A counter for the investigation of plasticity and fatigue in metals

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A Counter for the Investigation of Plasticity and Fatigue in Metals

Un compteur pour la recherche de la plasticité et de la fatigue des métaux

Ein Zählrohr für die Forschung nach Plastizität und Ermüdung in Metallen

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Inducing a metal to emit electrons, requires supplying energy to it. This liberating energy may be provided by:

1. raising the temperature of the metal (thermal emission);
2. irradiation of the metal with light (photo-electric effect);
3. applying a very high voltage to the cathode (cold emission);
4. bombarding the metal with high-energy electrons (secondary emission), etc.

When measurings were being made with the aid of brand new counters, it was found that their zero level was very high, to diminish only gradually to normal: [1]. The interior of the counter itself namely, represented in that state of newness a source of electron emission. KRAMER [2] was the first to find out that freshly abraded metal surfaces did emit low-energy electrons, the so-called exo-electrons. The interested reader may be referred to some publications dealing with the subject in question in a general way, cf. [3, 4].

As a rule, it may be stated that the rate of emission of exo-electrons, decreases according to the formula: $I = ct^{-a}$. In this equation, I stands for the intensity (rate) of emission, t for the time elapsed since the surface has been disturbed, c and a are constants determined by the kind of metal, the treatment of the surface, the temperature and the illumination. Furthermore, the gas surrounding the test object, influences the emission also.

Detection of the electron emission is effectuated by means of specially built counters. The energy of the exo-electrons is so low indeed (< 1 eV) that the commercially available counters cannot be put to use. The entrance orifice namely of the latter is covered with a foil, through which the low-energy electrons cannot pass. Much research has been performed with open counters with the use of air of 1 atm., or a mixture of argon and alcohol as counting gases [5]. Other tests have been carried out in vacuo. The electrons, in this case, were accelerated to such a degree that they could pass through the window of a closed counter [6], or could be led into an open electron multiplicator [7, 8].

The arrangements mentioned have one disadvantage in common, namely that small test specimens can be dealt with only. Therefore, they do not seem very useful in technical application, whilst still this electron emission is to be considered as a means to give valuable information in many various problems, such as plastic deformation and fatigue respectively.

If there should exist a correlation between the degree of fatigue and the intensity of the electron emission, it would be possible to test structural parts, for instance, in a non-destructive way, as for fatigue, and, possibly even to predict the eventuality of fracture.

The apparatus which we intended to develop should therefore fulfil the following demands: 1. the counter should remain manageable; 2. it should be able to stimulate the emission; 3. its resolving power should be high. The first-mentioned condition was intended to make the apparatus useful not only for investigating small test objects but also to allow its mounting on large structural parts to be examined (fig. 1).

For stimulating the electron emission the metal surface to be investigated is irradiated with light, as has been done by other investigators too [9, 10, 11]. Our light source is projected through the counting orifice on the metal surface in question (see fig. 1).

The special filtering equipment enables to keep the wavelength of the light striking the metal surface of the test piece below the so-called "limit wavelength" for electron emission of the metall in its undeformed state. Under plastic deformation, a very intense emission occurs.

The counting orifice can be provided with a grid. Under a positive d. c.

