THE AUTOGENOUS SOLDERING OF METALS.

BY M. U. SCHOOP.

Notwithstanding that intensely hot blow-pipe flames, particularly the oxy-hydrogen gas flame, have been known and used for many years, it was the last decade which first saw the introduction, on a large industrial scale, of the autogenous soldering of various metals, such as iron, copper, nickel, and aluminium. The attempts to introduce electricity into this branch of metallurgy have, it is true, been numerous; but a general utilization of electrical processes of this character has not been effected, at least in Europe, doubtless because of the numerous disadvantages possessed by these methods. In the so-called electric arc welding, in which the metal to be welded itself constitutes one pole, while the other pole is formed by a carbon rod which is moved over the welding points, the latter become as hard as glass. With the Zerener apparatus, in which the flaming arc is formed into a jet flame by means of a magnet, the temperature regulation is extremely difficult of accomplishment. Both these processes possess the disadvantage that the eyes and all unprotected portions of the body are strongly affected thereby. The process of Hohe and Lagrange, the so-called "under-water resistance welding method," has not been possible of introduction in practice because it is too expensive and complicated. The well-known Thompson method is also based upon the resistance principle, and is characterized thereby that the pieces to be welded are blunt in form and are so brought into contact that they offer great resistance to the passage of the current. Thus, the desired temperature is obtained in a very short time, whereupon the circuit is opened and the pieces are mechanically forced together under pressure. The disadvantage of this method which, of all the electrical processes, has alone attained practical significance, is the considerable expense of installation. Furthermore, the Thompson process is available for a certain class of welding operations only. This may also be said in regard to the Goldschmidt Thermit welding process.

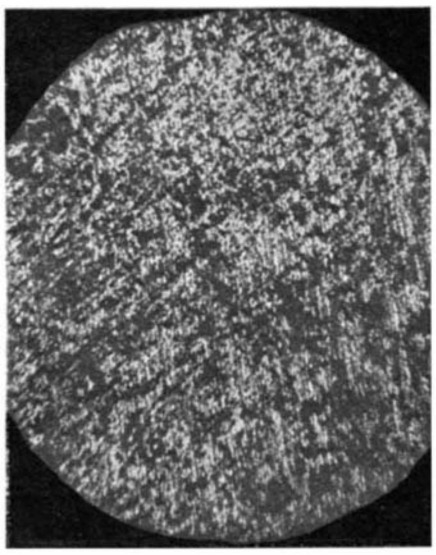


Fig. 1.—Cross-Section Through the Soldered Joint. Greatly Enlarged.

The above are substantially all the more recent soldering—that is, welding—processes; they are, however, inferior in regard to practicability, facility in operation, and cheapness, to autogenous soldering or welding. An exception to this is found in lead soldering, which can be effected with great ease and at little cost by means of an electric resistance method. Furthermore, the process is cleanly and can be carried out without special technical training or experience; it has been introduced and is used exclusively in a number of French accumulator factories.*

There are several processes for carrying out autogenous soldering, which make use of the combinations given below for the production of the flame:

1. Hydrogen-oxygen.
2. Acetylene-oxygen.
3. Illuminating-gas-oxygen.
4. Hydrogen-atmospheric air (for lead and hard lead).

The existing conditions govern the choice of the flame in each case, but it is to be remarked that where illuminating gas is available, the combination of the latter with oxygen is without doubt the most rational for the usual cases encountered in practice, and in such cases will almost always provide a sufficiently hot flame, which, in its characteristics, closely resembles the oxy-hydrogen flame. If it is a question of metals possessing exceptionally great heat conductivity, as, for instance, electrolytic copper, the acetylene-oxygen flame should be used, as it is possible to provide a temperature of 3,000 deg. C. (5,432 deg. F.) with it, whereas the temperature of the illuminating gas, or hydrogen-oxygen flame, is in the neighborhood of 2,000 deg. C. (3,632 deg. F.) only. These are degrees of heat which practically no material is capable of resisting. Brick, pumice stone, carbide, platinum, are liquefied by means of the acetylene-oxygen flame, and graphite alone can withstand this temperature.

