

# Pressure Points

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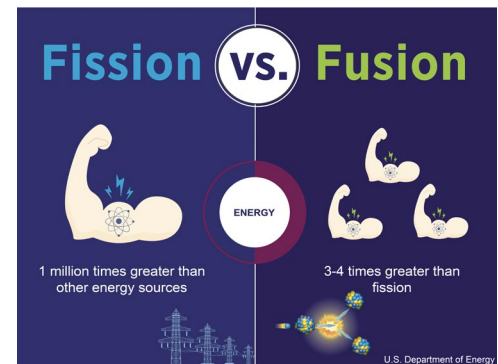
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## Nuclear Fusion – The Future of Energy?

*Author: Paul Coco, Senior Engineer*

Nuclear fusion has the potential to be a future source of energy because it offers several advantages over traditional nuclear fission and fossil fuels. Fusion is a process that generates energy by fusing together light elements, like hydrogen, to form heavier elements. This releases a large amount of energy in the form of heat and light, much like the process that powers the sun.



Fusion has several advantages as a potential energy source, including its safety, sustainability, and scalability. Unlike fission, fusion does not produce long-lived radioactive waste and may be safer than fission because a fusion reaction will naturally shut down if conditions become unstable. Furthermore, fusion reactions are likely fueled by additional elements such as hydrogen which makes it a nearly limitless energy source.

Nuclear fusion can be a promising technology for providing clean and renewable energy which involves combining two atomic nuclei to produce energy. This process enables engineers and scientists to create a virtually unlimited power from only a small initial input of fuel.

There are two types of fusion processes:

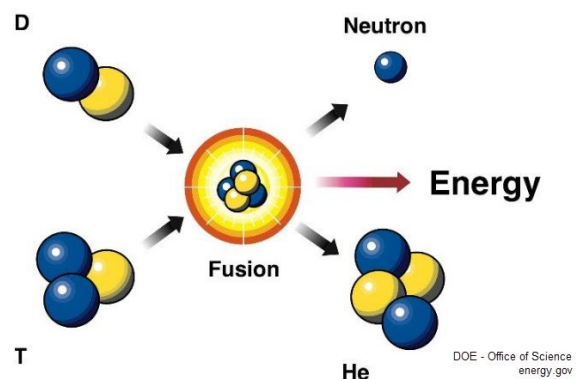
- The first, Magnetic Confinement Reactors (MCR), which contain plasma held in place using strong magnets. MCRs are designed to contain extremely hot plasma within a vessel known as a “tokamak”, which uses an intense magnetic field produced by superconducting magnets. Despite being studied for many years, tokamaks have yet to reach the stage where they can produce more energy than they consume, but they are considered one of the most promising technologies for achieving practical fusion power.
  - Construction of a 500-MW power generating fusion plant using this design, the International Thermonuclear Experimental Reactor (ITER), began in France in 2007. Completion is slated for 2025 based on the most recent, publicly released schedule. ITER will be the largest facility of its kind with ten times the plasma volume of any other tokamak operating today.
- The second, Inertial Confinement Reactors (ICR), which uses lasers or other high-energy machines to concentrate the fuel into a tiny space until it becomes hot enough for nuclear fusion reactions to begin. The targets are small, spherical pellets about the size of a pinhead, typically containing a mixture of about ten milligrams of deuterium  $^2\text{H}$  and tritium  $^3\text{H}$ . When the pellets reach high enough temperatures and pressures, the pellets undergo nuclear fusion reactions releasing substantial amounts of energy in the form of heat and light.
  - The world’s largest ICR facility is located at Lawrence Livermore National Laboratory in California, known as the National Ignition Facility (NIF). NIF has successfully achieved ignition, but not yet sustained burning plasma conditions necessary for net power gain from fusion reactions. On December 13, 2022, the NIF announced that it would achieve fusion ignition for the first time, by delivering 2.05 megajoules (MJ) of energy to the target, resulting in 3.15 MJ of fusion energy output. Thermo-nuclear weapons or hydrogen bombs are examples of inertial confinement fusion but use considerably higher amounts of fuel compared to a nuclear fission device.

