ENVIRONMENTAL GUIDELINES FOR PERMITTING HYDROGEN PLANTS PRODUCING LESS THAN 2 TONNES PER DAY

Doc 220/19

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Prepared by WG-5 Environment

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1 Introduction

The European Union *Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control)* [1][1] has the aim to minimise pollution in large industrial facilities.

All installations covered by Annex I of the Directive are required to obtain a permit from local authorities, without which operation is not authorized. Hydrogen production is covered in §4.2. *Production of inorganic chemicals* from Annex I of the Directive with no threshold applied.

Hydrogen plants used in, for example, fuelling applications are currently subject to the full requirements of the IED for permitting. These plants have a low environmental impact due to size and technology employed.

Over regulation of these plants is a barrier to the development of hydrogen as an energy carrier. Motivated by sustainability objectives, this will involve the small-scale distributed production of hydrogen from a variety of renewable sources, by electrolysis or reforming. On-site hydrogen production by such means is also expected to be required in relation to road vehicle refuelling.

2 Scope and purpose

2.1 Scope

Hydrogen production plants with capacity less than 2 tonnes per day, primarily those used for fuelling applications .

2.2 Purpose

This publication is on the environmental impacts and operational controls for these packaged hydrogen plants and is intended to be used as guidance for permitting these plants so that simpler permitting can be applied.

3 Definitions

3.1 Publications 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

Indicate 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.

[1] References are shown by bracketed numbers and are listed in order of appearance in the reference section.

4 Background

4.1 Generally Binding Rules

General Binding Rules (GBRs) are limit values or other conditions (defined in particular in environmental laws, regulations and ordinances) at sector level or wider, that are given with the intention to be used directly to set permit conditions. They provide direct conditions or minimum standards. GBRs are binding either to the authority or to the operator.

4.2 Permitting for hydrogen plants less than 2 tonnes per day

There is very limited environmental impact from small scale electrolysis and reformer technology, both of which are detailed in this document

Hydrogen production for installations for refuelling applications could be subject to a standard rules permit under the general binding rules provision of the IED. This document forms the basis of the generally binding rule or low impact permit.

4.3 Electrolysis process

In the electrolysis process, water is split by means of electrical energy to obtain hydrogen plus oxygen. In this process hydrogen is produced at the cathode with a purity of virtually 100%.

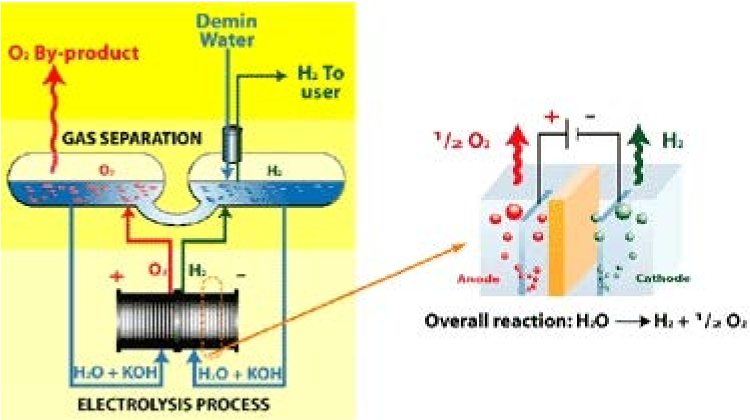

Figure 1 Electrolysis process simplified diagram

4.4 Steam Methane Reforming process (SMR)

The steam methane reforming process can be used industrially to produce hydrogen, carbon monoxide and their mixtures. Depending on the quantities of the desired products, the elements of the process can be adapted. In its simplest form, the steam methane reforming process for pure hydrogen production consists of four stages as shown in Figure 2: a desulphurization unit, a steam methane reformer, shift reactor(s), and finally pressure swing adsorption (PSA) [2].

