THE CONSULTANT

The Newsletter of the IEEE Consultants Network of Long Island

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Chairman
Jerry Brown
(631) 271-9714
jbrown@essexsys.com

First Vice Chairman
Peter Buitenkant
(631) 491-3414
peterbui@optonline.net

Second Vice Chairman
Sam Sadinsky
(631) 476-5780
s.sadinsky@ieee.org

Treasurer
David Rost
(516) 599-6202
ConsultDPR@ieee.org

Secretary
Dr. Richard LaRosa
(516) 486-7827
r.larosa@ieee.org

Newsletter Editor
Dr. Richard LaRosa
(516) 486-7827
r.larosa@ieee.org

Jr. Past Chairman
John Dunn
(516) 378-2149
ambertec@ieee.org

Sr. Past Chairman
Murray Kleiner
(516) 822-1381
m.kleiner@ieee.org

Alliance of IEEE Consultant Networks
Irwin Weitman, P.E.
(631) 266-2651
i.weitman@ieee.org

Voice-Message Referral Service
(516) 379-1678

Visit our web page
http://www.consult-li.com

Chairman's Corner – Jerry Brown, Essex Systems

There have been discussions in our group about outsourcing. That is obviously something that concerns all of us, both professionally and as citizens. Last night, on Charlie Rose, I saw an interview that dealt with this issue in a larger context.

The guest was Fareed Zacharia, Editor of Newsweek International. To set the stage for the discussion he started by mentioning that there are only three countries left that have not officially adopted the metric system – the United States, Liberia and Myanmar. Then, he went on with some revealing statistics. He pointed out that India's biggest trading partner is no longer the U.S. It's China. China and India together account for 1/3 of the world's population compared to 1/22 for the U.S. Right now their combined GDP is only about $4.5E12 compared to our $13.8E12. However, their growth rates are 11.4 and 9% compared to our 2.2. Furthermore, our ranking for growth rate is 179 out of a list of 216. So, there are lots of countries growing faster than we are.

Regardless of one's politics, it is apparent that the world around us is changing. And it could be argued that it's changing faster than we are.

Zacharia has written a new book, which of course, is why he was doing an interview. It's called "The Post-American World." He believes there are ways we can insure we continue to prosper. I don't know if he's right. But, it may be worth reading.

Meetings

March 2008

Topic: "Using Google AdWords To Promote Your Website"
Speaker: David Pinkowitz, DCP Marketing Services

April 2008

Topic: "What to Expect When Working on Projects Involving Manufacturing in China"
Speaker: John Weiss, Weiss Instruments

May 2008

Topic: "Introduction to LabVIEW and Computer-Based Measurements Hands-On Seminar"
Speaker: Robert E. Berger, National Instruments District Sales Manager for Long Island and New York City
7:00 PM, Wednesday, May 7
Briarcliffe College, 1055 Stewart Avenue, Bethpage, NY.
CEU credits available for Professional Engineers.
$ 20 Fee for CEU's payable at the meeting.
Admission is free (no charge) for those not receiving CEU's.
Guests are welcome.
Light refreshments will be served.
Non-members please inform Peter Buitenkant so that we can order refreshments. peterbui@optonline.net
Directions: See our website www.consult-li.com.

The objective of this CEU-yielding seminar is to provide attendee/participants with the latest electronics techniques and procedures. Unique discoveries discussed in the presentation may be the first public disclosure by the author. Some of the content may be to refresh the knowledge of the attendee so as to clarify the newly presented material.

National Instruments LabView is an industry-leading software tool for designing test, measurement, and control systems.

June 4, 2008

Sensor Technology

Other Meetings

Consult the Events Calendars on the Section website: www.ieee.li and the LICN site: www.consult-li.com

Remember to inform the members about seminars and other items that might be of interest. E-mail them at members@consult-li.com.

