



CAPACITY ANALYSIS OF THE SILVER OXIDE-ZINC CELL (PHASE 1)

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Summary:

Electrical behaviors of the divalent silver oxide-zinc cell were analyzed for improving capacity and keeping electrodes from passivation or sharp increases of cell internal resistance in the course of discharge.

One of primary factors in relation to lowering performance can be depicted by cell internal resistance increase being created by various routes, first by insufficiency and/or the carbonation of the electrolyte, secondly by barrier blockage, thirdly by electrode passivation which are due to improper material use or wrong processing, and by gassing as fourth cause. The carbonation causes electrolyte to have impedance up as well as poor amalgamation, resulting in vigorous corrosion reaction of copper plated inner top, evolving hydrogen gas. Electrical characteristics of the cell was reviewed to elucidate relationships between the discharge capacity and the cell internal resistance.

1. Objective

I have tried to find out factors influencing to the low capacity distribution in Ago-Zn small button cells prepared from the labora-

tory scale production line.

It will be found some influential factors summarized in the section of the Discussion, but you feel it seems to require more extensive research to arrive in a firm conclusion for the more prevalent factors together with its mechanism degrading capacity performance.

Laboratory scale evaluation in parallel with that of preproduction scale were carried to dig out right causes and to apply them to actual production line.

Those major subjects I will review are as follows,

1) To point out factors and causes affecting on limited capacity being less than that of a rated, expected value.

2) To survey the possibility if the some amperage level (and/or impedance) could be used as a sorting tool for between poor capacity cells and the good ones without dead discharging tests.

3) To improve the deviation property, or obtain the uniform capacity distribution.

4) To establish a new cell design as to enhance processing and productivity increase, and so also to reduce production cost by eliminating or replacing by cheaper raw material, or

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changing of current manufacturing processes.

2. Introduction

Electrical test lab has run capacity tests of those button cells as indicated in Table 1, for Type I and Type 2 cells, and their rated discharge capacities, are at the load of 12.5K Ohm, averaged, 51.34 mah (standard deviation 5.0 mah), and 184.59 mah respectively.

For Type I cell case shows a little, about 6%, less performance than that of expected outcome level, the lot acceptance sets in limitation of 55mah for Type 1 cells.

Table 1.1 Type 1 Cell Capacity Status

(Cell feature: 55 mah at 12.5 K Ohm load to 1.2V at 20°C, Approximate volume 0.16cc, Weight 0.69 gram, OAH 3.556mm, Cell dia 7.874mm, Pellet Wt 0.180 gr, Zn Wt 0.0778 gr)

Lot No.	Lot Size	Capacity Status			
		Total ea	\bar{X}	S	Max
1	4,752	49	3.45	55.4	41.5
2	9,503	52.4	4.7	60.6	40
3	17,890	53.5	4.5	61.3	48.8
4	5,397	49.7	4	61.5	43.7
5	12,740	53.1	3.65	63.6	43.6
6	10,260	53.4		62.7	50.8
7	11,573	54.5		61.6	48.7
8	19,861	55.6		63.6	48.7
9	13,645	54.3		62.6	45.8
10	14,225	50.7		59.6	41.6
11	8,279	50.3		57.7	43.6
12	18,675	50.7		59.6	42.8
13	20,165	56.6		65.5	51.7
14	17,777	50.4	5.4	63.6	43.6
15	23,442	50.3	5.1	65.4	43.7
16	18,925	47.1	5.6	65.3	37.6
17	22,137	51.0	7.9	59.8	30.9
18	19,011	47.1	2.3	51.7	41.5
19	15,015	42.1	4.16	47.9	37.8
20	22,161	55.7	6.7	63.6	41.7
21	22,197	53.4	6.3	61.6	44.5
22	18,366	48.7	6.6	61.6	41.6

Table 1.2 Type 2 Cell Capacity Status

(Cell feature: Rated capacity 175 mah at 6.5K Ohm load to 1.2V at 20°C, Approximate volume 0.41cc, Weight 1.5gr, OAH 4.115mm, Cell dia 11.56mm, Pellet Wt 0.602gr, Zn Wt 0.240 gr)

Lot No.	Lot Size	Capacity Status			
		Total	\bar{X}	S	Max
1	3,368	180.4	10.9	189.3	143.7
2	11,986	186.0	2.9	193.4	183.2
3	9,336	187.0	2.8	193.4	182.0
4	4,408	188.7	2.52	193.4	183.3
5	5,231	188.0	2.24	193.5	182.4
6	12,901	186.7	3.06	193.4	181.9
7	6,482	180.6	19.9	193.4	130.4
8	6,432	182.7	2.5	187.0	176.7

Another noticeable problem as appeared in the data, that we have to consider strictly, is the wide range distribution of those respective cell capacity between highest and lowest one, furthermore, the big problem is the wide capacity variation particularly for those cells of Type 1 all by 15 mah in these test lots and the trouble which we are faced to in the course of pact-out operation is that how to sort out the bad cells from the good cells.

