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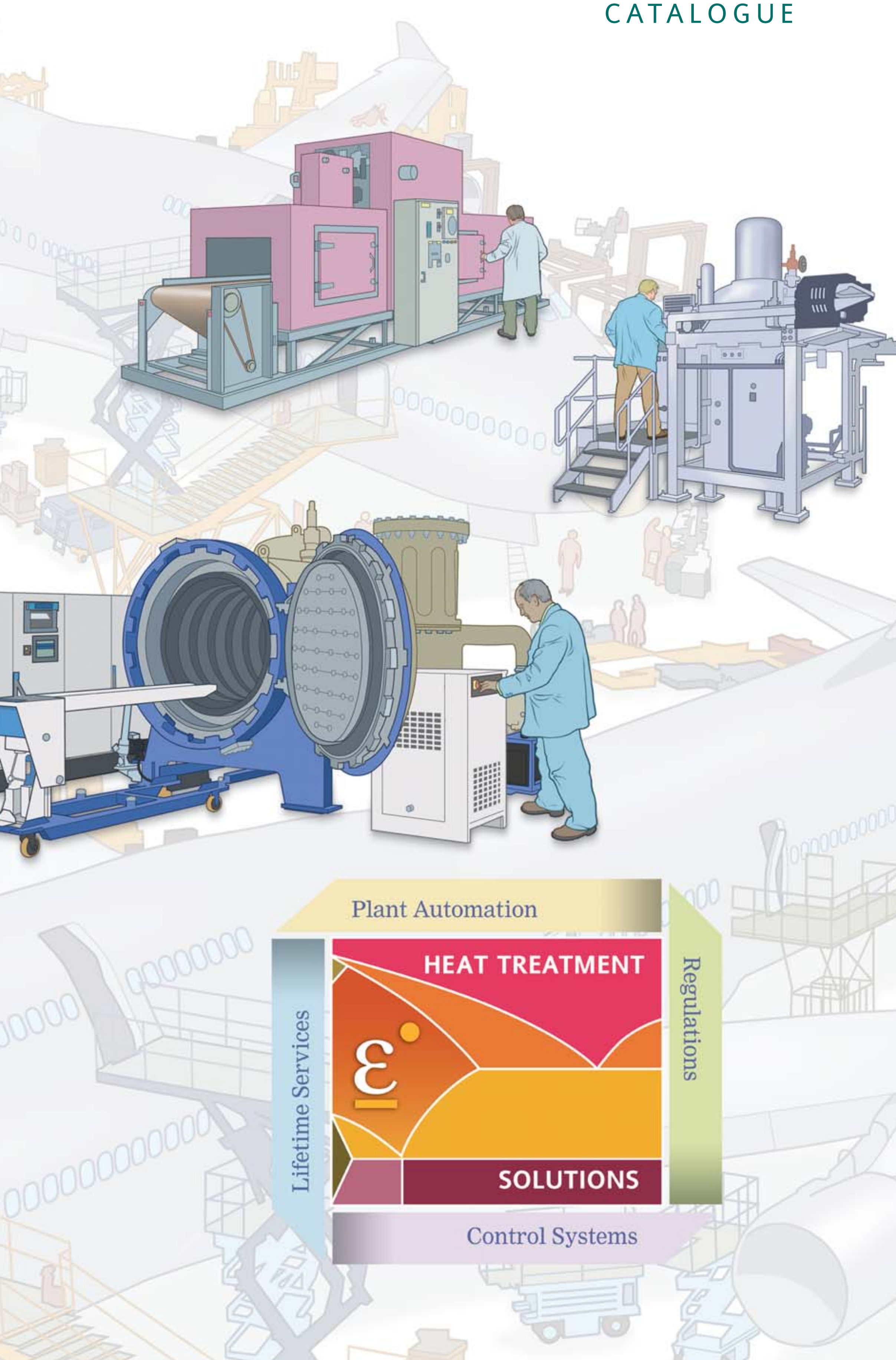
Heat Treatment

CATALOGUE



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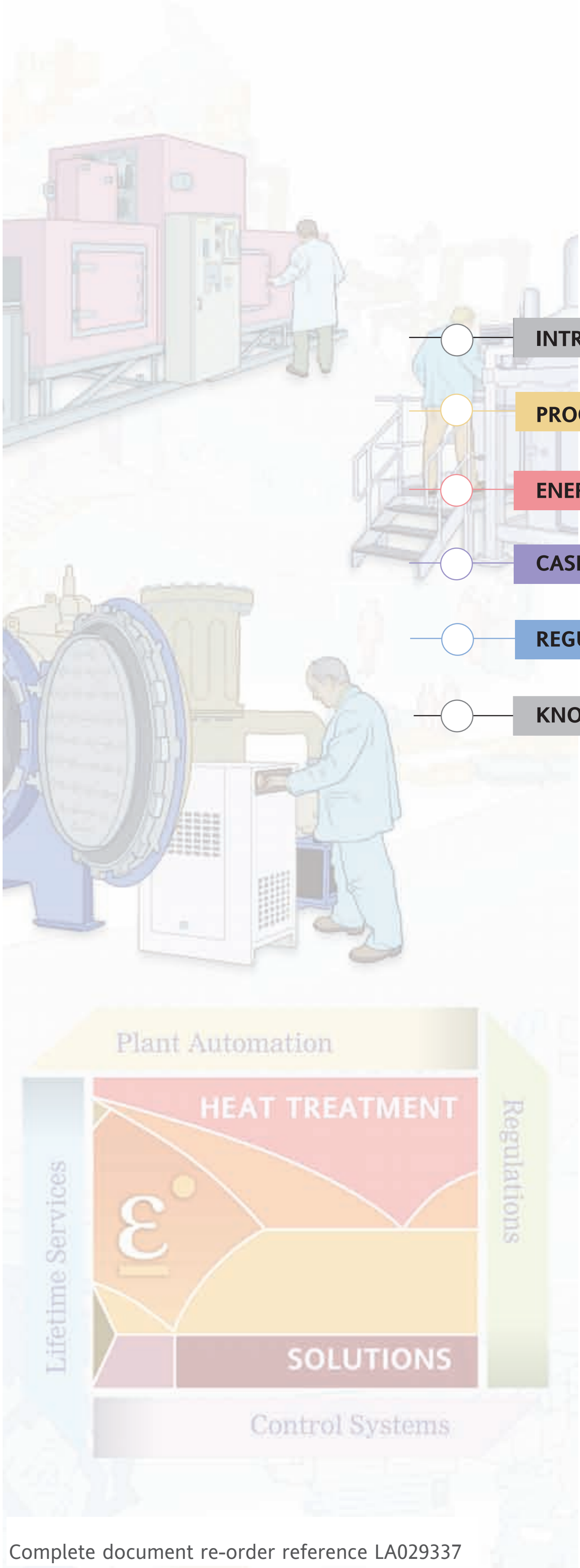
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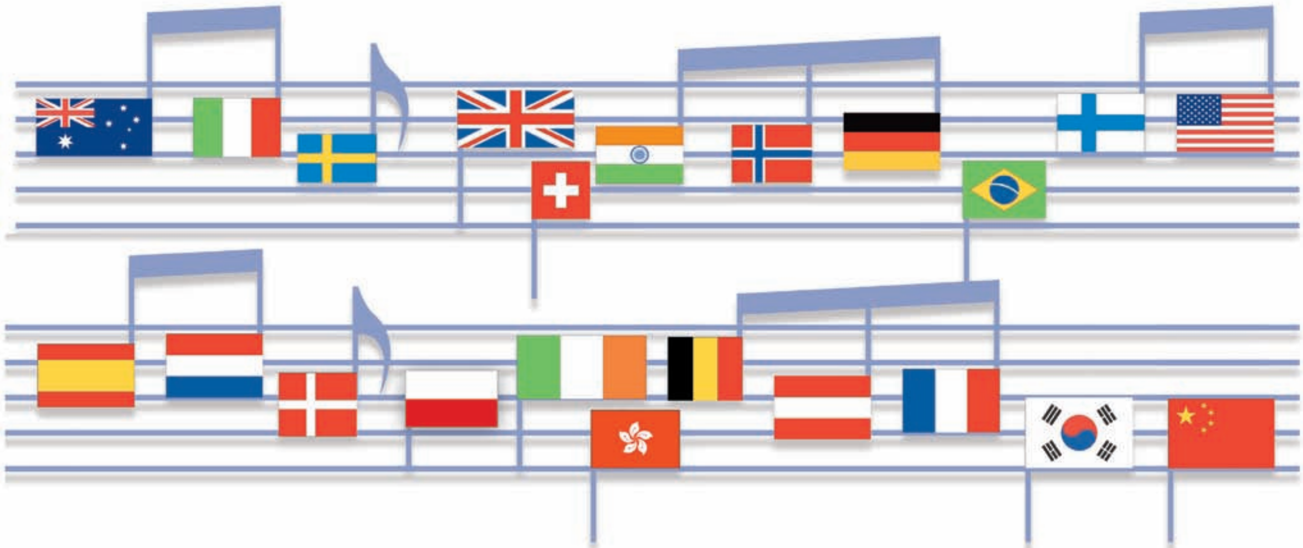

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ED53

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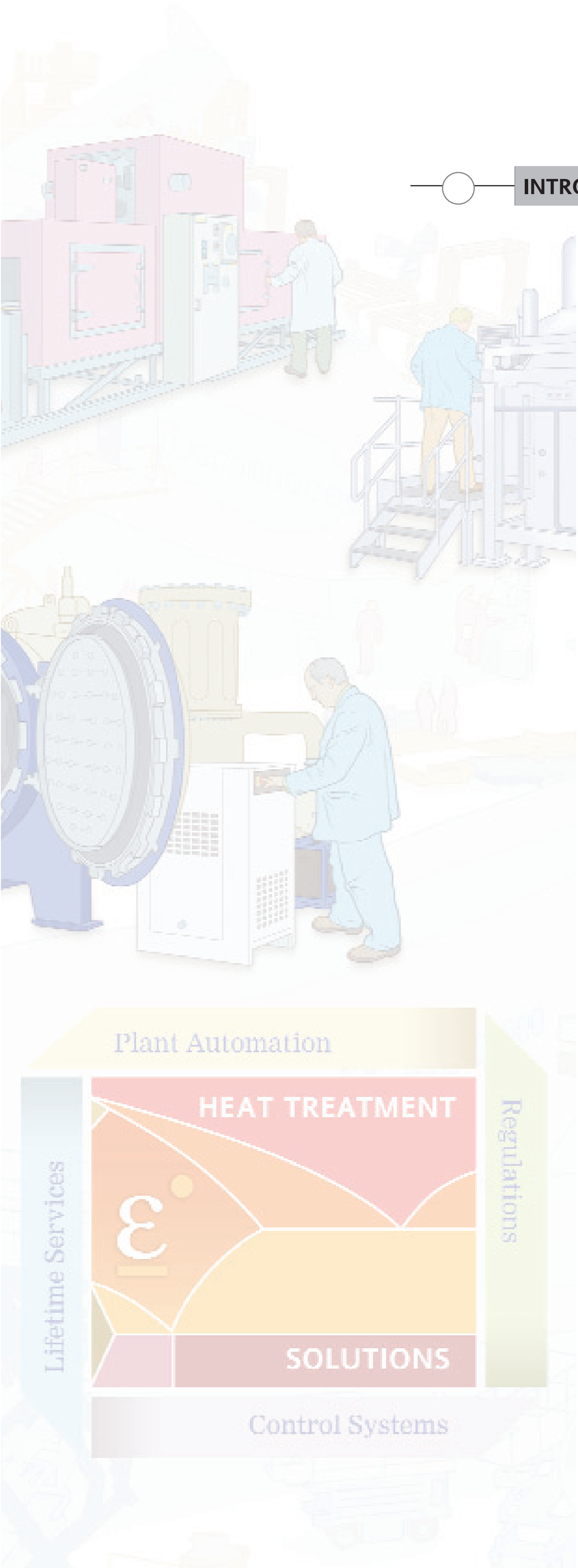


INTRODUCTION

- Eurotherm® Heat Treatment Executive Summary
- An Introduction to the Heat Treatment of Metallic Alloys

Eurotherm® Heat Treatment Executive Summary

Leading the way in Innovation and Solutions

Eurotherm®, part of the Invensys group of companies, are a global supplier of automation and process control systems and products to the process and manufacturing industries, of which the Heat Treatment and Metals market represents a major part of our supply.

By combining automation and process control knowledge with validation expertise and world class specialist products, Eurotherm are able to offer an extensive range of the most cost effective Heat Treatment solutions. Eurotherm is committed to developing products and services specifically for the Heat Treatment industry to enable the continual reduction of costs, while maximising productivity.

- **Serving the diverse demands of heat treatment applications**

  Eurotherm is recognised for its expertise in working with both end users and process equipment suppliers to produce advanced solution systems.

- **A successful history in supplying scalable automation solutions**

  Eurotherm has over 40 years of history in providing scalable system solutions to a large and expanding customer base. Our solutions are designed to meet the business needs of our customers by applying wide ranging control systems knowledge to the critical factors identified by our customers that will help to ensure that they remain successful and competitive in a demanding manufacturing world.

Increase process efficiency

Helping to improve customers cost of production through:

- Optimising the process and equipment usage
- Optimising energy usage
- Reducing waste through increased accuracy of control and specialist control algorithms
- Curtailing rework and reducing scrap by improving consistency and repeatability
- Increasing plant availability using Eurotherm's plant proven reliable control systems
- Reducing and eliminating paper trails by utilising the extensive data management, archive and reporting facilities
- Enhancing personnel productivity with a structured view of plant operation and training

Reduce cost of ownership

Eurotherm's control systems are designed to provide the best value for our customers by reducing plant downtime and maintenance costs, by:

- Ensuring increased equipment availability through the use of products with high MTBF, redundant control strategies, online re-configuration and hardware 'Hot Swap' capability.
- Utilising up-to-date proven technology designed to international standards with the future firmly in focus
- Offering total life cycle support including commissioning, training and on-site support service
- Phased migration from legacy systems

Improve product quality

Achieve marketplace leadership through quality and customer satisfaction by:

- Decreasing the risk of human errors with secure recipe management systems and advanced control strategies
- Improved, more demanding, quality tolerances by application of process diagnostics and process modelling
- Out-of-specification product identification, with automatic alerts
- Improved information flow with seamless integration to business systems

Providing vertical integration

At Eurotherm we understand that our control systems form an important part of our customers demand for overall business efficiency. Systems are designed to include, or be part of, the integration of the shop floor automation and the business scheduling systems to provide access to:

- Information transfer systems via relational databases and secure historic data files
- Business systems with Enterprise Resource Planning systems, such as SAP
- Manufacturing planning systems (MRP, MRP2)

Meeting legislation and regulatory requirement

Eurotherm recognise the importance of legislation and accreditation in Heat Treatment.
Our control systems are designed to facilitate regulatory compliance at all levels of the solution, by:

- Working within the audited environment of Nadcap, TS16949 and other industry specifications
- Comprehensive secure data management solutions that assist customers' needs for long-term traceable provenance of their products
- Eliminating guesswork and making more accurate and timely decisions to improve safety
- Providing tighter control to lower emissions and provide cleaner effluent

At any one time Eurotherm are pleased to be involved with over 3700 heat treatment original equipment suppliers and end user customers from across the world.
Some of our major end user heat treatment customers include:

Snecma – Bodycote – Peugeot Citroen – Dassault Aviation – EADS – Aalberts Group - Federal Mogul – Vallourec Mannesman – Timken – Delphi Group – Renault – Ferry Capitain - Rolls-Royce – PCC Group- Wyman Gordon – Special Metals – Aermacchi – American Axle – Agusta – Howmet – Hexcel Composites – Bombardier Aerospace – Alcan Rolled Products – Outo Kumpu – Saab - Volvo Aerospace – Sandvyk - Kanthal – Corus – Timet – Alcoa – Boeing – Denso Manufacturing – ILVA Spa - Forgital – Airbus Industries - Eurocopter – British Aerospace – Arcelor

World-wide presence

Operating through Eurotherm companies, authorised agents and channel partners across the world guarantees customer access to local expertise backed up by global specialists.

Regional systems engineering centres in strategic locations operate advanced engineering methodologies to provide high quality, reliable systems solutions on time and within budget.

Above all, at Eurotherm we believe in understanding and solving our clients needs through personal contact and individual commitment. This blend of capabilities within a global organisation creates an unmatched opportunity of success for our customers.

An Introduction to the Heat Treatment of Metallic Alloys

Heat treatment can be defined as a combination of heating and cooling operations applied to a metal or alloy in its solid state to obtain desired conditions or properties.

Heat treatments can be used to homogenise cast metal alloys to improve their hot workability, to soften metals prior to, and during hot and cold processing operations, or to alter their microstructure in such a way as to achieve the desired mechanical properties.

Thermal treatments of metallic alloys are also used to alter the surface chemistry of a material. This is achieved by diffusing Carbon, Nitrogen and other gaseous or solid material in to the surface of the component. These processes are used to give defined surface hardness and to improve wear, corrosion and fatigue resistance.

The parameters and processes that can effect the composition and material properties of metal components include the following:

Alloy type - Heating - Cooling - Work input - Time - Atmosphere - Surface plating - Surface diffusion

To ensure that any metal component is suitable and adequate for the designed purpose, it may need to be exposed to a selected range of conditioning and finishing treatments. The treatments are conducted in such a way so as to ensure that the required combination of these parameters are carefully controlled to achieve the desired finished component.

The heat treatment of metals involves raising the temperature of an alloy, often through a prescribed thermal profile, to a defined temperature. The material is then held at this temperature for a period of time before being cooled either at a prescribed rate or under rapid quenching conditions to a fixed temperature.

Treatments are carried out in furnaces and ovens where, in addition to the changes in temperature, gases are used to control the atmosphere for the process. Controlled atmospheres are either used to reduce the effects of oxidisation or to provide an enriching atmosphere for surface chemistry effects, on the component being treated.

Heat Treatments are classified by their purpose:

General treatments

- **Homogenisation**

  This treatment is used prior to hot working processes and is performed to equalise temperatures throughout an alloy or to reduce the coring effect caused by the non-uniform chemical composition.
- **Annealing**

  Annealing covers a variety of heat treatment processes used to soften alloys and increase their ductility as an aid to cold working.
- **Normalising Stress Relieving**

  Thermal treatments performed to remove internal stresses within components following welding, casting or rapid cooling.

Treatments which change the phase structure of an alloy

- **Hardening**

  Metallic alloys can all be work hardened but specifically steel-alloys can also be hardened through heat treatment.

  The harden-ability of a steel-alloy is dependent on its carbon or other alloys content. The higher percentage carbon alloys can achieve a greater degree of hardness.

  The hardening process is achieved by heating an alloy to a predefined temperature and then quenching in oil, water, air or a special polymer quenchant. The temperature and quenching parameters are dependent on the type of steel being processed.

- **Tempering**

  Tempering usually follows the hardening process and is used to remove much of the brittleness of the alloy while retaining the components hardness.

  To understand how successful these processes may be and the temperatures at which the treatments should be performed, it is necessary to study the phase diagram of the particular alloy.

- **Induction hardening**

  Rapidly heating using an induction coil immediately followed by quenching in a quench jet can also harden medium and high carbon steels. This process can also be carried out using alternative hot flame impingement or laser technology heating techniques.

Treatments which alter the surface chemistry of an alloy

- **Carburising, nitriding, carbontriding and nitrocarburising**

  In these processes the surface layers of the alloy are both hardened and strengthened by exposing the component to an enriched gaseous atmosphere of species carbon or nitrogen while the material is subjected to an elevated thermal profile prior to quenching. Similar component properties can be achieved using other surface molecular components with processes such as Ion Implantation – Chemical Vapour Deposition (CVD), Physical Vapour Deposition (PVD), Boriding and Aluminising.

Other specialist processes

- **Hot Iso Static processing (HIP ping)**

  This process is used for the densification of castings and pre-sintered components as well as in the diffusion bonding of alloys. The process usually uses very high temperatures and pressures within a specially designed vessel.

- **Sintering**

  Many products with complex cross sectional forms are manufactured from powdered, core material, which is pressed or moulded into the component shape. Sintering takes place in an atmosphere controlled environment and is used to strengthen the bonding of powder compacted components over a timed temperature process cycle.

Thermal Processing Equipment

Thermal processing equipment used to provide heat treatment falls into a number of classifications depending upon the scope of production and the nature of the business. The three general equipment classifications are: batch, semi-continuous or continuous.

While the science behind heat treatment remains principally the same whatever equipment type is used, certain advantages can be achieved from particular oven and furnace types. As an example it is possible to carry out the annealing process in air furnaces, vacuum furnaces, and gas purged retort furnaces, amongst others. Similarly the surface chemistry process of carburising can be carried out in a range of equipment types including batch and continuous atmosphere controlled furnaces, pusher furnaces, or vacuum furnaces.

The range of furnace types is extremely diverse. So, if the furnace equipment type does not define the process, why should there be so many different options for users to choose from?

Other issues that influence the choice of processing equipment include:

- Captive shops: These are in-house processes usually carrying out work of a similar nature where continuous processes and large-scale batch processes can be most economically employed.
- Commercial shops: Usually carry out a variety of work for external customers where batch production allows the flexibility required to meet the demands of a wide number of processes.
- The desire to achieve the final finished product compliance without the need for further processing.
- Physical size of the component.
- Mixed batch production.
- Reduced surface oxidation.
- Final surface finish for wear, corrosion and fatigue resistance.
- Reduced component deformation.

For example:
Automotive gears have been hardened and tempered for many years in standard gas carburising and draw furnaces. Recent advances in Low Pressure Carburising for these components in a vacuum furnace have brought advantages to production cycle integration and component quality.

Aircraft components can equally be annealed in gas purged retort furnaces or in vacuum furnaces. The distinction often lies in the stage of the process, with annealing of raw or core material being carried out under controlled atmospheres, while finished components are processed in vacuum where there is a much greater need to maintain control of components shape, dimension and surface finish as well the material properties.

The following gives typical examples of furnace types, but this is by no means an exhaustive list

Integral Quench Furnaces
Roller Hearth Furnaces
Rotary Hearth Furnaces
Atmosphere Furnaces - Carburising
Atmosphere Furnaces - General
Laboratory Furnaces
Shaker Hearth Furnaces
Lead Baths and Salt Baths
Batch Air Furnaces - General
Tempering or Draw Furnaces
Slot Forge
Bell - Top Hat Furnaces
Mesh Belt Furnaces

Soaking Pits & Pit Furnaces
Billet Furnace
Drop Bottom
Muffle Furnaces
Bogie Hearth Furnaces
Drum Rotating
Box Furnace
Dryers
Tip Up or Tilt Furnaces
Brazing Furnaces
Electric Resistance Furnace
Tool Room Furnaces
Brazing Atmosphere Furnaces

Elevator Hearth
Oil Fired Furnaces
Tube Furnaces
Burn Off Oven
Fluidised Bed Furnaces
Ovens General
Car Bottom Furnace
Forging
Pot Furnaces
Gantry Furnace
Plating & Galvanising Lines
Vacuum Furnaces
Continuous Bright Annealing Furnace

Gas Fired General Purpose Furnaces
Pusher Furnaces
Conveyor Furnace
Radiant Tube Furnaces
Creep Test Furnace
Sealed Quench Furnaces
Cryogenic Vessels
Recuperative Furnaces
Walking Beam Furnaces
Diffusion Furnaces
Retort Furnaces
Walking Hearth Furnaces

The following gives typical examples of process types, but this is by no means an exhaustive list:

Aluminium Solution Treating
CarboNitriding
Annealing
Nitro-Carburising
Aluminising
Hot Isostatic Pressing
Tempering
Quenching
Austempering
Plasma ION Nitriding
Sintering
Martempering/Marquenching
Local Heat Treatment
Solution Annealing
Neutral Hardening
Strip Annealing
Nitriding General
Precipitation Hardening
Vacuum Brazing
Vacuum Carburising
Carburising
Vacuum Furnaces
Gas Nitriding
Vacuum High Pressure Gas Quench
Flame Hardening
Homogenisation
Gas Quench
Vacuum Low Pressure Carburising
Diffusion Bonding
Gas Quench High Pressure
Reheating
Harden/Quench and Draw Temper

Control Systems for Heat Treatment Processes

Since heat treatment can be carried out in a wide variety of furnace or oven types operating in either the Batch or Continuous mode, it is necessary to have a very diverse approach to control system design.

The important elements for design are:

Furnace sequence control

Whether furnaces are of the batch or continuous design, there is often an element of sequential control to be provided by the control system. Very often this is a secondary consideration to the process parameter control. For convenience, the sequencing can often be incorporated into the process controller itself.

The range of furnace dependent issues that will influence the sequence control requirement:

- Work piece transfer
- Furnace door actions
- Furnace hearth or hood movement
- Furnace transfer mechanisms
- Quench transfer
- Gas/Fan quench control
- Heat shield door actions
- Cooling water control

Temperature control and thermal profiling

Accurate and repeatable temperature control is at the heart of most heat treatment processes. It is important that special measures are taken to control the process to the metallurgical requirements of the component. This requires accurate control for both the programming setpoints and the steady state temperature control over a wide range of temperature setpoints and furnace loadings.

To ensure repeatable and consistent performance across the widest range of furnace use, Eurotherm® build into their control solutions special routines for gain scheduling, overshoot inhibition and ramp/dwell transitions. Control structures must also be incorporated to ensure that temperature control complies with the metallurgical requirements of the work piece and where necessary the control system should be designed to accommodate separate work-piece thermocouples.

Furnace testing and audits

Most thermal processing equipment is audited to ensure that parts are processed in accordance with the applicable specification.

To achieve maximum furnace loadings and equipment utilisation, temperatures in a defined workload region must be within given tolerance and Temperature Uniformity Surveys (TUS) are often carried out to determine the degree of compliance.

Furnaces are grouped into different classes depending on the degree of (TUS) tolerance and workload treatments can be defined to be undertaken in furnaces of a particular accredited class.

Heat treatment furnaces are also controlled by a range of System Accuracy Tests (SATs), which define the type and accuracy requirements for control instrumentation and sensors.

It is important that consideration is given to the needs of required SAT and TUS compliance when designing control systems to meet the users furnace class and processing requirement.

In many processes where there is considerable time delay between the process and the furnace, (such as a retort furnace or during low temperatures regions on vacuum furnaces), it may be required to control the furnace from 'work-piece' sensors. Having strategies for Cascade or Override control and being able to implement effective routines for guaranteed soak times and holdback on thermal profiles are a necessary requirement of the control system design in these applications.

The thermal profiling requirement is defined by the metallurgical process and is very often determined through the use of 'controlled' recipes systems. It is important that an easy secure method is available that enables users and operators to set-up and run repeatable recipes, without the fear of unauthorised changes.

Gas atmosphere control

Since many heat treatment and surface chemistry processes rely on being performed in a gaseous atmosphere, it is important to include provision for this in the control system. It may be as simple as including timed or temperature driven events within the profile when gasses like Nitrogen, Argon and Hydrogen are required. Traditionally the control system does not provide feedback control on the atmosphere for these type of processes; typically only providing the capability to set fixed gas flow rates at defined parts of the cycle via simple On/Off flow or more complex, self contained, mass flow control devices.

With the advent of new low cost analysers and the growing application of zirconia probes, more users are using analysis equipment to ensure their processes are maintaining the desired levels of oxidising reduction.

Since many of the gasses are volatile, special care needs to be taken with control system design to ensure that the sequence and safety of gasses is maintained.

For many of the surface treatments it is also necessary to control the flow of enrichment gas or dilution air into the furnace against a defined setpoint for a defined period. Enrichment gases are used to provide the gaseous atmospheres for processes such as Carburising and Nitriding. In these cases feedback control is used, and special algorithms are required to convert the output from zirconia probes into application specific functions.

The purpose for controlling the atmosphere in these applications is to gain a specific surface hardness and finish by diffusing nascent gas particles into the surface of the component. Various algorithms have been employed to determine the diffusion rate rather than applying fixed time/temperature/atmosphere profiles. Much of the new OEM equipment makes use of these diffusion calculations, while the majority of the installed base relies on simple carbon potential profiling. For example: Using 3 gas Infrared analysis to aid the carburising processes adds a high degree of additional confidence to the conventional carbon potential control.

Vacuum atmosphere control

Vacuum furnaces are widely used in heat treatment, particularly in the Aerospace and Automotive industries. Almost all conventional heat treatment cycles can be carried out in a vacuum, such as: homogenisation, stress relieving, normalising, hardening, tempering, and annealing. Vacuum furnaces are also used for brazing and out gassing of material and are becoming more widely used for low-pressure carburising.

Chambers typically operate in the atmospheric range from ambient atmosphere down to 10-9 millibars. Control systems need to accommodate the interface between complex vacuum gauges and the process sequence, taking particular account of:

- Pump start up and the pumping sequencing
- Vacuum pumping efficiency and chamber leak rate
- Partial pressure control and back fill control
- Vacuum out gassing and heater interlocks

Quenching systems

One of the most important aspects of heat treatment is the quench process. Many of the phase structure changes that occur in the treatment of alloys do so during quenching.

Once a component has been held for a desired period of time at the temperature required to effect the correct crystalline structure it must be quenched in air, oil, water or special polymer. Control systems need to accommodate the rapid transition from temperature control to quenching, since the rate of change of temperature during cooling greatly determines the micro grain structure of the component.

For example:
A component which consists of a 0.6% carbon steel, that has been heat treated above the Upper Critical Temperature to achieve a micro-grain structure consisting of Austenite, will convert to a material suitable for rework when air cooled in an annealing process (Pearlite with Ferrite). When satisfactorily rapidly quenched in oil the same component will harden by a different conversion of the micro-structure to Martensite, The component can be further processed in the tempering process to remove much of the brittleness. Variations in the quench process provide a range of material properties.

Industry regulations

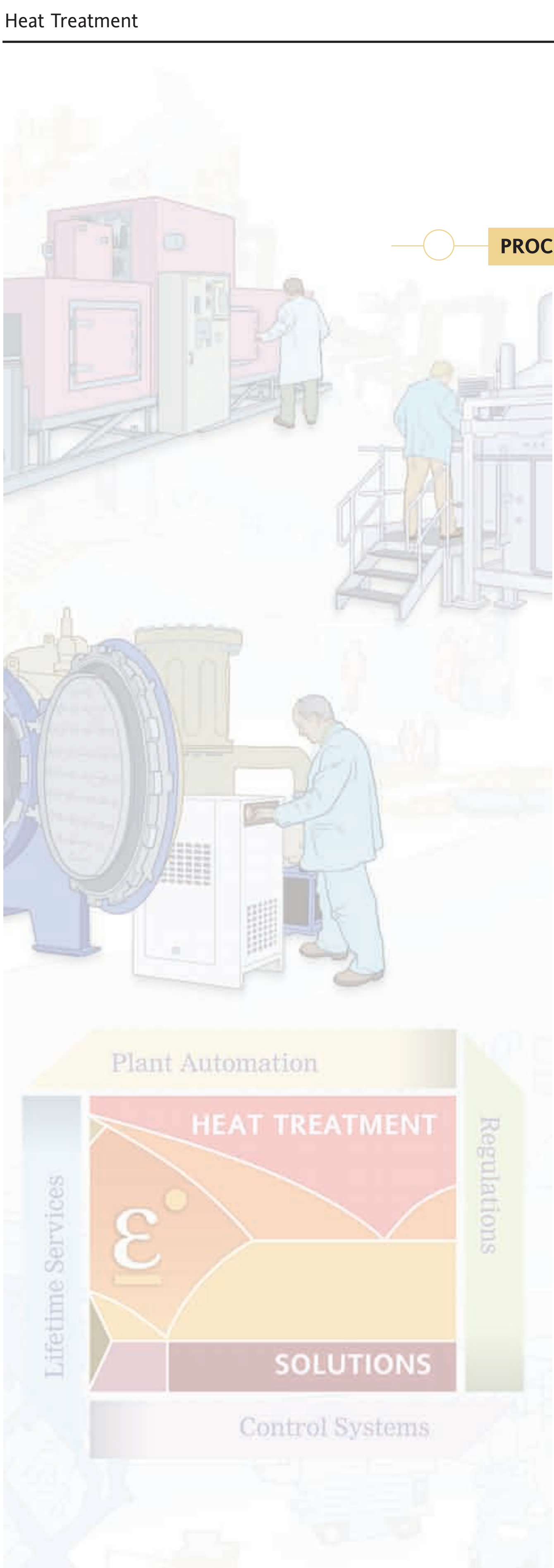
Much of the heat treatment sector is regulated either by prescriptive specifications or by the demands of industrial quality procedures. Demands are made of treatment providers to show that the processes they adopt stand up to scrutiny under some type of audited environment. The audited environments tend to be industry specific with both global and regional variations.

The automotive industry have widely adopted the (Automotive Industry Action Group) recommendations contained in CQI-9 which refers to the SAE Pyrometry guide for heat treatment AMS2750D. Alternatively they rely on quality systems contained in TS16949. where the specification is based on business quality procedures and individual quality manuals, which show how process compliance is achieved and maintained.

The aerospace industry have widely adopted the more prescriptive methods of accreditation which are covered in the Nadcap global specification with sections 7102 and the associated AMS2750D specifically applying to heat treatment.

Data management

As part of the need to comply with industry regulations there is a demand on heat treatment suppliers to record and retain process information. The control system usually includes recording equipment, which enables data to be conveniently displayed, archived, saved and recalled. Specific rules are laid down in the prescriptive specifications or in quality manuals, which advise on the procedure for data management. Additionally, records must be maintained regarding the accredited status of the process plant detailing data on instrument calibration, information about process sensors and reports of temperature uniformity surveys. Recent trends towards digital data management have enabled Eurotherm to build solutions which encompass all these data management needs in a suite of complimentary products that meet the needs of both the process and analysis.



PROCESSES

- Vacuum Furnaces

  Processes
  The Vacuum Furnace Process
  Dual Sensor Vacuum Furnace Control
  High Temperature Vacuum Furnace

  Product
  2704 Vacuum Control

- Gas Carburising Furnaces

  Continuous Gas and Batch Carburising Furnace

  Processes
  Carburising Gas Reactions

  Products
  3500 Atmosphere Furnace Control
  2704 Atmosphere Furnace Control

- Materials Testing Furnaces

  Processes
  Creep Testing Furnace

- Metals

  Eurotherm® in the Raw Materials Metals Industry

  Processes
  Modulating Burner Combustion Control
  for Heat Treatment Furnaces
  Sinter Plant
  Blast Furnace and Stoves
  Blast Furnaces Gas Flare
  Steel making/BOS Plant
  Soaking Pit
  Continuous Annealing and Galvanising Lines
  Single and Multi-stack Batch Annealing

Heat Treatment

INDUSTRY

- **Homogenisation**
- **Stress relieving**
- **Normalising**
- **Hardening**
- **Tempering**
- **Annealing**
- **Brazing**
- **Out-gassing**
- **Low pressure carburising**

The Vacuum Furnace Process

Application Note

Vacuum furnaces are widely used in heat treatment processes, and vary widely in capacity and size.

Equipment has consistently been improved over the last 30 years such that vacuum processing has become a widely used application in the Aerospace and Automotive Industry.

Vacuum is considered to be any pressure which is below atmospheric pressure and in industrial applications may be expressed as torr, microns or millibars.

Typical ranges for furnaces

Vacuum Range	mBar
Atmospheric (ambient)	10E+3
Rough to medium vacuum	10E+3 to 10E-3
High vacuum	10E-3 to <10E-7

Vacuum effects

The effects of treating components in a vacuum are two fold:

1. In the medium-high vacuum region the partial pressure of the residual air in the furnace particularly O_2-H_2O is significantly reduced and will provide an environment to process components with little or no surface oxidation.

   The reduction of residual Nitrogen (N_2) is also beneficial for materials, which would otherwise form nitrides.

2. Decomposition of existing oxides in the surface of components may occur depending on the temperature and material type.

Mechanical equipment

Vacuum furnaces take many different mechanical formats, designs include common components, such as;

- Work piece chamber or multiple chambers usually with water-cooled jacket, loading and transfer mechanism
- Heat shields made of graphite board or high temperature material
- Furnace furniture constructed of graphite or other high temperature material
- Heating element often Graphite or alternatively Molybdenum or high temperature material for temperatures above 1000°C
- Vacuum pumping system
- Partial pressure control
- Optional fan assisted circulation systems for annealing processes
- Quenching vessels and/or gas/fan quenching system
- Cooling system
- Control system

The cellular concept of vacuum processing is becoming more widespread with multi-cell layouts used to integrate heat treatment into shop floor production and manufacturing.

A typical simple single chamber vessel furnace is shown in figure 1.

Application note

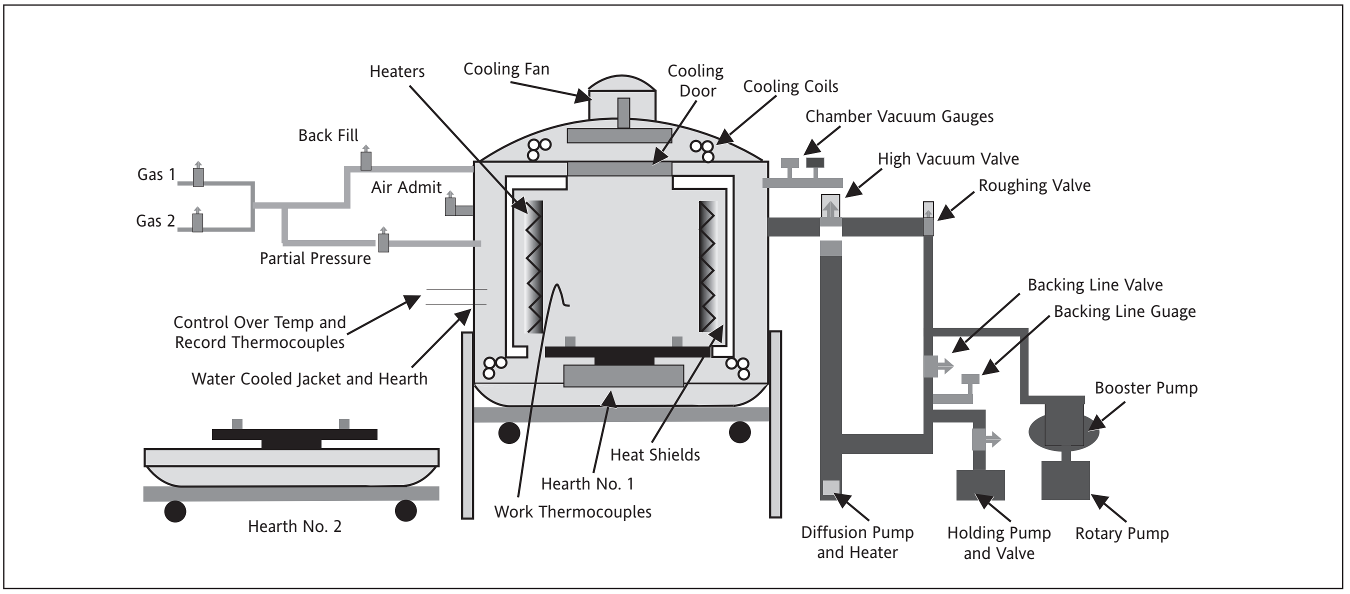


Figure 1 Typical single chamber bottom loading vacuum furnace

Control system

Each part of the process cycle calls for specific control features.

1. Furnace programmable controllers to accommodate sequencing and monitoring of digital actions and overall furnace interlocks.

2. Vacuum pump sequencing control system.

The vacuum pumping cycle requires the control system to interface with multiple low, medium and high vacuum gauge types. The mechanical pumps and high vacuum vapour pump

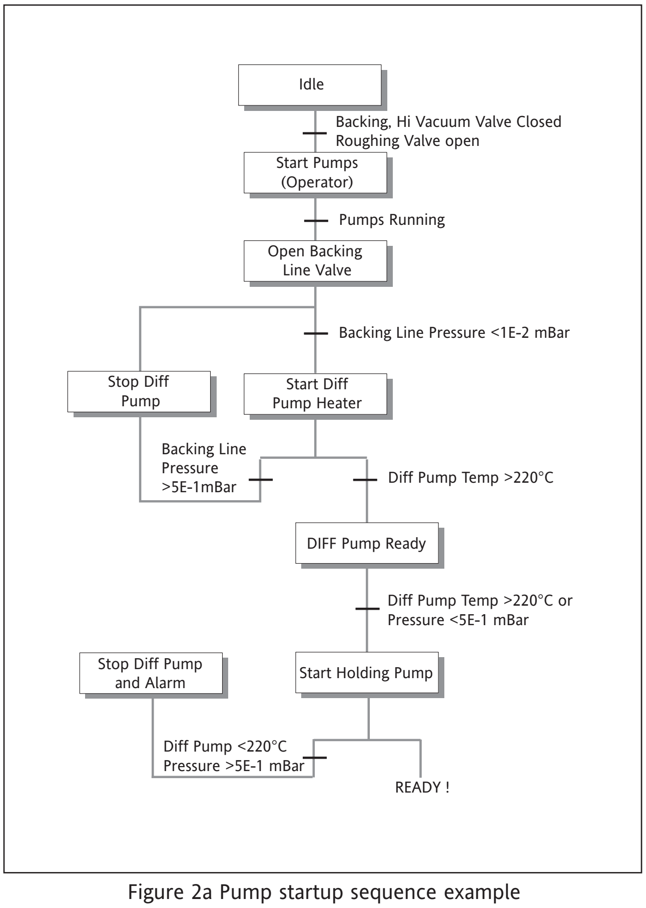


Figure 2a Pump startup sequence example

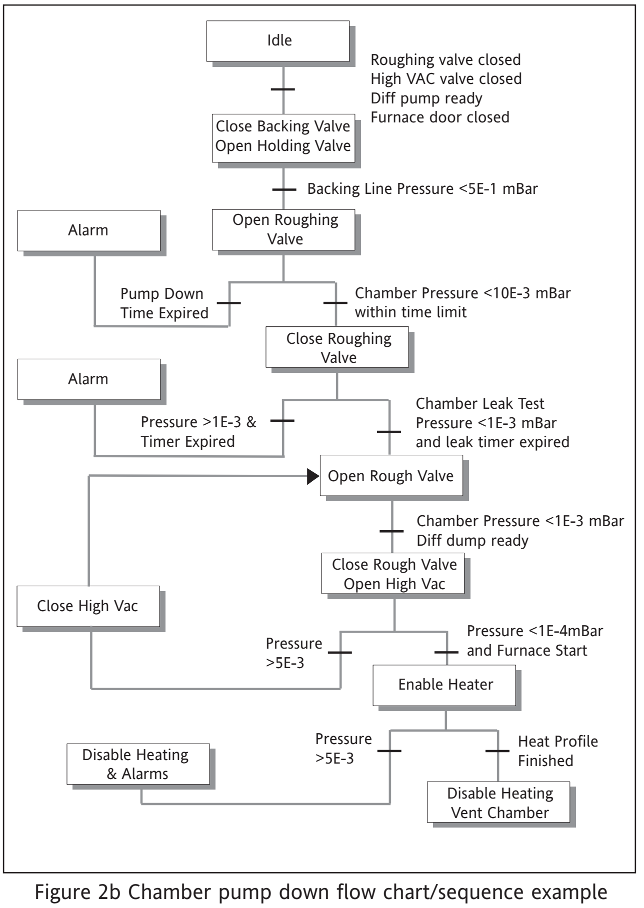


Figure 2b Chamber pump down flow chart/sequence example

need to be sequenced in a controlled way to ensure that the furnace is properly evacuated without damage to the pumps or back streaming of oil into the work chamber. The sequence is processed by comparing the actual value of backing line or chamber pressure to series of pressure setpoints in the medium/high vacuum range. The sequence may also include, pump rate efficiency timers, leak rate testing and out gassing algorithms as well as furnace process and heater interlocks.

3. Heat treatment programming controllers

Vacuum heat treatment cycles are often complex and require multiple stage profiles. These profiles are defined against material and component specifications and are usually maintained against controlled recipes.

Temperature programming profiles are often carried out over multiple segments where accurate control needs to be maintained during both the black heat and radiant heat regions. The cycle will most often follow defined heating rates and dwell periods depending on the treatment process being carried out. Special control optimisation routines to automatically deal with the variation in process gain for large size furnace loads and the black heat radiant boundary, can lead to improved cycle times and product quality.

Since heat treatment is a scientific process it is important to ensure that the workload follows the defined profile and special mechanisms must be employed to eliminate overshoot and to provide work piece thermocouple tolerance and compliance.

Partial Pressure may be contolled within the work chamber by adding a controlled flow of high purity inert gas. Since some materials have relatively high vapour pressures they will exhibit signs of surface evaporation at medium to high vacuum levels. The purpose of partial pressure control is to raise the pressure level of the work piece chamber to prevent this otherwise detrimental effect.

The Cooling process either, vacuum or aided cooling and Gas-Gas/Fan quenching routines are common requirements.

Most modern furnaces include highly efficient heat exchangers and rapid cooling fans to aid the cooling and quench process. Vessels are designed to operate at back fill pressures in excess of 10Bar and the sequence must provide control of this part of the cycle.

Some furnace cycles also make use of back filling with inert gas or the use of circulation fans during the heating process this is to aid heat transfer below the radiant heat range. For cellular installations optional oil quench systems may be built into the design.

A simple typical profile is shown in Figure 3.

4. Electrical power control

Vacuum Furnace heaters are made of Graphite, Molybdenum or occasionally other high temperature alloys, they usually operate at voltages lower than the available mains supply and are connected to the supply through a transformer or saturable reactor.

The element material must not be exposed to an oxidising atmosphere whilst it is at temperature and special pressure interlocks in the vacuum controller are employed to prevent this. Thyristor power controllers are used to give the best results when the heaters are coupled to the supply via a transformer.

5. Interface with vacuum gauges

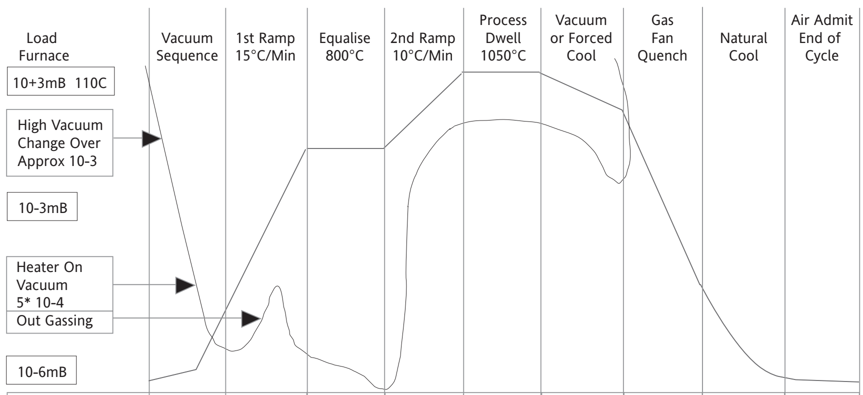
Special consideration needs to be taken over the interface of the control system with various types of vacuum gauges which are available.

Modern gauges tend to be of the wide range or active type where the output span is scaled to coincide with a defined logarithmic range of vacuum. Eurotherm® control solutions employ standard input linearisation to accommodate many industrial vacuum gauges and where new ones are used a simple technique is available to recalculate the linearisation required.

Typical active gauges are:
Atmosphere to medium vacuum 10E0 to 10E-4; Pirani gauges; Thermocouple gauges; and Strain gauges

Vacuums in the range 10E-2 to 10E-9, Ion gauges; and Inverted magnetron gauges.

Wide or full range gauges employ more than one measuring technique but have a continuous output across the range 10E0 to 10E-9.



	Vacuum Sequence	1st Ramp 15°C/Min	Equalise 800°C	2nd Ramp 10°C/Min	Process Dwell 1050°C	Vacuum or Forced Cool	Gas Fan Quench	Natural Cool	Air Admit End of Cycle
Furnace Interlocks Vacuum Sequence	Active Pump down	Active Monitor	Active Monitor	Active Monitor	Active Monitor	Active Monitor	Active Isol	Active Isol	Active Isol
Partial Pressure				On	On	On			
Workpiece Monitor			On	On	On	On			
Vacuum Cool						On			
Forced Cool						Choice			
Gas fan Quench							On		
Natural Cool								On	
Air Admit									On

Figure 3 Typical profile

Heat Treatment

INDUSTRY

- **Reduces maximum heater temperature**
- **Guarantees workpiece setpoint profile**
- **Optimises startup and settling times**

Dual Sensor Vacuum Furnace Control

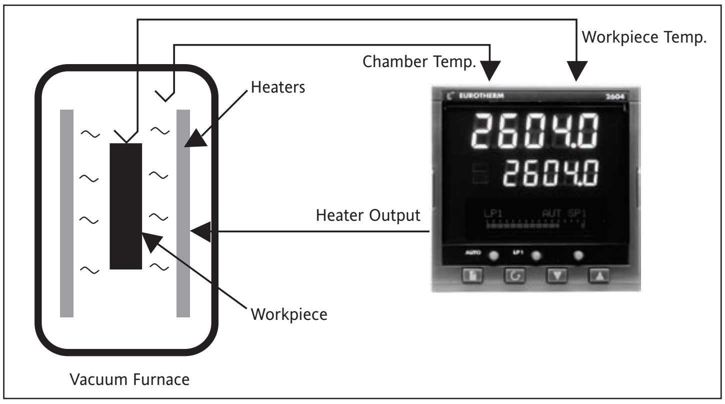
Application Note

Application note

The characteristics of a vacuum furnace cause the chamber temperature to be 5 to 10 degrees hotter than the workpiece. This is called a thermal gradient or Delta Temperature (Delta T).

Many metallurgists prefer to control their vacuum furnaces using a thermocouple placed next to, or into, the furnace workpiece. This however can cause undesirable effects such as excessive heater temperatures and overshoot of the desired setpoint.

Furnace manufacturers often use a chamber thermocouple placed near the furnace heaters in order to get around these problems. The ideal solution is to use a controller that has two separate control loops, each with its own thermocouple input. One loop will use the chamber thermocouple that is located near the heaters and the other loop will use the workpiece thermocouple. The control loop with the lowest output demand will be used to control the furnace temperature.



2604 Solution

- Reduces maximum heater temperatures, increasing heater life.
- Guarantees that the workpiece follows the required setpoint profile.
- Optimises startup and settling times.
- Automatic switching from workpiece control, to chamber temperature control as conditions require. Provides a method of controlling maximum delta T.
- The ability to change the maximum delta T as the controller progresses through its setpoint program.
- A simple effective method to control a furnace.

For this application Eurotherm® has implemented a control technique called override control. Override control consists of two control loops, each with it's own input and setpoint, but they share a common control output. The lowest output of the two loops is directed to the common output circuit.

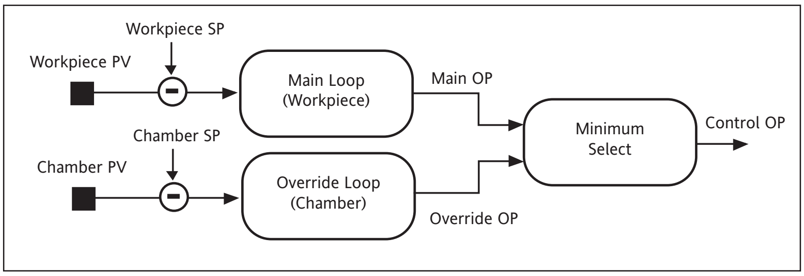


Figure 1 Simple Override Control

Figure 1 shows a simple override controller. The main and override control outputs are fed to a low signal selector. The override setpoint is set to a value somewhere above the normal operating setpoint, but below any safety interlocks or unexpected values.

There is one auto manual switch for both loops. In manual mode the control outputs of both loops track the actual output therefore ensuring bumpless transfer when auto is selected.

Although the 2604 is multi-loop controller it needs only one control loop to implement override. Each loop is capable of being set-up as an override control loop. Two profiles can be used in the setpoint programmer, one to set the chamber setpoint and the other to set the workpiece setpoint. In this manner the setpoints and their relationship to each other can change as the process is being run. Alternatively, one of the profiles can set the workpiece setpoint and the other can be used to set the Delta T between the workpiece and the chamber.

Heat Treatment

INDUSTRY

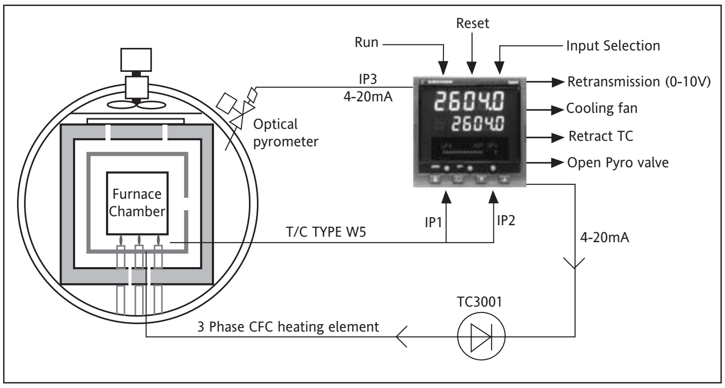
- **Accurate high temperature control**
- **Reduced thermocouple wastage**
- **Control flexibility - using TC only or TC/Pyrometer combination**
- **Automatic retraction of thermocouple**

High Temperature Vacuum Furnace

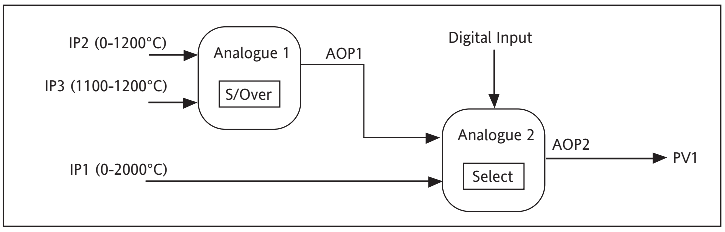
Application Note

High temperature vacuum furnaces are used to manufacture silicon carbide tubes and rings, which are used in high quality bearings. Due to the high working temperature of up to 1675°C and the silicon atmosphere thermocouples can only last for a few cycles. As these thermocouples are made from Tungsten they are very expensive. To reduce the T/C wastage a pyrometer is used at higher temperatures. Normally T/C's are used for temperatures up to 1200°C and pyrometers from 1100°C. This gives a 100°C switchover range between the T/C and the pyrometer. However, there can also be a requirement to use thermocouple control on the full cycle in certain processes which go above 1200°C.

A 2604 single loop programmer is used utilising its Toolkit blocks. Three PV inputs are used. The thermocouple is connected in parallel to two inputs, with one input (IP1) ranged 0-2000°C and the other (IP2) ranged 0-1200°C. The Pyrometer input, which is a 4-20mA linear signal representing 1100°C to 2000°C is connected to the third PV input (IP3).



Using "Toolkit Blocks" we calculate Analogue 1 using the switchover function between IN2 and IN3. The result (AOP1) is then used as an input Analogue 2, which dependent on the state of a digital input will connect either IN1 or AOP1 to the actual process varaible.



Other features include:

Alarms on PV1 at 1090°C to open the sight glass window for the Pyro, and at 1210°C to retract the T/C when using Pyrometer mode.

A 0-10Vac retransmission of PV1 to a chart recorder.

Digital inputs for run and reset.

Application note

Heat Treatment

INDUSTRY

- **Direct interface to "active" vacuum gauges**
- **Integrated temp/ vacuum control**
- **Roughing pump timeout**
- **Diagnostic features**
- **Maths and logic functions**
- **Open communications**
- **Leak detection**

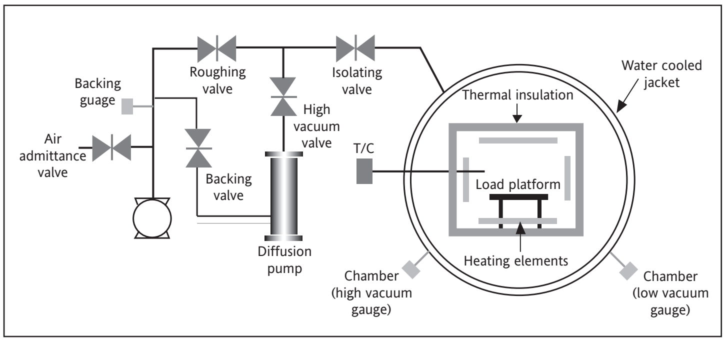
Vacuum Control using the 2704 Controller/Programmer

The 2704VC is a fully programmable controller suitable for precision temperature, and vacuum control in heat treatment applications.

Capable of being used solely to control the vacuum pump down sequence of a furnace or as an integrated controller where both temperature and vacuum are controlled. Additional features provide maths and combinational logic functions.

