ISSN 1611-616X VULKAN-VERLAG · ESSEN
1 2009

HEAT PROCESSING

INTERNATIONAL MAGAZINE FOR INDUSTRIAL FURNACES · HEAT TREATMENT PLANTS · EQUIPMENT

http://www.heatprocessing-online.com

Innovative safety concept for endogas generators guarantees compliance with legal regulations

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Mercedes Benz Gaggenau Plant operates seven endogas generators in building 131 at the Rastatt site for carburizing parts. The endogas is used to protect and harden parts in a carburising gas atmosphere. To bring the facilities into compliance with the current european statutory provisions for explosion safety, the company hired the IBExU institute and Air Products to develop a new explosion safety and engineering concept for the generators. Through a combination of technical innovation and process and equipment adjustments the facility now complies with all legal requirements. In addition, the Mercedes Benz Gaggenau Plant realized economical advantages by employing the new concept too.

For many years the Mercedes Benz Gaggenau Plant has been operating standard commercially available endogas generators at its Rastatt site to supply the carburising and hardening furnaces with a protective gas atmosphere, composed of approx. 18.5 to 20 Vol.-% carbon monoxide (CO), approx. 37.5 to 39 Vol.-% hydrogen, a small proportion of carbon dioxide (CO_2) and water (H_2O), along with a correspondingly high residual proportion of approximately 40 Vol.-% nitrogen (N_2). As a result of the revised legislation in the field of explosion protection and the associated increased degree of operator responsibility for industrial processes, Mercedes Benz Gaggenau Plant has undertaken a project to check the operational safety of its endogas generators and to bring the design of the generators up to today's standards. In order to execute this project, Mercedes Benz Gaggenau Plant hired the IBExU institute and requested they produce the explosion protection documents and hired Air Products to provide system engineering and system design. Within this context, the targeted objective was to modernise the existing systems, while keeping the costs to a minimum.

Description of process

In Building 131 at it's site in Rastatt, Mercedes Benz Gaggenau Plant operates seven endogas generators for the production of protective gas atmospheres for carburising and hardening carbon-steel components. The seven generators feed the protective gas into a main house line feeding the furnaces at the plant. Furthermore Mercedes Benz Gaggenau Plant operates two additional generators in building 311 at Rastatt and 4 generators at the site in Gaggenau.

The individual generators are practically identical in their construction. The principle of endogas generation is fairly standard and at this point requires only a brief explanation to promote understanding of the safety concept. (**Fig. 1**).

"Endothermic gas" is generated through the combustion of a pre-mixed flow of natural gas and air in a retort oven (catalytic oven) operating at approx. 1030°C and approx.0.3 bar. This gas mixture is then cooled to

