Examining Design Factors for Safe and Effective Hydrogen Vents for Waste Packages – 9248

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ABSTRACT

The possibility of a nuclear renaissance, and the possibility of large scale new build to meet both the concerns of the environmental lobby and the economic imperatives created by the political hostage taking of unreliable fossil fuel markets throughout the world, coupled with the need to resolve issues still outstanding from a previous generation of wastes create the need for a widely accepted understanding of the needs for venting waste packages which are being prepared for term storage.

In the US the technologies to immobilising the legacy wastes are being developed, in the UK the NDA is gearing up to decommission a range of sites and throughout Europe facilities are being demolished and the wastes taken to term storage. In several cases, the waste containers require venting, both to allow the thermal relief of the container during climatic variation and to allow the venting of generated gases from radiolysis, decomposition and corrosion of the contents, including Hydrogen and Hydrocarbons.

The paper will examine the disparate demands of the market place, and propose strategies to rationalise the specification of filter breathers so that both producers and users have a common framework from which to determine their individual venting needs.

Examining the mutually exclusive demands of permeability (affecting both pressure differential and Hydrogen diffusion) and filtration efficiency, the paper will explore economic solutions in an attempt to provide a framework against which the large number of waste containers requiring venting in the future can have their vent filters designed to meet both the best possible combination of efficiency and permeability, as well as exploring the limits of knowledge of corrosion of the filter media and suggesting strategies to tackle the possibility of the filter media failing before the waste container, and the consequences of such an event.

INTRODUCTION

For many years the nuclear industry in general has been storing waste and product in specially designed containers, and the need to both allow the container to ‘breathe’ (which is to say, allow the safe movement of the air in and around the container to move in and out of the container as environmental conditions changed) and to allow the diffusion or removal of generated gases (typically Hydrogen in the short term and hydrocarbons on the longer term) was recognised.

There are famous cases of waste containers which have inflated like balloons for want of a venting arrangement. The lack of any venting in such containers also creates additional hazards once the compromised container is selected for re-packaging.

If gases are being moved in and out of waste containers, it is clear that it is essential to minimise any migration of activity (in the form of solid particulate) in the moving gas.

Work over many years in the USA, in Europe and in the UK has lead to a better understanding of role and the requirements of permeable barriers used in conjunction with hazardous and active waste packages.

Gas Diffusion

Waste containers in the USA, Europe and the UK are, in the main, protected by permeable barriers. Those permeable barriers are designed to provide either or both a defined degree of particulate removal and/or a defined ability to allow the diffusion of Hydrogen or other hazardous gases out of the package, keeping their content in the package below the lower explosion limit in air (~4% by volume for Hydrogen).
Much work has been conducted by several organisations to try to understand the mechanisms which generate Hydrogen (and other gases), the rates at which gases (primarily air) moves in and out of the packages as environmental conditions change and the transport properties of the particles most likely to be transported out of the packages by any migration of the gases within.
The long established values for HEPA filtration in the UK and the USA (and THE in France) may be used as a bench mark, and indeed the specification for the vents used for Tru bearing waste destined for WIPP determines that those filters should have a proven Hydrogen diffusion rate, a proven HEPA filtration efficiency and a proven flow/DP character.

In the UK, as the Government comes to terms with the decommissioning of the Magnox stations and, to some extent, Sellafield, the country's long experience in the many and varied vents and breathers it uses in it's many and varied package forms is being added to as the long term disposal needs of a very large volume of material are being identified.

For the sake of this paper, Hydrogen will be examined. The US has established a base value for the diffusion of Hydrogen across the vent section of waste packages destined for the WIPP site in New Mexico (although the filters themselves are used in various other applications also).

Fig. 1. Typical WIPP type ¾" filter vent bungs.

The units defined by this base value are Mols (H2)/second/Mol fraction. The units themselves illuminate the problem. The rate at which the Hydrogen can be diffused out of the package is a function of the partial pressure of Hydrogen within the package. The greater the partial pressure, the greater the diffusion rate, so a self limiting system, except that in order to establish a vent area sufficient to maintain the self-limiting system, the generation rate of the Hydrogen must first be accurately established. Whether the route of Hydrogen generation is corrosion or radiolysis, the same general argument – that the phenomenon is temporary – is true.

The economic consequence of this truth is that owner must make a value judgement as to the risk of allowing initial H2 content to exceed the safe limit in the short term for a capital benefit (which is to say use fewer/smaller filters), or to plan for the worst case and ensure that during peak H2 production, the package is protected. The difference in cost can be substantial. The author's own company is in discussion with a number of waste owners proposing very similar waste packages, but developing radically different vent solutions, from engineered gaps and single ¾" vent bungs to 500mm (20") dia. filter plates and large pleated cylinders.