For a comparable information, let's review in Table 2, "A" Company's Reliability Summary Report. With the latter data we can see directly that with the smaller cell height and the diameter, the more difficulty brings about in the cell assembly, besides yields the worse capacity.

Table 2. "A" Company Cells Capacity

Cell Size	Load (Ohm)	Spec. requirement (Rated Min.)		\bar{X} (min)	S (min)	Lot No.
Type 1	12.5 K	58	52	56.11	4.59	131
	6.5 K	—	—	50.4	2.51	47
Type 2	6.5 K	180	162	186.0	1.64	141

Based on the principle of expected capacity from the construction of Type 2 cell, the

technically expectable power capacity, possibly drawn, from such Type I cell is about 64 mah, so far all the most of the various processing problems associated to its miniaturization are not concerned, say, troubles appearing in making the smaller cells.

Therefore this Phase I report is to deal first with the discharge characteristics out of the good and the poor capacities, and takes a little theoretical reviews in connection to the Observations in the section of the Discussion.

Therefore, this report is to emphasize that what kind of factors or causes are relating to the used material and to the employed operations that limits and lowers available driving capacity, and in Phase 2 is to find possible sorting processes of the poor capacity cells from the good ones.

It is further aim of this report in the Phase 2 how to increase Type 1 cell capacity, one of most triky cell size, to about 64 mah by improving anode reaction efficiency, while considering of all objectives described in the first page, and having a new cell design or

having a new cathode construction with a new cathode formulation. But in this Phase 1, discussions shall be concentrated to the Objective 1) and 3) as for primary review.

3. Observation

As represented in Table 1 both Types 1, 2, cells are resulted in inferior performance than that of "A" Company cells, particularly, it was severe for the Type I cells.

So five cells performing good capacity over 60 mah, and 33 poor cells below 45 mah were opened carefully and examined under 30 power microscope and those observations schetched in Fig 1.

It was remarkably distinguishable abtween good and poor ones, the latter showing anodes passivated along with partially discharged and so also for cathodes the featur of the typical and undesirous capacity performance for Type 1 cell is illustrated in Fig 1.1 and for Type 2 cell it was taken picture Fig 1.2.

Lets observe Type 1 poor cells' characteristics,

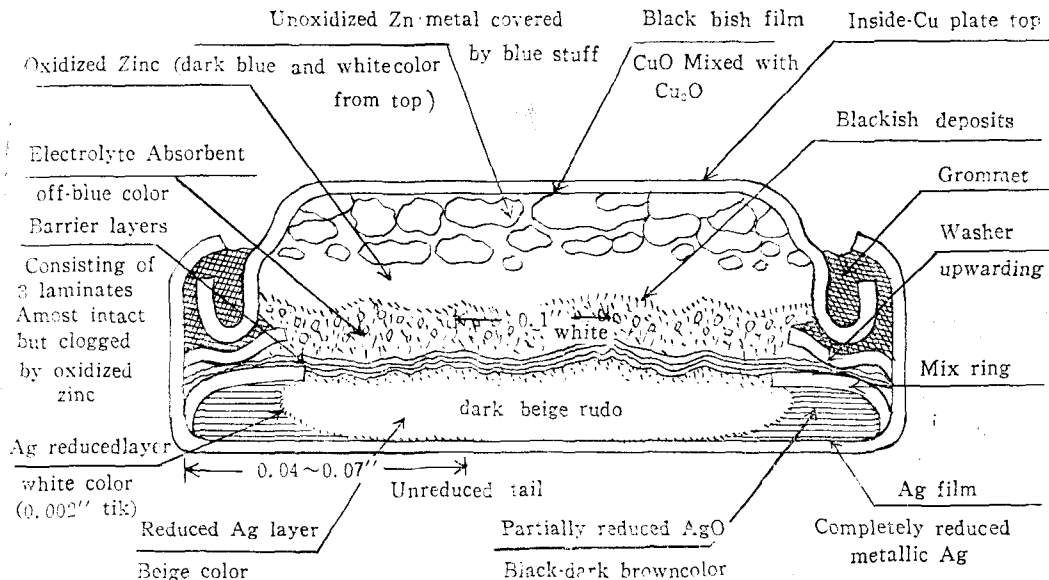


Fig 1.1 Cross-sectioned view of the Type 1 poor-capacity cells feature showing the weak power drain below 47 mah

