

STORAGE BATTERY
MANUFACTURING MANUAL



by
NELS E. HEHNER

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by

NELS E. HEHNER

for

IBMA

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by

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Largo, Florida 33540

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PREFACE TO SECOND EDITION

A great deal has happened in the automotive battery industry since the first edition of the Storage Battery Manufacturing Manual was published in 1970. This was recognized several years ago when work on updating the manual was begun.

This edition brings to the industry the very latest in manufacturing techniques and has been written in the same step-by-step procedure which brought acclaim to the author, Nels Hehner, after publication of the first edition. His "cook book" approach will help even the uninitiated understand the needs of a battery manufacturing plant and, will be an even greater aid to those already manufacturing, as discussed in the preface to the first edition.

As an added item of interest, the author has included some early history of the lead acid storage battery industry as it applies to the starting, lighting, and ignition segment.

For those who are not completely familiar with the author, Nels Hehner has set up battery plants in several countries and is well known as an authority on the subject in many parts of the world. Most of his life has been spent within the industry and he has continued his interest and activity in retirement, having made himself available on a consulting basis since that time.

We wish to acknowledge with thanks all those who helped the author and us in bringing this updated edition to you. While listing each and everyone would be practically a volume in itself, we have chosen instead to list the companies whose personnel contributed much of their time and effort.

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DAN A. NOE, Executive Secretary
Independent Battery Manufacturers Association, Inc.
100 Larchwood Drive
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PREFACE TO FIRST EDITION

Although the automotive battery industry has had available excellent technical data for the complete battery, there has been a need for a practical battery manufacturing manual. The demand for this has come primarily from the smaller battery manufacturers throughout the United States. In addition there has been a growing demand for such information throughout the world due to the rapid increase in production and use of automotive vehicles using secondary storage batteries.

It will be obvious from the following pages why this should be a tremendous help to battery manufacturers who have been operating for a few years, and particularly for those starting in the battery manufacturing business for the first time. In addition, battery manufacturers have indicated particular interest in the need for this manual to train their department employees.

Without the proper knowledge of factory building needs, proper equipment and procedures or methods, it might not be economical to start such a venture. Caution should be observed regarding the use of used or faulty equipment. Consideration should be given to the minimum unit production for a safe economic return on investment. It is possible to produce unintentionally a low quality battery at just about the same cost that would be involved in making a good quality battery using reliable manufacturing information. It is the intent of this publication to present information to assure a final product worthy of the manufacturer's name.

During the past fifty or more years the battery industry has advanced considerably in manufacturing improvements, both in processes as well as over-all efficiency of the completed battery. It is intended that this presentation will bring up to date the essential items necessary for good manufacturing practice. No doubt there will be continuing advancement made in the years to come.

This presentation is based on methods of battery manufacture that would apply to (1) temperate climate battery construction and (2) those that are preferred in tropical areas. It is assumed that the factories will not make their own lead oxide and would be producing wet batteries. Since dry-charge battery manufacture requires special processing and equipment this phase of manufacture is described in a separate chapter. By way of explanation, a temperate climate is one where water freezes sometime during the 12-month year. In such a climate the temperature may go considerably below the freezing point of water. This condition results in a cold, stiff automobile engine and therefore the maximum attainable power from the battery is required to start the engine. The colder climate batteries must produce higher discharge rates at sub-freezing temperatures for the same size battery containers. A tropical climate is one where water never freezes. Thus batteries are not required to produce such high discharge rates, but on the other hand they may have to operate in higher atmospheric temperatures and for long periods of time. It immediately becomes apparent that there is no such thing as one basic ideal procedure for battery manufacture considering all the variations such as climate, service types, market conditions, material costs and availability. The changes in processing will be discussed in the same order as the manufactured product progresses through a battery factory.

Some subjects treated herein may be covered by United States and/or foreign patents. The publisher has endeavored to note the possibility of existing patents wherever practicable, but disclaims any responsibility for failure to note applicable patents. The reader is cautioned to make his own independent search for applicable patents as to any information herein which he may adopt and practice.

Likewise the writer and the publisher cannot be responsible for the application or interpretation of this manual.

TABLE OF CONTENTS

		Page No.
CHAPTER 1	EARLY AUTOMOTIVE BATTERY MANUFACTURING REPORTS	1
CHAPTER 2	CASTING DEPARTMENT	4
	Raw Materials	
	Equipment	
	Utilities Required	
	Mold Spray Formulas	
	Grid Casting	
	Reasons For Rejection	
	Small Parts Casting	
	Reasons For Rejection	
	Thermo-Metric Method for Determination of Antimonial-Lead Alloys	
CHAPTER 3	STORAGE BATTERY LEAD OXIDES	17
	"Lead Oxides"	
	Oxidation Process	
	Tumbling Process	
	Considerations	
	Cost Items	
	Specifications	
CHAPTER 4	PASTING DEPARTMENT	20
	Raw Materials and Specifications	
	Paste Mixers	
	Paste Machines	
	Plate Drying Ovens	
	Utilities Required	
	General Paste Mixing Instructions	
	Belt Pasting Machine Instructions	
	Beltless Pasting Machine Instructions	
	Plate Drying Oven Instructions	
	Control of Wet Paste Plate Weights	
CHAPTER 5	CURING OF FRESHLY PASTED PLATES (HYDROSET)	32
	Process and Precautions	
	Reasons For Rejection	
CHAPTER 6	ELEMENT BURNING DEPARTMENT	35
	Materials Required	
	The Process and It's Equipments	
	Reasons For Rejection	
CHAPTER 7	ASSEMBLY OF ELEMENTS INTO CONTAINERS	39
	New Materials Required	
	Specifications For Battery Containers and Covers	
	Sealing Materials	
	Assembly Description	
	Reasons For Rejection	
CHAPTER 8	*FORMING AND CHARGING OF BATTERIES	46
	Equipment Required	
	Charging Instructions	
	Reasons For Rejection	
	High-Rate Discharge Battery Testing	
	Comparison of "Two-Shot" vs. "One-Shot" Fill Method	

