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The Acoustical Measurement of Extension: its Application to the Determination of "Singular Points" in Structures.

Akustische Dehnungsmessung. Anwendung zur Bestimmung der singulären Punkte in den Bauwerken.

Mesure acoustique des allongements. Application à l'étude de points singuliers dans les constructions.

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One of the simplest, cheapest and most certain methods of auscultation available is that which makes use of acoustical principles, an idea which occurred to many workers a long time since and which has been brought into practice simultaneously in Germany and France during the last few years. The principle is as follows:

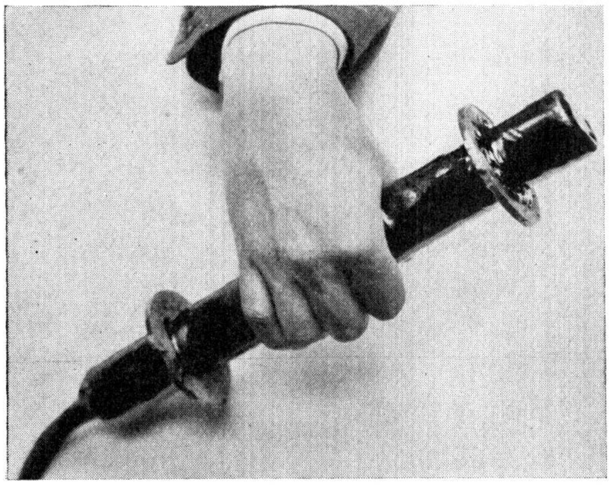

Fig. 1.
Outside appearance of the "acoustic telltale".

A vibrating cord having its ends fixed to the piece to be auscultated participates in the deformation of the latter, and its natural frequency varies in accordance with the elongations or compressions undergone. Where it is required to measure the stresses in concrete the cord is enclosed in a water tight corrugated tube which protects the apparatus without impairing its elasticity (Fig. 1 and 2).

The cord is excited from a

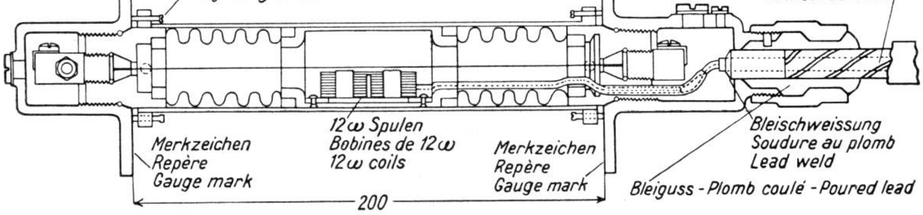

Fig. 2. Longitudinal section.

distance by means of an electro-magnet, receiving the discharge from a small condenser, and this has the effect of setting the cord into vibration. The vibrations are detected in the same circuit by means of a valve amplifier (Fig. 3), the electro-magnet acting like a Bell telephone. At the central measuring station the sound produced by the cord is compared with that of a standard frequency meter (Fig. 4), so affording an immediate indication as to the state of tension or

Fig. 3.

Valve amplifier for "acoustic telltale".

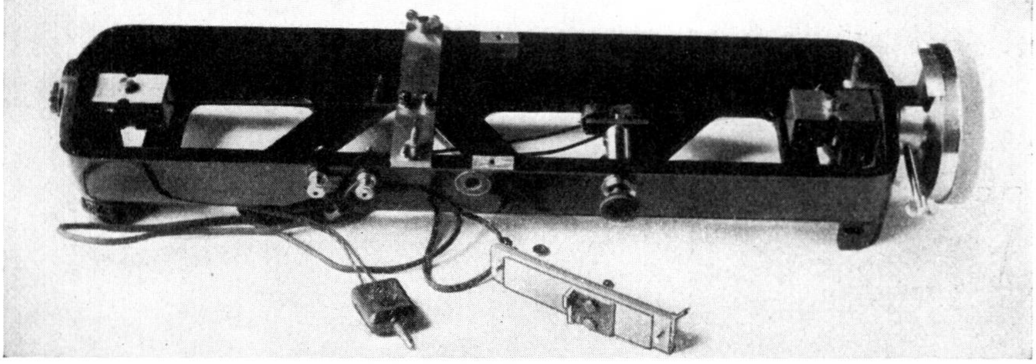

Fig. 4.

Standard frequency meter.

compression in the concrete around the instrument. The amplifier and frequency meter may be housed in a case which is readily portable (Fig. 5).

