In this whitepaper Emerson will address the state of the hydrogen market in North America, its emerging trends and challenges, its electrical code requirements, and ways heat trace products can help industry stakeholders as they face mounting pressure to increase hydrogen production.

Hydrogen is set to play a dominant role in the global transition to a net zero economy. Decarbonization is now a defined goal for governments worldwide which are offering incentives to industry to embrace green hydrogen. Emerson supports this journey toward a sustainable, clean energy future, and the solutions that ensure safe and efficient hydrogen production, conversion, transportation, and storage.

Emerson's Solution
Emerson provides a broad line of Nelson Heat Trace self-regulating and constant wattage electric heating cables, monitoring equipment, controllers and accessories that solve temperature management issues at every stage of hydrogen's value chain. Our heat trace systems keep critical processes flowing by precisely maintaining the temperature inside pipes transporting gases and liquids in-plant and from supply sites to demand locations. When outside temperatures dip, our heat trace systems also prevent the freezing of instrumentation, pipes, pumps, compressors, valves, and other auxiliary equipment, helping to reduce downtime and protect capital investments.

The Hydrogen Market

According to the International Energy Agency, hydrogen represents "the biggest innovation opportunity" to reduce carbon dioxide (CO_2) emissions and usher in net zero by 2050. Hydrogen's ability to replace fossil fuels without releasing CO_2 when consumed has led to new applications being explored on numerous fronts. In California, for instance, there are currently 15,000 hydrogen fuel cell vehicles on the road. Operators of power plants are discovering new ways hydrogen can supplement or replace natural gas. Bolstering these initiatives, the U.S. Department of Energy in 2023 announced an investment of $7 billion to launch seven Regional Clean Hydrogen Hubs to accelerate the commercial-scale deployment of low-cost, clean hydrogen.

While green innovations hold great promise, hydrogen as an alternative energy represents only a small sliver of current overall consumption. Of the 120 million metric tons (MMT) of hydrogen consumed worldwide in 2022, the vast majority was concentrated in the traditional sectors of petroleum refining and chemical processing. Each year approximately 55% of hydrogen goes into the creation of ammonia for fertilizer. Another 25% goes to petroleum refining hydro-desulfurization and hydrocracking operations, 10% to produce methanol, and the remaining 10% to treating metals, flat glass manufacturing, chemical synthesis of plastics, and the manufacturing of semiconductors. Gaseous hydrogen is also utilized as a coolant for generators due to its high thermal conductivity.

Owing to government support for green hydrogen's adoption and its continued consumption by traditional industries, the hydrogen market is set to witness impressive growth over the coming decades. In financial terms, the global hydrogen industry was valued at $155.9 billion in 2022 yet is expected to register $292.0 billion by 2032. McKinsey forecasts a fivefold rise in hydrogen demand to six hundred million metric tons annually by 2050 if bottlenecks in permitting and access to capital are resolved.

Hydrogen Color Codes

Different methods of producing hydrogen are often referred to by certain colors:

- Brown hydrogen — Produced from the gasification of coal. Releases large quantities of CO_2.
- Gray hydrogen — Steam refined methane production. Releases large quantities of CO_2.
- Blue hydrogen — Steam refined methane production with carbon capture and storage. Releases around 10% CO_2 emissions.
- Green hydrogen — Hydrogen produced by electrolysis, powered by renewable energy sources like wind and solar. Release of emissions is close to zero.
- Yellow hydrogen — Hydrogen produced by electrolysis, powered by existing grid sources like coal and natural gas. Releases typical CO_2 emissions associated with power production, but cam be limited by relying on production overages.
- Pink or Purple hydrogen — Hydrogen produced by electrolysis, powered by nuclear energy. Release of emissions is close to zero, but nuclear waste is produced.
- White Hydrogen — Hydrogen mined from underground sources. The CO_2 emissions come from the mining process.

