130 psi is also delivered via a second outlet over a wide range of flow rates. The device is extremely lightweight (less than 1 lb) and compact, affords maximum mechanical integrity, high reliability (0.9999 at 95% confidence level), and offers extremely long storage life. Specialized design and fabrication techniques are employed that guarantee gas purity and negligible leakage for more than 20 years, in widely varying conditions of storage temperature, humidity, altitude, and vibration environments. The technology offers unique advantages in fast, high pressure discharge applications. For example, when combined with a cryostat, cryogenic temperatures can be achieved such as those used in missile seeker technology. The technology has many additional applications such as: emergency power sources for safety devices such as those needed in nuclear power plants, refineries, collision cushioning devices, superconductor cooling devices, emergency egress systems, miniature mechanical devices that employ gas bearings, and other areas where long storage, extremely high reliability and/or high energy density power sources are required.

INTRODUCTION

ARRAL is a world-class manufacturer of precision electromechanical systems and assemblies, stored energy devices, and fluid systems for the international aerospace and defense communities. The company specializes in the manufacture, assembly, and testing of a broad range of complex mechanical, electromechanical and electronic devices. Particular expertise rests in special and unusual applications where our turnkey engineering and R&D capabilities can apply creative and innovative solutions to the design and manufacturing operations.

Our premier areas of specialization include on-board gas bottles and accumulators for sustained cooling, and stored energy devices that provide pneumatic pressure for fin stabilization and actuation control. A wide array of specialty and high production items have been manufactured, as shown in Figure 1. The latest product line is the Gas Vessel Assembly discussed below.

GAS VESSEL ASSEMBLY DESCRIPTION

The Gas Vessel Assembly (GVA) is shown in Figure 2. Its major components are: the manifold assembly, a partial toroid-shaped gas storage vessel, and a squib valve-flex circuit connection to an external firing signal. Key elements in the design of the gas storage vessel which were critical in achieving technical objectives were the development of a miniature pressure regulator in the manifold assembly, the use of a high strength specialty steel for the storage vessel, and a proprietary gas release system.

Manifold Assembly

The manifold assembly is shown in Figure 3. It is fabricated from high strength aluminum alloy, and provides mounting and interconnection for the squib valve and the regulator. Additionally, the manifold provides routing and discharge connections for the two different gas outputs. The dual output nozzles are shown in Figure 4.

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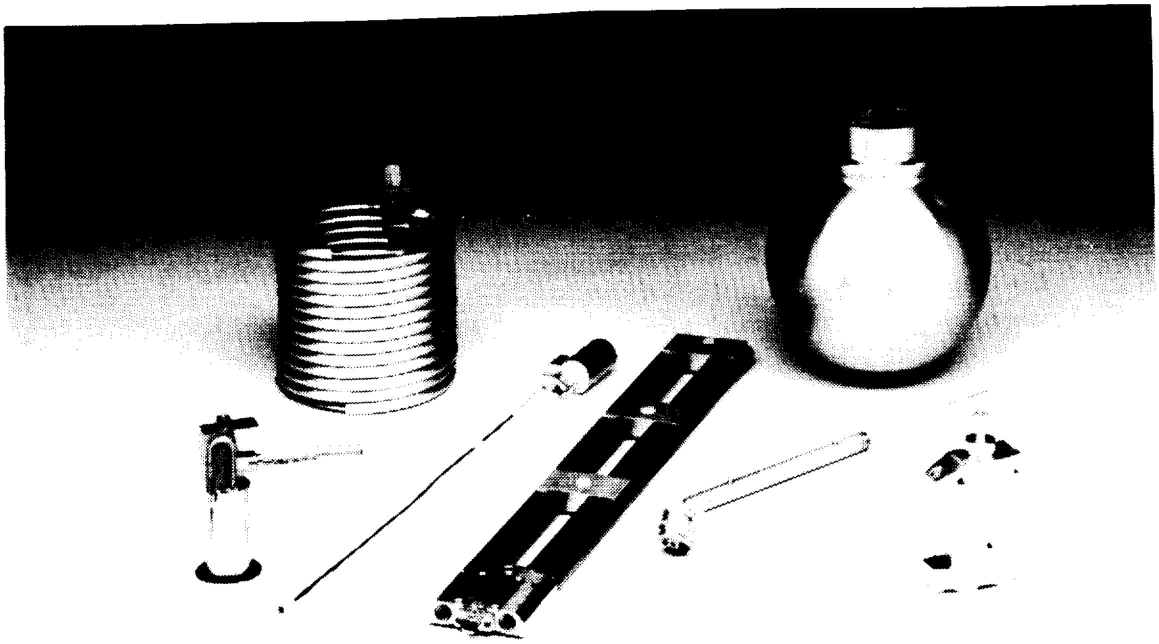

