



MECHANICAL INTEGRITY OF SYNGAS OUTLET SYSTEMS

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1 Introduction

Large scale hydrogen production has been commercially practiced for decades and the demand for such production has grown over that period. In the last several years, developments in crude oil processing, such as the increased use of hydrogen to remove sulfur and the refinement of heavier crude oil stocks, has driven significant growth in the demand for hydrogen supply.

In response to this demand, industrial gas companies operate and maintain large scale hydrogen production facilities worldwide and have done so with an exemplary safety record for many years. However, it should be noted that large scale hydrogen production involves potential personnel and process safety hazards that must be addressed in design and operation. Such hazard potential is inherent to the processing of toxic and flammable gases via high temperature reforming as practiced in hydrogen production.

The steam reformer represents the core operating unit of most large scale hydrogen production facilities. The products from the steam reformer are collected and transferred to downstream unit operations by a collection and transfer header system. The interior of the outlet system is subjected to high temperature, pressure, and hydrogen attack, while the outside is subjected to ambient conditions. The increasing severity of the service has resulted in a number of failures and therefore requires appropriate operation and maintenance.

It should be noted that there are other industries, such as ammonia and methanol production, that operate large steam reformers. Therefore, it can be instructive to consider the learning and experiences from those industries through organizations such as the American Institute of Chemical Engineering: Ammonia Plant Safety Symposium and the International Methanol Producers and Consumers Association (IMPCA).

Steam reformer furnace design will continue to develop along with methods to implement combustion safety in these furnaces. A wide variety of steam reformer designs, configurations, and component equipment exists today. Therefore, this publication includes generalized statements and recommendations on matters which there can be diversity of opinion or practice. Users of this publication should recognize that it is presented with the understanding that it can supplement, but not take the place of, sound engineering judgment, training, and experience. It does not constitute, and should not be construed to be a code or regulations.

2 Scope and purpose

2.1 Scope

This publication applies to steam reformers that are operated with natural gas, refinery off gas, naphtha, and other light hydrocarbon streams. It specifically applies to large volume hydrogen production plants, defined for this publication as a nominal production capacity of 10 000 Nm³/hr (approximately 9 MMSCFD) or greater. This publication may also be applied to smaller reformers depending on the technology used.

This publication may also be used for similar applications such as internally insulated piping in a partial oxidation unit. Applicability for cases other than what is described in the publication is left to the reader.

2.2 Purpose

The purpose of this publication is to inform and guide interested parties on the procedures and practices related to the mechanical integrity of syngas outlet systems. This publication presents a baseline for safe reformer header system operation. This publication provides a technical basis that can be used to present a common viewpoint to government and regulatory authorities, ensuring proper application of rules and regulations.

3 Definitions

For the purpose of this publication, the following definitions apply.

3.1 Publication terminology

3.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

3.1.2 Should

Indicates that a procedure is recommended.

3.1.3 May and need not

Indicates that the procedure is optional.

3.1.4 Will

Is used only to indicate the future, not a degree of requirement.

3.1.5 Can

Indicates a possibility or ability

3.2 Technical definitions

3.2.1 Back purging

Technique to protect the root side (i.e., opposite from the weld side) of a weld joint from oxidation by applying an inert gas or mixture such as helium, argon, or nitrogen to exclude oxygen on the root side of the weld.

3.2.2 Boiler

Closed vessel in which water is heated and steam is generated by heat input from combustible fuels in a self-contained or attached furnace.

3.2.3 Catalyst tube

Metallic alloy cylinder used to contain the catalyst in the reformer furnace. Catalyst tubes typically measure 8 cm to 13 cm (3 in to 5 in) across the inside diameter with a vertical orientation and a length spanning the height of the reformer furnace].

3.2.4 Cold collector

Refractory lined piping system wherein the exit of multiple catalyst tubes are directly connected to a refractory lined piping manifold or header system, see Figure 1.

3.2.5 Convection section

Portion of the reformer, downstream of the furnace, where flue gas passes over heat exchangers and heat transfer occurs via radiation and convection.

3.2.6 Cross header

Refractory lined pipe that connects the reformer outlet manifold to the inlet of the waste heat boiler.

NOTE Also known as a transfer header.

3.2.7 Draft

Negative pressure (i.e., vacuum) measured at any point in the furnace, typically expressed in millimetres (inches) of water column.

3.2.8 Extended outage

Period of time after a plant shutdown that can range from several weeks to months.

3.2.9 Fill passes

Additional layers other than the first layer (i.e., root pass) in a multi-layer weld.

3.2.10 Filler metal

Metal or alloy to be added in forming a welded joint.

3.2.11 Flame

Body or stream of gaseous material involved in the combustion process and emitting radiant energy at specific wavelength bands determined by the combustion chemistry of the fuel. In most cases some portion of the emitted radiant energy is visible to the human eye.

