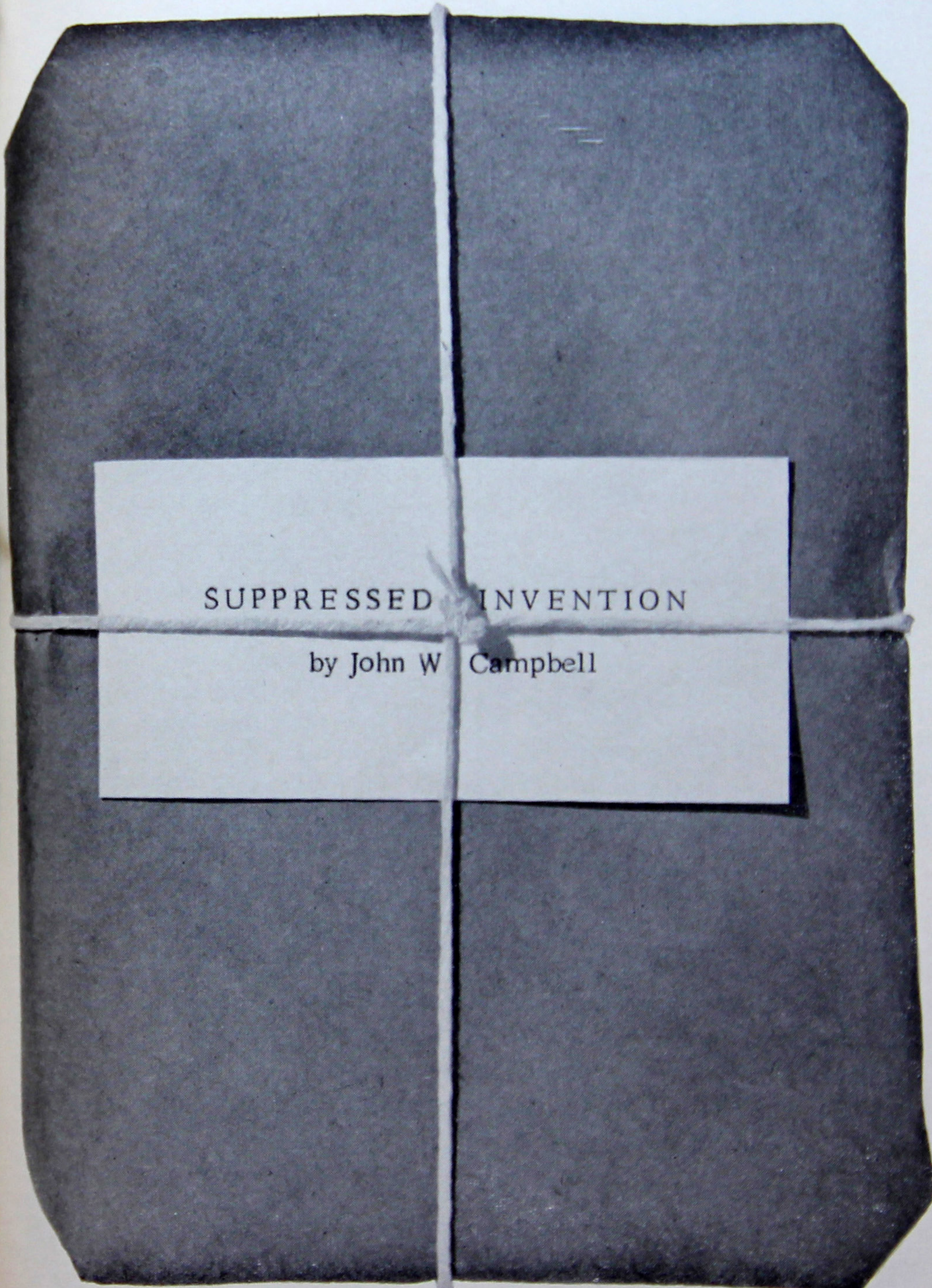

SUPPRESSED INVENTION
by John W Campbell

The high point in the movie "Edison The Man", featured a scene in which we see Edison and his crew of laboratory workers gathered around a single glowing electric light . . . waiting for it to burn out. And hoping it will last a long, long time.

The audience, of course, knew all

> A "suppressed invention"
> is one that Vested
> Interests have surpressed
> for their Own
> Selfish Reasons. . ?
> And of course that can
> only mean the Villains
> of Wall Street, huh. . . . .?
> Not this one, though—
> it was Ivory Tower
> Street that did it!

the time that *this* lamp was really going to work. But, if you happened to see that movie, did you think to wonder just what power supply was running that marvelous new invention, the electric light? It wasn't plugged into the wall outlet, you know! Edison and his gang didn't start inventing electrical power distribution systems until after they'd developed a working electric lamp, and a workable electric generator!

After Galvani first observed a dead frog's leg twitch when touched with two different metals, and Volta did his work on electrochemical cells, science for the first time had available a source of current electricity: the electrochemical cell—which was as remarkable and immense a breakthrough in its day, as the atomic pile was in 1942—and lead to the Voltaic Pile.

The early work done in electrochemistry—the first isolation of sodium, potassium, etc., by electrolytic methods—stemmed from the development of the electrochemical cell, the only source of electric power Man had.

That first electric lamp may have been powered by a type of battery that Edison had developed—one known as the Edison-Leland cell.

Dynamos existed at the time Edison developed his lamp—but they were marvelously inefficient, unreliable and impractical. The Edison-Leland cell was, actually, a type of fuel cell—not in quite the modern meaning of the term, but nonetheless effectively a true fuel cell. It burned zinc, lye, and air and produced electric power. The zinc plates were immersed in a sodium or potassium hydroxide solution; the positive plates were copper with copper oxide depolarizer. The cells delivered about 0.8 volts, and would supply a good husky current. They were simple, rugged, and relatively cheap—zinc is, actually, a fairly cheap fuel. The battery would yield a good current until the copper oxide gave out, whereupon the voltage dropped off sharply. So then the copper plates were simply lifted out of the battery, dunked in clear water, and shoved in the oven for a while—and the hot copper absorbed oxygen from the air, formed copper oxide again, and was put back for another go-round.

mary battery! Why waste time and effort, then, building the storage battery at all?

Once Edison developed the electric light, and the technology of a dynamo that was practical for supplying power efficiently, and then the technology necessary to ship power

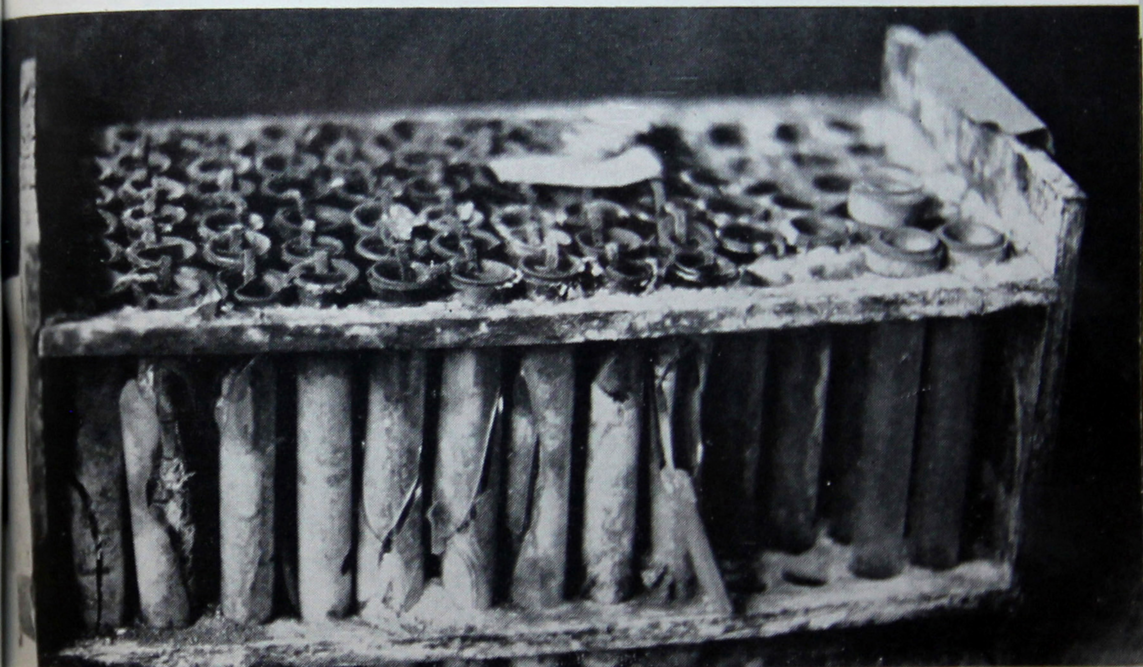


Fig. 1. Back in the 1920's, this was an Edison type Ni-Fe 135-volt Storage B battery for a broadcast receiver. Along about 1928 it was displaced by a powerline-operated receiver—and the owner stored it in a back corner of his basement. Some 30 years of 100% solid neglect later, it had achieved this state of obvious total ruin.

Nobody was much interested in storage batteries in those days; there wasn't any reason whatever for a storage battery, since the only practical source of power with which to charge the battery would be a pri-

from dynamo to point of use, *for the first time storage batteries became practical devices.* For the first time, there was a source of electric power cheaper than that produced by "burning" zinc electrochemically, and

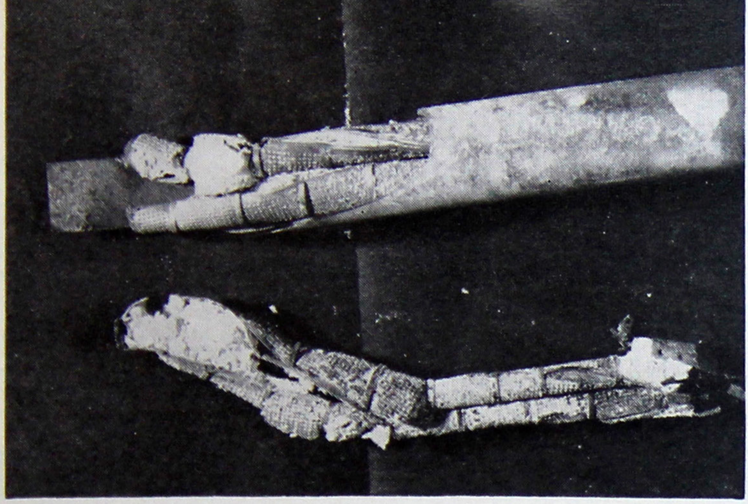


Fig. 2. The electrolyte—KOH—had dried out, absorbed carbon dioxide from the air, and in crystalizing out burst the steel tubes of the anodes, and the glass test-tubes in which they were mounted. Ruin obviously beyond redemption.