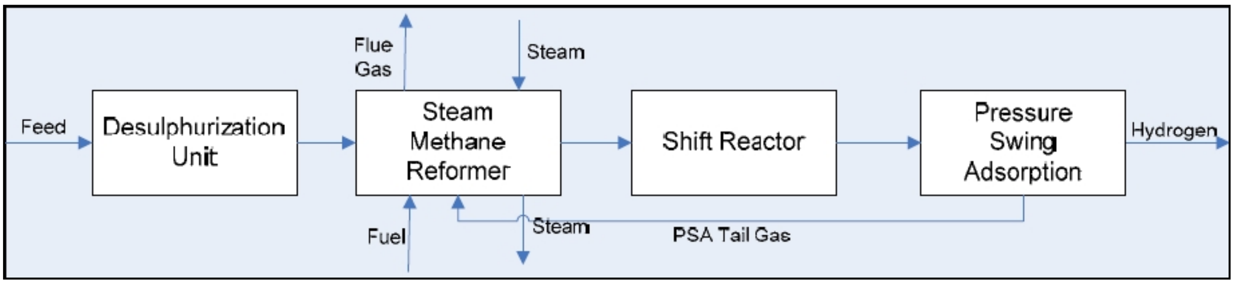

Figure 2 Hydrogen Production by Steam Methane Reforming

The process can use a light hydrocarbon feedstock such as natural gas or naphtha. As a first step, this feedstock is desulphurized because the catalysts used in the steam methane reformer and the shift reactor are extremely vulnerable to sulphur poisoning.

Next, the steam methane reformer provides the principle step of the process through the following general reaction:

$$C_nH_m + nH_2O \rightarrow nCO + (n + \tfrac{m}{2})H_2 \quad \Delta H < 0 \qquad (1)$$

This reaction is achieved by passing the steam/feedstock mixture through the reformer tubes filled with a catalyst (usually nickel-based). Applied to methane, which is the most widely used feed-stock, reaction (1) gives reaction (2):

$$CH_4 + H_2O \leftrightarrow CO + 3H_2 \quad \Delta H = -206 kJ/mol \text{ at } 15°C \qquad (2)$$

This reaction is highly endothermic and temperatures in the range of 750-1000°C are common. The heat necessary to compensate it is radiated to the reformer tubes by burners that may be mounted on the top, side or bottom walls of the reformer box. The burners may use as a fuel a combination of the feedstock, refinery fuel gas, and PSA tail gas.

In the third step, the process increases the hydrogen production by shifting the hydrogen / carbon monoxide product gas according to the following reaction:

$$CO + H_2O \leftrightarrow CO_2 + H_2 \quad \Delta H = +41.2 kJ/mol \text{ at } 15°C \qquad (3)$$

This time, the reaction is exothermic and occurs at a lower temperature in the range of 200-450°C in the presence of a catalyst (for example iron-chromium or copper alloys).

The last step separates the hydrogen from the product stream by pressure swing adsorption (PSA). The remaining PSA tail gas contains primarily carbon monoxide (CO), carbon dioxide (CO_2), hydrogen (H_2) and methane (CH_4) and is usually fed to the reformer's burners.

5 Environmental impacts of hydrogen production

Environmental impacts of hydrogen production and best practice to minimise the impacts are qualitatively described in EIGA Doc 122 *Environmental Impacts of Hydrogen Plants* [3].

The Best Available Techniques (BAT) for large hydrogen plants (>50000 Nm^3/day), under the IED, are described in EIGA Doc 155 *Best Available Techniques for Hydrogen Production by Steam Methane Reforming* [4].

Hydrogen plant producing less than 2 tonnes per day meets the technical criteria for UK low impact installations. There are additional criteria around location of the plant that needs to be checked

5.1 Energy consumption and optimisation

In the case of electrolysis, energy consumption is mainly electricity. The average range is 4.2 – 4.6 kWh/ Nm^3 hydrogen produced (from EIGA Doc 122 [4]).

Other hydrogen production processes involve a combustion process. Therefore, energy is brought by the fuel used in this combustion process. The typical energy consumption of a hydrogen production unit of 900 Nm3/h capacity is:

- Natural gas: 410 Nm^3/h → around 0.45 Nm^3 gas / Nm^3 hydrogen produced
- Electricity: 35 kW peak (from EIGA Position Paper PP 16 *Proposal to change the IPPC Directive with regards to hydrogen production* [5]).

These small plants are typically used in standalone applications such as vehicle fuelling where the opportunities for synergies with nearby processes are limited.

5.2 Air emissions

5.2.1 Electrolysis process

For the electrolysis process, air emissions consist only of oxygen, apart from the produced hydrogen.

Oxygen is one of the main components of air (around 21% oxygen in air) and is not classified as a pollutant.

