THE CONSULTANT

The Newsletter of the IEEE Consultants Network of Long Island

Volume 25, Number 3 *March 2008*

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*

Most of you have probably heard Paul Harvey's show called the REST OF THE STORY. It's been on the air since 1976. Well, here's an engineering equivalent of one of his tales. I think it illustrates something we engineers often forget − emotion usually trumps reason.

In 2003 Nova aired a show called BATTLE OF THE X-PLANES. It described the design competition between Boeing and Lockheed Martin for the Joint Strike Fighter now known as the F-35. It was supposed to replace the F-22, deemed too expensive. A key requirement, aimed at cost reduction, was that the basic airframe had to meet the needs of both the Air Force and the Navy. For the Navy version, this meant providing for vertical takeoff and landing like the Harrier. To do this requires a way to generate direct vertical lift near the center of the aircraft.

Boeing's approach was to locate the engine near the front and, then, for the Navy version, provide a thrust vectoring assembly similar to the Harrier's that could provide lift at the center of gravity. This had the advantage of mechanical simplicity. But, since the air intake also has to be in the forward area, it created a short, squat shape that some people said looked like a hippopotamus.

Lockheed created a design that was visually attractive by using a new concept called a lift fan. In the lift fan design, the engine sits in the usual fighter position in the tail. A drive shaft connects it to a large fan placed behind the pilot. To hover, engine exhaust is directed downward, but the fan is also engaged, taking in air from above the plane and blowing it out below. That creates two balanced sources of thrust, potentially a more powerful and stable arrangement than the Boeing solution. But to accomplish this feat, the drive shaft must be spun at an incredible rate. Someone compared the design problem to "taking the propulsion system in a Navy Destroyer, shrinking that down into a smaller package and putting it into a jet fighter airplane". Furthermore, it had to be possible to modulate the ratio of vertical to horizontal thrust.

continued on p.3

Meetings

February 2008

Topic: "Alternative Dispute Resolution for Engineers" or "Everything You Always Wanted to Know About Avoiding Court Litigation"

Speaker: Mr. David J. Abeshouse, Esq., Uniondale, NY

This was all about arbitration and mediation. There wasn't a dry eye in the room when he told us how mediation of a business dispute resulted in a family reconciliation.

March 2008

Topic: "Using Google AdWords To Promote Your Website"

Speaker: David Pinkowitz, DCP Marketing Services

7:00 PM, Wednesday, March 5

Briarcliffe College, 1055 Stewart Avenue, Bethpage, NY.

Admission is free (no charge). No pre-registration is required. For information, contact John Dunn at (516) 378-2149 or e-mail ambertec@ieee.org. Guests are welcome. Light refreshments will be served.

Directions: See our website www.consult-li.com.

Dave's marketing experience includes ten years as Director of Marketing at a $90 million Long Island electronics firm. Since 1996, he has been working with a variety of technology-based clients to build awareness, develop relationships, and generate sales leads through creative strategies, marketing communications, and introductions to potential business partners.

He is an active networker and leader in the Long Island technology community.

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.

THE CONSULTANT is published monthly by the IEEE Long Island Consultants Network and is available free of charge to its members.
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

Deadlines: Flexible
Articles for publication in ***THE CONSULTANT:*** Send them in. We need them.

The IEEE Consultants' Network of Long Island maintains a referral service of engineering, computer, managerial, and technical professionals. Call or write for more information. There is no charge to the client for this service.

Referral Service and Voice Mail:

516-379-1678

Web Page: http://www.consult-li.com

continued from p.1

There were other issues in the competition. However, the one emphasized by the Nova writers was the vertical lift schemes. It was clear that the lift fan of the Lockheed Martin design was going to be an engineering nightmare. The Boeing design met the requirements and from an engineering standpoint it was, by far, a more reliable and cost effective design. But it looked awkward and in the short time allowed for the tests the functional advantages couldn't be made apparent.

Of course, the Lockheed Martin design won. If you can't guess, it's the one on the right.

Now, for the rest of the story:

It seems that about 20 years ago when working on the F-22 (The plane that turned out to be too expensive and again competing with Boeing), Lockheed Martin had learned a very valuable lesson about the importance of emotion. Here's the story from the February 2008 issue of "Mechanical Engineering"

▸▸Heart of the Matter

NEARLY 20 YEARS AGO, TOM WHITE LEARNED HOW AN EMOTIONAL STORY COULD HELP SELL DEFENSE PRODUCTS. At the time, he was at Lockheed Martin Corp., working on the Advanced Tactical Fighter (the ATF, which became the F-22 Raptor). The story he told did not change the design, but it did alter the customer's experience so that decision makers saw the aircraft through different eyes.

