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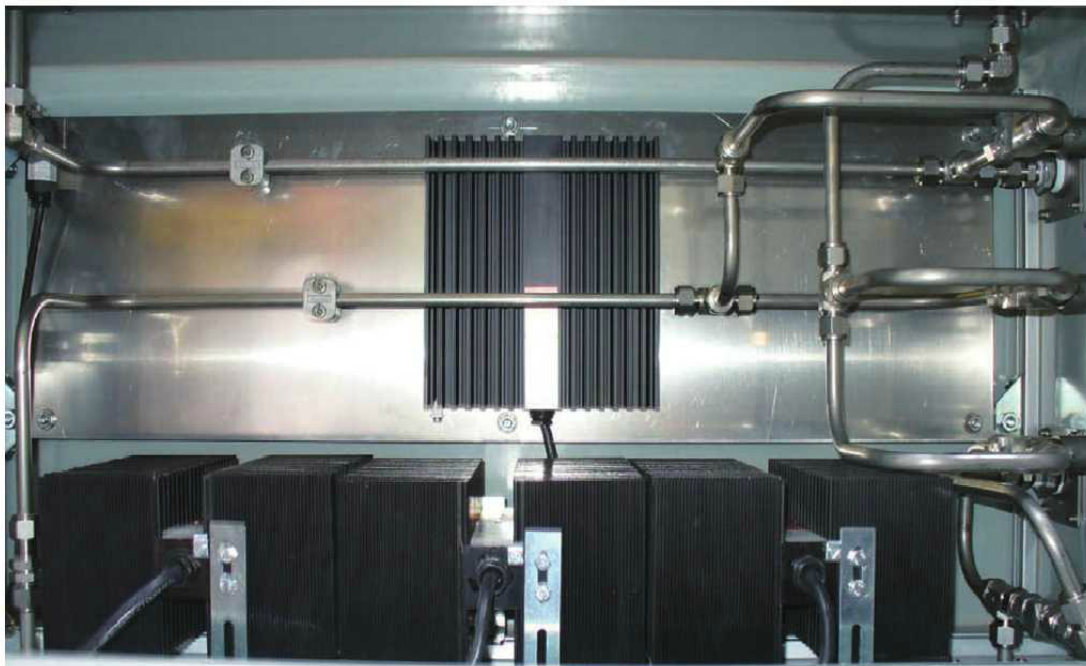
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“热箱”——在高温时机柜外表面的分析过程  
Hot Box' – outdoor cabinet for analytical processes at higher temperatures



## 在危险区域的高温加热 High temperature heating in hazardous areas

作者说明了为什么建议考虑并规定作为一个相关系统的加热元件和附件

The authors explain why it is advisable to consider and specify the enclosure and the heating element as an interrelated system

当

具体说明或建设造加热设备时，一个相关系统的加热元件提供了一个要考虑的关键因素的概况。

在化学和石化工厂中的仪器仪表，尤其是在取样条件系统下的分析仪器，为了预防介质冷凝或结晶，保持一个升高的温度经常是基本的条件。因为需要保养和校验，完全绝缘的计量方法和分析站几乎是不可能的。

一些使用者创造了特别的解决方案，在局部环境中通过一个风扇或空气压缩机加热，形成了一个“热空气浴”。这些是能量集中区域并且在危险区域很难建造（并且通常不适用于接近常温的要求）。

The elements of an interrelated system provide an overview of key points to consider when specifying or building heating equipment for process instrumentation.

For instrumentation in chemical and petrochemical plants, and especially in sample conditioning systems for analysers, the maintenance of an elevated temperature is often essential in order to prevent the condensation or crystallisation of media. Complete insulation of the measurement and analysis station is rarely possible due to the requirement for maintenance and calibration.



最优的解决方案是一个称作“热箱”，包括一个密封的设备，并且配备一个加热元件和控制器。然而为了建造最佳加热箱，设计时需要小心：选择和考虑作为一个相关系统的加热元件，而不是将分离的组件简易组装成箱子。

#### 危险区域的加热器

在化学和石化工厂内的大多数介质是爆炸物；consequently heaters must be certified for use in hazardous areas according to the standards and laws of the country. 因此用在危险区域的加热器必须根据国家的法律和标准认证。今天基于IEC 60 079规定的标准适用于世界上很多国家，并且已经发展为欧洲ATEX标准，EN 50 014 ft。

在美国或加拿大使用的加热器必须根据不同的NEC或CEC标准认证。许多非洲国家批准接受了IEC或ATEX标准。对于南非的矿山应用应用遵守IEC标准。进口设备的合格证必须由当地的测试机构重新认证。（根据新的ARP 0108协议，可以预测面上的设备，也必须从新认证。）

Some users create ad hoc solutions in the form of a 'hot air shower' where a fan (or compressed air) warms the local environment. These can be very energy intensive and can be difficult to build for hazardous areas (and are not usually suitable for applications demanding closely regulated temperatures).