### American Society of Mechanical Engineers (ASME) and Fusion Technology

ASME Boiler and Pressure Vessel Code (BPV) Division 4 is a draft standard that addresses fusion technology and is currently focused on magnetic confinement reactors. The code is based on the design of the ITER fusion experiment and is one of the only proposed standards for fusion technology, along with the French code, Regles de Conception et de Construction des Matériels Mécaniques des Îlots Nucléaires PWR (RCC-M). However, it has yet to be fully developed or updated to include other types of fusion reactors, such as Inertial Confinement Reactors. BPV Division 4 will be published in July of 2023.

Hydrogen is one fuel source that could potentially be used for commercial fusion power plants since it can be easily extracted from seawater using electrolysis or other means such as thermolysis or photolysis processes. The most common fuel used in fusion reactions today is deuterium-tritium (DT) because its reaction produces more neutrons than any other combination making it easier to convert into electricity via steam turbines or generators connected directly to the reactor core itself. Furthermore, DT can also be produced via neutron bombardment inside the reactor core itself making it a self-perpetuating fuel cycle unlike traditional fission reactors which require uranium fuel rods replaced periodically over time.

DT is a byproduct of nuclear reactors that is radioactive, making it unsuitable to meet the large energy demands of the world. One possible alternative to using DT is helium-3. He3 can be used as a fuel in nuclear fusion reactions and produces much less dangerous waste than traditional nuclear fission reactions. Scientists predict there are sizeable deposits of helium three on the moon’s surface.



Despite the advantages, nuclear fusion remains a challenging area of research and is still in the development stage. Significant scientific and technical hurdles must be overcome before fusion can become a viable source of energy for widespread use. Currently, there are several experimental fusion reactors being developed and tested around the world. There are more than seventy-five test facilities in operation and being constructed globally to create a sustained fusion reaction with a target goal of 2035-2040.

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<https://www.cnn.com/2022/12/12/politics/nuclear-fusion-energy-us-scientists-climate/index.html>  
[Home | Commonwealth Fusion Systems \(cfs.energy\)](#)

## Fueling the Hydrogen Economy: Hydrogen Production

*Author: Paul Coco, Senior Engineer*

Hydrogen (H<sub>2</sub>) has the potential to be a clean and renewable energy source that can help reduce dependence on fossil fuels. However, producing H<sub>2</sub> on a large scale and developing the infrastructure needed for a sustainable hydrogen economy are significant challenges that will need to be addressed in the coming decade. These efforts are crucial in the struggle against climate change and securing energy supply.

The Department of Energy (DOE) has identified several processes for producing H<sub>2</sub>, including steam methane reforming, electrolysis, and biomass gasification. A goal of the DOE, the Hydrogen Energy Earth Shot, is to develop technologies that can produce H<sub>2</sub> at a cost of \$2 per kilogram by 2025 and \$1 per kilogram by 2030 through net-zero-carbon pathways. This goal aims to reduce the cost of clean H<sub>2</sub> by 80% to \$1 per kilogram within a decade. The global demand for H<sub>2</sub> in 2021 was 94 million metric tons, with a projected demand of 179 million metric tons by 2030. (Sönnichsen, 2022) The DOE is working with industry leaders and investing in research and development to achieve this goal and to support the growing demand for H<sub>2</sub> as a clean energy source.

### Hydrogen Producing Processes

#### Steam-Methane Reforming (SMR)

SMR is the most common process for H<sub>2</sub> production worldwide. This process accounts for 76% of global production and 95% of H<sub>2</sub> production in the United States. (Office of Energy Efficiency & Renewable Energy, 2023) The process involves reacting methane with steam under high pressure and high temperature in the presence of a catalytic reactor, typically made of nickel. The reaction is exothermic and proceeds according to the following equation:



SMR is a well-established industrial process that has been in use for over a century. It is widely used to produce H<sub>2</sub> for industrial and energy applications and is considered one of the most efficient and cost-effective ways to produce H<sub>2</sub> from natural gas. Most of the H<sub>2</sub> produced in the U.S. is used for refining petroleum, treating metals, producing ammonia for fertilizers, and processing foods. SMR can provide a pathway to expand the current H<sub>2</sub> economy, but it does not meet net-zero-carbon objectives.

