The Challenge of Expanding the Ethanol Distribution System

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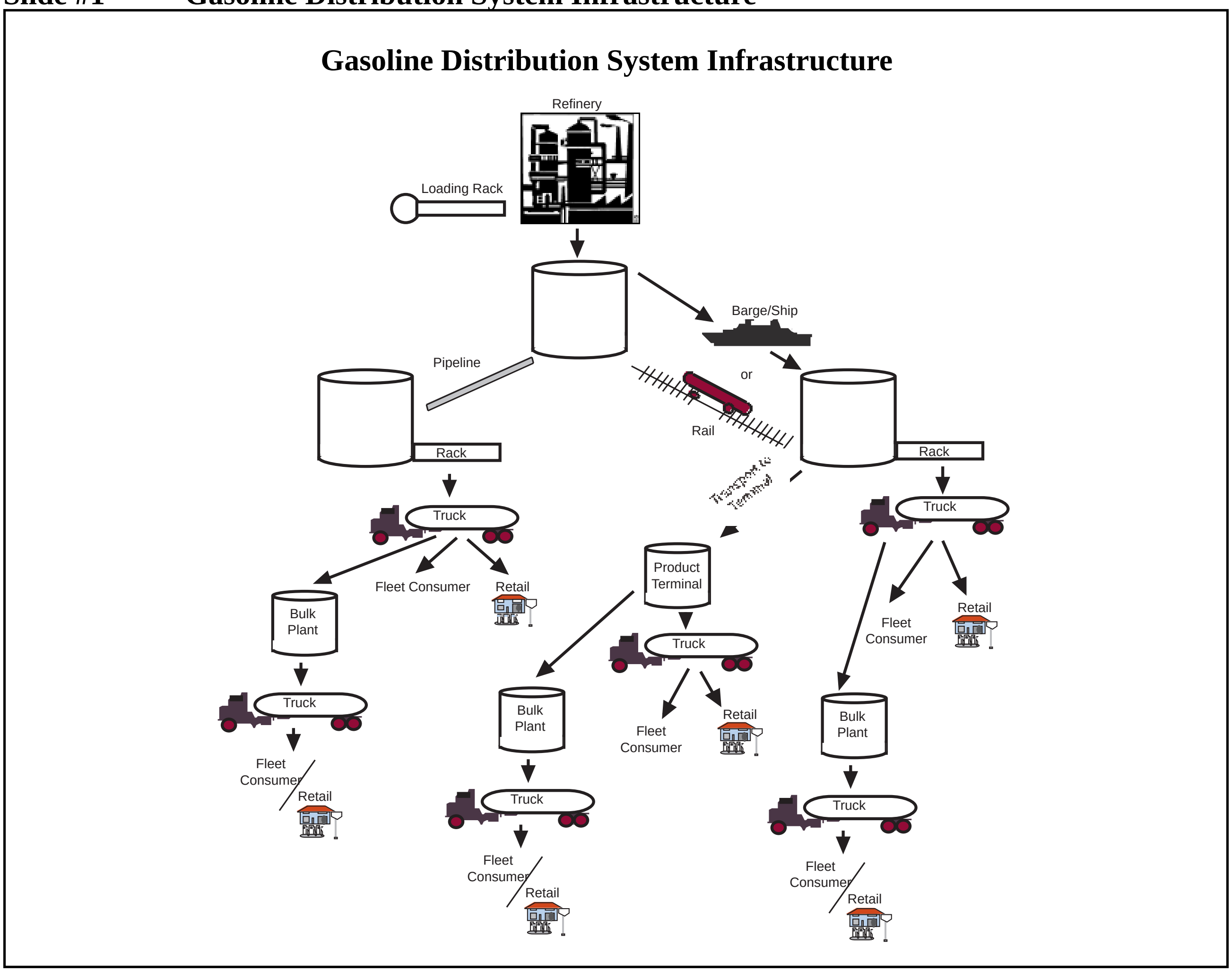
Good morning, it is a pleasure to be here and participate in BioEnergy 2000. Many of the presentations this week deal with ethanol related topics ranging from production and technical topics to public policy issues. I think many of us here believe that the market for ethanol, both from corn and biomass can, and will, grow significantly. But as we address the various challenges in increasing production and lowering production costs, we must also recognize the role the transportation fuels distribution infrastructure plays. That is the focus of my presentation, to cover logistics and operational considerations of ethanol distribution.