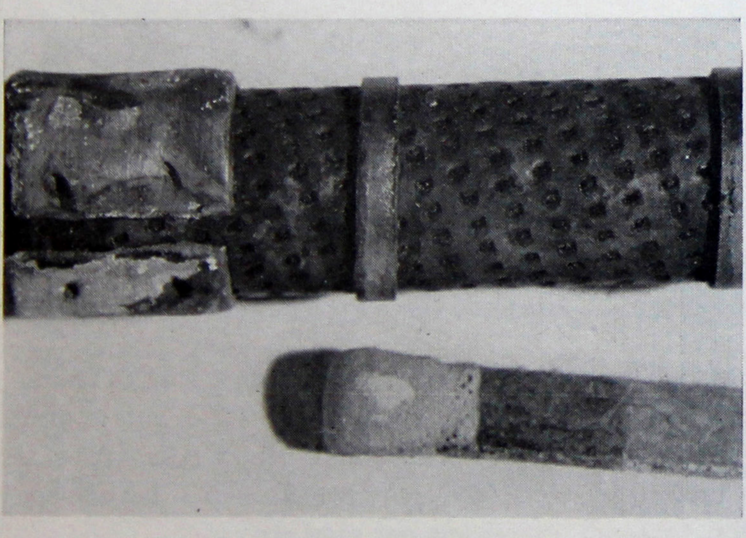


Fig. 3. Only . . . by soaking in hot water to leach out the carbonate, immersing in KOH electrolyte, and charging them . . . they proved to be in perfect electrical working order! Even 30 years of total neglect couldn't kill 'em! This close-up shows the mechanical structure of the Edison type $Ni(OH)_3$ anodes. Standard paper match for size comparison.

therefore cheap enough to make it desireable to store it instead of simply producing it on the spot.

The Planté storage cell—the original lead-acid storage battery—was invented long before, but strictly due to accident and misunderstanding; Planté had been trying to store electricity all right—but he was trying to make a condenser-type storage device, having no idea of inventing a secondary battery at the time. The original lead-acid cell consisted of nothing more complex than two sheets of lead dipped in dilute sulfuric acid; it's a fundamental system that works fine today, of course, as it did then—and for some special purposes makes a highly desireable type of battery. The capacity is limited, it's extremely heavy ("heavy as lead!") but it has a long, long life.

Once Edison developed electric power technology, however, the desireability of having a secondary cell

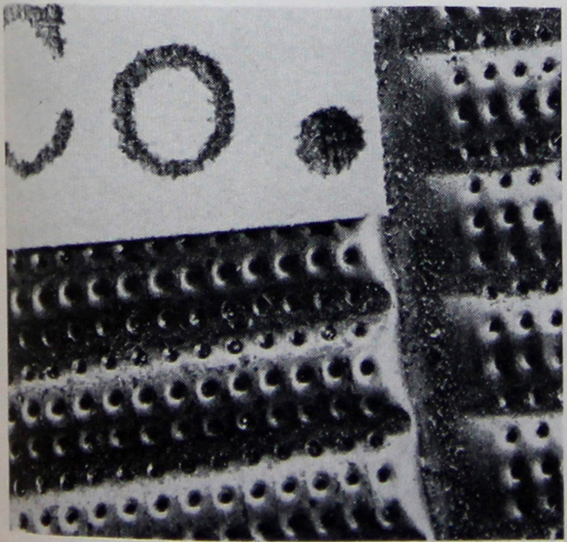


Fig. 4. The Jungner-type nickel anode uses a much finer-structured design for holding the active material—which is a major part of the reason Jungner batteries could be used for engine starting, while Edison batteries could not.

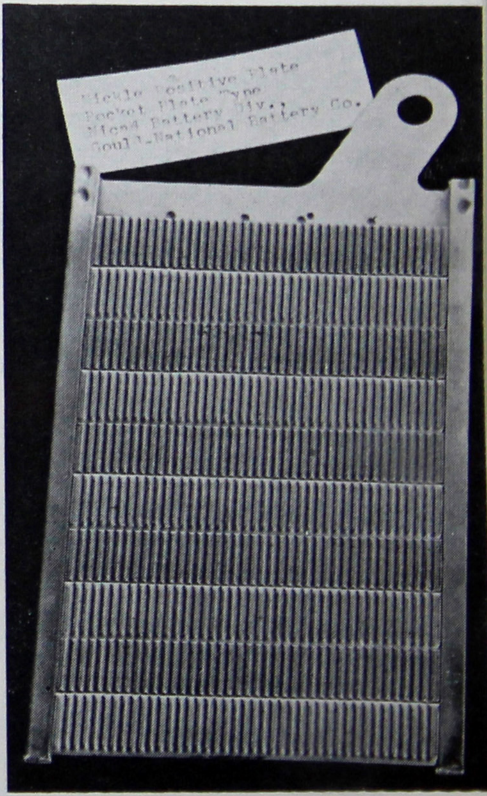


Fig. 5. Compare the very fine perforations of the Gould-National Nicad plate with the coarser structure in the Edison anode of Fig. 3. That's standard Pica typewriter type for size comparison!

became apparent—and for the first time serious efforts were directed toward their development. Edison always did think direct current was the only right way to work with electricity; for one thing, the problems of alternating current engineering were, actually, considerably beyond the theoretical capabilities of mathematical physics at the time.

But direct current presents some extremely rugged problems in shipping power from A to B. You can't build DC transformers to step voltages up and down, which means you've got to work with low-voltage, high-current equipment. Copper cables as thick as a man's arm are expensive—particularly when you want to run them ten or fifteen miles!

So Edison set about developing a better "bucket" to carry his "juice" from the end of his pipe-line to points beyond—and to make mobile electric-powered devices possible.

The Edison nickle-iron storage battery resulted from that effort; a storage battery that was enormously superior to anything that had existed, far lighter than the lead-acid type, far more rugged mechanically, chemically, and electrically. It had very real, and very great advantages over the lead-acid cells that were its only competitors—and a couple of minor disadvantages. Only—the minor disadvantages just happened to be crucial, and almost completely ruined its potential.

The Ni-Fe battery uses an electrolyte of KOH, laced with a little LiOH; the alkalie electrolyte is not

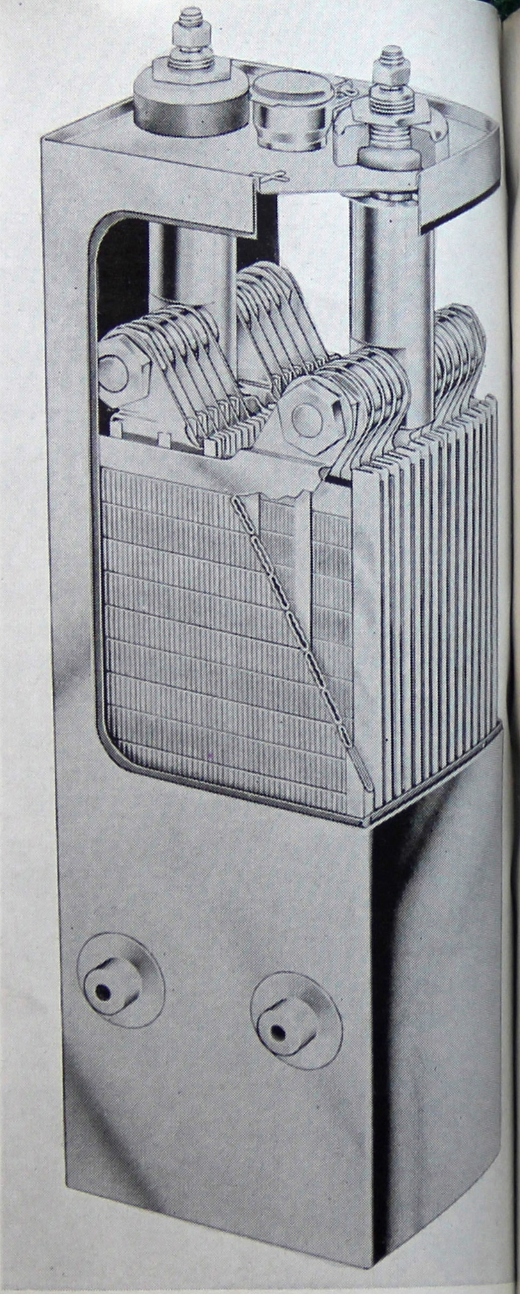


Fig. 6. This is a Gould-National Nicad cell in cut-away; both Edison and Nicad cells use the general structure made possible by the very high strength of the nickel-plated steel plates, and steel cell case. Separators aren't needed, because the plates themselves are adequately rigid.

anywhere near as destructively corrosive as sulfuric acid, and actually protects most metals against corrosion. The cells, therefore, instead of having to be made of glass or hard rubber, could be made of nickle-plated sheet steel.

The Edison battery is almost incredibly resistant to destruction either mechanically, chemically, or electrochemically; the plates are made of nickle-plated steel with small tubes of nickle oxide for the positive, and small flattened packets of iron for the negative. Currently, nickle sells for about 50¢ per pound, and iron is, of course, even cheaper.

The Edison Ni-Fe battery is very decidedly lighter per kilowatt-hour of capacity, and per ampere-hour, than the best lead-acid batteries. Their normal service life is about 5 to 10 times that of a lead-acid cell—15 to 20 years of service is quite normal for an Edison cell.

So—then how come we don't see Edison cells in use all around us? How come this wonderful battery never got much beyond first base?

