CHALLENGES IN HYDROGEN RCS' STAKEHOLDER ENGAGEMENT IN SOUTH AFRICA

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ABSTRACT

There is a great deal of knowledge and experience on the safe handling of hydrogen, and the safe operation and management of hydrogen systems in South Africa. This knowledge and experience mostly sits within large gas supply companies and other large producers and consumers of hydrogen. However, there appears to be less experience, leading to a level of discomfort, within regulatory bodies such as provincial and municipal fire departments and the national standards association. This, compounded by a national policy of disallowing gas cylinders indoors, has resulted in delays, and indeed stalling, in the process of obtaining permission to operate laboratories such as those of the national hydrogen programme, HySA. In an effort to break this impasse, two workshops were organised by HySA. The first was held at the CSIR's facilities in Pretoria in October 2016. The second was held at the campus of the University of the Western Cape, in Cape Town, in May 2018. Four international experts and local experts in hydrogen regulations, codes, standards and safety addressed the 50-strong South African audiences via 5-way videoconferencing. This proved to be a very powerful tool to educate the audience, and in particular the Tshwane (Pretoria) and Western Cape Fire Departments, on the real issues, risks and safety of hydrogen. The paper describes the South African Hydrogen RCS landscape, the organisation and running of the workshops, and the outputs achieved.

NOMENCLATURE/ACRONYMS

BRHS	Biennial Report on Hydrogen Safety
CoC	Centre of competence
CSIR	Council for Scientific and Industrial Research
DST	Department of Science and Technology
dti	South African Department of Trade and Industry
ESKOM	South African Electricity Supply Commission
FC	Fuel Cell
FCV	Fuel Cell Vehicle
HRS	Hydrogen Refuelling Station(s)
HSE	Health and Safety Executive (UK)
HSL	Health and Safety Laboratory (UK)
HyRAM	Hydrogen Risk Assessment Models
HySA	Hydrogen South Africa (national hydrogen programme)
ICHS	International Conference on Hydrogen Safety
IEC	International Electrotechnical Commission
KIT	Karlsruhe Institute of Technology
KP	Key Programme

LOHC	Liquid Organic Hydrogen Carriers
Mintek	South African Minerals Technology science council
NWU	North West University
PEM	Proton Exchange Membrane
P&ID	Piping and Instrumentation diagram
PFD	Process Flow Diagram
PGMs	Platinum Group Metals
PNNL	Pacific Northwest National Laboratories
PV	Photovolataic
QRA	Quantitative Risk Assessment
RCS'	Regulations, Codes and Standards
RD&I	Research, Development and Implementation
RPW	Research Priority Workshops
RTS	Rand Technical Services
SABS	South African Bureau of Standards
SANS	South African National Standard
SHE	Safety, Health and the Environment
SWOT	Strengths, Weaknesses, Opportunities and Threats
TC	Technical Committee
TPRD	Thermal Pressure Relief Device
UCT	University of Cape Town
UWC	University of the Western Cape

1 INTRODUCTION

The South African hydrogen programme (HySA) is a relatively young programme. Its establishment followed studies undertaken by the CSIR [1], the CSIR and Industry [2], and the CSIR and the Department of Science and Technology (DST) which culminated in a national Hydrogen Fuel Cell workshop, or "Indaba" [3]. The primary purpose of the CSIR/DST study was to determine the potential impact on South Africa of "the Hydrogen Society". The conclusion of this study was that the major potential impact on South Africa of the Hydrogen Society is Platinum Group Metals (PGMs), and in particular Platinum itself. This is expanded on in section 2.0 below.

HySA was structured in line with other international programmes, and consists of three Centres of Competence.

