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A METHOD FOR FINDING UNKNOWN SIGNALS USING REINFORCEMENT FFT DIFFERENCING

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ABSTRACT

This note addresses a simple yet powerful method of discovering the spectral character of an unknown but intermittent signal buried in a background made up of a distribution of other signals. Knowledge of when the unknown signal is present and when it is not, along with samples of the combined signals for each case is all that is necessary for this method. The method is based on reinforcing Fast Fourier Transform[1] (FFT) power spectra when the signal of interest occurs and subtracting spectra when it does not. Several examples are presented. This method could be used to discover spectral components of unknown chemical species within spectral analysis instruments such as Mass Spectroscopy, Fourier Transform Infrared spectroscopy (FTIR) and Gas Chromatography. In addition, this method can be used to isolate device loading signatures on power transmission lines. The examples shown within this paper are based on deterministic sinusoidal composite signals.

Key words: SAS-STAT, SAS-SYST

INTRODUCTION

Let's start by introducing a simple thought problem: how might one isolate and identify the spectral trace of a recurring chemical species amongst a series of other randomly occurring chemical species. This is akin to isolating a chemical spectral *fingerprint* amongst a plethora of unknown chemical spectral *fingerprints*[2]. Moreover, such chemical *fingerprints* are deterministic signals, however their occurrence or lack there of can be random when samples are obtained from say composite materials such as rock samples. Similarly, one might be interested in identifying the spectral *fingerprint* of a device being powered on and off via a power distribution transmission line along with numerous other devices also being turned on and off at seemingly random occurrences. Once again the start-up/shutdown signal might be primarily deterministic given standard power-on and power-off firmware actions programmed into many devices today.

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The key to both of these problems is that one desires to know what portion of any given composite spectral signal contains our unknown chemical species *fingerprint* or device signature. This unknown signal, in this case the spectral component due to our unknown signal, is a "hidden" signal within the larger composite of many unknown or known signals. In solving this problem, we will only assume that we know when our *fingerprint* exists or does not exist within its sample signal segment. For the example given in Sec. 3 we also constrain the spectral components of the background signals to exist throughout the duration of each sample signal segment (but allow the content of the background signals to change from sample segment to sample segment). The examples given in Secs. 4 and 5 do not have this restriction. Instead background signals are allow start and stop throughout a sample segment, e.g. a particular spectral component might only exist in the first half of a signal sample segment.

This approach will work for any positive statistic, e.g., periodogram, magnitude of Fourier Transform, or a wavelet decomposition. In our efforts, we will consider the following positive statisitics: the power spectra developed from the squared magnitude of a FFT signal segment, and the square-windowed periodogram of a signal segment.

REINFORCEMENT DIFFERENCING

The method entails estimation of a power spectrum of an unknown signal by differencing the power spectra of combinations of signals with and without the unknown signal of interest. It is this combination that is used to reinforce/isolate the power spectral contributions of the of the unknown signal while reducing the contributions of the undesired signals, i.e. the clutter. This is done simply by subtracting the power spectra of the samples without the unknown signal from the sum formed by adding the power spectra of the samples containing the unknown signal. We only assume a priori knowledge of when the unknown signal signal is present and when it is not present within the power spectra being used. In practice, this knowledge might be gained by noting when an unknown chemical substance is contained within a process by a change in the substance's color or it's chemical reactivity.

This process can be stated as an average difference of a positive statistics, e.g. the power spectra, with and without the unknown signal, i.e. the statistic, PS_{full}, can be estimated as follows:

$$PS_{full} = \frac{1}{N}\left(\sum_{i=1}^{N} PS_i - \sum_{j=1}^{M} \overline{PS}_j\right), \tag{1}$$

where the PS_i's are positive statistics of signal segments containing the desired representation of the signal (*the composite*), and $\overline{PS_j}$'s are the same positive statistics not containing the signal (*the background*). Moreover, N is the number of samples containing the desired representation of the signal, i.e. its *fingerprint*, and M the number of samples without it. It should be noted that N need not equal M, although the effectiveness of this method degrades as they grow apart from each other. As a clarification, both the *composite* and *background* segments are made up of background signals that start and ended throughout each sample

segment. Nevertheless, we will consider both cases when the background spectra durations are constant across each sample segment as well as when they are allowed to vary across a sample segment. When allowed to vary, background signals need not exist across the full segment, only during some portion of its duration. Our work does not fully investigate the limits of how short a duration is feasible, but it appears that a 50% duration does not create any issues for this method within our studies to date. In this work, we did not consider limiting the duration of the unknown signal of interest's *support* across a sample segment, i.e. it exists across the entire duration of the sample.

In our examples, we choose the positive statistics to be the power spectra of numerous combined signals, both with and without our signal of interest. The power spectra calculated in Secs. 3, 4 and 5 clearly show the spectral characteristics of the unknown, intermittent signal. In this paper, we use two similar statistics for *PS*'s, a standard, square-windowed periodogram and the square magnitude of the Fourier transform. Eqs. (2) and (3) show how the latter is calculated.

$$PS_i = \left(\left|FFT\left(sample\ of\ composite_i\right)\right|\right)^2, \quad i = 1 \ldots N \tag{2}$$

$$\overline{PS_j} = \left(\left|FFT\left(sample\ of\ background_j\right)\right|\right)^2, \quad j = 1 \ldots M \tag{3}$$

A SIMPLE EXAMPLE

Given a composite signal containing many individual components, the method we propose can isolate and identify an itermittent but unknown component of that signal given a composite of signal samples of when the unknown signal is present and when it is not. Fig. 1 shows an example composite signal in question as the sum of the unknown signal and a multi-spectral background signal.

The unknown signal in this demonstration (Fig. 1, middle frame) shows an harmonic sum with random phases and amplitudes. It will be added to the background signal at intervals and then the method of reinforcement differencing will be applied to the composite signal to ascertain the power spectrum of the unknown signal.

The top frames of Fig. 2 show the power spectra of the unknown signal determined as described by Eq. (1). The Periodogram-based results in Fig. 2 (b) were derived by using a standard, square-windowed periodogram for *PS* and $\overline{PS}$. The FFT-based results in Fig. 2 (a) were obtained by using the square magnitude of the FFT, (|*FFT*|)2, for *PS* and $\overline{PS}$.

For comparison, the middle frames of Fig. 2 show the power spectra derived directly from the unknown signal in Fig. 1 before being combined with the background signal. The bottom frames show the power spectra from the combined unknown and background signals. The small peaks in the top frames of Fig. 2 are a result of the algorithm's amplification of high-frequency noise, but are negligible when compared with the large peaks representing the signal. This noise is believed to be largely due to computational roundoff and spectral bleed occurring within the computational process. Additional, work remains on

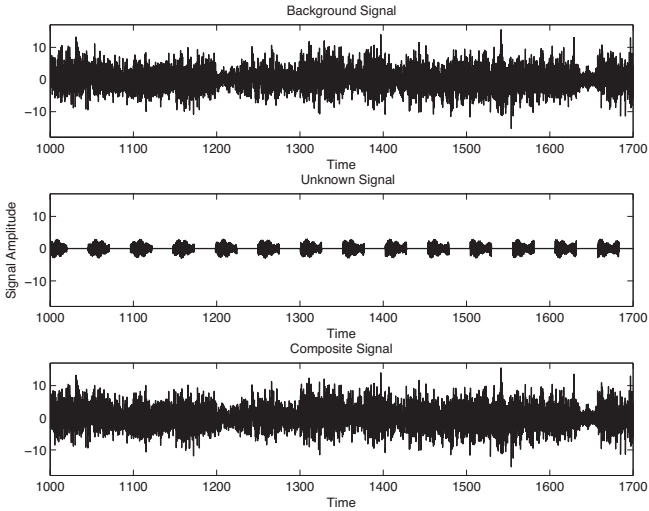


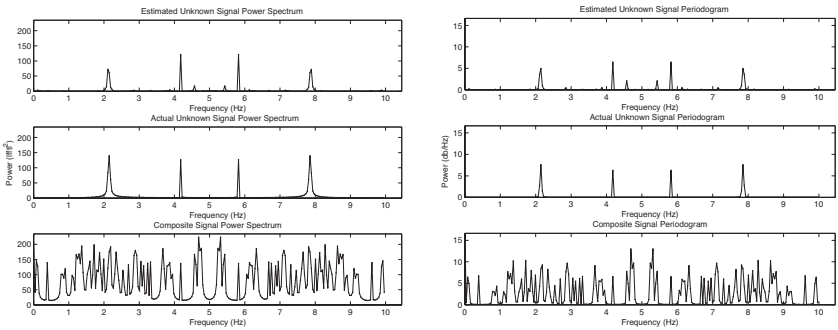
Fig. 1. The background signal (top) is combined with the unknown signal (middle) to produce the total or composite signal (bottom). The method of reinforcement differencing will be applied to the composite signal to identify spectral properties of the unknown signal. For the sake of clarity, this figure show only a small, representative portion of the actual signals used in the calculation.

improving the noise artifacts shown in Fig. 2. Nevertheless, the current method remains is very useful.

MORE COMPLEX MIXING

In this section we apply the reinforcement method to a variation on the theme of the previous example. Instead of keeping the a constant background signal with timeinvariant spectral components throughout each sample (while allowing it to change from sample set to sample set), we allow the spectral components to change midway through each sample set. Fig. 3 is a close-up of a particular sample showing the change in the background signal at the midpoint. The sample is namely, the sum of the unknown signal and the two partially time-invariant signals (i.e. each background signal being time-invariant over each half of the sample period).

Fig. 4 compares the power spectra estimation of the unknown signal in this new, changing background just as in Fig. 2. The top frames of each figure show the power spectra of the unknown signal determined by the method of reinforcement differencing, while the middle frames show the power spectra calculated directly from the unknown signal. The bottom frames show the power spectra of background and unknown signals combined.



(a) FFT-based method (b) Periodogram-based method

Fig. 2. The power spectra calculated using the method of reinforcement differencing (top frames) are compared with the power spectra calculated directly from the unknown signal (middle frames). The power spectra of the background and unknown signal combined are shown in the bottom frames. The spectra in (a) were generated via square magnitude of sample FFT's, and those in (b) by using a square-windowed periodogram. The estimated frequencies in (a) and (b) are within 2% of the real frequency of the unknown signal.