The optimal solution is a so-called 'hot box' consisting of an enclosure for the equipment in question, fitted with a heating element and controller. For best results when building a hot box, care needs to be taken with the design: choosing and considering the elements as an inter-related system, rather than simply assembling the box from a collection of discrete components.

#### Heaters for hazardous areas

Most media in chemical and petrochemical plants are explosive; consequently, heaters must be certified for use in

在更高温度下运行的过滤和样品装置  
Filtration and Sample device, operated at higher temperatures





不管适用于什么标准，防爆加热器总是自相矛盾的：加热器必须加热到高温，但是他们可以不获得热量。表面温度没有超过温度等级。内部温度可以不超过材料的温度等级。

除了加热器的自我限制之外，在实际中加热器禁止在电力不足时应用——每个防爆加热器必须配备限温器，可以不用重新设置。

为了安全，在温度组别和限温器动作温度之间有一个差值，在加热器的最高温度和动作温度之间也必须有一个差值。

如果加热系统没有很好的控制，和/或设计不合适（例如，在太短的时间间隔内，电能太大——加热器温度和箱体内部的温度存在温度差），风险是加热器内部的限温器开关和加热器失灵，则必须更

hazardous areas according to the standards and laws of the country. Today, the rules that apply in most countries around the world are based on the IEC 60 079 standard, which has been developed from the European ATEX standard, EN 50 014 ft.

Heaters for use in the USA and Canada must be certified according to different standards: NEC or CEC. Most African countries accept IEC or ATEX approvals. South Africa follows IEC standards, for mining applications. The certificates of imported equipment have to be formally re-certified by a local testing house. (According to the new ARP 0108, it is anticipated that re-certification will be also necessary for above-surface applications)

Regardless of what standards apply, explosion proof heaters are something of a paradox: they must heat to high temperatures, but they may not get hot. Surface temperatures may not exceed the temperature class. Internal temperatures may not exceed the rated material temperatures.

With the exception of self-limiting heaters – which in practice are limited to low power applications – every explosion proof heater must be fitted with a temperature limiter that may not be reset.

For safety, there is a margin between the temperature class and the switching temperature of the limiter, and there has to be a margin between the peak maximum temperature of the heater and the switching temperature.

If the heating system is not controlled well and/or laid out appropriately (for example, too much power at too low ‘delta T’ – the difference between heater temperature and temperature inside the cabinet), there is a risk that the heater’s internal temperature limiter will switch and the heater fails and must be replaced. It used to be the case that fusible links were field-replaceable, but the new ATEX rules demand that units are sealed and maintainable only at the factory.

#### Physics involved

With any heating process, there is a constant flow of thermal energy from the heat source to the room that shall be heated, and from there to the ambient. In the steady state (constant temperature) flow rates are constant. The maximum temperature of the heater is determined by the temperature limit required, and the ambient temperature, which depends on the plant’s location.

The heater needs to be specified for the worst case (the minimum ambient temperature the plant will ever see). Thermal flow can be usefully considered as an electrical model, in a serial configuration with two temperature drops – with the heat output divided between them in the same way as a potentiometer divides a voltage. Equipment temperature (the temperature inside the enclosure) depends on the relation of:

- heat transfer resistance between the heating element and the equipment that has to be maintained at temperature



化工厂使用的“隔热箱”  
"Hot Box" in Chemical Plant



换。过去引起保险熔断在现场可更换，但是新的ATEX规定要求，保险设备需密封，并且仅在工厂能够维修。

#### 物理部分

在加热过程中，从加热源到应被加热空间，再从应被加热的空间到封闭的环境应有一个持续流动的热能。在恒稳态（稳定的温度）时流量稳定。加热器的最大温度是由温度极限要求和工厂位置的环境温度决定。

加热器需要准确确定最差的情况（工厂曾经遇见的最小环境温度）。有效的热流被认为作为电动模式，在一系列的结构中使用两个温度降——使用分离的热输出，在他们之间采用分压计分离电压的相同的方式。设备温度（内部封闭的温度）与以下有关：

发热元件和设备之间的热阻必须维持在相同温度（通常加热管和调节器等装置浸在加热介质内）。

- 设备和环境之间的热阻（封闭的设备周围的环境温度）。

(usually the tubing and devices such as regulators that contain the medium)

- heat transfer resistance between the equipment and the ambient (temperature of the air surrounding the enclosure)
- the heat transfer ratios are what matter. If the enclosure is well insulated (with no large heat losses) then the heater output needs only to be in a certain power range to make precise temperature control easy. Over-specifying the heater power can cause problems.

