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Autor: Matting, A.

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The Testing of Welds.

Über die Prüfung von Schweißnähten.

Le contrôle des soudures.

Dr. Ing. habil. A. Matting,
Professor an der Technischen Hochschule Hannover.

The importance of the personal element in welding makes it necessary that careful supervision should be supplemented by testing of the seams, and apart from this the welders themselves must be subjected to tests at regular intervals (see for instance DIN 4100). Such testing must be carried out rapidly and by simple means, and must yield conclusive results.

The bending test is very simple, and is carried out in Germany as indicated in Figs. 1—3. The scientific value of this test is a matter of dispute¹ since it is subject to very wide variations (as in the bending test, the quenching bending test, etc.) which have a considerable effect on the values obtained. In spite of much criticism the test is widely applied, especially in workshops. For high quality welds it has not been found to constitute a sufficient criterion.²

The tensile test is principally of importance in laboratory work. Various types of test specimen are adopted, the usual one for butt welds being that shown in Fig. 4. In the round notch bar breakage is forced to take place within the weld seam, and if the protrusion is smoothed down this serves as a test of the material. The prismatic form of bar which allows breakage to take place also in the transition zone or in the material itself, is intended as a test of workmanship. The determination of yield point and elongation is difficult and uncertain.

In structural steelwork great use is made of the cruciform test specimen which serves for testing fillet seams (Fig. 5). The requirements are closely defined in DIN 4100.

The significance of fatigue bending and fatigue tensile tests is being more and more recognised. With proper design, seams free from defects, and a gradual transition between the parent metal and the weld metal,³ values of 15 kg/cm² are being obtained and even exceeded. Properly formed welded connections are as good as or even better than riveted connections.⁴ No standardised dimensions of specimen for fatigue tests have as yet been established.

¹ G. Fiek and A. Matting: Autogene Metallbearbeitung 27 (1934), № 4, p. 61.

² A. Matting and H. Otte: Ibid 29 (1936), № 19, p. 289.

³ A. Matting and G. Oldenburg: Elektroschweißung 7 (1936), № 6, p. 108.

⁴ O. Kommerell: Erläuterungen zu den Vorschriften für geschweißte Stahlbauten. II. Vollwandige Eisenbahnbrücken. Wilhelm Ernst & Sohn, Berlin 1936.

Hardness tests serve, in the first place, for the examination of deposition welding. The notched bar impact test (Fig. 6) is carried out in the case of structural steelwork under DIN 1913 only for the purpose of testing electrodes in the case of heavily loaded welded connections. This test is preferred as an acceptance test for the use of welding rods, the value required being between 5 and 7 kgm/cm^2 , and as a rule this is obtained without any difficulty.⁵

For the assessment of welding rods, apart from the mechanical and technological method of testing, the bead test (Fig. 7) is also used, in order to indicate whether such rods can be used also for welding in difficult positions. Welding rods for gas welding and also bare electrodes as a rule give a good bead, but this characteristic may be impaired as the carbon content increases, and it is more difficult to obtain good beads with covered electrodes, especially if the covering is thick, though excellent results have sometimes been obtained. In testing the adhesion of covered electrodes in accordance with DIN 1913 use is now made of vertical fillet seams, one half of the length being deposited upwards and one half downwards. The bead allows conclusions to be drawn as to the performance of the welding rod in overhead welding at the same time.

Specimens composed entirely of weld metal have not hitherto been much used. The determination of deformability in welded specimens is difficult and unreliable. A proposal to carry out measurements of elongation on cruciform specimens⁶ is now being investigated. In the stretching test,⁷

Fig. 8, a proportional bar with a longitudinal weld seam is used, the proportion of the total cross section occupied by the weld being about 30 %. The specimen is stretched in a tensile testing machine until the capacity of the weld for elongation is used up. The difference in elongation between different kinds of welding rod, the effect exerted by the nature of the material and the effect due to the welding method may in this way be readily estimated. Specimens without a reinforcement as a rule give from 2 to 3 % higher values of elongation. This form of specimen has not yet come into general use.