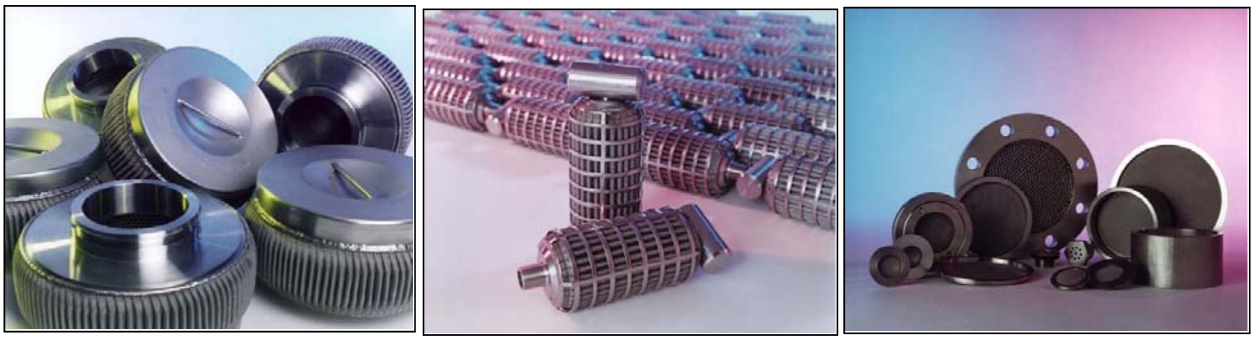

Fig. 2. Examples of various types for waste/storage filter breathers.

By establishing the initial production rate or Hydrogen, and then determining a risk analysis against the possibility of the H2 content rising above the safe limit, owners, in co-operation with filter designers, can mitigate both costs and risk in Hydrogen venting.

Below are curves from recent, on-going test work on Hydrogen diffusion, which clearly show that, for given conditions, Hydrogen diffusion is a function of flow area, but, unexpectedly, not a linear function. The test work continues to understand this apparent anomaly, but it serves to illustrate that in waste package venting, the situation is rarely as simple as it seems.