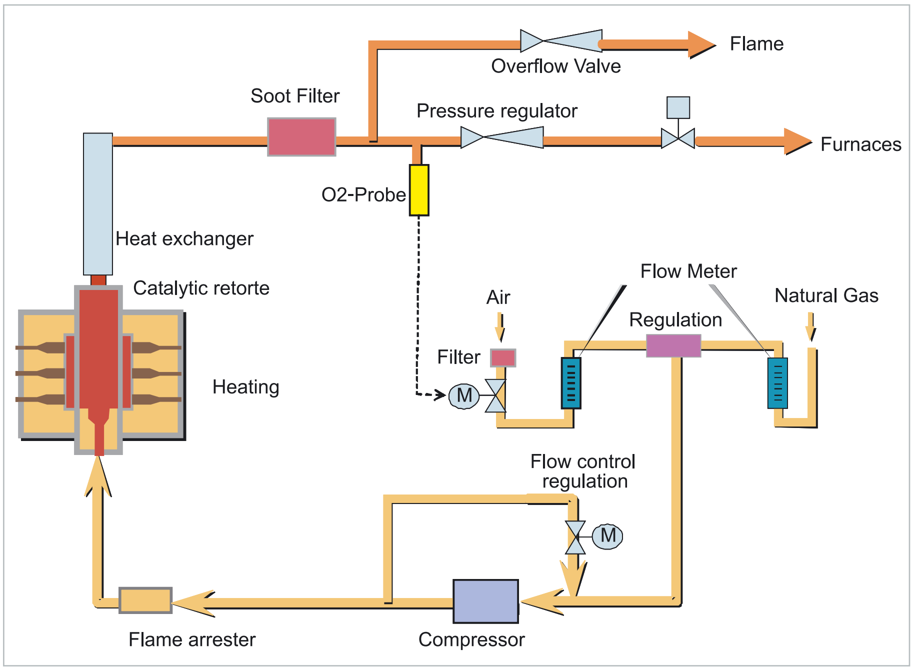

Fig. 1: Functional diagram of an endogas generator

approx. 40°C as it passes through heat exchangers, and is fed into a house line at a maximum pressure of 0.05 bar. In regulation-compliant operations, both the natural gas/air mixture and the protective gas generated are not in the explosion concentration area. Nevertheless, under certain operating conditions the blends can be explosive. Also, endogas systems operated in the past have displayed technical shortcomings in respect to explosion protection if operated under these conditions. The technical modifications required to meet the new explosion protection legislation have been individually discussed and agreed to with reference to the safety requirements imposed by the new legislation by Air Products acting in conjunction with Mercedes Benz Gaggenau Plant and the IBExU safety technology institute, and implemented within the technology.

Safety requirements under the new legislation

A standardised set of requirements for legal explosion provision have been applicable since the expiry of the transitional deadlines in July 2003 and are set out in the Directives 94/9/EC (ATEX 95) and 99/92/EC (ATEX 137). ATEX 95 replaces the national requirements with a standardised safety system for explosion proofed equipment and protection systems applicable across Europe, and specifies the targeted safety objective. Implementation and details are now dealt with by European standards which can be rapidly adapted to reflect the latest technical knowledge. The content of ATEX 137 deals with the minimum requirements, which are necessary to meet when working with explosive atmospheres, to avoid explosions and protect against explosions. It includes measures for assessing risks and defines explosive zones, as well as the required standards for protective measures. One significant innovation is the condition imposed by which an up-to- date explosion detection document must be maintained. Since the transitional deadlines expired on 1 July 2003, all new systems must comply with the conditions of both directives. By 1 July 2006 at the latest, existing systems must have been checked by the operator for compliance with the minimum requirements as per ATEX 137, which in Germany can be found in the Operating Safety Directive.

Fulfilment of requirements within a new safety concept

In accordance with the new requirements and the present technical designs of the endogas generators in place, the following necessary technical safety modifications were undertaken on the existing systems:

1) The gas-channelling sections downstream from the natural gas/air junction point through to the point at which the gas is fed into the main house line are classified internally as Explosion Risk Zone 1. If the system is operated in accordance with the regulations, there is no potentially explosive atmosphere present. However, in the event of operating malfunctions, during start up and shut down, the possibility of a potentially explosive atmosphere being created within the system cannot be totally eliminated.
2) All pipeline connections within the endogas generator which cannot be rated as "permanently technically tight" by means of purely constructional measures are bonded in place using a certified sealing and securing material and checked for tightness at regular intervals, to be determined on the basis of future empirical values. In this way, with only one exception, the area outside the actual pipelines can be considered "zone-free". So in this external area of the endogas generator, there is no requirement for the use of explosion proofed appliances. The exception is the flange connections between the retort oven and the heat exchanger, which, due to the thermal loading applied, is not rated as "permanently technically tight". In the external area, around these flanges connection Zone 1 is specified within a radius of 50 cm and Zone 2 within a radius of 1 m. Due to local conditions of the described generators, no further measures are necessary here (there being no operating materials within this protection area). These zones must be documented in the operating manual, and identification markings must be applied on site, within the system.
3) The endogas generator is equipped with an automatic nitrogen emergency purge system, which in the event of safety-critical conditions is switched to a "fail safe" open state. In this case, at the same time the supply of air and natural gas is cut of automatically by "fail safe" closed solenoid valves, the entire generator is purged with nitrogen and returned to a safe condition.
4) The natural gas/air mixture ratio is reliably set by a mechanical mixing regulator with a fixed setting and a plate metering orifice in the air line and a regulator valve in the natural gas line during normal operation and maintained to an adequate safety margin above the upper explosion limit for natural gas (min. 25 Vol.-% CH_4).

