Possibilities of Welding

By J L RUGE*

The procedures of modern welding technique such as arc welding, gas welding etc. are going to celebrate their 70th birthday but knowledge of welding as such is very much older. The method of forge welding is assumed to be known since the first application of malleable iron, dated about 3700 B.C. the pyramid of Cheops, was erected where the first "technical iron" is said to have been found. In 1800 B.C. an Egyptian spear tip made of iron was found in a Nubian tomb. The first real report on welding and this may be taken as the birthday of welding literature, was given by Herodot and Pausanias describing the famous work of Glaucos from Chios : A holy-water font founded by King Alyattes to the sacred place of Delphi. Perhaps this man Glaucos can be considered the inventor of welding.

For more than 2500 years forge welding was the only welding procedure and the extremely rapid development of welding—science as well as application—which we have encountered during the last decades of the 20th century surely can be taken as a direct criterion of the industrial revolution of this century which determines now the life of mankind.

Possibilities of Welding

The development of new materials for extremely high or low temperatures, for improved resistance against corrosion, for higher static and dynamic strength etc., the transition to allowable stresses as high as possible especially in aircraft and spacecraft construction and for other light construction purposes as well, the upward tendency with respect to security requirements and the necessity to achieve a high economy of operation were followed by a corresponding development in the field of welding.

Instead of forge welding of former times we have now a great number of pressure welding procedures (*Fig. 1*). It is naturally impossible and not necessary to go into particulars. It may be sufficient to state that there is quite a lot of fusion welding processes each of which is suited for application in special fields of industrialp roduction. *Fig. 2* gives a survey of fusion welding procedures in the same way. It may be said in addition that further welding procedures are at hand for joining plastics, and that adhesive bonding and brazing are playing their part as well.

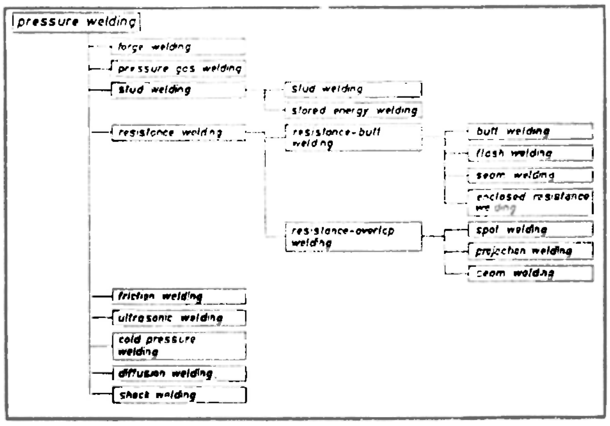

Fig. 1

Thus we have the tools necessary to match the requirements arising out of the development and application of new materials. Welding of aluminium and aluminium-alloys for example, formerly quite a problem, now belongs to conventional welding practice using inert-gas arc-welding. Improved electrodes for arc-welding in combination with the necessary precautions against hydrogen absorption render it possible to weld low alloyed high strength steels. Corrosion resistant and heat-resistant high alloyed steels can be welded without deterioration of their properties. Titanium and zirconium, materials used in spacecraft or nuclear power plant construction can be welded despite their tendency towards gas absorption. Many further examples of the usefulness of the now existing welding procedures to match the multifold requirements with

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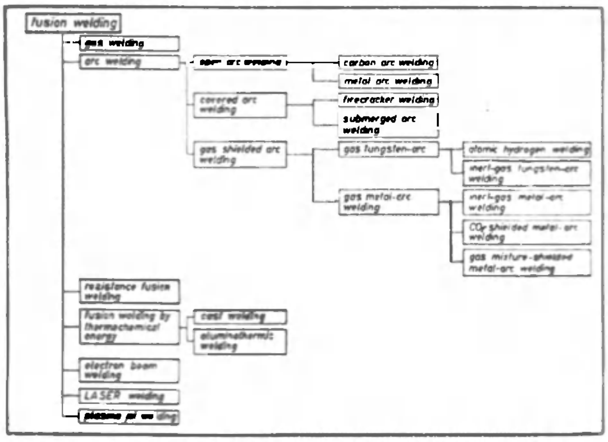

Fig. 2

respect to the joining of new or improved materials could be given.

Development and improvement of nondestructive testing methods—with X-rays, gamma-rays, ultrasonics or by magnetic means—have rendered possible higher allowable stresses and higher factors of safety. The IIW has established a collection of radiographs enabling the welding engineer to classify defects as pores, flaws, fissures etc. with respects to their effect on the behaviour of welded structures.

Finally the necessity to achieve a high economy of operation can be matched by mechanization or even automation of the welding operations and by a transition to lightweight construction.

