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Cold Welding

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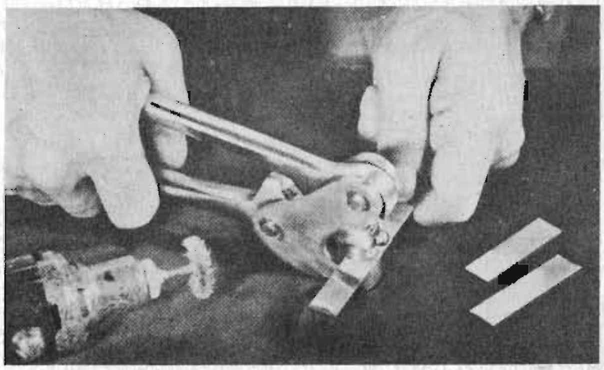
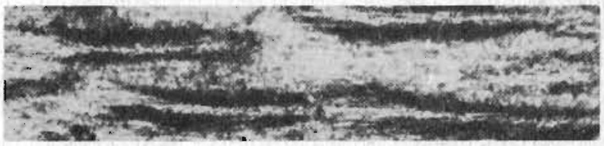
A cock-simple English invention may greatly simplify the joining of nonferrous metals.

THE DISCOVERY that General Electric Co., Ltd., announced in England two years ago is so simple it is hard to believe: the easiest way to join two pieces of nonferrous metal is merely to squeeze them together. The truth of this was doubted even by metallurgists at first, but G.E.C. (no relation to G.E. in the U.S.) has supplied convincing proof that pressure alone is enough to produce bona fide, homogeneous welds in aluminum, copper, zinc, lead, silver, cadmium, and nickel. And in its laboratories at Wembley, G.E.C. has demonstrated the industrial potentials of its "cold pressure welding" process by using it to produce wire joints, cable sheaths, armature conductors, airtight cans, and other special items without benefit of solder, rivets, or any of the various complicated brazing and hot-welding techniques. Moreover, cold welding has joined aluminum to zinc and to lead—unions that for practical purposes cannot be achieved by electrical welding at all.

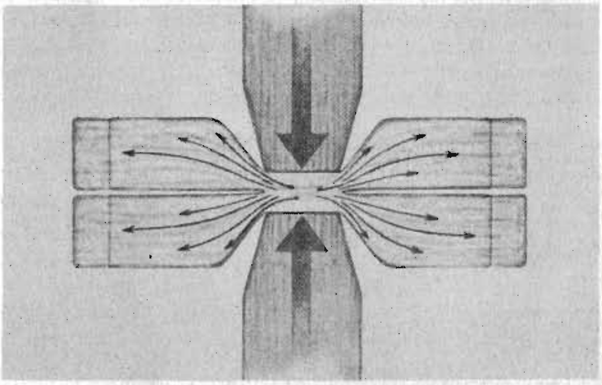
When these developments were publicized in the U.S. last year, they excited thousands of engineers, and by this summer nine companies, including Alcoa, Bohn Aluminum, Republic Aviation, Union Carbide, and Copperweld Steel, had taken out licenses to experiment with cold welding. None of their experiments has yet succeeded in discovering ways to apply cold welding commercially. But, as this was written, they were just getting word of a new G.E.C. development, the "projection cold weld," which is the most spectacular discovery yet. For this beautifully simple technique—illustrated on the opposite page for the first time—eliminates both the necessity for the special dies used in G.E.C.'s original process and the defects that have hitherto inhibited the application of the process. The projection cold weld, indeed, promises to make the joining of nonferrous parts one of the most elementary jobs in industry. This should be good news for war industries.