- HySA Systems Integration and Technology Validation ("Systems", hosted by the University of the Western Cape) www.hysasystems.com

- HySA Catalysis, co-hosted by The University of Cape Town and Mintek, the national minerals technology science council www.hysacatalysis.uct.ac.za

- HySA Hydrogen Production, Storage and Distribution; Safety, Codes and Standards ("Infrastructure", co-hosted by North West University and the Council for Scientific and Industrial Research, CSIR) www.hysainfrastructure.org

There are five Key Programmes (KPs) under which Research, Development and Implementation

(RD&I) are undertaken. These are shown in Table 1.

Table 1. Key Programmes under HySA

Key Programme	Focus	Lead CoC
KP1	Combined Heat and Power	Systems
KP2	Portable Power systems	Catalysis
KP3	Fuel Cell Vehicles	Systems
KP4	Hydrogen Filling Stations	Infrastructure
KP5	Renewable Hydrogen Production	Infrastructure

The work on RCS' is undertaken in KP4, project I03. The goal of the RCS' work is to ensure that research is conducted in a safe manner, that barriers to the research (such as an inadequate or inappropriate Hydrogen regulatory framework) are addressed and that the products and processes developed are safe and that they can be readily adopted by local and international markets.

2 SOUTH AFRICAN PGM RESOURCES

Southern Africa (principally South Africa and to a lesser extent Zimbabwe) possesses 96% of the world's PGM reserves. In 2016, Southern Africa produced 77% of the world's platinum and 40% of the world's palladium. [4]

Table 2. World PGM production and resources, 2016

Region	Mine Production				PGM Reserves	
	Platinum		Palladium			
	Ounces	%	Ounces	%	Ounces	%
Southern Africa	133 000	77%	83 000	40%	64 200 000	96%
Russia	23 000	13%	82 000	39%	1 100 000	2%
North America	12 900	8%	36 200	17%	1 210 000	2%
Rest of World	3 400	2%	6 600	3%	-	-
World total	172 300		207 800		66 510 000	

Source: [4]

During the Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis of the national Hydrogen Society strategic review [3], PGMs were highlighted as both an opportunity and a threat.

The opportunity lies in the use of PGMs, especially Platinum itself, in Proton Exchange Membrane (PEM) Fuel Cells (FCs), in particular in Fuel Cell Vehicles (FCVs).

The threat is that currently a very large market for South African PGMs is for vehicle catalytic converters. If the world converts to FCVs, this market would be gone. In theory, the catalytic converter PGM market would be replaced by a market for PGMs for FCVs. However, much research is being conducted worldwide to remove or substantially reduce the PGM content in fuel cells. One of HySA's goals is to promote the continued (affordable/practical) use of PGMs in fuel cells.

3 SOUTH AFRICAN HYDROGEN RCS' ENVIRONMENT

Hydrogen is a commodity in South Africa, as it is across the world. It is produced, primarily through Steam Methane Reforming (SMR) and distributed by gas companies such as Air Products, Air Liquide and Afrox. The uses include hydrogenation in the food industry and reduction in the minerals industry (including in the PGM industry). The South African Electricity Supply

Commission (ESKOM) produces hydrogen via electrolysis to cool the bearings in steam turbines. The South African petrochemical company, Sasol, produces and uses a large amount of hydrogen in its coal to liquids process. By-product hydrogen is also produced in the local chlor-alkali industry, for example approximately 5 tonnes per day of hydrogen is produced at NCP Chlorchem in Chloorkop, Johannesburg.

These industries have in-house knowledge and guidelines regarding the production, storage and distribution of Hydrogen. A good example is ESKOM's Hydrogen Systems Standard [5]

However, at a national level, there appears to be less understanding of hydrogen, and a dearth of RCS' related to hydrogen, particularly in the field of FCVs. This is simply due to the fact that the Hydrogen Society has not yet noticeably impacted on Southern Africa – Hydrogen is an unknown element, and there has been no real need for hydrogen RCS', particularly in relation to FCVs and Hydrogen Refuelling Stations (HRS').

Initial investigations by the other co-host of HySA Infrastructure, NWU, on the use of hydrogen in mining applications, also showed a lack of South African standards and understanding of the properties of hydrogen for this application [6]. This study is to be developed further and will be presented at an appropriate forum.

