Left: An uncalorized sheet of iron and a smaller calorized rectangle of the same stock, after identical furnace tests—the untreated piece is covered with severe scale, the other is not affected. Center: Calorized (front) and uncalorized (rear) retorts after equal service. Right: Diesel-engine valves, a fair sample of the sort of thing that may profitably be calorized

Several exhibits designed to show the immunity to rusting under severe heat conferred by the new process of "calorizing"

Preventing Rust at High Temperatures

Aluminum-Coated Metals That Will Go to the Melting Point Without Formation of Scale

By Robert June

THE problem of devising means of protecting metals from oxidation at high temperatures has occupied the attention of metallurgical engineers for many years. The remarkable industrial developments of the past few years, particularly with respect to heat treating processes, have made this problem of pressing importance; and it has consequently received greatly increased consideration.

To say at the outset that this problem has largely been solved by the development of what is known as a calorizing process is to sum up the experiences and opinions of many metallurgists and industrial engineers who have encountered serious and at times seemingly unsurmountable difficulties in the rapid oxidation of metal parts at high temperatures.

In the calorizing process, the metal chosen is aluminum, and the protective action is due to the oxide formed by the action of heat on the protecting alloy rather than to any electrolytic relations between the aluminum and the base. The product is distinguished from that of other processes such as sherardizing, hot galvanizing, etc., in that these are intended primarily to give protection against oxidation at ordinary temperatures, or corrosion, as it is frequently called, while the calorizing process is intended primarily to protect against oxidation at high temperatures.

Practically all metals suitable for structural work, with the exception of those in the platinum group, began to oxidize at quite low temperatures; on the Centigrade scale, steel at about 370 degrees, copper at 360, nickel at 660, nickel-steel (58 per cent nickel) at 530, chrome-nickel (10 per cent chromium) at 650, German silver at 530, and aluminum-bronze (9.2 per cent aluminum) at 600. As a matter of fact most of these metals or alloys may be run at a higher temperature than that indicated before serious disintegration sets in, but none of them has a very short life at or above a full red heat.

It is well known that an aluminum wire heated by an electric current above its melting point will still maintain its shape due to the tough and resistant oxide of aluminum formed on its surface. It is this oxide which is the basis of the oxidation-resisting properties of calorized metal. It is necessary, however, to have sufficient aluminum present to form a continuous coating of Al_2O_3 over the whole surface. Experiment has shown that this requires, in the case of iron alloys, at least 14 per cent of aluminum.

The calorizing process was developed about 1911 in the electrical research laboratory at Schenectady, in the course of a series of experiments instituted to find a method of protecting electric heating elements. The process was later turned over to an independent corporation, as its industrial and commercial importance warranted its handling by a separate organization specializing in oxidation problems.

In treating metals by the calorizing process, they are first thoroughly cleaned by sand-blasting, then placed in a stationary or rotary retort in a reducing atmosphere, with a mixture composed of finely divided aluminum and aluminum oxide. This treatment, conducted at a

temperature of 600 to 1,100 degrees Centigrade, depending upon the depth of alloy desired, so thoroughly infuses aluminum into the exposed portion of the metal being treated as to form a homogeneous aluminum alloy for a certain depth. This depth ranges from a few thousandths of an inch to the permeation of the entire mass, varying with the duration of the treatment.

The essential point in difference between the effects of calorizing and most of the processes hitherto used commercially, such as galvanizing, plating or coating, is that the protective metal is not imposed as coating or skin upon the metal to be treated, but rather enters into intimate association with it, forming a "solid solution" alloy. For this reason, should the outer surface become slightly injured, the protective surface renews itself. Calorizing is not intended to protect against rusting or corrosion, as is sherardizing for example, but is primarily a protection against burning or scaling. Calorized copper, brass and nickel, however, are also excellent non-corrosive elements and are strongly resistant to the acid. The dimensions and weight of the metal treated are very slightly increased by calorizing. The increase in dimensions is usually not over a few thousandths of an inch.

An example of its commercial application is in the manufacture of soot blowers, which as applied to boilers must be exposed continuously to furnace gases at high temperatures, and are not cooled by water or steam as are boiler tubes. Ordinary iron or steel will not give successful service. Under these conditions, one of the early means employed in protecting this equipment against burning out consisted of two extra heavy steel pipes, placed one within the other, the space between being filled with insulating material of special composition. This type of installation was fairly successful, but involved an excessive first cost; therefore, manufacturers of soot blowers were constantly on the lookout for material from which these units could be economically made, and which would give even more satisfactory results. Very soon after the calorizing process was announced, a comprehensive in-

vestigation of it was made in this application.

In addition to mechanical tests, trial installations were made in all the different types of water-tube boilers. In making tests, calorized soot-blower units were placed in the hottest passes where the temperatures ranged from 1,800 to 2,500 degrees Fahrenheit. The need of blowers at these locations had long been recognized, but their application had been considered impracticable. Performance of the calorized units was watched with keen interest for months. In the end they proved that they fully met the hardest service conditions. There were no signs of scaling or disintegration from the long exposure to high temperatures. Thousands of successful installations have been made, and are now giving satisfaction in all types of water tube boilers. In addition to the matter of oxidation, many gases contain sulfur dioxide and carbon monoxide, which have an extremely deleterious effect on ordinary metal, while tests have shown that calorized metal is not affected by them in the percentages in which they occur in furnace gases.

The resistance of calorized iron to oxidation is a time-temperature function. It will resist oxidation up to its melting point for a short time, but to obtain a reasonable life, temperatures exceeding 900 to 1,000 degrees Centigrade should not be used unless the calorizing treatment was unusually heavy. The reason for this is evident when we consider that the diffusion of the aluminum into the iron is extremely rapid at high temperatures. It is about five times as fast at 1,300 as at 110 degrees Centigrade, which would cut the life to one-fifth when used at the higher temperature. By using thin sections and a heavy coating, however, steel may be calorized to stand the higher temperature for months.