Oh, they were used all right—they powered battery-operated electric locomotives, electric trucks, and are, today, being used in electric fork-lift trucks, baggage trucks and the like. They are, beyond question, excellent batteries.

But, look—how come the U.S. Navy didn't use these rugged, light, long-lived, reliable efficient cells in the pre-nuclear submarines? Certainly there was a place for a rugged, reliable, long-lived, low-weight, high-capacity battery if ever there was one—and it's a vehicle application, such as Edison had in mind when he worked out the battery?

Here, it seems, was a major invention that was somehow being neglected.

Well, there were a couple of leeetle defects.

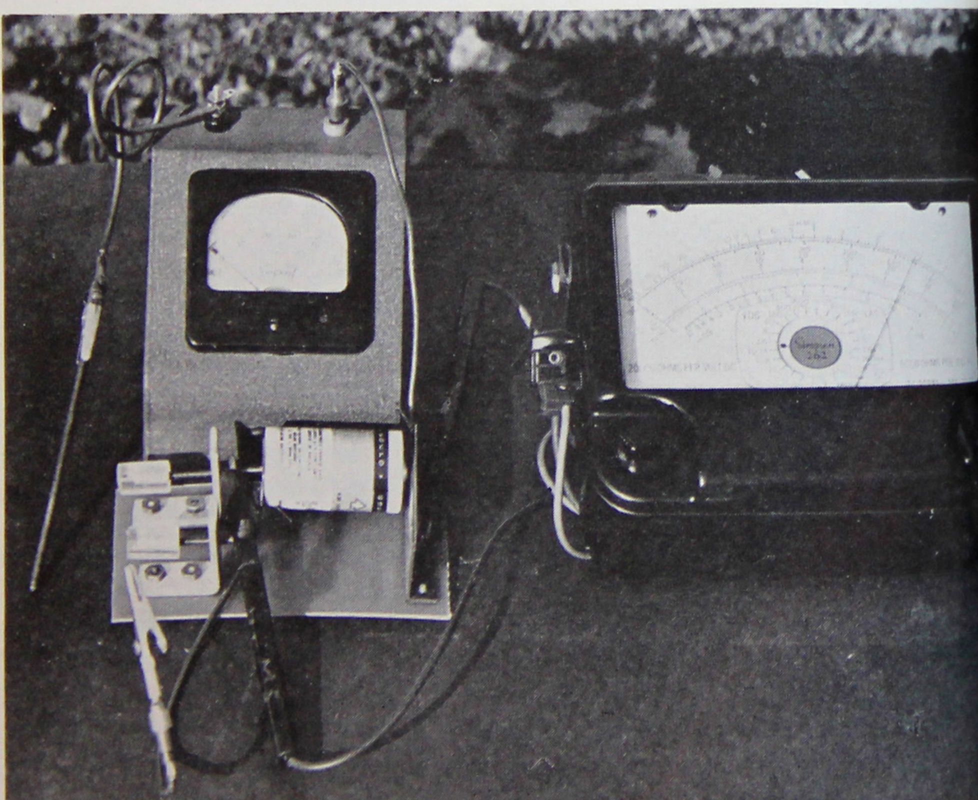
An Edison cell will *not* deliver its charge in a great rush of high-current output. It's got lots of stored energy, maybe—but it insists that you be patient about taking it out. Nothing hurried about it. The normal voltage per cell is approximately 1.2 volts; if you spend 5 to 8 hours drawing out the energy, it's an efficient cell. Try getting it all out in, say, 20 minutes—and you get only a small fraction of the charge, and the voltage collapses to about 0.2 volts.

In a submarine, the standard system is to have two electric motors, and two big battery banks. For underwater cruising, the batteries are connected in parallel, and the motors in series—say a 100 volt battery, working into a 200 volt motor. For getting some place at a more active speed, the batteries are connected in parallel, and the motors in parallel—a 100 volt battery working into 100 volt motors. And when there is reason to get the hell outa there, but fast! the technique is to connect the battery banks in series, and the motors in parallel—a 200 volt battery working into a 100 volt motor.

Try that last trick with an Edison battery bank, and you'll find you have a 50 volt battery working into a 100 volt motor; the cell voltage simply collapses under heavy current demand.

The reason you haven't seen Edison batteries around much lies right there—the voltage collapses under any sudden heavy-current load, and the great use for storage batteries that developed in the 20th century was, of course, for automobile starting, a use that consumed millions of batteries every year. And the service involves exactly the type of work an Edison battery can *not* handle; the standard six-volt starter system for a standard light car such as the Ford or Chevrolet of a few years ago imposed

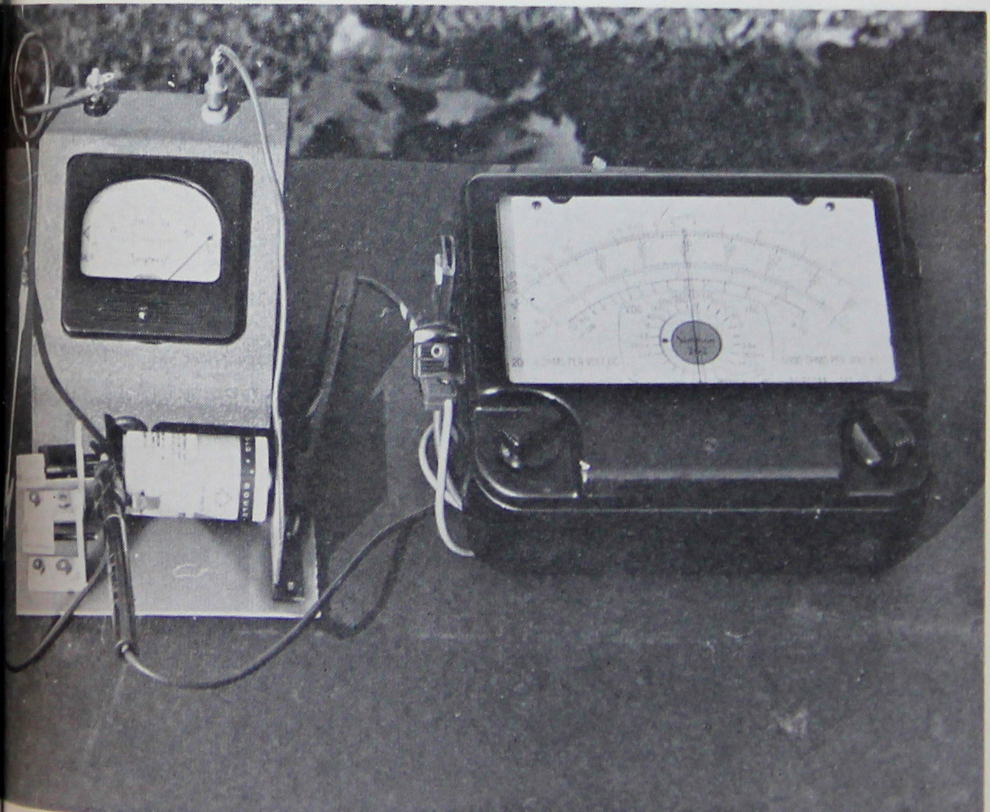
Fig. 7-A. The Nicad sintered-plate size D flashlight cell set up for extreme-load test. I had to build a special cell-holder; no commercial cell-holder can handle the massive currents a Nicad cell delivers. This is the starting set-up; the multirange meter is on a 1.6 volt scale, reading the freshly-charged Nicad cell at 1.28 volts.



a load of up to 550 amperes on the battery when starting a cold, stiff, new engine. Even a well-broken-in engine, on a warm summer day, would draw 300 amperes or so.

For submarine work, however, the Edison cell has another unpleasant little habit; the iron electrode gases off hydrogen continuously. It gases off hydrogen while it's being charged; it gases off while it's standing idle, and it gases off while it's working. And submariners simply do not like having hydrogen gas added to the atmosphere of their cramped little ship full of all sorts of electrical equipment. Hydrogen may not be

Fig. 7-B. The Triplet 50-ampere meter shows a 47 ampere drain, with the cell voltage holding up to 0.78 volts under that load. The "inefficient" long leads and alligator clips in the circuit—plus the piece of 6-32 threaded brass rod—are needed to protect the 50-ampere meter from the full violence of the flashlight battery!

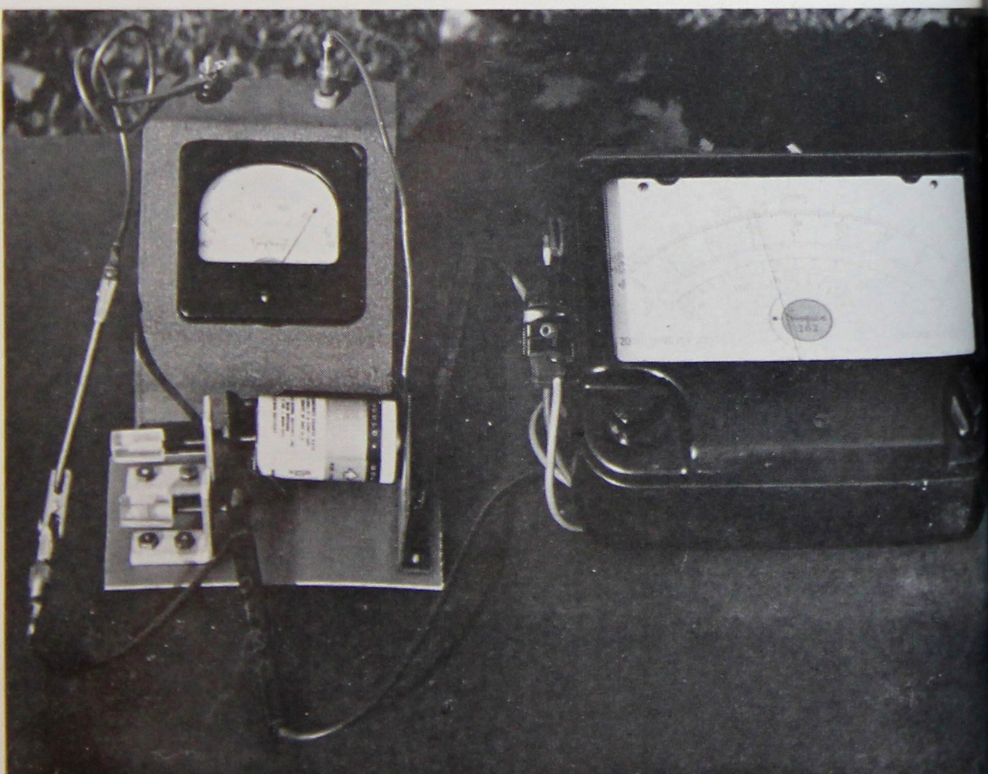


poisonous in the usual sense—but in a submarine's atmosphere it's strictly sudden death!