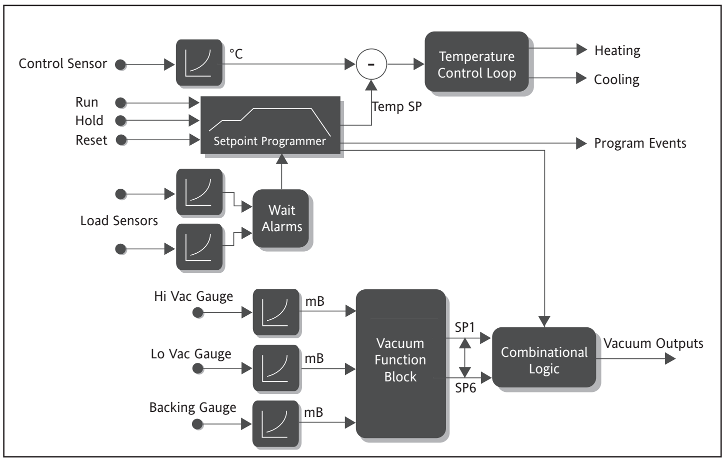
At the heart of the vacuum controller is a specially designed function block capable of accepting up to three vacuum inputs. Standard features include automatic and bumpless switchover between the high and low vacuum gauges and an additional input that can be used for inputs such as backing vacuum or backfill pressure. Six switched outputs are available and other features include a gauge enable signal for high vacuum, roughing pump timeout alarm and a leak detection routine.

For standard applications, controllers are shipped pre-configured to the users specification, using a simple to complete order code. User customisation can be achieved by reconfiguring the controller via its front panel interface or the Eurotherm® iTools configuration software.



A typical vacuum setup

The 2704VC is fully compatible with the standard 2704 three loop controller data sheet number HA026669.

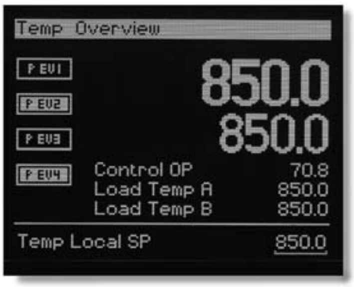


2704 Functional block diagram

White paper

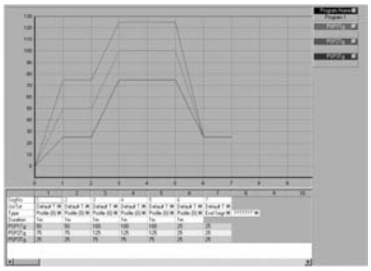
Temperature

- **0.1% Accuracy, 0.25µV resolution**
- **Multiple PID sets**
- **50 Setpoint profiles**
- **16 Program event outputs**
- **Load thermocouples**
- **Program graphical display**
- **Trend view of PV and SP**



Trending enables the user to view, both current and historical information on the process variable and setpoint of each control loop.

The 2704 user interface offers the user an extremely easy method of editing, selecting and running programs and all programs can be given a meaningful name. Its programmer functions are very advanced and can be easily interfaced to remote instruments including specialised Mass Flow controllers. Program editing can be achieved using a PC running the iTools setpoint program editor.



iTools setpoint program editor

Vacuum

- **Compatible with "active" gauge**
- **Auto Hi/lo gauge selection**
- **Six setpoint outputs**
- **Roughing pump timeout**
- **High vacuum enable output**
- **Leak detection**

The 2704VC can interface directly to active vacuum gauges that output signals in the range of 0-10Vdc. Special linearisation tables have been created for many industry standard gauges and additional gauge linearisations can be created upon request.

Two inputs are used for the high and low main chamber vacuums and a third input is available for inputs such as backing, foreline or backfill. Total number of vacuum inputs can be as much as five.

Switchover between chamber gauges is automatic and bumpless. To prevent damage to the high vacuum gauge, power is not applied until a preset vacuum level has been achieved. Six vacuum setpoint outputs are available, each of which can operate on any gauge.

When the roughing pump starts, a diagnostic timer is started that generates an output if the backing vacuum does not achieve a preset vacuum level within a specified time. A leak detection routine can also be implemented.

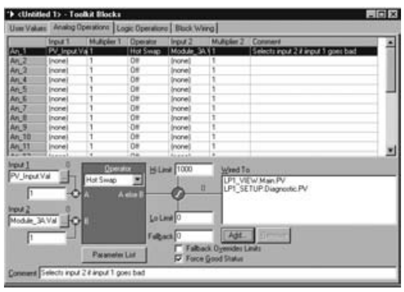
Toolkit functions

- **Mathematical calculations**
- **Combination logic**
- **Real Time Clock**

Operators include;

Add, Subtract, Log, Exp, SQRT, AND, OR, Max, Min, Select and many more.

Toolkit blocks allow the user to create custom solutions by internally wiring analogue and digital operations together in flexible ways. 24 analogue and 32 digital operations are available. Other functions are available including timers, totalisers and a real time clock.



iTools toolkit block editor

Vacuum furnace control system

- **Vacuum control**
- **Temperature profiling**
- **Multiple temperature zones**
- **Load thermocouple monitoring**

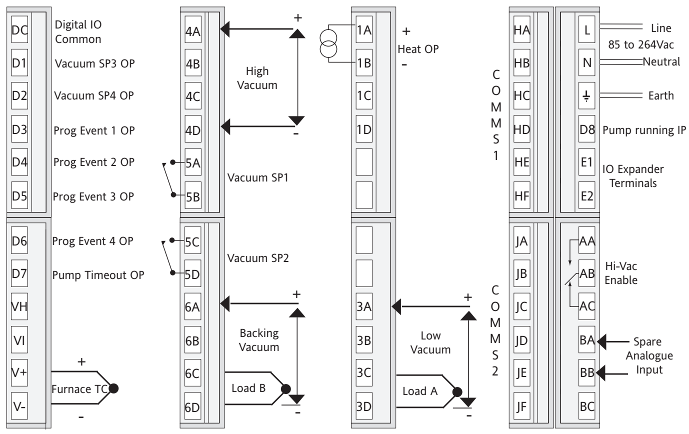
In combination with the 2500DIN rail controller, a very powerful and low cost vacuum furnace system can be implemented. The 2704VC acts as the master vacuum controller, temperature programmer and user interface for the 2500.

Each 2500 can implement up to 8 zones of PID control and these control loops can follow the same setpoint profile as the master programmer, additionally the 2704VC can provide the setpoints for other PID loops implemented in the 2500 strategy.

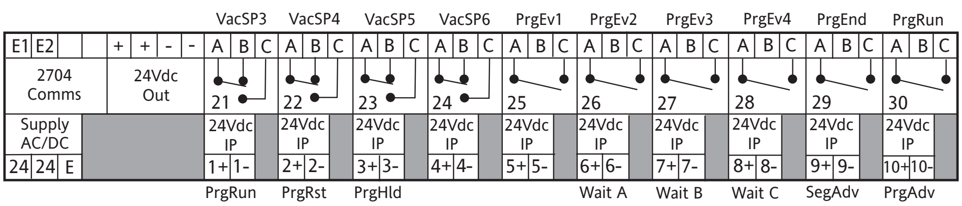
The 2500 can measure up to 32 thermocouple inputs, fully isolated to 250Vac potential. A strategy within the 2500 can monitor all thermocouples to detect the minimum value, which can then be sent via digital or analogue communications to the 2704VC to be used as wait condition ensuring temperature uniformity within the furnace and provide a guaranteed soak. The furnace operator using the 2704VC user interface can at any time deselect any unused or faulty thermocouples.

Rear terminal connections

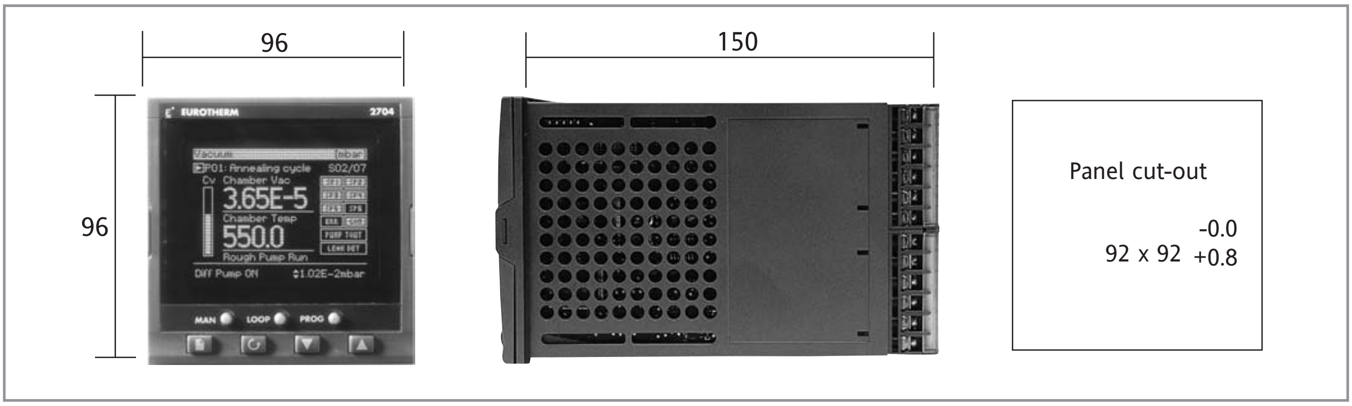
Notes:-
1) Module 1 only supplied when temperature loop is ordered
2) IO functions can be reconfigured by user
3) Spare analogue IP can be 4-20mA pyrometer input.



2000IO Expansion terminal connections



Dimensional details



Heat Treatment

INDUSTRY

Continuous Gas and Batch Carburising Furnace

Application Note

Sealed quench furnaces, continuous carburising furnaces and pit furnaces provide three of the most popular methods for treating low carbon and alloy steels to improve the surface hardness and surface durability of steel-alloy components.

A group of processes are carried out, each of which brings specific benefits to the finished part.

Why Eurotherm®?

Eurotherm® can provide control solutions for continuous and batch gas carburishing furnaces to meet regulatory demands including AMS2750 Revision D and TS16949. Eurotherm offer:

- Accurate temperature and carbon setpoint control
- Asynchronous control of heating and quenching cycles
- Carbon diffusion control
- Tamperproof data archiving
- Furnace diagnostics and maintenance
- Gas sequence and mass flow control
- Power control and energy management
- Alarm visualisation and strategy
- Touch screen HMI panel with furnace mimics

Application note

The Process

Gas Carburising

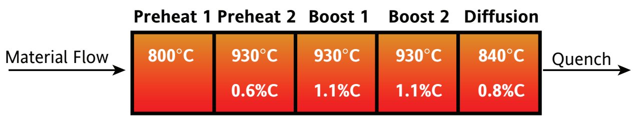
A surface chemistry process, which improves the case depth hardness of a component by diffusing carbon into the surface layer to improve wear and fatigue resistance.
The work pieces are pre-heated and then held for a period of time at an elevated temperature in the austenitic region of the specific alloy, typically between 820 and 940°C.

During the thermal cycle the components are subject to an enriched carbon atmosphere such that nascent species of carbon can diffuse into the surface layers of the component. The rate of diffusion is dependent on the alloy and carbon potential of the atmosphere. Care must be taken to ensure that only sufficient carbon is available in the atmosphere at any one time to satisfy the take up rate of the alloy to accept the carbon atoms. In practice this is defined in a carbon potential setpoint profile which runs concurrently with the temperature cycle. The setpoint may give a boost phase where the carbon potential would be typically set above 1.0% carbon but, as the cycle progresses and the effective case depth increases, the carbon setpoint will be reduced to complete the diffusion stage. Depending on the final requirement for effective case depth, the whole cycle may take many hours.

Once the heating and carbon diffusion part of the process are complete it is necessary to rapidly quench the components to a defined alloy recipe. The recipe will specify the quench method, the quenchant temperature and time. The purpose of the quench process is to provide the required hardness of the component by completing a Martensitic phase change in the alloy.

Continuous Carburising

Where a significant volume of similar parts is to be processed, it is common for continuous furnaces to be used. A continuous furnace allows material to be moved through heating zones, either by a pusher mechanism or on a conveyor belt, at a rate to ensure the correct carbon depth profile. The number of zones in a furnace will vary depending on the material being processed but typically a furnace will have at least 2 pre-heat zones, 2 boost zones and 1 diffusion zone.

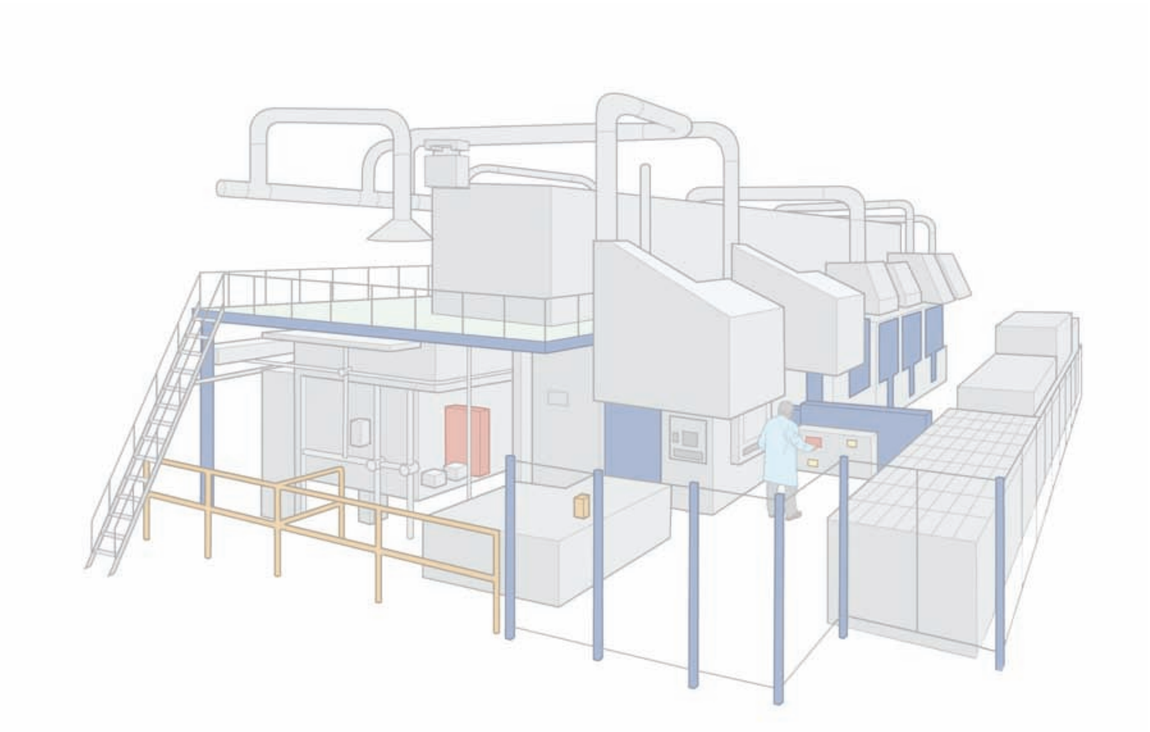


Typical continuous carburising furnace

Batch Carburising

Pit and sealed quench batch carburising furnaces are very popular amongst contract heat treaters where multiple product loads can be processed in combined batches.

There are many furnaces designs but for efficiency many sealed quench furnaces are of the dual chamber type where fully automatic control systems are used to accommodate asynchronous operation of the thermal/carbon cycle and the quench program. This enables two independent batches to be in process at any one time one batch of items completing the quench cycle associated with the last batch recipe while a new batch is being processed to a new carburising recipe.



Carbonitriding

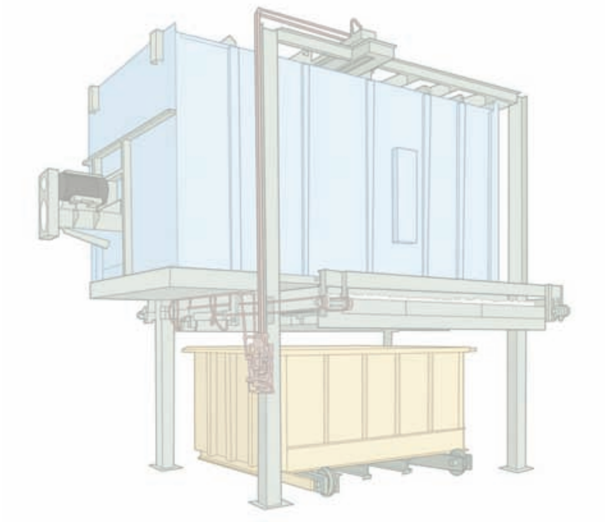
Carbonitriding is a variation of carburising where both carbon and species nitrogen bearing gasses are used together in a batch or continuous furnace.

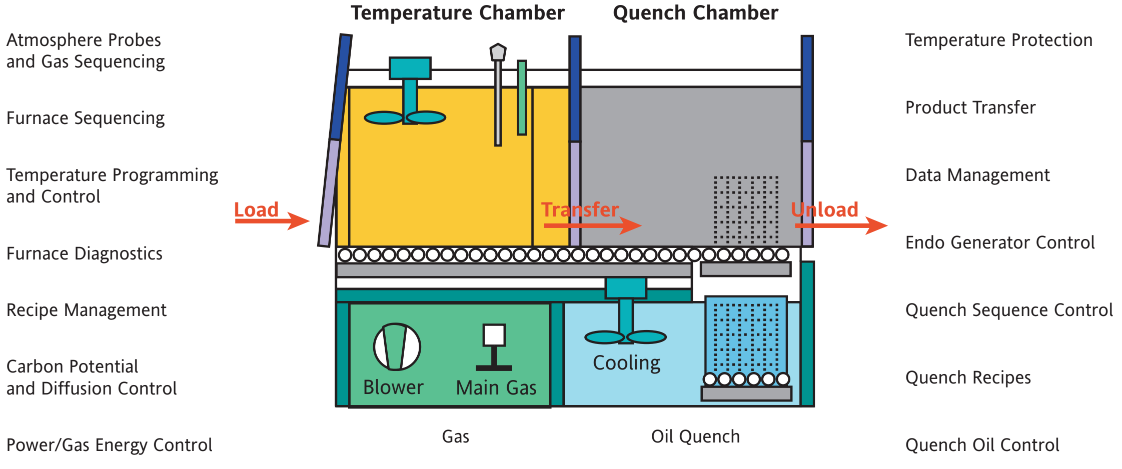
The single nascent molecule of Nitrogen can be obtained by cracking ammonia (NH_3) in the furnace. The resultant gas then combines with the carburising gas to form the diffusion mix. For larger section components, Carbonitriding can offer significant advantages in terms of depth of hardened case.

Tempering

A tempering/stress relieving cycle usually follows the processes above to condition the hardness and produce components with a hard wear resistant surface and toughened softer core.

A variety of equipment types are available for gas carburising including new vacuum techniques for low-pressure carburising. However the majority of the installed base is of the conventional batch sealed quench furnace or continuous furnace type. A large number of OEM furnace manufacturers build this type of equipment.





Typical features of a batch sealed quench furnace

Control Systems

Thermochemical heat treatments are widely used in the aircraft and automotive industry manufacturing process. Many components such as gears, shafts and bearings, as well as a host of sub-parts, are subject to some case hardening techniques and there is a world wide installed base of furnace equipment.

Eurotherm supply a wide variety of control solutions in to batch and continuous carburising furnace applications. The scope of supply may vary but there are some key common requirements:

- Temperature programming and control
- Atmosphere (Carbon Potential) programming and control of case depth diffusion control
- Atmosphere probes and atmosphere probe diagnostic features
- Gas control (sequence and mass flow control) for some specific applications
- Quench programming and control
- Furnace sequence control
- Furnace safety alarms

- Recipe control and programme management
- Data management
- Power control and energy management
- Furnace diagnostics and maintenance
- Furnace mimics and screen navigation

Furnace Temperature Control and Programming

Temperature control is normally achieved using an independent furnace sensor. It is possible to use the sensor input of the zirconia probe but, to achieve best results, the zirconia probe and temperature probes must be located in their optimum positions within the furnace. The heat control output can either be connected to gas burners or thyristors. In some applications a cooling output may also be connected to a circulation fan or an exhaust damper.

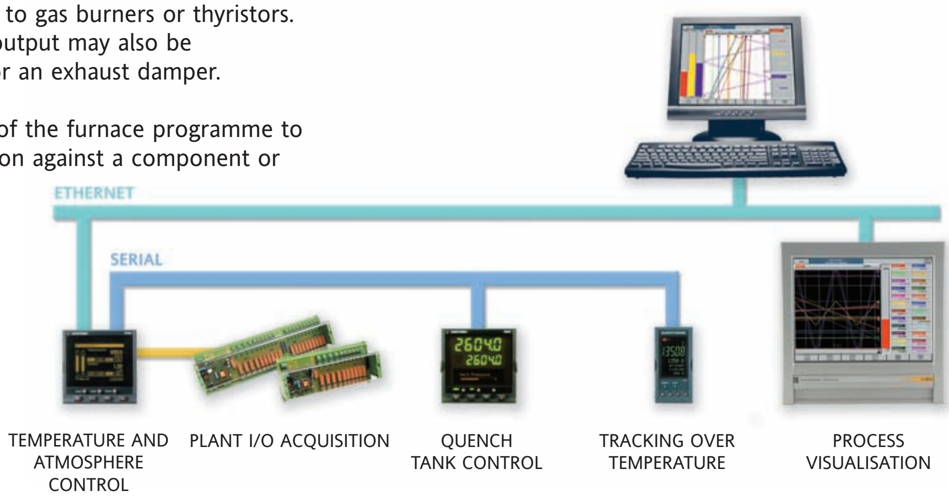
It is normal for many instances of the furnace programme to be available for operator selection against a component or batch reference.

Carbon Potential Measurement

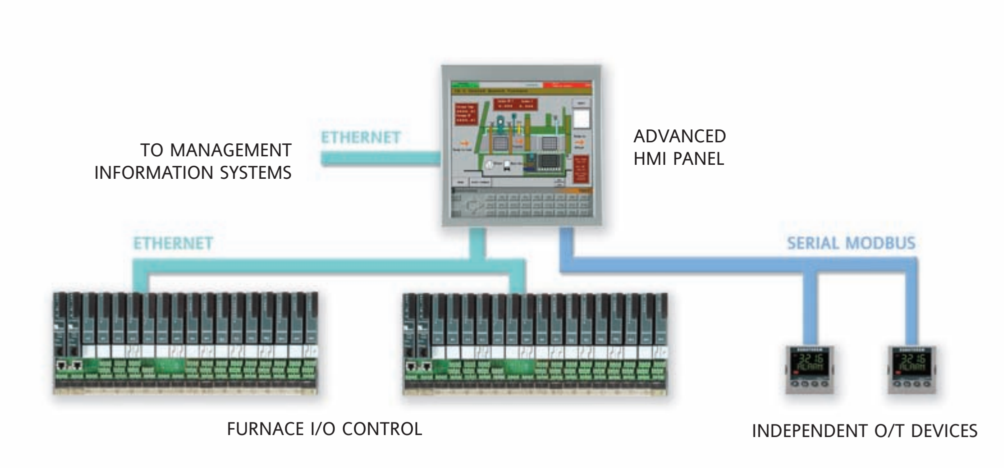
Accurate measurement of the furnace atmosphere is critical to the application. Normally a zirconia probe is used to measure carbon potential. The zirconia probe generates a millivolt signal based on the ratio of oxygen concentration between the reference airside of the probe (outside the furnace) and the amount of oxygen actually inside the furnace. Temperature is measured using a built in thermocouple at the tip of the probe. An application specific zirconia function block uses the millivolt and temperature signals together to calculate the actual percentage of carbon in the furnace atmosphere. The condition of the probe is again vital to furnace performance and Eurotherm use many techniques to maintain and diagnose the performance of the insitu probe.

Furnace Atmosphere Control

Gas carburising furnaces may be powered either by gas or electricity. Whichever method is used it is necessary to maintain a sealed environment and take precautions with the burners (typically radiant tube burners) to avoid the products of combustion entering the furnace work chamber The zirconia probe can measure very low concentrations of % oxygen in the furnace, typically less than 1×10^{-20}. To supply the required species carbon it is usual for the furnace to be supplied with a base endothermic carrier gas which conditions the furnace, at say 20% CO for a methane based carrier gas. Carrier gas will typically be supplied by an Endo Generator or through direct injection of a Nitrogen/ Methanol mix. In the atmosphere loop, the controller uses the carbon potential calculation based on the known oxygen reading to increase the carbon potential by opening a solenoid valve, which allows additional carburising gas (ie methane) to enter the furnace. Conversely, to decrease the carbon potential, controlled air is introduced into the furnace. Automatic probe cleaning functions ensure that the reading is accurate, while probe health and sooting alarms warn of a deterioration in the probe performance.



Typical discrete control solution



Typical integrated solution

Gas IR

The Carbon potential calculation using an oxygen probe is based on furnace gas equilibrium conditions. Equilibrium conditions rarely exist during short or medium carburising cycles. As a consequence atmosphere carbon potential, based on an oxygen probe, is often overstated. Furthermore and more importantly, the carbon potential is only calculated from a single gas constituent, the oxygen content of the furnace atmosphere, and a **fixed value** for the carrier gas CO.

The solution –

Three Gas Infrared system with automatic probe compensation

A three gas infrared system calculates, with higher accuracy, the carbon potential using furnace realtime CO, CO_2 and CH_4 values. The infrared system then calculates the process factor or CO factor based on the IR carbon % and sends this new process factor, via a special communications link, to update the Eurotherm atmosphere carbon controller's process factor. As a result, the atmosphere controller now reads the same as the calculated IR carbon. The oxygen probe may be sooted or even failing and the infrared system will compensate.

The system combines the convenience and response of a oxygen probe with the superior accuracy of multi-gas infrared measurement to provide the very best control available.

Benefits

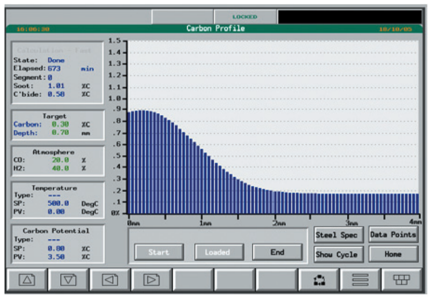
- Accurate calculations of atmosphere carbon potential
- Automatic oxygen probe compensation
- Verification of oxygen probe accuracy and performance
- Easy identification of furnace atmosphere problems and furnace condition
- Evaluation of Endo Generator performance and catalyst condition
- Optimise nitrogen methanol system performance

Diffusion Control

Traditionally carburising is carried out against a timed setpoint profile where the time periods for the different temperature/carbon stages are selected against empirical post-process material results.

This method provides a steel/alloy dependent recipe, which gives good repeatable performance but heat treaters tend to process at the high end of the case depth tolerance to ensure good repeatable results.

Since the purpose of the process is to provide components with a defined effective case depth usually with a minimum tolerance other methods, which allow effective case depth to be selected as the controlling setpoint, have become more widely available.



A typical diffusion cycle

The case depth diffusion solution is available as a function block within the T800 and uses an algorithm based on carbon potential, temperature, material specification and process factors to determine the carbon setpoint profile.

In this case the traditional recipe hands control to the dynamic on-line diffusion calculation, which completes the carburising cycle to the required effective case depth.

Atmosphere Probe Diagnostics

Sooting alarm

By careful analysis of the furnace temperature and carbon potential, it is possible to determine when the atmospheric conditions are such that carbon will be deposited as soot on all surfaces inside the furnace, including the workpiece. It is obviously desirable to avoid this situation and in Eurotherm solutions an alarm is preconfigured and can be used to trigger a furnace event. Eliminating sooting protects the furnace lining, maintains the accuracy of the zirconia probe and stops formation of a soot barrier on the workpiece, which can prevent carbon diffusion.

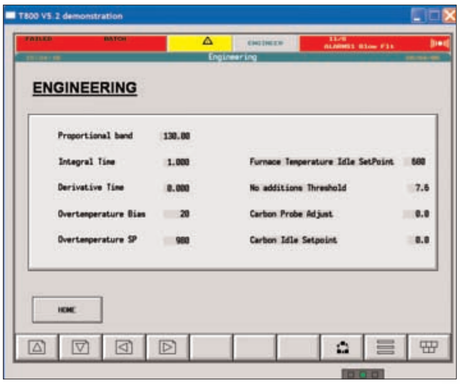
Automatic probe cleaning

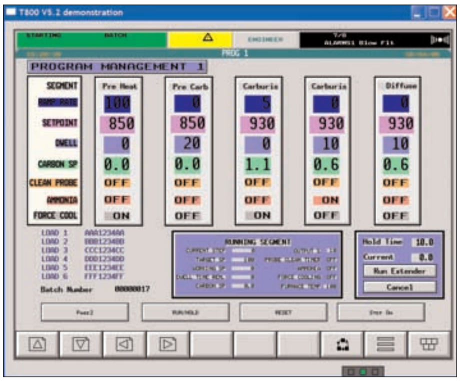
A probe clean and recovery strategy can be programmed to occur between batches or manually requested by an operator. A short blast of high flow burn off is used to remove any soot and other particles that may have accumulated on the probe. During the cleaning and recovery cycle the %CP reading is frozen, thereby ensuring continuous furnace operation.

Probe impedance monitoring

When the output impedance of a zirconia probe increases above a certain level, it indicates that the performance of the probe has deteriorated and that it should be replaced. The 26/2704 controllers have the ability to measure the impedance of the sensor connected to its input and, in conjunction with User Alarms, an alarm strategy can be created to alert an operator of an impending probe failure. This feature is not only useful in new installations where the 2604/2704 will actually control the carbon potential, but it can also be retrofitted into existing installations where the customer is happy with the carbon control system but wishes to provide additional probe diagnostics.

During the burn off period the probe mVs and temperature are monitored to determine the status of the probe. Once the burn off is completed an alarm will be set if the probe mVs do not recover to 99% of the original value within the probe recovery time setting. The alarm indicates that the probe is ageing and should be changed.





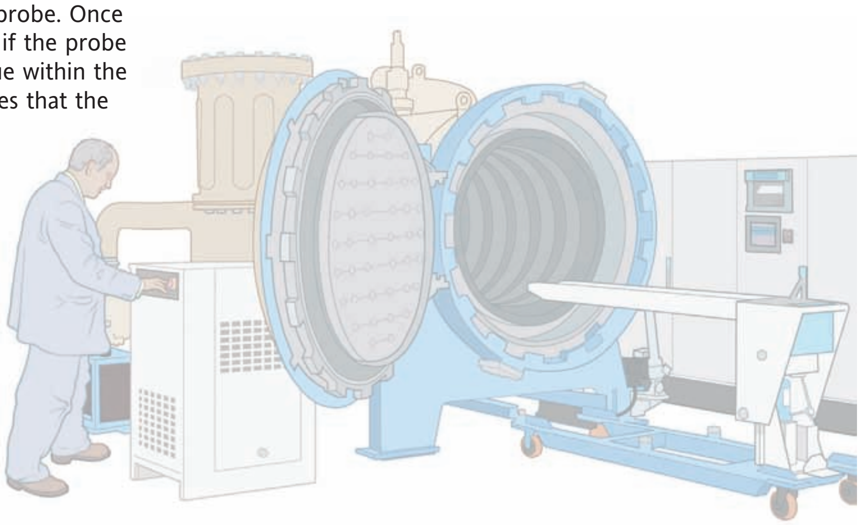
Carburising Gas Correction

A gas analyser can be used to determine the CO concentration of the carburising gas. If an analogue output is available from the analyser, it can be fed into the controller to automatically adjust the calculated % carbon reading. Alternatively, an operator may enter this value manually.

Gas Sequencing

For Nitro Carburising it is necessary to introduce other gasses, such as species nitrogen, into the furnace during the carburising process. This is often achieved by having a digital event to allow a controlled flow of ammonia to enter the furnace at a specified part of the sequence.

Alternatively, an analogue value can be transmitted to a mass flow controller to achieve the same purpose.



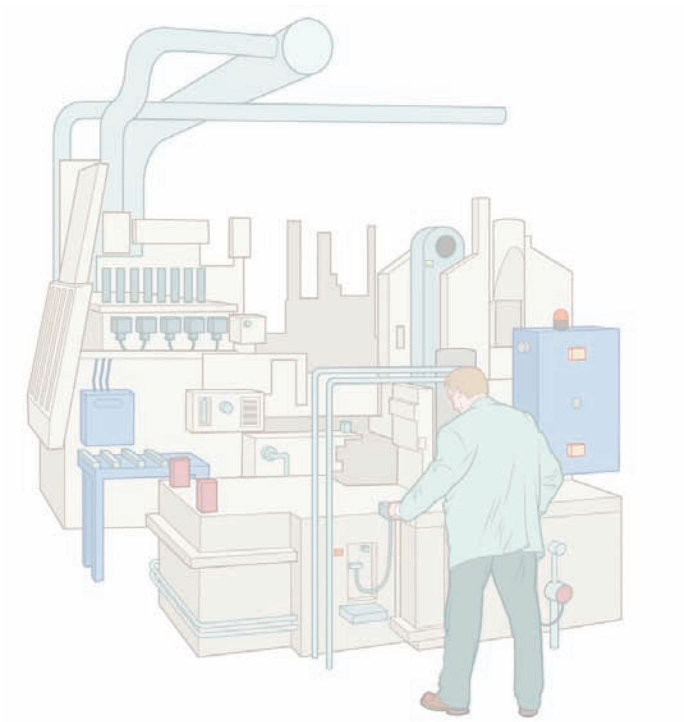
Quench Control

Quenching of components is an integral and critical part of the process. Parts must be transferred to the quench quickly and be treated using an alloy dependent recipe.
The quench recipe, which is normally held as part of the overall process profile, will contain options for oil or air quench, the quench oil temperature, time and oil flow circulation speed and direction. The recipe may also include the drip timer setting. Safety measures need to be considered for quench elevator failure position and pressure interlocks between the oil pressure and the oil cooler heat exchanger water pressure.

The control system must be designed to ensure that the thermal/carbon profile and the quench profile can operate asynchronously. This allows one product to complete its process cycle in the quench tank while a new product is being treated in the furnace.

Furnace Sequencing Control

The control system needs to cater for or interface with furnace sequencing. The sequencing is required for work-piece transfer through the furnace, cycle control, quench sequencing and burner or energy control. Discrete control solutions tend to interface with an external PLC but, in integrated solutions, it is possible to carry out the entire furnace sequencing in one control environment.



Furnace Alarms

Alarms are provided for the following:

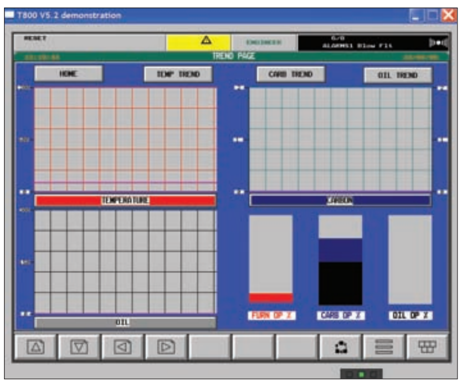
- Furnace over temperature
- Quench oil over temperature
- Burner system alarm
- Process enabling temperature alarms at 600°C and 750°C
- Atmosphere out of tolerance alarm
- Probe diagnostic alarms
- Furnace fan unbalance alarm (option)
- Quench flow and pressure alarms
- Quench oil heat exchanger flow and pressure alarms

The following thermal chemical processes are also part of the family of surface hardening treatments:

Nitriding
Nitriding is a low distortion thermochemical process conducted at temperatures between 480-560°C. In the case of nitriding the active gas is often produced by cracking ammonia in the furnace to release the nascent species of nitrogen having first purged the furnace with nitrogen.

Process times involved with the diffusion of nitrogen into the surface to produce the controlled hardness depth may be very long, and can be up to 80 hours. The results, however, produce components with high surface hardness and good wear resistance without the need to quench. When combined with nitrocarburising it is possible to achieve surfaces with enhanced self-lubrication and aesthetic qualities.

Nitrocarburising
Ferritic nitrocarburising conducted at 550-580°C or austenitic nitrocarburising conducted at 590-720°C involve enrichment of the surface with both nitrogen and carbon to impart a compound layer consisting of iron-carbonitride. The compound layer is apparent on the surface of the nitrogen bearing diffusion zone and greatly changes surface characteristics. The process may include subsequent quenching and other post-process oxidation techniques to create specific surface characteristics.



Data Recording and Data Management

Data logging is a key requirement for many carburising applications particularly where processes are associated with either aerospace and automotive quality systems.

Eurotherm control systems include data management products, which meet the most exacting demands of Nadcap and AMS2750D including the following:

- Accurate time and date stamps
- All process data including actual values and demand setpoint profiles
- Selected Recipes
- Product batch information
- Alarms and events
- User login and logout
- User notes and user actions
- Electronic signatures
- All data is saved in write once read only format

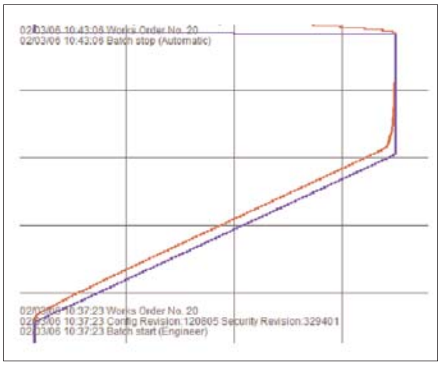
Eurotherm gas carburising systems log plant data to tamperproof files and SQL relational databases.
Data logging can be offered as:

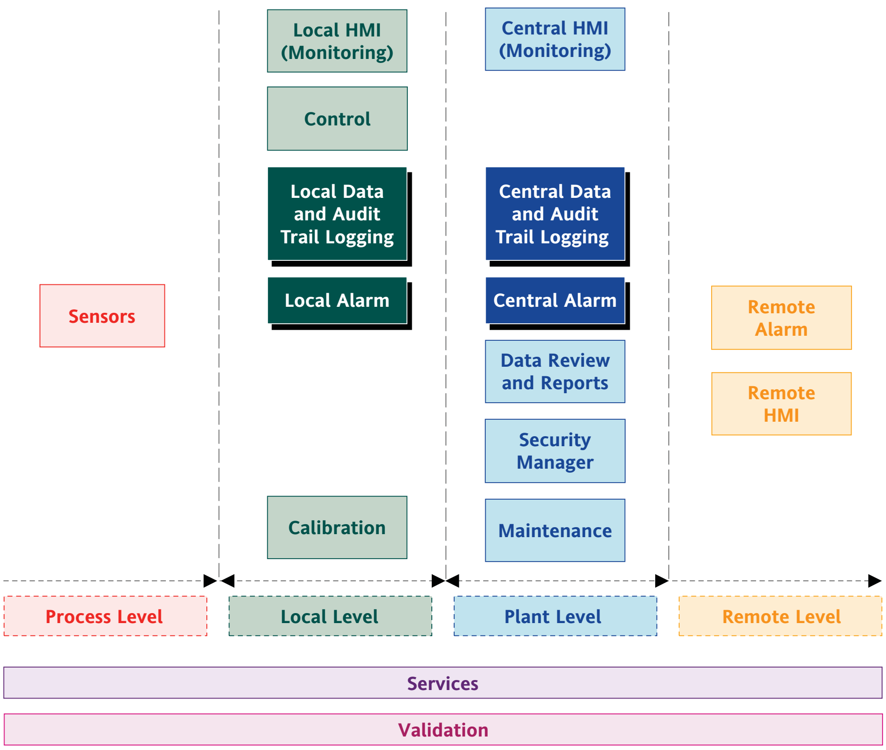
- Local logging (tamperproof files)
- Central logging (SQL Database)
- Local and central logging (tamperproof file and SQL database)

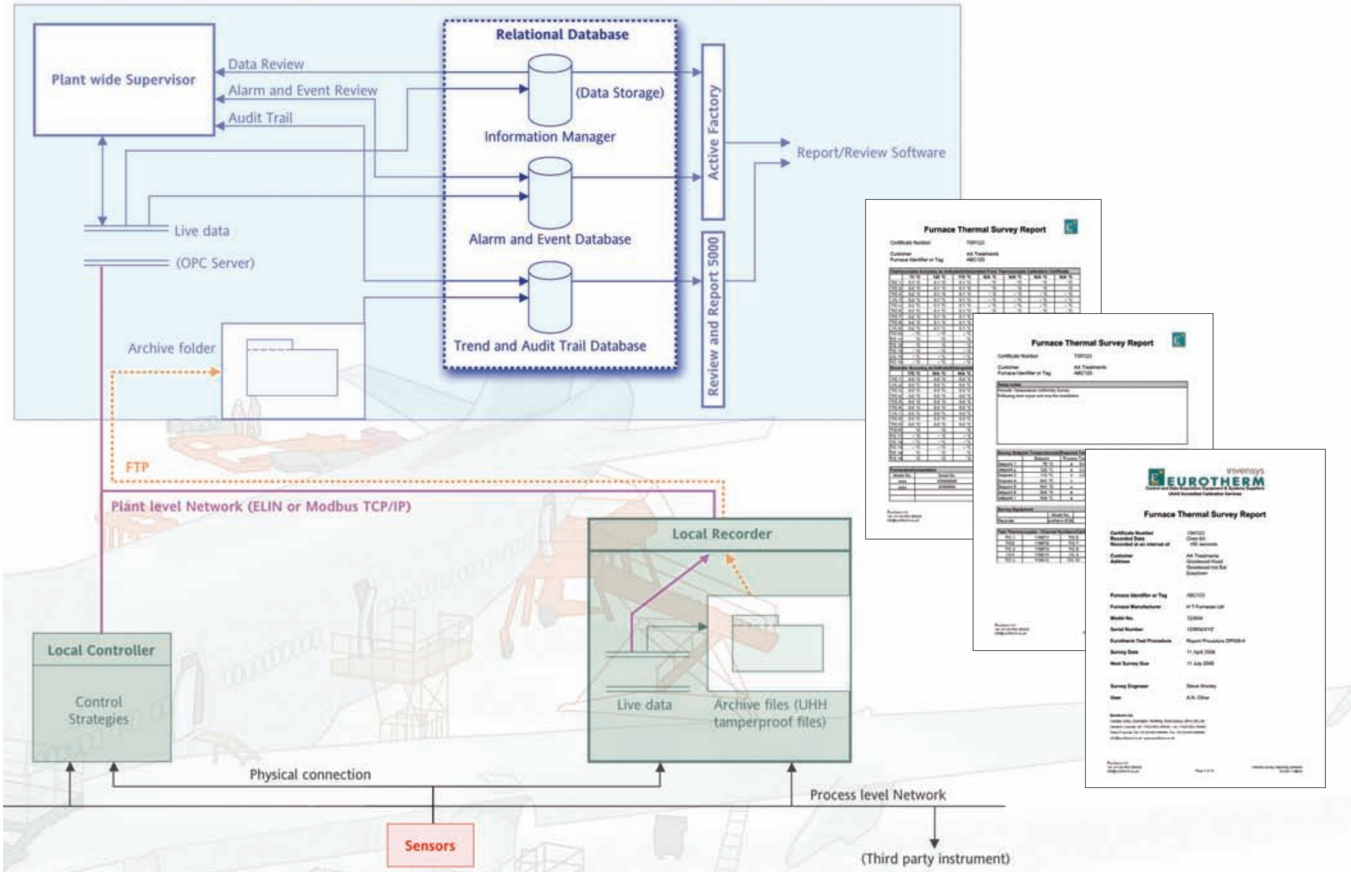
Data archiving strategies that keep your data safe

Data management solutions from Eurotherm assist with the important task of information housekeeping by providing multiple destination archiving routines.

- Local data backup or remote over Ethernet communications
- Multiple archiving strategies
- Automatic, secure data file backup and transfer routines
- Archive on demand, archive automatically or archive using Eurotherm 'Review' Package
- Multiple archiving destinations, archive to CF/SD, archive to USB memory stick or archive to FTP Server
- Primary and Secondary Server Function







Support for historical reporting and review of data

- Review software facility to replay secure data files
- Ability to generate accurate and complete copies of records in human readable format and in industry standard electronic packages.
- Report 6000 flexible software facility to provide custom records and reports
- Sort records on parameter data or batch data

Support for Temperature Uniformity Surveys (TUS) and System Accuracy Tests (SATs)

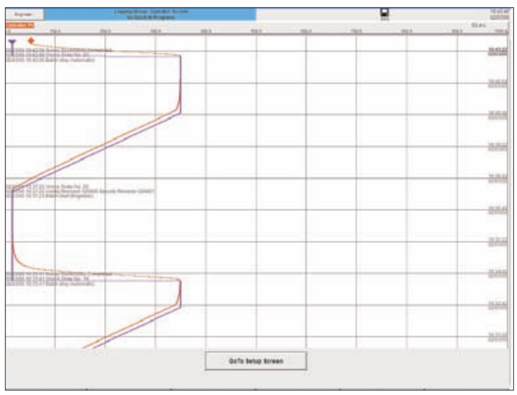
Eurotherm Digital Data Management products are ideal for TUS and SATs with application specific configuration and reporting designed for the accredited heat treatment work-shop including:

- Products meet the demands of field test instruments as defined in AMS2750D
- Automatic routines are available for the automation of Temperature Uniformity Surveys
- Tamperproof records can be appended with user notes and operator information
- TUS and SATs data can be exported to Eurotherm Report 6000 for the automated production of accredited reports.

Support for Maintenance and Efficient Energy Usage

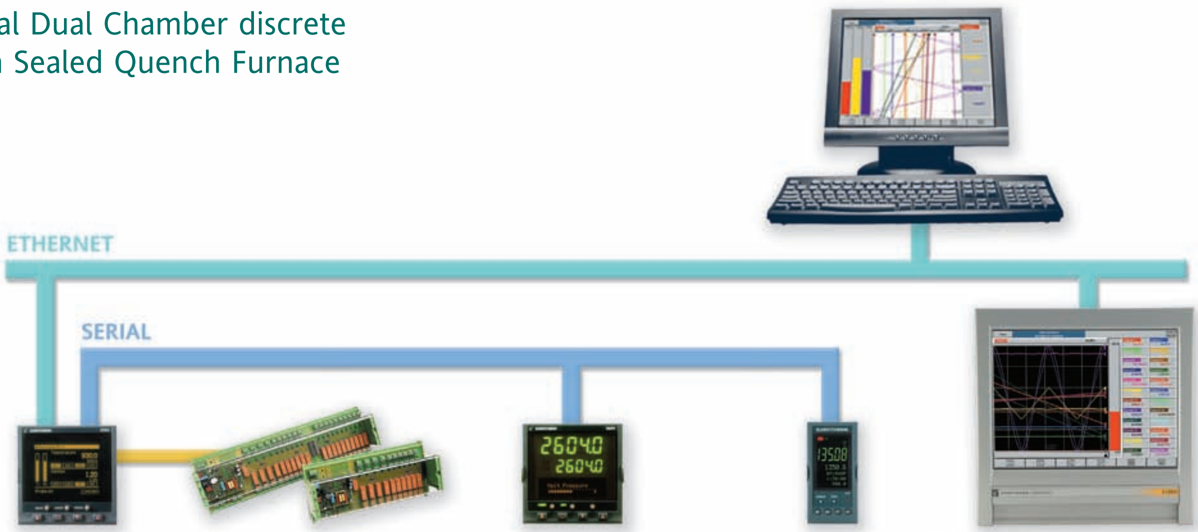
Gas Carburising Data logging systems from Eurotherm can be configured to aid the efficient use of plant and equipment and advise of maintenance events and audit requirements.

- Energy usage and furnace energy profiling
- Plant uptime and equipment running time
- Maintenance events frequency
- Calibration and audit frequency alarms



Control Solution

Typical Dual Chamber discrete Batch Sealed Quench Furnace



TEMPERATURE AND ATMOSPHERE CONTROL

Furnace T/C
Probe T/C
Probe mv
Air/Gas additions
Probe clean
Safety gas
Protection gas
End of program
Carbonitride gas
Select quench cycle
Carbon loop in standby

PLANT I/O ACQUISITION

Furnace start
Transfer to quench
N2 gas available
Quench empty
Furnace door I/O
Load in furnace
Load in quench tank
Enable heating

2704 AND I/O EXPANDER
Used for temperature programming and control, carbon potential programming and control furnace I/O access and control

QUENCH TANK CONTROL

Quench T/C
Oil flow up
Oil flow down
Oil not over temp
Atmosphere quench
Load next quench cycle
End of quench
Start quench
Heat/cool O/P
Oil flow fast
Oil quench

2604
Used for quench oil control and quench sequence control

TRACKING OVER TEMPERATURE

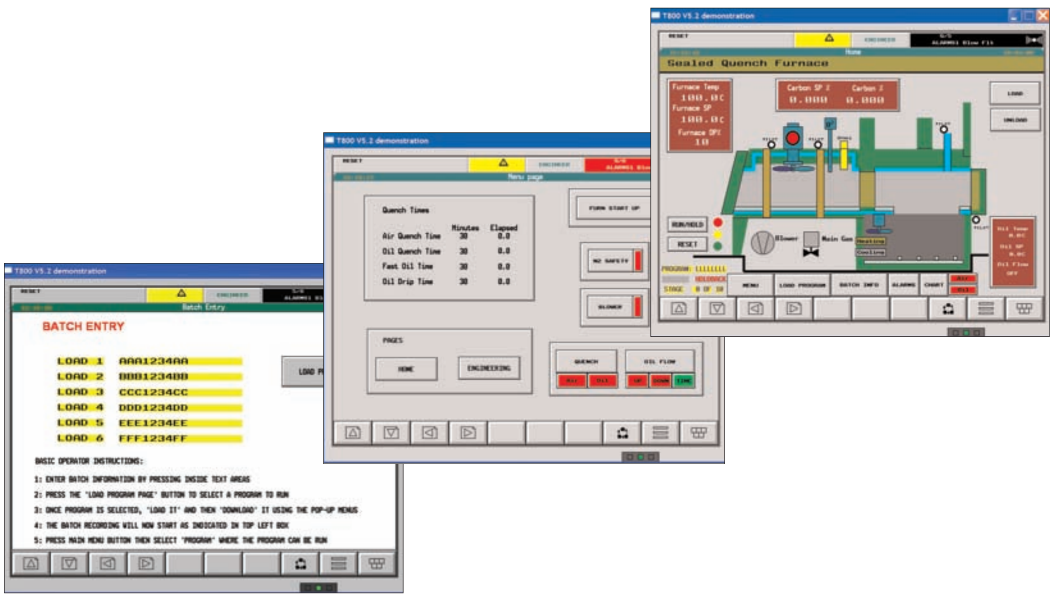
Over temperature
Tracking alarm
Full scale alarm

3504
Used for furnace absolute high temperature alarm and deviation high process temperature alarm

PROCESS VISUALISATION

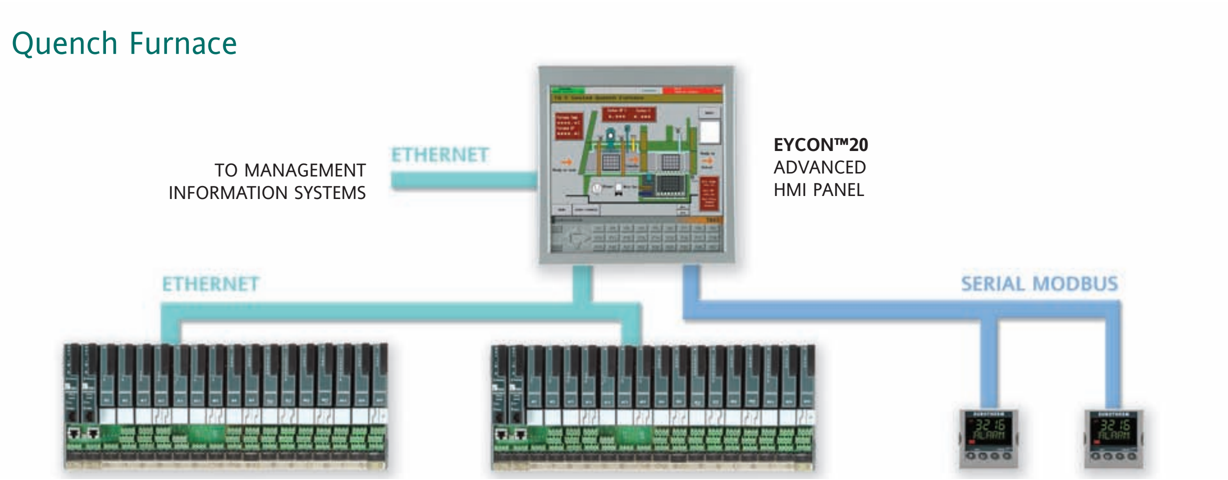
Work T/Cs
Programme select
Energy monitoring
Alarms
Tamperproof data storage

6180A
Used for data management and operator HMI

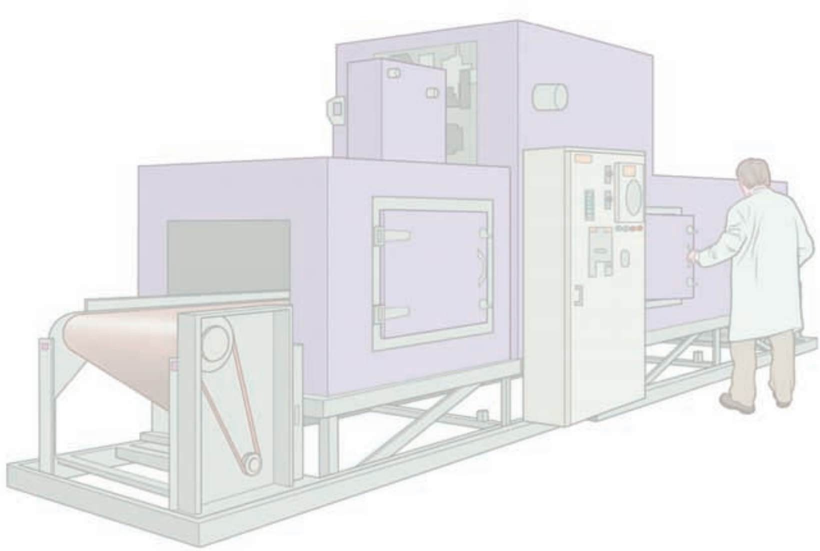


Integrated Solution

Batch Quench Furnace



FURNACE I/O CONTROL	FURNACE AND OIL OVERTEMPERATURE DEVICES
Direct field wiring connection to analogue and digital inputs and outputs contactors, solenoids, motors, switches, actuators, thermocouple sensors, carbon probes Integration with local printers for reports Atmosphere control Batch management Temperature programming and control Integration with 3rd party products Plant wide visualisation and navigation Alarms and process diagnostics User login/logout and secure passwords Furnace sequence control Integration with power transducers and energy monitoring Recipe control Secure digital data management Optional processor redundancy Historical and real time trends Optional diffusion case depth control	
T2550	**3216**



Heat Treatment
INDUSTRY

White paper

Carburising Gas Reactions

In the gas carburising process, a low carbon bearing carrier gas is used, which is enriched with a hydrocarbon gas, such as propane or methane (natural gas), to increase and control the carbon availability of the atmosphere. The carrier gas is usually of the Endothermic gas type produced from a sub stoichiometric mixture of a hydrocarbon and air at elevated temperature in the presence of a catalyst. The production of Endothermic gas is usually carried out in an external gas generator.

Alternatively, a nitrogen – Methanol mixture, injected into the furnace can be used to produce a synthetic Endothermic gas. Dependent upon the type of hydrocarbon used and the mixture ratio, the typical composition of the carrier gas is:

15-25% CO, 35-45% H_2, Balance N_2,
plus small quantities of CO_2, H_20, CH_4

The gases CO and CH_4 are carburising, whilst H_2, H_2O and CO_2 are decarburising. In order to control the carbon availability of the atmosphere – the CARBON POTENTIAL, a hydrocarbon gas is used to enrich the carrier gas, by reducing the H_2O (DEWPOINT) according to the reaction:

$$CH_4 + H_2O \longrightarrow CO + 3\ H_2 \quad \text{(2)}$$

And by reducing the CO_2 according to the reaction:

$$CH_4 + CO_2 \longrightarrow 2\ CO + 2\ H_2 \quad \text{(3)}$$

as well as allowing the following carburising reaction to take place:

$$CH_4 \longrightarrow C_{Fe} + 2\ H_2 \quad \text{(4)}$$

in addition to reaction (4) the other main carburising reactions in a CO – CO_2 – H_2 – H_2O – CH_4 atmosphere are:

$$CO + H_2 \longleftrightarrow C_{Fe} + H_2O \quad \text{(5)}$$

$$2\ CO \longleftrightarrow C_{Fe} + CO_2 \quad \text{(6)}$$

Reactions (5) and (6) are considered the main equilibrium reactions for the basic method of carbon transfer into the steel surface. The assumption is that the carburising is taking place as a direct result of the CO content in the atmosphere. However, the oxygen probe has no way of measuring the %CO. A fixed value has to be introduced into the Carbon potential controller in the form of a process factor or CO factor (see below). Furthermore, equilibrium conditions do not exist in a furnace until several hours have passed – the actual %CO will be considerably lower than expected.