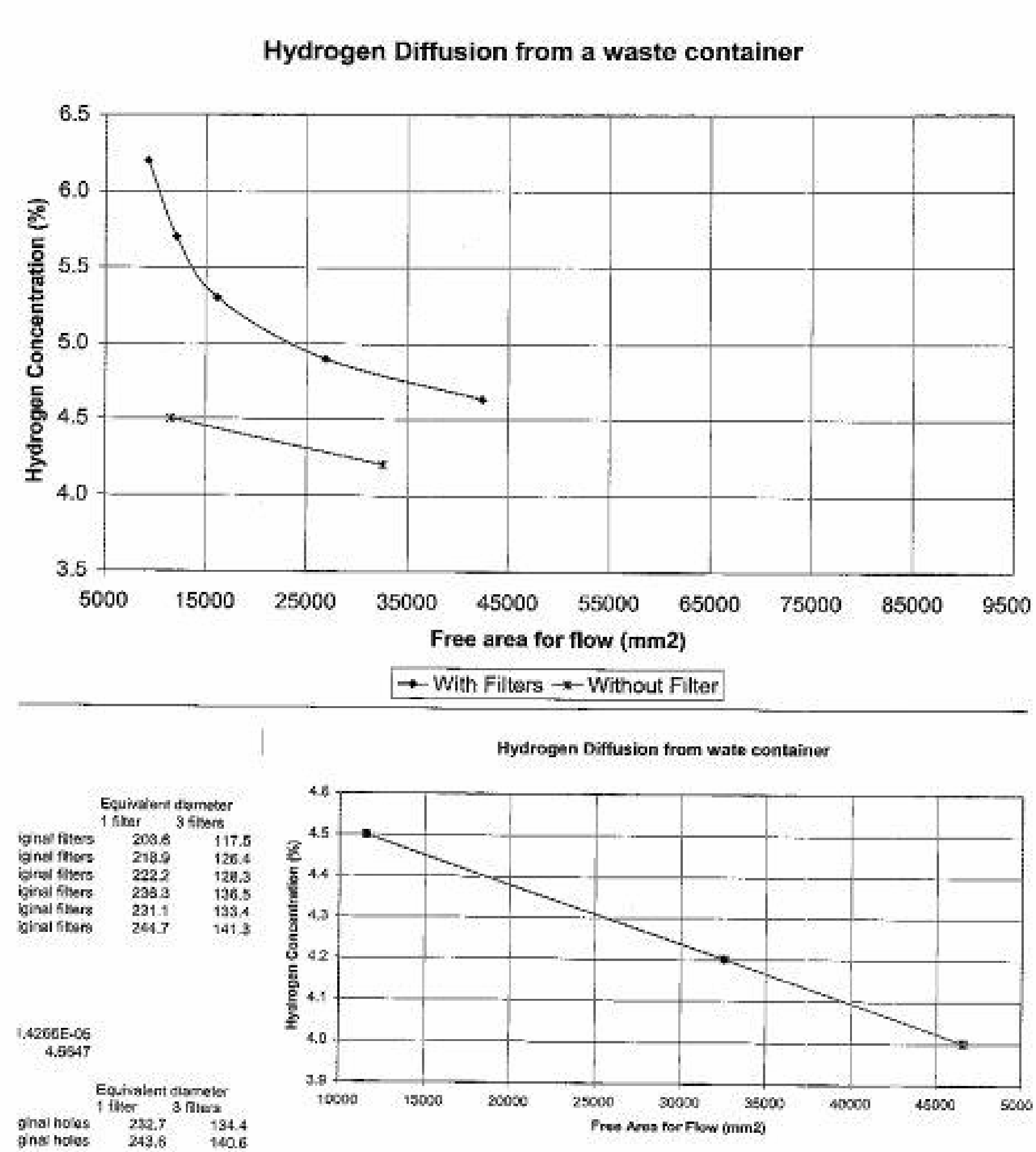

Fig. 3. Hydrogen diffusion from a waste container.

Particle Separation/Filtration Efficiency

The author's own company, in its work developing vents for various waste packaging systems, has been required to provide filters to a wide range of separation efficiencies, and within the company the question, 'Why?', is often asked.

Surely, waste, even low level waste, is dangerous. Surely two packages containing similar waste forms present similar risks and should be protected by similarly efficient filters. Surely, there is a requirement somewhere that says that the minimum DF for a given challenge must be provided by a hazardous package vent.

Apparently there is not. This is purely apocryphal, and the opinion of the author only, but my impression is that a lot of specifiers are using their own knowledge to suggest vent filter efficiencies, without fully understanding the implications of their specification, or the range of alternatives available.

It is now possible to define precisely to performance of various long life filter media, to the extent that the obverse, that the duty itself be fully defined, and the filter medium be made to fit the purpose must be possible.

Whether a Fluoriscine type test challenging at the most likely MPPS (typically used to validate THE type systems in France and elsewhere), or a more conventional DOP/ONDINA HEPA standard be proposed, surely the danger of leakage from a waste package is as important as the effluence from an HVAC system, the industry needs to come together and determine a common attitude to the risk particulate presents.

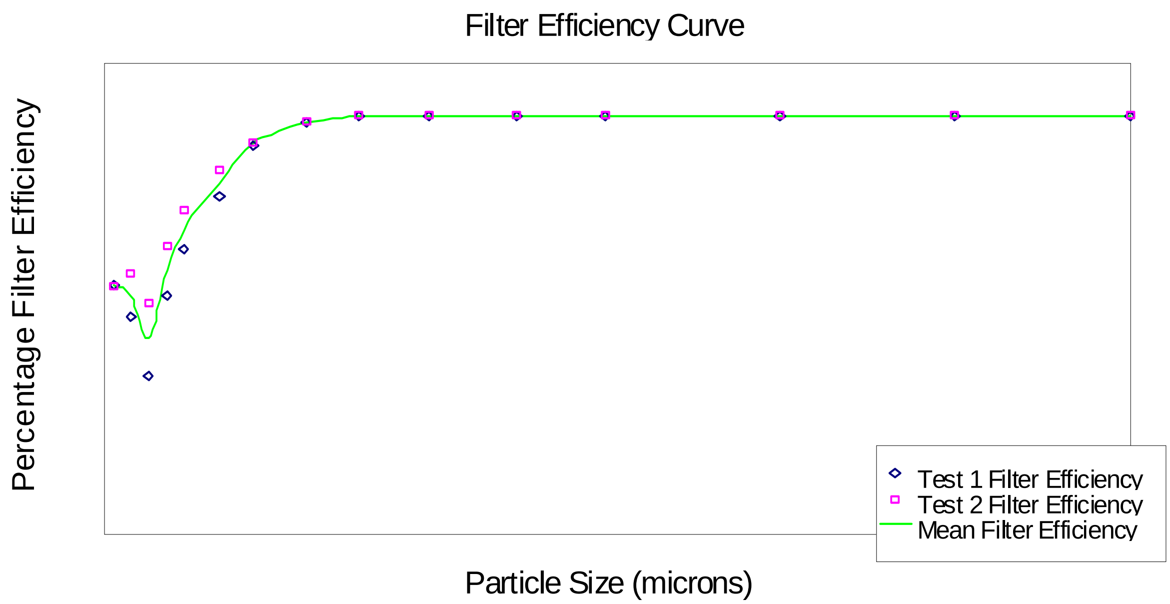

Fig. 4. Typical filter efficiency profile showing MPPS.

