# STUDY OF SOME APPARENTLY ABNORMAL DEFORMATIONS AND TRANSFORMATIONS OF METALS

C. CRUSARD AND J. BOUVAIST

## INTRODUCTION

After one of us was suddenly confronted with a case of deformation of a metal specimen without apparent action of an external force*, we considered it our obligation as metallurgical investigators to attempt systematically to study phenomena of this type. Thus we contacted J. P. Girard, who reputedly could produce "abnormal" effects in metals and

* Sciences et Avenir, No. 345 (November 1975), 1108.

other less satisfactory tests, since it would have been incorrect to present too optimistic a selection. In these presentations, and to expand the information on J. P. Girard, we also showed films of various external origins and also of unequal value. French and foreign illusionists observed certain presentations. They helped to firm our opinion on certain points. One of them discovered a sign of fakery on a film which J. P. Girard had obtained for us without telling us that it had been faked. The opinions gathered in the course of all these discussions helped us in the critical study of our documents, and in various checks which we have run since. J. P. Girard agreed to some control experiments, at least one of which is very interesting*. All this was time-consuming, and explains the long delay between our first tests and the appearance of the present article. However, we believe that this critical study has gone on long enough, if not too long, and that the time has come to publish the most typical of our experiences.

The selection which we present therefore is the result of prolonged screening work. Of 150 test specimens which J. P. Girard deformed or transformed before us or our colleagues, there are only twenty or so for which we might be able positively to affirm the "abnormal" character of the observed effects. In the course of this article, we describe eight of these most typical cases. However, we must point out that, among the tests eliminated, the majority were certainly valid,

---

* Test No. 4 of Table II.

but we rejected any demonstrations which did not follow a predetermined mode of operation. Thus our screening process was too severe. Other tests with extensometers will be published later.

Our concern for rigor thus eliminated quite remarkable observations on deformations at a distance, deformations of objects or test specimens in the very hands of observers of undoubted integrity, or of objects held in turn by J. P. Girard and by an observer.

The tests which we are about to describe were performed under our personal responsibility, with the authorization of Pechiney-Ugine-Kuhlmann. We wish to thank those colleagues who assisted us in the tricky study of this controversial field, particularly J. Rauch, G. Jollant and B. Dubost. We also wish to express our appreciation to Professor J. B. Hasted, professor of physics at Birkbeck College of London University, for kindly having sponsored a test in his laboratory.

## DESCRIPTION OF THE TESTS

### Bending of metal test specimens

So that J. P. Girard could not surreptitiously bend a test specimen, we often used fairly thick bars of various metals, particularly aluminum and light alloys (bars 250 to 350 mm long and 8 to 17 mm thick), but also copper, mild steel, stainless steel and magnesium. We determined the forces (bending moments) necessary to bend our specimens by measurements and calculations. To be able to compare the values of resistance of the specimens to the forces to which they could have been subjected if fakery involving surreptitious bending had been used, we determined the maximum moment that a man can develop by grasping a bar in both hands and exerting all his force... which does not go unnoticed. For this we used a dynamometric wrench with handles, 400 mm long, which we had numerous persons try. Depending on the individual, the maximum moments varied from 20 to 38 N·m. The median was around 25 N.m. J. P. Girard developed 26 N·m with a very visible effort. These values were confirmed by direct tests on the bars. We shall discuss one such example below (session of October 27, 1976).

It is out of the question to describe all these tests here, or to present a critical review. For this article, we have chosen the two most typical tests:

*Session of March 31, 1976,*

at the Centre Technique de l'Aluminium.

*Investigators:*

J. Rauch and G. Jollant, with an assistant for video recording.

During this session, in a room close to that in which J. P. Girard was waiting, G. Jollant took a bar of duralumin hardened to AU4G alloy of state T4 (quenched, matured). The bar was 250 mm long and 8 mm in diameter. Its fairly high critical bending moment (15 N·m) ruled out the possibility that it could be bent without visible effort. G. Jollant rolled it on a table, confirmed that it did not have any roundness defects, marked it and placed it in a glass tube which he sealed with a stopper. This is the only time that we were able to arrange that J. P. Girard did not touch a bending-test specimen before it was enclosed in a tube.

G. Jollant carried the closed tube to J. Rauch, who gave it immediately to J. P. Girard. From this moment, everything was filmed. The stopper, or the bar in the tube, or both, were always visible. After having concentrated and having declared that he felt something, J. P. Girard returned the tube, still closed, to J. Rauch. J. Rauch opened the tube, removed the bar -- which was visibly bent -- and placed it on the table and then on a flat bar, so as to highlight the deflection, which was thus made very visible. This deflection was 2 mm.

*Session of October 27, 1976,*

at Grenoble.

*Investigators:*

J. Bouvaist and B. Dubost.

Here we describe the test performed on the largest bar. This was a bar of 17 mm diameter and 300 mm length, consisting of AU2 alloy (with 2.05% Cu) in the T4 state (quenched in cold water and matured for one year). This bar had been provided with marks engraved in the body. The positions of small characteristic defects had been observed. It had been transported to the experimental station in a vehicle other than that which brought J. P. Girard, and it was the only one of its kind in the experimental lot.

This bar had previously been subjected to bending tests by very strong men, and only one 300-pound individual had been able to produce a small but significant deformation of this bar, after coating his hands with magnesia (deflection of 0.6 mm, corresponding to an applied moment of 38 N·m). The bending plane had then been marked by scratches at the two ends. Later tests had permitted us to verify that an average man could not increase this deformation, even by using a support at the center of the bar and bringing his entire weight (140 pounds) to bear on the two ends.

During the test, the two investigators were seated on opposite sides of J. P. Girard, approximately three feet from him. J. P. Girard worked in shirt sleeves, with the sleeves rolled up and unbuttoned. He produced four deformations of this bar in succession, by holding one end in his right hand and gently stroking the free part with his left hand (deformations (1 and 2), or by holding his left hand 5 cm above the specimen (deformations 3 and 4). After each deformation, one observer recorded the profile of the specimen, while the other remained close to J. P. Girard. The two largest deformations (3 and 4) could be followed visually. They both occurred downwards over an interval of 10 to 20 seconds. After each deformation, it was verified that no heating was detectable by manually touching the bar, and that the deformations produced effortlessly by J. P. Girard were all in the same plane (at an angle of 34° relative to the initial bending plane mentioned above), marked by the scratches indicated above. These scratches also permitted the observers at each instant to verify that the same bar was always in view. Immediately after the experiment, the specimens were locked in a briefcase and taken to the laboratory.