Ethanol's sensitivity to water requires special handling considerations that are not applicable to hydrocarbon fuels. This results in ethanol being blended at the terminal level rather than the refinery, and precludes shipment of gasoline ethanol blends in the pipeline.

It might be advantageous to start by providing a primer on the gasoline/petroleum products distribution system.

Slide #1 Gasoline Distribution System Infrastructure



Gasoline Distribution Infrastructure

The gasoline distribution infrastructure is divided into three major segments; Primary, Secondary, and Tertiary. Collectively these systems employ tankers, barges, rail cars, tank trucks, thousands of miles of pipeline, and hundreds of storage terminals, and of course the refineries. By petroleum industry definition the Primary Distribution System includes oil gathering at the well head, transport to gathering tanks, crude oil storage, and refinery processing. The secondary system is downstream of the refinery and includes finished product pipelines and destination terminals.

Product is moved to refinery finished product tankage for distribution into the product transportation network. This includes transfer to tanks for shipment into pipelines and for many refineries to tankage for loading waterborne cargoes (i.e. tankers or barges).

The refined products pipeline system consists of approximately 72,000 miles of line and carries well over half of the gasoline to market. Product moved by pipeline, ship or barge is transported to bulk storage finished product terminals.

A finished product terminal may consist of just a few small tanks storing perhaps 50,000 barrels or numerous tanks, both large and small, storing a combined total of millions of barrels of finished product. It may in some cases be owned by an individual petroleum company, jointly operated by two or more companies, or it may be independently owned by a company whose sole purpose is the storage and outloading of their customers' products. Some terminals may store and distribute only gasoline or diesel. Larger terminals typically handle a full range of light products.

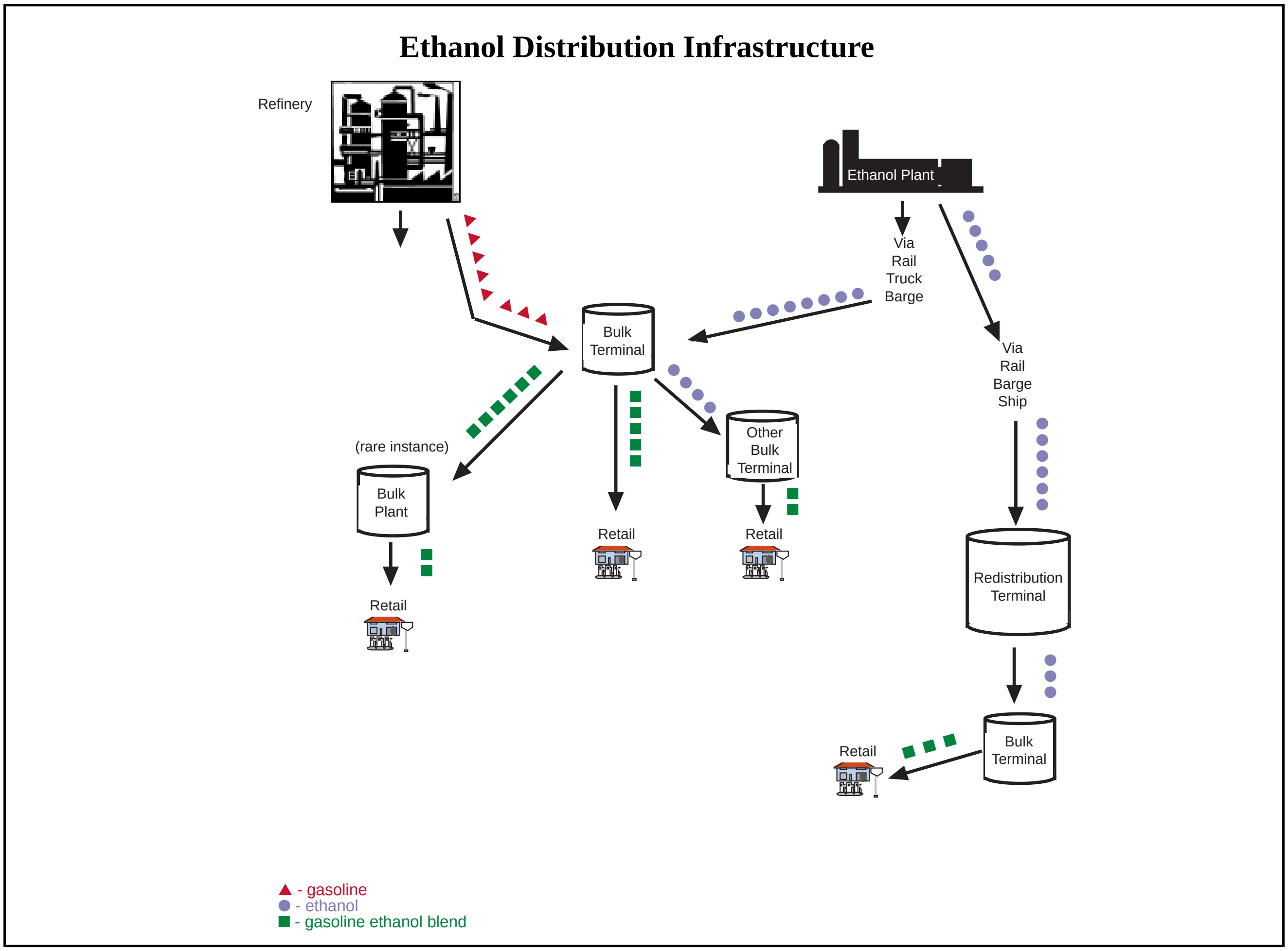
Terminals may receive product by either pipeline, barge, ship, or rail or some combination thereof. In addition, some terminals can receive product via transport truck. Terminals serving the retail markets have one or more transport truck loading racks. There are hundreds of gasoline distribution terminals across the United States.

