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Conservation-The First Alternate Fuel

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ABSTRACT

A great amount of attention and funds is being focused on alternate forms of energy. These efforts on a broad front should and must continue, but it is clear that the quickest, cheapest, and most reliable way to make more energy available for our use is through conservation. It can be demonstrated that the potential energy savings are twice the energy we now import from foreign sources.

Any serious student of the World's energy situation can find ample cause for alarm. The world isn't going to be dark in 50 years as the doomsayers put it, but there is no question that energy is one of the true superproblems facing our country. The most immediate concern in that problem is how to proceed most rapidly to free ourselves of our crippling dependence on foreign oil? How can we eliminate forever the embarrassing situation in which the greatest nation in the world can be brought to its knees by the whims of a few Arabian princes.

I think history will show that one of the most fortunate things that happened to our country and to other industrial countries of the world was the 1973 oil crisis. This provided the forcing function needed to focus attention on the energy needs of the world, in general and on the extreme dependence on Middle East oil, in particular. This led to President Carter declaring our energy problems were the "moral equivalent of war" requiring similar dedication and drastic actions.

Many new programs have sprung up, most aided by federal programs, and today extensive efforts are underway across a broad spectrum - oil and gas explorations, shale oil, coal, solar, biomass, nuclear, geothermal and winds. Progress is being made but also many obstacles have developed. Environmentalists are preventing or fighting the exploitation of many areas, solar has not emerged as yet as an economic competitor except in specialized instances. Growth of nuclear power has been brought to a standstill. Last year four permits for new nuclear plants were issued, none were started and twenty-two were halted in mid-construction. Large windmills have problems ranging from structural to strong complaints of interference with TV reception. And the list goes on.

The push on the broad frontier should and must continue. But it is clear that the quickest, the safest, and the cheapest way to produce more energy is through conservation.

Let's look first at the big picture. It is convenient to use the energy unit quad, or one quadrillion BTUs. To put that unit into perspective, it takes about 250 quads a year to run all the nations of the world; 170 supertankers can haul one quad of oil; 20 Three Mile Island nuclear plants generate one quad of electricity per year. A quad is equivalent to 7½ billion gallons of gasoline, 46 million tons of coal or 300 billion kwh.

Last year our country used about 80 quads of energy, all but 5 quads from coal, oil and natural gas (Figure 1). About 17 quads came from imported oil. The chart is a little complex but very interesting. Note about half of the energy is lost in the conversion process. A typical generating plant can only convert one-third of its coal energy into electricity delivered to the user. Much of this loss is unavoidable resulting from fundamental laws of physics, but more than 17 quads are estimated to disappear in cooling towers or into rivers in the form of waste heat.

Let's concentrate on the bottom half with some examples with which we are familiar. There are 35 quads that are available for use. There are studies that say that 50% of this energy is wasted because of simple inefficiencies! This may sound high, but I have no trouble accepting this number because of my experience at Kennedy Space Center. About the time I took over as Director of the Center in 1975, NASA established energy conservation goals. By operational changes and by equipment retrofit, we were able to reduce energy consumption by 47% during a period that the center population increased from 7800 to 11,000. I understand this is still about the savings even though the population is up to 13,000.

The worst problems in energy conservation exist with buildings designed in the decade or two prior to 1973 with much glass, minor insulation, and oversized equipment the general rule. Today electricity is 6¢ per kilowatt-hour and oil is $1.00 per gallon. In 1973 electricity was less than 1¢ per kilowatt-hour and oil 9¢ per gallon. Obviously in the sixties energy cost was a very minor consideration. KSC buildings are good examples of the fashion: the architects designed for the worst heating and cooling days. The Corps of Engineers who were supervising probably added a factor and the NASA approval chain added another. It didn't cost much to be ultra conservative, but the designers knew they would catch hell if it was too warm that one day a year. Lighting was designed for 100 footcandles at desk top level instead of half of that in use today. A single light switch would turn on a large bank of offices. A whole wing of a building was on one cooling system, so one person working late required the whole system operating. At KSC there are additional special problems. Construction occurred just before the state-of-the-art of computers shifted to solid state technology, so systems were designed to remove the heat from massive banks of vacuum tubes. In some areas there was concern about interference from fluorescent lights, so many far less efficient incandescent lights were used. Most KSC systems used were designed for reheat - that is, the air was cooled excessively then reheated to the desired temperature so the humidity is kept low - very comforting, but very expensive today.