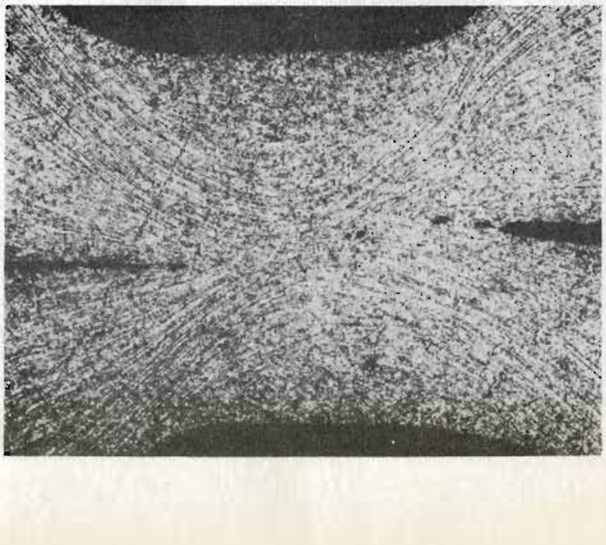
NO ONE IS HAPPIER about G.E.C.'s latest advance in cold welding than the sixty-two-year-old American, William Dubilier, who last year organized the Koldweld Corp. to handle the U.S. licensing rights for G.E.C. A prolific inventor himself, Dubilier confidently expects that, once suitable production techniques are devised, industry will find countless applications for cold welding. His imagination roams from such uses as making instrument containers tight against tropical fungi—an application the Signal Corps is investigating—to welding the edges of aluminum envelopes for carrying State Department documents. He foresees that electricians will be quickly cold-welding wires with a special pair of pliers, and that the common steel-covered BX cable used in house wiring will be replaced by cable sheathed in cold-welded aluminum. And he points out that by replacing the heavy lead sheaths on

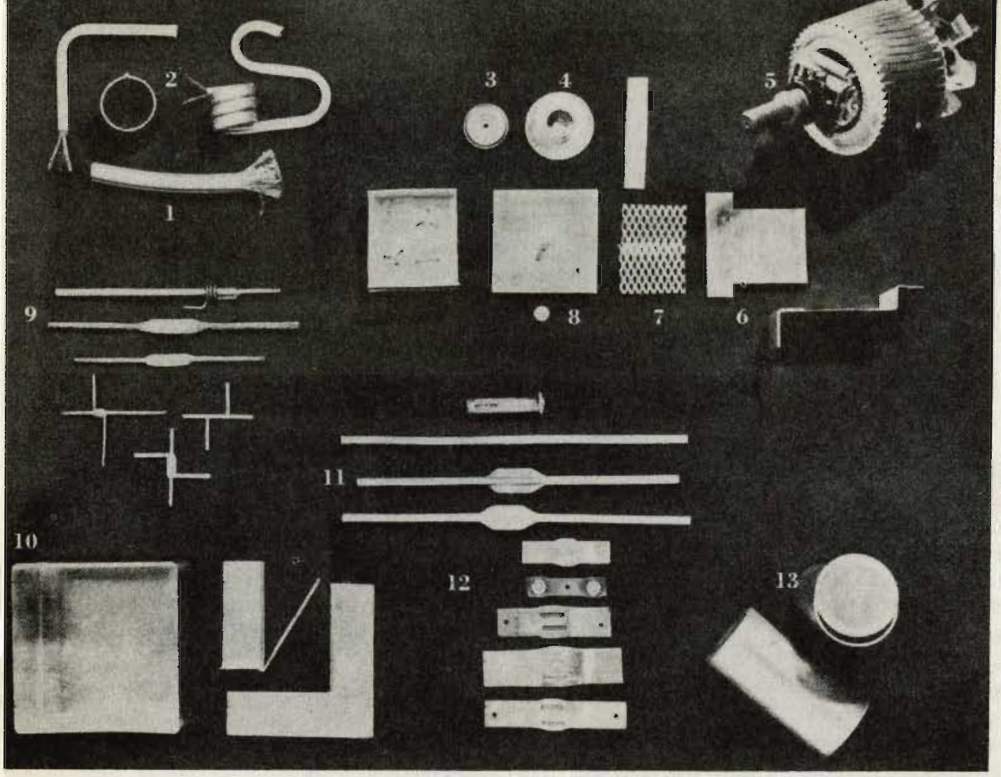




The original cold-welding technique *requires only (1) scratching off the surface oxide with a spinning wire brush and (2) squeezing the two cleaned surfaces together between specially shaped dies. The photomicrograph above shows how the wire brush cuts furrows in the metal, while the diagram below shows how pressure between two dies causes the metal to fuse and flow out from the welded section, widening the two strips. Photomicrograph of the weld's cross section reveals the "cold flow" lines.*

