BRITISH COMPRESSED GASES ASSOCIATION
Registered office: 4a Mallard Way, Pride Park, Derby, UK. DE24 8GX
Company Number: 71798, England
www.bcga.co.uk

POSITION PAPER 2

RECOMMENDATION FOR ENVIRONMENTAL PERMITTING TO EXEMPT HYDROGEN PLANTS PRODUCING UP TO 2 TONNES PER DAY

Background

The *Environmental Permitting (England and Wales) Regulations* (EPR) [1] provide a consolidated system of environmental permitting in England and Wales. A permit allows you to carry out various activities which may have an impact on the environment and human health.

All installations covered by the EPR [1] are required to obtain a permit from Local Authorities, without which operation is not authorized. Hydrogen production is covered in the EPR [1] Chapter 4.2, Part A(1), "*Inorganic chemicals*" but there is no threshold applied.

Hydrogen is being developed as an energy carrier, motivated by sustainability objectives with proven benefits for the environment and in particular emissions. Its use as a fuel is being promoted by both UK Government and through the European Union. This would typically involve the small scale distributed production of hydrogen from a variety of renewable sources, by electrolysis or reforming. In particular, there are increasing numbers of gas fuelled vehicles, such as hydrogen fuel cell electric vehicles, and the infrastructure necessary to fuel these vehicles is being developed and installed at many sites across the UK.

In compliance with the EPR [1] hydrogen plants used in, for example, vehicle fuelling applications, are currently subject to the full requirements of the EPR [1] for permitting. However, these plants have a low environmental impact due to their size and the sophisticated modern technology employed. Over-regulation of these plants is seen as a barrier to the development and introduction of this technology.

The scope of this document is hydrogen production plants with a capacity of ≤ 2 tonnes per day, excluding processes having hydrogen generated as a by-product, such as those used for the production of chlorine or carbon monoxide. These remain covered by the EPR [1] under the existing classification of the primary product.

Annex 1 of this document provides information on the environmental impacts and operational controls for packaged hydrogen plants and is intended to be used as guidance to determine permitting guidelines so effective permitting can be applied by both Regulators and Industry.

Reference

1. SI 2016 No 1154. Environmental Permitting (England and Wales) Regulations 2016. (as amended).

ANNEX 1

ENVIRONMENTAL IMPACTS AND OPERATIONAL CONTROLS FOR PACKAGED HYDROGEN PLANTS

1. DEFINITIONS

Generally binding rules.
General binding rules 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. General binding rules are binding either to the authority or to the operator.

More information available from: http://iris-test.eea.europa.eu/ippc/

2. PERMITTING FOR HYDROGEN PLANTS PRODUCING LESS THAN 2 TONNES PER DAY

There is very limited environmental impact to either small scale electrolysis or reformer technology, refer to Section 3.

Hydrogen production on an installation for small scale production applications, such as vehicle fuelling, could be subject to a standard rules permit under the general binding rules provision of the EPR [1]. This document forms the basis of the generally binding rule or low impact permit.

3. PRODUCTION PROCESSES

There are two common production processes, electrolysis (refer to Section 3.1) and steam methane reforming (refer to Section 3.2).

3.1 Electrolysis process

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

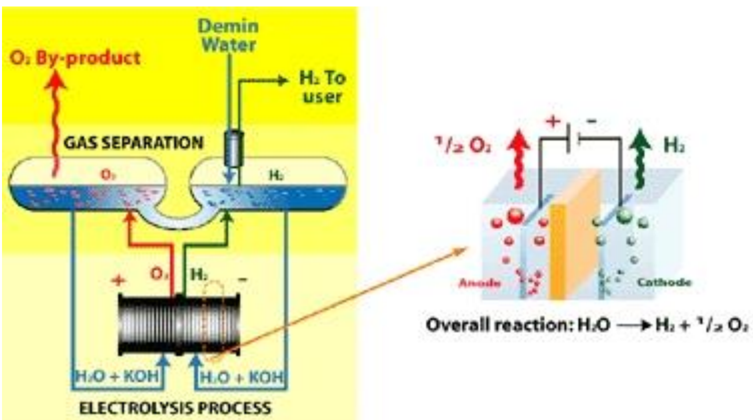

Figure 1: Electrolysis process simplified diagram

3.2 Steam methane reforming

The steam methane reforming (SMR) 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 [3].