		Page No.
CHAPTER 9	BATTERY STOCK AND SHIPPING Method of Stacking Batteries Battery Stock Procedures Specific Gravity Loss In Stock Preparing For Shipment	56
CHAPTER 10	DRY-CHARGED BATTERY CONSTRUCTION Plate and Element Formation Plate Forming Methods Element Forming Methods Washing Of Elements Positive Plate Drying Negative Plate Drying Assembly and Testing Oil Processed Negative Plates	61
CHAPTER 11	MAINTENANCE-FREE SEALED BATTERIES Lead-Calcium Alloy Sheet-Cast, Punched and or Expanded Grids Rolled Sheet, Punched and or Expanded By Slitting Grids Cast Grids Lead-Calcium Alloy Grid Mold Coating Calcium Control Impurities and Suggested Formula Testing For Percentage Of Calcium Pasting and Hydroset Of Plates Separators Post Straps-Element Assembly Containers, Covers and Vents Formation "Non Lead-Calcium" Maintenance-Free Batteries Some Electro-Chemical Characteristics	69
CHAPTER 12	WATER AND SULFURIC ACID Types Of Water and Effects Sulfuric Acid (Electrolyte Grade)	85
CHAPTER 13	RECLAIM OF SCRAP BATTERY MATERIAL Lead Items Separators Containers and Covers Sulfuric Acid	91
CHAPTER 14	HAND PASTING OF PLATES Equipment and Method	93
CHAPTER 15	AUTOMOTIVE STORAGE BATTERY SEPARATORS Description of Materials Types	95
CHAPTER 16	HEALTH AND BATTERY PLANT ENVIRONMENT Plant Layout Plant Housekeeping Tropical Climates Lead Pot Operating Temperatures	98

	Respirator Protection	
	Exhaust Ventilation	
	Lead Effects	
CHAPTER 17	FINISHED PRODUCT BATTERY TESTING	101
	Specifications	
	Testing and Equipment	
	Pretesting Conditioning Procedure	
	Cranking Performance Test	
	Reserve Capacity Test	
	Cold Activation Test (Dry-Charge Batteries)	
	Charge Rate Acceptance Test	
	Overcharge Life Test	
	Vibration Test	
	Hot and Cold Cycle Test	
	Electric Vehicle Battery Test	
	Sources For Further Specifications	
CHAPTER 18	BATTERY PLANT BUILDING SUGGESTIONS	106
	Building Location	
	Structural Factors	
	Codes and Regulations	
	Floor Space	
INDEX TO CHARTS AND ILLUSTRATIONS		108

CHAPTER 1

EARLY AUTOMOTIVE BATTERY MANUFACTURE EFFORTS

Before going into this second edition involving the present day methods of automotive battery manufacture, we will describe some of the procedures and experiences in the early years of this industry. This serves as an historical record and to acquaint newer arrivals in the industry with some of the action that took place in that period. This discussion will follow about the same order as the usual route of battery manufacture.

LEAD CASTING

All lead castings were produced at first by hand and in many cases from single cavity molds. After World War I and well into the 1920's, casting machines and multi-cavity molds replaced the slower production equipment and methods. Mold coatings of cork were not known. Acetylene smoke and talc powder were two of the materials used on mold surfaces. The acetylene smoke use had developed into a detailed procedure wherein a "hard" smoke coating was followed by a "soft" smoke coating. Some of these coatings had a durability of about half a working day. Talc powder use was an entirely separate and different procedure than the acetylene smoke method. One the clean hot mold, a liberal application of talc powder was made by a large porous cloth bag or "powder puff" to the mold surfaces, between every lead casting pour. By the late 1920's most of the industry was changing to cork powder mold spray coatings, using sodium silicate and water as the essential liquid ingredients. This has continued with many other material additions and formula modification.

Grid molds were made as now, with a double grid design in each mold cavity. Some were made as now, with the cavity mounted vertically and the long dimension in such position that the lead was poured along the long side adjacent to the grid lugs. Other molds were mounted vertically along the long axis of the mold and the lead was poured on the top of the cavity. Gate trimming was by hand, sometimes with some mechanical help. Grid antimonial lead varied from 7% to 12%, with the majority around 9% to 11% range.

During the first decade of automotive batteries, many grid designs appeared and disappeared after a rather short field service experience. In addition to the vertical and horizontal grid wire design which from rectangular active material pellet shapes (still prevailing in today's grid designs) there were other geometrical shapes of various sizes on the market. Such designs were square, diamond, triangular or hexagonal shaped pellet areas. To justify such shapes, a variety of claims were made, including increased grid structure strength. Some claims went further to boast proof against buckling of the positive plates. Field experience, however, did not usually substantiate the claims. Popular grid thickness of grids was about 1/8 inch (3.20 mm.). There was practically no paste weight control at that

time. To be certain that active material did not shed prematurely in service, the active material was, (what one would now describe as very dense), namely a high paste weight. In addition, the charging systems had little, if any voltage controls to reduce or prevent overcharging. Therefore, a common cause of battery failure was buckled positive plates, which cut through the adjacent separator corners and oxidized holes in the separator centers, regardless of grid design.

Many a newcomer to the industry has raised the question why such lead castings are not "die cast", (which is a well developed art and production is fairly high.) The reason for this is that "die castings" tend to be porous, having some blow holes. Such blow holes or air pockets in the castings would result in defective grids, producing short-lived batteries.