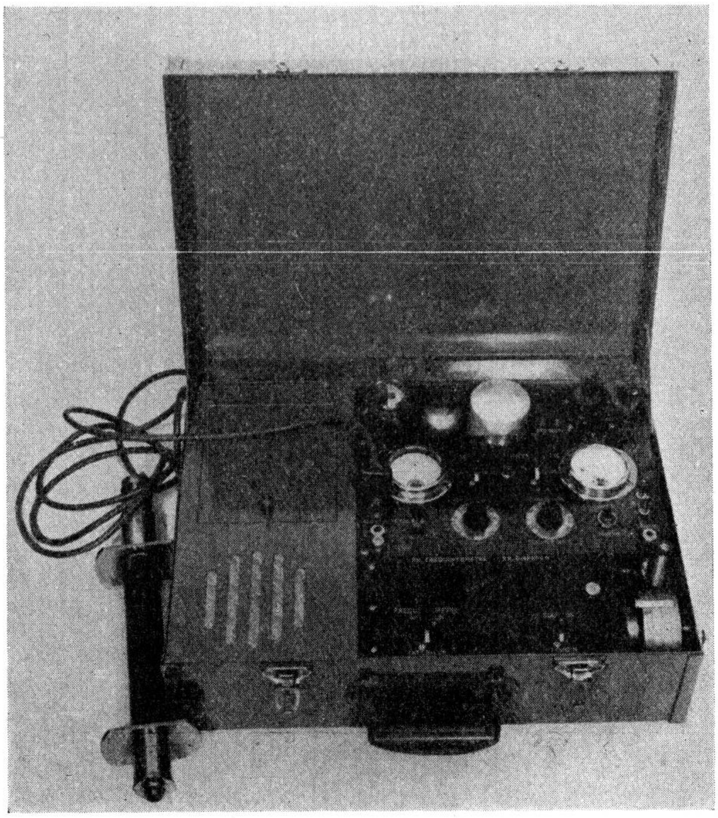

Fig. 5.

Acoustic set.

The first applications to be made by the author had reference to concrete and reinforced concrete, but the method is equally suitable for metal structures and has been of special use in studying the complex stresses existing at the intersections of frameworks and at the joints of pressure pipe lines. The steel wire is

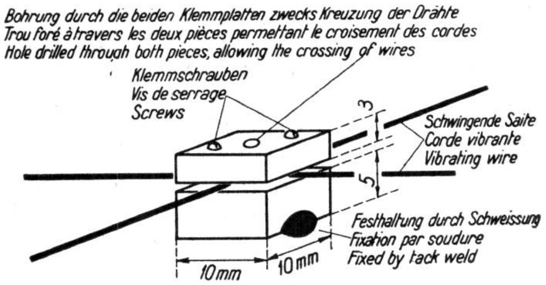

Fig. 6.

Attachment of acoustic cords to metal; diagrammatic.

attached to the metal structure in a very simple way by means of welded clamps (Fig. 6). The accompanying photographs (Figs. 7 and 8) show the application of the system to a thick sheet of metal.

Two examples of this kind of auscultation will now be given. One of them relates to an intersection point in the main girder of the Port de Pascau bridge over the Garonne, a structure which was auscultated at 51 points, by this acoustical method in the course of the acceptance tests. The diagram (Fig. 9) shows the variations in elongation along the flange plates of one of the booms in the neighbourhood of the connecting gusset under a certain loading, the influence exerted by this gusset being clearly apparent.