I recall a couple of interesting data points relative to the oversizing at KSC. The astronaut quarters were on the main system of the Operations and Checkout Building. On occasion this was the only space occupied. The smallest compressor that could be run was 800 tons. Probably 5 tons would have been sufficient. I remember hearing of a large unoccupied volume of the VAB being air conditioned to take care of one small bonded storage room.

On cool days it was necessary to do some air conditioning at the launch control center for humidity control. The smallest unit that could be used was 2500 tons. The load was so low that the unit wouldn't operate unless a false load was added.

These kinds of stories abound at KSC in common with many large buildings all over the country. The basic point is that KSC has been able to reduce its energy consumption by 47% with greatly increased population. More is possible when funds are available for retrofitting to smaller, more efficient units. This excellent result to date stems from the basic interest of many of us in energy conservation and from the targets that were established by NASA Headquarters. For non-government buildings the only pressure comes from economics. Unfortunately, far too many building managers look with despair at rising utility bills and accept them as the cost of doing business.

In our consulting work we continually run into older designs in which large amounts of energy can be saved. At an Air Force base in Florida, a central heating plant generated high pressure steam for use in space heating and for hot water. Much of the distribution system was underground and poorly insulated. We calculated that 60% of the energy generated was lost before ever reaching its destination. The plant was operated continuously which precluded repairs to the distribution system. Yet for eight months of the year it was only used for heating water. Our recommendation here was to install satellite domestic water heaters and shut down the central plant for these eight months. The savings were well over $200,000 per year and the payback was less than two years.

Technology often isn't required - simply awareness. We did an energy study on a hospital and found that one of the cooling systems was operated continuously even though the spaces were occupied only 8 hours a day. The reason was that they stored medicine which has an upper temperature limit. The area was below ground. On a hot summer evening we turned the air conditioning off at the end of the normal working day and demonstrated that the area in question would not come within 10^{o} of their upper limit. In this particular hospital there were almost no funds available for energy investments, so we were limited to no-cost or low cost recommendations. For an expenditure of about $5,000, mostly for timeclocks, they were able to save 19% of their large energy bill. The payback was a little more than three weeks!

With another hospital there was a requirement to have an operating room at 60^{o}F with low relative humidity. The air was being subcooled to 50^{0} then heated. However there were a number of patient rooms in that same zone and their air too was being cooled to 50^{0} then reheated to the comfort level. The obvious solution here was a small separate unit for the operating room alone.

Recently I was in a bank in St. Marys, Georgia. They had installed a twenty-four hour automatic teller in a corner of the lobby. It was essentially a cage inside about the size of a telephone booth. Because of temperature limits on the computer of the automatic teller, the entire bank was being air conditioned continuously - 24 hours a day instead of the 40 hours a week previously used. They hadn't thought of enclosing the small booth and putting the smallest type of separate unit in it.

Some problems would be inordinately expensive to fix. One of our clients was a hotel and shopping complex in Miami. It was constructed in the past ten years. It has a slanted glass wall four stories high at the lower levels. Esthetically, it is beautiful. Energy-wise it is terrible. It faces due west catching the sun from noon until sunset. It is a massive greenhouse - an excellent design for solar space heating which isn't of the highest priority in Miami.

Let's look for a moment at the 17 quads that are estimated as being lost as waste heat. One of our group was involved in a study of use of waste heat from gas turbines at a gas pipeline pumping station. The heat wasted was 43 million BTU per hour. This particular one was at a site where a 10 million gallon per year ethanol refinery was under consideration. This waste heat is sufficient to operate the entire refinery. The cost of the installation to convert the waste heat to steam was $505,000. If instead the refinery were gas fired, the fuel cost would be $1.3 million per year. Payback was just over 5 months. This particular pipeline has 15 such stations and waste heat available for use is 5.6 trillion BTU/yr.

Here in Florida work is just starting on using the waste heat from the same type of natural gas pumping stations for the generation of electricity and then putting it back on grid.

It is in industrial plants that opportunities exist for effective use of vast quantities of waste heat as well as for other forms of energy conservation.

As a typical example let's look in a little depth at a representative Florida industry. Phosphate plants are the biggest energy consumers with utility bills typically over a million dollars per month! Another important user group are the citrus processing plants who average several million a year on energy. These plants are primarily used to convert oranges into frozen concentrate, and the peels into cattle feed although there are a number of by-products.

This process starts with trucks unloading fresh fruit onto conveyor belts (Figure 2). Leaves, branches and bad fruit are separated by mechanical means while the good fruit is stored in large open air bins. The oranges are conveyed from this storage area to the grading and juice extraction room. Here the oranges are graded according to size and fed into the appropriate extraction machine. These machines and other auxiliary machines in the extraction room separate the oranges into three parts; the outside peel, the pulp and the juice.