Lockheed and The Boeing Co. were competing for the contract. Lockheed decided to build the best possible fighter, even if it meant ignoring some Air Force specifications. It was a risky strategy. It would have to shift the Defense Department's thinking to sell its design. In 1988, it had pitched its design at the Air Force Association's annual meeting. Its short movie, which focused on technology, had fallen flat. "The military brass thought we were telling them their business," White recalled.

The next year, White produced a movie celebrating the 50th anniversary of Lockheed's famed P-38 Mustang. In the 12-minute film, World War II ace Dick Bong appears to a boy who dreams of being a fighter pilot. "The movie was not about the airplane. It was about the pilot," White said. "We wanted people to remember what it's like to be a fighter pilot."

White showed the movie to some Lockheed managers and Air Force officers one week before the meeting. "We thought we had a real winner, but when it was over, there was absolute dead silence," said White. "The head of the ATF program said to me, 'We can't show this. I'd rather show a Bugs Bunny cartoon than show this.'"

With one week to go, though, Lockheed had no choice but to show the movie. Its small exhibition theater drew crowds all day. The real payoff, however, came after the evening's black-tie dinner, when the Secretary and Under Secretary of the Air Force, some top generals, and Lockheed executives and their wives visited Lockheed's theater.

"Twelve minutes later, the doors opened and the Secretary emerged with tears streaming down his cheeks," White recalled. "He walked through the crowd, not wiping away a tear, and went up our chairman, Dan Tellep, clasped his hands, and said, 'You've captured the spirit of this program.'"

White, now executive vice president at RKS Design Inc. in Thousand Oaks, Calif., believes the movie helped Lockheed win the ATF contract by getting decision makers to see Lockheed's design as more than a series of specifications.

.

The experience reaffirmed White's belief that emotion and reason easily trump reason alone. "People are not interested in products. They don't understand them," he said. "We all have our degrees and we spend our careers trying to understand these technologies. When two technologies are competitive, how do we convince someone? We connect with both their heart and their head."

White connects with the heart through story telling. Not just any story, either. RKS's model for product design is the hero's journey, described by scholar Joseph Campbell as the basis for all the world's myths. In it, the hero sets off on a quest, undergoes trials, and finally secures a treasure that he brings home to benefit the community. The myth runs through world literature, from *The Odyssey* to *Star Wars.*

White admits engineers might have problems dealing with that kind of talk from people who say they are involved in human factors. "Until now, industrial designers and engineers used to think more alike," he said. "Engineering at its best and worst is about understanding requirements, specs, and data. The hero's journey is fundamentally very spiritual, but it's also a core component of every human being on earth."

It's easy to ridicule a trip to the mall to buy a new phone as a heroic quest. Yet most of us know people (maybe ourselves?) who return with a new purchase seeking approval. According to White: "When your friends affirm your purchase ('You bought an iPhone. You're on the edge. You're such a visionary.') it cements a bonding relationship between consumer and product. The product has made the consumer the hero. In a sense, the product has become their mentor."

Most people know that feeling. For White, this is the moment of truth because it turns customers into emotional evangelists for his client's brand. As RKS's Web site proudly announces: "It's not how you feel about the design; it's how the design makes you feel about yourself.'"

Addendum to the REST OF THE STORY.

The Air Force version of the x-plane was named the F-35A. The Navy's vertical takeoff version is now called the F-35B. The current status of the aircraft is as follows.

The F-35A made it into production in February of 2006. A number of problems were found in the first test flights by Lockheed test pilots. They were corrected without major design changes. However it took two more years before it was turned over to the Air Force on Jan 31, 2008. It appears to be doing well. The Air Force plans to eventually acquire 1,753 to replace its F-16s and many other versions will be sold to international customers.

The F-35B may never make it. The following comes from a web site called Globalsecurity.org run by John Pike, a noted scientist who consults on security issues.