It has been shown that reaction (5) is 10-100 times faster than reactions (4) and (6), and is therefore rate determining.

In most systems, the addition of a hydrocarbon gas such as methane is used for the control of carbon potential. If all the methane was “cracked” using reactions (2) and (3), the atmosphere would remain in equilibrium and predicting carbon potential would be straight-forward. Unfortunately, these reactions occur at very slow rates and only near catalytic surfaces. They are never close to equilibrium.

(In the gas reactions described in this White Paper C_{Fe} is the available carbon, from the atmosphere, for diffusion into the steel surface.)

In an atmosphere with a significant level of free methane, some carburising will be taking place according to reaction (4), but increasing levels un-reacted methane will result in the dilution of the %CO. Without measuring and including the effects of free methane in the carbon calculation, the real potential of the atmosphere is not known.

Calculation of carbon potential using oxygen probes

The equilibrium composition of the gases is determined by the “water – gas” reaction:

$H_2 + CO_2 \longleftrightarrow CO + H_2O$ .... (7)

Combining reactions (5) and (7):

$2\ CO \longleftrightarrow C_{Fe} + CO_2$ ....(6)

By using the thermochemical equilibrium constant for the above reaction the carbon activity of the atmosphere can be calculated:

$ac = \dfrac{p\ CO_2}{p\ CO^2}\ K6$ .... (8)

Since K6 is temperature dependent only, it can be seen that the carbon activity can be calculated from the CO and CO_2 and since the CO is relatively constant, the CO_2 alone can be used.

We have already seen that the oxygen probe measures the small amount of oxygen in equilibrium with the CO and CO_2 which is according to the following reaction,

$2\ CO + O_2 \longleftrightarrow 2\ CO_2$ .... (9)

Combining reactions (6) and (9), and using the equilibrium constant to calculate carbon activity,

$ac = \dfrac{p\ CO}{p\ O_2^{\ 0.5}}\ K10$ .... (10)

Hence the oxygen probe can be used to determine the carbon activity of the atmosphere, and the carbon potential can be shown to be a function of carbon activity (ac), temperature and steel composition (q).

Therefore:

Cp = f (T, V, CO, q) ....(11)

Where
Cp is the Carbon potential (%)
T is the Temperature (K)
V is the Probe voltage (v)
CO is the Carbon Monoxide (%)
q is the Steel alloy factor

The dependence of carbon potential on the steel composition, can be explained by the fact that in the presence of alloying elements the effective carbon potential of the atmosphere is increased be elements which form more stable carbides than iron, i.e. Cr, Mo, whereas less strong formers, i.e. Ni, Si, decrease the effective carbon potential.

The complex mathematical calculations necessary to determine the Carbon potential of the atmosphere are built into most controllers. Probe voltage (mV) and temperature are input directly into the instrument, whilst the CO and alloy factors are combined as a constant for a given set of load conditions known as the “Process Factor” (PF), or CO factor, where:

$29\ (PF) + 400 = \dfrac{945.7}{CO}\ q$ .... (12)

From the above equation it can be calculated that for a plain carbon steel (q=1) processed in a methane generated Endothermic gas (CO = 20) the process factor will be 147. However, practical experience has shown that the process factor, under these conditions can vary between 150 and 250, dependent upon unique furnace conditions. An important aspect when determining the process factor is the cycle time, since it has been shown that the steel surface does not reach equilibrium with the gas atmosphere until 20 hours have elapsed. Therefore, if the carbon potential is controlled at 0.8%, the steel surface will have only reached 0.7% after 4 hours.

For non-equilibrium atmospheres or when the CO may be constant during a cycle, it is possible to input a CO value from an infrared analyser via the auxiliary input.

For absolute carbon control accuracy the process factor can be continuously updated based on the carbon potential calculated from a 3 gas (CO, CO_2, CH_4) ULTRACARB 1000 INFRARED SYSTEM. This system gives the absolute accuracy of 3 gas carbon calculation with the speed of response of oxygen probe control.

Heat Treatment

INDUSTRY

White paper

Atmosphere Furnace Control using the 3500 Controller/ Programmer

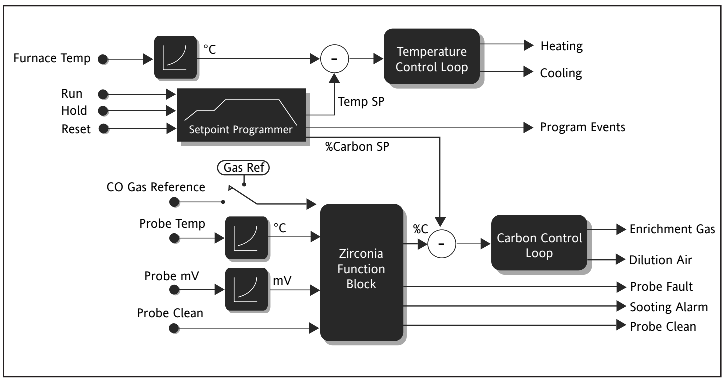
The 3500 is a fully programmable controller suitable for precision control of temperature, carbon potential, dewpoint and oxygen in atmosphere heat treatment applications.

It is capable of being used solely to control the carbon potential, dewpoint or oxygen in a furnace, or as an integrated furnace controller where any of these variables are controlled in conjunction with temperature. Additional features provide maths and combined logic functions.

At the heart of the controller is a specially designed function block capable of accepting most zirconia probes. Standard features include an automatic probe cleaning routine, a sooting alarm and diagnostics indicating that the probe is about to fail and should be replaced.

For standard solutions controllers can be configured with features and user screens as described in this application note.

User customisation can be achieved by reconfiguring the unit either via the front panel or the comprehensive PC based Eurotherm® iTools. A complete data sheet on the dual loop version of the 3500 is available HA029045.

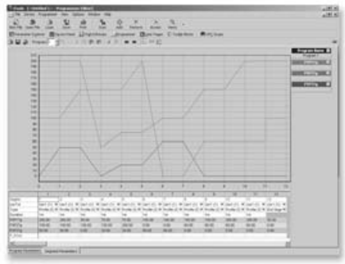


- Zirconia probe input
- Temperature
- Carbon, dewpoint or oxygen
- Probe cleaning
- Probe diagnostics
- Maths and logic
- Open communications

Temperature

- **50 Setpoint programs**
- **8 Program event outputs**
- **Simple program editing**

The 3508/04 user interface offers the user an extremely easy method of editing, selecting and running programs and all programs can be given a meaningful name. Its programmer functions are very advanced and can be easily interfaced to remote instruments. A simple programme user value labelled carbon is used to set CP setpoint in each segment program editing can be achieved using a PC running the iTools setpoint program editor.



iTools setpoint program editor

Standard screens provide the operator with an easy view of the programme running status including all those important features such as time remaining in segments and time remaining to end of programme.

Zirconia input

- **Compatible with most zirconia probes**
- **Carbon, dewpoint or oxygen**
- **Automatic probe cleaning**
- **Sooting alarm**
- **Probe impedance monitoring**

The 3508/04 can interface directly to most commonly available zirconia probes including Barber-Colman, Drayton, SSI, Marathon and Bosch Lambda.

The zirconia probe input can be configured to measure carbon potential, dewpoint or oxygen making the 3500 ideal for applications such as carburising furnaces and endothermic generators.

An automatic probe cleaning routine is available where either by a digital event or on a timed basis, an output is energised to perform a probe "burn off". While the burn off is in progress and during a timed recovery period the measured PV is frozen so that closed loop control can continue. Other control options during cleaning can be configured.

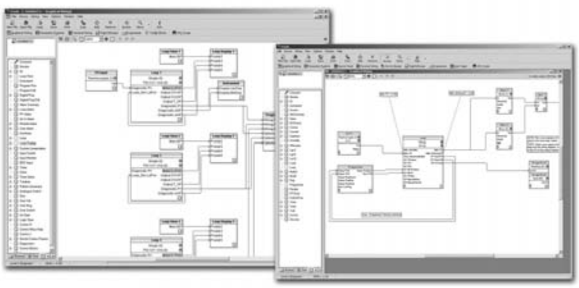
Diagnostic facilities are also included. A sooting alarm indicates that potentially soot is about to be deposited in the furnace. Continuous measurement of probe impedance and automatic monitoring of the probe recovery from cleaning ensures optimum furnace operation.

Application blocks and graphical wiring editor

- **Mathematical calculations**
- **Combination logic**
- **Real Time Clock**
- **Timing Functions**

Operators include; Add, Subtract, Log, Exp, SQRT, AND, OR, Max, Min, Select and many more.

Application blocks allow the user to create custom solutions by internally wiring analogue and digital operations together in flexible ways. Up to 250 soft wired connections are available to produce intelligent control strategies. Other functions are available including timers, totalisers and a real time clock.



iTools graphical editor

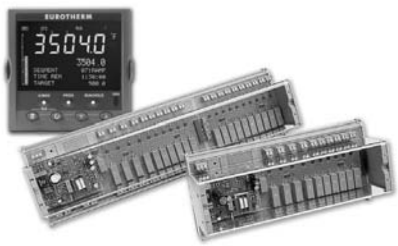
Atmosphere furnace control system

- **Furnace temperature**
- **Carbon potential**
- **Quench temperature and timing**
- **Digital control functions**

In combination with the I/O Expander the 3508/04 can be configured to provide a very powerful small control system for a heat treatment furnace.

Two versions of the I/O Expander are available one unit having 10 digital inputs and outputs and the second unit having 20 digital inputs and outputs.

In combination with the Graphical Wiring Editor this remote I/O can form part of the furnace strategy enabling links with other control items as well as furnace and quench system actuators and sensors.



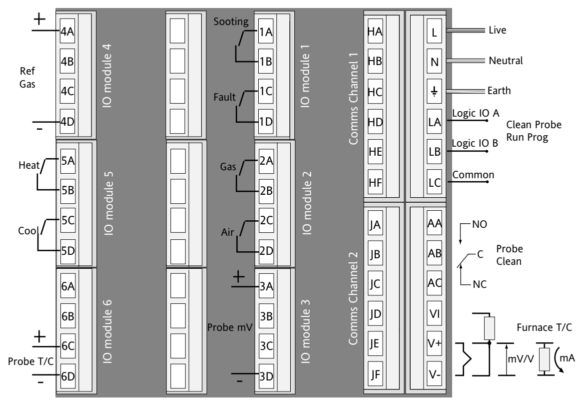
3508CP

When combined atmosphere/temperature solutions are not required customers may wish to consider the 3508 for independent temperature or atmosphere control applications.

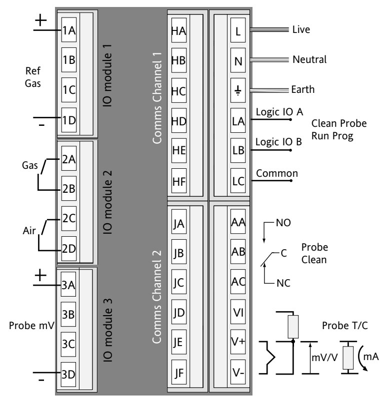
The 3508 retains all of the functionality of the 3504 and can be supplied into carbon - dewpoint and oxygen control and programming applications.

Rear terminal connections

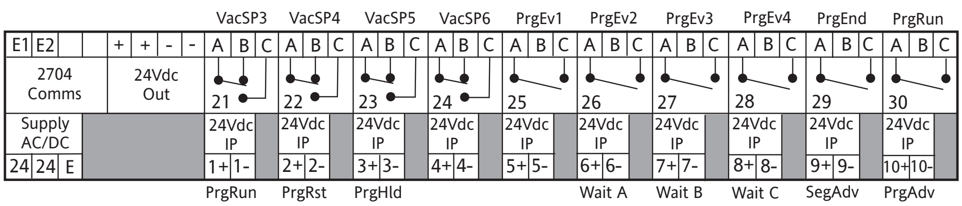
3504 Carbon/Temperature/Programmer



3508 Carbon/Control Programmer

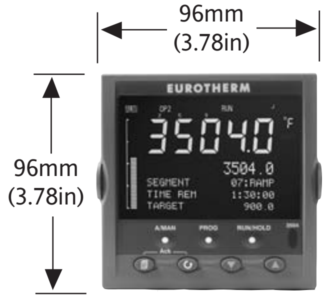


2000IO Expansion terminal connections

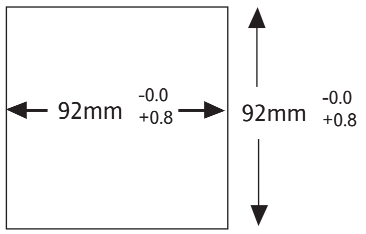


Dimensional details

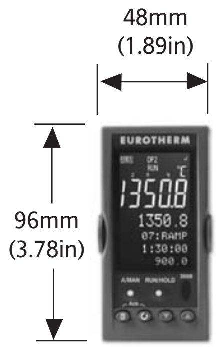
3504

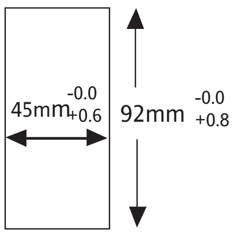


Panel cut-out

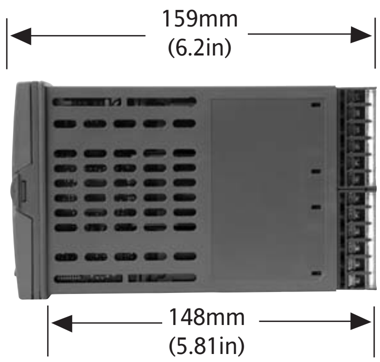


3508





3504/08



Heat Treatment

INDUSTRY

- **Zirconia probe input**
- **Temperature**
- **Carbon, dewpoint or oxygen**
- **Probe cleaning**
- **Probe diagnostics**
- **Maths and logic**
- **Open communications**

Atmosphere Furnace Control using the 2704 Controller/Programmer

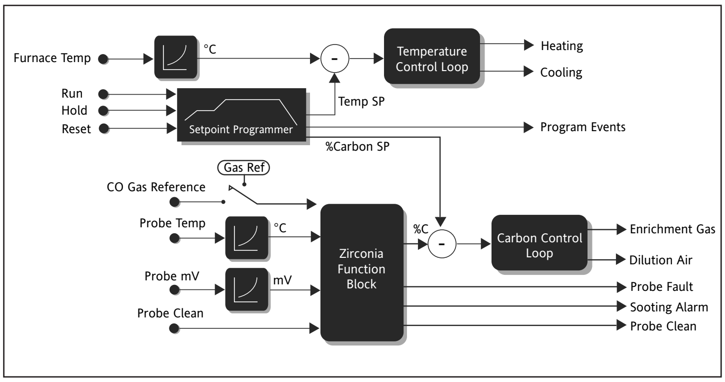
The 2704CP is a fully programmable controller suitable for precision control of temperature, carbon potential, dewpoint and oxygen in atmosphere heat treatment applications.

It is capable of being used solely to control the carbon potential, dewpoint or oxygen in a furnace, or as an integrated furnace controller where any of these variables are controlled in conjunction with temperature. Additional features provide maths and combined logic functions.

At the heart of the controller is a specially designed function block capable of accepting most zirconia probes. Standard features include an automatic probe cleaning routine, a sooting alarm and diagnostics indicating that the probe is about to fail and should be replaced.

For standard applications, controllers are shipped pre-configured to the users specification, using a simple to complete order code. User customisation can be achieved by reconfiguring the controller via its front panel interface or the Eurotherm® iTools configuration software.

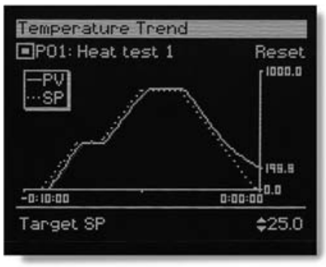
The 2704CP is fully compatible with the standard 2704 process controller which is capable of up to three PID control loops; data sheet number HA026669.



White paper

Temperature

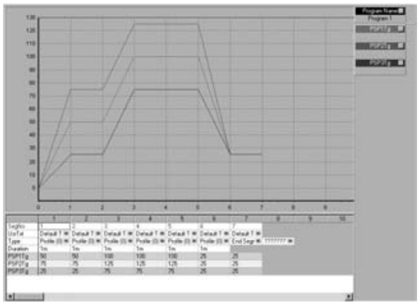
- **50 Setpoint programs**
- **16 Program event outputs**
- **Simple program editing**
- **Program graphical display**
- **Trend view of PV and SP**



Trending enables the user to view, both current and historical information on the process on the process variable and setpoint of each control loop.

The 2704 user interface offers the user an extremely easy method of editing, selecting and running programs and all programs can be given a meaningful name. Its programmer functions are very advanced and can be easily interfaced to remote instruments including specialised Mass Flow controllers. Program editing can be achieved using a PC running the iTools setpoint program editor.

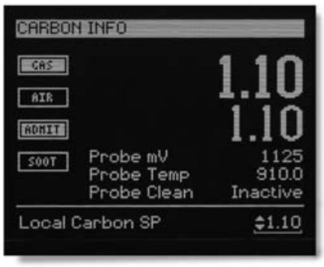
Trending enables the user to view, both current and historical information on the process on the process variable and setpoint of each control loop.



iTools setpoint program editor

Zirconia input

- **Compatible with most zirconia probes**
- **Carbon, dewpoint or oxygen**
- **Automatic probe cleaning**
- **Sooting alarm**
- **Probe impedance monitoring**



The 2704CP can interface directly to most commonly available zirconia probes including Barber-Colman, Drayton, SSI and Marathon.

The zirconia probe input can be configured to measure carbon potential, dewpoint or oxygen making the 2704CP ideal for applications such as carburising furnaces and endothermic generators.

An automatic probe cleaning routine is available where either by a digital event or on a timed basis, an output is energised to perform a probe “burn off”. While the burn off is in progress and during a timed recovery period the measured PV is frozen so that closed loop control can continue. Other control options during cleaning can be configured.

Diagnostic facilities are also included. A sooting alarm indicates that potentially soot is about to be deposited in the furnace. Continuous measurement of probe impedance and automatic monitoring of the probe recovery from cleaning ensures optimum furnace operation.

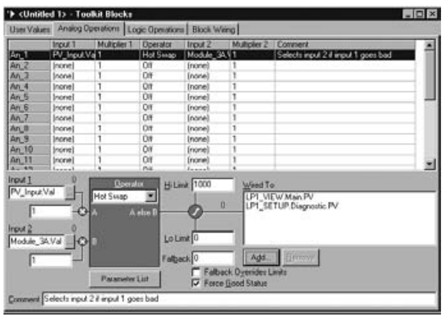
Toolkit functions

- **Mathematical calculations**
- **Combination logic**
- **Real Time Clock**
- **Timing Functions**

Operators include;

Add, Subtract, Log, Exp, SQRT, AND, OR, Max, Min, Select and many more

Toolkit blocks allow the user to create custom solutions by internally wiring analogue and digital operations together in flexible ways. 24 analogue and 32 digital operations are available. Other functions are available including timers, totalisers and a real time clock.



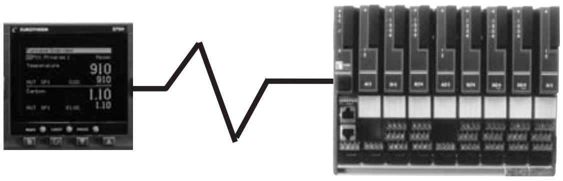
iTools toolkit block editor

Atmosphere furnace control system

- **Furnace temperature**
- **Carbon potential**
- **Quench temperature and timing**
- **Digital control functions**

In combination with the 2500DIN rail controller, a very powerful and low cost vacuum furnace system can be implemented. The 2704CP acts as the master temperature/carbon programmer and user interface for the 2500. A typical use of the 2500 could be to implement additional control loops such as quench oil and control the logic and timing functions of the furnace.

The 2500 can measure up to 32 thermocouple inputs, fully isolated to 250Vac potential. A strategy within the 2500 can monitor all thermocouples to detect the minimum value, which can then be sent via digital or analogue communications to the 2704CP to be used as a wait condition, ensuring temperature uniformity within the furnace and provide a guaranteed soak.



2500 Controller

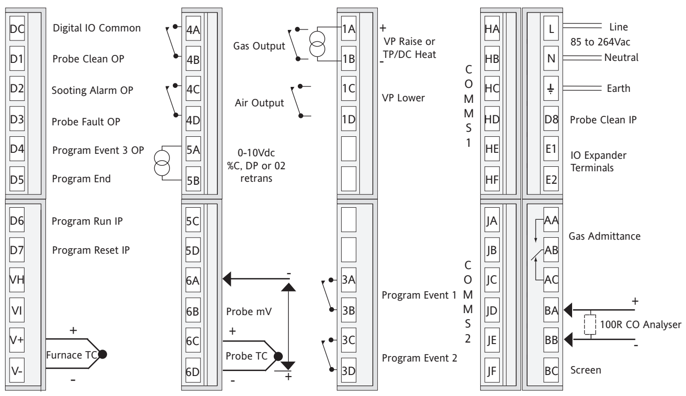
2604CP

A 2604CP is also available. Its display incorporates a 2 line 5 digit display for dislay of setpoint and process value, plus an LCD text panel that the operator uses for entry of program data and other parameters.

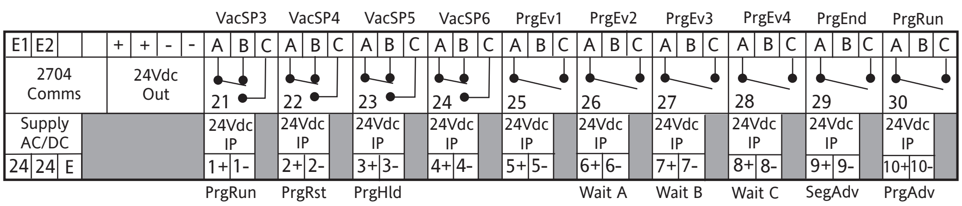
The 2604CP is functionally capable of performing the same control strategy as the 2704CP. However, the customisable display of the 2704CP significantly simplifies the user interface for the operator.

Rear terminal connections

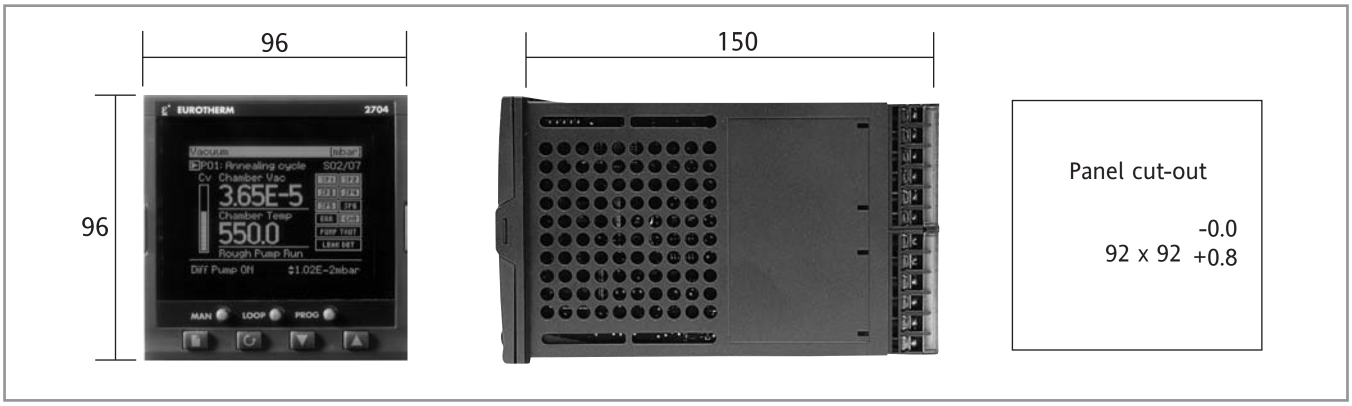
Notes:-
1) Modules 1 and 3 only present with temperature.
2) IO functions can be reconfigured by user.



2000IO Expansion terminal connections



Dimensional details



Heat Treatment

INDUSTRY

Creep Testing Furnace

Application Note

Application note

To meet the demands of specific applications, steels and alloys are produced in a wide variety of material structures.

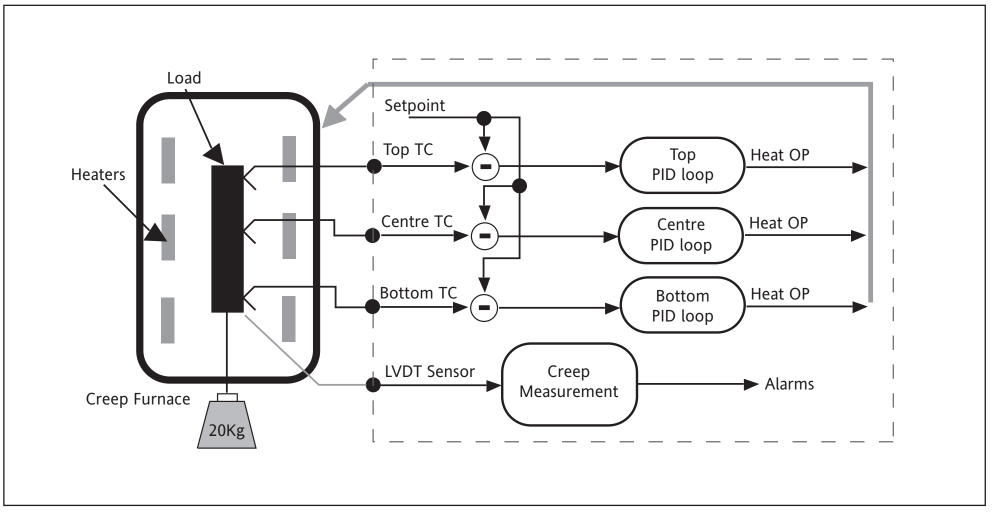
In order to evaluate the suitability of individual batches of material for any particular application samples may undergo a number of destructive and non-destructive tests. Creep testing is one method of material evaluation which is widely used in the following markets:

- Aerospace and Automotive
- Iron and Steel raw material
- Ordnance
- General Engineering

The "Creep Test" is performed on an alloy sample to determine material structure and evaluate its stress characteristics. In very simple terms, a sample is heated to a material dependent stable temperature between 300°C and 1200°C. A load is then applied to the sample to exert a longitudinal force on the grain structure of the alloy. The sample is maintained in this state for the period of the test or until the component ruptures. During the test, data is continuously monitored and recorded to qualify the stability of the temperatures, loading and sample extension. It is important to maintain tight control of the temperature across the entire sample with 0.2 degrees centigrade being typical for the sample uniformity tolerance. To achieve this many furnaces employ highly accurate control devices with three zones of heating. Tests may run for many months and occasionally years, it is important therefore that control systems are designed to accommodate power fail and abort strategies which will allow tests to be continued after unplanned interruptions.

Large creep laboratories may have several hundred furnaces, carrying out simultaneous testing of samples. The results from the tests form part of the audit trail of data for eventual components and for convenience many users rely on communicating control systems to provide automation to the process of data management:

- Isolated thermocouple inputs
- Easy adjustment of Setpoint
- Power fail and recovery routines
- Long term process stability
- Measurement of "creep" and detection of sample break
- Digital communications and Data management solutions



In a typical Eurotherm® multi loop solution the master loop controls the temperature at the centre of the sample with two slave loops controlling the top and bottom zones. User wiring is employed to ensure the working setpoint for the master loop is also used by the slave loops. Temperature is measured by thermocouples attached to the samples. Heating control is most often via a solid state relay.

Creep (or strain), can be taken into the control system either via an analogue input from a suitable transducer or through master communications from other digitally communicating devices.

The control system can also access digital inputs and outputs to detect sample rupture and to control and monitor load beam leveling.

Eurotherm® in the Raw Materials Metals Industry

For over 40 years Eurotherm® have been supplying solutions into the raw materials metals industry.

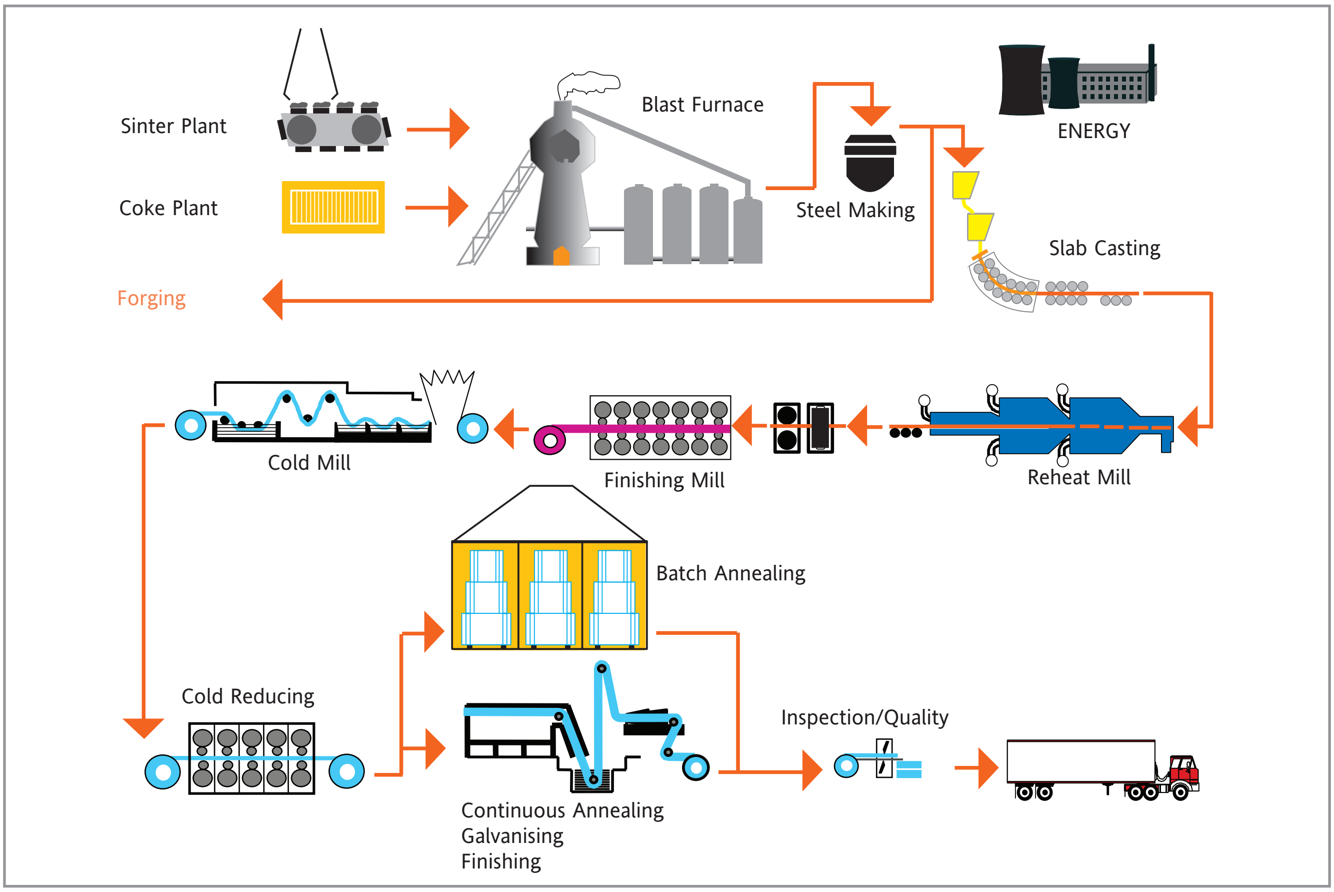
Our global network of companies have an impressive installed base across the ferrous and non-ferrous sectors, providing control systems and business system software over the widest range of process applications.

Solutions are developed to bring benefits to our customers from the considerable strengths Eurotherm have in continuous control and vertical business integration.

As a world renowned provider of process control systems, our goal is to work in long-term partnership with customers to add success to their business by working with them in the following areas:

- Increased process efficiency
- Reduced cost of ownership
- Meeting the requirements of regional and global legislation
- Improved product quality
- Improved energy efficiency
- Dependable systems partner
- Worldwide presence
- Excellence in automation and control
- Complete life cycle support

The following diagram shows the typical application focus Eurotherm have in the steel industry.



Steel process flow diagram

Heat Treatment

INDUSTRY

- **Burner modulation**
- **Air/fuel cross-limiting**
- **Regulation of excess air**
- **Oxygen trim**
- **Total heat control**

Modulating Burner Combustion Control for Heat Treatment Furnaces

Application Note

Fossil fuel burners are often used as the principle medium for delivering energy to industrial furnaces and ovens.

Increasing focus on reducing energy costs has led manufacturers to concentrate on new burner design techniques and important advances in efficiency gains have been made over the years. Burner management and control systems must be equally adaptive.

Eurotherm® provide efficient, well implemented control techniques capable of reducing operating costs whilst providing resources for greater flexibility in plant management and control. Burner combustion generally includes one or a combination of the following methods:

- Regulation of excess air
- Oxygen trim
- Burner modulation
- Air/fuel cross-limiting
- Total heat control

Excess air regulation

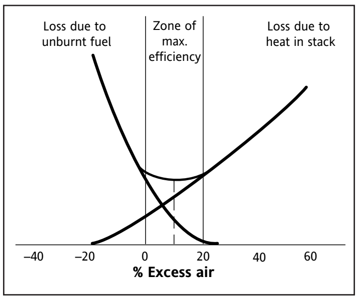


Figure 1 Boiler efficiency

In actual practice, gas, oil, coal burning and other systems do not do a perfect job of mixing the fuel and air under the best achievable conditions. Additionally, complete mixing may be a lengthy process. Figure 1 shows that in order to ensure complete combustion and reduce heat loss, excess air has to be kept within a suitable range.

The regulation of excess air provides:

- A better furnace heat transfer rate
- An ‘advance warning’ of flue gas problems (excess air coming out of the zone of maximum efficiency)
- Substantial savings on fuel

Application note

Oxygen trim

When a measurement of oxygen in the fuel gas is available, the combustion control mechanism can be vastly improved (since the percentage of oxygen in the flue is closely related to the amount of excess air) by adding an oxygen trim control module, allowing:

- Tighter control of excess air to oxygen setpoint for better efficiency
- Faster return to setpoint following disturbances
- Tighter control over flue emissions
- Compliance with emissions standards
- Easy incorporation of carbon monoxide or opacity override

Burner modulation

Modulation control is a basic improvement in controlling combustion. A continuous demand signal is generated by a controller monitoring the furnace atmosphere.

Reductions in temperature lead to an increase in firing rate. The advantages of introducing burner modulation in combustion control include:

- Fuel and air requirements are continuously matched to the combustion demand
- Furnace temperature is maintained within closer tolerances
- Greater furnace efficiency
- Weighted average flue gas temperature is lower

Air/fuel cross-limiting

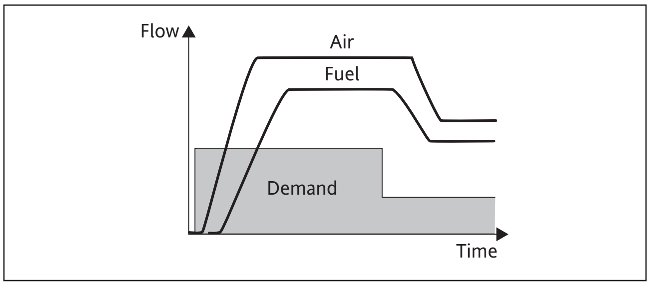


Figure 2 Cross-limiting combustion mechanism

A cross-limiting combustion control strategy ensures that there can never be a dangerous ratio of air and fuel within a combustion process. This is implemented by always raising the air flow before allowing the fuel flow to increase, as shown in Figure 2, or by lowering the fuel flow before allowing the air flow to drop.

Figure 3 depicts a simplified control block diagram of the cross limiting combustion circuit. Combination firing of multiple fuels simultaneously can also be easily accommodated within the scheme.

Cross-limiting combustion control is highly effective and can easily provide the following:

- Optimisation of fuel consumption
- Safer operating conditions by reducing risk of explosion
- Fast adaption to variations in fuel and air supplies
- Satisfaction of the plant demand for steam

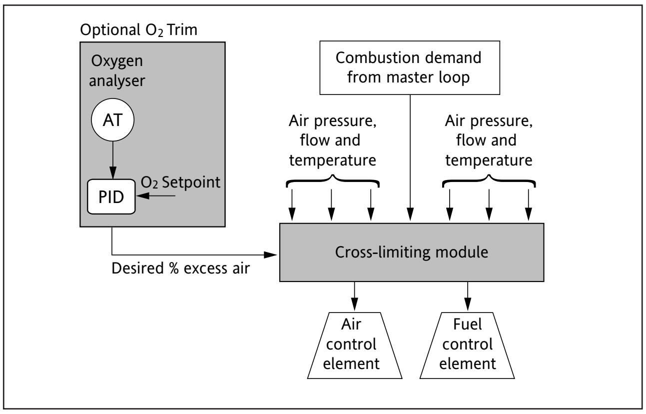


Figure 3 Cross-limiting combustion control with 06 trim

Enhanced cross-limiting

Double cross-limiting combustion control is an enhancement to the above. It is achieved by applying additional dynamic limits to air and fuel setpoints. This translates to having the actual air/fuel ratio maintained within a preset band during and after transition. This method protects against having the demand signal driving the air/fuel ratio too lean, therefore reducing heat loss.

Close coupled control

Most heat treatment processes require accurate control of the material temperature. With the advent of fast acting burners and burner control systems it is easy to implement very responsive cascade control to the furnace.

In this mode the burner is held under tight temperature control from a sensor very closely coupled to the delivered energy. The closely coupled slave loop responds to the demands of the master loop where the sensor is located within the work-piece. In this way the furnace can be completely optimised to the needs of both burner dynamics and the work-piece requirements giving maximum efficiency and guaranteed thermal processing.

HR084054U008

Heat Treatment

INDUSTRY

- Sinter handling
- Mixing drum moisture control
- Hood temperature and pressure control
- Calorific value control of ignition hood fuel gas
- Burn-through point control
- Main fan suction and waste gas overtemperature control
- Cooler speed control

Sinter Plant
Application Note

The function of the Sinter Plant is to supply the blast furnaces with sinter, a combination of blended ores, fluxes and coke which is partially 'cooked' or sintered. In this form, the materials combine efficiently in the blast furnace and allow for more consistent and controllable iron manufacture. Figure 1 shows a simplified diagram of a sinter plant.

Materials enter the sinter plant from storage bins. They are mixed in the correct proportions using weigh hoppers, one per storage bin, except for the return fines for which an impact meter is used instead. Weighing is continuous, as is the whole sintering process. The weighed materials pass along a conveyor to the mixing drum where water is added either manually or as a calculated percentage of the weight of material entering the drum.

The moisture content of the coke is measured in the strand roll feed hopper and used to trim the secondary water flow rate. The mix permeability is also measured and used to modify the amount of water required.

The mix material is fed onto the strand from the hopper by a roll feeder. The bed depth is set and kept constant by adjusting the cut-off plate which is fitted with probes to sense the depth of material and automatically vary the roll feeder speed. The quantity of material in the feed hopper itself is held constant by automatic adjustment of the feed rates from the individual raw material bins.

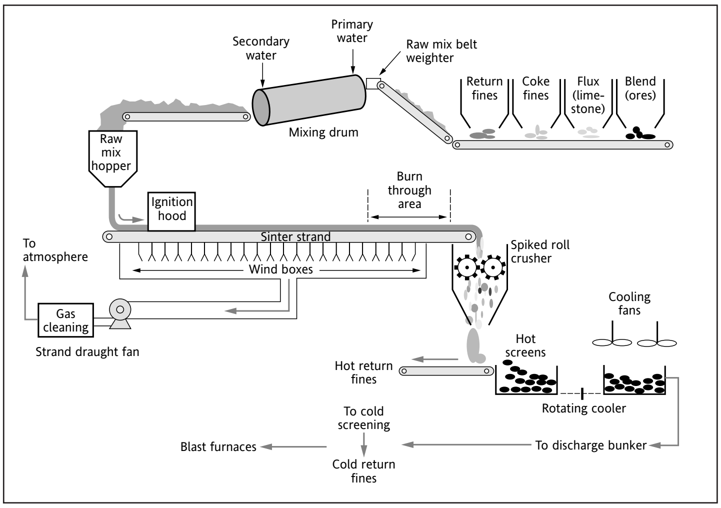


Figure 1 Simplified diagram of a sinter plant

Application note

Sintering

The raw mix is ignited by the ignition hood, which is fuelled by a mixture of coke oven gas, blast furnace gas and sometimes natural gas. The calorific value of the mixture and the set hood temperature are controlled. A separate control system is provided to maintain a fixed hood pressure by adjusting the windbox dampers immediately under the ignition hood.

The sinter strand is a moving conveyor of hot sinter, which continues to 'cook' after leaving the hood, where air is pulled from the sinter by a strand draught fan.

An important part of the sintering process is burn-through. This is where the sinter layer has completely burned through its section and is detected by temperature probes under the sinter bed. Burn through should be achieved but must not occur too soon after the ignition hood. The draught on the strand is maintained at a preset value by controlling the main fan louvers from pressure measurements in the wind main. This governs the point at which burn through occurs.

Sinter handling

After the end of the strand, the sinter passes through a spiked roll crusher and the hot screens to the rotating circular cooler. A number of fans are usually used for cooling, and the speed of the cooler is determined by:

- Strand speed
- Bed depth

The fines removed by the hot screens are conveyed to the return fines bin.

After cooling, the sinter is passed into the discharge bunker. At this stage, the level is controlled by varying the outlet feed rate (usually vibros).

The sinter then passes to the cold screening area, where it is passed through crushers and screens to produce particles in a specific size range. Sinter below the required size passes over a belt weigher and returns with the hot fines to the return fines bin.

The difference between the weight of the cold fines, and the weight of the total fines produced, gives a measure of the hot fines. Any abnormal variation in the rate of production of hot or cold return fines indicates a possible plant fault.
The following factors can affect the rate at which fines are produced:

- Mix control
- Particle size
- Chemistry
- Weight
- Moisture content
- Bed depth
- Ignition hood temperature and pressure
- Warm screens

Two important properties of sinter are basicity, which is controlled by the amount of limestone, and strength, which is controlled by coke content.

The sinter is now suitable for use in the blast furnace. Conveyors transport the material to the blast furnace stock house, where it is added to other materials to form the blast furnace burden.

Mixing drum moisture control

The amount of primary water added is proportional to the weight of raw mix entering the mixing drum. This can be easily achieved using a Eurotherm Process Automation control module as shown in Figure 2.

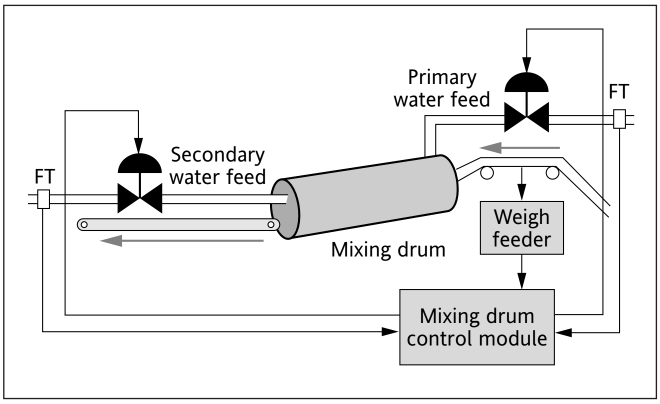


Figure 2 Mixing drum moisture control

The secondary water feed setpoint is frequently taken as a proportion of the raw mix belt weigher PV. For greater accuracy, the moisture meter reading is used to trim the material/water ratio. This corrects the water flow rate according to the measured moisture content of the raw mix.

Cascade control is not always used but since the water flow loop responds faster than the moisture loop it does produce better results.

Ignition hood temperature control

Figure 3 depicts the implementation of ignition hood temperature control with options for the control ratio.

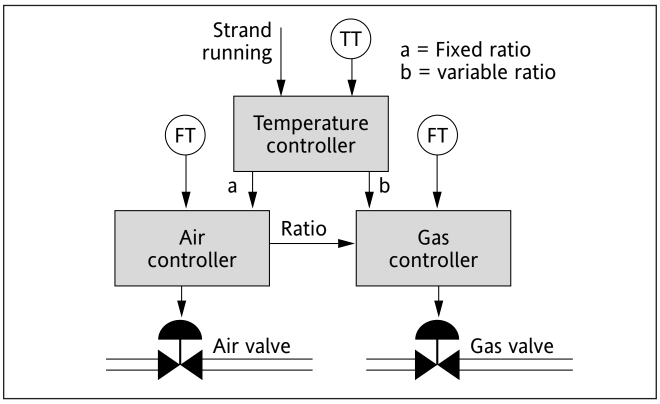


Figure 3 Ignition hood temperature control

With the fixed ratio air lead temperature control, the temperature demand provides a setpoint for the air flow. The fuel follows the air flow in a fixed ratio making this a fuel efficient method.

On the other hand, with variable ratio air lead temperature control, the air flow is fixed and the hood temperature controller output (the heat demand signal) feeds the ratio setpoint trim input of the gas controller. This method is normally used when there is a readily available source of cheap fuel e.g. blast furnace gas.

Ignition hood pressure control

This is normally achieved by varying the setting of dampers in the windboxes under the ignition hood. A single loop PID controller is generally used to automatically maintain the pressure at a desired value.

Calorific value control of ignition hood fuel gas

Blast furnace gas and coke oven gas are used to fuel the ignition hood burners. The calorific value of the fuel is controlled to a consistent value by a separate control loop. If the strand stops, a digital signal forces the ignition hood into a 'low fire state' and holds it there until the strand re-starts.

It is easier to keep the ignition hood temperature constant if the calorific value of the fuel is controlled to within pre-defined limits, about 4,000 - 6,000 kJ/m3. By mixing coke oven gas with blast furnace gas, this calorific value is achieved. Figure 4 shows the calorific value control strategy.

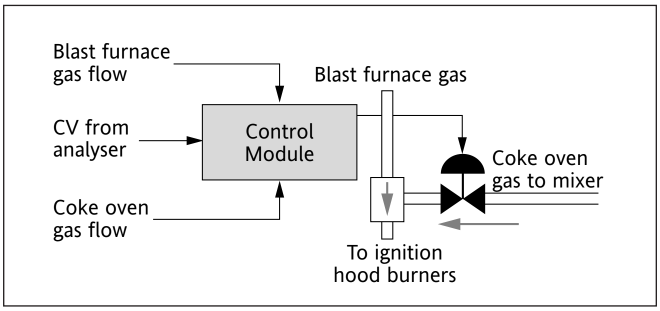


Figure 4 Calorific value control of ignition hood fuel gas

Burn-through point control

Burn-through point should ideally occur near the end of the strand bed. It is controlled by altering the strand speed. A number of variables will affect the burn-through point, such as strand bed depth, water content and the quality of the sinter.

The strand speed is either controlled manually, or by measuring the waste gas temperatures as an indication of the burn-through point. If it occurs too early, the average waste gas temperature rises. If it occurs too late, the waste gas temperature decreases and the strand speed is slowed to compensate.

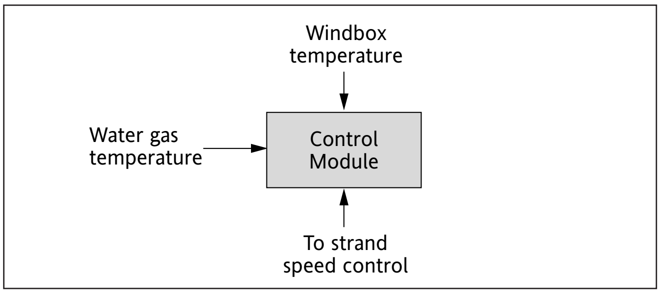


Figure 5 Burn-through point control

Windbox temperatures can be used to improve the monitoring and are added as a setpoint bias. Figure 5 shows this in the control strategy.

Main fan suction and waste gas overtemperature control
The suction produced by the main fan is varied by louvers near the fan inlet, which are controlled by a fan suction controller. If the waste gas temperature increases above a safe working limit a selector switch allows the waste gas overtemperature controller to position the louvers.

Cooler speed control
After leaving the strand, the hot sinter is cooled on a rotary cooler. The speed of the rotary cooler is controlled to match the strand demand defined by the bed depth and the strand speed.

For information on this application or to review other Heat Treatment applications available from Eurotherm®, please visit our website at www.eurotherm.com or contact us directly as detailed over the page.

HR084054U005

Heat Treatment
INDUSTRY

- Blast furnace construction
- Chemical & physical aspects of iron making
- Monitor burden passage
- Stoves
- Gas enrichment
- Oxygen enrichment of cold blast
- Stoves combustion control
- Hot blast temperature control
- Tuyere flows control

Blast Furnace and Stoves
Application Note

Blast furnace

The blast furnace area provides the raw material for steel-making. Iron produced in the blast furnace contains a high proportion of carbon, typically 4%, and lacks any of the additives needed to give the steel its various special properties.

Chemical & physical aspects of iron-making

Figure 1 shows a schematic of a blast furnace and indicates the chemical reactions which take place in each area. This section discusses the physical properties of the materials at each stage of the iron-making process, and considers the conditions which encourage the chemical reactions.

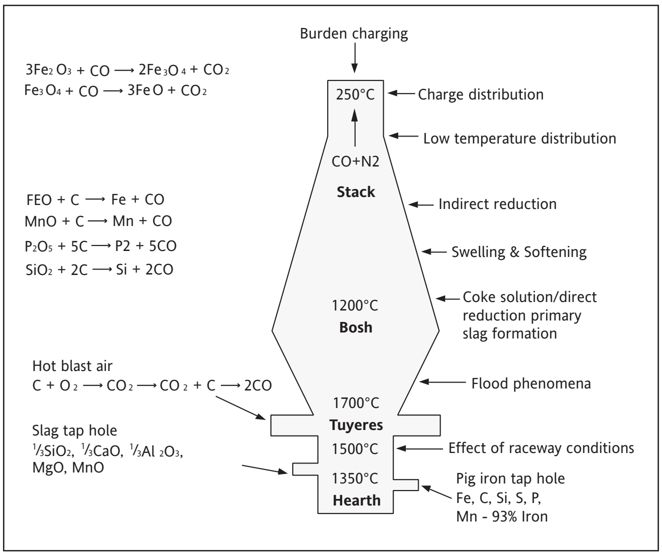


Figure 1 Blast furnace

Monitor burden passage

The furnace is charged with sinter pellets and rubble ore (iron-bearing materials), flux and coke. Conventionally, the materials are charged through a rotating hopper distributor and two-bell system, although many modern furnaces have the Paul Wurth bell-less top which uses a rotating chute. Correct distribution at the furnace top is achieved by controlling the feed rate and the order in which the materials are fed in.

At the top of the blast furnace stack, indirect reduction of the iron ore by carbon monoxide takes place:

$$3Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO_2$$
$$Fe_3O_4 + CO \rightarrow 3FeO + CO_2$$

The iron-bearing ore and pellets then undergo low temperature breakdown, where the particle size is broken down. With some grades of ore, this can result in a large amount of fine material, which causes poor aerodynamic characteristics in the stack. It may fluidise and the furnace will not then ‘drive’ efficiently, causing output to drop.

At the bottom of the furnace, stack temperatures exceed 900-1000°C and the iron-bearing material can swell up, again causing low output, particularly when sinter pellets are used.

Application note

When the iron is hot enough to soften, two more reactions begin; carbon *solution loss*

$C + O2 \rightarrow CO2$
$CO_2 + C \rightarrow 2CO$

and *direct reduction*

$FeO + C \rightarrow Fe + CO$
$MnO + C \rightarrow Mn + CO$
$P_2O_5 + 5C \rightarrow P_2 + 5CO$
$SiO_2 + 2C \rightarrow Si + 2CO$

The best coke rate conditions are when maximum indirect reduction has taken place and before direct reduction begins. This is achieved by correct charge distribution and by using materials that are easy enough to reduce.

As softening progresses and the rate of reaction between coke and iron oxide increases, *primary slag formation* starts.

The final result of the movement of material through the furnace is the accumulation of molten iron and slag in the furnace hearth. Slag is the less dense material and it floats on the surface of the iron. There are tapholes or 'notches' at different heights in the hearth, so the iron and the slag can be tapped off separately through channels in the cast house floor.

Once solid, the slag takes the form of volcanic-like rock, and is sold mainly as infill material. The iron is now ready to be sent to the steel plant for further chemical processing (see Steel making application note).

Stoves

The hot blast air is produced by passing cold blast air through preheated chambers or 'stoves', and heating the air to above 1000°C.

The stove is first heated up by burning gas and combustion air within the chamber and allowing the heat to be absorbed into the brickwork, or 'chequerwork'. This mode is called *on-gas*. When sufficient heat has been absorbed, the stove is put *on-blast*. In this mode, no combustion takes place, but cold blast air is forced through the stove and absorbs the heat to become hot blast. This is then mixed with cold blast to bring it to the right temperature, and is then forced into the blast furnace via the tuyeres near its base, as shown in Figure 2.

It is quite common to have three or four stoves, so that at any time one stove is on-blast while the others are on-gas or *boxed*. A boxed stove has been heated up to temperature and sealed, so that it is ready to go on-blast. If one stove is down for repair, it is possible to run on just two stoves.

Stove changeover

Figure 2 shows the layout of a typical stove system. The procedure for changing over from one stove to another is as follows:

- assume stove 2 is on-blast and stove 1 is heated up and boxed ready for use
- valve 1 of stove 1 is opened first, allowing cold blast into the stove to pressurise it
- valve 2 of stove 1 is opened, so that stoves 1 and 2 are now on blast
- stove 2 now comes off blast by shutting valves 1 and 2 of stove 2

Stove 2 is now put on-gas, to heat up again, now that its stored energy has been used. Valves 3 and 4 of stove 2 are opened during this stage, allowing gas and air to enter the stove, and the waste gases to leave once the gas has been burned. When the stove is up to temperature these valves are closed again, leaving the stove boxed.

Gas enrichment

The waste gas produced by the furnace is used as fuel in many areas of the steel works. Generally, however, its calorific value is very low and it requires the addition of natural gas and/or coke oven gas.

Figure 3 shows a typical control scheme, where the blast furnace gas flow rate is inferred by subtracting the natural gas and coke oven gas flow rates from the total mixed gas flow rate. This calculated value is then used as a ratio setpoint for the natural gas and coke oven gas control blocks, keeping the proportion of each type of gas entering the stove constant and achieving the desired calorific value of the total mixed gas.

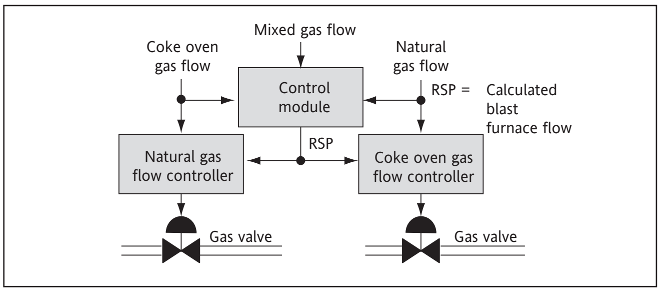


Figure 3 Gas enrichment control

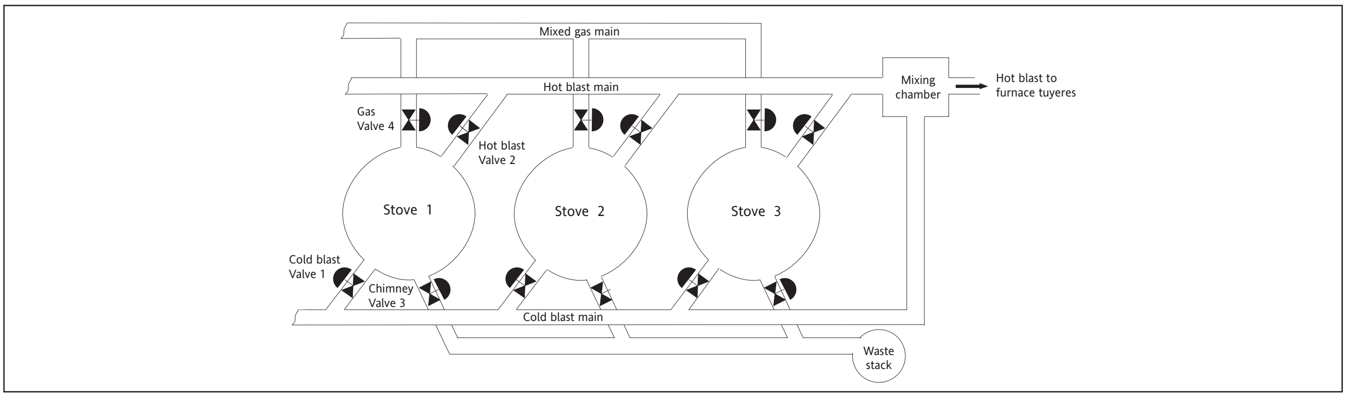


Figure 2 Stoves schematic

Oxygen enrichment of cold blast

It has been proven that a small increase in the oxygen content of the cold blast, to 22-24% instead of the 21% O_2 content of normal air, improves the efficiency of the furnace.