Let's follow the juice flow first. It is pumped to a short term storage tank and from there the juice flows to the evaporator. This device takes juice that is approximately 12% solids and removes water by heating the juice until the juice is about 65% solids. This juice concentrate is pumped to large double walled chilled tanks called blend tanks because this is where the different batches of concentrate, oils and essences are blended to make the best tasting concentrate. This juice concentrate is then stored at temperatures below 20^{0}F in a tank farm or a barrel storage room.

Two products were left back in the extraction rooms - the pulp and the peel. There are numerous ways these products can be processed. The pulp is usually washed and pasteurized and stored for future addition into the concentrate for a more natural tasting juice.

Use of the peel has an interesting background. Until about 25 years ago peel was thrown away or used in its natural state as a feed for nearby cattle. This caused disposal and environmental problems since the peels spoiled so quickly. Someone came up with the bright idea of drying the peel, storing it, then shipping it anywhere there was a demand for cattle food. This feed has now become a significant part of the profit margin for citrus processors.

The peel is conveyed into a storage bin (Figure 3). Screw conveyors move the peel through a lime addition system. The lime breaks down the cell structure of the peel which facilitates the removal of the water in the peel at a later stage. The peel is then moved through a hammermill which cuts up the peel into small pieces. From the hammermill, the peel is pressed in a screw press to remove as much moisture as possible.

The pressed peel is then dumped into a rotating dryer that is fired by natural gas or fuel oil. The peel is dried as it is pulled through the dryer by induction fans. The dried peel is cooled and pelletized for use as cattle feed.

When investigating energy conservation opportunities in a plant of this type, the prime areas of study are; 1) boilers, 2) evaporators, 3) refrigeration, and 4) feedmill dryers.

1) A citrus plant usually has one or more packaged boilers that provide saturated steam at 150 psig. This steam is mainly used to evaporate water from the juice in the evaporators. Oxygen analyzers can be integrated into the boilers control loop so that the excess oxygen can be kept at a level of 2 or 3% as opposed to 5 to 10% on some boilers that have been analyzed by our engineering group. Since most of the steam from the boiler is used in the evaporator, it is usually a fairly easy task to return the condensate back to preheat feed water for the boiler. An economizer can be considered for using waste heat in the stack. For every 40°F that the stack gases exceed 400°F, one percent of the fuel is wasted. Savings of 5% can be accrued by installing an economizer in a stack that previously exhausted 600°F flue gas.

2) The evaporators use steam in two ways. Steam is injected into the steam chest of the first effect of the evaporator. Here it transfers its latent heat to the juice feed, thereby driving off water vapor from the juice. This vapor is carried to the next effect or stage where it is the heating agent for the juice in that effect. Typical evaporators have between 3 and 7 effects. The original steam from the boiler is therefore only used once, but it provides a steam economy of between 3 and 6 pounds of water evaporated per pound of steam. This figure would depend on a number of effects that a particular evaporator had. Steam in the evaporator is also used in steam ejectors which pull a vacuum through the system so that boiling temperatures are lowered in each successive stage. Finally steam is used in flash coolers used for cooling the concentrate as it comes out of the last stage of the evaporator.

There are many areas of potential conservation in the evaporator. All high temperature (above 150°F) tube bundles in the evaporator should be insulated. This action typically yields a simple payback of about one year.

When water is evaporated from the juice, it forms a vapor. This vapor, after it has been used in subsequent stages, is condensed and usually thrown away. The temperature of this condensate is typically 140°F-150°F. This condensate can be used to preheat boiler make-up water. Another area of potential savings in the evaporator operations comes from proper maintenance. One example is air leakage. Since the evaporator is operated below atmospheric pressure, air can leak into the system. Only 1.5% air in the vapor space can reduce the heat transfer rates by over one-half. Therefore proper maintenance of seals and gaskets is a must. At present most evaporators are manually controlled. This type of control can lead to various problems such as juice quality control, scheduling, start-up and cleaning. The product can vary just due to weather changes. We've seen operators start up the evaporator in the morning and not run juice until the afternoon. This is an excellent area for installing microprocessor controls which can operate an evaporator more efficiently than a man. Implementation of all of the above actions can easily result in a savings of 20-25% in the evaporator energy use.