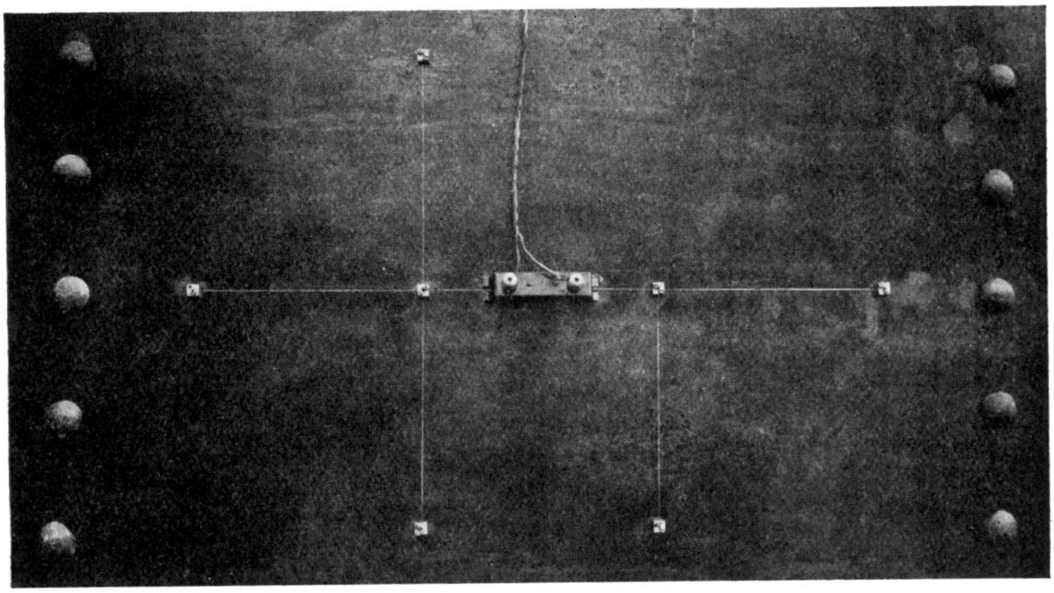

Fig. 7.

Attachment of acoustic cords to metal.

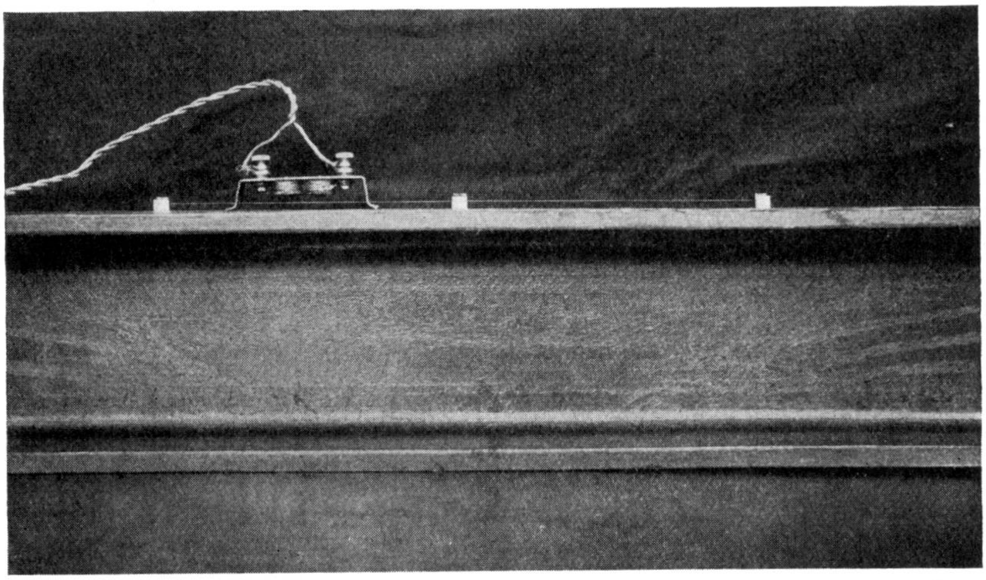

Fig. 8.

Auscultation of upper surface of an I-beam.

The other example is that of a small scale model of a branch piece in pressure piping subjected to internal pressure. This was covered by a network of vibrating wires, as indicated in the drawing (Fig. 10), and the variations in length of these wires along two generatrices and two directrices are indicated for a particular pressure (Table I). It will be noticed that apart from the elongation of the plate itself the wires are affected by a considerable amount of elongation due to bending in consequence of their distance from the surface. These two elongations are distinguished by coupling each instrument with a second instrument fixed at the same point but further removed from the surface.