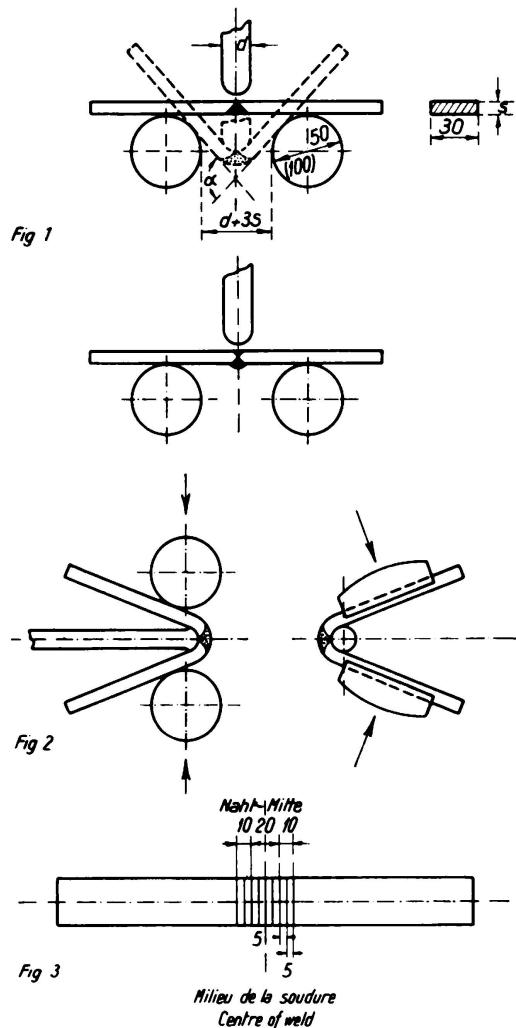


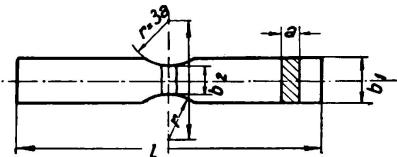
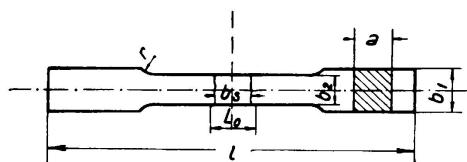
Fig. 1—3.
Arrangement of bending test in accordance
with the provisional DIN standard.
DVM A 121.

⁵ P. Bardtke and Matting: *Autogene Metallbearbeitung* 26 (1933), No 18, p. 279 and No 19, p. 290.

⁶ H. Blomberg: *Elektroschweißung* 6 (1935), No 4, p. 61.

⁷ A. Matting: *Elektroschweißung* 7 (1936), No 3, p. 53.

These are the methods of testing which enable both welders and forms of welding connections to be easily supervised, and examples of these are provided by the wedge and angle tests shown in Fig. 9. More accurate indications are not required in these cases. Frequently, also, specimens are cut out from the current work in hand, and are subjected to suitable destructive tests.



Thickness a	10 ¹ to 25	over 25 to 35	over 35 to 45
Length of bar 1	250	300	350
Gauge length L ₀	should equal the width of weld $b_s + 5$ to 10 mm		
b ₁	30	35	40
b ₂	20	25	30
r	15	20	25

¹ For a = 6 mm the DVL test bar is to be used.

Thickness a	6	8	10	12	14	16	18	20
Length of bar 1	250	250	250	250	250	250	250	250
b ₁	18	24	30	36	42	48	54	60
b ₂	12	16	20	24	28	32	36	40
r	18	24	30	36	42	48	54	60

Fig. 4.

Shapes of tensile test bars according to the provisional DIN standard. DVM A 120.

No numerical relationships can, of course, be obtained between the various methods of testing welded connections, except those between strength, elongation and hardness in the case of carbon steels. In the case of welds the conversion figure, that is to say the ratio of the breaking stress to the hardness number, is not 0.36 but is between 0.29 and 0.32.⁸ The notched bar tenacity depends only on the structure and cannot be directly related either to the elongation at breakage or to the fatigue strength. There is also no satisfactory relationship between fatigue strength and tensile strength, yield points and elongation. There is, therefore, no way of avoiding the necessity for separate experiments to determine each of the properties it is desired to ascertain.

