

Re-Inventing the Liberty Cap – Part 1

by Kip Lankenau

The story of the Liberty distributor cap project has very humble beginnings. Being primarily a supplier of parts for less popular antique British automobiles, Kip Motor Company began operations by purchasing and reselling parts. As years went by, many of the parts we had been selling on a regular basis started getting very difficult to source, as original and aftermarket manufacturers began rationalizing product lines and obsolete stocks were depleted. After some investigations, it soon became apparent that our meager requirements were insufficient to encourage even small production shops to undertake many of our desperately needed components. It was a crossroads; either we abandon our primary market and find a new line of business, leaving thousands of customers and vehicles with virtually no dependable source of essential spares, or we could develop creative ways of economically producing high quality parts in very tiny quantities. Stubborn, or just plain foolish, we chose the latter path, and today Kip Motor Company manufactures over 50% of the products we sell.

Once the path had been chosen, we never looked back. Over the years we've developed a unique method of thinking and through it developed small batch production techniques for almost any part fitted to a motor vehicle, from plastics and metal castings to stampings, rubber moldings, engine and brake components, interior kits and etc. Many of our techniques required research and re-invention of old technologies long ago discarded by modern production facilities. Such was the case with the Liberty cap.

The distributor cap problem was one we had foreseen by several years, yet still looked upon with dread. Some of our more common caps had gone through periods of unavailability as manufacturers exported their tooling to overseas subsidiaries with lower labor costs. We hedged our position by maintaining sufficient inventory to ride out lean periods. However, no tooling lasts forever and over a relatively short period of time, many caps disappeared from original and aftermarket sources.

While all this was happening, we'd been in contact with some of the primary sources and understood the dilemma. Modern distributor cap production is based on injection moulded components which are then machined to final configuration. The cost of making a single injection mould for even a relatively simple cap is in excess of \$100,000 and most cost three to four times as much. As demand tapers off, a manufacturer has little incentive to replace worn out tooling, as the capital costs have no chance of recovery. We understood the economics of the situation and the magnitude of the problem, but the time had arrived where a solution had to be found, and it was obvious to us that injection moulding wasn't a part of the solution.

We had developed the ability to cast highly detailed plastic, rubber and metal parts utilizing very cost effective silicone moulds. The mould theory and materials are similar to what a dentist uses when taking a mould of your teeth. We start with an original part as a pattern. This pattern, even if new old stock (NOS) usually requires some repair or restoration. The pattern is set into a container, around which silicone is poured and allowed to cure. This method results in a mould, which exactly replicates every detail of the pattern, including any flaw or blemish. The type of silicone used in the mould varies depending on the chemical makeup of the pattern and the material to be cast into the mould during production. As an example, some silicone formulations interact with natural rubber and never fully cure, a common problem when making moulds of original engine mounts or gearshift boots.

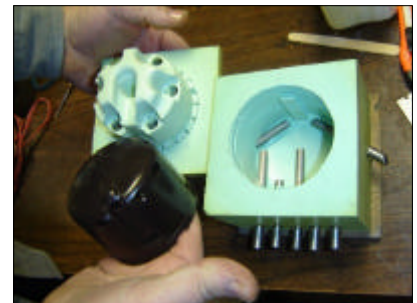
Tooling costs for silicone moulds are only hundreds or thousands of dollars, not the tens or hundreds of thousands of dollars required for traditional injection moulds. The downside is mould life. These 'soft' moulds generally last only 25-50 pieces, as opposed to the thousands or hundreds of thousands of pieces for 'hard' injection moulds. In applications where higher quantities are required it may be necessary to make several moulds. Also, silicone moulds are not compatible with injection methods of manufac-



A typical day at Kip Motor Company



Research & Development



Distributor Cap Production



Metal casting moulds for Metropolitan door handle

ture, but instead rely on casting material into the mould at ambient pressure, thus requiring an altogether different palate of production resins and epoxies. The technology doesn't lend itself well to mass production, but it is ideally suited for production of high quality parts in very small quantities.