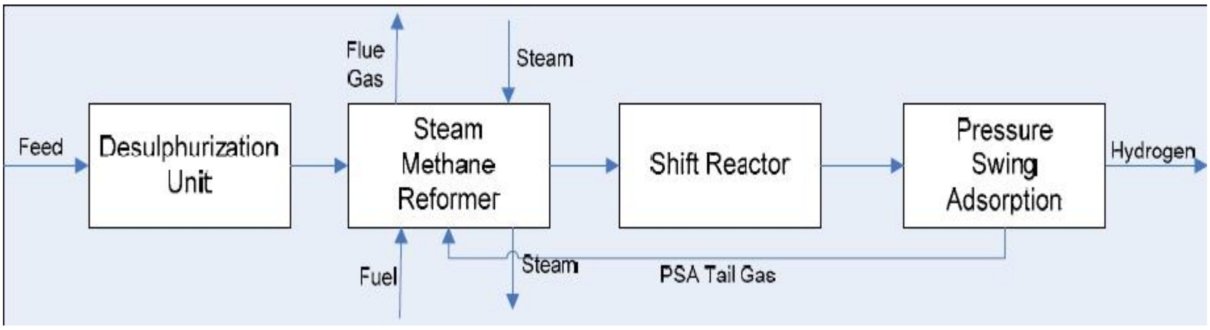

Figure 2: Hydrogen production by steam methane reforming

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:

$$C_nH_m + nH_2O \rightarrow nCO + \left(n + \frac{m}{2}\right)H_2 \quad \Delta H < 0$$ Equation (1)

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

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

This reaction is highly endothermic and temperatures in the range of 750 to 1000 °C are required. These temperatures are generated in the reformer burners using a fuel combination of the feedstock, refinery fuel gas, and pressure swing adsorption 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:

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

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

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

4. ENVIRONMENTAL IMPACTS OF HYDROGEN PRODUCTION

Environmental impacts of hydrogen production and best practice to minimise the impact are qualitatively described in EIGA Document 122 [7], *Environmental impacts of hydrogen plants*.

The best available technique (BAT) for large hydrogen plants (>50,000 Nm^3/day), under the EPR [1], is described in EIGA Document 155 [8], *Best available techniques for hydrogen production by steam methane reforming*.

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

BCGA proposes that Generally Binding Rules apply for these plants, refer to Appendix 1 for the proposed rules.

5. ENERGY CONSUMPTION AND OPTIMISATION

In the case of electrolysis, energy consumption is mainly electricity. The average range is 4.2 to 4.6 kWh / Nm^3 hydrogen produced (refer to EIGA Document 122 [7]).

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 Nm^3/h capacity: - Natural gas: 410 Nm^3/h → around 0.45 Nm^3 gas / Nm^3 hydrogen produced - Electricity: 35 kW peak.

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

6. AIR EMISSIONS

6.1 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 (approximately 21 % oxygen in air) and is not classified as a pollutant.

Nevertheless, for safety reasons, it is recommend that the oxygen exhaust is vented under controlled conditions to a safe area, away from potential excessive heat and ignition sources.

6.2 Steam methane reforming process

For 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 a reduction in air emissions. These techniques are not always compatible, as one technique can decrease the emission level of one pollutant but have an adverse effect on the emissions of another pollutant or on energy consumption.

Techniques include:

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

- Low NOx burners → NOx abatement.
  Low NOx burners are used to burn pressure swing adsorption tail gas and other gaseous fuels. This technology in steam methane reformers 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 will also minimise sulphur dioxide (SO_2) emissions.

- Oxygen / carbon monoxide monitoring → Carbon monoxide (and unburned) abatement.

- Air preheating → Carbon dioxide abatement / NOx increase.

7. LIQUID WASTE AND WASTE WATER

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

Apart from process-specific liquid effluents, refer to Section 7.1 and 7.2, as with many other industrial processes, hydrogen production has to dispose of:

- Rain / surface water;

- Oily water from base plates of pumps and machinery.

7.1 Electrolysis

For electrolysis processes, 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 / potassium chloride diluted in water.