PASTE MIXING AND PASTING

Lead oxides used at this time were red lead (Pb_3O_4) and litharge, as the main materials for positive plates. Sometimes smaller amounts of fumed litharge or basic lead sulfate were added as "bulking agents" to lower the weight of paste in the plates. Negative plates generally used litharge as the lead oxide material. Some manufacturers used a little fumed litharge and basic lead sulfate here also. Expander, if used, consisted initially of barium sulfate and lamp black. Later, expander was prepared by digesting cotton or scrap cotton material in hot 50%-60% sulfuric acid, to which barium sulfate and lamp black were sometimes added. Some plants used wood dust or wood flour in place of the cotton items mentioned in the above expander formula. Mixing solutions varied from 1.100 - 1.300 sp. gr. sulfuric acid to mixtures of such acid strength with water solutions of ammonium sulfate in the 1.050 - 1.200 sp. gr. range. Pasting was accomplished by hand, one double plate at a time on heavy canvas or several plates at a time on a board with paper below as the water absorbent. Later some of the larger battery companies used crude pasting machines, some of which were mainly mechanized canvas belt conveyors with some heat applied. One early pasting machine incorporated an acid dip treatment to the plates. However, this soon proved unsatisfactory as the acid corrosion was beyond control and subsequent plate handling was very difficult.

FORMING, ASSEMBLY AND FINAL CHARGE

Plates, after pasting, were given one of several types of treatment:

- Placed in racks in forming tanks with dilute sulfuric acid for a few hours and then charged for several days, producing positive and negative formed plates. In the event the plates were likely to become surface air-dried enroute to the forming tanks, a water dip was given the plates.

EARLY AUTOMOTIVE BATTERY MANUFACTURE EFFORTS

- Pasted plates immediately were given an acid dip and stored overnight.
- Pasted plates were immersed for 16 hours in large tanks containing about 1.300 sp. gr. sulfuric acid. Such plates were sometimes designated as "pickled plates."

Limited production was attempted using super-heated steam under pressure which quickly removed the excess paste moisture and "set-up" the active material. This generally produced high plate scrap and increased the lead in air in the department.

Another method in the forming line was burning the treated plates into unformed elements and forming these in the acid tanks for several days.

Battery assembly consisted of dried formed plates and, as such, assembled batteries could be charged for several days prior to shipment or placing in stock. Such batteries could be shipped uncharged, to be charged later by the dealer at his convenience. The other type of assembly consisted of the wet formed elements which, after battery assembly, were placed on charge over night and then shipped or placed in stock.

Separators were almost entirely of Port Orford Cedar wood, treated in boiling dilute caustic soda and water washed free of caustic. This treatment usually required 24 hours.

MISCELLANEOUS ITEMS

Some batteries appeared on the market, of "special construction," supported by broad claims. A few batteries used corrugated perforated celluloid separators without wood and "non expanding" negative plates. Sometimes such combinations were also used with "gel" electrolyte, made by adding sodium silicate to the battery acid. Usually, all such "special" batteries failed early in service because of shorts developing through the perforated separators.

During this period, attempts were made to apply lead materials to grids by other methods than the usual lead oxide paste mix. Making a water or acid slurry of lead peroxide (PbO_2) and applying this to the grid was one such unsuccessful attempt. The same thing was tried with powdered lead to make negative plates, which also failed. Dry, powdered lead peroxide was also forced in position in the grids by applying tons of pressure. Powdered lead was also given the same treatment. All such efforts, after charging in dilute acid, resulted in failures as either the lead peroxide or powdered lead would soon start shedding and falling away from the supporting grid structure. No method was found to be as satisfactory as using the lead oxide paste mix and applying it to the grid. Electro-formation produced the maximum active material bond, rigidity and at the lowest cost.

One battery manufacturer, during the early years, made batteries by stamping grids from sheet antimonial lead instead of casting grids in the conventional manner. The stamped grids had no pellet interlocking active material pattern, but simple rectangular openings or holes, arranged in a pattern that gave

the final appearance of a regular grid. The usual battery paste filled the openings in the stamped grids for respective positive and negative plates. The final batteries in service gave rather short performance. The formed active material in the stamped grids becoming loose in the grid openings and the battery failed. This created the condition of having very little, if any, actual bond or contact between the grid metal and the active material in the many openings. Some active material areas appeared to have contracted or pulled away from the metal grid surfaces. Naturally, with practically no bond between active material and grids, there was no performance or electrical output of the battery.

In the early 1920's, the battery industry's first "non-wood" separator appeared, a completely synthetic product. Although it was expected that a battery with such separators would have excellent electrical performance, the opposite was the result. Wood separators in batteries out-performed "non-wood" separator batteries. These conditions led to the fact that wood separators, not only served their normal purpose in the battery but in some manner also improved the electrical performance of the battery. All this soon led to the fact that some additional property of the wood separators in the battery contributed to improve negative plate performance. Thus, negative expander formulas started to include such items of wood, as wood dust or wood flour. Such additions to the negative paste produced the desired performance with the use of synthetic separators. Thus, wood products, the present day use of lignin, found the way into battery manufacture.

Early synthetic battery separators made possible the first dry-charge battery in the early '20's. Such batteries were more expensive because (1) the separators were higher in price than the wood types and (2) the dry-charging of the plates was a costly operation.

