Appendix C

Pipeline Regions and Operations

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U.S. Regions for Distribution of Petroleum and Their Key Pipelines

The supply and demand characteristics for refined petroleum products across the United States vary across regions (Petroleum Administration for Defense Districts, or PADDs). The reasons are historical, demographic, geological, and topographical.

The *East Coast* (PADD I), the most heavily populated PADD, has the highest petroleum consumption. It has virtually no indigenous crude oil production and only limited refining capacity. The Northeast is unique in its dependence on heating oil: 70 percent of all single-family homes in the Northeast are heated with oil. Hence, the Northeast has the largest market for the transportation of high-sulfur distillate, as opposed to low-sulfur diesel oil. The region covers its deficit in refined product supply with shipments from the Gulf Coast by pipeline and with imports of refined products by tanker. Colonial Pipeline (Gulf Coast to the New York area) and Plantation Pipe Line (Gulf Coast to the Washington, DC, area) are trunk lines that transport a wide product slate to the area, including distillate fuel oils. Delivering lines, such as Buckeye Pipe Line Company, distribute products within the New York Harbor and from the New York Harbor area to Pennsylvania and upstate New York. Buckeye also serves Connecticut and Massachusetts from an origin in New Haven. ExxonMobil and Sun also operate delivering product pipelines in the region.

The *Midwest* (PADD II) is less heavily populated than PADD I and has a greater balance of supply and demand for both crude oil and refined products. It receives pipeline supplies of distillate fuel oil from both the Gulf Coast and the East Coast. The main trunk carriers of refined petroleum products in the Midwest are TE Product Pipeline and Explorer Pipeline. The role of delivering carriers in the Midwest is a key to product distribution. The region's refining hubs depend on pipelines to deliver their output. As logistics hubs, as well as refining hubs, areas such as Chicago ship product output from refineries and also re-ship product received from refineries on the Gulf Coast or in Oklahoma. Pipelines serving the Chicago hub include Williams, Equilon, and Phillips (in addition to Explorer and TE Products), Citgo, Marathon Ashland, Buckeye, and Wolverine. Other refining centers or single refineries also depend on pipeline transport of their products. Kaneb and Conoco are two of the pipelines serving the western part of PADD II, the plains States, where distances are long and consumption volumes low.

The *Gulf Coast* (PADD III) is the Nation's main oil supply region. It is the largest refining area, with facility design and sophistication unrivaled in the world. It is a major crude oil producing area, with output greater than all but two members of the Organization of Petroleum Exporting Countries. It also has a low regional demand for finished petroleum products. Thus, its shipments of products to other regions are a central facet of supply east of the Rocky Mountains. The Gulf Coast is the origin of trunk carriers such as Explorer, TEPPCO (to the Midwest), Colonial, and Plantation (to the Southeast and East Coast). These pipelines also deliver to points within PADD III.

The *Rocky Mountain States* (PADD IV) are thinly populated, with a low volume of oil shipped across long transport distances. Its consumption of diesel fuel for transportation on a per capita basis is about 60 percent greater than the average in the lower 48 States, but its consumption per square mile is less than 30 percent of the lower 48 average. The region's highway consumption of diesel—a proxy for the low-sulfur diesel required—is about 60 percent of its total distillate market, but low-sulfur diesel accounts for more than 80 percent of the total distillate supplied in the region. The market is so thin that many companies have opted to market (and hence require transport and storage for) only low-sulfur diesel fuel instead of both low- and high-sulfur fuel. The pipelines serving the region distribute products from refineries in the Denver area and from refineries in Billings, MT; and Casper, WY, as well as product received from terminals in PADD II. Pipelines such as Yellowstone and Cenex distribute across the Northern Tier States. Chevron moves products out of Salt Lake City through Idaho and to western Washington, and a variety of pipelines go into and out of the Denver area (Phillips from PADD III; Chase from PADD II; and Conoco, WYCO, Sinclair, and others within the Rockies).

