July 11, 1944. E. L. McCANDLESS 2,353,254

BURSTING DISK

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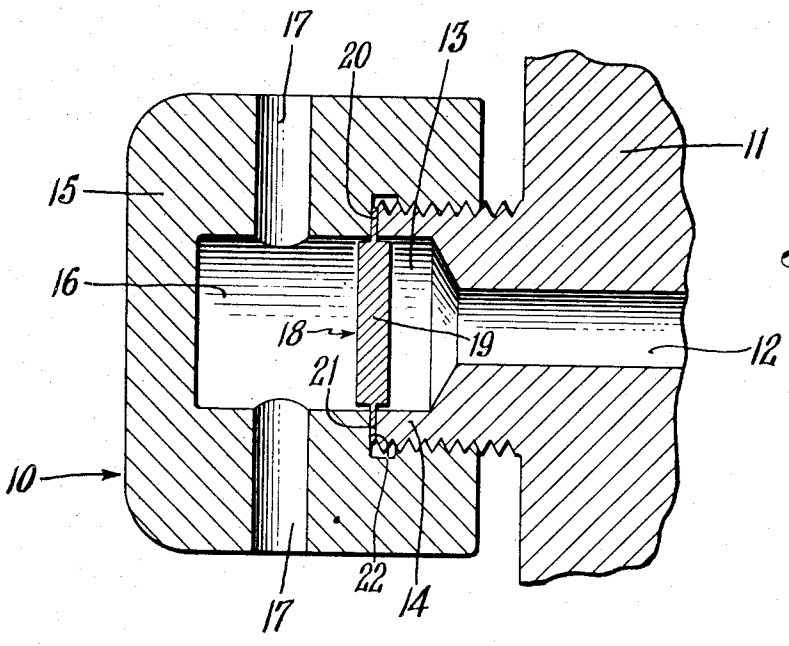


Fig. 1.

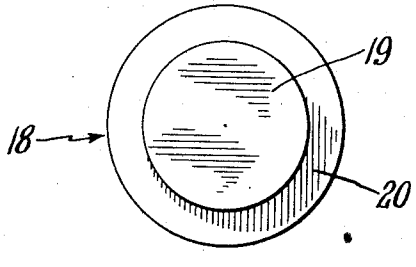


Fig. 2.

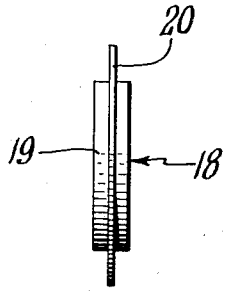


Fig. 3.

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BURSTING DISK

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1 Claim. (Cl. 220—89)

This invention relates to bursting disks and more particularly to an alloy for frangible diaphragms adapted to be ruptured by fluid pressure by a substantially pure shearing action when the fluid pressure reaches or exceeds a certain predetermined value.

It has been found convenient to store oxygen compressed in containers such as steel cylinders. These cylinders are initially charged with oxygen at a pressure of about 2000 lb. per sq. in., at about 70° F. Since all gases expand when heated and contract when cooling, the pressure of oxygen in a closed cylinder goes up or down as the temperature changes. If, for example, a full cylinder of oxygen is allowed to stand outdoors for several hours when the temperature is, say 30° F. or just below freezing, the pressure of the oxygen will register approximately 1800 lb. per sq. in. When the temperature on a warm day goes above 70° F., the pressure in a full cylinder will rise above 2000 lb. per sq. in. To provide against a dangerous excess of pressure, such as might occur if the cylinder were directly exposed to fire, for example, every cylinder has a safety device arranged to release the oxygen before a dangerous pressure is reached. For instance, the cylinder valve has a safety nut containing a disk of special metal that will burst if the pressure goes too high.

A suitable bursting disk metal must possess not only excellent corrosion resistance but also metallurgical stability, freedom from cold flow tendencies under high stress, freedom from any inhomogeneities, and adequate ductility. The metal for one-piece frangible type disks must also possess the highest degree of machinability.