We now describe the laboratory examinations:

First of all we verified in the laboratory that all the marks, scratches and defects initially present on the bar were present on the bar returned from the experiment, thus permitting us to affirm unequivocally that there had been no substitution of the specimen. Figure 1 shows a photograph of the bar after the experiment.

The following examinations were aimed at characterizing, in non-destructive fashion, the modifications introduced into the bar, and more particularly into section A, which corresponds to the maximum curvature. We noted:

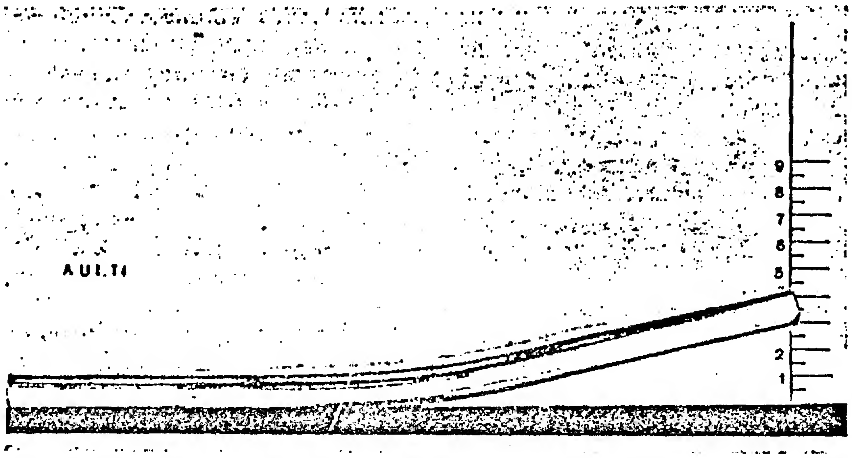



FIG. 1

Photograph of the AU2 bar of 17 mm diameter after bending. Scale in centimeters.

- a significant increase in hardness of the two fibers located in the bending plane, attaining a maximum of 11 points Vickers (i.e. 27%) in section A, which corresponds to the maximum curvature. The length of the zone where the hardness was greater than the initial hardness is ca. 120 mm (60 mm on both sides of section A).

- in section A, and perpendicular to the bending plane, the hardness measured at the circumference is maximum in the bending plane, and varies linearly with height relative to the neutral line, as in the case of simple bending.

To determine the moment which would have to be applied by mechanical bending of the bar to obtain the observed permanent deformation, we subjected a reference bar identical to the

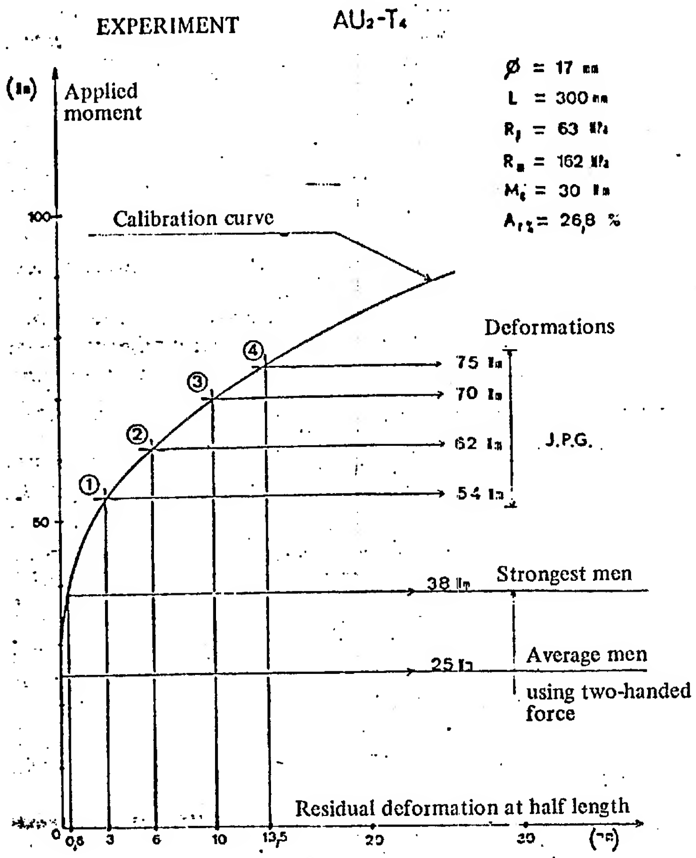



FIG. 2

Diagram of deformation as a function of applied moment for a reference bar identical to that of Figure 1.

test bar to mechanical bending with a distance of 200 mm between fixed supports. The variation of residual deformation measured as a function of applied moment is shown in Figure 2. We can thus deduce that, to obtain the deformation observed for the bar bent by J. P. Girard (deformation = 13.5 mm), a moment M of ca. 75 N·m would have to be applied. This is two and one half times the critical moment Mc = 30 N·m, and twice the moment exerted by the strongest man we tested. The total deformation energy can be calculated as 11 J.

The preceding results permit us completely to rule out the hypothesis of surreptitious deformations of muscular origin which would have escaped the notice of the observers. Moreover, the fact that "normal" consolidation of the deformed zone was observed permits us to rule out the surreptitious use of thermal or chemical means which had locally diminished the mechanical strength of the alloy.

Finally, the group of observations made during and after the experiment on the duralumin bar deformed by J. P. Girard in the experiment of October 27, 1976, permits us to conclude:

- that the successive deformations achieved were not, and could not have been produced by application of the normal muscular force of the subject;
- that the final deformation obtained is comparable at all points to what would be obtained by applying a point force of 1500 N to the center of the bar resting on two supports.

## Tests on stainless steel in closed tubes

### *Materials and operating conditions*

During a session at the Centre Technique de l'Aluminium on March 25, 1976, martensitic transformations, with or without deformation, of test specimens were observed in front of three investigators (C. Crussard, J. Rauch and G. Jollant) and four other spectators. These specimens had been obtained from a casting of austenitic stainless steel of special, non-commercial composition, which had previously been used in a study of martensitic transformation by deformation. This casting contained essentially: Cr = 17.8%, Ni = 7.4%, Mn = 1.56%, Si = 0.36%, C = 0.050%, N = 0.034%.

Two test specimens remaining from this study were used for our purposes. They were cylindrical bodies (diameter 7 mm and length 85 mm) with smooth heads of 12 mm diameter. These specimens had been subjected to quenching in air at 1050°C (1 hr in salt bath), finish machining and nitrofluoric attack, giving the body of the specimen a satiny appearance. The resulting structure is amagnetic, except for some parts of the surface layer of machining. The martensitic transformation points in this state are: Ms = -40°C and Md = +90°C.

