July 14, 1970 W. KNAUER 3,520,110

ELECTRICAL ISOLATOR FOR GAS FEED LINE

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Fig. 2.

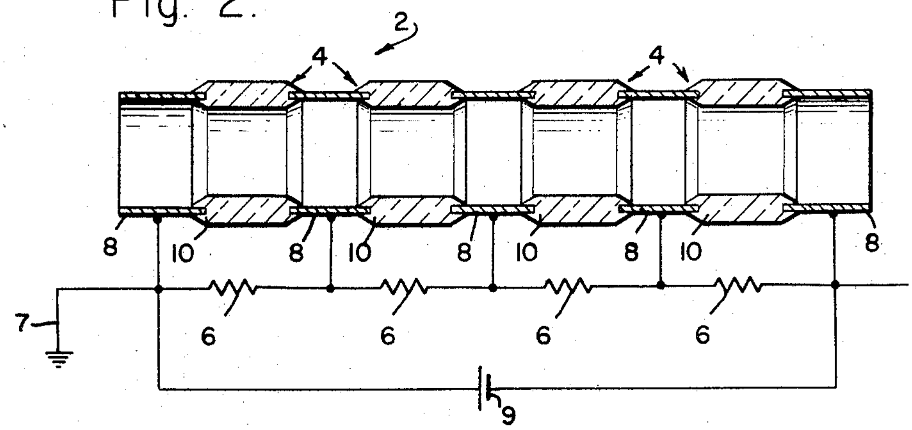
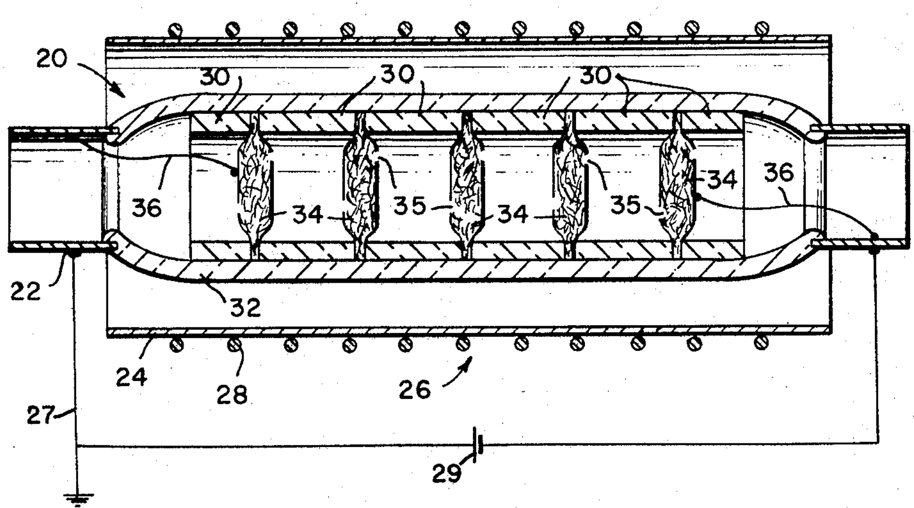


Fig. 3.



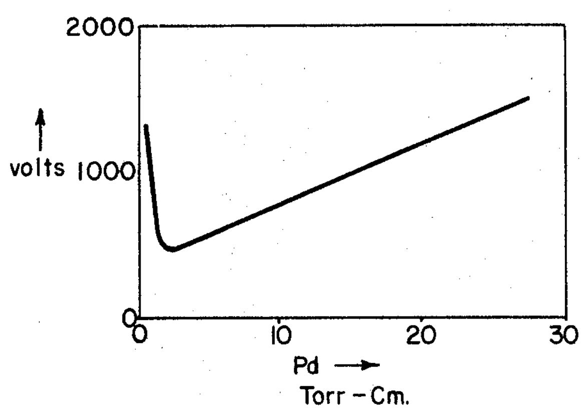


Fig. 1.

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ELECTRICAL ISOLATOR FOR GAS FEED LINE

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U.S. Cl. 55—131 9 Claims

ABSTRACT OF THE DISCLOSURE

Electrical isolation of a feed line carrying vapor is accomplished by dividing the feed line into a plurality of sections. The voltage is divided between the sections, and section length is sufficiently short that conditions within each section fall to the left of the Paschen curve minimum. In the preferred embodiment, isolators comprising conductive metal wool in perforated envelopes insure the voltage division in the vapor column.

BACKGROUND

This invention relates generally to gas feed systems and in particular to isolators for use therein to electrically separate the devices connected by the gas feed line.

