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Aspects of quality control in foreign manufacturing operations

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ASPECTS OF QUALITY CONTROL
IN FOREIGN MANUFACTURING OPERATIONS

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INTRODUCTION

The present thesis is being written to illustrate some aspects of quality control in foreign manufacturing operations; that is, foreign to the United States. It is obvious that the conditions and probable variations from U. S. practice in any manufacturing industry will vary tremendously according to the industry under review. In the present case we shall be dealing with manufacturing operations involving the production of so-called "dry cells" and "dry batteries", and to a somewhat lesser degree with the production of projector arc carbons for use in motion picture theater projection. It will be, therefore, helpful if a brief history of these industries be included, with a consequent discussion of present manufacturing methods in the United States, before specific discussion is made of the problems attendant with the manufacture of dry cells and projector carbons in Southeast Asia.

The dry cell is, of course, only one of many different types of primary cells. Due to its utility as a portable and easily handled source of electricity, however, it is by far the most familiar type of primary cell to the public, and represents by far the greatest fraction of all primary cell production in terms of units produced. The so-called dry cell with which we are familiar today is, however, a relative latecomer in the field of primary cells since the first description was made by Georges Leclanche[1] in 1868, which was some

(1) Leclanche, G. Pile au Peroxyde de Manganese a Seul Liquide. Lés Mondes. Vol. 16, p. 532 (1868).

sixty-eight years after Alessandro Volta made known his development of the voltaic pile to the Royal Society in London[2]. It should be pointed out, however, that

(2) Volta, A. On the Electricity Excited by the Mere Contact of Conducting Substances of Different Kinds. Phil. Trans. Roy. Soc. Vol. 90, p. 403 (1800). (In French).

Leclanche's development, and indeed the practical application of his development, pre-dated his publication by several years. Between the time of Volta's primary experiments and the first usage of manganese dioxide as a depolarizer in Leclanche's cell, there were a great many experimental and semi-commercial varieties of primary electrochemical cells described and used with varying success. Briefly in passing we may mention the developments by William Cruikshank[3], William Wollaston[4],

(3) Cruikshank, W. Account of Some Important Experiments in Galvanic Electricity. Tilloch's Philosophical Magazine. Vol. 7, p. 337 (1800).

(4) Wollaston, W. Description of an Elementary Galvanic Battery. Gilbert's Ann. Physik. Vol. 54, p. 1 (1816).

Guissepe Zamboni[5], Robert Hare[6], Antoine Becquerel[7],

(5) Zamboni, G. Dissertazione Sulla Pila Elettrica a Secco. Giorn. Fis. Chim. Stor. Nat. Vol. 5, p. 424 (1812); Vol. 7, p. 220 (1814); Vol. 9, p. 289 (1816);

Gilbertis Ann. Physik. Vol. 51, p. 182 (1815); Vol. 60, p. 151 (1819); Edinburgh Phil. J. Vol. 1, p. 388 (1819).

(6) Hare, R. Notice of a Galvanic Deflagrator. Silliman's Journal. Vol. 4, p. 201 (1822); Vol. 5, pp. 94, 97, 105 (1822); Vol. 7, p. 347 (1824).

(7) Bacquerel, A. Memoire sur l'Electrochemie et l'Emploi d'Electricite pour Operer des combinations, Ann. Chim. Vol. 41, p. 22 (1829).

J.F. Daniell[8], William R. Grove[9][9a][9b], R.W. Bunsen.[10][10a]

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(8) Daniell, J. F. On Voltaic Combinations. Philosophical Magazine. III, Vol. 8, p. 421 (1836).

(9) Grove, W. R. On a New Voltaic Combination. Philosophical Magazine. III. Vol. 14, p. 388 (1839).

(9a) Grove, W. R. On a Small Voltaic Battery of Great Energy. Philosophical Magazine. III. Vol. 15, p. 287

(9b) Grove, W. R. On the Voltaic Series and the Combination of Gases by Platinum. Philosophical Magazine. III. Vol. 14, p. 127 (1839).

(10) Bunsen, R. W. Uber die Anwendung der Kohle zu Volta'shen Batterien, Pogg. Ann. Physik. Vol. 54, p. 417 (1841).

(10a) Bunsen, R. W. Uber die Bereitung einer das Platin in der Grove'shen Kette ersetzenden Kohle. Pogg. Ann. Physik. Vol. 55, p. 265 (1842).

Benjamin Silliman, Jr.[11], Alfred Smee[12], and Johann

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(11) Silliman, B., Jr. On the Use of Carbon in Grove's Battery. Am. J. Sci. Vol. 43, p. 393 (1842); Vol. 44, p. 180 (1842)

(12) Smee, A. On the Galvanic Properties of the Metallic Elementary Bodies, with a Description of a New Chemico-Mechanical Battery. Philosophical Magazine. Vol. 16, p. 315 (1840).

Poggendorff[13]. For an excellent historical survey,

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(13) Poggendorff, J. Uber die mit Chromsaure

Construirten Galvanischen Ketten. Pogg. Ann. Physik. Vol. 57, p. 101 (1842).

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the reader is referred to Vinal[14]. This same author

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(14) Vinal, G. W. Primary Batteries. New York, John Wiley and Sons, 1950, p. 336.

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some very helpful bibliographical data in the above cited reference. Also see the article on this subject in the Encyclopaedia Brittanica[15], and the article in Perry[16].

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(15) "Battery". (Article) Encyclopaedia Brittanica, 1946 Ed., Chicago, En. Brit., 1946. pp. 214-218. Vol. 3.

(16) Perry, J. H., (Ed. in Chief). Chemical Engineer's Handbook, N.W., McGraw-Hill, 1941. pp. 2754-2763.

As noted above, Georges Leclanche was apparently the first worker in the field who recognized and utilized the depolarizing characteristics of manganese dioxide as applied to primary electro-chemical cells. His application of this fundamental idea was, however, far removed from the modern dry cell, as Leclanche's original cells were no more dry than other wet primary batteries of the period, the manganese dioxide being utilized as one of the components of the depolarizing mix which was contained in a porous cup which was, in turn, surrounded by a glass jar full of the electrolyte solution. It is interesting to note that Leclanche unwittingly resorted to a form of air-depolarization which effect has, in recent years, been utilized in a far more efficient way in the well known Eveready Air Cell Battery.

Various modifications of Leclanche's basic design were made and used in succeeding years. Naturally enough, most of the modifications were aimed at simplification of manufacture and the obtaining of higher efficiency. It was not, however, for some twenty-five years that any great attention was focused on the problem of immobilizing the electrolyte so that the cell could become more portable and less likely to leak or spill, causing damage to surrounding objects. These developments have been covered in a paper by Krehbiel[17].

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(17) Krehbiel. Vergleichende Untersunchung von Trochen-elementen. Elecktrotech Zeitung. Vol. II, p. 422 (1890).

Interestingly enough, the first successful "dry" cell did not utilize manganese dioxide as a depolarizer. Shortly thereafter, however, the combination of a manganese dioxide depolarizer with an immobilized electrolyte took place, and in its crude basic form the modern dry cell was thus born. It may be well to remark parenthetically here, that the so-called "dry cell" is not really dry at all, but could be more accurately described as a cell having no liquid components. In actual practice the moisture content of the active components of "dry" cells may be as high as twenty-five percent.

The industrial picture in regards to primary batteries has seen some rather abrupt changes. At first, of course, the primary battery was the only source of dynamic electricity. With the advent of the electro-magnetic generator, electro-chemical sources of dynamic electricity lost a great deal of their primacy. However, at the same time, industrial developments again and again created the need for various types of small current sources which could be most efficiently filled by in situs installations of primary batteries. A notable illustration of this trend is found when one considers the large number of primary cells used in our present day by the railroads and in various other signalling applications. Too, with the advent of the filament electric light and consequent development of its tiny relation, the flashlight bulb, a huge new field was opened to primary batteries, specifically the small dry cells. The dry cell received a large, but very temporary boost in the early 1900's due to use in the automobile industry as a power source for ignition and lighting[18]. The flashlight field has grown

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(18) Encyclopaedia Brittanica, op. cit.

steadily in terms of usage of dry cells per year, and has been in that respect a steadying influence on dry cell production. The largest single jump in dry cell production, however, occurred in the first thirty years of the present century with the advent of wireless telephony and the consequent huge demand for various types of high voltage batteries to be used in home wireless sets. The tremendous spurt in production caused by radio battery demands was relatively short-lived due to the subsequent development of radio sets operating off regular line current and at the same time by the large scale electrification of rural districts. At the present time the radio battery business depends largely on the more undeveloped areas of the world and on the increasing demand for batteries suitable for use in portable radios. As we shall see, these factors play a large part in the prosperity of the foreign battery manufacturing operations with which the writer has been concerned.

From time to time there have been brief outbursts of enthusiasm for the so-called hand generator type of flashlight. This flashlight consists simply of a small dynamo actuated by a hand grip lever which serves to provide current for the light source. None of these developments has ever been any threat to dry battery manufacture due to the relative inconvenience and fragility of the articles involved.

Exact figures are not available for the current world-wide production of dry cells, but it is safe to say that the annual production is measured in terms of billions of cells. It is only fair to point out that the dry cell as such is by far the least economical source of electric current, but the factors which are generally termed space utility and convenience utility have been so predominant that the dry cell has suffered little for its apparent economical weakness.

Once again, it is difficult to state in exact figures the increase which has been brought about in the past fifty years in the service life of dry cells, but it may be stated generally that the modern dry cell yields roughly five to ten times as much service as its predecessor of the same size thirty to forty years ago. This amazing increase in service has been brought about by intensive and continued research on the make-up of Leclanche cells. One of the leaders in this work has been National Carbon Company, and the accomplishments made by the National Carbon research group can be held directly responsible for a large part of the improvement in the art of manufacture of dry cells.

A calculation was recently made by the writer as part of the basis for a quiz given to the monthly paid employees in the Singapore factory which showed that the ordinary "D" size cell, which is the most familiar flashlight size, would lift a 150 pound man some forty-six feet if its energy level were reduced to the same point at which it is generally considered a flashlight cell no longer gives usable illumination in a standard torch. The modern flashlight cell is indeed a far cry from the original pile of Volta.

A thorough theoretical discussion of the chemical reactions in the dry cell is far beyond the scope of the present paper. Although the complete picture of dry cell reactions is not yet available, a great deal of progress has been made in the past few years on the theoretical background to this problem. A fairly good introduction to dry cell reactions may be found in Vinal[19], although his picture of the formation of the component hetaerolite

(19) Vinal, op cit., pp. 25-40.

is notable mainly for the omission of the most important factor involved, i.e., the crystal structure of the manganese dioxide used. Basically, of course, the over-all reaction which takes place in a dry cell on discharge is an oxidation-reduction reaction, as are all electrochemical reactions. There are various metals used as anodic material in dry cells, but regardless of the metal used it is oxidized, giving up electrons to the circuit and resulting in metallic ions going into solution. An equal reduction reaction must, therefore, take place at the cathode to balance this oxidation of the anodic materil. In the familiar Leclanche cell this reduction results in lowering the valency of the manganese from a quadri-valent condition to a state of tervalency. Depending on the conditions in the dry cell during reaction, the severity of current drain, the original concentrations of active materials, and the crystal structure of the manganese dioxide, the manganese may eventually show up as one of several components. In any case, there are at least two distinct cathodic reactions which take place as a result of current being drawn from the cell. We suggest that the following reactions be considered:

Cathodic Reactions:

1) Electro-chemical reaction occurring only during periods of drain on cell:

1) $MnO_2 + ZnCl_2 + 4\ NH_4Cl + Zn^{++} + 2e \longrightarrow$

$$MnCl_2 + 2(Zn\ Cl_2 \cdot 2\ NH_3) + 2\ H_2O$$

2) Recuperation reactions which can go on continuously providing necessary substances are present:

2a) $MnO_2 + Mn\ Cl_2 + Zn\ Cl_2 \cdot 2\ NH_3 + 2\ H_2O \longrightarrow$

$$Mn_2O_3 \cdot H_2O + Zn\ Cl_2 + 2\ NH_4cl$$

or,

2b) $MnO_2 + MnCl_2 + 2\ ZnCl_2 \cdot 2NH_3 + 2\ H_2O \longrightarrow$

$$ZnO \cdot Mn_2O_3 + 4\ NH_4\ Cl + ZnCl_2$$

Combining,

3a) $2MnO_2 + 2NH_4Cl + Zn^{++} + 2e \longrightarrow$

$$Mn_2O_3 \cdot H_2O + ZnCl_2 \cdot 2NH_3$$

3b) $2\ MnO_2 + Zn^{++} + 2e \longrightarrow$

$ZnO \cdot Mn_2O_3$

From the above reactions it is immediately obvious that a great deal of importance must be attached to the second or recuperation reaction, Nos. 2a) and 2b) above, since a comparison of the two final reactions, Nos. 3a) and 3b), will show that in the one case each molecule of manganese dioxide reduced results in immobilization of a similar amount of ammonium ion, whereas in the other possibility, No. 2b) above, all of the original ammonium chloride is released by the recuperation reaction. If this condition does not obtain, a shortage of ammonium ions will ensue and may lead to the following reaction:

$$2\ MnO_2 + 3\ ZnCl_2 + 2\ Zn^{++} \longrightarrow ZnCl_2 \cdot 4ZnO + 2MnCl_2$$

A preponderance of reaction No. 2a) will, of course, result in depletion of the zinc chloride of the cell and a lowered service potential. If it is possible to obtain a cell constituency such that the ultimate service of the cell does not depend on the amounts of electrolyte salts originally put into the cell, it is thus possible to increase the service of the given cell by making use of the maximum amount of active material, that is, the depolarizer. As Vinal[20] points out, the type of recuperation reaction will depend partly on the type of

(20) Vinal, op. cit., pp. 38-39.

service drain which has been put on the cell, but it is also dependent on the type of crystal structure in which the manganese dioxide present is found.

Although terms for manganese dioxide ore have become considerably differentiated during the past few years, one generally hears of "pyrolusite" as the chief commercial ore of manganese dioxide. Using the more specific modern terminology in connection with manganese dioxide crystal forms, the term pyrolusite has become the appellation of a particularly hard and sharply crystaline allotrope of manganese dioxide, which is, at the same time, the poorest possible form of this material for dry battery use.

From the above brief discussion it may be seen that the manganese dioxide component of the dry cell is the least easily characterized as to quality for dry cell use, and at the same time the most important component of the cell use, and at the same time the most important component of the cell from a service standpoint. An immense amount of work has been done on the identification of the crystal modifications of both natural manganese dioxide ores and the synthetic versions of manganese dioxide prepared by various chemical or electrolytic means. One of the chief approaches to this problem has been through X-ray diffraction studies. Such tests have been the most definative in establishing a correspondence between quality of manganese dioxide for use in dry cells and the physical attributes of the various crystal types.

At the same time we should not like to give the impression that research has been non-existant or static in regard to the other components of dry cells, because this would be entirely incorrect. All of the many different dry cell components have been the subject of intensive study by National Carbon Company, the National Bureau of Standards, and other battery manufacturers.

The difficulty of writing one, or even a series of definative equations which would describe the complete series of reactions in an operating dry cell has been such that with all the advances made during the past few years, the manufacture of dry cells remains, in some particulars, an art, rather than an exact science. We should like to emphasize the point of uncertainty which exists in connection with previously untested sources of standard battery materials since this factor will be seen to play a large part in quality control in dry battery manufacturing operations, especially so when such operations are being carried on in a relatively primitive industrial complex.