Materials

It seems to be useful now to report about the application of welding in a field of technical activity where uncommon materials are widely used, i.e. the manufacture of chemical apparatus. Here the main task is to protect the construction against corrosion. A tower made of a titanium-palladium-alloy (0.2%Pd), nearly 30 metres high and 2 metres in diameter, plate thickness 4-5 mm, has been manually tungsten inert-gas welded (*Fig. 3*). Titanium, zirconium, molybdenum and tantalum are highly reactive materials which embrittle when small amounts of gases like H_2, N_2 and O_2 are absorbed. Therefore the inter-gas shielding must be as perfect as possible and high purity gases are to be used. TIG welding procedures have been applied too for the manufacture of a titanium pressure vessel with 6—10 mm wall thickness and tubes welded upon it made of 1.5 mm sheets (*Fig. 4*). The cylindrical part of a big tank 15 m high and 3 m in diameter (s= 12 mm) made of unalloyed boiler plate was clad by titanium sheets of 2 mm thickness to reduce the production costs as compared with a tank made of titanium

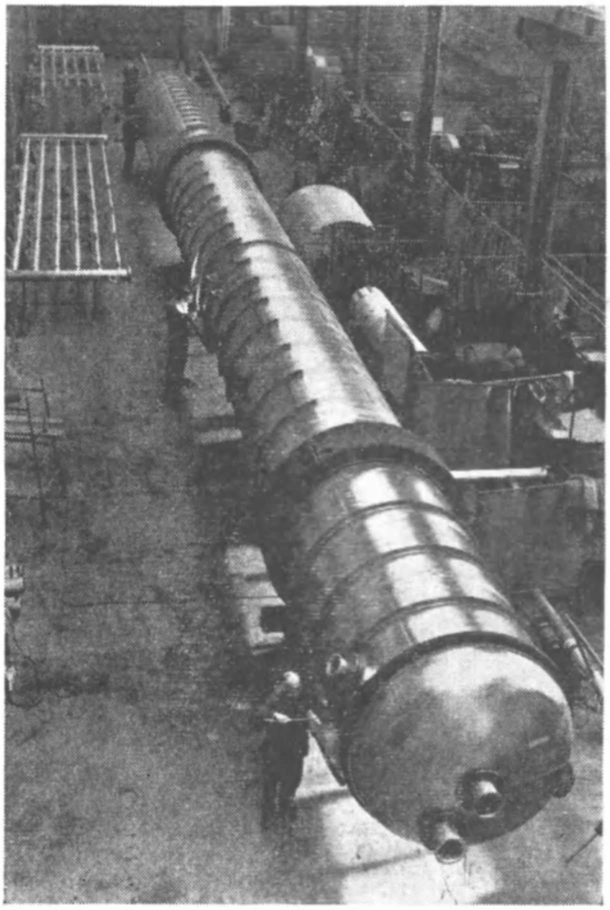

Fig. 3

alone (*Fig. 5*). Whilst this again has been made by the TIG process, another pressure vessel was plated with titanium by explosion welding (*Fig. 6*). Titanium is used in the cases just described because of its good corrosion resisting quality and it is also an important material for the construction of high speed aircrafts where its low weight to strength ratio is utilized. Here again inter-gas shielded arc welding is widely used.

Nickel and nickel-alloys as Inconel are also used for chemical apparatus. This container runs at a temperature of 425°C (*Fig. 7*). All butt welds are made by TIG welding, fillet welds including those between Inconel and plain steel by manual arc welding. A reaction chamber made of nickel has been welded wholly using the manual arc welding process (butt and fillet welds).

A special welding technique—low heat input, local cooling of joint helps to avoid secondary precipitations at the grain boundaries and to secure the corrosion resisting quality of the material in the vicinity of the weld.

Quite different requirements are of interest when nuclear power plants are to be erected. The moderater