Hydrogen has started to make an impact in Southern Africa in the field of back-up power for remote telecommunications towers. This is either by generation on-site via photovoltaic (PV) panels or, more frequently, by delivery of hydrogen cylinders. A list of known Fuel Cell installations in South Africa is given in Table 3.

Table 3. Southern African FC projects

Project Description	Fuel Cell type and size	Project Partners
Fuel Cell mini grid providing primary power to 34 homes	3X5kW PEM FCs	Anglo Platinum and Ballard Power systems, plus other local companies
Back-up power to ICT equipment in three rural schools	3X5kW PEM FCs	DST, Anglo Platinum, Clean Energy, Air Products
Back-up power to vaccine fridges in a Johannesburg clinic	5kW PEM FC	DST, Anglo Platinum, Clean Energy, Powertech System Integrators, Air Products, Gridline Construction, City of Johannesburg
Base-load power to Chamber of Mines building in Johannesburg	100kW PAFC powered by natural gas	Department of Trade and Industry (dti), Chamber of Mines, Egoli Gas, Mitochondria Energy, Powertech System Integrators
Provision of power to UWC's Nature Reserve building	2.5kW PEM FC	DST, HySA systems, Hot Platinum
Telecomm back-up power	300 X 5kW PEMFCs (Methanol on-site reforming)	Idatech, Inala Technology, Ballard
Telecomm back-up power	133 X 5kW PEMFCs	Powertech System Integrators
Primary power to rural school (Poelano High School)	2.5kW PEMFC, 48000NL H2 stored at 14 bar.	HySA Infrastructure, Systems and Catalysis (under the SA Department of Science and Tehnology)

Source: [7,8]

HySA Infrastructure at North West University have installed four solar PV to hydrogen systems. This was to demonstrate such systems and to generate hydrogen for additional uses, such as loading Liquid Organic Hydrogen Carriers (LOHCs). Information on these projects is given in Table 4.

Table 4. Solar to Hydrogen installations at HySA Infrastructure

Installed PV (kW)	Hydrogen Production (Kg/hr)	Hydrogen storage	
		Pressure (bar)	Mass (kg)
21	0.128	200	55
17	0.103	14	4.4
50	0.354	200 350	110 9.5
1.6	0.022	N/A	N/A

Source: [8]

This has catalysed the adoption of a number of South African National Standards (SANS) related to mostly stationary installations. This has been driven through the International Electrotechnical Commission (IEC) with the South African Bureau of Standards (SABS) (Technical Committee (TC) 105). These are shown in Table 5.

Table 5. Fuel Cell - related South African National Standards

SANS code	**Description**
SANS 62282-1	Fuel cell technologies Part 1: Terminology
SANS 62282-2	Fuel cell technologies Part 2: Fuel cell modules
SANS 62281-3-100	Fuel cell technologies Part 3-100: Stationary fuel cell power systems – Safety
SANS 62282-4-101	Fuel cell technologies - Part 4-101: Fuel cell power systems for propulsion other than road vehicles and auxiliary power units (APU) - Safety of electrically powered industrial trucks
SANS 62282-3-200	Fuel cell technologies Part 3-200: Stationary fuel cell power systems - Performance test methods
SANS 62282-3-201	Fuel cell technologies Part 3-201: Stationary fuel cell power systems - Performance test methods for small fuel cell power systems
SANS 62282-3-300	Fuel cell technologies - Part 3-300: Stationary fuel cell power systems - Installation
SANS 62282-5-1	Fuel cell technologies Part 5-1: Portable fuel cell power systems – Safety
SANS 62282-6-100	Fuel cell technologies Part 6-100: Micro fuel cell power systems – Safety
SANS 62282-6-200	Fuel cell technologies Part 6-300: Micro fuel cell power systems – Performance test methods

SANS 62282-6-300	Fuel cell technologies Part 6-300: Micro fuel cell power systems - Fuel cartridge interchangeability
SANS 62282-7-1	Fuel cell technologies Part 7-1: Single cell test methods for polymer electrolyte fuel cell (PEFC)
SANS 62282-7-2	Fuel cell technologies - Part 7-2: Test methods - Single cell and stack performance tests for solid oxide fuel cells (SOFC)

Source: [9]

As indicated previously, the majority of these standards are related to the stationary use of hydrogen, for primary and back-up power provision.