The initial challenge was not in making the moulds, but of finding a suitable casting material. We had a lot of experience with polyester, urethane and polyurethane formulations and some of these were electrically suitable, but none would maintain their shape at the temperature ranges encountered in an engine compartment. Our investigations and testing revealed no commercially available material that met our electrical and temperature requirements and that could be cast using our moulding technology.

Prior to the introduction of modern injection moulding, most distributor caps were made from what is commonly called bakelite. Early on, we considered this option and spent some time researching its formulation and production methods. None of our research garnered sufficiently detailed information to allow modern replication. If a bakelite type of material was what we wanted, it would be necessary to develop its modern day equivalent.

We approached one of our suppliers who had shown a flexibility and willingness in some of our earlier endeavors. After discussing our requirements, they developed and furnished samples of a phenolic resin, suitable catalyst, a variety of additives and some baseline possibilities for mixing ratios. Just finding a mixture that could be cast became a challenge as the early ratios resulted in a thick fudge-like gooey semi-liquid that required many hours to cure into something like vulcanized rubber, very flexible and easily deformed. Increasing the catalyst resulted in a workable syrup with a fast setup, but once cured would shatter at the slightest pressure. It took nearly six months of testing and development before we'd found just the right additives, mixing ratios, casting and curing techniques to finally start pre-production of our first distributor caps.

In its developed form, this phenolic resin turned out to be just what we had hoped for and it had many of the characteristics of bakelite, including color, appearance and similar weight as well as some of its drawbacks, still being somewhat brittle. It was this later characteristic that most greatly affected the manufacturing process. Most machining of metal inserts would need to be done prior to the casting process, just the opposite of common practice.

The first caps attempted were those we calculated to have the highest demand and also required the fewest machining operations. These initial caps allowed us to develop our casting and finishing operations before adding complexity. Although the pre-machining and casting operations went smoothly, the minor machining and finishing did not. Nearly 50% of the early production was discarded due to cracking. Once we'd learned to work with the product, the defect rate quickly dropped by an order of magnitude. Well into the learning curve, we were able to calculate actual tooling and production costs, allowing us to finally establish pricing.

Complexity was gradually increased through an evolutionary process. Soon, we had reintroduced most of the distributor caps considered essential to our product line. It was during this time that others became aware of our activities and demand forced an evolution from small batch to consistent low volume production. Sizeable orders were now coming in and one customer in particular began to commission large lots of new caps we'd not previously considered. It was an inquiry to this customer, Holden Vintage and Classic of the UK that became the Liberty spark.

In search of someone capable of making a small run of perhaps six distributor caps for his own Liberty engine project, Denis Kay of Kay (UK) Engineering contacted Holden's. As a supplier of vintage automotive rather than aircraft components, they recommended he contact us directly.



Process begins with a mould (left).

Pouring phenolic resin (right)



Bake mould in oven (right).

Moulds ready after baking (left).



Above: taking top of mold.

Right: popping out product (in this case, a rubber fuel casket).

Below: trimming nubbins.



Being a pilot and somewhat familiar with the Liberty engine, it's historical significance and many of the aircraft with which it had been fitted, but never really having given much notice to it's ignition system, when Denis asked if we could do it, I of course said "sure, no problem". I believe the next words out of my mouth were "What does it look like?" and "How big is it?" He then went on to say that he actually had several broken examples but no complete caps. When I explained to him that although it was possible to work with broken examples if absolutely necessary, it was in his economic best interest to locate a decent pattern, he promised to beg or borrow as required.

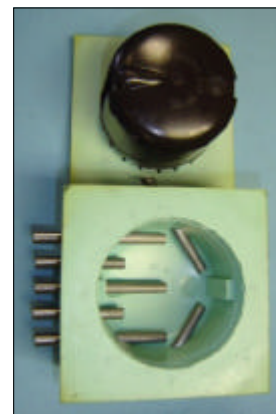
With Denis now in search of the Holy Grail, it was time for us to do our homework. First, we wanted to see what we were really getting ourselves into, so we began to search for decent photos with some detail. This ended up not quite as easy as expected. A quick perusal of on-line museum photo galleries all seemed to have one thing in common, pictures of Liberty engines with broken distributor caps. It took some real serious hunting to find any decent photos.

