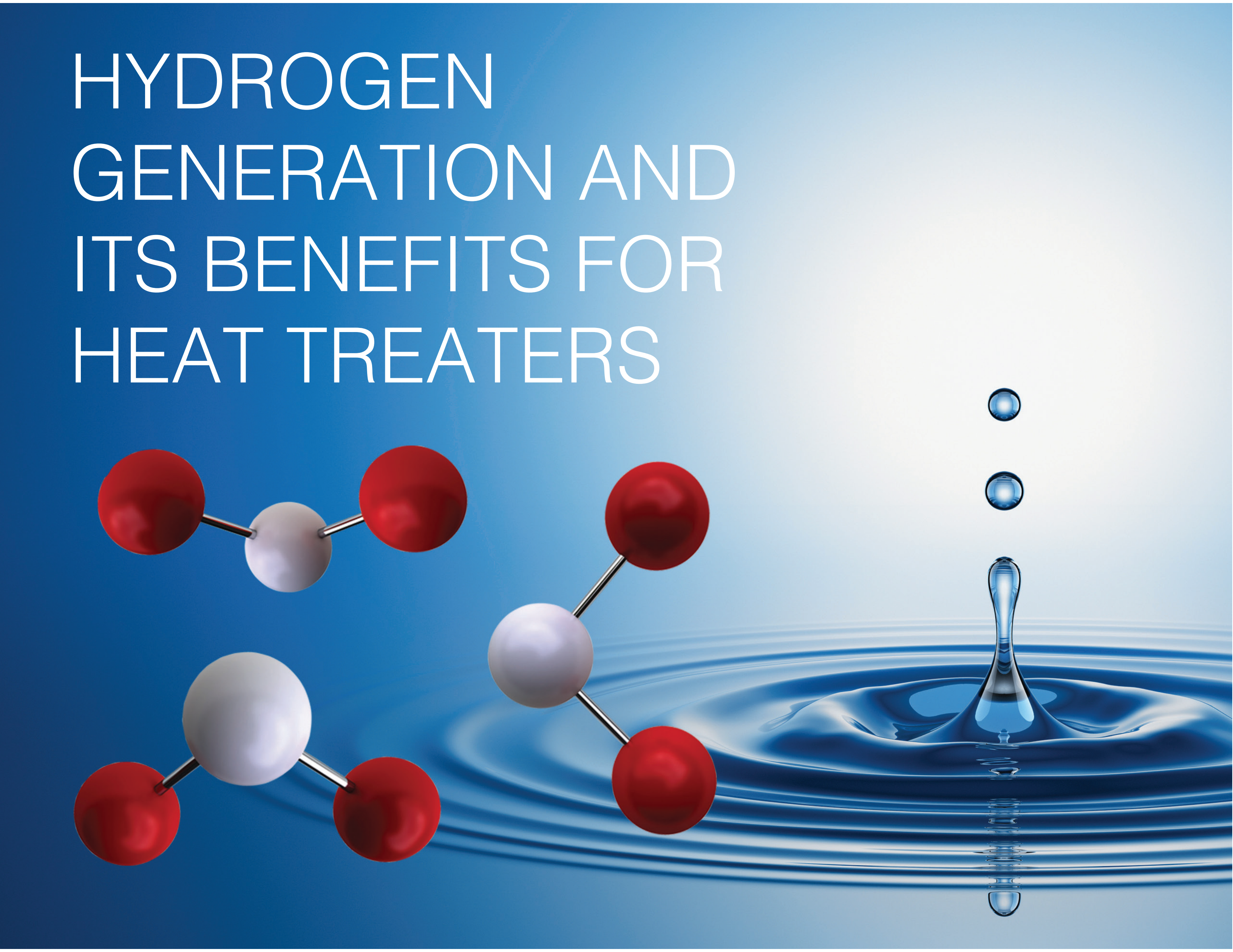
Heat Treat Today

Technology, Tips & News for Manufacturers with In-House Treat

ebook series

HYDROGEN GENERATION AND ITS BENEFITS FOR HEAT TREATERS



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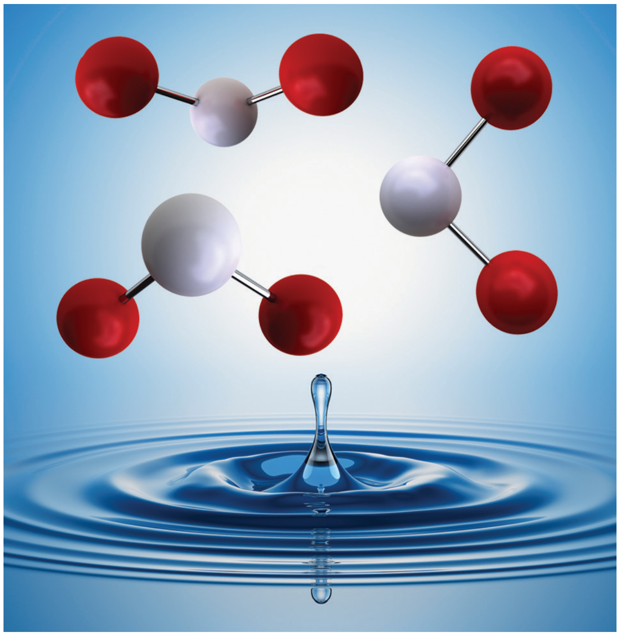

Hydrogen Generation and Its Benefits for Heat Treaters

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Reducing atmospheres are widely used in thermal processing. High temperature thermal processing is used to improve a metal's physical and chemical properties as a key process step in many fabrication processes.

Processes that we'll specifically focus on here include annealing, brazing and sintering – as applied in powder metallurgy – metal injection molding, additive manufacturing, and glass to metal or ceramic to metal sealing. Oxygen presence in these atmospheres, the surface contamination of your parts, or the particles making up your part, becomes destructive at high temperatures, and reducing atmospheres actively scrub and remove oxygen to expose and also protect metal surfaces.

Hydrogen is a key reducing agent in thermal processing atmospheres. Generally, reducing atmospheres are required if you're going to achieve excellent results for many of the types of thermal processing mentioned above. Reducing atmospheres generally contain hydrogen or carbon monoxide (CO) to scrub oxygen. Both act as an oxygen sponge, tying up oxygen to eliminate its effect on metals at high temperature. While CO, like hydrogen, can scrub oxygen, the carbon presence changes the atmosphere effects on metals. That effect may be desirable or not. If you're carburizing, it's desirable. If you want your metals to remain soft, then it is undesirable to have carbon in the atmosphere. Also, be aware that CO is extremely poisonous and requires special care in using that atmosphere.

Assuming you're going to use an atmosphere where hydrogen is the primary reducing agent, that hydrogen may originate from deliveries of pure hydrogen or generation of pure hydrogen, Dissociated Ammonia (DA) or as a component of endo or exo generation from hydrocarbons. Endo and exo gas both contain CO, therefore, pure hydrogen would be delivered, generated or originate from DA.

The composition of a reducing gas atmosphere for annealing, brazing and sintering is typically a hydrogen-nitrogen blended atmosphere, and that blend may be anything from pure hydrogen through all of the blends of hydrogen and nitrogen – and in some cases, pure nitrogen. But keep in mind, nitrogen by itself is primarily a space filler in your furnace. It is generally regarded as being inert, and it is not a reducing gas. You need to be a little careful in assuming nitrogen is inert, because it is not truly inert. (Later in the book, we'll address where nitrogen can cause issues with metallurgy.)