The above theoretical discussion will apply generally to all types of dry cells, but since the present paper will deal mainly with the type of round cell commonly called a "flashlight battery", we will limit our discussion of the physical make-up of dry cells to this familiar form without taking into account the numbers of flat cell batteries now being produced for higher voltages. Even when the field to be considered is limited to round cells per se, a fairly large number of cell types are included[21].

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(21) Letter Circular No. LC965. Electrical Characteristics of Dry Cells and Batteries (Leclanche type). U.S. Dept. Commerce, Nat. Bur. of Stand., 1949. Washington D.C., p. 3.

We may divide the conventional cell into five basic functional parts. The first of these is the cylindrical zinc can which forms the container for the cell and acts at the same time as the anode material for the cell reaction.

The zinc which makes up this can must be carefully controlled as to composition and grain size. Such impurities as iron, copper, or arsenic are literally poisons in a dry cell and if these materials are allowed to be present in the cell either through incorporation in the zinc or in other materials, they are likely to form electro-galvanic couples with the zinc, so-called "local action", which leads to wasteful discharge and perforation of the zinc can with consequent leakage trouble. (In passing, it may be well to note that all advertising claims to the contrary, metal jacketed cells are not necessarily truly leak-proof, even though such cells do show much greater resistance to damaging leakage. This extra resistance is, of course, not due to less likelihood of perforation in the zinc can, but is thanks to the paper, asphalt, and steel corset that is tied around the zinc can. A better solution would be a thin impervious plastic jacket, eliminating the weight and expense of the steel jacket, and at the same time allowing the use of a full size unit cell which is ruled out by present steel jacketed brands, since these brands must use a smaller basic cell in order to conform to over-all size requirements set up by the National Standards Association.) The grain size is important since the free energy of the zinc atom varies according to the size of crystal in which it is found. Thus, the possibility exists in a cell in which the zinc can is not homogeneous in grain size that a bi-metallic couple effect can actually be set up between adjacent areas of the zinc can even though the only metal present is zinc. This problem of grain size becomes much more important if zinc cans of the drawn or extruded varieties are used, since these operations are prone to change the grain structure of the zinc crystal, especially in drawing.

Besides the drawn can and the extruded can, the industry makes use of a soldered construction. In this construction flat zinc strip is formed into cylinders and lap-seam soldered. The zinc bottom is then inserted and a butt-soldered joint is formed to secure it in place. The use of such solder joints is permissible due to the fact that the hydrogen over-voltage on tin and lead is high enough that no couple formation results with the zinc can even though the solder components fall well below zinc in the electromotive series. Usually a small percentage of cadmium is added to the zinc to be used in dry cell can manufacture to act as a deterent to can perforation.

Next in order of spacial configuration in the dry cell comes the separator. This separator generally consists of an organic jell of starch, with or without wheat flour, and the electrolyte materials. A great many electrolyte materials have been tried in varying proportions and although certain special compositions are sometimes used for low temperature applications, or for other unusual reasons, the conventional composition includes zinc chloride, ammonium chloride, and mecuric chloride. This last named substance is present in very small quantities to amalgamate the zinc anode and to thereby diminish local cell action and wasteful corrosion of the zinc. The separator, of course, serves a duplicate purpose in that it serves at once as the vehicle for electrolyte storage and transfer, and at the same time isolates the zinc can anode from the central mass of depolarizing mix. With such a separation very little ionic transfer takes place when the cell is not delivering current. Were the zinc anode to be in direct, rather than electrolytic, contact with the depolarizing mass, it would, of course, discharge steadily and immediately, to the quick ruination of the cell. The function of separator in the bottom of the cell between the can bottom and the depolarizing mass can be filled by several types of paper or composition washers. The most usual type found in conventional dry cells is a circular, wax-impregnated paper washer having short tabs extending from the body of the washer which lie along the can walls when the cell is assembled, and thus serve to center the depolarizing mass in the middle of the can and avoid short circuit.

Generally speaking, the gelatinous separator may be either of the so-called "cold set" variety or a cooked paste. There are various factors which influence the choice of the paste to be used which will not be gone into at this time, except to mention that the all-starch pastes are generally of the cold set variety, while the pastes containing flour must be cooked to set them. The addition of gluten in the form of wheat flour, incidentally, serves an additional purpose in that it reduces zinc corrosion by the protective action which it tends to exert on this material.

A revolutionary type of separator should be mentioned briefly here in the interest of completeness of background. This separator is methylcellulose which is usually utilized in the form of a coating on paper sheeting. The methylcellulose layer acts electrolytically in an analogous manner to the paste layer but occupies very little space in so doing and thus gives rise to the possibility of larger amounts of active material being included in the depolarizing mass. In such cases, of course, the electrolyte salts must be included in the depolarizing mass and at the same time the mixes used must be considerably higher in moisture content to make up for the loss of moisture due to the absence of paste.

For many years some dry cells, notably the large six inch cells, have used a paper separator with paste coating on one side rather than a jell solution, but such cells are essentially using a paste separator even though it is of such thinness that provision must be made to supply the necessary chemicals and water in the depolarizing mix itself.

The third main component of the conventional round dry cell is the depolarizer which forms the cathode of the cell. Due to the physical appearance of the depolarizing mass when it is formed into a compact cylinder with the carbon electrode protruding from the center of one end, this depolarizing mass is universally known as a bobbin. Strictly speaking, the manganese dioxide itself is the cathode of the cell since reduction takes place at the manganese dioxide atom. If manganese dioxide were itself a good conductor and if its reduction products were also good conductors, there would be no need for the carbon component which is universally used as a conducting substance in the dry cell bobbin. An interesting substance which has both a depolarizing effect and good conductivity is graphitic oxide. This material has been used experimentally in dry cells but the difficulty of producing a consistent and "standard" form of this substance has prevented any serious application to dry cell manufacture. The carbon itself has no part in the chemical reactions involved and in essence is only an extremely fine form of a current collecting network. Since the carbon plays no part in the reaction, it will be seen that the only criterion as to quality of the carbon to be included in the mix is that of electrical conductivity. If an extremely fine carbon with good properties of conductivity can be found it will obviously be possible to use considerably less of such a product to obtain a given short circuit amperage than the amount necessary of a carbon coarser in dispersion or of one having poorer electrical properties. Many types of carbon have been tried and are being used at the present time in dry cell bobbins: generally speaking, acetylene black is far superior to other types of carbon in this function, allowing much smaller ratios of carbon to ore in the mix. From photomicrographs of acetylene black, it can be seen that the extremely small particles in which this substance occurs tend to form chains which no doubt accounts, in part at least, for the excellent electrical conductivity of such black.

The writer has not seen any published material on the possible catalytic influence of such a fine grained carbon on the depolarizing actions with which it is so intimately associated in the dry cell; however, it seems that this problem would be one which might warrant further study. The adsorption qualities of this highly divided substance, acetylene black, should be such that a positive catalytic effect would result from its availability as a reaction locus.

Also included in the bobbin of a dry cell are various amounts of the previously mentioned electrolyte salts, zinc chloride and ammonium chloride, as well as a considerable quantity of water. The limitation on water content is largely mechanical since in the cells of conventional paste separator type with which we are primarily concerned, the bobbin must be strong enough mechanically to be formed in a mold, pierced with a carbon rod which is left in position and finally handled both in the bobbin stamping operation, and later during the assembly of the cell. Another factor which limits the amount of moisture which can be put into a conventional bobbin is the danger that with excessive moisture, the bobbin's friability will be increased to the point where pieces of the bobbin will sluff off in the paste wall--with subsequent short circuits--before the paste wall becomes set and solid.

The carbon rod which has been mentioned above as being embedded in the bobbin is merely a continuation of the current collecting system formed by the carbon component in the depolarizer mass proper, but is usually referred to (incorrectly) as the cathode. In all modern dry cells this carbon rod is capped on the extended end with a brass cap which forms the positive terminal of the completed cell.

The manufacture of the carbon rod is one which presents many complexities. Once again we must point out that such detail is beyond the scope of this paper but will note one of the fundamental difficulties faced by the producer of these carbon electrodes. This is the fact that the electrode must be porous enough to vent the small amounts of hydrogen formed in side reactions in the cell while being at the same time, completely impervious to the creepage of electrolytic salts. These salts, if allowed to reach the brass or other metal electrode cap, will soon result in damaging corrosion and subsequent short circuit of the cell. Luckily, it is hydrogen that must be vented and its low molecular weight aids diffusion following Graham's Law even while the electrode in question may be made impervious to salt solutions and to water vapor.

The final portion of the dry cell to be considered are those entities which together make up the top seal of the cell. Here again, manufacturing operations differ, with some cell types being made up with a black or red colored rosin seal which is poured into place over a so-called top collar which fits fairly tightly in the annular space between the zinc can and the carbon rod in an assembled cell, while other manufacturers use various types of plastic covers which are spun or crimped into place. One of the best methods of cell closure is that involving a metal cover spun onto the zinc can and fitting tightly on top of a flanged electrode cap from which it is insulated by some non-conducting paper or plastic washer. Sometimes in such construction an inner seal of some type is used to protect the underside of the metal cover and electrode cap from electrolyte and at the same time to act as a seal against moisture exit. Usually in these types of metal sealed cells, a top collar is used to isolate the mix and paste from the metal cover. This top collar may be of some type of impregnated paper or cardboard.

We have not considered the actual covering or label of the dry cell as one of the main operating portions of the cell since it is primarily a problem in packaging. That it can become, nonetheless, very important to dry battery manufacturers will be brought out in later sections of this report.

The problem of seal effectiveness of a dry cell is an important one since diminution of cell moisture while in storage can lead to very serious losses in delayed service. It is for this reason that all manufacturers strive to prevent the exit of cell moisture as completely as possible whether or not a sealing material is used as an inner seal. It may be worthshile noting that the problem of cell moisture control is complicated in any location where production is being carried on intended for a wide variety of climatic extremes. This point also will be referred to later in the report.

The carbon arc might be said to have been discovered as soon as possible in that Sir Humphrey Davy first demonstrated this phenomenon in 1801, within a year after the first communication had been made to the Royal Society by Volta in regard to his battery(22). It was not until

(22) Volta, op. cit.

1821, however, that the flame or continuous discharge produced between charged carbons was first termed an "arc". The first patented arc lamp was invented in 1845 by Wright in England, but even at that date the lack of a supply of cheap and dependable current forestalled the arc lamp from being much more than a scientific curiosity, or at best a device of extremely limited application.

Both the individuals mentioned above did their work in England, but during this same period there were several workers in the same field in the United States who were active in arc lighting development, some of whom were to become figures of the first importance a few years later.

We may mention here briefly; William Wallace, Professor Moses G. Former, Edward Weston, Charles F. Brush, Eliju Thompson, and E. J. Houston.

The year 1876 saw two developments of the first magnitude of importance. The first of these was Jablochkoff's "candle". This was a form of carbon arc light which consisted basically of carbon electrodes mounted parallel to one another with a ceramic insulating material placed between the electrodes. In this construction, as the electrodes burned down the ceramic material directly adjacent to the arc volatalized so that a steady supply of fresh electrode was exposed to the arc as the consumption of the candle progressed. The second, and most important, development of 1876 in the arc light field was Charles F. Brush's development of the first open arc lamp. Mr. Brush was one of the most direct ancestors of the present National Carbon Company, since it was his original organization which, in later years, served as the foundation of National Carbon.

In 1879 the development of the arc cynamo by Thompson and Houston, mentioned above, filled the major remaining gap in the practical application of arc lighting effects to general illumination problems. From this time onward, increasing use was made of arc lighting in verious applications. In 1894 Marks developed the enclosed arc lamp, but it was not until 1899 that Bremer, working in Germany, developed a substantially new approach to the production of visible light by means of the carbon arc, the "flame arc".

Previous to Bremer's development of the flame arc, the production of light in the carbon arc had been primarily due to the incandescence of the tips of the carbon electrodes themselves and the positive crater; the luminescence of the arc stream was distinctly a minor factor in the over-all production of light. While cored carbons were known before Bremer's work, the coring materials were primarily present to provide evenness of illumination by maintaining a steady arc. In Bremer's flame arc, however, the coring materials were so selected that at, or somewhat below, the temperature of the electric arc they became intensely luminescent. Generally speaking, rare earths were and are the favored coring materials for flame type arc carbons. In such carbons the light producing role is almost entirely due to the arc stream made up of these light giving materials in vapor form, and little of the total light is directly obtained from the carbon rods themselves. As may be seen, this is a direct reversal of the light producing mechanism of the earlier type of arc carbon, and the direct role of the carbon in producing light is even further reduced in the flame type arc by the fact that the sublimation of the flame materials in the arc results in a cooler arc and consequently in a temperature at which the carbon rods themselves radiate very little in the visible range.

In 1900, Steinmetz, working in the United States, produced his famous magnetite arc which was a flame type arc in which the electrodes were composed entirely of metals and metallic compounds, with no carbon at all in their makeup.

Looking briefly at the further developments in arc lighting, we may mention the enclosed flame arc developed by Jones in 1908, working in England; the white flame arc lamp, invented by Macbeth in 1910 in the United States; and finally, the very important development of the high intensity search light lamp of Beck and Sperry working respectively in Germany and the United States in 1914. In succeeding sections of this report we shall see the far reaching importance of the high intensity principle in the production of visible light by means of the electric arc.

It is common knowledge, of course, that the arc lamp enjoyed a relatively brief reign of widespread use for lighting purposes between the era of gas lighting and the development in a practical form of the incandescent bulb by Thomas Edison. What is perhaps overlooked in this generally accepted view is that during the very period that arc lighting was in rapid decline as a source of general illumination, it was being applied to more and more specific problems of light production which this type of lighting could fill far, far better than any other light source. This increasing collateral use of arc lighting has gone on to the present day and with modern technical developments it is only reasonable to expect this progress to continue. In the present paper we are primarily concerned with the use of arc illumination in motion picture projection, but should mention at least the large use of arc illumination in such fields as studio lighting, photo engraving, photochemical reaction stimulation, searchlights, blue printing, medical and therapeutic fields[23], and various and sundry scientific

(23) Coblentz, W., Dorcas, M.J., and Hughes, C.W. Radiometric Measurements on the Carbon Arc and Other Light Sources Used in Phototherapy. Scientific Papers of the Bureau of Standards. No. 21539, p. 535 (1926).

applications.

Arc light has been used almost from the earliest days of cinema production as a means of projecting the image from the film onto a screen for viewing. An obvious exception to the use of arc light for projection purposes of movie film was the early kinetoscope of Edison, but as this development was more of a one person peep show than a projected cinema as we know it today, it hardly represents an important exception. Even today, of course, our 8mm. home movies and many 16mm. movies are projected by means of incandescent bulb illumination, but commercial cinema projection has continued to rely on arc illumination from its very inception. The limitations of size and operating complexity will probably always deter application of arc illumination to 8mm. movies, but an increasing number of 16mm. projectors are now being manufactured for use with arc illumination due to its much better quality as a source of light for cinema projection, particularly with color film.

The development of cinema arc carbons has roughly paralleled that of arc carbon development in general, except that the necessity of a highly concentrated light source dictated by optical considerations has resulted in a more specilized approach to the general problem and has largely precluded any use of the flame type arc. As Kalb(24) has pointed out, the development of the motion

(24) Kalb, W. C. Progress in Projection Lighting. Journal of the Society of Motion Picture Engineers. Vol. 35, No. 1, pp. 17-31 (1940).

picture industry has been largely associated in the public mind with a glamorous procession of stars, directors, producers, and extravaganzas, with little thought being given to the vast amount of technical work which has gone into the making of modern cinema as we know it today. Nevertheless, this technical development is perhaps the most important factor in the successful growth of the industry to its present size.