These specimens had been entrusted to J. P. Girard for a few days. At the start of the session, they were marked with an electric pencil with large figures, Nos. 2 and 3, surrounded by an irregular circle. Another specimen, marked No. 1 in the same way, was used for another non-significant test, and will be used again later for a simulation control experiment. Its mark can be seen in Figure 5. This was the first time with J. P. Girard that we used specimens of this type and marked them in this manner. It was these specimens marked in this way that were recollected at the end of the test under conditions which we shall see: there was no possibility of substitution.

After marking, one of us (C. Crussard) verified the straightness of these specimens Nos. 2 and 3 by rolling them. There was no "out-of-round". He also verified their magnetic state. For this purpose, a rapid and simple method of evaluating the magnetization from point to point consists in using a small, powerful horseshoe magnet of Ticonal (pole areas 7 x 4 $mm^2$, spacing 8.5 mm) suspended at the end of a small chain. To perform the measurement, we start from a position in which the magnet is in contact with the specimen and the suspension is vertical. We then pull the specimen away until the magnet detaches. By measuring the horizontal distance from the magnet to the specimen at this point D, and knowing the weight of the magnet (22 g) and the length of the suspension, we can calculate the force F of separation. During this verification, which was performed on the center of the two specimens and on the heads, the distance D defined above did not exceed 2 to 3 mm, which corresponds to forces F of separation on the order of 0.01 N. These forces were due to some traces of surface martensite produced by machining.

After this verification, the specimens were placed on the table behind which J. P. Girard was operating (with rolled-up shirt sleeves) in the field of the video camera, which kept them in view constantly (while J. P. Girard disposed of other specimens and made an attempt on a bar of light alloy, without leaving his seat) until the moment when the following experiments commenced:

(a) J. P. Girard took specimen No. 2 lightly by one head and, without exerting any force (the film confirms this), placed it in a tube, closed the tube with a stopper (always in front of the camera), took the closed tube full in the hand (left hand, the stopper always being visible), and concentrated. He then gave the tube to C. Crussard and, from this moment on, no longer touched the specimen.

C. Crussard removed the specimen from the tube: it had a slight but distinct deformation close to one end. The deformation was visible to the eye, and was verified by rolling the specimen. A check with the magnet revealed strong local magnetism close to this same end (see Table I). Since the entire operation had been filmed, there was no possibility of substitution. C. Crussard replaced the specimen in its box for subsequent study.

(b) J. P. Girard picked up specimen No. 3, which had always remained in view. The operations were the same as for No. 2, except that a spectator obstructed the camera for a moment. After J. P. Girard had concentrated, C. Crussard retrieved the closed tube, removed the specimen and rolled the specimen. This remained straight, although it exhibited local magnetism similar to that of specimen No. 2, this time without deformation. It was also replaced in its box for further study.

*Preliminary measurements*

The next day, C. Crussard evaluated the magnetism and the deformations. The same magnet was always used for the magnetism. The separation forces F defined above are indicated in Table I (to within ca. 0.01 N). For the deformations Y, one of the ends was applied against a straight-edge and the distance between the other end (inner side) and the straight-edge was measured. At the start of the test, it was verified that the specimens "turned round".

Figure 3 very clearly reveals the deformation close to one head.

TABLE I

| Measurement | Specimen No. 2 | Specimen No. 3 |
|---|---|---|
| Deflection from one side y1 (mm) | 2.5 | < 0.3 |
| Deflection from the other side y2 | 1.7 | < 0.3 |
| Average deflection $y = \frac{y1 + y2}{2}$ | 2.1 | < 0.3 |
| Separation force F of the magnet (N): | | |
| - one head | 0.12* | 0.03 |
| - one end of the cylindrical body | 0.15 | ≧ 0.22 |
| - center | 0.02 | 0.03 |
| - other end of the cylindrical body | 0.02 | 0.02 |
| - other head | 0.05 | 0.01 |

* Maximum value.

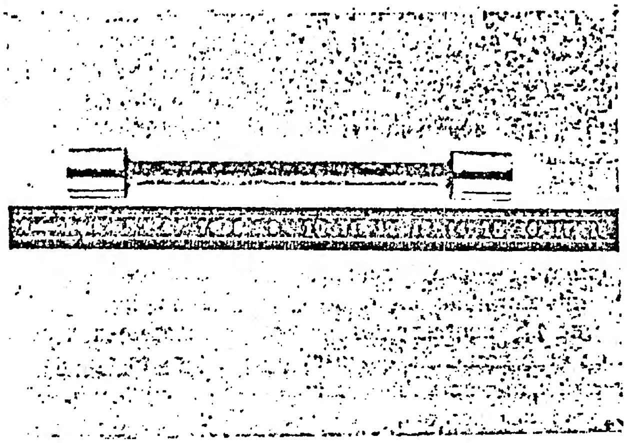


FIG. 3

Photograph of stainless steel specimen No. 2, after the experiment.

*Laboratory examinations*

Various examinations (which, moreover, were destructive) were performed on specimen No. 2. The bar was sawed electrolytically close to the magnetic head. We were thus able to introduce the magnetic end of the cylindrical part of the bar into the coil of a Sigmatest apparatus: the specific magnetization at saturation was 2.8, corresponding to a proportion of 1.9% magnetic phase ($\alpha'$).

For specimen No. 3, a non-destructive study with x-rays revealed $\alpha'$ and $\varepsilon$ martensites, the latter in high proportion, in addition to austenite in the magnetic zone.

Photomicrographs (specimen No. 2) on the surface polished mechanically and then electrolytically (Figures 4a and 4b)

FIG. 4

Photomicrograph of the locally transformed zone of stainless steel specimen No. 2: (a) near the surface; (b) at the core.

revealed a mixture of ε and α' martensites. By comparison with the previous studies on this steel, we can affirm that these structures have neither the appearance of a martensite obtained by cooling, nor that of a martensite produced by desensitization of austenite by heating it. It can only be a martensite of deformation (with some traces of martensite due to preparation of the polished surface). The martensite density seems fairly uniform over the entire section. Despite the uncertainty which always results in photomicrography due to the choice of fields, Figures 4a and 4b exhibit comparable appearances at the surface and at the core. The quantity of martensite observed in these photomicrographs corresponds to that obtained in this steel by tensile deformations of 5 to 10%. Thus it is much higher than what would correspond to the slight bending deformation observed (Figure 3). Its position is very surprising.

*Simulation tests*

The local magnetism of the head of specimen No. 2 could not have gone unnoticed in the verification performed before the test, particularly on the ends.