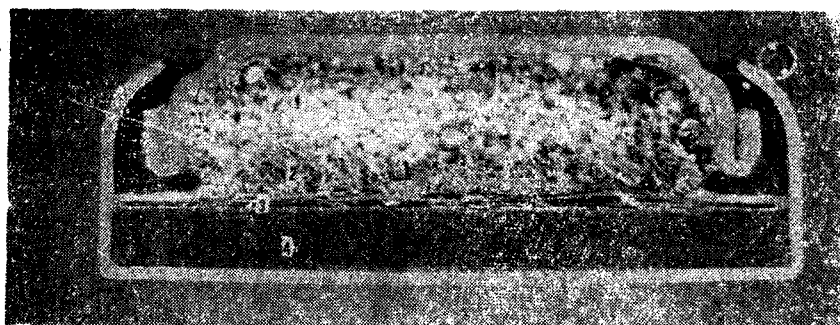


Fig 1.2 Cross sectioned view of Type 2 cell

- | | |
|--------------|--------------------------|
| 1. Anode | 2. Electrolyte Absorbent |
| 3. Separator | 4. Cathode Core |

1) Amalgamated Zinc anode:

Generally, highly oxidized product of the Zinc powders was observed near to webril side, whereas partially unoxidized Zinc lump cake appeared onto inner top surface. Mercury, now, appears in like small drops, not being amalgamated with Zinc cake and with copper plated surface of the inner top.

The whole anode looks dried owing to the lack of electrolyte supply and, resultantly, the surface-partially discharged Zinc cake adheres too strong onto inner top surface to remove it from it.

The partially discharged Zinc powder cake has shown blackish spots just beside metallic Zinc lump on which surface was covered by white or off-blue color Zinc-discharged-product.

There appeared often dark brown or blackish thin film on the interface between the undischarged Zinc cake and the inner top, of which film was analyzed and known as oxidized copper product, whereas good cells keep on amalgamated phase, being intact but partially oxidized upon the interface. This phenomenon in the poor cells seems to be explained that part of copper plate has been dissolved into electrolyte to react with it the-reon evolving hydrogen gas, this happens

even if plenty of electrolyte was supplied at the operation of cell closing.

2) Electrolyte absorbent:

It also looks quite dried out and discharged Zinc product has imbedded into throughout the disc and being colorful, but a little different, depending upon the cell discharging degree or on the color of intermediate species of the discharged Zinc products. It is dark blue around periphery of the disc, while being white and being intact at the center of the disc about "0.1" as dia, which constituting whitish granular of the Zinc discharged products or Zinc oxide species. This is translated into as for poor discharged cells the material trans-ference between opposite electrodes was limited and narrowed solely to central part of the disc, thus producing impedance increase in the course of discharging but not in the beginning as well as the end of discharging, and for those good cells remained undischarged although having sufficient active source, and the trans-ference might maintain proper balance and the disc contains high zincate on the side of anode. And those discs out of the poor cells very deteriorated, became almost to be shorted and we can see those small pieces of the fragments as shown clearly in Fig 2 of actual feature, this regards to vigorous

chemical reactions between electrolyte, mix core, and the absorbent material itself.

3) Barrier:

This barrier consists of three proprietary laminates, Permion red colored laminate that is sandwiched by Pudo made of transparent film of weak cationic cellophane. Poor cells the up-side Pudo still keeps on clear around the center of the disc, not blockaged due to any migration of discharged electrode chips, but contaminated to blue color at its periphery. Then the Permion layer was clogged by metallic Ag species, down-side Pudo also severely clogged by reduced metallic Ag, producing thick hilly layer and it was analyzed not to retain any Zinc oxide particles. Now by common sense, we can say that one of factors affecting to the low capacity performance was due to this blockage in the barrier, and most times the barrier seems to be clogged by hydrolyzed Ag_2O species during cell aging, it was characterized for poor capacity cells. There seems to be other causes creating blockage of barrier by reducing or hydrolyzing AgO pellets.

4) Cathodic core:

Particularly, under the mix ring, black Ag_2O core containing a little bit of AgO remains undischarged and dried. The borderline between of the discharged and the undischarged parts looks like a bow or a distorted 2nd order function curve as shown in cathode part of Fig 1. The worse capacity brings about when the more the x value and the constant increase in that 2nd order equation. The consolidated cathode core surfaces facing to the mix ring and the can has turned to thin Ag layer, as having metallic silver blisterness, which genuinely formed in the course of discharging. However, this is thinner than

that of good ones with better capacity. Silver layer generated at the bottom part of the cathodic core has indicated beige color or brown color, and there appeared on white layer between the undischarged Ag_2O core and this aforementioned fully reduced Ag layer. The undischarged Ag_2O core is likely to be sliced from that fully reduced Ag layer.