It should be noted that in regard to expense the oxy-hydrogen flame is, in most cases, more costly than the acetylene-oxygen or illuminating gas-oxygen flame. I say "in most cases" advisedly, as various considerations are of importance in the question of operating expense, such as the kind and thickness of the metals to be welded and the local conditions which must be taken into account. In certain cases where repairs are to be made on the spot, the only possibility lies in welding by means of the oxy-hydrogen flame, as the entire apparatus for the latter consists of two steel surfaces, a welding burner, and a few yards of tubing, and it can, therefore, be easily transported to a repair point, at which illuminating gas or acetylene is not available. However, if it is a question of welding exceptionally heavy bodies, or of sheet metal 0.8 to 1.2 inches in thickness, it is absolutely necessary to utilize the acetylene-oxygen flame if the expense is to be kept from becoming too great. The cost per welding seam with sheet iron 0.12 inch in thickness is approximately 7.5 cents if acetylene gas is used, and is about 20 cents with metal of double the above thickness. In this connection it should be remarked that, as is always the case in soldering or welding operations, the skill of the workman is an important factor in increasing or lowering the cost of the work.

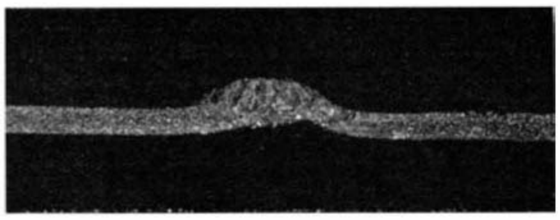


Fig. 3.—Soldered Joint Corroded by Hot Potassium Solution.

Autogenous soldering is capable of utilization in an exceptionally great field, and this is demonstrated by the fact that in France alone there are over twelve hundred factories in which the various metals are autogenously soldered or welded, in every possible branch of metallurgy. Examples of the possibilities offered by autogenous soldering are given in the following list, which is by no means complete:

1. The manufacture of boilers and reservoirs, and the making of repairs upon the same, with sheet metal up to 1 inch in thickness.
2. The replacing of riveting in thinner sheet metal.
3. The manufacture of tubes of all dimensions.
4. The welding on of struts, flanges, etc.
5. The repair of castings (gas bubbles, pipes, and casting faults).