   To safely prevent the creation of explosive mixtures internally when the system is being put into and taken out of operation, the following measures are applied:

   a) when being put into operation, the system is rendered inert with

Fig. 2: Bidirectional, type-tested flame arresters

Table 1: Theoretically-calculated oxygen contents

		Sample					Calculations			
	Note	Sum 02/%	CO/%	CO2/%	H2/%	T/C	ac calc.	Cp calc.	H2O/%calc.	Tp/C calc.
worst case, not normal Production	dry, heavily sooting Endogas out of Retorte		20	0.055	40	950	1.00	1.30	0.16	-15 °C
	Tp-Max Set point 18 °C		17.3	2.7	37	650	3.35	1.14	3.00	+18 °C
	O2 regulating window /%	2.74		1.32					1.42	

an appropriate volume of nitrogen is flowed for adequate period of time, before the natural gas/air operating gas mixture is introduced

and

b) when being taken out of operation, the system is similarly purged with nitrogen to remove an explosive gas mixture.

5) Adequate purging depends on the free volume of all components within the generator, with this having been established and documented on the basis of CO/H_2 measurements undertaken when the endogas generators were commissioned. The targeted objective here is to have the entire endogas protective gas system flushed free of CO and H_2, and thereby of CH_4, in no more than ten minutes.

6) Because of the specification of explosion risk zones (see above) within the gas channelling sections the existing compressors have been replaced by compressors licensed for Zone 1 (internal area, Category 2(i)).

7) Between the new compressor and the retort oven bi-directional flame arresters of approved design with temperature monitors at each side were installed (**Fig. 2**). The compressor in use has no integrated flame arresters. If, despite the Category 2(i) design, any ignition spark should be triggered by the compressor, the flame arrester in place will prevent an explosion from travelling to the retort oven. The retort oven itself is regarded as a further potential source of ignition. In the event of an ignition of explosive gas in the retort oven, the flame arrester will prevent the explosion from entering the compressor. For both sources of ignition, the effect of the flames on the flame arresters will be recorded by the temperature sensors and an emergency safety nitrogen purge will be initiated automatically.

8) It was not possible to establish whether the retort ovens in place were designed to withstand explosion pressure. Any transmission of an explosion caused by compression ignition is unikely due to the Category 2(i) compressor design and the flame arresters fitted retrospectively. Due to its operating temperature (> 900°C) the inner surface of the retort oven must be classified as a permanent source of ignition (hot surfaces). Accordingly, within the retort oven it must be guaranteed that no additional oxygen will lead to an explosive gas mixture.

9) The natural gas/air supply system and the endogas line are pressurized. This means that the possibility of aspiration of significant volumes of air from the outside into these lines can be practically excluded. Nevertheless, if due to unforeseeable circumstances (e.g. incomplete conversion of the air in the reactor or leaking connections) an unacceptably high oxygen content was introduced into the protective gas generated, this would be recorded by an indirect O_2 measurement by the "Lambda probe" in place. At the temperatures present at the Lambda probe, oxygen penetrating into the probe would react with H_2 to produce H_2O and with CO to produce CO_2. Both reactions affect the mV signal emitted by the Lambda probe.

In **Table 1**, the theoretically calculated oxygen contents providing complete equilibrium of the gas blend within the measurement cell were considered, ignoring the changes in dew point due to fluctuating natural gas/air ratios at the retort oven inlet. At the same time the initial state considered was a dry endogas composition with a carbon activity of 1, at a retort outlet temperature of 950°C and as maximum oxygen input, the balanced state at an oxygen probe temperature of approx. 650°C and a maximum dew point of +18°C.

