CONTINUOUS CODES AND STANDARDS IMPROVEMENT (CCSI)

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ABSTRACT

As of 2014, the majority of the Codes and Standards required to initially deploy hydrogen technologies infrastructure in the US have been promulgated[1]. These codes and standards will be field tested through their application to actual hydrogen technologies projects. CCSI is process of identifying code issues that arise during project deployment and then develop codes solutions to these issues. These solutions would typically be proposed amendments to codes and standards. The process is continuous because of technology and the state of safety knowledge develops there will be a need for monitoring the application of codes and standards and improving them based on information gathered during their application. This paper will discuss code issues that have surfaced through hydrogen technologies infrastructure project deployment and potential code changes that would address these issues. The issues that this paper will address include:

1. Setback distances for bulk hydrogen storage
2. Code mandated hazard analyses
3. Sensor placement and communication
4. The use of approved equipment
5. System monitoring and maintenance requirements

NOMENCLATURE

ANSI- American National Standards Institute
CCSI- Continuous Code Improvement Process
CDP- Composite Data Product
CGA-Compressed Gas Association
CSA- Canadian Standards Association
DOE- US Department of Energy
FCEV- Fuel Cell Electric Vehicle
GTR-Global technical Regulation
IBC- International Building Code
ICC- International Code Council
IFC- International Fire Code
ISO- International Standardization Organization
MTBF- Mean Time Between Failure
NFPA- National Fire Protection Association
NREL- National Renewable Energy Laboratory
RCS- Regulations, Code and Standards
SAE- Society of Automotive Engineers
SDO- Standard Development Organization

1.0 INTRODUCTION

In the 1990s, a developing interest in hydrogen as a fuel for fuel cells brought on a new round of RCS work focused on developing requirements for stationary fuel cells, FCEVs, fuel cell powered industrial trucks, and infrastructure to support FCEVs[2]. The interest in fuel cells was driven by several factors including their higher efficiency compared to internal combustion engines and the absence of carbon emissions from the operation of the fuel cell.

This interest in these new applications for fuel cells in the 1990s translated into RCS project work in the early 2000s. One of the major issues that RCS needed to address was bringing hydrogen out of the industrial environment and into the retail environment. Hydrogen fueling stations for FCEVs would in most cases be publicly accessible. The general public would be conducting vehicle fueling operations. The new hydrogen technology applications required RCS development work in the following areas; retail fueling infrastructure for FCEVs, safety requirements for FCEVs for commercial vehicle sale, and stationary fuel cell siting and fuel storage requirements.

1.1 Baseline RCS

The RCS development efforts produced a baseline set of RCS. Key baseline documents are shown in Table 1. RCS for Hydrogen Technologies Deployment

Table 1. RCS for Hydrogen Technologies Deployment

Requirements for the design, installation, and operation of stationary fuel cells that would be addressed	
Documents	Subject Matter
NFPA 853 Standard for the Installation of Stationary Fuel Cell Power Systems	Addresses installation requirements for stationary fuel cell systems including hydrogen powered systems
NFPA 55 Compressed Gas and Cryogenic Fluids Code	Addresses requirements for storage of hydrogen in bulk and non-bulk configurations
CSA Fuel Cell FC1	Addresses requirements for the design and operation of fuel cells
Requirements for FCEVs that would be addressed in the following documents:	
Documents	Subject Matter
SAE J2578 Recommended Practice for General Fuel Cell Vehicle Safety	Addresses general safety issues
SAE J2579 Standard for Fuel Systems in Fuel Cell and Other Hydrogen Vehicles	Addresses fuel system integrity and performance
SAE J2719 Hydrogen Fuel Quality for Fuel Cell Vehicles	Addresses allowable contaminant levels for select materials
SAE J2601 Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles	Addresses fueling protocols setting allowable temperature and pressure parameters to achieve desired fill time
SAE J2600 Compressed Hydrogen Surface Vehicle Fueling Connection Devices	Addresses requirements for the fueling nozzle
GTR Global technical regulation (GTR) on hydrogen and fuel cell vehicles Established in the Global Registry on 27 June 2013	Addresses requirements for vehicle fuel system
SAE J2601/2 Fueling Protocol for Gaseous Hydrogen Powered Heavy Duty Vehicles	Addresses fueling protocols setting allowable temperature and pressure parameters to achieve desired fill time
SAE J2601/3 Fueling Protocol for Gaseous Hydrogen Powered Industrial Trucks	Addresses fueling protocols setting allowable temperature and pressure parameters to achieve desired fill time
Requirements for Infrastructure that would be addressed in the following documents:	
Documents	Subject Matter