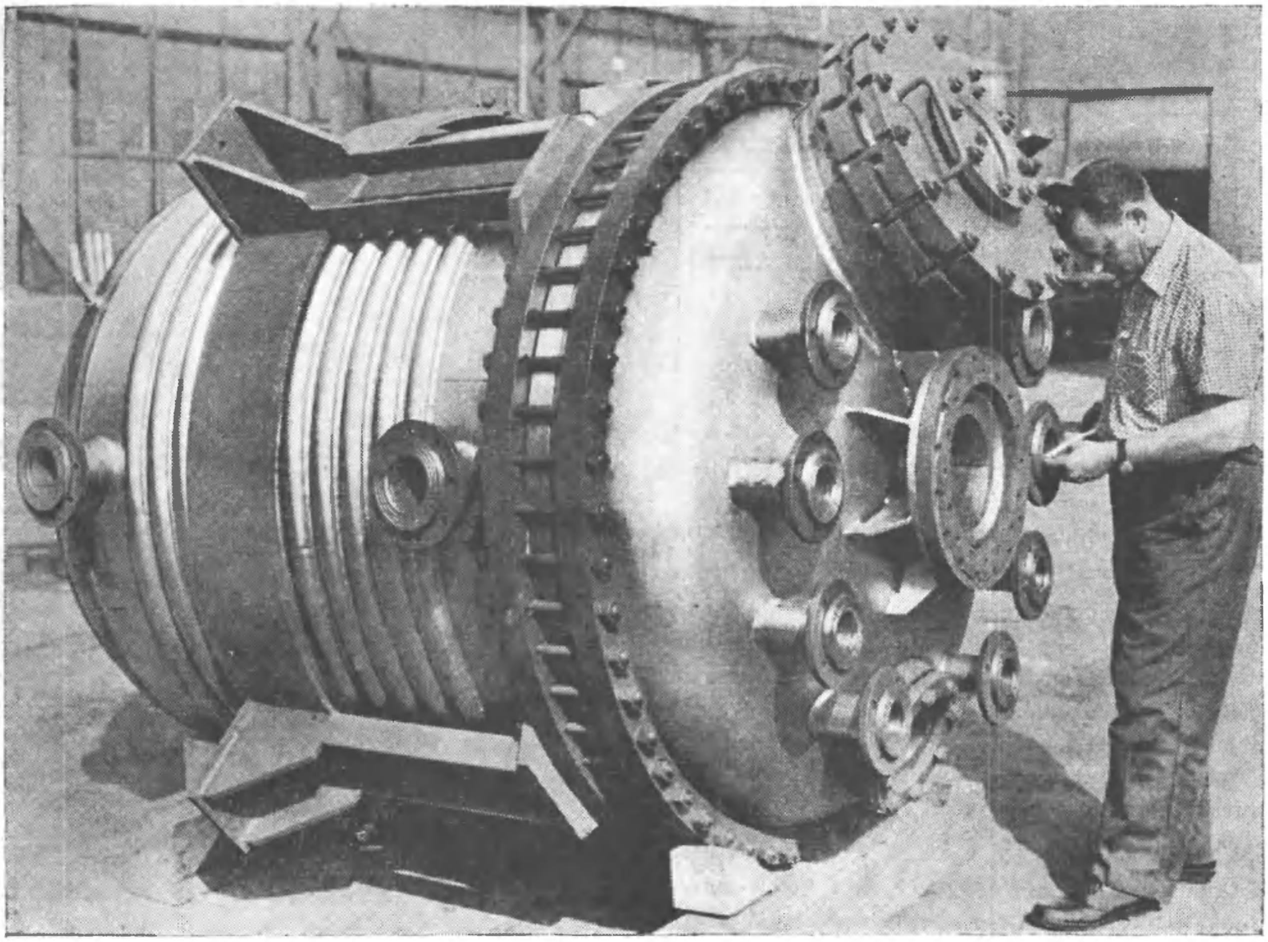

Fig. 4

tank for a water cooled plant (*fig. 8*) is made of plated boiler steel. The thickness of the steel was 46 mm, of the stainless steel plating 4 mm. To achieve a satisfactory weld the vertically arranged boiler plate (*fig. 9*) received first an austenitic cladding. Afterwards the actual joint was completed by manual arc welding with stainless steel electrodes.

The pressure vessel of a boiling water cooled nuclear power plant (*fig. 10*) was also made of plated boiler steel, but this time the wall thickness of the low alloyed steel vessel amounted to about 100 mm. So for reasons of economy manual arc welding cannot be recommended. As shown in the picture, the preparation of the joints for longitudinal and transverse welds is done in the form of U-grooves. Stainless steel tubes are rolled in and welded to the header of a boiler by TIG welding. Thus hundreds of tubes can be joined absolutely leakproof.

The production of heavy structures is essentially facilitated by combining castings with rolled steel parts (*fig. 11*). Frames of machines such as hydraulic presses or heavy cylinders are examples of such a compound arrangement.

Heavy plates with a wall thickness of about 150 mm can be welded by electroslag welding.

Weight-saving constructions are possible by the use of aluminium as structural material. For the purpose of satellite tracking, an antenna system was built (*fig. 12*). It consists of a welded tube construction made of the age-hardening aluminium alloy AlZnMg 1.

A cargo ship introduced in a South-East Asian line was equipped with a welded aluminium travers (AlMgSi) which, with a dead weight of 6.2 tonnes, takes up a service load of 152 tonnes. It has a box-type cross-section and plate thickness upto 32 mm.

A transport vehicle with an especially large volume of almost 40 cubic metres made of AlMgMn weighs 13.3 tonnes with a service load of 18.7 tonnes. The wall thickness ranges from 6 to 8 mm.