Here, we shall raise a question, what the determining process in this cell system is to control the reduction mechanism majorly in pellet, and what kinds of contributing processes are associated to that major determining process for the reduction. Many foregoing researchers (1, 2, 3, 4, 5) described somewhat clearly in this subject, therefore I will not discuss it in detail. In this silver oxide-zinc, system because of vigorous reaction of the zinc the Ag_2O pelletcathode reactive material is limited, hence, the poor discharging rate of the Ag_2O under the mix ring seems to be governed exclusively by the poor electrochemical reactions and half as possibly due to anodic passivation, since because Ag_2O remained undischarged for more than equivalent reactions, confirmed by chemical analysis. Possibly there may be some other subsidiary processes contributing to poor discharging rate, specially, under the mix ring, that developed by from outspecified subassembling conditions like loose pellet hardness, high carbonate concentration on the pellet surface and the uneven or partial pellet reduction degree ($\text{AgO} \rightarrow \text{Ag}_2\text{O}$), they are in combination or in sole playing just a role as obstacle. But the most remarkable thing to be aware seems to be the gap or the separation, as we observed, between the undischarged Ag_2O core and the reduced Ag layer, it should work on the impedance up resulting in ohmic polarization. Then those capacity-good-cells have not like this partial discharge.

5) Dimensional feature:

We have targeted Type 1 cells at 55 ohm after 30 days aging and assessed on the changes of their physical dimensions, before and after discharging tests. Lets see Table 3,

high capacity cells over 60 mah is showing the average capacity 62.28 mah and for the lowers below 45 mah is showing 42.02 mah, 45 mah the dead line is the minimum required range.

As shown the indications of the electrical

Table 3. Discharge characteristics and cells dimensional change of the Type 1 cell, total samples 140 pcs.

Capacity (Mah)	Discharge tested, before/after					
	OCV (V)	CCV (V)	IMPEDANCE (Ohm)	AMPERE (A)	OAH(mm)	Height(mm)
Higher $\bar{X}=62.28$	1.5906	1.3167	8.69/39.28	0.143	3.442/3.447 Increased rate 0.15%	2.5183/2.5506 1.28%
Lower $\bar{X}=42.02$	1.5895	1.3283	8.67/29.19	0.150	3.427/3.471 Increased rate 1.28%	2.5196/2.6248 4.18%

- * Passing point:1.3V
- ** Specification 3.25-3.48mm
- *** " 2.49-2.54mm

features above, the capacity-low-cells still hold working power, say, active material for more draining of power, and then the discharge reaction takes place in sluggish speed as illustrated in Fig 2 as of the limited capacity discharge. Something, changed

chemically or phsically being influenced by various factors during discharging, modifies the mass transference and the electrochemical reactions.