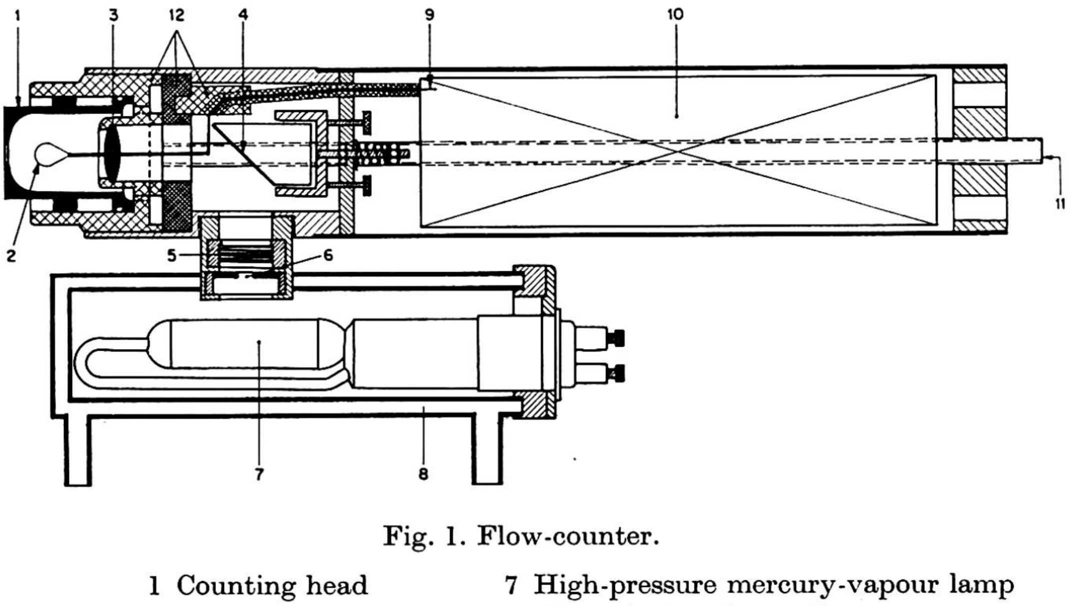

Fig. 1. Flow-counter.

1 Counting head	7 High-pressure mercury-vapour lamp
2 Collector wire	8 Water jacket for cooling
3 Quartz lens	9 H. V. connection
4 Aluminium mirror	10 Place for cathode follower
5 Light filter	11 Gas inlet
6 Diaphragm	12 Insulation

potential of the latter, the emission can be stimulated, and the liberated electrons guided into the counting chamber.

As a gas for counting the rate of emission, methane of technical purity was chosen, owing to its very suitable properties to that end. Measurings are carried out in the domain of proportionality [12]. The abundant emission of electrons even in case of considerable plastic deformation may be accurately measured.

The gas flowing at a rate of 10 l/h from the gas cylinder is led, via a drying chamber and a sensitive differential pressure-controller, into the top of the counting chamber, to pass the latter and to escape through the counting orifice.

The counting head is made of stainless steel, with a carefully finished interior surface. The stainless steel collector wire of 50 μ diam. is mounted in the counting head. By virtue of the rather small counting orifice (3 mm ∅) the problem caused by dust particles, always present when using open flow counters, is virtually eliminated on account of the speed of the outflowing methane. As another considerable advantage of this small orifice may count the screening effect of the bottom of the counting chamber. The eventuality of any cold emission occurring under the large difference of potential between the collector wire and the test piece is greatly diminished in that way.

In Fig. 2 is to be found a schematical presentation of the arrangement for measuring.

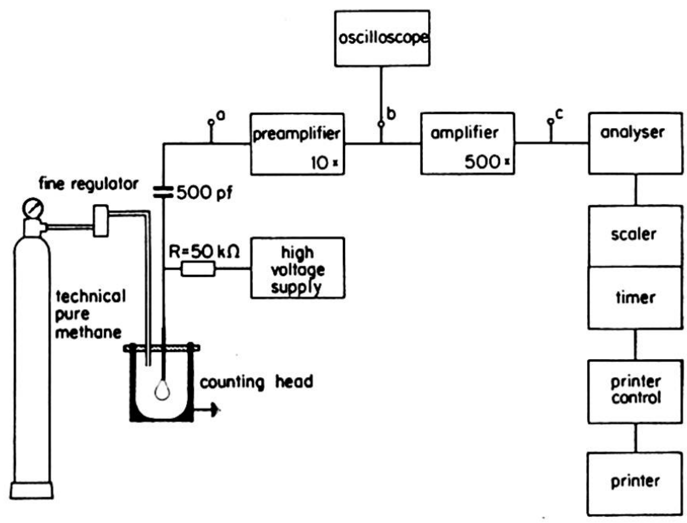

Fig. 2. Block diagram.