The second thing was, with all those Liberty engines produced we couldn't believe there wasn't a supply of distributor caps available out there somewhere. We chased many leads, including a supplier with a website that actually listed caps, but eventually all leads turned back upon themselves or just stopped dead. But all this effort wasn't totally wasted, as we ended up with a number of people who were now interested in purchasing new caps, some with very pressing needs.

By our calculations, what started as a very small run of six or so caps now had an immediate potential of at least eighteen. This larger figure would fit well with our production methods and spread the amortization of our already economical tooling and development costs. A number of these potential customers were for marine applications in projects nearing completion and these guys weren't particularly concerned with historical accuracy. If we weren't able to bring the project to fruition in a relatively short time frame, they wouldn't think twice about adapting another type of distributor or, god forbid, an electronic ignition.

Within a short time, we'd heard from Denis that he'd managed to borrow a sample cap from a friend. Less than a week later, a courier service delivered to us one complete and several broken cap assemblies, oh and a rotor. "Yes, could you please do up some rotors as well? Mine are knackered. And what about the ignition coil, isn't that part of the cap?" What started as a very small run of a hideously complicated distributor cap, was now a full blow reverse engineering and development project with time constraints! It was beginning to feel strangely like 1917, all over again.

For days we looked over the broken pieces and the complete cap, analyzing and debating how it had been made and pouring over the various manuals we'd collected, trying to understand and speculate why they were made the way they were. An interesting early observation was that the high tension contacts had been cast into an asbestos ring and machined. This contact ring was then placed into a mould and the cap cast around it. Was this asbestos ring essential? If so, it would require an additional set of moulds and we'd need to develop a suitable asbestos casting material. Careful examination and comparison of various manuals led to the conclusion that two different types of ignition rotors were used; an early type with a spring-loaded carbon brush, and a later type with a fixed metallic brush of which we had a sample. With the spring-loaded carbon brush type rotor, the carbon brush actually ran in continuous contact with the high tension contact ring, necessitating a close tolerance machined surface. The asbestos was required to withstand the heat and wear caused by the constant brush contact. This early rotor type was obviously a design weakness quickly remedied with the introduction of a fixed brush type rotor. The new type rotor no longer required the asbestos brush track, but as the cap was already in production and would work with either rotor type, no cap change was apparently warranted. By understanding why it was made, we were able to determine that the asbestos track would not be required on our new caps, as long as the later rotor type was used, thus allowing a single mould and a monolithic casting.



Sample of a reproduction distributor cap. Made in small batches, caps are concourse quality.



The original pattern Liberty distributor cap. Note the asbestos high tension ring.

The more we studied the Liberty cap and contemplated the mould requirements, the more we realized that the mould itself would be very complicated, at least an order of magnitude greater in number of pieces than any we'd done previously. We also realized that special tooling and equipment costs would need to be kept to a minimum, as any capital costs unique to the project would have to be amortized over the small production run. Various production methods were discussed for each component or sub-component with an eye to using existing tooling and equipment wherever possible. A few quick calculations revealed that our largest pressure chamber would be marginally up to the task. If we made the mould casing out of high-density particle board, as per our normal practice, it would be too large to fit into the pressure chamber and fabricating a larger pressure chamber would be an expensive option. A rigid casing is essential to limit the mould distortion during the various heating and cooling phases required during pouring and curing. Welded steel sheet was the option eventually chosen. It works, but is more difficult to work with than the preferred particleboard, especially when breaking down the mould to remove the cured distributor cap.



Our most complicated cap to date was the 6-cylinder Lucas cap. It dwarfs in comparison to the Liberty pattern distributor cap.