Hydrogen Production Methods

Hydrogen is the simplest and lightest of all Earth elements, consisting of only one proton and one electron. It is also the most abundant element in the universe, yet rarely is it in its pure state. Because of hydrogen's high reactivity, it quickly bonds to elements such as carbon, fluorine, oxygen, or nitrogen. To produce hydrogen, it must be separated from the other elements in the molecules where it occurs. Technologies enable the separating of hydrogen gas from its companion substances in purities in the order of 99.999%.

In the United States, steam methane reforming (SMR), or steam refining, accounts for 95% of hydrogen produced. The SMR process is a reaction between a methane source, such as natural gas, and high-temperature steam (+700 to +1,100 °C or +1292 to +2012 °F). In a final process step called pressure-swing adsorption (PSA), impurities are removed from the gas stream, leaving essentially pure hydrogen. Coal gasification, a procedure combining coal with oxygen and steam at high pressures, produces another 4%, while water electrolysis yields 1%.

Although SMR is highly cost-effective, it requires fossil fuels as feedstock and to generate heat. In fact, for every kilogram of hydrogen produced in SMR, seven kilograms of CO_2 are released into the environment. Carbon capture and storage techniques (CCS) seek to trap the CO_2 released by SMR and store it in the ground, converting "gray" to "blue" hydrogen.

Like SMR, electrolysis relies heavily on fossil fuels. The only way the process is CO_2 neutral — that is, it produces almost no greenhouse gases or other pollutants — is when renewable energy sources are employed, such as geothermal, hydro, wind or solar. Because this "green" hydrogen approach is considerably more expensive than hydrogen sourced from fossil fuels, it constitutes less than 0.04% of all hydrogen produced globally.

One promising new technology is so-called "pink" or "purple" hydrogen made thermochemically in nuclear reactors. The US Department of Energy predicts that a single 1000-megawatt reactor could produce up to 150,000 tons of clean hydrogen annually.

Hydrogen Storage

There are numerous methods to store hydrogen.

GAS: One of hydrogen's main characteristics is its low volumetric energy density. Hydrogen gas takes up four times more space than natural gas, and therefore is often compressed for storage and transportation. As a compressed gas, hydrogen is stored and transported in cylinders made of thick-walled aluminum, steel, or composite materials capable of withstanding high pressures of 5000 to 10000 psi, or within vacuum insulated tanks.

CRYOGENICS: Alternatively, hydrogen can be liquefied at cryogenic temperatures (-253 °C or -423 °F), although liquefaction is both energy-intensive and technically complex.

ABSORPTION: Another storage option is to chemically bind hydrogen with solids or liquids able to absorb it. Palladium, for instance, can absorb nine hundred times its own volume of hydrogen. Other alternatives are magnesium, aluminum, and certain alloys. The most promising carrier is probably ammonia, a mixture of nitrogen and hydrogen.

CAVERNS: Lastly, hydrogen can be stored in unique conditions below ground. Bulk storage of uncompressed hydrogen has proven viable in salt caverns, and to a lesser extent in porous sandstone or shale, or in engineered cavities. Salt is very dense, preventing hydrogen leakage, and is the most common underground storage method. Locating a suitable geological formation near the point of generation is one of many difficulties with this approach.

Hydrogen Transportation

If hydrogen is not consumed at its point-of-origin ("captive" production), bulk hydrogen must be transported to its point-of-use by railcar, barge, or over the road in gaseous tube trailers or in cryogenic liquid tanker trucks. Long-distance pipeline investments have been made by merchant producers in areas where there is a significant, steady demand for hydrogen. In the United States, there are approximately 1600 miles of active pipeline for hydrogen transportation, 90 percent of which is located along the Gulf Coast of Texas, Louisiana, and Alabama, serving refineries and ammonia plants. Pipelines are the least expensive method of transporting hydrogen. As demand for hydrogen grows, one potential transportation solution is to modify a portion of the 300,000 miles of existing natural gas distribution infrastructure in the United States to hydrogen delivery.