The first carbons used in projection lamps for motion pictures were generally burned in a position inclined from the vertical by about 20^{o}, with the positive carbon in the upper position and so positioned that the crater formed on this carbon by the arc stream from the negative would face the condenser lens system between the arc and the film gate on which the lens system was focused. A steady development in carbons and in optical systems for movie projection has gone on from that time. Generally speaking, the first need was for more light, both to increase the brightness of the screen image and to provide sufficient flux to fill the larger screens of the movie houses, which were even then increasing in size beyond that of the average legitimate theater. Greater steadiness of the arc light was obtained by making the positive carbon into a thick walled tube with a central core of soft neutral carbon; a change from the solid carbon rod previously used. The steadiness of the arc was further improved by making the negative carbon somewhat smaller than the positive carbon while maintaining its capacity for high current by copper coating the negative. This diminution in size of the negative tended to obtain better focusing of the arc stream, and hence a more even operation with less flicker.

However, the limit of available light from the low intensity carbons of the type we have been describing was soon reached since these carbons are rarely used at a current density greater than 200 amperes per square inch. Any further increase of current over this figure simply increases the rate of volatilization of the carbons without increasing the brightness of the light source. The limit of crater brilliancy in the low intensity DC arc is about 17,500 candles per square centimeter.

It was at this juncture that the development of the high intensity effect played such an important part in further progress in projection lighting[(25)]. The core of

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(25) Joy, D. B., and Downes, A.C. Characteristics of High Intensity Arcs. Journal of the Society of Motion Picture Engineers. Vol. 14, No. 3, pp. 291-301 (1930).

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the positive carbon used in high intensity arc is larger in proportion to the diameter of the carbon than in the low intensity type and is made up partially of rare earth materials which become luminescent due to the bombardment of the electrons emanating from the negative carbon. Basically the mechanism of photon production here is similar to that mentioned previously in the flame arc, but due to different chemical characteristics of the core and to the confining effect of the focused arc stream, the production of light is primarily due to a small ball of extremely hot incandescent gas trapped in the positive crater. The temperature of this gas is much higher than that at which carbon sublimes, 3670° centigrade, and thus the light production in this type of arc is not limited by the vaporization temperature of the base materials. The current density in the positive carbon may now approach or even exceed 2000 amperes per square inch, and the small size of the major light producing area is a further advantage from optical considerations.

The first high intensity projection lamps were developed mainly for large theaters and used an uncoated positive carbon which was rotated in a horizontal position with the crater facing a condenser lens system and the negative carbon at an angle of about 45^{o} position below the positive carbon. The negative carbon were copper coated for current carrying capacity. Due to the spacial arrangement of the carbons, then, the concentration of magnetic flux in the gap between the carbons is much greater in this type of set up at the bottom of the gap than at the top. This results in the vaporized materials being given an electromagnetic impetus up and slightly away from the positive crater so that vaporization products do not present a problem in obscuring crater light. In general, this type of illumination system is still used in the very large cinemas.

The smaller cinemas did not receive the benefit of high intensity projection until about 1933 when the non-rotating high intensity projection system developed by National Carbon Company, as was the original high intensity system, became available(26)(27)(28). The main differences

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(26) Joy, D. B., and Downes, A. C. Direct Current High Intensity Arcs with Non-Rotating Positive Carbons. Journal of the Society of Motion Picture Engineers. Vol. 22, No. 1, pp. 42-49 (1934).

(27) Joy, D. B., and Geib, E. R. The Non-Rotating High Intensity D-C Arc for Projection. Journal of the Society of Motion Picture Engineers. Vol. 24, No. 1, pp. 47-61 (1935).

(28) Joy, D. B., Lozier, W. W., and Simon, R. W. Large Size Non-Rotating High-Intensity Carbons and Their Application to Motion Picture Projection. Journal of the Society of Motion Picture Engineers. Vol. 34, No. 3, pp. 241-251 (1940).

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between the non-rotating system and the previous high intensity systems were the use of a non-rotating positive, horizontally positioned and copper coated, facing away from the film gate into a collecting mirror, and the re-arrangement of the negative carbon into a horizontal position in line with the positive carbon, but slightly below it. The negative carbon is fed through the collecting mirror in this system. Actually, the optical system of such a projection lamp described here had been utilized some time before(29) with the old style low intensity

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(29) Joy, D. B., and Downes, A. C. Properties of Low Intensity Reflecting Arc Projector Carbons. Journal of the Society of Motion Picture Engineers. Vol. 16, No. 6, pp. 684-694 (1931).

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carbons since this system with the elliptical reflector, made it possible to increase the cone of light picked up from the crater from about 45° to 120°.

A modification of this same approach was made in the so-called "hi-low" reflector lamp utilizing the high intensity effect in which the negative carbon was slightly inclined to the positive, thus occluding less light from the crater. The combination of high intensity principles using horizontal carbons with the elliptical reflector system was a major advance as this combination gave considerably greater light than the low intensity arc but less illumination than the "hi-low" lamp or the high intensity condenser lamps suited for the larger theaters.

The most simplified version of the high intensity reflector lamp is represented by the so called "one kilowatt lamp" which uses an arc current of about 40 amperes at a voltage of about 27 1/2 volts across the arc. This lamp and carbon combination was developed for the use of small theaters not needing the large light outputs of earlier high intensity types, but desiring the almost invaluable properties of the high intensity arc for color film projection. The development of the one kilowatt lamp was made possible only by National Carbon Company's research efforts, since previous attempts at extremely low current high intensity arcs had been defeated by the tendency of the negative carbon to form a so called carbide tip in such arcs if operated at low current and the close spacing demanded by a relatively low arc voltage. This carbide tip is formed by incomplete volatilization of the rare earth materials and their combinations with the other materials making up the projector carbons at low currents and short spacing. The development of the "orotip" C carbon eliminated this trouble and made possible the development of the one kilowatt lamp in 1940[30]. Thus,

(30) Lozier, W. W., Joy, D. B., and Simon, R. W. A New Negative Carbon for Low-Amperage High-Intensity Trims. Journal of the Society of Motion Picture Engineers. Vol. 35, No. 4, pp. 349-360 (1940).

at the present time no theater, however small, need use low intensity arc illumination as a projection light source. In all the arcs having both carbons horizontally positioned, it has been found necessary to provide auxiliary magnetic flux to remove vaporization products from the arc since no such concentration of flux comes about naturally as in the case of the rotating positive high intensity arc.

Alternating current arcs have also been developed which make use of the high intensity principle in the lower current and voltage levels. Some of the projection lamps utilizing alternating current arcs avoid the troublesome flicker sometimes noted with such arcs by an ingenious application involving a supply of current to the arc at such a cycle speed that any flicker corresponds to the periods during which the shutter blade is interposed between the light source and the screen.

We list herewith some comparative figures showing the cost per hour per 1000 screen lumens for the various types of light sources which have been used in motion picture projection:

Type of Lamp and Trim	Cost per Hour per 1000 Screen Lumens (Per Cent)
Early D.C. Low Intensity, Condenser Type	100
Later D.C. Low Intensity, Condenser Type	72
Early D.C. High Intensity, Condenser Type	60
"Hi-Low" Reflecting High Intensity	38
Low Intensity D.C. Reflecting	24
Present D.C. High Intensity, Condenser Type	22
D. C. Simplified High Intensity	11
"One Kilowatt", High Intensity	10.5

We should touch in somewhat greater detail upon the question of light quality from arc carbon light sources used in motion picture projection[(31)(32)(33)]. As mentioned briefly above, the question of light quality became extremely pressing at the time the first large scale usage of color film in cinematography took place. The low intensity carbon arc, while appearing extremely brilliant to the naked eye, contains a larger proportion of the longer visible wave lengths than does sunlight, to which our eyes are adjusted by nature. If such yellower light from low intensity arcs is used either for

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(31) Joy, D.B., Lozier, W.W., and Zavesky, R.J. Recent Improvements in Carbons for Motion Picture Studio Arc Lighting. Journal of the Society of Motion Picture Engineers. Vol. 33, No. 4, pp. 373-383 (1939).

(32) Bowditch, F.T., Null, M.R., Zavesky, R.J. Carbon Arcs for Motion Picture and Television Studio Light. Journal of the Society of Motion Picture Engineers. Vol. 46, No. 6, pp. 441-453 (1946).

(33) Linderman, R.G., Handley, C.W., and Rodgers, A. Illumination in Motion Picture Production. Journal of the Society of Motion Picture Engineers. Vol. 40, No. 6, pp. 333-343 (1943).

photography or for projection of movies at a later stage, the color values are altered and do not appear natural. A certain artificial balance can be achieved, of course, by means of chemical transformations in the film emulsions, but such a solution is far from ideal. The high intensity carbon arc can be made to give radiant energy in the visible spectrum which, in its distribution, closely approaches the color balance of natural sunlight and it is this quality of the high intensity arc which has made this projection of color movies the success that they are.

Indeed, it is possible for special applications to obtain practically any section of the visible and near-visible spectrum in an intensified form from high intensity or flame carbons by varying the core constituents of these carbons(34). Of course, all carbon arcs contain the

(34) Radiation Characteristics "National" Industrial and Therapeutic Carbons. Catalogue Section A-4300, Carbon Sales Division, National Carbon Co., Inc. 23 p. (undated).

prominent cyanogen band emission around 3,800 angstrom units, but in addition to this practically any other band can be selected for reinforcement in spectral intensity. Examples of various emission curves from industrial and therapeutic carbons are available(35). As mentioned

(35) Ibid.

previously, high intensity carbons intended for motion picture projection are balanced to conform as closely as possible to normal sunlight.

For a general discussion of recent work in the field of projector carbons, we refer the reader to Holloway, Bushong, and Lozier[36], and for an interesting disserta-

(36) Holloway, F. P., Bushong, R. M., and Lozier, W. W. Recent Developments in Carbons for Motion-Picture Projection. Journal of the Society of Motion Picture and Television Engineers. Vol. 61, No. 2, pp. 223-240 (1953).

tion on the theoretical determination of motion picture screen light as a function of carbon arc crater brightness distribution to Jones[37]. For a general modern discussion

(37) Jones, M. T. Motion Picture Screen Light as a Function of Carbon-Arc-Crater Brightness Distribution. Journal of the Society of Motion Picture Engineers. Vol. 49, No. 3, pp. 218-240 (1947).

of high intensity arcs, see Bowditch[38], and for some

(38) Bowditch, F. T. Light Generation by the High-Intensity Carbon Arc. Journal of the Society of Motion Picture Engineers. Vol. 49, No. 3, pp. 209-217 (1947).

data on systems newly developed for cinema projection, we refer the reader to Gretener[39] and Greider[40].

(39) Gretener, E. An Improved Light Source for Three Dimensional and Wide Screen Projection. Journal of the Society of Motion Picture and Television Engineers. Vol. 61, No. 4, pp. 516-524 (1953).

(40) Greider, C.E. Performance of High Intensity Carbons in the Blown Arc. Journal of the Society of Motion Picture and Television Engineers, Vol. 61, No. 5, pp. 525-532 (1953).

The most important substance which goes into projector carbons is, of course, carbon, from the standpoint of bulk, and of function as well, The raw materials used include the purest available forms of petroleum coke, lamp black, tar, and pitch; the latter two are used in their original purified and blended form as binders, but appear in the finished projector carbon as coke since several baking operations take place during the course of manufacture.

The first important step deals with these tars and pitches which must be refined and distilled to exact qualities. The lamp black, which has previously been produced by burning oil in special furnaces, must be milled thoroughly, as must be the petroleum coke. After milling, the solid materials are blended with lots of previous "flour" to insure uniformity. After such blending, the flour can be mixed with the bonding materials in heated mixers which produce a plastic mass of blend. Obviously the type of flour and binder chosen will depend on function which the projector carbon or other type of arc carbon is expected to fill. After mixing, the doughy mass is extruded from huge hydraulic presses in various sizes and cross-sectional shapes and with various size core hole. The extruded product is allowed to cool and becomes fairly rigid, but not really hard. The next step in production of the projector carbon is the baking of the carbons at a high temperature and for a reasonably long period of time to convert the bonding materials into coke, giving a homogeneous shell of pure carbon.

After coming from the first bake, the carbons are cleaned, cut to the proper length, and after several inspection operations are cored with a mixture of rare earth compounds for the high intensity positives and with some neutral arc supporter and soft carbon for the low intensity positive and the negative carbons. A second period of baking then is given the carbons to coke the binding materials used in the cores, much as the previous baking was given the carbons to coke the binding materials in the shell. With various inspection operations intervening, the carbons are then chamfered, plated (only certain types), sawn or butted to length, and finally marked and packed. Immediately before packing, the carbons are given a final X-ray check to show up any voids in the core and a final inspection to pick out any visual or dimensional rejects. In the Singapore factory, only those operations from coring forward are carried out, and it is with these we will be primarily concerned in our discussion. For a general review of arc carbon lighting, we refer the reader to the Encyclopaedia Brittanica[41],

(41) Lighting and Artificial Illumination. (Article). Encyclopaedia Brittanica. 1946. Ed. Chicago, En. Brit. pp. 105-115, Vol. 14.

and to the National Projector Carbon Handbook[42].

(42) "National" Projector Carbons. Fourth Edition, New York, National Carbon Company, Inc., 1948. 100 p.

The above discussion on theoretical and general aspects of the products with which the writer has been involved was felt necessary since the manufacturing problems associated with these products and the corresponding quality control operations are fairly unique and it was felt that such a background dissertation was necessary before any specific discussion of the writer's own work in this field was taken up.

This introductory section will be closed now with a short description of the work done and the training received by the writer during his approximately one year's stay at the Edgewater plant of National Carbon Company in Cleveland, Ohio. This work served as background for his assumption of the responsibilities of quality control and evaluation work at National Carbon (Eastern) Limited, located in Singapore.

The first several weeks of the tour of duty in Edgewater were devoted to study of the various operating departments of the large Edgewater plant in company with the various general inspectors working there. This training not only gave an opportunity for gaining an over-all picture of dry cell manufacturing techniques, but was also useful in that inspection operations and quality control check points were stressed and much background in this phase of the work was obtained.

Following this period of general survey in company with the inspection staff, a number of weeks were spent in various of the more important production departments working with the departmental foremen and in obtaining a somewhat more detailed picture of certain phases of individual operating departments than was possible in the first survey made with the inspectors. The writer, during this period, made a point of drawing up organizational charts for each of the departments in which he worked with reference to inspection and quality control personnel especially. Unfortunately, this work was largely wasted for reasons which will be brought out a bit later.

It was the writer's good fortune to be in training during a period of rapid expansion of evaluation and development work at the Edgewater plant. While the actual manufacturing operations of National Carbon Company have been tremendously increased during the past few years, the major portion of the evaluation and development work was still being done at the Edgewater plant in 1951. Several factors account for this centralization of development work, one of them being the fact that the research laboratories of the entire company are located in physical conjunction with the Edgewater plant, even though they are a completely separate administrative unit in the company framework. A second factor in the placement of the development section at Edgewater was the variety of types of production which was being carried on there at that time. Most of the newer plants have been designed for a more specialized output, whereas the Edgewater plant in 1951 was still capable of producing practically every type of dry cell or battery being marketed. Since development's function is to mediate between research and operation, one can see that the centralization of development work at Edgewater was inevitable even aside from the fact that previous manufacturing centralization had brought it about.