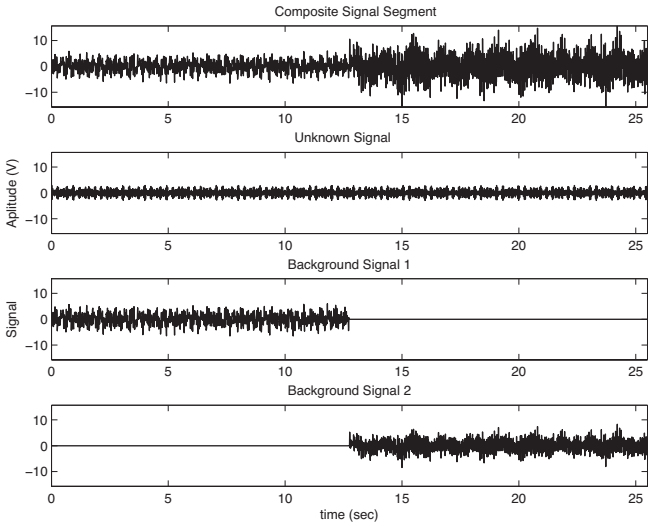
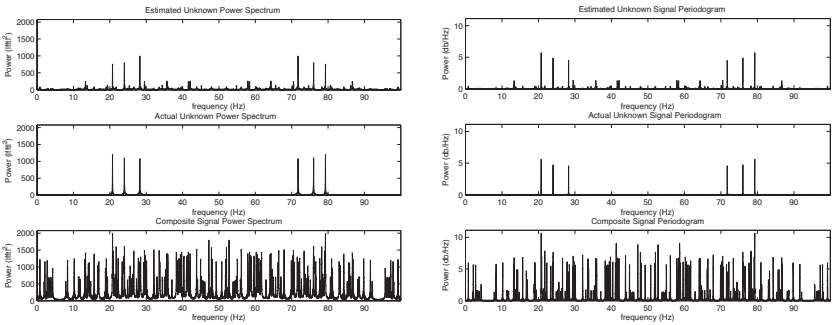


Fig. 3. Details of a single representative sample in which the background signal has been allowed to change from one set of component signals to another set of component signals. These two sets are constant in this sample, but are allowed to be different than those in all other samples. The two different background signals are shown in the bottom two frames while the unknown signal and the sum of all three are showed in the top two.



(a) FFT-based method (b) Periodogram-based method

Fig. 4. The power spectra calculated using the method of reinforcement differencing (top frames) are compared with the power spectra calculated directly from the unknown signal (middle frames). The power spectra of the background and unknown signal combined are shown in the bottom frames. The spectra in (a) were generated via square magnitude of sample FFT's, and those in (b) by using a square-windowed periodogram. The estimated frequencies in (a) and (b) are within 2% of the real unknown signal frequency.

APPLICATION TO POWER SYSTEMS MONITORING

As a final example of the method of reinforcement differencing, we apply it to the problem of non-intrusive load monitoring[3]. Specifically, our method is applied to the contrived problem of detecting a circuit fault in a power distribution system.

In this example, we create a series of random signals to represent the electrical current usage signal at the input to a residence as measured at the main power feed. Then we simulate a circuit breaker failure by adding an additional intermittent signal to the composite household signal and use reinforcement differencing to isolate and determine the power spectrum of the failure signal.

Once we have obtained the signal *fingerprint* on the main power system input, we could develop a detection system to diagnose this type of failure within a house. An additional application of this process is for monitoring of a machine's activation within a large plant so that appropriate compensation steps might be taken to load balance the overall real and imaginary power loads within the plant by starting up an additional compensating machine.

We begin by simulating a background signal by summing several distinct power signatures. Each component of the background signal could be thought of as a time trace of the current drawn by a certain device or appliance as measured at the home's main power feed. For example, the signals shown in Fig. 5 might be representative of the current drawn by an incandescent light bulb, a kitchen toaster oven, a microwave oven, a garage door opener, etc., on a typical school morning in suburbia. In our case however, these are just random signals generated for the purpose of illustration and are not actual signals from real devices.

Each of the different appliances has a distinctive *fingerprint* determined by the physical properties of the respective systems. However, when the signals are mixed together, it becomes difficult to distinguish one from the others, and seemingly impossible to detect any unusual behavior in the system.

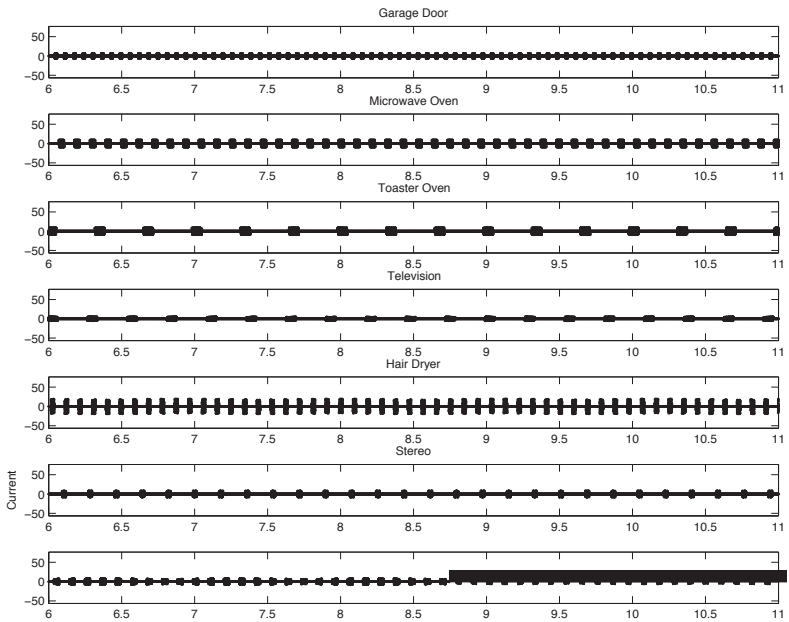


Fig. 5. Individual current load signatures from a number of household appliances and devices with the unknown signal and total current shown on the bottom. These signatures are contrived for use in this example.

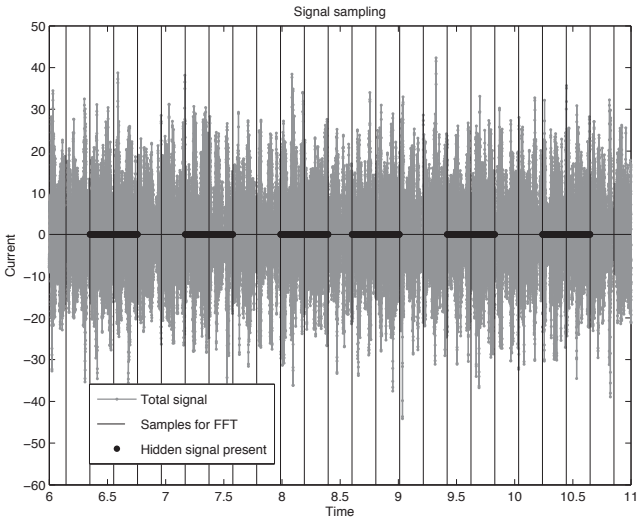
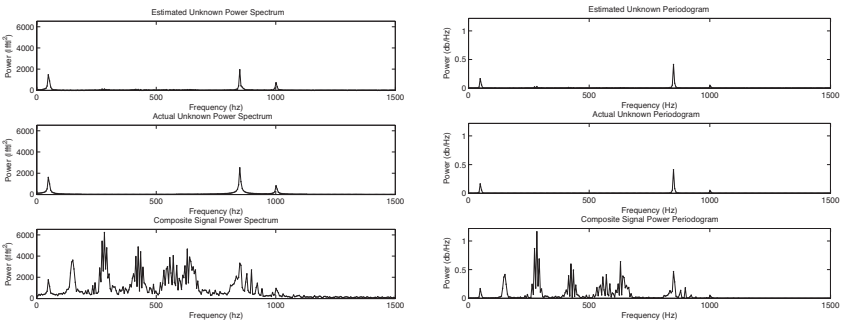


Fig. 6. The method of reinforcement differencing divides the entire load signal into samples (shown by vertical black lines). FFTs of samples containing the unknown signal (black dots) are added to the total whereas those not containing the unknown signal are subtracted.



(a) FFT-based method (b) Periodogram-based method

Fig. 7. The power spectra calculated using the method of reinforcement differencing (top frames) are compared with the power spectra calculated directly from the unknown signal (middle frames). The power spectra of the background and unknown signal combined are shown in the bottom frames. The spectra in (a) were generated via square magnitude of sample FFT's, and those in (b) by using a square-windowed periodogram. The estimated frequencies in (a) and (b) are within 2% of the real unknown signal frequency.

For this example, a *priori* knowledge of circuit fault occurrences is assumed. Fig. 6 shows the time periods when the "unknown" signal was present (when the arcing occured), and it denotes sampling of the signal used in calculation the FFTs. Fig. 7 compares the power spectra determined by reinforcement differencing (top frames) with the power spectra computed directly from the unknown signal (middle frames). The bottom frames show the power spectra of the combined background and unknown signals. Fig. 7 also compares results of the reinforcement differencing method using power spectra based on the square magnitude of the FFT, $(|FFT|)2$, with those based on a square-windowed periodogram.

This example is more complicated than the previous examples because the background signal is the sum of many other non-stationary signals whose starting and ending points often occur within the sample used to calculate the FFT. Also, unlike actual data from chemical spectral analysis or power system load records, the various constituent signals used in the preceding examples are not continuous at their endpoints.

CONCLUSIONS

We have presented a method for ascertaining spectral information for an unknown signal which is intermittently present in a composite of many other signals. This method of reinforcement differencing identifies spectral content to within two percent in the examples shown in this paper, but gives only a qualitative indication of spectral power of the unknown signal. Future work will address accuracy in calculating the spectral power of the unknown signal as well as the tendency of this algorithm to amplify high-frequency noise. Results of the application of this method to chemical spectral analysis will also be presented.