From the finished product terminal, product is then distributed by transport tank truck to the retail outlets and, in some cases, to bulk plants. A small amount of product is also moved by rail.

Ethanol Distribution

Gasoline ethanol blends are sensitive to water and a little less than 0.5v% water will cause ethanol to phase separate from the blend. Pipeline systems have residual moisture from the products they carry. Consequently, gasoline ethanol blends have not been moved by pipeline other than on a test basis. It is simpler to ship neat denatured ethanol via pipeline but again this has only been done in this country on a test basis. This is in large part because volumes have been insufficient to justify the special precautions required. Moreover, most pipelines originate in the south moving north to the east, central, and western U.S. Conversely, most ethanol plants are located in the Midwest. In fact, over 90% of current production capacity is in the Midwest states of Indiana, Illinois, Iowa, Minnesota, and Nebraska.

Slide #2 Ethanol Distribution Infrastructure



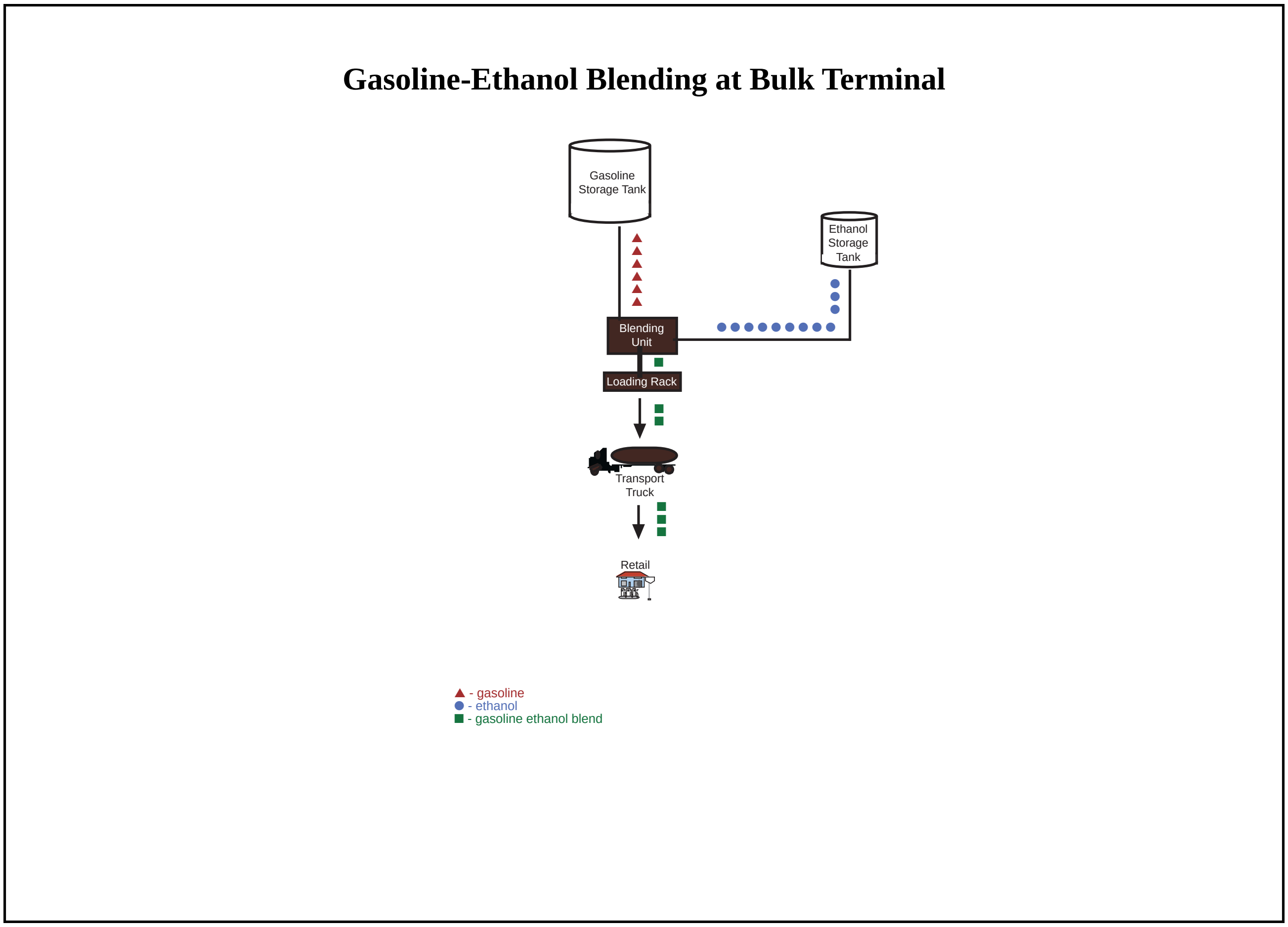
Distribution of Ethanol

The ethanol distribution infrastructure consists primarily of movements from ethanol plants to bulk terminals. Distribution of ethanol starts at the ethanol production facility. Near anhydrous ethanol is denatured at the plant and for fuel use must meet ASTM D 4806 “Standard Specification for Denatured Fuel Ethanol for Blending with Gasolines for Use as Automotive Spark-Ignition Engine Fuel”

Product is shipped from the plant by one of three modes; transport truck, rail car, or river barge. From the plant, the ethanol is transported to one of two primary destinations, either a bulk terminal or a redistribution bulk terminal. In most cases ethanol is shipped by truck, rail car, or river barge to a bulk terminal where it is stored until it is blended with gasoline as the transport truck is loaded. In some cases ethanol will be lifted from these terminals in full transport truck loads for distribution to other terminals that may not be capable of storing larger quantities. In some cases, such as servicing terminals in more distant coastal locations such as the