In the past it has been customary to make such frangible disks of relatively hard copper or bronze, an example of a disk of relatively hard copper being disclosed in Patent No. 1,579,141, dated March 30, 1926, to Raymond C. Pierce, assignor to The Linde Air Products Company, entitled "Safety pressure relieving device." Before applicant's invention, a number of service failures were experienced in the bursting disks of oxygen cylinder valves. Such disks were made of "commercial bronze," an alloy of about 10% zinc with about 90% copper. Examination of a number of prematurely failed disks and correlation of their appearance and properties with the conditions at the time of failure indicated that such failures were probably due to stress-corrosion attack by a variety of extremely mild corrodants encountered in service.

Intergranular corrosion as found in the prematurely failed disks is similar to the more widely known season cracking of copper alloys. The conditions necessary for intergranular failure are, first, a fibre stress which amounts to a high fraction of the ultimate strength of the material and, second, the presence of a corrosive agent. Reports in the literature indicate that weak corrosives are more prone to cause intergranular failure than strong agents and that caustic reagents are usually more dangerous in this respect than acid reagents. The presence of high stress, however, is absolutely necessary in order that intergranular corrosion can take place. In the absence of stress, any corrosive attack, however severe, takes the form of general surface attack or pitting. In the presence of stress, corrosion takes place preferentially at the grain boundaries of the material, so that the line of fracture follows the grain boundaries rather than going through the body of the grains as is the case in the fracture of a healthy metal at ordinary temperatures.

In the case of season cracking of brass, the standard preventative measure consists in stress-relieving or annealing the brass article prior to use. In the case of bursting disks this procedure is obviously useless, since the service stresses alone necessarily amount to approximately two-thirds of the ultimate bursting strength. The prevention of failure, therefore, must take the form of either elimination of the corrosives which are responsible or the adoption of a more resistant disk material.

Because of the extremely small quantity of corrosion products present on failed disks, it has not been found possible to identify the particular agents responsible for intergrannular attack of the disk, although traces of a variety of chemicals have been found in the safety device assemblies.

The primary object of this invention is to provide bursting disks of an alloy which is more corrosion-resistant than "commercial bronze" to afford protection against the ordinary corrosive substances or atmospheres to which the disks are exposed. Another object of the invention is to provide bursting disks of an alloy which is highly resistant to creep as well as highly resistant to corrosion, particularly stress-corrosion. Further objects of the invention are to provide an alloy for bursting disks that is easily machined, of a strength low enough to give a practical flange thickness, extreme uniformity of properties in commercial lots, and one which is resistant to attack by high pressure oxygen. A further object

is to provide an improved metal bursting disk or diaphragm that is economical to manufacture.

Referring to the drawing:

Fig. 1 is an enlarged fragmentary view in cross-section of an oxygen cylinder safety device assembly exemplifying the invention;

Fig. 2 is front elevational view of the safety disk; and

Fig. 3 is a view in side elevation of the safety disk.

The safety device assembly 10 comprises a support 11, such as an oxygen cylinder, having a passage 12 which flares at 13 within a nipple 14 the outer cylindrical surface of which is threaded to receive a nut 15 having a central socket 16 and lateral vents 17, 17. A safety disk 18 of the one-piece frangible type is secured in place normally to close and seal the flared portion 13 of the passage 12. Such disk is composed of a single phase alloy consisting of substantially 96% silver and 4% copper. The disk 18 consists of a round flat relatively thick central portion 19 of uniform thickness having an integral external annular relatively thin flat peripheral flange 20 of uniform thickness which is positioned in a medial plane between the faces of such central portion and clamped between the inner annular shoulder 21 of the nut 15 and the annular end 22 of the nipple 14. Should the fluid pressure in the cylinder 11 become excessive, i. e., exceed atmospheric pressure by a predetermined value, the flange 20 is adapted to shear, opening the passage 12 to the atmosphere through socket 16 and vents 17. The socket 16 receives the central portion 19 of the disk, preventing it from causing any damage upon the opening of the assembly 10.

The requirements for an alloy for general bursting disk service are primarily (1) resistance to creep, since the working stress is ordinarily a major fraction (i. e., ⅔) of the stress for short-time failure; and (2) resistance to corrosion, particularly stress-corrosion. For oxygen cylinder valve shear-type bursting disks, further requirements are (1) good machinability, (2) a strength low enough to give a practical flange thickness, (3) extreme uniformity of properties in commercial lots, and (4) resistance to attack by high pressure oxygen. The materials heretofore ordinarily used for bursting disks for miscellaneous types of pressure equipment include copper, copper-rich copper-zinc alloys, stainless steel, "Monel" metal, aluminum, gold and platinum.