> **"Pure hydrogen will be used with certain grades of metallurgy and most metals can be processed in a hydrogen-nitrogen blend."**

Pure hydrogen will be used with certain grades of metallurgy, and most metals can be processed in a hydrogen-nitrogen blend. Specific atmospheres have specific processing capabilities and materials compatibility. A key thing to keep in mind is that pure hydrogen costs 5-10 times more than delivered pure nitrogen, so diluted hydrogen atmospheres are less expensive. In general, the less hydrogen you use, the less expensive your atmosphere. Drier atmospheres – those with a lower dew point – may enable you as a thermal processor to use a lower hydrogen concentration. In order to process nitrogen-sensitive materials, the availability of pure hydrogen, whether from storage or generation, creates more atmosphere flexibility than using DA. And broad furnace atmosphere blend flexibility, that is the ability to provide atmospheres all the way from pure hydrogen to virtually pure nitrogen, and higher atmosphere purity may also enable you to improve your results and have the lowest possible processing costs.

Hydrogen atmospheres are used in diverse furnace types. Hydrogen containing atmospheres are used in continuous and batch atmosphere furnaces. Hydrogen is used as a partial pressure atmosphere for backfill during vacuum processing. In these applications, hydrogen provides superior heat transfer and a superior reducing chemical activity to clean the surface of your parts. Hydrogen atmospheres allow you to decrease cycle times because you can move the belt faster or push parts through the furnace more quickly due to the improved heat transfer properties. Protective and cleaning atmospheres are used for annealing, brazing, sintering, plus glass and ceramic metal sealing.

This first image shows you the various ways you might get raw materials for your atmosphere furnaces. On the top, you'll see a picture of a delivery vehicle and storage tank for anhydrous ammonia (NH_3). NH_3 is ammonia intended not to contain water, to break down into a dry atmosphere. In the thermal processing industry, buyers of NH_3 would buy metallurgical grade NH_3, which is the highest quality, intended to break down cleanly in a dissociator.

Two pictures in the second row show the compressed hydrogen tubes, both in a tube trailer and a tube bank. That is where gaseous hydrogen is stored at high pressure. The pictures in the center and bottom are of liquid hydrogen tanks. Liquid hydrogen is stored at very cold temperatures and is constantly vaporizing in that tank, necessitating an elevated vent stack.

Alternatively, you may get your atmospheres through generation. The previous image displayed 'delivered atmospheres,' while this image is of 'generated atmospheres.' On the left side, top and bottom, are two different photographs of ammonia dissociators. Ammonia dissociators bring in NH_3 and crack that ammonia into its constituent molecules. The top center and right images are photographs of proton exchange membrane hydrogen generators. These hydrogen generators crack water into pure, dry, pressurized hydrogen and its by-product, oxygen. In the lower center, the blue and yellow boxes illustrate a nitrogen generator. You can generate nitrogen by filtering pure nitrogen from the air, removing oxygen, water, and CO_2.

Furnace Atmospheres – Stored Raw Materials

Atmosphere type	Supply Options	Typical inventory
Nitrogen	Stored liquid nitrogen (LIN)	3-15,000 gallons – to 1.4 MM scf N_2
	Gaseous compressed nitrogen (rare)	50,000 scf N_2
	On-site nitrogen generation	<1,000 scf N_2
Hydrogen	Stored liquid hydrogen (LH_2)	3-10,000 gallons – to 1.13 MM scf H_2 = 5,900 lbs
	Gaseous compressed hydrogen TT	~100,000 scf H_2 = 520 lbs
	PEM On-site hydrogen generation	<6 scf (14 grams) H_2 = 0.03 lbs
Dissociated Ammonia	Stored liquid ammonia	500-1,000 gallons – to 116,000 scf NH_3 = 5,150 lbs → 232,000 scf DA gas (H_2 + N_2)

This chart provides information about furnace atmospheres and the atmosphere materials needed to store and blend those atmospheres. The first section talks about nitrogen. You may store liquid nitrogen (LIN). You may store gaseous compressed nitrogen, though that's relatively rare in the thermal processing industry, or you might generate nitrogen from air using the equipment introduced at the top of the page.

This next section talks about hydrogen. Large users might store liquid hydrogen (LH_2) in tanks up to 10,000 gallons, which equates to about 1.13 million standard cubic feet and 5,900 pounds of hydrogen. By comparison, if you store gaseous compressed hydrogen in a large tube trailer – a "jumbo" – or tube bank, it would hold up to 520 pounds of hydrogen or 100,000 standard cubic feet.