IFC	Addresses basic hydrogen fueling system safety and flammable gas and cryogenic fluid storage
NFPA 55 Compressed Gases and Cryogenic Fluids Code	Addresses the safe storage, handling, and use of flammable gases including hydrogen
NFPA 2 Hydrogen Technologies Code	Addresses all aspects of the safe, design, use, and storage of hydrogen
ASME Boiler and Pressure Vessel Code , Section XIII	Addresses safe design of pressure vessels for hydrogen storage
ASME B31.12 Hydrogen Pipelines and Piping	Addresses the design, installation, and testing of hydrogen piping and pipelines
CGA standards for pressure relief and venting CGA S-1.1-1.3 *CGA H-5, Installation Standards for Bulk Hydrogen Supply Systems* *CGA G-5.5 hydrogen vent Systems*	Addresses safe design and use of hydrogen storage system components
CSA Standards for fueling system components	Addresses safe performance of hydrogen fueling system components

The development of these RCS created the basic requirements for the deployment of hydrogen technologies and is a major accomplishment in addressing safety concerns for the emerging technologies that employ hydrogen. These RCS are now in position to be tested by the deployment of hydrogen technology projects.

As hydrogen technology projects are deployed it is likely that issues with the RCS will surface. Examples of these issues are:

- Conflicting requirements
- Poorly worded requirements that can be addressed through rewriting the text for existing requirements
- Unforeseen gaps in RCS
- Technology developments that are not addressed in current RCS
- Field data that indicates that RCS requires revisions to

1.2 The ANSI Process for Codes sand Standards Revision

The American National Standards Institute (ANSI) sets rules for the creation and modification of Codes and Standards[3]. The majority of RCS developed in the US comply with ANSI requirements. Other standards development processes allow for public input. ISO Standards are developed through a process that allows for public input and review.[4] One of the key provisions of the ANSI rules is that codes and standards must be revised on a regular basis. The minimum number of years between codes and standards revisions is five years. This requirement ensures that new information is incorporated into the documents. This new information could be feedback from codes users who have identified needed clarifications in code language or changes in technology that require new sections.

Basic elements of the ANSI documentation process include:

- Consensus body established with defined interest categories for members
- Draft document developed according to developer's written procedures
- Draft document is announced by developer
- Draft document balloted to consensus body

- Comments resulting from public review and consensus body resolved to the extent possible
- Recirculation of unresolved comments and unresolved votes from consensus body members
- Written notification of right to appeal at the standard developer level sent to originators of unresolved comments
- Appeals process concluded
- Documentation of process submitted to ANSI
- Notification issued by ANSI of the right to appeal procedural issues in the development of the document
- Notification of the right to appeal ANSI decision to the ANSI Appeal Board

After ANSI documents are created they must be maintained according to the ANSI document maintenance process. Key elements of this process include the requirements that standards must be revised at least every five years, the revision process follows the document development process where public input is sought and conflicting positions resolved, and all actions are made available for public review and input.

NREL, with the support of the DOE, recognized the need to go beyond the minimum requirements of the ANSI process for code revision to actively incorporate lessons learned from project deployment. The CCSI process incorporates elements of the ANSI document maintenance process with addition of a proscribed effort to identify issues with documents that would be addressed in the revision process. The CCSI process is one which all ANSI compliant documents will, to a large extent, already follow through ANSI compliance.

2.0 NREL'S DEVELOPMENT AND APPLICATION OF THE CCSI PROCESS

2.1 The CCSI Process

The development of the baseline set of codes and standards for the deployment of hydrogen technologies has set the stage for the development and application of the CCSI process.

Figure 1. CCSI Process graphically illustrates the process of feeding deployment information back into the codes and standards development process to continuously improve codes and standards. When many of the codes and standards requirements were developed, there were very few hydrogen infrastructure facilities deployed. With an increase in the number of facilities, there will be a better understanding of the issues with safe operation. These issues are identified in the Field Monitoring portion of the CCSI process and fed back into the Research Testing portion of the process which produces data or other analysis to support codes and standards changes. These codes and standards changes are implemented in the codes and standards development portion of the process. The process forms a continuous loop that will address codes and standards issues and produce required codes and standards changes on an ongoing or continuous basis.