Joule-Thomson Effect and Frozen Valves

It is common for hydrogen to carry some moisture, opening the possibility of a valve freezing whenever a process involves large pressure drops. According to the Joule-Thomson Effect, the gas temperature drops by -14 to -13 °C or 6 to 8 °F for every 100-psi cut across a valve. Once frozen, a valve will require expensive downtime, repairs, and maintenance. This is even more likely when the outside temperature falls below 0 °C or 32 °F.

Methods to combat valve freezing can involve using methanol injection, thermal jackets, or steam.

A more effective solution involves wrapping vulnerable valves with heat trace cables. Unlike steam, heat trace cables will not deteriorate seals and seats in the valve, and heat trace cables are far less expensive than methanol.

Winterizing Hydrogen Operations

Malfunctions and catastrophic failures in hydrogen plants have resulted from frozen pipes, equipment, sensing lines, and instrumentation. Recent cold weather events, such as winter storms Elliott (2022) and Uri (2021) demonstrate these challenges. Frozen equipment may cause a forced outage or will prohibit a hydrogen processing plant from restarting. Burst pipes, wrecked instrumentation, and damaged processing equipment all must be repaired or replaced. A fault in a pipeline, if unnoticed, has the potential to escalate into a substantial environmental concern.

As part of plant winterization procedures, any potential freeze-related risks to piping and processing equipment are to be identified and mitigated. Where insulation is not sufficient, heat trace cables can be installed to respond to freeze threats, coupled with end-of-circuit heat trace indicator lights and remote monitoring displays in the plant control room.

Hydrogen Dangers

All fuels have some degree of danger associated with them. Hydrogen is no exception.

Although the ignition temperature of hydrogen is similar to natural gas and propane, it has a wider flammability range of 4% to 74%, meaning the amount of hydrogen necessary to initiate combustion is much lower. Once ignited, hydrogen flames burn at extremely high temperatures (500 °C or 932 °F) yet mostly outside of the visible light spectrum, making hydrogen fires both destructive and nearly impossible to initially detect. Worse still, at concentrations of 18.3% to 59%, hydrogen will explode.

These characteristics underscore the importance of Temperature Classification (T-Rating) to the safe handling of hydrogen. T-Ratings indicate the highest temperature allowed in an area that will not cause an ignition. What makes T-Ratings even more important is that hydrogen gas is prone to leakage.

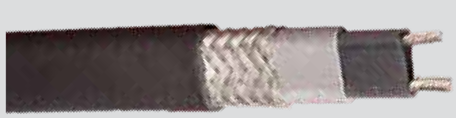
Hydrogen atoms permeate through conventional gas line infrastructure formed of steel, nickel, iron, cobalt, and various alloys. Once absorbed, hydrogen gas will embrittle metals by lowering the stress it takes for cracks to form and propagate. A hydrogen leak, no matter how slight, generates a serious risk of fire.

Hydrogen has one safety advantage over other flammable fuels: hydrogen is fourteen times lighter than air and rises six times faster than natural gas, which means that it disperses rapidly when released. Unless leaking hydrogen is contained by a roof or some other structure, it will quickly dissipate before it reaches a flammable concentration. The laws of physics prevent it from lingering near a leak unlike heavier propane or gasoline fumes. For that reason, hydrogen explosions and fires are most likely to occur in confined, poorly ventilated spaces where hydrogen is processed or stored in massive quantities.

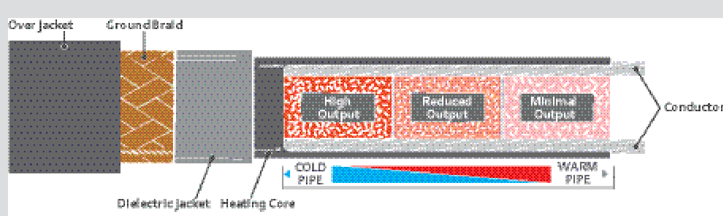
Nelson Heat Trace cables — certified for hazardous areas — feature T-Ratings well below hydrogen's ignition point of +585 °C or +1085 °F. Nelson self-regulating cables may be used based on their maximum T-Rating, yet under no conditions will the cables exceed those temperatures. Nelson constant wattage and mineral insulated cables are designed not to exceed the ignition temperature. For classified areas, this is achieved by limiting the watt density so sheath temperature will not exceed the required temperature. Nelson cables feature a metal shield or sheath that acts as an effective return ground path as well as providing added physical protection.