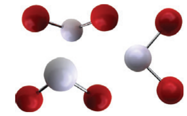
If you generate hydrogen using a proton exchange membrane hydrogen generator, the largest capacity hydrogen generator normally used in thermal processing, it will store 14 grams (three hundredths of a pound) of hydrogen.

If you use a DA atmosphere, you store liquid ammonia. Typically, you'd store between 500 and 1,000 gallons of liquid ammonia, which would provide up to 232,000 standard cubic feet of DA gas. You'll notice that ammonia doubles in volume when you dissociate it because you're cracking one molecule into two. 1,000 gallons of ammonia would be just over 5,000 pounds of ammonia.

We invite you to consider your answer to the following question:

What H_2/N_2 atmosphere blend do you use today?

- **Pure N_2**
- **Forming Gas $< 5\%$ H_2 in N_2**
- **$< 50\%$ H_2 in N_2**
- **50+% H_2 with N_2 (including pure DA)**
- **Pure H_2**
- **No Atmosphere**



Consider DA – a little background on what it is, where it originates, its advantages and disadvantages. NH_3 is a relatively inexpensive source of fixed blend hydrogen and nitrogen. When you break down ammonia in a dissociator, you get 75% hydrogen and 25% nitrogen – a fixed blend. An ammonia dissociator is a heated, catalytic reactor, as it dissociates or breaks down ammonia into a single stream of blended hydrogen and nitrogen. DA has some benefits: It's simple. It's historical, meaning there are still procedures and recipes written around DA. It's a relatively reliable and inexpensive atmosphere, so there is a lot to like about it.

Background of DA

Ammonia dissociator – heated catalytic reactor that "dissociates" ammonia into a blend of 75% H_2 and 25% N_2

Drawbacks and limitations:

- Requires ammonia storage
- Relatively fixed capacity – limited turndown
- Energy intensive – must remain heated 24/7
- Maintenance intensive
- Limited atmosphere flexibility
- Generated atmosphere is often wetter than ideal
- Many installed systems are old and trouble-prone
- Ammonia prices rising – only two suppliers

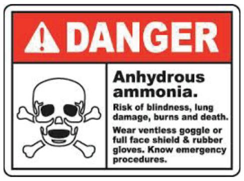
The drawbacks to DA are that it requires ammonia storage and it's relatively fixed in capacity (it has limited turndown). It's energy intensive because the dissociator must remain heated 24/7 in order to maintain the retort. Dissociators are relatively maintenance intensive and the expertise to maintain dissociators is less available than it once was in our industry. You have limited atmosphere flexibility because you don't have the availability of pure hydrogen, only 75% hydrogen and 25% nitrogen – your richest atmosphere possible. Generated atmosphere is often wetter than ideal, and often thermal processors will utilize a dryer to dry their DA. Many installed dissociators are old and trouble-prone. Plus, ammonia prices are relatively volatile and rising in a highly concentrated market. There are basically just two suppliers of metallurgical grade ammonia today.

There are problems with storing ammonia. Ammonia releases are common and very public and are treated very seriously with evacuations, publicity and fines. Anhydrous ammonia is highly toxic, flammable, and corrosive to mucous membranes. Ammonia releases disperse slowly and ammonia has a powerful and unique odor, so releases are detected quickly. Many ammonia systems are old, and some are not well maintained. As discussed earlier, NH_3 is a highly hazardous chemical under federal law and storage is subject, depending on the quantity stored, to OSHA process safety management and EPA-responsible management planning. Many existing ammonia installations are grandfathered and do not meet current standards for distance and security.

Problems With Stored Ammonia

- Ammonia releases are common, public, and serious – evacuations, publicity, and fines
- NH_3 is toxic and corrosive to tissue
- Ammonia gas disperses slowly and has a powerful and unique odor – releases are quickly detected
- Ammonia systems may be old and poorly maintained
- NH_3 may be subject to OSHA PSM and EPA RMP
- Many existing ammonia installations do not meet current standards for distance and security

As the next graphic illustrates, ammonia leaks occur daily worldwide. However they rarely involve metallurgical operations. The primary market for industrial ammonia is refrigeration ammonia. Between refrigeration ammonia and agricultural ammonia, there are large numbers of releases, virtually every day; and because ammonia is still ammonia from the standpoint of the public, all users, including metallurgical ammonia users, are equally affected by bad publicity. Even though you may be highly responsible, other users of ammonia may not be.