#### Carbon Capture and Sequestration (CCS)

CCS is a process that captures Carbon Dioxide (CO<sub>2</sub>) emissions from power plants and industrial facilities before they are released into the atmosphere. The captured CO<sub>2</sub> is then transported and stored underground in geological formations. Geological formations may include depleted oil and gas reservoirs, deep saline aquifers, and unmineable coal seams. CCS is considered a key technology for mitigating greenhouse gas emissions and addressing climate change. CCS can be costly and reduce plant efficiency by 10%-40%. (Finkenrath & Smith, 2012) Current CCS success rates are 85-90% with the goal of reaching 99-100% by 2030. (Moseman, 2021)

## Electrolysis

Electrolysis is a process to produce H<sub>2</sub> without emissions by using two electrodes to split an alkaline solution or water into H<sub>2</sub> and Oxygen (O). The main types of electrolyzers are alkaline, Polymer Electrolyte Membrane (PEM), and Solid Oxide Electrolysis cells. Today, global capacity to manufacture electrolyzers stands at 8 gigawatts a year but could exceed 60 gigawatts a year by 2030.

### Alkaline Electrolysis

Alkaline electrolysis is a process for producing H<sub>2</sub> gas through the electrolysis of water. It involves passing an electric current through an aqueous solution of Potassium Hydroxide (KOH) as an electrolyte. The process splits water molecules into H<sub>2</sub> and O gases, which are collected at the cathode and anode respectively.

Alkaline electrolysis has a long history as an industrial process, dating back to the early 20th century. During that time, large-scale plants (up to 165 MW) were built to meet the demand for H<sub>2</sub> in the ammonia industry. These plants were typically built between the 1920s and 1980s. However, with the emergence of cheap H<sub>2</sub> from steam methane reforming in the late 1980s, the production of small-scale plants (around 1 MW) dominated the electrolysis market. These smaller plants were more cost-effective and provided a reliable source of H<sub>2</sub> for various industrial applications. In recent years, there has been a shift toward larger plant scale, with an increasing number of plants being built at 10 MW, and few at 100 MW. Some industry reports have alkaline electrolyzers representing about 60% of the market share in 2022. (FMI, 2022)

### Polymer Electrolyte Membrane (PEM) Electrolyzer

In a PEM electrolyzer, the electrolyte is a solid specialty plastic material. The PEM electrolyzer uses a proton-conducting membrane as the electrolyte. It works by passing a direct current through the electrodes and the electrolyte, which causes the water molecules to dissociate into H<sub>2</sub> and O. The H<sub>2</sub> ions, or protons, are able to pass through the membrane, while the electrons are forced to travel through an external circuit, creating a current.

PEM electrolysis is considered to be a relatively new technology, and it is considered to be more efficient and faster than alkaline electrolysis. Also, when renewables such as wind and solar are used for electricity, PEMs can handle fluctuations in the availability due to changing weather conditions.

### Solid Oxide Electrolysis Cells

Solid Oxide Electrolysis Cells (SOECs) use a solid ceramic material as the electrolyte, typically made of zirconia or yttria-stabilized zirconia. The high operating temperature of SOECs allows for a higher efficiency of the electrolysis process. Additionally, the high operating temperatures allow for the integration of the electrolysis process with other high-temperature processes, such as power generation or chemical synthesis.

In SOECs, the high-temperature steam (above 500C) is passed over the anode side of the cell, where it is split into H<sub>2</sub> and O. The electrons from the external circuit combine with water at the cathode to form H<sub>2</sub> gas and negatively charged ions. O then passes through the solid ceramic membrane and reacts at the anode to form O gas and generate electrons for the external circuit.