> *As of 2002 the Marine Corps planned to deploy 609 F-35Bs. STOVL first flight was to be in early 2006, with firs delivery in 2008, and IOC 2010. The Marine Corps, with an IOC planned for 2010, would be the first of the military services to operate a fleet of F-35s.*
>
> *By February 2004, dark clouds were gathering, and it was clear that the team was sailing into stormy technical waters. As detailed design progressed, weight estimates from early in the design phase were found to be overly optimistic. Program leadership was soon faced with the grim reality that the short takeoff/vertical landing (STOVL) variant would need to lose as much as 3,000 pounds to meet performance requirements. This was a sobering development, and there were more than a few who said that a fix was either impossible or too expensive and time-consuming.*
>
> *The Joint Strike Fighter (JSF) program entered a re-plan phase as a result of a number of technical issues with aircraft design (principally with aircraft weight of the Short Take-Off and Vertical Landing (STOVL) variant). The STOVL aircraft is considered to be the linchpin to the program's*

success. These technical issues resulted in an acknowledged minimum slip to the IOC dates for the three aircraft variants of up to two years.

I suppose that one moral you can draw from this story is that even though emotion trumps reason, it costs more.

Build Your Own Hybrid Car ?? -continued *–– Carl E. Schwab*

VFSM, PMSM, Induction, Brush-less DC Motors

In my discussion of how one could, "BUILD YOUR OWN HYBRID CAR ??", I have only considered the induction motor as a candidate for powering an electric final drive. But two others should be considered and indeed just may by the final winners in the unlikely case there is a single winner.

At the present time the induction motor and the PMSM have both been used and the purpose here is to show similarities and differences.

Some definitions: PMSM is short for Permanent Magnet Synchronous motor. VFSM stands for Variable Field Synchronous Motor. In both cases the term "Synchronous" appears so let's consider that first.

The synchronous motor differs from the induction motor in that the synchronous motor has no "slip" region i.e. as you apply load the rotor phase shifts but the rpm does not change. If you load sufficiently, the rotor "cogs" or jumps forward or backward to the next stable torque point. For example for a PMSM having 8 poles (or 4 pole-pairs), there are 4 stable points in one rotation i.e. 360 degrees or 90 degrees. Interspersed between the 4 stable points are 4 "cogs". For use in powering the final drive of a car we are concerned with the torque range between two adjacent cogging points.

Explanation: Once the motor has cogged it is easy for it to continue doing so and the effective torque drops to near zero. In fixed frequency applications care has to taken to drop the load and get the motor back in synch. For the electric drive application we will be using a VFD, Variable Frequency Drive, and the rotor will always be in synch.

Whether PMSM or VFSM are driven as motors, either will require VFD (Variable Frequency Drive) and indeed it does appear that a separate VFD will be required for
each PMSM (or VFSM) motor since they do not have a "slip" region. Again the VFD has to deliver a constant "volts/hertz". Now for comparison of differences between the VFSM and PMSM.

The VFSM is the same device as the 3-phase alternator and as such the VF magnetic field strength determines the "volts/hertz". Add a 3-phase rectifier (often 6 diodes) you can produce a low ripple DC for battery recharging. To make the field variable, a slip-ring is required to bring the DC current into the field coil in the rotor. For operation, as a alternator, a VFD is NOT required. In our home grown "series Hybrid", VFSM would be used to convert the ICE shaft rotation into DC for battery recharging and DC current for TRIP cruising. Conceivably a VFSM with "smart" VFD could provide a wider range of variable torque for the drive motor(s). More thought is required.

Cost Comparison Comment: The most significant cost difference between the PMSM and the VFSM is the cost of permanent magnet material (many magnets) against the copper cost for the single field coil and brush slip-ring in the VFSM. Presently the VFSM, as the ordinary battery charging alternator in virtually all cars, are made in the millions, and all over the world.

But now some other considerations: Suppose one wanted to make a very simple E-car using basically only one motor and did not want the expense of a full-blown VFD?
The immediate thought, "Why not a brushed DC motor with a simple speed control?" The answer is, certainly you can, but brush life will certainly be a factor and RFI a serious consideration. Assuming you did NOT want to use a brushed DC motor (because of the brush wear problem), what are the alternates? Actually there are two.

1) Referred to as a brushless DC motor; it is essentially PMSM but has a shaft position sensor to advance the field generated magnet field thus causing the PM rotor to rotate. This technology has been around for about 30 years and first found large-scale use in disk drives for computers. They behaved very much like a brushed DC motor in all regards BUT had no brushes to wear out. And for disk drives this was a godsend.

2) Referred to sensorless-brushless DC motors; these are PMSM motors that use a simplified 3-phase drive circuit to rotate the field-generated magnetic field. This drive circuit senses the cross-over voltage of the back-emf waveform to pace the drive to the circuit. This type motor is used as motive power for RC model airplanes and model boats etc. For the cross-over circuit to work requires the shaft be rotating. A bit of a problem for an E-car.

