Analysis of an Intermittantly Operated Ammonia - Water Absorption Refrigeration System

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CONCLUSION

In this report we have made an attempt to assess and demonstrate the suitability of Ammonia - Water (NH_3 - H_2O) absorption system for the production of ice and other refrigeration applications. The results of the thermodynamic analysis of an intermittant system were presented graphically. These results clearly showed that the Ammonia - Water system could be used to produce ice using hot water from a solar collector as the source of power. We also experimentally demonstrated that ice can be produced with the system built at TAET Laboratory.

However, the closest competetor of this system is the Lithium Bromide system. Although this unit has a high C.O.P. it requires much higher generating temperature than that required by the Ammonia - Water system. An example is the Lithuim Bromide Water system operated by Dr. Yellot. This system was using 190^{0}F hot water as the generating temperature source for a 45^{0}F Evaporating Temperature and a 75°F cooling water temperature at the Absorber and Condensor. Under these same conditions the Ammonia Water system will operate at a much lower generation temperature of 110°F. Also the Lithium Bromide system has a further disadvantage due to the fact that its operating pressure is below atmosphere thus susceptable to system failures due to atmosphere air leakage into the system which is worst than leakage of ammonia out of the ammonia water system which operates at atmosphere pressure.

In this report we did not carry out an analytical investigation of system economics. The vapor compression system which has a much higher C.O.P. cannot compete with the vapor absorption system at rural locations where electricity is not available. Looking at the two system (the vapor compression and evaporation apsorption) purely from the energy balances, acording to the first law of thermodynamics, the vapour compression system appears to be far more attractive.

However, taking the analysis further into second law of thermodynamics where credit is given to the quality of energy in addition to its quantity one finds that the vapor absorption system looks more favourable. This is due to the reason that the latter uses low grade thermal energy in contrast to high grade electrical energy in the vapor compression system.

For industrial application where the industrial waste heat in the form of low temperature hot water is available, the closed cycle vapor absorption system is the best choice. However, for rural food preservation application when no electricity or shaft power is available this system cannot be used for it requires a liquid pump to circulate the refrigerant. Thus, the only practicable application in these situations would be the intermittent cooling system.

ABSTACT

In this project we have analytically and experimentally demonstrated the possibility of ice production in the tropical region where the ambient temperature is above 80°F using moderately hot water as the source of power. The refrigeration system is based on an open cycle intermittenly operated Ammonia - Water vapor Absorption system.

3.6 OTHERS

3.6.1 HYDROGEN

Another energy source envisioned to be a potential alternative to fossil fuels is hydrogen. The lightest of all elements, is very chemically reactive and would normally be found combined with other elements as in water, fossil hydrocarbons, biological materials, and other minerals. Because of this nature, hydrogen cannot be regarded as a primary energy source obtainable from nature like petroleum and coal, but rather as an energy carrier or a medium of energy storage (requiring another energy source to produce it in its usable form).

In general, hydrogen posses some inherent properties that can make it an attractive fuel source, foremost of which is its high specific energy (energy content per unit mass) believed to be greater than most any other chemical fuels (Figure 3.6.1.1)

Upon combustion, hydrogen produce water as the only exhaust product, and does not give off carbon monoxide (CO) and carbon dioxide (CO_2) as by-products of reaction. Hydrogen therefore practically produce "clean air" and rids of air pollution problems which is one of man's primary concerns. Other properties of hydrogen would be that it is obtainable from water, it can be transmitted and consumed in gaseous forms, and it can replace hydrocarbons in most of its applications, most often even with increased combustion efficiency. Athough many of these characteristics make hydrogen seem an ideal fuel source, some qualifications may still have to be made to make hydrogen, in reality practical energy source. In view of the wide difference in the characteristics of our present energy forms from hydrogen, people may have yet to evaluate and determine the implications of a hydrogen energy economy through an assessment of the benefits, risks, and uncertainties involved therein.