The control scheme includes O_2 analysis and independent shutdown equipment, but only the controller and its I/O will be discussed here. Figure 4 shows a schematic for this part of the process.

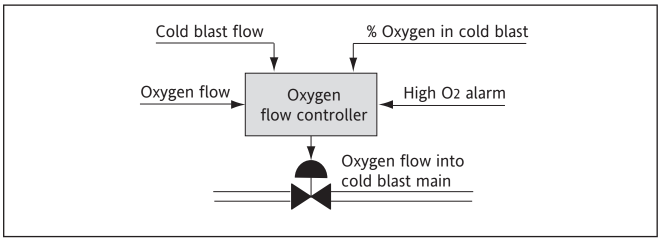


Figure 4 Oxygen enrichment of cold blast

The cold blast flow is measured and oxygen is injected into the main, controlled by a ratio control block with the control blast flow as a ratioed PV. The actual O_2 content of the cold blast is also measured, and this signal is used to trim the ratio of the oxygen to the cold blast, maintaining a constant value.

When a high O_2 alarm is activated, the usual requirement is that the O_2 control valve is immediately closed. Additional and separate alarm circuitry shuts the isolation valves. The control valve closes due to the track action of the controller.

Stoves combustion control

Three control modules are required in order to achieve the following:

- dome temperature control
- air flow control
- gas flow control

The gas flow into the stoves is measured and controlled to a local setpoint. The gas flow reading is used as a setpoint for the air flow ratio controller. The combustion control mechanism is similar to the one described in the Soaking Pits Application Note.

The O_2 reading trims the air/fuel ratio, until the dome temperature nears its required value - then the dome temperature controller output replaces the O_2 trim signal activated by the dome controller high target temperature. This action increases the air flow to the stove, while keeping the gas flow constant. This mode is known as excess air, and has the effect of increasing the heat distribution in the stove while cooling the stove dome. A steady temperature is maintained within the stove, and the heat is absorbed into the chequerwork.

This on-gas phase continues until the stove has absorbed enough heat, when it can be boxed or put back on blast.

Hot blast temperature control

After leaving the stoves, the hot blast enters the base of the blast furnace via the tuyeres. It passes up through the furnace, reacting with the coke, ores and fluxes, and emerges as top gas, containing mainly CO and CO_2. The upwards pressure from the gases supports the burden, so that there is a pressure drop of 1.4 bar across the burden, irrespective of the top gas pressure. With this pressure difference, the furnace permeability is good - i.e. the materials move downwards through the furnace at the right speed.

The hot blast temperature needs to be kept constant, to maintain good furnace efficiency. The temperature of the hot blast leaving the stove decreases as the stove cools down, so to achieve a constant temperature the hot blast is mixed with cold blast in the mixing chamber (see Figure 2).

The proportion of hot to cold blast is controlled by a control module which also throttles the cold blast to the stoves. As the stove's energy is used up, the hot blast temperature falls, and the amount of cold blast which is mixed with it is decreased. The flow of cold blast into the stove is also reduced, so that the gases spend longer in the stove to absorb the heat.

The hot blast temperature control scheme is depicted in Figure 5.

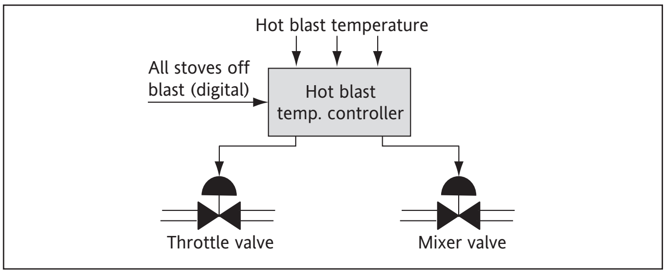


Figure 5 Hot blast temperature control

Tuyere flows control

The hot blast air and natural gas are injected into the blast furnace through tuyeres distributed around the perimeter, typically 24 or 36 off.

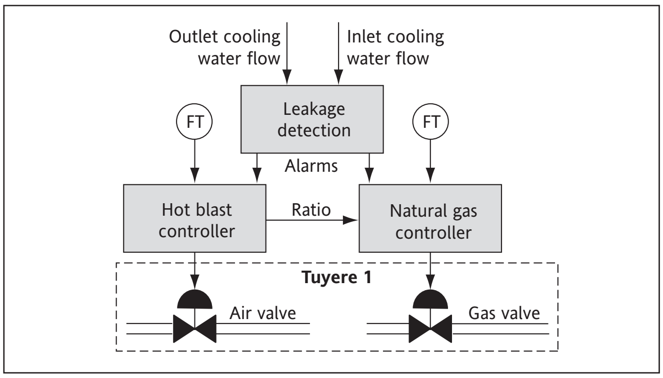


Figure 6 Tuyere control

Whilst the overall natural gas flow is ratioed to the cold blast flow, each individual tuyere also has natural gas to hot blast air ratio control. Figure 6 illustrates the use of one control module to ratio the natural gas flow to hot blast air for one tuyere.

Additional analogue inputs are used to check for water leakage within the tuyere by comparing inlet and outlet water flows.

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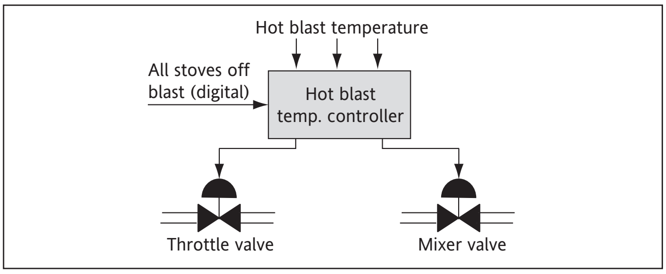

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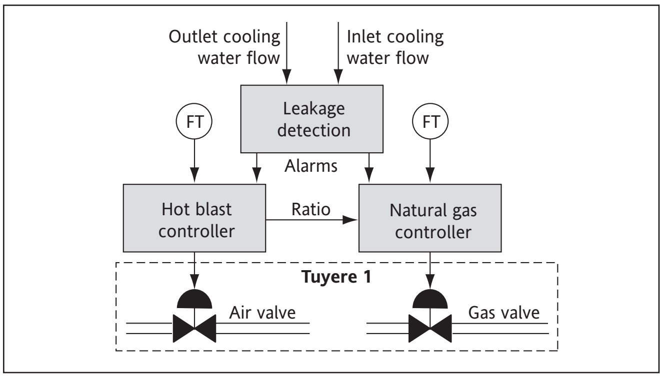

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Additional analogue inputs are used to check for water leakage within the tuyere by comparing inlet and outlet water flows.

HR084054U004

Heat Treatment

INDUSTRY

Blast Furnaces Gas Flare Application for the Eurotherm® Visual Supervisor

Application Note

- **Controlled pressure in the blast furnace**
- **Reduced gas emissions**

Following its enormous success with packaged applications such as electrode breakage detection for the glass industry and automation of the sterilisation process for hospitals, the Eurotherm® Visual Supervisor has now demonstrated its potential in the steel industry with it's recent integration in a gas flare control system for a blast furnace.

The system consists of a flare tip located on top of a stack and is equipped with six circumferentially mounted natural gas pilot burners each monitored by one thermocouple. The main flame being itself monitored by four thermocouples or infrared sensors.

During normal flaring operations, the blast furnace gas pressure is controlled. Any increase is relieved by flaring the excess gas.

The application includes a pressure loop and a flow loop sharing one unique analogue output. The functionality is such that when the system is under pressure control, the flow loop output tracks the active control loop output. When flow control is selected, the pressure loop enters Track mode.

Under normal conditions, the operator has a choice of controlling either the gas pressure or the gas flow. Interlocking sequence permitting, the above is carried out by using the appropriate soft-key button on the Visual Supervisor mimic. An automatic switchover dictated by various furnace conditions is also built-in.

Pilot burner monitoring

There are six pilot burners on the stack, continuously lit during operation. All six are provided with a thermocouple to monitor their status. Any failure (temperature reading below 100°C – adjustable) produces an alarm and should any four from six fail, then the flaring system is automatically shut down. Flaring is restarted once three or more pilot burners are operational.

Main flame detection

The main flame status is monitored by four thermocouples. Any failure produces an alarm. If none of the thermocouples succeed in detecting a temperature higher than a preset value, within an adjustable ignition time from asking for flaring, the control valve is automatically closed.

If the blast furnace gas pressure is still higher than the setpoint, the control valve is released again for automatic control. The main flame detection is attempted a certain number of times and following a total failure, the controller is then locked out for 20 minutes (adjustable) with the control valve held at 0%. Flaring is now inhibited.

Coupled with features such as trending, logging, reporting, messaging, batch handling and barcode reading, the Visual Supervisor is proving itself as one of Eurotherm's strongest unit solutions.

Please refer to Eurotherm's Blast Furnace and Stove Application Note HR084054U004 for more information on the processes involved in metal manufacturing.

Application note

HR084054U007

Heat Treatment

INDUSTRY

- **Basic oxygen steelmaking**
- **BOS carbon elimination**
- **Converter angle control**
- **Bath agitation (inert gas) control**
- **Gas flow control**

Steelmaking/BOS Plant

Application Note

What is steel?

Steel consists in the majority of iron but with high levels of carbon e.g. 4% removed and a controlled amount remaining. The amount of carbon in the steel is very important to the way the material behaves after heat treatment. Table 1 gives some indication of these properties.

Carbon range (%)	Uses
0.05 - 0.12	Wire, pipe rivets
0.1 - 0.2	Structural steel and machine parts
0.2 - 0.3	Gears, shafting bars
0.3 - 0.4	Cranehooks, axles and machine parts
0.4 - 0.5	Crankshafts, gears axles and heat treated machine parts
0.6 - 0.8	Low carbon tool steels, drop hammer dies, set screws, locomotive tyres, screwdrivers
0.8 - 0.9	Punches for metal, rock drills, shear blades, cold chisels, rivet seats, many hand tools
0.9 - 1.0	Springs, high tensile wire, knives and axes
1.0 - 1.1	Drills, taps, milling cutters, knives, ball bearings, drills, wood working and lathe tools
1.1 - 1.3	Files, knives, tools for cutting brass and wood
1.25 - 1.4	Razors, saws, boring and finishing tools

Note: The hardness will depend mainly on the carbon content and the way in which the metal has been heat treated.

Table 1 The effect of carbon on steel applications

What else is added to steel?

Various additives are used to improve the basic carbon steel properties; for example molybdenum is used to improve the hot strength and hardness, nickel improves toughness and ductility. The different properties required of the steel for different uses (e.g. hammer head, car body) will dictate the type of steel used and the way it is treated by controlled heating and hot and cold rolling. Table 2 gives further details on steel additives.

Steel additives	
Manganese (1-2%)	Often used for structural steels. The carbon content can vary from 0.08 to 0.55%
Nickel (3.5 - 5%)	Another additive used for structural steels
Nickel/Chromium	This combination adds toughness and ductility along with wear resistance e.g. 1.25% Nickel, 0.6% Chromium used for piston rings 3.5% Nickel, 1.5% Chromium used for aircraft gears
Corrosion and Heat Resisting Steels	Molybdenum steels consisting of: Carbon/Molybdenum or Chromium/Molybdenum to improve the hot strength and hardness of the steel Chromium/Nickel/Molybdenum to improve impact properties
Chromium Steels	Chromium/Vanadium for improved strength and toughness Nickel/Chromium/Molybdenum Manganese/Nickel/Chromium/Molybdenum
Boron Steels	Boron is used in very small quantities (typically 0.0005%) greatly improving the hardening properties of steel

Table 2 Steel additives

Application note

BOS (Basic Oxygen Steelmaking) plant

Molten iron from the blast furnace is transported in specialised refractory brick lined 'torpedoes' on rail cars (varying in capacity from 200-450 tonnes) to the BOS plant where the iron is refined to produce steel of desired quality and composition.

At the BOS plant, the iron is treated in two stages; firstly to remove carbon and secondly to receive additives which modify the steel's properties.

In the first stage, the iron is mixed with scrap and fluxes, agitated with inert gas and burned with oxygen until required carbon levels are reached as measured by dip-sampling probes. This oxygen 'blowing' process is in large tilting vessels called converters. In the modern steelworks it is typical to see BOS vessels able to convert 350 tonnes of metal in one 'blow'. A converter vessel itself, see Figure 1, would weigh 650 tonnes. Typically, a BOS plant has two or three converters available for converting iron to steel, with usually one or two in operation at a time and occasional operation of multiple converters simultaneously.

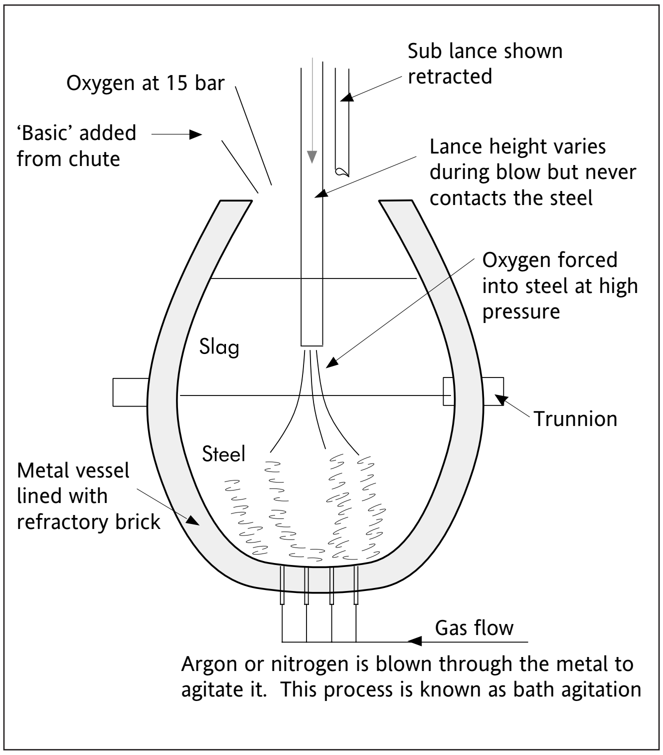


Figure 1 BOS converter

In the second stage, the raw steel is mixed with additives in smaller vessels, and receives a short 'blow' cycle prior to casting in the CONCAST (CONtinuous CASTing) plant.

Impurities within the iron due to the powerful reducing conditions of the blast furnace have to be removed by oxidisation. Residual carbon and silicon are oxidised with the help of the added basic fluxes.

BOS is a sequential process centering around the converter positioning and contents processing. Automation of the total process is possible from centrally stored process recipe information to the front end instrumentation, while still allowing manual intervention and re-processing steps.

The converter is a vessel that tilts 180° from the upright vertical on the charging side, and over 90° on the tapping side. The converter is tilted to one of several pre-determined angles during the sequence as shown in Figure 2.

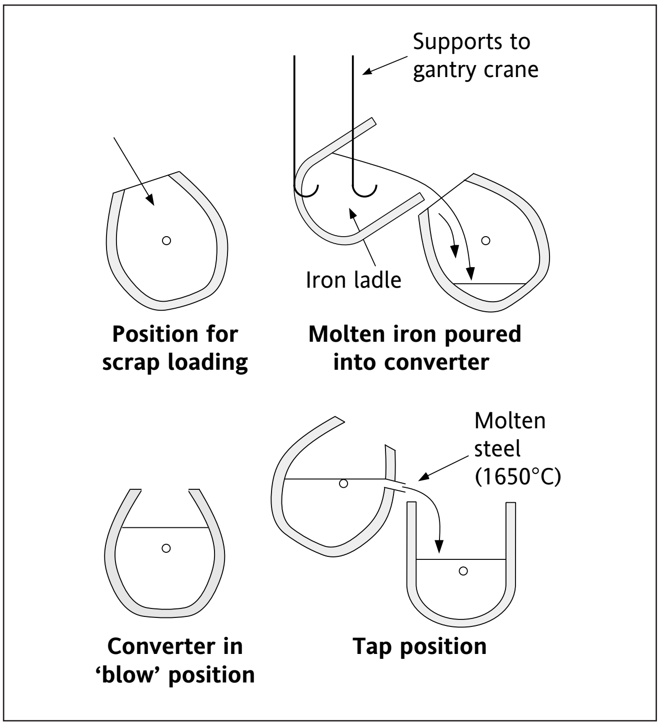


Figure 2 Converter positions

The converter is rotated to its charging position to be loaded with scrap metal (50 tonnes), molten iron (300 tonnes), lime (15 tonnes) and the 'basic' fluxes magnesium and limestone (6 tonnes).

The converter returns to the vertical and the main lance lowers, injecting oxygen at high velocity onto the molten metal surface for 15 to 20 minutes.

After injecting a pre-determined quantity of oxygen, the 'blow' is complete and the main lance is withdrawn. At 80% and 100% oxygen flows as calculated by a thermochemical model, a sub lance is lowered to measure temperature which is used to calculate carbon arrest.

Assuming that temperature and sample analysis are acceptable, the converter is rotated from vertical to tapping position.

After tapping, the converter is rotated back to its slag position for emptying occasionally, returned to the vertical for addition of thickeners, then gently rocked for slag-wash prior to emptying which is conducted by taking the converter to the opposite (180°) vertical position.

Practically, there are other intermediate steps depending on other variables. For example:

- re-blows may be necessary according to temperature or analysis
- an anti-slop interruption may be necessary to reduce slop by increasing the inert gas flows for a period
- increased inert gas flow stirring may be needed to reduce temperature

Throughout the cycle, inert gases such as nitrogen and argon (during blow and re-blow) continuously flow to agitate or stir the converter contents, and to keep the converter stirring elements clear for the duration of the converter campaign.

The result is steel of very low carbon content. The percentage needed for the type of steel being manufactured will be higher than this, so a controlled amount of carbon is added to meet the specification.

After the metal has been poured, the cycle starts again and if no problems delay the steelmakers, typically 8 'blows' will be achieved in one shift of 8 hours producing nearly 3,000 tonnes of steel.

Converter angle control

The converter is positioned to the desired angle by comparing the corresponding absolute desired angle with the absolute actual angle and driving the positioning motors in the correct direction.

The positioning motors are driven progressively at increasing and subsequently decreasing speeds according to the error size and time intervals until the position is within the tolerance band set.

Bath agitation (inert gas) control

To stir the converter contents, Argon or Nitrogen is injected through a number of cans on the converter base as shown in Figure 3. The total flow and type of gas for each sequence step are pre-determined from the loaded recipe for the current blow.

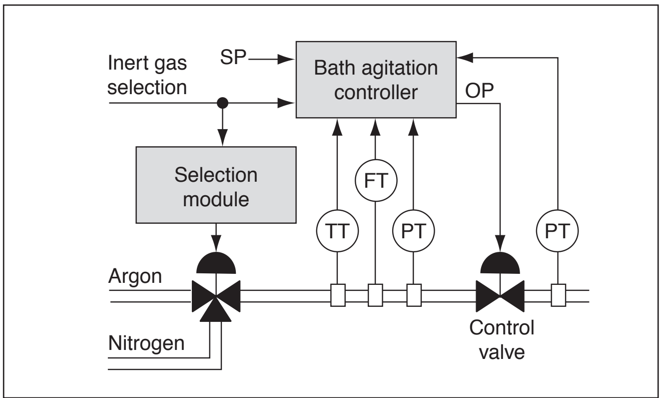


Figure 3 BOS bath agitation control

The total flow is divided equally to a number of controllers, one for each can to maintain an even distribution, and becomes the controller remote setpoint. The measured flow is mass-compensated for temperature and pressure for each can and gas type and input to the control module. The 4-20mA control output then modulates the valve position.

If the can becomes covered with heavy slag, the downsteam pressure increases. Should it increase beyond a preset limit, control changes from flow control to pressure control and the control valve then responds to a different control algorithm. On reduction of pressure (less a hysteresis value), control reverts to flow control. Changeover between control modes is automatic and bumpless, as the non-active loop tracks the output of the active loop.

Gas flows

The BOS process uses expensive gases (Argon, Oxygen and Nitrogen) and the accurate measurement and totalisation of these gases assists economic operation and tight quality control by using these values in the generation of spreadsheet reports and logs.

HR084054U006

Heat Treatment

INDUSTRY

- **Cross-limiting combustion control**
- **Temperature profiling**
- **Gas mixing station**

Soaking Pit

Application Note

Soaking pits are necessary to heat up and soak metal ingots to a uniform temperature sufficient to allow passage through the various rolling stages of the mill.

Steel feed stock to the pits can be hot ingots from BOS plant, hot skelps (cast slabs or blooms) from CONCAST plant, or cold stock.

The rolling stages may be several, from Primary and Secondary mills through Scarfing, Roughing, Intermediate and Finishing mills.

As the ingots are being fed to the mills every few minutes but the heating and soaking cycles take hours (ingots weigh several tonnes), many soaking pits are needed to ensure availability of material to the mills 24 hours a day.

A soaking pit, is a thermally insulated chamber with a top sliding lid to add or remove ingots. The pit is gas fired and therefore the continuous control requirements are temperature, gas flow, air flow and pit pressure. Further control could involve diluting the waste gas with air to maintain recuperator protection, and would include shutdown logic for over temperatures and low pressures.

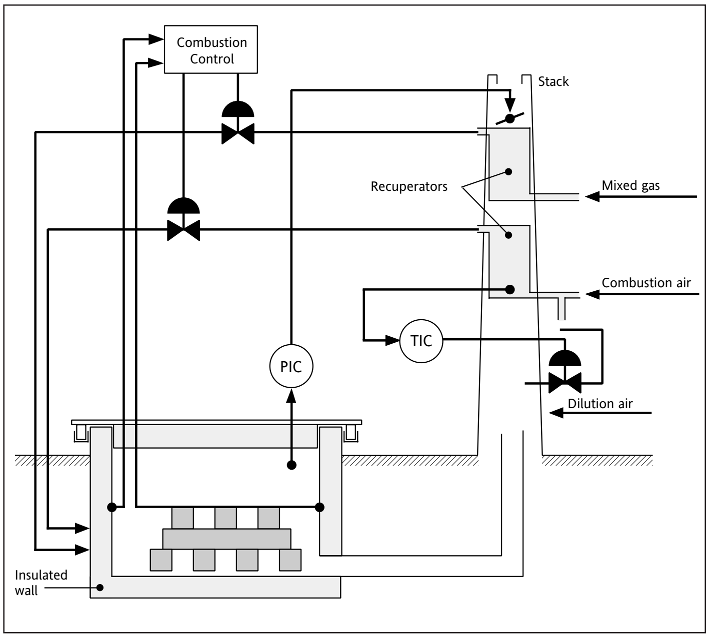


Figure 1 Soaking pit

Application note

Cross-limiting combustion control

A cross-limiting combustion control technique ensures that there is always an efficient ratio of air and fuel within a combustion process. This is implemented by always raising the air flow before allowing the fuel flow to increase, as shown in Figure 2, or by lowering the fuel flow before allowing the air flow to decrease. A combination of high and low select modules is therefore used in the implementation.

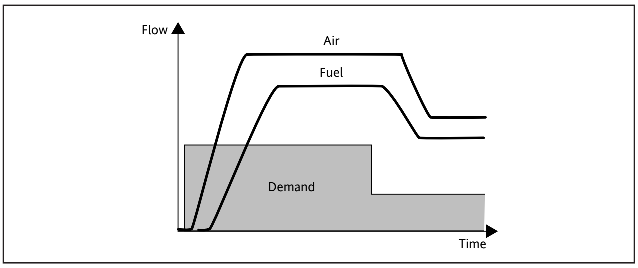


Figure 2 Cross-limiting combustion mechanism

Figure 3 shows a simplified control block diagram of the cross-limiting combustion circuit. Combination firing of two fuels can also be accommodated within the scheme.

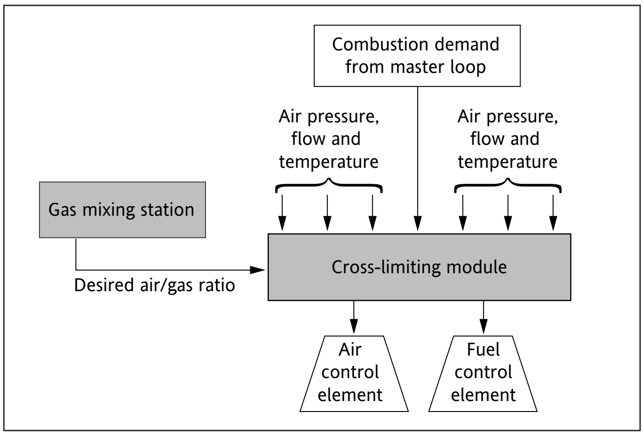


Figure 3 Cross-limiting combustion control

There are generally two thermocouples used in soaking pits, one at the burner wall and one at the end wall. The operator can select either, or automatically the highest, to generate the combustion demand for the control module.

Cross-limiting combustion control is highly effective and can easily provide the following:

- Optimisation of fuel consumption
- Fast adaptation to variations in fuel and air supplies
- Fast adaptation to types of fuel available

Double cross-limiting combustion control is an enhancement to the above. It is achieved by applying additional dynamic limits to air and fuel setpoints. This translates to having the actual air/fuel ratio maintained within a preset band during transitions. This method protects the demand signal driving the air/fuel ratio too lean and therefore reducing heat input.

Temperature profiling

The soaking requirements for the ingots in a pit vary according to the total load mass and thermal cycle. This is calculated in the supervisory system and a set of profiles is downloaded to the temperature controller by setting target temperatures and ramp rates. Once downloaded, the front end instrumentation maintains the profile without further operator intervention.

Gas mixing station

The gas used for the soaking pits is a mixture of fuel gases from other areas of the steelworks such as BOS, Blast Furnace and Coke Oven gases. At the Gas Mixing Station, theses gases are mixed by ratios, according to availability. Because of this, the calorific value of the mixed gas is variable. A mass spectrometer is utilised to calculate the Wobbe index from the specific gravity. The resultant ratio correction factor for optimum combustion is then fed to the combustion control module.

Heat Treatment

INDUSTRY

- Continuous annealing
- Accumulators
- Variety of furnaces
- Atmosphere control
- Line stop
- Operation
- Galvanising

Application note

Continuous Annealing and Galvanising Lines

Application Note

Continuous annealing

Annealing is a process in which metals, glass and other materials are treated to render them less brittle and more workable. Continuous steel annealing subjects rolled strip product to a sequence of furnaces to elevate and profile the strip temperature according to grade and dimension. The end result is an increased ductility and removal of strains that lead to failures in service.

Figure 1 shows the linear nature of a continuous annealing line. Because the overall length of strip in the furnace system is a few kilometres long, the furnaces are vertical, with the strip making several traverses within each furnace.

Continuous annealing lines have the following features:

- Accumulators
- Variety of furnaces
- Atmosphere control
- Line stop

Accumulators

Accumulators provide storage areas between static steel coils ('unwinding' at entry end and 'winding up' at the exit end) and continuous strip running through the furnace sections. As the empty feed coil is stopped, replaced with a new full coil and both strips welded together, the entry accumulator unwinds to provide continuous strip. Similarly, the exit accumulator winds up while the full take-off coil is unloaded at the exit end.

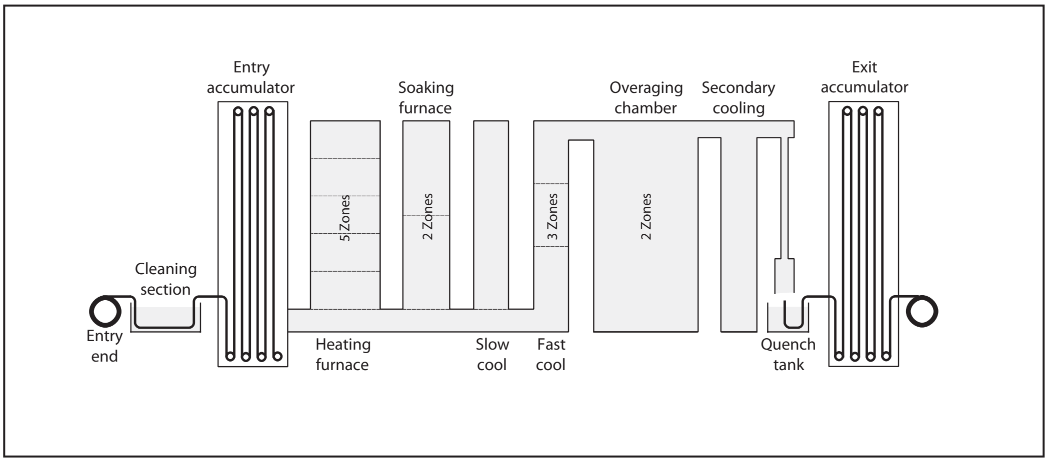


Figure 1 Continuous annealing line

Variety of furnaces

Furnaces are necessary to give steel the desired properties by heating to particular temperatures and profiles thereby determining the grain structure within the metal, and to prepare for further processing such as galvanising.

In the heating furnace, the cold strip is heated to the highest temperature of the annealing profile. Because of the danger of oxygen contamination and flame length hotspots, the heat is radiated to the strip using ceramic radiant tubes, themselves fired by gas.

The soaking furnace is required to maintain strip temperature and is electrically heated.

The first of the primary cooling sections is the slow cooling chamber, where two variable speed blowers circulate the atmosphere gas through two water-cooled heat exchangers. The second of the primary cooling sections is the fast cooling chamber, where the strip is cooled by a variable speed fan and the cooling length is determined by the positions of three dampers along its vertical length. This chamber is also split vertically for temperature profile control across the width of the strip using a scanning pyrometer.

The overaging chamber provides electrical heating to maintain the strip at an intermediate temperature.

The secondary cooling section cools the strip by variable speed cascaded fans blowing recirculation atmosphere gas cooled by water-cooled heat exchangers.

Final cooling is achieved by spraying and immersion in water.

Atmosphere control

To prevent oxidation of the strip, the atmosphere around the strip inside the furnaces is a controlled mixture of H_2 and N_2 (cracked ammonia NH_3 providing 5% H_2 and 95% N_2) although hydrogen only is sometimes used. The furnaces themselves are sealed gas tight and each of them is maintained under slight positive pressure.

Line stop

It is desirable for productivity to maintain strip movement through the furnaces at all times. However, it is inevitable that faults occur and the strip stops. At this stage, there is a risk of the strip being overheated and breaking, causing major disruption.

The control system, therefore, looks ahead and takes action at low line speed, line deceleration and line stop. These essential actions are to minimise the heating furnace firing and maintain atmosphere gas pressure due to the cooling strip.

Operation

The plant has three normal modes of operation illustrated in Figure 2.

- Line model mode
- Strip standby mode
- Zone control

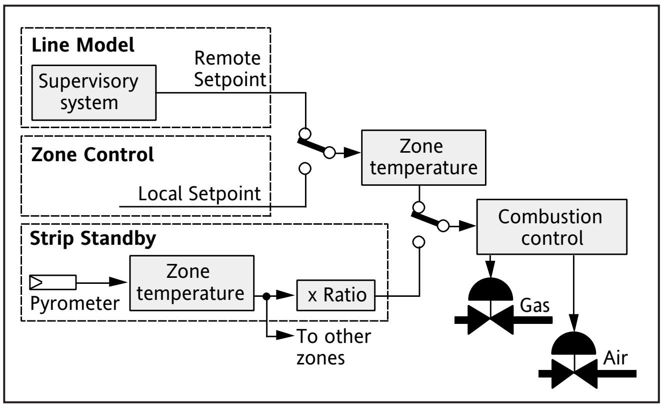


Figure 2 Operating modes

In line model mode, the modelling supervisory system provides speed, tension, zone temperature and damper setpoints plus other outputs based on the current strip gauge, width and temper. The supervisory system calculates and optimises controller setpoints and uses feedback and feedforward to modify the various algorithms. For example, if a newly loaded coil is wider and heavier than the current strip, the modelling database predicts (from weld detectors) when the new strip will enter the heating furnace. It therefore increases furnace zone temperature setpoints in advance, but also increases line speed to ensure that the current strip does not overheat. When the current strip exits the hot furnaces, the speed is reduced to allow the new heavier strip a longer time in the heating furnace.

In strip standby mode, the zone temperature controllers are not used. Combustion demand for each zone is derived from the succeeding strip temperature controller, see Figure 3. In this mode, the zones are progressively increased from different starting points to allow smooth thermal response.

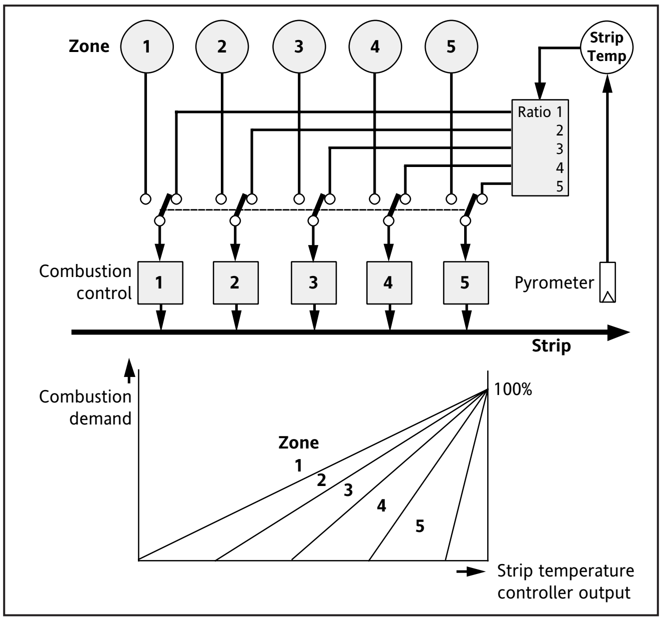


Figure 3 Strip standby mode (heating furnace)

In zone control mode, the zone temperature controllers are used with local setpoints.

Selection of operating modes is made by the operator for each of the furnaces. However, under certain circumstances, automatic actions are taken immediately. For example, if line speed drops below a limit, strip standby is automatically de-selected because the pyrometer reading is no longer representative. Either the zone controller setpoints are reduced (if in line model mode), or the controllers are set to a depressed setpoint (if in zone control).

Galvanising

Galvanising is the practice of immersing clean, oxide-free iron or steel into molten zinc in order to form a zinc coating that is metallurgically bonded to the iron or steel's surface. The zinc coating protects the surface against corrosion by:

- Shielding the base metal from the atmosphere
- Providing a cathodic or sacrificial protection since zinc is more electropositive than iron or steel

Even if the surface becomes scratched and the base metal is exposed, the zinc is slowly consumed while the iron or steel remains protected from corrosion.

Galvanising consists of four fundamental steps:

- Surface preparation: consists of cleaning and pickling operations that free the surface of dirt, grease, rust and scale.
- Preflux: serves to dissolve any oxide that may have formed on the iron or steel surface after pickling and prevents further rust from forming.
- Galvanising
- Finishing: includes quenching, removing excess zinc and inspection

The hot dip galvanising process, illustrated in Figure 4, is adaptable to coating nearly all types of fabricated and non-fabricated products such as wire, sheets, strip, pipes, tubes, etc. This process uses control features very similar to those used in the continuous annealing process, where the major control areas are:

- Strip temperature
- Bath immersion time
- Bath withdrawal rate
- Steel cooling rate

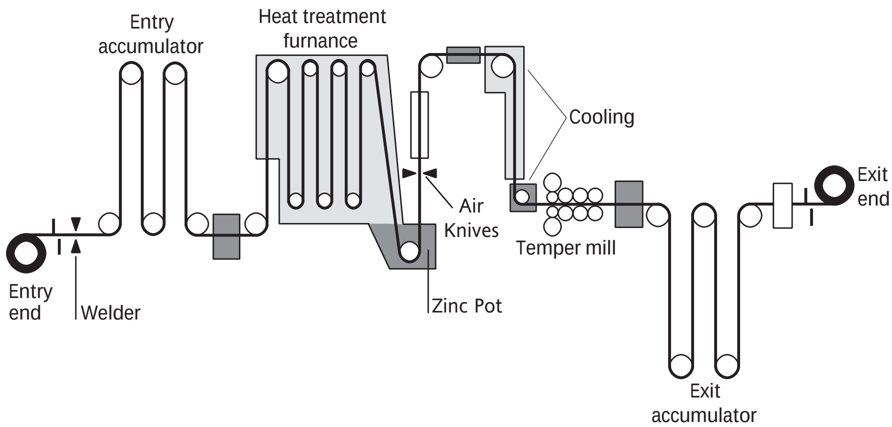


Figure 4 Galvanising plant

HR084054U002

Heat Treatment

INDUSTRY

- **Single stack batch annealing**
- **Atmosphere control**
- **Thermal profiles & annealing control**
- **Multi-stack batch annealing**

Single and Multi-stack Batch Annealing

Application Note

Application note

Annealing is a process in which metals, glass and other materials are treated to render them less brittle and more workable. In the steel industry, the steel is heated and profile controlled, with times and temperatures set according to the properties desired to reach an increased ductility and relieve strains that lead to failures in service.

Single stack batch annealing

Unlike continuous annealing, where the strip of steel is uncoiled, treated and rewound in approximately 15 minutes, batch annealing heats the coils intact in small furnaces over approximately 3 days.

The coils are usually stacked four or five high on fixed bases, covered, and mobile furnaces lowered onto them. Figure 1 shows a typical single stack gas-fired annealing furnace. Coils weigh between 10 and 20 tonnes.

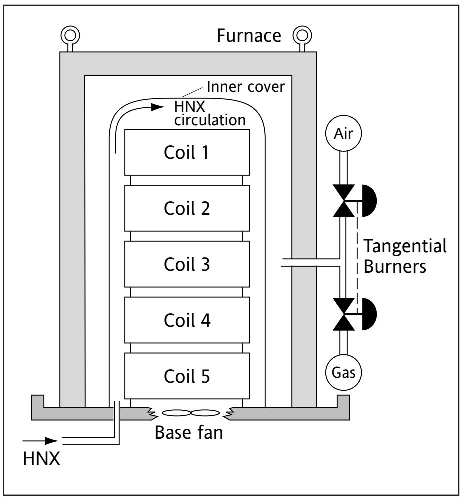


Figure 1 Single stack annealing furnace

The space between the inner cover and furnace is heated by the gas/air combustion and the HNX inside the cover is fan circulated to convey heat to the coils. The burners are located tangentially around the circumference of the furnace. Quick fit connectors on the furnace are provided for coupling to gas main, electrical control valve drive motor and thermocouples.

To speed up cooling after soaking, the HNX is cooled by a heat exchanger.

Atmosphere control

To prevent oxidation of the strip, the atmosphere around the strip inside the furnaces is a controlled mixture of H_2 and N_2 (cracked ammonia NH_3 providing 5% H_2 and 95% N_2) although hydrogen only is sometimes used because of its increased conductivity. The furnaces themselves are sealed gas tight and each of them is maintained under slight positive pressure.

Thermal profiles & annealing control

With a single stack batch annealing base only two control loops are required with all the relevant base information made available to the supervisory system.

The gas and air valves are mechanically linked to operate together and preserve the correct ratio over the full travel. The link is operated by an electric motor and the control module includes a boundless control algorithm to position the gas valve. Two digital outputs operate the open and close motor coils. Values are entered in the control module for end-to-end travel time and minimum pulse time for the motor. The input to the open/close algorithm is the 3-term output of the gas control loop, cascaded from the master temperature controller.

The temperature controller setpoint is a profile that represents the temper (treatment) cycle. The parameter values that define the cycle are downloaded to the controller by the operator, who determines the temper. These values include:

- Temper number
- Ramp rate
- Soak temperature
- Soak time
- HNX bias
- Strip temperature

Once the profile is downloaded to the instrument, the controller automatically follows the temperature profile. Initially, the control loop operates on the HNX temperature, but the ramping is frozen if the temperature difference between HNX and steel (bottom thermocouple) exceeds a pre-determined value. The ramp continues until HNX reaches the steel soak plus HNX bias temperature, then the control loop operates on the steel temperature. When the soak temperature is reached, a soak timer is started and on expiry the gas valve is closed. The steel cools naturally until the accelerated cooling temperature (nominally 550°C) is reached, at which time the cooling fan is pulse started to accelerate cooling. At approximately 100°C the cooling fan is pulsed off and the furnace can be removed.

During the cycle, the controller reports back the following information:

- Temper number
- Ramp rate
- Cycle started
- Soak started
- Steel control
- Soak ended
- Gas used
- HNX overtemperature
- Cooling water overtemperature
- Base fan on

The Eurotherm® approach to single stack batch annealing offers:

- Safe operation of enriching gas
- Tight temperature control preventing overshoots
- Optimum use of atmosphere gas
- Unlimited number of recipes minimising operator errors and allowing entry of custom material grades
- Custom and efficient batch reports providing valuable production data
- Cost effective expansion capability to additional annealing bases

Multi-stack batch annealing

Not all stack annealers are single. Figure 2 depicts a multi-stack annealing furnace. This particular type of furnace is for high temperature (over 1000°C) annealing of electrical steel used for transformers and such specialist applications. Hydrogen is used for atmosphere gas and electrical heating is used for the furnaces.

The furnaces are laid out in eight batteries, each battery comprising four bases and each base comprising four stacks of two coils each.

For each battery of four bases, two electrical supplies are available, so that only two bases can be heated at any one time. Therefore, normally two bases would be being heated, one cooling and one being loaded or unloaded.

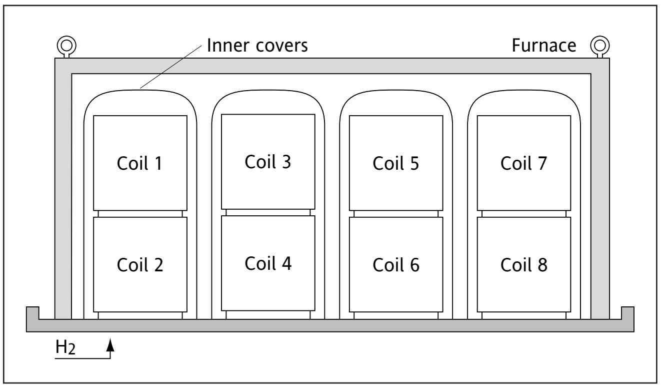


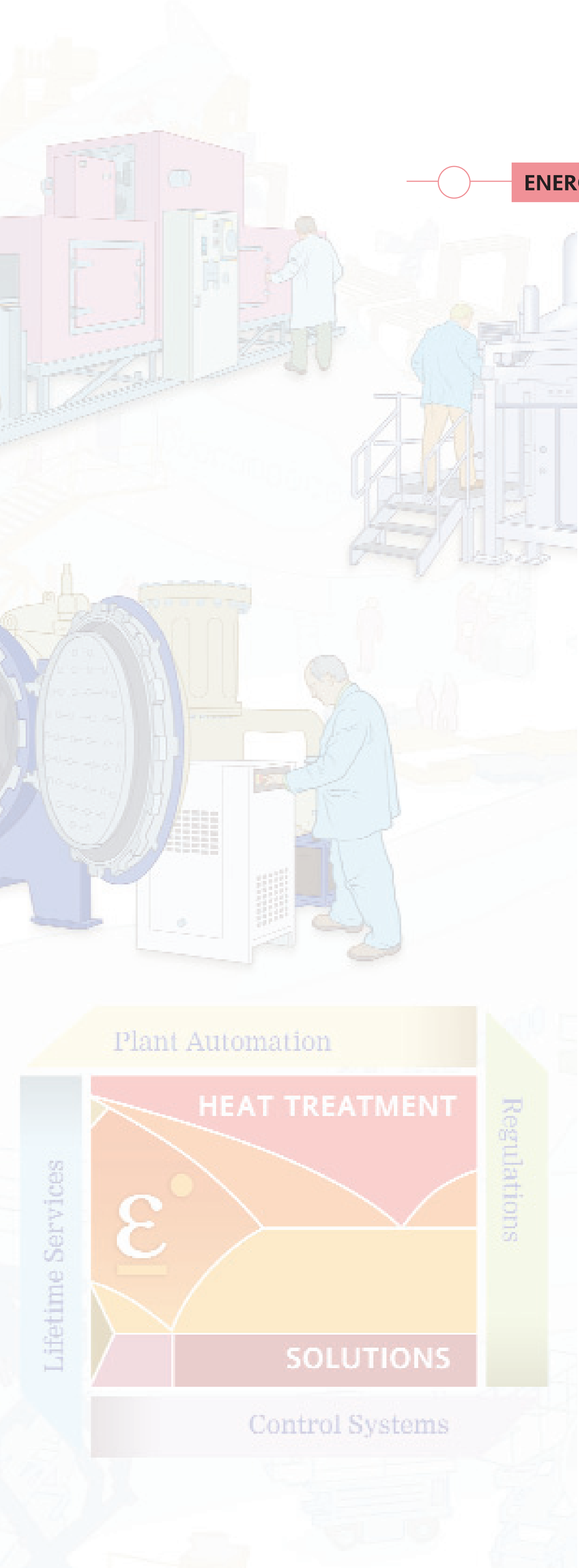
Figure 2 Multi-stack annealing furnace

The furnaces, which are mobile in order to be used on any base, comprise four heating zones plus a fifth in the base floor. For each electrical supply, the five heating zones are controlled in on/off or time proportional mode. A supply control module selects and stores the analogue inputs from the appropriate bases depending on which supply is being used, and averages the two base temperature measurements for control.

Also provided by the control module are the following functions

- The average zone temperature is calculated and used if one zone thermocouple fails
- A hydrogen permissive flag is set when all zones are above 610°C
- The power supplies' digital inputs are checked (only one base must be selected for each supply, and only one supply must be switched to a base)

An additional control module provides health monitoring of the zones' heating elements. The actual current flowing through each phase of each zone element is compared with the demand. If the current indicates an open circuit (high resistance) when on or a high current (welded contact) when off, a discrepancy alarm is flagged. All currents are summed to provide an instantaneous total power.



ENERGY SOLUTIONS

- Eurotherm® Energy Solutions for Heat Treatment Applications
- Power Control and Energy Management Solutions
- Furnace Energy Optimisation
- Current Limit Operation
- Thyristor Firing Silicon Carbide Heating Elements

Eurotherm® Energy Solutions for Heat Treatment Applications

Eurotherm® are a principle supplier of control systems for heat treatment energy applications and have a global reputation for innovative fossil fuel and electrical energy delivery solutions.

Our extensive range of thyristor products and fuel control devices is supported by control algorithms and energy software solutions, which bring benefits across the whole business for the efficient use and management of energy.

Thyristor products

Robust design for heat treatment and furnace applications.

Complete range of single, dual and three phase devices from 10 Amps to 10,000 Amps.
Suitable for firing into all furnace and oven heater materials including:

- Standard resistive materials
- Silicon Carbide
- Molybdenum Di-Silicide
- Graphite
- Molybdenum and Tungsten Wire
- Shortwave Infrared lamps and Quartz tubes
- Transformer coupled loads including Scott wound and unbalanced transformers

Built for control system integration with features including:

- Inbuilt alarms with supply and load protection.
- Alarms for system and heater element diagnosis
- Digital communications
- Routines for power sharing and load shedding

Please contact Eurotherm for more information on firing modes and the use of thyristors with specific heater materials.

Fossil fuel control systems

An extensive range of control strategies and algorithms including:

- Simple On-off and high low fuel control
- Bounded and boundless fuel valve control algorithms
- Simple fuel-air ratio systems
- Special dual fuel-air with excess air trim ratio control systems
- Specialist burner control algorithms
- Single and multi zone pulse burner control systems
- Lead-Lag fuel control systems

Energy management

A selection of energy monitoring and management features and capabilities:

- Single and three phase electrical power, plant monitoring solutions
- Gas usage and fuel flow monitoring
- Batch process energy profiling
- Furnace and batch process energy consumption recording

- Management software systems for energy recording and reporting
- Furnace energy optimisation routines
- Electrical power maximum demand avoidance solutions
- Furnace electrical load sharing techniques

Please contact Eurotherm for more information on the efficient use and management of energy.

Power Control and Energy Management Solutions

Electrical heating for industrial furnaces

The debate over increasing energy cost has caused suppliers in the metal production and treating industry to look at control refinements for furnace heating systems.

Reducing energy costs remains a key area of focus and successful companies are finding ways to improve their competitiveness by concentrating investment in this area of their business. This article aims to highlight further savings, which can be made by paying careful attention to the way electrical energy is used and distributed around thermal processing equipment.

Energy monitoring

Since most of the Metals Supply and Heat Treating process industry is audited, there is a need to record and store batch and process data. With the advent of simple communicating power metering equipment it is a natural extension of the control system to embed plant energy usage in to the stored records. Having access to energy data in real time and historic format allows users to evaluate the following:

- Instantaneous overall shop-floor power demand
- Instantaneous power demand for individual furnaces
- Energy usage against furnace loading
- Energy usage against plant utilisation
- Fiscal costing against customer batches
- Plant priority for load shedding

Using wireless technology as a cost effective way to acquire and distribute energy information over Ethernet allows the data to be shared in real time around groups of internal management and engineering clients. Experience has shown that where users have access to energy data it has always been possible to define areas of savings.

Electrical energy switching methods

Except for the most complex heater loads i.e. those element materials which have resistance change with temperature or complex transformer coupled loads, it is recommended that simple whole cycle switching methods are employed to control electrical energy with thyristors.

The continuing use of Phase Angle (Cycle Chopping) for simple heaters including modern Silicon Carbide causes disadvantages to users through poor power factor, harmonic disturbance on the supply and RF interference around the installation.

Figure 1 shows typical harmonic disturbance associated with phase angle firing for single and 3 phase loads. It can be seen from the diagrams that when switching the sine wave at 90 degrees a high proportion of odd harmonic current is reflected into the supply.

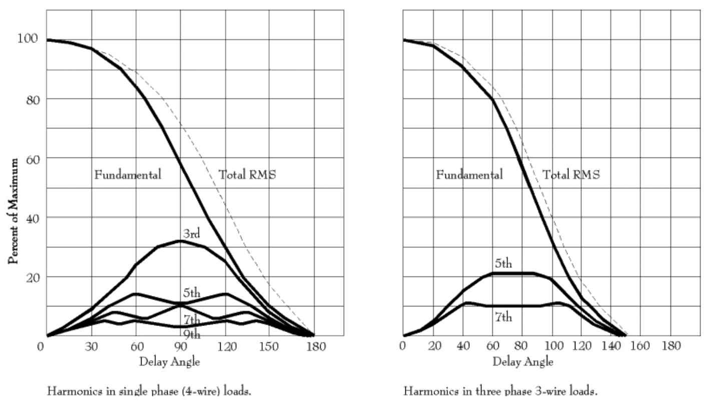


Figure 1

Poor power factor associated with phase angle firing is the principle concern for energy cost. Since most electrical installations are designed to operate at around 50% output power at the nominal operating setpoint, the supply mains cycle will be chopped at the worst case of 90 degrees when operating in PA mode, Under these conditions the resultant power factor could be as low as 0.72 instead of above the desired level of 0.95. Dependent on the metering type and the supply impedance this could have a very detrimental effect on the billing value adding 7-10% cost with no benefit to the process.

Two simple solutions can reduce or overcome the disadvantages associated with phase angle thyristor control:

1) For installations where phase angle control cannot be avoided, using an electronic supply tap changer will automatically keep the power factor and supply disturbance to a minimum.

   Figure 2 shows typical response from a 4. tap change control system. Notice how the power factor is above 0.9 for most tappings at the critical 50% demand level compared to the fundamental curve which shows 0.72 for 50% demand.

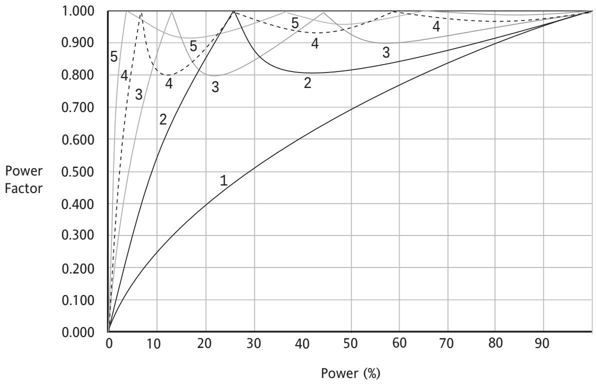


Figure 2

2) For non complex heater loads it is possible to use any of the whole cycle firing modes including single cycle and advanced single cycle switching methods to satisfy the watts density loading and thermal mass characteristics of most common heaters whilst eliminating the poor power factor and harmonic problems.

Advanced single cycle can be particularly effective for shortwave infra-red loads or for loads where it is desirable to minimise the effect of long bursts of power on the elements.

For element materials, which have a positive resistance/temperature coefficient, it is also possible to use intelligent thyristors to switch from phase angle firing to whole cycle firing when the element resistance increases to allows full mains volts to be impressed across the load.

Information is available from Eurotherm® on the benefits of alternative thyristor switching methods for particular heater materials.

Algorithms and routines to minimise furnace energy usage

It has long been recognised that analysis of furnace power behaviour can indicate furnace performance. Consumers are using power profile recognition to determine operational changes on their processing equipment against batch types. A recent advance in on-line power monitoring for batch heat treatment cycles has produced a furnace power optimisation solution for homogenisation, annealing, normalising and similar heat treatment processes.

In this application the point at which the temperature within the stock has become homogeneous is recognised by a steady state control algorithm acting on the derivative of power consumption. Clients are using this control system intelligence to recognise the point at which equilibrium is reached to shorten process times and improve plant utilisations. Eurotherm uses their proprietary algorithm to give customers this cost saving benefit without the need to include additional work piece monitor sensors.

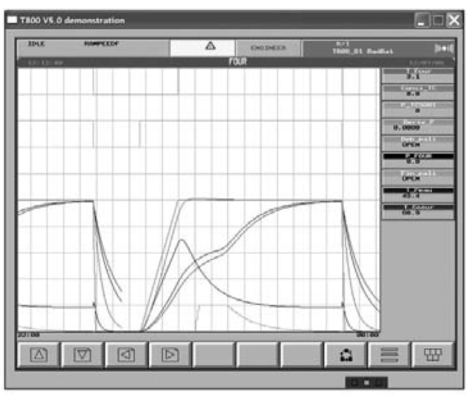
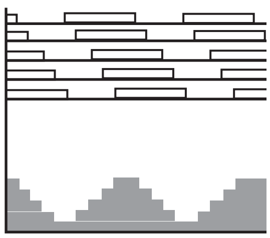


Figure 3 shows curves associated with furnace and work-piece temperature performance against the derivative of the energy usage used in Eurotherm Furnace Energy Optimisation algorithm.

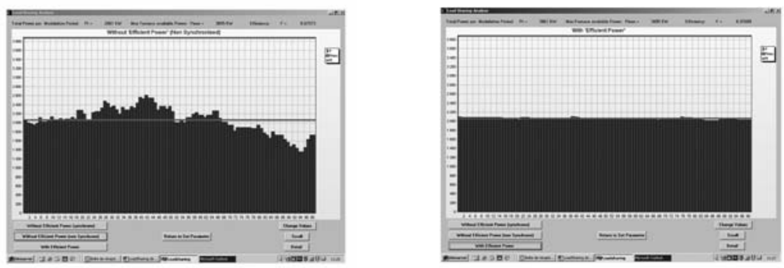
Load sharing and load shedding techniques

Where a heat treatment shop has a large installed base of electrically heated thermal processing equipment it is often desirable to sequence the firing of individual furnace zones or independent furnaces to minimise the supply fluctuation. By using intelligent thyristor firing methods it is possible to limit the power surge and instantaneous supply loading associated with any installation through a selectable combination of firing patterns. In this mode none of the zones are switched on simultaneously and individual furnace or zone power demands are synchronised to give a very even loading on the factory supply.