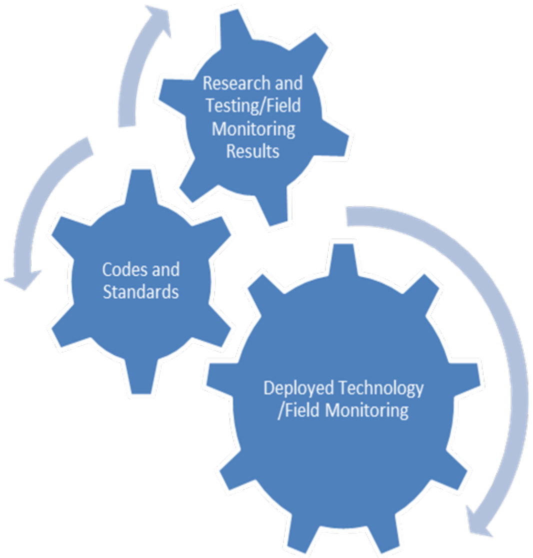

Figure 1. CCSI Process

NREL is well positioned to implement the CCSI process because of several NREL projects related to deployment of hydrogen technologies that allow NREL to collect information on issues associated with field deployment of hydrogen technologies. These projects include:

2.1.1 Technology Validation Project is an NREL project to collect and analyse data from hydrogen fueling stations and FCEVs Review NREL data, identify codes and standards issues and develop code proposals as needed.[5] NREL staff will perform biannual reviews of data collected on hydrogen fuelling stations to identify safety and performance issues that can be best addressed through codes and standards modifications. Examples of the results of this analysis would be if a compressor continues to fail in a particular manner there may be additional maintenance or inspection requirements that could be added to NFPA 2 to address the issue. Figure 2 Infrastructure Mean Time between Failure for the hydrogen fuelling stations participating in the NREL data collection effort provides information on the hydrogen fuelling station components performance.[6]

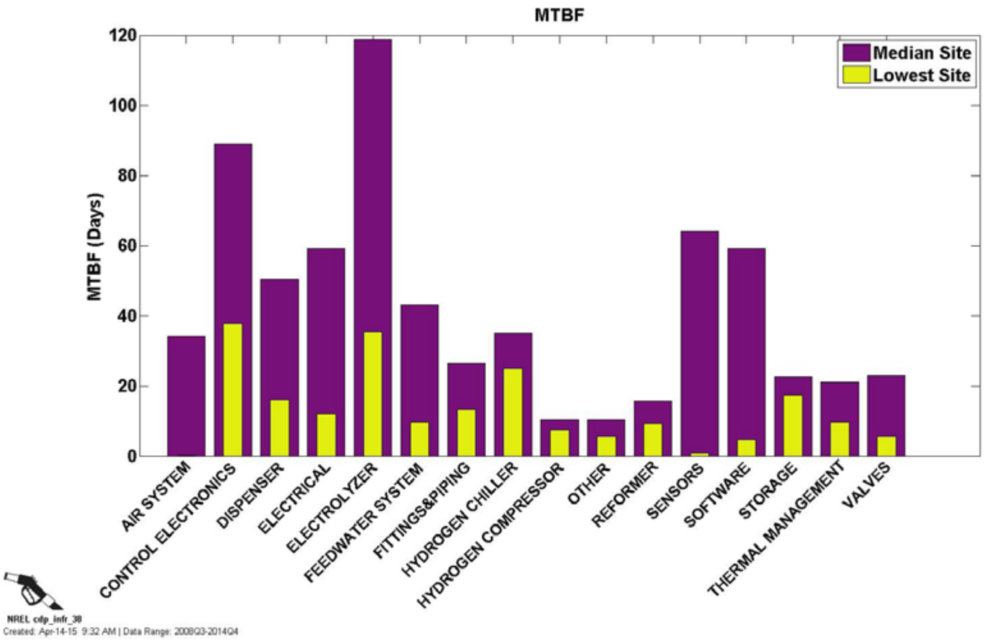

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Figure 2. Infrastructure Mean Time Between Failure

2.1.2 H2First is a joint NREL/Sandia National Laboratories project to conduct research and testing required to deploy required infrastructure for FVEVs.[7] H2First projects include developing a testing device for evaluating station fuelling performance, reviewing technologies for performing in-line fuel quality analysis, and evaluating fuel metering technology.