The toughest challenge would be in locating the brass high-tension contacts accurately. Threaded at one end and knurled at the other, their depth and placement would be difficult. Measurement of a number of original contacts from the broken caps was revealing. All of the contacts were of different lengths, not by deliberate calculation and placement, but as a result of the machining of the original asbestos rings. This frustrating discovery meant that we would need to be able to manually adjust the placement of the contacts in the mould after the phenolic had been poured to ensure correct radial depth of the high-tension ring. Pounding our heads on the table, we decided to drill and tap nylon rod to place over the threaded portion of each contact. These twelve rods would protrude beyond the steel casing and would slide within the silicone mould and through the still liquid cast phenolic until each was in direct contact with the inner mould, thus achieving the correct radial distance.

Concurrent with all this mould work had been the analysis and search for sub-components. In one way we really lucked out, as despite our worst fears, every threaded component turned out to be a standard 10-32. Apparently, this was to be the only 'standard' item of any sub-component.

Our first search was for the brass high-tension contacts and knob inserts. Although the inserts desired were of rather obsolescent patterns, a bit of searching turned up a number of manufacturers who claimed great flexibility in accommodating customer special requirements and quantities. Several days were spent working up quotation requests in on-line, email and fax formats to our most likely prospects, depending on each manufacturer's preferred method. We even bulked up our requested order quantities to ensure their interest. Within a few days we received our first and only voluntary response, "our minimum order is 10,000 per insert and the cost will exceed \$2 each". Not even a quick calculation in my head was necessary to analyze the economic reality of that quotation. As another week passed without further response, we took the proactive course and began calling to follow up on our outstanding quotation requests. Most of these inquiries generated less than cordial responses, but apparently out of pity, one did throw us a life-line "Call so-and-so. They have a limited selection of inserts, but they do sell in smaller quantities. They should have a rep in your area."



Contact Knobs

We were able to locate a website and on-line catalog for so-and-so. Although their selection was very limited, they did have some brass inserts of the correct dimension with a knurling pattern virtually identical to our original samples. Unfortunately, they were female rather than male, but we could always insert and solder a threaded brass stud to achieve the desired final product. A call to so-and-so's local sales rep as listed on their website was very strange "Who are you? Are you a sub-contractor to an existing account? And, now how did you hear about us?" My answers to his questions didn't seem to satisfy, but I was eventually allowed to state my request "I'd like to order 1000 of part number xx and 100 of part number xy." He informed me that it would be

necessary to check stock and I could expect a call back in several days time.

This fellow was true to his word and did call back several days later “You can have 750 of part number xx and 300 of part number xy.” “But I requested 1000 of xx and 100 of xy.” “Yes, but you can have 750 of xx and 300 of xy.” He then went on to explain that xx and xy were obsolete designs (no big surprise there) and the only reason they had any on the shelf was because they were part of an overrun from an order placed many years ago. If we wanted any, we had to take whatever was left. The good news was they were really cheap. Just to satisfy my curiosity, and on the off chance the Army Air Service decided a large stock of Liberty distributor caps was necessary for war reserve, I asked if it would be possible to order xx and xy in the future. “No problem, but you’ll have to order 10,000 of each.” He took the words right out of my mouth.

With the contact problem solved and the mould and production details worked out in our heads we were now ready to proceed. As things were starting to come together I found myself doing a little late night web surfing one weekend when I spotted something interesting on the Air Force Museum home page “World War I Aircraft Fly-In”. Monday morning I walked into our shop office and handed a copy of the page to Dave. “What do you think? Do you want to go?” As a smile comes creeps over his face I drop the other shoe, “Me too, but it’s only two weeks away and there’s no point in going without a sample cap for people to see.” That was exactly the impetus we needed, a challenging deadline.

Now with a sense of urgency, we began to fabricate the steel mould casing and then started casting the silicone mould; three large sections (two exterior and one interior) plus several nylon alignment pins and twelve threaded nylon tubes for the high-tension contacts. One large section was poured per day and allowed to cure overnight before prepping for the next pour. Three days before our scheduled departure for the fly-in we were ready to cast the first cap.