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Address All Correspondence to:

IEEE Consultants Network
Of Long Island
P.O. Box 411
Malverne, NY 11565-0411

Tel: (516) 379-1678
Web: http://www.consult-li.com

Newsletter Staff
Editor: *Dr.Richard LaRosa*
Tel: (516) 486-7827
e-mail: r.larosa@ieee.org

Associate Editors:
John Dunn, Ambertec, Inc.
Tel: (516) 378-2149,
e-mail: ambertec@ieee.org

Peter Buitenkant
Tel: (631) 491-3414
e-mail: peterbui@optonline.net

Printing and Distribution:
Dr. Richard LaRosa
Tel: (516) 486-7827
e-mail: r.larosa@ieee.org

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Nano-Engineering - What is It? – ***Carl E. Schwab***

Now and again you see the term nano-engineered. And then you see some pictorial of say a carbon nanotube.

What nano-engineering, I think, means is manipulating material at the molecular level and more specifically actually imaging a molecule in some useful way to facilitate fabrication of some desirable product.

To gain an appreciation of working at the molecular level we need to establish some useful dimensions to appreciate the difficulty.

First off -- 1 nanometer (nm) = 1 meter x 10^-9 .

Next-- 1 Angstrom =1 meter x 10^-10.

So-- 1 nanometer = 10 Angstrom.

Now for some examples: The diameter of an atom is reasonably defined since the outer electron shell is spherical. When we speak of the diameter of molecule this is the diameter of a circumscribing sphere since the outlying atoms act as points. With this in mind, a CO_2 molecule is 3.25A in diameter; an H_2O molecule is 2.75A in diameter. An H_2 molecule is only 2.72A in diameter while an H atom is about 1.0A in diameter. An O_2 molecule is 2.96A and an N_2 is 3.16A. A CH_4 molecule is about 4.26A. So you see for many of the common molecules the diameter range is 1A-5A.

To image objects this size the rule of thumb of 10x shorter wavelength suggests hard X-rays, or Gamma ray sources.

Visible light spectrum is 400nm to 700nm.
X-ray spectrum is from .03nm to 3nm.
Gamma ray spectrum is from 0.1nm to 0.000001nm.

<u>Some things nano-engineering can accomplish</u>

Working with nano-engineering tools engineers have been able to devise schemes to parse out sheets that are only 1 or 2 molecules thick. This has been done for some time in graphite form i.e. carbon.

Carbon has drawn much initial attention since it naturally occurs in rigid form, diamond; flat form, graphite; or in tubular/spherical form, fullerenes, nanotubes, bucky balls.

The spherical and tubular forms are particularly useful when attached to a carrier sheet so that the "effective area" useful area can be increased by 1000 to 10000 times the simple projected area.

This has BIG payoffs. For the SuperCap the direct gain in the carbon fabrication is increased capacitance i.e. up from 3,000F to 15,000F i.e. a 5 to 1 increase in capacity.

Another company, QuantumSphere Inc, is specializing in materials other than carbon. They call their product nanoparticles and they are in perfect spherical shapes. Typical diameters range from 16nm to 25nm. Currently they can fabricate nanoparticles in nickel-cobalt, iron-cobalt, nickel-iron or silver-copper.

End applications besides SuperCaps are alkaline AA batteries, NiMh batteries and Li-ion batteries. For the AA alkaline cell the mah capacity will increase about 5.5 times and power output up by 3.2 times. That means literally 10,000-20,000mah capacity and up to 2000 ma. steady state for a single AA cell. Fantastic. AA cells made using this technique are projected by the end of 2008.

For the NiMh cells the capacity increase is expected to be 3-5 times and should benefit hybrid cars directly. Cell impedance will reduce by 3 to 1.

Currently one manufacturer, A123S Inc, is using a nanophosphate, to make a much more durable and safe Li-ion cell. Three companies are fabricating packs for hybrid car designers using the A123S cells.

The next use of these nanoparticles is in fabrication of electrodes for hydrogen electrolysis generators. With just electrode replacement the efficiency is expected to rise from 70% to ultimately 96%. QuantumSphere believes this will be a huge market.

So an emerging engineering field is the design and manipulation of materials at the molecular level to achieve enhanced parameter performance of the substance. And I think we're just at the beginning.

Enhancing Brake Energy Recovery – *Carl E. Schwab*

In a series of short articles I have laid out thoughts of how I would, "BUILD YOUR OWN HYBRID CAR??". In general I am convinced that a proper Series Mode hybrid car is the best approach.