From the beginning, automotive batteries were assembled so that in each cell there was always one more negative plate than positive plates. Thus, the outside plates of an element are always negative plates, i.e. a seven plate element has four negative and three positive plates. During the early period, one brand of batteries was assembled exactly opposite in element structure. This meant that a seven plate element had four positive and three negative plates. Such construction was called "positive end zones." In actual car service of such batteries, the two outside positive plates were generally buckled and shorting through the adjacent separators. The outside active material surface of the outside plates was usually all in place and of a dense and hard texture. The active material on the inside of the same positive plates showed normal service-life shedding characteristics. The other inside positive plates showed the same normal service shedding. After a few years on the market, the "positive end zone" construction was discontinued.

A description of the first production automotive storage battery for electrical engine cranking, is of some historical interest. It was for a USA manufactured car announced in late

EARLY AUTOMOTIVE BATTERY MANUFACTURE EFFORTS

1911 for the 1912 model. The battery for this car was described in literature later by the battery manufacturer as follows:

“The 1912 battery had 12 small cells, each consisting of three plates in a small hard rubber jar with a soft rubber cover. No sealing compound was used. These cells assembled in four groups of three each, were connected in series for starting at 24 volts and in parallel for lighting and ignition at 6 volts. This battery, weighing about 67 pounds, had been used during previous years in connection with other devices requiring high rates of discharge.”

Up to about 1920, the car electrical systems were either 6 volt, or 12 volt or a combination of 12 volt starting and 6 volt lighting and charging. The latter combination included series-parallel switching mechanisms which were troublesome.

It was not unusual for the parallel charging connection for one of the 6 volt battery sections to fail to make proper contact. Thus that part of the battery would not charge. Three cells would be fully charged and three cells would be completely discharged. By 1925, all cars were completely on 6 volt systems except one manufacturer, who changed about 1928 from 12 volt to 6 volt electrical equipment.

In 1931 the first car was introduced in the USA which had no provision for a crank for hand engine starting for emergency occasions. This new feature soon applied to all new cars. The absence of the crank signaled the acceptance of the storage battery as a dependable part of the automobile.

Direct “through-the-partition” connections between battery cells were first used in 1935. This construction was used only with rubber containers and was standard battery equipment for one car manufacturer and one truck manufacturer. It was also

used on a high performance airplane battery. One large city used such construction on their heavy duty batteries for city buses. Everyone involved in servicing batteries at that time, vigorously opposed the “buried connections.” One of the main objections of the construction was the difficulty in obtaining all the individual cell readings. Although no service failures were encountered, the construction was discontinued after a year or two, rather than trying to overcome the continuing opposition of battery service personnel. Without question, the construction was ahead of its time.

During the first years of World War II, the USA War Production Board found there was a shortage of antimony for storage battery grids. Batteries were one item needed for military purposes. The Board then specified that all battery grids would be of 7% antimonial-lead. At that time, 7% was about the minimum amount of antimony used by any battery manufacturer, while a number were using percentages as high as 11% antimonial-lead. A few manufacturers were granted special permission by the Board to use higher than 7% antimony usage, because their machines were not capable of casting the required 7% grids and these companies did not have the know-how to cast grids of lower antimony content.

The grid casting of lead-calcium-tin (Pb-Ca-Sn) alloys for maintenance-free batteries points to the progress the industry has made in the last 30 years. Today, very few battery manufacturers use antimony as high as 7%, probably more nearly 4-5% or even lower. The Pb-Ca-Sn grids are being machine cast without many serious difficulties. In addition to all this, the present grids for batteries are produced at casting speed as high as 20 strokes per minute, far in excess of any World War II casting rates, when a few producers were able to go as high as 14 strokes per minute.

CHAPTER 2

CASTING DEPARTMENT

RAW MATERIALS

The casting department produces the lead-antimony grids and lead-antimony small parts (post straps, connectors, burning bar, etc.) for the battery. To produce satisfactory lead parts for the succeeding plant operations, as well as for acceptable battery service life, the lead alloys should meet certain material specifications. Specifications are also important as they will insure a uniform product, shipment after shipment, from the lead suppliers.

All alloys, whether for grids or for small lead parts, should be homogeneous and free from occluded solids other than the slight metallic impurities. The metal should possess suitable physical characteristics to make it satisfactory for use in molds. A practical casting test should be made in the casting department.

GRID ALLOY SPECIFICATIONS

(A) A satisfactory alloy for positive grids to be used in average service battery conditions is shown below. It may also be used for all negative grids for all batteries. For successful casting operations, once a grid alloy has proven satisfactory it is important that the specified tolerance be held within the limits.

Antimony	- See next paragraph
Arsenic	- .200% maximum - .100% minimum
Tin	- .500% maximum - .300% minimum
Silver	- .010% maximum
Iron	- .005% maximum
Copper	- .100% maximum
Nickel	- .010% maximum
Cobalt	- .005% maximum
Zinc	- .006% maximum
Bismuth	- .050% maximum
Cadmium	- .005% maximum
Manganese	- .005% maximum

The usage of antimony varies among different battery manufacturers for this type of alloy, from about 3% to about 6%. The normal tolerances are plus or minus .25% of the desired percentage, thus a 5% antimony value may vary from 4.75% to 5.25%. Antimony adds to the rigidity of the casting, and aids against the corroding effects of sulfuric acid and the charging current. Arsenic also aids in resisting corrosion of the charging current and control shrinkage of the finished casting. Tin is important as it imparts an improved "fluidity" to the molten alloy and helps in mold filling. Other elements found in battery lead alloys can be considered impurities. It has been demonstrated that it is impossible to make satisfactory castings from an alloy of only pure lead and pure antimony.