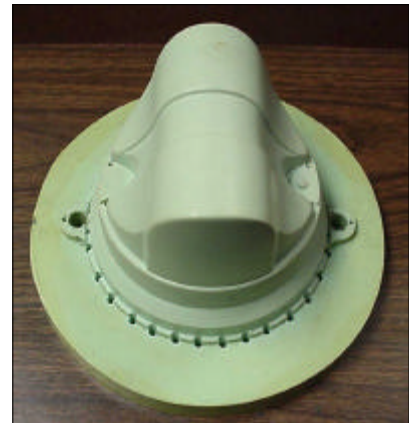
It was early in the morning when we loaded the twelve threaded nylon tubes with brass high-tension contacts and carefully put them into place in the two assembled exterior mould sections. A predetermined amount of the viscous phenolic mixture was slowly poured into the partially assembled mould to avoid creation of air pockets or bubbles. With the phenolic now in the mould, the large inner mould section was placed on top and slowly pushed down until fully seated on the outer sections. The threaded nylon tubes containing the high-tension contacts were then pushed in until the face of each contact seated against the interior mould. The entire steel wedding cake appearing monstrosity was then pressurized and baked.

After cooling, we began removing the mould from the steel casing. This process was much more difficult than expected and we later ended up modifying the steel casing to allow easier removal. Removing the cap from the silicone mould went without a hitch. The first cast looked perfect, much better than usually goes on the first pour and certainly much better than we had hoped. It wasn’t until we tried to remove the threaded nylon tubes that problems arose. We had made these threaded tubes on our lathe, but they weren’t perfect and most had .001-.002” eccentricity. When this was combined with the radial imperfections of the original pattern cap, it spelled disaster. The cured phenolic is very brittle, and when each nylon tube was unscrewed its’ surrounding parapet cracked.

Quick thinking was in order as we were now running out of time. Several options were discussed, but only one would work within our time frame. We decided to reduce the diameter of the threaded nylon tubes and reassemble the mould, then pour silicone mould material around each tube cavity, thus providing a tube within a tube. We hoped this silicone tube would provide enough give to allow successful removal of the nylon without cracking the parapet. The required modifications were completed in a matter of hours, the silicone poured and was allowed to cure overnight. We had time for just one more try and if it didn’t work the trip was off.



Mould bottom.



Mould top



Mould steel shell



Mould shell ready to pour.

The preparations and casting process of the previous day were repeated. If all went well we would leave for the fly-in early the next morning. We began stripping the new cap from the mould with great anxiety. When the time came to remove the threaded nylon tubes, we all held our breath and listened for that telltale cracking sound that meant we'd failed again. One by one they came out and no cracks. A sigh of relief came over us as we looked at each other in disbelief. We'd done it! Careful examination of the cap confirmed it was virtually perfect, no flaws, no bubbles. Very minor finishing was required to remove a little flash, the casting vents and clean up the face of the high-tension contacts. As our hands ran over it we realized what we were touching, the first new Liberty engine distributor cap produced in over eighty years!



Our first Liberty reproduction cap!

Part 2

We did make that fly-in at the Air Force Museum and had a grand time. Meeting the people and once again seeing the aircraft provided more than sufficient motivation to carry us through our next phase, from components to complete assembly. A few hours time viewing complete Liberty engines and the minor cap variations up close helped to reaffirm our previously arrived deductions and analysis. Once back at our shop, we felt as though the toughest part of the project was now behind us. In that we were only partially right.

Considering the previous challenge, we approached the rotor with an almost cavalier attitude. After all, it was a much smaller casting and at first appearance seemed simple enough; three primary metal components in a phenolic casting with a spring steel brush. Just as with many of our previous similar projects, we planned on pre-machining the metal components which would then be fitted into the mould prior to the casting of the phenolic. Then came the glitch. We realized the holes in the metal base piece were critical in aligning the rotor and we didn't have original drawings to provide the allowed tolerance. A few thousandths error could leave us with a great looking finished product that wouldn't fit and given the properties of the phenolic material would not be correctable after the fact. We knew that our original pattern was within tolerance so the only safe choice was zero tolerance from the pattern. Using this mode of thinking, the center hole became our working constant.