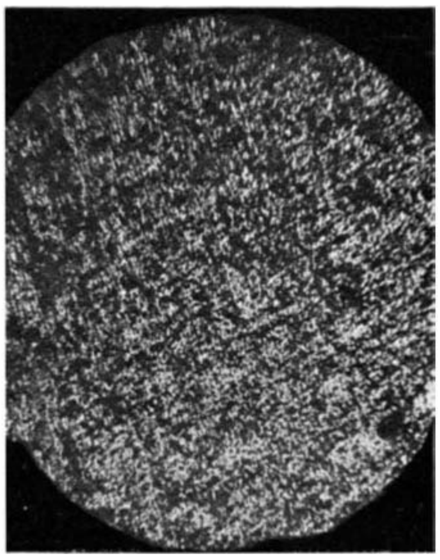
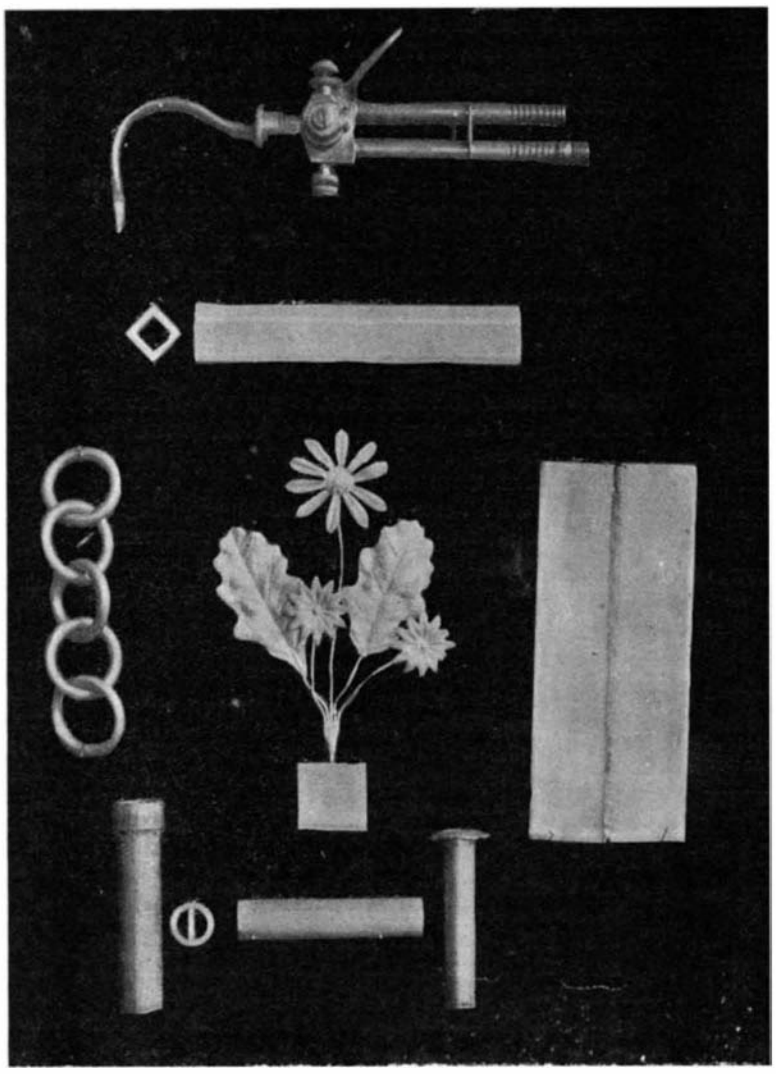


Fig. 2.—Cross-Section of Unsoldered Aluminium. Greatly Enlarged.

6. Repair of valves and autoclaves, the production of pipe conduits without connections for the chemical industries.
7. Artistic wrought metal work, industrial sheet metal and enamel ware, and safes.
8. The manufacture of military articles.
9. The manufacture of iron casks and superheaters.
10. The bicycle and automobile industries.
11. The working of rare metals, such as gold and platinum.

The two metals which formerly appeared to be absolutely precluded from autogenous soldering are nickel and aluminium. Nickel possesses the characteristic that when heated it absorbs oxygen from the air, and for this reason becomes brittle and useless. Aluminium, when it comes into contact with a hot flame, becomes covered with a film of oxide which, despite the fact that it is extremely thin, absolutely prevents the combination of the two softened aluminium parts. If it were possible to discover for nickel some borax-like substance which would effect the hermetic exclusion of the air during the soldering process, and for aluminium a substance with which the gathering aluminium oxide films would enter into solution, that is, would be reduced, it would be possible to effect the soldering of nickel as well as aluminium with the same ease with which other metals are similarly worked. The writer has succeeded in solving these two problems, and both soldering or welding processes have been in operation on a large industrial scale for some time past. The vast field offered by the soldering or welding of aluminium, the "metal of the future," is seriously belittled by no one competent to judge. And it is demonstrated by this fact alone, that the solution of the problem has occupied the attention of a considerable number of inventors and industrial experts from the time of the discovery of the metal, and that, lacking a proper soldering process, some forty hard soldering methods have been tried, proposed, or patented. All these numerous attempts to weld aluminium to aluminium with the aid of the bond provided by a "foreign metal" must be considered unsuccessful, as at the soldering points local electrolytic action, due to the formation to a certain extent of galvanic currents, arises. This manifests itself very rapidly and unpleasantly, particularly in the presence of water, and it attacks the soldered point with absolute certainty. As a matter of fact, it is a characteristic property of aluminium that its behavior with regard to other metals is unfavorable and, regardless of soldering or welding, it behaves better the purer it is. Recognizing the truth of this theory, the various aluminium factories have attempted, at all times, to supply the metal in as pure a condition as possible. According to different tests, it would appear



Aluminium Objects Soldered by the Schoop Process. At the Top Appears the Blowpipe Which is Used.