From the Table 3, we can also point out the low capacity cells have expanded

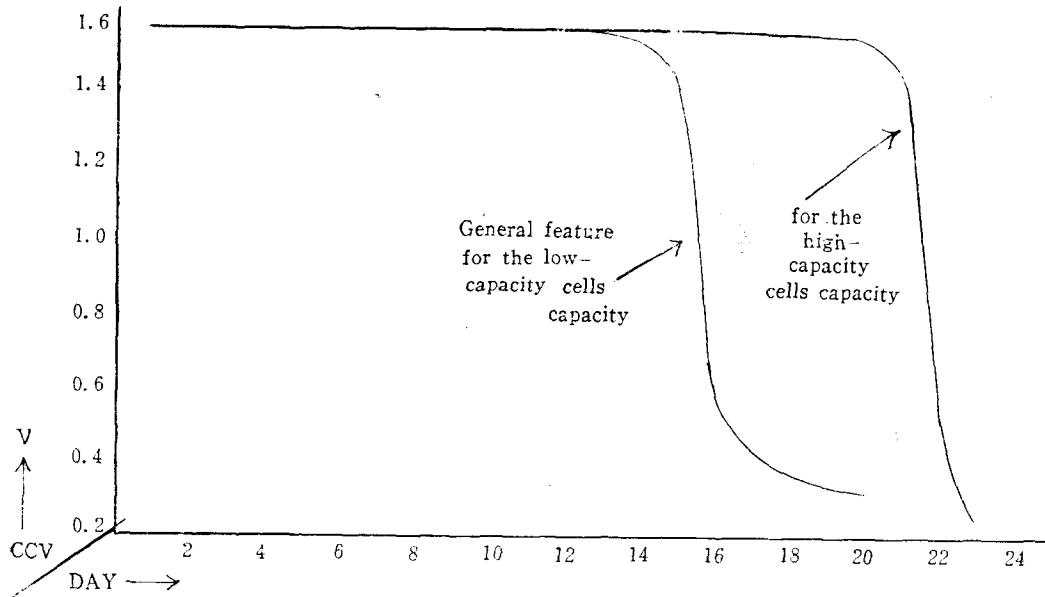


Fig 2 Discharge Profile of the typical Type 1 cell

apparently. This can be explained as the poor capacity cells might produce more gasses during the course of discharge, as referring to the results of background of the Fig.3 and Fig.4.

And the low capacity cells have shown a little higher amperage along with lower

impedance in the initial days or 7 days of the cell aging, then, this good properties would not be consistant all along across cell aging period of 30 days. This high amperage or lower impedance at the initial stage or during cell aging, might be ascribed somewhat to self discharge reaction and/or to