#### Enclosure insulation quality

Achieving a stable and well-managed thermal environment depends on a well-insulated enclosure with no large heat losses. The usual way of achieving this is to improve the insulation by adding a thick layer of material such as PUR foam ( $\lambda = 0,02 - 0,05 \text{ W/m}^2\text{K}$ ).

But the better the insulation of the walls, the more important the effect of any heat sinks.

When designing a hot box, the construction materials and processes of an enclosure become very important. Steel enclosures (galvanized or stainless) ( $\lambda = 15 - 50 \text{ W/m}^2\text{K}$ ) are made of materials with high thermal conductivity (up to 250 times higher than that of glass-reinforced polyester or GRP for example;  $\lambda = 0,2 \text{ W/m}^2\text{K}$  – of which more later). Any metal connection between outer and inner shell provides a thermal shortcut. And with metal constructions, it is almost impossible to avoid metal parts in some designs because the stability of this type of housing is based on bent sheet metal, and insulation materials are typically soft.

An interesting solution to manufacturing enclosures without thermal sinks is a sandwich construction housing based on glass-reinforced polyester (GRP) sheeting, surrounding an inner layer of insulation. The use of long fibre reinforced GRP sheeting provides great structural strength, combined with high resistance to weather and the corrosive effects of aggressive chemicals. All the construction materials have a low thermal conductivity, and the sandwich construction means that enclosures can be made using bonding techniques, avoiding heat short cuts between inside and outside shells. The overall thermal insulation of GRP sandwich shelter is typically more than twice as good as a steel shelter with the same insulation thickness.

#### Choice of heating technique

Heat transfer efficiency from the heater to the equipment should be as good as possible. The choices available are conduction, convection or a combination.

Conduction is a very effective heat transfer method. As air surrounds the equipment inside the enclosure, it acts as a good insulator. As a rule of thumb, conduction is roughly five

## 温控器一般地作为一个低温的温度控制机构

● 热传导率是重要的。如果热浴箱被良好的绝缘(没有大的热量损失),那么加热器输出的热量仅仅在一定的范围内,容易实现精确的温度控制。超过规定的加热器功率可产生问题。

### 封闭包裹设备的绝热品质

实现一个稳定、良好的热控制环境依靠一个良好的绝热封闭,没有大量的热损失。通常实现这种方式是通过增加像聚氨酯发泡层的厚度,来提高绝热( $\lambda=0.02-0.05\text{W/m}^2\text{K}$ )。

较好的绝热壁,比散热器的作用更重要。

当设计一个封闭过程时,建造材料和封闭的过程很重要。铜外壳(镀锌或不锈钢)( $\lambda=15-50\text{W/m}^2\text{K}$ )制造材料具有较高的热传导率(比玻璃纤维增强聚酯或玻璃钢 的250倍高,例如: $\lambda=0.2\text{W/m}^2\text{K}$ 更

times as effective as convection, so conduction is usually the preferred method if it is possible to use it.

Conduction heaters have a flat surface for good heat transfer. Therefore, the equipment to which they are fastened must have good flat surfaces for proper heat transfer. Other equipment gets its heat by conduction through the fittings and tubing. In conduction heating, the block heater is attached to the rear of the substrate; the controller is at the bottom of the cabinet.

When positioning the conduction heating element, it is very important to get most heat to the equipment in the cabinet that acts as a heat sink, such as a regulator (which acts as a constant heat sink due to Guy-Lussac's law, because of the pressure drop in flowing media). For the effective heating of gas cylinders, special conduction heaters with a cylindrical surface, called Cylindertherm, are available.

Often, the equipment that has to be heated has no flat surface, and is not suitable for conduction heating. Another problem can arise when a cabinet contains numerous items of

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### 详细情况,请联系:

梁涛 Tao Luan

德国英特泰克公司上海代表处

地址:上海市西康路1068号维多利亚广场B座7E

邮编:200060

电话:+86 21 62994453

传真:+86 21 62994452

手机:+86 13918455059

E-mail: Tao.Luan@intertec.info

intertec\_china@163.com

www.intertec.info www.intertec-china.com.cn