The following figures show a zone sequencing pattern and the overall effects on the supply by evening out the load on the plant. The benefits allow clients to operate higher installed equipment base from the existing supply.



Zone sequencing



Supply switching pattern before and after load sharing

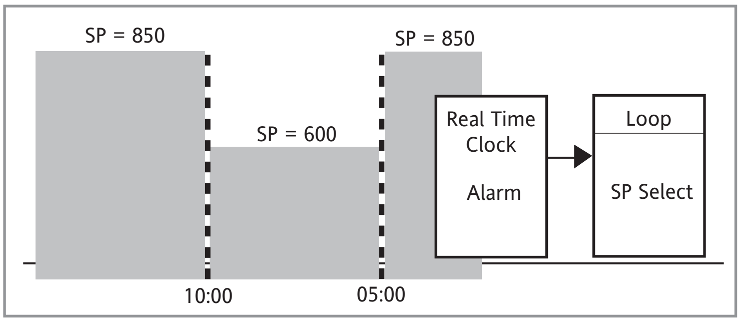
A further benefit can be obtained from this solution by setting a threshold on the smoothed power level to trap excursions of energy use through the site maximum demand point. Setting alarms on the threshold level can trigger prioritised load shedding and thus avoid costly excess-tariff penalties.

Out of hours furnace setpoint control

Using the intelligence of modern control systems it is possible to automate out of hours setpoint control for thermal processing equipment. In the example shown below the control systems understands the dynamics of the furnace and can recognise the power required to maintain the standby setpoint and the power required to achieve the operating setpoint.

The controller has a user screen which allows the operator to enter the required duty setpoint and time for the furnace to be back at temperature. The controller uses the furnace tuning information and an internal real time clock to ensure the furnace is back at the duty setpoint as required for work.

Benefits allow much more consistent and repeatable energy savings through the use of out-of-hours furnace turn down.



Eurotherm supply control systems which are specially designed to incorporate the unique energy saving routines.

Furnace Energy Optimisation

Overview

The Furnace Energy Optimisation application uses the steady state algorithm to shorten process cycle times on batch furnaces running processes that transform the micro-structure of the work piece. By calculating the moment that the work piece reaches a uniform temperature, the soak period can be started with confidence at the earliest possible time. As the soak is accurately monitored, safety margins traditionally included in the process time to allow for uncertainty can be eliminated. This results in the metallurgical integrity of the process being maintained whilst the process time and corresponding energy consumption are reduced, giving cost savings and productivity improvements.

Technical

The steady state algorithm uses the power output of a furnace control system to calculate the temperature uniformity of the work piece within the furnace. In order to detect uniformity, the core temperature of the work piece is required. Using traditional pyrometry this can only be measured invasively, which is impractical in most applications. However, this can be measured by analysing the energy input to the furnace.

During a ramp/dwell heating cycle, the power output of the control algorithm runs at 100% during the initial heating of the work piece, and then tapers off to a constant value as the work piece reaches the furnace temperature (setpoint). When the work piece reaches the setpoint and the temperature of the work piece is uniform, then the only heating required is to compensate for furnace losses. At this point, the rate of change of the power output (dP/dt) is zero.

The power output can be measured from the controller output or from the energy consumption of the furnace. On an electrical furnace the RMS current can be measured, on a gas furnace either the flow rate or the pulse frequency can be measured.

The steady state algorithm samples the power output and calculates the rate of change. Using filtering and statistical analysis, the algorithm is able to calculate the moment that the work piece has uniformly reached the setpoint, and therefore is ready to start the soak. With this information, the work piece can then be soaked for the time required for the metallurgical transformation and safety margin added to allow for uncertainty in the soak start time can be eliminated.

Applications

Furnace Energy Optimisation application is suitable for all types of batch process where the whole work piece is subject to a metallurgical transformation. These processes include:

- Annealling
- Homogenising
- Normalising
- Stress relieving
- Tempering

The algorithm can be applied to gas and electric furnaces, and is not dependant on the mass or physical dimensions of the load.

The furnace optimisation routine has been developed as a direct response to customers needs in improving productivity and reducing costs whilst maintaining or improving product quality and process conformance.

The reduction in cycle time, which has been clearly established from this procedure has enabled customers to improve throughput with a resulting reduction in costs per unit load.

The furnace Optimisation application has been developed as a LIN function block within the Eurotherm® control system. This can be incorporated into new schemes or retrofitted into existing Eurotherm LIN solutions. The procedure can also stand along side other non-Eurotherm systems as an independent application.

The application has been used in a wide range of batch furnace processes and brings confidence to the metallurgical performance of the process cycle without the need for invasive use of work thermocouples.

Feedback has shown that the Furnace Energy Optimisation algorithm can bring rapid return on investment with customers showing up to 9% savings on energy use and up to 20% improvement on processing time.

Heat Treatment
INDUSTRY

White paper

Current Limit Operation

Introduction

Thyristor stacks are provided in many cases with a means of limiting the maximum current which they will allow to pass. This has been traditionally referred to as Current Limit. This name has been responsible for much of the design misunderstanding in recent years.

If the Thyristor stack is considered in isolation then the way in which the current is limited is probably of little importance provided the resulting control of current is stable and does not permit an operator to blow fuses or heating elements once the correct limiting value has been reached.

In most cases however the stack is part of a closed loop temperature control system and the implementation of the limit circuitry has a direct influence on the controllability and stability of the control loop. It has always been our aim to produce the best temperature control, so it is important that new stack designs continue to include the necessary control strategies to ensure this aim is achieved.

It is often assumed that current limit action is only of importance when the load resistance varies with temperature but this is not actually the case since the customer will often use the current limit setting to limit the loading on the supply or to limit the element current for safety reasons. This can just as easily occur when the elements are Nickel alloys as when they are Kanthal Super™ or other very high temperature material when load current limitation is required during the warm-up phase of operation.

To see how current limit should work let us look first at the case of Nickel alloy furnaces.

Constant Load Resistance

Here we can consider the case of a user who, for whatever reason, has chosen a heater resistance which will overload his supply. He sets the current limit in the stack to the maximum current which the supply can stand.

Figure 1a shows several ways in which the stack could be designed to achieve this effect.

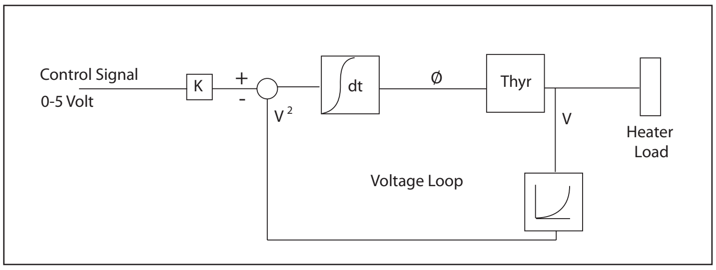


Figure 1a. Simple Attenuator System

Figure 1b shows an absolute current limit control. Here, at some control signal value, the stack current will meet bounding value. For control signal values greater than this the stack current will remain fixed.

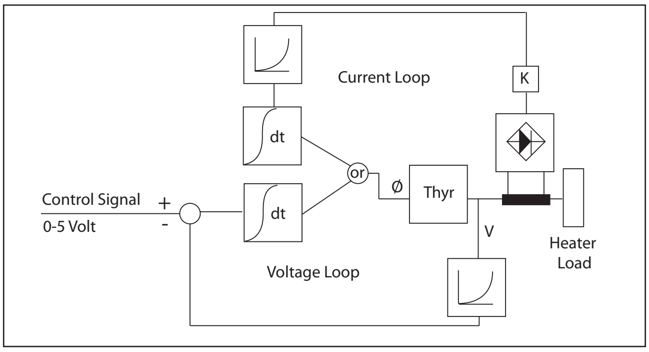


Figure 1b. Absolute Current Limit

Figure 1c shows a scaled current limit control. Here the stack current value is scaled by the control signal, always reaching its greatest value at maximum control signal. It differs from the situation in 1a in its behaviour if the control signal exceeds the nominal maximum value.

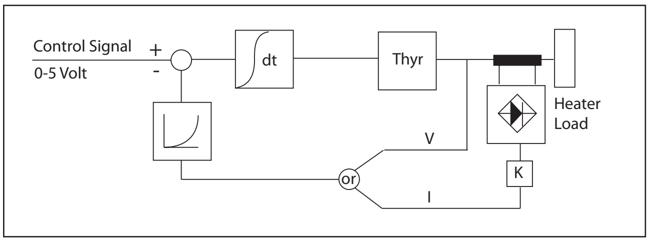


Figure 1c. Voltage/Current Transfer

Figures 2a - 2c show the control characteristics for the three situations described in Figures 1a-1c.

Why is it important to differentiate between these methods? In terms of the stack behaviour when driven manually there is not much difference. However, consider the case when the control signal is derived from a temperature controller. Here the control loop is effectively opened whenever the current cannot be influenced by the control signal. This is the case whenever the stack is in limiting current.

For the cases of 2a and 2c this will be when the control signal reaches 5 volts, whilst for the case of 2b this will be when the stack reaches the absolute limit. (2.5 volts for the case of 90 degrees conduction). In 2a and 2c the maximum corresponds to the maximum output from the controller so that the three-term controller integral limiting circuits will operate to prevent integral wind-up.

In the case of 2b though, the controller output will continue to increase beyond the point at which limiting value of load current is reached. This means that the dynamic range of the control signal is no longer matched with the dynamic range of the Thyristor stack and will result in integral saturation problems in the temperature control loop. Of course it could be possible to adjust the "maximum output power" setting to match the Thyristor control signal requirement, but this also has the effect of decreasing the effective resolution of the output stage and is only really feasible if the reduction is very small.

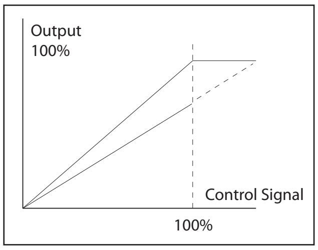


Figure 2a. Current Limiting by Input Attenuator

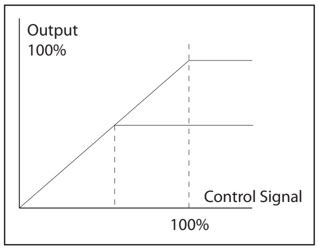


Figure 2b. Absolute Current Limit

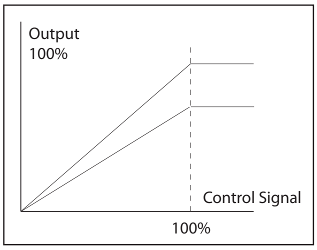


Figure 2c. Current Limit by Voltage/Current Transfer

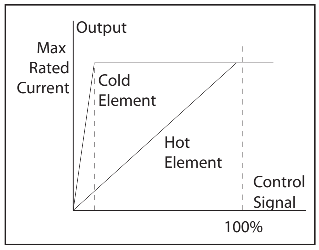


Figure 3. Absolute Current Limit with Variable Hot/Cold Resistance

Low Cold Resistance Loads

Materials coming into this category are Tungsten, Molybdenum, Platinum and alloys such as Kanthal Super™ (Molybdenum-Disilicide). These materials have a very large ratio between their cold and hot resistivity, often between 10 and 20 times. When put as the load on a thyristor stack therefore it is essential to use current limit action when cold in order to avoid the 10 to 20 times possible current over-rating of stack, supply and heater element. As the element warms up it is possible to relax the current limit action until at operating temperature when no limiting action is needed. It is therefore clear that a gradual and automatic transfer between the limited mode and the non-limited mode is needed for operation with this type of element.

Possible current limit strategies are of course the same as discussed previously, with the same disadvantages and advantages. However, there is an additional disadvantage associated with strategy 1a. Since the load resistance will vary continuously the degree of attenuation needed to allow maximum permitted load power to be achieved will vary from very high when cold through to nothing when hot. This must be done automatically. There is also an extra disadvantage associated with the absolute limit scheme of 1b. The very large current which can flow into a cold element means that the current limit will operate very close to zero. This is shown in Figure 3. The effect of this is that if the user is trying to control the temperature warm up of the load the control loop will behave as almost ON-OFF with PID action and integral wind-up; not a good combination at all, particularly for stable control!

Other Load Materials

There are other load materials such as Graphite or Silicon Carbide which have resistance change either with time or temperature. However, all these materials have requirements for current limit action which have been described already. They may well have other requirements for control strategy which will influence the design of the stack but they are the subject of another role.

Choice of Current Strategy

In order to achieve the required control loop behaviour as well as to limit the maximum permitted load current the current limit action should therefore operate as follows:

a. The adjustment of the limit should represent the current flowing at maximum control signal value.

b. The load current should be zero at the minimum control signal value.

c. The load power at any element temperature should vary linearly as the control signal is varied between minimum and maximum values. This is to ensure that the loop is linear, even though the loop gain will vary with the element temperature.

d. The current control loop itself must be as fast acting as possible. This is to ensure that when included in the temperature loop, a change of setpoint which calls for a rapid increase of power does not allow the current to overshoot the maximum limit value, causing fuse blowing.

e. When the current limit is not operating, the stack should be designed to operate in a mode which preserves the linear relationship between load power and control signal. (There may occasionally be exceptions to this requirement due to particular load or control demands).

f. In addition, it is desirable to have an input attenuator available at all times in order to allow the unit to operate with V/I Transfer current limit and still have a maximum output limit adjustment in the V squared mode which preserves the full dynamic range of the control signal of the controller. This then allows the element rating when hot to be controlled whilst still preserving controllability of the overall temperature loop when the elements are cold.

g. For direct conduction heating in glass systems and for carbon heater systems V/I transfer has shown itself to provide the most satisfactory control strategy.

Heat Treatment
INDUSTRY

Thyristor Firing Silicon Carbide Heating Elements

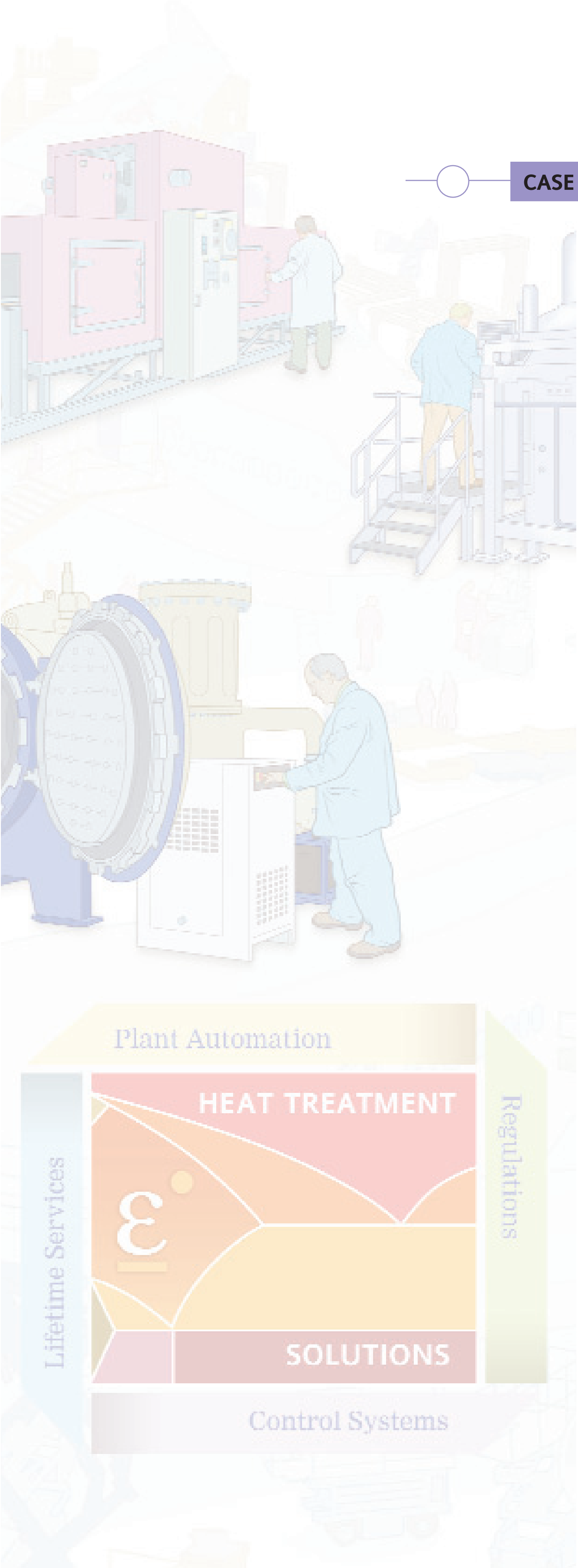
Silicon Carbide heating elements are widely used in thermal processing applications from 600-1600°C (1110-2910°F).
They can be supplied in a range of sizes and forms and are one of the worlds most popular heating elements.

Silicon Carbide in general has an asymptotic relationship between temperature and resistance with a minima at approximately 800 to 850°C. To further complicate matters there is a 2.5:1 increase in resistance with 'age'. Ageing of the element material takes place over a period of time dependent on a variety of prevailing conditions.

Summary of salient features:-

1. Minimum resistance in all cases is at 800/850°C
2. Normal resistance value is quoted at 850°C for Cruscelite and 1050°C for others
3. Resistance tolerance in worst case -20%
4. Material is purely sensitive
5. Resistance at room temperature bears no resemblance to nominal resistance
6. Ageing – takes place usually over years up to maximum of 2.5:1, dependent on the following conditions:
   a. Element loading (expressed in ϖ/cm2)
   b. Operating temperature
   c. Surrounding atmosphere
   d. Number of 'cold starts'
7. Silicon Carbide is sensitive to thermal shock so increase in temperature from cold should be cautious to avoid premature ageing, or fracture
8. It is common practice to burst fire Silicon Carbide though the manufacturers insist that this severely degrades the lifespan of elements – users tend to dispute this
9. Whilst it would appear to customers that use of the current limit control would enable a form of power compensation to be achieved this is manifestly untrue as power = $I^2R \therefore$ as R increases with age the power is progressively increased
10. Phase angle control would appear to offer the desired smooth adjustment of power input to the element necessary to avoid rapid deterioration. It unfortunately offers disadvantage of radio frequency interference, waveform distortion and a reduction in apparent power factor
11. Burst firing on the other hand creates the thermal shock to elements that manufacturers say is damaging
12. Single cycle firing would appear to offer the most acceptable form of power regulation which could be further improved if this were related to element temperature
13. It seems that as Silicon Carbide absorbs moisture at low temperatures and significant damage on degradation can occur if substantial power is dissipated. To avoid this, a variety of methods can be applied to progressively increase the power limit proportional to elevate temperature. This method not only satisfies the concerns of the manufacturers, it also demonstrates to our customers an awareness of practical applications. This compensation can be readily achieved at relatively low cost with the current range of digital instrumentation

White paper



CASE STUDIES

- Eurotherm® to supply replacement Extrusion Press Supervisory System (ESS) at Special Metals Wiggin Limited (SMW)
- Improving Performance for Accredited Thermal Processes

Heat Treatment

INDUSTRY

Case study

Eurotherm® to supply replacement Extrusion Press Supervisory System (ESS) at Special Metals Wiggin Limited (SMW)

SMW, located in Hereford, UK is a major manufacturer of a wide selection of high performance nickel based alloys in the form of rod, bar, sheet, strip, section, tubing and wire products. The manufacturing processes involve melting, primary hot working, hot rolling, cold rolling and cold drawing, generally categorised as metal forming processes.

Production is usually carried out against customer orders, hence the environment is primarily batch manufacturing. The 5650 ton Extrusion Press and associated furnaces for preheating are critical to dealing with approximately 75% of the SMW product range.

The Extrusion Press is supported by six batch furnaces for preheating of the raw product (billets) before extrusion can take place. Charging patterns are created to show the positioning of the billets in each furnace, depending on the size of the billet, type of furnace and required discharge order.

The benefits to SMW of operating the Extrusion Press using a supervisory system as opposed to manual operation are:

- Improved quality
- Increased productivity
- Increased product yield

The existing Extrusion Press Supervisory System supplied these benefits by providing functions that deliver:

- Compliance to standard operating procedures
- Efficient use of plant
- Effective use of labour
- Association of specific events with a product for full traceability (real time recording)
- Search and retrieval of historical data
- Recording of product quality and associated events
- Process analysis and quality performance measurement
- Continuous improvement in process, product quality and efficiency

The Section Leader, Systems Development Section and the SMW Project Manager said: "It was important that we selected the right company to replace the existing Extrusion Press Supervisory System. We invited several companies to tender for the contract and upon receiving the tenders we carried out an extensive review of each tender. The review culminated in a shortlist of potential vendors who we assessed by visiting them, meeting their key people and visiting their reference sites.

Eurotherm® was selected as our preferred vendor because their proposal, experience in our industry, and the positive feedback received from their major customers met all our requirements for the development and support of the new system."

Eurotherm proposed a replacement Extrusion Press Supervisory System based on a blend of standard, configurable, and off the shelf Windows® operating system software that will be augmented with bespoke software services and broadly comprises of:

- Microsoft® Windows® operating system 2000 SQL Server
- EurothermSuite® Operation Server and Viewer Clients
- EurothermSuite® Information Manager
- Microsoft® SQL Server Reporting Services
- OPC® servers and clients
- Microsoft® Windows® operating system services
- Microsoft® Windows® operating system forms applications

Eurotherm selected this architecture as the most appropriate solution to SMW's requirements, as it provided:

- The SCADA system but, most importantly, the middleware link between the shop floor and the MES/MIS business layer
- Open system environment
- Hardware portable and future proof
- Cost efficiency

Heat Treatment

INDUSTRY

White paper

Improving Performance for Accredited Thermal Processes

“...the move to a greater degree of furnace compliance for thermal treatments is building confidence between thermal processing equipment manufacturers and customers. This is especially true when the furnace design is coupled to the design of expert process control systems.”

Furnace builders are employing new design features to improve the overall temperature distribution of their equipment. Careful design of the energy and power density along with improved atmosphere flow patterns has led to very good useful working volumes.

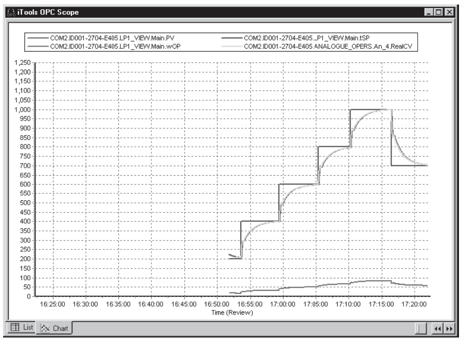
Process conformity is a major issue for aerospace (typically Nadcap AMS2750) and automotive (TS16949) customers and the move to a greater degree of furnace compliance for thermal treatments is building confidence between thermal processing equipment manufacturers and customers. This is especially true when the furnace design is coupled to the design of expert process control systems. Eurotherm® has built a unique knowledge of aerospace and automotive thermal processing specifications. This, with specially designed products and systems, helps ensure the controlled parameters are maintained inside accredited limits at all times.

Three issues drive consideration for modern control system design:

1. The gain and thermal lag in most modern furnaces with low thermal mass insulation is principally becoming a factor of the load size and setpoint value rather than the furnace structure or its inherent components.
2. Customers are seeking ways to take much more account of actual workload temperatures in their control algorithms, so a greater number of processes are utilizing some method of workload temperature optimization.
3. Accredited processes often define furnace approvals by specific classification. To obtain maximum efficiency in production planning with the highest value in workload capability, it is critical that thermal processing equipment performs consistently to its most appropriate class.

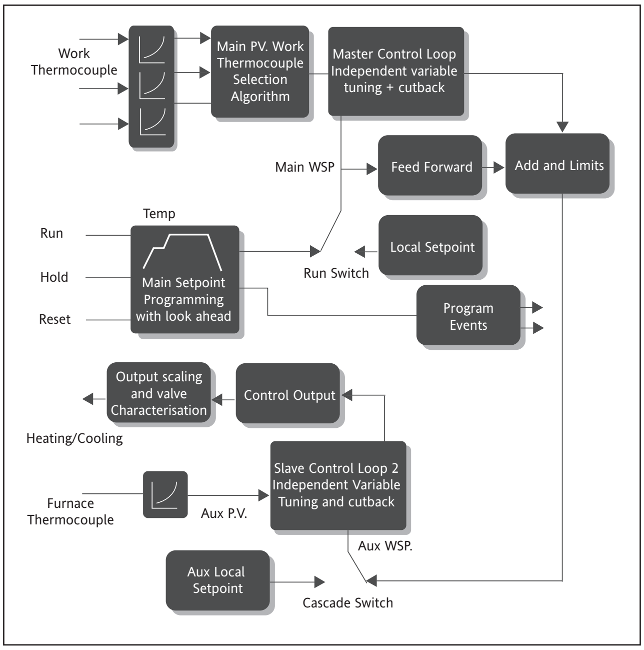
A recurring problem for customers is excessive workload temperature excursions that can occur on start-up or on profiled ramps, even when the controlled zones stay close to the desired thermal profile. Since many work piece components have variable cross sections, undesirable temperature excursions can have a detrimental effect, particularly on thin-section parts of the load. These excursions can cause furnaces to fail audit. Because of this, many users resort to quite crude methods of overshoot elimination and gain optimization, which invariably add to the process cycle time.

A typical thermal cycle is shown in the graph below. No account has been made of the need to optimize the furnace control based on the load requirements.



The graph shows a very cautious approach to control. While this ensures there are no excessive temperature excursions, it exposes parts of the work piece to long process delays and extends work-in-progress time.

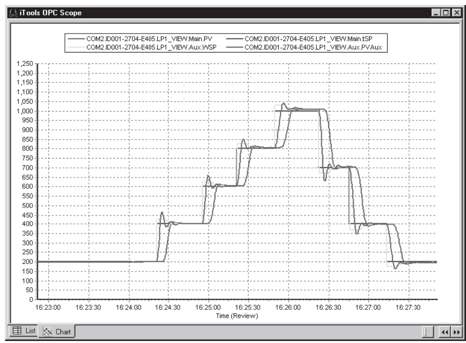
Eurotherm provides an easy to implement range of solutions within their multi-loop, soft-wired products to build a range of control strategies. A typical example is shown in the diagram below:



Some of the benefits of such an arrangement follow:

- Ability to select from a number of work thermocouples based on mathematical functions
- Look ahead on program ramp/dwell transitions to avoid overshoot on profiled ramps
- Unique cutback feature on both master and slave loops providing ability to achieve fastest work temperature settling time with no compromise to tuning for steady state control
- Shared integral action intelligence between master and slave control loops
- Holdback on programming segments gives guaranteed dwell times
- Ability to provide cascade-feed-forward based on setpoint or process value with defined limits to ensure that thin/thick section material temperature differentials are tightly controlled
- PID control on both the master and slave loops ensure correct control optimization for the fast furnace loop and slower work piece loop
- Variable dynamic tuning to improve black-heat/radiant-heat boundary transition
- Output valve gear characterisation for non-linear burner systems
- Excess air profiling

The changes in the thermal cycle are shown in the graph below:

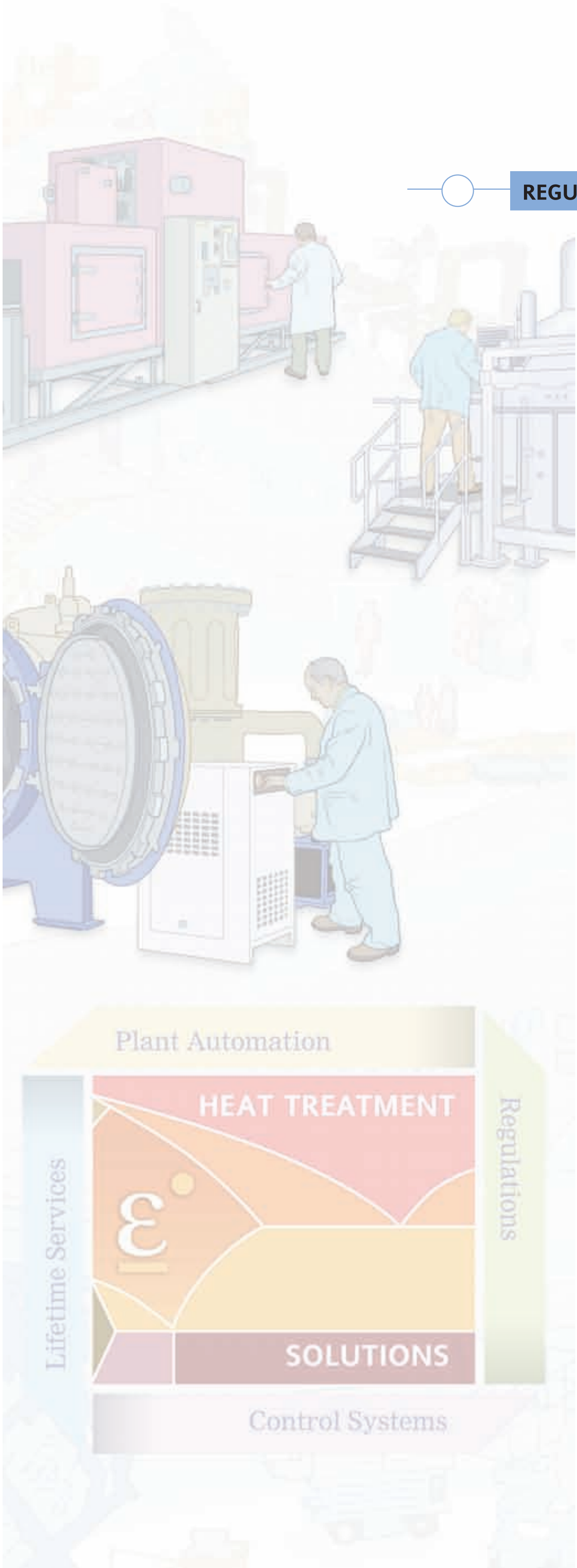


Typical cycle with cascade control and T/C selection

The graph shows that when the solution is able to precisely control the thermal head and, hence, the stored heat in a furnace, it is possible to achieve fast-work-piece temperature-settling times, while continuing to maintain the approved accuracy limits.

As the demand grows for wider equipment usage, improved processing costs, and compliance to higher accredited standards, it is important for users of thermal processing equipment to recognize that simple attention to the control performance of their furnaces and oven equipment can bring benefits in processing time, energy usage, and audited compliance. Eurotherm provides a service to optimize equipment to meet this need.

Eurotherm is committed to developing solutions for heat-treatment and design solutions, which continuously enhance and improve the competitiveness of heat-treatment customers across the world.



REGULATIONS

- Accredited Services for Heat Treatment
- Eurotherm® and Nadcap
- Aerospace Standard AS7102a
- Nadcap Heat Treating Task Group Pyrometer Guide
- SAT Guide
- Digital Data Management in Nadcap Compliant Aerospace Applications

Heat Treatment

INDUSTRY

Application note

Accredited Services for Heat Treatment

Eurotherm® has a wide range of products and services designed to meet the audit regulations for Heat Treatment.

Regulations fall into two main categories and Eurotherm provide solutions to meet both requirements:

- Accreditation quality systems such as the aerospace standard AS7102 (Nadcap) and AMS2750
- Company quality manual processes such as the automotive industry standard QS9000 and TS16949

Nadcap (National Aerospace and Defense Contractors Accreditation Program).

Eurotherm are committed to helping customers achieve the quality standard which comes from the requirements of these specifications:

AS7102	Nadcap requirements for heat treating
AS7102/1	Requirements for national aerospace and defense contractors accreditation brazing program

Publications are available from www.pri-network.org

AMS2750D	Pyrometry

Specifications are SAE publications and are available from www.sae.org

TS16949

ISO/TS 16949:2002 is an ISO Technical Specification which aligns existing American (QS-9000), German (VDA6.1), French (EAQF) and Italian (AVSQ) automotive quality systems standards within the global automotive industry, with the aim of eliminating the need for multiple certifications to satisfy multiple customer requirements.

Together with ISO 9001:2000, ISO/TS 16949:2002 specifies the quality system requirements for the design/development, production, installation and servicing of automotive related products. The standard is maintained by an international group of vehicle manufacturers, plus national trade associations: The International Automotive Task Force (IATF). In addition, there are customer specific requirements that are required by individual subscribing vehicle manufacturers.

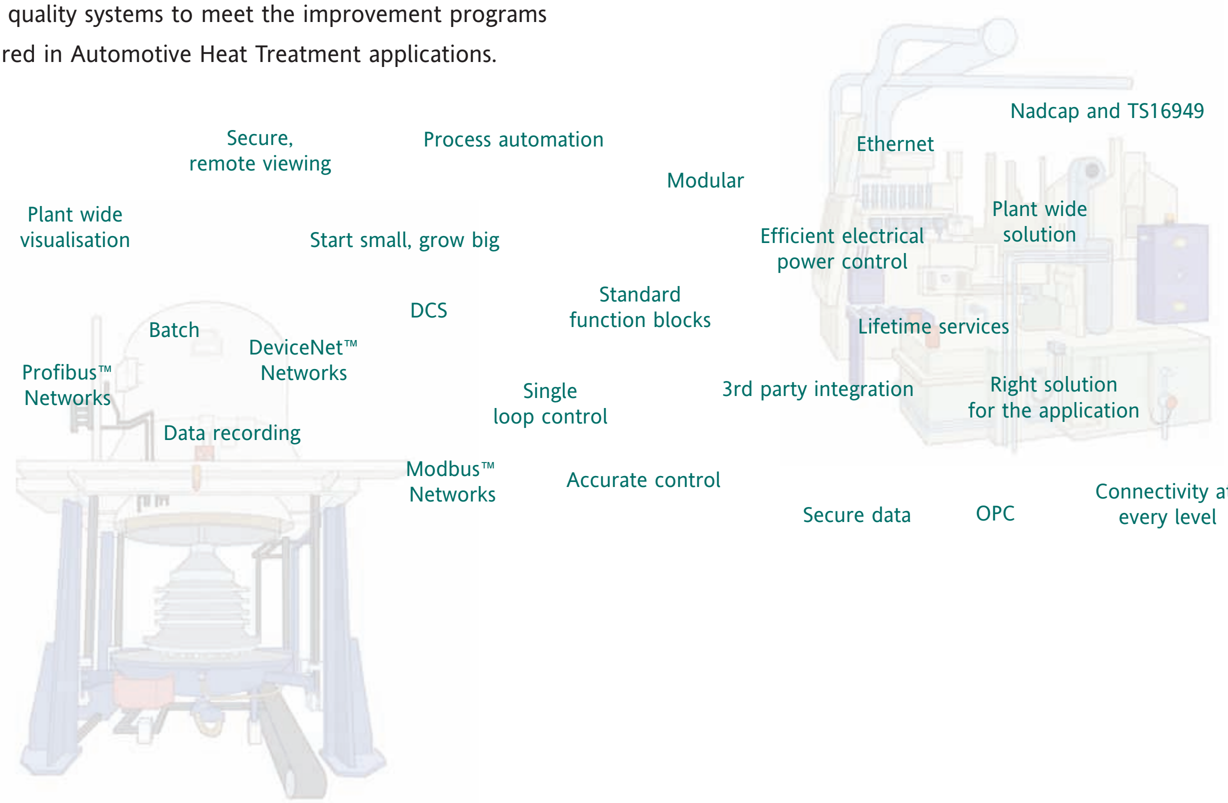
Publications are available from an abundance of web sites and example is shown below:

http://emea.bsi-global.com/Automotive/ISOTS16949/TSQandA.xalter

Eurotherm offer products and services which help customers build quality systems to meet the improvement programs required in Automotive Heat Treatment applications.

How do Eurotherm Help Customers Meet these Quality Requirements?

- Business focus on regulations for industrial process at all levels within Eurotherm
- Global involvement with Heat Treatment industry bodies
- High capability manufacturing and service quality systems
- Full range of field test instrumentation, control monitoring and recording instruments
- Products and services designed to help customers meet requirements of AS7102 and AMS 2750D
- High performance products to meet requirements of System Accuracy Tests (SAT)
- Compliance with demands for maintenance of electronic records and electronic signatures
- World renown control to aid Temperature Uniformity Surveys (TUS)
- Advice and support documentation to aid understanding of the specifications



General Quality Systems (AS7102 Section 3)

Eurotherm understand the demands of working to quality systems and has a key business focus to deliver products, services and advice to support companies with Nadcap accreditation and those seeking future accreditation.

Eurotherm Ltd operates a Management System in accordance with ISO9001 and the TickIT Guide to ensure and demonstrate the design, development and manufacture of products and services conform to their specified requirements.

The organisation intends to maintain its reputation as a supplier of high quality equipment and software and a provider of efficient engineering services throughout the lifetime of its products.

Process Planning and Control (AS7102 Section 4)

- Batch management routines
- Systems for recipe management, recipe revision control and recording of recipe selected
- Simultaneous recording of actual process and required process parameters
- Support for automated record keeping and multiple archive backups
- Embedded logging of furnace malfunctions and interruption events

Personnel (AS7102 Section 5)

- Comprehensive product user manuals
- Application guides for heat treatment equipment
- Training services and advice

Material Handling and Protection (AS7102 Section 6)

- Systems for shop floor automation
- Systems for monitoring remote time temperature records for refrigeration and sub zero temperatures

Test and Inspection (AS7102 Section 7)

- Ability to manually or electronically embed relevant client test results into tamperproof process data files

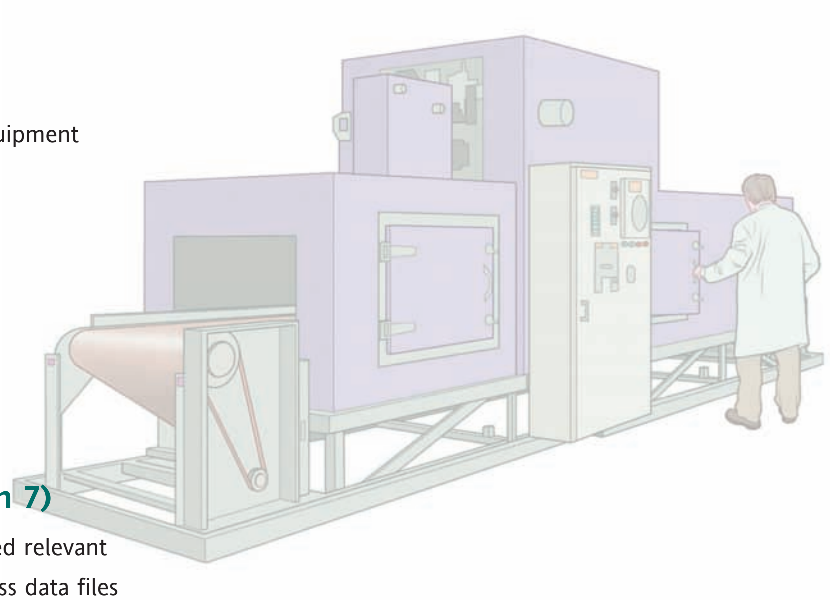
Furnace Control and Maintenance (AS7102 Section 8)

AS7102 section 8 covers the requirements for Furnace Control and Maintenance. This is a key area of business for Eurotherm where we provide Aerospace manufacturers and suppliers services and support, particularly with respect to the following areas:

- Records of heating cycles
- Furnace diagnostics
- Control of the heating environment
- Control routines and records for quench systems
- Pyrometry testing
- Automated vacuum furnace leak rate and pump down routines

Supporting Documentation

A comprehensive response to AS7102 can be found in Eurotherm's document HA029289U001 Available on request or via our website: **www.eurotherm.com**



Eurotherm working with Aerospace Material Specification AMS2750D

Eurotherm provide control solutions to meet the widest range of Nadcap requirements covering instruments as defined in AMS2750D, classes A – E and across furnace classes 1 – 6. Solutions can either be made up from discrete products or integrated systems which include unique benefits for Aerospace and Automotive manufacturers and suppliers.

World Class Products for Control

- Eurotherm has over 40 years reputation for high quality control in the aerospace and automotive industry
- High precision and high accuracy products, with long-term repeatability and performance
- World renown control algorithms
- High precision temperature and process profile programmers
- Excellent for use in integrated temperature vacuum and atmosphere applications
- In-built features to aid Systems Accuracy Tests
- Batch and recipe management
- Multi-user password protection and complete audit trail systems
- Support for furnace diagnostics and maintenance
- Communication to work-piece tracking over-temperature protection

Features to Aid Calibration and Instrument Systems Accuracy Test

- All products covered by unique serial number and/or password protected Instrument tag
- Thermocouple input conversion complies with ASTM230 or national standards
- Routines to restrict thermocouple use outside authorised range
- Routines to record control monitoring and work load thermocouple cycles and usage
- Calibration of instrumentation to meet requirements as defined by AMS2750 in table 3 for:
  - Field test instruments
  - Control, monitoring or recording instruments
- Chart recorders and data management solutions to meet the resolution and speed requirements of AMS2750D tables 4 & 5
- Products designed for long-term calibration stability
- Fully documented manufacturers procedures for recalibration and introduction of offsets
- Procedures to meet accuracy requirements for:
  - Field test instrumentation
  - Controlling, monitoring and recording instruments
- Password protected calibration and offsets
- Digital communications of all parameters for easy recording of SATs and offsets
- Digital instruments have readability to meet requirements of AMS2750D table 4 Note 2
- Products meet the sensitivity requirements of AMS2750D table 3 Note 4
- Error checking for digitally processed parameters used in control systems

Enhanced Features to aid Furnace Temperature Uniformity Performance

- Specialist cutback overshoot parameters
- Specialist overshoot techniques for ramp/dwell transitions
- Alternative high stability control algorithms for gas and electric furnaces
- Multiple tuning sets or dynamic tuning to aid TUS over wide range of setpoints and load sizes
- Work thermocouple monitoring and control routines
- Power feedback routines to eliminate impact of supply
  voltage changes on control stability
- Mathematical functions and graphical soft wired solutions
- Capability for continuous and sequential furnace control

Support and Applications Knowledge

- Provision of local accredited services and application knowledge
- Furnace instrumentation system audits
- Data management network service support
- Furnace optimisation services
- Regional onsite services for system accuracy tests to national accredited standards
- Regional onsite services for Temperature Uniformity Survey tests

Confidence with Process Records and Data Management

Secure process data protection with traceability:

- Creation of write once, read only electronic records
- Compressed, binary, check-summed data files that cannot be altered without detection
- Secure audit trail with operator notes and furnace actions embedded with process data
- Batch details included in secure data files
- Master communication access to other process control system components
- Record of process recipes and requested heat treatment cycles
- Multi-user password protection
- Bridge software for remote viewing of process

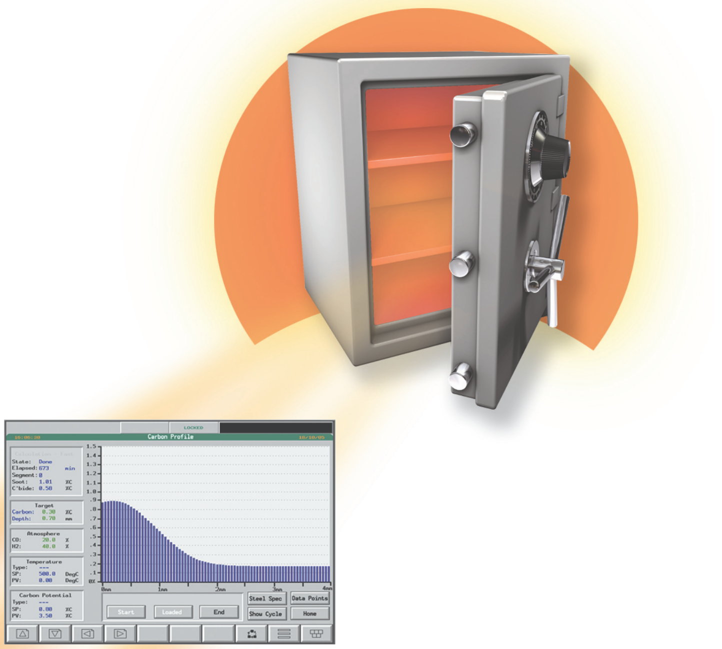
Data archiving strategies that keep your data safe:

- Local data backup and secure data transfer over Ethernet via FTP
- Multiple archiving strategies
- Automatic, secure data file backup and transfer routines
- Archive on demand, archive automatically or archive using Eurotherm 'Review' package
- Multiple archiving destinations: archive to CF/SD, archive to USB memory stick or archive to FTP server
- Provision for primary and secondary FTP server for added security

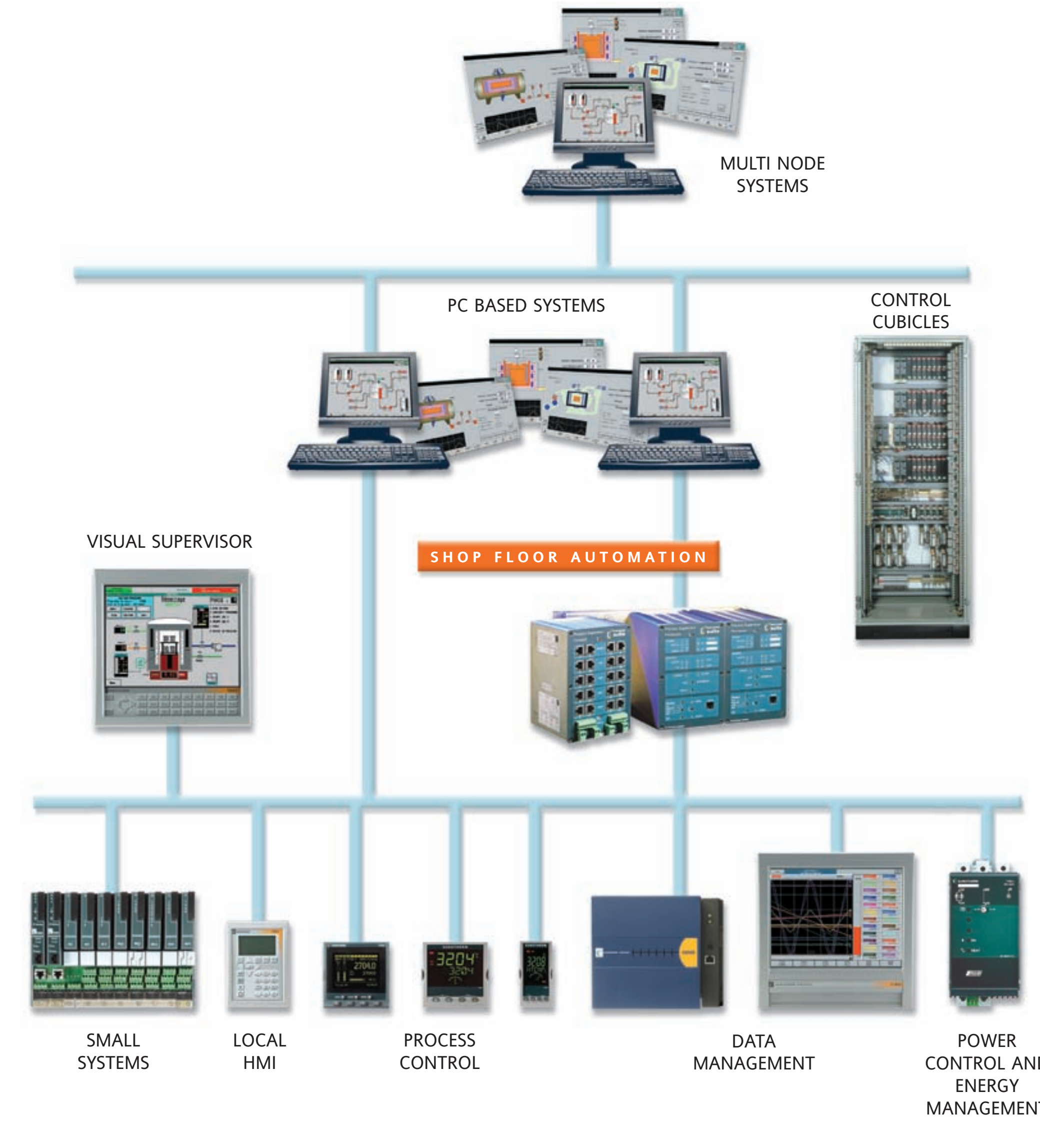
Support for historical reporting and review of data:

- Review software to view encrypted, archived data files
- Ability to generate accurate and complete copies of records in human readable format and in industry standard electronic packages
- Report flexible software facility to provide custom records and reports
- Facility to sort or search for records using parameter or batch data

A comprehensive response to AMS2750D can be found in Eurotherm's document HA029265U001 Available on request or via our website: **www.eurotherm.com**

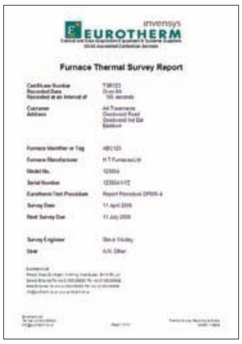


Control systems for Quality Heat Treatment Solutions



Automated Temperature Uniformity Survey Reports

- Saves hours of manual report generation
- Includes automatic production of trend report
- Uses 6000 series secure data file format
- Reporting software securely accesses data from review database



- Includes summary data as defined in AMS2750 3.5.21.1
- Custom data entry pages for all detail as defined in AMS2750D
  - Customer and plant data
  - Custom notes
  - Survey sensor calibration offsets
  - Furnace Instrument data
  - Load sensor location
  - Operator and quality organisation
  - Sign off sheet

HA029339

Heat Treatment INDUSTRY

White paper

Eurotherm® and Nadcap

Aerospace Material Specification
SAE AMS2750D

EUROTHERM TECHNICAL RESPONSE
Instrumentation Supply and General On Site Services

The specification AMS2750D defines pyrometric requirements for thermal processing equipment used for heat treatment. It covers temperature sensors, instrumentation, thermal processing equipment, systems accuracy tests and Temperature Uniformity Surveys.

These are necessary to ensure that parts or raw materials are heat treated in accordance with the applicable specifications.

The following notes offer some guidance on the clauses contained in the specification and the way that Eurotherm can help customers meet the exacting demands of heat treatment accreditation.