Nevertheless, since two assurances are better than one, we asked ourselves if we could imagine a metallurgical process capable of producing these localized martensites while leaving the specimens quite straight or only slightly bent.

Since the martensite involved here is the result of work-hardening, it was necessary to operate by deformation. The closest method of reproducing this position close to one head, with this abundance, is alternating bending. We ran tests on another specimen (No. 1), which initially was non-magnetic.

It was necessary to clamp one head in a vise, and bend the specimen by about 30° and then restraighten it. Then, however, because of the special properties of this steel, the specimen had a very visible S-shape (Figure 5). To restore the straightness, it would be necessary to machine a die and recompress the specimen with a press! Another difference: in specimen No. 1 treated in this way, the magnetism of the end of the shaft is comparable to that of specimen No. 2, but the head is not magnetic, which is obviously normal.

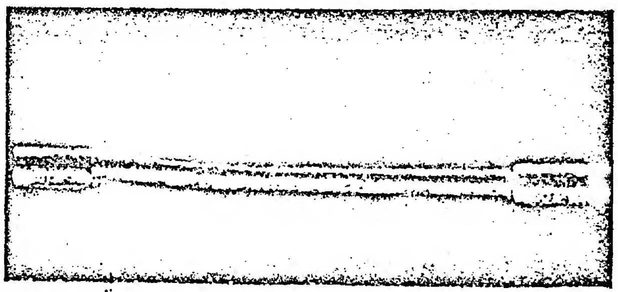
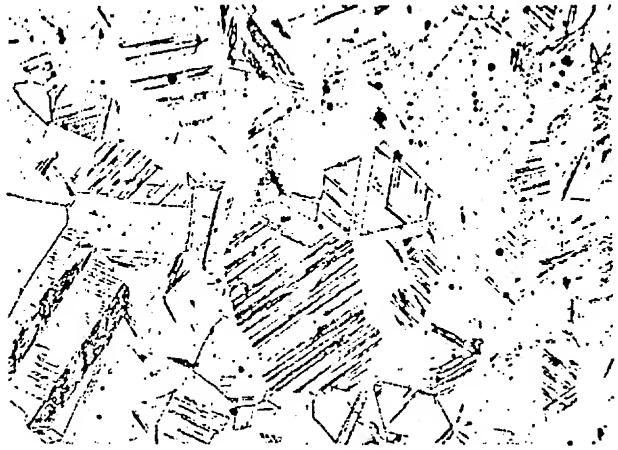


FIG. 5

Stainless steel specimen No. 1 after a simulation test.

A photomicrographic examination of another specimen which was bent even more strongly and then restraightened revealed martensite of work-hardening, but with a very distinct heterogeneous distribution: the density of martensite is lower at the heart than at the surface (Figures 6a and 6b), which is

a)



b)

FIG. 6

Photomicrographs similar to those of Figure 4, but for a specimen subjected to a similation test: (a) near the surface; (b) at the core.

normal, but constitutes a difference with respect to specimen No. 2. To obtain a uniform density in the cross section, and in the concentration observed, it would be necessary to be able to exert a tensile deformation localized in the end of the shaft and in the head (of around 5 to 10% for specimen No. 2, and at least 10% for specimen No. 3), without appreciably altering the diameters of the shaft and head*. A succession of hammering and molding operations would be necessary, all without leaving a trace on the specimen!

* In the case of specimen No. 3, we measured a very slight decrease of cross section (0.5%) in the zone which had become magnetic. Note that we could also have considered simulation by torsion. However, we do not see how to accomplish a localized deformation near a head and in it by this method.

*Conclusion*

The group of observations described above permits us to state:

- that a local martensitic transformation occurred during the test on two specimens, accompanied in one test by a small deformation near one of the heads;

- that we have been unable to conceive of any simple metallurgical operation capable of exactly reproducing the structures observed in the transformed zones.

Local modifications in hardness of metal plates

This experiment was performed four times by J. P. Girard in different places and before different observers. During the first session (October 27, 1976), one of the investigators unexpectedly proposed a new type of test to him: to harden a metal plate by trying to "compact" the metal. The experimental routine used for this test and repeated for the other three, with some minor exceptions which will be mentioned, was the following: a duralumin plate of dimensions, composition and mark known only to the investigator (and different for each new experiment) was submitted to J. P. Girard. At the outset, J. P. Girard made contact with the specimen by rubbing or stroking it with his fingers under close inspection by the investigators. The specimen was then placed by the investigator in a closed glass tube, after he had verified the straightness and the marking. The tube was then returned to J. P. Girard for the test. The specimen remained in the tube until the laboratory examination. For test 4, the step with the glass tube was eliminated, since it did not provide any additional guarantee relative to the initial routine, which accepted manual contact during the initial phase.

*Test materials and operating conditions*

The four modified plates all consisted of duralumin in the T351 state (quenched at 505°C in cold water, stress-relief stretching of 1.2 to 2%, maturing for at least 48 hr). Two compositions were used (a quaternary alloy, A-U4SG, of non-commercial composition, and an industrial alloy, 2017). An anonymous symbol scratched by iron on the metal and different for each experiment permitted the observers unequivocally to identify the test plate at a glance. Each plate was taken from a lot of identical plates which had been subjected to the same treatment, and reference plates from each lot were kept in the laboratory for comparison and for subsequent simulation tests.

Table II summarizes the places and the characteristics of the test materials for the four experiments.

Table II

| Test | Date | Place | Observers | Initial characteristics of the specimen | | Nature |
|---|---|---|---|---|---|---|
| | | | | Dimensions | Mark | |
| 1 | Oct 27, 1976 | Grenoble | J.B. et B.D. | 16 × 2.5 × 150 | 11 - I | A-U4SG-T351 |
| 2 | Nov 25, 1976 | Lyon | J.B., P.G. et J.G. | 14 × 2,4 × 160 | 11 - J | A-U4SG-T351 |
| 3 | Nov 25, 1976 | Lyon | J.B., P.G. et J.G. | 14 × 2,6 × 160 | 11 - H | A-U4SG-T351 + ball-tested |
| 4 | Oct 10, 1977 | London | J.B. et J.H. | 12 × 3,0 × 160 | VG | A-U4G-T351 machining + polished |

*Observations during the experiment*

FIRST TEST:

During the phase of contact at the ends of the fingers (ca. 2 min), we observed two successive slight flexures of the plate (11-I), in opposite directions, with deformations of +1 mm and -0.5 mm. The specimen was then placed in a glass tube with a total residual deformation of +0.5 mm (the slightly convex fiber corresponded to the scratched face). The tube was then given to J. P. Girard for two periods (5 min).