South Africa (the South African Bureau of Standards (SABS)) is not currently a member of ISO TC 197, Hydrogen Technologies. We have been tasked by SABS Technical Committee 22, Sub Committee 09 (Alternate fuelled vehicles) to assess if this would be of value to South Africa and, if so, propose the way forward.

The conversion of inner-city commuter vehicles from petrol to Compressed Natural Gas (CNG) has been on-going in South Africa for a number of years now. In order to facilitate this process ISO 15501-1 (Road vehicles - Compressed natural gas (CNG) - Part 1: Safety requirements) and ISO 15501-2 (Road vehicles - Compressed natural gas (CNG) – Part 2: Test methods) have been adopted/adapted as SANS 15501 – 1&2 respectively. The ISO hydrogen "equivalents", ISO 21266-1 and ISO 21266-2, have not yet been adopted/adapted as SANS'. HySA is generating a New Work Request with SABS to initiate this.

4 USE OF HYDROGEN IN LABORATORIES IN SOUTH AFRICA

Being chiefly interested in the development of hydrogen storage materials and systems, HySA Infrastructure at the CSIR needs to be able to measure the hydrogen uptake of the synthesised materials. A key piece of equipment to determine this is a PCT-Pro. A PCT-Pro measures gas (in our case hydrogen) sorption based on the Sievert's method, where a sample at known pressure and volume is connected to a reservoir of hydrogen at known pressure and volume through an isolation valve. HySA Infrastructure purchased a PCT-Pro from Setaram Instruments 4 years ago. However, the use of the equipment has proved problematic. This is largely due to a law and a standard.

Gas cylinders may not be stored indoors, including in laboratories, in South Africa. This is due to safety considerations for fire fighters/first responders. This originated in the province of Gauteng (incorporating Pretoria and Johannesburg) (Gauteng Provincial Gazette, 2016, [10]), and is being implemented in all other provinces. The CSIR has in the past received a specific warning for this. So, hydrogen cannot be used directly from the cylinder in laboratories.

A key South African National Standard (SANS) related to the reticulation of hydrogen is:

SANS 10260-2: Industrial gas pipelines: Distribution of Hydrogen at consumer sites.

SANS 10260-2 limits the hydrogen pressure in the line to 16 bar. Although this was drafted to regulate industrial gas pipelines, it by default also regulates reticulation lines in, for example, laboratories. SABS Technical Committee (TC) 1019 is reviewing this, and intends to increase the pressure to 50 bar. Even this pressure, however, would be insufficient to make proper use of the PCT-Pro.

In addition to the PCT-Pro, it is planned to operate a storage vessel charge and discharge test facility, an ortho/para hydrogen converter and a CO_2 (plus hydrogen) to methanol reactor. These will use hydrogen and other gases at similar pressures.

The PCT-Pro installation, gas storage and gas reticulation are shown in Figure 1.

Figure1. PCT-Pro, gas storage and gas reticulation

The intention, in order to properly utilise the equipment, is to reticulate the gas from the cylinder in the gas storage cage to the laboratory at 110 bar. Depending on cost, either the hydrogen cylinder will be replaced with a new cylinder when it falls to approximately 110 bar, or a compressor and receiver may be included at the gas enclosure to enable full utilisation of the cylinders.