(B) Grid alloy specification used by some battery manufacturers is as follows:

Antimony	- As stated in (A)
Arsenic	- .400% maximum - .300% minimum
Tin	- .150% maximum - .100% minimum
Silver	- .010% maximum
Iron	- .005% maximum
Copper	- .100% maximum
Nickel	- .010% maximum
Cobalt	- .005% maximum
Zinc	- .006% maximum
Bismuth	- .050% maximum
Cadmium	- .005% maximum
Manganese	- .005% maximum

This alloy is sometimes designated as a low tin alloy. The market price of tin is rather high and this is the basic reason for this specification, as it could lower the alloy cost slightly. This alloy does not have as good "hot fluidity" as the (A) alloy or any other higher tin content specification. Thus, this property makes grid casting more difficult. To partly overcome this characteristic, the pouring ladle of the grid casting machine should have "V" notches, about one-quarter inch (6 mm.) deep and one inch (25 mm.) apart along the center of the pouring edge for about 8-10 inches (20-25 cm.). This creates a pouring spout of hot lead at each notch and improves grid mold filling. Grid alloys having higher tin content as shown in (A) or (D) (next page) alloys may use a straight edge pouring ladle, since such alloys will pour in a thin sheet form along the entire ladle pouring edge.

(C) Lead smelters may use almost entirely scrap automotive storage batteries as their essential lead supply. The smelters' final alloy, at the present time, has an antimony content of about 3%. The smelter then adds pure antimony metal to the scrap battery alloy, to make higher antimony content alloy for the battery manufacturer. Some battery manufacturers are willing to accept such an alloy, with little regard to arsenic and tin percentages present. The usual experience has shown that these two metals are generally present in sufficient percentages to ensure satisfactory grid casting operations. The advantages of such an understanding between smelter and battery manufacturer is a lower than normal grid alloy price. This is possible as the smelter spends a minimum amount of effort and time to make a salable grid alloy. With such an arrangement, the usual impurities are in the low percentage ranges.

It is immediately apparent that with such an antimony-lead alloy, there is very little specification control. This condition could cause trouble with the battery grid casting department or

CASTING DEPARTMENT

the final battery product. Any such attempts between smelter and battery manufacturer should be made only after considerable experience and trials, to make certain that the end result will not be a low quality battery.

CORROSION RESISTANT POSITIVE GRID ALLOY

(D) In certain battery applications it may be necessary for the battery to withstand extreme resistance to corrosion of positive plate grids. In that event, some of the grid alloy specifications given above are hardly durable enough for such service and an improved grid alloy composition is required. This is generally used only in positive grids intended for such corrosion resistant batteries. Corrosion resistance means the ability to better withstand the destructive effects of excessive charge or overcharge. Alloy specification for this purpose is listed:

Antimony	- See next paragraph
Arsenic	- .550 % maximum - .450 % minimum
Tin	- .500 % maximum - .300 % minimum
Silver	- .010 % maximum
Iron	- .005 % maximum
Copper	- .100 % maximum
Nickel	- .010 % maximum
Cobalt	- .005 % maximum
Zinc	- .006 % maximum
Bismuth	- .050 % maximum
Cadmium	- .005 % maximum
Manganese	- .005 % maximum

The percentage of antimony may be left to the battery manufacturer. Various manufacturers use from 3.0% to 6.0%. The normal tolerance is as previously stated: plus or minus .25% of the desired percentage. As can be seen from the chart of "Freezing Points of Antimony-Lead Alloy" (Figure 1) the lower antimony content freezes about 45°F (25°C) higher than the greater antimony (6%) content. This means that in grid casting operations the lower antimony content (3%) makes casting more difficult and the operating temperature of the grid mold must be increased at least in relation to the alloy freezing point increase. The greater amount of arsenic in this specification gives this alloy improved corrosion resistance against overcharging as compared to the alloy specification in (A). The arsenic content as shown here is about as high as it is practical to go under ordinary conditions to keep the alloy in a liquid state during casting operations (re-melting trimmings, etc.) and not have it "dross out." Higher arsenic values tend to be lost in the dross. This alloy is a bit tricky as it sometimes may harden in the first twenty-four hours after casting, becoming almost brittle, and produce cracks in the grid frames, etc.

SMALL LEAD PARTS ALLOY SPECIFICATIONS

This alloy is for use in all lead small parts (post straps, connectors, burning lead, special terminals, etc.). The following specification is an example which secures satisfactory results for small parts lead castings.