The electric capacity of the counter and of the wiring of the input of the pre-amplifier has been kept as low as possible, ± 10 pF. The intermediate capacity, 500 pF, is determined by the input-impedance of the preamplifier. In determining the anode resistance a compromise has been sought between pulse height and pulse duration. In our case 50 kOhm proved fully sufficient. As a requisite, the whole set of equipment should have one single common earth, in order to obviate interference by pick-up fields from other electric sources. At the points a, b and c an oscilloscope may be connected, enabling to control the shape of the pulse during observation and measurings. The dead time of the entire set-up is not determined by the flow counter, but by that of the apparatus to which it is branched, the latter being $< 2\ \mu$/sec. The counting chamber is regularly calibrated by means of C^{14}, an emitter of β-particles. The "plateau" (fig. 3a), begins at 2600 V and ends at 3000 V, irrespective of the mercury lamp's being switched on or not.

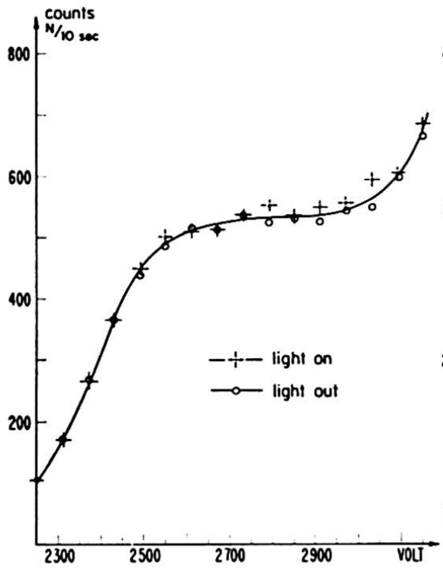

Fig. 3a. Shape of the plateau C-14.

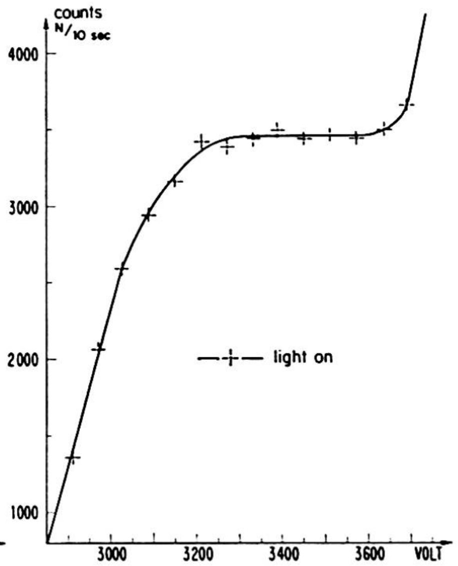

Fig. 3b. Shape of the plateau Fe-scratched.

The same measuring is repeated with plastically deformed construction steel (Fig. 3b). In order to obtain accurate measurings for the "plateau", a waiting time has to be included to let the electron emission diminish to a virtually constant rate. The observable presence of a "plateau" is an indication of the fact that the counting head does sufficiently screen off the metal surface, and that no cold emission does occur.

We intend to use the flow counter as a means of research in the domain of plastic strain and of fatigue in construction metals. Some results obtained by means of this flow counter in creep tests of short duration will be given here.

The test bars of mild construction steel (St. 27 yield-limit: 2500 kgf/cm^2, ultimate tensile stress: 4500 kgf/cm^2) have a measuring length of 25 mm, the cylindrical part having 10 mm diam. The counting head is positioned at a distance of some mm from the surface of the test bar. The stressing load is applied as rapidly as possible and then kept at a constant value. Elongation is measured every 10 seconds, simultaneously with the intensity of the emission occurring. The curves resulting from such experiments pertaining to the creep phenomenon and the accompanying emission, are plotted, as in Figs. 4 and 5.

From Fig. 4 it may be seen that, after reaching a maximum shortly after completion of the loading, the emission rate decreases. A corresponding maximum is to be found in Fig. 5. In case of pure relaxation the emission drops immediately. In case of creep, however, strain goes on increasing, although the increase in elongation per fraction of time diminishes. This increase in longitudinal strain incites by itself also an emission of electrons. The greater the increase in strain, the greater the increase in emission proves to be. It is from this point of view that the (still not exactly determined) relationship found is to be held liable for the maximum in the curves as observed.