A tank truck made of AlMnMg is intended for transporting plastics with a service load of about 20

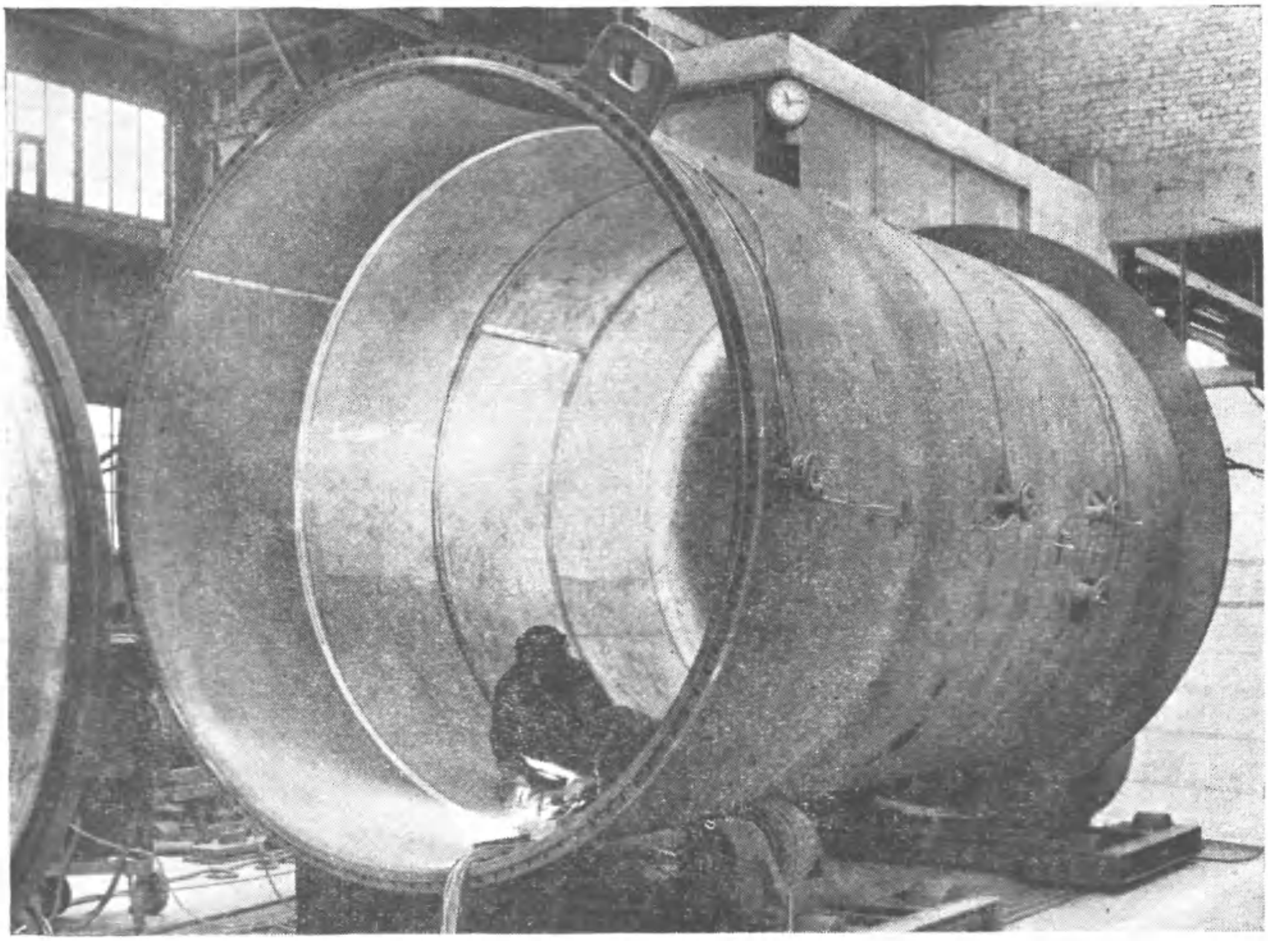

Fig. 5

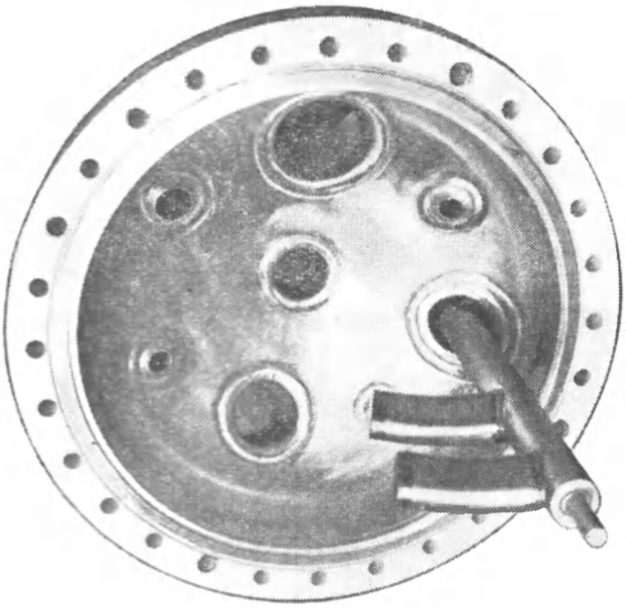

Fig. 6

tonnes. With a pay load factor (Service load/Total weight) of 0.65, one is near the optimum that is at present attainable.

Heavy-duty trough tips of AlMg 5 (*fig. 13*) have rendered possible an increase in service load capacity of 12–15% over steel constructions, e.g. from 17 to 19 tonnes (constant permissible total weight). Also the hydraulic equipment can be constructed lighter in weight.