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REFERENCES

[1] John G. Proakis and Dimitris G. Manolakis, *Digital Signal Processing Principles, Algorithms, and Applications*, Macmillan Publishing Company, 866 Third Avenue, New York, New York 10022, 2nd edition, 1992.

[2] J.Michelle Kotler, NancyW. Hinman, Beizhan Yan, Daphne L. Stoner, and Jill R. Scott, "Glycine identification in natural jarosites using laser desorption fourier transform mass spectrometry: Implications for the search for life on mars," *Astrobiology*, vol. 8, no. 2, pp. 253–266, April 2008.

[3] C. Laughman, Kwangduk Lee, R. Cox, S. Shaw, S. Leeb, L. Norford, and P. Armstrong, "Power signature analysis," *Power and Energy Magazine*, IEEE, vol. 1, no. 2, pp. 56–63, Mar-Apr 2003.

DISTRIBUTION OF *PASTEURELLA TREHALOSI* GENOTYPES ISOLATED FROM BIGHORN SHEEP IN WATERTON- GLACIER INTERNATIONAL PEACE PARK

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ABSTRACT

We studied the distribution of *Pasteurella trehalosi* genotypes isolated from oropharyngeal tissues of Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) in Waterton Lakes National Park, Alberta, Canada and Glacier National Park, Montana, USA. A separate radio-telemetry study indicated the bighorn metapopulation consisted of at least three neighborhoods of multiple ewe and ram social groups, with varying degrees of interchange among them. Genetic analysis using random amplified polymorphic DNA from 25 *P. trehalosi* isolates revealed three major genotypes. Our predictions were that genetic relatedness would be greatest among organisms collected in the same neighborhood, and that those collected from adjacent neighborhoods would show greater relatedness than those from distant or isolated neighborhoods. Results did not fully support these predictions. Nonetheless, the spatial distribution of *P. trehalosi* genotypes did vary with the observed neighborhood structure. Two of three genotypes occurred throughout the study area, but the third was found only in Waterton Lakes National Park. Because *P. trehalosi* is believed to be transmitted only via direct contact between individual sheep, this suggests the north Glacier neighborhood was further partitioned into two subpopulations. Overall, our results show the utility of using DNA from pathogens to elucidate the spatial structure of host populations.

Key words: *Bibersteinia trehalosi*, Glacier National Park, metapopulation, *Ovis canadensis canadensis*, *Pasteurella trehalosi*, Rocky Mountain bighorn sheep

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INTRODUCTION

Bacteria in the family Pasteurellaceae act as opportunistic pathogens in the upper respiratory tract of wild and domestic ruminants, and are the most commonly identified infectious agents for respiratory diseases in bighorn sheep (Jaworski et al. 1998, Rudolph et al. 2003, Weiser et al. 2003). Viral and mycoplasma infections, poor nutrition, overcrowding, and stress are some of the factors associated with reduced physical and immunologic defenses which permit these commensal organisms to invade the lower respiratory tract and cause respiratory disease (Monello et al. 2001, Rudolph et al. 2007).

Most Pasteurellaceae isolates have been characterized by serotype and biotype (Kilian and Frederiksen 1981). More recently, DNA profiling has proven effective in discriminating isolates from domestic and wild ruminants (Chaslus-Dancla et al. 1996, Jaworski et al. 1993, Rudolph et al. 2003, Weiser et al. 2003). Isolates from domestic and bighorn sheep have been characterized using phenotypic and genotypic traits to determine whether *Pasteurella* organisms carried by one animal are the same as those carried by others (Ward et al. 1997). Random amplified polymorphic DNA (RAPD) assays are useful in distinguishing among strains belonging to the same species and have been shown to yield the same results as ribotyping patterns of *Pasteurella* (*Mannheimia*) *haemolytica* strains (Chaslus-Dancla et al. 1996). Although RAPD results are sometimes less discriminative than pulsed-field gel electrophoresis, RAPD is less costly and laborious and often yields highly discriminatory results (Katsuda et al. 2003). Genetic markers produced by the RAPD assay have been preferred to DNA fingerprinting because the analysis of patterns is much simpler than the analysis of the complex number of bands generated by restriction endonuclease fingerprinting of total cellular DNA (Myers et al. 1993).

We used RAPD assays to identify different strains of *Pasteurella trehalosi* type 2 non-hemolytic (hereafter referenced simply as *P. trehalosi*) from Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) in Waterton Lakes National Park (WLNP), Alberta, and Glacier National Park (GNP), Montana. We consider whether different strains show evidence of spatial clustering, and whether those clusters are coincident with bighorn subpopulations identified in earlier studies. Since isolating these strains, the genus name for *P. trehalosi* was changed to *Bibersteinia* (Blackall et al. 2007); however, we retain the name in effect at the time of isolation. A separate radio-telemetry study showed a metapopulation partitioned into several neighborhoods, each comprised of multiple ewe and ram social groups (Keating unpublished data). The telemetry data, together with studies of bighorn sheep DNA (Luikart et al. 2008) and incidence of the pathogen *Anaplasma ovis* (de la Fuente et al. 2007), also suggest varying degrees of interchange among neighborhoods. At least three neighborhoods were identified by these earlier studies: GNP north of St. Mary Lake (NGNP), GNP south of St. Mary Lake (SGNP), and WLNP west of Waterton Lakes (WWLNP) (Fig. 1). In this study we test the general hypothesis that relatedness of *P. trehalosi* corresponds to this neighborhood structure. Specifically, we test two hypotheses: (1) relatedness is greater among samples collected in the same neighborhood, and (2) samples collected from closely connected neighborhoods show greater relatedness than samples collected from distant or isolated neighborhoods. According to our second prediction, *P. trehalosi* collected from WWLNP and NGNP should be genetically more similar than samples collected from NGNP

and SGNP, and samples from WWLNP and SGNP should show the greatest inter-neighborhood difference.

STUDY AREA

Encompassing 408,031 ha, GNP straddles Montana's Continental Divide immediately south of the US-Canada border, while the adjacent WLNP (49,856 ha) is located in the extreme southwest corner of Alberta (Fig. 1). Within these sister parks, bighorn sheep typically occupy steep, rocky habitats in or near patches of the polar and high montane vegetation class (Keating unpublished

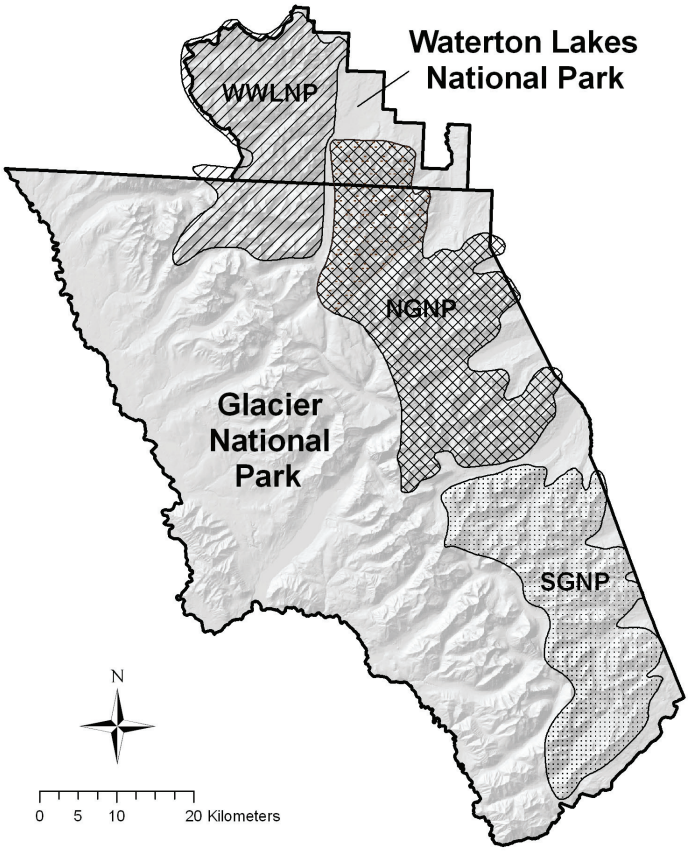

Fig. 1. Map of study area, showing the west Waterton Lakes National Park (WWLNP), north Glacier National Park (NGNP), and south Glacier National Park (SGNP) neighborhoods postulated for the Waterton-Glacier bighorn sheep metapopulation, based on radio telemetry data collected prior to this study. Boundaries for the WWLNP, NGNP, and SGNP neighborhoods were initially estimated based on 142,190 relocations of 7, 56, and 25 radio-collared individuals, respectively.

data). Bighorn sheep habitat also generally occurs along or east of the Continental Divide, where drier conditions and relatively high winds maintain accessible winter ranges. Remnant glaciers, although melting rapidly (Key et al. 2002), are scattered throughout both parks; vestiges of once-extensive valley glaciers that shaped much of the current topography. In turn, this topography is an important factor shaping the contemporary structure of the area's bighorn sheep metapopulation.

METHODS

During 2002–2006, 99 bighorn sheep (49 males, 50 females) were immobilized according to ground darting (GNP) and helicopter net-gunning (WLNP) protocols approved by an Animal Care and Use Committee. All animals were fit with Telonics model 3500 radio collars equipped with global positioning systems (GPSs) and CR-2A programmable release mechanisms (Telonics, Inc., Mesa, AZ, USA), and programmed to record their location once every five hours for about one year. Our initial estimate of the spatial structure of the Waterton-Glacier bighorn metapopulation was inferred from the telemetry data by first assigning each collared animal to a unique social group. Clear separation in annual ranges of the groups made unambiguous assignments possible, except for a very few adolescent (3- to 4-year-old) males who exhibited exploratory behavior, a single yearling ewe whose movements may have been influenced by unique circumstances associated with the Waterton town site in WLNP, and a single adult ewe who crossed the Waterton Valley to access a salt lick during early summer. Neighborhood-level spatial structure was inferred from telemetry-based evidence of regular contact with or interchange between adjacent social groups. In addition, initial descriptions of neighborhood structure also considered evidence of interchange implicit in differing incidences of the pathogen *Anaplasma ovis* (de la Fuente et al. 2007) and in the genetics of the sheep themselves (Luikart et al. 2008). Our initial estimate of metapopulation spatial structure is depicted in Fig. 1, which was constructed by circumscribing the GPS locations for all individuals assigned to social groups comprising the identified neighborhoods. This initial estimate was believed to be conservative, in the sense that divisions between identified neighborhoods were deemed reliable, but further subdivisions of those neighborhoods could not be ruled out.