SOECs have the potential to become much more efficient than PEM and alkaline electrolysis, with some studies suggesting that SOECs could reach efficiencies of up to 85%. However, SOECs are still a relatively new technology and are still under development.

## Biomass Gasification

H<sub>2</sub> can be produced from biomass gas through a process known as biomass gasification. Biomass gasification is the thermal conversion of biomass into a mixture of gases, primarily composed of carbon monoxide (CO) and H<sub>2</sub>, known as synthesis gas or syngas.

The process involves heating biomass in the absence of O<sub>2</sub>, which causes the organic matter to break down into its component gases. The resulting syngas can then be cleaned and processed to remove impurities, such as tars and acids, before being used to produce H<sub>2</sub>.

Biomass gasification can be done using a variety of feedstocks, including wood, crops, and agricultural waste. It is considered a sustainable and renewable energy source, as the biomass used in the process is a renewable resource.

## Looking to the Future

The H<sub>2</sub> economy is poised for significant growth in the coming years as governments, corporations, and consumers increasingly prioritize decarbonization efforts. With ongoing advancements in H<sub>2</sub> production, storage, and transportation technologies, H<sub>2</sub> is expected to play an increasingly important role in the transition to a low-carbon future. Some predictions suggest that the global H<sub>2</sub> market could be worth over \$150 billion by 2027, with significant growth in sectors like transportation, power generation, and industrial applications as a viable alternative to traditional fossil fuels. (Global Market Insights Inc., 2021) However, the widespread adoption of H<sub>2</sub> will depend on several factors, including the cost of production, the development of reliable storage and transportation methods, and government policies and incentives. The future of the H<sub>2</sub> economy could play a critical role in achieving a sustainable energy future and complementing renewables for integration in stable power grids.

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Paul joined HSB in January 2014. Paul is a graduate of the United States Naval Academy where he earned a Bachelor of Science degree in aeronautical engineering. Paul also holds a Master's degree of Engineering Management and a Master of Science degree in Mechanical Engineering. Paul served in the U.S. Navy from 2002 through 2010. During this time, one of his many responsibilities included, the role of Reactor Mechanical Division Officer and Training Officer where Paul was responsible for the safe operation of a nuclear power plant onboard a Nuclear Powered Aircraft Carrier. From 2007 through 2010, Paul joined the Mechanical Engineering Department at the U.S. Naval Academy where he taught Applied Engineering Thermodynamics for Naval Applications as a Military Professor.

After Military Service, Paul then joined the US Nuclear Regulatory Commission (NRC) as a Reactor Operations Engineer where he conducted detailed technical reviews of nuclear licenses in accordance with federal codes and standards and performed quality assurance inspections on domestic and international nuclear vendors for nuclear safety related components.

Within the HSB Codes and Standards group, Paul is responsible for providing code technical support to internal and external clients with a focus on nuclear construction to ASME Section III and the associated nuclear conformity assessment programs. He is responsible for the development, maintenance, and delivery of technical training related to nuclear construction, as well as supporting the HSB NQA Services Program. Paul is also responsible for the development of HSB's remote inspection program and is the technical lead on emerging renewable technologies. He holds a Professional Engineer License in the state of Maryland, National Board Endorsements as an AI and ANI, and is a member of various ASME Section III committees.



## Ask the engineer

### ASME Section VIII, Division 1

*Author: Sandy Babka, Sr. Design Manager*

#### Part 1

**Question:** Is it required by Section VIII, Division 1 of the ASME Code to consider static pressure due to contents when designing a vessel?

**Response:** Yes, this is a question that has been asked of the ASME Boiler and Pressure Vessel Code Committee several times in the past. Please review the previously published Interpretations on the subject matter: VIII-1-86-115, VIII-1-86-191, VIII-1-01-82, and VIII-1-17-02.