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* See Electro-Chemical and Metallurgical Industry, July, 1905. "On Autogenous Lead Soldering," by M. U. Schoop.

that chemically pure aluminium is capable of resisting even sea water, a fact which is of great importance in marine engineering.

The credit for having first welded aluminium must be conceded to the Heraeus Company of Hanau, Germany, which, as early as 1900, exhibited at the International Exposition at Paris a number of aluminium articles, which had been welded by means of a special process (German patent 118,868). This process is based upon the fact that at a certain degree of heat aluminium becomes soft, and can be combined with a similarly-heated aluminium body by means of hammering. In principle this method corresponds exactly to the well-known welding process used for iron in the ordinary smithy. This method, however, has a disadvantage which tends to prevent its introduction into practice, which is that it is extremely difficult to maintain the exact temperature necessary for the welding, and it is possible only if the workman is extremely skillful. If the temperature is too high the metal, when hammered, will spurt in all directions, while if the heat is insufficient, no combination of the surfaces in question takes place. Accordingly, it is apparent that this process leaves much to be desired in practice, and is absolutely unsuited to the working of thin material or complicated objects.

In the autogenous blowpipe welding of aluminium according to the Schoop process, no question of this character can arise. Upon purely theoretical grounds it appears that the formation of local galvanic circuits is impossible if foreign metals are not present. Furthermore, the thickness of the metal is quite immaterial, and it is possible to weld sheet aluminium 1 inch or 0.008 inch in thickness with the same ease.

On the recommendation of the Neuhausen Aluminium Factory, of Switzerland, a series of tests were made, the purpose of which was to show whether or not the welding point underwent disadvantageous changes if immersed in water for a longer time. As was to be foreseen from the theoretical considerations underlying the process, the results were in every particular negative. That is, even after months in contact with water the soldered or welded points were found to be in exactly the same condition as the other parts of the material. In one particular case a soldered aluminium article remained for three months in salt water, without the appearance of the slightest chemical or physical change at the soldered points. Similarly favorable were the results of the official rupture and tension tests executed by the testing laboratory of the Conservatoire National des Arts et Métiers at Paris in May, 1905. Of greatest interest by far are the results of a photo-micrographic investigation carried out by the same institute. As is well known, a test of this character is extremely sensitive, and the slightest changes of a metal in regard to its structure, color, and constitution are at once perceptible with mathematical certainty. The result of this test showed that the welding points possessed exactly the same characteristics in regard to their chemical and physical properties as did the pure aluminium, and, furthermore, not even the slightest trace of impurities (resulting from the flux) could be determined.

The soldering or welding process itself is as follows: The parts to be joined are either bluntly placed against each other or one above the other, after all adhering dirt has been removed from the surfaces. However, aluminium which has a bright appearance needs no preliminary cleansing, in contrast to that usual in the hard-soldering process with copper, brass, etc. The Schoop reducing liquid is now applied with a brush, and the flame, which is regulated according to the thickness of the material, is then applied to the metal. Aside from the application of the reducing liquid, the process of operation is exactly the same as in the case of the well-known process of lead burning.

The following table gives the cost of sheet aluminium soldering in which the illuminating gas-oxygen flame is used for heating purposes, the mixture consisting of about 2 parts of illuminating gas and 1 part oxygen:

Thickness of the sheet metal in inches	Mixture of oxygen and gas.		Wages in cents.	Total in cents.
	Cubic feet.	Cost in cents		
0.02	0.35	0.57	0.57	1.14
0.04	0.42	0.67	0.75	1.42
0.08	1.27	2.07	1.50	3.57
0.12	2.65	4.37	2.00	6.37
0.20	4.59	7.50	3.75	11.25
0.32	12.37	20.00	6.25	26.25
0.40	15.90	28.00	7.50	35.50
0.48	26.14	42.50	10.00	52.50

Illuminating gas at $1.12½ per 1,000 cubic feet.
Oxygen at 1.35 cents per cubic foot.
Labor at $1.50 per 10 hours.