The list of possible disk materials has been surveyed quite carefully. In most cases, some one consideration will immediately preclude a particular material from consideration, as for example, the high strength of stainless steel would necessitate a disk flange too thin to be practical particularly for frangible type oxygen cylinder-valve bursting disks.

It was concluded from studies of available materials that none of the common pure metals, other than certain of the previous metals, possessed properties more suitable than the high copper alloy now used. Silver was the most promising metal, the only objection being its susceptibility to cold flow.

According to the invention it is proposed to make frangible diaphragms, such as the bursting disk 18, of a single phase alloy of silver with a relatively small proportion of another material which will eliminate the tendency of silver to cold flow without reducing the corrosion resistance, without increasing hardness excessively, without reducing machinability materially, and without increasing the cost or difficulty of manufacture of the metal. These requirements are best met by alloying the silver with a small quantity of a metal which will go into solid solution with the silver without altering the type of crystal structure of the silver and without decreasing the recrystallization temperature of the silver (i. e., without reducing creep resistance). From technical, engineering, and economic considerations the alloy element which was selected and which was found by extensive laboratory and field tests to be outstandingly suitable is copper in the amount 2 to 6%. However, other alloying elements fulfilling the above conditions would also be suitable under certain circumstances. For example, any of the following might be used: 2 to 5% arsenic, 1 to 3% bismuth, 3 to 35% cadmium, 2 to 8% magnesium, 1 to 2% nickel, 1 to 9% palladium, 2 to 8% platinum, 2 to 8% thallium, or 2 to 21% zinc.

By extensive laboratory and service testing, it has been found that a silver base alloy containing about 94 to 98% silver and the remainder principally copper, preferably 96% silver and 4% copper, provides an economical solution to the above outlined requirements. Silver alloyed with 4% copper is superior to fine (99.9%) silver in the matter of creep, fine silver failing rapidly by creep when the service pressure is ⅔ of the ultimate failure pressure. Silver with 4% copper is superior in corrosion resistance to sterling silver (7½% copper), the latter being a two-phase alloy at ordinary temperatures and with ordinary heat treatment. The 4% copper alloy is also not as susceptible to age-strengthening as is sterling silver.

The 96% silver, 4% copper alloy can be manufactured and heat-treated (quenching from annealing temperature after cold reduction) to give exceptionally uniform and reproducible physical properties. It possesses machinability equal to that of the 90% copper, 10% zinc alloy previously used for bursting disks. Its strength, and therefore the flange thickness of shear-type bursting disks machined therefrom, is about equal to that of the 90% copper, 10% zinc alloy. It is not attacked appreciably by oxygen at a pressure of the order of 2000 lb. per sq. in. at ordinary temperatures.

Regarding impurities in the 96% silver, 4% copper alloy, the iron content should be particularly restricted, since iron markedly lowers the recrystallization temperature of silver and would thus increase any tendency toward creep under high stress. The limits of iron 0.02% maximum and other impurities 0.05% maximum total are commercially suitable.

At its current price of about $6.00 per pound, the cost of silver for the disks is not unreasonable, while platinum, which would otherwise be a perfect bursting disk metal, would cost on the order of 100 times as much.

After melting to the correct composition, the alloy is poured into small ingots and rolled to a predetermined thickness. The resulting sheet is annealed at a certain temperature for a predetermined time in a controlled-atmosphere furnace preferably with automatic pyrometer temperature control. The metal is then quenched in water from such temperature. The rate of quenching is as rapid as possible. The entire annealing and quenching operation is intended to keep the alloy in the solid solution form. The annealed sheet is then cold rolled to the required

thickness, which hardens the alloy to the desired value.

In forming the bursting disks, the thin sheet it cut into strips from which individual disk blanks are punched. The blanks are then machined to form flange portions thereon of very accurate and uniform thickness, the bursting pressure being regulated by controlling the thickness of the flange. The thick center portion or button that remains insures the rupture of the disk by substantially pure shearing action when the bursting pressure is exceeded. A single disk is then assembled with an oxygen cylinder valve, for example, in the conventional manner. Actual tests over a long period of time have indicated that bursting disks made according to the invention are entirely satisfactory.