More generally serious is the fact that that hydrogen gas is generated at the expense of the chemical energy stored in the iron of the cathode—it's due to self-discharge of the energy you want stored. An Edison battery simply will not hold a charge; it leaks off in the form of hydrogen bubbles. One of the inefficiency factors in the Edison battery is the fact that hydrogen bubbles are discharged continuously during charge—at the expense of the energy of the charging current. Edison battery operators say

Fig. 7-C After ninety consecutive seconds, the sintered-plate cell is still throwing a current of 42 amperes, at 0.64 volts.

Fig. 7-D. An equivalent test of a fresh, first-quality standard dry cell shows approximately 6 amps, at 0.10 volts at the start. The cell was, naturally, ruined in a few seconds.



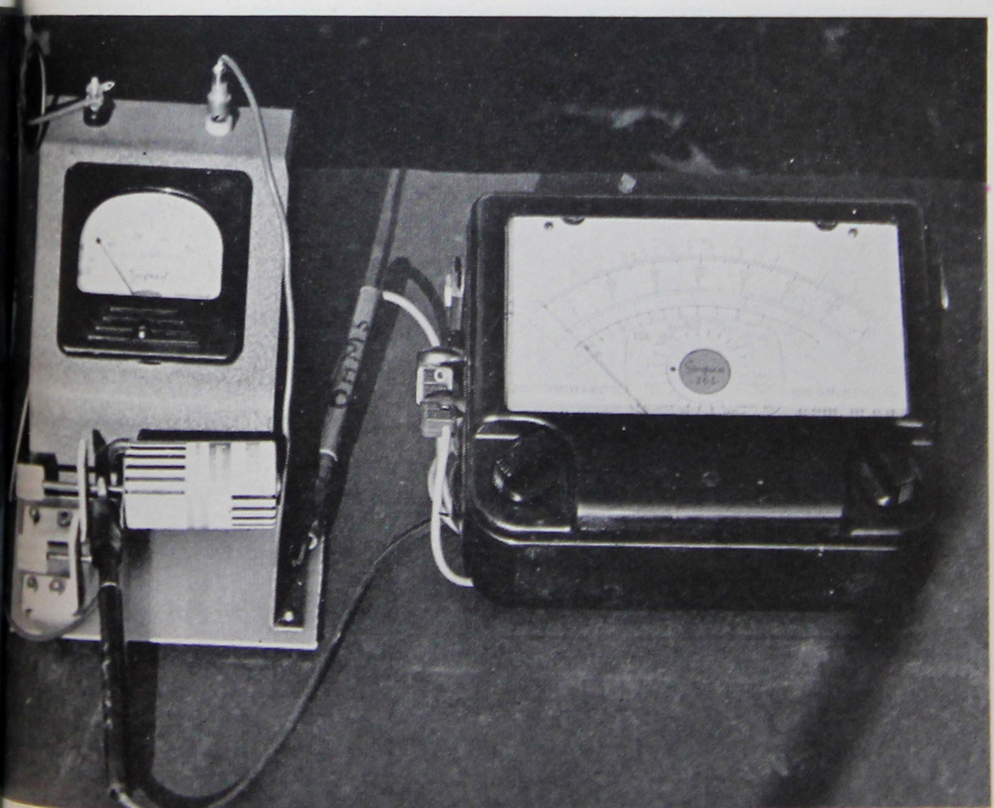
"If it ain't gassing off, the iron ain't taking a charge."

Put an Edison battery on the shelf for a few months, and it will be completely discharged when you come back to it.

Of course, that doesn't harm an Edison cell in the slightest; the normal technique for putting Edison cells in storage in a warehouse is to strap their terminals together—they're normally stored for weeks, months, or years if you wish, short-circuited. While it doesn't harm the cells—it does make them useless as emergency power reserves in many instances. When you need the stored power, you discover it's gone off into the wild blue yonder in the form of hydrogen bubbles.

So, the lead-acid storage battery, with its long catalog of extremely serious faults, won the market because it had one essential, and one desireable, characteristic: The lead-acid cell is able to throw very heavy currents without complete voltage collapse, which was essential for automobile starting, and it's first price, its purchase price, is far lower than that either of the two competing batteries.

Its faults, however, are major, numerous, and inherently incurable.



The first fault is obviously incurable; it's heavy as lead. Acutally, a lead-acid battery is even more weight-loaded than that, because the sulfuric acid has to serve two functions. The chemical reactions of the lead-acid battery are:

Anode reaction: $PbO_2 + H_2SO_4 = PbSO_4 + H_2O + O^{--}$

Cathode reaction: $Pb + H_2SO_4 = PbSO_4 + 2H^+$

Combined Reaction: $PbO_2 + Pb + 2H_2SO_4 = 2PbSO_4 + 2H_2O$

The sulfuric acid is consumed, and water produced, which is why the state of charge in a standard lead-acid battery can be determined by

Fig. 7-E. Equivalent test of a high-quality pressed-plate type Ni-Cd cell shows it acts almost exactly as the standard dry-cell does—about 7 amps at 0.10 volts. With the major difference that it is perfectly rechargeable, and entirely unharmed by this treatment.

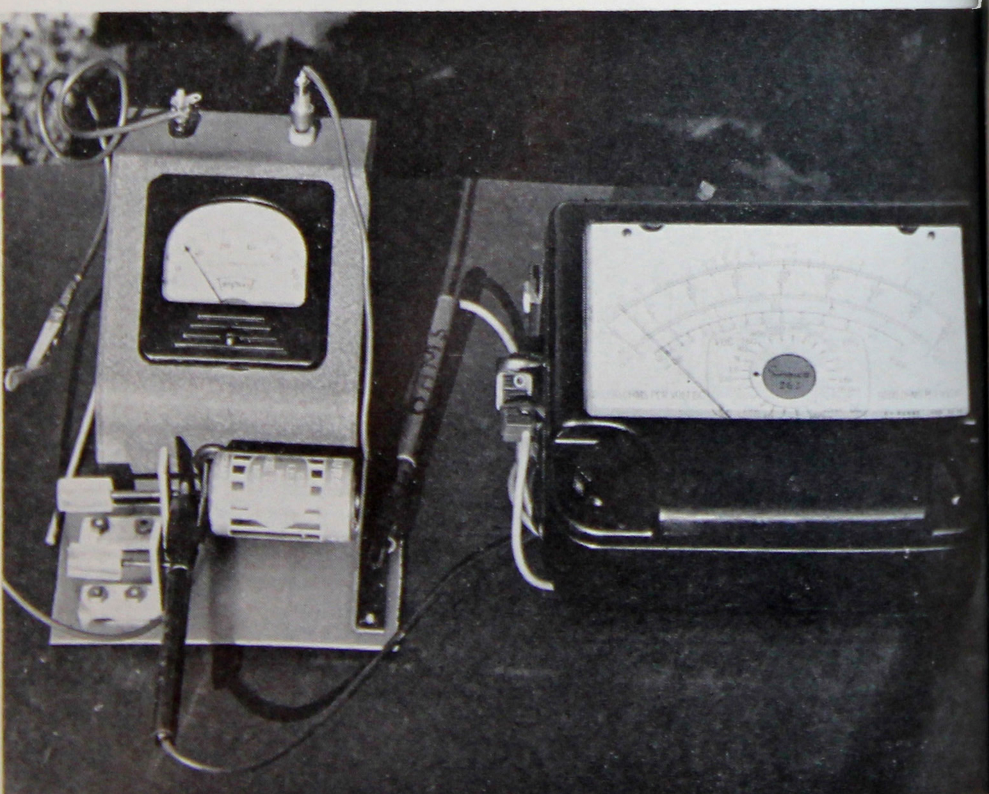


Fig. 8. One handful of Nicad sintered-plate cells can deliver power enough to start a standard 6-volt light automobile. Five cells deliver just over 6.2 volts.

measuring the specific gravity of the electrolyte. The state of charge of an Edison battery cannot be so determined, because in the Ni-Fe cell, the electrolyte serves, in effect, simply as a sort of conveyor belt for OH^- ions. The reactions in the Edison cell are:

Andoe reaction: $Ni(OH)_3 = Ni(OH)_2 + OH^-$

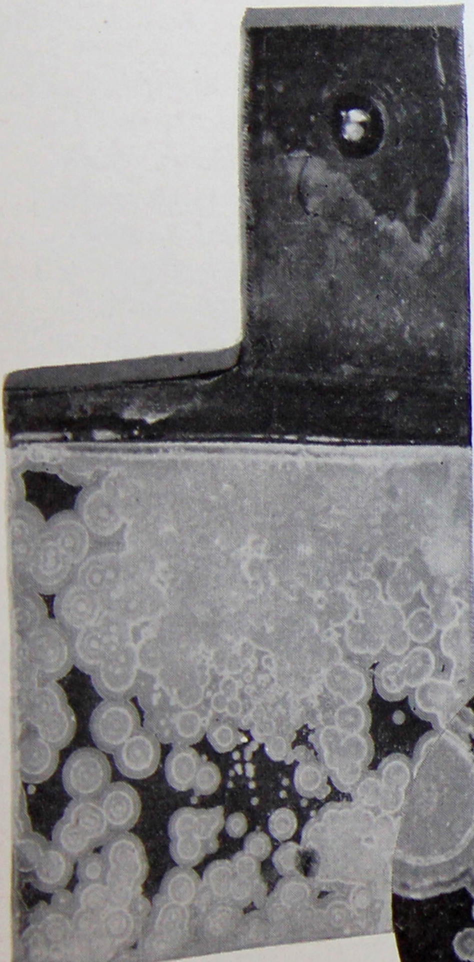
Cathode Reaction: $Fe + 2OH^- = Fe(OH)_2$

Combined reaction: $2Ni(OH)_3 + Fe = 2Ni(OH)_2 + Fe(OH)_2$

In this system the electrolyte—potassium hydroxide—does not enter into the reaction; it merely serves to transport OH^- ions from the Ni anode to the Fe cathode.