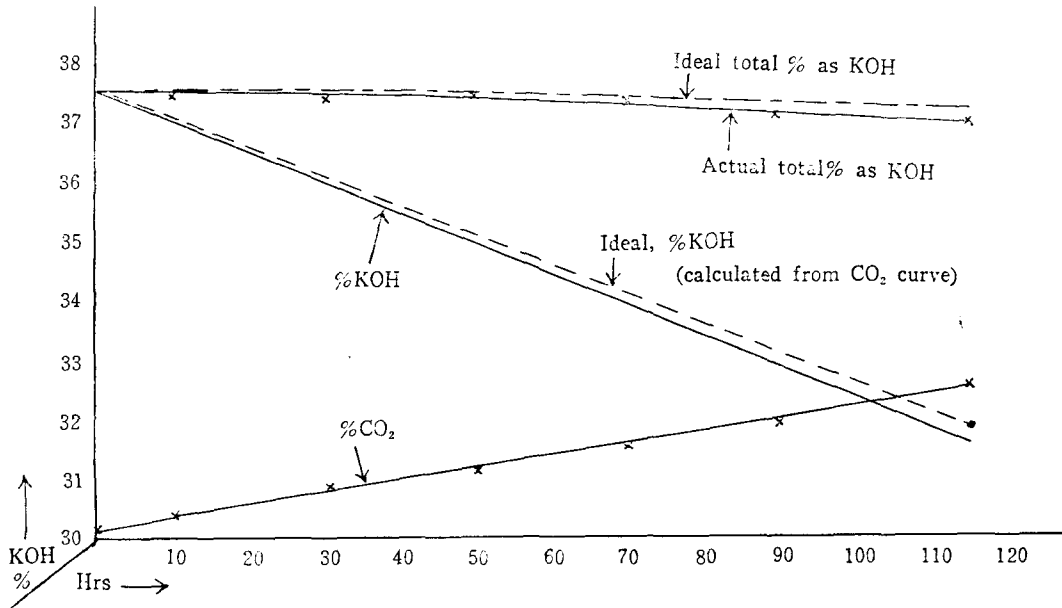


Fig 3. CO₂ Absorption rate in 40% KOH electrolyte
% CO₂ absorption/20cm² 10ml

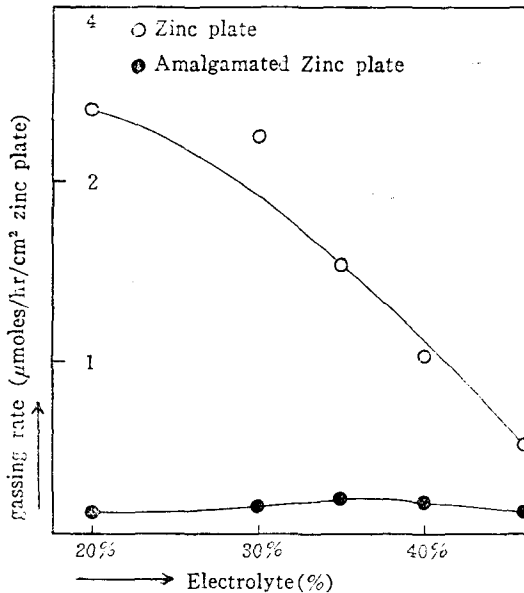


Fig.1 Rate of hydrogen evolution in KOH solutions at 44°C

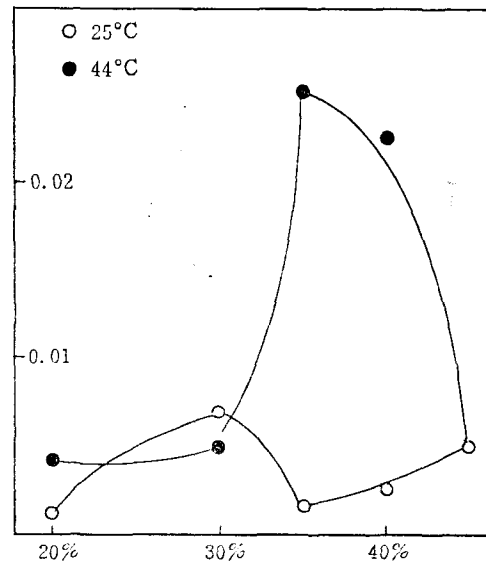


Fig.2 Rate of hydrogen evolution of Amalgamated zinc plate in KOH solutions

other side electrochemical reactions.

6) Materials and cell assembly processes:

All efforts have been exercised to meet the "A" Company's specification which is generally accepted and recognized as good processes to button cell designers, and all my attention have been paid to see if troubles would not happen to in the reduction-processing of the AgO cathode pellets, and in the consolidating of that pellets onto the cans, and in the cell closure.

All used materials have met the specified requirements in its purity except the use of a little higher grommet than provided spec. Therefore, the closing operation stopped often to secure right cell dimensions, changing dies and punchies, thus causing the anodic assembly (zinc powder-KOH electrolyte) to be exposed to open air. Consequently, electrolyte absorbent disc goes to pick up moistures from the air and there forms carbon dioxide, hence decreasing KOH concentration of the electrolyte as represented in Fig 3. The effects of carbon dioxide to the cell performance will be considered a little more in the Discussion and further more again in detail at the next Phase-2.

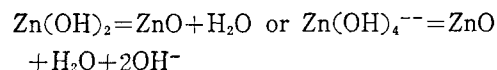
4. Discussion

4.1 Anode Reactions:

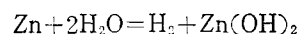
According to generally accepted knowledge and based on the observations as revealed in the foregoing Tables and the Figures, low capacity is governed by from all sources, or the processes associating to manufacturing, used materials or instinctive characteristics of the Type 1 cell like the cell miniaturization, and they are all working for the anodic passivation along with bad effects to material

transference.

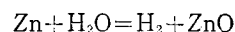
Since zinc is one of reactive metal group it is very likely to that a thin film of oxide is present on any zinc metal in contact with an aqueous solution, but is generally accepted that the discharge capacity of the zinc electrode in alkaline cell like this said system is proportional to the amount of KOH present per unit area of zinc. Because the extra KOH will dissolve more ZnO or Zn(OH)₂ before the passivating film is developed. In other words, capacity is limited and governed by the solubility of the discharge products into the available electrolyte. Zinc oxide being produced at the anode is done by processes,



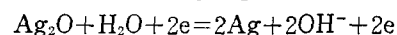
Because of the high solubility of the zinc-discharged products in the electrolyte, in such this case of low capacity of the Type 1 cells, that capacity performance is highly limited by the problems arisen at the anode side or the solubility limitation of the discharge products of the zinc. However discharge product's particles may form away from zinc surface which is surrounded by the electrolyte, and this phenomenon hinges on the various dependent and/or other independent variable factors. As shown in Fig 2, capacity-low-cells had made another discharge level at around 0.6-0.4V, such profile can be acknowledged certainly that zinc-anode turned to that of partially passivated,



$$E^* = 0.421 (\text{vs Hg/HgO} \dots \dots 1)$$



$$E^* = 0.420 (\text{vs Hg/HgO} \dots \dots 2)$$



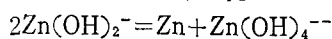
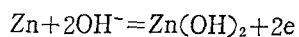
$$E^* = 0.342 (\text{vs Hg/HgO} \dots \dots 3)$$

(H₂O being supplied by the H₂O molecules bounding to K⁺ ions, i.e., K(H₂O)₄⁺, and it is more reactive than uncombined H₂ molecules.)

As the concentration of KOH increases, the activity of the water decreases, so resulting in a lower rate for hydrogen evolution. Moreover, the corrosion rate of Zinc surface decreases with increasing of KOH, and the formation of carbonate therein brings to decrease useful KOH concentration.

Now it comes to arrive in a prediction through above equations (1,2,3) along with the result of decrease of the KOH concentration, that the anodes of the capacity-low cells take the discharge level on which the reaction of hydrogen evolution generates. At this level most of the electrolyte would be used up due to development of this side reaction. However the capacity-good cells generally seem not to have this level.