Data Collection and Analysis

Apparently, the production of hydrogen would essentally require the knowledge of the availability of raw materials needed, the processes needed to produce hydrogen, as well as their technical and economical practicability and acceptability.

Raw Materials

At present, the most used raw materials for the production of hydrogen is water and methane (from natural gas and/or coal). Over 80% of the industrial hydrogen now in use is produced from the above hydrocarbon source and it is felt that this is likely to be so for another 20 to 25 years.

Obviously, water would appear to be most preferable as it comprises roughly 75% of the worlds total surface area. However, the decision would have to take into account the characteristics of the process that produce hydrogen from water, its complexities, and its viability. On the other hand, although methane (in the form of natural gas) provides an ideal hydrogen source, it seems that reserves are declining (due to continously increasing demands) and it may not be available for the large scale production of hydrogen. Coal, however, could warrant the previously mentioned 20 - 25 years production, considering the presently known resources avaliable.

Hydrogen Production Processes

In broad, hydrogen may be produced in one of several processes. However, only six (6) of these will be discussed, focussing mainly on those that use hydrocarbons (natural gas and coal) and water as raw materials.

A. Reformation of Methane

Among fossil hydrocarbons, methane (CH_4) seems to possess the most ideal hydrogen to carbon ratio (4:1) suitable for the production of hydrogen. Through a process termed "reforming", this hydrogen is obtained by decompostion of the substance, together with steam.

The reformation process essentially consists of chemical reactions involving water (in the form of steam) and methane, in the presence of a catalyst. At the same time, heat is supplied to the reaction. In effect, both the methane and water are stripped off of their hydrogen, with the reject carbon and oxygen discarded as carbon dioxide (CO_2). This series of reactions is given in Table 3.6.1.1 below. When all the energy inputs needed to achieve the complete reformation processes are considered, usual efficiencies come up to about 70%.

Table 3.6.1.1

Chemistry of Steam Reforming of methane

Reforming reaction	$CH_4 + H_2O \longrightarrow CO + 3H_2$
Shift reaction	$CO + H2O \longrightarrow CO_2 + H_2$
Net reaction	$CH_4 + {}_2H_2O + Heat \longrightarrow CO2 + 4H_2$

B. Coal Gasification

Coal gasification has been employed for several years. Although emphasis was mainly given to the production of methane (as natural gas) from coal, proper modifications can produce hydrogen with a relatively simple process. If one is to consider the implementation of a hydrogen energy economy, coal gasification must be considered as it is expected to be the lowest cost large-scale hydrogen source for many years.

A typical gasification process felt most likely to be used for future systems has steam reacting with coal at high pressure and temperature (about 950°C). Carbon dioxide (CO_2), carbon monoxide (CO), and hydrogen are in turn produced, and the oxides are later separated in the reaction leaving essentially pure hydrogen as the final product (see figure 3.6.1.2).

Figure 3.6.1.2

Coal Gasification Process

	Steam Oxygen	Steam	Lime	
Coal	Gasification	Shift Reaction	Purification	Hydrogen
	Ash		Residue	

C. Electrolysis of Water

Essentially, the electrolysis of water resultings in the production of hydrogen is a technology well-known and demonstrated to make hydrogen, water is dissociated through the use of heat, supplied in the form of electricity (see

Figure 3.6.1.3). Although relatively simple, this process has not been commercially used tc produce hydrogen mainly because of its cost and its overall low net efficiency (about 36%). One advantage of the system, however, is its versatility due to its flexibility in terms of the natural size of the practical electrolytic cell.

Figure 3.6.1.3 The Electrolysis of Water

Water

Electric Current

Electrolytic Cells

Hydrogen

Oxygen

Heat

D. <u>Closed Cycle Thermochemical Decomposition of Water</u>

By using thermal energy, the need for electricity to generate hydrogen may be eliminated. However this temperature required may be too high and the hydrogen produced may be too small. Through a series of chemical reaction steps, water can be broken into its hydrogen and oxygen constituents. For one or more of the steps in the cycle, very high temperatures would be required and this may be supplied by gas-cooled nuclear reactor and highly concentrated solar radiation.