The notes must be read in conjunction with the specification document AMS2750D a copy of which can be obtained from SAE International at:
http://www.sae.org

The reference to Eurotherm products in this document refers to:
4000, 5000, and 6000 series data recorders
2000 and 3000 series control products

Section	Topic	Comment
3.1	Temperature Sensors	Applicable to suppliers of accredited thermocouples and sensors Clause defines that sensors must comply with AMS2750D Table 1 and defines how exclusions are detailed
3.1.1	General Sensor Information	Applicable to suppliers of accredited thermocouples and sensors The clause defines general comment on thermocouple manufacture AeroDAQ is capable of recognising inputs from base metal and noble metal thermocouples across the operating range of thermocouples
3.1.1.1	Sensor Certificate of Compliance Requirements	Applicable to suppliers of accredited thermocouples and sensors Clause defines certification for thermocouples and sensors
3.1.1.2	Degrees to Millivolt Conversion	Eurotherm Instrumentation can receive direct inputs from furnace Thermocouples and sensors Conversion from degrees to millivolts is in accordance with ASTM E230 or other national standards
3.1.1.3	Thermocouple Calibration Requirements	Applicable to suppliers of accredited thermocouples and sensors Clause Defines Calibration range for thermocouples and sensors
3.1.1.4 3.1.1.4.1	Thermocouple usage	Clause defines range of usage for thermocouples and sensors Password protected setpoint limits in Eurotherm products restrict use of sensors outside their authorised range AeroDAQ has built-in functionality to calculate time at temperature and number of instances above threshold temperature for specific thermocouple types. See 3.1.8.5 AeroDAQ is capable of recognising inputs from base metal and noble metal thermocouples across the operating range of thermocouples
3.1.1.5	Extension Wire	Applicable to suppliers of accredited thermocouples and sensors Clause defines requirements for thermocouple extension wire
3.1.1.6	Wire Rolls – Calibration Requirements	Applicable to suppliers of accredited thermocouples and sensors Clause and sub clauses defines requirements for calibration of thermocouple wire rolls
3.1.1.7	Wire Rolls – Maximum Allowable Length	Applicable to suppliers of accredited thermocouples and sensors Clause defines maximum thermocouple wire roll sizes
3.1.1.8	Reuse of Type K and E thermocouples as	Applicable to suppliers of accredited thermocouples and sensors
3.1.1.9	Secondary Standards or SAT Sensors Reuse of other Thermocouples	Clause defines conditions for reuse of thermocouples
3.1.1.10	Expendable Base-Metal Test Thermocouple “U” Formula	Applicable to suppliers of accredited thermocouples and sensors Clause and sub clauses defines recalibration of expendable thermocouples and their use and reuse
3.1.2	Reference Standard Sensors	Applicable to suppliers of accredited thermocouples and sensors Clause defines reference standards and refers to AMS2750D Table 1
3.1.3	Primary Standard Sensors	Applicable to suppliers of accredited thermocouples and sensors Clause defines Primary standards and refers to AMS2750D Table 1
3.1.4	Secondary Standard Sensors	Applicable to suppliers of accredited thermocouples and sensors Clause defines Secondary standards and refers to AMS2750D Table 1
3.1.5	Temperature Uniformity Survey Sensors	Applicable to suppliers of accredited thermocouples and sensors Clause and sub clauses defines Temperature Uniformity Survey sensors must comply with AMS2750D Table 1
3.1.6	System Accuracy Test Sensors	Applicable to suppliers of accredited thermocouples and sensors Clause and sub clauses defines System Accuracy Test sensors must comply with AMS2750D Table 1
3.1.7 3.1.7.2	Control, Monitoring, and Recording Sensors	Clause and sub clauses defines Controlling, Monitoring or Recording sensors must comply with AMS2750D Table 1 Also refers to the use of expendable sensors and positioning of Controlling, Monitoring or Recording sensors Eurotherm provide hardware and software features to include load sensors into control equipment and routines for inclusion of load sensors in optional control strategies

Section	Topic	Comment
3.1.8 3.1.8.2 3.1.8.5	Load Sensors	Clause and sub clauses defines that load sensors must comply with AMS2750D Table 1 And further defines how load sensors can be used Eurotherm provide routines to inhibit Controlling, Monitoring or Recording sensors from exceeding maximum allowed processing temperature when load sensor used for control For in-situ sensors, records can automatically compute maximum allowable sensor usage and elapsed usage with alarms against expired sensor periods. See 3.1.1.4
3.2 3.2.1 3.2.2 3.2.2.1 3.2.2.2 3.2.3	Instrumentation	Clause and sub clauses define general requirements of instrumentation referenced in AMS2750D Eurotherm manufacture Heat Treatment instrumentation suitable for use in Nadcap approved aerospace accredited control systems Equipment can be supplied with Factory or On-Site calibration traceable to national standards, ensuring that products meet the requirements of Field Test Instruments and Controlling, Monitoring or Recording Instruments as defined in Table 3, AMS2750D Eurotherm provide on-site control system audit services to determine the suitability of a clients instrumentation to meet demands of AMS2750D Temperature uniformity and resolution of Eurotherm chart recorders meets the requirements of Table 4. Print and Chart Speeds of Eurotherm recorders conform to Table 5, AMS2750D Eurotherm manufacture digital Test Instruments which have a readability of 1 degree F or 1 degree C
3.2.4 3.2.4.2 3.2.4.3 3.2.4.4	Controlling, Monitoring or Recording Instruments	Clause and sub clauses define use and requirements of Control Monitoring and Recording Instruments Eurotherm manufacture Digital Controlling, Monitoring or Recording Instruments have a readability of 1 degree F or 1 degree C Full Installation instructions are provided for all equipment Simple single offset adjustments and multipoint calibration adjustments are available in Eurotherm products Procedures for entering offsets and adjustments are fully documented. Eurotherm products interface directly with sensors and receive unmodified signals Digitally process or communicated values are error checked before representation as direct measured values Eurotherm digital instruments meet the calibration accuracy demanded for Field Test Instruments and Controlling, Monitoring or Recording instruments as defined in Table 3
3.2.5 3.2.5.2 3.2.5.3.2 3.2.5.3.3 3.2.5.5	Instrument Calibration	Clause and sub clauses defines requirements for instrumentation calibration AeroDAQ contains alarm routines to alert user when calibration is due in accordance with Table 3 Eurotherm chart recorders conform with 3.2.5.4 Eurotherm supply manufacturer's instructions for instrument calibration procedures. Operator notes can be appended to the recorder secure data file to record in process calibration Each measuring circuit on Controlling, Monitoring or Recording Instruments and Field Test Instruments is independent and can be calibrated and adjusted independently Instruments meet sensitivity requirements of Table 3 note 4 +/- 1 degree F or C for instruments in class 1 & 2 +/- 3 degrees F or 2 degrees C for instruments in class 3-6
3.2.6	Instrumentation Records	Clause and sub clauses define records, documentation and labelling associated with Instrumentation calibration See separate AMS750D "Onsite Services Response" For Regions where accredited services are provided by Eurotherm

Section	Topic	Comment
3.2.7 3.2.7.1 3.2.7.1.1 3.2.7.1.2 3.2.7.1.3 3.2.7.1.4 3.2.7.1.5	Electronic Records – Instrumentation	Clause and sub clauses define the method, format and procedure for recording, saving and supporting electronic records Eurotherm manufacture data management products which generate, store, archive and replay electronic records Records are stored as compressed, binary, check-summed throughout (for each record) Data files are generated in write_once read_only format which cannot be altered without detection Review Lite and Review Full software applications are available to playback archived data. It is not possible to alter the records of source data in these applications. Data can be exported from Review so that complete copies can be generated in human readable and electronic format. Audited data trail and a lockable media flap is available for data management security File archiving is provided by secure automatic or manual backup and transfer routines Multiple archiving strategies are available. Archive on demand, archive automatically and Archive using 'Review' Multiple Archiving Destinations can be defined, archive to Compact Flash(CF) Secure Digital(SD), archive to USB memory stick, archive to FTP Server Primary and Secondary FTP Server Function Password protection is available with multiple user accounts and custom access
3.3	Thermal Processing Equipment	Clause heading for All Thermal Processing clauses
3.3.1	Furnace Classes Definition of the instrument types can be obtained from the Aerospace Material Specification AMS2750D	Clause defines the range of designated Furnace classes 1 -6 Eurotherm manufacture Controlling, Monitoring or Recording instrumentation suitable for all Furnace classes 1 through 6 and for all Instrumentation types A through E Eurotherm provide application support to advise on Instrumentation class requirements
3.3.1.1	Instrumentation Type A	Clause and sub clauses define the scope of requirement for Instrumentation type A Eurotherm manufacture independent or multi-loop digital control products and digital recording products, which when subject to systems accuracy tests meet the requirements of class A instrumentation. Digital recorders support error checked master communications for recording process values from other instrumentation such as independent zone controllers Control systems support tracking over-temperature devices which provide work piece protection and furnace protection through independent Hi-Hi alarms
3.3.1.2	Instrumentation Type B	Clause and sub clauses define the scope of requirement for Instrumentation type B Eurotherm manufacture independent or multi-loop digital control products and digital recording products, which when subject to systems accuracy tests meet the requirements of class B instrumentation. Digital recorders support error checked master communications for recording process values from other instrumentation such as independent zone controllers Control systems support tracking over-temperature devices which provide work piece protection and furnace over protection through independent Hi-Hi alarms
3.3.1.3	Instrumentation Type C	Clause and sub clauses define the scope of requirement for Instrumentation type C Eurotherm manufacture independent or multi-loop digital control products and digital recording products, which when subject to systems accuracy tests meet the requirements of class C instrumentation. Digital recorders support error checked master communications for recording process values from other instrumentation such as independent zone controllers Control systems support tracking over-temperature devices which provide work piece protection and furnace over protection through independent Hi-Hi alarms
3.3.1.4	Instrumentation Type D	Clause and sub clauses define the scope of requirement for Instrumentation type D Eurotherm manufacture independent or multi-loop digital control products and digital or paper recording products, which meet the requirements of class D instrumentation. Digital recorders support error checked master communications for recording process values from other instrumentation such as independent zone controllers Control systems support tracking over-temperature devices which provide work piece protection and furnace over protection through independent Hi-Hi alarms

Section	Topic	Comment
3.3.1.5	Instrumentation Type E	Clause and sub clauses define the scope of requirement for Instrumentation type E Eurotherm manufacture independent or multi-loop digital control products, which meet the requirements of class E instrumentation
3.3.1.6.1	Instrumentation – Refrigeration Equipment	Clause defines the scope of requirement for Instrumentation suitable for use on Refrigeration equipment
3.3.1.6.2	Instrumentation – Quench Systems	Clause defines the scope of recording equipment for use on quench systems. Eurotherm manufacture recorders suitable for use on quench systems. Recorders can be used to monitor process parameters and record the transfer to quench time for quench hardening processes
3.4	System Accuracy Tests (SAT's)	Clause and sub clauses define the general requirements for System Accuracy Tests and refers to AMS2750D Table 3 Eurotherm manufacture Field test instrumentation and control monitoring and recording equipment as defined in Table 3. Routines are included which aid accurate calibration to meet the requirements of (SATs) for all classes of instrumentation Eurotherm manufacture Field test instrumentation suitable for testing calibration performance of systems accuracy tests On site services by Eurotherm and its service channel partners are available on a regional basis for the provision of (SATs) See separate System Accuracy Test guidance document available from Eurotherm
3.4.2	System Accuracy Test Frequency	Clause and sub clauses define frequency and requirements for System Accuracy Tests AeroDAQ includes routines to calculate the SAT frequency period for specific furnace and instrumentation class as defined in Tables 6 and 7 and notifies the user of the furnace's TUS status
3.4.3 3.4.3.6	System Accuracy Test Waiver	Clause and sub clauses define the conditions under which SATs may be waived Eurotherm provide routines to enable load sensors to be used for control within the constraints identified in clause 3.4.3.1 6100 AeroDAQ has routines to calculate the due dates for SATs when a waiver is applied
3.4.4	System Accuracy Test Procedure	Clause and sub clauses define the procedure for SATs See separate System Accuracy Test guidance document available from Eurotherm
3.4.4.2.1 3.4.4.3	Resident Test Sensors	Clauses and sub clauses defines process for use of resident SATs thermocouple and the mechanism for measuring and dealing with system accuracy differences and correction factors
3.4.4.8	Alternative System Accuracy Test Procedure	Clause defines an objective set of requirements for an alternative to System Accuracy Tests
3.4.5	System Accuracy Test Instrumentation	Clause and sub clause defines that Instrumentation used in System Accuracy Tests must comply to Table 3 Eurotherm manufacture Field Test Instruments and Controlling, Monitoring or Recording Instruments which meet requirements as defined in Table 3
3.4.6	Records – System Accuracy Test	Clause and sub clause defines the scope of recorded information which must be included in SATs reports
3.5	Furnace Temperature Uniformity Surveys (TUS)	Clause and sub clause defines the general requirement for Temperature Uniformity Surveys and refers to AMS2750D Table 8 and 9 Eurotherm manufacture Field test instrumentation suitable for use in Temperature Uniformity Surveys (TUS) Eurotherm manufacture Field test instrumentation suitable for testing calibration performance of systems accuracy tests Eurotherm provide control algorithms which improve furnace performance and aid the ability to achieve TUS conformance Routines are included to eliminate setpoint overshoot for step changes and ramp-dwell transitions Eurotherm provide world renowned steady state control algorithms. On-site services by Eurotherm and its service channel partners are available on a regional basis for the provision of Temperature Uniformity Surveys (TUS)

Section	Topic	Comment
3.5.2	Multiple Qualified Operating Temperature Ranges	Clause and sub clauses define the conditions for a furnace to operate across multiple operating temperature ranges Eurotherm include automatic furnace optimisation routines in control equipment to aid the approved use of thermal processing equipment across the widest range of setpoints with a wide range of furnace load sizes Password protected setpoint limits are available to inhibit the use of equipment outside its approved range
3.5.3	Furnace Modifications	Clause defines furnace modification conditions which result in the requirement for a Temperature Uniformity Survey Eurotherm provide control systems which include automatic optimisation routines such as Multiple gain scheduling. Such routines employed to achieve TUS results across wide setpoint ranges are automatically applied during production heat treatments
3.5.4	Furnace Repairs	Clause defines furnace repair conditions which do not require a Temperature Uniformity Surveys. Engineer electronic signature can be recorded on the AeroDAQ and archived
3.5.5	Initial TUS Temperatures	Clause defines conditions for the initial Temperature Uniformity Survey qualified operating range and the interval between uniformity survey temperatures On site services by Eurotherm and its service channel partners are available on a regional basis for the provision of temperature uniformity surveys (TUS)
3.5.6	Periodic TUS Temperatures	Clause defines conditions for the periodic interval between Temperature Uniformity Surveys On site services by Eurotherm and its service channel partners are available on a regional basis for the provision of temperature uniformity surveys (TUS) AeroDAQ has features to calculate TUS dates as defined in Tables 8 + 9
3.5.7	TUS Frequency	Clause and sub clause defines that the frequency of TUS must be in accordance with Table 8 & 9 and the conditions for extending TUS frequency On site services by Eurotherm and its service channel partners are available on a regional basis for the provision of temperature uniformity surveys (TUS) AeroDAQ has features to calculate dates of extended TUS frequency as defined in Table 10
3.5.8	Furnace Parameters During TUS	Clause defines that conditions pertaining during Temperature Uniformity Surveys, must be maintained during production cycles On site services by Eurotherm and its service channel partners are available on a regional basis for the provision of temperature uniformity surveys (TUS)
3.5.9	Furnace Temperature at Insertion of TUS Sensors	Clause defines conditions under, which load sensors may be inserted into the furnace for Temperature Uniformity Surveys On site services by Eurotherm and its service channel partners are available on a regional basis for the provision of Temperature Uniformity Surveys (TUS)
3.5.10	Load Condition	Clause and sub clause defines the use of production or simulated loads for carrying out Temperature Uniformity Surveys On site services by Eurotherm and its service channel partners are available on a regional basis for the provision of Temperature Uniformity Surveys (TUS)
3.5.11	Furnace Atmosphere during TUS	Clause defines conditions for atmospherically controlled furnace during Temperature Uniformity Surveys Eurotherm provide application specific input linearisations on Field Test Instrumentation and Control Monitoring and Recording instruments to monitor and record furnace atmosphere in engineering units during TUS
3.5.12	Furnace Vacuum Level during TUS	Clause defines conditions for vacuum levels during Temperature Uniformity Surveys on vacuum furnaces Eurotherm provide application specific input linearisations on Field Test Instrumentation and Control Monitoring and Recording instruments to monitor and record furnace vacuum levels in engineering units during (TUS)

Section	Topic	Comment
3.5.13	Batch Furnaces, Salt Baths, Controlled Temperature Liquid Baths and Fluidised Bed Furnaces	Clause defines general conditions for Temperature Uniformity Surveys on this type of Furnace On site services by Eurotherm and its service channel partners are available on a regional basis for the provision of Temperature Uniformity Surveys (TUS)
3.5.13.1	Number of TUS Sensors	Clause defines the number of Temperature Uniformity Surveys sensors for furnaces types covered in 3.5.13 should be in accordance with Table 11 On site services by Eurotherm and its service channel partners are available on a regional basis for the provision of Temperature Uniformity Surveys (TUS)
3.5.13.2	Location of TUS Sensors	Clause and sub clauses define the general arrangement for location of Temperature Uniformity Surveys sensors associated with furnaces types covered in 3.5.13 and defines that number of sensors against work zone volume should be in accordance with Table 11 On site services by Eurotherm and its service channel partners are available on a regional basis for the provision of Temperature Uniformity Surveys (TUS) 5000 and 6000 Series recorders can take up to 48 thermocouples directly connected or upto 176 over Modbus communications
3.5.13.3	TUS Data Collection	Clause and sub clauses define the requirement for monitoring and recording Temperature Uniformity Survey data
3.5.13.3.1		Field Test Instrumentation supplied by Eurotherm, provides secure write once read only files which records information about the TUS Recorders can be scaled and configured to show accurately the following
3.5.13.3.2		That the Recording starts before lowest sensor achieves lower tolerance limit or for prestabilised process when the load is placed in the furnace Records show accurately any sensor exceeding the upper tolerance limit Record frequency can be selected to a maximum frequency of all channel records 9 times per second
3.5.13.3.3		Digital communication or manually entered operator notes which provide detail of other control and recording equipment, as defined in the instrumentation class can be embedded in the secure data files The record shows a time stamped signature of the TUS period and any excursions or trends outside the tolerance limits Manually entered operator notes can be added to the secure data files to show TUS actions
3.5.13.3.4		Eurotherm provide special algorithms to aid the control and uniformity performance of retort furnaces
3.5.13.4	Alternative Probing Method for Salts Baths, Controlled Temperature liquid Baths and Fluidised Bed Furnaces	Clause and sub clauses define the alternative probe method for temperature conformity of equipment defined in these furnace classes On site services by Eurotherm and its service channel partners are available on a regional basis for the provision of temperature uniformity surveys (TUS)
3.5.14	Continuous and Semi-continuous Furnaces	Clause and sub clauses define the general arrangement for carrying out Temperature Uniformity Surveys on continuous furnaces Eurotherm supply Field Test Instrument which can be configured for use in Temperature Uniformity Surveys on continuous furnaces to record data from either the volumetric or plane method Record frequency can be selected to accurately reflect temperature uniformity over the traverse speed of the furnace On site services by Eurotherm and its service channel partners are available on a regional basis for the provision of Temperature Uniformity Surveys (TUS)
3.5.14.1	Number and Location of TUS Sensors – Volumetric Method	Clause and sub clauses define the number and location of sensors for volumetric method tests to be in accordance with Table 11and sub clauses of clauses 3.5.13.2 On site services by Eurotherm and its service channel partners are available on a regional basis for the provision of Temperature Uniformity Surveys (TUS)
3.5.14.2	Number of TUS Sensors – Plane Method	Clause and sub clauses define the number of sensors required for Temperature Uniformity Surveys carried out using the plane method On site services by Eurotherm and its service channel partners are available on a regional basis for the provision of Temperature Uniformity Surveys (TUS)

Section	Topic	Comment
3.5.14.4	TUS Data Collection	Clause and sub clauses define the requirement for Temperature Uniformity Survey data collection on Continuous and semi-continuous furnaces Field Test Instrumentation supplied by Eurotherm provides secure write once read only files which records information about the TUS Recorders can be scaled and configured to show accurately the following That records are produced for each sensor Records are produced for each zone or furnace region Records show accurately any sensor exceeding the upper tolerance limit Record frequency can be selected to a maximum frequency of all channel records 8 times per second Digital communication or manually entered operator notes which provide detail of other control and recording equipment as defined in the instrumentation class can be embedded in the secure data files. Furnace traverse speed can be incorporated in the data record The record shows a time stamped signature of the TUS period and any excursions or trend outside the tolerance limits Manually entered operator notes to show TUS actions can be added to the secure data files On site services by Eurotherm and its service channel partners are available on a regional basis for the provision of temperature uniformity surveys (TUS)
3.5.15	Alternative TUS Methods for Continuous or Semi-continuos Furnaces or Furnaces with Retorts	Clause and sub clauses define alternative test methods for continuous or semi-continuous furnaces or furnaces with retorts or muffles Manually entered operator notes can be embedded into the secure TUS record files to show the result for alternative probe method on continuous furnaces On site services by Eurotherm and its service channel partners are available on a regional basis for the provision of Temperature Uniformity Surveys (TUS)
3.5.15.1	Probing Method	Clause and sub clauses define alternative probe test method retort or muffle furnaces Eurotherm supply recorders which can accept operator notes which are embedded in the secure parameter data file associated with retort of muffle furnace survey On site services by Eurotherm and its service channel partners are available on a regional basis for the provision of Temperature Uniformity Surveys (TUS)
3.5.15.2	Property Surveys	Clause and sub clauses define an alternative method for verifying thermal characteristics of continuous or semi-continuous and retort or muffle furnaces through material analysis and property surveys Not applicable to Eurotherm
3.5.16	TUS Sensor/Failures	Clause and sub clause defines the requirements for dealing with sensor failures during Temperature Uniformity Survey tests Eurotherm supply Field Test Instrumentation that clearly identifies TUS Sensor failures within the TUS records, and via the reporting package, temporary conditions can be identified Operator notes can be embedded into the secure record file to show cause and corrective action associated with any sensor failure
3.5.17	TUS Pass/Fail Requirements	Clause and sub clause defines the pass/fail requirements of Temperature Uniformity Surveys Eurotherm supply Field Test Instrumentation which can be configured to automatically define pass/fail criteria for particular tests The archived file can be used in report software to present TUS data for evaluation Eurotherm supply a TUS reporting package which clearly identifies whether the survey has passed or failed On site services by Eurotherm and its service channel partners are available on a regional basis for the provision of Temperature Uniformity Surveys (TUS)
3.5.18	Relocation of Hot or Cold Recording Sensors for Class A or C Instrumentation	Clause defines the requirements for relocating hot and cold recording sensor in class A & C furnaces. Following successful TUS. Eurotherm report software advises hottest and coldest sensor location On site services by Eurotherm and its service channel partners are available on a regional basis for the provision of Temperature Uniformity Surveys (TUS)

Section	Topic	Comment
3.5.19	TUS Failures	Clause and sub clause defines the requirements for dealing with TUS failures outside the limits in tables 8 & 9 Effects of failures must be evaluated against possible effects as in clause 4.2 AeroDAQ will calculate revised frequency of TUS in case of a failure (Table 6 or 7) On site services by Eurotherm and its service channel partners are available on a regional basis for the provision of Temperature Uniformity Surveys (TUS)
3.5.20	TUS Instrumentation	Clause and sub clause defines that Temperature Uniformity Surveys must only be carried out using equipment which meets the requirement for Field Test Instruments of Table 3 and that TUS sensors must meet the requirement of Table 1 Eurotherm manufacture Field test instrumentation suitable for use in temperature uniformity surveys (TUS Temperature Uniformity Survey instrumentation meets the accuracy calibration requirement of Table 3 (+/-) 1 degree F or 0.6 degrees C or (+/-) 0.1% of reading in degrees F which ever is the greater Compensation for known deviations can be electronically or mathematically appended to the records for correction of results
3.5.21	TUS Report	Clause and sub clauses defines the requirement of mandatory data and alternative data to be included in the TUS report Eurotherm Field Test Instrumentation used for Temperature Uniformity Surveys produces a secure data file of results including all parameter data from the survey sensors and the furnace control and monitoring equipment as well as manually entered actions, sensor failures or special furnace conditions. Eurotherm provide a TUS reporting package to which can provide a printed report from the recorded TUS data conforming to 3.5.21 Control instrument tuning parameters can be stored on AeroDAQ
3.5.22	Prepublication TUS's	Clause defines conditions for accepting Temperature Uniformity Surveys carried out prior to release of AMS2750D On site services by Eurotherm and its service channel partners are available on a regional basis for the provision of Temperature Uniformity Surveys (TUS)
3.5.23	Radiation Surveys	Clause defines the requirement for carrying out and appending data to TUS results for radiation tests on aluminium alloy solution heat treating air furnaces Eurotherm provide Field Test instruments which can collect radiation data automatically or via operator notes The results of the radiation test can be embedded into the TUS data On site services by Eurotherm and its service channel partners are available on a regional basis for the provision of Temperature Uniformity Surveys (TUS)
3.6	Laboratory Furnaces	Clause and sub clauses define the requirements for carrying out SATs and TUS on laboratory furnaces On site services by Eurotherm and its service channel partners are available on a regional basis for the provision of Temperature Uniformity Surveys (TUS)
3.7	Records	Clause and sub clauses define the requirements for saving and storing data associated with SATs and TUS Eurotherm Field Test Instrumentation used for the TUS produces a secure data file of results including all parameter data from the survey sensors and the furnace control and monitoring equipment as well as manually entered actions, sensor failures or special furnace conditions Results can be replayed in Eurotherm Review or exported in an human readable format to other common electronic applications Regional and on-site calibration services provided by Eurotherm are traceable back to National Standards

Section	Topic	Comment
4.0	Quality Assurance Provisions	To aid end user quality responsibility Eurotherm operate an exacting quality programme supported by the following statement Eurotherm Ltd aims to establish, document, review and continually improve an effective and economical Management System in accordance with ISO 9001 and the Tick IT Guide to ensure and demonstrate that the design, development and manufacture of the products and services conform to their specified requirements The achievement of quality shall be the prime responsibility of all personnel and compliance with the organisation's Management System (Quality) is mandatory. Line Management where necessary, shall delegate authority for personnel to identify and investigate quality problems Quality Department will monitor customer satisfaction, the performance, and the agreed quality objectives and ensure adherence to the quality procedures within Eurotherm Ltd The objective of Eurotherm Ltd is continued profitable growth in its role of supplier of quality instrumentation, control equipment and principal systems integrator of group products. This will be achieved through open communication, teamwork and by the implementation of a continuous improvement programme aimed at providing customer satisfaction by increasing efficiency and reducing costs. In addition, the development of application expertise and the total life cycle cost management programmes will enable the organisation to maintain its competitive edge and ensure its international expansion The organisation intends to maintain its reputation as a supplier of high quality equipment and software and a provider of efficient engineering services through out the lifetime of its products
Table 1	Sensors and Sensor Calibration	Table 1 Defines types, usage, calibration period and reference with permitted maximum error associated with multiple sensor categories Where Eurotherm provide On-site services for the provision of AMS2750D System Accuracy Tests (SATs) or Temperature Uniformity Surveys (TUS), Sensors Usage and Sensor calibration is undertaken in accordance with Table 1
Table 2	Thermocouples and Extension Wire	Table 2 Defines standards associated with thermocouples and extension wire Colour codes are in accordance with ASTM E 230 + other relevant National Standards Where Eurotherm provide On-site services for the provision of AMS2750D System Accuracy Tests (SATs) or Temperature Uniformity Surveys (TUS) Thermocouple and extension wire usage and identification is in accordance with Table 2
Table 3	Instruments and Instrument Calibration	Table 3 defines aspects of instrumentation types, calibration periods and calibration accuracy and instrument use associated with multiple categories of instrumentation Eurotherm manufacture Heat Treatment instrumentation suitable for use in aerospace and automotive accredited control systems Equipment can be supplied with fully documented SATS calibration to national standards, ensuring that products meet the requirements of the following instrumentation groups from Table 3 **Field Test Instruments** Digital instruments, Electronic data recorders and data acquisition systems **Controlling, Monitoring or Recording Instruments** Digital instruments Electro Mechanical Chart Recorders Instruments meet the sensitivity requirements of note 4 Table 3
Table 4	Resolution Requirements for Furnace Chart Recorders	Table 4 defines the resolution requirements for chart recorders Eurotherm manufacture chart recorders, which meet the resolution requirement Table 4 and associated notes Digital instruments have a readability of 1 degree F or 1 degree C
Table 5	Process Recorder Print and Chart Speeds	Table 5 defines the requirements for chart recorder print speeds Eurotherm digital and paper chart recorders meet the requirements of Table 5 and associated notes for print and chart speeds

Section	Topic	Comment
Table 6	Parts Furnace Class, Instrument Type, and SAT Interval	Table 6 defines for classes of Parts Furnaces the instrumentation type, SATs interval and performance with associated levels of temperature uniformity, accuracy and permitted offset Eurotherm manufacture Field Test Instruments and Controlling, Monitoring or Recording Instruments which meet the requirement of Table 6 and associated notes On site services by Eurotherm and its service channel partners are available on a regional basis to achieve SATs and TUS performance on thermal processing equipment to meet the requirement of Table 6
Table 7	Raw Material Furnace Class, Instrument Type, and SAT Interval	Table 7 defines for classes of Raw Material Furnaces the instrumentation type, SATs interval and performance with associated levels of temperature uniformity, accuracy and permitted offset Eurotherm manufacture Field Test Instruments and Controlling, Monitoring or Recording Instruments which meet the requirement of Table 7 and associated notes On site services by Eurotherm and its service channel partners are available on a regional basis to achieve SATs and TUS performance on thermal processing equipment to meet the requirement of Table 7
Table 8	Parts Furnace Class, Instrument Type, and TUS Interval	Table 8 defines for classes of Parts Furnaces the instrumentation type, TUS interval and performance with associated levels of temperature uniformity, accuracy and permitted offset Eurotherm manufacture Field Test Instruments and Controlling, Monitoring or Recording Instruments, which meet the requirement of Table 8 and associated notes On site services by Eurotherm and its service channel partners are available on a regional basis to achieve SATs and TUS performance on thermal processing equipment to meet the requirement of Table 8
Table 9	Raw Material Furnace Class, Instrument Type, and TUS Interval	Table 9 defines for classes of Raw Material Furnaces the instrumentation type, TUS interval and performance with associated levels of temperature uniformity, accuracy and permitted offset Eurotherm manufacture Field Test Instruments and Controlling, Monitoring or Recording Instruments, which meet the requirement of Table 9 and associated notes On site services by Eurotherm and its service channel partners are available on a regional basis to achieve SATs and TUS performance on thermal processing equipment to meet the requirement of Table 9
Table 10	Permitted Calibration/Test Interval Extension	Table 10 defines the allowable days extension allowed for any Calibration test interval
Table 11	Number of TUS sensors required	Table 11 and associated notes defines the number of TUS sensors required for batch furnaces, salt baths, controlled temperature liquid baths, Fluidised bed furnaces, or continuous furnaces tested by the volumetric method Eurotherm manufacture Field Test Instruments with up to 48 channels of recording Sample rates can be selected with a maximum speed of all channels sampled at 8 times per second ensuring that complete data files are maintained for even the highest level of TUS sensor densities
8.1	Notes	Notes contain a publishers note for locating specific sections of the specification
8.2	Definitions	Definitions includes a useful glossary of words and phrases as defined in ARP1917 and used in AMS2750D

HA029320

Heat Treatment
INDUSTRY

Aerospace Standard AS7102a

Aerospace Standard
SAE AS7102 Revision A

EUROTHERM® TECHNICAL RESPONSE
Instrumentation Supply and General On Site Services

The specification AS7102 Rev A is the Aerospace Standard for the National Aerospace and Defense Contractors Accreditation Program requirements for heat-treating.

The standard is used in association with AC7102 which is the Audit Criteria document used by officers of the Performance Review Institute NADCAP Heat Treating Task Group to verify the accredited status of suppliers. These regulations are necessary to ensure that parts or raw materials used in the aerospace industry are heat treated in accordance with the applicable specifications.

The following notes offer some guidance on the clauses contained in the specification and the way Eurotherm can help customers to meet the exacting demands of heat treatment accreditation for clauses, which are appropriate to Eurotherm's business.

The notes must be read in conjunction with the specification document AS7102 RevA a copy of which can be purchased from SAE International at the following web address:
www.sae.org/servlets/productDetail?PROD_TYP=STD&PROD_CD=AS7102AD
The audit criteria AC7102 can be obtained from the Performance Review Institute at **www.pri-network.org**

White paper

Section	Topic	Comment
2.1.1	SAE Publications	Clause defines other SAE publications which bear relevance to AS7102 Of particular interest are · AMS2750 Pyrometry · AS7102/1 NADCAP Requirements for heat treating accreditation programs – Brazing Requirements · AMS2801 Heat Treatment Titanium Alloy Parts
2.1.2	PRI Publications	Clause defines other PRI publications which bear relevance to AS7102 Of particular interest are · AC7102 NADCAP Audit criteria for Heat Treating · AC7102/1 NADCAP Audit criteria for Heat Treating-Brazing
2.2	Definitions	Clause provides a definition for documents which are used for instructions and procedures associated with specific tasks Also provides a definition for interpolation of values between two known points
3.	General Quality System	Clause defines the requirement for a general quality system
3.1	Quality Policy	Clause defines the need for a clear quality system which must be reviewed at least annually by senior people in the organisation
3.2	Organisation	Clause and sub clauses define the need for a formal organizational chart and clearly defined roles and procedures It also defines the objective to function without longstanding vacancies with employees working to defined procedures
3.3	Quality System	Clause and sub clauses define the need for quality systems to be implemented to meet customer requirements and be subject to revision control
3.4	Document Control	Clause and sub clause defines the need to have a documented system to control standards and other details pertinent to quality It also defines the requirement to hold revision information relating to material processing standards and customer standards on file
3.5	Communications	Clause and sub clause defines the need to have procedures for communications between management and employees to benefit the development of business and quality
3.6	Contract Review	Clause and sub clauses define the need to have proper procedures to deal with customer orders, enquiries, quotes and proposals. And that records support the suppliers business with the customer for commercial, technical and quality requirements
3.7	Internal Procedure Planning	Clause and sub clauses define the need to have business and shop floor procedures that comply with the contract review
3.8 and 3.9	Purchasing Supplier selection and Purchasing - Incoming QDA	Clauses and sub clauses defines the need to have procedures for selecting and auditing suppliers Procedures shall also be in place to qualify the source and quality of incoming products and services. Documents supporting incoming goods and service quality and methods to deal with nonconformance must be maintained
3.10	Product Identification and Traceability	Clause and sub clauses define that procedures are in place to deal with identification of parts and samples, conformance of the items to traceable drawings throughout the process
3.11	Stamp and Signature Control	Clause and sub clauses define that procedures are in place to deal with all aspects stamps and signatures control
3.12	Control of Nonconforming Product	Clause and sub clauses define that procedures are in place to deal with all aspects of non-conforming parts including records, parts segregation and reports to customers
3.13	Corrective Action	Clause and sub clauses define that procedures are in place to deal with causes and notify actions associated with corrective action required for non-conforming parts
3.14	Delivery and Service	Clause and sub clauses define that procedures are in place to deal with protection and correct actions for shipment of goods which conform to the requirements of the contract review
3.15	Customer Service and Satisfaction	Clause and sub clauses define that procedures are in place to deal and record actions with regard to customer satisfaction and that discrepancies and authorization for rework are recorded
3.16	Statistical Methods – Process Integrity	Clause and sub clauses define that procedures are in place to determine that key parameters that effect product quality are maintained under statistical analysis. The analysis must lead to a programme of continuous improvement

Section	Topic	Comment
3.17	Statistical Methods – Process Control	Clause and sub clauses define that a documented system must be employed to monitor key process parameters and that the statistical quality system moves the company to improved processes and reduced out of control conditions
3.18	Data Analysis	Clause defines that statistical analysis shall be applied to appropriate test data to aid a programme of continuing improvement
3.19	Internal Quality Audits	Clause and sub clauses define that procedures are in place to carry out internal but independent quality audits where actions are taken and reviewed by management
4.	Process Planning and Control	
4.1	Process Planning	Clause and sub clauses define that procedures are in place to ensure supplier can meet and carry out the requirements of the work and that instructions are available to the shop floor
4.2	Quality Planning	Clause and sub clauses define that procedures are in place to incorporate quality requirements into the planning process and that evidence is available of quality requirements on the job travelers
4.3	Job Documentation	Clause and sub clauses define that procedures are in place to document operations, part numbers, process status, inspection status, engineering changes and other relevant data *Eurotherm Digital Data Management control and recording products and supervisory systems support the association of product batch information with the process and process parameter data. Eurotherm products support barcode readers and local or remotely communicated entry of test data, engineering changes and operator notes. Result are compounded in a secure file for local access and reports*
4.4	Change Control	Clause and sub clauses define that procedures are in place to maintain change control and the revision of travelers is carried out in accordance with authorized requests *Eurotherm produce digital data management and control products, which support password protected audit features for the secure access to recipes and process selection. The audit features are supported by multiple user login and access, which is fully, documented in the stored data files*
4.5	Specification Changes	Clause and sub clauses define that procedures are in place to control the use and introduction of new specifications and the use of old or retired specifications *Eurotherm produce digital data management and control products, which can track specification revision and secure access to current or retired process recipes. Automated equipment supports remote access from online supervisory equipment to control the revision and updating of programs and recipes*
4.6	Process Control	Clause and sub clauses define that procedures are in place to ensure that parts are processed and data is recorded in accordance with information on the traveler *Eurotherm produce digital data management and control products, with batch management routines to ensure products are processed to the correct traveler instruction. Secure data files are produced to show that parameter data associated with the process conform to the instructions on the traveler. Process information associated with batches and product can be appended to the records through batch fields or operator notes*
4.7	Automated Processes and Recordings	Clause and sub clauses define that procedures are in place To ensure that magnetically stored programmes cannot be altered with out authorization and can be stored when requested in separate location That records are tamperproof and cannot be altered *Eurotherm automated control and data management products support password protected audit features, which restrict the access to programmes to authorized personnel. Program information can be transferred in a clone file for storage in a separate secure location. Automated equipment supports remote access from online supervisory equipment to control the revision and updating of programs and recipes* *Automated data management equipment supports tamperproof binary check summed write once read only data files which can be archived to multiple destinations*
4.8	Furnace Malfunctions/Cycle Interruptions	Clause and sub clauses define that procedures are in place to deal with and document actions required for furnace malfunctions *Eurotherm Digital data management and controlling equipment can include procedures or operator instructions to deal with furnace malfunctions* *Operator notes can be added to the secure data file to record the actions associated with any specific malfunction for future analysis*

Section	Topic	Comment
5.	Personnel	Clause and sub clauses define that procedures are in place to train personnel involved in heat treatment duties in accordance with ARP1962
5.2	Training	Clause and sub clauses define that procedures are in place to define and record training regimes for personnel involved with heat treatment duties including required competencies and records of training attendance and attainment
5.3	Evaluation of Personnel	Clause and sub clauses define that procedures are in place to evaluate skills and proficiency of approved personnel. Records shall be maintained of results of evaluation working towards a program of continuous improvement
6	Material Handling and Protection	
6.1	Receiving Procedure	Clause and sub clauses define that procedures are in place to record information on incoming material and to report discrepancies on the count and quality on the received goods. Procedures shall also be in place and documented regarding handling packaging and protection of the goods
6.3	Lot Integrity	Clause and sub clauses define that procedures are in place to specify lots and sub lots and procedures to eliminate mixing of lots and that information of lots is maintained on travelers for in process and finished goods
6.4	Housekeeping	Clause and sub clauses define that procedures are in place to define plant cleanliness, space control, Titanium cleaning handling regimes, and handling of parts. The procedures should be supported by documentation
6.7	Plating and Cleaning	Clause and sub clauses define that records should be in place to record defined process data about plating processes and the periodic review of test results of plating processes *Eurotherm provide data monitoring equipment for the acquisition retrieval and long-term storage of plating bath data. Process information associated with batches and product can be appended to the records through batch fields or operator notes Results of test data can be entered locally or remotely over digital communications and embedded with the stored parameter data files*
6.8	Refrigeration	Clause and sub clauses define that procedures should be in place for the use and time temperature routines of refrigerators in the cooling of aluminium and steel alloys and records must be maintained that the procedures are followed *Eurotherm provide data monitoring equipment for the acquisition retrieval and long-term storage of refrigerator data. Process information associated with batches and product can be appended to the records through batch fields or operator notes*
7	Test and Inspection	
7.1	Survey for Hardness Testing	Clause and sub clauses define procedures for hardness testing and the relevant specifications associated with PRI AC7101/5 accreditation for hardness testing. The clauses define audit/verification requirement for hardness testing equipment and the need to demonstrate repeatability reproducibility and any dimensional scale conversions
7.2	Metallography/Microhardness	Clause and sub clauses define procedures for metallography/microhardness testing and the relevant specifications associated with PRI AC7101/4 accreditation. The clauses define test requirement for surface contamination and surface chemistry associated with partial decarburizing, intergranular oxidation carburization and Nitriding, Current records must be maintained and frequency of test regimes must comply with the specifications
7.2.3	Titanium	Clause and sub clauses defines that systems must be in place to control and record the use of test coupons when processing Titanium to AMS2801 or MIL-H-81200
7.3	Mechanical Testing	Clause defines that SAE AS7101/3 applies when conducting mechanical testing and that SAE AS7101 shall satisfy the requirement
7.4	Non-conventional and Engineering Tests	Clause and sub clauses defines that systems must be in place to carry out non-conventional test in accordance with customer instructions
7.5	Preparation of Mechanical Test Specimens	Clause and sub clauses defines that if mechanical testing specimens are prepared SAE AS7101/7 shall apply and that SAE AS7101 shall satisfy the requirement
7.6	Conductivity Testing	Clause and sub clauses define procedures for periodic testing calibration and recording of data associated with relevant standards for conductive test equipment and test blocks Records drawings and evidence must be maintained to show that procedures regarding the location and orientation of the test meet the requirements of the specification
7.7	Periodic Maintenance of Testing Equipment	Clause and sub clauses defines procedures for periodic maintenance of equipment and that records are kept to show that maintenance is undertaken according to the procedures and relevant standards

Section	Topic	Comment
7.8	Test Materials and Specimens	Clause and sub clauses define that procedures must be in place to deal with test materials and specimens. Records must show the correct use of test coupons and that there is periodic review of results to aid a programme of continuing improvement
7.9	Dimensional Testing	Clause and sub clauses define that procedures must be in place to deal with dimensional testing
7.10	Sampling Plans	Clause and sub clauses define that procedures must be in place to deal with Sampling Plans
7.11	Acceptance/Rejection Standards	Clause and sub clauses define that procedures must be in place to deal with acceptance and rejection standards
7.12	Test Reports and Records	Clause and sub clauses define that procedures must be in place to deal with test reports and records for hardness and conductivity records Procedures need to specify periodic review and a programme of continuing improvement
8	Furnace Control and Maintenance	*Eurotherm supply Control and Data management products, which meet the requirements of "Field Test Instruments" and "Control Monitoring and Recording Instruments" suitable for use in NADCAP compliant heat treatment applications* *Regionally Eurotherm supply accredited services to meet the demands of thermal processing equipment compliance and to aid the effective use of plant*
8.1	Furnace Document Control	Clause and sub clauses defines that operating manuals and instructions are available to personnel requiring access to the information *All Eurotherm products are supported by installation and operating manuals which define the correct use of products within a Nadcap audited environment*
8.1.2	Heating Times	Clause and sub clauses defines that procedures are in place to determine the correct heating/cooling times for processes and that records are kept which show the compliance of the heat cycle. Where required records must show that the actual metal followed the correct heat/cool profile *Eurotherm manufacture control products, which accurately define and control the process to the required thermal profile, including workpiece holdback routines and guaranteed soak times* *Data management products record details of the thermal profile selected and accurately monitor and record the setpoint point demands and the actual process temperature of the process* *Eurotherm control and data management solutions provide cascade/thermal head or override control algorithms which enable the furnace to be accurately controlled from the work-piece metal temperature with recorded data to prove that the metal achieved the required thermal profile*
8.1.3	Maintenance	Clause and sub clauses defines that furnace equipment shall be maintained and inspected in accordance with the defined schedule and that records are maintained to demonstrate compliance and a programme of improvement *Eurotherm Control and Data management products can be configured to include maintenance period/scheduling alarms and user help screens to aid maintenance and test actions. Operator notes can be added to recorded parameter data on the furnace records to indicate the results of periodic maintenance and test routines*
8.2	Furnace Condition	Clause and sub clauses define the need for inspection and the determination of sound furnace operating conditions of all internal and external furnace components
8.3	Control of Heating Environment	Clause and sub clauses defines the need to determine how furnace atmospheres are to be controlled, maintained and monitored and that records are kept to verify that procedures are met *Eurotherm manufacture atmosphere sensors and control equipment which allows furnace and generator atmosphere control to be part of the component specific recipe. Atmosphere parameters are always available to the data management products to monitor and record that atmosphere values follow the defined process recipe*
8.3.4	Metering	Clause and sub clauses define the requirement and procedures for using and checking the use of flow meters *Eurotherm control products include digital events, which can initiate metered gas flow as part of the process cycle. The events are included as part of the furnace log and operator notes can be attached to the log to record the test regime for flow meter equipment*

Section	Topic	Comment
8.3.5	Purging	Clause and sub clauses defines the requirement for purging to eliminate the effects of previous atmospheres and the requirement for ammonia cut off and purge during Nitriding cycles Records must indicate that the procedure is followed Eurotherm provide data management products where actions can be included as part of the furnace log and operator notes can be attached to the log to record the test regime for purging
8.3.6	Salt Baths	Clause and sub clauses defines the requirement for testing and verifying the performance and conformance of salt baths and that records are to kept to indicate that procedures are followed
8.3.7	Aluminum Alloys	Clause and sub clauses defines the procedure, requirement and precautions for processing aluminium alloys and that records are maintained to show the procedures are met
8.4	Carbon Control – Steels	Clause and sub clauses defines the procedures for the correct maintenance, calibration, use and testing of Carbon control systems and that the accuracy of the system is controlled through the results of tests from the heat treatment specification and that records show that procedures are followed *Eurotherm provide discrete and integrated Control and Data management solutions for Gas Carburising and Atmosphere controlled furnaces which operate in a NADCAP compliant environment* *Instrumentation provides accurate control and recording of carbon atmospheres. User booklets include routines for the calibration of the equipment*
8.5	Quench Systems	Clause and sub clauses defines the requirement for quench system operation and delay recording *Eurotherm Control and Data management products include routines to determine the delay time between the thermal carbon process and quenching. The results are monitored and recorded and alarms can be linked to identify out of tolerance delay time*
8.5.2	Quenchant Control	Clause and sub clauses define the requirement for control, operation, compliance use, and records of quench equipment and polymer quenchants *Eurotherm provide control and data management equipment to ensure that the quenchant temperatures and quench tank agitation are in accordance with the requirements of the process traveler before and after the process and that the parameters are recorded as part of the process secure data file* *Instructions are provided in the operator documentation to aid calibration of the control and recording instrumentation*
8.5.3	Quench Effectiveness	Clause and sub clauses defines the requirement and frequency for evaluating the effectiveness of quenchants and that records must be kept to show procedures are followed
8.5.4	Press Quench Checklist	Clause and sub clauses defines the requirement for location and press attributes for quench presses and that the settings shall be in accordance with information on the traveler Procedures must eliminate actions which add to local cooling or mechanical
8.6	Racks, Fixtures and Baskets	Clause and sub clauses defines the requirement and procedures for controlling the design, use authorization and integrity of racks fixtures and baskets and that records must be kept to show that procedures are followed
8.7	Pyrometry Testing	Clause and sub clauses defines the requirement and procedures for applying and conforming with the demands of AMS2750 pyrometry specification or other defining specifications for heat treatment

Section	Topic	Comment
8.7.1	Temperature Uniformity Tests	Clause and sub clauses define the requirement and procedures for carrying out temperature uniformity survey (TUS) tests on thermal processing equipment Eurotherm supply products and services to aid the compliance of furnace equipment to AMS2750D including: · *Regionally available accredited on-site TUS services* · *Supply of Field Test TUS recording and control equipment* · *Supply of TUS reporting software* · *Onsite furnace optimization services to aid TUS compliance* · *Special control routines to aid TUS compliance* · *Password protected products to ensure security of control monitoring and recording equipment* · *Site surveys to verify suitability of control instruments to operate in a NADCAP environment*
8.7.2	System Accuracy (Probe) Tests	Clause and sub clauses define the requirement and procedures for carrying out System Accuracy (Probe) Tests (SATs) Eurotherm supply products and services to aid System Accuracy probe Tests including: · *Regionally available accredited on-site (SATs) services* · *Supply of Field Test (Sats) recording and control equipment* · *Supply of records and certificates to show compliance of the tests to AMS2750D* · *Advice and training on System Accuracy Tests compliance*
8.7.3	Instrument Calibration	Clause and sub clauses define the requirement and procedures and accuracy associated with instrument calibrations according to AMS2750 or more stringent regulations as they apply Eurotherm supply products and services to aid the compliance of Instrument calibration including the following: · *Regionally available accredited on-site instrument calibration services* · *Supply of Field Test instruments and Control Monitoring and Recording instruments that meet the requirements of AMS2750D tables 3, 6 and 7* · *Supply of records and certificates to show compliance of instrument calibration to AMS2750D* · *User instructions for the introduction and use of offsets* · *User Calibration and recalibration instructions* · *Supply of products, which meet the sensitivity tests for analogue and digital Field Test instruments and Control Monitoring and Recording instruments* · *Site instrument audits to verify suitability of instruments to operate in a NAPCAP environment* · *Advice and training on Instrumentation calibration compliance*
8.7.4	Aluminum Solution Heat Treating Furnaces Having Heat Source in Walls	Clause and sub clauses define the requirement for preventing radiant heating in aluminium solution heat treatment furnaces and to provide radiation test prior to initial use and after repairs or refurbishment
8.7.5	If offsetting is used, there shall be a procedure that specifies the use of offsets	Clause and sub clauses define procedures for introducing and use of offset and that procedures must be in line with customers requirements and records kept to confirm that procedures have been followed *Eurotherm supply Control and Data management products suitable for use in NADCAP compliant heat treatment applications which support the introduction and use of offsets* *Offsets are under password protection such that only authorized adjustment is made with in the limit of the customer requirement and the relevant specification*

Section	Topic	Comment
8.8	Vacuum Furnaces	Clause and sub clauses define requirement and procedures for use and validation of vacuum furnaces, vacuum furnace equipment and quench gas purity and system integrity Eurotherm supply discrete and integrated control systems for use in vacuum furnace applications, which meet the demands of NADCAP compliant solutions. Control and data management equipment interfaces directly with vacuum gauges and sensors Routines are included in the instrumentation to verify the following Furnace pump down performance Automatic leak rate test routines Gauge head swap-over Furnace vacuum pressure levels and partial pressure control Recording of the vacuum pressure levels pump down rates and leak rate test can be included with the furnace recorded secure logged data file User manuals include procedures for calibration of the instrumentation Regionally Eurotherm provide On-site services for the calibration of vacuum gauges and vacuum instrumentation Certificates and reports support calibration records
8.9	Vacuum Procedures	Clause and sub clauses define requirement and procedures for use of vacuum furnace including furnace furniture and fixings, cleaning, loading and shielding, heat/cool/pressure profiles and measurement and procedures or photographic evidence of the placement of load sensors and racking/location of parts to meet the required specification *Eurotherm provide vacuum furnace control and data management solutions, which provide secure recipes that include temperature heat/cool and pressure profiles.* *Control systems can accommodate work load thermocouples which are used to provide guaranteed conformance of the work piece to the requirements of the recipe profile* *User screens can be incorporated to include furnace loading instructions*
9	Brazing	Clause and sub cause specifies that brazing must be carried out to AS7102/1
10	Compliance	Clause and sub cause specifies that the compliance of this specification is controlled by the NADCAP heat treating task force

HA029289

Pyrometry Guide

HEAT TREATMENT

Nadcap
Heat Treating Task Group
Pyrometry Guide

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Table of Contents

PYROMETRY REFERENCE GUIDE

BACKGROUND

During the period that the Nadcap Heat Treat Task Group has been reviewing audits, we have found Pyrometry to be the least understood and the causes of the most problems and confusion. A recent study indicated aside from job audit NCRs, 8 of the top 10 NCR causes are related to Pyrometry.

However, Pyrometry is also the core and basis of all heat treatment practice.

We have prepared this guide to improve the understanding of Pyrometry and the performance of Pyrometric functions.
It provides guidance and interpretations of AMS2750D, as well as fundamental Pyrometry principles and tells you what a Nadcap auditor will expect to see during an audit.

SCOPE: This guide is not intended to replace AMS 2750D or waive any of its requirements or those imposed by customers. The following are Nadcap interpretations of the specification and these interpretations must be used only as guidance to the specification. Customer requirements may exceed those discussed here. It is the responsibility of the supplier to understand and comply with all customer requirements.

OUTLINE

This guide parallels the structure of AMS 2750D by direct reference to its paragraph numbers. The Section headings are:

- Temperature Sensors (usually Thermocouples, but also others)
- Instrumentation
- Thermal Processing Equipment
- System Accuracy Tests (SATs)
- Temperature Uniformity Surveys (TUS)
- Laboratory Furnaces
- Records
- Quality Assurance Provisions
- Definitions

REMEMBER

You the heat treater are ultimately responsible for the product and service you supply. Many heat treaters rely on outside sources to perform Pyrometry. While many of these sources are competent, the heat treater is still responsible for properly documenting the scope of the outside source's work including specification references, and reviewing their work to determine that customer requirements are being met.

INTRODUCTION

If you are a heat treater, you need to know what you need to know.

- A furnace
- Certain heat treating work to do for your customer

In order to be a successful aerospace heat treater, you may need to obtain....

- Nadcap approval
- Specific prime approvals

So then you will need.....

- A contract review (flowdown) process to understand and account for what your customer requires
- A quality system, including calibration, control of product, inspection, etc, to ensure that you supply it. Nadcap requires AC7004 or AS9003 3rd party accreditation.

That's all outside our scope in this document.

So....what IS in this Guide?
As a heat treater, you have special calibration requirements and – you need to know how to control your furnace temperature **by Pyrometry**.

What am I going to heat treat?
What temperatures will I be using?
What temperature tolerance does my customer require?

That determines your furnace classification

What type of temperature sensors will I need?
What kind of errors must be compensated for (correction factors)?
Will I elect to or be required to use load sensors/thermocouples?

That determines what thermocouples to use,

How do I know that the temperature on my instruments is correct?
How is the accuracy of my temperature control and recording changing over time?
How often do I have to check it?

That determines the system accuracy of your furnace

How large is my qualified working zone?
What is the variation of temperature around the set point in my qualified working zone?
How many test sensors (thermocouples) are required to check it and where are they to be placed?
How often do I have to check it?

That determines the temperature uniformity of your furnace

In addition, we will tell you what the Nadcap auditor will be looking for during the audit. You, as the supplier, must have a detailed procedure covering your means of compliance with customer requirements, including documentation. This is required whether you perform these calibrations (tests) yourself or subcontract it to an outside source.

SECTION I
TEMPERATURE SENSORS (AKA TC'S)
WHAT IS A THERMOCOUPLE?
WHAT IS A CORRECTION FACTOR?

Section 3.1 OF AMS 2750D discusses Temperature Sensors.
Tables 1 & 2 of AMS 2750D summarize the entire subject.

THERMOCOUPLES

Thermocouples are the sensors that convey information about what temperature the furnace is operating at and/or what temperature the parts are experiencing. By their very nature, thermocouples have errors associated with them that must be corrected if you want to know the true temperature.

Correction factors are used to adjust the readings of thermocouples, which have some degree of error, to the actual (true) temperature. Your procedures must clearly state when and how you calculate and use correction factors.

Correction factors are supplied with your thermocouple or thermocouple wire certification. You must be sure that you understand whether the certification is reporting error deviation or correction factor. Ask for the report in tabular format.

CORRECTION FACTORS
Used in Temperature Uniformity Surveys and System Accuracy Tests

All certification and documentation must be completely clear and unambiguous, e.g. (for a wire roll calibration)

<table>
<tr><th>ACTUAL TEMP</th><th>Location</th><th>INDICATED READING</th><th>ERROR</th><th>Correction Factor</th><th>Average</th></tr>
<tr><td rowspan="2">1500°F</td><td>Front End/ Lead End /Outside End</td><td>1502°F</td><td>+2°F</td><td>-2°F</td><td rowspan="2">-1.5°F average</td></tr>
<tr><td>Back End/ Lag End/ Inside End</td><td>1501°F</td><td>+1°F</td><td>-1°F</td></tr>
</table>

Otherwise deviation, correction, and error terminology gets mixed.

Documentation should always be set up so that you algebraically add the Correction Factor to the indicated reading to get the actual (true) reading.

Interpolation (estimating **between** known points) is allowed, but extrapolation (estimating **beyond** known points) is **not allowed**.

	1500°F actual	← →	1700°F actual	← →	1900°F actual	→
No extrapolation between		Interpolation allowed between		Interpolation allowed between		No extrapolation above

Paragraph 3.1.1.3 of AMS 2750D covers calibration temperature intervals for thermocouples. At which temperatures and at how many temperatures do the error or correction factor of my thermocouples need to be known.

Calibration of thermocouples (furnace, test, and load) is allowed by this paragraph to be performed at 250°F maximum temperature intervals. Calibration at smaller temperature intervals is allowed and may be advantageous in some circumstances.

During the transition from AMS 2750C to 2750D, there will undoubtedly be thermocouples in stock that were calibrated to AMS 2750C requirements. Provided that the date of calibration precedes the release date of AMS 2750D, these thermocouples may be used. Calibrations performed after the release of AMS 2750D must conform to AMS 2750D requirements.

When correction factors are used:
They may be calculated
Using a mathematical ratio (interpolation) between documented values on the thermocouple calibration report (250°F maximum intervals).
Graphically by plotting the correction factor versus the temperature and reading the correction factor from the corresponding graph.

In both cases, the assumption made is that there is a straight line (correction factor varies linearly with temperature) between each calibration point, though this is not always the case – particularly with base metal thermocouples such as type K.

Alternatively, it is allowable to assume that the correction factor is that for the closest temperature of the 250°F range. The supplier must be consistent and the procedure must clearly define the method for choosing the correction factor. AMS 2750 does not require interpolation and suppliers are not required to interpolate if calibration intervals are 250°F or less. Rounding per AMS E-29 to a whole degree is allowed to be applied at the final result only.

Correction factors may not be extrapolated above or below calibration data listed on the certifications. (i.e.: If the highest calibration temperature on a certification is 1800°F, correction factors for higher temperatures may not be extrapolated and the wire may not be used at higher temperatures).

The use of correction factors on load thermocouples is optional (except where required by a specific customer). However, you must be consistent.

If you USE correction factors, then ALWAYS use correction factors!

If you DON'T USE correction factors, then NEVER use correction factors!

Note: Load thermocouples are subject to System Accuracy Test (SAT) requirements, except as allowed by AMS2750, 3.4.1.2.

GUIDELINES FOR TEMPERATURE SENSORS

GUIDELINES

When ordering wire or thermocouples, be sure that:

- **Any prime specific requirements are known and incorporated into the P.O.**
- **The end use is known (i.e., primary, secondary, test, furnace or load)**
- **The desired thermocouple material type is known**
- **The maximum range of use is known**
- **The test point schedule is specified to the supplier.**

Upon receipt, review the certification for compliance to P.O. requirements, especially the test point schedule. The Quality Assurance System requires that Quality Assurance reviews the certification report and documents the review.

The user must determine the TC material type & end use before purchase.

TERMINOLOGY FOR TEMPERATURE SENSORS

You should be familiar with the following terms. See AMS2750D section 8, for their definitions:

- **Primary Sensor**
- **Noble Metal**
- **Secondary Sensor**
- **Expendable thermocouple**
- **Nonexpendable thermocouple**
- **Base metal thermocouple**
- **Test Sensors**
- **Load Sensor**

REMEMBER: The user must determine the intervals between calibration temperature test points based on end use.

Acceptable practice may be defined as follows:
Calibration test points must be at temperatures and intervals determined by the end use. The lower test point must be equal to or less than the lowest value of the range of use. The upper test point must be equal to or greater than the highest value of the range of use. No interval between any two test points may be greater than 250°F, unless the thermocouples are to be only used at fixed points.

Unacceptable practice may be defined as follows:
The lowest temperature calibration test point is greater than the lowest value of the range of use, or the highest temperature calibration test point is lower than the highest value of the range of use, or where any interval between calibration test points is greater than 250°F.
Remember: No Extrapolation!

THERMOCOUPLES AND THEIR USAGE

Section 3.1 of AMS2750D covers <u>Temperature Sensors</u> and should be reviewed closely for the detailed requirements. Some of the key areas that should be studied include, but are not limited to:

Para 3.1.1.4 - States thermocouple type selection with respect to temperature range usage.
Para 3.1.1.4.1 - States that even though the calibration and usage intervals are maximums, but that the user is still responsible for ensuring that excessive drift has not occurred between calibrations and/or replacements.

Para 3.1.1.5 - States that extension wire in new installations (one year after the issue of revision D) shall conform to ASTM E 230 or national equivalent, and that connectors, plugs, jacks and terminal strips are permitted if they are the compatible type.

Para 3.1.1.6 - States requirements for length and calibration of roll thermocouple wire and what to do if the roll does not meet the accuracy limits.

Para 3.1.1.7 - States requirements for maximum length of a roll of thermocouple wire.

Para 3.1.1.8 - **IMPORTANT** – In order to re-use Types K and E thermocouples above 500°F (260°C) the depth of insertion shall be equal to, or greater than, depth of insertion of any previous use.

Para 3.1.1.9, 3.1.1.10, and 3.1.1.11 list requirements for reuse and recalibration requirements. **NOTE**– This requires appropriate record keeping establishing that limits are maintained.

REMEMBER: Recalibration of Types K and E thermocouples that have been exposed to temperatures above 500°F (260°C) is ALWAYS prohibited.

Para 3.1.8 - States the requirements for Load Sensors.

SECTION II
INSTRUMENTATION
HOW DOES THERMOCOUPLE DATA GET USED FOR RECORDING AND CONTROL?
WHAT ARE THE REQUIREMENTS FOR INSTRUMENTS?

The instrumentation takes the electrical impulses (millivolt, emf) supplied by the thermocouples and converts them into a readable format.

Table 3 of AMS2750D details the requirements for Test and Furnace Instrumentation, and their Calibration Standards, including their use, calibration interval and accuracy, and what type of standard is required to calibrate the instrument.