Standard aging and creep tests were at first considered for the study of the proposed silver alloys, but after careful consideration it was decided that data obtained on standard specimens could be applied to oxygen safety disks only with difficulty and uncertainty. It was considered much more preferable to carry out all such tests on actual disk installations where the conditions of stress and stress concentrations would be directly related to field conditions.

The requirements for a material suitable for oxygen cylinder valve bursting disks are very complex. It much possess not only good corrosion resistance, but also excellent machinability, freedom from any inhomogeneities, freedom from excessive work hardening, resistance to cold deformation under high stress, metallurgical stability and other characteristics of a less obvious nature. Pure metals or metals alloyed with a sufficiently small content of a second metal to consist of a single-phase solid solution are generally considered the most suitable bursting disk materials. Disks for certain purposes have been made of pure aluminum or copper. The "commercial bronze" currently used in oxygen disks is a solid solution alloy of 10% zinc in copper. This alloy has the general chemical and mechanical properties of pure copper, combined with very superior machinability. In the chemical process industries there is a trend toward the use of platinum, this metal having essentially perfect corrosion resistance, good workability and uniformity of properties. There is little question but that platinum would be the perfect metal for the present purpose except for its cost.

It was early determined that none of the copper-base alloys possessed corrosion resistance markedly superior to that of pure copper or "commercial bronze." The common corrosion-resistant alloys, such as "Monel metal" and 18–8 stainless steel, have been found unsuited because of poor machinability, excessive susceptibility to work hardening, or non-uniformity of properties. After careful consideration an alloy of silver containing 4% copper was selected to provide the chemical resistance of fine silver combined with the mechanical resistance of sterling silver. A large number of tests have shown the various characteristics of this 4% alloy to be quite suited to bursting disk service.

The particular characteristics of the 4% alloy which were investigated in detail were the consistency with which disks burst on hydrostatic test in the desired pressure range, the resistance of the disks to stress-corrosion attack by a variety of chemical agents, the resistance of the disks to long-time applications of high pressures, and the susceptibility to aging. The final proof of the superiority of the new alloy was obtained by testing under field conditions for an adequate period an experimental pilot lot of disks made of the alloy.

By subjecting samples of bursting disks made of "commercial bronze" and of the 96–4 silver-copper alloy to the same conditions of oxygen pressure and to the same temperatures, it has been found that the silver alloy disks have greater resistance to creep effects and therefore possess quite satisfactory resistance to continuous applications of high pressures.

The silver-rich portion of the silver-copper alloy system is of the general type in which age hardening may be expected to occur when the alloy is reheated after quenching or rapid cooling from a high temperature. If for example, the 96–4 alloy is heated to 700° C. (as in the annealing heat treatment), water quenched to room temperature, and then reheated to 200° C. for a long period such as 500 hours, a considerable increase in hardness of the 96–4 alloy will occur. However, no evidence has been found to indicate that the 96–4 alloy will age harden at normal service temperatures.

The resistance of the 96–4 silver-copper alloy disks to a change of bursting strength due to corrosion effects while under stress and service conditions has been proven by testing a pilot lot of disks in marked oxygen cylinders subjected to service conditions.

The hardness of the silver-copper alloy is preferably the same as that of the "commercial bronze" customarily used for safety disks; namely, quarter-hard, or Rockwell B–30 to B–50. This hardness corresponds to a tensile strength of roughly 37,000 to 45,000 lb./sq. in., and to a disk flange thickness of approximately 0.0070 to 0.0085 inch.

The mechanical properties of a suitable 96–4 silver alloy sheet have been determined, with the following results:

Tensile strength	lb./sq. in.	40,300
Yield strength, 0.5%	lb./sq. in.	37,500
Elongation in 2"	per cent	21
Hardness, Rockwell		B–40
Flange thickness of a disk having 3200 lb./sq. in. bursting strength	inch	0.0076

The machinability of the 96–4 silver-copper alloy is fully equal to that of the "commercial bronze."

What is claimed is:

A bursting disk for oxygen containers and the like, said disk consisting of a round flat relatively thick central portion of uniform thickness having an integral external annular relatively thin flat peripheral flange of uniform thickness, said flange being positioned in a medial plane between the faces of said central portion and adapted to be clamped between annular members so that said flange will shear when the pressure on one side of said disc exceeds by a predetermined value that on the other side, said disk being composed of a single phase alloy consisting substantially of 96% silver and 4% copper.

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