The *West Coast* (PADD V) is a singular oil market, separated from the rest of the country. From the earliest days, the Rockies prevented the easy transfer of oil in and out of the region. More recently, California's adoption of uniquely stringent oil product specifications has exacerbated the region's supply isolation. The region is populous as a whole because California is populous; consumption is high, but not on a per capita basis. In California, the Kinder Morgan pipeline system (formerly Santa Fe Pacific Pipeline) is the most important. It redistributes product from area refineries and, in southern California, receives product from its system in Arizona. The system in Arizona, in turn, connects with

PADD III and receives supplies from El Paso, TX. The Calnev Pipeline connects southern California with Las Vegas, NV. There are also pipelines transporting product in western Washington and Oregon from refineries in the northwest corner of Washington (Kinder Morgan and Olympic). As noted previously, Chevron supplies the eastern part of those States via pipeline from Salt Lake City, and Yellowstone delivers across Montana and Idaho into eastern Washington as well.

The East Coast is the only region where all pipelines consistently carry both diesel fuel (currently 500 ppm) and high-sulfur distillate fuel oil (heating oil). In other regions, some demand for non-road fuel is met by 500 ppm product. This is important to the demands of a phase-in.

Key Pipeline Operations

Oil pipelines operate under a range of corporate structures and face a range of operational and financial challenges. Some are independent and face capital markets on their own. Others are subsidiaries of integrated oil companies. Oil pipelines also serve their markets in different ways, and their divergent operations patterns dictate that the impact of the rule will vary across pipelines and thus across regions. The options for minimizing contamination may be different for a trunk line than for a delivering pipeline carrier, or for a pipeline in batch service versus one in fungible service. In addition, the opportunities for offsetting a supply interruption caused by a quality problem are fewer for the delivering carrier in batch service. The sequencing of product flow is central to maintaining product integrity and, possibly, reducing system flexibility by requiring changes in batch sizes or product scheduling.

Trunk Line and Delivering Pipeline Carriers

Refined petroleum products pipelines in the United States fall into two fundamental service categories. Trunk lines serve high-volume, long-haul transportation requirements; delivering pipelines transport smaller volumes over shorter distances to final market areas. Trunk pipelines provide transportation between major source points, such as the Gulf Coast, and major consumption locations, such as the East Coast. An example of a trunk pipeline is Colonial Pipeline Company, which operates from Houston to New York City. Delivering pipelines provide transportation from source points to multiple, but relatively nearby, market areas. An example of a delivering pipeline is Buckeye Pipe Line Company, which operates in the middle Atlantic and upper Midwest regions of the country from various source points, such as New York and Chicago, to markets such as Pittsburgh and Detroit. While the average haul length on Colonial Pipeline is over 1,000 miles, the average haul length on Buckeye is 125 miles.

Both trunk line and delivering pipeline carriers are necessary for meeting the Nation’s demand for refined petroleum products, and each type of pipeline carrier is economically sound in performing its type of service. Many pipeline companies provide both types of service. It is clear, however, that trunk and delivering pipeline carriers encounter different operating environments and different economics. Trunk lines tend to have lower costs and revenues per barrel mile than delivering carriers. Trunk line carriers also tend to be more capital intensive than delivering carriers. Costs and revenues per unit of throughput are higher for delivering carriers than for trunk lines, and delivering carriers tend to be more labor intensive than trunk carriers. Delivering carriers also tend to operate physically smaller pipelines and to use more and smaller storage tanks than do trunk carriers.

The fundamental difference between trunk line and delivering pipeline carriers is scale. For pipelines closer to ultimate demand locations, the magnitude of operations tends to be smaller and the number of operating tasks performed tends to be larger. The trunk carriers that serve as the central arteries have flexibility to redirect product, for instance. As the system reaches its furthest capillaries, the inflexibilities imposed by the smaller scale become more apparent. The chances for “operating lockouts” increase. A lockout might occur if a terminal does not have room to accept a scheduled shipment and there are no other terminals at hand to accept the product. The pipeline is thus stalled until the product can be delivered.

