On the Physical Properties of Gold Leaf at High Temperatures.

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In a paper by Prof. T. Turner* some experiments were described which show that gold leaf becomes transparent when heated in contact with glass. The following experiments, suggested by Prof. H. A. Wilson, were undertaken to see if this effect takes place when the gold leaf is heated by itself.

The apparatus in which the leaf was heated consisted of a double walled fused quartz crucible. The outside of the crucible was 6 cm. deep and 5 cm. wide, and the inner chamber was 4·5 cm. deep and 3·5 cm. wide. Both chambers were fitted with lids. Inside the inner chamber, as near to the leaf as possible, a thermocouple, composed of platinum and nickel wires, was placed. The other ends of the couple dipped into mercury cups immersed in melting ice, from which wires led through a reversing key to a dead-beat galvanometer, with lamp and scale, a resistance of 800 ohms being included in the circuit.

In the first experiment the gold leaf was stuck all round the edges to a platinum loop by means of thin lacquer. The loop was then placed in the inner chamber and the crucible was heated with a large Bunsen flame. No increase in transparency took place, but as heating continued it was noticed that the gold leaf was becoming more taut, and eventually the tension became so great that the leaf tore in places. The gold leaf was then removed and examined microscopically, when it was seen that the gold had lost its polished appearance and its structure appeared to be decidedly more granular. The above shows that at a certain temperature gold leaf, instead of elongating, contracts. The following experiment was then performed to see if any relation existed between the temperature at which the elongation gave way to contraction and the tension in the leaf.

For this purpose a small rectangular piece of gold leaf was cut (about 1·5 cm. long, 1 cm. broad). This leaf was suspended by fixing its upper edge lengthwise to a horizontal platinum wire which could be laid across the top of the inner crucible, yet allowing, at the same time, the lid to be replaced. To the bottom of the leaf a small weight, in the form of a platinum bar, was stuck by means of a thin lacquer. Latterly the platinum bar was discarded in favour of pieces of aluminium foil which were much

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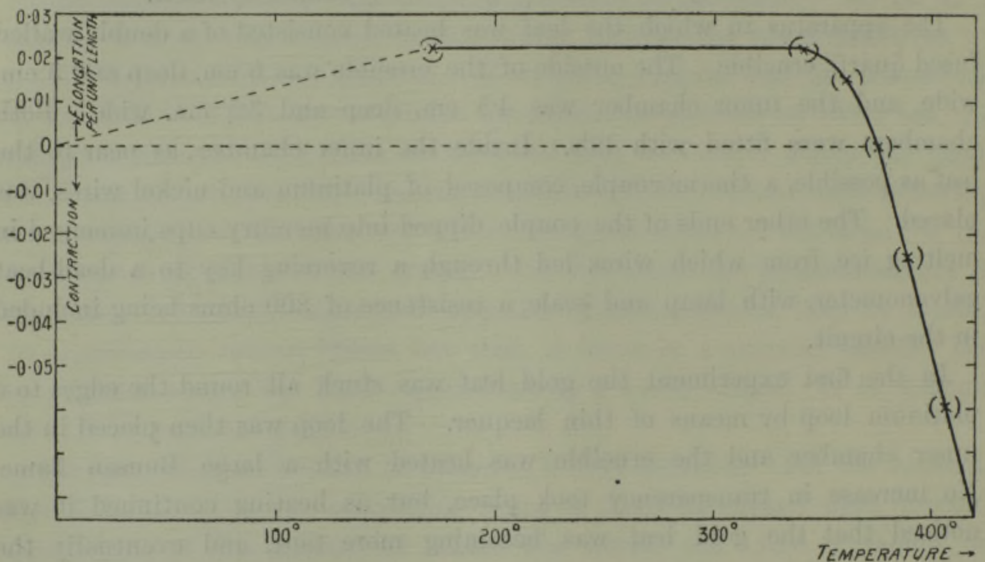
more easily handled. The breadth of the strip was in each case the same as that of the leaf. The leaf was then placed in the crucible, and the top of the aluminium bar, which was illuminated by a Nernst lamp, was observed with a microscope fitted with a scale in the eyepiece.

On steadily raising the temperature a gradual increase of length of the gold leaf took place. Later this elongation ceased, and for some time the length was constant. Finally (the temperature still rising) a rapid contraction of the leaf commenced, the contraction being much greater than the initial elongation. The following curve shows the relation between the temperature and the length of the leaf:—



CURVE I.