FIGURE 1. ARRAL-produced on-board gas bottles, accumulators, and stored energy devices.

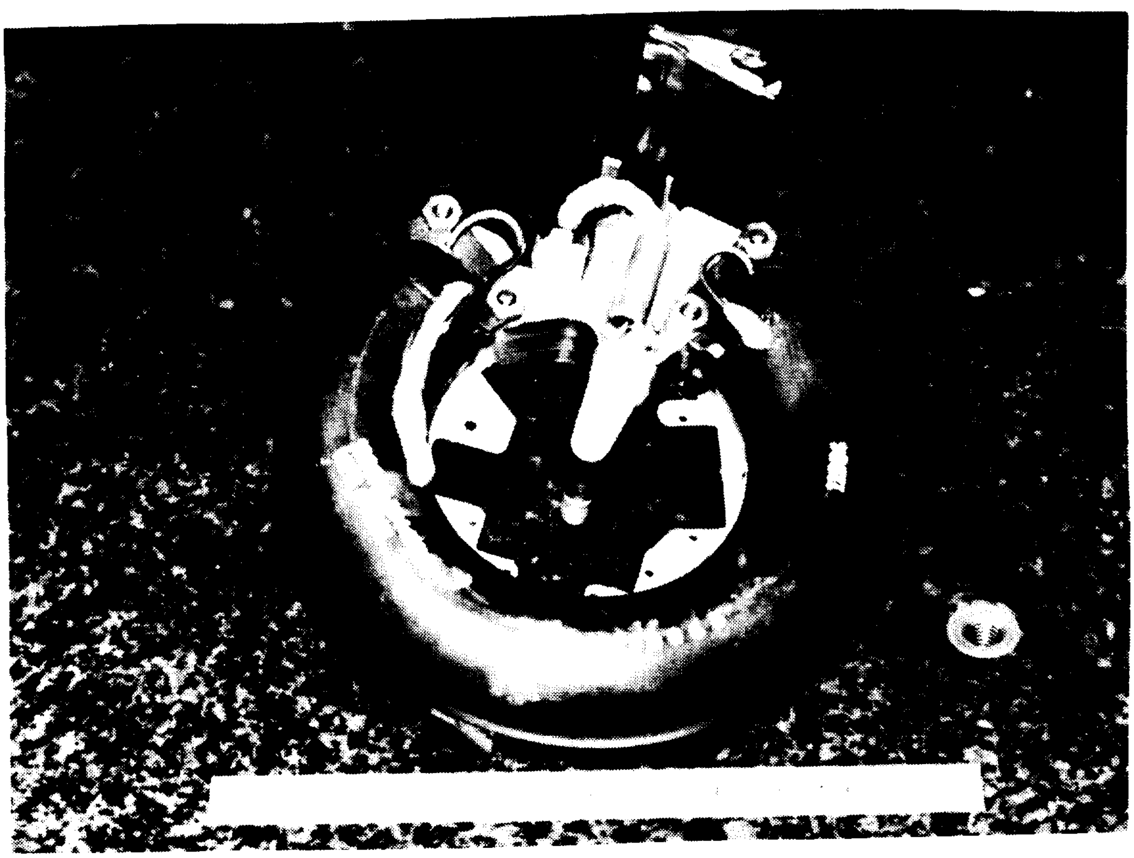

FIGURE 2. The Gas Vessel Assembly is extremely lightweight, compact, and reliable.