In propellant feed systems for electron bombardment ion thrustors such as are shown in Kaufman Pat. No. 3,156,090 and Dryden Pat. No. 3,345,820, it is necessary or at least desirable to maintain electrical separation between the high voltage ion thrustor and the propellant reservoir. The propellant (for example, mercury) feed line can provide the undesired conductive path. In previous propellant feed systems the electrical isolation has been accomplished with a section of insulating or isolating material in the feed line. The propellant is passed through this section as a gas or vapor, and is an isolator too as long as the pressure and length of the isolating section are chosen properly. For both small and large pressures the breakdown voltage is high. At an intermediate pressure the breakdown voltage falls quite rapidly to a minimum (as illustrated by the "Paschen curve"). As the propellant flow varies from zero to a maximum, the product *pd* of the gaseous propellant in the isolator section passes through the region of minimum breakdown voltage.

SUMMARY

According to the present invention the pressure *p* and the length *d* of the isolator region are chosen such that for maximum flow, the quantity *pd* falls sufficiently to the left of the potential minimum whereby safe isolation is provided for all flow levels. However, operation of the isolator at a point to the left of the Paschen minimum requires short lengths *d*. The field strength along the surface of the isolating feed line is therefore large and the danger of surface breakdown arises. Surface breakdown is particularly likely in the case of metal vapor propellants since the isolator surface is likely to be covered with a partial metal layer. As a consequence, points with increased field strength will arise therein which enhance the likelihood of breakdown.

The isolator according to the present invention comprises a plurality of isolating sections or gaps in series. Since only a fraction of the potential is applied across each section, the probability of breakdown is much reduced. In fact, in accordance with the Paschen characteristic, each individual section can be longer than the

entire gap of a single-section isolator. Thus, with n sections, the surface field strength is reduced to less than $1/n$ of a single section isolator. It is therefore a primary object of the present invention to provide an isolator for a feed system in which the probability of voltage breakdown is reduced.

These and other objects and advantages of the present invention will be more fully understood by reference to the following detailed description when read in conjunction with the attached drawings wherein like reference numbers refer to like elements.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a graph showing the Paschen curve for mercury,

FIG. 2 is a cross-sectional view of a preferred embodiment of the present invention, and

FIG. 3 is a cross-sectional view through another preferred embodiment of the present invention.

DESCRIPTION

Referring now to FIG. 1, the choice of the product of *p* and *d* has to be made in accordance with the breakdown characteristics (Paschen curve) of a specific gas or vapor. It can be seen from FIG. 1, where the Paschen curve for mercury is shown, that for both small and large pressures the breakdown voltage is high. In these regions mercury vapor (other gases behave similarly) can be considered a good isolator. As discussed above, the high pressure region is not too well suited for use in propellant feed systems because as the propellant flow varies from zero to a maximum, the product *pd* would pass through the Paschen curve minimum. According to the present invention the quantity *pd* always falls sufficiently to the left of the potential minimum. The manner in which this is accomplished will be more fully understood from the following description of two of the preferred embodiments of an isolator made according to the present invention.

FIG. 2 shows an isolator **2** comprising a plurality of isolating sections **4** in series for use in a propellant gas feed line. In order to realize fully the improvement made by the present invention, the applied potential should be distributed uniformly across each of the sections **4**. This is accomplished in the embodiment shown in FIG. 2 by means of a chain of resistors **6** acting as a voltage divider and connected to the conductive sections **8** of the isolator **2**. The conductive sections **8** are separated by a series of insulating sections **10** which may be made, for example, of glass.

The isolator **2** comprises an elongated conduit which connects a source of propellant gas to the gas outlet in the ion thrustor. For example, the isolator **2** serves as part of the conduit in Dryden Pat. No. 3,345,820. It is placed between his source **24** of propellant gas in his main conduit **28** or branch conduits **26** which conduct the propellant gas to the cathode. At the cathode it is forced through the holes **18A** in the cathode into the chamber of the engine. The isolator **2** of the present invention electrically isolates, as is pointed out above, the source of propellant gas from the cathode. If Dryden mounted his source of propellant gas **24** upon the frame of his device, which is desirable when the source of propellant gas is fairly large, then the two ends of Dryden's conduit **28** will be at different potentials. The left end will be at ground, while the right end will be at the cathode potential which is negative with respect to ground due to the negative side of potential source **32**. It is in such electrical isolation that isolator **2** finds its utility. In FIG. 2, the ground is illustrated at **7**, while the negative potential applies to the other end of isolator **22** is applied by potential source **9**. In FIG. 2, potentials are illustrated as being applied in accordance with usage in conduit **28** of Dryden, with flow from left to right.