This process sometimes appear to be more attractive than electrolysis due to its projected net efficiency of 55% being higher than for the former process.

E. <u>Mixed Thermal / Electrolytic Process</u>

Through a combination of thermal and electrolytic processes, the electricity needed to dissociate water may be reduced to two tenths ($^2/_{10}$) that of which would have been consumed in electrolysis. In a series of chemical reactions snown below, hydrogen is produced first through the use of electrolytic processes, and second, by thermochemical reaction.

Electrolysis	$2H_2O + SO_2 \longrightarrow H_2SO_4 + H_2$
Thermal	$2H_2SO_4 \longrightarrow 2H_2O + 2SO_2 + O_2$
Net Reaction	$2H_2O \longrightarrow 2H_2 + O_2$

F. Biophotolysis

Through processes of photosynthesis, it was discovered that hydrogen production was also possible. Solar radiation could provide energy that may excite electrons from a hydrogen donor such as water, and some of these may go to form hydrogen gas.

The mechanisn by which this process works is that solar radiation is absorbed by pigments of plant materials, transmitted to an electron (hydrogen from water), and this electron, through physico-chemical conditions, combines with hydrogen protons to form the gas. This usually occurs at ambient temperatures, due to the presence of biological catalysts.

All the above processes inherently possess respective advantages over one another, and they could only influence ones decision to choose one process from the rest. A summary of these advantages/disadvantages is given in Table 3.6.1.2, and shows that electrolysis presents distinct advantages of being independent on fossil fuels (unlike coal gasification) and being able to operate at temperatures much lower than that of thermochemical cycles. Likewise, it could be intergrated with terrestial solar energy collection systems.

Table 3.6.1.2

Comparison of Hydrogen Production alternatives *

Process	Advantage	Disadvantage
Reformation of thane	Presently the cheapest method	Scant long term potential

		as a source because of limitations on methane supply
Coal Gasification	Cheapest and most secure near-term alternative to methane reformation; abundant coal resources (in some parts of the world).	Ultimate limitation is exhaustion of the coal resource; requires large plant size.
Eletrolysis of Water	Proven reliable technology small unit plant size; need suited to all terrestial solar energy collection approaches; oxygen coproduct, easily separated for possible use and economic credit improves the economics; improvements in efficiency quite likely; can produce hydrogen at high pressures, thereby eliminating the need for costly compression to pipeline pressures.	High cost, lower net energy efficiency, possible resource limitations on catalysts.
Thermochemical decompositions	Potentially most efficient nonfossil processes; not tied to fossil-fuel resources; possibly compatible with high temperature, focused solar collectors.	Not a proven technology; materials problems in containment; complex large unit plant size expected; expected release of harmful chemicals.

Source: . The Hydrogen Energy Economy

Storage/Transmission

There are essentially three methods by which hydrogen may be stored - as a compressed (high pressure) gas, as a liquid, or as a hydride (like metal hydrides).

Compressed hydrogen storage may be useful for small systems but may present problems for large scale utilization as it has a very low energy density. On the other hand, it may appear attractive for areas where suitable reservoirs such as depleted oil or gas wells, exist.

For liquid storage, vacuum or foam-insulated vessels would be needed in order to maintain a temperature below - 423°F. Although this storage system reduce the hydrogen storage volume by a factor of about 850, one should also be aware that large amounts of energy are necessary to liquify hydrogen.

Hydride storage involves combination of hydrogen with metals (or other suitable elements). This may be done by exposing metals or alloys to pressurized hydrogen. The metal hydride formed may then be disassociated through the use of heat energy, after which hydrogen may be liberated. This energy needed to start the decomposition is believed to be 10 - 75% that of the energy content of the hydrogen stored, depending on the metal hydride used. Compared to liquid some hydride systems hold as high density per unit volume.