Examinations of the coarse structure, as illustrated in Fig. 10, are very suitable as a method of testing penetration and porosity, and for detecting slag inclusions. Microphotographs, as in Fig. 11, serve for amplifying such information and for detecting foreign matter. Special attention is now

⁸ A. Matting and H. Koch: Elektroschweißung 5 (1934), № 7, p. 127.

being paid to the behaviour of welded connections as regards corrosive influences.⁹

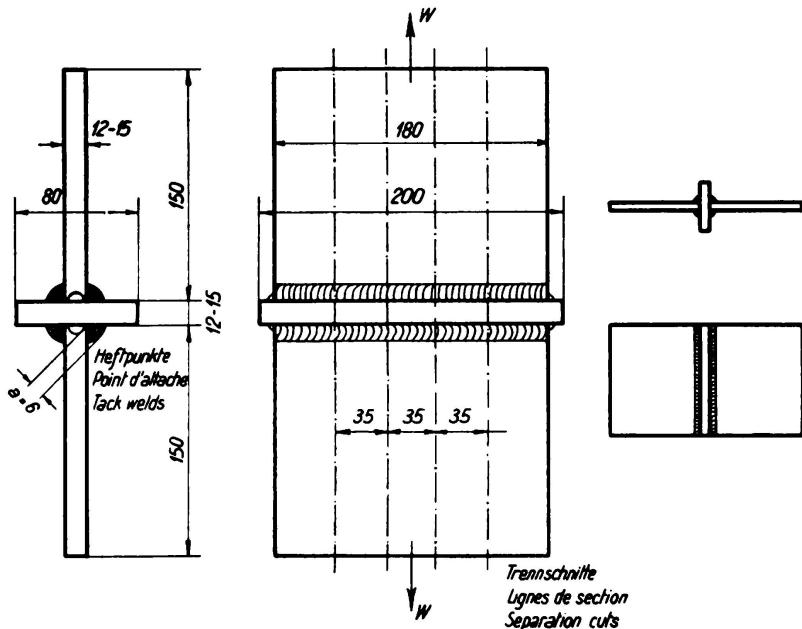


Fig. 5.
Testing of end fillet welds.

In order that, apart from considerations of safety, economic advantage may be realised from additional care taken in testing the welds, great importance

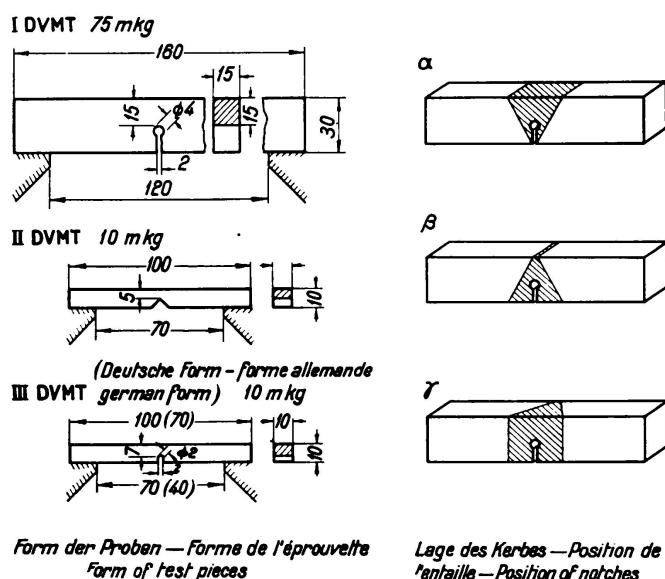


Fig. 6.
Notched impact bar specimens.

attaches to intelligent application and improvement of the testing methods.¹⁰ The high demands which are now imposed upon weld seams have been rendered

⁹ E. Diepschlag: Autogene Metallbearbeitung 29 (1936), № 8, p. 113.

¹⁰ H. Koch: Stahlbau 9 (1936), № 26, p. 206.

acceptable (apart from the improvement in human factor) only by the fact that it is possible to obtain seams of perfect quality.