FIG. 3 shows another embodiment of the present invention comprising an isolator **20** for use in a gaseous propellant feed line **22**. Positioned concentrically around the isolator **20** and spaced therefrom is a heated enclosure **24**. The heated enclosure **24** may comprise for example a glass cylinder **26** in contact with an electrical resistance heating element **28** spirally wound thereon. The purpose of heated enclosure **24** is to prevent vapor condensation in the isolator **20**. In this embodiment uniform distribution of the applied potential is achieved by use of a material for the isolator sections **30** which is slightly conductive and which provides its own voltage divsion. In the embodiment shown in FIG. 3 the isolator sections **30** are formed, for example of a glass having a slight conductivity, such as lead glass. The sections **30** are separated from each other and are in contact with a glass envelope **32** which houses the isolator. Another method of uniformly distributing the applied potential (not shown) is to provide the required conductivity by coating all of the spaced insulating sections with a high resistance film.

In addition to providing for the uniform distribution of the applied potential, the embodiment shown in FIG. 3 includes the use of obstructions **34** for preventing the spread of discharges whereby the reliability of the isolator **20** is improved. In the embodiment shown in FIG. 3 the obstructioins **34** are composed of steel wool in a stainless steel envelope which construction permits the passage of neutral gas and vapor molecules, for example, through perforations **35** in the envelopes, but intercepts all charged particles so that a discharge cannot penetrate through an obstruction to spread from one isolator section to another. Contact strips **36** connecting the conductive gas feed line **22** to the outermost of the obstructions **34** are provided in order to prevent a breakdown therebetween. Such strips are desirable in this embodiment because the construction is such that a breakdown is more likely to occur there than between the inner obstructions because the line **22** and the two outermost of the obstructions **34** are spaced further apart than are the inner obstructions.

Similarly to the structure of FIG. 2, the isolator **20** of FIG. 3 is an elongated conduit which is conveniently suplied at its left end from a reservoir which is connected to ground **27**. A power supply which holds the thrustor cahtode negative with respect to ground is indicated at **29**. This is a portion of the necessary power supply of the thrustor. Vapor molecules are fed through isolator **20**, in the left to right direction in the illustration shown in FIG. 3.

Although the isolator of the present invention has been described with reference to the preferred embodiment thereof it is clearly useful in fluid feed lines other than propellant feed lines for ion thrustors, as will be evident to one skilled in the art.

What is claimed is:

1. An isolator for a fluid feed line, the improvement comprising:

an elongated, continuous conduit adapted to conduct fluid and adapted to be connected at each end to conduct fluid,

said conduit including a plurality of first spaced-apart electrically conducting sections, said sections being connected together to form said continuous conduit by a plurality of second electrically insulating or electrically semi-conducting sections, one of said second sections being placed between each adjacent pair of said first sections, and

means constructed and arranged for dividing electrical potential along said conduit substantially uniformly across each of said first sections when potential is applied along said conduit; said fluid being a gas having a range of pressures p and said second sections have a length d such that the product pd falls to the left of the Paschen curve potential minimum for the product pd.

2. The apparatus according to claim **1** in which:

said second sections are composed of low conductivity material whereby said material provides said means for dividing potential.

3. The apparatus according to claim **2** wherein said first sections are a plurality of discharge obstructions mounted substantially uniformly spaced-apart within said conduit to define a plurality of discharge regions, said obstructions preventing the penetration of a discharge from one discharge region to an adjoining discharge region while allowing the flow of gas therethrough.

4. The apparatus according to claim **1** in which said second sections are composed of insulating material, and

said potential dividing means comprises a plurality of resistors connected in series externally to and across said conduit with connections therefrom to the first portions of said conduit separating said insulating sections such that each of said sections is provided with a substantially identical resistance connected thereacross.

5. An isolator for a fluid feed line, said feed line having relatively conductive walls, the improvement comprising:

a plurality of spaced-apart wall sections of relatively low conductivity whereby voltage applied across said isolator is substantially uniformly divided across said section;

a plurality of discharge obstructions mounted within said isolator and between said sections to define a plurality of discharge regions, said obstructions comprising steel wool housed in perforated stainless steel envelopes, said obstructions allowing the flow of neutral gas therethrough but preventing the passage therethrough of charged particles.

6. The apparatus according to claim **5** in which said sections are composed of a low conductivity glass.

7. An isolator for use in a propellant feed line for feeding gaseous mercury from a reservoir to an ion thrustor, the improvement comprising:

an elongated conduit forming a length of said feed line and comprising a plurality of spaced-apart sections which form the walls of said line in said sections, and

means for dividing potential along said conduit substantially uniformly along each of said sections, such that the product of the gas pressure and distance for each such section falls to the left of the potential minimum of the Paschen curve for mercury.

8. The apparatus according to claim **7** including a heater enclosure surrounding said conduit to prevent vapor condensation.

9. The apparatus according to claim **8** including a plurality of spaced-apart discharge obstructions mounted in said isolator for allowing the pasage therethrough of neutral gas molecules but preventing the passage therethrough of charged particles.

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