Examples from the wagon-building industry (Subway Berlin) with an underframe (*fig. 14*) and the car body (*fig. 15*) made of aluminium, indicate the trend towards light alloy construction.

Many further examples can be cited from the same wagon-building industry. That the shipbuilding industry can also profit from the switch-over to aluminium is shown by the example of a merchant vessel made of AlMgMn. (*fig. 16*) The aluminium consumption amounted to 345 tonnes. Welding was done by the MIG processes.

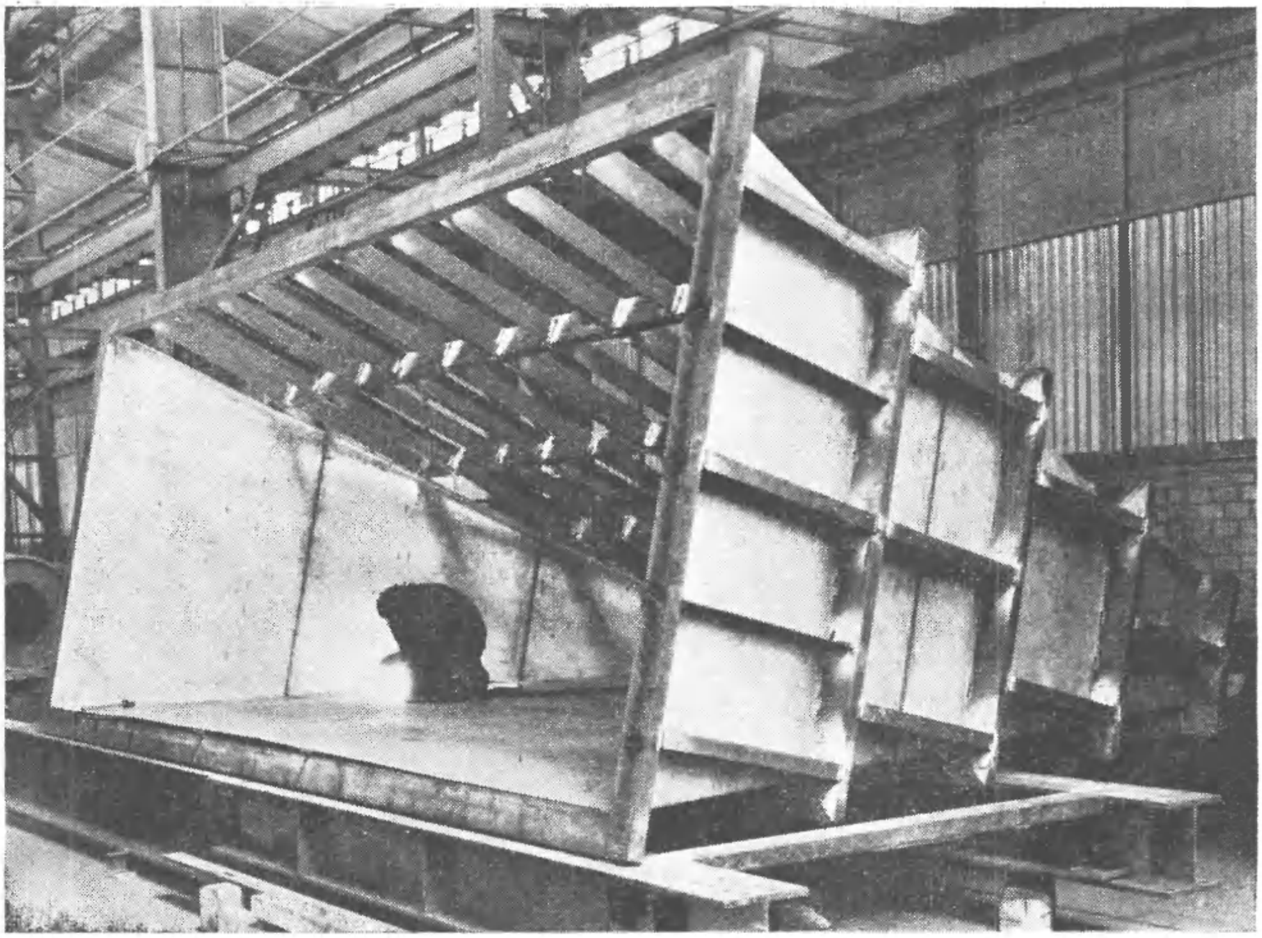

Fig. 7

Inspection

High safety requirements are necessary not only for space—or aircrafts and nuclear power plants but also for many other purposes. An example may be the bedding of pipes for the transport of oil or gas. A pipeline has been run from Genua at the Mediterranean Sea over the Alps to Ingolstadt/Germany. Testing was done with Gamma-ray.