FREEZING POINTS OF ANTIMONY-LEAD ALLOYS

Tin 0.25 %
Copper 0.05 %

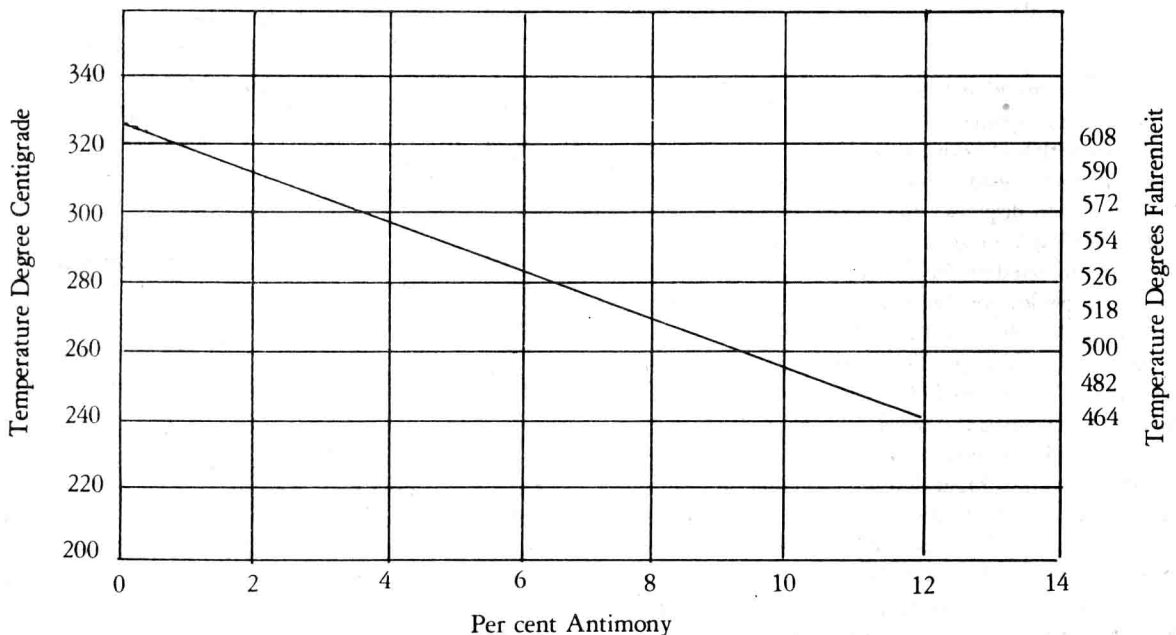


FIGURE 1

CASTING DEPARTMENT

Antimony	- 3.25 % maximum - 2.75 % minimum
Arsenic	- .120 % maximum - .025 % minimum
Tin	- .500 % maximum - .100 % minimum
Silver	- .010 % maximum
Iron	- .005 % maximum
Copper	- .100 % maximum
Nickel	- .010 % maximum
Cobalt	- .005 % maximum
Zinc	- .006 % maximum
Bismuth	- .050 % maximum
Cadmium	- .005 % maximum
Manganese	- .005 % maximum

There may be the temptation to use only one alloy for all casting operations: for example, a 6% antimonial lead. However, it is important to know that antimony is many times more costly than lead. Therefore it is more economical to use this lead alloy for small lead parts.

A few manufacturers extend the economy program by specifying an alloy for small lead parts of 2% antimony instead of the 3% listed above. This lower antimony content in the alloy may require a greater casting skill to produce acceptable castings.

EQUIPMENT

GRID CASTING MACHINES AND GRID MOLDS

Grid casting machines including the lead pots are usually gas fired, although some are available as oil fired or electrically heated. Most grid casting machines are similar and cast a single double grid in a vertical position from a vertically mounted mold, one-half of which is stationary. The other half is moveable on leader pins. The machines deliver trimmed grids for use or stock.

One grid casting machine has a separate lead pot of 3000 pound (1364 kilogram) capacity. It is possible to supply two casting machines with lead from one lead pot, if properly located on the floor. A rotary lead pump supplies molten lead to a dispenser valve which dispenses the proper amount of lead to the ladle (no overflow back to the lead pot). The usual book mold is used and operated on the leader pins by an air cylinder. This operation provides positive opening and closing action, thereby reducing "flash" on the grids. All trim scrap is conveyed back to the furnace. This type of casting machine attains a maximum stroke speed of 16 casts per minute with 12 to 16 strokes per minute as the usual daily production casting speed. Casting speed is a result of many factors, such as grid alloy, grid thickness, grid mold design, including air venting, mold coat, mold coat application, and proper temperature control of the pouring lead as well as the mold. Mold temperature is controlled by water flow in cooling channels. However, on most automotive battery grids, cooling is required in the top gate area and in the center of the mold only. In the lower portion of the mold automatically controlled electric

heaters are used to preheat the mold and also to introduce heat into the lower portion of the mold during the casting operation. This is necessary because the amount of lead in the thinner grids does not bring sufficient heat to maintain the proper mold temperature to produce quality grid castings. With all casting equipment in good working condition and experienced operators, it is possible for one operator to produce satisfactory grids from three machines.

Another kind of grid casting machine is a single unit design with the lead pot as an integral part of the machine. A minimum amount of floor space is required because the entire unit is more compact. A metering pump regulates the amount of lead to the pour head with no excess lead return to the pot. This machine produces about a tenth of the dross of the machine mentioned above. This means some metal savings. Also dross carries with it a fair amount of antimony and tin of the grid lead alloy. This machine attains, in production, about 18 strokes per minute, with about 20 strokes as a maximum. Automatic temperature controls are on the lead pot, the pouring head and the mold. One mold operator can easily handle two or three such machines.

A rotary casting machine system has been popular. This machine is made up of four units. The first unit is a separate lead pot, such as mentioned above for the first type of grid casting machine, which furnishes molten lead to the second unit. This unit is a circular power driven horizontal table top, about 5 feet (1.5 meters) in diameter. Eight grid molds of the conventional design are mounted, equally spaced along the table top's circular edge. Adjacent to the table is the third unit which contains a belt conveyor, a grid trimming die and another belt conveyor. The fourth unit is another circular power-driven horizontal steel plate, about 7 feet (2.2 meters) in diameter, on which are mounted eight trays for stacking the trimmed grids. The grid molds are air cooled which makes them different from the two machines previously mentioned. The grid mold table rotates at a constant speed and all production mold operations occur in motion. The center unit carries the grid casting from the mold through the trimming die and finally drops it off the conveyor to a collecting tray which holds the grids only from a certain mold. Usually it is best that the grids during any given set-up of operation be approximately of the same thickness. The usual production from this machine is fairly high. Whenever it is necessary to stop the machine to make a major or minor correction on any one mold, such as mold spray application the production of the other molds stops also.