The author's own company is currently working on a project where the package owner is looking to coarser and coarser filter efficiency (so larger and numerically more particles will pass through the medium) in order to meet Hydrogen diffusion requirements within a limited space envelope. Is it safe to do so? Is Hydrogen really the main risk? Is their assessment of the Hydrogen generation rate accurate? Could the problem be ameliorated by operating process changes? More to the point – do these questions ever get asked, or if the venting of the package such an afterthought that the very real dangers of released particles is overshadowed, or even hidden, by fears about a theoretical probability of an unsafe Hydrogen environment?

Flow/Differential Pressure

It has become apparent that advantageous permeability (which is to say low DP), fine particle removal efficiency and high Hydrogen diffusivity are mutually exclusive parameters. A fine filter is a more impermeable filter. A more impermeable filter has a lower Hydrogen diffusivity. Good Hydrogen diffusivity demands high permeability.

Typically, in normal (non-diffusional) operation, flow through waste package filter breathers is very low, the consequence of environmental changes (temperature, atmospheric pressure etc). In this condition, pressure loss (which is a function of both flow and permeability/filtration efficiency) is meaningless as the flow through the filter breather is so low. It is when the generation of hazardous gas is at a maximum that flow/DP (permeability) becomes important as this is a primary affector of the diffusion rate out of the waste package and a primary controller of the safe limit being reached or not.

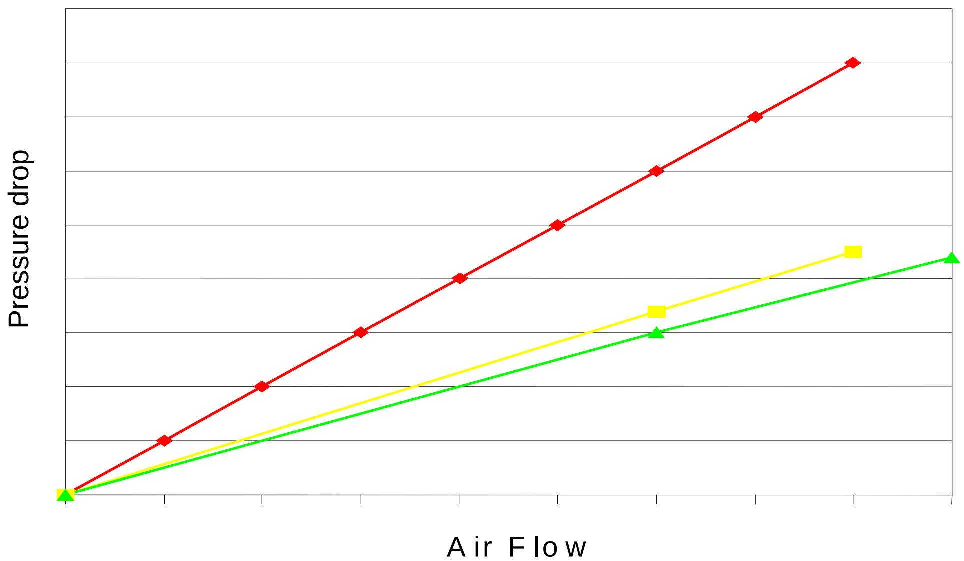

Fig. 5. Typical variation in permeability between media grades.

The curves show real data taken from tests done some time ago on various types of long life (metallic) filter media by AREVA for a project in France. The lines, made deliberately obscure for the purposes of this paper, describe various solutions to the same problem. The point being made is that the size/cost/diffusion rate/DP of a vent breather solution would be somewhat in proportion to the values described in the curves, that is to say, a variation of perhaps 2-fold between the best and worse cases.

CONCLUSION

This paper has tried to present, in non-technical, layman's language, the challenges facing filter designers charged with venting waste packages. Too often, venting of the packages starts as an afterthought and ends up being the critical path to final design.

By recognising a few simple truths earlier in the process simpler, more economic and less technically compromised solutions can be reached in a timely fashion.

Whilst the demands of size, Hydrogen diffusivity and particle removal efficiency may be mutually exclusive, enough is known about each that reliable and effective combinations of their limitations maybe achieved to ensure that packages are kept safe in terms of their contents remaining in place, they do not inflate over time and their Hydrogen (and other flammable gas) content is kept within acceptable limits.