One of the keys to the success of the reservoir configuration is its minimum pressure boundary surface area design. The manifold is not a reservoir boundary, and sees gas pressure only after squib valve actuation or a test port is used. The manifold and the mounted components are in contact with the stored gas only during discharge. This insures stored gas purity and a minimum chance of potential leak paths. The manifold is separate from the gas storage vessel. Its fittings are adjusted for precise location without the risk of potential leaks, or the introduction of contaminants upstream of the filter.

The regulator is of a conventional piston-driven spool design, of very compact physical dimensions, and very lightweight. It is constructed of an aluminum alloy and stainless steel. The design incorporates a spring-actuated Teflon seal and a bellows seal. The regulator and the squib actuator are mounted on the manifold and sealed. Regulated gas is directed through a filter to the gas bearing fitting.

Gas Storage Vessel

The gas storage vessel shown in Figure 2 is constructed of specialty stainless steel toroid halves and spherical end caps, machined from solid material. The gas storage vessel is formed by welding two identical thin wall half torus rings together, removing a section of the resulting torus ring, and welding hemispherical end caps on each end of the resulting toroid. In addition, brackets are welded to the vessel for mounting the manifold, as well as to support the entire assembly. The gas storage vessel is heat treated, cleaned, charged with gas to 6,700 psi and checked for leakage prior to mating with the manifold. Under testing, the vessel has displayed a capability to withstand test pressures of almost 20,000 psi and a leakage rate roughly equivalent to a pressure loss of 3½ psi over 20 years.

The end caps have small diameter tubes for filling and discharging the pressure vessel. One end cap holds the discharge tube which is inserted into the manifold and becomes part of the squib valve. The storage vessel component currently in production holds 8.0 cubic inches of pressurized ultra-pure argon gas.

A key element in the design of the gas storage vessel was the use of a specialty steel for its higher strength. Heat treatment and surface treatment are performed after welding, returning the material to its near homogeneous, pre-welded condition. In thousands of applications, there has been no evidence of stress corrosion problems.

MANUFACTURING PROCESSES

A substantial inventory of manufacturing and test equipment was developed specifically for this application. The equipment and procedures provide a very accurate determination of the leak rates of the reservoir, and thus pressure as a function of storage time. These were developed specifically for the high volume, high reliability requirements imposed on these units. Highly specialized equipment designed by company engineers is required for compression, purification, and verification of the gas quality on a production basis.

To minimize "touch labor" cost to an absolute minimum and to minimize the required skill levels, specific design approaches were employed to facilitate automated manufacture and assembly of the tight tolerance, high reliability parts and subassemblies. For example, the regulator employs a variety of miniature screw machine parts that emerge from their primary fabrication step as completed parts, requiring no secondary operations. Furthermore, the parts are compatible with vibratory parts feeders and simplified assembly and fastening techniques. The completely self-contained regulator is then inventoried as a finished item that is subsequently mounted in the manifold using only a wrench.