Hydrogen Classification

Depending on the jurisdiction where a hydrogen facility is located, a set of electrical codes will outline the specific requirements for electrical heat trace systems and the other electrical equipment that is being installed. These codes help ensure the uniformity of safety requirements and give local inspectors and safety officials the information they need to approve systems and installations. As mentioned earlier, in North America, electrical systems installed in hydrogen applications follow Article 500 of the National Electrical Code (NEC). The NEC is incorporated into most state and local jurisdiction regulations and therefore carries the weight of law. Products intended for installation in hazardous locations must be listed or certified for that specific Class, Division, and Group. Article 505 of the NEC covers the Zone classification system for hazardous locations, which is based on the IEC hazardous location classification system for flammable gas, and introduces IEC based protection techniques. Within both classification systems, similar protection techniques and methods are employed to reduce or minimize potential risks, see chart 1. Class I, II and III, Division 1 as well as Zones 0 and 20 represent areas where there is a hazard present continuously or frequently during normal operations in sufficient quantities to produce an explosive mixture. Class I, II and III, Division 1 as well as Zones 1 and 21 represent areas where a hazard may likely be present during normal operations in sufficient quantities to produce an explosive mixture. Class I, II and III, Division 2 as well as Zones 2 and 22 represent areas where a hazard is not likely to occur, but may accumulate infrequently in sufficient quantities, to cause a hazard for only short periods of time.



Nelson Type LT Self-Regulating Heater Cable



Operating Principle of Self-Regulating Heater Cables

CHART 1 — AREA CLASSIFICATION — NEC/CEC/ATEX CLASS/DIVISION/GROUP/ZONE							
		NEC®/CEC			IEC/CENELEC		
Material Type	**Inflammable Material**	**Class**	**Division**	**Group**	**Zone**	**Group**	**Sub-division**
Gases and Vapors	Acetylene	I	1 or 2	A	0, 1 or 2	II	C
Gases and Vapors	Hydrogen	I	1 or 2	B	0, 1 or 2	II	B + H_2
Gases and Vapors	Ethylene, Propylene oxide, Ethyl oxide, Butadiene	I	1 or 2	C	0, 1 or 2	II	B
Gases and Vapors	Propane, Cyclopropane, Ethyl ether, Ethylene	I	1 or 2	D	0, 1 or 2	II	A
Gases and Vapors	Methane, Acetone, Benzene, Butane, Propane, Hexane, Paint solvents, Natural gas	I	1 or 2	—	0, 1 or 2	I	—
Dusts	Metals	II	1	E	20, 21 or 22	III	C
Dusts	Conductive (Carbonaceous)	II	1 or 2	F	20, 21 or 22	III	C
Dusts	Nonconductive (Grain)	II	1 or 2	G	20, 21 or 22	III	B
Fibers and flyings	Combustible (Wood, paper or cotton processing)	III	1 or 2	—	—	III	A

Emerson Nelson Heat Trace Solutions for Hydrogen Operations

We have stressed throughout this white paper that there are serious hazards connected with hydrogen. Establishing safety in an industrial-scale hydrogen operation requires adherence to best practices and standards. Heat trace systems, like any other electrical device installed near hydrogen, have physical characteristics and performance features that must be incorporated before they can be safely deployed at production, storage, and distribution phases. Below we highlight a selection of Nelson Heat Trace cables, controllers, thermostats, and connection kits engineered for safe use in hydrogen processes including those areas rated by NEC 500 as Class I, Division 1 and 2, Group B. In addition, Emerson offers a full line of Nelson Heat Trace solutions for non-hazardous industrial and commercial applications.

