Engineering Research Report
High Gravity Batteries

Director of Research
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SUBJECT: High Gravity, Lead-Acid Lift Truck Batteries

Our Research & Development facility has undertaken a research program on High gravity industrial batteries. The purpose of this research on high gravity is to determine what benefits, if any, that could be achieved by increasing the specific gravity of the industrial lead-acid battery for the fork lift truck application.

Research is continuing and some interesting results are being compiled. The general methods used in the research are to manufacture and test in the laboratory the high specific gravity batteries. In any research program, careful attention is given to be precise and all data has been collected to support any conclusions.

Some research observations on high specific gravity are outlined below:

(1) **Charging Equipment:** The automatic battery chargers in the field today are not going to maintain high gravity batteries, but will operate the batteries in a partially discharged condition, which will accelerate deterioration, grid corrosion and loss in capacity. Recharging the battery back to full charge is touchy and critical. The normal voltage curve "knees" at 1.75 volts per cell has been increased to 1.85 volts (or higher) per cell in the high gravity batteries. Successful operation of industrial batteries in the customers place of business will depend upon development of a charger that matches the voltage characteristics of the high specific gravity battery.

(2) **Manufacturing:** The present normal lead-acid specific gravity battery (1.275-1.285) is quite tolerant of manufacturing processing and operating errors with normal specific gravity. The use of high specific gravity (1.325-1.380) reduces the parameters of the manufacturing processing operation.

(3) **Manufacturing Temperature:** When a battery cell is filled with 1.325 sp. gr. or higher, it requires a soak time of 6 to 8 hours (minimum). The cell temperature will be quite hot for each cell. If the cell temperature is allowed to drop (which it should be) to 110 degrees F or so before starting formation, soak will be too long and deep formation will be slow to start. The effect of high initial formation temperature are known to adversely affect battery quality. It is possible to form out in low gravity acid and dump the acid before final high gravity formation. This approach seems to be a very expensive one.

(4) **Acid Volume:** Excess acid is believed to be necessary even with the high gravity acid. The laboratory tests show that extra acid volume would increase initial capacity. This keeps the cells from becoming acid limited.

(5) **Capacity:** The maximum capacity is reached between 1.375-1.400 for plates formed in high gravity. Above 1.400 very little capacity is gained.

(6) **How is extra capacity obtained in high gravity batteries?** It is strongly believed by many researchers that the depth of formed material in the plates is increased by increased gravity penetration. Battery plates are never formed completely through the initial manufacturing plate processing in the factory. (This includes all manufacturers of lead-acid batteries).

Complete formation only occurs at the end of plate life in service, in plates that no longer have a "core" (Core refers to plate material that has not formed out yet. Located in the center of the plate.) Thus, any extra capacity that research reveals in high gravity acid was due to greater depth penetration into the "core" of the plate. Death of the battery is when the "core" is used up. Higher gravity, of course uses up the "core" at an accelerated rate.

(7) **How much capacity gain in high gravity batteries?** A capacity gain of 20% was recorded in laboratory development by using high gravity acid and variations in processing. No changes in active materials, grid configuration or the use of special additives were required. Figure 1 illustrates the discharge curves for identical batteries. One battery was processed normally and the other identical battery was processed in high gravity. As can be seen, in addition to increased capacity with high gravity, the discharge voltage for a high gravity battery is elevated.

(8) **Did the extra Capacity hold?:** Cycle testing of high gravity batteries revealed that after 100 cycles:

High Gravity Battery No.	A.H. Capacity @ Start	Capacity @ 100 Cycles	Approximate % Capacity loss
1	78.0 A.H.	68 A.H.	15%
2	77.0 A.H.	60 A.H.	22%
3	77.5 A.H.	63 A.H.	18%

The above capacity loss was disturbing because the voltage remained high due to the high gravity. It was hard to detect that the capacity was somewhat low because of the high voltage readings.

An extended boost charge was given for 4 days to the high gravity batteries at I/2 the finish rate to restore the high gravity batteries back to the original capacity. This boost restored part of the lost capacity ln high gravity batteries. Shown below are the charge back results.

High Gravity Battery No.	A.H. Capacity @ Start	4 day boost @ 1/2 finish	% Capacity loss
1	78.0 A.H.	75 A.H.	4%
2	77.0 A.H.	68 A.H.	11%
3	77.5 A.H.	69 A.H.	11%

This loss in capacity is disturbing in that shortened life due to high gravity operation is indicated. Remember, the "core" is being penetrated at a very rapid rate. At 100 cycles, only an indication can be obtained for a battery which should have a life of l5OO + cycles.