Using polyester tipped swabs, oropharyngeal samples were collected from captured animals and placed in 11 ml BBL™ Port-a-Cul™ tubes (Becton, Dickinson and Company, Sparks, Maryland, USA). The tubes were then insulated, placed on ice packs, and shipped to the Caine Veterinary Teaching Center, Caldwell, Idaho, USA within 72 hr (Wild and Miller 1994). We examined 25 of the 31 samples that subsequently tested positive for *Pasteurella trehalosi* type 2 non-hemolytic, which was the most commonly observed species and type of *Pasteurella* in our samples.

We isolated DNA according to directions supplied with the Generation capture column kit (Gentra Systems, Minneapolis, MN) and quantified using Hoechst 33258 fluorometry (Labarca and Paigen 1980). Ten ng of DNA were amplified in each reaction. A RAPD DNA analysis PCR (GE Healthcare, Piscataway, NJ 08855) was conducted for DNA amplification of oligonucleotide sequences. The primer used for PCR amplification was the RAPD analysis primer 5 (5'-d[AACGCGCAAC]-3'). The first cycle of PCR was denaturing at 95° C (5 min), followed by 45 cycles of amplification, each including denaturing at 95° C (1

min), annealing at 36° C (1 min) followed by one final extension at 72° C (2 min).

Banding patterns of the amplified DNA were visualized on 20 cm 1.5% agarose gels in ½ x TBE buffer, and stained with ethidium bromide following electrophoresis at 120 v, 85 mA, for 2½ hr. Banding patterns were analyzed using the BioRad Gel Doc apparatus and Quantity One software program (Bio-Rad Laboratories, Hercules, CA 94547) according to manufacturer's instructions. Similarity coefficients (SC) were calculated by Quantity One, and the dendrogram (Fig. 2) was created using the complete linkage algorithm.

In addition to examining genotypes, we compared incidences of occurrence of *P. trehalosi* among the neighborhoods comprising the bighorn metapopulation in our study area. For each neighborhood we calculated incidence as the proportion of samples testing positive for *P. trehalosi*. For each proportion, we calculated 95% confidence bounds using the Clopper-Pearson equations, as per Johnson et al. (1993:129–130). Two proportions were considered significantly different if their 95% confidence bounds did not overlap. When evaluating incidence, data for the WWLNP and east Waterton Lakes National Park (EWLNP, identified below) neighborhoods were combined due to small sample sizes and similarly high and statistically indistinguishable infection rates between the two areas.

To show implications of our results, we redrew Fig. 1. Evidence of restricted interchange between the northern and southern portions of the NGNP

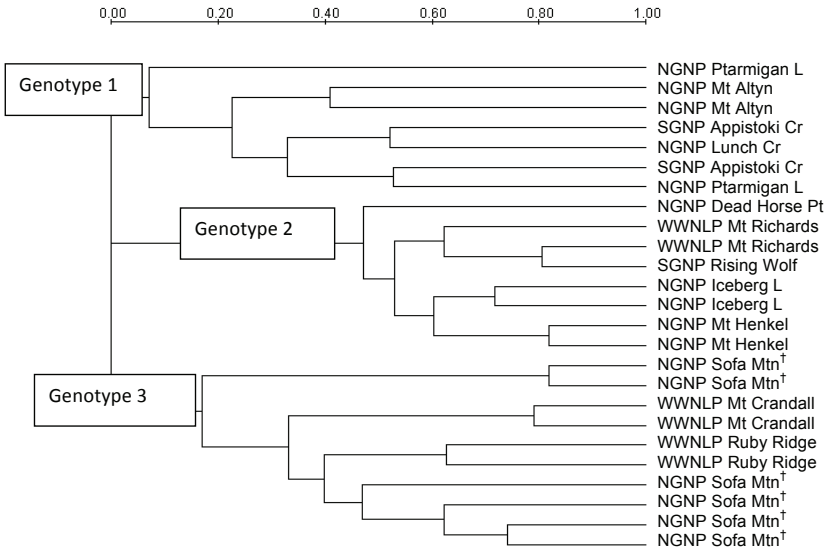

Fig. 2. Dendrogram showing clustering of *Pasteurella trehalosi* genotypes according to genetic similarity. † Indicates areas redesignated as East WLNP based upon the results from this study.

neighborhood (see below) was used to further partition animal social groups in this region, distinguishing an EWLNP neighborhood from the rest of the NGNP neighborhood. When interpreting our data, we assumed *P. trehalosi* is transmitted only via direct contact between individual sheep; i.e., that differences in the distributions of *P. trehalosi* genotypes indicate differences in the degree of interchange among animals belonging to different neighborhoods. As we did for Fig. 1, our revised estimate of metapopulation structure (Fig. 3) was constructed by circumscribing GPS locations for all individuals assigned to social groups

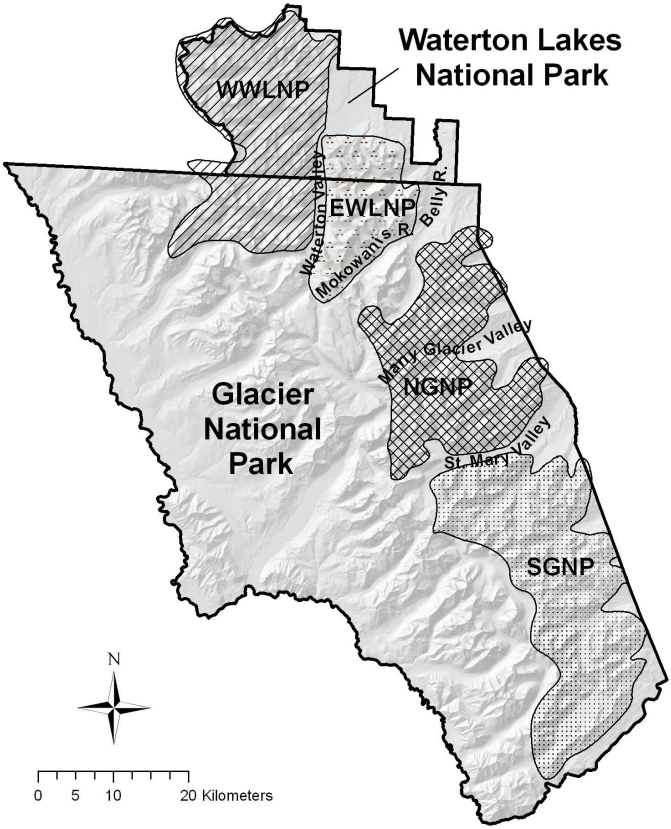

Fig. 3. Map of study area, showing the west Waterton Lakes National Park (WWLNP), east Waterton Lakes National Park (EWLNP), north Glacier National Park (NGNP), and south Glacier National Park (SGNP) neighborhoods postulated for the Waterton-Glacier bighorn sheep metapopulation. Neighborhoods boundaries were estimated from 142,190 relocations of 7, 6, 50, and 25 radio-collared individuals, respectively, from the four areas. The EWLNP and NGNP areas were separated based on 2 additional lines of evidence: (1) movements of the 12 individuals carrying *P. trehalosi* genotype 3 were confined to WWLNP and EWLNP, and (2) observed interchange between EWLNP and NGNP was limited to adolescent males and was, thus, attributable to exploratory behavior.

comprising the neighborhoods identified. Again, we believe this structuring provided a conservative estimate of the number of neighborhoods, in the sense that additional information or analyses might lead to further subdivision of the neighborhoods described thus far.

RESULTS

Banding pattern analysis, as described above, identified three major clusters of genotypes (Fig. 2). Each showed a variety of similarity coefficient (SC) values: genotype 1 ranged from 7% to 53%, genotype 2 ranged from 48% to 82%, and genotype 3 ranged from 17% to 82%. Each genotype included related groups. There were two major related groups in genotype 1: one contained two isolates from Mt. Altyn (NGNP) with a SC of 41%, and the other had a SC of 33% and contained isolates from Lunch Creek and Ptarmigan Lake (NGNP), and two isolates from Appistoki Creek (SGNP). There was one outlying isolate from Ptarmigan Lake. Genotype 2 also contained two major groups of related genotypes. Group 1 had a SC of 62% and included two isolates from Mt. Richards (WWNLP) and one from Rising Wolf (SGNP). The four isolates in group 2 were all from NGNP. The two isolates with a SC of 82% were from Mt. Henkel (NGNP), while the other two from nearby Iceberg Lake (NGNP) had a SC of 72%. There was one outlying isolate from Deadhorse Point (NGNP). Genotype 3 contained one large major group with a SC of 33%. This group contained two isolates from Mt Crandall (WWLNP) with a SC of 79%, two from the adjacent Ruby Ridge (WWNLP) with a SC of 63%, and four from Sofa Mountain (NGNP). Two isolates outlying the major group had a SC of 82% and were from Sofa Mountain (NGNP).

In addition to differences in the distributions of the three genotypes, we observed differences in the incidence of *P. trehalosi* among neighborhoods. Data for the combined WWLNP and EWLNP neighborhoods showed an incidence of 0.846 (n = 13, 95% CI = 0.545–0.981) and nearly all isolates were of genotype 3. Estimated incidences for NGNP and SGNP were 0.567 (n = 30, 95% CI = 0.374–0.745) and 0.167 (n = 18, 95% CI = 0.036–0.414), respectively. Thus, we conclude that the incidence of *P. trehalosi* was significantly lower in SGNP than in the combined WWLNP and EWLNP areas. Incidence in NGNP, although statistically indistinguishable at the $\alpha = 0.05$ level from areas to the north or south, was intermediate in value.