We have often seen low-capacity cells having a blackish film or particles on the interface between electrolyte absorbent and zinc anode as shown in Fig 1. This black film under naked eyes is considered the deposition of finely divided zinc derivatives as given a formal mechanism, as we takes it in the Observation of the Zinc Anode,



4.2 Amalgamation:

We have tested gassing rate of amalgamated zinc powder with 18% NaOH solution at $74 \pm 0.5^\circ\text{C}$, hydrogen gas evolution from the amalgamated zinc has generally higher value tendency than nonamalgamated zinc, for instance, the latter 3.75 micro liter/hr/gram and the former 45.53 micro liter/hr/gram. Such phenomenon occurring at amalgamated zinc seems not to be expected as predicted from the indication of Fig 4-1, but higher gassing rate will be expected at higher temperatures as noted in Fig 4-2. However, the increased rate is regarded almost neglig-

ible as compared to nonamalgamated zinc plate. Then the gassing evolution tendency from this amalgamated zinc powder shows contrary results against to Dr. Dirkses' laboratory scale experimental results (6) which is based on the testing of the zinc plate. The difference can be interpreted as that there might be differences in the amalgamation % and also the amalgamation distribution for particle to particle, as well as in the test temperature difference, or 44°C and 74°C .

My sample of amalgamated zinc electrodes have shown lower-anodic overvoltage over a temperature range of 0°C to 50°C , and have higher limiting current density, i.e, they did not passivate as readily as unamalgamated zinc powder, based on the various effects of the mercury which is aiming to raise the hydrogen overvoltage, to minimize the self discharge reaction of the zinc electrode, and to lower exchange current for hydrogen evolution that is reducing open circuit voltage.

Zinc powders, after discharging test, turned to be a strong lump which composed of majorly undischarged zinc powders, since because water has been reacted partially generating hydrogen gas, having self or normal discharge reactions, leaving behind the condensed guar gum. Amalgamated zinc powder near to the inner can shall relatively lose some mercury to produce the copper-amalgamation. And there may be happen that the poor amalgamation of the zinc powders may play role to exercise another possible route for the tendency of hydrogen gassing and consequently cause to cell bulging upon discharging test as seen in Table 3.

Furthermore, thin copper plate on inner top was dissolved out and oxidized during the cell aging period thus certainly lowered the hydrogen overvoltage of amalgamated zincs

electrode. The corrosion speed of copper plate of the inner top became rated up in the presence of carbonated radicals in the electrolyte. As proved some cells producing long power drain have shown a inner top having intact copper plate, never noticing corroded spots or bleached spots.

4.3 Electrolyte:

A) Concentration of KOH

KOH concentration could affect to some extent to cell discharge capacity in certain range of electrolyte concentration, high

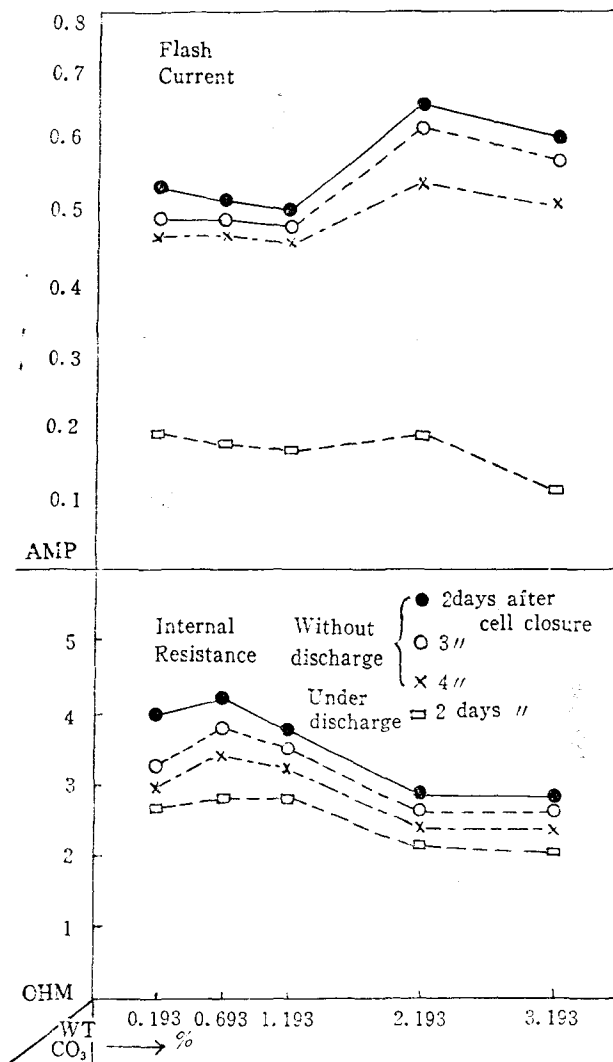


Fig 5. Type 2 Cells target data

concentration of free OH can be related to greater solubility of zinc oxide and hence larger amount of zincate is necessary in solution for replacing of zinc.