Ammonia Leaks Occur Daily Worldwide

While Met ammonia users (Thermal Processors) may be better stewards than Refrigeration ammonia users, all users suffer from bad publicity:

Hazmat, ambulance response at Oxnard onion facility after leak
https://www.usatoday.com › local › communities › oxnard › 2019/10/28

Ammonia leaks in the news, how to keep your employees safe
https://www.analoxsensortechnology.com › blog › 2017/09/02 › ammonia...

Company Exposed Workers to Ammonia | Respiratory ...
https://www.ehstoday.com › respirators › spokane-business-fined-more-15...

OSHA Cites Florida Farm After Ammonia Leak Hurts Worker ...
https://ohsonline.com › Articles › 2019/06/05 › OSHA-Cites-Florida-Farm-...

Anhydrous Ammonia Released from Refrigeration Unit | EPA ...
https://www.ehstoday.com › industrial-hygiene › no-thrills-blueberry-hill-...

We invite you to consider your answer to the following question:

Do you operate an Ammonia Dissociator today and what do you think of it?

- **I'm happy with DA**
- **I'm planning to get away from my current DA sometime in the future**
- **I need to make a change soon**
- **I'm having a problem storing ammonia**
- **I have dissociator maintenance issues**

The next discussion is about the methodology to replace stored ammonia with hydrogen and nitrogen. As discussed, stored ammonia yields hydrogen and nitrogen when it's dissociated. Therefore, you can replace stored ammonia for your atmospheres with the constituents hydrogen and nitrogen, and can custom blend those for your atmospheres in the exact proportions necessary, depending on the materials you are processing and the metallurgical results you are seeking. In doing so, you will eliminate the dissociator, ammonia delivery, storage, and piping, while providing drier gases and improving the atmosphere composition flexibility. In order to replace DA with hydrogen/nitrogen, you will need sources for pure hydrogen, pure nitrogen, and gas blending capabilities.

Replacing Stored Ammonia with Hydrogen and Nitrogen

- Replace stored ammonia for DA with custom-blended H_2 and N_2
- Eliminates ammonia and DA infrastructure
- Requires H_2 and N_2, and blending capability
- Encounter minimal issues with nitrogen generation and delivery/storage
- Replacing ammonia delivery/storage with hydrogen delivery/storage may not be attractive

Nitrogen can be generated, or you can get it delivered and stored in liquid or, occasionally, in gaseous form. Nitrogen generation is easy and economical and often a good fit for thermal processing. The difference between nitrogen generation or delivery, and storage is primarily an economic decision.

One of the challenges with replacing the hydrogen component in ammonia atmospheres is that hydrogen delivery and storage may not be attractive because hydrogen is also a highly hazardous material. Some people ask, "What have I gained by replacing ammonia with storing hydrogen?" We'll talk about that shortly.

> **Challenges with Stored Hydrogen**
>
> - A hazardous flammable material – storage compliant to NFPA 55 which requires considerable space
> - One pound of hydrogen ≈ energy of 25 pounds of TNT
> - Hydrogen has wide flammability range and low activation energy
> - Storage may require expensive leak-prone underground piping, keeping in mind that a pipe leak or regulator failure can empty the entire contents of your storage vessel into your facility

The challenges with stored hydrogen: While hydrogen is odorless and nonpoisonous and doesn't present an issue to the public, it is a highly hazardous and flammable material whose storage must comply with the applicable NFPA regulations as well as local regulations as determined by Authorities Having Jurisdiction, i.e. the fire marshal. In general, hydrogen storage ties up a lot of space. One pound of stored hydrogen has the energy potential of 25 pounds of TNT, so you need to follow the rules. Hydrogen has a very wide flammability range and low activation energy. Compressed hydrogen leaks generally ignite. To meet NFPA distance criteria, hydrogen storage tanks (for liquid) and tubes (for gas) may require expensive underground piping to keep it away from your building. With stored hydrogen, a piping leak inside your facility can drain the entire contents of your storage vessel into your facility causing an emergency. Hydrogen storage over 10,000 pounds is subject to OSHA process safety management (PSM) and EPA risk management planning (RMP).