DISCUSSION

We identified three distinct genotypes of *P. trehalosi* among the 25 samples examined from bighorns in GNP and WLNP. The spatial distribution of these types conformed partially, but not entirely, to our predictions. We predicted, first, that relatedness would be greater among samples collected in the same neighborhoods identified by GPS radio-telemetry data, and second, that samples from close neighborhoods would show greater relatedness than samples from more distant neighborhoods. Contrary to both predictions, genotype 1 was well distributed among samples taken from the SGNP neighborhood and the NGNP neighborhood as far north as Many Glacier. Moreover, within the type 1 branch of the dendrogram, the greatest similarity was often not between samples isolated from animals belonging to the same or adjacent social groups. We note, however, that relatedness among samples in this branch was generally lower than for the type 2 or 3 branches of the dendrogram.

Among eight isolates obtained from the seven animals carrying *P. trehalosi* genotype 2, those from four ewes from the Iceberg-Ptarmigan social group in the Many Glacier area showed the high degree of relatedness expected for animals sharing the same home range. However, the remaining three animals (four isolates) were spread among SGNP, NGNP, and WWLNP, and relatedness was uncorrelated with geographic location.

In contrast to genotypes 1 and 2, the geographic distribution of animals with *P. trehalosi* genotype 3 showed an unambiguous pattern, with all 10 isolates coming from animals captured in WLNP. Indeed, 10 of 12 *P. trehalosi* isolates obtained from WLNP animals were genotype 3. The remaining two isolates (genotype 2) were collected from a single 4.8 year-old ram. Two isolates were selected from this one animal because, while they were biochemically the same, one showed a slightly faster growth rate. Because telemetry data from this study suggest that 3.5–5.5 year-old rams are most likely to engage in long-distance exploratory movements, it is possible that this ram (captured west of Upper Waterton Lake on Mt. Richards) may have come from populations farther south, where genotype 2 was more commonly observed. Regardless of this animal's origin, however, no genotype 3 isolate was collected from any animal captured in GNP. Together with telemetry data that show only limited movement across the Waterton Valley, this points to the existence of a fourth, previously unidentified neighborhood that is distinct from the rest of NGNP, and which we denote as East WLNP (EWLNP, Fig. 3) to indicate the areas of GNP and WLNP north of the Belly and Mokowanis Rivers and east of the Waterton Valley.

Our results underscore the value of using multiple, disparate sources of information to characterize metapopulation structure. Earlier studies using the same GPS telemetry data used here, information about bighorn sheep DNA (Luikart et al. 2008, Keating unpublished data), and incidence of the pathogen *Anaplasma ovis* (de la Fuente et al. 2007), suggest that bighorns in the SGNP neighborhood form a distinct subpopulation from those farther north. By studying the geographic distribution of animals carrying different genotypes of the relatively common and benign pathogen *P. trehalosi* type 2 non-hemolytic, we contribute to this picture by identifying a new neighborhood (EWLNP) that exhibits a previously unsuspected degree of isolation from bighorns occupying the Many Glacier area immediately to the south. We also further confirm the results of those earlier studies by showing that, like *Anaplasma ovis* (de la Fuente et al. 2007), incidence of *P. trehalosi* varies significantly between the southernmost and northernmost parts of our study area.

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LITERATURE CITED

Blackall, P. J., A. M. Bojesen, H. Christensen, and M. Bisgaard. 2007. Reclassification of [*Pasteurella*] *trehalosi* as *Bibersteinia trehalosi* gen. nov., comb. nov. International Journal of Systematic and Evolutionary Microbiology 57:666–674.

Chaslus-Dancla, E., M. C. Lesage-Descauses, S. Leroy-Setrin, J. L. Martel, P. Coudert, and J. Lafont. 1996. Validation of random amplified polymorphic DNA assays by ribotyping as tools for epidemiological surveys of *Pasteurella* from animals. Veterinary Microbiology 52:91–102.

de la Fuente, J., M. W. Atkinson, V. Naranjo, I. G. Fernández de Mera, A. J. Mangold, K. A. Keating, K. M. Kocan. 2007. Sequence analysis of the *msp4* gene of *Anaplasma ovis* strains. Veterinary Microbiology 119:375–381.

Jaworski, M. D., A. C. S. Ward, D. L. Hunter, and I. V. Wesley. 1993. Use of DNA analysis of *Pasteurella haemolytica* biotype T isolates to monitor transmission in bighorn sheep (*Ovis canadensis canadensis*). Journal of Clinical Microbiology 31:831-835.

Jaworski, M. D., D. L. Hunter, and A. C. S. Ward. 1998. Biovariants of isolates of *Pasteurella* from domestic and wild ruminants. Journal of Veterinary Diagnostic Investigation 10:49-55.

Johnson, N. L., S. Kotz, and A. W. Kemp. 1993. Univariate discrete distributions. Second edition. John Wiley & Sons, New York, New York, USA.

Katsuda, K., M. Kohmoto, K. Kawashima, H. Tsunemitsu, T. Tsuboi, and M. Eguchi. 2003. Molecular typing of *Mannheimia (Pasteurella) haemolytica* serotype A1 isolates from cattle in Japan. Epidemiology and Infection 131:939–946.

Key, C. H., D. B. Fagre, and R. K. Menicke. 2002. Glacier retreat in Glacier National Park, Montana. *In* R. S. Williams, Jr., and J. G. Ferrigno, (editors), Satellite image atlas of glaciers of the world, glaciers of North America - glaciers of the western United States. U.S. Geological Survey Professional Paper 1386-J-2. U. S. Government Printing Office, Washington, D. C., Pp. J365–J381.

Kilian, M., and W. Frederiksen. 1981. Identification tables for the *Haemophilus-Pasteurella-Actinobacillus* group. *In* M. Kilian, W. Frederiksen, and E. Biberstein, (editors), *Haemophilus, Pasteurella,* and *Actinobacillus*. Academic Press, San Francisco, California, Pp. 281-287.

Labarca, C., and K. Paigen. 1980. A simple, rapid, and sensitive DNA assay procedure. Analytical Biochemistry 102:344–352.

Luikart, G., S. Zundel, D. Rioux, C. Miquel, K. A. Keating, J. T. Hogg, B. Steele, K. Foresman, and P. Taberlet. 2008. Low genotyping error rates and non-invasive sampling in bighorn sheep. Journal of Wildlife Management 72:299–304.

Monello, R. J., D. L. Murray, and E. F. Cassirer. 2001. Ecological correlates of pneumonia epizootics in bighorn sheep herds. Canadian Journal of Zoology 79:1423–1432.

Myers, L. E., S. V. P. S. Silva, J. D. Procunier, and P. B. Little. 1993. Genomic fingerprinting of "*Haemophilus somnus*" isolates by using a random-amplified polymorphic DNA assay. Journal of Clinical Microbiology 31:512–517.

Rudolph, K. M., D. L. Hunter, R. B., W. J. Foreyt, E. F. Cassirer, R. B. Rimler, and A. C. S. Ward. 2003. Sharing of *Pasteurella* spp. between free-ranging bighorn sheep and feral goats. Journal of Wildlife Diseases 39:897-903.

Rudolph, K. M., D. L. Hunter, R. B. Rimler, E. F. Cassirer, W. J. Foreyt, W. J. DeLong, G. C. Weiser, and A. C. S. Ward. 2007. Microorganisms associated with a pneumonic epizootic in Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*). Journal of Zoo and Wildlife Medicine 38:548-558.

Ward, A. C. S., D. L. Hunter, M. D. Jaworski, P. J. Benolkin, M. P. Dobel, J. B. Jeffress, and G. A. Tanner. 1997. *Pasteurella* spp. in sympatric bighorn and domestic sheep. Journal of Wildlife Diseases 33:544–557.

Weiser, G. C., W. J. DeLong, J. L. Paz, B. Shafii, W. J. Price, and A. C. S. Ward. 2003. Characterization of *Pasteurella multocida* associated with pneumonia in bighorn sheep. Journal of Wildlife Diseases 39:536–544.

Wild, M. A., and M. W. Miller. 1994. Effects of modified Cary and Blair medium on recovery of nonhemolytic *Pasteurella haemolytica* from Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) pharyngeal swabs. Journal of Wildlife Diseases 30:16–19.

THE FUTURE OF HYDROGEN IN IDAHO—AN OVERVIEW

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ABSTRACT

The utilization of hydrogen energy in the global context is discussed with attention to the roles of Idaho's research universities and the Idaho National Laboratory (INL) in various aspects of the hydrogen economy. Recent developments in hydrogen production, the life cycle assessment of hydrogen technologies and properties of hydrogen are briefly described. The educational activities undertaken by the University of Idaho and Idaho State University are also described. Future activities in both research and education arenas are identified.

Key Words: Hydrogen economy, High temperature electrolysis, Life cycle assessment, thermophysical and transport properties

INTRODUCTION

Hydrogen economy, a concept popularized in the 1970s, involves the use of hydrogen as the energy currency for satisfying the service demands (transportation, power generation, etc.) of the consumers (Scott 1993; Rogner and Scott 2000). The need for transitioning to a hydrogen economy has come into focus recently due to increased concerns about the limitations of fossil fuel (petroleum and natural gas, in particular) supply and climate change (Ledley et al 1990; Silberud 2001). Hydrogen economy, with its apparently carbon-free characteristics, is presumed to be one of the solutions to these energy and environment challenges. However, the progress toward a hydrogen economy has been very gradual, and hydrogen has not attained the prime position in the energy systems optimistically forecast by many studies conducted in the 1970s (Smil 1974; Valette et al 1978). The reasons for this lack of realization of the hydrogen economy include: absence of the presumed growth of nuclear power with which hydrogen economy was invariably linked, technological and economic challenges to hydrogen production from water and utilization in fuel cells, on-board storage challenges, and lack of infrastructure (Lattin and Utgikar 2007).

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In general, commercialization of and transition to new energy technologies is a difficult task, requiring fundamental transformations in both energy supply and demand (National Academy of Sciences 2004; Romm 2005). This transformation period presents opportunities for the scientific and technical communities to make contributions in every facet of the hydrogen economy. This paper describes some of the on-going research, development, and education activities in Idaho, and presents possible future roles for the scientific community in the state.