Nevertheless, for safety reasons, it is recommended to collect the oxygen exhaust of the electrolyser and to vent it in safe area, away from any heat and ignition sources.

5.2.2 SMR processes

For the such processes, the involved combustion processes bring typical air emissions such as carbon dioxide, carbon monoxide, nitrogen oxides (NOx) and sulphur oxides (SOx).

Several techniques allow achieving air emission reduction. These techniques are not always compatible in a way as one can decrease the emission level of one pollutant but have an adverse effect on the emissions of another pollutant or on energy consumption:

- low excess air → NOx abatement;
- low-NOx burners → NOx abatement;
- oxygen/carbon monoxide monitoring → carbon monoxide (and unburned) abatement;
- air preheating → carbon dioxide abatement / NOx increase.

Low excess air

Steam methane reforming typically requires 5-10% excess air with the minimum value being limited by safety considerations.

Low NOx burners

Low-NOx burners are used to burn PSA tail gas and other gaseous fuels. This technology in steam reformers (SMR) for hydrogen production is considered to be a Best Available Technique.

The use of low-NOx burners as a process-integrated measure provides a significant reduction of NOx emissions compared with conventional burner designs based upon the same fuel. The application of gaseous fuel also minimises SO_2 emissions.

5.3 Liquid waste and waste water

Trade effluent consent for effluent (water) to foul drainage is typically required.

5.3.1 Electrolysis

As far as electrolysis is concerned, liquid waste is mainly related to the electrolytic solutions which have to be regenerated periodically. These are salty solutions with no specific hazardous products except sodium or potassium chloride diluted in water.

When using PEM (Polymer Electrolyte Membrane) electrolysis, only pure water is used, and there are no hazardous products from this, apart from the concentration of tap water that is rejected to create extremely pure water used in the electrolysis process. Reverse Osmosis (RO) treatment will concentrate pollutants already present in tap water, but should not add other pollutants to this.

5.3.2 SMR

For an SMR-based hydrogen production unit, the following types of liquid effluent streams may have to be considered:

- Demineralized water production unit effluents: these are salty diluted water solution.
- Boiler blowdown: method used to divert to soluble contaminants accumulated in the boiler water to avoid scaling and corrosion.
- Cooling water blowdown: When a semi-open recirculating system is used to cool water, this blowdown is required to balance corrosion, scale, and bio-fouling.
- Process condensates from gas cooling: these are generally collected together with the boiler blowdown.

Apart from those process-specific liquid effluents, as with many other industrial processes, hydrogen production has also to dispose of:

- rain/Surface water;
- oily water from base plates of pumps and machinery .

5.4 Solid waste

Hydrogen production generally has little potential for waste generation. To meet legal obligations and requirements it is necessary to define the categorization and type of waste together with the requirements for waste storage, handling, transfer and disposal in accordance with European Waste Catalogue Code and Labelling.

Appropriate waste management should be applied, by selecting the highest practicable option from the following waste hierarchy:

- Prevention and minimization of waste at source.
- Maximum recycling and reuse of materials and energy.
- Safe disposal of waste that cannot be reused or recycled in the following order of options:
  - physical, chemical or biological treatment;
  - incineration;
  - landfill.

Waste from a typical small sized hydrogen production unit mainly consists of small quantities of nickel and zinc catalyst which are replaced periodically and which is sent for recycling; and purification absorbent or activated carbon. Care must be taken in handling catalysts as some can be pyrophoric.

Main waste treatment possibilities are:

- Recycling / regeneration of catalysts and absorbents.
- Recovery as raw material feedstock in production of road aggregate or cement or as raw material feedstock in production of chemicals is sometime possible.
- Disposal to landfill when no better solution is available (technically and/or economically).
- Catalysts to be sent for recycling or recovery.

5.5 Noise

Continuous contributors to the noise profile of any hydrogen plants when in operation include process equipment such as compressors, if it is needed to compress the produced hydrogen above atmospheric pressure to ensure its delivery to customers; and the PSA unit, which is operated through continuous cycles of compression and expansion of gases. Non-continuous sources include start up and shut down noise, alarm testing and venting or gas flaring.

There are several well-established techniques that should be evaluated to reduce the potential for noise nuisance from these sources. Reference should be made to EIGA Doc 85 *Noise Management for the Industrial Gases Industry* [6] for a suitable list of techniques for consideration.