The Tshwane (Pretoria) Fire Department was approached about three years ago to ascertain how high pressure hydrogen could be used in the laboratory. This meeting was positive, and the department was supportive of the planned installation provided the correct process was followed. However the outcome was inconclusive, it is believed due to a combination of the plans not being adequately concrete and there being insufficient experience with hydrogen at the department to enable a final decision to be made. Both the plans and the knowledge of hydrogen needed to be improved.

5 HYDROGEN SAFETY WORKSHOPS

It was from discussions about this situation with Nick Barilo of Pacific Northwest National Laboratory (PNNL) during ICHS2015, in Yokohama, that the idea of running educational workshops grew.

Using the HySafe network, three other contributors were identified, namely Thomas Jordan of the Karlsruhe Institute of Technology (KIT), Stuart Hawksworth of the UK Health and Safety Laboratory (HSL) and Brian Ehrhart (through Chris LaFleur) of SANDIA National Laboratories.

The first workshop was held in Pretoria (which is in the Tshwane Metropolitan area) on 31 October 2016. The primary target audience for this workshop was the Tshwane fire department. Local companies and experts in the field of hydrogen generation and reticulation were also invited.

The second workshop was held in the University of the Western Cape, Cape Town. Again, the local and regional (Western Cape) fire authorities were invited.

Rather than the expensive and time-consuming (for the presenters) option of travelling to South Africa, they presented by video-conference.

A large South African audience attended. Approximately half the attendees at the Pretoria workshop were from the Tshwane fire department, which was excellent to see. The additional target groups such as the CSIR’s Safety Health and the Environment (SHE) practitioners, electrolyser suppliers and large gas companies were also present.

In both workshops, an overview of HySA and the current situation with South African hydrogen RCS’ was first provided by members of HySA.

The three presentations from the experts in the Pretoria workshop outlined the international H2FC programs, and specifically the RCS' being developed, experiments being conducted and models being developed to enable a rational approach to the handling of hydrogen. There was one hour of presentations, followed by an hour of Q&A. The three presentations are summarised below.

First, Thomas Jordan, KIT, presented on the activities and goals of HySafe. (Presentation available on request)

An introduction to HySafe was given

- Origins, HySafe today, Vision and Mission, Members
- ICHS and Further Activities (Knowledge dissemination and research priorities

This was followed by a discussion on the development of the State-of-the-Art in Hydrogen research

- ICHS and Research Priority Workshops (RPW) (RPW report example [11])
- Continuous development and the Biennial Report on Hydrogen Safety (BRHS)

Then current research priorities were detailed, prioritised by category, with the following conclusions and recommendations.

- The need for user-friendly, validated, Quantitative Risk Assessment (QRA) models backed up with validated Reduced Modelling tools was highlighted.
- It was concluded that hydrogen behaviour in unintended releases indoors, and liquid and gaseous releases, was not yet fully understood.

Second, Stuart Hawksworth presented on the Activities and Facilities at the Health and Safety Laboratory (HSL), UK. (Presentation available on request)

An overview of HSL was given

- Originally set up as the Safety in Mines Research Establishment
- Became part of the Health and Safety Executive (HSE) after the Flixborough incident in 1974
- Vision: Workers to arrive home safe and healthy each day.

Recent work and projects were highlighted

- Controlled and uncontrolled releases
- Energy transition, and transport, including High Hydrogen (aviation)
- National projects such as Experimental Gas Network and Hybrid Energy Grid
- Guidance and educational programmes

Nick Barilo of PNNL concluded the Pretoria workshop with a presentation on Safety Resources for Hydrogen and Fuel Cell Applications. The content of this presentation was particularly relevant to the members of the audience from the Tshwane Fire Department, as it relayed real incidents and examples, and first responder training. The presentation is available on request

PNNL's collaborative hydrogen safety activities, training and resources were listed, collated under http://www.h2tools.org