The spring and summer of 1951 were, of course, a period of industrial and developmental concentration in most industries due to the then recent broadening of the Korean war situation. Coupled with the natural need for more technical workers at such a time was the additional shortage caused by the absence of those men returning to, or being inducted into, the armed services. Thus it was that the writer was given an opportunity to work in the development laboratories as a development engineer rather than being more or less forced to spend the entire projected year of training in various temporary jobs around the plant.

Experience has since shown that the eight to nine months time spent in the development laboratory at Edgewater has been far more helpful in building up technical experience on battery chemistry and construction than any similar period could have been if spent in the factory proper. It is, of course, ridiculous to hold that factory experience is not necessary and beneficial, but it has been the writer's experience that all too often the factory training is carried out in a very careless way on the part of those persons responsible for the training of the incoming engineer. There are exceptions, of course, but it seemed to this writer and to his fellow trainees in Edgewater, that frequently it was a question of one foreman's passing the neophyte along to another with a comment something like, "You're supposed to have this guy in your department for a week; I don't know what you're supposed to do with him, but you can let him walk around and watch the work as long as he doesn't get in the way." With the best intentions in the world, it is hard for any trainee to get the maximum benefit from the time spent in a training program such as this. Being thrown into a high priority development program, the writer was freed from this application of the laissez faire principle, since development programs cannot be run on such a haphazard basis. Systematic work, experimentation, and conferences were rather the rule of the day.

It is perhaps not necessary to go into any great detail on the theoretical problems which concerned the writer during his work in the development laboratory at Edgewater. It is, however, germane to note that of the twenty-odd technical reports written during that period, most of them dealt with problems introduced into dry cell manufacture by tropical storage and usage conditions. This was an excellent opportunity since the writer's work was to be in tropical or semi-tropical locations, plus the fact that the studies made covered practically all phases of dry cell construction from the causes and effects of electrolyte diffusion in electrodes of dry cells, to determinations of electrolyte transfer between components of dry cells, to over-all studies of constructional defects of conventional round cells stored under extremely abusive conditions of heat and temperature.

It was a source of satisfaction to the writer that he was able to make some positive contribution to the study of conventional type round cells under extreme conditions, and even though this contribution was small in the over-all picture, it was one of the building blocks for an over-all summation of results and future aims made by the departmental head shortly before the end of the writer's tour in Edgewater.

Towards the end of the scheduled year's training in Edgewater, a period of approximately two and a half months was spent in the specifications and quality control division of the company, which was centralized at Edgewater for all battery problems. In any organization as huge as National Carbon Company it is natural to expect a high development of company standards and such indeed is the case in the National Carbon organization. The quality and specifications division not only establishes specifications in conjunction with the development laboratory, but also rules on permissable modifications for those foreign plants unable for one reason or another to meet exact material specifications. This latter function, reasonably enough, often leads to the necessity for evaluation tests, which, once again, are carried out in conjunction with the development laboratory.

Progressing as he did from the development laboratory to the quality section, the writer experienced no break in continuity, but rather was given a different view of the same over-all mechanism. In view of impending overseas work, problems in correspondence pertaining to such locations formed the work of the writer while in the quality and specifications division. The personal contacts here were equally good from the long range standpoint, as made in the evaluation and development laboratory, since, as quality control head at Singapore it has been the writer's function to carry on, among other things, much of the correspondence and quality reporting directed to the specifications and quality division in Edgewater.

This work in Specifications was followed up by a final rather quick refresher tour through the plant at Edgewater, which was a great deal more helpful than the earlier plant tour had been due to the fact that the writer, with one year's experience behind him, knew more about the operations involved and therefore about the points worth concentrating on in his departmental studies.

DISCUSSION

In the introduction of this paper we have attempted to outline a background of information on modern day dry cell and projector carbon manufacture, as well as to give a brief picture of the writer's training preparatory to joining the foreign activities of Union Carbide International Company, as quality control head in the National Carbon (Eastern) plant in Singapore. In this discussion we will now deal more specifically with the work which the writer has done for the past three years at this location.

Singapore, as a geographical entity, is surprisingly unknown to many people in the United States, surprisingly unknown because it has long been the most important port, both for entrepot trade and outward shipping, in British Malaya; a country which produces more tin and more natural rubber than the rest of the world combined. Singapore may generally be said to be a part of British Malaya with qualifications, as herein undernoted, and is most definitely not part of India or of China, as so many people seem to think. Physically, Singapore is an island, roughly ten by twenty miles in extent, located approximately a mile off the southern most tip of Asia, the end of the Malay Penninsula. The dominant city on the island is also called Singapore. The population in mid-1953 was estimated at 1,123,172 excluding armed forces[43]. This population is dominated by the Chinese

(43) Colony of Singapore Annual Report 1953. Singapore, Government Printing Office, 1953.

segment of approximately 860,000, which is followed by the subjects of Malay blood, with about 138,000, and by Indians and Pakistanis, 87,000. The Europeans make up a rather diminutive fourth with about 16,000. As can be understood from the population distribution, Singapore is basically a colony of Chinese language and habits, modified by the local Malay customs and climate, and veneered over with a thin cast of dominant whites.

Politically, Singapore is a Crown Colony, separate and distinct from the Federation of Malaya and from Penang. The former political unit of the Straits Settlements, comprising Singapore, Penang, and Malacca, has now been dissolved. For a general review of the Colony, see the Annual Report, 1953[44].

(44) Ibid.

Since the end of the Japanese war, the governing powers in Singapore have seen that the Colony's old role as a trade center and entrepot for Malaya and British Borneo, while increasingly large in extent, was not enough to cushion any economic slumps which might occur due to loss of world markets for local produce. To partially buffer this condition, encouragement has been given to industry's setting up of manufacturing plants in Singapore. Until 1948 there was no income tax levied in the Colony on either personal or corporate income, and this, of course, acted as an added inducement. It might be mentioned here, parenthetically, that the British authorities in Singapore have been most fair in all their dealings with non-British firms who have elected to set up manufacturing units in Singapore. Exchange control and import licensing has been most reasonable and in general, very liberal.

It was into this healthy economic atmosphere that National Carbon's foreign department (the predecessor of Union Carbide International) decided to enter. This decision was further urged by the necessity of setting up manufacturing facilities somewhere in the Pound Area, which were at the same time in such a location that they could serve large soft currency areas conveniently and be in a position to obtain the liberal exchange control and import licensing so necessary for international trade of any kind.

The first in situs planning for National Carbon (Eastern) Limited was started in 1946, and construction of the actual plant followed soon afterwards with some of the senior staff arriving in 1947, and the junior expatriate staff arriving in the very early part of 1948, when production commenced. At that time the National Carbon (Eastern) plant in Singapore was designed to manufacture a small range of dry cells and batteries with many of the manufacturing operations being carried out in a fashion a great deal more dependant on manual labor than the current practice in similar operation in the United States. Since that time, the business has prospered beyond the most optimistic forecasts, and at the present time, National Carbon Eastern's production of dry cells is well over twice the original design figure. Construction of an arc carbon manufacturing unit was begun in 1950, and installation of equipment proceeded throughout 1951 and '52, with production getting under way in 1953 in this unit.

Like any other institution, a manufacturing plant is colored by its surroundings. In addition to the points previously mentioned of good transport facilities, liberal foreign exchange, and geographical aptness of site, there are two further major factors which have influenced the operation of the Singapore plant to a large extent. The first of these is climate. Some people feel that Singapore's climate is horrible, others find it idyllic. No matter which view one tends to, the climate in Singapore is certainly warm, and certainly humid. Being only about seventy miles north of the equator, Singapore has, of course, no winter or summer, and does not even experience the sharply demarcated line between wet and dry seasons which is found on the China coast to the northeast, and more particularly in Burma and India to the northwest.

The relative humidity in Singapore rarely goes below 60% and is frequently over 95% while a day-time temperature of under 80° is not common. Sling psychrometers of standard design and recording thermo hydrograph instruments are used for humidity determinations. These factors of climate make raw material and finished product storage a major problem in dry cell manufacturing.

In many cases, a great deal of extra work is necessary to overcome the harmful effects of the high humidity particularly. From a quality control standpoint, this humidity also plays havoc with control instruments from the most sensitive potentiameter to a relatively crude platform scale. One of the writer's first decisions as quality control head in Singapore was to establish primary standards for all the various measuring instruments, refined or crude, with storage of these standards in air conditioned or desiccated enclosures.

The second additional conditioning factor applying to manufacturing operations in Singapore is the nature of the population and the political considerations which apply to this population at the present juncture in world affairs. As mentioned above, Singapore, as a unit, is largely Chinese in population and is even more so in terms of factory worker population, since the Malays in general are a very easy going, non-competitive race, the members of which prefer to work as chauffeurs, gardeners, etc., thater than as production line labor. The attitude of the

Singapore Malay population, which attitude has regretably been partially assimilated by the Chinese, is best described by the phrase, "Tidak apa" or "Tidapa", which, very broadly translated means a combination of "So what", "Never mind", "I couldn't care less", and "It can wait 'till tomorrow".

This sort of mental attitude has unfortunately been coupled with the worst features of the welfare state philosophy, in modern Singapore. The British have become so chary of seeming to rule in colonial areas that they panic at even the suggestion of local pressure. It is no tribute to America that we have nagged at Britain for so many years to pull out of her colonial possessions. It is rather a beautiful example of unqualified "experts" poking their noses in with absolutely no knowledge of prevailing conditions. The lessons of the past few years have shown all too graphically the horrible results of the cession of power in Southeast Asia by European nations to fanatic minorities of Asians.

Be that as it may, Britain seems to be in retreat even in Singapore, and is hurrying her own downfall here by giving way to the most far-fetched demand for welfare state institutions. As a result of this tendency, hastened during the years of labor government in England, the local populace, particularly among the Chinese, have gone a long way down the road of belief and practice which leads to the ultimate "hand-out" government. Such conditions do not, of course, make for the best labor atmosphere in the world and it is only Singapore's population pressure which has made the labor situation here as livable as it has been.

It might be interesting to mention here one of the outstanding faux pas of so-called American Foreign Policy in this area. Several years ago a notorious leftist labor agitator was selected by the U.S. Department of State for an extended visit to America, all expenses paid. Within a few months after his return to Singapore, this same man did everything within his power to cripple and disrupt the operations of National Carbon (Eastern) Limited, a 100 per cent American owned firm, by a wildcat and completely unjustified strike. It is a sad commentary on the way American taxpayers', both individuals' and firms', money is spent.

With the exception, however, of the incident mentioned above, and following the complete failure of this strike, labor relations have been extremely good in National Carbon (Eastern) Limited due to, in large part, the very liberal attitude taken by management. The points noted above, however, are worthy of mention since it is not always possible to be absolutely sure that a zealous scrap drive, for instance, is accomplishing all it might were the local workers solidly co-operative.

The problem of language, of course, enters into all questions of manufacturing operations in Singapore, since few of the workers speak English. This point has been found a most unhandy one at times in the writer's own job of quality control. Many of the supervisors at the monthly paid level are Eurasian, while others are Chinese; all of these people of necessity have been chosen from English speaking segments of the population. Most of the Chinese as well as the Malays and Indians employed in National Carbon (Eastern) Limited speak the bastardized Malay of Singapore, commonly called "Bazaar Malay". This polyglot language is the simplest form of rudimentary Malay, coupled with many loan words of English; and a speaking knowledge of it is relatively easy to obtain. However, as the writer has found, even with a working knowledge of this Bazaar Malay, it is very easy to meet with blank looks from Chinese workers in the factory; in any case, however, he has found that the time spent on acquiring the local language has been well invested, especially so since few other Europeans in National Carbon (Eastern) Limited speak Malay.

Let us hasten to add that Bazaar Malay, as spoken in Singapore between races, is a far cry from the beautiful elided language of the educated Malay speaking to his peer.

The total strength of the National Carbon (Eastern) Limited plant and office is approximately 475 (1955), made up mostly of Chinese in the more demanding production jobs, with a few Malays and quite a few Tamils from southern India also employed. This latter group of Tamils represents one of the Dravidian races of southern India which, as a group, is the most primitive and least gifted of any Indian species, which is saying a lot. These Tamils generally work as sweepers or clean-up men, and will concern us little in quality control work, although many of the clerk class in Singapore come from the same Dravidian group, but are termed Malayalams, and are generally somewhat brighter than the average Tamil.

When the writer arrived in Singapore, the abortive strike mentioned above had just started. This strike followed a period of several months during which the communist agitators had become increasingly bold and insolent within the plant and during which many of the workers deliberately caused scrap and low quality production. This, coupled with a raw material problem, due in large part to lack of adequate raw material control, had led to a serious drop in quality and a rise in scrap. The situation was somewhat aggravated by the fact that no senior quality control personnel had been available in the Singapore plant for over a year, which led to a less efficient quality control at the same time.

Coming, as the writer did, into the plant at that time, he found the situation bad in that sloppy methods and deliberate mischief had created a very careless attitude toward quality on the part of the supervisors and workers, but good from the standpoint that with cessation of labor trouble after the strike there was presented a field in which management's efforts towards better quality could not be ignored by the rank and file of supervisors and workers. At the same time, a good effect of the strike was that it resulted in the clearing out of the deliberately careless workers and presented in most cases a new and untrained labor staff which could be taught proper work methods from the beginning.

In connection with the training and supervision of Asian workers, it must be understood that these workers are essentially different from the average production worker in American industry in that they are generally less intelligent, much less schooled, and much, much less inclined to indulge in thinking aimed at bettering the operation of which they are a part. As is generally recognized now in America, a large percentage of the worthwhile suggestions for improving operations and methods nowadays come from the hourly paid workers directly concerned with the job under review. Such a co-operative and independent attitude of thought makes the quality and production engineer's job much easier, not only due to the direct contributions received from the workers, but due to the fact that generally once the reasons for an improvement change in any operation is explained, the production people will co-operate intelligently. By and large, the Asian worker does not, or will not, contribute to job betterment in this fashion. This factor makes it necessary to approach quality control from a rather more arbitrary standpoint in that it is useless to hope for any grass roots initiative. If this stagnant attitude of mind on the part of the Asian worker were completely consistent, it would be possible for the quality control man to depend at least on rigid adherance to instructions on the part of the worker, if nothing else. Unfortunately, the Asian worker is all too ready to do things in a sloppy, haphazard way, and thus must be watched and checked continually to obviate poor quality products due to sloppy handling or procedure.

The net result of all this is that generally speaking, a much higher proportion of inspection staff must be maintained on any given operation in such plants as that one in Singapore, than would be necessary in the United States. This increase in inspection staff is equally necessary on the monthly paid level, since the type of individual usually found in junior supervisory jobs tends to have the same faults, albeit on a less pronounced scale, as the coolie shifting bags of material.

The battery plant operations in Singapore will be covered from a quality standpoint at this time, with following sections devoted to the arc carbon plant and other collateral activities. The writer would like to emphasize at this point that while most of the quality control details brought out in the following pages are either new since his tenure in Singapore, or revisions of existing methods, the object is not to give the impression that the great improvement which has resulted in Singapore quality control during the past three years is due to any one-man effort on his part. Without the co-operation of all the other foreign assigned personnel, the writer's efforts for a codification and extension of the quality control system in Singapore would have come to very little.