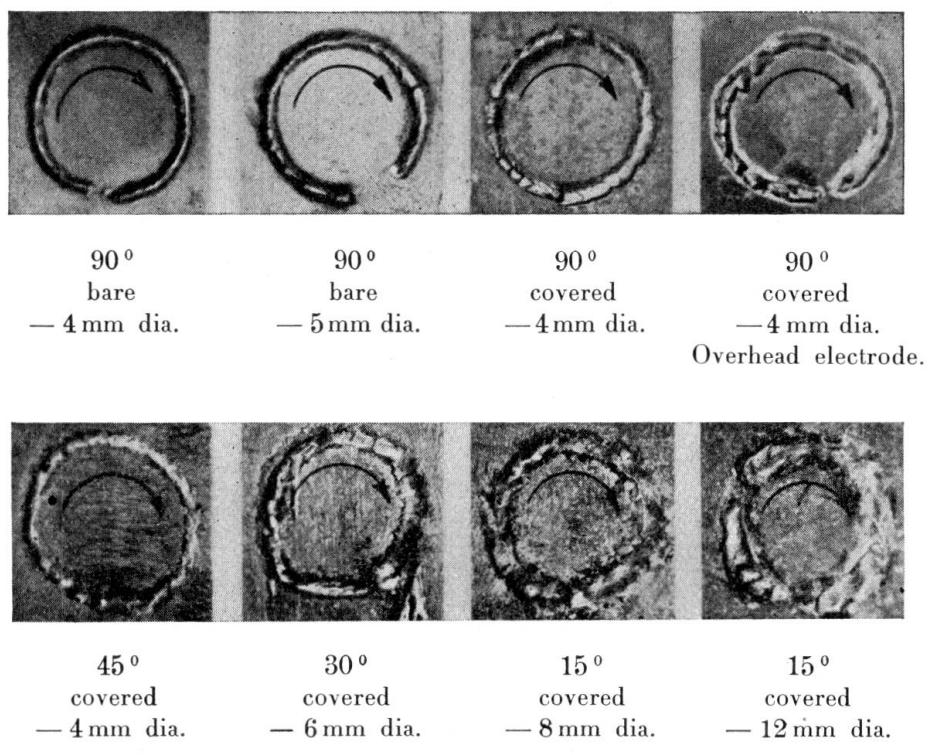


Fig. 7.
Adhesion tests.

In the testing of finished work non-destructive methods are to be preferred to destructive. The act of weakening the seam by opening it up may indeed have an educational value, but apart from this it should be avoided except as a very rough and ready form of test.¹¹ The part affected can be rewelded, but in doing

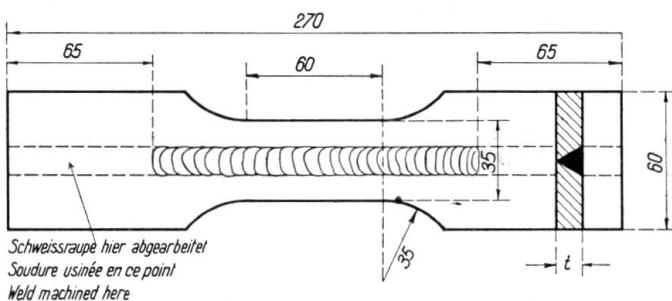


Fig. 8.
Tensile test bar.

this additional thermal stresses may arise, and moreover an unknown factor is introduced in place of the known (Fig. 12).

If the weld seam is not to suffer damage some non-destructive method of testing has to be adopted, and moreover this should be one which allows con-

¹¹ R. Bernhard and A. Matting: Stahlbau 5 (1932), № 15, p. 114.

clusions to be drawn as to the quality of the seam. In the construction of containers, tests by water, air or steam pressure are possible, and in special cases

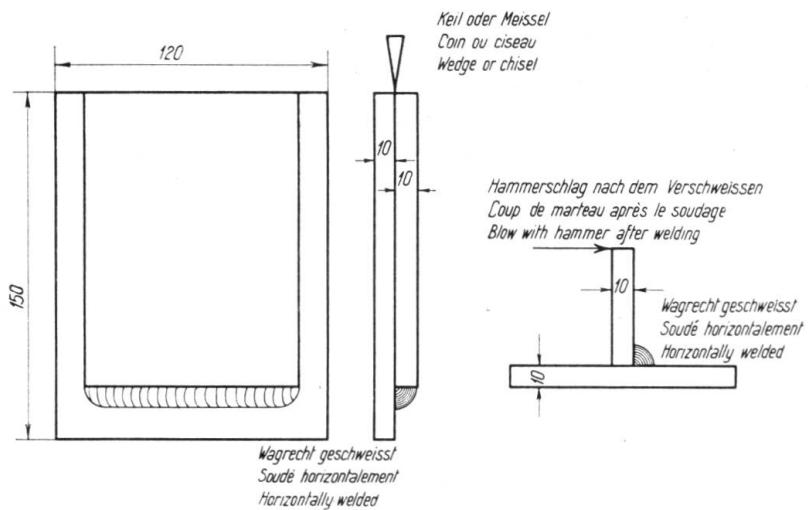


Fig. 9.
Wedge and angle tests.