The weight of the contents is one of many loadings which must be considered when designing a vessel referenced in paragraph UG-22(b) of the ASME Code. Section VIII of the ASME Code does not explain to a designer how to consider the weight, however the Code does cause a pressure that needs to be part of the design pressure used to evaluate each component. You can find various calculators on the internet, but essentially the pressure depends on the height of the liquid level, specific gravity of the liquid (i.e., ratio of the liquid density to the density of fresh water), and the value of gravity (g).

Maximum allowable working pressure (MAWP) and design pressure are defined in Section VIII, Div. 1, Appendix 3 of the ASME Code. If we consider MAWP to be the pressure shown on the nameplate, then all of the components of the vessel could experience this pressure. The design pressure for each component is this MAWP plus any pressure due to the weight of the contents. For a vessel with a liquid or solid particulates in a slurry, this added pressure could be significant, even in a horizontal vessel. For example, if the MAWP is very close to the pressure rating of a B16.5 flange, then a flange at the top and one at the bottom could be different Classes just due to the weight of the contents during operation.

#### Part 2

**Question:** Is it required by Section VIII, Division 1 of the ASME Code to consider static pressure due to the water for a hydrostatic test when calculating minimum required thickness of a vessel?

**Response:** According to the second part of paragraph UG-22(b) in Section VIII, Division 1 of the ASME Code, the weight of contents under test conditions need to be considered. The inclusion of "under test conditions" often results in confusion whether or not to add the static pressure due to the weight of the water during a hydrostatic test if the vessel will not hold a liquid during operation (e.g., an air receiver).

Section VIII, Division 1, does not intend to make the designer use the static pressure of water, added to the nameplate Maximum Allowable Working Pressure (MAWP), when calculating minimum required thickness/maximum allowable working pressure of each part, just for a one-time hydrostatic test. The intent of UG-22(b) and UG-22(j) is to bring to the designer's attention the fact that, if the vessel is designed for contents that are lighter than water (e.g., gas, vapor, etc.) and it is hydrostatically tested, then the designer needs to ensure that this water weight will not damage the vessel. For example, for vertical vessels, they might be tested in the horizontal position or more temporary supports may be needed.

#### About the author

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Sandy joined HSB in 1993. He is a Registered Professional Engineer and holds a Bachelor of Science degree in Mechanical Engineering from Worcester Polytechnic Institute. He holds a National Board of Boiler & Pressure Vessel AI and IS Commission. Since joining HSB he has worked in the Pressure Equipment Technology Group, the Insurance Inspection Services Division as a Boiler and Machinery Inspector, and has been in the Codes & Standards group since 1998. Since 2008 he has been the Design Manager for design review activity involving pressure equipment exported to countries such as Australia, New Zealand, Malaysia, Singapore, Brazil, and India, as well as general Third Party for fee design reviews. In addition to this, he provides technical assistance for ASME Boiler and Pressure Vessel Non-Nuclear Codes as well as some International Standards and regulations.

Sandy is currently a member of the Committee on Pressure Vessels (BPV VIII), Subgroup on Design (BPV VIII), Subgroup on Heat Transfer Equipment (BPV VIII), Subgroup on Interpretations (BPV VIII), and Working Group on Plate Heat Exchangers (BPV VIII).

## ASME Section III, Division 5 Update

*Author: Paul Coco, Senior Engineer*

In January 2023, the U.S. Nuclear Reactor Commission (NRC) issued Regulatory Guide (RG) 1.87. The NRC's issuance of RG 1.87 is a significant development for the nuclear power industry, as it provides a clear regulatory endorsement for the use of the 2017 Edition of ASME Code Section III, Division 5, in the design, construction, testing, and quality assurance of mechanical systems and components for non-light water high temperature reactors, with exceptions and limitations.

In addition to the Division 5 endorsement, RG 1.87 endorses the use of certain values in the 2019 Edition of ASME Code, Section II, Part D and Mandatory Appendix HBB-I-14 of the 2019 Edition of the ASME Code, Section III, and Code Cases N-861, N-862, N-872, and N-898 related to ASME Code, Section III, Division 5.