Noise issues will be subject to local authority planning control.

5.6 Inventory

Usually these sites have low hydrogen inventory but the inventory of hydrogen will require permission if >2 tonnes or as specified in local regulation.

5.7 Location and spill containment and accident prevention

- Build near the end customer to reduce transportation impacts and need for hydrogen storage (risk reduction).

- Locate on concrete/contained area for spill prevention.
- EIGA documents provide guidance on other considerations:
  - Safety distances, EIGA Doc 75 *Determination of Safety Distances* [7].
  - Gaseous hydrogen stations, EIGA Doc 15 *Gaseous hydrogen stations* [8].
  - Hydrogen storage – for back up or for use, EIGA Doc 171 *Storage of Hydrogen in Systems Located Underground* [9].

5.8 Management and operational control

These plants are operated remotely with a high degree of automation with remote monitoring/ remote control and operation/emergency shutdown capability.

5.9 Decommissioning/ reuse/relocation

These plants are modular and designed to be easy to relocate or to be taken away for reuse/ recycle.

6 References

Unless otherwise stated the latest edition shall apply.

[1] *Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control)*. European Commission. OJ L 334, 17.12.2010, p. 17–119

[2] Nazim Z. Muradov, *Production of Hydrogen from Hydrocarbons*, in *Hydrogen Fuel: Production, Transport and Storage*, R.B. Gupta, Editor. 2009, CRC Press: Boca Raton, FL. p. 33-101.

[3] EIGA Doc 122 *Environmental Impacts of Hydrogen Plants*. www.eiga.eu

[4] EIGA Doc 155 *Best Available Techniques for Hydrogen Production by Steam Methane Reforming.* www.eiga.eu

[5] EIGA Position Paper PP 16 *Proposal to change the IPPC Directive with regards to hydrogen production*. www.eiga.eu

[6] EIGA Doc 85 *Noise Management for the Industrial Gases Industry*. www.eiga.eu

[7] EIGA Doc 75 *Determination of Safety Distances.* www.eiga.eu

[8] EIGA Doc 15 *Gaseous hydrogen stations*. www.eiga.eu

[9] EIGA Doc 171 *Storage of Hydrogen in Systems Located Underground.* www.eiga.eu

7 Other References

Advanced Reforming Technologies for Synthesis Gas Production. Sandra Winter Madsen, et al. International Symposium on Large Chemical Plants. 1998. Antwerp, Belgium.

Best Available Techniques (BAT) Reference Document for the Refining of Mineral Oil and Gas Industrial Emissions Directive 2010/75/EU Integrated Pollution Prevention and control. 2015. European Integrated Pollution Prevention and Control Bureau (EIPPCB). EUR 2710EN. http://eippcb.jrc.ec.europa.eu/reference/

Appendix 1 - Environmental Impacts

Impact	Electrolysis	Reformer technology	Low impact Criteria (https://www.gov.uk/guidance/a1-installations-environmental-permits)
Air emissions	Oxygen to atmosphere (harmless)	Combustion emissions <1 tonne per hour < 100 kg/ year of NOx	Do not have to use equipment to reduce or remove emissions before they're released into the outside environment
Water emissions effluent	To treatment plant or sewer Limited suspended solids and salts form water purifier	To treatment plant or sewer ph 6-12 blow down of suspended solids	< 50 cubic metres per day of waste water
Water emissions groundwater	None	None	No emissions to groundwater
Water emissions run off	No contaminated run off - Containment in place	No contaminated run off - Containment in place	Containment measures to prevent emissions escaping to surface water, sewer or land, which are maintained at all times
Hazardous waste		Catalyst change once every 3-5 years	Produce more than 1 tonne of waste or 10kg of hazardous waste per day, averaged over a year, with not more than 20 tonnes of waste or 200kg of hazardous waste being released in any one day
Energy	<3 MW	<3 MW	Consume energy at a rate greater than 3 megawatts (MW) or, if the installation uses a combined heat and power installation to supply any internal process heat, 10MW (through both imported electricity and by burning fuel on site)
Noise and Odour	Low noise and odour potential	Low noise and odour potential	Only a low risk of causing offence due to noise and odour - you cannot be a low impact installation if noise and odour are noticeable outside the boundary of your site