2.1.3 Identify issues from in-person training sessions and develop code proposals to address these issues. NREL has conducted over twenty in-person codes and standards training sessions focused code officials and project developers.[8] These training sessions have produced several suggestions for code changes based on efforts to comply with or enforce RCS. NREL conducts ongoing training for code officials, project developers, and other interested parties on codes and standards, permitting, and general hydrogen technology safety concerns. Often attendees at these sessions have valuable insights into code issues that are problematic when enforced. When drafting code text, committees cannot always foresee issues with compliance and enforcement. They may also not be aware how complying with one requirement affect compliance with other sections of a code.

Examples of issues that have been identified at these training sessions are:

- Placement of sensors in large facilities such as warehouses
- Actions to be taken at various hydrogen alarm levels (10% LFL, 25% LFL) such as when a facility should be evacuated rather than a portion of the facility
- The effect of barrier walls on system safety
- Code mandated hazard analysis found in NFPA 2. The level of detail and scope of these analyses is not well defined.
- The use of approved versus listed components in hydrogen fueling systems. Approved means approved by the enforcing authority. Listed means listed by a third party listing laboratory

2.2 CCSI Applied to Specific Projects

To help address the code issues identified in section 2.1.3, NREL is taking the following actions.

- Lead the NFPA Hydrogen Storage Task Group in their efforts to develop science based setback distances for hydrogen storage and a methodology for reducing these distances based on employing safety measures beyond the base code requirements. These safety measures will eventually be codified in the NFPA 55 and NFPA 2.
- Support CCSI task group that is part of the code development efforts organized by the Fuel Cell and Hydrogen Energy Association (FCHEA)
- Support validation testing for key component standards to help address the issue of lack of listed components for hydrogen fueling systems

2.2.1 Lead the NFPA Hydrogen Storage Task Group

The NFPA Hydrogen Storage Task group was formed in April 2014 and is comprised of member of both the NFPA Industrial and Medical Gas (NFPA 55) and the NFPA Hydrogen Technologies (NFPA 2) technical committees. The group has the objectives of developing science based setback distances for liquid hydrogen storage and a process for reducing setback distances based on safety measures. Siting bulk systems has been identified from deployment efforts as an area of the codes where modifications are needed.

The goal of this group is to have proposals submitted for these new setback distances and reduction methodology for the next edition of NFPA 55 which would also appear in the next edition of NFPA 2.

This work will employ *CGA P-28 Risk Management Plan Guidance Document for Bulk Liquid Hydrogen Systems 2009* to define the representative bulk liquefied hydrogen storage system and the hazard scenarios to be evaluated. The NREL Risk matrix REF was used to rank the scenarios and the higher risk scenarios will be modelled using the Sandia model for liquid hydrogen releases. An acceptable risk threshold will be established using criteria similar to those used to establish an acceptable risk threshold for bulk gaseous hydrogen.

2.2.2 Support and Manage CCSI task group

NREL formed a CCSI Task Group to address high level building and fire code issues and coordinate hydrogen technology requirements in the ICC Codes (IBC and IFC primarily) with the NFPA codes and standards. As deployment proceeds there will likely be construction issues that may need to be addressed in the IBC and IFC.

The CCSI Task Group is a small group, approximately ten individuals, with direct experience in code enforcement, plans review, or code writing. They will monitor changes in the ICC codes, NFPA codes, and propose changes, primarily to the ICC Codes and NFPA codes, as needed. This group will have unique expertise in drafting code proposals that will comply with the formats required by the ICC, NFPA, and other RCS development organizations. In the United States, ISO documents are generally not used in the built environment. The IBC and IFC, the most widely used building and fire codes in the US, contain no relevant hydrogen references to ISO documents.[9]

2.2.3 Support validation testing for key hydrogen component standards

NREL is working with SDOs to evaluate which hydrogen component standards require validation testing to determine whether the tests proscribed in the documents will produce data that are a good measure of whether the component will perform safely for the time interval set in the standard. These standards address hydrogen fueling and storage system components. The hydrogen nozzle and fueling hose are in close contact with the individual performing the vehicle fueling operation which makes them of particular concern. There are other component standards that are of concern but because the individual performing the fuelling operation is in direct contact with the fuelling nozzle and proximate to the fuelling hose they will likely be evaluated before other standards

2.2.4 Evaluate hydrogen fueling station maintenance and testing requirement

NREL will utilize their hydrogen fueling station to evaluate maintenance requirements. This evaluation would include records of time and costs required to meet code requirements, particularly the maintenance requirements found in Chapter 10 of NFPA 2. These requirements are shown in Table 2. NFPA 2 Maintenance and Inspection Requirements. NREL will evaluate the effectiveness of these requirements using the hydrogen station constructed at NREL in 2015. This information combined with information on leaks and other incidents could form the basis for code proposals to NFPA 2 and other documents.