Whilst some time ago X-ray testing was nearly the only method of nondestructive testing we now have at our disposal quite a lot of testing methods. Of special importance is ultrasonic testing as it is not very

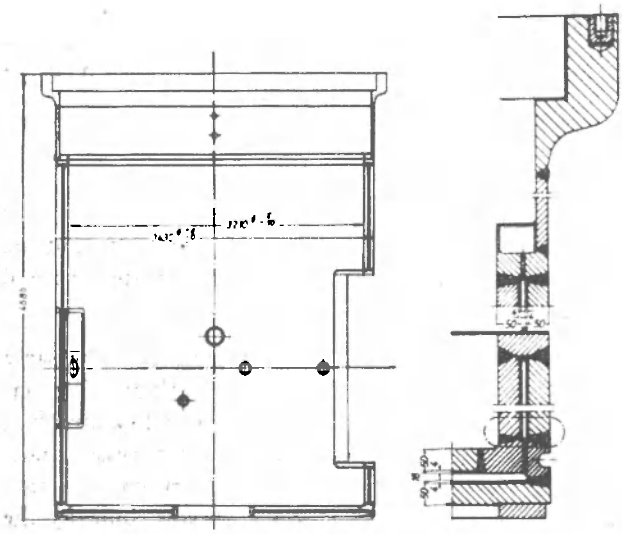

Fig. 8

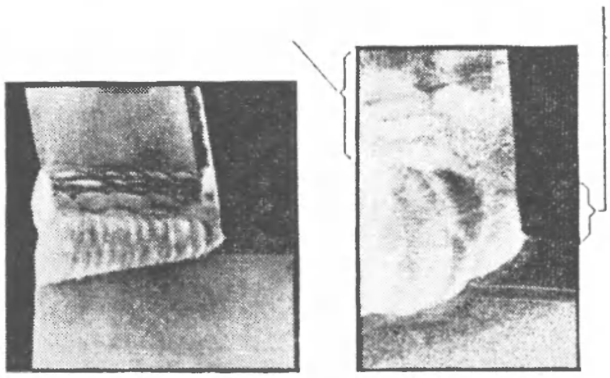

Fig. 9

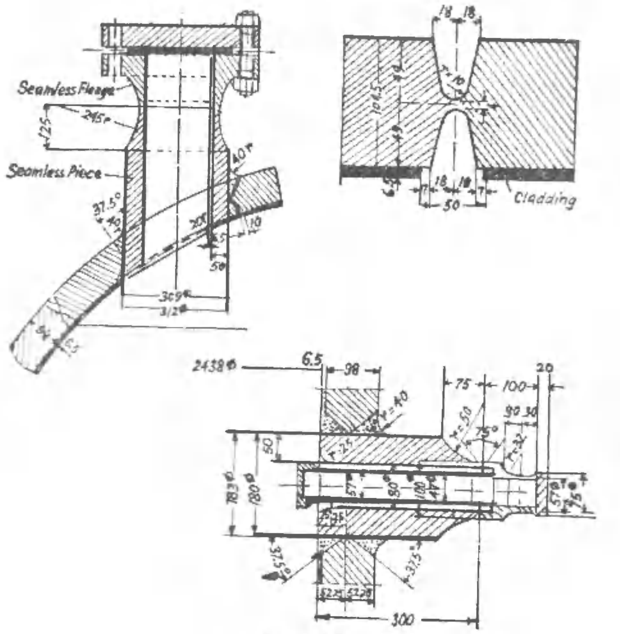

Fig. 10

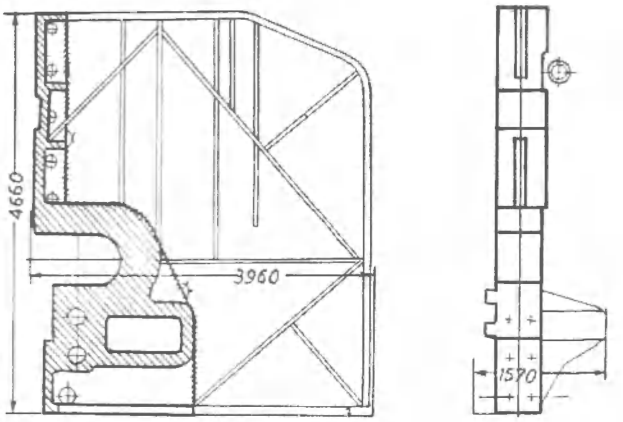

Fig. 11

Fig. 12

Fig. 13

expensive but at the same time, very useful in many cases. Thickness control on pipes is made with unit run from a battery and independent of the electric supply system. Small transportable X-ray units are available for X-ray inspection. Even more mobile are gamma-ray units. Finally magnetic testing apparatus can be applied if fissures near the surface are to be identified. For very big plates linear or circular accelerators (betatron) can be employed. A collection of reference radiographs of welds in steel facilitate the evaluation.

