BATTERY DESIGN
FLAT PLATE VERSUS TUBULAR

There are two basic types of industrial forklift truck batteries available to the user today; the flat pasted plate heavy duty type as manufactured by Bulldog Battery Corporation and the majority of battery manufacturers and the "tubular" type produced by a few companies. These different battery types get their name from the design of the positive plate. In general, the negative plates are identical in both types. The essential difference is that in the flat plate design, the positive plate is a rugged lead alloy grid which is filled with a specially compounded paste active material whereas in the "tubular" design the positive plate is composed of a series of parallel tubes filled with lead oxide. To understand the differences in the performance of the two types, it is helpful to know how the two positive plate designs are produced since different manufacturing methods are used which have a major influence on the way the batteries perform in service.

THE FLAT PASTED PLATE

The manufacturing process begins with a rugged cast grid usually made from a lead alloy containing from 3-6% antimony. The grids are pasted on an automatic machine with a specially compounded mixture of lead oxide (finely divided lead) water and sulfuric acid. Following the pasting operation, the plates are "cured" by a process that converts the active material in the plate to the desired composition and which causes the paste to set to a hard cement-like mass. Plates made this way are extremely rugged and will "ring like a bell" when struck. The plates and cells made in this process are very consistent and have the following characteristics:

1. **Good Electrical Performance**
2. **Long Cycle Life**
3. **Tough And Durable**
4. **Good Reserve Of Pasted Material For Long Life**
5. **Good Reserve Of Lead For Long Life**
6. **With Their Glass Wrap The Plate Is Well Protected Against Life Limiting Shedding.**

TUBULAR PLATE

The design is more complex and the manufacturing process is more involved than for flat pasted plates. The manufacturing process starts with the production of the grid which is usually a series of fifteen parallel lead rods or spines cast on to a bar. This is usually fabricated from 6-10% antimonial lead alloy.

Following the casting process, a series of parallel porous glass fiber tubes are fitted over the grid spines, these tubes are then filled with a mixture of lead oxide and red lead powder by vibration. Once the tubes are filled, they are sealed by knocking a plastic fitting onto the ends of the lead grid spines. The resulting assembly is then "pickled" by soaking in dilute sulfuric acid to convert the lead oxides to lead sulfate. The finished product comprises a series of tubes filled with lead sulfate with a center core of lead to carry the current.

Compared to the processes used to make flat pasted plates, this has considerably more steps and is more difficult to control.

Batteries made from tubular plates have the following characteristics:

1. **GOOD ELECTRICAL PERFORMANCE**
2. **ADEQUATE LIFE**
3. **LOW RESERVE OF LEAD**
4. **LOW RESERVE OF ACTIVE MATERIAL**
5. **SENSITIVE TO ACTIVE MATERIAL SHEDDING WHICH SHORTENS CELL LIFE**
6. **SENSITIVE TO TOP BAR BREAKAGE WITH SIGNIFICANT LOSS OF PLATE AREA**
7. **SENSITIVE TO SPINES BEING OFF CENTER OF THE TUBE WITH SIGNIFICANT LOSS OF PLATE CAPACITY**

BATTERY PERFORMANCE CHARACTERISTICS

When a battery is purchased for a forklift truck, the customer expects that it will provide sufficient energy to drive the truck for the necessary time, give a long life and be sufficiently heavy to provide satisfactory counter-balance to the equipment. All industrial truck batteries meet the above criteria but the flat plate type combines the best all around performance characteristics.

Usually the manufacturers of tubular industrial truck batteries stress as one of the benefits of their design that it is more efficient because it uses less lead than the flat plate design. This statement is true, but it is important to recognize that it is irrelevant. Lead is the substance that makes the battery work, gives it its durability and is what the customer pays for. Less lead means less of the material that makes the battery work. Some manufacturers of "tubular" batteries fabricate their plates from round tubes while others employ tubes with a square profile. This improvement in efficiency is only obtained from the round tube design and is hardly noticeable with the square tube design of the tubular battery.

Another important point to consider is that all industrial truck batteries are manufactured to meet specific capacity (ampere hour) requirements. For example, a 500 ampere hour battery will deliver this amount of electricity regardless of whether it is a tubular or flat plate design. Any advantage in efficiency benefits the manufacturer more than the user since less lead is used thereby reducing the manufacturing cost. This reduced use of lead and active material in the tubular design means that there is less grid metal to withstand the corrosive acid environment of the battery and less active material to withstand repeated discharging and charging. The flat pasted plate design, on the other hand, contains a reserve of both lead grid metal and active material to prevent premature failure.

FACTORS THAT INFLUENCE RELIABILITY AND LIFE

All batteries gradually wear out with use. This is caused by the wear and tear of repeated cycling of the active material and by corrosion of the lead grids or spines. Flat pasted plate batteries and tubular batteries have different operational characteristics and different wear-out mechanisms. These will be discussed in some detail so that these differences can be understood.