tests may be carried out by means of explosion within the containers, though these are of course destructive in their nature.¹² In welded structures the place of these

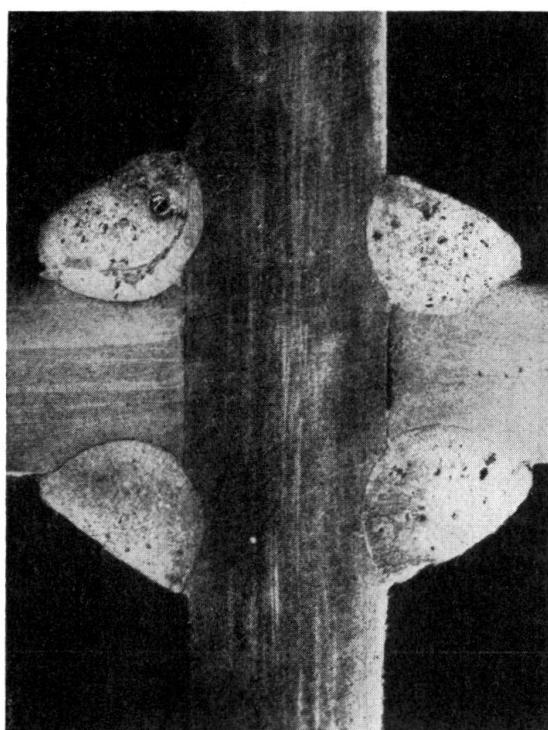


Fig. 10.
Coarse texture of fillet weld
made with bare electrodes.
Good penetration.

is taken by loading tests, or by fatigue tests combined with measurements of stress.¹³

¹² E. C. Hutchinson: Power, 7th Oct. 1930.

¹³ W. Rosteck: Organ für die Fortschritte des Eisenbahnwesens 1934, Nos. 10 and 11, pp. 187 and 197.

Attempts to examine weld seams acoustically or by reference to electrical fields of stress have been without success, but magnetic methods have been more suc-

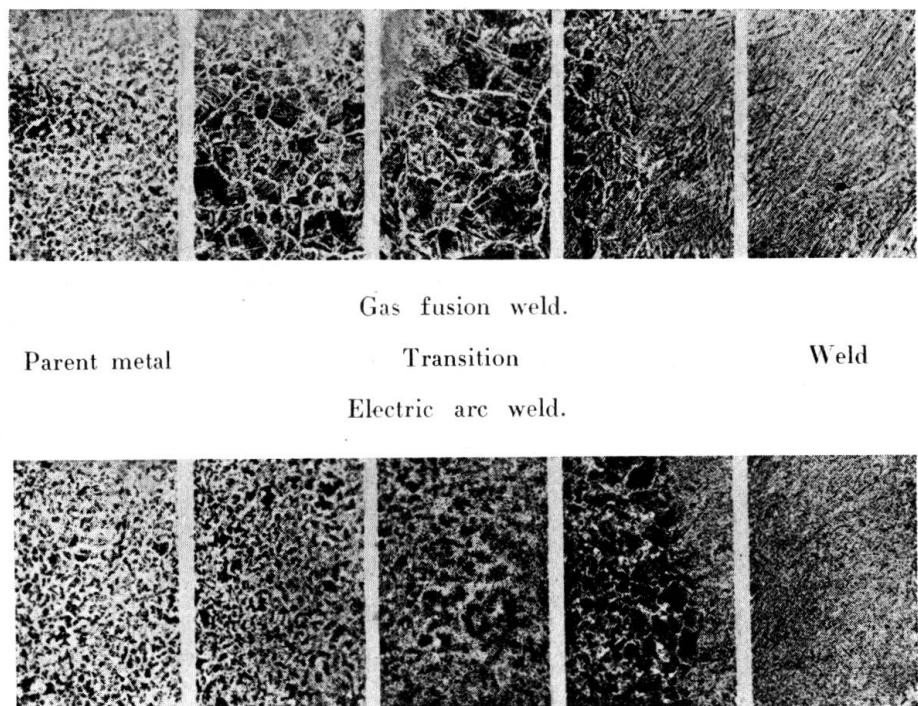


Fig. 11.
Fine texture of gas and arc welds.

cessful. In these the work is magnetised and iron filings are scattered upon it, the uniform arrangement of which would be disturbed if there are any hollow places, slag inclusions or defects of bond.