Although tests show that the mechanical properties of the steel are not injured by calorizing, it must be pointed out that the rich aluminum alloy which forms the protective coatings is very hard; any bending or mechanical working should be done as far as possible before calorizing. If it must be done afterwards, the piece should be first heated to redness. Calorized metal cannot be hammered or bent cold, but at a bright red heat can be bent without affecting its resistance to oxidation. However, calorized metal is capable of withstanding all ordinary handling without destruction of the alloy or calorized portion.

Calorizing has been put to a great variety of uses including its application to retorts, carbonizing and annealing boxes, pyrometer tubes, furnace castings, tubes for preheating air, flue lining, pipe for conveying molten glass, torch nozzles, blast furnace tuyeres, oil crackers, soot-blower units, lead pots, valve and piston heads for Diesel engines, preheating coils for oil burners, hot bulbs for oil engines, etc. Calorization has been successfully applied to carbonizing and annealing boxes and a variety of heat treating equipment of this nature, the treatment prolonging the life from three to thirty times.

It is entirely feasible to make up calorized coils of pipe in a wide variety of
(Continued on page 412)

Retorts and furnaces in which the calorizing process is carried on

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(Continued from page 409)

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Costly experience in the early days of the Zeppelin experiments showed that the greatest peril to the airship occurred when it came near the earth, and several years ago the SCIENTIFIC AMERICAN pointed out that some form of mooring post to which the dirigible could make fast was necessary if landing disasters were to be avoided. The problem has been very ably worked out in the Vickers mooring gear, and R-80 carries in her nose the necessary gear for sailing up to one of these posts and making fast. A covered gangway can be thrown across from the moored airship to the mooring post through which the passengers pass to elevators arranged within the post. Gas, oil and water pipes form a permanent part of the mooring-post equipment, and they are provided at their upper ends with suitable connections for supplying the airship.

Preventing Rust at High Temperature

(Continued from page 404)

shapes, lengths and sizes. Straight pipe 1/8 inch to 18 inches diameter has been calorized in lengths up to 20 feet. There is no limit to the size of material which may be treated. Calorized steel is particularly adapted to pyrometer protection tubes because of the high temperature to which they are exposed. Not only is it cheaper than any of the chrome steel alloys which have at times been offered for this purpose, but it possesses other advantages.

Perhaps the largest and most easily developed field for calorizing lies in its application to the various pots, boxes, tubes, retorts, and special equipment employed in the many heat treating processes. A large quantity of the above mentioned articles have been successfully calorized, their average life being over eight times that of the uncalorized equipment, resulting in a great saving. A notable feature is that calorizing can be applied to any of this equipment without necessitating change in its design or construction.

Many furnaces, kilns, ovens and retorts employed in various manufacturing processes were originally made of iron or steel. This metal has a limited heat-resisting quality and was reduced to scrap in a short time. It was repeatedly replaced, its life being short because of the excessively high temperatures and the same performance continued indefinitely. As the price of the metals increased, the use of the other materials was considered by engineers in an effort to reduce costs. They built these furnaces from fire-brick and various refractory materials. In a great many instances these materials were used at a loss of

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25 to 75 per cent efficiency, but were adopted because the repair costs on iron and steel were prohibitive. Calorizing can be applied to metal furnace lining, baffle plates, etc., the cost of these calorized plates per unit of service being in a great many cases much less than that of refractory materials. There is an unlimited field for calorizing as applied to equipment of this nature.

There are many possible applications of calorized metal which have not been considered, for the reason that only within the last six months has calorizing been available to the commercial world. It is impossible to enumerate or describe in detail the great number of applications. Every plant presents its individual problem and it is the object of the writer to illustrate several applications with the idea of suggesting to the engineer, metallurgist, and plant manager, possible applications to special equipment used in his particular process of manufacture.

A Pocket Machine Gun

(Continued from page 405)

obliged in his work to sit behind various machine guns in erosion, function, and ballistic tests for a matter of six months or more, and he was not impressed at the end of this time with the reliability of function of any machine gun at present used by civilized armies, examples of which we tested. Used under the most favorable conditions, in the hands of skilled mechanics, they all were made to look simply childish in certainty of function and endurance when compared to that other gas engine—the motor of the small car. A stoppage, a broken part, a jam—one of the three would occur with the most reliable machine gun of them all, the Browning, about every 1,000 rounds fired.

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I cheerfully admit the difference in conditions, such as the far greater pressure of the machine gun and the higher speed of the parts; but still I believe that there is not enough difference in conditions to justify the wide difference in reliability between the two types of gas engines. Possibly, therefore, the decision of the latest entrants into the machine gun market to use lubrication is based on sound judgment. There is also the possibility that they are making a virtue out of a necessity.

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The writer, after firing the gun several hundred rounds, would class it as the equal of a score of average policemen firing as the average policeman fires, provided of course the gun were fired by a man accustomed to it. And of course it is far easier to train one man to become expert with the gun than it is to raise the shooting of twenty policemen to the expert stage with their pistols.

There would be no trouble whatever for one man firing the gun to sweep a street clear from curb to curb, but after all, its greatest strength lies in its moral effect. Killing many of the common American sort of mob is unfortunate unless the right ones can be selected for the slaughter. Mobs as a rule are composed of ten per cent vicious (the leaders), and ninety per cent fools. Wherefore the dispersing of the crowds without bloodshed is usually desirable. It would be a most vicious and determined

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