All of which didn't seem to mean much, once the electric power lines got spread across the country—or at least, across those parts of the world where there was economic wealth enough to be able to do anything about electric power problems. There's been no great point in running highly expensive electric power facilities into Amazon jungle areas—nor any great demand from such areas for portable stored power, no demand great enough to support an industry, to reward a research effort to produce a better storage battery. Nobody thought there was any re-

Fig. 9. This is a picture of why you have to buy a new lead-acid battery every couple of years. This sheet-lead plate was made the positive plate in a test-cell, and charge-discharge cycled until the chocolate-brown layer of PbO_2 formed. It then acted as a vigorous anode plate. But next it was over-discharged, then over-charged a few times. . . .



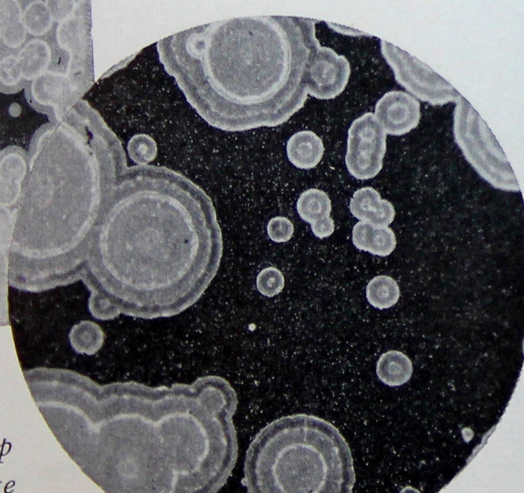


Fig. 10. . . and this is a close-up of "lead-battery-disease". These are not bacteria colonies on a biologist's culture-plate, but growth-rings of white lead sulfate in process of ruining a lead-acid battery plate. The useful area of the whole plate was about 1½ x 1½ inches.

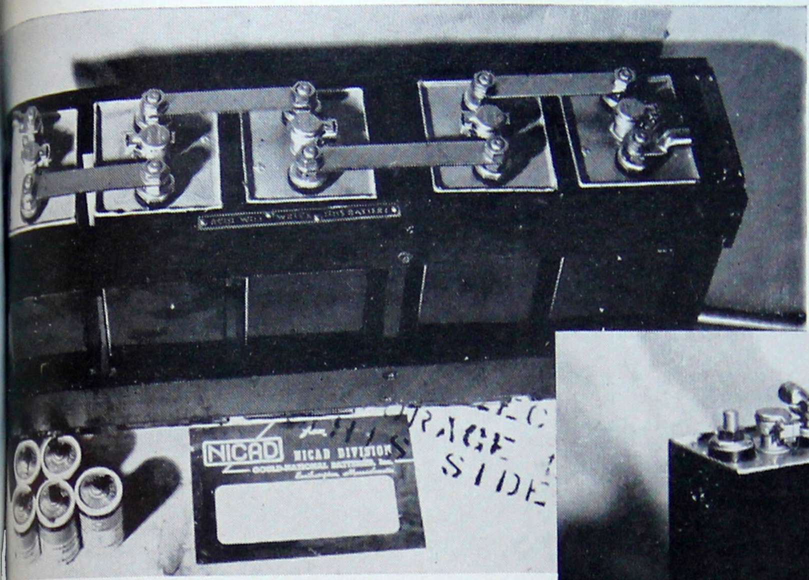


Fig. 10-A. A 1962-model of the original style Jungner Ni-Cd battery—five 30-ampere-hour cells to make a six-volt battery. Steel-cased cells are held and insulated in well-made hardwood racks. (Wood isn't new—but it's an excellent structural material still!) The steel cells must be insulated from each other. On the packing case lid beside the old-style Nicad are five sintered-plate cells—they yield six volts and four ampere-hours.

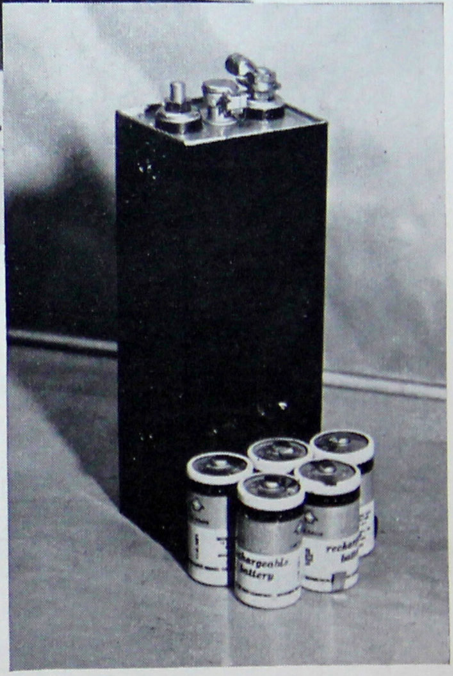


Fig. 10-B. A single cell of the original Jungner type compared with what an active research program yielded. The five-small ones, in parallel, yield the same voltage, and 2/3rds of the capacity of the big one.

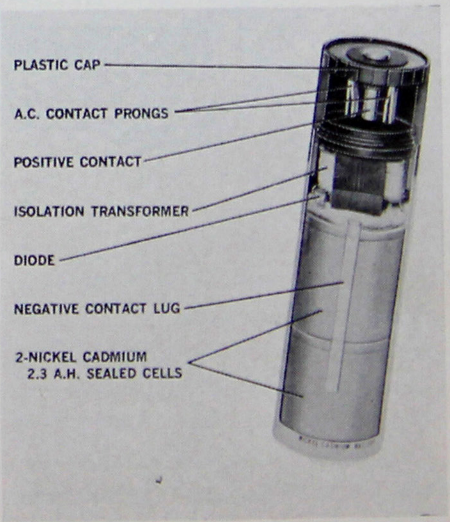


Fig. 11. Cut-away view of the typical plug-in-the-wall rechargeable Ni-Cd flashlight battery unit. This one's the Nicad Battery Co. design, but Nicad supplies them to a number of companies for sale under assorted brand-names.

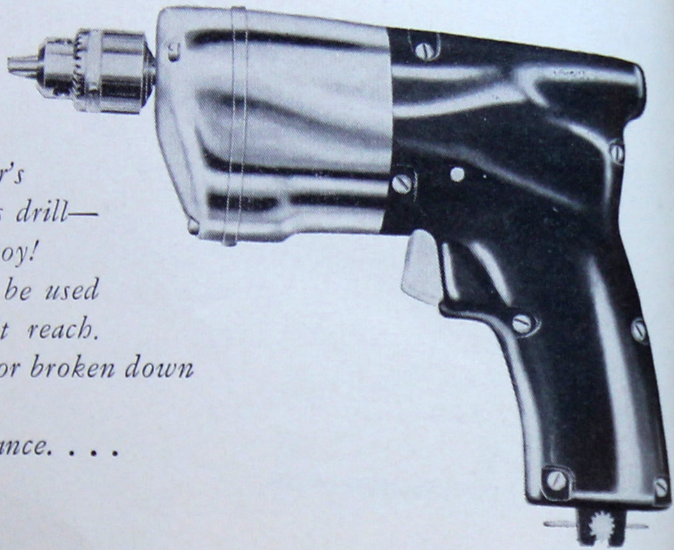
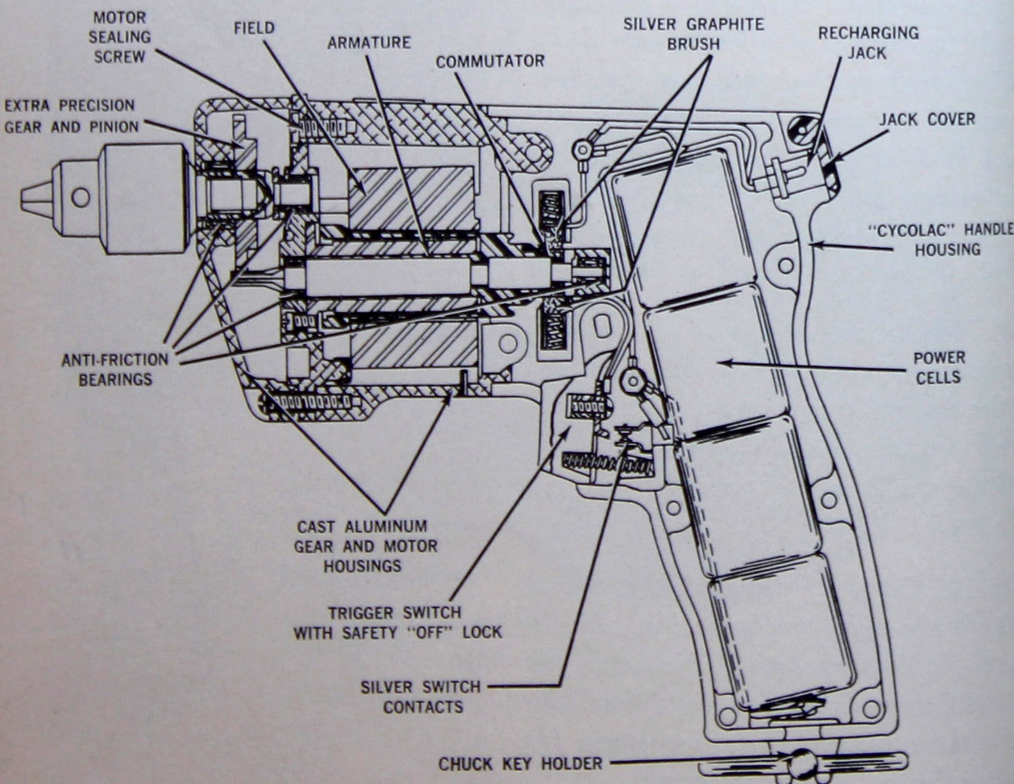


Fig. 12. Black & Decker's Nicad powered cordless drill—a full-size, tool—*not a toy! A power-tool that can be used where powerlines don't reach. A farmer with his tractor broken down in the far corner of that south 40, for instance. . . .*



ward to be gained from devoting the time, effort, and ingenuity required to produce a really new, and really good storage battery. Besides, ever since Edison's dynamos first went to work, people have known that batteries were pretty puny stuff, not really good for anything except very temporary heavy loads, like car starting, or small loads like children's toys. Batteries aren't *real* power sources!