This article is about enhancing BER, Brake Energy Recovery. A brief recap; when using a final electric drive it is natural to use the drive motor(s) both as prime forward movers and also to provide the braking force.

The simplest form is dynamic braking with no effort to recover the electrical energy generated while braking. The energy is simply dissipated. The more useful mode is called regenerative braking with the object to capture the braking energy and somehow make it available for accelerating again.

Most of the current hybrids use a combination of regenerative and dynamic braking. The reason for this is that as the car slows down the drive motor rpm reduces which in turn drops the voltage below that required to deliver charge into the battery.

Recall in the previous article about the various type motors the term Krpv was introduced. Recall Krpv = rpm/volt. When applied to a motor this scale factor defines how many volts are required for a specific free shaft speed. When applied to the motor used as a generator this scale factor defines the unloaded output voltage for a specific RPM.

In the case of DC shunt motor/generator, the field strength is adjusted to set the speed. When you wished to brake you simply INCREASED the field strength and the mot/gen now pushed DC current back into the battery. Typical range of field strength variation was about 5 to 1 so you put charge back into the battery down to a 5-10 mph. After that, the motor was disconnected from the battery and a low value shunt resistor was placed across the mot/gen armature. This was all taken care of in the lever control that controlled FORWARD-NEUTRAL-REVERSE. The main disadvantages of this type motor is brush life and manufacturing cost.

The preferred package for a PHEV (plug-in hybrid electric vehicle) seems to be either an induction motor/VFD or a PMSM/VFD. Both of these mot/gen types have no brushes. Both of these packages have scale factor, volts/RPM, which with gear ratio conversions becomes volts/Mph. This has been treated in previous articles.

Also mentioned in previous articles is the VFSM , variable field synchronous motor which can offer the field control of the brushed DC mot/gen, BUT, require slip rings to bring field current into the rotor. Wear life is much better for slip rings than brushes and such devices are warranted for 100,000 miles routinely because they are the type used for the alternator on current conventional cars.

How much energy is there to be concerned about? Using the basic equation for kinetic energy, KE

KE=1/2 x M x V^2

Where: M=W/32

Using old engineering, non-metric units, W is in pounds, V is in feet/second, and KE is in (ft-lbs), I have constructed a table of KE values based upon a 3200 lb. Car. This helps get ones arms around how much energy (in easy to comprehend ft-lbs) is wasted in mechanical brake pads as heat. For info a Drag column is added.

KE Table

Speed Mph	KE (ft-lbs)	KE (Kwh)	Drag (Kw)	
				xxx
80	*688,355*	*259.25x10^-3*	*27.83*	
60	387,200	145.83x10^-3	11.74	
40	172,088	64.811x10^-3	3.48	
30	96,800	36.456x10^-3	1.47	
20	43,022	16.203x10^-3	0.435	
15	24,200	9.114x10^-3	0.183	
10	10,755	4.050x10^-3	0.054	
5	2,688	1.012x10^-3	. 007	

<u>Conversions</u>

Hp-hr= 1,980,000 ft-lbs   Kwh=2,655,223 ft-lbs=3.6 megaJ

Energy in 1 gal of gasoline=132 megaJ=36.67 Kwh   J=watt-sec

Driving patterns

Using myself as the test subject, I noted the following;

a) Local trips were mostly in the 5-15 mile length.
b) Most were comprised of segments between turns and/or stops.
c) Speed ranged up to 35-45 mph and down to about 10 mph for turns.
d) The segments averaged 0.5 miles in my driving.

The assumed KE value of 40 mph, 172,088 ft-lbs, was used for segment that came to a complete stop. For segments that ended in a turn, 172,088-10,755 or 161,333 ft-lbs was used.

So for a 10 mile local trip the result was (10 x 172,088) + (10 x 161,333) or

3,334,210 ft-lbs. This converts into 1.26 Kwh that has gone into wearing out the brakes on just one 10 mile local trip. That wasted energy, 1.26 Kwh, would cost 1.26 x 0.21= $0.26 if purchased from LIPA.

The Drag(Kw) column was taken from a source for a full size 4-door sedan tested in a low speed wind tunnel. The actual data was in horsepower and I simply converted them to Kw. For assumed local driving varying form 0 to 40mph I used an averaged Drag value of 1.377 Kw.