Off the shelf fender washers became the starting point. None was available in the exact dimension so we chose some with a smaller than required center hole and a larger than required overall diameter. After first drilling out the center holes to the correct size, a stack of washers was through bolted and placed on a lathe where they were cut down using a grinding attachment, to an outer diameter several thousandths less than the original pattern. The alignment holes were then located and drilled, this time oversize from the original. Small dished plates, actually by-products of our hand punch, were spot welded into place over the center hole. Each washer was then deburred, belt sanded flat and sandblasted.

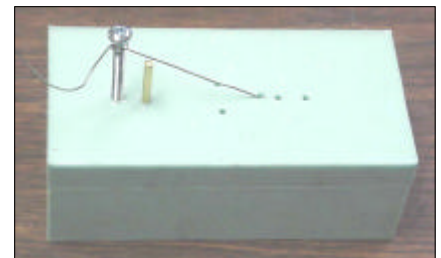
For a short time, we contemplated making both types of rotor; floating and fixed brush. After a thorough discussion of the principles of each, we came to the conclusion there could be no situation where the fixed brush wouldn't work and plenty of situations where the floating type wouldn't. In addition, the fixed type would be both easier to produce and to install.

The fixed brush of our pattern rotor consisted of a hollow brass tube with what appeared to be a tungsten tip. Doubtlessly durable, we reasoned such a tip would survive long after all other ignition components had failed (to say nothing of the engine itself!). This potentially costly feature was quickly discarded and replaced by a brass brush cut from solid round stock and tapered at one end.

A silicone mould of the pattern rotor was made in our conventional fashion using high density particle board for the mould casing. We opted to pour the casting with the rotor metal base at the bottom of the mould. A 10-32 screw through the top of the mould sufficed to locate the threaded insert, but holding the brass brush tight to the top of the mould took some thought. We eventually decided to attach length of



Open Liberty Distributor Rotor Mould



Closed Liberty Distributor Rotor



Machining Washers

fine solder wire to the center of the brush. A hole was then punched in the top of the mould through which the solder wire passed thus holding the brush tight against the underside of the top of the mould. Actual casting of the rotors was very straight forward and uncomplicated, requiring only minimal work to remove flashing and vent stubs.

One rotor component kept us scratching our heads for a simple solution, the spring brush/coil contact. This small piece of spring steel was a critical element, but even if we decided to make a large run of rotors, very little material would be required. Finding a small amount of spring steel of the proper gauge ended up being more like a scavenger hunt than a thought out procurement decision. We scoured the shop in search of suitable material; pallet banding strap (too thick), ignition feeler gauge (right size but what a waste with only one useable piece of the right thickness per tool), band saw blades (too thick), etc. One evening, just before bedtime, Dave called with excitement in his voice "Steel tape rule spring!" Before I'd reached the shop early the next morning, Dave had already dissected a steel tape rule. Sure enough, the retracting spring was just the material we'd been looking for and in a quantity far in excess of our requirements. Once cut, punched and bent into shape they were the finishing element to the rotor assembly.

While Dave and I toiled away on the distributor cap, dismemberment of the coil plate assembly and the coil itself fell to John, our electrical specialist. To gain insight to other Kettering type coils of the same period, we turned to some of our well used basic handbooks *Self Propelled Vehicles* and *Motor-Cycle Principles and The Light Car* published in 1903 and 1914, respectively. It was these books that provided some insight into the animal we were about to attack.

As additional precursor training, we decided to dissect several post war automotive coils for the experience as well as to gauge their potential suitability as off the shelf replacements for the original. All of these coils ended up being oil filled, the PCB impregnated oils serving as both insulator and coolant. These efforts led us to the conclusion that although it would be possible to use one of these type coils if necessary, it would not be the preferred route.

Digital photos were taken of the coil plate before removing the coil and during the disassembly detailed notes were made to record stacking order of the numerous sub-components. Removal of the coils' phenolic end caps required soaking in mineral spirits to soften the eighty year old varnish and potting compound. Once free of the end caps, the varnish encrusted bobbin wound bare coil and wire ends were clearly visible.