3.2.12 Furnace

Portion of the reformer where the combustion process takes place.

3.2.13 Header

Pipe or duct through which liquid or gas is conveyed and supplied to or received from multiple branches.

3.2.14 Heat affected zone (HAZ)

Portion of a weld, braze, or solder joint that has not melted but where mechanical properties or microstructure have been altered by the heat of welding, brazing, or soldering.

NOTE Certain cutting processes can also result in a discernible HAZ.

3.2.15 Hot collector

Piping system wherein the exit of multiple catalyst tubes are directly connected to a metallic, non-lined piping manifold or header system such that the piping operates at the temperature of the syngas as it exits the catalyst tubes, see Figure 2.

3.2.16 Hot spot

Area of refractory lined metallic piping that is operating at a temperature significantly higher than its normal operating temperature, up to and possibly higher than its design temperature.

3.2.17 Infrared thermography

Equipment or method that detects infrared energy (i.e., heat) emitted from an object, converts it to temperature, and displays an image of temperature distribution.

3.2.18 Interlock

Device or an arrangement of devices in which the operation of one part or one mechanism of the device or arrangement controls the operation of another part of another mechanism.

3.2.19 Interpass temperature

Highest temperature in the weld joint immediately prior to welding, or in the case of multiple pass welds, the highest temperature in the section of the previously deposited weld metal immediately before the next pass is started.

3.2.20 Mechanical integrity

Program of inspection and monitoring to prevent loss of containment.

3.2.21 Monitor

To sense and indicate a condition without initiating automatic corrective action.

3.2.22 Permissive

Condition that must be met before a piece of equipment can be operated or a step in a sequence can be completed. After the equipment is operated or sequence step is completed, the permissive is ignored.

3.2.23 Pressure boundary

Portion of a vessel, valve, or piping system that contains the pressure (e.g., shell, heads, nozzles).

3.2.24 Pressure swing adsorption (PSA)

Multiple fixed bed gas purification process that uses materials that selectively adsorb one or more gas species from a mixture. Regeneration of the adsorbent is accomplished with a pressure reduction or swing.

3.2.25 Process gas cooler

First heat exchanger downstream of the reformer furnace and cross header used to reduce the temperature of the syngas by heat exchange with a cooling medium.

3.2.26 Purge

Flow of air or an inert medium at a rate that will effectively remove any gaseous or suspended combustibles and replace them with the purging medium.

3.2.27 Radiant section

Portion of the furnace in which the heat is transferred to the tubes, primarily by radiation.

3.2.28 Residual stress

Stress remaining in a structure as a result of thermal or mechanical treatment, or both. Stress arises in fusion welding primarily because the weld metal contracts on cooling the solid to room temperature.

3.2.29 Root pass

First layer of a multi-layered weld.

3.2.30 Start-up

Series of steps to initiate process flows, increase process temperatures, and start production.

3.2.31 Shutdown

Series of steps to stop production, feed, and fuel flows in a safe and controlled manner.

3.2.32 Slide plate

Linear bearing that can be part of the expansion joints of high temperature horizontal ducts, piping, or structures. In each case, one plate is fixed and the other slides on top as expansion or contraction occurs.

3.2.33 Solution annealing (solution heat treatment)

Procedure to heat an alloy to a suitable temperature, hold at that temperature long enough to cause one or more constituents to enter into solid solution, and cool rapidly enough to hold the constituents in solution.

3.2.34 Steam reformer

Processing unit where steam is reacted with hydrocarbons over a catalyst at high temperatures to produce hydrogen and carbon oxides.

NOTE The reformer includes a furnace/radiant section and a convection section.

3.2.35 Transition piece

Physical component that transitions from one material to another (e.g., carbon steel to stainless steel) or from one size to another (e.g., reducer).

3.2.36 Weld

Localized coalescence of metals produced by heating the metals to suitable temperatures with or without the use of filler metal.

4 Description of syngas outlet systems

4.1 General description and overview

The syngas outlet header piping system is defined in this publication as beginning after the catalyst support grid (i.e., bottom of the catalyst tube) and ending at the inlet of the process gas cooler.

Typical components of syngas outlet header piping systems include:

- Outlet pigtail—connects the individual catalyst tube with the outlet collector. Depending on the collector and furnace design, outlet pigtails might have a straight tube shape or a flexible hairpin (i.e., soft-tail) shape;
- Outlet collector—collects the catalyst tubes (i.e., from one or two rows) via the tube outlet pigtails. Such collectors are designed as hot collector or cold collector systems, see Figure 1; and
- Cross header—collects the outlet collectors for reformer units with more than one tube row. The cross header is also called the transfer line and follows internal design principles similar to a cold collector.

A typical top fired reformer furnace is shown in Figure 1.