Some battery manufacturers prefer to produce their own in-plant machines, to include grid casting machines. Most such casting machines have essentially the same basic design as the units mentioned, that is, a vertically mounted mold (casting one double grid) one half in a fixed position and the other half movable on a pair of leader pins. Naturally, modifications to such machines may be many, such as:

- Hot lead supply or lead pots.
- Adjustable automatic temperature controls on lead supply,

CASTING DEPARTMENT

GRID TYPE	WIDTH	HEIGHT	THICK- NESS	NUMBER OF HORIZONTAL WIRES	VERTICAL WIRES	APPROX. WEIGHT
Regular	5-5/8 in. 14.29 cm.	4-7/8 in. 12.39 cm.	.070 in. 1.78 mm.	24	8	.157 lb. 71 gm.
Regular	5-5/8 in. 14.29 cm.	4-7/8 in. 12.39 cm.	.080 in. 2.03 mm.	24	8	.174 lb. 79 gm.
Low	5-5/8 in. 14.29 cm.	4-7/16 in. 11.28 cm.	.070 in. 1.87 mm.	21	8	.150 lb. 68 gm.
Low	5-5/8 in. 14.29 cm.	4-7/16 in. 11.28 cm.	.080 in. 2.03 mm.	21	8	.165 lb. 75 gm.
High	5-5/8 in. 14.29 cm.	5-1/4 in. 13.32 cm.	.070 in. 1.78 mm.	27	8	.167 lb. 76 gm.
High	5-5/8 in. 14.29 cm.	5-1/4 in. 13.32 cm.	.080 in. 2.03 mm.	27	8	.190 lb. 86 gm.
Narrow	4-1/4 in. 10.8 cm.	5-1/4 in. 13.32 cm.	.070 in. 1.78 mm.	27	6	.132 lb. 60 gm.
Narrow	4-1/4 in. 10.8 cm.	5-1/4 in. 13.32 cm.	.080 in. 2.03 mm.	27	6	.145 lb. 66 gm.
Utility	4-4/5 in. 12.2 cm.	4-1/2 in. 11.42 cm.	.070 in. 1.78 mm.	21	7	.123 lb. 56 gm.
Utility	4-4/5 in. 12.2 cm.	4-1/2 in. 11.42 cm.	.080 in. 2.03 mm.	21	7	.134 lb. 61 gm.
Bus- Truck	5-5/8 in. 14.29 cm.	4-7/8 in. 12.39 cm.	.125 in. 3.2 mm.	30	7	.300 lb. 136 gm.
Bus- Truck	5-5/8 in. 14.29 cm.	4-7/8 in. 12.29 cm.	.156 in. 4.0 mm.	30	7	.400 lb. 181 gm.
Regular Thin	5-5/8 in. 14.29 cm.	4-7/8 in. 12.39 cm.	.060 in. 1.53 mm.	24	8	.140 lb. 63 gm.
Low Thin	5-5/8 in. 14.29 cm.	4-7/16 in. 11.28 cm.	.060 in. 1.53 mm.	21	8	.135 lb. 61 gm.
High Thin	5-5/8 in. 14.29 cm.	5-1/4 in. 13.32 cm.	.060 in. 1.53 mm.	27	8	.145 lb. 66 gm.
Narrow Thin	4-1/4 in. 10.8 cm.	5-1/4 in. 13.32 cm.	.060 in. 1.53 mm.	27	6	.120 lb. 54 gm.
Regular Extra Thin	5-5/8 in. 14.29 cm.	4-7/8 in. 12.39 cm.	.050 in. 1.27 mm.	24	8	.124 lb. 56 gm.
Low Extra Thin	5-5/8 in. 14.29 cm.	4-7/16 in. 11.28 cm.	.050 in. 1.27 mm.	21	8	.114 lb. 52 gm.
High Extra Thin	5-5/8 in. 14.29 cm.	5-1/4 in. 12.32 cm.	.050 in. 1.27 mm.	27	8	.130 lb. 59 gm.
Narrow Extra Thin	4-1/4 in. 10.8 cm.	5-1/4 in. 13.32 cm.	.050 in. 1.27 mm.	27	6	.107 lb. 49 gm.

Feet height for all grids - 3/32 inches (2.4 millimeters)

Lug width - 1/2 inch (1.27 centimeter)

The above grid thicknesses are applicable for plate pasting machines that normally paste plates to grid thickness. Pasting machines having fixed orifices (beltless types or equivalent) usually require grids about

.006 inch (.15 millimeter) thinner, allowing that amount as "over-pasting." The resulting decreased grid weights for such new thicknesses can be approximated from the above suggested weights, making allowance for the reduced grid thickness.

CASTING DEPARTMENT

lead ladle and the various grid mold areas.

- More dependable opening and closing mold mechanism.

Items listed above result in more uniform machine operations and the finished grids have improved characteristics. Also, with greater automatic control of grid casting, the casting labor does not require as much continuing skill. An operator should be able to operate a number of such machines, at a maximum casting speed, thereby reducing the labor cost to produce grids.

Mention has been made of various casting machine speeds as strokes per minute. It is important to realize that any such speed is not continuously possible for an entire working period, such as an eight-hour shift. Present work regulations in the USA usually include two "rest or break periods" per shift and also a wash or clean-up period at the end of the shift. Thus, actual production time may be 30-45 minutes less than then total shift time (normally about 8 hours). Also in grid casting operations, mold spray application involves time when no grids are produced. For this reason, the casting machine speed or output for the entire work shift may be lowered still more. For lead-antimony alloy grid casting, the optimum casting output would be about 90% of the actual production time spent on each shift. To achieve such a degree of production efficiency, a number of conditions must be favorable:

- The grid mold must have such characteristics that there would be few, if any, casting problems.
- The grid alloy must be such that mold filling and hot alloy flowing properties would be favorable.
- The mold spray formula must have a long life of many hours (one shift if possible) of durability on the mold.
- The casting machine operator must be experienced and know exactly the best casting techniques.