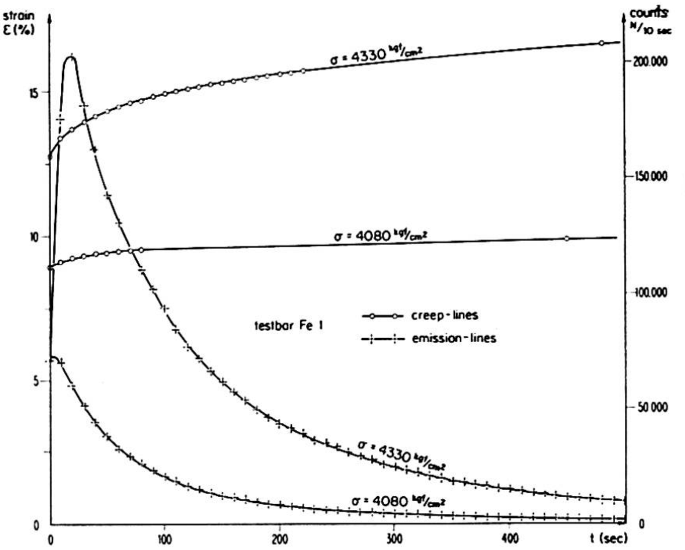

Fig. 4. Curves for creep and electron-emission simultaneously determined with Fe-testbar.

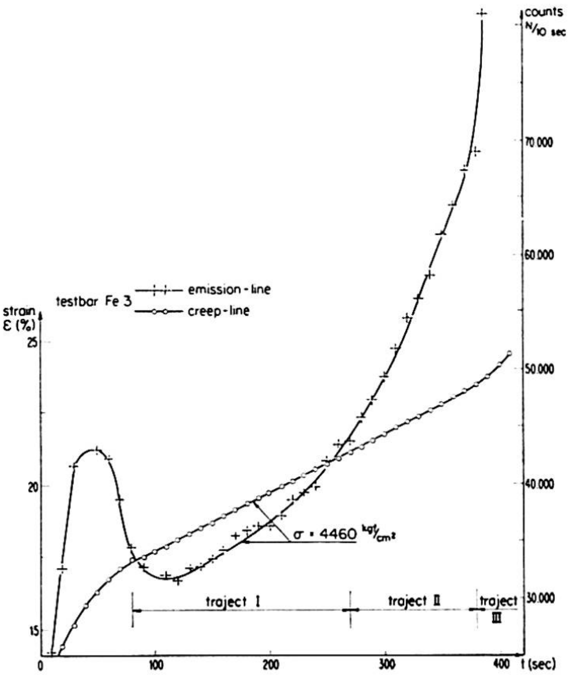

Fig. 5. Curve for creep and electron-emission simultaneously determined with Fe-testbar.

Fig. 5 shows how a minimum is reached after the first maximum recorded. Traject I is covered by the continuous increase of strain at 50 μ/10 sec, and traject II by a uniformly growing rate of such increase from 50 μ/10 sec up to 60 μ/10 sec, whilst traject III stands for a rapidly growing strain increase from 60 μ/10 sec to very large values.

The three trajects in the graphical presentation are to be recognized again in the emission graph, pointing to a clear relation between the rate of strain-increase per unit of time and the rate of electron-emission.

By means of this flow counter an electron emission can be detected, arising from very small plastic deformations. Hence, passing of the elastic limit (proportionality limit) can be observed, notwithstanding the feeble rate of electron emission above the normal effect under zero stress. We intend to raise the susceptibility of the apparatus in the domain between the elastic limit and the yield point, in order to be able to observe the phenomena more accurately.

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Summary

When a metallic surface is plastically deformed an emission of electrons is an accompanying phenomenon (exo-electrons). After a short review of counters devised by others, a description is given of the proportional flow counter developed by us, besides some other test results.

Résumé

Quand une surface métallique est déformée plastiquement, on constate une émission d'électrons (exo-électrons) comme phénomène connexe. Après une description succince des compteurs développés par d'autres, l'auteur présente une description détaillée du «flow-counter» proportionnel qu'il a construit, ainsi que quelques résultats expérimentaux.

Zusammenfassung

Als Begleiterscheinung der plastischen Deformation von Metalloberflächen tritt eine Elektronenemission auf. Nach einer kurzgefaßten Übersicht über die von andern Forschern konstruierten Zählrohre folgt die Beschreibung eines neuen, proportional anzeigenden Zählrohrs des Verfassers. Es werden einige Versuchsergebnisse angegeben.