MASTCO INC.
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PTFE in Temperature Probes

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The advanced fluoropolymer PTFE is one of a group of materials consisting almost entirely of Carbon and Fluorine. High molecular weight and long chain molecules characterize these polymers. The structure is essentially a central Carbon core shielded by a layer of Fluorine atoms held together by a high strength C-F bond. This makes the material almost totally chemically inert. The same molecular structure makes PTFE almost totally insoluble. The extreme rigidity of the fluorocarbon chains is responsible for PTFE's high melting point and the retention of order in the melt explains the high melt viscosity.

PTFE material has an extremely high intrinsic purity; this is due to the use of a free radical initiation process without the need for additives such as plasticisers, extenders or stabilizers. The resultant material is ideal for use in the semiconductor industry and to some extent in combinatorial chemistry. Like all materials the degree of contamination by inclusion of foreign material, either in the forming process or by surface contamination, determines the practical limitations of the form.

There are a number of modified variants of **PTFE** developed to give the material extended performance in manufacturing and end use. Modification with two co-monomers, hexafluoropropylene **(HFP)** and perfluoropropylene **(PPVE)** produce principally these forms. Once incorporated into the PTFE chain, materials are produced with thermoplastic properties - Fluorinated ethylene propylene **(FEP)** and per-fluoro alkoxy **(PFA)**. The thermoplastic nature of these two modified forms of PTFE makes them suitable for melt-processable applications such as injection molding, coating and foaming.

The processes used to manufacture PTFE components from raw resins differ between the modified forms. Pure PTFE is processed by cold processing using pressure in a mold followed by a sintering regime where the modified resins are formed by melting and molding processes. Sintering pure PTFE alone produces a material with a small proportion of microscopic voids controlled by the pressure and depth of sintering. Isostatic pressure prior to sintering greatly reduces the proportion of microscopic voids giving a higher density material. An enhanced form of PTFE namely **PTFE-TFM** uses a very low addition of **PPVE** (0.1%), which increases the coalescence of the resin particles during the sintering process. The resulting material has excellent surface properties resistant to contamination and is especially suited to the manufacture of PTFE temperature probes for semi-conductor and chemical applications.

PTFE is an excellent material to use in the construction of temperature probes. It has a dielectric strength of 48KV/mm and volume resistance of 10^{18} Ωcm making it an exceptional insulator.

PTFE probes significantly differ from their metallic counterparts in that the outer surface is non-conducting. This can be a beneficial feature for electrical insulation but does pose a problem regarding thermal insulation. Ideally a temperature-sensing device will not interfere with the environment into which it is introduced but conversely must extract some of the energy of the system in order to measure the temperature. A PTFE probe will not draw as much heat away from the medium as a steel probe and therefore takes longer to absorb the necessary energy.

Our design and construction of probes is critical in producing a product that will give an accurate representation of the real temperature in as short a time as possible. The controlling factor is the

Effective Thermal Diffusivity = k/(c x ρ).

Where k is the effective thermal conductivity, c is the effective specific heat and ρ is the density. This function represents the rate at which a temperature change will be propagated through a material. An ideal material has a high conductivity, a low specific heat and a low density.

It is not simply the PTFE that needs to be taken into consideration. Since the probe is made up of over-lapping layers of media of differing thickness from the sensing element outwards, each layer diffusing heat energy at a different rate. This includes platinum, air, ceramic material, heat transfer material, steel then the PTFE. In fact the proportion of PTFE actually makes it less significant than the other insulators. In addition, the rate of thermal diffusivity longitudinally through the body of the probe reduces the transfer of energy radically towards the sensor. This loss of energy is lessened with PTFE probes.

Mastco's temperature probes are designed to limit the Net Thermal Diffusivity. We introduce a low mass thermal transfer medium into the diffusion path, reducing the mass of the sensing element. This eliminates the air gap and reducing the mass of the PTFE at the sensing tip. The choice of sensor technology for use in PTFE probes also contributes to the increased speed without affecting the probe accuracy or stability.

Since Mastco does not make 'Standard' probes there aren't standard figures for response times. However designs used throughout the semi-conductor industry consistently yield figures between 6 and 12 seconds in 100˚C water. (ISO 60751 tests)