Hydrogen Incidents Can Be Catastrophic

Emergency Responders Clear Hydrogen Tanker Crash

TOWN OF NIAGARA – Accident involving truck hauling liquid hydrogen shuts down Military Road.

By Mia Summerson and Rick Pfeiffer rick.pfeiffer@niagara-gaqzette.com

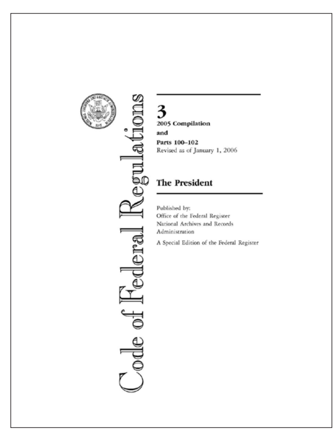
James Neiss/staff photographer. A damaged tanker, left, and a transfer tanker, right, are escorted from the Wegmans parking lot.

Hydrogen emergencies, whether related to deliveries or at a facility, can be scary and get a lot of attention. While there are no odors and gaseous hydrogen dissipates quickly, with liquid hydrogen incidents, the hydrogen is relatively slow to dissipate and such incidents do warrant a lot of attention. This image illustrates an incident that occurred in Niagara, NY.

Briefly, let's discuss OSHA PSM and EPA RMP. These regulations apply to all Highly Hazardous Chemicals (HHC) and both hydrogen and ammonia utilize a 10,000 pound threshold for psm and rmp. 10,000 pounds is approximately equal to 15,0000 gallons of liquid hydrogen and about 1,950 gallons of ammonia. While most thermal processors will not store 15,000 gallons of liquid hydrogen, many may have tanks that will store more than 2,000 gallons of ammonia. And if you're storing more than 1,950 gallons of ammonia, you must comply with federal mandatory requirements: specific emergency response plans, training, record keeping, and equipment.

OSHA Process Safety Management and EPA Risk Management Planning

- Threshold storage quantities of HHC's
- 10,000 lb threshold for hydrogen and ammonia ~15,000 gal LH_2, and ~1,950 gal NH_3
- Requires emergency response plan, training, records and equipment



If you want to avoid the paperwork of OSHA PSM and EPA RMP, your approaches should include shrinking your stored hazardous gases, switching to less hazardous gases, or generating gases as they are required.

Approaches to Reducing HHC Compliance Costs/Storage Hazards

- Shrink stored hazardous gases below 10,000 lbs to eliminate OSHA PSM
- Reduced storage capacity increases number of deliveries
- Install smaller storage tank or use “administrative controls” to fill only part-way
- Number of deliveries increases proportionally – a particular issue with ammonia deliveries
- Switch to less hazardous gases
- Generate gases as they are required

Just a couple of words about shrinking the amount of hazardous gases stored. Remember, 10,000 pounds is the key determinant, but if you reduce the amount you store while continuing to use the same amount as before, then you would need to increase the number of deliveries. The risk of mishap is therefore increased, as accidents often happen on deliveries. It’s particularly tricky when you try to use so-called “administrative controls” where you tell the delivery driver, “I only want you to fill my tank halfway.” That is often a recipe for unhappiness.

Here are some benefits of eliminating ammonia storage: While you’re eliminating the hazards of stored atmosphere raw materials, you’ll eliminate the fear of releases and related publicity, disruption, and costs. You’ll eliminate rising prices for metallurgical-grade ammonia. Your atmosphere costs can become more predictable if you can eliminate volatile pricing. You’ll increase your atmosphere flexibility and blend range and you’re more likely to have a drier atmosphere which will give you enhanced processing results. By eliminating the dissociator, you won’t need to worry about the loss of expertise to maintain dissociators, and you won’t have a cost situation with only two suppliers of met-grade ammonia.