Batch and Fungible Pipeline Service

Petroleum products pipelines also differ by whether they operate on a batch or fungible basis. In batch operations, a specific volume of refined petroleum products is accepted for shipment. The identity of the material shipped is maintained throughout the transportation process, and the same material that was accepted for shipment at the origin is delivered at the destination. In fungible operations, the carrier does not deliver the same batch of material that is presented at the origin location for shipment. Rather, the pipeline carrier delivers material that has the same product specifications but is not the original material.

A pipeline carrier operates in a batch or fungible mode based on its circumstances. Unless there is a more compelling reason, a pipeline operator’s selection of its mode of service is based on maximizing operating and economic efficiency. In general, fungible product operation is the more efficient mode of operation. Fungible operation tends to minimize the generation of interface material (see below). Another efficiency of fungible operation is that it permits split-stream operations. In a split-stream operation, material originating at Point A and destined for Points B and C can be delivered at both distant points simultaneously; part of the stream can continue on to Point C while delivery is still underway at Point B. In a batch mode, a delivery operation to Point B means that all pipeline movements beyond Point B cease while the delivery to Point B is completed.

Fungible operations also support more efficient utilization of storage tanks. In fungible operations, large storage tanks are used to accumulate or deliver multiple consignments of identical refined products. In batch operations, only one consignment of material is typically held in each tank. Accordingly, storage tanks used in batch pipeline operations tend to be smaller (and, possibly, more numerous) and are not utilized as intensively as storage tanks used in fungible service.

Among the pipeline characteristics that determine whether a refined petroleum products pipeline operates in a batch or fungible mode, customer requirements for segregation are an important factor. (Many pipelines operating on a fungible product basis can make provision to accept a distinct batch from a shipper. In doing so the carrier might impose a higher minimum volume requirement or charge a higher tariff rate to cover the higher operating cost of providing the special service.) Nonetheless, many pipelines or pipeline segments serve areas where the structure of the market does not support the "one size fits all" character of fungible service.

Another important factor in determining a pipeline's type of service offering is the possible availability of multiple pipelines in the same service corridor. If existing practice and customer service arrangements initially mandate batch pipeline service, it is difficult for a refined petroleum products pipeline carrier to change to fungible service subsequently. On the other hand, if a pipeline carrier serves a transportation corridor using multiple pipelines, it has more flexibility to adopt fungible service.

Thus, while an oil pipeline is likely to prefer fungible service, batch service is often the only feasible choice. Like the difference between trunk and delivering carriers, the difference between fungible and batch service is one of scale for many operating parameters. An oil pipeline in batch service has considerably less flexibility to offset operating "hiccups" (such as product contamination at a shipper's terminal tank) than does an oil pipeline operating in fungible service.

Sequencing Product Flow

Refined products pipelines carry more than 60 percent of all petroleum products transported in the United States.[162] Products pipelines are routinely capable of transporting various types of products or grades of the same petroleum products in the same pipeline. For example, it is common for a single refined products pipeline to transport various grades of motor gasoline, diesel fuel, and aircraft turbine fuel in the same physical pipeline. (For the most part, oil pipelines do not transport both crude oil and refined petroleum products in the same pipeline.)

To carry multiple products or grades in the same pipeline, different petroleum products or grades are held in separate storage facilities at the origin of a pipeline and are delivered into separate storage facilities at the destination. The different types or grades of petroleum products are transported sequentially through the pipeline. While traversing the pipeline, a given refined product occupies the pipeline as a single batch of material. At the end of a given batch, another batch of material, a different petroleum product, follows. A 25,000-barrel batch of products occupies nearly 50 miles of a 10-inch-diameter pipeline.

Generally, product batches are butted directly against each other, without any means or devices to separate them. At the interface of two batches in a pipeline, some, but relatively little, mixing occurs. The actual volume of mixed material generated depends on a number of physical parameters, including pipeline diameter, distance, topography, and type of material. As a guide to understanding the volume of interface generated, it would be typical for 150 barrels of mixed material to be generated in a 10-inch pipeline over a shipment distance of 100 miles. The hydraulic flow in a pipeline is also a crucial determinant of the amount of mixing that occurs. "Turbulent flow," as occurs in most pipelines, minimizes the generation of interface, while operations that require the flow to stop and start will generate the most interface material.