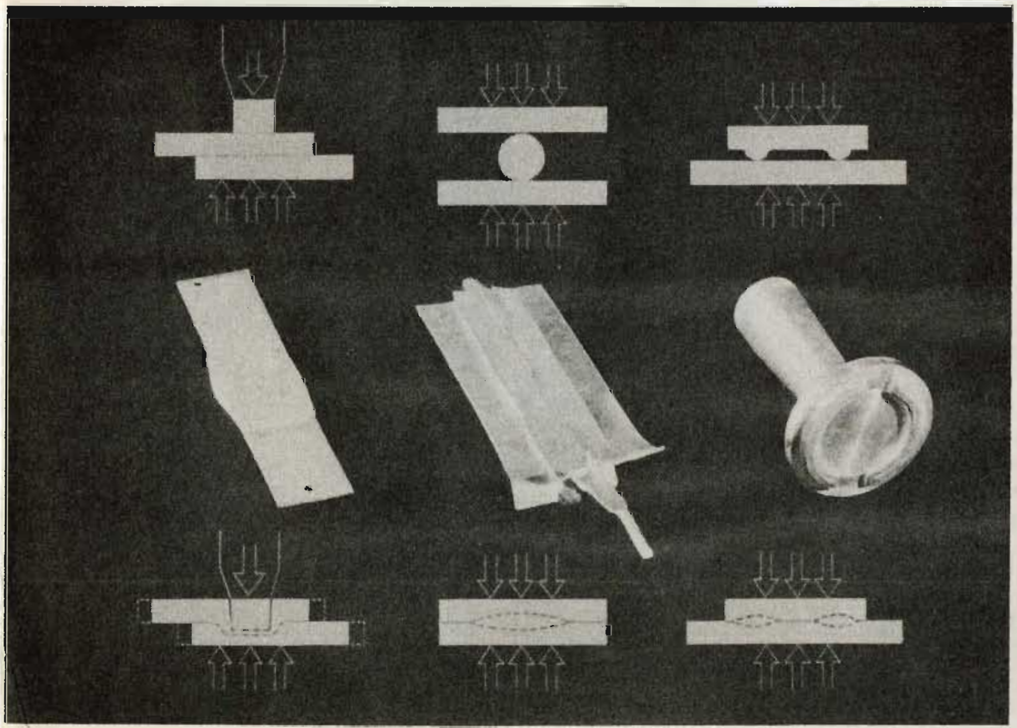






What cold welding can do *is indicated by this collection of samples produced in G.E.C.'s laboratory: (1) cable sheaths of cold-seam-welded aluminum strip; (2) cross section of cable sheath; (3) an instrument bellows; (4) socket on round plate; (5) armature made with fifty simultaneously cold-welded aluminum conductors; (6) thin sheet joined to thick block; (7) screen mesh to screen mesh; (8) gastight screw stud to plate; (9) various copper and aluminum wire welds; (10) aluminum box and parts; (11) welded rods of copper and aluminum; (12) combination welds of other nonferrous metals. Note the two small silver contacts on copper strip; electrical uses of cold welding appear promising, since it increases the conductivity of wire at the joints and avoids corrosion hazards of soldered connections. (13) Airtight aluminum containers.*

The latest startling development *in cold welding does away with the original special dies that deform and groove the metal. The evolution of the projection cold weld is shown below: first G.E.C.'s engineer Sowter tried filling in the groove by using the die to sink a metal plug into the two strips; then, at inventor Dubilier's suggestion, he put a round length between two strips, squeezed this sandwich between two flat dies, and found that the round piece flattened out into a cold weld just as two wires do when pressed between round dies (see samples in group 9 above). Finally Sowter cast rounded projections on the base of a handle and found that under sudden high pressure these could be cold-welded to a flat plate, as shown at the right.*



telephone cables with cold-welded aluminum sheaths it would be possible to place telephone poles three times as far apart.