Table 4 of AMS2750D lists the resolution (readability) requirements for furnace chart recorders. (See 3.2.2 for further clarification)

Table 5 of AMS2750D gives the requirements for printing and chart speeds for furnace recorders. (See 3.2.2 for further clarification)

Section 3.2 of AMS2750D covers Instrumentation and should be reviewed closely for the detailed requirements. Some of the key areas that should be studied include, but are not limited to:

Para 3.2.1 - Users shall review all instrument requirements in AMS 2750D as not all instruments approved for use in AMS 2750C will meet the requirements of this revision.

Para 3.2.2 - The following requirements (3.2.2.1 and 3.2.2.2) apply to control, monitoring, or recording instruments purchased one year after the issue date of AMS 2750D. Control, monitoring, or recording instruments purchased prior to one year after the publication of AMS 2750D may meet the requirements of AMS 2750C.

Note: The issue date of AMS2750D was September 1, 2005, so this paragraph takes effect on September 1, 2006.

Para 3.2.3 - Test instruments shall be digital and have a minimum readability of 1°F or 1°C.

Note: This also means that where test recordings are required such as with a Temperature Uniformity Survey (TUS) that the recordings and printings must also be digital and automatically recorded.

Para 3.2.4.1 - At least one recording and/or controlling instrument for each zone shall have a minimum readability of 1°F or 1°C.

Para 3.2.4.3 - deals with Offsets. Please study this section and the sub-paragraph carefully if you are using offsets. Either manual or electronic offsets may be used as long as the method is detailed in a documented procedure and the offsets do not exceed the limits allowed in AMS2750D, Tables 6 and 7, as applicable.

Para 3.2.5.3.1 - States the option for, "calibration of controlling, monitoring or recording instruments shall be performed to the manufacturer's instructions or, if the manufacturer's instructions are not used, a minimum of three simulated sensor inputs shall be used at the minimum, midpoint and maximum of the furnace Qualified Operating Temperature Range."

Para 3.2.5.4 - States the requirement for annual verification of recorder speeds.

Para 3.2.5.5 – States that sensitivity shall be checked during calibration. See Table 3 Footnote 4.

Para 3.2.6 - States explicitly that A) The calibration sticker be affixed to the furnace instruments, and B) the calibration report include the complete list of detail items included there.

Para 3.2.7 - States the requirements for Electronic Records. If you utilize computer data acquisition type or recording equipment, this is a section you should review carefully.

SECTION III
THERMAL PROCESSING EQUIPMENT
DOES MY FURNACE HAVE THE PROPER UNIFORMITY AND INSTRUMENTATION FOR THE JOBS I WANT TO PROCESS?

Note: This section is considerably different than AMS2750C. The Thermal Processing Equipment, Section 3.3, is now categorized by Furnace Class (based on Temperature Uniformity) and by Instrumentation Type.

Section 3.3 of AMS2750D covers Thermal Processing Equipment and should be reviewed closely for the detailed requirements. Some of the key areas that should be studied include, but are not limited to:

Para 3.3.1 – States that Furnace classes are defined in Figure A and are based on the minimum requirements for temperature uniformity. Instrumentation types are based on the level of instrumentation used to control, record, or indicate the desired temperature. Frequencies for system accuracy tests, temperature uniformity surveys, and controlling, monitoring, and recording instrument calibrations are based on the furnace class and instrumentation type, and are summarized in (Table 3, 6, 7, 8, or 9).

Furnace Class	Temperature Uniformity Range (Degrees F)	Temperature Uniformity range (Degrees C) Range (Degrees C)
1	± 5	± 3
2	± 10	± 6
3	± 15	± 8
4	± 20	± 10
5	± 25	± 14
6	± 50	± 28

FIGURE A - Furnace Classes

Para 3.3.1.1, 3.3.1.2, 3.3.1.3, 3.3.1.4, and 3.3.1.5 describe what comprises the various **Instrumentation Types A, B, C, D, and E**, respectively. The required instrumentation is for each Control Zone in the furnace. Therefore, multi-zone furnaces will require multiple sets of the required instrumentation.

NOTE to EUROPEAN SUPPLIERS AND OTHERS WORKING TO CELSIUS (±5°C) most closely match Class 2, but the furnace must still meet the ±5°C uniformity requirement if required by a material or processing specification.

It should be noted that AMS2750D does not require any particular Instrumentation Type for any specific heat treatment application or use. These minimum requirements, if any, are driven by the applicable heat treatment or processing specification that references AMS2750 for Pyrometry requirements.

There are incentives for having higher Instrument Types namely longer intervals for System Accuracy Test (SAT) and Temperature Uniformity Surveys (TUS).

It should also be noted that all Instrumentation Types, except for Type E require each furnace control zone to have over-temperature protection.

Para 3.3.1.6 - Instrumentation - Refrigeration Equipment and Quench Systems This is changed from AMS 2750C, as there are new requirements for instrumentation of refrigeration equipment and quench systems.

Other Issues – Parts vs. Raw Material

Nadcap INTERPRETATION

The differentiation between “Part Heat treatment” and “Raw Material Heat Treatment” is a very controversial subject. It is the prerogative of each prime OEM to designate whether they consider certain materials as either “Parts” or “Raw Material”. This controversy is most common with, but may not be limited to, castings and forgings. AMS2750D provides a default definition, but it is only to be used in the absence of a definition from your prime OEM customer.

NOTE: If a supplier wishes to designate all of their furnaces as "Raw Material", then they must have concurrence on this interpretation from ALL of their prime OEM customers.

Use the definitions from AMS2750D:
Para 8.2.34 "Parts Heat Treatment": Heat treatment by a source other than the raw material producer. Product is tested to the requirements of the heat treat processing specification or to applicable requirements of other specifications.

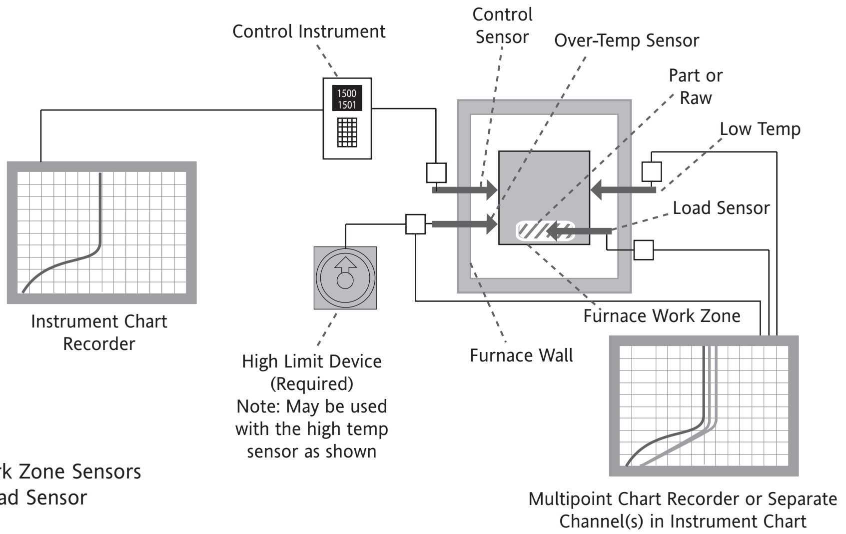
8.2.42 “Raw Material Heat Treatment (e.g., sheet, plate, bar, extrusions, forgings, castings)”: Heat treatment performed by or for the raw material producer and product is tested as required by a material specification.

8.2.43 “Raw Material Furnaces”: Equipment used by or for a material producer (or an approved supplier of a material producer) in accordance with a material specification which may require by reference conformance to a heat treating specification.

USE OF OUTSIDE CALIBRATION SOURCES
You the heat treater must inform the outside Calibration source which of these Definitions apply to the heat treating you are to perform.

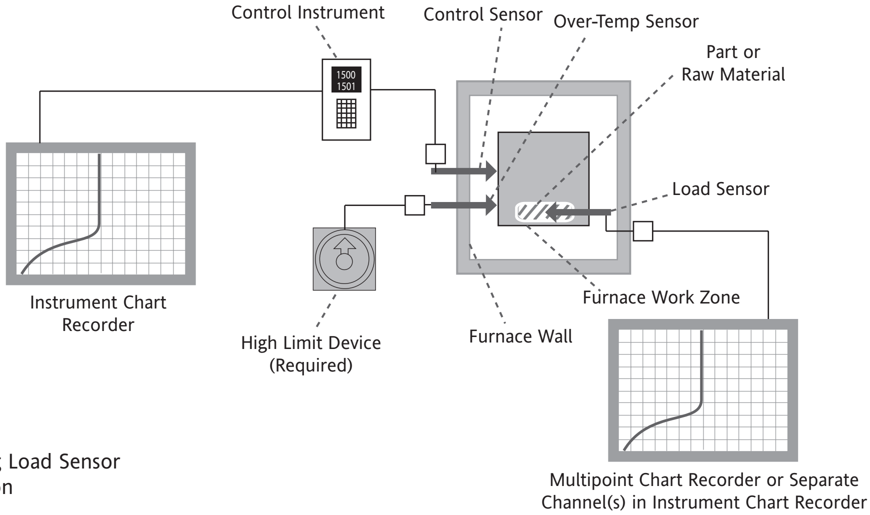
From this the calibration source can determine your requirements from the specifications invoked and the size of the furnace. You, the heat treater, will need to be able to supply evidence that you reviewed and approved the calibration source's procedures, and that you also reviewed their certifications.

Type A Instrumentation



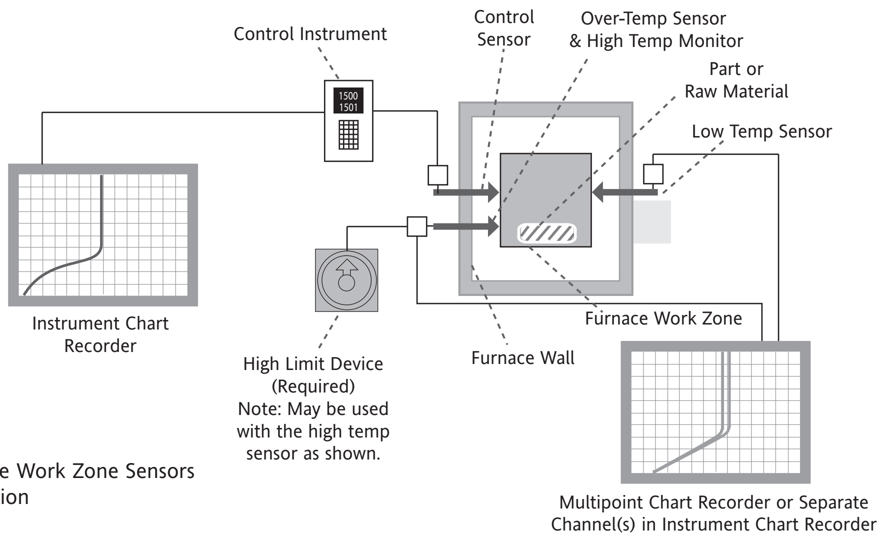
Control Instrument
Control Sensor
Temperature Display
Recording Instruments(s)
High and low Temperature Work Zone Sensors
Minimum of One Recording Load Sensor
Over Temperature Protection

Type B Instrumentation



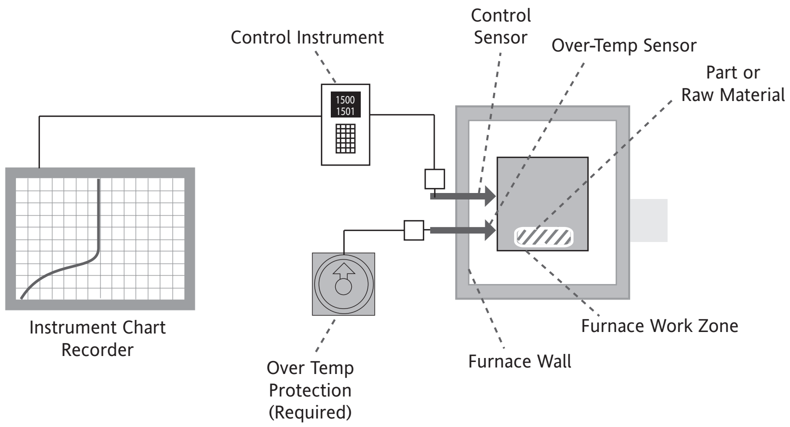
Control Instrument
Control Sensor
Temperature Display
Recording Instruments(s)
Minimum of One Recording Load Sensor
Over Temperature Protection

Type C Instrumentation



Control Instrument
Control Sensor
Temperature Display
Recording Instruments(s)
High and Low Temperature Work Zone Sensors
Over Temperature Protection

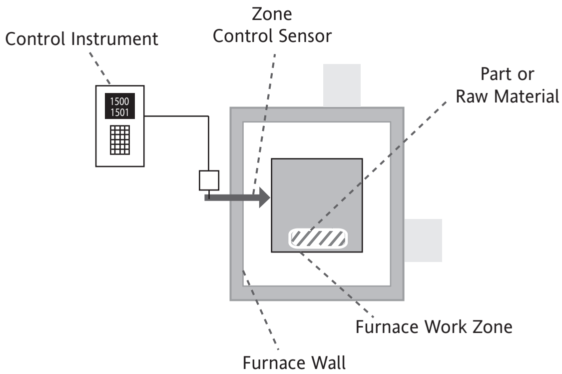
Type D Instrumentation



Control Instrument
Control Sensor
Temperature Display
Recording Instrument
Over Temperature Protection

Nadcap and Re-write Team Interpretation – Although it was not the intended interpretation, AMS2750D requires that the control thermocouple in each zone be recorded and does not allow the use of separate thermocouples for the control and recorder. However, until these changes, any thermocouples that are recorded must be in addition to and not in lieu of the control thermocouple.Nadcap and Re-write Team Interpretation – Although it was not the intended interpretation, AMS2750D requires that the control thermocouple in each zone be recorded and does not allow the use of separate thermocouples for the control and recorder. However, until these changes, any thermocouples that are recorded must be in addition to and not in lieu of the control thermocouple.

Type E Instrumentation



Control Instrument
Control Sensor
Temperature Display

SECTION IV
SYSTEM ACCURACY TESTS (SAT)
IS MY TEMPERATURE INFORMATION CORRECT?

This is simply a test done to determine that the thermocouples, lead wire, and instruments are giving an accurate depiction of temperature. It also provides information as to changes in accuracy of the system over time. It works by comparing the control and/or recording thermocouples in each furnace control zone with a test thermocouple placed near the furnace thermocouple (control and/or recording). If all is well, the same result is obtained (within allowable error limits). If not, something is wrong and corrective action must be taken if the error exceeds allowable limits.

SOME BACKGROUND ON TERMINOLOGY
AMS2750C used the term” Working” when referring to instruments and sensors. Due to various interpretations of “Working”, AMS2720D does not use this term. All instruments are referred to as Controlling, Monitoring, or Recording. All thermocouples are referred to as Furnace, Test, or Standard.

Definition from AMS 2750D:

8.2.59 “System Accuracy Test (SAT) or Probe Check”: An on-site comparison of the instrument/lead wire/sensor readings or values, with the readings or values of a calibrated test instrument/lead wire/sensor to determine if the measured temperature deviations are within applicable requirements. It is performed to assure the accuracy of the furnace control and recorder system in each control zone.

ERRORS and CORRECTON FACTORS

Error is the deviation of the indicated reading of an instrument or sensor under test from the true value.

Example 1: If the indicated temperature is 1000°F and the true temperature is 1002°F, the error is -2°F. To correct the error, you must reverse the sign of the error to make it the correction factor. Then you algebraically add the correction factor to the indicated treading. To correct the indicated temperature, you must add +2°F to 1000°F to get 1002°F.

Example 2: A Test Instrument reading a Test Sensor has an indicated reading of 1000.4°F. The calibration error for the Test Instrument is +0.1°F, and the calibration error for the Test Sensor is -0.3°F The corresponding correction factors are -0.1°F for the test instrument and +0.3°F for the test sensor.

To obtain the true temperature, you must add the correction factors to the indicated reading of the Test Instrument/Test Sensor combination in this way.

This is: 1000.4 + (-0.1) + (+0.3) = 1000.6°F.

NOTE: Some may choose to also correct for the furnace instrument and furnace sensor. **This is not required and not recommended.** However, if correction factors other than test sensor data are used, these correction factors must be used when reading all temperatures during production.

NOTE: It is NEVER acceptable to use the same recorder for system accuracy tests as is used to record furnace data. The only exception would be if totally separate channels are used in the same instrument and they are independently calibrated with a field test instrument that meets the accuracy requirement of a secondary standard instrument. See Table 3 of AMS2750D.

The requirements for SAT frequency are listed in Tables 6 and 7.

Section 3.4 of AMS2750D covers System Accuracy Tests (SAT) and should be reviewed closely for the detailed requirements. Some of the key areas that should be studied include, but are not limited to:

Para 3.4.1 - States that SATs are performed on the temperature control and recording systems in each control zone of each piece of thermal processing equipment. It further requires that SATs are performed on the additional recording systems (furnace and/or load) that qualify the furnace for Types A, B, or C, instrumentation.

Para 3.4.1.2 – States that a SAT is not required for A) sensors whose only function is over-temperature control, B) load sensors that are limited to a single use (one furnace load/cycle), C) sensors not used for acceptance as part of production heat treatment, or D) load sensors whose replacement frequency is shorter than the SAT frequency. See 3.1.8.4 and 3.1.8.5

Para 3.4.1.3 – States that a new SAT shall be performed after any maintenance that could affect the SAT accuracy. Examples include replacement of the thermocouple and recalibration of the instrument when any adjustment has been made. Quality Assurance shall be consulted for direction on whether specific maintenance requires a new SAT.

Para 3.4.2 and Table 6 or 7, as applicable - States the conditions where SAT frequency may be reduced within the limitations allowed.

Para 3.4.3 - States the conditions where the SAT may be waived. Note that all subparagraphs of 3.4.3 must be met to exercise the SAT waiver.

Para 3.4.4.2 – States that the tip (measuring junction) of the SAT sensor shall be **as close as practical** to the tip (measuring junction) of the controlling, monitoring, or recording sensor, but the **tip to tip distance shall not exceed 3 inches (76 mm)**. Subsequent SAT tests shall utilize SAT thermocouple(s) placed in the **same locations/positions/depth as the initial test**. The SAT sensor may be inserted temporarily for the test or may be a resident test sensor, subject to the limitations of 3.4.4.2.1.

Para 3.4.4.2.1 - Addresses the use of **Resident SAT Thermocouples**. AMS2750C was silent on this use, but it is now documented and similar to what was recommended by Nadcap in the past.

Para 3.4.4.3.1 - States in detail about the use of correction factors when and how they may be applied depending on whether there has been any electronic offsets introduced into the instruments. There are also a couple of very good examples on page 17 that show how to calculate the SAT result.

Para 3.4.4.4 – Note the change from AMS2750C. The SAT tolerances listed in Tables 6 and 7 are requirements and these values must be met. There is no more of the "greater than 2°F, but less than 5°F" gray area. If the SAT does not meet the tolerance, the test is failed, corrective action must be taken, and a new SAT must pass before processing may continue in the furnace.

NOTE: The allowable SAT differences are now expressed as x°F or 0.x% of reading, whichever is greater. **Example**: 5°F or 0.5% of reading for a Class 5 furnace; at 1700°F, the allowable SAT difference is 0.5% of 1700°F or 8.5°F.

Para 3.4.4.8 - States an alternative method for performing an SAT where it is impossible or impractical to perform the SAT in the traditional manner.

Para 3.4.6 - States an explicit list of items to be documented for the SAT test.

SECTION V
TEMPERATURE UNIFORMITY SURVEYS (TUS)
IS MY TEMPERATURE OK OVER THE WHOLE FURNACE?

These tests are to ensure that there are no temperature variations outside acceptable limits from place to place within the Qualified Work Zone of the furnace.

TEMPERATURE UNIFORMITY REQUIREMENTS

Calculation of the actual temperature uniformity must be done for each test performed. The calculation is determined by taking the deviation of the **corrected** test sensor reading from the **specified** test temperature. It is not necessary to re-record the data from the digital charts onto a table for each data point. It is sufficient to identify the highest and lowest temperature point on the actual digital chart and apply the correction factors to those two data points, not the entire table. It is not necessary to re-type all the data points from the survey charts.

It is allowable to offset the furnace control set point to center the uniformity as long as it does not exceed the limits of Table 6 or 7. Offset data from the uniformity survey can be used to "center" the temperature of parts being heat treated.

The requirements for TUS frequency are listed in Tables 8 and 9.

Section 3.5 of AMS2750D covers Temperature Uniformity and should be reviewed closely for the detailed requirements. Some of the key areas that should be studied include, but are not limited to:

Para 3.5.2 - States the concept of the Qualified Operating Temperature Range and tells you how to deal with furnaces that may have multiple Qualified Operating Temperature Ranges that may therefore have multiple, different Furnace Classes based on TUS.

Para 3.5.3 and Para 3.5.4 – There are new features to AMS2750. They contain a partial list of:

A) Furnace Modifications, where a new initial TUS must be performed; and
B) Furnace Repairs, where a new initial TUS need not be performed.

The important feature of this section is: **"All furnace modifications shall be documented and the responsible Quality Assurance organization shall make the determination whether an initial TUS is required based on the modifications made and the particular furnace configuration."**

Para 3.5.5 - Requires that the initial TUS is performed at the minimum and maximum temperatures of the Qualified Operating Temperature Range(s), and at intervals of no more than 600°F (335°C) in between.

Para 3.5.6 – States that periodic survey temperatures shall be any temperature within each Qualified Temperature Operating Range(s). Temperatures shall be added as required to ensure that no two adjacent survey temperatures are greater than 600°F (335°C) apart. Additionally, **at least once within each calendar year periodic tests shall be performed at the minimum and maximum temperatures of each Qualified Operating Temperature Range.**

NOTE: Revision C did not require a periodic TUS at the minimum temperature, and allowed the periodic maximum temperature survey to be within 100•F of the furnace's qualified operating range, but periodic TUS above 2000•F were not required.

NOTE: The temperature conversions from Fahrenheit to Celsius degrees given in the example may have typing errors and should not be taken for granted. The temperature values are only examples and not hard requirements.

Para 3.5.7 –States that survey frequency shall be in accordance with Table 8 or Table 9.

Para 3.5.7.1- States that frequency reductions are based on both instrument type and history of the required number of successful surveys. In addition, **a documented preventive maintenance program shall be in effect.**

Para 3.5.8 - States that furnace parameters used during TUS except as outlined in 3.5.9, 3.5.10, 3.5.11 and 3.5.12, shall reflect the normal operation of the furnace and equipment in production.

Para 3.5.10 - This is a change from AMS2750C. It states that a TUS may be performed with an actual production load, simulated production load, a rack, or empty. **Once a method of surveying a furnace is established during an initial TUS, subsequent surveys shall be conducted using the same method.** If changes are made to the established method, an initial TUS shall be performed to validate the revised method.

Para 3.5.10.1- States that if the TUS is performed empty or with a rack, and if TUS sensors are attached to or inserted into **heat sinks**, the thickness of the heat sink shall:

A) Not exceed 0.5 inch (13 mm), and
B) Not exceed the thickness of the <u>thinnest material being processed in that furnace</u>. Heat sink material shall be the material with the highest room temperature thermal conductivity consistent with the predominant material processed in the furnace.

Para 3.5.11 – States that the furnace atmosphere during a TUS shall be the normal atmosphere used for production. Furnaces used for those processes whose required atmospheres could contaminate the test sensors (i.e., carburizing, Nitriding, endothermic, and exothermic) or atmospheres that could pose a safety hazard (i.e. hydrogen or ammonia containing) may be tested with an atmosphere of air or inert gas.

Para 3.5.12 - States that the furnace vacuum level during TUS on vacuum furnaces shall be run at the lowest vacuum level used in production, but need not be less than 1 micron Hg (1 ? 10-3 Torr, or 1.3 ? 10-3 millibar).

Para 3.5.13.1 – States that the number of TUS Sensors shall be in accordance with Table 11.

Para 3.5.13.3 TUS Data Collection: **<u>There have been many changes in this section compared to AMS2750C. Please review carefully.</u>**

Para 3.5.13.3.1 - States that data collection shall begin before the first furnace or TUS sensor reaches the lower tolerance limit of each test temperature so that any furnace or TUS sensor exceeding the upper temperature uniformity tolerance is clearly detected. If the furnace is prestabilized, data collection shall begin as soon as the test load or rack is loaded in the furnace.

Para 3.5.13.3.2 – States that once data collection begins, temperature data shall be recorded from all TUS sensors at a frequency of at least one set of all readings every two minutes for the duration of the survey. Data from furnace sensors required by the applicable instrumentation type (see 3.3) shall be recorded as follows: (Sensors whose only function is over temperature protection do not need to be recorded.)

a) If the normal interval of temperature data recording in production is two minutes or less, or is continuous as in the case of analog recorders, manually recorded data shall be reported at two minute intervals.

b) If the normal interval of temperature data recording in production is greater than two minutes, data shall be recorded at the normal production frequency, but whether temperature data is recorded manually or automatically, in no case shall the furnace sensor recording frequency intervals exceed six minutes.

Note: Since 3.2.3 requires Digital Test Instrumentation, this also implies that Recording Test Instrumentation such as used for the performance of Temperature Uniformity Surveys (TUS) must also be digital.

Para 3.5.13.4 - States the alternative probing method for performing a TUS's in Salt Baths, etc.

Para 3.5.14 - States the requirements for performing a TUS on Continuous and Semi-Continuous Furnaces, by either the Volumetric Method, or the Plane Method, and the data collection requirements associated with these methods.

Para 3.5.15 - States the alternative methods for performing a TUS on Continuous and Semi-Continuous Furnaces including the Probing Method and the use of Mechanical Property Surveys in lieu of performing a TUS.

Para 3.5.16 is another new feature of AMS2750D and states provisions for
Temperature Uniformity Survey Sensor Failures: No TUS sensor failures at the corner locations of the work zone are permitted. A temporary condition such as a short or loose connection where normal temperature readout is restored shall not be considered a failed survey thermocouple. Catastrophic failure of a TUS sensor (except at a corner location) during a TUS need not be cause for survey failure unless:

A) 2 adjacent TUS sensors fail or
B) The number of TUS sensor failures exceeds the following:

- Survey with 3 to 9 sensors No failures
- Survey with 10 to 16 sensors 1 failure
- Survey with 17 to 23 sensors 2 failures
- Survey with 24 to 39 sensors 3 failures
- Survey with 40 or more sensors not more than 10% failures

For test temperatures of 2000°F (1093°C) and above:
- Survey with 3 to 5 sensors No failures
- Survey with 6 to 9 sensors 1 failure
- Survey with 10 to 16 sensors 2 failures
- Survey with 17 to 23 sensors 3 failures
- Survey with 24 to 39 sensors 4 failures
- Survey with 40 or more sensors not more than 10% failures

Para 3.5.18 – States that when the hottest and coldest temperature locations change within the furnace (based on the final readings from the most recent Temperature Uniformity Survey), the recording sensor locations for types A and C instrumentation may need to be moved within the furnace to reflect the new hottest and coldest locations within the work zone. These sensors do not require relocation if the overall temperature uniformity does not exceed one half of the maximum temperature uniformity tolerance for the applicable furnace class at all temperatures surveyed, or if the difference between the measured temperature at the current recording locations and the actual respective hottest and coldest measured areas is less than the system accuracy test (SAT) tolerance for the applicable furnace class.

Para 3.5.19.1.1 - States that for equipment tested at reduced frequency, failure of a temperature uniformity survey shall cause the test frequency to revert to the initial test frequency specified in Table 8 or 9. Frequency shall not be reduced until the specified number of successful consecutive tests in Table 8 or 9 have been completed.

Para 3.5.19.1.2 - States what must be done if the form of corrective action for a failed survey is adjusting (offsetting) the control instrument.

Para 3.5.21 - States that a **Temperature Uniformity Survey Report** must contains an explicit list of items, and states additional information that must be accessible to supplement the TUS report.

Para 3.5.22 – States that surveys performed prior to the issue date of this revision, in accordance with AMS 2750C section 3.4.2, may be considered equivalent to tests performed in accordance with this revision for the purpose of qualifying furnaces for (1) waiving initial temperature uniformity tests or (2) reducing frequency of periodic temperature uniformity tests.

Para 3.6 - States unique requirements for Laboratory Furnaces used for “response to heat treating testing” per material specifications.

Para 3.7.1 – States that all calibration and test records including sensors, standard cells and instruments, system accuracy tests, and temperature uniformity surveys, including any test or survey failures shall be available for inspection and maintained for not less than five years (or in accordance with customer requirements, whichever is greater).

Para 3.7.2 – States that calibration records of sensors, standard cells, and instruments shall include traceability to the NIST or equivalent National Standard.

SECTION VII
Quality Assurance Provisions
What are my obligations to my Quality Assurance System?

Para 4.1 - States that the processor shall be responsible for the performance of all required tests and for conformance to all requirements specified herein. The purchaser reserves the right to witness any of the tests or calibrations specified herein to ensure that processing conforms to the prescribed requirements, but such witnessing shall not hinder operation of the facility.

Para 4.1.1 - States that any instrument/sensor/test failing to meet these requirements, or that has exceeded its test interval including any applicable permissible extension period (See Table 10), shall be taken out of service.

Para 4.1.1.1 - States that corrective action shall be documented including the actions taken to bring the instrument/sensor/test into compliance.

Para 4.2 - States that in the event of any test failure or out-of-tolerance condition, an evaluation of the possible effects of the non-conformance on product processed since the last successful corresponding test shall be performed and documented. The evaluation shall be documented per established material review procedures. Appropriate corrective action shall be taken, documented and maintained on file. When material processing conditions deviate from specification requirement affected purchaser(s) shall be notified.

Para 4.2.1 - States that a conforming corresponding tests shall be required as evidence of adequate corrective action.

SECTION VIII
Definitions
What do all of these terms mean?

Section 8 of AMS 2750D has a list of approximately 75 Pyrometry terms and their definitions that are used in that Specification and in Pyrometry in general.

		REVISION RECORD
REV	**DATE**	**Description of Changes**
A	April 3, 2006	Complete revision including update to AMS2750D requirements

Heat Treatment

INDUSTRY

Instrumentation System Accuracy Tests (SATs) and Eurotherm® Products

White paper

The specification AMS2750D covers pyrometric requirements for thermal processing equipment used for heat treatment. It covers temperature sensors, instrumentation, thermal processing equipment, systems accuracy tests and temperature uniformity surveys.

Adherence to the specification is necessary to ensure that parts or raw materials are heat treated in accordance with the applicable specifications.

The following notes offer some guidance on the requirements for instrumentation accuracy and the way Eurotherm® can help customers to meet the exacting demands of heat treatment accreditation.

The notes must be read in conjunction with the specification document AMS2750D. A copy of which can be purchased from SAE International at http://www.sae.org/servlets/productDetail?PROD_TYP=STD&PROD_CD=AMS2750D

The Pyrometry specification AMS2750D referred to by Nadcap identifies procedures for performing calibration and system accuracy tests on instrumentation, temperature sensors and thermal processing equipment.

The purpose of calibration associated with instrumentation is to provide an authenticated record of the instrument accuracy within a defined level of tolerance difference through a chain of traceability to NIST or equivalent national reference standard.

Before instrumentation is applied to a Nadcap application:

1) The instrument must be calibrated in accordance with AMS2750D section 3.2.

2) A label must be attached to the instrument confirming calibration status in accordance with AMS275D section 3.2.6.1.

3) Results of the tests must be recorded on a certificate in accordance with AMS275D section 3.2.6.2.

4) The AMS275D specification further defines in Table 3 note 5 the instrument calibration frequency:

Digital instruments	
Class 1 Furnaces	Monthly
Class 2,3 and 4 Furnaces	Quarterly
Class 5 and 6 Furnaces	Bi-Annually
Analogue and electro mechanical instruments	
Class 1 and 2 Furnaces	Monthly
Class 3,4,5 and 6 Furnaces	Quarterly

Eurotherm provide two types of instrumentation, which meet the Nadcap requirements of thermal processing equipment as defined in the specification AMS2750D:

1) Field test instrumentation

2) Controlling, monitoring or recording instrumentation

All instrumentation, used either for field test Instrumentation or controlling, monitoring or recording instrumentation must be fully subjected to calibration, before application to any process.

Flowcharts for instrument preparation, introduction and verification for a Nadcap application are shown on page 5.

System accuracy tests must also be carried out at a frequency specified in AMS2750D Table 6 and 7. Records must show that instrumentation types meet the accuracy requirements of AMS2750D Table 3.

Onsite services into Nadcap applications must be supported by relevant quality systems.

The following notes provide guidance on defined levels of accuracy as they apply to the selection and use of instrumentation for use in Nadcap accredited solutions.

These notes do not cover system accuracy tests as they apply to the use and selection of thermocouples and sensors.

The notes must be read in conjunction with AMS2750D section 3.2 Instrumentation and section 3.4. System accuracy tests.

Levels of traceability

Figure 1 shows an outline of the layers of instrumentation traceability and limitations of use. Refer to AMS2750D Table 3, for the allowable maximum calibration accuracy differences between the layers.

Within Eurotherm it is common practice to use a secondary standard instrument to provide laboratory calibration of test instrumentation and calibration of controlling, monitoring or recording instruments.

The arrows shown in Figure 1 indicate that a category of instrumentation can only be calibrated or tested by equipment with a superior traceable level of calibration compliance to the national standard.

Maximum allowable levels of accuracy tolerance for field test instrumentation and controlling monitoring instrumentation as defined in AMS2750D Table 3 are as follows:

1) “Field Test Instruments”
Calibration accuracy +/- 1.0 degree F (+/-0.6 degree C) or +/- 0.1% of reading in degrees F, which ever is the greater. Use is limited to control, monitoring or recording instrument calibration, performance of system accuracy tests and temperature uniformity surveys.

2) “Control Monitoring or Recording Instruments” (Digital)
Calibration accuracy +/- 2 degree F (+/-1.1 degree C). Use is limited to measurement of the recording and controlling temperature of thermal processing plant.

Practical considerations

AMS2750D section 3.2 specifies that:

Output of sensors shall be converted to temperature readings by instruments specified herein or instruments of equivalent or greater accuracy. Instruments shall be calibrated by NIST or an equivalent national standard, or against standards whose calibration is traceable to NIST or other recognised national equivalent(s) according to AMS2750D Table 3.

As part of the reporting procedures for instrument calibration defined in AMS2750D section 3.2.6.2 it is also necessary to show approval of the quality organisation under which the system accuracy tests have been completed.

The suitability of instrumentation to meet a specific type, listed in AMS2750D Table 3 is not defined by the manufacturers data sheet but by the following criteria:

1) The ability to show an observable level of calibration accuracy equal to or better than the difference shown between two layers of traceability as defined in AMS2750D Table 3.

2) To retain the level of calibrated accuracy for a time period equal to or in excess of the maximum allowable calibration interval as defined in AMS2750D Table 3 note 5.

AMS2750D Table 3 defines aspects of instrumentation types, calibration periods and calibration accuracy for various instrumentation categories.

When subject to the calibration, certification and labelling requirements of AMS2750D section 3.2 all Eurotherm digital instruments and electro mechanical recorders are suitable for use in Nadcap compliant applications.

Equipment can be supplied with fully certified calibration to national standards, ensuring that products meet the requirements of the following instrumentation groups from AMS2750D Table 3.

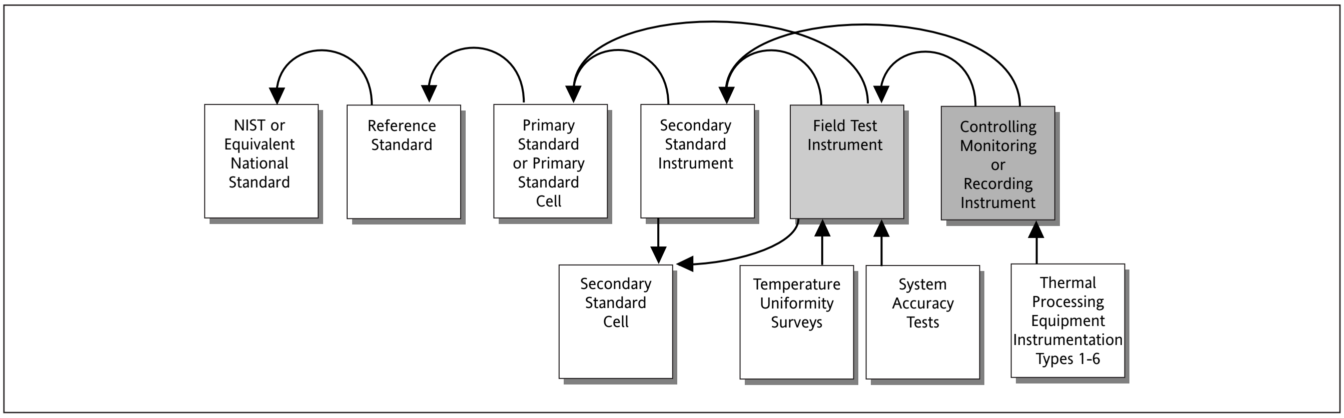


Figure 1

Field test instruments

Digital instruments, electronic data recorders and data acquisition systems meet the requirements of +/- 0.6 degrees C or 1.0 degree F.

Control monitoring or recording instruments

Digital control monitoring and recording instruments meet the requirements of +/- 1.1degrees C or 2.0 degrees F.

Electro mechanical chart recorders +/- 1.1degrees C or 2.0 degrees F or +/- 0.3% of maximum survey temperature of the equipment which ever is the greater.

Digital Instruments meet the sensitivity requirements of AMS2750D Table 3 note 4. Better than +/ 1.0 degrees C or 1.0 degrees F.

Procedures are provided in Eurotherm manuals to allow suitably qualified organisations to calibrate or re-calibrate Eurotherm instrumentation products to meet the requirements of Nadcap applications.

Eurotherm products include comprehensive 2 point or multipoint calibration routines, which enable instruments to be re-calibrated when necessary to meet accuracy difference tolerances under NIST or an equivalent national standard, or against standards whose calibration is traceable to NIST or other recognised national equivalent(s) according to AMS2750D Table 3. (field test instruments and control monitoring or recording instruments)

System accuracy tests (SATs)

AMS2750D section 3.4 defines the principles and method for applying system accuracy tests to sensors and instrumentation used in thermal processing equipment.

System accuracy tests are simple tests, which must be carried out to determine that the thermocouples, lead wire, and instruments are giving an accurate depiction of temperature.

They also provide information as to changes in accuracy of the system over time by comparing the control and/or recording thermocouples in each furnace control zone with a test thermocouple placed near the furnace thermocouple (control and/or recording).

If repeatable results are obtained (within allowable error limits), all is well, if not, corrective action must be taken.

The method of carrying out system accuracy tests is defined in AMS2750D section 3.4.

System accuracy test differences for individual furnace class are defined in AMS2750D Table 6 and 7 as follows:

Class 1 Furnace
Maximum SAT difference +/- 2 degrees F (+/-1.1 degrees C) or 0.2% of reading which ever is the greater.

Class 2 Furnace
Maximum SAT difference +/- 3 degrees F (+/-1.7 degrees C) or 0.3% of reading which ever is the greater.

Class 3 Furnace
Maximum SAT difference +/- 4 degrees F (+/-2.2 degrees C) or 0.4% of reading which ever is the greater.

Class 4 Furnace
Maximum SAT difference +/- 4 degrees F (+/-2.2 degrees C) or 0.4% of reading which ever is the greater.

Class 5 Furnace
Maximum SAT difference +/- 5 degrees F (+/-2.8 degrees C) or 0.5% of reading which ever is the greater.

Class 6 Furnace
Maximum SAT difference +/- 10 degrees F (+/-5.6 degrees C) or 1.0% of reading which ever is the greater.

AMS2750D Table 6 and 7 further defines the maximum permitted adjustment offset, which can be applied to instrumentation for each furnace class to correct for SATs differences as follows:

Class 1 Furnace
Maximum SAT offset +/- 2.5 degrees F (+/-1.5 degrees C).

Class 2 Furnace
Maximum SAT offset +/- 5 degrees F (+/-3 degrees C).

Class 3 Furnace
Maximum SAT offset +/- 8 degrees F (+/-5.0 degrees C) or 0.38% of maximum qualified operating which ever is the greater.

Class 4 Furnace
Maximum SAT offset +/- 10 degrees F (+/-6 degrees C) or 0.38% of maximum qualified operating range which ever is the greater.

Class 5 Furnace
Maximum SAT offset +/- 13 degrees F (+/-7 degrees C) or 0.38% of maximum qualified operating range which ever is the greater.

Class 6 Furnace
Maximum SAT offset 0.75% of maximum qualified operating range.

Many Eurotherm products provide password protected offsets, which can be applied to remove errors within the allowable level defined above.

Calibration accuracy and systems accuracy tests for degree centigrade installations

Tables in AMS2750D refer to tolerances in degrees F with alternative decimal point resolution conversion to degrees C. Care must be taken when applying instrumentation particularly to Class 1 and Class 2 Furnaces operating in degrees C to ensure compliance with the specification.

Care must also be taken when choosing instruments for use in any specific application so that instruments can be configured to accommodate the desired range of use, whilst retaining required decimal point resolution.

The range of use, which allows observable calibration error to decimal point resolution may restrict instrument use to 999.9 degrees C for 4 digit products.

Furnace class temperature uniformity

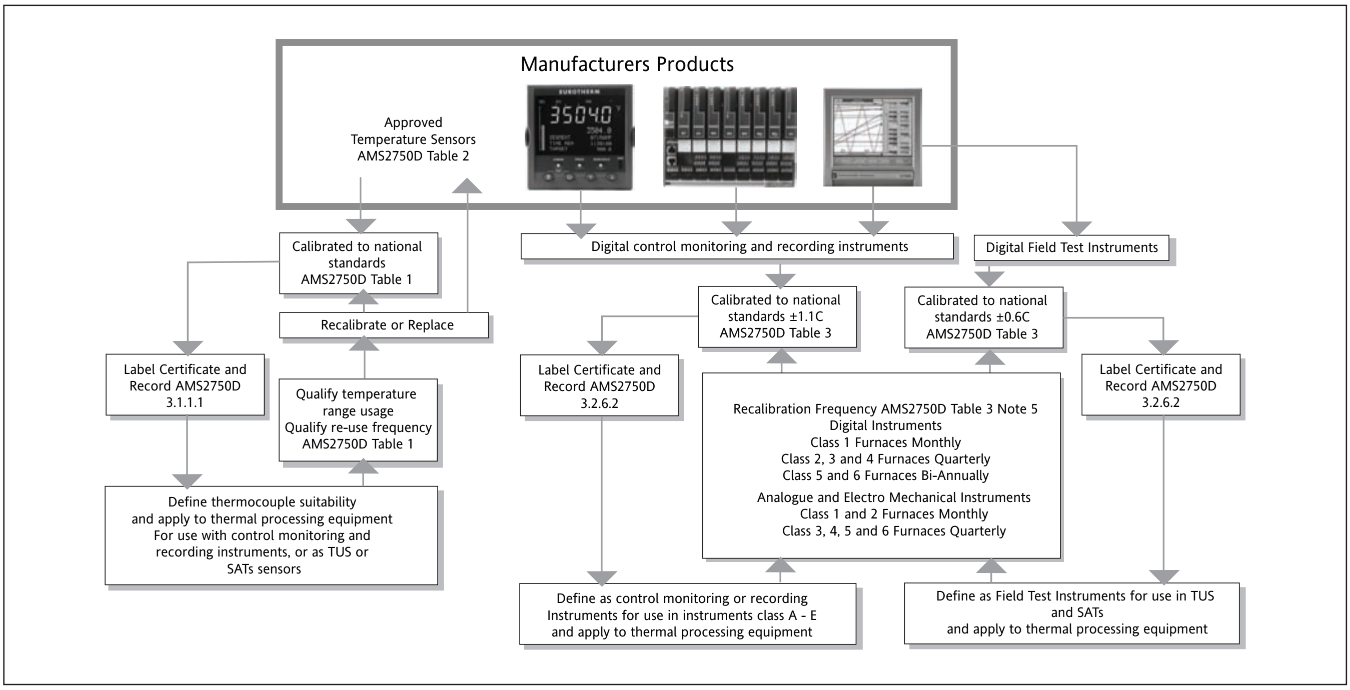
AMS2750D Table 6 and 7 further define the allowable level of temperature uniformity tolerances allowable for each furnace class.

Temperature uniformity survey tolerances are as follows:
Furnace Class 1 +/- 5 degrees F or +/- 3 degrees C
Furnace Class 2 +/- 10 degrees F or +/- 6 degrees C
Furnace Class 3 +/- 15 degrees F or +/- 8 degrees C
Furnace Class 4 +/- 20 degrees F or +/- 10 degrees C
Furnace Class 5 +/- 25 degrees F or +/- 14 degrees C
Furnace Class 6 +/- 50 degrees F or +/- 28 degrees C

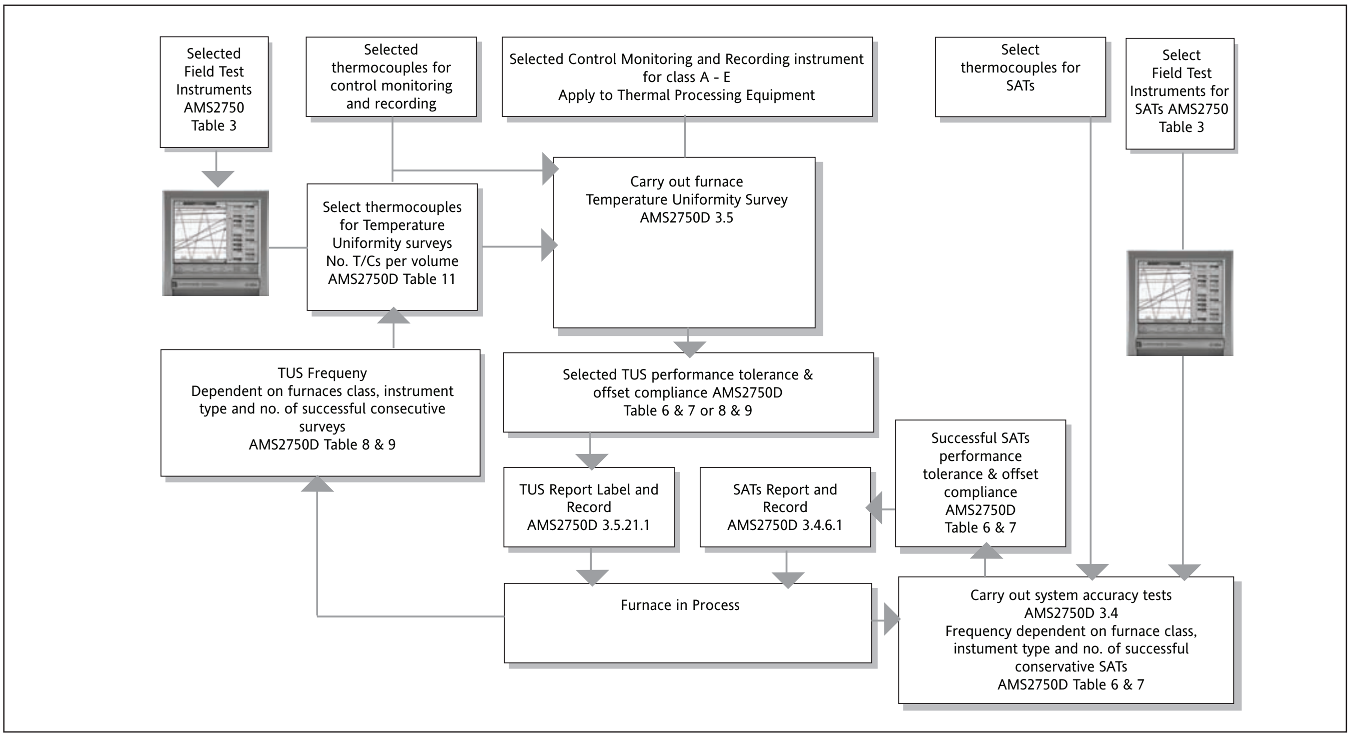
Class 1 furnaces are invariably used for high value precision work. To achieve the level of uniformity tolerance required for this class of furnace across the furnace volume and across the desired setpoint range will invariably require a controller which aids not only SAT compliance but will also provide the necessary control over temperature uniformity stability and overshoot elimination.

It can be seen from the above that choosing a controller for use on a class 1 and 2 furnace needs careful consideration not only on the ability to meet calibration accuracy and SATs demands, but also the demands for overall furnace performance.

Training and advice on system accuracy tests can be obtained from the Eurotherm Heat Treatment group.



Preparing instruments for use in a Nadcap application



Incorporation and verification of an instrument in a Nadcap application

Heat Treatment
INDUSTRY

Application note

Digital Data Management in Nadcap Compliant Aerospace Applications

- *AMS2750D Compliant Recording Instruments*
- *Solutions for temperature Uniformity Surveys*
- *AMS2750D Compliant Field Test Instruments*
- *Automated TUS Reports*
- *Services to aid furnace performance and compliance*

Eurotherm® working in the Aerospace Industry

Eurotherm and Eurotherm Chessell have been supplying thermal processing and test instrumentation to the Aerospace Industry for 40 years.

In many parts of the world the Eurotherm brand has become a byword for reliability, accuracy and consistency in aerospace applications and we are honoured that we can continue to support customers in the performance and testing of their thermal processing equipment.

Eurotherm Chessell recorders and Eurotherm digital data management products are used widely across the world offering our customers complete confidence in the results they achieve from their equipment.

Advances in digital data management now enable customers and services providers to add the efficiency of providing automated reporting to the already excellent qualities of our products.

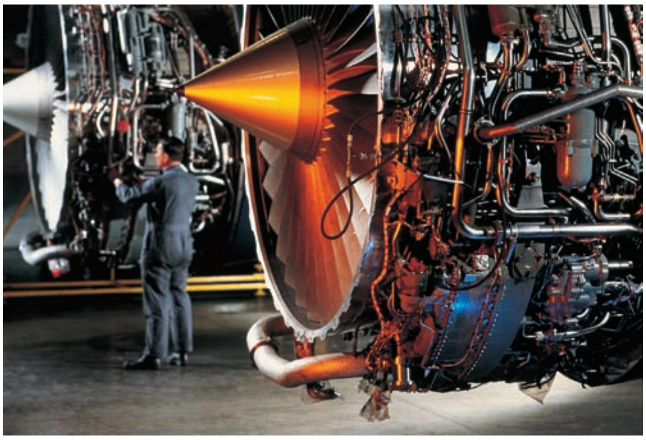
6180 AeroDAQ

Specific

Designed to help you to comply with Aerospace industry standards

Thermocouple Life Monitoring

The 6180 AeroDAQ provides thermocouple life monitoring functionality based on AMS2750D, Sections 3.1.8.4 and 3.1.8.5. Both thermocouple Uses and Days remaining are accounted for to help assure that thermocouples are not used beyond their maximum life as per AMS2750D.



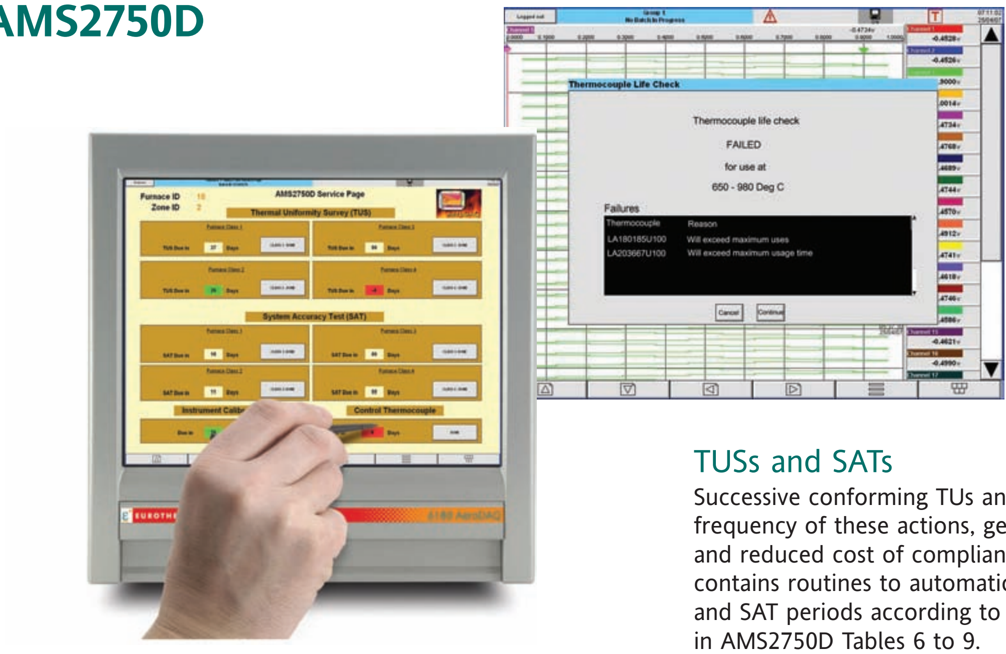
Automated Scheduling

Using a furnace when it has exceeded the allowable period for calibration, TUS (Thermal Uniformity Survey), or SAT (System Accuracy Test) can result in audit non-compliance, and monetary loss.

The 6180 AeroDAQ provides notification of due dates for

- Calibration
- TUS
- SAT

AMS2750D



TUSs and SATs

Successive conforming TUs and SATs can lead to reduced frequency of these actions, generating incresed productivity and reduced cost of compliance. the 6180 AeroDAQ contains routines to automatically calculate extended TUS and SAT periods according to the Furnace Classes as stated in AMS2750D Tables 6 to 9.

6180 AeroDAQ

Compliant

Meeting the requirements of AMS2750D

AMS2750D, Section 3.1.8.5 (Load Sensors)

For in-situ sensors, the 6180 AeroDAQ can automatically compute maximum allowable sensor usage with alarms against expired sensors.

AMS2750D, Section 3.2.3 (Field Test Instruments)

The 6180 AeroDAQ mets the requiremenrts of Table 3 and Section 3.2.3 for Field Test instruments.

AMS2750D, Section 3.2.5 (Instrument Calibration)

Next instrument calibration due date is calculated by the 6180 AeroDAQ, with alarms to alert the user that calibration is due as per AMS2750D, Table 3.

AMS2750D, Section 3.4.2 (SAT Frequency)

The 6180 AeroDAQ functionality includes calculating the SAT period for a specific furnace class and instrument type as defined in Tables 6 and 7 of AMS2750D, and will alert the user to SAT status.

AMS2750D, Section 3.5.7 (TUS Frequency)

As with the SAT frequency, the 6180 AeroDAQ will calculate required TUS date as per Tables 8 and 9 of AMS2750D, and provide alerts as to TUS status.

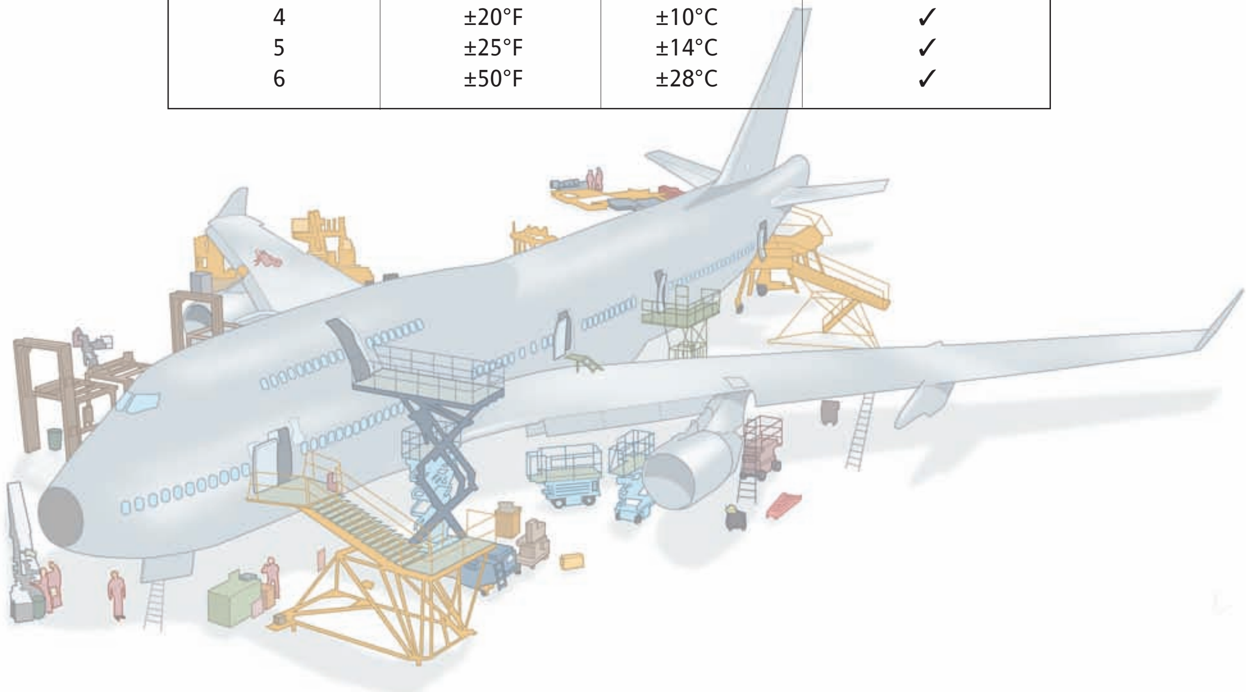
AMS2750D, Table 2 (Thermocouple Types)

The 6180 AeroDAQ is capable of inputs from all types of thermocouples as listed in Table 2 of AMS2750D.