The quality control operations in Singapore National Carbon (Eastern) battery plant can be conveniently broken down into four major divisions:

1. Raw material examination and control.
2. Process quality control.
3. Evaluation, development, and experimentation.
4. Solution of unexpected difficulties in manufacturing.

A total of thirteen monthly paid assistants are now (1955) under the writer's direction, filling jobs as follows: eight departmental or assistant departmental inspectors, two analytical assistants, one general inspector, and two general staff assistants. In addition, roughly forty full time hourly paid inspectors come under the control of Works Laboratory in Singapore.

As we have mentioned above, the Singapore factory owes its location to a number of factors, one of these being the desirability of a location in the soft currency area of the British Commonwealth. A corolary of such location is the possibility of obtaining certain raw materials from soft currency sources to avoid using any more hard currency exchange for raw material purchase than is absolutely necessary. Another reason for attempting to obtain as great a percentage of the necessary raw materials from localities other than the United States, is that almost always such materials are available at lower prices from European or other sources than from the United States. Since Singapore is a dutyfree port on practically all materials (the only exceptions are liquors, tobaccos, pharmaceuticals, and cosmetics), and since the Colony is located closer to Europe than to the United States, it can be seen that other economic factors such as shipping costs reinforce the desirability of obtaining necessary raw materials from non-United States sources. Assuming a given quality of material, it is only natural that dry cell producers, like anyone else, should prefer to buy their raw materials at the cheapest price.

In the years since National Carbon Company was formed in the United States, a sizeable literature has grown up on product and material specifications. These specifications are, of course, available to the Singapore factory for guidance, both in purchasing raw materials and in production of National Carbon products. On the surface it might seem that raw material procurement becomes a matter of feeding the pertinent specifications to the various prospective suppliers, and then sitting back and waiting for the bids to roll in. Unfortunately, it is not quite so simple as this, since all too often the exact type of material specified as used in America is not available in the same form from other sources. The difference may be one simply of nomenclature, or possibly one of different approach to the same problem on the part of European industry in general.

In such cases it becomes the quality control section's job to reinterpret the specifications in some degree, if necessary, always keeping in mind the essentials from which deviation cannot be considered at any cost. In more serious cases, of course, clearance must be obtained from higher management. Most often the denoument of any serious question regarding raw material quality is a series of evaluation tests run on the material in question. We will cover this phase of quality control work in greater detail later on.

Due to the necessity of maintaining far larger stocks than usual in the United States of raw materials in an operation so far from its major sources of supply, a steady flow of material shipments reaches Singapore for National Carbon (Eastern) Limited. Since it is necessary to maintain this forward stock of raw materials as a cushion against possible dock strikes, lost shipments, etc., it is essential to determine as far as possible the quality of all incoming goods immediately upon receipt, so that if necessary, due to condemnation of the shipment, an immediate reorder to correct the situation can be placed. A system was set up in Singapore to accomplish this aim and was written up as comprehensively as possible as one of a series of "Standard Works Laboratory Methods" which the writer has built up during the past three years.

This codification of methods, procedures, and technical records has been one of the guiding principles of the writer's work in Singapore. We have striven unceasingly to inculcate the idea that these "Standard Works Laboratory Methods" are tools to be used as aids to routine work carried out in the Works Laboratory and not stumbling blocks put in the way of the typical Asian laboratory assistant. In this codification of methods, it has been found necessary to think in terms of the failings of the Asian mind, which is essentially static and to walk the tightrope between incompleteness of instruction and complete negation of individual initiative. On the one hand we have found that, given any formal loop hole in an instruction, the typical Singaporian will use such a loop hole later on as a carte blanche excuse for failing to do something which obviously was covered by the spirit of the instruction, if not the letter. Thus, while the codification of method and procedure has been a major advance in Works Laboratory practice in Singapore during the past three years, it has always been necessary to write such procedures in such a way that all possibilities for the future which could be envisioned were covered.

In the case of raw material examination, the standard method takes up about five single spaced typewritten pages, and covers all necessary points from the initiation of the sample order for any raw material shipment through such considerations as the number of containers to be opened and sampled for any shipment, the amount of sample to be taken from each container, the proper method for taking this sample, detailed instructions on the appropriate tests to be applied to each raw material or part sampled, the method of recording the results of the appropriate tests, the method of calculating the conversion factor for individual battery parts, the correct circulation of results, and finally, the procedure to be followed in case substandard material is revealed by the applied tests. The application of this particular lab method has been so successful that all the sampling and testing of routine incoming raw material shipments is now being carried on with very little direct supervision by the writer.

At the present time each and every part or material which comes into the National Carbon plant is checked and the results recorded by the raw material record system. To facilitate the recording of such results, the writer has drawn up approximately sixty individual mimeographed forms which cover the range of raw materials and are so constructed that a complete record of the raw material quality is easily prepared and with a minimum of time and effort.

Before the writer's arrival in Singapore, no raw material shipments had been tested for about eighteen months, and it was felt necessary to carry out retroactive testing on some of the materials still in stock which would have the most pronounced effect on battery quality.

The conversion factor for battery parts mentioned above is developed for each individual shipment of raw material which comes in the form of already fabricated individual parts, such as brass caps, etc. This factor is a weight number conversion which is used for accountancy and inventory purposes. Before the Singapore Works Laboratory began this factor evaluation, the accountancy and inventory figures were based only on packing slip numbers and weights and the factors thus arrived at have proved to be very unsatisfactory.

Raw material examination and check, while not particularly difficult in itself, is one of the major time consuming functions of the Singapore Works Laboratory, and as such, the time spent on its organization and streamlining has paid off many times already in easing the work load of the laboratory staff and in speeding up the check of incoming shipments so that if necessary these shipments can be released directly to production.

One other minor function of the Works Laboratory comes under the general head of raw material examination, but is one which will tend to increase from this time forward. This is the hourly running examination of battery parts produced in the Singapore factory from bulk raw material. This phase of production has only recently been initiated, but present plans are that it will grow rapidly in the future. The checks made for this type of raw material examination will be limited to dimensional and appearance checks, unlike the tests given to incoming raw material which include as well some fairly complicated chemical analyses.

The second phase of quality control work in the Singapore National Carbon (Eastern) Limited battery plant was listed above as "process quality control". Perhaps this is too broad a classification, because the term, as we use it here, is meant to cover a great deal more than mere inspection operations throughout the manufacturing system, although such inspection details are a most necessary part of the over-all frame work of quality control in the National Carbon plant.

Dealing with this phase of process quality control first then, we must indicate the organization of the plant as to operating divisions. There are four such major divisions as follows:

1. The can manufacturing department in which the raw materials for the manufacture of soldered

cans are assembled into the various sizes and types of zinc containers which are used in the range of products manufactured by National Carbon (Eastern) Limited.

2. The mixing and stamping department in which the components of the depolarizer mix are blended, mixed, and conditioned and then stamped into the bobbins used in round cell construction.
3. The cooking or assembly department in which the various components such as cans, bobbins, paper parts, and separator paste are assembled and sealed into individual cells. This department includes facilities for the manufacture of electrolytic paste and for the metal top sealing of the familiar flashlight cell which forms the largest part of the Singapore plant's production.
4. The finishing department in which the cells, after a preliminary period, are cleaned, tested, and are furnished with suitable jackets and labels preparatory to final packing in cartons and wooden cases.

These operating divisions of the battery plant are served by several auxiliary departments such as the Engineering Department, the Stores Department, Works Laboratory, etc.

At the time the writer first arrived in Singapore, the production of the cylindrical zinc cans was being carried out by relatively primitive hand methods. The low local cost of labor in comparison to the United States makes possible the use of less efficient methods in manufacturing operations, and the hand construction of cans would definitely be classified as a rather inefficient method, even though it has the advantage of requiring very little capital expenditure for equipment.

The first action that was taken in regard to quality in the can department was to list all process conditions which might have a bearing on the quality of the finished product, and to evaluate these various points as to relative importance and as to whether or not a decided improvement could be effected in the operation within the framework imposed by labor skill and the basic procedure of the operation. As a matter of interest, we list herewith some of the points which were found worthwhile ones for the improvement of the final product; most of these points were ones to which the departmental inspector's attention was directed and on which he was required to submit written reports in an approved inspection form periodically:

HAND MAN. - Dept. Insp. Check Points

<u>Fluxes</u>. no. 1, 2, 3, and 9 - Density

Uses of the above mentioned fluxes.

Cutting. (Hand operation)

(1) Zinc Gage

(2) Length of Zinc Blank

(3) Condition of Zinc

(4) Squareness of cutting

Scrolling. (Hand operation)

(1) Condition of Scrolls

Beading. (no. 27 only)

(1) Condition of Bead

(2) Inside Diameter

(3) Depth of Bead

Side Seaming. (Hand operation)

(1) Type of fluxes used

(2) Condition of seams

(3) Fluxing

(4) Quality of inspection by operator

Bottom Soldering. (Hand operation)

(1) Depth of Bottom before soldering

(2) Method of fluxing

(3) Condition of side seam

(4) Method of soldering

(5) Inspection

(6) Solder temperature

The above listing is not intended to be a comprehensive one, but only a brief list of some of the process variables which we found important enough to particularly deal with. You will note under both side seaming and bottom soldering, there occurs a mention of "inspection" or "inspection by operator". This refers to the last worker in each production unit who was expected to inspect the article produced, at the stage at which it left that team. As might be supposed, quite a lot of time was spent with each individual team in an attempt to imbue the team members with the proper techniques so that their production could be maximum and high in quality at the same time. The fact that these people worked on piece rate and consequently lost money if a great deal of their work had to be recycled helped us in this regard. The same fact, however, tended to make the inspector member of the team, who was also a production worker at the same time, sometimes less strict than desirable. Generally speaking, however, it was found that once the team members had been shown by actual demonstration that high quality and maximum operation could be best obtained via the same route, the team members would pretty well stick to proper quality evaluation and methods.

With the advent of automatic can making machinery shortly after the writer's arrival in Singapore, the picture changed considerably, since the operation of the department was almost entirely mechanized by this change to automatic can making machinery. Only a very small number of workers are kept on the hand operation at the present time, and these mainly for repairing and odd-lot jobs.

The mechanization of can manufacture, however, immediately posed an inspection problem. In the hand operation the final member of the production team who was primarily a production worker was responsible for the inspection of the product as the team finished with it, but with the automatic machines, the job that this person formerly filled no longer existed, so it was necessary to set up a regular inspection system to maintain quality control on can production. This has been done successfully, and, unlike comparable American and European practice, the production of the can manufacturing department is one hundred per cent inspected. This is possible only because of the relatively low labor cost of such inspection in Singapore, and is dictated by the difficulties which are experienced in can manufacture which must be carried out with zinc strip which has been stored for considerable lengths of time in the local humid climate. Indeed, the can manufacturing operation in Singapore is one of the more outstanding examples of a special difficulty inherent in the Singapore climatic conditions. Zinc strip such as must be used steadily in Singapore would probably be rejected on sight by departmental foremen in the United States. With the complete coverage of inspection in operation here no poor quality cans are used, but in spite of all possible gambits, the storage of zinc in a humid climate presents great difficulties to can manufacture and inevitably entails a somewhat higher number of reworked cans than would be found in an average United States location. Some of the more important check points which have been set up for the departmental inspectors on mechanized can production are listed herewith:

Automatic Can Machine. - Dept. Insp. Check Points

(1) Condition of side seam.

(2) Condition of bottom joint.

(3) Insertion depth (bottom) and type of bottom.

(4) Askewness of cans.

(5) Out of Round?

(6) Can inner diameter.

(7) Temperature of side and bottom soldering pots.

(8) Scoring of cans.

(9) Condition of solder.

(10) Fluxes used.

(11) Special conditions present.

Proceeding next in our discussion to a consideration of the mixing and stamping department, we at once note an important difference between this department and the can department just considered. The difference is that in the can department is was possible to run at a very low level of mechanization due to the type of operation involved and to the availability of cheap labor, even though this low mechanization resulted in a somewhat lower efficiency than desirable, in terms of units per man hour.

In the mixing and stamping department, however, the blending and forming operations have a very pronounced effect on the characteristics of the eventual dry cells and do not present simple and dependable visual criteria for their evaluation as do the can manufacturing operations. It is necessary, therefore, to mechanize and standardize this phase of production to a much greater extent even at the lowest level of mechanization than is absolutely essential in can manufacturing operations. As a result of this situation, the mixing and stamping operations in the Singapore factory have remained virtually unchanged since the inception of the factory and the main contribution of the author in this field of quality control has been the tightening of inspection and the constant checking of all the various measuring instruments involved.

One measurement has been added to the departmental routine inspection, and this is a twice daily calculation of the packing density of the bobbins produced on each standing machine. This measurement gives an indication as to the quality of the stamping operation itself and can be made rapidly for any machine under adjustment or suspicion of poor quality production by means of standardized curves and tables which have been laid out in such a way that they are very simple to use. Here again, the tendency on the writer's part has been to produce a tool to be used as an aid in the efficient quality control of the particular operation.

We cannot emphasize too much in the present paper that this systematization of method, and attempt to train the supervisors involved to think analytically has been the major aim of the writer in his work in Singapore. The details of inspection and analysis are, of course, very important and cannot be neglected, but nevertheless, it is felt that the writer's major contribution to quality control work in Singapore has been the creation of a state of mind in the more responsible local individuals involved in inspection work, rather than the elaboration of detail and method which has also been carried out.

We list below some of the more important check points which the departmental inspector in the mixing and stamping department is expected to cover:

Mixing and Stamping Dept. - Dept. Insp. Check Points

(1) Scale (balance) and timing of wetness tester.

(2) Sal ammoniac (for lumps and dampness).

(3) Weights of ingredients.

(4) Density.

(5) Tank volume checks.

(6) Set up of mixing equipment.

(7) Cleanliness of flow systems in mixing equipment.

(8) Order of placing ingredients into mixer.

(9) Dry mixing time (record)

(10) Wet mixing time (record)

(11) Wetness of mix.

(12) Conditioning of finished mix.

(13) Labelling of mix such as to type

(14) Temperature and humidity of mix room.

(15) Reclaimation of used mix.

<u>At the Stampers</u>.

(1) Condition of machines.

(2) Wetness of mix before tamping.

(3) Condition of Bobbins.

(a) top surface

(b) top centering

(c) condition of electrode surface

(d) depth of piercing rod

(e) tightness of electrodes

(f) electrode seating

(g) condition of bottom surface of bobbin.

(4) Weight; diameter; height of bobbins (for % packing as well).

(5) Bobbin coating operations.

One major addition has been made in the stamping department during the writer's tenure in Singapore which is essentially a method for cleaning and coating the completed bobbins so that fewer mix shorts occur during assembly operations and consequently few low volt reject cells result in the final product. As in the can department, the production of the mixing and stamping department is one hundred per cent checked for gross faults, at least, before being approved for transfer to the assembly department.

The cooking and assembly department operates in Singapore at what might be best termed a semi-mechanized level. The department as a whole is not so completely mechanized as a similar department in the United States would be, but a great many of the operations in this department which could be carried out by hand are done by machine.

The department can be subdivided into three divisions as follows:

(1) The paste manufacturing unit.

(2) The assembly and cooking section.

(3) The closing section.