RESEARCH AND DEVELOPMENT ACTIVITIES

Hydrogen Production and Primary Energy

Hydrogen production in the U.S. is almost entirely (>95%) based on steam-reforming of methane, the most economical production route that consumes limited fossil fuel resources and emits greater amounts of greenhouse gases than any alternative production method (Lattin and Utgikar 2007; Spath and Mann 2001). Hydrogen needs to be produced using water as the only raw material *and a carbon-free primary energy source* in order to have a hydrogen economy that is free from fossil fuel and climate change limitations. The splitting of water molecule can be accomplished by water electrolysis, thermochemical cycles, photobiological or photoelectrochemical techniques to obtain hydrogen (Ohi 2005). The last two techniques require solar energy, while electrolysis can be effected by nuclear and other renewable energy sources as well. The thermochemical cycles can be driven by nuclear energy as well as solar energy (Ohi 2005; Schultz et al 2005). It should be noted that biomass in various forms – energy crops, agricultural and other waste – is also a hydrogen resource with zero- or low net carbon emissions (Ni et al 2006). However, in general, it is a rather hydrogen-poor (low mass % hydrogen), low-energy (high oxygen content) resource with significant technology development challenges (Milne et al 2002). This paper deals mainly with the water-splitting electrolysis and thermochemical cycle processes, driven by nuclear-energy. These two production routes are described briefly, followed by the discussion of research and development activities pertinent to implementation.

Hydrogen via Electrolysis

Electrolysis of water into hydrogen and oxygen has been known for almost two centuries, and commercially used for production since the 1890s (Sorenson 2004). The reactions occurring in a conventional alkaline electrolyzer are (Kreuter and Hofmann 1998):

Anode: $2OH^- \rightarrow H_2O + \frac{1}{2}O_2 + 2e^-$

Cathode: $2H_2O + 2e^- \rightarrow 2OH^- + H_2$

The electrolytic hydrogen production plants use this well-established technology which suffers from the disadvantages of low efficiency and low current density. Commercial units typically operate at 70-90°C, require high voltage (~2.25 V) and can have power consumption of ~ 5 kWh per Nm^3 of hydrogen with an efficiency of 77-80% (Dutta 1990). High temperature steam electrolysis (HTSE), operating at elevated temperatures of 750-900°C, has several advantages over the conventional alkaline electrolysis including lower operating voltages (~1.2 V) and higher efficiencies that can result in significantly (25-30%) lower power

consumption (International Nuclear Societies Council 2004). The electrolyte in HTSE is composed of solid oxides (yttria-stabilized zirconia, typically), and the reactions taking place are (Sandstede 1992):

Anode: $O^{2-} \rightarrow \frac{1}{2}O_2 + 2e^-$

Cathode: $H_2O + 2e^- \rightarrow H_2 + O^{2-}$

The primary energy source for conventional electrolysis can be any power plant, however, commercial plants are invariably coupled to hydropower due to economic reasons (Sandstede 1992). The high temperatures and power requirements for HTSE exclude nearly all the primary energy sources except the very high temperature nuclear reactor (VHTR), one of the Generation IV reactors currently under development (Schultz et al 2005).

Hydrogen via Thermochemical Cycles

Thermochemical cycles accomplish the splitting of the water molecule into hydrogen and oxygen through a series of reactions in which all the other chemicals consumed in one step are regenerated in some other step. Evolutions of oxygen and hydrogen also occur in separate reactions, obviating a need for hydrogen-oxygen gas separation step (Schultz 2004). A large number of thermochemical cycles have been postulated and studied, however, the sulfur-iodine (S-I) cycle (shown below) has been considered to be the most promising of all (Schultz 2004).

Decomposition of sulfuric acid (oxygen evolution):

$H_2SO_4 \rightarrow SO_2 + H_2O + \frac{1}{2}O_2$ (~850°C)

Decomposition of hydrogen iodide (hydrogen evolution):

$2HI \rightarrow H_2 + I_2$ (~450°C)

Bunsen reaction (regeneration of reactants for the steps above)

$SO_2 + I_2 + 2H_2O \rightarrow H_2SO_4 + 2HI$ (~120°C)

The first two reactions are endothermic, while the Bunsen reaction is exothermic. As with the HTSE, VHTR is the primary energy source of choice due to the high temperatures required for the decomposition of sulfuric acid.

The Department of Energy (DOE) through its Nuclear Hydrogen Initiative (NHI) has also identified the Hybrid Sulfur (HyS) cycle as another priority cycle (Gorensek and Summers 2008). The sulfuric acid decomposition step is common to both S-I and HyS cycles, however, a single low-temperature electrochemical step accomplishes the oxidation (and subsequent conversion) of sulfur dioxide to sulfuric acid and hydrogen evolution as shown below:

$SO_2 + 2H_2O \rightarrow H_2SO_4 + H_2$

The standard cell potential for the above reaction is -0.158 V at 25°C. Sulfur is the only element (other than hydrogen and oxygen) involved in the HyS cycle. The troublesome HI decomposition and Bunsen reactions are replaced by a single reaction. However, this reaction is electrochemical (although with a standard potential requirement lower than that for water electrolysis) necessitating inefficient thermal to electrical energy conversion from the nuclear plant.

Hydrogen Research at INL

INL has a strong research and development program in hydrogen production technologies. One of the major R&D effort focuses upon experimental and theoretical studies on the planar solid oxide cell-based HTSE (Herring et al 2007). INL has successfully demonstrated efficient hydrogen production at progressively larger scales starting from a single button cell (active electrode area 3.2 cm^2) to a 720 cell-3 module integrated demonstration plant (active area ~46,000 cm^2). The operation of the integrated plant successfully demonstrated the technical feasibility of HTSE process through continuous production of hydrogen at a rate in excess of 1000 N liter/h. Advanced computational fluid modeling techniques have been used to obtain temperature and current density profiles on the electrodes (Herring et al 2007).

INL is also involved in R&D efforts related to the thermochemical cycles. The decompositions of sulfuric acid and hydrogen iodide are facilitated by heterogeneous catalysts. The design of a catalyst that can withstand high temperatures of the process in a severely corrosive environment is critical for commercialization of the process. Most conventional active catalysts used in acid decompositions have only short-term stability. Ginosar and coworkers (Ginosar et al 2006; 2007) at INL have investigated various platinum group metals for sulfuric acid decomposition and activated carbon for hydrogen iodide decomposition. Their work is a crucial component of the DOE's integrated laboratory scale (ILS) demonstration plant for hydrogen production via the S-I thermochemical cycle. The experiments on the ILS plant are being conducted by General Atomics with the involvement of Sandia National Laboratory and the French Commissariat a l'Energie Atomique (CEA) (Gelbard et al 2007). Research on the catalyst for the sulfuric acid decomposition will be valuable in the development of HyS cycle as well.

Research and development work on other thermochemical cycles is relatively limited, due to DOE's designation of the sulfur-iodine cycle as the top priority cycle, relegating the other cycles to second priority or lower tiers (DOE 2004). The calcium-bromine based cycles involve gas-solid reactions, and one of the major challenges to the development of these cycles involves change in the molar volume of the solid reactants, which limits the conversion (Amir et al 1992). One of the possible solutions is to immobilize the reactants on a support matrix that offers large specific surface area. Utgikar et al (2005) have presented preliminary experimental results from their study, which show the promise of this approach. Further developments of this cycle (as also other thermochemical cycles) are contingent upon the availability of DOE funding.

Life Cycle Assessments

Life cycle assessment (LCA) is an effective analytical tool for investigating the total environmental impact of any activity (such as, hydrogen production and/or utilization), as well as comparing various alternative systems (U.S. Environmental Protection Agency, 2001). LCA of the HTSE coupled to a VHTR for hydrogen production was performed by Utgikar and Thiesen (2006). Their study found that the greenhouse gas emissions (per unit mass of product hydrogen) from this production route were only one-sixth of those from the conventional process for hydrogen production – steam reforming of methane. The acidification potential (based on the emissions of the acid gases – SO_x, NO_x, halogens, etc.) of HTSE was also only one-third of the steam reforming process. Similar results were ob-

tained in the LCA of hydrogen production via thermochemical cycle (ISPRA Mark 9 cycle) utilizing the thermal energy of a VHTR (Utgikar and Ward 2006). Table 1 lists the global warming potentials of various hydrogen production processes. It can be seen that both HTSE and thermochemical cycles are superior to the steam reforming process, with emissions from thermochemical cycles slightly higher than those from the HTSE process.

Table 1. Life cycle Global Warming Potentials of Hydrogen Production Processes

Process	Emissions CO_2 -equivalent/kg H_2	Reference
Steam Reforming of Methane	9000-12000	Koroneos et al (2004)
HTSE	2000	Utgikar and Thiesen (2006)
S-I Cycle	2500	Lattin and Utgikar (2009)
ISPRA Mark 9 cycle	2515	Utgikar and Ward (2006)

Utgikar et al (2006) have also presented an energy and environmental impact analysis of alternative metallic nanofuels proposed for transportation applications. Iron or aluminum, in nanoparticulate forms, are proposed as transportation fuels by some researchers (Beach et al 2005; Kleiner 2005). Utgikar et al (2006) showed that such system will have a substantially negative energy balance. Further, systems based on these fuels will be significantly worse environmentally with at least an order of magnitude increase in greenhouse gas emissions as compared to the present-day gasoline engines. Hydrogen was shown to be superior to these proposed transportation fuels.

Thermophysical Properties of Hydrogen

In preparation for a global hydrogen economy, there will be a need for accurate hydrogen thermodynamic properties for use in design and analysis of engineered systems for production, storage and use of hydrogen. Two recently completed surveys of the thermophysical properties of hydrogen establish the need for new equations of state for the thermodynamic properties of the various forms of hydrogen and for new formulations for the transport properties, viscosity and thermal conductivity (Jacobsen et al 2007; Leachman et al 2007). New fundamental equations of state for parahydrogen, orthohydrogen and normal hydrogen were developed to replace the previous standards (Younglove 1982).

Further details of this work are given in the Masters thesis of Leachman (2007). These new models are used in the current version of NIST's standard properties package, REFPROP (Lemmon et al 2007).