Northeast coastal area or California, ethanol is shipped by river barge (or could be shipped by rail) to New Orleans where it is staged in storage tanks until sufficient quantities exist for loading ocean going barges or ship compartments. It is then shipped to a redistribution terminal in the destination market. Once at the redistribution terminal, the ethanol is broken down into smaller quantities, usually transport truck loads, and delivered to other terminals in the area. Some of the ethanol may also be blended into gasoline and distributed as a blend directly from the redistribution terminal.

It should be noted that storage tanks must meet certain requirements such as having fixed roofs with floating internal covers. In addition terminal operators typically use computerized in-line blending to control the blending process.

Slide #3 Gasoline-Ethanol Blending at Bulk Terminal



Ethanol is typically stored separately at the terminal, being blended only as the transport truck is loaded. This is done for two reasons. First to avoid excessive moisture contamination of the gasoline ethanol blend and secondly, to minimize the tankage requirements.

When a transport truck pulls to the loading rack, the driver activates the process with the use of magnetically striped cards that identify the transport carrier and truck as well as the end customer. Information for the desired grade and volume is input. If an ethanol blend is ordered the computer will activate the gasoline and ethanol flow into a blending unit where the two products are combined in the proper proportion and transferred on to the loading rack for delivery into the transport truck.

There are several variations of blending equipment that are used but in general in-line computerized blending is the preferred method. Once the blending process is accomplished, the gasoline ethanol blend is then handled and delivered to retail and commercial facilities like any other gasoline. For retail locations first converting to gasoline ethanol blends, there are also a number of preparatory steps prior to receiving the first load of gasoline ethanol blends. These are related primarily to eliminating moisture and, in some cases, cleaning of tanks.