Monthly Batch Scheduling

As a part of their strategy to minimize the generation of interface material, pipeline operators sequence batches on the basis of the total number of products routinely shipped and the number and capacity of storage tanks available at the origin, destination, and intermediate breakout locations. Most often, pipeline operators use a recurring monthly schedule of "cycles," shipping all the available petroleum products of the same type in sequence. For example, only gasoline grades would be shipped during the days that constitute the gasoline cycle, and only distillates would be shipped during the days that constitute the distillate cycle. The actual duration of the cycles might vary from 6 to 10 days, depending on the volume of each material to be shipped during a particular month. Operators accommodate increased seasonal demand and stock builds, for instance, by adjusting the cycle schedule. The schedule is published

[162]Based on ton-miles. See Association of Oil Pipe Lines, *Shifts in Petroleum Transportation—1999* (2001).

far in advance, however, leaving little opportunity for last-minute flexibility.

Batch sizes are determined by the availability of storage tankage (not only to pipeline operator directly, but also to originating shippers and receiving terminal operators), the batch sizes consigned by shippers, shippers' time requirements, and whether the pipeline is operated on a batch or fungible basis.

Interfaces and Transmix

The composition of the mixed (or interface) material reflects the two materials from which it is derived. While it does not conform to any standard petroleum product specification or composition, it is not lost or wasted. For interface material resulting from adjacent batches of different grades of the same product, such as mid-grade and regular gasoline, the mixture is typically blended into the lower grade. This "downgrading" reduces the volume of the higher quality product and increases the volume of the lower quality product.

The interface between two different products—gasoline and a distillate, for instance—produces a hybrid called "transmix." Transmix cannot be blended back into either of its components, as gasoline's flash point will contaminate the distillate, and distillate's higher boiling point will contaminate the gasoline. Transmix, therefore, is segregated and then reprocessed in a full-scale refinery or a purpose-built facility. When it has been separated again into its component products (gasoline and distillate, for instance), the distinct products are reintroduced into the appropriate segregated transportation and storage system. (If an operator utilizes two physical pipelines in the same corridor, it may minimize the generation of transmix by carrying only gasoline in one line and only distillates in the other. The problem of downgrade within a family of products, however, still exists.)

As shown in Figure C1, a refined products pipeline typically "wraps" the current highway diesel (at 500 ppm) with kerosene and/or jet fuel (2,000 ppm or so), and non-road diesel (up to 5,000 ppm). The chance that the 500 ppm material will be forced off-specification by sulfur contamination is low. The product tendered is around 300 ppm, leaving leeway for any minor contamination from the neighboring product.

Typically, refined oil products are transported from a source location, such as a refinery or bulk terminal, to a distribution terminal near a market area. Large aboveground storage tanks at an origin location accumulate and hold a given petroleum product pending its entry into the pipeline for transport. Petroleum products are also stored temporarily in aboveground storage tanks at destination terminals.

Storage tanks usually are dedicated to holding a single petroleum product or grade. Most storage tanks used in pipeline operation are filled and drained up to four or more times per month. Operators usually are able to place the same type of petroleum fuel in a given tank on each drain and fill cycle, and the tank is not purged and cleaned between the routine drain and fill cycles. When a tank is filled and drained with a given material, small to substantial quantities of the former material remain in the tank. To the extent that the previous material was different from new material being placed in the tank, contamination can occur. Generally, such contamination is inconsequential because the new material is substantially the same as the old material or its volume is small.

Making the Cut: The Mechanics of the Interface

Each petroleum product—in fact, each batch of products—has a distinct and identifiable specific gravity. Different products have widely different specific gravities. Different grades or batches of the same product have slight but measurable differences in specific gravity.