The aluminum manifold body is designed to be manufactured from custom extruded bar stock. The extrusion has all of the manifold's complex outer profiles, minimizing machining and inspection time and complexity to render the final part. Additionally, expensive operations such as radiography (to detect voids and porosity in the metal) can be performend on the entire bar at one time. With this approach, per part radiography cost is minimized and flawed material is discovered prior to machining. The regulator, squib valve actuator, flex circuit assembly, and discharge connectors are then installed in the manifold. Final adjustment is

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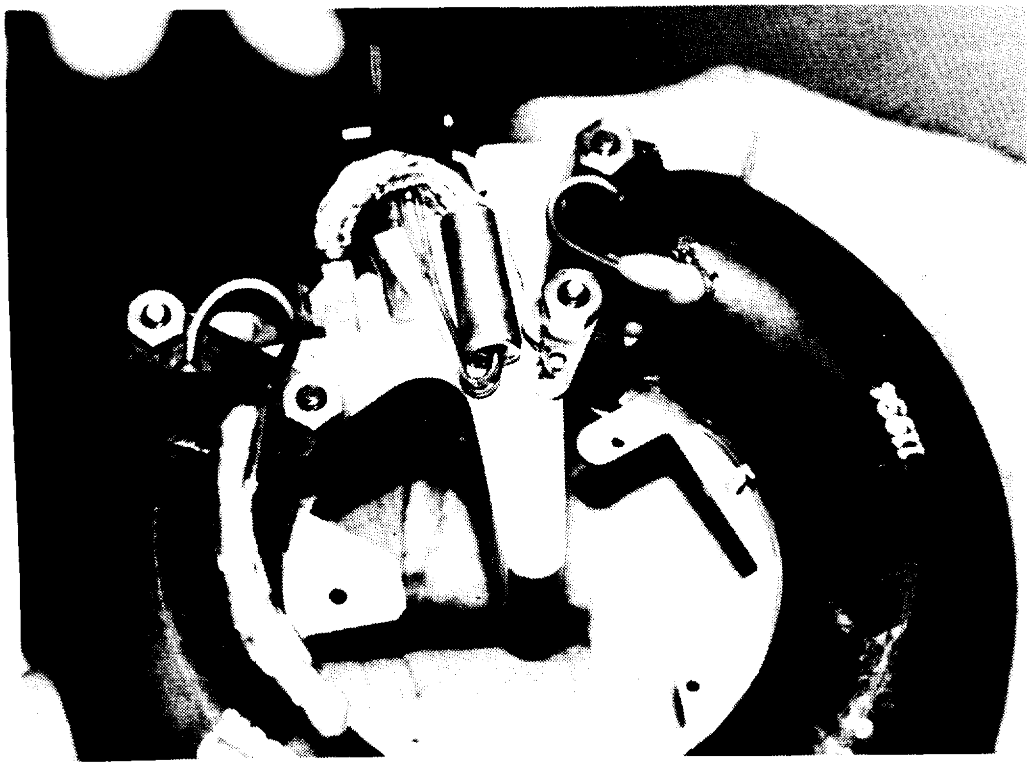

FIGURE 3. Close-up showing the unique manifold design and mounted gas release system.