When using electrolysis membrane technologies, only pure water is used, and there are no hazardous products produced, apart from the concentration of tap water that is rejected to create extremely pure water used in the electrolysis process. Reverse osmosis treatment will concentrate pollutants already present in tap water, but should not add other pollutants to this.

7.2 Steam methane reforming

For a steam methane reformer 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 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.

8. 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 (European Waste Catalog Code and Labeling).

Appropriate waste management has to be applied, i.e. 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 of a typical small sized hydrogen production unit is mainly small quantities of nickel and zinc catalyst which is replaced periodically and which is sent for recycling, as well as absorbent and 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;

- Recycling or recovery of catalysts;

- 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).

9. NOISE

Continuous contributors to the noise profile of any hydrogen plants when in operation include:

- process equipment, such as compressors (if needed to compress the produced hydrogen above atmospheric pressure);

- the pressure swing adsorption 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;

- venting / gas flaring.

There are a number of well-established techniques that should be evaluated to reduce the potential for noise nuisance from these sources. Refer to EIGA Document 85 [6], *Noise management for the industrial gases industry*, for a suitable list of techniques for consideration.

Nosie issues will be subject to local authority planning control

10. INVENTORY

Usually these sites have a low hydrogen inventory, but if the hydrogen inventory is > 2 tonnes then the site will require permission under planning hazardous substance consent. Refer to *The Planning (Hazardous Substances) Regulations* [2].

11. LOCATION, SPILL-CONTAINMENT AND ACCIDENT PREVENTION

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

Location on concrete / contained for spill prevention for liquid and solid process materials.

Reference documents for consideration:

- EIGA Document 15 [4], *Gaseous hydrogen stations*.

- EIGA Document 75 [5], *Determination of safety distances*.

- BCGA CP 41 [10], *The design, construction, maintenance and operation of filling stations dispensing gaseous fuels.*

- BCGA CP 44 [11], *The storage of gas cylinders*.
- BCGA CP 46 [12], *The storage of cryogenic flammable fluids.*

12. MANAGEMENT AND OPERATIONAL CONTROL

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

13. DECOMMISSIONING, REUSE AND RELOCATION

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

14. REFERENCES

Document Number		Title
1.	SI 2016 No 1154	Environmental Permitting (England and Wales) Regulations 2016 (as amended).
2.	SI 2015 No. 627	The Planning (Hazardous Substances) Regulations 2015 (as amended).
3.	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.
4.	EIGA Document 15	Gaseous hydrogen stations.
5.	EIGA Document 75	Determination of safety distances.
6.	EIGA Document 85	Noise management for the industrial gases industry.
7.	EIGA Document 122	Environmental impacts of hydrogen plants.
8.	EIGA Document 155	Best available techniques for hydrogen production by steam methane reforming.
9.	EIGA Position Paper 16	Proposal to change the IPPC Directive with regards to hydrogen production.
10.	BCGA Code of Practice 41	The design, construction, maintenance and operation of filling stations dispensing gaseous fuels.

Document Number		Title
11.	BCGA Code of Practice 44	The storage of gas cylinders.
12.	BCGA Code of Practice 46	The storage of cryogenic flammable fluids.

Further information can be obtained from:

UK Legislation	www.legislation.gov.uk
European Industrial Gases Association (EIGA)	www.eiga.eu
British Compressed Gases Association (BCGA)	www.bcga.co.uk

ANNEX 1

APPENDIX 1
Sheet 1 of 2

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 to 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

APPENDIX 1
Sheet 2 of 2

Hazardous waste		Catalyst change once every 3 to 5 years	Produce more than 1 tonne of waste or 10 kg of hazardous waste per day, averaged over a year, with not more than 20 tonnes of waste or 200 kg 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, 10 MW (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 can’t be a low impact installation if noise and odour are noticeable outside the boundary of your site.

ANNEX 1

APPENDIX 2
Sheet 1 of 1

REGULATORY THRESHOLDS FOR HYDROGEN PRODUCTION

The current regulatory thresholds for hydrogen production are:

- Best available techniques reference documents (BREF) for large hydrogen plant covers production >10,000 Nm^3/hr
- European Union Emissions Trading Scheme (ETS) threshold >11,000 Nm^3/hour- 25 tonnes per day for a greenhouse gases permit.