- Hydrogen Safety Panel (http://www.h2tools.org/hsp)
- Best Practices (http://www.h2tools.org/bestpractices)
- Lessons and event records (http://www.h2tools.org/lessons)
- Introduction to hydrogen for code officials https://h2tools.org/training-materials
- First Responder Hydrogen Safety Training - Support the successful implementation of hydrogen and fuel cell technologies by providing technically accurate hydrogen safety and emergency response information to first responders (https://h2tools.org/firstresponder and http://h2tools.org/fr/nt)
- Classroom and hands-on training
- Support of national and state efforts
- QRAs, such as Hydrogen Risk Assessment Models (HyRAM)

An additional international presenter participated in the Cape Town workshop. Brian Ehrhart (on behalf of Chris LaFleur) of SANDIA National Laboratories presented an overview of the Hydrogen Risk Assessment Models (HyRAM) software, developed by Sandia National Laboratories (available at: http://hyram.sandia.gov/).

An overview of the challenges to a full quantitative risk assessment (QRA) were given, as well as the Sandia approach to address these challenges.

- Sandia coordinates activities in three areas: hydrogen behaviour research, risk research, and applications in safety codes and standards
- A quality QRA incorporates models and data from many different areas, it is non-trivial to validate and combine all of these models into a single framework.

An overview of the HyRAM software functionality, features, and organization was given.

- First-of-its-kind integration platform for state-of-the-art hydrogen safety models & data - built to put the R&D into the hands of industry safety experts
- Core functionality is QRA methodology, frequency & probability data for hydrogen component failures, and fast-running (reduced-order) models of hydrogen gas and flame behaviours
- Graphical user interface (GUI) for Windows enables widespread usage of the software

A demonstration of the main components of the HyRAM software was then given.

- The "Engineering Toolkit" mode demonstrated simple calculations of temperature, pressure, and density of hydrogen gas, calculations of the mass of hydrogen in a tank, and the flow rate of hydrogen leaving a tank, as well as an estimation of the chemical energy in a given mass of hydrogen.
- The "Physics Mode" demonstrated a 2-dimensional profile of an unignited jet plume, time-dependant profiles for accumulation of hydrogen in an enclosure, and an ignited jet flame temperature and heat flux calculation.
- The "QRA Mode" showed the different types of inputs, including leak frequency probability distributions, fuelling dispenser failure probabilities, and facility layout. These were combined

in an overall QRA calculation to produce overall risk metrics as well as importance measures of different leak scenarios.

The audience was very receptive to the information relayed. Additional information was provided from experts within the audience, notably from Air Products, Explolabs and Rand Technical Services (RTS), a local electrolyser vendor. The workshop went a long way to dispel the “fear of the unknown” around hydrogen.

A very practical question from a member of the fire department, which summed up the needs of many in the audience, was along the lines of “What do I need to know if I come upon a hydrogen incident such as a leak or a flame – what do I need to know about hydrogen, and what precautions and actions do I need to take?”

The answer was based on two scenarios. For a vehicle incident, a hydrogen vent from the Thermal Pressure Relief Device (TPRD) would most likely be audible, and therefore evident. Secondly, although the hydrogen flame itself is invisible, secondary fires and combustion products from gasoline, tyres etc. being entrained in the burning hydrogen jet would likely render it visible. An ignited jet should generally be left to burn, and it will self-extinguish in under 2 minutes, but the secondary fires should be dealt with using standard firefighting procedures. For stationary applications, such as HRS’, the safety interlocks such as hydrogen concentration or flame detectors should automatically shut off the hydrogen. The emergency stop button should also be pushed. Standard firefighting procedures should be used in the unlikely event of the storage tanks being exposed to fire. The value of thermal imaging cameras to assist in spotting hydrogen flames was highlighted. In the absence of such equipment, a suspected invisible hydrogen flame can be detected, with caution, by using a “feather duster”.

It was evident during the Q&A session, however, that some lack of understanding of the properties of hydrogen still existed. For example, a question was raised concerning the environmental impact of a hydrogen release. Answering this question aided in promoting the positive aspects of hydrogen.