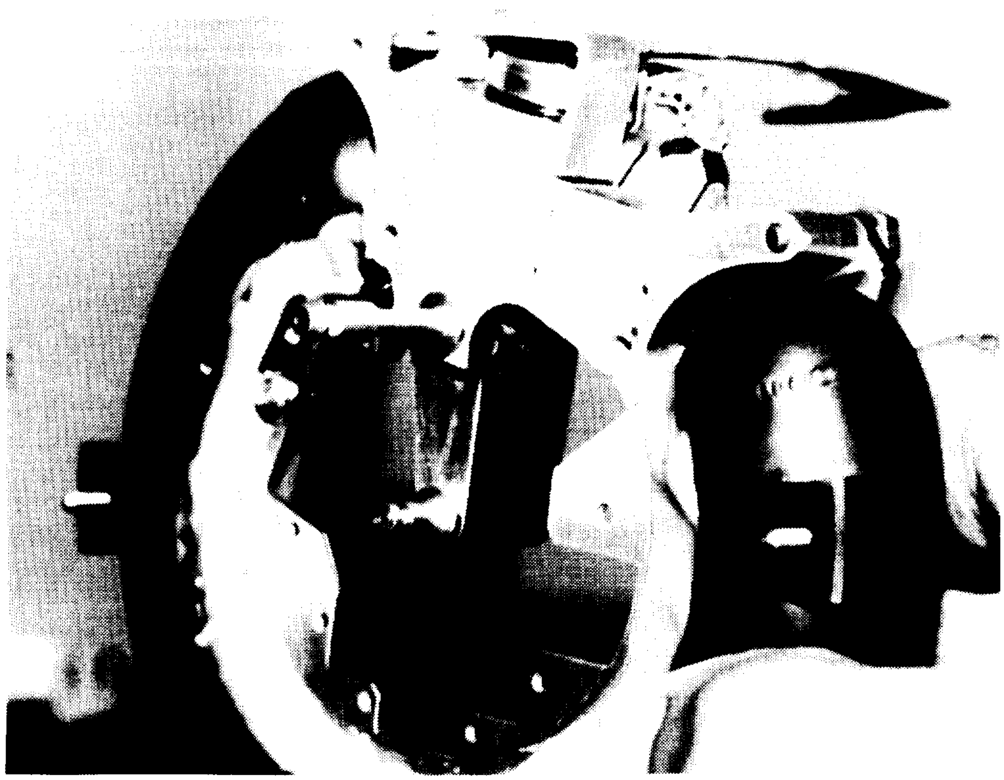

FIGURE 4. Dual output nozzles provide regulated gas pressure at 6700 psi and 100 psi.

then made to the regulator. A fixture is used to accurately locate and epoxy bond many components to the manifold body, in lieu of traditional fasteners, to achieve cost savings, more accurate placement, and reliability enhancement. The fixture is also designed as an in-process inspection device, to insure that all components will meet the final, extremely tight location requirements.

The gas storage vessel employs design approaches similar to the manifold. The thin wall torus ring halves, used to build the main torus ring, are machined from custom extruded specialty stainless steel tubing. This tubing has an outside diameter slightly larger than the outside diameter of the torus and an inside diameter slightly smaller. The part emerges from the machine ready to use without any further proccessing or handling required. The spherical end caps are made in a similar fashion from standard round barstock. Although considerable material is cut away to yield the final part, the extra material cost is more than made up for in reduced handling versus the multiple operations that would be required for forging an initial "blank" then multiple hand loading it for final machining. As in the case of the manifold, radiography can be done on the entire tube and bar prior to final machining.

By machining from solid material rather than forging or casting, the final parts also exhibit far less potential for microfractures, porosity, and residual stresses in the material. The consequences of the above could be leakage and dimensional change after heat treating. Small diameter 304 stainless steel fill and discharge tubes are then furnace brazed all at one time to the end caps. Mounting pads and brackets are precisely located by a fixture and welded. Although presently hand-welded, plans call for performing these operations using automated TIG welding equipment employing specialized assembly fixtures. In contrast to the present hand-welding, the latter automated process will not require the same skill level or specialized training to produce dimensionally accurate storage vessels. After annealing, heat treating, cleaning, proof pressure testing (at 1½ times the final storage pressure) and leak checking, storage vessels are connected in groups, via the fill tubes, to charging manifolds. Each group of vessels is then vacuum baked to eliminate any internal moisture, and charged to final storage pressure.

Final GVA assembly and interconnection of the storage vessel to the manifold is performed in an assembly fixture to insure proper dimensional location of the major assemblies. The same epoxy bonding material previously used on the manifold is used to fill the gaps purposely left between the parts to be mated, and prior to the attachment of fasteners. By the use of this technique, a wider range in manufacturing dimensional tolerences can be allowed for the individual components than are acceptable for the final GVA assembly.

CONCLUSIONS

The technology incorporated in the Gas Vessel Assembly, and the precision manufacturing techniques developed in its support, were developed for specific military applications. They offer multiple opportunities for commercial development of products based on the technology. The manufacturing techniques and process quality control methods were used to satisfy stringent product specifications.

ACKNOWLEDGEMENTS

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