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GLASS FIBRE TUBE FOR LEAD/ACID BATTERIES

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Design of lead/acid batteries

The lead/acid cell consists, essentially, of lead dioxide positive material and spongy lead negative material, each mechanically supported on some form of electronically conducting lead-alloy grid or spine, immersed in sulphuric acid electrolyte. Positive electrodes are manufactured in three forms, namely, Planté (Fig. 1(a)), flat pasted (Fig. 1(b)), and tubular (Fig. 1(c), (d)) plates. On the other hand, negative electrodes consist of one type only: the flat pasted plate.

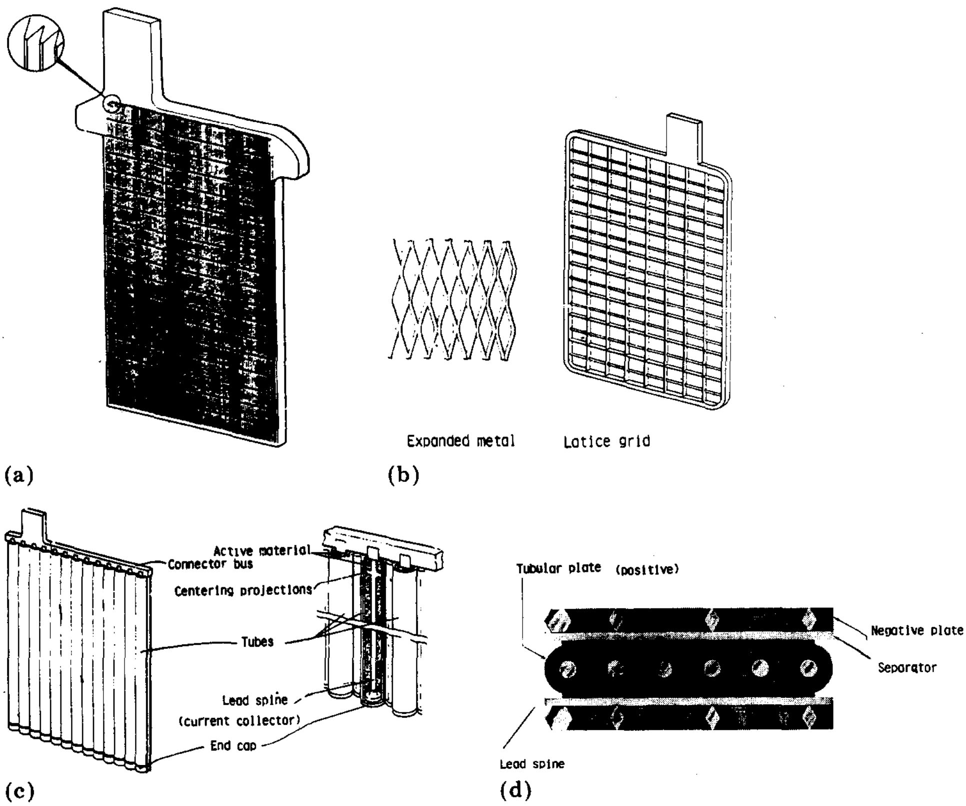

Fig. 1. Designs of positive plate for lead/acid batteries: (a) Planté; (b) pasted; (c), (d) tubular.

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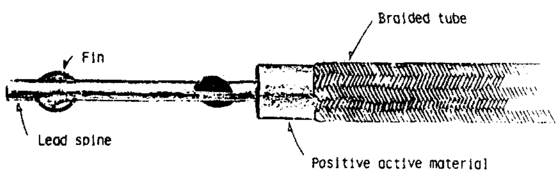
Tubes for positive tubular plates

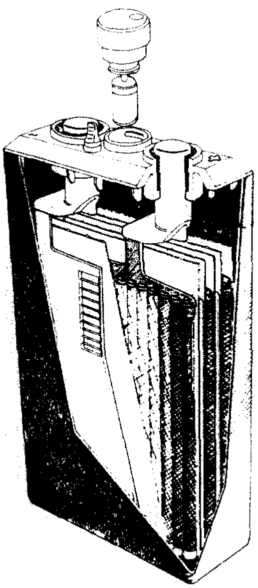
Both in Europe and in Japan, tubular lead/acid cells dominate all other types for use in industrial applications. In the U.S.A., however, tubular-plate manufacturers are in the minority.