As regards hydrogen transmission, the most attractive seems to be the use of gas pipelines. However, the volume of energy that could be transmitted would be less than that of natural gas. Hydrogen may also be transported in its liquid and hydride form, through trucks, rails, or freighters.

Applications

Of all hydrogen applications, the most appealing is that of as an air transport fuel. Hydrogen seem to be attractive because of its mass energy density (28, 641 Cal lg) which leads to lighter fuel loads and overall weight savings to aircrafts. With a few simple modifications, existing aircraft engines may be made to operate on hydrogen. Space aircrafts of today utilize hydrogen as one of its primary fuel sources.

In the case of liquid hydrogen it could find use as a convenient fuel for marine vessels. However, it would probably be best suited for shorter range domestic shipping as longer storage time would require much insulation to avoid boil-off.

Hydrogen may also be used for automobiles, trucks or buses, but the widespread use of the fuel is hindered by the on-board storage of hydrogen. It appears today impractical to carry storage tanks in vehicles, not to mention someof the hazards thus created.

Several other applications exist, most of them in areas where electricity is used. At present, however, one would tend to choose electricity from the standpoint of safety, cost and convenience. What is needed most is through research and development efforts that would make hydrogen a variable fuel source.

Environmental Aspects / Limitations / Safety

The first chief disadvantage of hydrogen is its extremely low boiling point (20°C) causing handling problems. When mixed with air, it forms a combustible mixture and at normal temperatures, hydrogen gas heats upon expansion, accompanied with the possibility of ignition. Fuel-air explosion at confined space is thereby possible. However, due to hydrogen's low energy content with respect to volume and its tendency to diffuse rapidly, its explosive potential in open areas is greatly reduced.

The use of hydrogen is expected to have minimal enviromental impacts. As earlier stated, its principal product of combustion is water, and thus creates no significant environmental imbalance. Although combustion may possibly produce nitrogen oxides at high temperatures it could be reduced to negligible levels and may be contained more earily than in hydrocarbon combustion systems.

One major impact of hydrogen utilization on the environment may be that which is associated with hydrogen production and manufacture of related equipment.

On summary, hydrogen may serve as a chemical common demoninator in the energy economy, mainly because hydrogen is derivable from water (a inexhaustible resource), and that it has a close relationship with electricity (as hydrogen is most readily obtained from water by electrolysis and hydrogen can be used to generate electricity). There would thus be a great interchangeability between the above two forms of energy, which may in turn offer quite many opportunities for economic, technological and social benefit.

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3.6.2 TIDAL / WAVE ENERGY

Another potential source of electricity and power may be that which could be derived from the ocean's tidal and wave motions.

Ocean tides refer to the periodic increases and decreases in the surface level of the oceans, which are principally caused by the gravitation exerted by the earth, sun, and moon. The difference between the high - tide levels and the low-tide levels (tidal range) produced may then be used to run turbines.

Waves on the other hand, are created when winds pass across the open waters of the ocean. This would involve the gravitational potential energy of elevated water and the kinetic energy from the forward motion of the waves. This energy that may be extracted from the waves are renewable as it could be rapidly replenished by wind and ocean-surface interaction.

Data Collection

In order to harness the tidal power potential of any ocean site, it is essential that a tidal range sufficient to warrant energy production exists. Tidal ranges may be measured as the difference in height or level between successive high and low waters at a given station. They vary in different locations and may have large values in areas where tidal oscillations are amplified by relatively shallow bays, inlets, or estrearies. The other parameters important in the evaluation of tidal energy potential is the surface area of the tidal basin, and the length of the barrage necessary to enclose the basin. In a tidal cycle, the maximum electrical energy which may be produced will be: $E_{max} = \rho \, g \, R^2 \, S$

Where ρ = sea density, g icm^3

g = gravitational acceleration, cm/sec^2

R = tidal range, cm

S = Surface area, cm^2

ϵ = tidal-to-electrical conversion efficiency

$$\max = \frac{g - cm^2}{sec^2}$$

A suitable tidal power site would usually have a small length-of-barrage to energy-produced ratio.