Both brushless and sensorless-brushless DC motor drive circuits generate 3-phase voltages that are phase synched to the shaft rotation. Because of this, both types usually operate at much higher RPM rates than would normally be used in an E-car. In the hobby applications typical RPM are between 4,000 and 40,000 RPM. These motors are characterized by a constant, Krpv, measured in RPM/Volt. Typical numbers vary from as low as 100rpm/V to as high as 5000rpm/V. The required RPM is set by varying the DC drive voltage. Note this constant, Krpv, relates to, and is the reciprocal of, the "volts/hertz" used in the discussion of the VFD.

{For the VFD the constant is volts/hertz; but hertz = (rpm x constant) i.e. volts/(rpm x constant).}

Either the brushless DC motor or the sensorless-brushless DC motor can function as a generator for regenerative braking. Could either or both of these motors be used to drive an E-car? If so what are advantages and what are the drawbacks?

The quick answer is "Yes". But there is a subtle (or not so subtle) point. If the brushless motor has a shaft sensor it can vary rpm down to "0" and into reverse. (The shaft sensor also senses direction of rotation.) If the brushless motor does NOT have a shaft sensor i.e. is a sensorless-brushless DC motor, the cross-over circuit depends on back-emf which requires rotation. But at "0"rpm there is no rotation -- Catch 22.

Comment: The sensorless-brushless , when first turned "on" is not rotating hence the "0" cross-over circuit generates no signal. This necessitates a "start up" circuit to supply a sequence to start rotation and make the "0" cross-over start functioning. Above say about 100 rpm the "0" cross-over circuit is fine. Reversing rotation direction is done by swapping any 2 of the 3-phase drive wires.

For the simple single motor E-car drive, either can be used and either the sensorless-brushless or brushless DC motor will cost less. For this case the brushless DC motor (with a shaft sensor) will work the best because it can vary through "0" rpm and reverse.

Krpv vs Volts/hertz:

Krpv represents RPM/volt (usually dc) and is the constant delineating how much voltage is required for a specific RPM. Implicit is the fact the near "0" volts are needed for near "0" RPM. Also associated with this type motor is another constant Ktpa which expresses Torque(oz-in) per amp. For PM motors

$$\text{Krpv} \times \text{Ktpa} = 1352.$$

This term, Ktpa, determines how much current is required to generate a specific torque (in oz-in) at “0” RPM. This equation clearly shows that lower RPM (low Krpv) motors produce higher torque (higher Ktpa). This relationship applies to PM motors where the frequency and phase of the AC current are synched with the rotor position. This obviously applies to a brushed DC PM motor. And as with the brushed DC PM motor, when you apply a voltage the rotor quickly accelerates to an RPM. These relationships are most useful when the mechanical load is a fan, propeller, blower, mixer etc. When you desire a particular RPM, if the inherent speed regulation of the motor alone is not sufficient, you need a feedback arrangement and an RPM sensor to get the desired accuracy. Where the load fluctuates (such as an E-car) the current drive to the motor has to vary to produce the needed torque. In actuality you need a hi-efficiency drive circuit that has both voltage AND current feedback. Synchronizing two such motors to share a mechanical load as in an E-car can be done but is a bit tedious.

Volts/hertz connotes a Variable Frequency Drive, VFD, with a PMSM motor. At “0” RPM the hertz=0. To generate torque the VFD outputs a 3-phase current required for torque and the frequency required for the RPM. To perform acceleration we continuously vary the frequency, which in turn sets a voltage to match the expected back-emf. BTW the frequency of the 3-phase current is both positive or negative i.e. forward or reverse. Also as “0” frequency the motor can receive a “holding” current to prevent rolling.

Which Is Best?

For our E-car it seems that the VFD makes possible many advantages under computer program control. Current day costs of generating this program are reasonable AND modifications can be tested and made without having to make extensive mechanical modifications.