Because of their rugged, reliable, and abuse-resistant properties, tubular cells are widely used in fork-lift trucks, mining locomotives, electric delivery vehicles, and stand-by power supplies for telephone and computer systems.

Tubular plates (also known as 'armoured' or 'clad' plates) consist of a row of tubes containing co-axial lead rods (also known as 'spines') surrounded by active material. This construction prevents the loss of active material during cell operation, and provides superior energy density throughout the life of the cell: a marked advantage over other positive-plate designs. Figure 2(a) shows the construction of a tube and Fig. 2(b) a typical tubular cell.



(a)



(b)

Fig. 2. Tubular lead/acid cell: (a) tube element; (b) cell construction.

Tube design parameters

The performance of tubular plates can be associated with two main parameters of the tube design, namely, the structure of the tube wall and the cross-sectional shape of the tube.

The tube wall (Fig. 3) has many functions:

(i) it retains the active material and resists the highly oxidizing atmosphere in the cell throughout the service life;

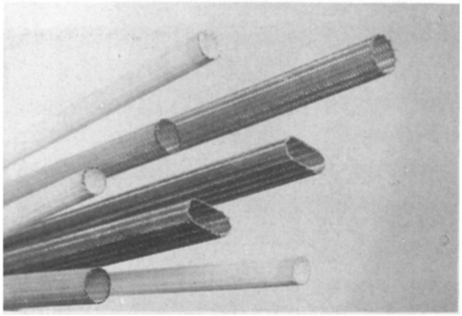


Fig. 3. Tube designs.

(ii) it allows maximum electrolyte flow and volume, but prevents sludging or shedding of the active material;

(iii) it resists uncontrolled growth of enclosed material;

(iv) it allows easy filling of the tube with lead oxide.

Therefore, the tube material must possess a high porosity, have low electrical resistance and good chemical stability, be harmless to battery operation, and must have a low cost.

Tube material

Materials used for tubes can be classified into (i) glass fibre, and (ii) synthetic fibre. Glass fibre tube has two forms: one variety is made solely from braided glass fibre, the other consists of an inner, glass fibre-braided sleeve, and an outer, perforated-plastic film or foil. The latter is well known as the Pg tube developed by AB Tudor in Sweden (Fig. 4).

Glass fibre tube usually takes the form of a single tube. On the other hand, synthetic fibre tube can either be a single element or a multiple connected tube. The latter is termed a 'gauntlet' (Fig. 5). Gauntlets are manufactured by Mecondor group in Italy and by Intes S.A. in Switzerland. Single tubes of synthetic fibre are manufactured by a company in Korea.

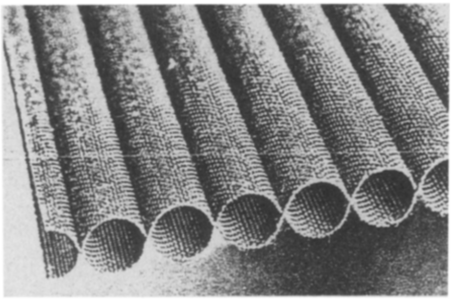


Fig. 4. Pg tube made by AB Tudor.

Fig. 5. Gauntlet or multiple connected tube.