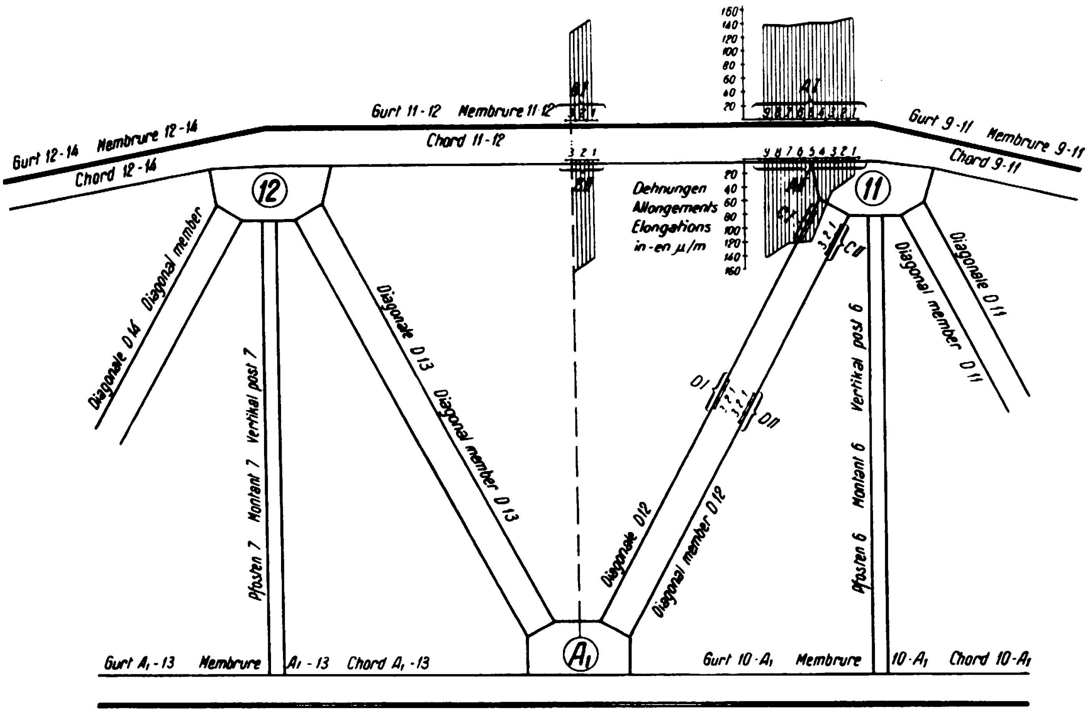

Fig. 9.

Auscultation of a steel girder.

The first advantage of this method lies in its economy, for it will be noticed that the number of measurement made on any given piece of steel can be multiplied very considerably at very small cost. A single wire, as shown in Fig. 7, might be used to indicate the elongations at a number of points, simply by dividing it into as many sections as are desired by means of clamps welded on intermediately between the two end points. In this way a whole network may be formed, from which no point is excluded. It will further be noticed that the auscultation is carried out by the operator from a central measuring post from which he has no need to move; this again greatly simplifies and cheapens the measurements and renders them almost simultaneous, since the adjusting operation adjustment when listening is very short. The method also allows of auscultating inaccessible points.

Finally it will be noticed that the causes of error are minimised by the use of sound as the medium of transmission. Indeed nothing is easier at the present time than to transmit a sound, either over a wire or even without wires, *without* *altering its frequency.* The sensitiveness of the apparatus is very high, and in the laboratory it may reach one millionth. In practice, it need hardly be stated, so