The paste manufacturing unit is a very important one from both physical and chemical quality standpoints, and as such, receives a considerable amount of attention from the departmental inspectors and supervisors. This unit is also charged with the responsibility of the manufacture of these solutions, as well as that of the electrolytic paste itself is done in a batch manner and exact weightments and volume measurements are essential to good results as well as a rigid observance of time cycles. It is perhaps this one small unit within the assembly department which offers the best opportunity for chemical quality control as distinguished from the more generally mechanical factors involved in the quality control of the departments already discussed. (One exception to this statement is, of course, found in the mixing operations, since rigid control of solution concentration, temperature, cycle time, etc., is maintained.) This exception not withstanding, the paste manufacturing unit is based almost entirely on such chemical or physical chemical measurements as temperature, viscosity, specific gravity of solutions, etc. Also important as mentioned above are considerations of weights and volumes and cycle times. From the paste unit the electrolytic paste in ungelled form is supplied to the assembly section which is also the focal point for the finished zinc cans, the completed stamped bobbins, and the various miscellaneous parts which go into the unit cell proper.

The assembly department of a dry cell plant is probably the most interesting from an outside visitor's viewpoint, since it is in this department that relatively unfamiliar components and materials first are united into a familiar form, even though they still present a far from finished appearance. Generally speaking, the assembly department is not responsible for the production of any of the components of the dry cell except for the electrolytic paste, a subject which we have already covered.

However, it is, of course, part of the assembly department's job to detect and reject any poor quality components which, for any reason, have escaped detection in other departments; and at the same time the assembly department must exercise a high degree of control on the actual operations carried out in its environs. The fact that the major portion of the assembly department's operations are ones of building up the individual cells makes it possible for this department, by careful quality control, to reduce the departmental scrap rate to the lowest possible level since most of the faults due to bad material will result in rejections in the other departments. Another factor which makes it extremely desirable to maintain a high degree of quality control in the assembly department is the fact that it becomes must more expensive to scrap a unit of production half way, or all the way, through this department than at an earlier stage of manufacture.

This is true both because the combined components are appreciated in price by addition and by the extra labor which has gone into them by this stage, and secondly due to the fact that most scrap in and after the assembly department is nonrecoverable.

An example will illustrate this point: if a zinc can is found faulty in the can manufacturing department inspection routine, it can be repaired almost without exception, and those few exceptions are usually due to material faults beyond departmental control. Similarly, a cracked or sub-height bobbin can be broken up, the mix re-conditioned, and stamped into a new bobbin. When we are faced with the problem of recovery of, say, a half cooked cell we may find that it is possible to repair minor defects in the cell as a unit, but it is not possible to take the bobbin out of the electrolytic paste and use the mix over. The bobbin insulation will be worthless for reuse, and even the zinc can is scrap. Unrecoverable, since the electrolytic paste contains a calculated quantity of mercuric chloride which is sufficient to amalgamate the inside surface of the zinc can. Since this is a very fast reaction, and would be instantaneous except for the occluding action of the semi-jelled organic molecules in the electrolytic paste, it is complete within a few seconds after the paste is placed in the can. If a zinc can which has been exposed to the amalgamation were cleaned out and re-used, the second measure of electrolytic paste allotted to the can during the formation of a new cell would increase the mercury content of the zinc to a point at which the can would be weakened sufficiently to result, in many cases, in rupture of the can in later mechanical operations.

Process quality control, therefore, becomes even more important in the assembly department than in earlier operations, and, indeed, is even more a subject of thought in this department than in the fourth and last of the major operating departments in the Singapore plant, the finishing department, since there are fewer opportunities for mechanical damage to the cell in the final finishing department, and no chemical pitfalls. This concentration of quality control in the assembly department is reflected in the increased number of monthly paid supervisors deemed necessary for adequate coverage in the assembly department.

As previously noted, the first operations which take place in the assembly department are those pertaining to the actual assembly and cooking of the basic components of the cells. Thus, the zinc cans are fed into so-called cooking trays. Any cans which are seriously dented or out of round are pulled out at this stage for recovery and after centering operations have been completed on the cans, each can is supplied with the calculated amount of electrolytic paste. From this stage on, the time element is of importance, for if the cans are left too long with only the paste in the bottom portion of the can, the amalgamation of the mercury with the zinc will proceed with intensified form with the mercury calculated for the entire cell being absorbed into a very small portion of the can. This will lead to the same defects mentioned above in connection with the reuse of already amalgamated zinc cans.

From the paste injection position, the cooking trays of pasted cans go to the next operation which is the insertion of the paper component to be used as a bottom insulator. A second rapid inspection follows this operation to make sure that no cans have been damaged or put out of line by the insertion of the bottom washers. The tray of cans containing paste and bottom washers then is carried forward to the bobbin feeding positions. While other operations in connection with cooking and closing of unit cells may be more or less mechanized, this is one operation, which to the best of the writer's knowledge, is always carried out by hand, and the Singapore plant operation is no exception. Highly trained and highly paid female workers insert the bobbins into the cans during this operation. Their work must be both rapid and careful because of the aforementioned considerations of high scrap cost from this stage onwards, and due to the fact that it is necessary to insert the bobbin into the paste containing can as soon as possible, and then to cook the cell as quickly as possible after that operation, if the paste is of the cooked variety.

Before the paste is jelled, however, centering jigs are placed on the cells in such a way that the bobbins are centered positively in the cans with an insulating wall of electrolytic paste surrounding the bobbin. The bobbin bottom is, of course, insulated from the can by the bottom washer. The worker putting on the centering jigs also acts, in effect, as an inspector, since she examines the cells rapidly before the final placement of the jigs for any obvious defects.

In the Singapore plant, using as we do, a cooked paste, the trays of cells are next carried through a hot water bath to cook or jell the paste. As the cells come out of the cooking bath and are removed for transfer to the closing sections, they are one hundred per cent inspected for any such defects as insufficient paste, high paste, bobbin chips, etc.

Since inspection labor is comparatively cheaper in Singapore than in the United States, the tendency of the writer has been to err rather on the side of too much inspection than not enough. Also, the factor previously mentioned of rather careless labor in general has made it seem wise to utilize a larger inspection staff whose function is strictly to find defective product and who, as a result, cannot adopt the "couldn't care less" attitude with respect to conscientiousness with any equanimity. Thus the cooked cells under the present system of inspection receive still another one hundred per cent inspection before they pass into the capping and closing lines. This inspection is in some respects a re-inspection at greater leisure on the same points which are check points for the end of cooker inspector, and are partly dictated by the fact that there is sometimes a considerable time lag, for one reason or another, between cooking and closing, and it may sometimes be possible after such a lag to pick up minor defects not readily noticeable before. After this pre-closing inspection, the cells are fitted with top-collars (see section in introduction on general construction of round cells), the electrodes capped with brass caps, and a blue metal cover spun onto the cell separated from the brass electrode cap which protrudes through its central hole by a red insulating washer. After the cell is thus closed with a blue metal cover, it is once again subjected to a searching inspection and if found wanting in any way, is removed, either for recovery if possible, or as scrap. We have instituted constant checks on the closing units to insure perfect adjustment within the narrow tolerances allowable, and consequently high seal effectiveness and long shelf life of the cells involved. A few of the more important check points for the assembly department are herewith listed:

Paste Platform.

(1) Check solutions: temp., sp. gr., volumes in tanks.

(2) Check scales and measuring tanks for accuracy.

(3) Make trial batch of paste, noting formula, manufacturing conditions and final viscosity.

(4) Check on cleanliness of apparatus and containers to avoid contamination of paste by foreign bodies.

(5) Check on storage conditions of paste materials.

(6) Check on purification operations for raw solutions.

(7) Check paste at storage tank and at cookers.

Cooking.

(1) Room temperature and humidity.

(2) Viscosity and temperature of paste at main barrel; and viscosity of paste pumps.

(3) Bobbin wetness.

(4) Cooking temperature.

(5) Paste height.

(6) Check can feeders to see that no out of round cans are passed for cooking.

(7) Check bobbin feeders - see that they insert bobbins into cans properly, see that they brush bases of same before feeding them into cans; See that their hands are clean and free from loose mix and paste.

(8) Centering Jigs - (a) See that the jigs have complete sets of studs before allowing same to be used. (b) See that jigs are placed the right way to avoid cracking any bobbins.

(9) Inspection at take-off. Keep close check on hourly inspector at this point.

<u>Spinning or Closing Section</u>.

(1) Keep close check on inspectors inspecting on the runway.

(2) Depth of top collar.

(3) Electrode caps.

(4) Insulating washers.

(5) Blue metal covers.

(6) Inspection after spinning.

  (a) Check spin for high or low spins.

  (b) Condition of metal covers.

  (c) Condition of insulating washers.

  (d) Gauge check of metal covers.

  (e) Seal effectiveness (vacuum or bubble tests).

(7) Grind base off cell after (a) spinning (b) after capping - check condition of star washer.

(8) Condition of top collars after spinning.

Any gross defects which might speedily lead to a shorted or otherwise ruined cell will have been spotted long before the cell has been passed after the spinning on of the blue metal cover. It may be, however, that some minor constructional defect has slipped by unnoted, and which, while not immediately apparent, could in some instances lead to eventual short circuiting of the cell or low service life thereof. Generally such hidden defects will take the form of a very small and relatively high resistance internal short circuit which may be caused by a small piece of mix which has crumbled off the bobbin and forms a bridge through the paste wall, or possibly a mispositioned bottom washer.

It is the writer's understanding that experiments on the internal resistance testing of dry cells by means of radio frequency currents have shown great promise and that test equipment making use of these principles will be available for production use in the not too distant future. If this projected equipment becomes an actuality, dry cell technology will have a tool capable of detecting these very minute short circuits in dry cells which are not sufficiently low in resistance to appreciably drop the open circuit voltage of the cell, so that detection could be made by means of an ordinary volt meter. With the advent of such equipment it will become, therefore, possible to test production immediately after closing and route this production, without further delay through the finishing operations and into finished stock.

At the present time, however, the best practical way of insuring against bad cells being packed into finished stock is the use of a so-called aging period of several days (even though we may only be talking in terms of a very few cells per thousand having such faults, if these faults may produce serious perforation and deterioration later on, it is obvious that one such bad cell might contaminate several adjacent ones in the final packing.

Too, the psychological effect on a customer of finding even one bad cell in a thousand in a newly opened consignment is not one which we like to envision. Notwithstanding all advertising claims to the contrary, there is no such thing as a "leak-proof" cell; there are simply some cells which are somewhat more resistant to leakage.)

By storing all cells for several days before final testing and packing, we are able to pick out the borderline defects by means of simple voltage checks, providing, of course, that a high degree of accuracy is maintained in voltage measurement, as even those cells only very slightly defective will fall off a few hundredths of a volt in a week's time. It is part of the uncertainty of battery production that all cells cooked on a given date, with exactly equivalent components and conditions, will not check out exactly at the same voltage. However, within a spread of a few hundredths of a volt, all good production will fall in a relatively tight grouping. The exact range of voltage depends on the type of mix composition being used. Once a fairly large sample of cells from any particular cooking date have been tested for voltage and the range applying to that date determined, it becomes possible to draw a line between voltages of cells having no defects and those few having small, but potential trouble making disqualifications.

In the past this testing after the aging period was done by hand by trained operators; at the present time it is being done by a fast and efficient automatic machine which rejects all defective cells without the necessity of any individual action on the part of the attendent personnel.

Into the finishing department, besides the flow of cells from aging stores discussed above, come the materials and components which are needed to put the basic cells from aging stores into finished form. These components include various types of paper in huge rolls for the manufacture of jackets, labels, cartons, wooden packing cases, etc.

All the operations which go into the manufacture and assembly of the labeled jacket are carefully controlled for quality points, but in general present relatively few problems once the machinery is properly set up. Generally the tube making operation is similar to that which would be encountered in a mailing tube factory. One point with special reference to Singapore might, however, be mentioned and that is the difficulty experienced in maintaining stocks of label adhesive in good condition in Singapore's very humid climate. The label adhesive being an organic substance tends to become damp and lumpy, and sometimes we have found that special formulae and treatments are necessary to produce adhesive mixes of suitable quality.

The main function of the finishing department is carried out in one more or less continuous assembly line operation. The cells from aging stores are fed into an automatic cleaning machine which results in the cells emerging with brightly polished bottoms both as an appearance factor and for improved electrical contact when used in regular cylindrical flashlights. Since most of the dry cell production in Singapore is devoted to individual round cell types, all the foregoing comments have been based primarily on the factors influencing their production, but we might point out here that in the relatively few batteries of other types produced in Singapore which utilize several cells in soldered connections, and which are surrounded by some special nest type provided with special terminals, the bottom cleaning becomes superfluous.

After this cleaning operation, the cells are fed directly into the automatic voltage tester described above and any defective cells are automatically rejected by this tester. At the same time the cells receive an intensive visual inspection with several inspectors concentrating on each line of cells going through and out of each automatic voltage tester. Here again, the departmental inspector is always on hand and makes continual checks on the operations being carried out by the inspectors.

After this intensive visual inspection, the cells continue down the finishing line and are placed in the labeled tubes by hand operation. Here again, this is an operation which can be done mechanically with good success, but the economics of labor costs and capital investment have been such in Singapore that manual finishing is still the preferred method. Also, here again, we are speaking of individual unit cell finishing as noted above, and not of battery finishing in the true sense of the word. After being tubed and placed into cartons by the tubing operators, the now finished cells are given a final inspection at the end of the line by a highly trained and highly supervised hourly paid inspector. Finally, the cartons of finished cells are wrapped in water-proof packages and encased in wooden boxes for immediate shipment or transferred to finished stores while awaiting final shipment. A few of the more important check points which we have categorized for the departmental in spector are given herewith:

Finishing Dept. - Check Points:

Chipboard Slitting.

(1) See to the setting of blades.

(2) Measure the thickness of paper and size to be cut.

Duplex Kraft Slitting.

As per Chipboard slitting.

Duplex Kraft cutting to length.

(1) Measure length.

(2) Measure width and record maximum and minimum of both.

Tube Winder.

(1) Temperature of melting tank

(2) Level and temperature of coating tank.

(3) Size of gap.

(4) Condition of cut edge.

(5) Tube length.

(6) Condition of saw.

<u>Tube Cutters</u>.

(1) Type.

(2) Length (maximum and minimum).

(3) Condition of cut edges.

(4) Condition of mandrel.

(5) Condition of blades.

<u>Labelling</u>.

(1) Condition of labels.

(2) Condition of labelling tables.

(3) Condition of labelling plates.

(4) Condition of adhesive

(5) Condition of bins.

(6) Condition of seams.

(7) Labels wet or dirty?

(8) Labels loosely wound or askew?

(9) Aging period.

(10) Code dates.

<u>Manufacture of Adhesive</u>.

(1) Weight of adhesive.

(2) Amount of H_2O.

(3) Temperature

(4) Mixing time.

Voltage Testing.

(1) Type.

(2) Cooking date.

(3) Cut off (target).

(4) Classification of low volts.

Finishing.

(1) Condition of polishing compound.

(2) Condition of machinery.

(3) Blast pressure.

(4) Speed.

(5) Condition of bottoms.

(6) Torch setting -(volts)) no. 27 only (a rosin sealed type)

(7) Condition of seal) no. 27 only (a rosin sealed type)

(8) Bottom inspection.

(9) Side inspection.

(10) Tubing.

(11) Final inspection.

Packing.

(1) Condition of lock seam wrap.

(2) Condition of packing cases, in and out.

(3) Condition of stencil.

(4) Number of nails used on 4" - 6" or 8" planks.