Complications, Complications – *Dr. Richard LaRosa, sealevelcontrol.com*

BASIC UPWELLING PUMP

Last month, the wave-powered upwelling pump being developed and tested by Philip Kithil's company, Atmocean, was described and analyzed. From information on their website, it is a vertical tube made of thin plastic film with a heavy check valve plate at the bottom. The tube is suspended from a float and a wire rope runs through the tube to connect the float to the check valve plate. A slack mooring keeps the float in somewhat of a fixed location while the waves lift it up and down. When the float is in a wave trough, the check valves open and the weight of the valve plate pulls the tube down to engulf a small volume of water. As the water surface rises, the float attempts to pull up the entire mass of water in the tube, but the buoyancy pull-up force is limited to avoid excessive bulging at the lower end of the tube. The float is therefore submerged until the next wave trough. While submerged, the sack of water is moved up slightly. The process is repeated with each wave cycle, so there is a slow, intermittent upward transport of water.

The wire rope relieves the vertical stress in the plastic film, but when the closed check valve plate is pulled up it creates a pressure at the bottom of the tube which tends to make it bulge out. The float buoyancy is limited to a value that avoids excessive circumferential (hoop) stress in the film. The upward pumping rate is proportional to the diameter of the tube and inversely proportional to its length. However, the tube diameter must be about the same as the diameter of the valve plate. Otherwise the tube could not easily move down to engulf another quantity of water. Also, the open check valves should create a minimum of drag as the plate drops down. I have the impression that the check valve plate and tube diameter should be limited to one meter to allow storage, handling, and deployment.

MODIFICATIONS

We are free to string any number of tubes with their respective check valve plates on a single wire rope. Breaking a single upwelling tube into N equal lengths multiplies the pumping rate by N because the float buoyancy can be multiplied by N and applied to N check valve plates without exceeding the allowable circumferential stress in any tube. The upper end of each tube might be joined to the valve plate above it to form a closed system, or each stage might simply discharge in the vicinity of the intake above it.

Furthermore, we can upwell from any level to some higher level, not necessarily the ocean surface. There are many different ocean situations that require custom design of remediation and enhancement systems. The upwelling pump described above is also an important component of a wave-powered aeration system to be introduced and described in the next two sections.

DEAD ZONES and AERATION

Dead zones are deficient in dissolved oxygen and are also called anoxic zones. A troublesome one has been appearing off the coast of Oregon. The California Current runs from north to south along the coast. The Coriolis force diverts the fast-moving surface water in the current to the right, out to sea. The sea level is higher on the right side of the current than it is on the shore side. This creates a return flow toward the shore underneath the current. This returned water upwells toward shore, bringing nutrients which are good for phytoplankton. But this deeper water has been depleted of oxygen by the respiration of ocean creatures and the decay of organic matter. What used to be a productive fishery is being destroyed. A wave-powered aeration system might help.

Aeration and oxygenation systems are commonly used in lakes and inland waterways. Aeration systems pump air through perforated pipes so that small bubbles are produced. The increased surface-to-volume ratio of the small bubbles helps them to dissolve more readily as they rise up through the water. Liquid oxygen is also used, perhaps because oxygen is the desired species and having to include four times as much nitrogen creates an excessive disturbance of the bottom sediment. Oxygen is used in lakes in heavily industrialized parts of northern Italy. Large compressors pump air through perforated diffuser pipes in Lake Elsinore (about 40 miles east of Los Angeles). Somebody was telling me about an aeration system near the Brooklyn Queens Expressway. I think it was in Wallabout Channel between Williamsburg and the Brooklyn Navy Yard. Electric power is available for these inland locations. This is not the case when we require remediation in the open ocean.

Wave motion is a possible source of power to aerate ocean water. We might rig up a float tugging on a pump against a mooring anchored to the bottom. Perhaps several anchors spread out in a 2-d pattern with slanted mooring lines would define a reference point in the ocean to react against the float and pump. However, I have difficulty figuring out how to compensate for changes in the ocean level due to tides. Perhaps a reader may know how this can be accomplished. However, I think I see how the float and pump can work against the inertia of the column of water trapped in the upwelling pump during its upstroke. This is described in the next section.

WAVE-POWERED AERATION SYSTEM

The air pump for this system is a vertical cylinder with intake and exhaust valves at the bottom end. The push rod for the piston comes out of the top end of the cylinder. The cylinder can be built into the float. To compress air, the push rod must be pulled down by at least a pair of wire ropes that are guided past the cylinder and attach to the wire rope that runs through a single upwelling pump or a stack of upwelling tubes and their respective check valve plates.