Benefits of Eliminating Ammonia Use and Storage

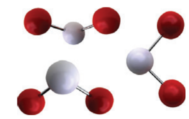
- Eliminates hazards of stored ammonia
- Avoids rising prices for metallurgical (Met) grade ammonia
- Makes atmosphere costs predictable
- Increases atmosphere flexibility and range
- Creates a drier atmosphere – enhanced results
- Eliminates need for expertise to maintain dissociator
- Overcomes situation of few suppliers

Hydrogen generation is the attractive alternative to storing hazardous gases. Hydrogen generation makes pure, dry, pressurized hydrogen from water using Proton Exchange Membrane (PEM) water electrolysis. Water, H_2O, is broken into hydrogen and oxygen. Pure dry hydrogen is pressurized for your process and the oxygen is vented at low pressure, either outdoors or diluted and vented indoors, depending on the size of the equipment. No hydrogen storage is required for PEM water electrolysis. Hydrogen is made at the exact same rate that you're using it in your blender and furnace.

Hydrogen Generation as Alternate to Stored Hazardous Gases

- Hydrogen generation makes pure, dry, pressurized hydrogen from water using PEM water electrolysis
- Water (H_2O) is broken into hydrogen and oxygen
    - process hydrogen for immediate use
    - oxygen is vented
- **No hydrogen storage** is required for the PEM water electrolysis process
- Hydrogen is made at the same rate that it is used

The goals of hydrogen generation are the simple and safest possible hydrogen supply. Generated hydrogen can be viewed as optimum hydrogen because hydrogen is hazardous, relatively expensive to store, its piping is a source of leaks and problems, and its pricing is higher for better grade hydrogen. Generation provides all the hydrogen you need, exactly when you need it, as pure as you need it, with virtually zero inventory and low facility impact from leaks (because the leak rate is so low), and for a fair and predictable price (based on your electric rate).



Goal of Hydrogen Generation: Simple, Safest Hydrogen Supply

- Hydrogen is hazardous and expensive to store
- Hydrogen purity often varies according to supply
- Hydrogen piping is a source of leaks and problems – generated hydrogen mitigates severity of leaks
- Hydrogen pricing increases for higher purity

We invite you to consider your answer to the following question:

What atmosphere issues would you most like help with?

- **Parts need to be cleaner**
- **Parts are slow to heat up/cool down**
- **Atmosphere costs are too high**
- **Atmospheres need to be drier**
- **Atmosphere flexiblility needs to be improved**
- **Ammonia delivery and storage needs to be eliminated**

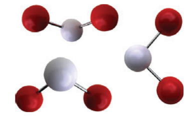
We typically see a preponderance of “atmosphere costs are too high” as the answer here.

Hydrogen generation systems are compact, simple, and available in the size range needed for thermal processing packaged systems. They deliver extremely pure hydrogen at the desired pressure for blending and subsequent use in your furnace. These systems are load following and you're able to turn them on and off if, for example, you only work two shifts or you only work five days. So, there is no electric use when you're not using hydrogen. They are simple to install, operate, virtually plug, and play. They are a true zero-inventory hydrogen supply. From an NFPA standpoint, you essentially create hydrogen, use it instantly and store nothing. The systems are zero-clearance, meaning they can go into a non-classified environment, even adjacent to your furnace. They offer fast delivery, are quick to install, and easy to permit. And their indoor installation eliminates the need for underground piping, which can corrode and cause leaks.

"From an NFPA standpoint, you essentially create hydrogen, use it instantly and store nothing."