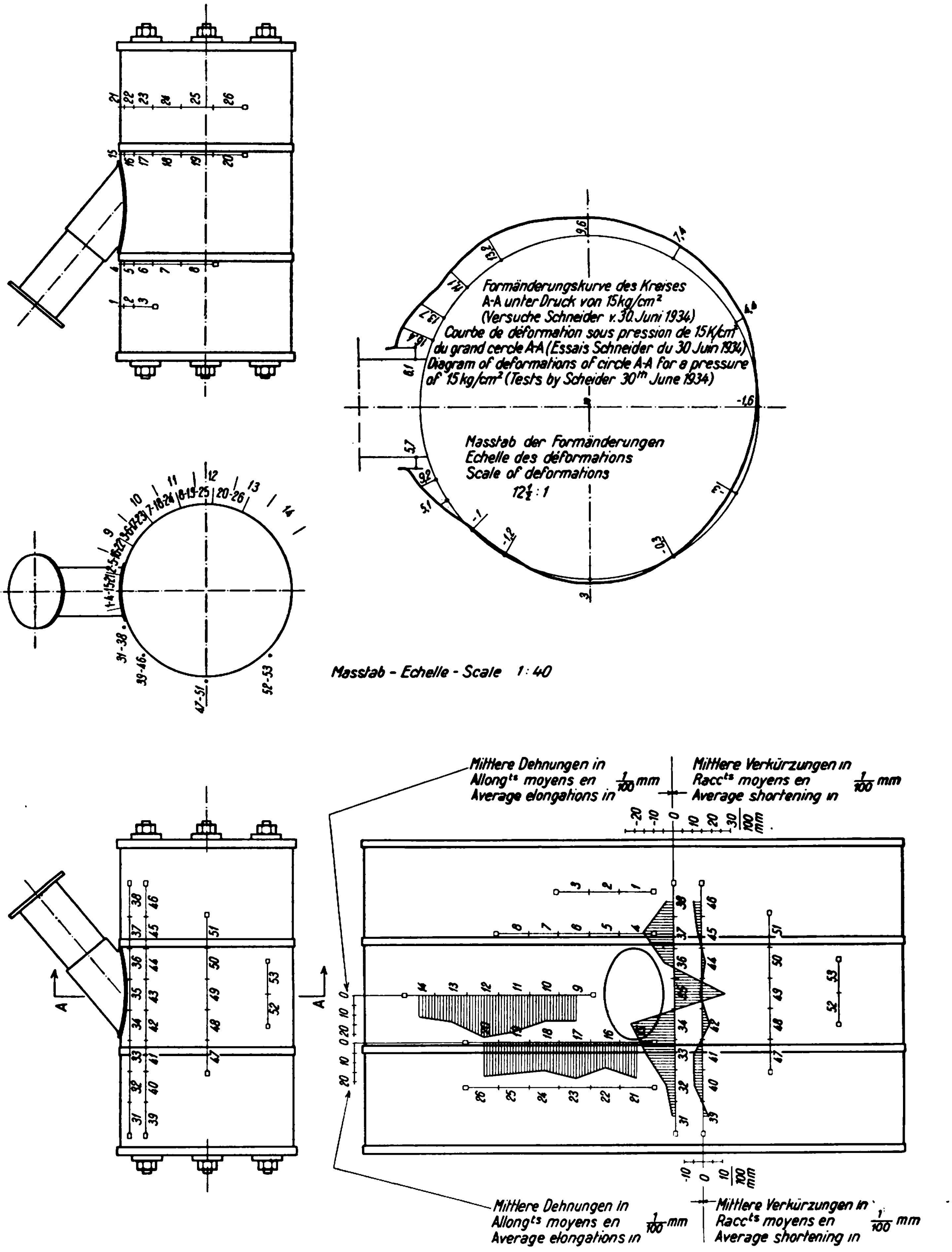

Fig. 10.

Auscultation of a small scale model of a branch in pressure pipe.

high a precision is unnecessary and in any case is unattainable on account of the inevitable differences in temperature as between the wire and the member under auscultation, but this difficulty — which is easy to circumvent — applies equally to all kinds of extensometer.

The method is also applicable for the measurement of dynamic stresses, by means of oscillographic recording.

Table I.

Elongation of strings in $^{1}/_{100}$th of mm in relation to test pressure.

Strings on parallel circles				
Nrs.	Test pressure			Observations
	5 kg/cm²	10 kg/cm²	15 kg/cm²	
1	18.6	36.6	55.0	
2	14.2	28.1	43.4	
3	17.7	34.6	54.6	
4	11.1	20.3	29.1	
5	10.8	24.0	36.4	
6	13.4	27.0	41.6	
7	15.4	32.9	46.2	
8	16.2	31.0	49.3	
9	13.4	24.6	35.2	
10	13.4	25.9	42.6	
11	18.9	39.4	58.8	
12	21.8	43.3	51.6	
13	13.7	29.1	48.1	
14	11.1	23.4	37.6	Length of string: 12.2 cm
15	18.4	38.2	61.5	
16	12.9	25.3	36.6	
17	18.5	37.0	57.0	
18	14.5	29.0	44.9	
19	15.9	32.4	51.0	
20	17.2	35.6	54.5	
21	18.8	34.8	54.3	
22	13.4	27.6	42.6	
23	12.7	26.4	41.3	
24	21.1	43.6	65.0	
25	16.6	33.6	52.3	
26	18.6	37.0	59.3	

Strings parallel to axis of tube				
Nrs.	Test pressure			Observations
	5 kg/cm²	10 kg/cm²	15 kg/cm²	
31	— 1.4	— 5.0	— 9.0	
32	— 4.3	— 8.1	— 12.5	
33	— 14.5	— 29.2	— 49.0	
34	— 22.6	— 47.4	— 79.0	
35	+ 26.3	+ 57.1	+ 86.0	
36	— 4,9	— 12.0	— 25.5	
37	— 15.6	— 34.6	— 60.0	
38	— 4.0	— 11.6	— 17.0	
39	+ 2.6	+ 1.2	+ 0.3	
40	— 4.6	— 10.1	— 21.2	
41	— 4.6	— 10.4	— 19.9	
42	+ 3.8	+ 6.1	+ 2.8	
43	— 0.8	— 3.2	— 8.0	
44	+ 2.1	+ 2.0	— 0.9	
45	— 1.7	— 6.0	— 13.6	
46	— 4.0	— 11.2	— 20.8	
47	— 2.5	— 4.9	— 11.2	
48	0.0	— 1.3	— 4.9	
49	— 1.8	— 3.2	— 9.2	
50	+ 2.0	+ 1.7	0.0	
51	— 2.9	— 1.4	+ 1.8	
52	+ 8.4	+ 3.5	— 5.0	
53	0.0	— 2.7	— 10.3	