ACTIVE MATERIAL DENSITY

The density of the active material in the battery plates has a major influence on both the capacity and the life of the battery. It is important that the correct density is chosen and also that the density is constant over the entire plate. Too high an active material density causes

low capacity while too low a figure causes early failure. Additionally, if the density is variable, this causes uneven discharge and charge in the plates which can also result in the battery wearing out prematurely.

In the flat plate design the density of the active material is controlled by the paste density which is automatically made in the paste mixing machines to a controlled value. The density of active material in the plate is also extremely uniform since it is applied automatically by pasting machines.

On the other hand, the tubes of a tubular plate are filled by a method which involves the vibration of the plate at high frequency while a mixture of red lead and lead oxide powder is fed to the tubes. The purpose of the vibration is to prevent the oxide powder mixture from clogging and to assist its flow into the tubes. As the plate is filled, the oxide at the bottom tends to be tamped down by the action of the vibration and by the weight of the oxide at the top.

Consequently, the oxide is more dense at the lug end of the plate. This variation in density results in uneven discharge and charge of the active material which can cause premature failure. In extreme cases, which will be referred to later,the extremely dense material at the top of the plate can burst the retaining tube which results in severe shedding with a consequent capacity loss.

THE RETENTION SYSTEM

The retention system is the combination of materials that the manufacturer uses to prevent the active material in the positive plate of the battery from softening and shedding. An effective retention system is essential to achieve a long useful battery life.

The retention system in a flat pasted plate cell is usually composed of 3 layers of materials, each with its own specific purpose. The inner layer, against the plate, is composed of a mat of parallel glass filaments oriented parallel to the length of the plate. This supports the active material,filters out any particles of active material that may have become detached from the plate, provides channels for gas bubbles to escape and to allow acid circulation and acts as a reservoir of sulfuric acid electrolyte. The next layer is a binding mat or randomly oriented glass fibers which holds the glass filaments in place and the third layer is a second mat. This system virtually eliminates two of the main reasons for early failure: paste softening and paste shedding.

Contrast the retention system used in the tubular plate design which is usually a single tube of woven, non-woven or braided glass fabric.

This system does not provide as efficient retention of the active material as the threefold wrap system because of uneven porosity of the tube structure.

Consequently, as much greater degree of shedding of active material takes place with the tubular construction. This increased amount of shedding can lead to other problems that may result in early battery failure. For example, the finely divided active material that is shed from the plate can become stirred up in the electrolyte by the gasses generated when the battery is charged. This suspended material, usually lead dioxide, gives the acid a black color and can settle on the negative plates where it is electrochemically reduced to a spongy lead mossy deposit. This mossy deposit can eventually cause a short circuit between a number of

positive and negative plates which leads to premature battery failure. Another characteristic of tubular type battery plates is the occurrence of split tubes. The usual cause of this problem is overfilling of the tubes resulting in a very dense active material. Another cause can be uneven filling that results in density gradients in the active material. When the battery is discharged and charged, as in normal operation, spine corrodes occupying a greater volume, the active material swells and exerts a very high pressure on the tubes. This can cause the tubes to split resulting in catastrophic shedding of the active material. In an extreme case, all the active material can lost from the tube resulting in a loss of capacity of up to 6. 7% for each split tube.

GRID AND SPINE CORROSION

One of the major differences in the design of flat plate and tubular industrial truck battery cells is that in the flat plate design, a grid of lead alloy is used to hold the active material in place and conduct the electricity whereas in the tubular design, a series of lead spines encased in glass fabric serves the same purpose.

The grid of a flat pasted plate is composed of a crisscross network of lead alloy with spaces that are filled with active material during the pasting process. The areas of pellets of active material are completely surrounded by lead alloy resulting in excellent material retention and conductivity. This network of conductive metal ensures that all parts of the plate are electrically connected for good current distribution and also provides a reserve of lead to with stand the corrosive action of the acid electrolyte. As the battery ages, the sulfuric acid gradually corrodes the lead.

This reserve of metal is essential to give the battery along, reliable life. If any one metallic member, or several for that matter, corrode through there is still sufficient lead remaining for the battery to still function well.

In contrast, the spines of a tubular plate contain no reserve of lead metal. If one spine corrodes through, the electrical connection is broken and a serious loss of capacity results. Since there are normally 15 spines in a plate, the corrosion of one spine can result in a loss in capacity of up to 6%. As the battery ages, corrosion of several spines can occur resulting in a serious loss of performance.

CONCLUSION

Although to many people a battery is a “black box”, there are significant differences in construction and performance between the two types available in the marketplace. The flat pasted plate construction has several advantages over the tubular design in terms of reliability, life and performance. It is important to know these advantages so that an informed decision can be made when choosing a battery. Once all the facts are considered, it is clear that the flat pasted type is the number one choice.