That's, a quick, albeit somewhat simpistic, overview of how ethanol is currently distributed. As the industry expands, it will be necessary to achieve greater distribution efficiencies. Even then additional investments will be required.

The consensus seems to be that as ethanol production expands there may be some shipments of ethanol by pipeline but that shipments of blends are unlikely. In short, blending would still occur at the terminal. If blending continues at the terminal level it is fairly easy to determine the necessary requirements.

Terminal Requirements for Ethanol Blending

If ethanol use is expanded it will need to be available at a greater number of terminals than is the case today. Assuming ethanol is blended to conventional gasoline at the terminal level, the primary needs would be for an ethanol storage tank, piping modifications, and blending units. It may also be necessary to make modifications to accommodate receipt of ethanol product (e.g. rail spur, transport truck unloading).

In many cases, an existing tank can be reassigned to ethanol storage although modification may be necessary. When selecting a tank there are also operational considerations.

Tank Type/Size: When a tank is selected or installed it must be suitable for ethanol storage. Tanks used for storing ethanol (or gasoline ethanol blends) should have a fixed roof with a floating internal cover. In the case of ethanol, a small fixed roof tank may suffice. The tank must be of sufficient size to meet not only necessary demand but to receive the minimum tender size while still having adequate working inventory. For instance, if shipments are to come in as a 10,000 barrel barge and demand is 1,000 barrels per day, the terminal operator will probably consider 5,000 barrels of inventory as a back up supply plus 10,000 barrels of space for product receipt which then requires a minimum of 15,000 barrels storage capacity. To provide a frame of reference, a suitable 25,000 barrel tank would cost approximately $450,000.

Piping Configuration: The piping configuration must be suitable for, or be modified for, planned operations. So the tank must be piped to the blend unit and/or loading rack as well as for product receipt by one or more delivery modes. Such requirements are difficult to describe here because they will be terminal specific. The same applies to projected cost.

Blending Unit/System: There are a variety of ways to handle the blending process at the temrinal. The preferred method is computer controlled in-line blending which provides the greatest ease of operation and greatest accuracy. Such systems also provide more accurate records for inventory control and documentation for compliance with various federal requirements such as antidumping, RFG, and oxyfuel program compliance.

Depending on the type of blending system selected and the number of loading racks at the given terminal, estimates for blending systems and attendant piping modifications, meters, and loading rack modifications range from $150,000 to $400,000.

Product Receipt: For terminals receiving product by transport truck, modifications to accommodate such receipt would be minimal, often under $10,000. However terminals receiving product by rail or barge may have more complicated modifications such as adding delivery lines, or installing a rail spur. Such modifications have been estimated to be as high as $300,000 per terminal in the case where a rail spur addition is necessary.

While these costs sound expensive, if one looks at it on a cost per gallon basis, these are relatively insignificant sums. For instance, combining the aforementioned investment sums for a 25m barrel tank, blending system/piping modifications, and a rail receipt facility results in high side cost estimates of approximately one million dollars. However if one assumes 24 inventory turns per year for ten years, this equates to 6 million barrels of throughput or a cost of $0.166 per barrel of ethanol ($0.004 per gallon). In turn, this equates to only $0.0004 per gallon of gasoline ethanol blend containing 10% ethanol. After amortizing the initial investment, this would equate to $0.294 per barrel ($0.007 per gallon) for ethanol or $0.0007 per gallon of gasoline ethanol blend (at 10 v% ethanol).

Transportation of Ethanol

Obviously a great deal of ethanol will require movement by the traditional modes of barge and rail. As volumes grow waterborne cargoes will be the preferred method due to larger quantity delivers and ease of receipt.

Just to provide an idea of what might be involved lets look at an increase of three billion gallons annual ethanol production (71.4 million barrels per year). This is roughly 6 million barrels per month. If one assumes that this product is shipped 70% barge and 30% rail, the monthly shipments would equate to 420 additional barge movements and 2500+ additional rail car movements per month. While these numbers may sound fairly large, keep in mind that there are currently 2800 river barges and 450 ocean barges in use by the petroleum industry. There are also over 211,00 rail tank cars deployed for petroleum product distribution. So in the grand scheme of petroleum industry distribution, these are not tremendously large numbers.

