Journal of Scientific Instruments

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To cite this article: G Arthur and J H Priest 1966 *J. Sci. Instrum.* **43** 364

An improved small high temperature electric resistance furnace

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MS. received 12*th November* 1965, *in revised form* 10*th March* 1966

Abstract. A small high temperature electric resistance furnace, which has been operated up to 2650°C in vacuum and in which all the high temperature components are of tungsten, is described and its performance discussed. The furnace can also be operated using an argon or hydrogen atmosphere.

1. Introduction

A small furnace having a tantalum heating element and capable of operating continuously for long periods in vacuum at 2200°C has previously been described (Arthur and Priest 1961). Tantalum was preferred to tungsten solely because of the greater ease with which it can be fabricated. It has the disadvantage of having a higher vapour pressure than tungsten (Sherwood 1956), with consequently greater wastage of the element and contamination of the test specimen. Moreover, the volatile oxides of tantalum are more stable than those of tungsten, and thus tantalum at high temperatures exerts a greater reducing action on oxides which were one class of materials to be heated in the furnace. For these reasons a furnace in which all the high temperature components are made of tungsten has been constructed.

2. Description of furnace

The general arrangement of the furnace is shown in figure 1.

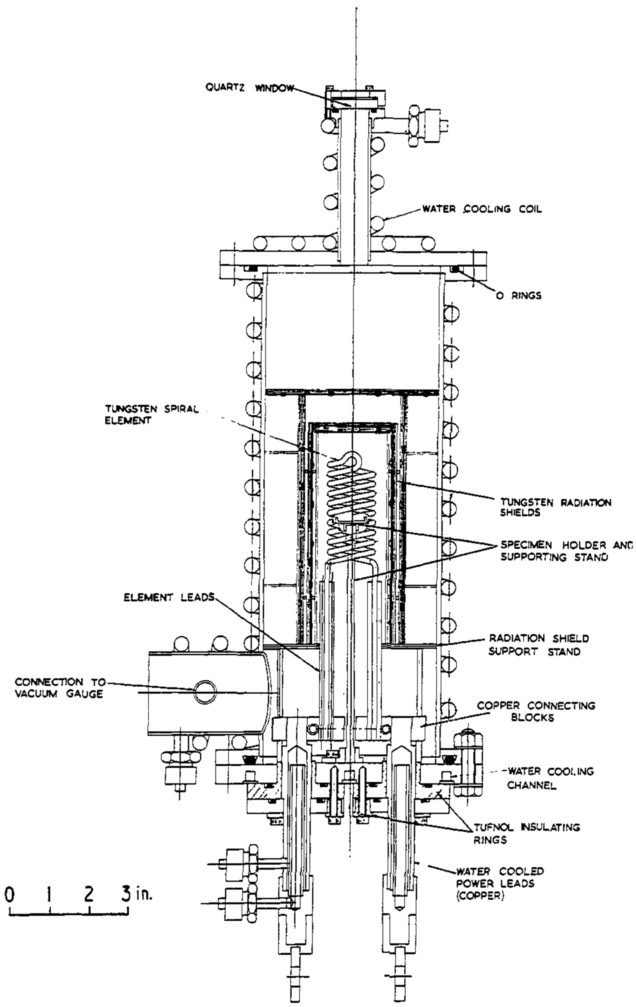

Figure 1. General furnace arrangement.

An attachment was later fitted to the furnace to prevent deposition on the quartz viewing window at high temperatures (i.e. >2200°c) (figure 2). The stainless-steel

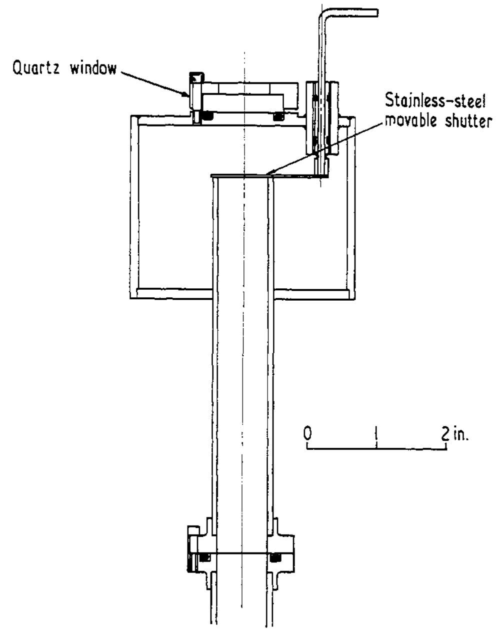

Figure 2. Top attachment for preventing deposition on quartz window.

shutter of this attachment is only swung aside to allow temperature measurement, which is made using a Leeds and Northrup optical pyrometer. The underestimate in sighting through the quartz window was found to be 25 degc at 1900°c, rising linearly to 50 degc at 2300°c and then remaining constant up to 2650°c, the highest temperature at which the furnace has been operated.

