This paper describes methods for the improvement of the utilization of the positive active material in tubular electrodes. First a lead dioxide matrix with a very high porosity, achieved by means of a granulated grey oxide powder, is described and secondly a special electrode geometry, promoting improved access of electrolyte into the active material and an increased convection of the electrolyte around each separate tube.

1. Introduction

The lead acid battery has been well established for traction use for decades and its use seems to be expanding during the 80's. Efforts are being made all over the world to increase the efficiency of battery operation. Consequently, many recent investigations deal with the structure and the structural changes in the positive material [1-12].

A regular and homogenous structure of the active materials is of great importance for a continuous progress of the electrochemical processes inside the electrodes. The conversion of the active material during discharge causes strains between the particles and a pressure against the surrounding material. Fortunately the active material has a prime porosity, which to a certain extent can eliminate the strains. At the same time, however, the reaction products create a hindrance for the progress of the electrochemical reaction, and can stop it despite the presence of remaining active material.

Investigations [13, 14] show that the active material in the layers nearest the free acid will be discharged first. Especially with high current drains the formation of lead sulphate in the outermost layers is highly marked. It is therefore obvious that a high utilization is promoted by an extra high porosity of the lead dioxide matrix. To increase the porosity in tubular electrodes, two methods are available (a) by mixing the paste or the powder with an additive, which dissolves in the electro-forming process leaving behind holes and pores in the material or (b) by transferring the lead powder to bigger units, the granules becoming microporous.

This work makes use of such granules and the result is an increase in porosity of about 25%. High porosity improves the supply of fresh electrolyte and this in turn promotes free convection both inside the tubes and in the bulk electrolyte.

Microporous granules are one way to improve the proper function of the electrode process. The geometry of the electrodes is another. This paper introduces a new tubular geometry, - the angular geometry - which also improves the supply of the electrolyte and consequently reduces the acid depletion around each separate electrode. This is, of course, very important in the final stage of the discharge process.

Fig. 1 is an example of an improved traction cell [15]. The envelope around the negative plate serves both as an electronic separator and as a protection against sludge falling from the active material. The energy density of a battery made of these cells could exceed 32 to 34 Wh kg⁻¹ at a 3 h regime. The highly increased cycle life due to the tubular plates, compared with the flat plate batteries, is an economic factor of great consequence.

As will be shown later, this design differs from earlier batteries with respect to the shape and the geometrical arrangement of the tubes in the multitudinous positive plate and to the structure of the lead dioxide material inside the tubes.
2. Preparation and properties of granulated oxide

The granules in this project were made in a simple spray process [16]. The original mixture is lead powder (red lead, grey oxide) and water. The ratio of powder to water was generally 4:1. The choice of binder was most important, because the binder and procedure of granulation have a great effect on shrinkage and dimension control. The binder used here was poly(vinylalcohol), 0.8 to 1.5% of the dry powder weight. The powder/water slurry was pumped through a forming die under a pressure of 1 to 1.5 MPa into a conical chamber, where the temperature range was about 150 to 300°C. The granules formed were spherical to oval with deep cavities (Figs. 2 and 3). The particle size of the granules can be varied according to the