The real question is whether ethanol will move by pipeline since that is usually the most cost efficient delivery mode for transportation fuels. The answer is a qualified yes. . Some pipeline operators have already expressed an interest in shipping ethanol in certain segments of their systems. There are however a number of technical and operational considerations that will need to be addressed.

Slide #4 Considerations for Shipping Ethanol Via Pipeline

Considerations for Shipping Ethanol Via Pipeline

Technical

- Water tolerance
- Product contamination/discoloration
  - Interface downgrade
- Corrosion
  - Electrical conductivity, acidity, etc.
  - Impact on corrosion inhibitors
- Materials compatibility

Operational

- Fungibility
  - Segregated/tight-lined shipments
- Low volumes
- Logistics
  - Plant locations relative to pipelines

Water Tolerance: As I mentioned, alcohols including ethanol, have an affinity for water. They will pick up and suspend water that is present in the pipeline system and terminal tankage. The pipeline system is a "wet" system containing residual amounts of moisture from petroleum products. In the case of neat denatured ethanol shipments, the product could pick up excessive water.

Ethanol with an excessive water content can phase separate from the gasoline to which it is blended. The maximum water level permitted by ASTM D 4806 is 1 v%. Similarly, in the case of gasoline ethanol blends the ethanol in the blend would pick up moisture. If the water level exceeds ~ 0.5%of the total blend volume it would induce phase separation. Once an ethanol blend phase separates it is extremely difficult and usually impossible to reblend. In many cases the ethanol/water bottoms must be disposed of in accordance with hazardous waste regulations.

Depending upon the pipeline configuration, pigs (cleaning devices) can usually be run through the pipeline to ensure minimal moisture levels. In the test programs run thus far (both ethanol and ethanol blends), moisture levels were kept to acceptable levels. However these tests were on specific pipeline segments that may or may not be representative of the majority of the U.S. finished products pipeline system.

Product Contamination/Discoloration: Ethanol has a stronger solvent effect than petroleum products shipped through the pipeline system. Consequently ethanol and gasoline containing ethanol will remove water, rust, gums, and other contaminants in the system. This can result in contamination and discoloration of the ethanol or gasoline ethanol blend. In some cases, a small portion of the trailing product (the product behind the ethanol or gasoline ethanol blend in the system) may also be contaminated. When this occurs it is necessary to downgrade out of spec products. Interface downgrade is that portion of product between two products in the pipeline that no longer meets the specification of either product. In some cases, this is handled by simply transferring to a lower specification product. For instance if the octane of a premium gasoline interface is lower than premium but higher than regular it could be downgraded to regular since it exceeds that specification. In the case of ethanol and gasoline ethanol blends, such options do not currently exist so it is important that product arrive on specification.

In test shipments, this has been addressed by cleaning the applicable pipeline segment with scrapper pigs followed by Super Pigs (scrapper pigs are brush type devices inserted into the pipeline to scrape and clean the system, super pigs are cup type devices which are more suitable for pushing sludge and water from the system) to minimize contaminants. However not all systems are set up for routine launch and receipt of pigs.

Once ethanol or gasoline ethanol blends are routinely shipped on the pipeline, it is likely that contaminants would be at very low levels precluding the need for frequent use of scrapers.

Corrosion: One of the issues that remains somewhat of an open technical issues is pipeline corrosion. The new pHe specification contained in ASTM D 4806 should eliminate some concerns related to corrosion. The pHe number for alcohol solutions is a measure of acid strength and is not directly comparable to pH values for water solutions. However ethanol's different electrical conductivity may have an effect on corrosion rates and any such effect cannot be thoroughly assessed based on the limited test shipments that have been made thus far. It is likely that if routine shipments are initiated, the pipeline companies would install metal corrosion coupons at various locations to monitor corrosion protection.

Ethanol and gasoline ethanol blends have also been shown to strip the corrosion inhibitor coating on the interior pipeline surface. This could be addressed by either development of more robust corrosion protection additives/coatings or by heavier dosage of corrosion inhibitors in the product following ethanol or gasoline ethanol blend shipments.

Materials Compatibility: The test programs conducted thus far have not indicated any materials compatibility problems with nonmetallic parts in the pipeline system. Various elastomers (i.e. rubber and plastics) are used in the pipeline system. These are believed to be compatible with both gasoline ethanol blends and ethanol. However once frequent routine shipments begin, it is likely that a periodic and routine inspection program will be needed until such compatibility is confirmed for long term use.