The new equations of state (EOS) each consist of 14 terms and are of similar form to the equation described in Lemmon and Jacobsen (2005). The

experimental data and non-linear least squares fitting processes are described in detail by Leachman (2007). The EOS is explicit in Helmholtz energy and is valid for temperatures from the triple points (13.8033 K for parahydrogen, 13.957 K for normal hydrogen, and 14.008 K for orthohydrogen) to 1000 K and for pressures up to 2000 MPa, and the extrapolation appears to be well behaved at much higher values. Comparisons to available experimental data were used to establish the accuracy of properties calculated using the equations of state. The uncertainty in density is 0.04 % in the region between 250 and 450 K and at pressures from 0.1-300 MPa. The uncertainties of vapor pressures and saturated liquid densities vary from 0.1-0.2%. Uncertainties of calculated properties including density at pressures above 300 MPa increase from 0.04 % to as large as 8 percent near 2000 MPa. Heat capacities are generally accurate within ±1 %, while speed of sound is accurate to within ±0.5 % below 100 MPa.

There are many applications of hydrogen in mixtures of other fluids including natural gas that may contain greater than 20 percent hydrogen at various equilibrium states. The EOSs created in this area of research could be used in a mixture model to accurately determine properties of hydrogen mixtures with other fluids.

HYDROGEN EDUCATION

The University of Idaho (UI) and Idaho State University (ISU) jointly offer a course on hydrogen to the students at both the Universities. It is a dual level course (for undergraduate senior and graduate students) that attracts students majoring in chemical, mechanical, and, nuclear engineering, as well as environmental science. The course on hydrogen has been offered every Fall semester since 2004, when it was first offered as a chemical engineering special topics course by Dr. Utgikar. It was offered as a joint course by Dr. Utgikar and co-PI Dr. Jacobsen in Fall 2005 as a special topics course in mechanical and chemical engineering to students at UI. The course originated at the Idaho Falls Center and was broadcast to the main campus of UI in Moscow via compressed video. Beginning in 2006, the course has been carried over the compressed video network to the main campus of ISU in Pocatello. The course has its dedicated web-site providing detailed information about the course including notes, assignments, syllabus, etc. The three-credit course covers the major topics related to hydrogen, which range from production, utilization, storage, transmission and distribution infrastructure, safety to environmental aspects. Salient features of the course are discussions of the following topics:

- Fossil fuel limitations and climate change concerns
- Production technologies including fossil fuel and biomass reformation, electrolysis, thermochemical cycles, and biohydrogen
- Fundamental thermodynamics and kinetics of electrochemical processes, and discussion of fuel cell technologies on the basis of these principles
- Conventional and emerging storage alternatives and technological challenges in achieving DOE targets.
- Infrastructure requirements visualizing different scenarios for production, transmission and distribution
- Materials for hydrogen duty and safety aspects
- Environmental assessment of hydrogen production and utilization

Each student enrolled in the course is required to choose a topic related to hydrogen, and complete a term project on this topic. The term project is the major component of the student assessment. The projects typically involve comprehensive literature surveys for undergraduate students, while the graduate projects require analysis and synthesis of the knowledge for a novel perspective on hydrogen technologies as well as identification of directions for future research. Several peer-reviewed journal publications have resulted from these term projects.

FUTURE RESEARCH, DEVELOPMENT AND EDUCATION ACTIVITIES

Considerable progress is necessary in all aspects of hydrogen technologies before the vision of hydrogen economy is realized. Some of the future research and education activities, that build upon the work described above, are outlined below.

Research and Development

Hydrogen Production

As mentioned above, the HTSE process has shown much promise for the commercial production of hydrogen necessary in a hydrogen economy. The scale-up of any process, particularly an electrochemical process such as water electrolysis, presents engineering challenges, and the subsequent steps will involve demonstrating successful operation of a plant with orders-of-magnitude increase in the hydrogen production rate. Larger electrolytic cells are prone to non-uniformity of flows and temperatures. Further, the cells typically tend to experience performance degradation with time. The causes of these phenomena have to be investigated and solutions devised to overcome the limitations imposed by them.

The optimum utilization mode of hydrogen in the hydrogen economy also needs to be determined. Use of pure hydrogen for transportation applications brings along with it challenges of on-board storage, extraction of useful energy, using either the internal combustion engine or a fuel cell, and the need for a new hydrogen infrastructure. A potential solution is using synthetic hydrocarbons that can use the existing infrastructure, and existing vehicles. INL is conducting co-electrolysis experiments wherein carbon dioxide and water are subjected to electrolysis to obtain syngas that can be converted into liquid fuels or chemicals (Herring et al, 2008). This approach may hold the greatest potential for energy independence and security.

Life Cycle Assessments

LCA is a vital tool that allows analysis and comparison of technologies from the life-span perspective. As the analysis of metallic nanofuel systems indicates, replacement technologies that are apparently attractive may actually be less efficient and cause considerably more environmental harm than the current technologies. Similarly, an LCA conducted by Koroneous et al (2004) has indicated that hydrogen production using solar photovoltaics is in fact more harmful to the environment than steam methane reforming. A comprehensive evaluation of any process, technology or product must include LCA for sound decision-making. Two of the hydrogen related LCA research projects involve assessment of the S-I thermochemical cycle, and the impact of new nuclear plants. The S-I LCA

project assesses not only the global warming and acidification potentials of the process, but also investigates the resource depletion aspects. The resource depletion may be more significant than any other factors in view of the process requirements for iodine, an element limited in both worldwide supply and known resources. The LCA of new nuclear plants focuses upon the future US and global energy requirements, and the impact of the large number of nuclear plants needed to supply this demand, particularly if the transportation energy requirements are also to be satisfied by harnessing nuclear energy. Further, the LCA will be refined by assessing the impact as a function of time, rather than basing it on the average life-span of the nuclear plant.

Hydrogen Properties

The importance of accuracy in property formulations and estimations has been described above. Research in this area will investigate properties of hydrogen-natural gas mixtures, various mixtures of orthohydrogen and parahydrogen, and the properties of hydrogen-methane mixtures pertaining primarily to storage, transmission and distribution applications.

Education

Along with the research needs, the educational activities also need to be expanded to reach larger populations. Plans for expanding hydrogen education activities include:

Course Expansion

The current course on hydrogen is comprehensive, and covers all the aspects of hydrogen economy and technologies, ranging from production, storage, utilization, to safety and environmental aspects. This course provides the students with an appreciation of the breadth of technological challenges in hydrogen and related technologies, and caters to the interests of a diverse group of students, whose backgrounds range from chemical/mechanical engineering to environmental science and energy policy. This comprehensive course is planned to be expanded into two separate courses focused upon specific areas related to hydrogen: (1) Hydrogen Production and Utilization, and (2) The Global Hydrogen Economy. The first course will focus upon the production of hydrogen and its utilization, with special emphasis on Fuel Cell Technology. The production processes covered will include reforming and partial oxidation technologies for production using carbon-based resources, electrolysis and thermochemical cycles for water-splitting, biophotolysis, and other alternatives. The topics will be subjected to quantitative treatment on the basis of rigorous thermodynamic and kinetic principles. Alternative production technologies will be examined in the context of the primary energy sources, energy requirements and efficiencies. The second course will focus on the technical and economic barriers in storage, distribution and infrastructure areas. This course will examine the storage alternatives – molecular hydrogen (gas, liquid) and bound hydrogen in combined form (adsorbed, hydrides, etc.), including the energy requirements for various storage methods. The influence of properties of hydrogen on storage as well as transmission and distribution will be discussed on the basis of the recent advances in the equations of state for hydrogen. The primary energy sources, infrastructure requirements, safety and life cycle assessment of environmental impacts will be

the other topics covered in the course. The first course (hydrogen production) will allow more quantitative analysis for a relatively focused group of students, while the second course (hydrogen economy) will accommodate the needs of more diverse group, that may not have the rigorous quantitative background (thermodynamics, kinetics, etc.) necessary for the first course. The expansion to two courses will also allow more detailed discussions of topics in the classroom.

Course Offerings in Boise and Distance Education

A statewide videoconferencing network exists within Idaho linking the educational centers – Moscow, Pocatello, Boise, Idaho Falls, and other extension centers. The courses described above will be broadcast over this network to make them available to the students in Boise, through the Boise Center of the University of Idaho (UI Boise). The Engineering Outreach program of UI is charged with the mission of serving off-campus students, business and industry by providing quality programs with innovative delivery. The courses described above will be offered through this Engineering Outreach program, and thus will be available to a much wider audience, potentially spread all over the country. As with most Engineering Outreach courses, the lectures will be recorded on DVDs. Supplemental course materials – syllabi, handouts, assignments will be provided at the course web-sites developed by the first two authors.

Short Courses on Hydrogen

A 1-credit short course (tentative title: *Energy Systems and Hydrogen Economy*) will be offered on hydrogen technologies in order to disseminate information and knowledge on hydrogen and fuel-cell related technologies. The content of the course will be tailored to attract participation from the general community, particularly individuals who want to increase their knowledge base, but are constrained by their responsibilities from undertaking intense, semester long studies in a regular university course. The course will last over two days, split into four sessions tentatively planned to be: 1) Energy and Environment – Drivers for the Hydrogen Economy, 2) Hydrogen Production and Storage, 3) Fuel Cells – Transportation and Stationary Power, and 4) Hydrogen Economy: Impact on Society.

CONCLUSIONS

The concept of hydrogen economy, while attractive, remains yet to be realized. This paper has outlined some of the research, development and education activities being conducted in Idaho Universities and the INL. Further expansion of these activities has also been described. These activities point to the roles of Idaho researchers and educators in contributing to the progress of the hydrogen economy.

LITERATURE CITED

Amir R., T. Sato, K. Yoko, Yamamoto, T. Kabe, and H. Kameyama. 1992. Design of solid reactants and reaction kinetics concerning the iron compounds in the UT-3 thermochemical cycles. *International Journal of Hydrogen Energy* 17: 783-788.

Beach D, Sumpter B, Labinov S. 2005. Metallic nanofuels: combustion in the solid state. Preprints of *Symposia – American Chemical Society, Division of Fuel Chemistry* 50 (1): 366-367.

Bockris JO'M. 1980. *Energy Options*. Halsted Press, New York.