Now it was testing time. Using an ohmmeter, we checked both primary and secondary windings for continuity. Although both windings checked out, this didn't necessarily indicate undamaged windings, as a short within either winding could also show continuity. After measuring the wire used in each, we checked resistance of the windings. Knowing the resistance of copper wire of a certain gauge over a given distance and plugging our measured resistance figure into the equation brought quizzical looks all around. The length of wire indicated was thousands of feet. When divided into the average estimated radius of each wind, I came up with a primary coil winding of nearly 15,000 turns! Both Dave and John thought at the very least that I'd misplaced a decimal. As none of us believed these calculated numbers could possibly be correct and were indicative of corroded windings, we decided the only way to get the correct information was a total post-mortem, to completely unwind the coil.

Again, mineral spirits was used to soften the varnish covering the coil windings. Due to the very fine and fragility of the wire used, it took Dave and John almost a full day to unwind a single layer, 500 turns of 38 gauge copper wire. With no appreciable decrease in the overall coil diameter, we decided to abandon our initial plans to hand wind the coils and to find a specialist to complete unwinding the original and then to machine wind the new coils.



Finished rotor components



Original Liberty Distributor Coil



Disassembled Liberty Coil

Finding a subcontractor willing to take on the coil project was reminiscent of the search for brass inserts. Being our electrical specialist, John undertook the search and discussed the project and our requirements with a number of firms. Our decision was made when we found someone truly interested, a small New England firm that specializes in prototyping and small production runs. We boxed up our partially unwound coil with all our relevant specifications, drawings, descriptions and findings to date and crossed our fingers.

With the coil monster foisted onto another poor soul, we now concentrated on the coil plate which was quickly disassembled to its component parts. The large copper brackets were cut by water jet, the smaller brass pieces holding the carbon brush were punched, hand stacked and then cut to size on the lathe again using a grinder attachment. Carbon brushes suitable for modification were found off the shelf and these were cut down, then hand tapered to fit using a small belt sander.

Locating phenolic of the original thickness for the base plate seemed hopeless. Using a thicker plate would cause interference problems with either the coil or the rotor and was not an option. Once again our small requirements precluded special order manufacture and off the shelf material of the correct type and thickness was unavailable.

We'd already decided it would be necessary to mill oversize stock to the correct thickness, when on a whim Dave decided to stop by a supplier we'd used before that handled overstock and reclaimed plastic. A description of our needs to the man behind the counter immediately set off light bulbs. He disappeared out back and shortly returned with a nearly four foot square sheet of material identical to the original! He then went on to explain that this stuff had been around forever and they'd given up hope of ever selling it. For a small amount of pocket change this piece changed hands, whereupon the counterman promptly said he had another sheet as well if we could use it. In disbelief, Dave returned to the shop to show off his prize. It was then we noticed a very old tag attached to one corner of the sheet "Vought Aircraft Company".

The phenolic was first cut into squares on a table saw before drilling the center hole for the carbon brush. Using this hole as a pivot, a simple jig was set up again using the table saw, this time to cut the squares into circles. This same jig was then transferred to the mill and used as a center to countersink each piece for the carbon brush retaining plate.

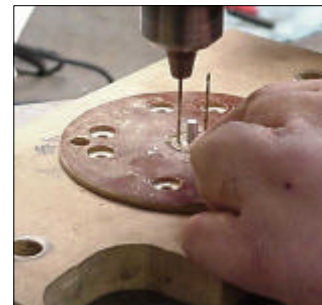
From this point forward, each coil plate became a hand fitted assembly with all pieces sequentially marked and matched. With a matched set of copper coil brackets held to its piece of phenolic, the same mill and jig were used as an off set pivot to drill through both copper and phenolic in eight different locations for the retaining rivet holes. Each of these holes through the phenolic was then countersunk for the rivet heads. The carbon brush plates were drilled in a similar fashion.

Copper rivets were then used to attach each phenolic plate to its corresponding set of coil brackets, each rivet then also soldered to its copper plate. The carbon brush and brass retaining plates for each were placed, then pinned through using brass push pins which were also soldered into place. Small amounts of the same phenolic mixture used to make the cap, knobs and rotor was used to fill over the recessed rivet heads. Each plate and bracket assembly was then hand fitted to a new cap and minor adjustments performed as required. As there is no variation between the caps themselves, once thus fitted the coil plates are interchangeable and will fit any cap.