Fig. 3: Modified endogas generator

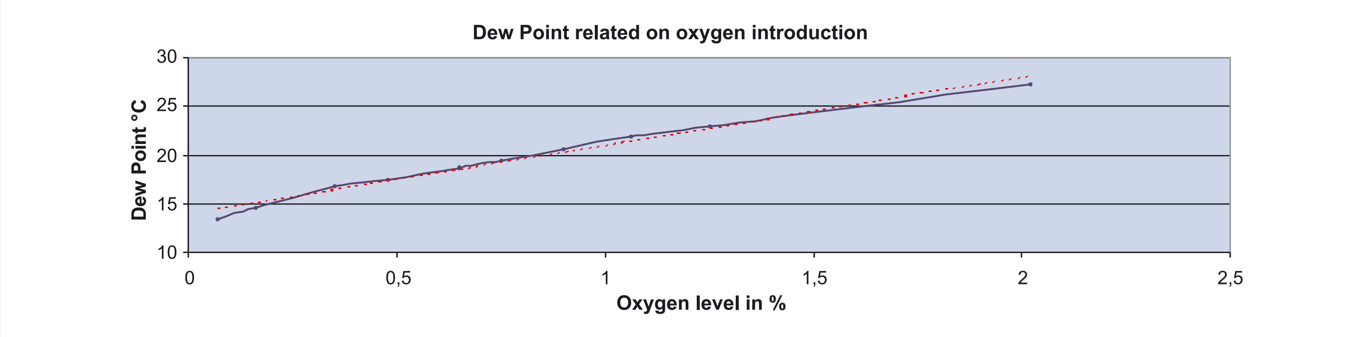

Fig. 4: Rise in dew point upon ingress of oxygen

In accordance with this, in the worst case scenario, when generating endogas in the retort oven with a dew point of approx. -15°C and setting of a safety-critical maximum dew point of +18°C, an oxygen content of approx 2.74 Vol.-% occurs. However, under these operating conditions, the endogas generator would produce large amounts of soot. Within the normal regulation range, the differences between the minimum dew point and the upper dew point limit are calculated at up to 2.5 Vol.-%. If the upper dew point limit should be exceeded, the emergency nitrogen purging system would be triggered. The upper explosion limit of H_2 in air is 75 Vol.-%, corresponding to an O_2 content of approx. 5.2 Vol.-%. The upper explosion limit of carbon monoxide is 74 Vol.-%, which in turn represents an O_2 content of approx. 5.4 Vol.-%. This means that the oxygen values that were theoretically calculated under consideration of the dew points represent on average 50 percent of the "maximum allowed O_2 limiting concentration".

It is assumed that in the oxygen probe the equilibrium state for reactions is not reached. So this safety function of the system for monitoring O_2 with the Lambda probe was checked. With the endogas generator running with a set dew point value of +13°C, free oxygen was mixed into the measured endogas. The Lambda probe reacted immediately to indicate a rise in the dew point, as can be seen from the following **Figure 4**.

The maximum dew point of +18°C, set as the limiting value, was reached at approx. 0.65 Vol.-% of free oxygen in the endogas. This test confirms that the Lambda probe is suitable for monitoring free oxygen in the endogas. This also represents compliance with EN 746-3, which requires that the oxygen content in flammable protective gas atmospheres must not exceed 1 percent. By monitoring O_2 content it is possible to avoid the creation of any potentially explosive endogas mixtures, there is therefore no need for the retort oven to be designed to withstand explosion pressures.

Empirical experience of the process

The first modernised endogas generators (**Fig. 3**) have been running flawlessly in Rastatt since the end of 2007.