3) The refrigeration system in a citrus processing plant provides refrigeration for the freezer warehouses, the blend tanks and various other pre-coolers and plate type heat exchangers. These refrigeration systems almost always use ammonia as a refrigerant in a direct expansion system. The ammonia is pumped to various air handlers and cold wall tanks to cool down or freeze concentrate in different areas of the plant.

Most of the major equipment in the citrus industry is moderately new (within 25 years). The evaporators that are presently being used have been designed in the last 10 years. Cattle feed production with the feedmills did not become commonplace until the late 50's and early 60's. The boilers are routinely replaced every 10 years or so. But the refrigeration of freezer warehouses is a very old process and usually the equipment is not changed until it quits operating. We've seen plates with refrigeration equipment as old as 50 years. Old equipment can be inefficient due to worn out valves, heads and cylinder sleeves. Inadequate air purging can reduce heat transfer rates in the condenser and increase head pressures beyond safe limits. Fouled condenser surfaces and inadequate condenser capacity can cause the same problem. By rebuilding or repairing compressors and insuring adequate condenser operation, up to 25% of the present energy use in refrigeration can be conserved.

4) The largest users of energy in a citrus

plant are the peel dryers in the feedmill. If the peel is dried to a 10% moisture content, the energy that is needed to make a ton of cattle feed can vary from 50 to 150 therms. (1 therm = 100,000 BTU)

The feedmill area is a plant process that usually provides excellent opportunities for energy conservation. One of the best is the use of a waste heat evaporator. The excess moisture from the screw press which is called press liquor contains valuable solids which can be added to the cattle feed if the water can be removed. The press liquor is pumped to the waste heat evaporator which uses the evaporated water (steam) from the dryer to remove the water from the press liquor. The resulting solids mixture is then poured back onto the press peel before it goes into the dryer.

A waste heat evaporator can be very cost effective. For example - at present a certain feed dryer is evaporating 30,000 lb/hr. of water at a cost for natural gas of $150. If a waste heat evaporator were added, the amount of water that would need to be evaporated in the dryer would be 17,600 lb/hr. costing $87. Over a season this represents a savings of $170,000/yr. The capital investment required would be about $400,000 yielding a simple payback of 2.4 years.

It is not difficult to demonstrate energy savings of at least 25% in citrus processing plants which is probably a typical industry. Unfortunately industries in general are recognizing investment benefits very slowly. Our perception as to the key reason is that capital investments for energy savings come from discretionary funds and far too many managers do not make a good economic analysis of their return on such investments.

One of the interesting things we see today is a great attention to one area of conservation and much less attention to another that may be more important. For example, today most people are very aware of automobile fuel consumption. Assume a car costs $10,000 and is driven 10,000 miles/yr. If it gets 20 mpg, we spend $625 for gasoline. If it gets 30 mpg, we spend $416 or a savings of $213/yr. The fuel used costs about 1/20 or 5% of the initial value of the equipment.

On the other hand take an electric motor of 125 hp. One can choose several levels of efficiency and of course pay more for the higher efficiency. One might find it difficult to select a 94% efficient motor for $4100 when one can get a 91% efficient motor for $3500. If it operates continuously, as many motors do, at $0.06 kwh the yearly operating cost is $42,000, 10 times or 1000% of the initial cost.

From our vantage point, we've barely scratched the surface in energy conservation - particularly in our industries. There are a few bright spots. For example, the National Society of Professional Engineers presented an Outstanding Engineering Achievement Award this year to the McDonnell-Douglas automation complex in Missouri. Waste heat from the computer equipment is used to satisfy most of the winter heating requirements in the seven building complex.

This is the type of action our country needs across the board. Referring back to Figure 1, we must make significant inroads into those avoidable losses in the conversion process and the avoidable waste in the energy we use. One should note specifically that this new energy source available for the taking is twice as much as we now import from the rest of the world.