For their part, however, Koldweld's licensees this summer were unwilling to say much more about cold welding than that "it looks promising." Bohn Aluminum, for instance, was not even ready to acknowledge its potentials for use in parts assembly (e.g., pots and pans) and in forgings, castings, extrusions, etc. However, Copperweld Steel Co. recently testified that its experiments have proved that a solid-copper grounding wire can be successfully cold-welded to its copper-covered steel ground rods, and the company is working out tools that will enable utility construction crews to make such welds in the field. Also, another licensee, the Wire Wall Products Co., is hopeful that with cold welding it will eventually produce aluminum refrigerator shelves that will be lighter and cheaper than its welded steel-wire shelves.

On the other hand, after six months of experiments Alcoa had not uncovered any ways to adapt cold welding to its customers' requirements, and its engineers would say no more than, "No one can tell now where this development will find its application." The aircraft industry also remains dubious about cold welding, but since the process might save millions of man-hours and dollars, the U.S. Air Force has given Republic Aviation a $36,000 contract to test and evaluate its applications to plane making.

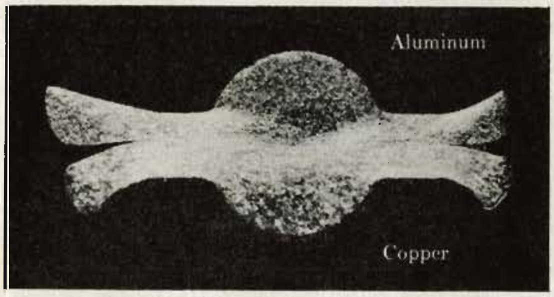
THUS IT MAY BE SEVERAL YEARS before cold welding finds its place in manufacturing. G.E.C. has put it to practical, commercial use in Britain in the manufacture of airtight condenser and valve containers. But its rapid development in G.E.C.'s laboratories has raised technical questions—especially about the strength of cold welds—that must be answered before manufacturers will accept it as a simple, fast substitute for present metal-joining techniques.

Part of Dubilier's business philosophy has been that Koldweld should let its licensees develop the necessary technical data on cold welding, but none has yet done so, and he has only recently been convinced by some of Koldweld's backers, including J. H. ("Jock") Whitney & Co., that the company should underwrite such work. Dubilier, however, is sticking by his original decision that cold welding should eventually be made available to as many licensees as possible, even down to "the man in the basement." And his ingenuity as an inventor is partly responsible for the fact that cold welding has lately come along as fast as it has.

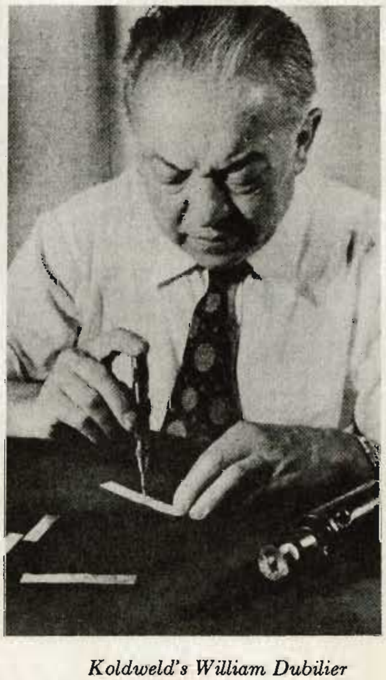
Accidental Marriage

BY THE TIME Dubilier first heard of cold welding early in 1949, G.E.C.'s Anthony Bagnold Sowter had been experimenting with it for nearly four years. Like most basic discoveries, this one was largely accidental. Sowter, an ex-R.A.F. pilot whose career had been cut short by crash injuries, had taken a job in G.E.C.'s laboratories at Wembley in 1939, and during the war he noticed that whenever he was in a hurry and used inefficient shears to cut two overlapping pieces of copper, the pieces stuck together. And often, when he wrenched them apart, one piece broke off not at but next to the point where the shears had squeezed them. This phenomenon roused his mechanical curiosity and, when the rush of war work subsided in 1945, he started to investigate it. After "messing around with a four-pound hammer and a hand stamp," he tried squeezing copper pieces in an old hand press, then found that aluminum also could be stuck together.