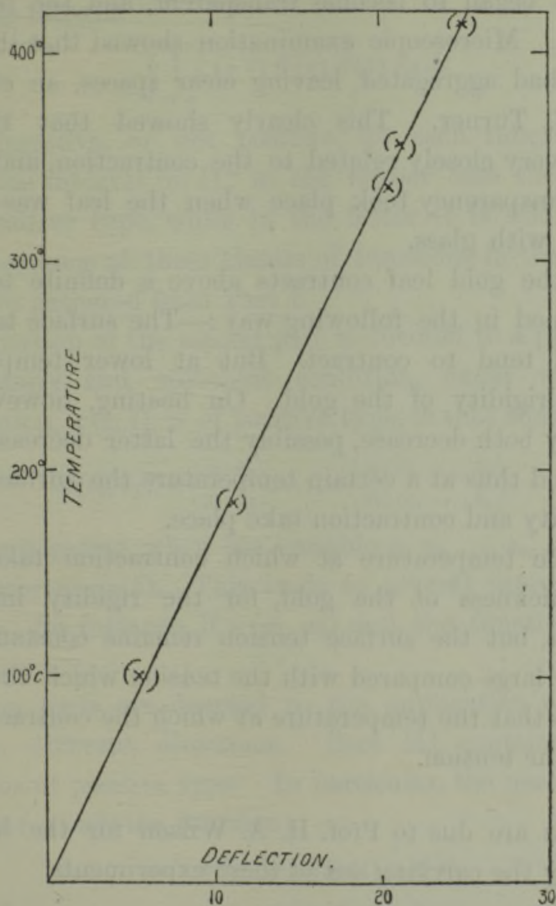
Curve I.—These experiments were repeated many times, using a series of different weights, the largest weight being the greatest the leaf could stand without tearing. The relation between the weight applied per unit breadth of leaf and the galvanometer deflection at which elongation gave way to contraction is given below—

Weight per unit breadth of leaf.	Deflection (giving temperature).
gramme.	
0·0066	20·6
0·0108	20·75
0·0162	20·6
0·0174	20·5
0·0215	20·5
0·0267	20·7

It will be seen that within the range of weights used the deflection observed was constant within the limits of error. This indicates that the temperature at which the leaf contracts is independent of the tension in the leaf.

The thermocouple was calibrated by immersing the junction in steam, boiling aniline vapour, boiling mercury vapour, and molten zinc. This gave the temperatures 100° C., 184° C., 356° C., and 415° C.

A fifth point was obtained by having a bead of potassium nitrate inside the crucible and observing the temperature at which it melted. This gave 336° C. From the results the curve below was obtained.



Curve II.

Curve II.—The temperature corresponding to the mean deflection 20·6 is 340° C. At this temperature the rapid contraction commenced. Very fine gold wire, 1/1000-inch in diameter, was tried in place of the leaf, the least weight required to stretch the wire being used as load. On heating up to 500° C. no contraction took place, the wire still continuing to increase in length.

The fact that the leaf contracts at a certain temperature probably explains the increase in transparency when it is heated on glass, for on the glass, when the leaf contracts, it will be torn into a great number of small pieces between which the light will get through.

To investigate this a portion of gold leaf was fixed on to a piece of glass of size suitable for placing in the inner crucible. The leaf was then maintained at a few degrees below 340° C. for about an hour. It was then removed, and on examination found not to have altered. It was then replaced in the crucible and heated to a few degrees *above* 340° C. In a very short time it began to become transparent, and the light transmitted ceased to be green. Microscopic examination showed that the leaf itself was still opaque, but had aggregated, leaving clear spaces, an effect which was observed by Prof. Turner. This clearly showed that the increase in transparency was very closely related to the contraction, and explained why no increase in transparency took place when the leaf was heated by itself and not in contact with glass.

The fact that the gold leaf contracts above a definite temperature can, perhaps, be explained in the following way :—The surface tension acts so as to make the leaf tend to contract. But at lower temperatures this is prevented by the rigidity of the gold. On heating, however, the surface tension and rigidity both decrease, possibly the latter decreases more rapidly than the former, and thus at a certain temperature the surface tension would overcome the rigidity and contraction take place.

On this view the temperature at which contraction takes place would depend on the thickness of the gold, for the rigidity increases rapidly with the thickness, but the surface tension remains constant. The surface tension is probably large compared with the tension which the leaf can stand without tearing, so that the temperature at which the contraction takes place is independent of the tension.

Our best thanks are due to Prof. H. A. Wilson for the kindly help and advice given during the carrying out of these experiments.