The finishing operations onthe battery types of production are also carried out in this same department and since the production of such types is relatively small, the assembly and checking of production is much less mechanized and consequently somewhat more prone to fall victim to the typical Singapore worker. For this reason we have found that a great deal more time proportionately must be spent on such small lots by more responsible wupervisory personnel than is altogether justified by the volume of production or the value of product involved.

As an example we list some inspection points pertaining to one small 4 1/2 volt battery produced in the Singapore plant which is at the same time one of the small number of batteries which are produced here using the older method of sealing by a rosin composition seal. It should be understood that these check points have been developed by the writer in addition to all the usual inspection operations on the component round cells going into this particular battery, and not as a substitute for them.

<u>Assembled Battery Check Points</u>.

(1) Are terminals symmetrical with ends of battery and with each other?

(2) Is rosin seal surface free from imperfections and generally satisfactory?

(3) Is terminal insulation properly fitted?

(4) Voltage and amperage check.

(5) Are battery sides and ends symmetrical?

(6) Are side and top labels secure and attractively fitted?

(7) Is physical construction generally sound?

(8) Is packing being carried out in proper fashion to insure good arrival of product?

All of these main operating departments which have been dealt with above have corresponding daily report forms as a part of the quality control exercised within the departments. Usually several full page sheets per day are used to record all the routine check point observations and measurements as well as the general remarks and observations of non-standard phases of the departmental operations by the departmental inspectors.

Similarly, the general plant inspector, who is detailed to visit each operating department twice daily, keeps comprehensive records of his tours. All these record forms are filed for reference in the laboratory and on many occasions recourse is had to them when information on some minutiae of long past operating conditions is found necessary. The writer has developed some of these forms to meet new and changed conditions, while others have been taken over from previous years.

As a part of process quality control, the need sometimes arises for the appraisal of changes in operational procedure or in elements of process condition. In such cases the Works Laboratory in Singapore proceeds to make careful analysis of the proposed changes from the standpoint of over-all quality, basing its recommendations on the ever present necessity for a balance between conditions ideal for quality, and those factors which must be considered from a production and efficiency standpoint.

All process changes, whether they be temporary or permanent, are entered in the so-called "lab-diary" for a permanent record. This lab-diary has proven an invaluable tool and its scope has been considerably expanded during the writer's period of work at Singapore. All senior quality control personnel have been encouraged to use this lab-diary extensively in order that all process changes, however unimportant they may appear at the time, can be entered into this book so that the human element of (possible) poor memory is insured against as far as possible. As we shall see, this lab-diary plays an important part in some of the periodic quality reports which are compiled by the writer and also in drawing up the various control graphs and charts which have been instituted in the past few years by the writer in Singapore. All material shipment changes are entered into this lab-diary as well as mechanical and process changes applying to manufacture. At least once, a possible major quality trouble was picked up in its early stages and eliminated before becoming serious due to the ubiquitous nature which this laboratory tool has been deliberately forced to assume.

One of the most important phases of quality control work in Singapore is the extensive routine service testing schedule which is carried out on all Singapore manufactured products. A large number of cells are taken each day for these service tests which are made on cells at various stages of age from immediately after spinning to many months. All the cells taken for test in the Singapore factory are given exactly the same treatment as the standard production being packed and are chosen at random so that a completely general character will result from the sampling procedure. Various tests are carried out on the cells so selected, these being the standard flashlight tests as enumerated by the Bureau of Standards[45].

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(45) Letter Circular No. LC 965, op. cit.

Testing is carried out in a humidity and temperature controlled room so that ambient climatic conditions in the laboratory proper will not cause fluctuations in service values. This safe-guard is necessary due to the fact that dry cells exhibit a positive and direct dependence on temperature in the service given. This is true, of course, only up to certain limits, but within the range of normal room temperatures in Singapore, this effect is large enough to cover any minor fluctuations to such an extent that the use of service curves drawn from cells tested in varying temperatures would have little value as a diagnostic device for quality control work.

All the routine service test results are recorded, of course, in our permanent records and with the addition of information from the previously mentioned lab-diary, these service results form the basis for the large quality control graphs maintained by Works Laboratory. Other routine tests which are carried out by the laboratory include daily determinations of the seal effectiveness of the cells produced as well as frequent calculations pertaining to bobbins for determination of packing percentage. This latter measurement is one which has been initiated during the writer's tour of duty in Singapore. Many other routine tests are made, among them daily determinations of moisture content in mixes, frequent checks on manufacturing equipment such as scales, measuring tanks, and allied equipment, to insure proper formulations of process mixes and so on. The routine service testing procedures have been written up as a standard method so that deviations in sampling and testing procedure could not creep in due to personnel change or other disturbing factors. Here again, the concept of the standard method as a tool has been emphasized to the individuals involved.

In order to be sure that shipping and storage conditions were not such as to cause serious deterioration in Eveready products, a system of checking such shipped products has been instituted. The method involved is simply to have various of our leading agents around the world send back small consignments of Eveready products for test in Singapore. Knowing the age of the products involved and the service results of equivalently aged control production, it is possible to evaluate the deterioration--if any--due to extreme conditions in shipping or storage. These returned product cells run the same gamut of tests which are applied to regular production samples. A standard method has been drawn up to cover the over-all system of test which has been set up for these returned products. A master record sheet has been designed for each year which shows all the important details of the returned cells and their test results, such as areas from which shipped, date received in Singapore, service given on the various types of test, and so forth. This master sheet gives a quick easy summation of the position in regard to the returned cell test program at any time.

Equally important to quality control in this field is information on the level of quality and service given by competing brands of analogous products. In order to maintain a comprehensive, up to date picture of competing products in the widely distributed markets for Singapore products, a program similar in operation to that involving our own shipped production has been set up. This program aims at testing as many as possible of the leading brands of competing products which are sold in the same areas as Eveready. Here again, reliance is placed on the local agents at various points to provide frequent samples of leading competing brands for our analyses and tests in Singapore. A master summary sheet similar to that described above for returned Eveready products is used to correlate the results from these competing product tests. A comprehensive file has also been set up to include detailed reports on the constructional peculiarities of the various competing cells. It has been gratifying to note that the emphasis on quality control in Singapore has resulted in a product far superior to any competition met with in the Singapore Factory's sales areas. A standard method covering the testing of competing product cells has been drawn up for the exact standardization of future efforts in this field.

One more category might be included under process quality control, and this is the handling of any complaints which come into the factory in regard to quality of Eveready products. Happily enough, this phase of our work has been increasingly small during the past few years, and it is only the occasional few cells which are returned to us for checking. In 99% of the product so returned, there is no material or manufacturing defect whatsoever, but merely a case of some dealer's having kept a few cells for three or four years in a back cupboard, and then finding that these cells did not result in a particularly bright light when sold to some trusting customer. It is, of course, obvious to anyone with the least technical knowledge that dry batteries are relatively perishable items but the average Asian dealer doesn't understand this, or prefers to pretend to not understand it. A standard method has been drawn up for the benefit of the laboratory personnel charged with the examination and analysis of such returned product, and could become an invaluable guide if the need arose. This possibility is satisfactorily minute.

A part of the laboratory's function which can probably be classified under process quality control is the periodic sampling for test specimens and for appearance samples to be sent to head office. Such samples are picked at random from process stock and are in no way "dressed up" for the benefit of the front office. Standard methods have been drawn up for the sampling in both these categories.

A vital part of process quality operations in Singapore is the constant analyses carried out on cells rejected during manufacturing operations. By making such detailed examinations, it is often possible to pinpoint the cause of any unusual type or number of rejects, even in those cases in which careful study of the operation involved might fail to show clear cut reasons for the scrap being encountered. One of the most important types of scrap encountered in dry cell manufacturing is a low volt scrap. While the procedures carried out in the Singapore factory give positive assurance that no such cells will find their way into the consumer's hands, the amount of money involved in scrap is such that a reduction of even a minute fraction of one per cent in the scrap rate will result in substantial gain to the organization. For this reason the writer has emphasized the dissection and analyses of low volt rejects and a number of such scrap cells are opened and examined daily. Procedure for this work has been outlined in a standard method which in this particular case can only be a skeleton guide to the analysis procedure since the range of possible conditions is too varied to lend itself to complete and exact delineation.

A lengthy training program was carried out for all the departmental inspectors in the Singapore factory. This program aimed at giving the various inspectors a better understanding of departments other than the ones in which they worked, as well as of their own departments. The overall relationship of one department to another was stressed so that all quality control operations carried out in individual departments could be related to their ultimate aims. As a corollary of this, it was hoped that the various departmental inspectors would be able to achieve a larger viewpoint and, by gaining additional latitude, would become more interested in carrying out their part of the team work. At the same time inspectors who have passed through such an over-all training course become more adaptable in quality control work in general and present more fertile prospects for any necessary transfers which need be made between departments. The course was carried out by means of lectures and demonstrations in the various departments concerned and certain more important points were emphasized by requiring written notes. Written tests were given at several stages of the course, which lasted for several weeks--on a part-time basis, of course. It is the writer's belief that this not inconsiderable work was not altogether wasted, but at the same time he cannot help but reflect once again that the average monthly paid inspector available in Singapore is far less interested in increasing his knowledge and his potential by means of such a study course than would be the average junior assistant in the United States.

There are exceptions, however, and the writer has been fortunate in that one of the inspectors available to him at the start of his tour has shown great capacity and energy. This man has been advanced in salary and responsibility as fast as possible, and has made it possible for the writer to delegate many matters of routine importance to him without any close supervision being necessary. This man is definitely an exception.

Another result of the course mentioned above has been the collation of the lecturer's notes used, into a series of "Laboratory Check Points for Inspectors" now used as standards and in training new inspectors.

The next major division of quality control work in Singapore is that concerned with evaluation work. If any of the process changes mentioned above are major ones, or if, as happens more often, a previously unused brand or source of material is contemplated, comprehensive evaluation tests are necessary. Great strides in developing the theoretical background of dry cell technology have been made in the past few years and are continuing to be made at the present time. Even so, the manufacture of dry cells is still in many respects a mechanical and chemical art rather than an exact science. In other cases, even though it has become possible to set standards by tests derived from theory and past experimentation, the equipment involved is so elaborate and expensive that only a huge organization can contemplate the installation and routine use of such equipment. An example of this is found in the application of X-ray diffraction methods to manganese dioxide ore. Even were this method capable of definitely determining the quality for dry cell use of manganese dioxide ore, which it cannot yet do, the installation of such equipment would be beyond the resources of a company such as National Carbon (Eastern) Limited. Thus, the only safe way to study the application of any previously untried material which forms a major component of the dry cell, is to use some of this material in actual production and test the resulting product by means of the standard service tests. The same arguments of ultimate uncertainty of result apply to any major process changes which must be handled in a similar fashion to avoid the possibility of major trouble which could result if any such process was put into general effect without this preliminary.

Since the Singapore factory, like most commercial enterprises, was built as a profit making entity, a primary consideration of raw material procurement is price, always with the proviso that quality standards cannot be sacrificed to gain temporary economic betterment. The world markets from which Singapore factory draws its raw material needs are extremely widespread, and for multitudinous reasons of world wide economics, politics, etc., are continually changing.

The net upshoot of all this is that it has been found necessary to embark on a very widespread program of evaluation tests. Since the writer's coming to Singapore something over two hundred such individual tests lasting from one year upwards have been initiated. Needless to say by now, the initiation and development of all such evaluation tests are covered by a standard method. These tests range through practically all the materials which go into dry cells and include as well many test lots of sample cells designed to elucidate the results to be expected from various types of process changes. Thousands of test cells are involved in this program and we envision no lessening of the load in the near future. It is not hard to understand that all this work has resulted in the need for expanded laboratory staff; such expansion has indeed been the dominant motif in the quality control department since the writer's tour began in Singapore.

The last division which was mentioned as a factor in quality control work in Singapore was "trouble shooting" in general. Actually, this rather sporadic work is largely taken care of in our discussion above of process quality control and evaluation. Such things as raising or lowering the concentration of several hundred gallons of incorrectly blended chemical solution due to some sleepy Indian's contemplation of Nirvana pretty well represents the type of thing which we run into occasionally. Usually such incidents, while annoying and resultant of lost time, can be cleared up by a few quick emergency calculations or a few process alterations. Sometimes, however, mistakes brought on either by carelessness or through no fault of anyone in particular, result in sizeable amounts of material being lost beyond redemption. In such cases it is the quality control department's responsibility to carefully check the material involved, first of all to make sure that it really is a total loss, and secondly to enable safeguards to be set up against a reoccurance of the faux pas.

Due more to exigencies of personnel in the early days of the Singapore battery plant's operation than to any cause, scrap control has always been vested in the Production Manager's hands rather than properly in Works Laboratory. As a result, Works Laboratory does not handle scrap reporting directly, but is of course "in" on this control. In the Arc Carbon plant, the control of scrap in all its phases is directly carried out by the Works Laboratory, however.

All of the major divisions of quality control which have been dealt with in some detail in reference to dry cell production are also present, potentially at least, in the production of projector carbons. However, due to a somewhat different raw material supply situation, the functions of the local quality control department in regards to arc carbon production are essentially limited to process quality control and to associated routine tests, plus occasional trouble shooting. It should be plain to see from the foregoing that raw material examination and the necessity for evaluation work in large measure go along together. If it is feasible or necessary to obtain the major components of a product from a single and inherently trustworthy source, it is obvious that both raw material examination and evaluation work become less paramount in importance. This position is largely in effect in the projector carbon manufacturing operations in Singapore; that is, the larger part of the quality-wise important materials are obtained from associated companies in the United States. Complete and comprehensive raw material examinations and all necessary evaluation work is generally carried out on such materials long before they reach Singapore. Part of the finalproduct is in semi-finished form, even before operations are commenced at this end.

Raw material checks are still carried out, but in some ways act more as a check on packing and shipping conditions than on the inherent quality of the materials themselves. Evaluation work of major components of projector carbon production is nil, but other evaluations are done such as packing for carbons.

Due to the extreme humidity in Singapore, it was early apparent that packing methods standard for normal temperate climatic conditions were far from adequate for the rainy part of the tropics in which Singapore is located. The result has been the development of an entirely new packing method and new packing materials. The methods change, of course, has been primarily the result of production engineering work, but the materials going into the new packing have undergone tests administered by the quality control department, and suggestions as to desirable chemical qualities of protective substances were of course forthcoming.

The process quality control in arc carbon is somewhat more complicated than in any one department of the battery factory, but taken as a series of sub-departments, the complexity of the problem is somewhat decreased and a better perspective obtained. Essentially, the arc carbon operation in Singapore consists of a large number of operations, most of which are carried out by hand, but which utilize machinery in each of these individual operations. We have previously given a brief outline of manufacturing technique for projector carbons, and it seems unnecessary and redundant to repeat that outline at this stage. We will instead talk briefly of the framework which has been set up for inspection operations.

The basis for the quality control in the arc carbon finishing department is a stage by stage inspection of the product as it progresses from the initial state of uncored shells to the final one of copper-coated, polished, and printed projector carbons. In each operation it is the operator's responsibility to check on and pick out any questionable product in the material supplied to him, as well as to pick out any faulty material resulting from his own work. Thus, the man at the pointing operation would be expected to pick out any short length carbons which might have resulted from poor technique or machine misadjustment on the immediately prior operation of sawing or butting to length. All such carbons picked out along the production line await eventual classification by the main departmental inspector.