Pressure measurement is by a Penning type cold cathode gauge, a pressure of 10 μtorr being obtained at room temperature and approximately 0·5 mtorr at 2000–2650°c.

The power supply is from a 6 kVA, 25 v continuously variable transformer.

Two tungsten elements have been tried. The first of these, similar in design to the original tantalum element and constructed from tungsten sheet by riveting, was unsuccessful due to splitting near where the leads were joined to the tungsten cylinder. The second element, which has proved satisfactory, is shown in figure 3. This consists of a 5/32 in. pitch double spiral of 5/32 in. tungsten rod constructed by slowly winding the wire, heated to about 900°c by an oxy-acetylene torch, on a suitably grooved mild steel former. Sufficient tungsten rod is used to provide leads from the furnace base to the heating spiral. These leads are fitted into an assembly of six 5/32 in. diameter tungsten rods. Before fitting, the bottom inch of the assembly is flame sprayed with copper which is turned to $\frac{9}{16}$ in. diameter and slit longitudinally between two of the tungsten rods. When placed in the copper connecting blocks this slit allows the six planetary rods to tighten around the central rod. At their upper end the rods are tightly bound with 0·040 in. multistrand tungsten wire again to ensure good electrical contact.

The side and top radiation shields are of 0·005 in. 'dimpled' tungsten sheet. The bottom radiation shield which also supports the other shieldings is of 0·060 in. tungsten sheet.

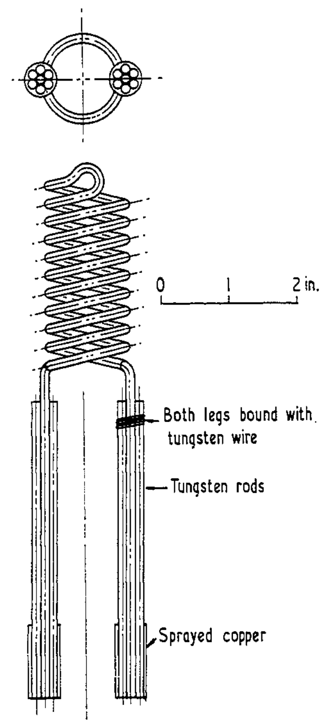

Figure 3. Furnace element.

3. Performance

The power and current required to maintain various temperatures up to 2650°c are plotted logarithmically in figure 4, the power temperature relationship being a straight line of gradient 0·220 degK W^{-1}. If all the heat loss were by radiation then from Stefan's law for the heat loss P from a radiating body at temperature T_1

$$P = K(T_1^4 - T_0^4)$$

the gradient would be expected to be 0·250 degK W^{-1} when it is assumed that second term containing T_0, the temperature of the final heat sink, is small compared with the first term. The small discrepancy is probably accounted for by conduction along the tungsten leads.

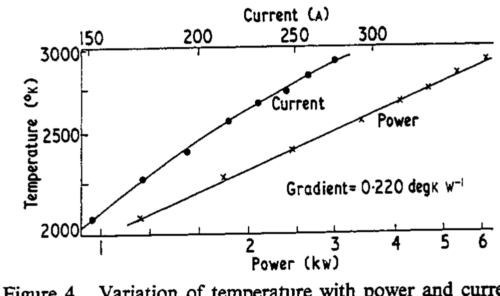

Figure 4. Variation of temperature with power and current (tungsten spiral element). (Plotted on logarithmic scales.)

To compare the extent of contamination from tungsten and tantalum heating elements a small tungsten specimen (6 cm^2 surface area) was placed in the hot zone of both furnaces and its weight determined after various times at different temperatures. In both cases the weight increased linearly with time, presumably owing to evaporation and condensation from the element to the specimen.

Weight increases (mg cm^{-2} h)

Element	Temperature (°C)					
	2000	2100	2200	2300	2400	2500
Tungsten	<1	<1	<1	1	3·5	11
Tantalum	<1	1·5	12	—	—	—

At 2200°C the weight increase from the tantalum element is approximately fifteen times that from the tungsten element, whereas the ratio of the vapour pressure of tantalum to that of tungsten at this temperature is only 5 : 1. The discrepancy may be explained by differences in emissivity; at 2500°K the emissivity of tungsten at 1·0 μm wavelength is 0·45 whereas that of tantalum is 0·32 (Croft and Titus-Glover 1964). Thus for a given heat transfer there will be a larger temperature difference and a correspondingly larger mass transfer between the tantalum heater and specimen than between the tungsten heater and specimen.

The present element has now been used for over 200 hours, usually in runs of one hour duration in the temperature range 2200–2600°C, without signs of deterioration. If higher temperatures were desired, more extensive water cooling would be required.

The furnace has also been operated using atmospheres of argon and hydrogen at slightly below atmospheric pressure. For a given temperature slightly higher power inputs than shown in figure 4 are required.

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