# Temperature Stressing Decides Condition of Engine Oil

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***Oil condition sensors make use of at least two measurement quantities. Exact temperature measurement is always one of them. The widespread use of inexpensive oil-condition sensors with precise temperature measurement will contribute to easing the environmental burden.***

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Oil additives are amongst the best-kept secrets and real car-rally fans always know which is the best for their car. The additives have a specific effect on the surface tension, viscosity, friction and abrasion, they bind soot and suspended particles, act as anti-oxidants, counter corrosion and suppress the formation of foam.

Both the oil and its additives are subject to a certain amount of wear and tear. Those who quickly rev up the engine to high speeds put the oil in the sump under severe thermal shock. Consequently, modification of the long-chain oil molecules follows, which, amongst other effects, drastically changes the tribological properties of the engine oil – in some cases rendering it unusable.

## Assessing the Oil Condition

Since it is still not (quite) possible to accommodate a mini-analysis laboratory in the oil sump, the major car equipment manufacturers such as Temic, Bosch, Hella and Delphi have adopted various approaches to an overall measurement of the engine-oil condition in internal combustion engines. Usually, the dielectric constant or the (alternating current) conductivity or the viscosity are monitored, always along with the temperature. Today, apart from the measurement quantities of oil level and temperature, a combined oil sensor should also supply the parameter, "oil condition", Figure 1.

The sensor system gathers the analogue electrical measurement signals, processes them and compares the result in a type of pattern recognition with the typical characteristic for the degradation of engine oil. During the signal evaluation, the stress history of the respective engine plays a significant role.

It is noticeable that none of the oil condition sensors currently available on the market can make do with the measurement of just one quantity. Apart from at least one of the quoted physical quantities, i.e. the dielectric constant, conductivity or viscosity, the temperature is also always determined as precisely as possible.

## Temperature as Basic Information

For temperature measurement there are currently three different technologies available for use in the large-scale production of oil-condition sensors. All use the "change of resistance with temperature" as the sensor effect.

The decision on whether to use NTCs (metal oxide), KTY (silicon) or Pt (platinum) sensors does not solely depend on the consid-


*Figure 1: Varied stresses on oil condition sensors are a challenge to all those involved in system development.*

eration of the material costs. A glance at the complex overall system reveals numerous aspects.

First of all, the measurement limits have to be specified. For an application in engine oil, currently a range of –40 to 150 °C is normally assumed. Some sensor manufacturers are already quoting maximum application temperatures of 160 °C. When approached, Bavarian engine designers put the trend as still rising, maybe up to about 180 °C. This means that in the near future a KTY (silicon) cannot be used as the sensor at this measuring point in new designs. This just leaves NTCs or Pt sensors in the discussion.

## Cost Savings with Platinum Technology

In the automotive field, the pressure of costs decides which materials and technologies are used. But due to the synergies of an integrated system development, the respective advantages and disadvantages must be reassessed in each case. Despite the use of platinum, HST's technology produces prices that compete very well against all other sensor technologies. In the last few years, millions of Pt sensors have already been supplied for oil temperature applications.

The scenario depicts sensors supplying constantly reliable measurements over the complete service life of the internal combustion engine, i.e. typically 5,000 – 10,000 operating hours for up to ten years. This means that they must operate almost free of drift even under oil-sump operating conditions with thousands of temperature cycles accompanied by severe vibration stresses, Figure 2.

Here of course, the proven long-term stability of platinum thin-film technology is impressive. But this irrefutable argument does not resolve the question of costs. At Heraeus this is resolved together with the customer. As Europe's market leader with an output of many tens of millions of platinum temperature sensors each year, there is a wealth of in-house experience available from the most varied customised models.

Just one example: different designs of engines and oil sumps mean that various geometrical shapes of oil condition sensors are necessary. In co-operation with customers, a customised modular system has been developed so that the Pt sensors to be supplied can be integrated into all the shapes