The carbons which he deems irreparable are scrapped and entered into a general form provided which covers each operation for each type of scrap. In the vast majority of cases, however, slightly faulty production in most stages of the projector carbon manufacturing cycle can be repaired and, therefore, is consigned to the appropriate repair operation after check by the departmental inspector. Of course, his approval is necessary before any repaired production is passed for reintroduction in the manufacturing cycle at the appropriate point. Usually this approval is one which involves little need for decisions of anything but the most straightforward nature. If, however such borderline cases on repaired material arises, they are referred to Works Lab directly for decision in co-operation with the departmental manager.

One reason for the slightly different approach to quality control in the projector carbon manufacturing operations as compared to those in the battery plant, aside from the differences already mentioned in connection with the raw materials used, has been the relatively recent initiation of the projector carbon division in Singapore. During its formative years, a full time European manager has been working in this department and in some respects has taken over some of the functions which would normally be handled by service departments, such as Engineering and Works Lab. This has been quite in order since the man involved has had far more experience with all phases of projector carbon manufacture than any of the associated European personnel in Singapore. At the present time, however, the time has come to integrate the arc carbon production department into the frame work of the production and service organization of the Singapore factory as a whole. This has resulted in a steadily increasing transfer of some of the collateral responsibilities involved.

The form mentioned above for the classification and recording of manufacturing scrap, which is a daily one, is only one of several forms which have been developed to record operating conditions and quality-wise important points in the arc carbon unit. The arc carbon department at the present time utilizes two departmental inspectors, and in addition is visited twice daily by the general plant inspector. This inspection strength is none too great since the departmental inspectors must, in effect, work with all the production workers as floor inspectors due to the system which we have outlined of having each production worker act as an inspector at the same time. In addition the functions of the departmental inspectors have been organized to include a great number of regular process condition checks involving temperature and electrical measurements as well as frequent checks on specific gravity and viscosity of various process solutions and the thixiotropic masses used as coring mixes in the operations which give the modern projector carbon its characteristic core.

It is the responsibility of the departmental inspectors as well to carry out the equivalent of the routine service tests made in the constant temperature room of the Singapore factory's dry cell production. These routine service tests in the case of projector carbon manufacture take the form of burn tests on finished projector carbons picked out of production at random. Just as the routine service tests on battery products define the service which is being given to the customer, the burning tests on finished projector carbons elucidate the quality of these carbons in terms which have a direct bearing on their eventual consumption in cinema theaters. A great many points of interest are drawn from each burn test, but we will mention only the most important: the consumption rate per hour of carbons involved, the brilliancy of the crater light produced, the reaction of the carbons to low and high current loads, etc. These burning tests, however, do not by any means constitute the sole control tests run on production in the arc carbon department.

Regular analyses and viscosity measurements are made in Works Laboratory proper, and are recorded on specially designed forms which have been developed with an eye towards making all routine daily, or twice daily, determinations as simple and fast to complete as possible. One way of doing this has been to set the forms up in such a way that the analytical assistant can simply put certain figures into the proper diagrams, "turn the crank", and come up with the desired correction, if any, necessary. Again, this is something which may seem ridiculous oversimplification on the part of the quality control departmental manager, and so it would be if it was designed for use in the United States.

In addition to supervising the various production workers' operations from the quality control standpoint, it is necessary for Works Laboratory, through the medium of departmental and general inspectors, to control directly certain full time inspection jobs in arc carbon production. The most important of these are resistance testing, X-ray inspection, and final inspection. The projector carbons are tested at several stages for linear resistance, the millivoltmeter deflection method being used. In this method, an exact and carefully controlled current is passed through the projector carbon and the very small voltage drop occurring in a specified length of carbon is measured. By a judicious control of the current value and of the length of carbon over which the voltage drop is measured, it is possible to obtain a direct correspondence of millivoltmeter reading to specific resistance, using only powers of ten in the ratio.

The projector carbons are tested at several points for resistance, the most important check being made immediately before marking and final packing. The inspection operators on this point are regularly rechecked at varying intervals so that an evaluation of the thoroughness of their inspection can be made regularly. An operator in this position is rated both as to accuracy and speed. On the final printing and finishing line, all the projector carbons are X-rayed where applicable for the detection of voids due to improper or faulty coring. Were such voids allowed to exist in final production lots, they could cause serious embarrassment due to excessive flickering and sputtering in use.

The final inspection operation is also carried out on this same finishing line and is one which requires a large amount of co-operation on the part of the departmental inspector, since the operator at this point is not only expected to pull out any defective production for scrap or repair, as the case may be, but also to classify this defective product as to type of defect and cause of defect.

Probably the overweening problem which has faced us in quality control of projector carbons in Singapore, has been that of the local high humidity. This same humidity which results in material handling and storage problems in the dry cell operations in Singapore becomes even more troublesome in projector carbon work. This is due to two main causes; the first of these is the tendency of the bright copper coat on the high intensity type carbons to become dull and oxidized due to the moisture in the air after a short time in storage, either during later stages of manufacture or in final packed condition. The second factor is the tendency of the cores of all types of carbons, both low and high intensity types, to pick up moisture from the air in any but the driest surroundings, and to develop sputtering when burned as a result. The first necessity in the Singapore operations on this score was for an improved type of protective covering for the copper coated carbons and has been successfully met by means of a major development effort in Works Laboratory directed towards producing a suitable blend of waxes to provide the necessary qualities of protection and good appearance while at the same time maintaining properties which make it possible to use the blends developed in production polishing operations without the necessity for special handling. This developmental effort was matched on the mechanical side by the development of specific machines for the necessary and unique protection operations tantamount to operation in Singapore. Since the desirable quality of simplicity in machinery was foremost in designing this unit, both from a constructional and a maintenance viewpoint, the waxes developed had to be tailored to the machine as well as to the primary protective function they filled, as pointed out.

The second part of the problem posed by moisture conditions in Singapore, that of protection for the core materials in assembled carbons, resulted in nothing less than the necessity for an entirely new method of process stock storage and final pack. We will not go into detail on this point except to state that the eventual solution has been the use of airtight metal packs for finished product, and a humidity controlled enclosure for process stock storage and certain manufacturing operations. The role of Works Laboratory in this work has provided only part of the solution, of course, and a great deal of the work has been done by others. Nevertheless, many man hours of thought and experimentation on the problems involved have been given by quality control staff, particularly in the evaluation of packing materials. That all this work has been well worthwhile is shown by the really great difference in the appearance of NATIONAL carbons as they come from unit packs compared with all other brands of competing carbons locally available, whatever their point of origin.

This mention of competing carbons provides another analogy between the quality control operations in dry battery production in Singapore and projector carbon production here. Just as we attempt to examine, analyse, and test as many competing dry cells and batteries as possible, so do we make regular checks on all available competing projector carbons which are given exactly equivalent tests to our own products. The results of these tests are, of course, summarized and examined carefully for comparative resolution.

Still another parallelism occurs in the handling of any complaints which may come into the Works Laboratory on projector carbons. A special data form has been developed for any such complaints which provides in concise form all the important information pertaining to original tests on the lot of carbons, as well as tests on any returned samples with special reference to whatever in the performance of these carbons had been the subject of complaint. Wherever possible, a follow-up is made on the original user of the projector carbons involved so that first hand information may be gained as to the operating conditions under which the projector carbons were burned. This latter point is most important, particularly in this part of the world, since practically all theater projectionists show an appalling lack of knowledge on the subject of proper use of projection equipment and an equally appalling lack of interest in learning correct techniques.

To achieve proper operation of arc carbon projection equipment, it is necessary to maintain such equipment in first class condition and to hold burning conditions within a relatively narrow range. Many factors enter into such proper control, such as arc voltage, arc amperage, spacing between carbons, and alignment of carbons. The disregard of these factors both by the semi- or wholly illiterate projectionist found in this part of the world and by the theater managers, who would be expected to have a little more respect for proper technique, has to be seen to be believed. In practically every case, "complaints" on arc carbon quality so far have turned out to be caused by ridiculous abuse of the niceties of projection rather than through any inherent fault of the carbons themselves. Although it is too much to hope that such visits to erring theaters will remove the attitude of carelessness altogether, they may at least go some way towards correcting the careless impression of the customers involved, that difficulties they have experienced in projection have been due primarily to failings of NATIONAL carbons.

An approach is now being made to this problem, on a local basis at least, in that it is hoped soon to institute a seminar on projection techniques and on the basic facts of carbon arcs for the benefit of local projectionists and theater managers. A special training film has been obtained from the parent Company in the United States and the plan is to show this film to theater personnel in Singapore, with an accompanying series of non-technical lectures, the whole to be followed by question and answer sessions on a multilingual basis to further impress some rudiments of correct projection techniques on these theater people's minds.

Unlike the scrap control system in the dry battery section of the Singapore plant, this phase of arc carbon operation also rests with Works Laboratory. The approach here has been three-fold. The first aspect of the problem is the necessity for the assigning of production scrap to the proper operation for accounting purposes. This is done by means of monthly reports which are drawn up from the daily production records and the inspector's scrap classification forms. This monthly report also gives scrap in terms of pieces per thousand for each operation in the arc carbon unit, and shows a comparative chart on the relative size of scrap for each operation during the month.

From a production and a quality control standpoint, however, it is not enough to know the operation to which scrap must be charged, but it is essential to have at hand as well a classification of scrap as to type and cause throughout the whole department. To accomplish this aim, detailed classification charts have been designed both for individual lots of the various sizes and types of carbons so that trends of scrap from order to order may be compared, and monthly control charts which show a similarly exact break-down by type and size of the scrap incurred during any production month. These latter charts are also prepared from the daily reports submitted by inspection and production personnel and ultimately depend on individual examination of every piece of scrap incurred in the entire department for whatever reason.

The utility of such scrap break-down charts can hardly be exaggerated as a diagnostic device and a great deal of time and thought has gone into them to make them as effective a tool as possible in the ultimate work at which all scrap control is aimed, which is the elimination, in so far as possible, of all scrap.

The third and final phase of scrap control involves graphical presentation of production scrap results from each operation in or near to the actual operation itself.

It has been found that such a public presentation of scrap trends does more than any other single thing towards inculcating an interest in scrap reduction in those workers actually on the various manufacturing operations. Here, of course, the element of competition between various workers on the same job comes into play even though the Asian worker is not so much a "company man" as is his American counterpart.

Theoretical planning and works methods control are essential in any scrap control operation as is the co-operation of the supervisory personnel concerned. After all this is admitted, it is still impossible to escape the observation that scrap control is primarily dependent on the actual workers who handle the production jobs. The element of managerial and supervisory initiative is perhaps greatly emphasized in dealing with Asian workers, but it has, nevertheless, been proven that these workers, in their desire to "keep face" if nothing else, are susceptible to the pressures resulting from graphical presentation of their efficiency or their lack of it. At the same time graphical presentation makes it possible for the supervisory level employees to spot trends sooner and more positively than if the same data were available only as a series of periodic reports, no matter how frequent the reports. Certain process variables in the arc carbon department are handled graphically for these same reasons. Again, the over-all concept is one of the use of such charts and records primarily as a tool and not simply as a form of record.

The major operations of the quality control department in Singapore have now been covered, and only one collateral activity need be mentioned in addition. This work is of comparatively recent advent and concerns the quality control and comparative evaluation of certain other products manufactured for, but not by, National Carbon (Eastern) Limited. A branch of this company is one of the world's largest producers of flashlight cases, in Hongkong, but the quality control of this part of the business is not vested in the Singapore Works Laboratory. The only important products not manufactured in Singapore which are being tested here at the present time are incandescent mantles for kerosene lanterns. We have not included any discussion of the history or present character of incandescent mantle manufacture, since, as we have just said, these manufacturing operations are not being carried out by National Carbon (Eastern) Limited in Singapore. However, for the reader's possible interest, we are including in the bibliography a number of excellent references dealing with this intensely interesting subject.

Suffice to say in our present discussion that various qualities of incandescent mantles are being tested in Singapore for such things as longevity under operating conditions, light output, resistance to mechanical shock, and color value of produced light.

Although this mantle testing work is relatively small in extent compared to other quality control operations carried out by the Singapore Works Laboratory, it has been an interesting subject for the writer since the tests developed have been largely of his own design and most background material has been obtained by personal library research (with kind assistance from the University of Malaya in allowing him to use their reference files and Chemical Abstracts), since no comprehensive specifications of National Carbon origin were available for this subject such as are used continuously for our quality control operation in Singapore which deal with dry cell and arc carbon production.

Besides his attempts to build up the organization and personnel of the quality department in Singapore, the writer has endeavored to add some of the necessary analytical equipment not already available to the Singapore Works Laboratory. Naturally enough, such additions of laboratory equipment, especially those expensive items such as analytical balances and electropodes, cannot be added by simply signing a purchase order, and the process of more fully equipping the Singapore laboratory is by no means yet complete. Nevertheless, the writer is able to finish his three year tour in Singapore at this time (Spring, 1955) with the belief that the control organization in Singapore is a good deal stronger in equipment, as well as in personnel and methods, than it was three years ago.

Having dealt at some length with aspects of quality control in foreign manufacturing operations, it may not be amiss at this point, the end of this report, for the writer to give briefly some of his own reactions to the personal aspects of modern overseas work for the American engineer.

First of all, the primary reason for the writer's desire for overseas work has been satisfactorily realized thus far: the possibility to acquire a much broader training and experience in industry at a higher level of responsibility than would be possible to a junior engineer in any but the most exceptional cases in the United States.

The consideration of life outside business hours varies tremendously now from location to location, especially so since so many former colonial areas have now been handed over to the locals. In Singapore this hand over is not yet complete and the amenities of life are still such that no one need fear living in an attap hut, or going without favorite American brands of consumer products. On the other hand, the good old days of the white man in the East have unhappily gone forever, and no prospective foreign worker should envision a life of nothing but pink gins and deference. It is perhaps unfortunate that many Americans tend to think of life in foreign work as either roughing it on the edge of a malarial swamp, or living in a slightly smaller version of the Taj Mahal, for each point of view is equally erroneous.

Perhaps the most disturbing fact about today's foreign work for the American engineer, at least on the basis of the writer's own observations and those of his acquaintances of the past three years, is its uncertain future. The combined pressures of Asian nationalism and management desire for cheaper administrative costs are combining to result in more and more replacement of Europeans by Asians. That this replacement beyond a certain point appears short sighted and ultimately ruinous to overseas European business units to many, does not alter the fact that it is taking place. To sum it all up, the writer's reaction to the question "Should I, as a young American engineer, go into foreign work?", would be, "Yes, but don't expect to make a career of it".

CONCLUSIONS

The approach to quality control work in foreign locations demands somewhat more flexibility of mind on the part of the individual concerned in applying standard quality control procedures. A necessity for adapting methods to the peculiar mentalities of the workers involved is quickly realized.

The writer's experiences have shown that the use of standard forms, methods, and routines in far greater numbers than usual, are essential to define operational procedures for Asian supervisory help.

With appropriate care and test procedures it is possible to maintain quality equivalent to U.S. production even though operations may be made more complex by the non-availability of standard materials and services.

SUMMARY

A review of the history and present manufacturing techniques connected with the dry cell and projector carbon industries is given.

After a brief outline of the writer's previous training, a discussion is made of the quality control operations which pertain to the manufacturing carried out in National Carbon (Eastern) Limited, in Singapore. Examples are given to illustrate the aims of the writer in extension and improvement of the quality control work in Singapore during the past three years.

The methods used in this work are analyzed from the point of view of difference due to local factors from equivalent control operations carried out in the United States.

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