SECOND TEST:

No flexure before being placed in the tube. Exposure time 3 min.

THIRD TEST:

Specimen 11-H had been shot-peened over the entire length of both faces, to determine whether supplementary local hardening was feasible. Duration: around 3 min, without deformation.

FOURTH TEST:

The specimen VG was held twice by J. P. Girard (exposure time: 2 times 2 min).

*Laboratory examinations*

For the four tests, comparative examinations of the scratched marks, dimensions, weights, and initial impressions of hardness of the specimens confirmed that the specimens sent to the laboratory were indeed those which had been prepared for the experiments.

HARDNESS:

After electrolytic polishing, hardness measurements with the Vickers microdurometer under 3-kg load (ca. 30 N) were performed on both faces of the test specimens as well as on reference specimens kept in the laboratory. The impressions were produced with a step of 1 to 2 mm (depending on the case). Duplicate control experiments by different operators working "blind" (for tests 2 and 4) led to equivalent results.

The results obtained by this technique, whose two cases are represented on Figures 7 and 8, permitted us to detect notable and simultaneous increases in hardness on the two

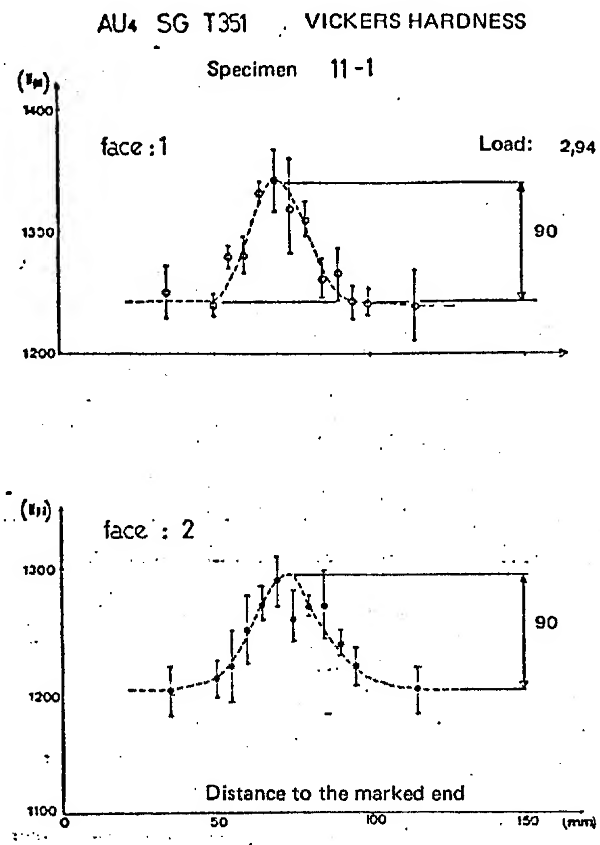



FIG. 7

Hardnesses measured on both faces of the light-alloy specimen 11-I, after the test.

opposite faces. The lengths of the modified zones and the maximum increases in hardness are collected in Table III. Allowing for the dispersion (characterized by the standard deviation, indicated in parentheses in the second-last column), these observations show in completely significant fashion that modification of the metal had occurred during the four tests.

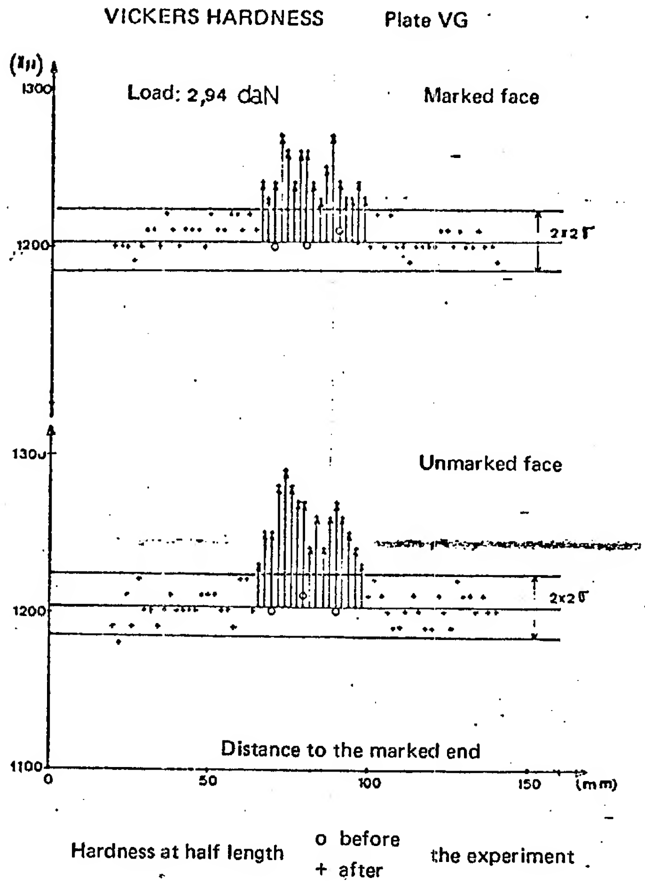



FIG. 8

Hardness measured on both faces of the light-alloy specimen VG, before and after the test.

We see that the maximum hardenings observed range from 6% (test 4) to 12% (test 2), and that they are 8% on average. For test 4, we had made six Vickers impressions at half-length before the experiment because, in the preceding tests, the hardening had always occurred in this zone, giving hardnesses of 1200 to 1210, which permits us completely to eliminate

Table III

| Test | Specimen | Maximum hardness in the modified zone (MPa) | Initial hardness | | Significantly modified length (mm) |
|---|---|---|---|---|---|
| | | | End of plate | Reference (standard deviation) | |
| 1 | 11-I | Face 1 1340<br>Face 2 (R) 1290 | 1240<br>1200 | 1220 (15)<br>1230 (14) | 20<br>30 |
| 2 | 11-J | Face 1 1340<br>Face 2 (R) 1310 | 1180<br>1190 | 1180 (20)<br>1200 (21) | 20<br>20 |
| 3 | 11-H | Face 1 1420<br>Face 2 (R) 1380 | 1290<br>1260 | | 20<br>15 |
| 4 | VG | Face 1 (R) 1270<br>Face 2 1290 | 1200 (7)<br>1200 (9) | 1210 (15)<br>1200 (10) | 35<br>35 |

the hypothesis of a pre-existing heterogeneity of hardness. We should note in passing that this test is particularly interesting, since it was performed in England, in the laboratory of Professor J. Hasted, and that the hardnesses were remeasured "blind" and confirmed in an independent English laboratory at the Electrical Research Association.