Sowter demonstrated his experiment to G.E.C. laboratories' chief, the late Sir Clifford Paterson, who was so impressed that he told Sowter to make this development a full-time job and authorized him to order power presses and dies to his own



The men behind cold welding *are as different as the metals that the process joins. G.E.C.'s inventive engineer Anthony Sowter (left) is a reserved young Englishman who has concentrated on new laboratory developments. Conversely, William Dubilier is an ebullient American inventor who has organized the Koldweld Corp. to patent, license, and promote the process in the U.S. Dubilier is here putting on a favorite demonstration: cold-welding two aluminum strips with a prick punch. What happens when an aluminum and a copper wire are cold-welded is indicated in the cross-section photomicrograph above: squeezed together, their facing halves fuse and flow out into welded flaps at each side.*



Koldweld's William Dubilier

G.E.C.'s Anthony B. Sowter

specifications. While cold welding was not directly in line with the laboratory's electrical-engineering work, Paterson saw that it might be used in making aluminum sheaths to replace the lead sheaths on the cables produced by Pirelli-General, one of G.E.C.'s associate companies. But after two years of hard work it was apparent that Sowter had achieved several metallurgical triumphs that could have industrial repercussions far beyond the cable industry.

There was, first, his demonstration that pressure alone could produce a genuine weld. When they heard of his work, metallurgists swarmed to the laboratory to help him with the theory and principle behind cold welding. Sowter's explanation of the principle is simply that when steel dies press two pieces of aluminum together, the pressure causes "intimate contact between the two surfaces," which blend together as the metal flows out from under the dies. Some metallurgists think that the heat generated by the pressure helps to soften the metal. What actually happens to the molecular structure of cold-welded metal, however, is still not clear. There may be merely "diffusion," in which an exchange of loose atoms or molecules occurs around the metal crystals, or a shifting of "grain boundaries," or "lattice deviation," or "recrystallization," in which the pressure-distorted crystals spring back into shape. Sowter merely admits the possibility of "interatomic forces" acting between the two surfaces. Whatever takes place, the result is a scientifically acceptable marriage of metal.

Sowter also demonstrated that most of the nonferrous metals commonly used in fabricating could be cold-welded. His experiments with lead, however, were not very satisfactory, indicating that malleability has little bearing on suitability for cold welding. At the same time, the hardness of some magnesium and aluminum alloys makes them nearly impossible to cold-weld without first annealing them.

Finally, Sowter worked out the practical techniques for cold welding. To get rid of the oxide coating that is the particular bugaboo of all aluminum welders, he tried various acid and degreasing solutions but eventually found that it could be most efficiently scratched off with a simple rotating wire brush. Though the oxide begins to re-form at once, the scratched surfaces can be cold-welded even twenty-four hours later. (Merely brushing a finger across the surface, however, will prevent them from welding.)

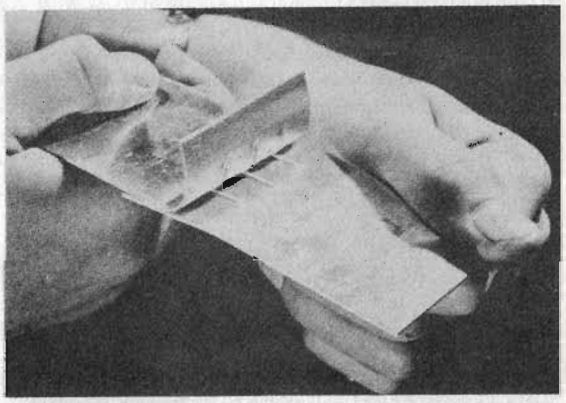
Merits and demerits

By trial and error, Sowter also devised four different die shapes: a small rectangular one for spot welds and a long one for seam welds; a ring die for sealing cans and joining tubes; a continuous-wheel die for making tube out of aluminum-alloy strip. The widths of the dies varied for different metals and different thicknesses, while the pressures needed ranged from 20,000 to 144,000 pounds per square inch. Sowter worked out a ratio between the thickness of the metals and the degree of compression required to cold-weld them. In commercially pure aluminum, for example, this ratio, called a "figure of merit," was 30, which meant that a satisfactory cold weld between two equally thick pieces of this metal would take place when they were squeezed down to 30 per cent of their combined thickness.