Section 3.2.4 (Controlling, Monitoring or Recording instruments)

The 6180 AeroDAQ meets the requirements of Table 3 and Section 3.2.4 for Controlling, Monitoring or Recording instruments.

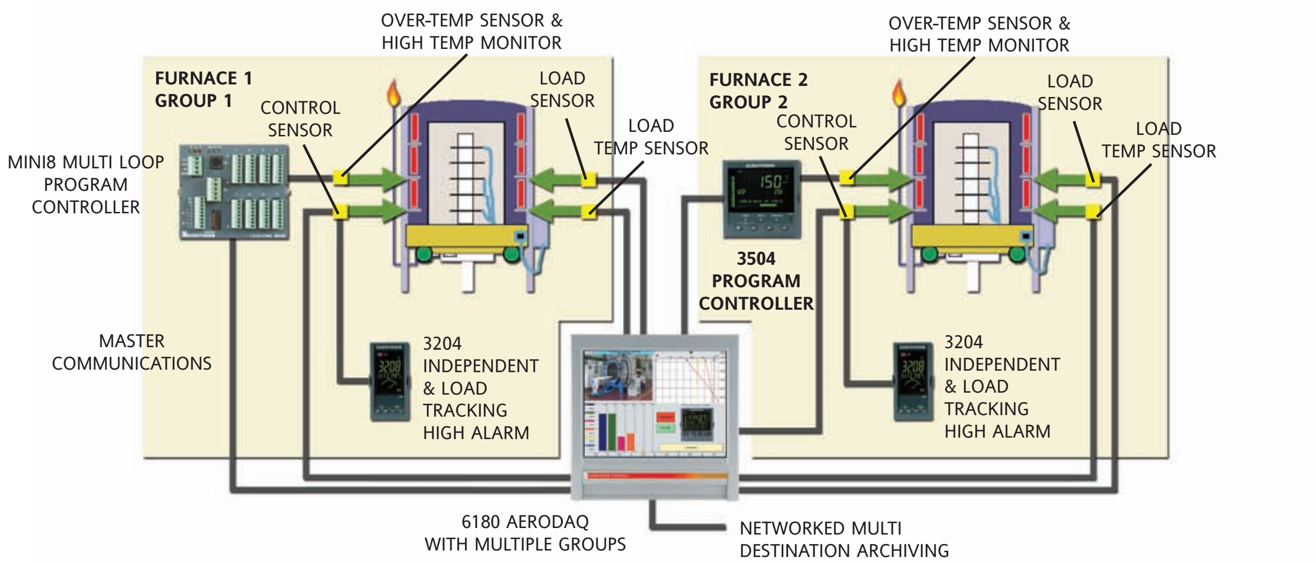
Furnace Classes	Temperature Uniformity Range		6180 AeroDAQ Conformity
	Degrees F	Degrees C	
1	±5°F	±3°C	✓
2	±10°F	±6°C	✓
3	±15°F	±8°C	✓
4	±20°F	±10°C	✓
5	±25°F	±14°C	✓
6	±50°F	±28°C	✓



6180A and 6100A

The ultimate AMS2750D paperless graphic recorder for Temperature Uniformity Surveys

- High accuracy with consistent long-term performance
- Meets and surpasses the requirements of control, monitoring and recording instruments and "Field Test Instruments" as defined in AMS2750D Table 3
- Multi Channel offering from 1 to 48 independent freely definable sensor types and ranges
- Up to 120 maths or communications channels
- Every channel includes individual calibration adjustment with input adjust, zero, and span calibration as required
- Multiple groups offering access to up to 12 furnaces on the same recorder at the same time
- Master communications to acquire data from furnace control equipment
- Automatic detection and alarm of sensor failures
- User screens on 6180 and 6100 recorder to act as furnace HMI
- Automated multi setpoint survey routines over master communications to controller setpoint
- Secure write once read only data files
- Local memory and backup with multiple destination archiving
- Up-load and down-load of furnace specific configurations
- Manufacturers user and calibration instructions
- Portable option on the 6100A
- Easy to view real time and historic trend charts
- Supplied with optional AMS2750D compliant calibration certificate and label on request
- Supported in Review off-line software with automatic and secure backup and transfer of data file
- Entry of operator notes
- Automatic email or SMS of alarms and events
- Bridge software for remote visualisation over networked communications of furnace performance
- Review software for the analysis of data and export to tamperproof data in other human readable formats
- TUS Auto Report Generator software for the automatic production of Temperature Uniformity Survey reports



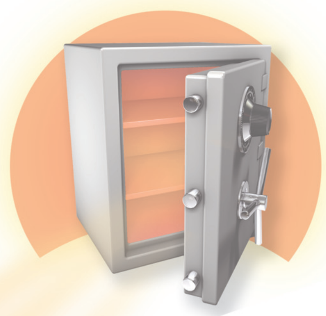
Discrete products solution showing Type A instrumentation

Secure Archiving

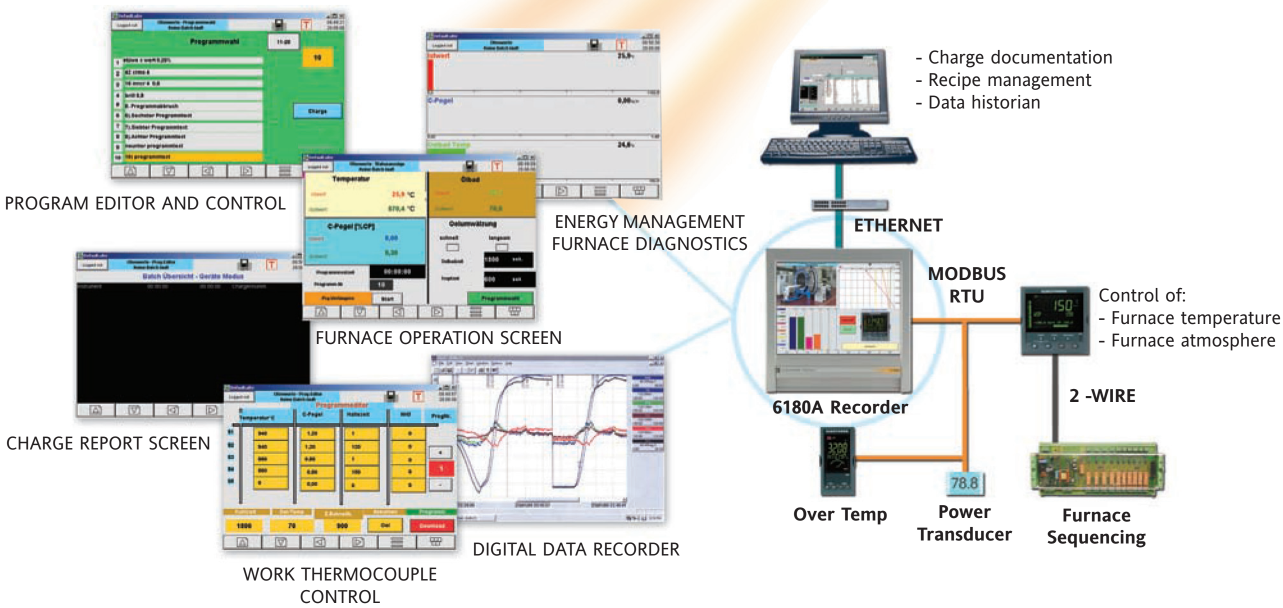
- Multiple archiving strategies
- Archive on demand
- Archive automatically
- Archive remotely using ‘Review’ package
- Multiple archiving destinations
- Archive to CF/SD
- Archive to USB memory stick
- Archive to FTP Server
- Primary and Secondary server function

Secure Data

- Data protection with traceability
- Compressed, binary, check-summed data files
- Auditor features
- Audit Trail
- Lockable electronic media flap
- Selectable sizes of onboard flash memory
- 32Mbyte or 96Mbyte
- Security Manager integration



Typical integrated compliant furnace control system



Typical Integrated Compliant Furnace Control System using conventional discrete controllers and recorders with a set of user screens designed for a Nadcap application

6000 Web Server

- Uses standard web browser
- Simple view of vertical trend, numeric display and message logs
- Allows access to history files
- No-charge feature

Batch

Simple configuration

- 10 user defined entry fields
- Files named by batch
- Auto increment batch number
- Continuous or individual mode
- Batch summary screen

Intuitive operator functions

- Local/remote start/stop
- Auto print on batch complete
- Batch data can be pre-typed until data is required

Complete traceability

- Prints batch data to display

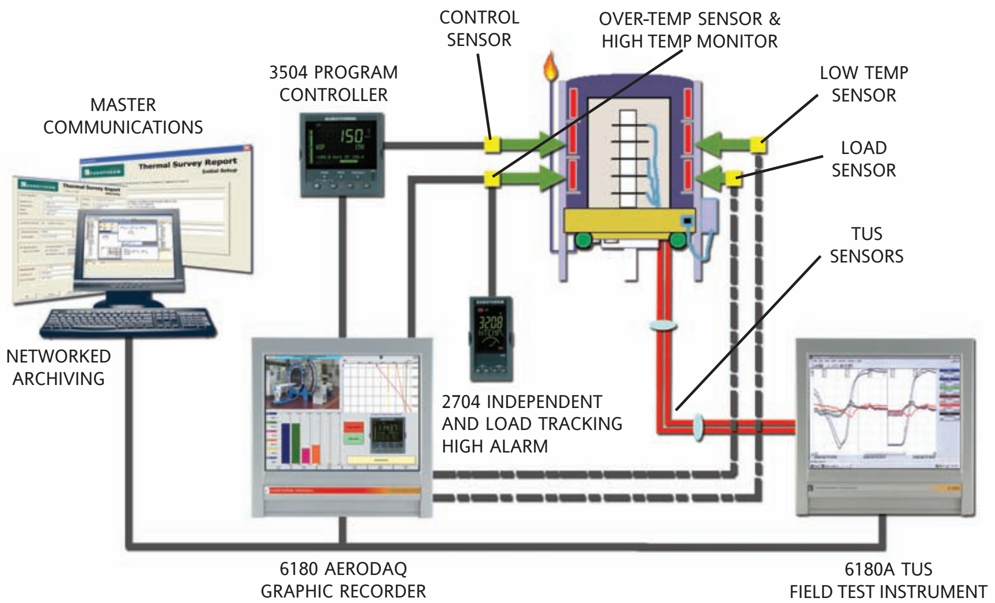
Email

- Emails can be sent by the instrument to one or more recipients
- User can enter 10 recipient email addresses in each of five mailing lists, giving a maximum of 50 addresses
- Up to 24 emails can be configured

Typical furnace control system showing TUS instrument

In this diagram the field test instrument is accessing sensors in the normal way. Information about the control setpoint and actual control temperature along with details of the over temperature value are being acquired over master communications from the furnace recorder and controller.

The 6180A instrument can be configured to operate with up to 12 different furnace groups on the same instrument and to automatically conduct furnace surveys at multiple setpoints when master communications allows setting of the furnace controller setpoint.

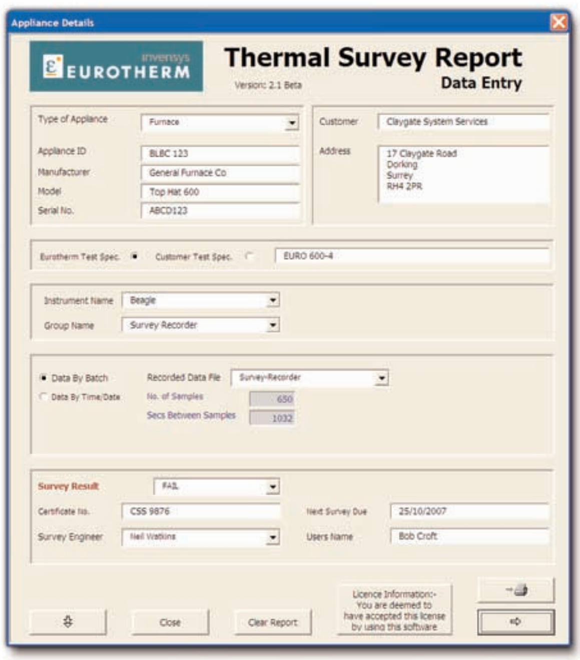


Automated Temperature Uniformity Survey Reporting

Temperature Uniformity Survey reports are a mandatory part of AMS2750D pyrometry compliance and the report content and format are well defined in the specification.

With the advent of paperless graphic recorders it is possible to take the output from the survey recorder and automate the production of the report.

This adds an increased level of efficiency to the whole process of Thermal Equipment accreditation.



Temperature Uniformity Reporting Software

TUS Auto Report Generator: Making reporting easy

Eurotherm have produced a fully automated survey reporting package based on the popular Report software.

Whilst Report can be used for a variety of process reporting from batch reports to charge documentation reporting, TUS Auto Report Generator provides an efficient way to transfer data from the Field Test Instrument and produce reports, which comply with the requirement of AMS2750D.

This application consists of two components, firstly a setup mode, which allows the engineering service provider or controlling quality organisation to determine the scope of the temperature uniformity test for an individual furnace.

Secondly the application enables the production of an auditable report by associating criteria entered in the setup data to be automatically linked with a defined secure .uhh data file from the field test instrument.

The Report Setup

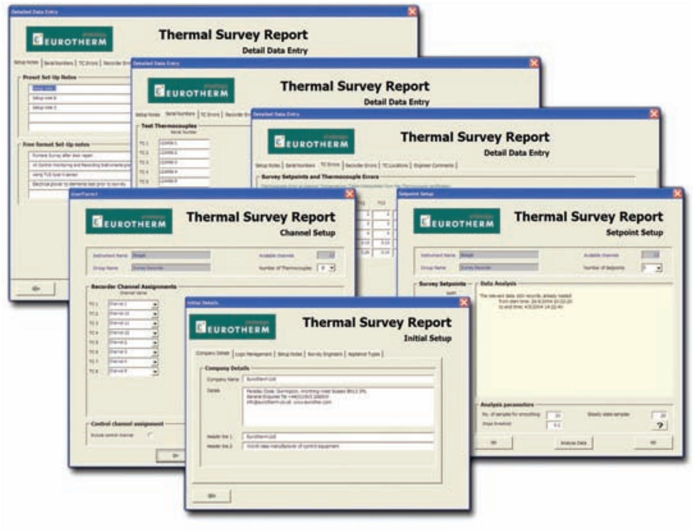
Data entry page content showing:

- Furnace identification
- Customer identification
- Calibration procedure
- Controlling quality specification
- Field Test Instrument name identification
- Field Test Instrument group identification
- Data sort by batch name or date and time
- Recorder data file name
- Sample frequency
- Certificate number
- Survey Engineers name
- Next survey due date
- Users name and identification
- Print to printer, file or pdf

Initial setup

Data entry page content showing:

- Survey company details
- Survey company logo management
- Initial setup notes
- List of authorised survey engineers
- List of thermal process equipment appliance types



Channel setup

Data entry page content showing:

- Selection of number of survey sensor channels
- Alignment of survey thermocouples to recorder channels
- Option to include control sensor in report through master communications to furnace control instrumentation

Detail data entry - serial numbers

Data entry page content showing:

- Data entry fields for TUS sensor serial numbers delimited to the number of sensors required for the survey
- Data entry fields for the serial number and calibration traceability of the Field Test Instrument
- Data entry fields for the serial numbers and calibration traceability of the furnace Control Monitoring and Recording instrument

Detail data entry set-up notes

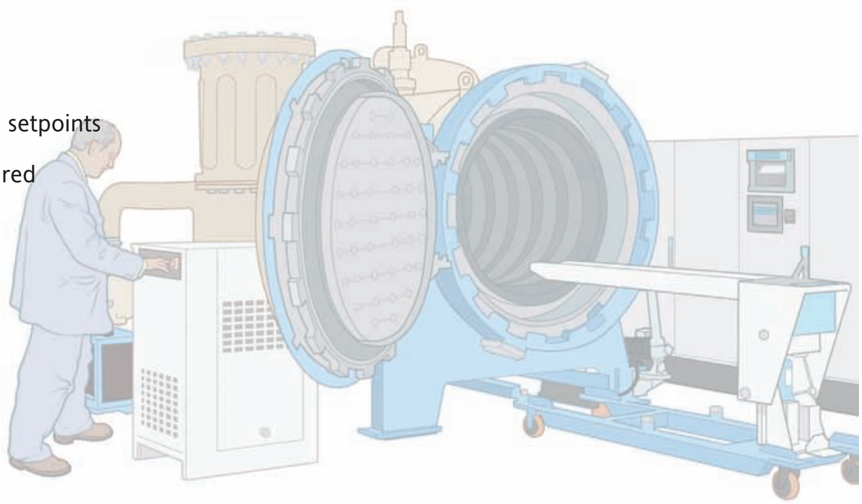
Data entry page content showing:

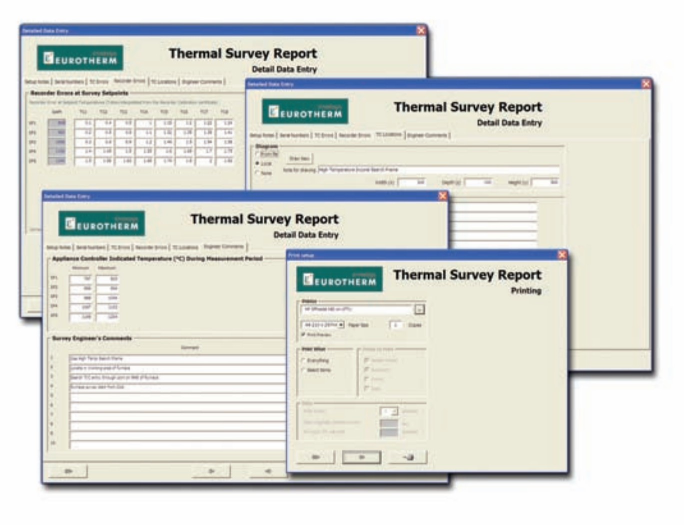
- Up to 5 fixed format data entry fields for inclusion within the report of standard text or actions
- Up to 5 free format data entry fields for inclusion within the report of operator text or instruction

Setpoint setup

Data entry page content showing:

- Select of the number and value of survey setpoints
- Selection of sampling criteria at the required setpoints
- View raw data





Detail data entry field test recorder correction factors

Data entry page content showing:

- Data entry fields for the Field Test Instrument correction factors at each of the required setpoints

Detail data entry engineers notes

Data entry page content showing:

- Data entry fields for manual entry of furnace control instrument performance at the required setpoints
  Note: the software can automatically link to furnace control instrumentation if suitable digital communication links are available
- Data entry fields for survey engineers notes associated with the test
  - Tuning parameters
  - Sensor failure comments
  - Any specific reportable actions

Detail data entry thermocouple correction factors

Data entry page content showing:

- Data entry fields for the furnace class tolerance at each of the required setpoints
- Data entry fields for the TUS test sensor correction factors at each of the required setpoints

Detail data entry search thermocouple locations

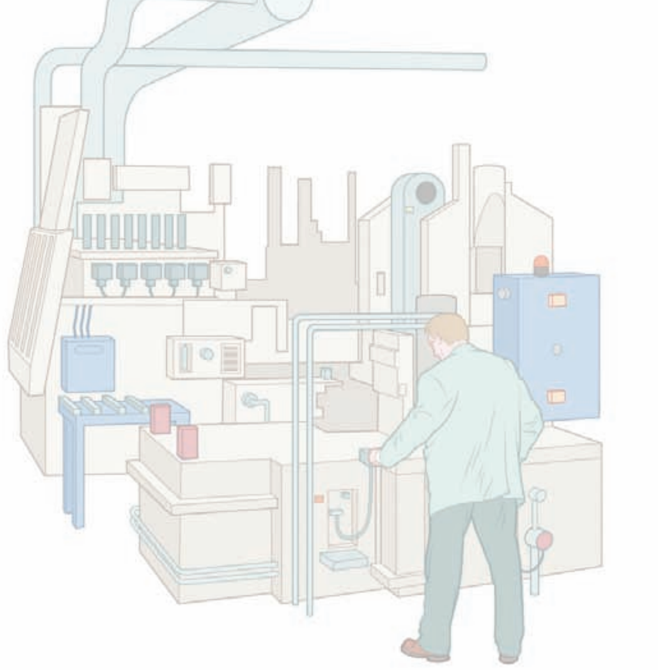
Data entry page content showing:

- Selection of survey frame or representative load from named file or drawing
- Data entry fields for survey frame or representative load dimensions
- Enter new frame of load drawing
- TUS test sensor locations

Print report set-up

Data entry page content showing:

- Selection of print output
- Print on demand button



Audit report format

Eurotherm's Temperature Uniformity Survey reporting application combines the efficiency of standard setup screens described above with the robust security of the Field Test Instrument data file.

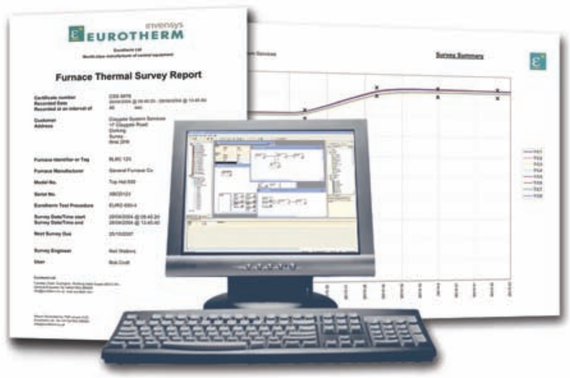
The files are linked to the report through Eurotherm Review software, which has automatic backup and transfer routines of data files.

The report can be regenerated at any time without corrupting the core data by re-specifying the test setup criteria and re-running the report.

The associated data file can be stored on the local reporting computer or can be archived under normal house keeping procedures on remote machines.

The report generator can recall the file from its archived location and each report can consist of a summary extract including detail as specified in AMS2750D or a full report, which includes the actual logged data.

Pages for the summary report are shown below:



Page 1

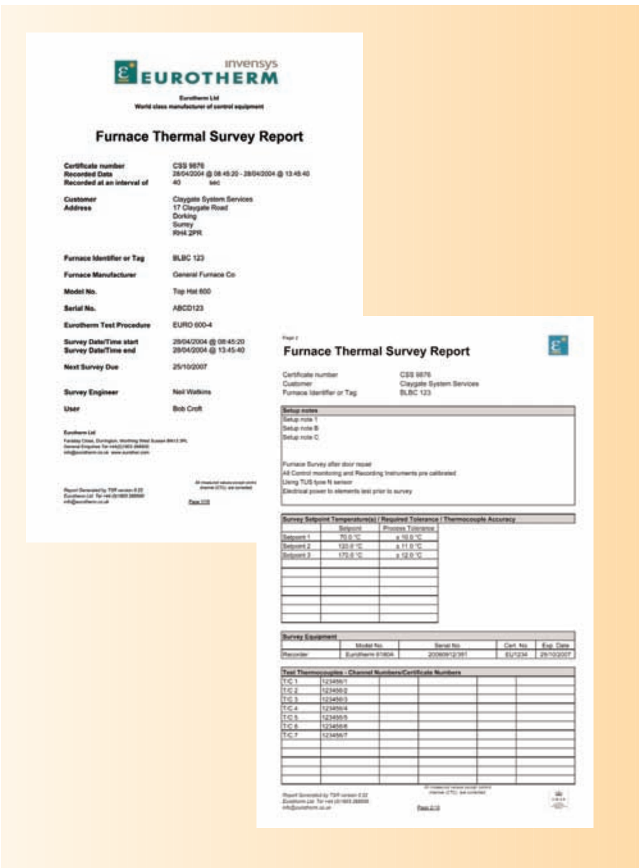
Report overview summary with records of:

- Key customer data
- Surveying company and engineer details
- Furnace/Thermal processing plant details
- Survey data and time
- Next Survey date
- TUS controlling procedure and quality organisation reference

Page 2

Records of:

- Setup notes
- Survey temperature setpoints and required furnace class tolerance
- Survey equipment summary
- Test sensor serial numbers



Page 3

Records of:

- Test sensor calibration errors at the required setpoints
- Field test recorder errors at the required setpoints

Page 4

Records of:

- Survey frame or representative load 3 dimensional diagram with thermocouple locations
- Survey frame or representative load dimensions
- Thermocouple locations by sensor number

Page 5

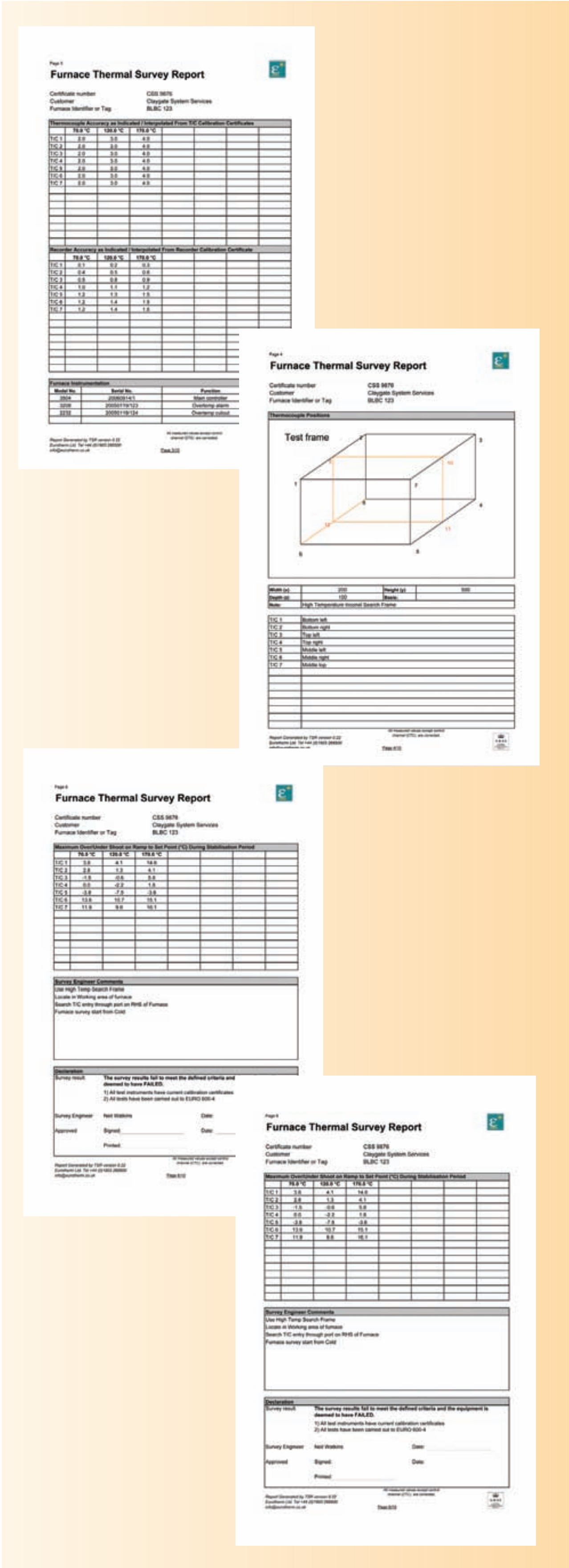
Records of:

- Maximum and minimum survey sensor readings at each of the required setpoint during the measurement period
- Maximum temperature difference across survey sensors during the measurement period
- Furnace controlling instrument indicated temperatures during the measurement period
- Selected stability criteria and survey duration
- Highest and lowest survey thermocouple measurements at each setpoint

Page 6

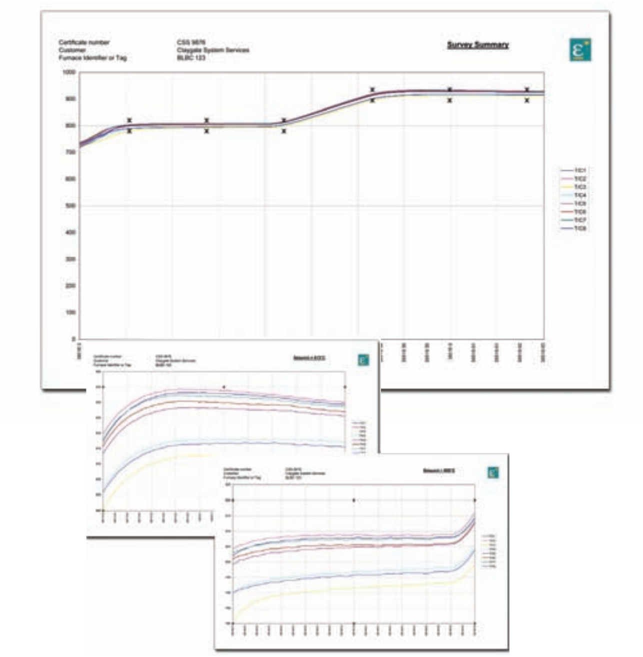
Records of:

- Maximum overshoot and undershoot for each survey sensor on ramp to setpoint at each of the required setpoints
- Survey engineers comments
  - Tuning constants
  - Sensor failures
  - Specific survey actions
- Identification of pass or fail status
- Date sign off and approval



Report Chart View

The report includes traditional chart view diagrams of the overall thermal survey and detailed views of furnace performance at the required setpoints.



Requirements for TUS Software

The TUS is a Microsoft Excel workbook with a VBA code implemented to generate the printed report. It has been developed using Microsoft Windows XP Professional using Excel 2003. The thermal data is taken from the Eurotherm Review database using the Eurotherm Report package to interface between the Review database and the TUS application workbook.

TUS Auto Report Generator Application comes on two CDs as part of the Eurotherm 6000 family of software products and can be ordered as 6000PLUS/TUS.

CD 1 6000 Plus/Report

CD 2 6000 Plus/TUS Auto Report Generator

The application software is designed to function using the following:

Operating Systems:
Microsoft Windows XP Professional SP2

Microsoft Excel:
Excel 2003

Eurotherm Review:
Full or Lite
V3.7.4 or above

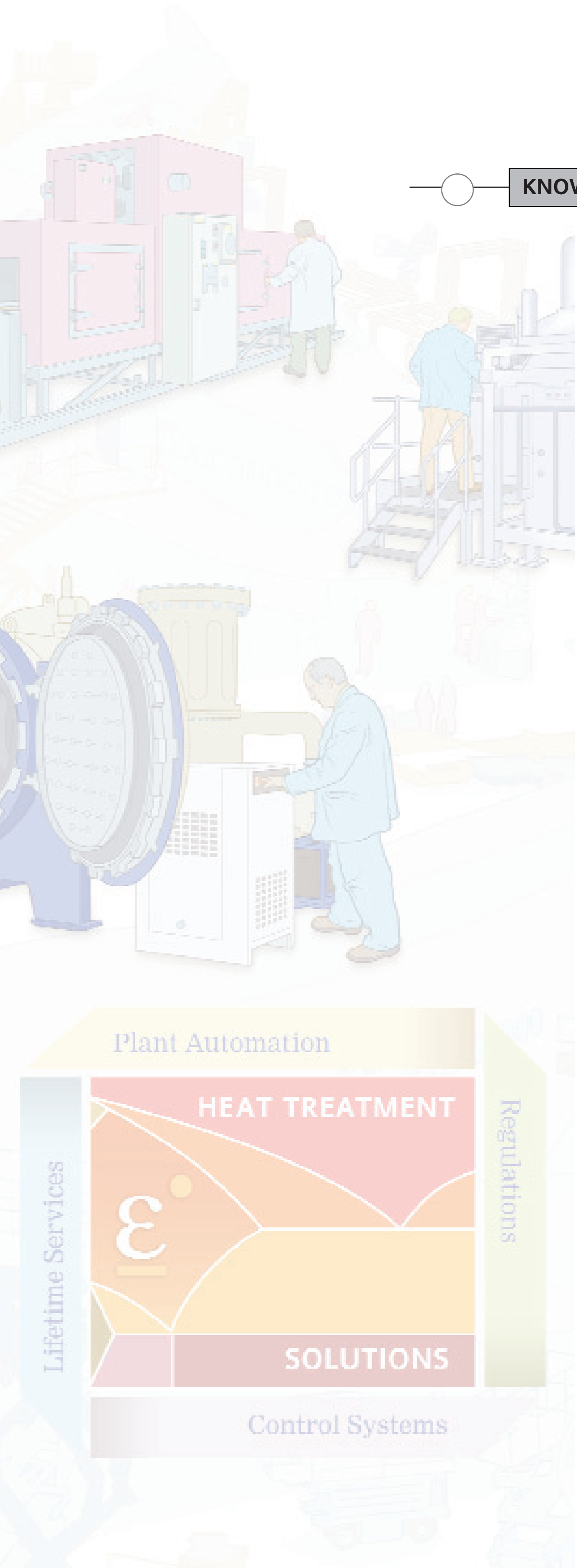
Eurotherm Report:
Issue 6 or above

Minimum Hardware:
Pentium 3 800MHz
256MByte RAM
3GByte free space on HDD

For use with up to 15 survey thermocouples

Up to 7 survey setpoints

Single zone operation



KNOWLEDGE

- A Glossary of Terms
- International Colour Codes
- FM/DIN 3440 Alarms Application Note

Heat Treatment
INDUSTRY

Reference

A Glossary of Terms

Heat treatment definition

Heat Treatment can be defined as a combination of heating and cooling operations applied to metals and alloys in the solid state to obtain desired conditions or properties.

The Heat Treatment of metals involves raising the temperature of a steel or alloy, often through a prescribed thermal profile to a defined temperature. The material is then held at temperature for a period of time before being cooled usually at a carefully controlled rate or in a quench process to a fixed temperature or to ambient temperature.

Treatments are carried out in furnaces and ovens where gases are often used to control the atmosphere of the process.

Controlled atmospheres are used to reduce the effects of oxidisation on the component being treated or to provide an enriching atmosphere for surface chemistry effects.

Heat treatments can be employed to homogenise cast metal alloys or to improve their hot workability, to soften metals prior to, and during hot and cold processing operations, or to alter their microstructure in such a way as to achieve the desired mechanical properties.

Thermal treatments of metallic alloys are also employed to alter the surface chemistry of a material. This is achieved by diffusing Carbon, Nitrogen and other gaseous or solid material in to the surface of the component.

These processes are used to give defined surface hardness and to improve wear, corrosion and fatigue resistance.

Thermal Treatments can be classified by their purpose;

Heat Treatments, which modify the microstructure of the material or change the phase structure to improve the mechanical properties for specific applications or further work processes

Annealing

A term used to describe a variety of softening heat treatments by changing the microstructure of an alloy.

Used mainly to remove stresses, to alter ductility, to induce softness or to produce amongst other things a defined crystalline grain structure.

Various degrees of annealing occur by slow cooling an alloy, which has been heated to temperatures between 0.3 and 0.5 of its melt temperature.

Homogenisation

Primarily used to equalise temperature in stock material prior to hot working, or to reduce excessive coring, which can occur in ingots and continuously cast alloys.

Coring

Non uniformity of the chemical composition of cast stock.

Stringers

Small quantities of impurity that align into long threads (stringers) on rolling. These threads restrict grain movement so providing improved creep-strength.

Stress relieving

A process used to remove stresses in welded, rapidly cooled components or cold work products. Relief is achieved by heat treating the component at a temperature for a period of time and then slowly cooling the product back to room temperature. The time and temperature are alloy dependent.

Normalising

A treatment used to remove undesired microstructure effects of previous heat treatments and performed to produce a uniform grain structure.

Hardening

One of a number of processes used to improve the hardness of an alloy superior to that normally present in the core stock. Usually achieved by quenching material from above its upper critical temperature.

Solution heat treatment

A process in which certain alloys mainly some stainless steels and copper based alloys are heated to a suitable temperature to allow the constituents to enter into solid solution. The process is then held at the defined temperature for a specified length of time dependent on the alloy mix to allow the various components to form a coherent solid but soluble mass before rapid cooling (precipitation)

The material is then said to be in a supersaturated, unstable state, and may subsequently exhibit age hardening.

Precipitation hardening (Age hardening)

A process in which the hardness and stress-rupture strength can be improved of hardenable high-temperature steels, as well as titanium and nickel and cobalt alloys. The process consists of a solution heat treatment followed by aging during which the constituents of the structure form a solid solution that is frozen during rapid cooling. The hardness increase is caused by the aging cycle.

Age hardening (Precipitation hardening)

A process in which certain nonferrous and ferrous alloys are heated, quenched, and then aged at a relatively low temperature above room temperature, to allow precipitation hardening to occur. This can significantly increase work-piece strength without any affect on work-piece ductility. The hardening process can be halted by refrigeration of the component.

Quench hardening

The objective of this treatment is to produce a fully Martensitic microstructure in the steel.

To achieve this the steel must be cooled rapidly from the austenitic condition.

The process is suitable for ferrous metal and alloys in which steel and cast iron alloys are heated above a certain critical temperature and rapidly cooled to produce a hardened structure. Either surface hardening or full-hardening can result, depending on the cooling rate. The process requires close control of temperature during heating and quenching.

One draw back from the fast cooling rate required to produce Martensite is that the outer surface is cooled more quickly than the core and thin/thick sections respond at different rates. This may result in distortion or cracking of the component.

When the quenching rate is insufficient or the section size is too large or the steel had insufficient hardenability Bainite is formed instead of Martensite.

Whether Bainite or Matensite is formed during the quench process the material is usually tempered before use.

In the case of Bainite the process is usually used to reduce internal stresses whereas in Matensite it is to improve ductility and toughness at the expense of strength and hardness.

Tempering

A treatment used to remove brittleness from mainly quench hardened steels and achieved by thoroughly soaking the material at an alloy dependent temperature prior to cooling.

Also referred to as the Draw process.

Martempering

To overcome the restrictions of conventional quenching and tempering, martempering can be used. The process, sometimes referred to as marquenching permits the transformation of Austenite to Martensite to take place at the same time throughout the structure of the metal part. This is achieved by interrupting the quench cycle, the cooling is stopped at a point above the Martensite transformation region to allow sufficient time for the centre to cool to the same temperature as the surface. Then cooling is continued through the Martensite region, followed by the usual tempering.

Austempering

This is another process that can be used to overcome the restrictions of conventional quench and tempering. The quench is interrupted at a higher temperature than for Martempering to allow the metal at the centre of the part to reach the same temperature as the surface. By maintaining that temperature, both the centre and the surface are allowed to transform to Bainite and are then cooled to room temperature.

Advantages of austempering are, less distortion and cracking than Martempering, No need for final tempering, improvement of toughness and improved ductility.

Case hardening

One of a number of heat treatment processes which improve the surface hardness of a steel alloy without affecting the properties of the core material.

Flame hardening

A localised hardening process where components are subject to mainly an acetylene flame and then spray quenched.

Induction hardening

A widely used process particularly in the automotive and tools market for the surface hardening of steel. The components are heated by means of an induction set which applies an alternating magnetic field to the work-piece.

The temperature of the components increases to the transformation range or just above before being immediate quenched. The physical properties of the core material remain unaffected by the process.

Steel

An alloy of iron, carbon and often other elements. The amount of carbon is below 2% by mass. Steels in which carbon is the main alloying element are termed carbon steels. Those with significant concentrations of other elements are termed alloy steels

Wrought iron contains less than 0.035 percent carbon. This high purity ensures good corrosion resistance. In structure it is classed as ferrite, but contains a little slag elongated into stringers by rolling. This reduces its strength and malleability.

Microstructure states

Heat treatments are used to change the micro structural state of steels and alloys.

Each of the states holds advantages in different applications and metals may be produced which exhibit combinations of the states

The principle transformations are as follows.

Austenite

A solid carbon/iron state with defined microstructure, which occurs in alloys when they are heated to a value range above it's upper critical temperature. The Austenising temperature is dependent on the alloy type and grade of material.

Austenite is one of the allotropes of iron, also known as gamma iron. It is formed when iron is between 912°C and 1,394°C and has a face-centred cubic structure. The structure is also found in carbon steel.

Pearlite

A lamellar constituent of steel consisting of alternate layers of ferrite (alpha-iron) and cementite (iron Carbide Fe3C) and is formed on cooling austenite at 727°C. This produces a tough structure and is responsible for the mechanical properties of unhardened steel.

When steel is cooled at the rate of about 400°C per minute austenite crystals change into pearlite (a fine lamellar structure of alternating platelets of ferrite and iron carbide) at about 727°C.

Faster cooling produces Martensite.

Bainite

A non-equilibrium phase, usually in steel, which is formed by quenching from the austenite phase. The rate of quenching required is slower than that necessary to form Martensite but faster than that which produce the equilibrium phase of Pearlite. Two types of Bainite are recognised; upper and lower. Upper Bainite forms at higher temperature and consequently the carbon present has sufficient to diffuse out forming carbides outside the bainite laths. Lower bainite forms at lower temperature and contains carbides within the laths as the carbon cannot diffuse out rapidly enough.

Marstenite

Very rapid cooling (quenching) of steel (at about 1,000°C per minute) produces a new microstructure, Marstenite. It is the hardest and most brittle form of steel. Subsequent reheating to about 400°C and holding it for a time (tempering) produces a strong and tough steel with lower hardness and brittleness.

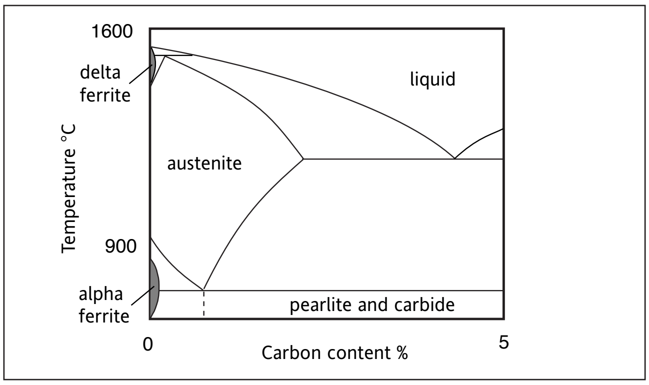
Ferrite

Ferrite, is a condition in iron that has a number of inherent properties at room temperature such as a large grain size, low hardness, good ductility and is easily machined.

The ferrite condition exists in a particular crystal form and will exist at low temperatures. Iron is therefore made up of millions of tiny crystals. The crystals are bound together in what is called a lattice structure.

Pure iron up to 912°C has a body centred cubic structure and is known as alpha ferrite. Between 1394°C and the melting point of iron the bcc structure is now known as delta ferrite. Also found in carbon steel.

Phase diagram showing typical transformation regions



Cementite

Iron carbide, Fe3C. Harder and stronger than ferrite, but not as malleable.

Treatments, which alter the surface chemistry of an alloy; typically carburising, nitriding, carbonitriding and nitrocarburising

In these processes the surface layers of the alloy are hardened and strengthened by subjecting the component to an enriched gaseous atmosphere of carbon or nitrogen whilst the material is taken through an elevated thermal profile.

Similar material properties containing other surface molecular components can be obtained in processes such as Ion Implantation - Chemical Vapour Deposition (CVD), Physical Vapour Deposition (PVD), Boriding and Diffusion Alloying Aluminising. Salt Baths.

Carburising

Various processes that add carbon to the surface of steel to improve case hardness and surface wear resistance.

The results of the carburising process is to produce an effective case depth of hardness which enable components manufactured from Low-carbon alloy - case-hardening steels to be used in applications which demand greater wear characteristics.

Gas carburising

A surface chemistry process, which improves the hardness of a component by diffusing carbon, into the surface layer to improve wear and fatigue resistance.

The work pieces are held at an elevated temperature and are subject to an enriched carbon potential atmosphere such that nascent carbon atoms can diffuse in to the surface layers of the component. The process is usually carried out in a combined sealed atmosphere quench furnace where components are immediately quenched after the diffusion process.

The conditions for producing a carbon potential atmosphere are generated by adding enrichment gas (often methane CH4 or Dilution air on top of a endothermic carrier gas which may consist of 40% Nitrogen - 40% Hydrogen - 20% Carbon Monoxide (CO) - and less than 0.1% Carbon Dioxide (CO2).

Carbonitriding

Carbonitriding is a variation of carburising where both carbon and nitrogen bearing gasses are used, This is most usually by the inclusion of ammonia in with the carburising gas mixture. Carbonitriding is carried out in the austenite state, i.e. temperatures above 850°C, typically 870°C. The case depths are typically lower than those achieved by carburising alone however the surface hardness levels can be higher.

Low pressure carburising (Vacuum carburising)

A reasonably modern process used to carburise components in an oxidising free environment.

The process is carried out at high temperature in a vacuum furnace utilising pulsed hydrocarbon gasses such as propane, ethylene and acetylene as the carburising medium.

The principle benefits are, an oxide free surface, low distortion, good finish, good penetration for complex shapes and holes, with consistent process performance and improved processing times

The process is not suitable for all steels and is used mainly for injection and transmission parts in the aerospace and automotive industries. Due to the relatively low quench pressure the treatment is not used universally across all steel and alloy types.

Gas nitriding

Gas nitriding involves the diffusion of nitrogen into the surface layers of a low carbon steel which is being held at an elevated temperature. This forms a nitrided layer, which improves surface hardness. Nitriding is typically carried out in the temperature range of 500 - 575°C where the material is in the ferritic state rather than the austenitic region used for carburising. This is possible since ferrite has a much higher solubility for nitrogen than it does for carbon.

The use of lower processing temperatures and the absence of the need to provide quenching leads to lower work piece distortion rates.

The advantage of nitriding in the ferritic state is that any previous heat treatment of the steel component is not disrupted and there is little / no distortion of the final component shape. This means that higher carbon steels that have been previously heat treated, can be surface hardened by nitriding. In fact it is normal to complete all thermal treatments to the component prior to nitriding.

Ammonia NH3 is the most common gas used for nitriding in batch furnaces.

One disadvantage is that some process cycles can be lengthy, up to 80 hours is not uncommon.

Nitrocarburising

Ferritic nitrocarburising conducted at 550-580 °C or Austenitic nitrocarburising conducted at 590 - 720 °C involves enrichment of the surface with both nitrogen and carbon to impart a compound layer consisting of iron-carbonitride. The compound layer is apparent on the surface of the nitrogen bearing diffusion zone and greatly changes surface characteristics. The process may include subsequent quenching of the parts or other post process activities to further enhance the surface compound layer.

Plasma diffusion

Plasma diffusion treatment aims at introducing species like nitrogen, carbon, boron, e.t.c into the surface of a component by bringing an activated gas into direct contact with the surface, which is being maintained at an elevated temperature. The plasma of an electrical glow discharge is used to derive positive ions from the active gas to produce the nitriding, carburizing or boriding process. This adds greatly to surface treatment to improve surface hardness and to create wear fatigue and corrosion resistant properties.

Plasma nitriding

Is particularly popular with common batch styles. In this process nitrogen atoms are diffused of into the metal surface in presence of a plasma environment.

This process is also called Ion nitriding where a differential potential of minimum voltage is applied to two electrodes held in a gas at reduced pressure, the work piece is maintained within the abnormal glow discharge region and as an increasing voltage and current are applied to the electrodes, the work piece becomes heated through the action of ionic bombardment.

As a result nitrogen is transferred to the work piece, which then penetrates the surface by diffusion.

Other specialist processes

Surface diffusion - Salt baths

A method of providing thermal processing of steels using a bath of molten salts. The process prevents oxidation and provides a very uniform heating environment for hardening, tempering or quenching. The type of salt used depends on the temperature range required. For hardening, sodium cyanide, sodium carbonate and sodium chloride are in common use.

The process is also used for specialist nitriding processes.

Due to environmental issues the process is becoming less popular in favour of other heat treatment methods, such as, aluminising.

As the operating temperature for gas turbines has increased beyond the natural safe operating point for the core alloys a process has been evolved to diffuse alumina on to the surface of the blades to form a protective oxide alumina layer. Most blades coatings have been applied by pack cementation where the blades are laid into trays of powder and subject to thermal process under atmosphere controlled conditions.

Because of the complexity of blade structure and associated cooling holes it is becoming more appropriate to carry out this process by chemical vapour deposition.

Hot Iso Static processing (HIPping)

This process is used for the densification of castings and pre-sintered components as well as in the diffusion bonding of alloys. The process usually uses very high temperatures and pressures within a specially designed vessel.

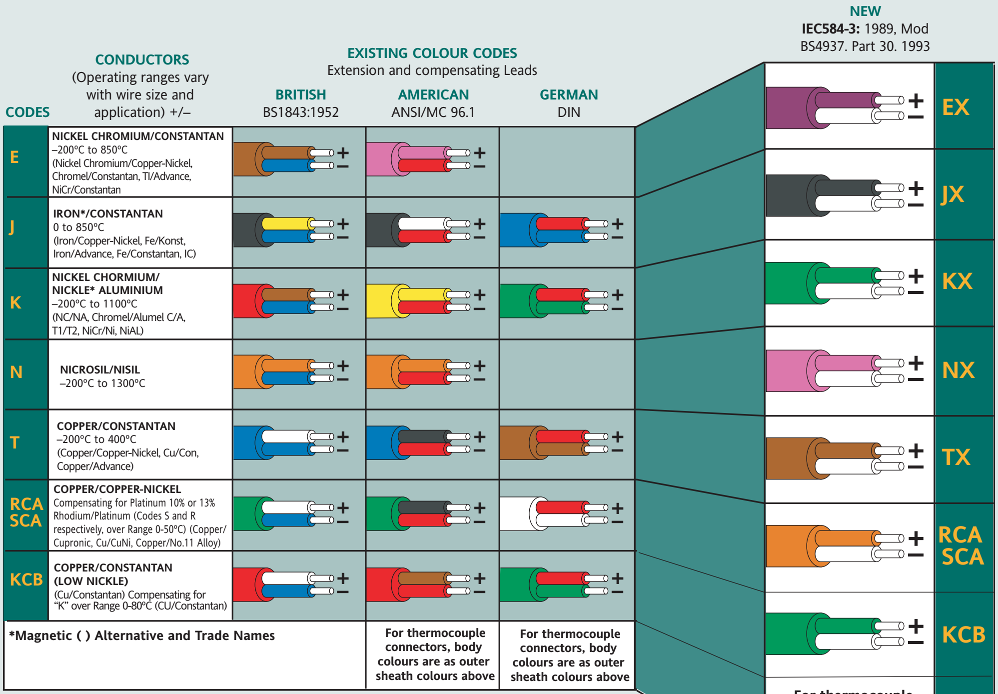
Sintering

Treatments, which strengthen the molecular bonding of powder compacted components.

Many products with complex cross sectional forms are manufactured from powdered, core material, which is pressed or moulded into the component shape.

Sintering takes place in an atmosphere controlled environment and is used to strengthen the bonding of powder compacted components over a timed temperature process cycle.

International Colour Codes for Thermocouple Compensating Cables



EXTENSION /COMPENSATING CABLES

Extension cables are designated by the suffix X (eg JX') and compensating cables by the letter C (eg NC). Different alloys may be used in certain circumstances and these are distinguished by additional letters (eg KCB)

THERMOCOUPLE CONNECTORS

New colour coded connectors are marked IEC and have a grey body with a clearly visible colour coded area (with exceptions of the fascia/panels sockets). This is to prevent any confusion regarding the use of the new and old colour coded connectors

Heat Treatment

INDUSTRY

- **Fail safe process operation**
- **Alarm on sensor failure**
- **Alarm on power interruption**
- **Parameter security**

Over Temperature Alarms to FM/DIN 3440

Application Note

Why protect against over temperature?

Over temperature alarm units, sometimes referred to as Policemen are essential in any oven or furnace application, where in the event of an excessive temperature, personnel safety can be compromised. To ensure failsafe operation, these alarm units must be on a separate circuit to the main temperature controller.

Why not include this alarm in the temperature controller?

Including the alarm within the temperature controller would not provide failsafe operation in the event of a low reading of temperature caused for example by shorting of the thermocouple leads.
The reason for this is that the temperature controller will keep increasing its output demand and the measured temperature will not, even though the actual temperature is. In this example the temperature will keep rising until a problem occurs or the system hits its temperature saturation point.

FM approval

FM (Factory Mutual) is an agency based in Boston who specialise in equipment functionality and ensure it works in a prescribed way. They list all manner of equipment from fire systems and sprinklers to industrial switches. Since FM is a US based agency it is mandatory on processes over 1000°F installed in the USA to be protected with an FM approved alarm unit.

The FM standard which applies to Eurotherm® products is Class Number 3545, which sets the requirements for temperature limit devices used to ensure safety within industrial temperature control systems. An FM approved installation requires the following:

- Changes to the alarm setpoint require some form of security, i.e. password protection.
- Reset of the alarm relay cannot be made until the process temperature has returned to a safe condition.
- Sensor failure shall result in the alarm relay becoming active.
- The installation should be failsafe with the relay de-energised in alarm.
- The alarm circuit should be independent from the main temperature controller.

DIN 3440 approval

DIN 3440 is a safety approval from the German TüV Rheinland Group.
TüV is responsible for documenting the safety and quality of both new and existing products, systems and services. One of the product types referred to by DIN 3440 is temperature limiting devices used in thermal process applications, including ovens and furnaces. It is normal that any thermal processing application in Germany and some other mainland European countries will require the fitting of a safety device approved to this standard.

The requirements of DIN 3440 are almost identical to that of FM with the two main criteria being:

- After an alarm becomes active and then returns to a safe condition it cannot be reset until acknowledged by an operator.
- If the process input detects a fault the alarm should become active.

Application note

Typical application

A typical application is shown in Figure 1. In this case the temperature is being controlled by a PID controller modulating a thyristor. The relay contact of the Alarm Unit is connected in series with the live feed to the thyristor. If, therefore, this contact is broken no heat will be applied to the heater. At the same time as the alarm becomes active, the other contact of the changeover relay will light a lamp or ring a bell to alert the operator of the problem.

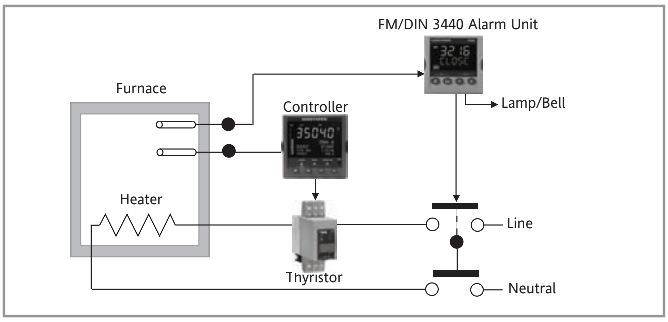


Figure 1

Figure 2 shows an example of how a 3216i can be used in the application shown in Figure 1.

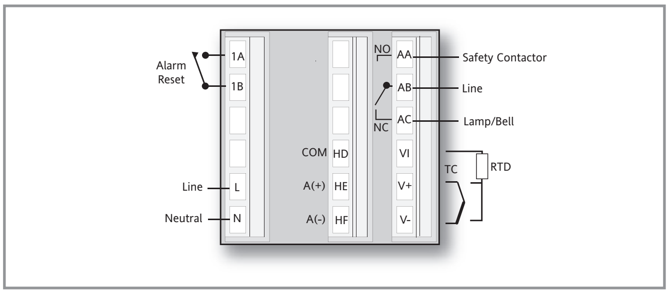


Figure 2

3200i Indicator and alarm units

Available in three formats, 3216i, 32h8i and 3204i, the 3200i range of indicators offer Over Temperature protection to both FM and DIN 3440 with the following features being available:

- FM/DIN 3440 approved changeover relay (Form C)
- Alarm on sensor break or power interruption
- Alarm reset via user interface or digital input
- Scrolling text alarm message
- Display colour change on alarm (32h8*i*)
- Alarm setpoint change protected by password
- Modbus RTU communications

The emphasis on the 3200i is ease of use. A simple ‘quick start’ code is used to configure all the functions that are essential for indicating and protecting the process. This includes input sensor type, measurement range and alarms - making out-of-the-box operation truly achievable.

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