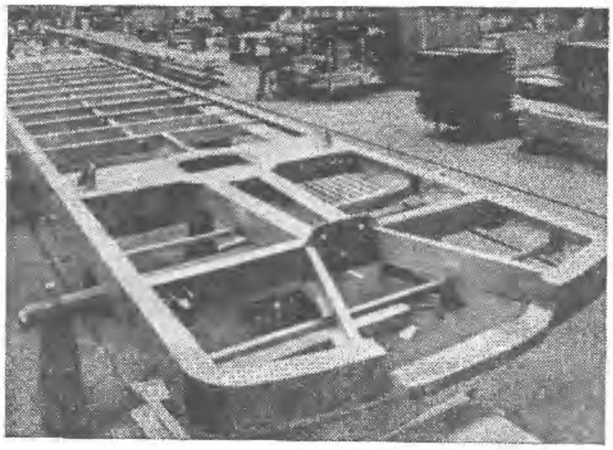

Fig. 14

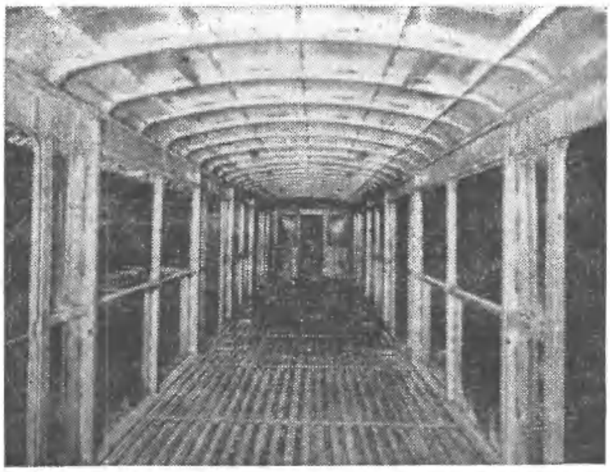

Fig. 15

Fig. 16

All these testing methods are applied when welded steel bridges are erected. A welded railway bridge (*fig. 17*) with structural built up beams shows the possibility of fastening the welded beams with high-tensile screws.

Economy

A number of examples can be quoted of the economies that can be effected by welding. First the application of stud welding. The principle is well known and the procedure belongs to the group of arc pressure welding processes. Considering that for a 1000 t/hr steam generator 4 million studs are needed (*fig. 18*) welding can only be done automatically. Controlled by a programme cylinder all the necessary operations are executed automatically.

Fig. 17

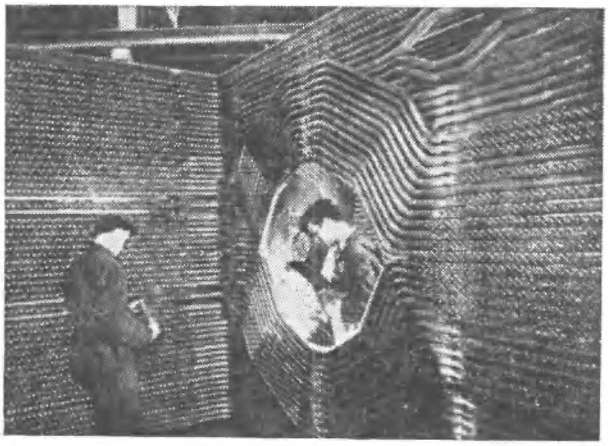

Fig. 18

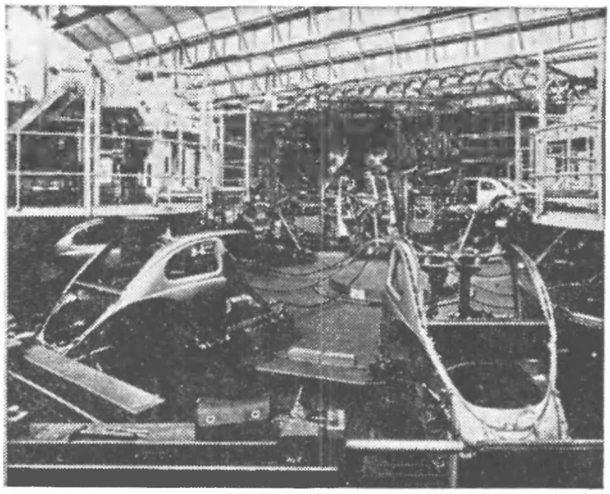

Fig. 19

A typical example for automation can be found in the production of cars. On fully automatic production lines, the back parts of the bodies are produced (*fig. 19*) using 5 welding stations, back and front part