In the case of wave energy potentials, wave measurements are usually taken. This may be possible through the use of several techniques and instruments, the most direct of which is stereo photogrammetry. This system would involve simultaneously taking stereoscopic photographs of the sea from two points about 5 meters apart (Figure 3.6.2.1).

Figure 3.6.2.1. Measurement by stereophotogrammetry

The positions of every part of the wave's surface is then measured from the two photographs through a process similar to that used for obtaining the contours of the ground from an aerial survey. This process however, has limited usefulness as it entails laborious mentlods of obtaining contours from the photographs, and includes only waves seen by the man inside the camera. Other devices which may be used continously measure the height of the water surface at one fixed point.

Another method which may be utilized is through the use of rivermills where no dam is required but only a vertical axis rotor which would be installed in the oceans in regions where strong tidal streams and currents exist.

Wave energy utilization, on the other hand, still needs further development. Although there are several possible schenes to convert wave motion to electricity, implementation is usually limited by the wide range of amplitudes and frequencies characterzing wave motion. A phototype wave energy extraction device (Scripp's Institution of Oceanography) is given in Figure 3.6.2.4. The system consists of a vertical riser tube, a buoyant float, and a flapper check valve. The buoyant float is made to respond to wave motions. At approximately one half of the wave cycle, the flapper check valve closes, and the water in the vertical riser tube follows the motion of the float. The check valve then opens when the float begins downward motion, and the inertical forces pump water to a greater height than that of the wave. With subsequent wave cycles, the water level of the reservoir is raised higher successively, until an energy head suitable for power generation is attained. This stored water may then be discharged through a turbine generator to produce electrical power.

Figure 3.6.2.4. Small Wave Power Generator

Such instruments may be connected to recorders and a permanent trace of the height of the water surface may be made on a time base.

The power developed from a wave cycle is taken to be the product of the potential energy change and the frequency of gravity waves.

Conversion Processes

Tidal motions, to be converted to electricity, requires relatively simple principles similar to these applied to pumped-water hydroelectricity systems. Techniques usually involve the creation of a single basin made by the closing of the estuary or bay by a barrage (Figure 3.6.2.2). Water would fill the basin in times of rising tides and this would be released when the level of the sea becomes lower than that of the basin.

Figure 3.6.2.2. One-way, Single-basin Tidal Power Installation

Through this, electrical energy is derived from the potential energy of the enclosed water by placing a turbine generator in the power house. Several modifications of this process may be used as in two-way or multi-basin schemes (Figure 3.6.2.3)

Figure 3.4.2.3. Two-way, Single - Basin Tidal Power Installation.

Environmental Effects / Limitations

In general, the ultimate energy potential of both tidal and wave energy is limited by the small number of suitable locations. Good tidal range and wave heights do not occur frequently.

As regards environmental view points, tidal power plant stations do not produce noxious wastes, consume depletable energy, nor produce pollutants. Possible major effects, however, would be the physical and oceanographic changes in the surroundings that such plants could bring about. Flooding and erosion may also be a possibility as well as modifications in the local weather patterns. Marine ecology should thereby be a major factor to consider in future installations. Quite important also would be the effect on the fishing industries. Although this may well be difficult to assess, it should never-the-less be given serious thoughts.

Wave energy, does not seem to have severe environmental impacts. Although a minute cooling of ocean water may result, no chemical pollutants or heat would be added to the atmosphere as a result of the wave energy extraction. One other effect would be the hazard to marine transport that would be caused by wave convertors and possible coastal erosions.

The utilization of both tidal and wave energy generally appear potentially significant. However, a need for further research and developments may still be needed to make tidal and wave technology available for feasible use.

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