After research I assumed the engine/transmission conversion efficiency of the to be 16% or .16.

I converted the 1.26 Kwh waste energy to gasoline fuel cost based on $3.30/gal. Result (1.26/36.67) x (1/.16) x 3.30=.$71 for .21gal.

I calculated a 10 mile local drive without BER and the result was
(3,334,210/2,655,223)+10/20 x 1.377=1.94Kwh which converts to
(1.94/36.67) x (1/.16) = .331 gal or 1/.331 x 10=30.24mpg.

I calculated the 10 mile local drive with "perfect" BER and the result was
10/20 x 1.377 x (1/.16) = .689Kwh which converts to (.689/36.67) x (1/.16) =.117gal or 1/.117 x 10 =85.2mpg.

Comparing the 30.24mpg to the 85.2mpg certainly illustrates the value of BER. But 85.2mpg figure assumes 100% efficiency of both the mot/gen and the storage battery. Neither realistic.

What's realistic? First the mot/gen should be able to achieve 85% as either motor or generator. The battery should achieve about 85% efficiency for both charge and discharge with the proviso that we stay in the 10%-90% window i.e never total discharge nor 100% charge. In either extreme the efficiency worsens.

FWIW, Toyota operates the NiMh pack in a 40%-80% window obstensively to maximize the life of the pack. This is one reason they are reluctant to push PHEV for the Prius since that goes to 100% at least at the trip start which is likely once a day.

We can now recalculate using our assumed 85% efficiency for both the mot/gen and the battery. The BER cycle starts with a charge level in the battery, accelerates to 40mph, decelerates to 0mph, and compares the battery charge level. This result is (.85)^4=.522. The .522 is what we recovery so the lost is 1-.522=.478.

The calculation this time is (3,334,210 x .478)/2,655,223)+10/20 x 1.337=1.289Kwh which converts to (1.289/36.67) x (1/.16)=.22gal or 45.5mpg. That is a reasonable for a 3200 lb. car.

What about a 300 mile trip at 60mph? The main contributor is now wind resistance. So the calculation is 300/60=5hours. Hence 5 x (11.74/36.67) x (1/.16)=10.005gal or 30mpg. That seems reasonable for a 3200 lb. car. Note here we have NOT used the PHEV feature i.e. we maintained the charge level in the battery throughout the trip. If you used the PHEV feature that would go some 40 to 60 miles without burning gasoline and improve your apparent "gas mileage" for the 300 mile trip.

PHEV mode, How much battery?

I have assumed a 25Kwh battery pack. At 60mph in PHEV mode the battery would be discharged 11.74Kwh at the one hour point. That is about 50% of the charge. In our original scenario the battery was to cycle between 80% and 20%. In the case just cited it will be at the 80-50=30% charge level.

In our scheme of PHEV hybrid we have an ICE driving a VFSM as an alternator. This is the conversion of gasoline into Kwh that can be stored in the battery OR can be used to power mot/gen unit(s) while driving at constant highway speeds. First let us address the achievable efficiency of converting gasoline to Kwh energy.

The conversion of the alternator is about .85 or slightly better. Because the ICE operates at constant load when on, it's efficiency can approach 30% because it can be tweaked for maximum efficiency due to the constant load of the alternator producing a constant Kwh output. This produces a combined efficiency of .85 x .3=.26 or 26%.

Now a subtle point. If the more efficiently produced Kw from the ICE/alternator can pass directly to the driving mot/gen(s) we avoid the losses of storing and reusing the energy. BTW the excess, is not needed by the drive mot/gen(s), can be used to increase charge level in the battery. Once the charge level reaches max we turn the ICE/alternator off and draw from the battery.

The battery pack-

My calculations for the 25Kwh pack were as follows. I assumed a so called M1 cell manufactured by A123S. The characteristics of the M1 cell is it stores 7.59wh and weighs .07 kg. The pack is comprised of 54 cells in parallel and in turn 61 of these groups are in series. Based upon 3.3 volts per cell the voltage is 201 volts with a capacity of 124 Ahr. This computes to 25,244 whr or nominally the 25Kwh we sought. This pack weights 241kg or 530 lbs.