Heat Trace Cables:

- *The Nelson Type NC Series constant wattage heater cable is a parallel resistance electric heater strip featuring a fluoropolymer sheath material extruded over two multi-stranded, nickel-plated, 12-gauge copper bus wires. It can be used for freeze protection or in process temperature maintenance systems including pipelines and process water. The Nelson Type NC Series is rated for Class I, Division 2, Groups B, C, D; Class II, Division 2, Groups F, G; Class III, Division 2 hazardous locations.*
- *The Nelson LLT Series self-regulating heater cable maintains fluid flow under low ambient conditions for freeze protection applications and low-watt density process temperature systems that require extended continuous circuit lengths. Its primary dielectric jacket is thermally bonded to the heating core to prevent moisture. It is rated Class I, Division 2, Groups A, B, C, D; Class I, Zone 1; Group IIC, and is certified by the Canadian Standards Association for hazardous locations.*
- *The Nelson MI (mineral insulated) cable is a metal sheathed heat trace cable that uses a metallic conductor as the heating element. Cables are custom designed and fabricated for specific applications requiring high temperature exposure, immunity to stress corrosion, high maintain temperature, under tank heating (cryogenic tanks), high power output, and constant power output. It is certified by UL, CSA and FM for Class I, Division 1 and 2, Groups B, C, D; Class II, Division 1 and 2, Groups E, F, G; Class III, Division 1 and 2; Class I, Zone 1 and 2; Zone 1, Ex de IIB + H_2 T1-T6.*
- *The Nelson XLT Series self-regulating heat cable maintains fluid flow over a wide range of operating temperatures. It is ideal for freeze protection of periodically steam (29 BAR) cleaned pipes and temperature maintenance for +232 °C or +450 °F or lower processes. This cable series is certified for ATEX and IECEx (Group IIC) Hazardous Locations.*
- *The Nelson™ Heat Trace HLT Series self-regulating heater cable is used for freeze protection of periodically steam (13.8 BAR) cleaned pipes and temperature maintenance for 120 °C or lower processes. It is certified for ATEX and IECEx (Group IIC): Hazardous Locations.*

- *The Nelson XLT Series self-regulating heat cable is for freeze protection of periodically steam (29 BAR) cleaned pipes and temperature maintenance for +232 °C or +450 °F or lower processes. It is certified for ATEX and IECEx (Group IIC): Hazardous Locations.*

Thermostats and Controllers

- *The Nelson Heat Trace TE760 thermostat is for high temperature piping on freeze protection and process maintenance applications in hazardous locations. Housed in a cast aluminum enclosure, the switch has 8 Amp/240 Volt single-pole double throw (SPDT) leads for use with Nelson LT, HLT, XLT and NC Series heater cables. It is rated Class I, Division 1, Groups B, C, D Class II, Division 1, Groups E, F, G, Class I, Zone 1, Ex d IIB+ H_2.*
- *The Nelson Heat Trace TA7140 thermostat is for ambient temperature control in hazardous locations. Housed in an aluminum enclosure, the switch has 22 Amp/480 Volt single-pole double throw (SPDT) leads. It is designed for use with Nelson LT, HLT, XLT and NC Series heater cables. It is certified for Class I, Division 1 and 2, Groups B, C, D; Class II, Division 1 and 2, Groups E, F, G (UL, CSA, FM), and Ex II 2 G D; EEx d IIC T6; -40 °C to +60 °C; IP65 (ATEX).*
- *The Nelson Heat Trace TH7325 thermostat is used for controlling heat tracing systems in hazardous locations. The switch has 22 Amp/480 Volt single-pole double throw (SPDT) leads. It is for use with Nelson LT, HLT, XLT and NC Series heater cables. It is certified for Class I, Division 1 and 2, Groups B, C, D; Class II, Division 1 and 2, Groups E, F, G (UL, CSA, FM), and Ex II 2 G D; EEx d IIC T6; -40 °C to +60 °C; IP65 (ATEX).*