Cox Kenneth E., and Kenneth D. Williamson. 1978. Hydrogen: Its Technology and Implications. Volume 1, Hydrogen Production Technology. Blackwell Scientific, Oxford, England.

Dutta S. 1990. Technology assessment of advanced electrolytic hydrogen production. *International Journal of Hydrogen Energy* 15: 379-386.

Department of Energy (DOE). 2004. Nuclear Hydrogen R&D Plan. Department of Energy, Office of Nuclear Science and Technology. http://www.hydrogen.energy.gov/pdfs/nuclear_energy_h2_plan.pdf. Website accessed April 21, 2008.

Gelbard Fred, Robert Moore, and Edward Parma. 2007. Status of Initial Testing of the H_2SO_4 Section of the ILS Experiment. Sandia Report SAND2007-7841.

Ginosar Daniel M., Lucia M. Petkovic, and Kyle C. Burch. 2007. Activated carbon catalysts for hydrogen production in the sulfur-iodine thermochemical water splitting cycle. 2007 AIChE Annual Meeting, Salt Lake City, November 5-9, 2007, paper 166e.

Ginosar Daniel M., Lucia M. Petkovic, Harry W. Rollins, and Kyle C. Burch. 2006. Platinum group metal catalysts for sulfur-based thermochemical water-splitting cycles. 2006 AIChE Annual Meeting, Conference Proceedings, 230a/1-230a/4.

Gorensek Maximilian B., and William A. Summers. 2008. Hybrid sulfur flowsheets using PEM electrolysis and a bayonet decomposition reactor. *International Journal of Hydrogen Energy* doi:10.1016/j.ijhydene.2008.06.049.

Herring J. Stephen, Carl M. Stoots, James E. O'Brien, and Joseph J. Hartivigsen. 2008. High temperature electrolysis for hydrogen production. Presentation at Materials Innovation in an Emerging Hydrogen Economy, Cocoa Beach, Florida, February 26, 2008. http://ceramicartdaily.net/postmeeting/Production/Production_Herring.pdf, website accessed April 25, 2008.

Herring J. Stephen, James E. O'Brien, Carl M. Stoots, G.L Hawkes, Joseph J. Hartivigsen, and Mehrdad Shahnam. 2007, Progress in high-temperature electrolysis for hydrogen production using planar SOFC technology. *International Journal of Hydrogen Energy* 32: 440-450.

International Nuclear Societies Council. 2004. Nuclear Production of Hydrogen. Technologies and Perspectives for Global Deployment. American Nuclear Society, La Grange Park, Ill.

Jacobsen RichardT, Jacob W. Leachman, Steven G. Penoncello, and Eric W. Lemmon. 2007. Current status of thermophysical properties of hydrogen. *International Journal of Thermophysics* 28: 758-772.

Kleiner K. 2005. The new iron age. *New Scientist* 188 (2522): 34-37.

Koroneos C., A. Dompros, G. Roumbas, and N. Moussiopoulos. 2004. Life cycle assessment of hydrogen fuel production process. *International Journal of Hydrogen Energy* 29: 1443-1450.

Kreuter W., and H. Hofmann. 1998. Electrolysis: the important energy transformer in a world of sustainable energy. *International Journal of Hydrogen Energy* 23: 661-666.

Lattin William C., and Vivek P. Utgikar. 2007. Transition to Hydrogen Economy in the United States: A 2006 Status Report. *International Journal of Hydrogen Energy* 32: 3230-3237.

Lattin William C., and Vivek P. Utgikar. 2009. TGlobal warming potential of the sulfur-iodine process using life cycle assessment methodology. *International Journal of Hydrogen Energy* 34: 737-744.

Leachman Jacob W. 2007. Fundamental Equations of State for Parahydrogen, Normal Hydrogen and Orthohydrogen. Masters Thesis, University of Idaho.

Leachman Jacob W., Richard T. Jacobsen, Steven G. Penoncello, and Marcia L. Huber. 2007. Current status of transport properties of hydrogen. *International Journal of Thermophysics* 28: 773-795.

Leachman Jacob W., Richard T. Jacobsen, Eric W. Lemmon, and Steven G. Penoncello. 2008. Fundamental equations of state for parahydrogen, normal hydrogen and orthohydrogen. To be submitted to *Journal of Physical and Chemical Reference Data*.

Ledley T, Sundquist E, Schwartz S, Hall D, Fellows J, and T. Killeen. 1999. Climate change and greenhouse gases. EOS 1999;80(39):453.

Lemmon Eric W., and Richard T. Jacobsen. 2005. A New Functional Form and New Fitting Techniques for Equations of State with Application to Pentafluoroethane (HFC-125). *Journal of Physical and Chemical Reference Data* 34: 69-108

Lemmon Eric W., Marcia L. Huber, and M.O. McLinden. 2007. National Institute of Standards and Technology, Standard Reference Data Program #23, REFPROP version 8.0, Gaithersburg, MD (2007).

Milne Thomas A., Carolyn C. Elam, and Robert J. Evans. 2002. Hydrogen from Biomass: State of the Art and Research Challenges. International Energy Agency Report # IEA/H2/TR-02/001, (2002).

National Academy of Science (NAS). 2004. The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs. The National Academies Press, Washington, DC.

Ni Meng, Dennis Y.C. Leung, Michael K.H. Leung, and K. Sumathy. 2006. An overview of hydrogen production from biomass. Fuel Processing Technology 87: 461-472.

Ohi Jim. 2005. Hydrogen energy cycle: an overview. Journal of Materials Research 20: 3180-3187.

Rogner Hans-Holger, and David S. Scott. 2000. Building sustainable energy systems: the role of hydrogen. The 1st Nuclear Hydrogen Production Information Exchange Meeting, October 2-3, 2000, Paris, France. Washington, DC: OECD Publications and Information Center.

Romm J. The hype about hydrogen. Washington, DC; Island Press, 2005.

Sandstede G. 1992. Status of technology and development in water electrolysis. *DECHEMA Monographien*, 125: 329-355.

Schultz Kenneth R. 2004. Use of modular helium reactor for hydrogen production. *The Nuclear Engineer* 45 (2): 37-41.

Schultz Ken, J. Stephen Herring, Michele Lewis, and William Summers. 2005. The hydrogen reaction. Nuclear Engineering International 50 (612): 10-11, 13, 15.

Scott David S. 1993. Hydrogen in evolving energy system. *International Journal of Hydrogen Energy* 18: 197-204.

Silberud R. Our future is hydrogen. Wellington, CO; New Science Publications, 2001.

Smil V. 1974. Energy and the Environment: a Long Range Forecasting Study. Manitoba Geographical Studies, Volume 3. Winnipeg, Canada; University of Manitoba.

Sorenson Bent. 2004. Hydrogen and Fuel Cells. Elsevier Academic Press, Amsterdam, The Netherlands.

Spath P, and M. Mann. 2001. Life cycle assessment of hydrogen production via natural gas reforming. NREL/TP-570-27637. Golden, CO; National Renewable Energy Laboratory.

Utgikar Vivek P., J. Paul Scott, and Michael F. Simpson. 2005. Hydrolysis of Calcium Bromide: Immobilization of the Reactant on a High Surface Area Support. Paper 348e, presented at the AIChE Annual Meeting, Cincinnati, Ohio, October 30-November 4, 2005

Utgikar Vivek, and Bradley J. Ward. 2006. Life cycle assessment of ISPRA Mark 9 thermochemical cycle for nuclear hydrogen production. Journal of Chemical Technology and Biotechnology 81: 1753-1759.

Utgikar Vivek, and Todd Thiesen. 2006. Life cycle assessment of high temperature electrolysis for hydrogen production via nuclear energy. *International Journal of Hydrogen Energy* 31: 939-944.

Utgikar Vivek P., William Lattin, and Richard T. Jacobsen. 2006. Nanometallic fuels for transportation: A well-to-wheels analysis. *International Journal of Energy Research* 31: 99-108.

Valette P., L. Valette, M. Siebker, and L. LeClerq. 1978. Analysis of a Delphi study on hydrogen. *International Journal of Hydrogen Energy* 3: 251-259.

Younglove B.A. 1982. Thermophysical properties of fluids: I. Argon, ethylene, parahydrogen, nitrogen nitrogen trifluoride and oxygen. *Journal of Physical and Chemical Reference Data*, Supplement 11 (1): 1/1-1/353

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College of Southern Idaho
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Twin Falls, ID 83303-1238
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Nominations must be typed and submitted in quadruplicate (four copies). All should include the following information:

- Nominee's name, institutional or company affiliation*, address, and phone number. [Optionally, the nominee's title and e-mail address may be included.]

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Nominations for Distinguished Communicator could well cite innovation and inventiveness, but they are also likely to focus on effectiveness, impact, and influence. Outstanding achievers in education devise innovative classroom or field exercises and programs, create new and better ways to present scientific materials, find fresh ways to reach out to more students . . . they do whatever it takes to effectively convey the facts and concepts of science, and an appreciation for the scientific enterprise. Of course, providing "hard evidence" for the value of some of these accomplishments may be difficult. Sometimes the work may result in the publication of a manual, a conference paper, news articles, or even a textbook; but such opportunities are generally relatively limited. Supporting the nomination with additional "testimonials" may be the best way to show effectiveness and impact . . . but supporters should be urged to be as specific as possible. Comparable factors would also apply to other communicators - article writers, TV or movie producers, radio commentators, and so on.

They too will be judged on their effectiveness, impact, and influence. In these cases, the nomination might describe how a local series of "hit" science programs was picked up by the national media and broadcast all over the country. Perhaps a book with a science/technical theme by an Idaho author suddenly becomes a national bestseller. Maybe a lecturer from Idaho starts turning up on national public television, or becomes a "hot item" on the national lecture circuit. Such accomplishments could well qualify an individual for this award.

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Tables and figures should be kept within economic limits. Tables should be typed on separate sheets. Lettering and line drawings must be of letter quality (i.e. laser printing). Figures should be planned for no reduction when printed; thus, they may be no larger than 11 X 17 cm (4-1/2 6 ¾ inches). If photographs are submitted they must be electronic files (jpeg, gif or tif files). Legends must be brief; legends for figures should be placed on a single, separate sheet.

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