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A high temperature furnace

The Sample Environment Group

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Résumé. — Un four pour hautes températures a été mis au point qui utilise directement la puissance du réseau (240 V). Il peut recevoir des échantillons de grandes dimensions et pour le refroidissement, il utilise de l'eau industrielle. L'élément chauffant en tantale consiste en un fil de haute résistance maintenu par des isolants en céramique. Des températures de l'ordre de 2 000 °C peuvent être atteintes mais sont limitées par le choix des céramiques.

Abstract. — A high temperature furnace has been developed which operates directly from the mains voltage (240 V). It is designed to accommodate large samples, and use low quality cooling water. The furnace uses a tantalum heating element in the form of a high resistance wire held onto ceramic insulators. Temperatures up to *ca.* 2 000 °C are achievable but are limited by the present choice of ceramic.

1. Introduction.

Interest in neutron experiments at high temperatures has resulted in many different designs. In general these have incorporated a cylindrical foil heating element operating at very low voltages but requiring several hundred Amps current to achieve the necessary power.

Our approach has been to design and test a furnace working directly from mains voltage and therefore obviating the need for a large current transformer. A summary of the design philosophy and its development are described.

The design criteria were easily defined knowing users requirements and our own operating constraints, they were :

1. Sample temperature of up to $\sim 2\,000$ °C.
2. Computer control of temperature and/or temperature cycling.
3. Only readily available high temperature materials to be used.
4. Power supply to be of minimum size yet accommodating large variations in element resistance.

2. Design development.

The working temperature defined a small number of materials having adequately high useful temperatures. Detailed study of their properties and commercial availability determined those most suitable. These were tungsten, tantalum, alumina stainless steel and molybdenum.

Several industrial power transmission modes were examined to satisfy requirement (4), and a thyristor power switch with phase angle firing was retained.

The phase angle firing mode is ideally suited to the variable power requirements of the resistance : temperature changes of the element.

Nomograms, i.e. diagrams relating, temperature, resistance and currents were constructed to enable power requirements to be assessed. In the case of tungsten, a wire diameter of 0.7 mm requires a current of ~ 40 A to attain 2 500 °C. Specification of mains volts, i.e. 240 V enables simple determination of maximum element resistance i.e. $\frac{240}{40} = 6 \Omega$.

A wire or ribbon element of this resistance has a length of 2-3 m and can be wound into a cylindrical « cage » configuration supported by high temperature insulators. The element has an effective diameter of 50 mm. The thyristor unit, which tolerates a resistance-temperature variation of up to 30X permits other resistive elements to be tested.

The mechanical support of the element was designed to permit flexibility of element type and configuration whilst also minimizing mass at the furnace centre. Tantalum and alumina were specified for these items.

Computer control has been achieved using a standard industrial temperature controller having BCD input and output of set point. A 0-5 V signal from the temperature controller then controls the thyristor power output.

Preliminary trials with ribbon elements while achieving $\sim 1\,800$ °C exhibited brittle failure of the element. The large surface area permitted nitrogen absorption with the subsequent formation of a brittle nitride at grain boundaries. Replacing the ribbon element by a wire element of similar resistance whilst

maintaining a similar geometry avoided this problem. Metallizing of the insulators is also reduced.

Recent tests with the sample temperature measured at 1 600 °C required a power of 3 kW. The outer shield temperature was measured by pyrometry as 720 °C. Calculations indicated the element temperature as ~ 2 200 °C whilst that of the innermost shield was 1 400 °C.

3. Future developments.

Several detail changes will be made in the final furnace design particularly to ensure neutron suitability. Some parts of the mechanical support structure originally manufactured in tantalum will be replaced by alumina ceramic. For the temperature range above

~ 1 200 °C the heating element will be of tungsten whilst temperature ranges below ~ 1 400 °C are expected to have heating elements of vanadium.

Tests will be made using alternative sensors in the primary control loop to study closer control of the furnace power at start up.

4. Conclusion.

A predefined constraint that the power supply to furnaces on SNS instruments should be small in size prompted a reappraisal of furnace element design in neutron beam furnaces. An apparatus was constructed specifically to test and develop the design. The new design has been successfully tested, and with certain modifications will form the basis of furnaces on SNS instruments.