The reader's first question is why 200 volts? Everyone else is 300 volt or more. In the Prius III, Toyota has changed to 200 volt and uses a high efficiency converter boost to 500 volts. Also they have increased the size of the mot/gen connected to the axle from 35Kw to 50Kw. The higher voltage, 500, makes acceleration quicker while the bigger mot/gen, plus lower battery voltage, 200, makes the BER better. In the Camry Hybrid, Toyota has boosted the 273 volt battery, with a converter, to 650vdc for similar reasons. My guess is they have figured out the advantage of hi-efficiency BER.

Actually the 200 volt level is great for the initial efficient acceleration from stop, with the switch to 500 volts near about 40mph. During deceleration, braking, the voltage is switched back to 200 volts after the mot/gen rpm is low enough the sufficient braking current can no longer be drawn.

Recalling some values I used earlier, the wheel rpm at 60mph is 760, the differential ratio was 2.73 yielding a mot/gen rpm of 2075. Based upon 300 volts DC yields a Krpv =6.92 or volts/rpm of 0.145 rpm/volt. With a boost to 500volts, the top speed is 100mph with a mot/gen rpm of 3458. Coincidentally the 200 volt level coincides with 40mph.

It seems we have enough knobs to turn to make the BER work over a range of 100 mph down to at least 10mph which should address all but 1.6% of the KE we want to recover i.e. 10,755/688,335=0.016. Or have we?

I am ending this article for now but I plan to research the BER item more completely. The VFD, (variable frequency drive) works well going up, i.e. taking the 500vdc and converting it into variable frequency and amplitude
3-phase sine waves to drive the mot/gen winds. For our purposes the VFD needs to be bi-directional and convert 3-phase into DC at the proper voltage to put charge back into the 200volt pack we have. BTW this pack can absorb surges of 58 x 10=580amps for up to several minutes without harm.

More work is needed<G>.

Rainmaking Gets Serious – *Dr. Richard LaRosa, sealevelcontrol.com*

PROPOSAL ACTIVITY

The April 10 Science abstracts had a link to the Bill and Melinda Gates Foundation Grand Challenges Explorations Round 1, which will award Phase I grants of $100,000. Successful projects may get Phase II grants of $1,000,000. My first reaction was that this would force somebody to at least look at my ideas. The work had to fit into one of four categories. One was "Create new ways of protecting against infectious disease." Clean fresh water for drinking, sanitation, and agriculture is necessary for protecting against infectious disease, and the way that I am proposing to get it is certainly new. So I downloaded the rules and applied. The proposal is due May 30.

A credible proposal requires that I establish a working relationship with one or more partners to provide organization, computer modeling, design, fabrication, and performance tests that are beyond my capabilities. These are only a few aspects that must be covered. More will be apparent during the proposal stage and beyond. The interests and capabilities of the partners must be aligned well enough to perform competently. May 30 is too soon to have all the details of the partnerships and the program finalized, but the direction should be clearly established by that time.

Al Gore is associated with Generation Investment Management LLP of London and Generation Investment Management U.S. LLP in Washington, DC. I have contacted them in regard to a proposal.

THE IDEA

Much rain and snow is caused by water vapor from the ocean being carried by winds to mountains. In rising over the mountains, the air expands, cools, water vapor condenses, and precipitation results. This has been happening in many places, such as the USA western states, Australia's New South Wales, China, and North Africa's Atlas Mountains. Now this precipitation is insufficient and we have drought. Disease is spreading, people are starving, and more wars will result.

It may be possible to increase evaporation from the ocean with dark-colored porous rafts whose top surface is covered with a thin layer of water which attains a higher temperature than water in the unmodified ocean. This is because the solar energy is totally absorbed by a thin layer compared to the unmodified ocean, where the sunlight must heat the thick layer that it illuminates. Also the raft body insulates the evaporation surface from the water under the raft so that a higher temperature is reached. Evaporation rate is increased by the higher temperature. Some preliminary calculations indicate that the domestic water requirements of the entire population of New South Wales might be supplied by an evaporator area 45 kilometers by 45 kilometers located off the coast of Sydney. This is enormous compared to a rooftop, but it is only a small dot on the map of Australia.