A constant communication had been going on with our coil winding subcontractor during this entire time. Sending the coil components off to someone else had apparently not made the process any easier, only passed the same problems we'd experienced on to someone else. Unwinding the layers and layers of fragile wire, paper and varnish was still a tedious and delicate hand process. Discussions back and forth on various types of solvents and methods never did save any appreciable amount of time but served to prop up the morale of our now beleaguered associate. As the coil diameter gradually diminished and the last turns of each winding finally gave way, the accuracy of those original calculations became evident; a single layer primary winding of 150 turns and a second



Original Phenolic Sheet



Coil Baseplate Fabrication and Assembly

dary winding of 29 layers or 14,500 turns! (The ratio of 97 to 1, being essentially the same as a 'modern' Kettering type coil at 100 to 1)

Eighty some years ago, those 14,500 windings, whether wound by hand or machine must have been one heck of a challenge. Even using the equipment available today, it is not a simple process and very difficult to do without splicing. The very slightest variation in tension will instantly snap the very fine wire. Initial winding attempts were tried using thin sheets of Kevlar as a replacement for the original paper between the layers. This material didn't pan out as the Kevlar had enough of a memory to preclude a tight wind. In the end, the coil was produced exactly as the original using three mil paper between each layer, then finished off with varnish and tape wrapped. By the time we received the first batch of coils, all other subcomponents had been completed and we were ready for final assembly.

A jig was made to hold the coil and end caps in alignment while the silicone used as the potting compound cured. With end caps in place, the core is then inserted; lengths of .050 piano wire surrounding a .250" diameter rod threaded at each end. Layers of steel shims, varnished paper washers, short insulating tubes and a stamped steel lockplate are used to hold the coil fast to the copper retaining brackets of the coil plate. Once assembled one last check is made for shorts before soldering the coil wires in place. Assembling and soldering the coil to the coil plate is particularly challenging and requires more fingers and hands than possessed by the average human. Correct stacking of these components is critical as engine vibrations would quickly short out an improperly or marginally assembled unit.

It was difficulties in this final process that drove our decision to design and build a testing device. This simple rig, consisting of an old distributor with contact set and condenser, spark plug, brackets, wire and a few clips attached to a piece of plywood, uses a six volt battery and provides a simple go/no go test for each coil plate assembly. Once tested, the coil plate assemblies are ready to be installed in a distributor cap and soldered into place.

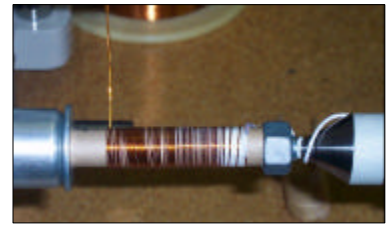
This challenging project was more a mixture of archeology and reverse engineering than a traditional research and development program, the fruits of our endeavors being all we could have hoped for. With final products virtually identical to the originals, all components are interchangeable; new caps, knobs, rotors, coils and coil plate assemblies equally at home together or as part of a mixture with original components. New distributor cap assemblies and rotors were completed and shipped within six months of the initial inquiry at an economical price and surprisingly within original estimates. Today these caps and components are functioning in a number of engines, once again providing the spark for Liberty.

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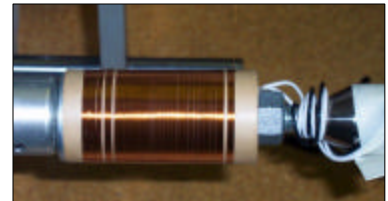
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Kip is the founder and president of Kip Motor Company, a parts, service, and restoration facility specializing in antique British automobiles and now, vintage aircraft parts. A member of the Antique Automobile Club of America by the age of five, antique automobiles and history are his lifelong passion.

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*Winding Coils: Primary (above)
Secondary (below)*



Coils potted using jig.



Coil Test Rig



Finished Coil and Plate Assembly