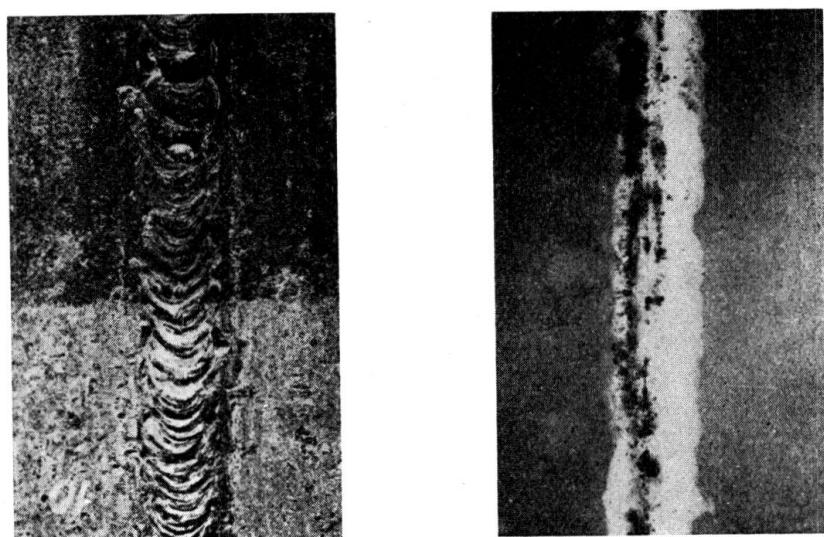


Fig. 12.
Bad arc weld.

In the author's opinion, however, the electro-magnetic acoustic method of testing welds has not fulfilled expectations.¹⁴ The weld seams are here explored electromagnetically and the impulses of current are rendered audible in headphones. It is not, however possible to locate defects definitely by this means.

Much the best method of testing is by radiation, particularly by means of X-rays.¹⁵ Gamma rays can also be used for testing,¹⁶ but in structural steelwork this method does not come into question. In the examination of the coarse

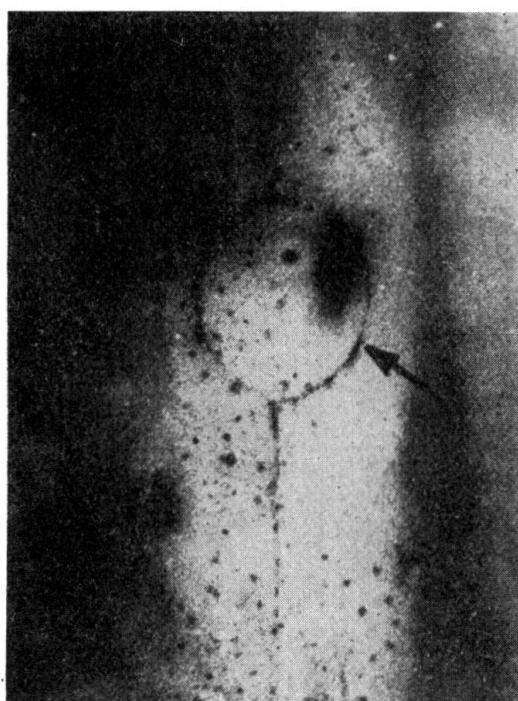


Fig. 13.

X-ray negative showing faulty welding of a hole.

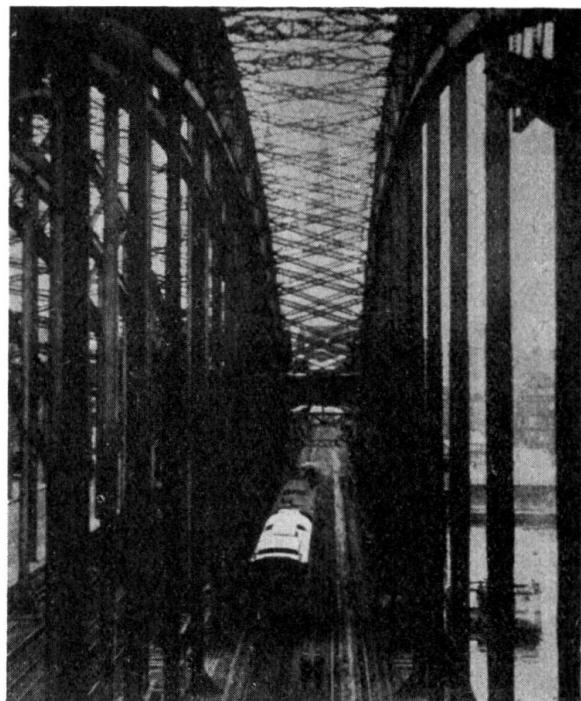


Fig. 14.