There are many challenges. The rafts must survive storms, and must maintain a wet surface while being tossed about by waves. Locations must be chosen to maximize the precipitation on land compared to that which falls uselessly into the sea. China has a monsoon which brings moisture in from the sea during the warm season. It has a long coastline and we will need to find locations for evaporator rafts that will maximize rainfall in the mountains while minimizing flooding in other areas. The four areas mentioned above have different wind regimes. The western US has westerlies at 40 degrees latitude and local monsoons further south, Australia has a daily monsoon when the desert heats up, the Atlas Mountains are in the easterly trade winds, and China has a seasonal monsoon. The microclimate in each location must be studied to optimize the evaporator raft placement.

For drought remediation in mountainous areas, I see no alternative to using the ocean as a source of fresh water, using solar energy to distill water vapor from the ocean, and using the wind to transport the vapor to the mountains where it is needed. This will also lower sea level and recharge aquifers which have been pumped dry.

THE PROPOSED PROGRAM

So far, I have estimated radiation, air convection, and evaporation losses for a solar-heated evaporator for a few times during the year. We will need to make some estimate of the losses due to water splashing over the evaporator in a rough sea. Someone with much greater knowledge of evaporation must choose the correct formulas and set up a computer program that will calculate the evaporation throughout each day of the year for all possible locations of the evaporators. Perhaps with sufficient literature search and study I will know enough about the subject and someone in the Consultants' Network can set up the computer modeling.

I anticipate that the evaporator rafts will be composed of square modules two meters on a side. One such module can be placed in a tray outdoors in natural sunlight, winds, and ambient temperature at a particular location. The evaporation rate can be measured throughout the day by measuring the water which must be added to keep the evaporator top surface wet. The tray must be elevated above ground so that leakage or overflow can be detected.. An open location is required, free of shadows and wind blocks. This will give the performance for horizontal orientation at one particular location for a particular weather sequence. Surface temperature can be measured with an infrared thermometer above the raft.

The solar industry has moved beyond testing devices at whatever intensity and sun angles prevail at the time of the test. They have moved indoors with artificial illumination. But they are testing dry photovoltaic and thermal panels. Testing evaporator rafts indoors is more difficult. We may not be able to simulate the wave motion in the test setup, so we may have to fill in the data gaps with computer modeling. This requires expertise in fluid mechanics.

There are many other complications in interpreting measurements on a small evaporator. It must be flush with the surrounding surface so that the turbulent airflow will be well developed. Elevating it on a bench will give excessive evaporation rates due to laminar flow over the raised evaporator. Evaporation rates are higher when the evaporator raft is on the crest of a wave, or its sloping surface is facing into the wind. Evaporation rate is lower when the raft is in a wave trough or its sloping surface is facing downwind. Perhaps these measurements can be obtained from experiment. We will need more fluid dynamics knowledge than I presently have to check whether the experimental measurements make sense, or to substitute theory for measurements that cannot be made.

My present concept for the raft module is a somewhat resilient block perhaps 6 inches in thickness with a wetable fabric or open-cell foam top surface supported by closed-cell floats so that the top surface can be kept wet in the ocean. Too high a position will allow it to dry out, and too low will allow waves to wash over it and cool it. The top surface must be a dark color to absorb sunlight, but must not be degraded by ultraviolet rays. The thickness of the top surface must be great enough to store water while the raft is tilted by wave motion, and the open cell pore size must retain the water in the tilted position. Somehow, we must make it sufficiently strong and durable to survive, and remain attached to all the other modules in the fabric of the raft. I envision a wire frame embedded in the foam with attachment ears at the module corners to connect to the bordering modules

I have a concept of a maintenance vehicle which rides on two large buoyant motor-driven cylinders, with one of them pivoted for steering. The vehicle rides on top of the raft, with its weight pushing the raft modules down into the water as it goes by.

PROGRESS AND QUESTIONS

Much of this article is excerpted from letters sent to universities seeking comments and expressions of interest in partnering. Some replies have been received but no details have been discussed.