And everybody was wrong.

Above I mentioned that the lead-acid battery had *two* competitors; the Edison battery was one—the other was one that you couldn't even find out about in the United States until after WWII!

It just happens that batteries have been something of a hobby of mine for some 35 years; I started experimenting with them as an amateur interest, when I was in high-school. I've never made a formal literature search of the subject, but I generally looked around in libraries to see what books they had on batteries, both primary and secondary, and over the course of years accumulated considerable information on them. Most of it sort of odd-ball stuff, but in the process, learned more than the elementary material about the standard battery types.

Fig. 13. Cutaway of the Black & Decker cordless drill shows how little space could be alloted to batteries. Under max load, the motor draws 55 amperes from the half-D size cells. Bet the engineers had fun designing a trigger switch to handle that current with only five volts maximum.

In various books, I've learned about some strange ones; I started doing some experiments on fuel cells back in 1932, somewhat before the current acute interest in the problem.

In the widely-known and respected Chemical Rubber Co. *Handbook of Chemistry & Physics,* there's a couple of pages devoted to discussing various types of primary and secondary cells.

Nowhere, before 1945, did I encounter any discussion of the Jungner battery.

The *Handbook of Chemistry & Physics* latest available edition still doesn't know the Jungner Ni-Cd battery exists! Yet that two-page listing describes the Grove, Bunsen, Danial, and assorted other one and two fluid cells. It mentions the Main Accumulater (PbO_2 — Zn in H_2SO_4; chiefly remarkable for having powered the electric car that, for several years, held the world's automobile speed record of about 78 mph) and several others—as well as, naturally, the lead-acid and the Edison cell.

It seems that, somehow, everybody thought the Jungner cell was a minor, unimportant variation of the Edison Ni-Fe cell. Jungner's battery simply used metallic cadmium as the negative instead of metallic iron. Gives essentially the same voltage—cadmium's \$1.70 a pound against iron's so-much-a-ton price—too unimportant to mention. . . .

The basic patents on Jungner's battery were issued in 1899 and the next few years, in England, Germany and Sweden. Jungner was a young Swedish engineer, who had developed a type of electrical fire alarm. It was a good alarm system, and sold very well—but got into difficulties because the batteries on which it depended weren't dependable. He'd been using primary cells—dry-cells of the familiar type—and the "shelf-life" killed the batteries while the fire-alarm was waiting for a fire. To save his successful business, Jungner had to come up with a new kind of battery that *could* be depended on—and while he was at it, since power-lines made electric power cheap—why not make the new battery a storage cell?

Edison was looking for a battery that could be used to extend the effective reach of his power-lines; for him, the Ni-Fe was fine. Jungner found the Ni-Fe system, too, at about the same time Edison did—and dropped it quick. That trick of self-discharge into hydrogen bubbles was precisely what he did *not* want!

The battery Jungner developed uses cadmium metal as the negative electrode material. The positive electrode is, like Edison's, nickle oxide-hydroxide. (Nobody knows exactly what that electrode actually is; the electrode reaction given above is a rough approximation of what actually happens, but not too close an approximation.) The negative electrode reaction in the Jungner battery is exactly that in the Edison battery, with Cd replacing Fe:

$$Cd + 2OH^{-} = Cd(OH)_2$$

At first glance, it does seem like a distinction-without-much-difference sort of thing, doesn't it?

I have a Ni-Cd storage battery the size, shape, and appearance of a standard D-cell flashlight battery—a development of the original Jungner cell—which can slam the needle on my 50 ampere meter against the stop-pin so hard it makes a distinct *clink.* It can deliver over 150 amperes on short-circuit.

It will deliver a current of *50 amperes for ninety seconds,* and at the end of that time the voltage is still above 50% of the full-charged no-load value!

Semi-straighten a standard wire paper-clip and clip it from one end of the battery to another—but don't hold on! It will get hot enough to lose most of its spring in a matter of seconds—and the cell won't be bothered in the least.

Repeated discharges at 50 amperes, recharge, and redischarge at that extreme rate, from the little D-cell size Nicad doesn't bother it in the slightest.

A standard lead-acid storage battery drops its voltage to less than 50% of the full rated value—the "6-volt" battery goes below 3.0 volts; the "12-volt" below 6.0—when the full load of the starter hits it. A Jungner battery of equal ampere-hour capacity drops, under the same load, only about 10%! If you directly replace a lead-acid battery with a Jungner battery of the same capacity and no-load voltage rating, your starting motor is going to get a surprise. The standard "12-volt system" starter motor has to be designed to work on about 5 volts—which is about what it can get when it's trying to start your car on a cold winter morning. With a Jungner battery, it would get about 10 volts—nearly twice what it's expected to get!

The Ni-Cd is no minor modification of the Edison Ni-Fe battery! It's what the Ni-Fe battery should have been, and never came near to being.

The Nicad battery cell delivers almost exactly the same voltage the Ni-Fe cell does: 1.2 volts. (Which means it takes ten Nicad cells for a "12 volt" battery, instead of the six a lead-acid battery requires.) It uses a nickel electrode, just as the Edison does, and a KOH electrolyte, as the Edison does—but from there on out, the differences are enormous!

The Jungner batteries have been available in Europe since the very early 1900's. Like the Edison battery, they're made of nickle-plated steel, and are mechanically, chemically, and electrically extremely rugged. Unlike Edison cells, they've been used for internal-combustion engine starting right from the beginning—and one Jungner battery put in service starting a diesel engine in 1913 was still in service, as of 1958! A forty-five year service life suggests the things can really be depended on. If a man bought a new Nicad battery for his car the day his son was born, about the time Junior got his PhD., the battery could be expected to need replacement.

Now here is the remarkable thing: the Ni-Cd batteries could be bought in Europe, in Tibet, in Central Africa and in the South Seas Islands all during the first half of the century—but *you couldn't get them in the United States!*

I didn't even find mention of them in technical literature in the United States! As I said, the Chemical Rubber *Handbook* didn't mention their existence.

The Ni-Cd battery, it is now clearly evident, is far and away the most reliable, powerful, long-lived storage battery yet developed. It is the only true, long-lived storage cell that can be truly hermetically sealed.

The Nicad battery actually represents a major new tool for both industry and science.

Yet technical information about it, even, was practically unobtainable in this country, previous to 1945—and became available then primarily because several hundred thousand Americans had been exposed to their wide-spread use in Europe, while over there on other business. An American Army colonel was primarily responsible for founding the Nicad Battery Co., in Easthampton, Mass., after the war, and making the Jungner type cell available in the United States.

The data above certainly makes a magnificent case for a deliberately suppressed invention, doesn't it? Obviously, the commercial battery companies, with the beautiful lead-acid battery business, combined to prevent development of the Nicad cell? Big Business at work, supressing an invention, and milking the poor citizen? Just think . . . the lead-acid battery business is practically a management ideal dream of a perfect business! The lead-acid battery has automatic, guaranteed built-in self-destruction mechanisms that they can't even be accused of putting in deliberately! It's inherent in the lead-acid system that the battery will destroy itself—because the *stable* form of the lead-sulfuric acid system is $PbSO_4$—and the system inevitably and inescapably goes slowly and steadily to that condition. There's no way of preventing it.

And this means that they can guarantee that the batteries they sell will destroy themselves in two, three or four years—and that the buyer will, with perfect certainty, be back for another battery.

But if he buys a Nicad—that's the last you'll see of him. His son will grow into manhood and buy a battery before *he* comes back!

Obviously Big Business and the Big Battery Cartels were at work, right?

Yeah . . . obviously. Only the obvious happens to be wrong,

Because that wouldn't account for the fact that the Chemical Rubber *Handbook* and all the other books on batteries printed in this country during the last half-century ignored the thing. Technology—professional science—ignored the battery. Naturally in our technical-based culture, Big Business ignored it too. If the Director of Research thinks the device is unimportant—the executive department isn't going to do anything about it.

One of the best over-all discussions of practical battery technology and management available in this country is the book "Storage Batteries", by Dr. George W. Vinal, of the National Bureau of Standards. The third edition of his book appeared in 1940. In it, he devotes about three pages total to references to the Ni-Cd battery; the rest is 80% devoted to lead-acid cells, and 20% to Edison cells. The major technical-data discussion of this authoritative book on storage batteries says of the Jungner battery,

> "Although nickle-cadmium cells are little known in this country, their production in Europe has increased greatly since 1930. They are used for train-lighting, mine lamps, tractors and trucks, military purposes, and, since 1935, for starting and lighting service on buses and trucks. Cadmium is said to be less subject to self-discharge than iron, and is relatively free of passivity at low temperatures. The average voltage of a cell during discharge is about 1.2 volts."

And that's all Dr. Vinal of the Bureau of Standards considered necessary to say about the Ni-Cd battery. Notice that he says "Cadmium is *said to be* less subject to self-discharge". This suggests that, as of 1940, Dr. Vinal, the Bureau of Standards battery expert, *had not himself investigated Ni-Cd batteries.* They'd been on the market since about 1905, and by his own statement, in wide, and rapidly increasing use in Europe for ten years before his book was published.

It wasn't Big Business and Cartels that surpressed the Ni-Cd battery in this country; it was Big Science.

If a business organization writes to the National Bureau of Standards for information about some new kind of battery they've heard about being used in Europe—you can imagine the enthusiastic report the Bu. Stan. would send them, in view of the fact that they'd been too lethargic to investigate the matter themselves!