INTERNAL STRESSES:

Two techniques were used to detect possible differences in longitudinal residual stresses of the modified zones. The technique of surface measurement by x-ray diffraction ($\sin^2 \psi$ method), used on specimen 11-I, indicated a large modification of the longitudinal residual stress on the two opposite faces of the modified zone: in fact, we observed a residual stress of -80 MPa on the unmarked face (slightly concave) and of +80 MPa on the opposite fiber (marked). At the unmodified ends, we found the initial stress condition which is normal for this metallurgical state (T351), i.e. $\sigma R \approx 15$ MPa.

This point was confirmed by measuring the relative deformations produced on face 2 of specimen 11-J by progressive chemical shaping of the entire opposite face (1). By this technique (the Rosenthal-Norton technique), we observed a large and significant variation of the gauge situated vertically above the modified zone, although a gauge situated on the same fiber, 25 mm from the modified zone, exhibited normal behavior similar to that of the two gauges situated on the reference. We can therefore conclude without ambiguity that the local modification of hardness is associated with a local modification of the residual stress condition of this zone.

MICROSTRUCTURE:

The specimens modified during tests 1 and 2, together with the corresponding reference specimens, were examined by the transmission electron microscope (100 kV). Thin laminas parallel to the surface and carefully machined down to avoid any deformation were sampled at half thickness and on the two opposite faces of the modified zone of specimen 11-I, and also on the modified surface zone (face 2) of specimen 11-J.

In both cases, we observed that the modified zones exhibited a characteristic microstructure consisting of a very high density of small dislocation loops with diameter of ca. 200 Å (Figures 9a, 10a and 10b). At half thickness, the density of loops was less, but was significantly greater than

Table IV

| Sampling | | Density of visible loops ($cm^{-3}$) | Relative density compared with reference |
|---|---|---|---|
| 11-I (reference) | HV = 1240 | $7{,}4 \cdot 10^{13}$ | 1 |
| 11-I modified zone | face 1 HV = 1340 | $130 \cdot 10^{13}$ | 18 |
| 11-I modified zone | face 2 HV = 1290 | $84 \cdot 10^{13}$ | 11 |
| 11-I half-thickness | | $61 \cdot 10^{13}$ | 8 |

in the initial metal sampled at the end of the specimen and from a reference specimen.

In the case of specimen 11-I, we made a comparative count of the loops which were visible in the (110) section, with $g = [111]$ $s > 0$. After having measured the respective thicknesses of the different laminas, we found the results given in Table IV (average of five fields).

In summary, we observed that the modifications produced by J. P. Girard on duralumin plates submitted to him simultaneously involved:

- a surface hardening on the order of 8%, localized on the two faces of the plates, over a length which can attain 40 mm and a width of 10 to 15 mm;

- modification of the surface residual stresses in the modified zone;

- the creation, in this zone, of a particular microstructure, consisting of a very high density of small dislocation loops (diameter = 200 Å);

- the absence of macroscopic bending deformation (except for test 1 -- see above).

*Simulation tests*

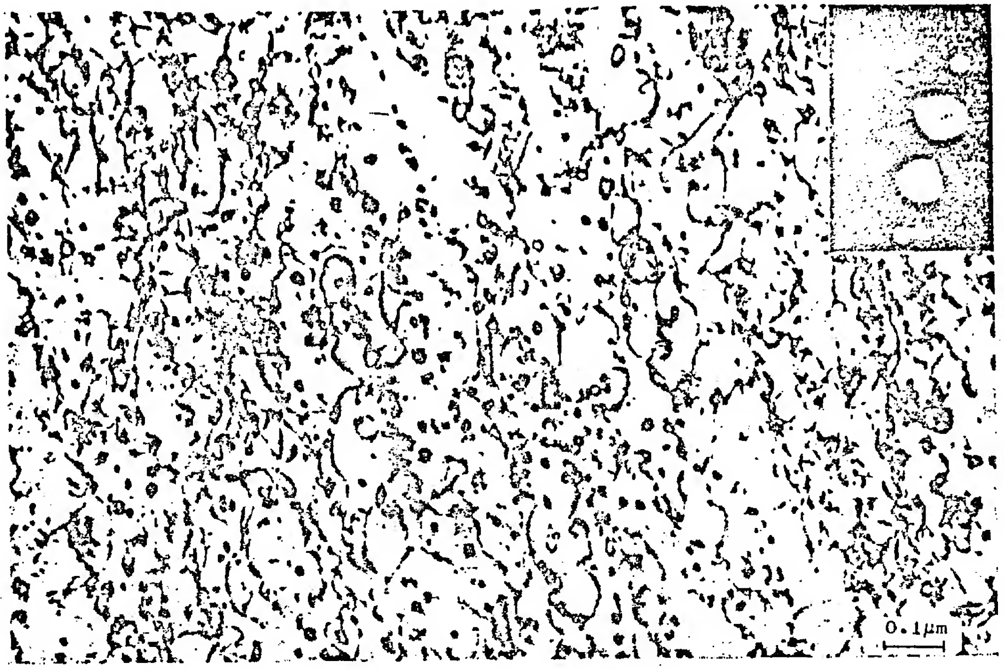
As in the case of stainless steel, we searched for double assurance by trying to conceive of simple methods of deformation which could simulate the preceding states.

Let us note first that the electron photomicrographs show that the Guinier-Preston zones are not dissolved and are the same at the end of the test as during the original state. This rules out any simulation by thermal treatment, specifically by surface heating (inductive or radiative). We were therefore led to conceive of mechanical simulation tests.