I let my mind calm down and started the spot evaporation calculations over from the beginning to be sure that I was not brainwashing myself. I discovered that for more than 30 years I mistakenly thought that the dew point was equal to the wet bulb temperature. No, the latter is the adiabatic saturation temperature and it is higher than the dew point at any relative humidity less than 100%. This is important because the evaporation rate is proportional to the vapor pressure of water at the sea surface temperature minus the vapor pressure of water at the dew point. Using the wet bulb temperature instead of the dew point would result in a lower prediction of the evaporation rate.

The generally accepted idea is that the airflow across the evaporator starts out laminar and transitions to increasing turbulence as it flows over the evaporator. The evaporation rate decreases with increasing turbulence. For the second set of calculations, I used a characteristic length of 10 km instead of the 1 km that I used the first time. This decreased the evaporation rate, but the evaporative heat loss also decreased, allowing the water surface temperature to increase and help restore the evaporation rate.

My calculations for the forced convection heat loss did not agree with the expected Bowen Ratio, the ratio of forced convection loss to evaporation heat loss. More work is needed on this point, but my calculations appear to be reasonable approximations. The 45 km by 45 km evaporator will supply the domestic water required by the population of New South Wales provided all of the vapor rains out over the mountains in southeast Australia. We will need to learn something about this aspect of meteorology and incorporate it into our computer model in order to predict the amount of rainfall recovered from the evaporated seawater.

This question about what fraction of the evaporated seawater is actually recovered as precipitation is crucial to the success of this program. I am guessing that we would like the vapor from the evaporator rafts to be concentrated in a narrow path to the mountains in order to insure that in rising, expanding, cooling and condensing, the amount of precipitation is maximized. Locating the evaporators close to shore should help to keep the vapor concentrated. Perhaps a study of the microclimate will locate places where the wind is funneled into a mountain pass. The Australian evaporator array has been described as a square. Perhaps a long strip parallel to the shore might be better. Or perhaps a long strip with some other orientation would work better. Commercial and sport fishermen, as well as ferry services and other marine entities will voice their preferences.

People often suggest trying the idea out on a small scale, but I suspect that the effects we are looking for are not linear or scalable. However, note that of the four examples mentioned, China is the largest geographic area, with western USA, Atlas Mountains, and southeast Australia following in size order. It does not matter if I have listed them in the wrong order. They are all too big for the effects of a small evaporator to be evident. If we can find a much smaller orographic feature, we may be able to use it for a small scale demonstration. The proposed program will include a search of world geography for such a feature. Perhaps we will be lucky enough to find it somewhere in the Great Divider Range on the east coast of Australia, or perhaps in the Snowy Mountains to the south. The detailed knowledge of local people will be a great help in the search, and their cooperation will be a needed in setting up the experiment and measuring the results. This is a good area to target because its drought is devastating rice production which many people have depended upon. We will still need to rely on computer modeling and good design sense to guide large-scale construction and test. We should also plan on cloud seeding. The Chinese have been shooting silver iodide crystals up from the ground without much success. I suspect that cloud seeding does not do much good if there is insufficient vapor. Floating evaporators in the right locations would improve their results.

For the Australian example, vapor will be produced during sunshine hours, but the wind does not have a clear direction toward shore until the afternoon. During the morning, the wind might blow in a sequence of different directions, but the velocity is low and the vapor is not transported far from the evaporator location. It should remain available to be brought to the mountains in the afternoon. We will need to incorporate similar behavior in the microclimate model that is developed for each continent that is studied.

In each location, the sea surface will be covered by many modules in close proximity to each other. For modules 2 m x 2 m, we will need 506 million modules to build the Australian evaporator. If each module costs $50, the array will cost about $25 billion plus moorings, installation, and maintenance. It cannot be built all at once and the modules will have a finite lifetime. It is a serious concern that the module replacement rate not be a significant fraction of the new module installation rate. We should always compare these costs to what is spent on warfare in order to maintain our perspective.

When such large areas of ocean are covered by evaporator rafts, will there be any reduction of wave amplitude? No doubt, the answer is known, but I don't know what it is yet. My guess is that the rafts will be too light weight to have much effect. However, there has been much development of wave attenuators. Perhaps these can be installed around the periphery to mitigate the effects of storms. Add this to the list of things to learn.