Grid designs are almost always vertical and horizontal wire construction type, forming horizontal rectangular shaped area for the paste. The length of this area, called pellet space, is about twice the width dimension.

There is now some experimentation in grid designs, with diagonal wires instead of vertical wires or diagonal wires to supplement some vertical wires. The diagonal wires generally originate just below the grid lug corner and extend downward spreading over the grid area, terminating at the opposite side frame and bottom frame. Grids of this design tend to add to some of the grid casting problems. Such designs are said to contribute or aid in conducting the electrical current of the plate to the plate lug. During the early years of automobile battery production, various diagonal grid wires were in use, and each design claimed to having vastly improved properties over the usual rectangular grid mesh.

Generally, the freshly produced double grids are placed on steel skids, carefully stacked, about 3-4 feet (1-1½ meters) high and in such a manner that the entire skid load is held together in a rigid manner. It is then moved to a grid storage location with a fork lift truck, awaiting transfer to the pasting department.

There are some manufacturers who accomplish this same material transfer by means of conveyors, usually of the overhead type. Another system in use to accomplish the same type of transfer, is by electro-mechanical equipment. It picks up the grids from the end of the casting machine, places them on power mobile storage racks and then when needed, positions the grids for pasting operations. The last two mechanized transfer-storage systems eliminate the need of a fork lift truck and driver.

SMALL PARTS CASTING EQUIPMENT

Types, sizes and number of cavities of both post straps and connectors must be determined by the battery manufacturer. He must survey the battery market in terms of battery sizes and specifications for the proper answer. Equipment is available from battery machinery manufacturers ranging from single cavity hand operated molds to small parts molding machines requiring one operator that will produce up to 14 different sizes and types of post straps and connectors at one time. Experience has shown that some 30-35 different cavities will be required for a battery manufacturer at the start. It is well for the battery manufacturer to make a detailed study of the local conditions, balancing mold tooling costs against labor costs. In fact, such comparisons are important throughout the battery manufacturing process.

A small parts lead pot of approximately 1000-1200 pounds (600 kilograms) capacity is required for parts casting operations.

UTILITIES REQUIRED

Depending on local conditions, the following are typical requirements for the casting department:

Electric	220 volt, 3-phase, 50-60 Hertz (cycles per second), 5 horsepower - 3.75 kilowatt maximum.
Gas	800 cubic feet per hour, assuming 530 BTU manufactured gas at normal pressure (23 cubic meters per hour, assuming 135 kilogram calories manufactured gas at normal pressure).
Water	City water 30-40 pounds per square inch (2.2-2.8 kilogram per square centimeter) pressure for mold cooling.
Air	From compressor 80 - 100 pounds per square inch (6 - 7 kilograms per square centimeter). 12 cubic feet (.04 cubic meters) per minute capacity.

The preceeding table includes the popular sizes that a battery manufacturer may need in a temperate climate. The last eight sizes represent thickness trends in the U.S.A. at the present time. Thinner grids present greater difficulties in casting operations. As the thickness decreases, greater skill and effort on the part of the operator is required to produce good grids on a production basis. Maintaining the correct mold temperature becomes more important and may justify mold temperature control equipment. The need for mold heating instead of mold

CASTING DEPARTMENT

cooling is not out of place when casting the thinner grid. It is not unusual with such thin grid thickness, to experience more handling problems as well as increased lead scrap.

The first twelve grid sizes listed should take care of most, if not all, of the grid size requirements of a tropical climate battery plant.

Mold spray is usually supplied by the manufacturer of the grid casting machinery. Such spray material generally includes finely powdered cork, sodium silicate (water glass) and water as the main ingredients. Outside the continental United States it is the usual custom for each battery manufacturer to make his own spray from materials obtained locally.

There are many formulas for battery mold sprays, and if a battery manufacturer wishes to make his own spray a number of mold spray formulas are presented in the following.

MOLD SPRAY FORMULAS

The purpose of the mold spray is essentially that of heat insulation, so that the hot liquid lead alloy will remain molten long enough to fill the mold. Cork powder and other materials give the insulating properties and must be of the best quality with a high degree of porosity. If the cork powder is not of the proper particle size it will not insulate adequately. The sodium silicate (or the glue, if included) makes the cork stick to the mold surface and also helps to withstand the charring action of the molten lead alloy.

The first essential in making good mold spray is highest quality cork powder. The cork powder must not be too coarse

nor too fine. The best criterion is just enough to get rid of grittiness when some mold spray is rubbed between the thumb and first finger. Actually, any coarse particles will tend to stick in the spray gun and the introduction of some fine particles is not a serious problem.

It is difficult to set down an exact formula because cork is a natural product that varies considerably with the location in the tree (the best cork being near the center and the poor cork containing some bark), rate of growth, age of tree, etc. The cork may be drier in some parts of a shipment or in different shipments, and so the amount of water needed will vary. Also the cork may vary in porosity, thus requiring different amounts of silicate.

In recent years, cork powder has been available that is satisfactory for mold spray use. The improvement is greater uniformity of fine particle size control. The particle size distribution chart shown below (Figure 2) gives data of two different samples found suitable as mold spray materials. Cork powder that contains essentially coarse particles 100 or larger microns (.003937 inch) diameter, produces mold sprays that are rarely suitable without additional processing. Two methods have been used to make cork powder more satisfactory. One method is pebble mill that grinds a liquid slurry of cork powder for as long as 48 hours. The other method is to pass the powder through 200 or finer mesh (74 microns or less) screen, using only the material that passed through the screen. In the formulas shown below, any reference to pebble mill grinding or cork screening may be eliminated by using an acceptable cork powder (satisfactory particle size).