Connection Kits

- *Nelson Heat Trace HASK Series connection kits are approved for use in Division 1 hazardous areas when used with Nelson LT, HLT and XLT Series field-fabricated heating cables. Four versions are available. Rated Class I, Division 1, Groups B, C, D; Class II, Division 1, Groups E, F, G; Class III, and Class I, Division 1, Groups B, C, D; Class II, Division 1, Groups E, F, G; Class III; Class I, Zone 1, IIB*
- *Nelson Heat Trace tee splice connection kits connect a maximum of three heater cables. The kits may be used to connect multiple heater segments, connect different wattage cables together, or to provide access to service removable equipment. Global-reach industrial-grade universal connection kits for hazardous locations are rated for NEC/CEC (AX Series) and IEC (EX Series).*
- *Nelson Heat Trace PLT Series non-metallic connection kits are approved for hazardous locations Nelson™ Heat Trace PLT-BC, PLT-BY and PLT-BS Connection Kits. It is rated Class I, Division 2, Groups A, B, C, D; Class II, Division 1, Groups E, F, G; Class I, Zone 2, Group IIC, and Class I, Division 2, Groups B, C, D; Class II, Division 2, Groups E, F, G; Class I, Zone 2, Group IIB+ H_2 (CSA).*
- *Nelson Heat Trace Lighted End of Circuit Termination Kit terminates one heater cable with a non-directional lens assembly. Red LED and Green LED long life LED output colors are available. The kit is used to connect and terminate Nelson™ Heat Trace LT-J, LT-JT, HLT-J, XLT-J and CLT-JT Series self-regulating heater cables. Global-reach industrial-grade universal connection kits for hazardous locations are certified for NEC/CEC (AX Series) and IEC (EX Series) installations: Class I, Division 2, Groups B, C, D; Class II, Groups E, F, G (Canada Only); Class III (Canada Only); Enclosure Type 4X; Class I, Zone 1; Ex e II, and Class I, Division 2, Groups B, C, D; Class II, Groups E, F, G; Class III; Enclosure Type 4X; IP66; Class I Zone 1; AEx e IIC.*
- *Nelson Heat Trace AXPC100 and EXPC100 power connection kits are used to connect and terminate Nelson LT-J, LT-JT, HLT-J, XLT-J and CLT-JT Series self-regulating heater cables. AXPC100 is designed per NEC requirements and the EXPC100 is designed per IEC requirements. Both feature rugged, non-metallic construction rated for IP66/NEMA 4X. AXPC100 is rated Class I, Division 2, Groups A, B, C, D; Class II, Division 2, Groups F, G; Class III, Division 1 and 2. EXPC100 is rated Ex II 2 G; Ex e IIC T5 Gb; Ex II 2 D; Ex tb IIIC T95 ° C.*

CONCLUSION

Partnering with Emerson offers you the ability to incorporate Nelson Heat Trace solutions as well as brands such as Appleton, ASCO, Fisher, Micro Motion, Rosemount and TESCOM. This means you can expect an end-to-end solution of innovative, precise, and reliable products that conform to high regulatory standards. As a global leader, Emerson is helping OEMs with all types of hydrogen fuel production solutions, ranging from building electrolysers and fuel cells to the fueling stations that drive energy transformation and decarbonization. Emerson technology provides unparalleled performance with comprehensive global support. Our industry specialists understand OEMs and designers' needs for reliability, safety, and affordability.

CM-1 Microprocessor Based Heater Cable Monitoring System

TA7140 Thermostat

Conclusion

As hydrogen begins to play a dominant role in the global transition to a net zero economy, solutions that ensure safe and efficient hydrogen production, conversion, transportation, and storage are critical. Utilizing self-regulating and constant wattage electric heating cables, monitoring equipment, controllers and accessories can help solve temperature management issues at every stage of hydrogen's value chain. By installing heat trace systems on pipes used to transport gases and liquids in-plant and from supply sites to demand locations ensure processes flow uninterrupted. while temperatures inside pipes used to transporting gases and liquids in-plant and from supply sites to demand locations remains consistent. By preventing the freezing of instrumentation, pipes, pumps, compressors, valves, and other auxiliary equipment, hydrogen producers can reduce downtime and protect capital investments.

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