These original cold-welding techniques, however, produced two undesirable results. The major complaint has been that the impact of the dies makes deep grooves in the metal, which would be detrimental in many welded products. In pots and pans, for instance, such grooves would be difficult to keep clean. The second defect is that the thinning down of the metal around the weld point reduces the tear strength around the joint. There is also the thinning down of the weld point itself, which lowers the shear strength. However, this loss is largely offset by the fact that the cold working of the metal in the compression process hardens it. Thus, squeezing two pieces of commercially pure aluminum to 30 per cent of their combined thickness makes them about twice as hard, and the shear strength of the resulting cold weld may be 87 per cent of the shear strength of one unwelded piece of the same metal. On this basis the cold weld would have approximately the strength efficiency of a hot, spot weld in the same metal.

Enter the entrepreneur

The importance of Sowter's discoveries, however, far outweighed these early defects, and in 1948 he patented his inventions jointly with G.E.C. When the process was made public, inquiries and congratulations poured in from British scientists, at least one of whom, R. F. Tylecote of the British Non-Ferrous Metals Research Association, had been experimenting with low welding temperatures and had concluded, theoretically, that cold welding was possible. In the U.S., interest was aroused in February, 1949, when the *Welding Journal* published Sowter's detailed description of the techniques, ratios, and principles underlying cold welding. The inquiries this produced set G.E.C. to thinking about licensing the process in the American market, and it accepted, quite understandably, the advice of its old friend Dubilier.



Tearing apart *two pieces of aluminum cold-welded by Sowter's original process indicates both the strength of the welded spots and the weakness caused by thinning the metal around each weld point.*

Dubilier certainly had all the international experience with new products that G.E.C. could have asked for. As a sixteen-year-old New York schoolboy in 1904, his enthusiasm for new inventions had landed him a job helping Marconi experiment with wireless telegraphy, and at twenty-two he was publicly hailed as a "wizard youth" in Seattle, where his experiments with wireless telephony made him one of the first broadcasters of voice and music. There he also set up for a Standard Oil subsidiary the first commercial wireless-telegraph station for communications with Alaska. The next year, 1911, he went to Russia on a $1-million contract with a $50,000 advance (all he ever got) to install a private wireless-telephone system between the Czar's palaces. Unable to get any more money for this project, and terrified by the brazen tactics of Czarist spies, he escaped to England where, backed by the British Government, he developed the mica condenser, which made him permanently famous. His condenser, which replaced the bulky glass Leyden jars, freed the British and U.S. navies from dependence on a German monopoly, and literally transformed the radio industry by making compact radios possible.

Since then, Dubilier has accumulated some 400 patents on other inventions, including the first practical wireless-telegraph set for aircraft, a portable X-ray machine, a submarine detector, and a flexible track for toy trains. And for nearly forty years he has been shuttling back and forth across the Atlantic (he made his hundredth crossing this spring), giving technical advice to the companies he founded, the Dubilier Condenser Co. in England, the Deutsche Dubilier Kondensator Gesellschaft in Germany (bombed out in the last war), and the Cornell-Dubilier Electric Corp. in the U.S., which does a $14-million annual business. He was in England early in 1949 when he was asked to look at G.E.C.'s cold-welding experiments, and though by that time he was getting ready to retire and "didn't want to see anything new," he was so fascinated by Sowter's process that he immediately decided to show G.E.C. how to market it in the U.S.

Dubilier's first advice to G.E.C. was to avoid licensing cold welding to one big American company. G.E. in the U.S., for one, had inquired about G.E.C.'s plans for licensing cold welding, but Dubilier knew from long experience that a novel process is not likely to get wide industrial use if one company controls it. Dubilier's scheme, which G.E.C. adopted, was to form an American company and sell a small amount of stock to a few influential men who could help him bring cold welding to the attention of top management in many companies. Accordingly the Koldweld Corp. was capitalized at only $37,600, and with the help of Verne Clair, a New York investment counselor, its fifty shares of preferred were carefully distributed. Two of the seven men who subscribed are directors of J. P. Morgan & Co., and J. H. Whitney & Co. became the eighth and largest preferred stockholder by taking fifteen shares ($11,250). In addition, the preferred holders received half of the 100 shares of $1 common issued, the rest going to Dubilier, Clair, and four others.