As you plan your atmosphere system, whether a new atmosphere system or an upgrade for desired changes, think about custom blending generated hydrogen and nitrogen to meet the precise atmosphere requirements for each and every product you want to thermally process. You might need a gas blender, or you might have blend panels on your furnace. You'll need nitrogen, whether in the form of liquid nitrogen or generated nitrogen. Think about whether you're going to distribute pure gases (pure nitrogen and pure hydrogen) and then blend them at each furnace, or distribute a gas blend analogous to your DA. Think about what gas purity is required for the hydrogen and nitrogen. In the case of hydrogen, generated hydrogen is very, very pure, 99.9995% or better. Nitrogen generation is available in a number of purity levels, and your cost for gaseous nitrogen can depend on the purity level selected. So, consider whether you're going to generate and distribute pure gases, or generate a kind of DA substitute gas.

Next are the steps in the successful change from DA. Understand and document your goals. What are you trying to accomplish? Document your current costs and expected changes. Those costs include electric costs, maintenance costs and the cost of rental of your ammonia tank and the cost of ammonia deliveries, including fees and delivery charges, plus the maintenance on your dissociator.



Understand and value the benefits that changes in atmosphere may provide. Better part quality – what's it worth to you? You may find that it is not cheaper, but you may find that better parts may make it worth the difference. Document your expected project costs and model your operating costs. Balance atmosphere flexibility, meaning distributing pure gases against operational simplicity in the way of mistake proofing. Often, users of DA will wish to distribute a DA substitute gas to maintain things identical for their furnace operators.

Do keep in mind the secondary effects. When you dissociate ammonia today, you get a blend of hydrogen and nitrogen. If you substitute pure hydrogen generation, you'll need to make up for that amount of nitrogen that you don't get from the ammonia. So size your equipment properly, and if you stay with liquid nitrogen, use this as an opportunity to negotiate volume pricing.

"Are you distributing pure gases and blending at the furnace, or are you distributing a DA substitute gas?"

It is very important to look at your furnaces and determine how much gas flow is needed. Gas flow to your furnace is absolutely critical. And very importantly, make sure that the indicators in the instruments on your furnaces are calibrated for the gas you're actually using. It is all too frequent to see rotameters and flow meters calibrated for air or calibrated for nitrogen being used for DA. If that is the case, you don't actually know what flow rate you're supplying – ensure they're calibrated correctly or that you have conversion data to understand what flow rate you're supplying your furnace, today.

You must keep air out of the furnace. Look at your furnace zones. What gas flow is needed in each furnace zone and what composition? Keep in mind, when blending gases, you can vary the composition by zone and take advantage of supplying hydrogen only where it is required.

Be aware of atmosphere burn-off considerations. Make sure that safety systems continue to operate as designed, whether flame curtains or pilot flames. That is particularly a concern if you're using a very diluted blend of gases.

Atmosphere system changes include removing your NH_3 tank and facility dissociator. You're going to eliminate your facility ammonia piping or re-purpose that piping. Keep in mind that ammonia piping is not usable for hydrogen in general. You may reuse your DA lines. No hydrogen can go in piping using threaded fittings; hydrogen piping must meet the fuel gas code.

Eliminate your ammonia deliveries. You're going to blend generated hydrogen with stored or generated nitrogen to meet your atmosphere requirements for any product.

Finally consider your customer process benefits. If you convert to generated hydrogen, you'll see a superior atmosphere quality and flexibility. You'll see stable and competitive atmosphere costs. You'll eliminate hydrogen and ammonia deliveries, storage and handling. You'll eliminate the need to maintain hazardous material inventories because you're making hydrogen as you need it. You'll comply with stringent local hazmat storage requirements. You'll eliminate connecting and disconnecting hazmat fittings, which is when a lot of mishaps take place. You'll eliminate extended piping, including underground piping, because you'll generate hydrogen where you need it. You'll eliminate impurities that enter your process when refilling storage. A hydrogen generator of the sort discussed here has less hydrogen inventory than an empty hydrogen cylinder. Our sponsor, Nel Hydrogen, builds hydrogen generators that can be expanded in the field, if your process requirements should increase.

For further information, please contact Doug Glenn at doug@heattreattoday.com or Kim Georgiades at kimgeorgiades@nelhydrogen.com.

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