The following feedback was received on the workshops:

- “I found the Hydrogen Safety workshop informative especially due to the insights shared by the renowned international hydrogen safety experts. The inclusion/participation of the first emergency responders (i.e fire fighters) in the workshop was useful especially during the Q&A time at the end of the presentations. I would even suggest organisation of follow-up seminars and extend the invitations to a much wider/general audience. Perhaps future events could be run as webinars, with a streaming link being shared beforehand to those interested, but not able to attend, so that they can participate at their convenience.”

- “Excellent overview and valuable to emergency responders. I think this should be a required module for all local authority emergency responders.”

- “The Hydrogen Safety Workshop was very informative. All the international experts were very knowledgeable and each tackled the subject from a different angle. Practical examples were illustrated which made the audience see that hydrogen is not "fictional" and could be handled safely with understanding of its safety issues, just like other gases. It was great that the experts gave in-depth presentations on the different aspects of hydrogen safety and brought it to the level of understanding of the diverse audience. As such the question and answer session that followed was interactive and rewarding. In addition, the audience was made aware of some key resources on hydrogen safety available on the Web. I believe many people left the workshop with a better understanding on hydrogen safety.”

- “I think that the workshop was a very good idea. To have international experts who have been working in the field being available to answer questions regarding the safety of hydrogen was really needed. My take was that the audience still had the negative impression of hydrogen and its dangers, and the experts helped answer those concerns through their years of experience. They highlighted the facilities available, and showed how hydrogen could be a safe carrier, if addressed, researched and handled correctly."

- "The workshop was very informative, though it would be better if more time was allocated to it. A good introduction to hydrogen safety as an energy carrier was given, and it was shown how we can develop knowledge and understanding by conducting research, training and education. It was very interesting to see that it can have an advantage on cars- the risks of vehicle fires might be reduced. (Disadvantage of petrol car, it ignite spontaneously, with fuming gases and hot flames.) As emergency personnel, we need basic training in regard of the standard. We need to know risks when it comes to ignition (personnel safety). Precautionary measures (Material Safety Data Sheet) should be taken and shown on vehicles using hydrogen."

- "More practical, "hands on" advice would be valuable." This was voiced particularly strongly in the Cape Town workshop.

The Tshwane fire department was again approached subsequent to the workshop, and a much more informed team was encountered. The path forward is clear:

- A process engineer will draw the Process Flow Diagram (PFD) and a Piping and Instrumentation Diagram (P&ID), including mechanical details of the equipment, piping, construction, etc. The likely hydrogen supplier will be included in this process. Specialised input will also be sought from a Pressure Systems Approved Inspection Authority (AIA).

- A facilitated haz-op study will be conducted to ensure that the design and safety features are complete, and the design will do everything it must do, safely. The services of a local haz-op/Risk Assessment company will be enlisted. The CSIR's SHE personnel will be involved in this.

- The final P&ID, and any equipment and installation drawings, then comprises 'the design'. The Pressure Systems AIA will certify the design.

- This design and approval will then be presented to the Tshwane Fire Department and the Building Control Officer.

6 CONCLUSIONS AND RECOMMENDATIONS

Due primarily to the lack of experience with hydrogen, and low public awareness of the energy carrier, the approach in South Africa to hydrogen appears to be "overly cautious". This was evident in the Tshwane Fire Department, but would also be a potential obstacle to the roll-out of FCVs. By utilising the experience of the international hydrogen RCS' community it was possible to provide factual information and to dispel the misconceptions and misunderstanding surrounding hydrogen. This has provided immediate benefits to HySA Infrastructure, in terms of enabling the use of high pressure hydrogen in our hydrogen storage laboratories.

It is recommended, based on HySA's perceptions and feedback gained from the audience, that follow-up workshops be run again in Gauteng, probably in the Johannesburg area, and that similar workshops are run at two other major metropolitan areas, such as Durban and Port Elizabeth.

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