The slowdown

This modest financial backing is in line with Dubilier's decision to set the license rights to cold welding so low that "it would be cheaper to buy them than to steal them." For companies doing less than a $1-million annual gross business, the license to experiment with cold welding is $500 a year for five years; and $25,000 for five years is the largest fee Koldweld has yet charged. If the process goes into production, the royalty is one-quarter of 1 per cent of the value of each part cold-welded, up to a maximum of $10,000 a year. The fact that only nine companies have accepted these liberal rates has disappointed Dubilier somewhat, but it is not too surprising in view of the obstacles cold welding has faced.

For one thing, it is the policy of many large companies not to take out a license on a new invention until it is patented, and it was only last June that the Patent Office completed its investigation and allowed the basic claims in one of Koldweld's original patent applications. Also, Dubilier has not been able to show prospects any basic test data on the process, for Sowter and his assistants have been too busy devising new techniques and applications to work up more than a few supporting technical details. Finally, many companies objected to the dents that Sowter's dies left in cold-welded metal, and preferred to let the present licensees develop the process. Other companies, like General Electric and Western Electric, had undisclosed reasons for not signing up with Koldweld.

Of these problems the lack of detailed test data has been the most serious—and embarrassing. Dubilier found that engineers continually brought him their toughest unsolved problems. Lockheed, for example, sent him some sample strips of aircraft aluminum that it hoped could be cold-welded. After repeated experiments, involving elaborate treatments of the metal, Sowter discovered that Lockheed had submitted 75S-T6 aluminum alloy, the hardest known. Eventually he *did* get a weld, though it was only 20 per cent efficient. Lockheed, which admitted the test was unfair, is still interested in cold welding, though not for primary structures. Koldweld's Executive Vice President, August C. Esenwein, who experimented with the process when he was with Piper Aircraft, says that successful cold welds can be made on some of the commonly used aircraft aluminums—but he still hasn't the complete data to prove it.

The speed-up

To hasten this end of the research, both Esenwein and Robert F. Bryan, a Koldweld director representing J. H. Whitney & Co.'s interests, have been urging that the company set up its own laboratory and spend perhaps $50,000 on testing cold welds and developing machines to apply them. By this summer Dubilier was about ready to agree to this, and at the same time he also favored offering manufacturers a one-year "experimental" license. What may do most to hasten the acceptance of cold welding is Sowter's latest development—projection cold welding. For this technique not only eliminates the undesirable die-produced dents; it also promises to make cold welding possible on all sorts of jobs regardless of how thick the metal parts may be.

With an important assist from Dubilier, Sowter arrived at the projection cold weld this spring in the three simple steps shown on page 115. His first solution—using a metal plug to fill in the dent made by the die—moved Dubilier to suggest that he sandwich a round length of aluminum between the two pieces to be welded. Dubilier figured that the inside piece would flatten out into a weld just as the facing halves of two wires did when compressed between a set of Sowter's round dies. It turned out that this sandwich-style technique both left the surface smooth and actually produced a cold weld about twice as wide as the diameter of the inside aluminum piece. Since it also showed that cold welding was possible without specially shaped dies, the third step followed logically: Sowter cast an aluminum handle with rounded projections on its flat base, drove the handle hard into an aluminum plate—and presto, handle and plate were cold-welded.

Both the sandwich and projection processes make a much wider, thicker weld than the die process, and presumably one that is much stronger, though test data is not yet available. Projection cold welding was so new when this article went to press that Dubilier had scarcely finished drawing up the details on it for Koldweld's licensees. Neither he nor anyone else appeared to know exactly why and how this technique worked, or how well it would succeed in industry. But Dubilier is jubilantly optimistic and sees no end of possible applications for cold welding. He even speculates that Sowter's process may one day be applied in the enormous field of welding ferrous metals, since "token" cold welds have already been achieved in stainless steels. As an inventor it is his business to dream—and cold welding seems eminently worth dreaming about. END