Operational Considerations: There are operational considerations when shipping ethanol or ethanol blends. In many cases the reality of these operational considerations has resulted in pipeline companies deciding against attempting to address technical considerations. Operational considerations include the following:

Fungibility: Ethanol and gasoline ethanol blends are not shipped on a fungible basis. Common carrier pipelines operate largely on the principal of fungibility. Refiners put product meeting the pipeline specifications in the pipeline. Downstream they lift like products meeting the same specification but not necessarily the product they input into the system. It may be from one of the other refiners. Companies receive a like barrel for the one shipped, not necessarily the same barrel.

Along the course of its pipeline shipment, product may be pulled off in breakout tankage (for instance to move another product ahead in the shipping schedule). So fungible products are routinely mingled with one another. Fungible grades can be placed in the pipeline in relatively small patches (e.g. 10m barrels) if desired although batches are often larger, in the 25m to 50m barrel range.

However ethanol and gasoline ethanol blends would have to be shipped as a segregated batch and "tight lined". It must bypass breakout tankage or any form of being mingled with other gasoline products because the product resulting from such mixing would not meet the pipeline specification and would not likely meet other product specifications for state and federal regulations.

It is more difficult to schedule shipments on a segregated basis which usually leads to the pipeline requiring bigger batches for such shipments. This in turn results in the need for more or larger shipping and receiving tankage (which may not be available).

Insufficient Volumes: The volume of ethanol sold represents about 1.2% of all gasoline sold. Gasoline ethanol blends represent about 12% of gasoline sold. In the grand scheme of total pipeline shipments this is not very much volume and is deemed insufficient for most pipelines to undertake programs to address the technical issues of shipping these products. Even in markets where gasoline ethanol blends approach 40% market share, such efforts have not been undertaken. However with increased ethanol available this could change.

Logistics: Another important consideration is the location of the plants and destination markets in relationship to pipeline movements. Most pipelines originate in the south, shipping product to the North, Northeast, and West. Conversely, most ethanol production is in the Midwest. Currently, pipeline shipments to most markets would require barge movement to the Gulf Coast, or at least southern destinations, for insertion into the pipeline and shipment north to destination markets. In many cases, this process would exceed the cost of simply delivering the ethanol to the destination market.

The most likely method for initial pipeline shipments will be one of three scenarios. The first scenario would be to utilize short segments of idle or underutilized lines exclusively for ethanol shipment. The second scenario would be utilizing segments of larger lines to move ethanol from a storage point to a major metropolitan network. The third scenario would be the possibility of shipping ethanol from Midwestern plants to major markets in the northeast. However even in these scenarios volumes will need to be large enough to justify special handling considerations.

Ethanol Blends at Retail

At the retail level there are no special requirements to handle the traditional ethanol blends (i.e. 10% ethanol or less). There are a few relatively inexpensive preparatory steps but no additional equipment is required.

For higher volume blends such as E-85, the problem is more complex. As many of you are aware in the past few years some automakers have started offering Flexible-Fuel Vehicles (FFV). These autos are capable of operating on 100% gasoline or up to 85% denatured ethanol or any mixture of the two. Such vehicles meet the definition of an alternative fuel vehicle to comply with the 1992 Energy Policy Act (EPACT92). The automakers receive credits for their Corporate Average Fuel Economy (CAFE) for each FFV produced. This provides their incentive to produce such vehicles which require relatively inexpensive modifications to achieve their fuel flexibility. These credits were established in the Alternative Motor Fuels Act of 1988. Current offerings of Flexible Fueled Vehicles along with the year 2000 production estimates include the following.

Slide # 5 Model Year 2000 FFV Offerings

Model Year 2000 FFV Offerings

Ford	Taurus	168,000
	Ranger Pickup (& Mazda B3000 twin)	200,000
Daimler Chrysler	minivans	160,000
GM	Chevy S10/GMC Sonoma Pickup (and Isuzu twin)	175,000
Total		**703,000**

Estimates put the current number of E-85 capable flexible fueled vehicles sold prior to 2000 at 1,000,000 units. Sales projections for these vehicles are 703,000+ units per year so the E-85 vehicle population is increasing very dramatically.