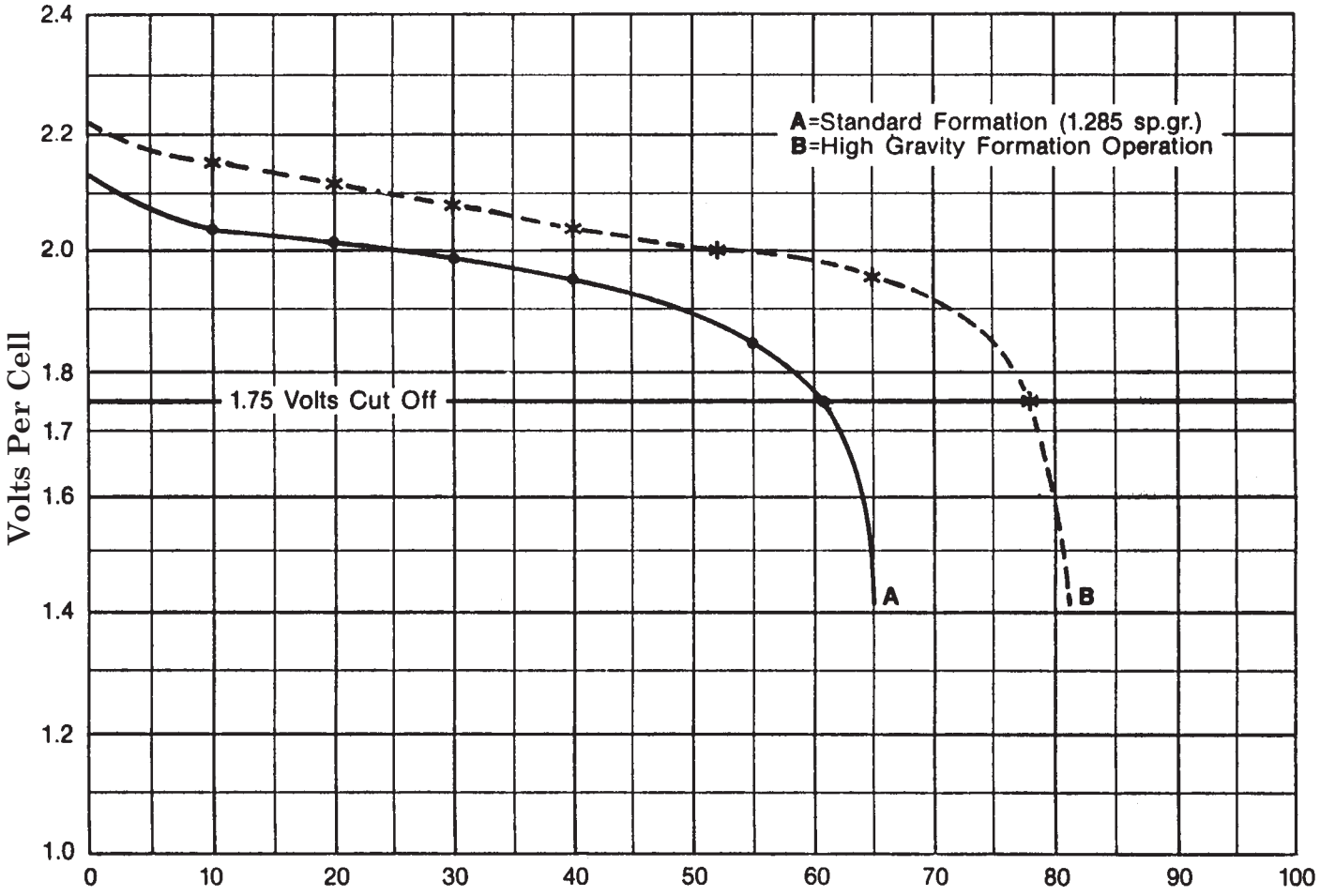
(9) **Battery Life:** Its too early to say how much the life of the high gravity battery will be shortened We are seeing indications that life shall be greatly affected because of the "core" of active materials being consumed at a rapid rate.

(10) **Comments:** High gravity batteries with increased capacity can be produced in the laboratory or in a very rigid manufacturing environment.

These high gravity batteries will only operate successfully in the field with special charging equipment and truck controllers which will match the voltage characteristics of the battery.

The customer must maintain a rigid charge back program to offset this capacity loss due to the high gravity. This special charger is not suitable for any other batteries except high gravity. Manufacturing companies can produce a high gravity battery but the difference in manufacturing techniques will vary between companies which further restricts charging opportunities on different high gravity makes.

In general, Research has concluded that the benefits of high specific gravity batteries does not provide the customer with an improved product. In fact, the high specific gravity acid could be inferior under certain conditions, i.e., restricted charging equipment, manufacturing variations, battery operating conditions, and other factors.



Amp Hours (Figure 1) Discharge curve, rate-10 amp discharge