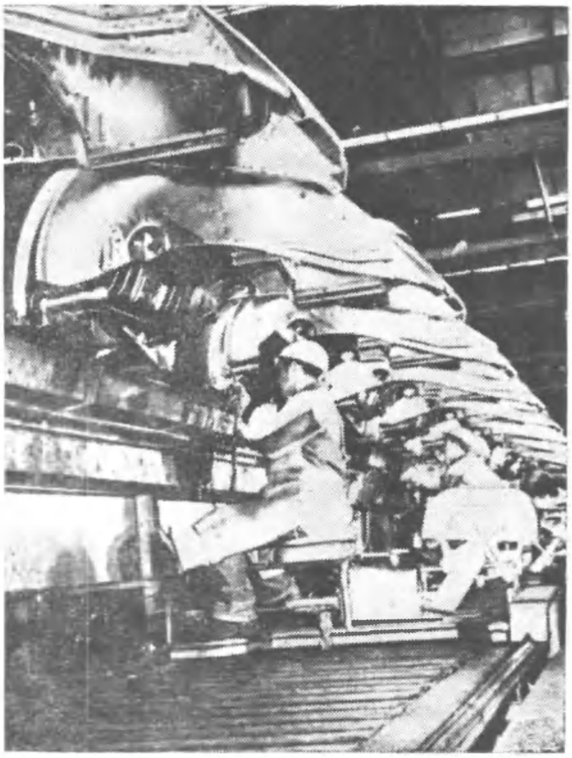

Fig. 20

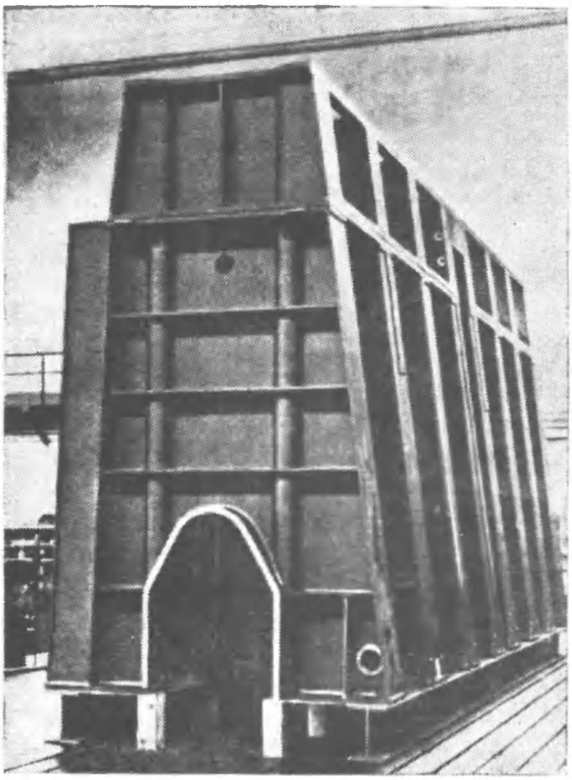

Fig. 21

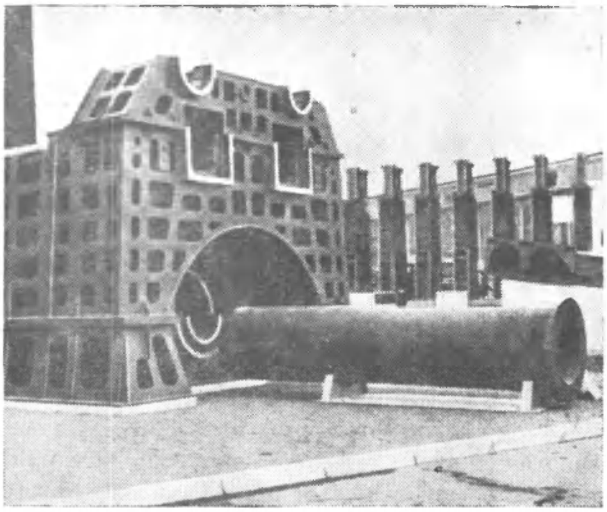

Fig. 22

are welded together, the roof is fastened and welded, finally some manual CO_2 welding completes the production of the bodies (*fig. 20*).

Modern Welding Design

I cannot end my report without a short review on modern welding design. Big diesel motor housings formerly made of steel castings are now welded (*fig. 21*)

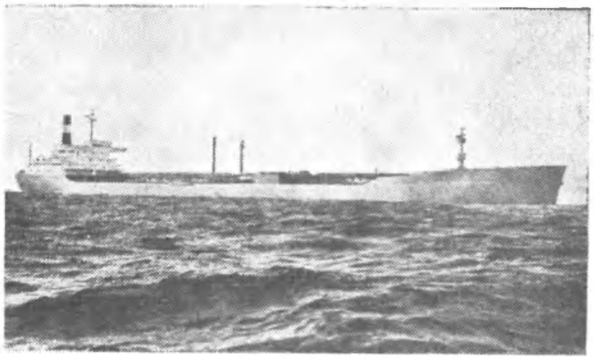

Fig. 23

combining a high production efficiency with lightweight construction. Another example is the gear box made of steel plates (*fig. 22*). Big ships for the transport of oil or other bulk goods, formerly riveted are welded in a sectional type of construction using modern mechanized welding procedures (*fig. 23*). Big cargo ships are extended by implanting an additional section.

Conclusion

Welding has become a production method now that enables the engineer to handle new materials, to match high safety requirements, to enlarge production economy, to produce beautiful and at the same time effective and appropriate constructions.