The real problem will not be vehicle availability, but rather fuel availability. E-85 fueling facilities are few and virtually nonexistent outside of the Midwest. Ethanol is available in at least a few terminals in every state which makes the blending of E-85 possible. However at the retail/consumer level, E-85 would require a dedicated dispensing unit. While E-85 could replace an existing low volume product such as mid-grade, most retailers have been reluctant to take this approach given the uncertainty of sales volumes and product margins. As a result the approach has been to install a new dispensing unit at existing locations. This also usually means installation of an underground storage tank. This approach is expensive ($50,000-$100,000) and time consuming, dramatically limiting the growth of dispensing facilities to date.

There are also specific requirements for the types of retail dispensing equipment used. For instance zinc, brass, lead, aluminum and other soft metals should be avoided. Specific types of retail dispenser hoses are required and stainless steel fittings must be used. The dispenser nozzles should be nickel plated.

(The applicable specification for E-85 is ASTM D 5798 Standard Specification for Fuel Ethanol (Ed75-Ed85) for Automotive Spark-Ignition Engines.)

By producing flexible fuel vehicles the automakers solve the "chicken and egg" problem by putting cars into the market that will operate on gasoline but can also operate on E-85 as the fueling infrastructure develops.

Theoretically the market potential for E-85 is very high. However it is dependent first on fuel availability and second on competitive pricing. By 2003 we will have at least 3.6 million FFVs on the road. If the fuel is made available such that these vehicles operate on E-85 for 25% of the time, it would create a demand for over 500 million gallons of E-85.

There are no easy answers on this one. The number of E-85 facilities are minuscule compared to the number of gasoline outlets and are likely to be so well into the future.

Fuel Cells: I want to add one final topic and that is the use of ethanol in fuel cells. There is currently a great deal of debate about which fuel should be used to power fuel cells. While hydrogen is the ideal technical choice, there is no distribution infrastructure with which to fuel vehicles. Establishing an infrastructure for a gaseous fuel that must be stored under compression or refrigeration would not prove easy. More likely an on-board reformer would be used with some other fuel providing the hydrogen to the fuel cell. To date, the majority of attention has gone to methanol and gasoline. Methanol with only one carbon atom in its molecular structure would prove easier to reform than many fuels. Gasoline of course has the most complete distribution infrastructure.

However ethanol also possesses many of these positive attributes, plus others. It's carbons structure is relatively simple providing for ease of reforming. There are fewer concerns about toxicity than with methanol. Ethanol is widely available at the terminal level in nearly every part of the U.S. and perhaps more importantly, ethanol is a renewable fuel. Consequently it would reduce greenhouse gas emissions compared to fossil based hydrocarbons. While the focus today may be on HC and NOx, ultimately, we will have to deal with the amount of carbon released into the atmosphere and its impact on climate change. To that end, ethanol and especially ethanol from biomass will prove to be a superior fuel.

So in summary the distribution infrastructure for ethanol can be expanded to accommodate increased volumes of low level blends. It will require investments at the terminal level, although such investments are relatively modest on an amortized basis.

Development of the infrastructure for E-85 is more problematic and on a per gallon basis more costly. There are no shortcuts. It will be a long slow process. Finally, as new fuel uses develop we should continue to see how ethanol fits into the picture. The prime example here is the fuel cell and how ethanol may prove to be one of the best fuels for this application.

For those of you who desire more detailed information on the transportation and distribution of ethanol, I would refer you to a couple of our recently completed studies that are available on the web. These include:

- *The Use of Ethanol in California Clean Burning Gasoline-Ethanol Supply/Demand and Logistics* , Downstream Alternatives Inc., February 1999
  available at www.ethanolrfa.org

- *The Current Fuel Ethanol Industry - Transportation, Marketing, Distribution, And Technical Considerations,* Downstream Alternatives Inc., prepared under subcontract No. 4500010570 for Oak Ridge National Laboratory, May 15, 2000
  available at www.ott.doe.gov/biofuels/database.html

Ethanol has waited a long time for its moment in the sun. But it appears it's time has finally come. Crude prices are high and projected to stay there. Some OPEC members are producing at or near maximum capacity. No new refineries have been built in the U.S. since the 1970s. Existing refineries are running near maximum capacity. Imports (both crude and finished product) continue to climb. It certainly seems that ethanol's day may finally be here and with increased volumes would come the incentive to address the logistical challenges I have discussed.

If I can answer any questions, I would be happy to do so. Thanks for your attention and I hope you enjoy the rest of the conference.