The battery experts "knew" they didn't need to waste time and effort investigating the Ni-Cd system; they knew all about the Edison cell, and therefore, since the Ni-Cd was an unimportant modification of the Edison, they didn't need to investigate it.

They didn't even react to the fact that the Jungner Ni-Cd cells were being used to do work that Edison cells can't possibly do—for starting busses, trucks, and heavy diesel engines!

The Bell Telephone Laboratories had a report worked up by one of their men, about 1947, as to the characteristics of the Nicad batteries. Most of the report had to be prepared from material furnished by the manufacturers, since Bell Labs hadn't had time to investigate the batteries themselves. (After all, they'd been on the market for only 40 years, you know.) At that time, they found that Ni-Cd batteries were very highly desireable for such service as railroad lighting, emergency power and the like in colonial areas; the Ni-Cd cells were the only kind of battery that could remain operating under the mismaintainance provided by completely ignorant native workers. They were liked in India particularly because the Ni-Cd cells could tolerate temperatures that completely ruined lead-acid and Edison batteries—the temperatures reached in the Indian central plains during mid-summer.

It wasn't Big Business Cartels that kept you from getting the possible developments of the Ni-Cd battery—it was the Big Science cartel that already knew they didn't have to investigate.

As a matter of fact, the Jungner battery, sad to say, can never replace the lead-acid battery—but for a reason that *none of the battery experts I've talked to knew about!*

The Ni-Cd system has one permanent, immovable, and absolute block. It can never become a mass-production, high-quantity item. This means, of course, that it will tend to remain expensive, because of hand-tooled construction methods imposed by the small-quantity business.

The reason it can never be a large-scale industry has to do with the peculiar structure of the cadmium nucleus. Cadmium is used as control-rods in nuclear reactors, because the nucleus soaks up neutrons like a sponge . . . and turns into something else, of course. This characteristic, plus a few others, contribute to the fact that when the atoms were being cooked up in the stellar atom-furnaces, cadmium was one that didn't stand up well.

There is not one cadmium mine on the entire Earth.

Cadmium is strictly a *very* small by-product of zinc mining; it is a minor impurity, about 0.25% on the average, in zinc. It is extracted from zinc quite largely because Cd is highly toxic, while pure zinc is non-toxic. Cadmium, like its conger mercury, is exceedingly bad stuff in human metabolism.

Because of this, the price of cadmium, in moderate quantities, is around $1.70 per pound . . . but if you want a great deal of cadmium, say the quantity needed to make 5,000,000 automobile batteries this year, the price will be about $800 per pound!

Which suggests that Big Business wouldn't have had any reason to suppress the invention anyway!

But the failure of science to appreciate that the Jungner battery was an entirely different kettle of fish is indicated by what has been done, since the interest in batteries, both primary and secondary, has been reawakened.

The electric automobile never got anywhere—despite the apparent advantage it had back around 1905. It was quiet, reliable, smooth, odorless, very cheap to maintain—it had lots of advantages. But the gasoline car, stinking, banging, breaking down, rattling, and in various ways offending nose, ears, and sense of economics, won out—largely because you could "recharge" a gasoline car in minutes, instead of overnight.

And after the gasoline car won—batteries were for toys, doorbell ringing, and flashlights. For a brief time, in the late 1920's, it looked as though radio receivers were going to give batteries a new job—but then they found out how to run those from a powerline too.

The first real new interest in batteries came in WWII, when the development of military electronics began to make portable power supplies important. Long-neglected research programs were dusted off, and work was done on ideas nobody'd bothered with for decades. The mercury dry-cell came into production. Batteries of far smaller size came on the market. Then the transistor arrived, and the market for batteries really boomed.

Photographic electronic flash supplied another market for batteries—and about that time the hermetically sealed Ni-Cd storage battery came on the market. It was the first truely *sealed* storage cell ever sold commercially.

The problem in building a sealed storage cell has always been the danger of gas explosion when the cell is fully charged . . . and the charging current is continued. When all the $Ni(OH)_2$ has been reoxidized to $Ni(OH)_3$, if the charging current continues—oxygen begins bubbling off the anode. When all the cadmium hydroxide has been reduced back to cadmium metal—hydrogen starts bubbling off the cathode. If the cell is sealed, the gas pressure will build up steadily until something pops. If the cell is not sealed, the electrolyte tends to escape, no matter how carefully you try to trap it—as anyone who had one of the lead-acid storage battery powered radio sets can tell you.

The Ni-Cd system is unique, in making possible a reaction system that completely eliminates gas-off, even when the cell is overcharged. It depends on the fact that oxygen is somewhat soluble in KOH under moderate pressure—and that the finely divided and highly reactive cadmium metal in the cathode of a Ni-Cd battery will react directly with the dissolved oxygen to produce $Cd(OH)_2$.

The very simple trick is that more cadmium hydroxide is built into the cell than the amount equivalent to he nickel oxide installed. Necessarily, then, the nickel anode will reach full-charge condition while there still remains some unreduced $Cd(OH)_2$. The anode will, then, tend to start producing free oxygen, before the cathode starts freeing hydrogen.

The oxygen freed from the anode, however, attacks the already-reduced cadmium of the cathode, and turns it back to $Cd(OH)_2$. The net result is that the over-charge current is simply consumed harmlessly by the catalytic oxidation-reduction of the Cd-$Cd(OH)_2$ system!

Because of that, the Ni-Cd hermetically sealed cells provided a type of storage cell that could be sent into space—which would have been sudden death to any unsealed cell, since the electrolyte would promptly boil away. And it meant a cell that could be permanently wired into delicate electronic equipment without danger of a spray of corrosive fumes. Hence the development of the rechargeable photo-flash equipment.

But another step was in the offing; since about 1946, the Nicad Battery Company had been working on a new approach to battery plates.

The Edison batteries are decidedly expensive; nickel and iron are cheap enough—but getting the darned stuff in place, in the form it's needed, is an incredibly elaborate process. The positive plate structure in an Edison battery involves making tubes by wrapping nickeled-steel perforated tape around a mandrel, slipping steel retaining rings over the tube so formed, then ramming the tube full of alternate layers of finely divided precipitated nickel hydroxide and fine nickel flake. (The nickel oxide material is a very poor conductor; the nickel flake is added in hopes of improving that situation.) A total of 600 layers of alternate nickel oxide and nickel flake is rammed in, the tube pinched shut, and mounted in a nickeled-steel grid. The cost isn't the materials—it's the cost of getting the darned stuff in the form needed, where you need it.

The original Jungner battery suffered from a similar problem—complicated by the fact that cadmium is expensive. The machinery used to make these plates was big, expensive, and specialized—it made it very difficult to produce many different sizes and styles of batteries.

(The lead-acid battery is cheap not because lead and sulfuric acid are so much cheaper, but because it's so easy to make a paste of lead oxide and glycerine, or other organic material, and "butter" a lead grid with the stuff. Charging the resultant pasted plate converts the anode-charged plates to PbO_2, and the cathode-charged plates to Pb. The whole process is cheap, easy, done by simple machinery, and easily altered as to size and thickness.)

The Germans, during WWII, started working on what is now known as the "pressed plate" type battery; it's made essentially of powdered nickel and active material formed under enormous pressure into a quasi-solid button of active and conductive material.

The Nicad Company, meanwhile, was working on the sintered-plate system—a technique using powder-metallurgy to make a "biscuit" of extremely porus nickel by lightly compressing nickel powder, and then, by a sudden heavy current, causing the individual grains to weld to each other at their points of contact. The result is a plate that's 80% open holes, and only 20% solid nickel. By chemical techniques (that they talk *about*, but not *of*) they load the pores with active material—nicklic salts in the anode-to-be, cadmium in the cathode-to-be.

A number of companies are now importing the Ni-Cd batteries from West Germany, and selling them under American brand names; Nicad—which is now a division of the Gould-National Battery Company—imports and sells under their brand a number of the smallest sizes of Ni-Cd batteries. These range from shirt-button size to overcoat-button size—and shape!—in the Nicad brand; Burgess, Eveready, and others offer similar West German made button cells, and some flashlight-type batteries of the pressed-plate type. So far, Nicad is the only make of sintered-plate I've encountered.

The pressed-plate and sintered-plate types are *not* interchangeable-equivalent!

It's a Nicad sintered-plate type of D-size flashlight cell that can throw a current of 150 amperes. The equivalent D-size pressed-plate cell acts exactly like a first-line high-quality drycell, except that it can be recharged several hundred times. A good, fresh, new drycell, on dead short-circuit, will yield about 7 amperes; so will a fresh-charged pressed-plate Ni-Cd D-size cell.

In addition, the sintered-plate cell has a capacity of four ampere hours, as compared to about 2.5 for the sintered plate. However, you *do* pay for the difference—the Nicad sintered-plate cells are more expensive.

But of major importance is this simple fact: The sintered-plate, hermetically sealed Nicad battery is a totally new tool for both industry and science. It will do things that no other device known has been able to do.

For the first time, battery-powered *tools* are possible—not *toys*, but *tools.* The Black & Decker cordless quarter-inch drill is a full-scale, he-man heavy-work tool, not a battery-operated toy. Four Nicad sintered-plate cells, each D-size in diameter, but only half as high, supply the power. The tool can drill ¼-inch holes through cold-rolled steel; when drilling under full load—a ¼-inch bit clawing its way into hard steel—the drill-motor *draws 55 amperes from the half-D-size cells!*

Naturally, the batteries can't maintain that sort of load for any long period—but the tool can drill about five ¼-inch holes in ¼-inch thick cold-rolled steel on one battery charge. Under more normal loads, it can drill over 100 ½-inch holes in "1-inch" pine boards on a single charge. It's a tool—not a toy! TV service-men, for one group, dearly love the gadget—it'll give them a power-tool up on somebody's roof.

For the first time, there's a chance for real battery-powered tools of all types. And for battery-powered equipment that requires *power*, great gulps of power, where you can't get at a powerline. Sylvania Electric is bringing out a modification of their "Sun Gun" home movie light gadget—the iodine-cycle incandescent lamp—that, for the first time, allows you to take movies at night without having to have a handy powerline outlet. On the beach—at a picnic—anywhere. It has a cannister of Nicad batteries, and supplies half an hour of brilliant light.