HSB has worked closely with ASME on the issuance of Division 5 scope expansions. Many of our Authorized Nuclear Inspector Supervisors and Inspectors have been trained and designated to support Division 5 activities. Additionally, HSB recently completed the first and only training available for our clients on Division 5 and was also one of the first Authorized Inspection Agencies (AIA) to include Division 5 within their scope.

Since RG 1.87 has been endorsed, certificate holders need to be mindful of the additional considerations and requirements imposed to ensure they have a comprehensive program in place to meet the regulatory requirements.

For more information, visit us at [ASME Inspection Services | HSB \(munichre.com\)](https://www.hsb.com/ASME-Inspection-Services), email us at [GetInfo@HSB.com](mailto:GetInfo@HSB.com), or contact your Authorized Nuclear Inspector Supervisor for scope extension, meeting RG 1.87 requirements, and ASME Section III, Division 5 technical training.

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## Take note!

### Distinguished Engineer Award

The American Society of Mechanical Engineers (ASME) recognizes the outstanding achievements in mechanical and multidisciplinary engineering through its honors and awards programs celebrating individuals who have made important contributions in various engineering disciplines.

It is with great pleasure we announce HSB's very own Jay Vattappilly, Vice President Codes & Standards, as recipient of the Distinguished Engineer of the Year Award at the ASME Hartford Section: 37th Distinguished Engineer of the Year Awards Celebration in Hartford, Connecticut last month.

Jay is currently Codes & Standards (C&S) Vice President for HSB Global Inspection and Engineering Services overseeing the C&S group and all the services they are responsible for, including technical support, internal and external training, management of HSB knowledge databases, and global design review activity.



Jay presently holds a Professional Engineering license from Ontario, Canada, and National Board Commissions "AI", "IS" & "R" endorsement. He is a member of Subgroup on Design (BPV I), Committee on Power Boilers (BPV I) and member of Technical Oversight Management Committee (TOMC). He is also a member of the Subgroup on Design (BPV VIII), Subgroup on Toughness (BPV VIII), Special Committee on Interpretations (BPV VIII) and Subgroup on General Requirements & Piping (BPV I). Jay provides technical support on ASME Boiler and Pressure Vessel Code Sections I, IV, VIII & IX, and is HSB's subject matter expert on the Indian Boiler Regulations (IBR).

### New product announcement!

#### Ministry of Manpower (MOM) Authorized Examiner Services Now Available!



HSB can now provide Ministry of Manpower (MOM) Authorized Examiner services to our Singapore MOM inspection services customers for registration of their pressure vessels.

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## Events Calendar

### 2023 virtual technical training seminar topics - [click here](#) to register

| Month           | Topic   |
|-----------------|---|
| March 28-30     | ASME Section I and B31.1 - Power Boilers and Components (E21)                   |
| April 25-27     | ASME Section VIII, Division 1 (E21)   |
| May 9-11        | ASME Section III, Division 1 - Overview and Nuclear Certification Process (E21) |
| June 6          | <b>HOT NEW TOPIC!</b> DOT: UN Portable Tanks (ASME Section VIII)                |
| September 12&13 | ASME Section IX - Welding Requirements (E23)                                    |
| September 19&20 | NBIC Repairs and Alterations (E23)  |
| October 10-12   | ASME Section III, Division 5 - High Temperature Reactors and SMR Overview (E23) |
| November 28-30  | ASME Section VIII, Division 1 (E23)   |
| December 5-7    | ASME Section I and B31.1 - Power Boilers and Components (E23)                   |

### 2023 code synopsis virtual training schedule - [click here](#) to register

| Month       | Topic                                   |
|-------------|---|
| August 16   | ASME 2023 Code Synopsis: Section VIII   |
| August 23   | ASME 2023 Code Synopsis: Section I & II |
| August 24   | ASME 2023 Code Synopsis: Section V & IX |
| September 7 | ASME 2023 Code Synopsis: Section III    |
| November 7  | ASME 2023 Code Synopsis: Section I & II |
| November 8  | ASME 2023 Code Synopsis: Section VIII   |
| November 9  | ASME 2023 Code Synopsis: V & IX         |

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