B) Carbonation

The presence of CO_3^{--} or oxidizing agent is assisting reportedly to attack and give the electrode surface to be rough, particularly, the insolubilizing CO_3^{--} tends to displace OH^- in the positive electrode resulting in a new electrochemical system as referred to Fig 3 and Fig 5 of which performance characteristics was far below than those of the corresponding electrodes in pure alkaline electrolyte. Fig 5 represents the relationship between the presence of carbonate in electrolyte and the all performance of the amperage and impedance.

The carbon dioxides normally develops in a large amounts during subassembly processes of negative electrode as aforementioned reasons and it plays to alter corrosion products from zinc oxide or its hydroxide to a basic carbonate of the formula $4\text{ZnO} \cdot \text{CO}_2 \cdot 4\text{H}_2\text{O}$. This reaction takes place in two stages, the zinc oxide forming first and later reacting with the dissolved CO_2 to form the basic salt, and then increases the rate of corrosion of zinc by aerated water.

With the increase of CO_2^{--} concentration in electrolyte it shows a tendency the decrease of KOH concentration as shown in Fig 3.

Another route for carbonate contamination into the cell electrodes comes from the process of the AgO pellet's reduction and AgO pellet's soaking process in the KOH solution for 24 hours. Carbonate concentrations in the silver oxide pellet after soaking increases about 10 times than that of original electrode mixture powder. Drastic phenomenon resulted from the presence of carbonate in the electrolyte influences for dissolved silver

species to migrate to the zone of the separator, and therein forming a circuit bridge toward negative electrode.

5. Closure

Generally whole, some lots, demonstrating low capacity are known that they have been assembled in the troubles of cell closing, calling for changes often of the closing-punches and its dies due to the control problems of cell's over all height (OAA) and closing height and also sharpening the bottom can edge.

These problems have been known in great part related to the use of the high grommets than spec dimension. During changing of punches and/or dies, as not being capped yet, cells shall absorb carbon dioxides or moistures to dilute electrolyte, sometimes, severely decreases to about 28% from 38%.

Therefore this process will modify or alter that expecting electrochemical reactions in cell owing to that decreased electrolyte concentrations, accompanying of the corrosion-reaction speed-up of copper and/or zinc, further increasing mobilities of discharged products.

Therefore it has been specified that the negative subassembly must not be exposed to open air over 20 minutes to protect this problem.

As noticed from the low-capacity cells they do not have amalgamated film onto the copper surface of the top, and the cell height has expanded, evolving gas.

So the increase of mercury thickness together with its uniform distribution onto zinc surface and copper plate have to be concerned in without overuse of mercury. The mercury

percentage in zinc powder should be maintained to acceptable range (7% Wt.) to retard hydrogen gas evolution.

The contaminations such as chloride or carbonate ions should be rejected as possible as it goes in amalgamation process because they shall prohibit the amalgamation to some extent.

Based on the discharged contour like of Fig 1 of which cathode pellet is surrounded by Ag_2O layer, we are possible arriving in to design a new cathode constructure, which will be rather simple and easy for pellet reduction operation. In such "A" Company's cell design (USP 4009056 2/22/1977), the cathodic reaction mechanism of $2\text{AgO} + \text{H}_2\text{O} + 2e = \text{Ag}_2\text{O} + 2\text{OH}^-$ starts from the upper pellet side. Therefore, to achieve one-plateau discharge even from AgO pellet for the sake of practical use, it seems not to be necessary certainly to cover the AgO pellet completely with Ag_2O layer with the beginning of consolidation.

Low capacity cells seem to have vigorous corrosion reactions of zinc metal during cell aging or in the beginning of the discharge and becomes passivated remarkably, so the anodic passivation plays highly to limited capacity.

References:

1. R.F. Amlie and P. Rüetschi, J. Electrochem. Soc., 108, 813 (1961)
2. T.P. Dirkse, *ibid*, 107, 859 (1960)
3. C.P. Wales, *ibid*, 116, 729 (1969)
4. B.D. Cohan and others, *ibid*, 107, 725(1960)
5. E.G. Gagnon and L.G. Austin, *ibid*, 118, 497 (1971)
6. T.P. Dirkse, Technical Report AFAPL-TR-69-90, Dec., 1969