Technical measures to optimise the process have also been carried out within the context of the technical safety modifications. In order to eliminate the changes in concentration of the gas composition inside and behind the retorts and the associated production of soot, caused in the past by the endogas generated taking too long to cool, and to freeze the endogas generated, new heat exchangers with an internally-cooled baffle plate were placed directly on top of the retorts. Furthermore, the transition from retort to heat exchanger was insulated. It was therefore possible to avoid the deposit of soot which had existed previously in the line between the retort and the heat exchanger and within the heat exchanger itself. With the same set point value for dew point regulation of +13°C maintained, during the first period of operation of the modernised generators, only one regeneration pro-

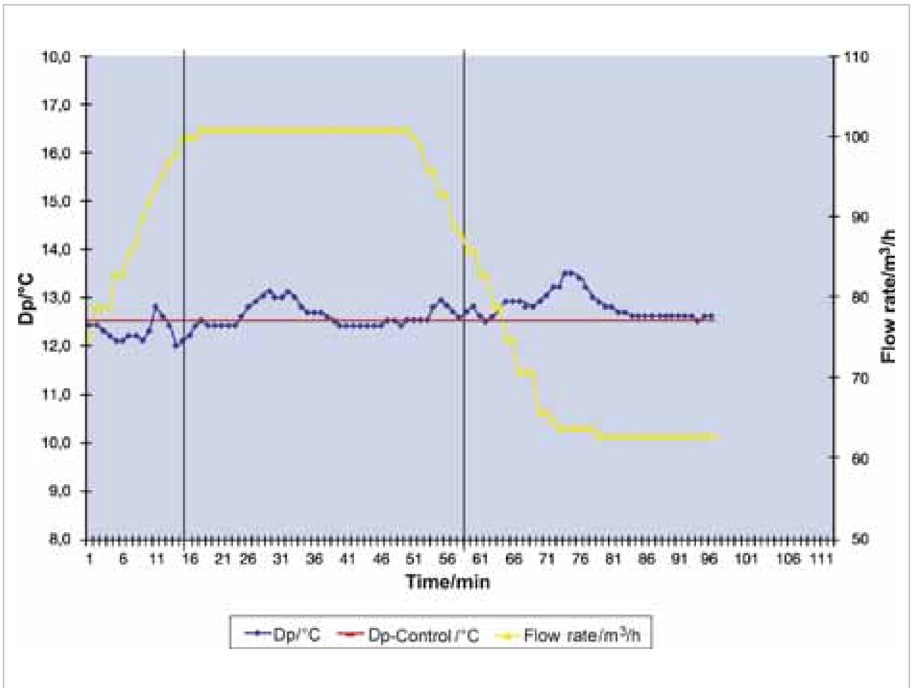

Fig. 5: Regulation of dew point upon change in flow rate

cedure had to be carried out whereas previously it was done every two weeks. In the course of a check up on sooting after a year, all that can be identified is an extremely slight coating of soot particles on the inner top surface of the heat exchanger. Before the modernisation of the generators the removal and cleaning of soot in the heat exchangers had to be carried out every four to six weeks.

Now, optimising dew-point regulation by modifying the regulating values for the mechanical proportional regulation system makes it possible to operate the generator within the flow range of 50 to 100 percent without any significant fluctuations in dew point, as previously occurred. This allows for more flexible production of the required volumes of protective gas in order to meeting actual requirements, thus reducing flare-off losses (**Fig. 5**).

Conclusion

The project undertaken in collaboration between Mercedes Benz Plant Gaggenau, IBExU and Air Products provides an example of how conventional endogas generators can be adapted, in line, to meet current legislation on technical safety, and optimize for the process. At the heart of the new safety concept is the combination of technical equipment and correspondingly adapted procedural instructions. In this way, the operator fulfils not only all the conditions required to protect the workforce, but also achieves commercial advantages. In its Rastatt works, Mercedes Benz Plant Gaggenau has managed to significantly reduce both maintenance costs and personnel costs, and to reduce flare-off losses. Further modernisations, similar to this concept, are being carried out at the Rastatt works in Building 311 and at the Gaggenau works. ■

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