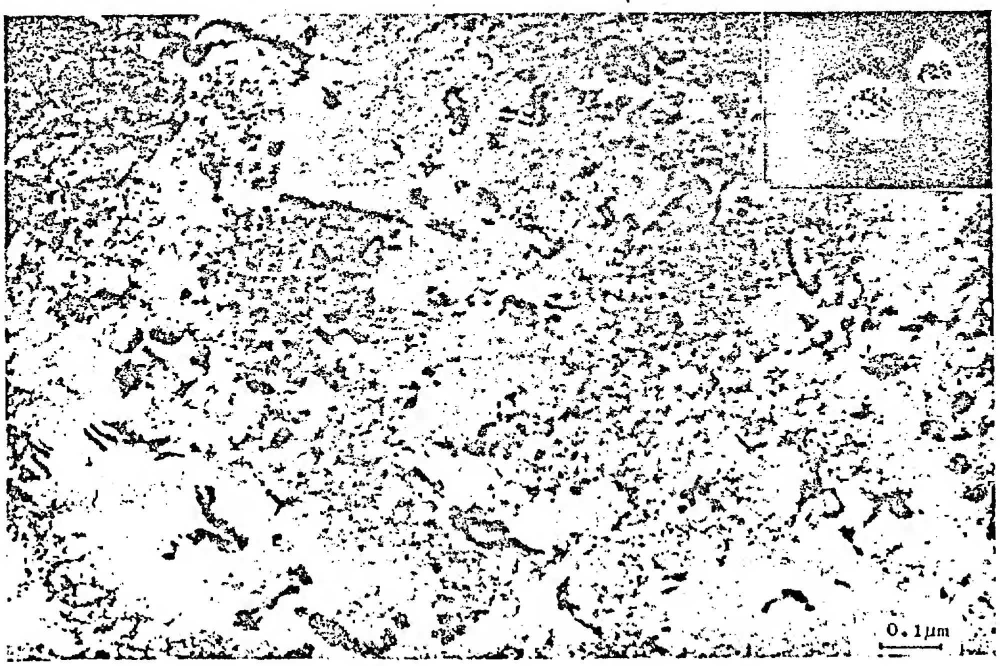
ALTERNATING BENDING

Considering that manual contact had been permitted during the first step of the experiment, we could ask whether a surreptitious operation of alternating bending in the plastic domain might be sufficient to lead to the observed modifications.

Alternating bending tests on reference specimens permitted us to see that it was necessary to introduce a total plastic deformation of at least 5% by alternating bending to obtain hardening on the order of that observed previously (ca. 8%).



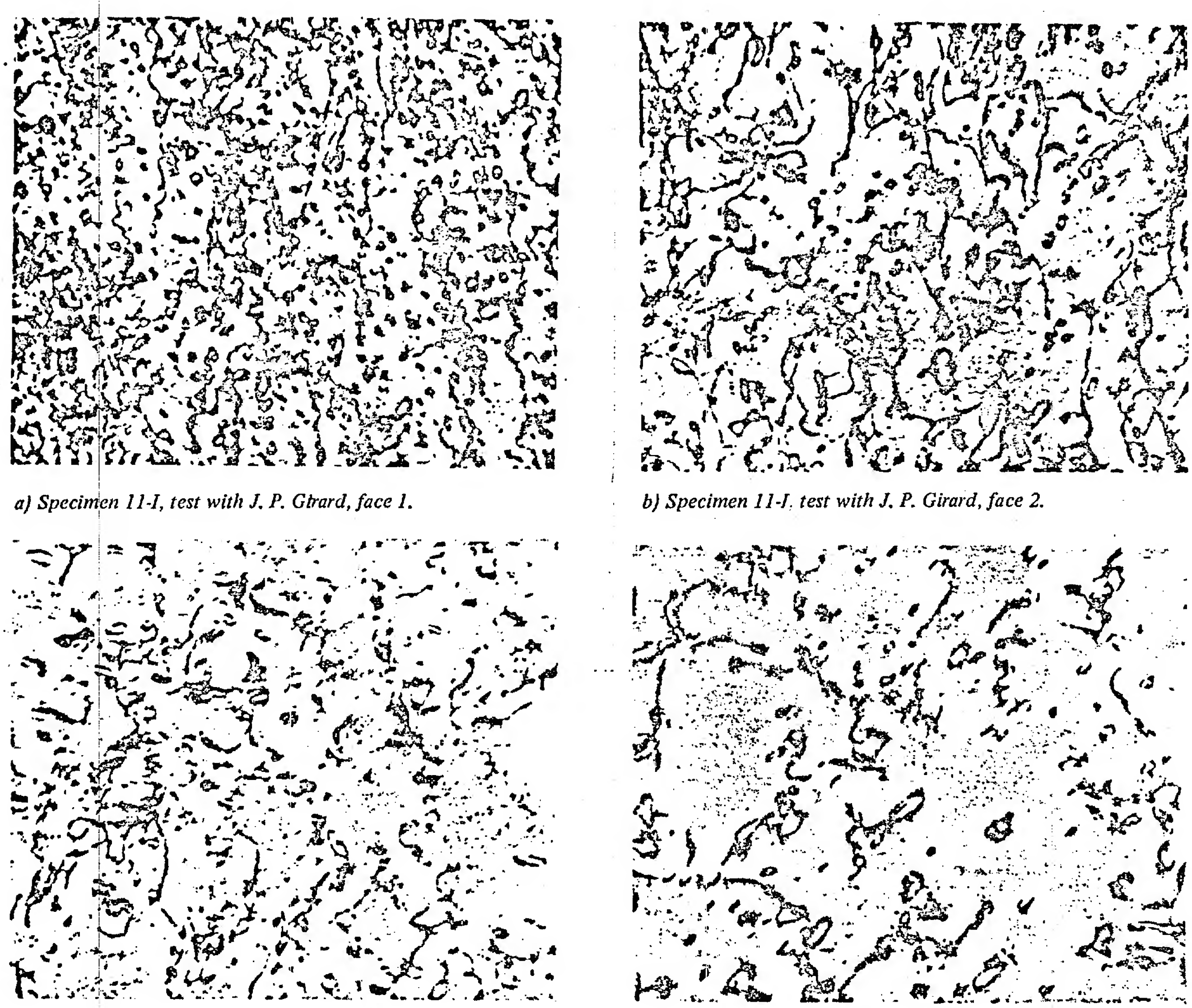

a)




b)

FIG. 9

Thin-film electron photomicrographs and electron-diffraction diagrams of the light-alloy specimen 11-I: (a) hardened sur-surface zone; (b) non-modified part. Contrast conditions identical in both cases.



*a) Specimen 11-I, test with J. P. Girard, face 1.*

*b) Specimen 11-I, test with J. P. Girard, face 2.*

*c) Specimen for simulation by shot-peening.*

*d) Specimen for simulation by compression with the press.*

FIG. 10

Electron photomicrographs of modified surface zones, at magnification 64,500 (before reduction).

For this it would be necessary to bend the specimen very strongly until a radius of curvature of 50 mm was attained (corresponding to a deformation on the order of 30 mm, which is incompatible with the observations made), and then to restore it by a deformation in the inverse direction.

However, this simulation did not permit us to reproduce the structural state observed in the specimens modified by J. P. Girard. In fact, electron microscopy of the hardened zones revealed tangles of dislocations, but not the significant increase in the number of dislocation loops.