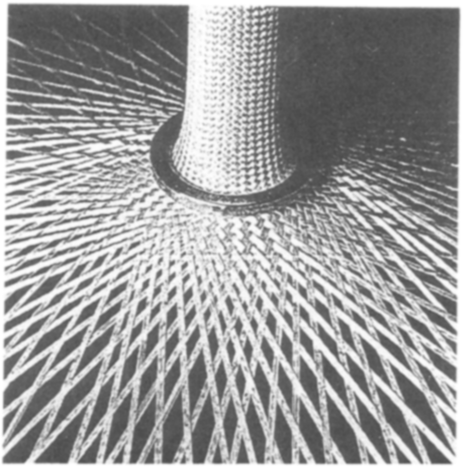


Fig. 6. Tube braiding process.

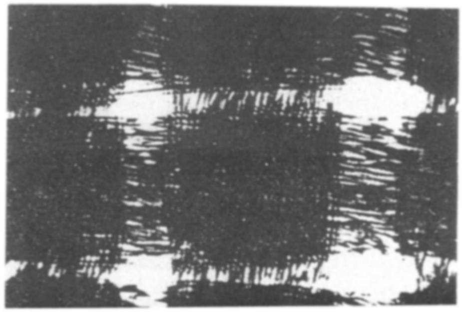


Fig. 7. Openings at woven (gauntlet) tube.

Tube construction

Single tube is usually made by braiding (Fig. 6). This is a technique that originated in the weaving industry. Gauntlet tube is made by plain weaving, which consists of horizontal and vertical yarn (Fig. 7): it is possible to make a one-piece woven gauntlet. In addition to braiding and weaving, tubes (single or gauntlet type) can also be made from non-woven material.

Tube forming

Glass fibre braided sleeve is formed or hardened. In the author's company, the sleeve is impregnated with phenolic resin and heated. The sleeve then hardens and is cut to the desired length. Both ends of the tube are treated with plastic for edge protection (see Fig. 3).

Tube shapes

Tubes are made in different shapes (Fig. 3). Various geometrical cross-sections can be formed in tube-making machines. However, circular tubes account for more than 99% of the production at the author's company. In the U.S.A., Exide Corporation manufactures a tubular plate consisting of square tubes (Fig. 8).

Tubular positive plates, regardless of their initial shape, tend to become circular on repeated discharge/charge operation. This is due to volume changes in the active mass from oxide to sulphate, and *vice versa*. Note, sulphate has a volume 1.5 times that of oxide.

Tube size

NBT's circular tubes have internal diameters (i.d.) ranging from 6.15 to 9.9 mm, and have lengths ranging from 103 to 569 mm. Typical tubes for traction batteries have i.d.s of 9.0 and 7.4 mm, while tubes for stationary batteries have i.d.s of 9.0, 8.5 and 8.4 mm.

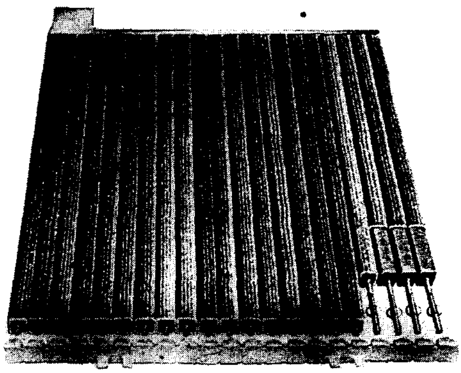


Fig. 8. Tubular plate consisting of square tubes.

Tube-wall construction

The wall of NBT's tubes consists of carriers and warps (Fig. 6). Carriers run spirally and form the main body of the tube. Warps run parallel to the tube and are crossed by the carriers. The wall construction can be varied by changing the thickness of the carrier and warp yarns, and by changing the braiding density.

Plate-making

The grid spines are inserted into the tubes either by machine or by hand. The space between the tube and the spine is filled with lead powder or lead oxide or a mixture of both, either as a dry powder under vibration, or as a pumped slurry with water. After filling, the bottom of the tube is plugged with a plastic cap.

The tube is soaked in sulphuric acid. The plates are assembled in groups, placed in a battery container, and subjected to a formation charge ('jar formation'). A variety of formation conditions are used, with variation in electrolyte density, current density, charging rate, temperature, etc. In this process, the filled powder is converted into lead dioxide active material.