This fueling system analysis would also include evaluating detector maintenance procedures as required under NFPA 10.3.1.19.1.2. The data collected through this process would provide information on sensor performance and potentially system modifications that would improve sensor performance. One of the parameters that would be monitored is the concentration level of hydrogen at which the sensor is acting. These modifications would include sensor placement and sensor type.

Table 2. NFPA 2 Maintenance and Inspection Requirements

Description	Citation in NFPA 2 2011 edition	Requirement text
General maintenance and recordkeeping requirements for hydrogen storage system	7.3.1.2.8	7.3.1.2.8 Maintenance. Maintenance shall be performed annually by a qualified representative of the equipment owner. The maintenance shall include inspection for: • physical damage, • leak tightness, • ground system integrity, • vent system operation, • equipment identification, • warning signs, • operator information and training records, • scheduled maintenance and retest records, • alarm operation, • and other safety-related features. Scheduled maintenance and retest activities shall be formally documented and records shall be maintained a minimum of 3 years. [55: 10.5.3]
Cathodic protection for containers	8.1.3.1.8.2	8.1.3.1.8.2 Inspection (A) Container systems equipped with cathodic protection shall be inspected for proper operation by a cathodic protection tester. (B) The cathodic protection tester shall be certified as being qualified by the National association of Corrosion Engineers.
Inspection and testing for out of service tanks	8.1.10.1.1	Containers out of service in excess of year shall be inspected and tested as required in 8.1.10.1.2
Hose testing	10.3.1.11.2	10.3.1.11.2.1 Hoses, nozzles, and breakaways shall be examined according to the manufacturers recommendations or at least monthly and shall be maintained in accordance with the

		manufacturer’s instructions. 10.3.1.1.2.2 Hoses shall be tested for leaks per manufacturer’s requirements and any leakage or surface cracks shall be reason for rejection and replacement. 10.3.1.11.2.3 Testing shall be carried out using an inert gas as the test medium.
Dispenser incident	10.3.1.14.5	10.3.1.14.5 Where an overpressure incident that results in operation of the overpressure protection system occurs, the dispenser pressure control system shall be examined and certified by a qualified technician prior to being returned to service.
Detector maintenance	10.3.1.19.1.2	10.3.1.19.1.2 The station owner or operator shall maintain a record of detector maintenance and calibration in good condition and accessible to the inspector.
Leak testing	10.3.1.10	Piping, tubing and hose, and hose assemblies shall be leak tested after assembly to prove them free from leaks at a pressure equal to at least the normal service pressure of that portion of the system.

3.0 CONCLUSIONS

The CCSI process has been implemented by NREL for approximately a year but the process has already shown the potential to produce valuable results. These developing results include the following.

- A plan, with substantial portions completed, to revise the setback distances for bulk liquefied hydrogen storage (that appears in NFPA 55 Code for Compressed Gases and Cryogenic Fluids) and produce a set of mitigation measures that could be employed to reduce setback distances. The methodology used to reduce setback distances should also be applicable bulk gaseous hydrogen storage systems. In current NFPA codes the only option available to reduce bulk gaseous hydrogen storage distances is the use of fire barriers. This plan developed and being implemented by the NFPA Hydrogen Storage Task Group will employ a risk informed approach to developing setback distances for bulk hydrogen storage and mitigation measures to reduce setback distances.

- Formation of the NREL supported CCSI Development team. The NREL supported CCSI code development team has identified a set of issues that will be addressed at their first meeting. An example of the issues that group will address are found in the 2013 NFPA analysis of gaps in NFPA 2 (NFPA Research Foundation 2013 report "Hydrogen Refueling Code Gap Assessment"[5]).

- The field performance data on hydrogen fueling system components has been evaluated and several projects are underway to better understand safety performance characteristics of these components. The data produced from these projects will likely be used to modify several of the hydrogen component standards.

- NREL has initiated a project to perform validation testing on several of the hydrogen fueling system component standards. This testing would be performed to determine whether the test required in the standard is a good evaluator of the hydrogen component safety performance.

- NREL will continue with implementation of the CCSI process. The process is similar to the ANSI process that most SDOs follow. It is a national expansion of the ANSI process that addresses the needs of the developing technologies.

4.0 ACKNOWLEDGMENTS

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3. The NREL Technology Validation project staff

4. The US Department of Energy’s Codes and Standards Technology Tech Team

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