COMPRESSION TEST WITH THE PRESS

A local compression test of the reference plate 11-U was carried out with the press under 300 MPa ($\sigma$ e ≃ 220 MPa). This permitted us to obtain hardening of the surfaces in contact with the stamper and with the table, with values close to that desired ($\Delta$ HV = 140 MPa). The microstructure was similar to that observed in the modified specimens (Figure 10d), but had a lower density of loops. However, we observed a 13% decrease of thickness and a uniform modification in the cross section of the structure and in the hardness, which was not the case for the specimens "hardened" by J. P. Girard. However, measurements of the thickness of plate 11-J revealed a reduction in thickness on the order of 2%, perpendicularly through the modified zone.

SHOT-PEENING TEST

A test involving surface shot-peening of the two opposite faces of reference specimen 11-M* permitted us to simulate the essential features of the points which we were trying to reproduce: surface hardening Δ HV of 70 MPa, absence of permanent deformation, similar microstructure (heterogeneous in the thickness, with maximum density of the dislocation loops close to the surfaces). By this method, however, we obtained a dull surface with a very different appearance from that of the specimens modified by J. P. Girard, and it was necessary to perform supplementary polishing to return to a comparable surface condition.

The set of observations and simulations showed that it would be necessary to exert a compression force on the plates normal to the surface, creating a heterogeneous plastic deformation through the section to reproduce the essential features of the physical peculiarities observed in the metal plates hardened locally and superficially by J. P. Girard. The mechanical energy required to simulate such a modification can be estimated from the test of simulation by compression: 1.6 J.

We can also produce loops of this type by neutron irradiation.

---

* Operating conditions: Matrasur machine; air pressure 7 bars; capacity 0.85 $m^3$/mm; glass balls (diameter 75 to 110 microns); duration 1 min.

*Conclusion*

The group of observations on the duralumin plates submitted to J. P. Girard permits us to state:

- that the required hardening was achieved four times during the test;

- that no simple metallurgical operation known to the authors permits us exactly to reproduce the different physical peculiarities observed in the locally hardened zones.

## DISCUSSION AND CONCLUSION

In this article we have described a certain number of deformations and transformations of metals under particular conditions. The places where these tests were performed, and the persons who observed them were varied. The only constant presence, common to all these tests, was that of J. P. Girard himself. Thus there was a correlation between his presence and the appearance of the particular effects observed. It therefore seems that we have the right to say that J. P. Girard was part of the "cause" of these effects. However, during these deformations or transformations, we neither observed nor recorded any use of muscular forces or of physical effects on his part capable of producing such phenomena.

It therefore seems that we can accept the "abnormal" character of these effects, particularly if we take the following observations into account:

- for one of the deformed specimens (see "Session of October 27, 1976"), the precautions taken to mark it and follow its deformation by tracing successive profiles are such as to prove that there was no substitution. The very high resistance of this specimen seems sufficient to preclude any explanation by a purely manual and muscular action;

- for the other specimen deformed in a glass tube (Session of March 31, 1976), the described method of operation seems to establish that the deformation, although slight, is quite distinct and was produced while the specimen was in the tube;

- for the cases of local transformation of structure, by martensitic transformation ("Tests on stainless steel in closed tubes") or by creation of numerous small dislocation loops ("Local modifications in hardness of metal plates"), the described precautions show that substitution did not occur. The production of these effects in a tube or with light contact rules out any "normal" explanation. Even if substitution had occurred, it would be necessary to note that we were completely unable to reproduce all the physical peculiarities of the transformed pieces, nor could we conceive of any simple metallurgical operation capable of doing so. Our simulation tests actually did permit us to reproduce the new structural elements produced during the tests with J. P. Girard. By combining several of these actions of simulation in complex fashion (incidentally, such actions would have left marks on the specimen), we would perhaps be able to simulate the local texture and arrangement of these structural elements, but we would produce much larger variations in dimensions than those observed, which are very slight or zero. The localized character of these transformations is surprising.

These experiments make up part of a group of much more numerous tests, which we have screened and subjected to prolonged critical study under the conditions described in the introduction. Within this group, we also had tests in which nothing happened, and others in which we clearly observed muscular efforts, in addition to effects which were positively "abnormal".

It is just as well to emphasize that the observed effects exhibit a certain reproducibility: the deformations of bars were produced many times, the local martensitic transformations twice, and the local hardenings four times. The last of these four tests, performed in the laboratory of Professor Hasted, is the most significant, since it involved a measurement of the hardness before the test in the zone where hardening was subsequently produced, and because the increase in hardness was verified in two independent laboratories, of which one English laboratory was working "blind".

In no one of these tests did J. P. Girard produce unknown structures. The structural modifications observed are similar to those produced by certain types of deformations. Their distribution is normal in the case of simple bending, but abnormal in the transformations without deformation or with slight deformation.

If these effects had been produced by application of forces, the work to be expended in the case of the largest specimen would have attained around 12 J. The corresponding enthalpy increase would be 2 to 3 J.

In this article, we by no means intend to impose our conclusions as complete scientific truths. However, we believed that it was our obligation objectively to describe the conditions and the results of these experiences. We have not found an explanation for the observed effects, either in modern physics or in possible fakeries. Perhaps someone else will be able to conceive of such an explanation.

---

REGARDING THE ARTICLE OF CH. CRUSSARD AND J. BOUVAIST

The above article was written following experiments revealing the abnormal behavior of metals or alloys in the presence of J. P. Girard. I can assure that these experiments were performed with great scientific rigor, such as to eliminate trickery as much as possible. However, several of these experiments are not convincing, since the possibility of fakery always remains.

Many phenomena are rejected by the learned world because they are regarded as irrational. However, it does not prove scientific honesty to refuse a priori to try and observe these phenomena and monitor them in isolation, in the search for truth.

Several scientific personalities did not hesitate to participate in the experiments of J. P. Girard, simply to "see" them objectively. I personally had this opportunity, and I have sometimes been troubled by these experiments which, as one of us has said, put us physicists in a very uncomfortable situation.

Of all these experiments, most of which were recorded on film, with a considerable luxury of controls, only those which form the subject of this article were kept by C. Crussard and J. Bouvaist. Until proof to the contrary, it has not been possible to give a rational explanation of the transformations observed and described -- although naturally this does not mean that such an explanation will not be found in the future.

It appeared interesting to the authors of the article to publish their observations, knowing well that they would be faced with fairly general scepticism -- but their decision should be regarded as no more than the desire to obtain information on phenomena which are obviously inexplicable at the present state of our knowledge.

For my own part, I agreed to add these few lines -- having had the opportunity to follow these experiments quite closely

-- simply to give my guarantee of the scientific rigor with which they were carried out by the authors. Too many factors are still undetermined for it to be possible to give a valid interpretation of the results.

J. J. Trillat,

Member of the Academy of Sciences.