But the sintered-place Nicad offers something entirely different in the way of a scientific tool. The definition of the electrical unit, *one farad,* is that capacity which, when charged at a rate of one ampere, shows a voltage increase of one volt per second. By that definition, a penlight size Nicad sintered-plate cell is approximately a one *kilo*farad condenser. I've used them in electronic circuits where a capacitance of the order of 5,000 microfarads would have been the minimum to get the required low-frequency response. Because the Nicad cell can be charged *forever* at up to 20 milliamperes, due to the trick $Cd\text{-}Cd(OH)_2$ reaction with oxygen, they make magnificent fixed-bias devices.

In this application, it represents a class of device that never existed before. A Zenner diode will do a similar job at higher voltage ranges—but not with such exceedingly low impedance.

This aspect as a super-capacitor has application in an entirely different area—on an entirely different end of the scale. More and more interest is developing in the production of ultra-intense magnetic fields—fields requiring enormous currents. Some work has been done by discharging a huge bank of condensers in a single shock blast, developing currents in the range of half a million amperes.

For the fun of it, I calculated what it would take to get a current of 1,000,000 amperes sustained for a full 60 seconds—not as a split-second discharge but as a sustained surge of power—from a bank of Nicad sintered-plate cells.

Anyone who happens to want that megampere current can order the necessary cells off-the-shelf from Nicad. They'll all fit in a volume somewhat less than that of a standard office desk. The switching arrangement, however, may be something else again; breaking megampere currents is apt to present some problems.

The type of cell considered here, incidentally, is the standard commercial plastic-cased, hermetically-sealed Nicad sintered-plate heavy-duty cell. The cells are relatively new—only about 5 or 6 years old—so they don't know, yet, how long the cells will last, but they have experience with these cells which were deeply, and very rapidly discharged, recharged, and recycled 2000 times . . . with no loss of capacity.

So little thinking has been done on the nature and possible characteristics of batteries, actually, that many "battery experts" have never happened to consider some of the most fundamental factors of battery design!

For example, I've found that many "experts" haven't noticed that iron is the lightest element that can be plated out of an ordinary water solution of its salts. If it weren't for iron's unfortunate habit of bubbling off hydrogen continuously, it would make iron the lightest possible material for use in a secondary cell cathode. One reason the Edison cell is so light per kilowatt hour!

The only familiar batteries have been drycells and the lead-acid storage battery; all of these have markedly limited life—inherently limited life. The lead reacts with sulfuric acid to form lead sulfate; at first the sulfate is in a microcrystalline form, but with the passage of time, the microcrystals grow into larger, though still invisibly small, crystals that will not reduce back to lead or go to lead dioxide . . . and the battery is useless.

The drycell is, necessarily, a metastable electrochemical system. Since it's a primary cell, it *has* to be unstable, or there could be no energy available for use. Any battery, in its charged state, must be a metastable system.

But because we have been used to the drycell—a perfectly valid primary cell—and the lead-acid storage battery, which is always in one metastable state or another, so long as it *is* a battery, we've grown accustomed to thinking "of course, it's natural for batteries to destroy themselves."

It isn't; it's natural only for primary cells, and badly designed storage cells to destroy themselves. A properly designed storage cell would be an inherently stable chemical system when it was in the discharged state—and a highly metastable system in the charged state.

The Ni-Fe cell *is* completely stable in the discharged state; that's why it can be stored with the plates strapped together for years at a time.

The Ni-Cd system is only slightly less stable in the discharged state; the excess cadmium metal can react slightly, very, very slowly with the nickle hydroxide, tending to drive it down from the Ni^{++} state to the Ni^0 state—and once the nickel is in the metallic state, it will not reoxidize under the conditions of the Jungner cell's anode.

However, where the Ni-Fe cell is perfectly stable discharged, it's not as stable as it should be when charged; the iron reacts steadily with the water to give of hydrogen. You *can't* store a Ni-Fe cell charged, because it self-discharges. The Ni-Cd cell, however, does just what old Jungner wanted—it holds its charge for *years.* A modern Nicad cell will retain over 30% of its charge after two years on the shelf.

The amount of research that has been expended toward getting basically new, and really effective batteries, is indicated by the complete failure of even the National Bureau of Standards to take the effort to make some actual tests on the Jungner batteries during the forty years it was successful in Europe . . . and ignored by American science and technology, because they "knew" it was a minor and unimportant variation of the Edison cell.

It *wasn't* a "minor" difference; it makes possible things the Ni-Fe cell simply can't approach—as those fantastically powerful little Nicad flashlight batteries demonstrate.

The thing that licked the electric car in the early 1900's was that you couldn't recharge it in minutes, as you could the gas car. It was *not* lack of speed; it was at that period that an electric-powered car set that 78 mile-an-hour automobile speed record.

Now, the objection that was raised to the gasoline car at that time is coming home to roost in a *big* way; they stink. Los Angeles, all California, all big cities, are learning that fact. It's called "smog", and it's lethal. Now that more careful medical research has shown that it's not the cigarettes that cause lung cancer, but city smog, California has started passing laws to force gasoline cars to use fume-eliminators.

The Ni-Cd battery can never be a mass-production unit. Cadmium, unfortunately, can't be had! But—it does suggest what batteries could be, if some real, honest, original research was done.

The Ni-Cd sintered plate cells can not only be discharged at fantastically high rates—they can be charged at equally violent rates. One of those sintered-plate cells can be given 80% of a full charge *in four minutes.* For the larger commercial cells, with 150 ampere hour capacity, that means a charge rate of thousands of amperes, at the beginning of the charge.

Here's a battery that doesn't have the characteristic that killed the electric automobiles—it *can* be refilled in minutes, not hours! The old electric cars were designed with the idea that it would have to run all day on one charge; the batteries were heavy, the motors small, and the speed slow. But suppose we have a car designed to run only two hours on a charge, and to pick up a new charge at a filling-station in a ten minute stop? A Nicad sintered-cell battery could do it! And man! Talk about hot-rod dragsters! Think of the acceleration-torque that little starter motor in your car develops—and scale that up to a pair of twenty-horse series-wound DC drive motors powered by a battery that's happy to deliver a current of 10,000 amperes or so! And be it remembered that a series-wound DC motor has to be very carefully restrained; they have a natural tendency to accelerate to speeds like 30,000 RPM.

But in grinning contrast to what could be done—the Edison storage battery is now owned by the "Exide" company, and, after half a century, the same design of cells remains. No effective change in half a century. It's a living fossil, embodying ideas of the period when electric power was very new, and modern metallurgical chemistry hadn't been invented.

We *need* electric cars—they're quite literally a matter of life and death. Electric cars that have the git-up-and-go that people want—that can be used for most of the ordinary round-town work that cars are used for. And to get that, we need some decent storage batteries.

It wasn't the Big Business Cartels that kept the Jungner battery out of the United States; they, quite provably, had absolutely nothing to worry about, because of that no-cadmium-mine problem.

It was the Big Science laziness, the failure to take the trouble to look and see—because they "already knew" the Jungner battery was just like the Edison, really.

And it was sheer scientific laziness that kept the Edison battery static for half a century. In some home experiments conducted to find out why the Jungner battery can throw such heavy currents, while the Edison battery is so given to fainting spells, like a belle of its birth era, when faced with a shock load, I found the answer quite simply.

Sheer bad design. The nickel anode has such high resistance, and such poor access to the electrolyte because of the method of filling, that it can't react rapidly. Naturally, I assumed at first that the difference must be that iron wouldn't hold up under heavy current, because after all the Jungner battery uses the same essential anode reactions.

It isn't the fault of the iron; just wrapping some fine grade steel wool around a sheetiron plate gave me a test electrode that was perfectly willing to deliver 15 or 20 amperes in a 400 ml beaker-size plate! It was the inefficient Edison nickel anodes that clobbered the thing.

The high-power, high-rate, lightweight batteries we need for a hundred uses are perfectly possible. They're a real, genuine suppressed invention—but *not* suppressed by what everyone always suggests as the Villains Of The Piece.

It wasn't Wall Street's fault at all —it was Ivory Tower Street.

COMPARISON OF MAJOR TYPES OF STORAGE CELLS

Characteristic	*Ni-Cd*	*Edison Ni-Fe*	*Lead-Acid*
Weight	Moderate	Low	Heavy
Cost	High	High	Low
Service life	Decades	Decades	Months
Cost/year	Low	Low	High
Voltage/cell	1.2	1.2	2.1
Mechanically rugged?	Yes	Yes	No
Can be hermetically sealed?	Yes	No	No
Availability?*	Difficult	Difficult	Anywhere
Heavy current discharge?	Extremely	No!	Yes.
Capacity available under high-rate discharge.	$> 80\%$	$< 10\%$	$\leq 40\%$
Damaged by repeated over-charge?	No.	No.	Ruined
Damaged by repeated over-discharge?	Some loss of capacity	No.	Ruined
Holds charge?	2 years	2 months	2 months
Long storage (years)	Unharmed	Unharmed	Ruined unless dry
Stand temperatures above 150°F.?	Yes	Damage	Ruined
Temperatures below 0°F.?	—40°	Loss of activity below 32°F.	—60°
Water needs?	Once a year. (Non-sealed type cells.)	Often	Often
Fast recharge?	Extremely fast—no damage.	No!	Moderately fast—some damage.

*The Nicad batteries are available from the Gould-National Battery Co.'s Nicad Division—but most Gould-National battery agents don't know this! You'll have to tell them their company handles them. Or write Gould-National Battery Co., Nicad Division, 7 Dey St., New York City. Edison cells are now manufactured by the "Exide" company, and can be obtained through "Exide" agents . . . . . but most agents don't know that, either!

The flashlight size Nicad sintered-plate cells are getting to be fairly widely available through electronic supply houses. But *note carefully* that not all nickle-cadmium batteries of the sealed flashlight cell design are the super-powerful sintered-plate type; the *pressed-plate* type will not handle currents heavier than about 8-10 amperes maximum.

There's a surplus outfit in the mid-west that is offering government surplus Nicad sintered-plate cells (spillproof but not hermetically sealed).