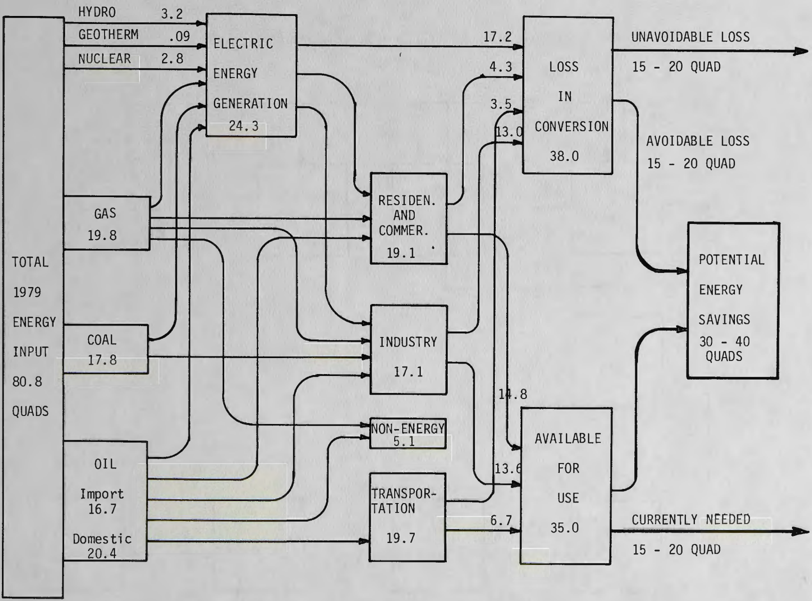

FIGURE 1

AMERICA'S WASTEFUL ENERGY MACHINE

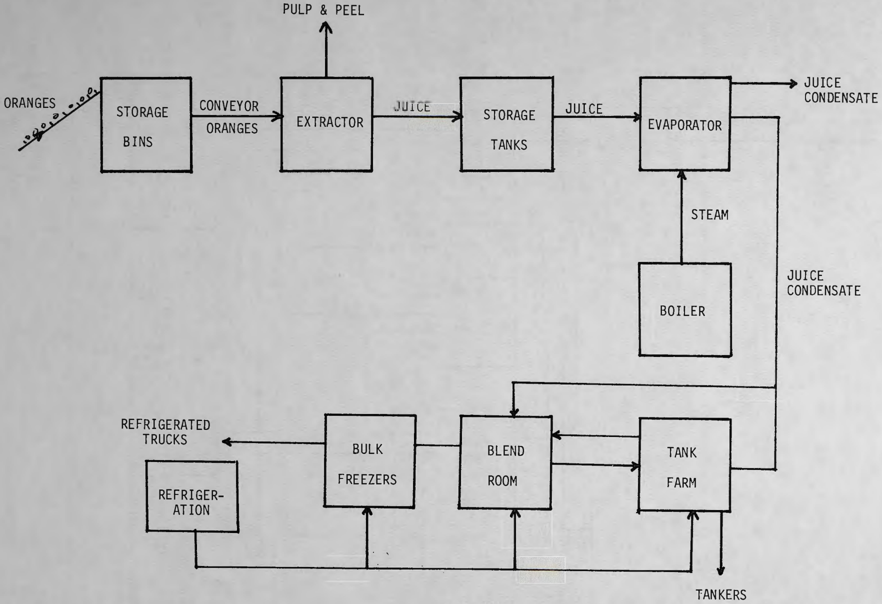

FIGURE 2
CITRUS CONCENTRATE PRODUCTION FLOW PROCESS

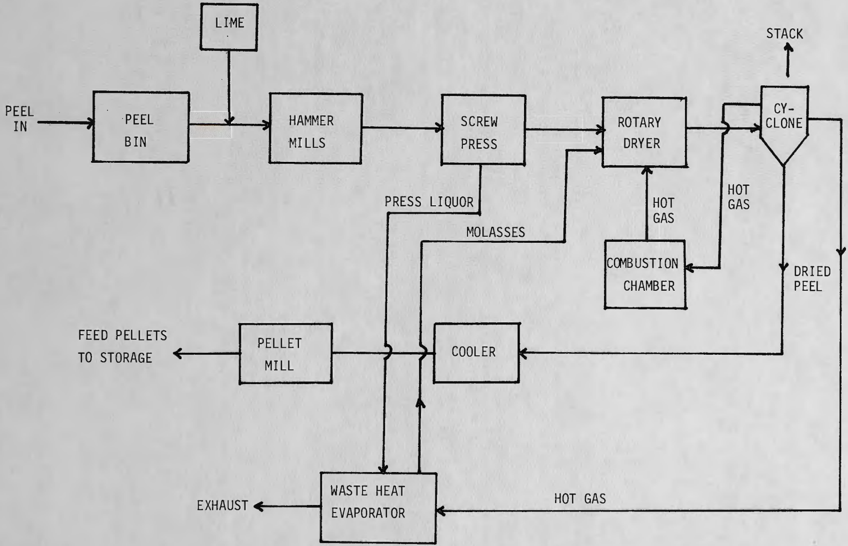

FIGURE 3
SIMPLIFIED SCHEMATIC OF CITRUS FEEDMILL