X-ray testing car on the Hohenzollern Bridge in Cologne.

structure by X-rays the image may be thrown directly on a screen or may be rendered visible on X-ray films provided the thickness of the work is not excessive (Fig. 13). Apparatus has been so developed that such tests may be carried out on the site and in actual service. Fig. 14 shows a portable X-ray testing set used for particularly difficult investigations. Figs. 15 and 16 show that X-ray tests may also be made on railway bridges. The limitations of X-ray technique lie in difficulties as regards apparatus, lack of sensitivity to faults, and the thickness of the material.

Non-destructive methods of testing may also be combined with destructive methods. It is a matter of dispute how far the results of non-destructive testing

¹⁴ S. Kießkalt: Autogene Metallbearbeitung 27 (1934), No 5, p. 65.

¹⁵ A. Matting: Anwendung der Durchstrahlungsverfahren in der Technik. Akademische Verlagsanstalt m. b. H., Leipzig 1935, p. 51.

¹⁶ R. Berthold: Z.V.D.I. 78 (1934), No 6, p. 173.

can be linked up with those of direct testing.¹⁷ By combining different methods of testing it is usually possible to obtain sufficiently conclusive results as to the structure of a weld seam.

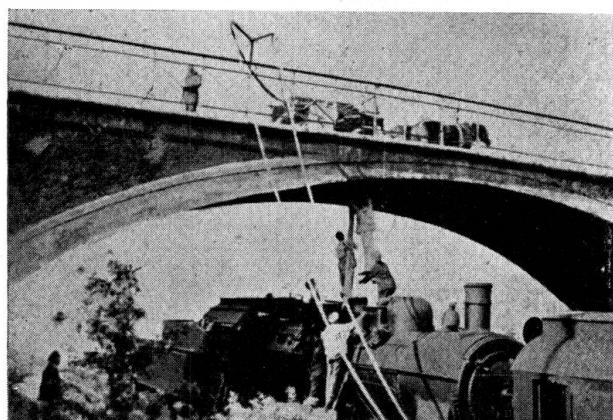
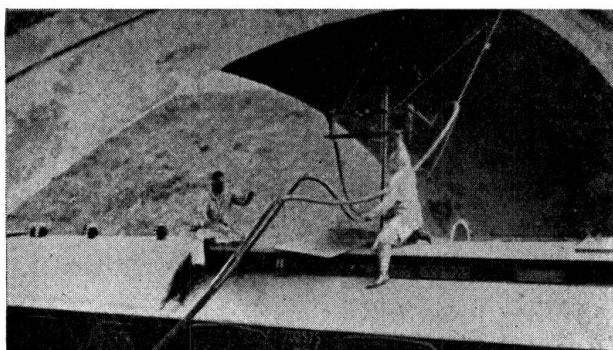


Fig. 15.

X-ray examination of a reinforced concrete bridge.

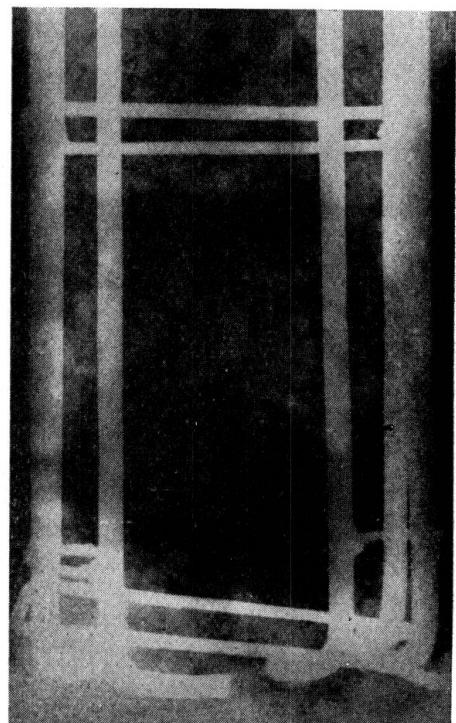


Fig. 16.

X-ray negatives of a reinforced concrete girder.

¹⁷ A. Matting and C. Stieler: *Stahlbau* 6 (1933), № 24, p. 185.