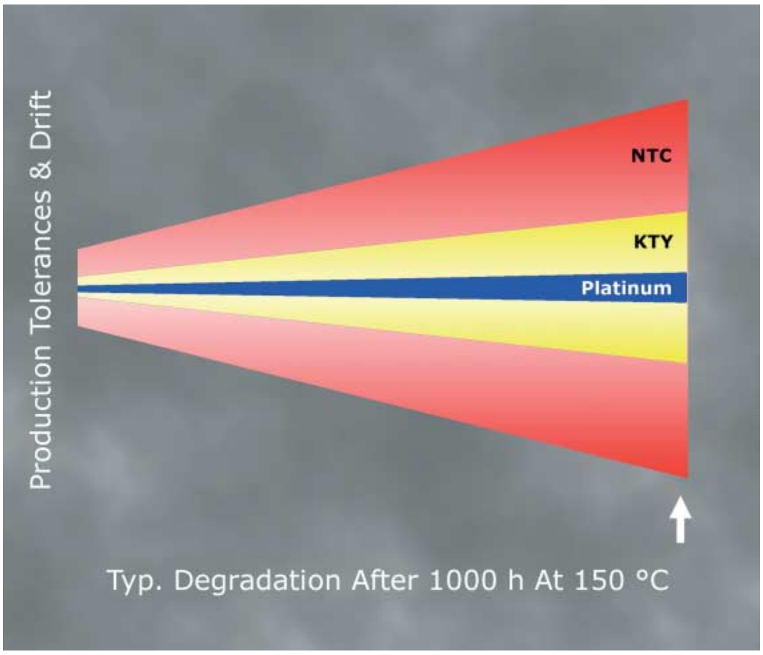


*Figure 2: Typical drift characteristic for different sensor materials. Also from other applications, platinum thin-film technology is well known for its long-term stability.*

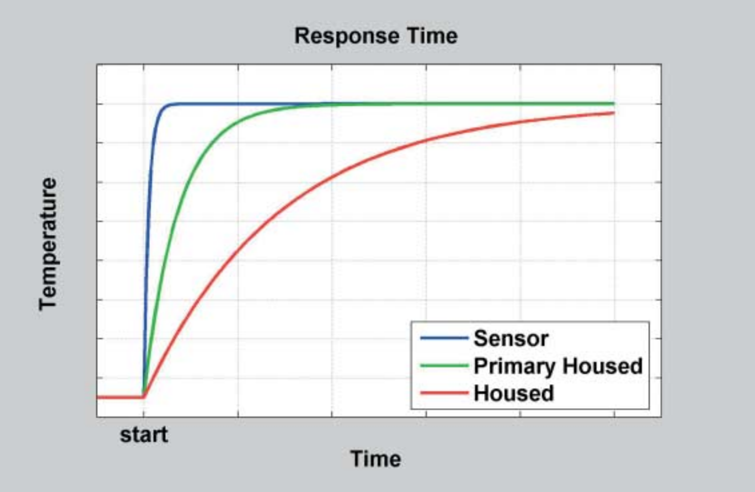


*Figure 3: Short reaction times are very dependent on the type of construction. Joining different materials that are frequently subjected to thermal shocks demands close co-operation in development.*

*Figure 4: Currently, the temperature sensor is still located within the housing. Before too long, the substrate will be in direct contact with the engine oil. The direct application of the temperature sensor remains a future objective.*

that arise despite different assembly (kit system).

The higher quantities of this special type lead to a significant cost reduction due to larger batches in production and during 100 % inspection. In addition, there are lower overhead and storage costs. In another development version, in which in particular the sensor integration into the overall mechanical system was optimised, an approximately 30 % reduction in the costs for the "measuring point – engine oil temperature" could be achieved.

## Cost Reduction in the Electronics

One of the important advantages of Pt sensors is their characteristic, which is standardised down to a tenth of a degree. The resulting benefit here is that the Asics in the following electronics of the overall oil-condition sensor system do not need to cope with any charge dependence in relation to the temperature sensor. Especially with NTCs, characteristic deviations may require the activation of various evaluation algorithms. With Pt sensors, due to the process used, even the production tolerance of the initial resistance has a magnitude of only ±0.1% – that is about one tenth of the values for selected NTCs. The standardised characteristic also ensures the interchangeability of Pt sensors – and not just for the individual sensors, but also for those from second-source suppliers.

A criticism of Pt sensors has often been the comparatively flat gradient in the characteristic. Since A/D converters with resolutions of 10-12 bits are nowadays available on the market for the same price as ones with 8 bit resolution a few years ago, this argument loses its validity. Additionally, appropriate A/D converters have to be provided anyway to achieve the system accuracy of the oil-condition sensor.

## Response Times Optimised

Due to the reduction in the quantity of oil, today's oils are subjected to much stronger thermal stressing. A sensor that can present the thermal stressing history as precisely as possible must be able to follow the oil temperature sufficiently quickly and without hysteresis. This response is decided by the thermal coupling between the platinum layer and the medium, Figure 3.

At present, sensors are still mounted in complete housings, which are optimised for the best flow. In some applications, measuring points are already being used as semi-open designs, i.e. half of the chip has contact with the medium, Figure 4.

But the next objective is already well in sight: applying Pt1000 sensors, where possible, directly in oil temperature measurement. In this way, the response time can be reduced at least by a factor of ten. To fulfil this objective, there are still many technological questions to be answered, in particular joining techniques with different combinations of materials, but the requirement of measuring rapid temperature changes has already been resolved with in-house expertise in various other applications.

## Outlook

At the Sensors Expo 2004, Donald Runkle, Vice Chairman of Delphi Corporation, declared during his keynote presentation in Detroit, Michigan (USA): "Our main quest is to help our customers take the vehicle out of the environmental equation." One thing is sure – the widespread use of inexpensive oil-condition sensors with precise temperature measurement will contribute to easing the environmental burden, because they reward careful drivers with lower operating costs and less frequent visits to the service station.