The orientation of the pump (piston on top and valves on the bottom) is chosen to facilitate clearing out water that might get into the pump. The air intake is via a snorkel whose open end should be above the water surface. A spring pushes the piston outward to draw air into the cylinder. This happens when the float is in the trough of the wave. There is always tension in the wire rope due to the gravitational pull on the check valve plate(s) of the upwelling pump(s). The spring must overcome this tension plus the water pressing on the outside of the piston. There is a complicated balancing act between all the parameters of the system (spring law, air piston area, check valve weight, spectral distribution of wave heights and periods, upwelling pump tube diameter and length, etc.) and I haven't got it all figured out yet. But I'm pretty sure everything will go together and we can see how well it works.

When the water surface rises and the upwelling check valves close, the air intake valve closes, the air pump starts to compress the air, the upwelling pumps are pulled upward, the float submerges, and the snorkel tube must protrude above the surface while the wave peak goes by. This can be accomplished by mounting the snorkel on its own float and connecting it to the air pump intake port by means of a flexible tube of sufficient length. There will be times when we get some water into the air intake due to wind and wave action, which is why I think we want the piston on top and the valves on the bottom.

The air pump outlet pipe extends down to the perforated diffuser at the chosen discharge depth. Suppose we choose to discharge at 10-meter depth. Water pressure increases by approximately one atmosphere (atm) for every 10 meters (32.8 ft) of depth so we must compress the water to an absolute pressure of 2 atm, 1 atm for the overlying air pressure, and 1 atm for the water depth. The air is taken in at 1 atm, so we must squeeze the volume in half, if the compression is isothermal. Some trial calculations suggest a cylinder a few inches in diameter, and a stroke of 20 inches. If the wave period is 10 seconds, the process is probably isothermal.

Just as in the case of the upwelling pump, the wave height does not appear explicitly. Pushing the piston into the cylinder lengthens the distance between the float and the upwelling pump, so the float surfaces sooner than if the air pump were not in the system. The exact relation between wave height and air pumping rate will probably require more analytical and programming skills than I have. Maybe I can get some help from SATOP. Let's look at the broader picture, which gets even murkier.

COMPLICATIONS, COMPLICATIONS

We have seen that both Nature and our upwelling pumps can bring up water with both low dissolved oxygen (O2) and high carbon dioxide (CO2). We may be able to help the O2 deficiency by aeration, depending on how the performance numbers turn out. But the possibility of upwelling high CO2 and having it outgas to the atmosphere is bothersome, although this out-gassing has probably been going on all along in natural upwelling and nobody worried about it. What can we do about it?

It's a dirty trick, but we can bring up one scarey thing to make another seem not so bad. We know that excess dissolved CO2 in the ocean is interfering with the formation of calcium carbonate (CaCO3) shells and skeletons due to the decrease in alkalinity of the ocean. The problem is expected to worsen, so the possibility of out-gassing CO2 from the ocean would help maintain its alkalinity. But this is just passing the buck between the ocean and the atmosphere. We want to decrease both the atmospheric and oceanic CO2. How?

Sequestration in geologic formations is being considered, but does not seem to have progressed very far, and appears to target concentrated CO2 sources like smokestack emissions before they are disbursed into the atmosphere. Removing CO2 that is already distributed throughout the atmosphere and concentrating it for sequestration adds another layer of difficulty. Studies are showing that biofuels produced by destructive farming practices (corn is a big offender) increase CO2. Not much help there.

CO2 and water are the raw materials required in bulk for terrestrial and oceanic photosynthesis. The ocean requires no irrigation and has the other ingredients, such as nitrate and phosphate ions, iron, and vitamin B12. They just have to be redistributed to where they can be most useful. In most of the tropical ocean, they are trapped below the thermocline, where stable stratification prevents them from circulating up into the euphotic zone, where the sunlight is sufficient to enable photosynthesis. Since the ocean food supply is declining, it would seem logical to upwell the nutrients needed to restore and enhance the ocean productivity. Then, on a full stomach, we can examine whether the oceanic or atmospheric CO2 is increasing or decreasing due to the upwelling. My guess is that more CO2 will be tied up in the carbon cycle of the ocean food chain

SURVIVING IDEAS

I have fiddled with a lot of ideas in the past eight years. Most were discarded. Here's what remains:

1. Upwell nutrients and cold water, and aerate where necessary. Wave-powered pumps can do the job.

2. Use solar heating to evaporate water from the ocean in places where air currents will carry it up coastal mountains where it will precipitate.

3. Turbines in the passages between the Antilles Islands will provide electric power where it is needed and lower sea level in the Gulf of Mexico by diverting Equatorial Current water directly into the Gulf Stream instead of flowing through the Gulf.