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The Current Supplement.

The first of three installments of an article on the manufacture of illuminating gas is published in the current Supplement, No. 1626. The first installment deals with the making of coal gas. Mr. C. W. Parmelee writes on the technology and uses of peat. A very good monograph on corn-harvesting machinery is also published. Henry H. Quimby writes on concrete surfaces. Prof. F. B. Crocker and M. Arendt discuss the advantages and applications of the electric drive. The second installment of the article on the utilization of waste materials is published. The black sands investigations of the United States Geological Survey are described and illustrated. The English correspondent of the Scientific American writes on types of early steam engines still working in England. A few problems of the preserving industry are considered by Dr. E. Krüger.

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THE MAGNITUDE OF THE GAS INDUSTRY.

Illuminating gas, which is piped into our buildings as freely as water, is the aeriform product of the destructive distillation of a liquid or solid hydrocarbon which may, or may not, be diluted by the admixture of other combustible gas or gases. Bituminous coal or petroleum, or some of the products of the fractional distillation of petroleum, form the basis of the manufacture of gas. Some idea of the size of the industry may be obtained when it is stated that in 1905 the total value of the raw materials used was $37,180,066. It is interesting to see how the materials are distributed. First we have the item of coal, 4,431,774 tons, costing $14,607,485; next we have 403,263,738 gallons of oil, which cost about the same, the sum being $14,531,585. Coke is a smaller item, 435,534 tons, costing $6,176,340. Vast quantities of water are required, no less than 5,430,361,158 gallons being used. Fortunately, water is not very expensive, $253,895 representing its total cost. Other materials amount to $6,176,340.

Our total cost was $37,180,066. Now, what is the value of the product? The hand of man—the chemist co-operating with nature by the use of the materials of her mineral kingdom—has succeeded in making a subtile aeriform mobile product, valued at $112,662,568 and occupying the enormous bulk of 112,486,783,148 cubic feet.

The product is divided both as to kind and value as follows:

	Cubic feet.	Value.
Straight coal gas	12,674,033,691	$12,868,604
Straight water gas	715,550,006	832,440
Carbureted water gas	54,687,118,030	48,071,180
Mixed coke and water gas	40,980,413,950	45,605,263
Oil gas	3,397,456,873	5,141,460
Acetylene gas	7,880,666	104,267
All other gas	24,329,932	39,354

Not only do we have these valuable gases, but we have by-products as well. Coke, valued at $5,195,461, represents 89,146,434 bushels; while $2,064,343 stands for the value of 67,515,421 gallons of tar. All other products are worth $972,992. A considerable revenue is derived from rents and sales of lamps and other appliances, such as stoves, the amount of this business being $4,249,581.

Comparison of raw materials and the product are always interesting, and especially so in the case of gas, where a graphical representation becomes positively spectacular. The total amount of gas of all kinds produced in the United States for 1905 would fill a gasometer 5,829 feet in diameter and 4,556 feet high. Assuming that a gas engine consumes 92 cubic feet of gas per hour, being the mean between a minimum consumption of 70 and a maximum of 115 feet per hour (Mathot's figures) this quantity of gas would run gas engines having an aggregate of 407,560 horse-power ten hours a day for 300 days. According to the Twelfth Census, there were 14,884 gas engines, which furnished 143,850 horse-power, a pitiful percentage of 1.3 of the total horse-power. Since this enumeration the number of gas engines in use has been materially increased; but even so, the great bulk of gas is used for illuminating and heating purposes.

A comparison of the yearly production of gas is unwieldy, owing to the lack of objects with which to compare. The Eiffel Tower would look lost compared with a gasometer 4,556 feet high, so we have taken a week's supply, which amounts to 2,163,207,368 cubic feet. This enormous bulk is shown in our engraving stored in a huge gasometer 1,620 feet high and 1,350 feet in diameter. The water is contained in a tank 241 feet high and 268 feet in diameter. The raw materials are also of a bulky nature. The coal would form a cone 268 feet across at the base and 200 feet high. The coke also forms a cone 120 feet high and 160 feet across the base. The oil would fill a barrel 155 feet high and 122 feet in diameter.

For the benefit of our readers, we are publishing in the Supplement an elaborately illustrated technical article on the production of both coal and water gas. There is nothing which is more conducive to comfort than this colorless aeriform fluid, which is brought to our doors and consumed for light and heat, our comforts.

Correspondence.

Eyeglasses as Telescopes.

To the Editor of the Scientific American:

In the Scientific American of December 29, 1906, page 484, appears an article on the use of a single lens as a field glass. I have made use of this principle for a long time, and it may not occur to many of your readers that they themselves have the necessary lens, with the proper correction for their eyes, ready for use at any time. I wear a compound lens, +.50 +.25 —90 deg. By holding this at arm's length, objects appear about one-third larger. Being able to use both eyes, and having each eye see through the *center* of its own lens, is a great improvement over using a single lens.

The easiest way to get objects in focus is to take the glasses from the nose, and while looking at the object through the glasses, extend the arm to full length, taking two or three seconds' time for the movement. In this way the object is easily centered, and the eyes are not strained.

I have made out the names of boats in a race, that without the glasses extended showed only by the difference in the color of the paint. Once when my arm was not long enough to get the desired magnification, the glasses were hung on a twig, and by getting about five feet back, the result was satisfactory.

Near-sighted people, and perhaps those wearing very strong plus glasses, cannot make use of this method, but there are many others who can.

John V. Frederick.

Lancaster, Pa., January 2, 1907.

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"The Battleship of the Future."

To the Editor of the Scientific American:

I was much interested in the article on the "Battleship of the Future" accompanied by sketch designs. The particular arrangement of turrets arrived at by the author, however, seems to me to be open to grave objections. The concentration of the weight of four turrets and the large barbette on a small area, itself not coincident with the area of maximum buoyancy, would produce enormous shearing forces, which in turn by their integration would give rise to great bending movements.

To resist these severe stresses it would be necessary to give the hull considerable local reinforcement near the turrets, and to provide the structure as a whole with excessively heavy longitudinal members.

The weight involved in these arrangements would probably balance the weight in armor saved by the peculiar location of the turrets.

The very arrangement of the barbette makes it difficult to secure proper continuity of the longitudinal strength, as it apparently cuts all the upper strength members except the sheer strake. Even supposing it were possible to build such a vessel, the design would not be practicable for the reason that the author has left the sheer strake entirely unprotected by armor. Now suppose she engages in battle in a moderate sea; a few high-explosive shells amidship would cut up her sheer strake, deck stringers, etc., and it is quite possible that she would break in two under the action of the waves. In the Japan Sea battle the shells tore huge gaps in all structural plating wherever exposed, and I think this design would be extremely vulnerable under these conditions.

Another important consideration is the location of the handling rooms, which are of course vertically under the turrets. The author does not take up this question, but it would be necessary to have either a single large room, or several smaller ones close together; and further, the handling rooms would extend well outboard on either side. Now a single torpedo explosion near this point, a single accident in the handling room, or a single 12-inch shell, would put all the turrets out of action—if, indeed, the adjacent magazines were not detonated, and the whole ship destroyed.

I believe that the battleship of the future will carry twelve 12-inch guns in six turrets on the center line.

The center line of the ship is the proper location for a turret, since there the guns command the maximum arc of fire, the magazines and handling rooms are kept inboard—a very important point in these days of the perfected torpedo—and the deck stringers and other important members are not cut. George B. Moody.

Bath Iron Works, Bath, Me., February 15, 1907.

To the Editor of the Scientific American:

After reading Mr. Cardullo's discussion of "The Battleship of the Future" I beg to say that while his facts and arguments are intensely interesting, and really valuable, he seems to fail to comprehend fully the work for which battleships are designed primarily—or ought to be designed.

Battleships are not built to resist attack. They are built to attack and destroy the enemy. Speaking of speed, Mr. Cardullo says "the faster ship may theoretically choose her position and range, but if she is