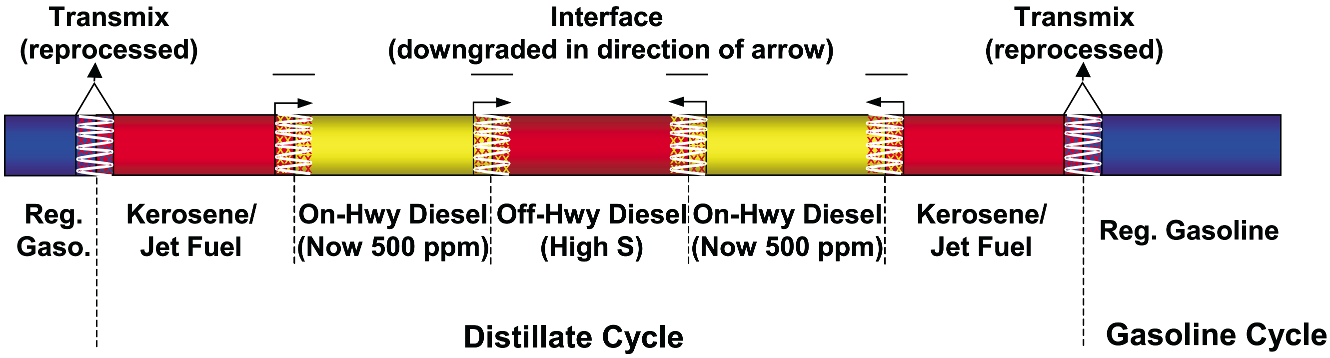
Pipeline operators monitor the specific gravity of a pipeline stream as it approaches a station or terminal. A change from one specific gravity to another indicates the end of the leading batch and the beginning of the following batch. Based on this signal of the interface location, the pipeline operator "swings" batches from one pipeline to another or from mainline transit into segregated tanks. The shift in specific gravity may be too gross an indicator, however, when dealing with ULSD. By the time the shift in specific gravity is discernible, the ULSD may have been contaminated by the sulfur in its neighboring product.

In addition to tanks at the origin and destination terminals, "working" or "breakout" tanks are used in the normal course of pipeline operation. Over a pipeline route, there may be various needs to interrupt the flow of pipeline material in transit, including branching of the pipeline, change in size or capacity, mainline pumping operations, change from fungible to batch operation, and others. In each case, breakout tanks provide the flexibility to temporarily stop or buffer different flow rates of pipeline segments.

The maintenance of material in continuous pipeline transit without need for diversion into breakout tankage is known as "tightlining." A pipeline operator's ability to tightline material will prove to be a slight advantage in protecting the integrity of ULSD. Overall, however, tightlining is not an easy option to engage if facilities and operating requirements do not already permit it.

In addition to the minor creation of interface material that occurs in pipeline transit, creation of interface material also occurs in the local piping facilities (station piping) that direct petroleum products from and to respective origin and destination storage tanks and in

Figure C1. Typical Product Sequence and Interfaces in a Refined Products Pipeline



Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

the tanks themselves. Essentially, station piping represents the connection between a main pipeline segment and its requisite operating tanks. The concept is simple in theory, but in practice the configuration of station piping is not. Station piping layouts become more complex as the tanks at a pipeline terminal facility become more numerous.

Configurations of station piping necessary to accommodate a given number of tanks and to provide flexibility in routing multiple products in and out of those tanks provide many possibilities for the creation of pipeline interface material. Each pipeline facility is different, not only among pipeline companies but within pipeline companies. There is no way to predict how easy or hard it will be to minimize possible sulfur contamination of ULSD in station piping, except to examine the risks on a case-by-case basis.

In fact, the interface generation in station piping and breakout tanks may be even more important than during pipeline transit. The volume of interface material thus generated is due to the physical attributes of the system. It has fewer variables but approaches being a fixed value on a barrel-per-batch, not a percentage, basis. For instance, one pipeline operator may create 25,000 barrels of high-sulfur / low-sulfur distillate interface per batch whether the batch is 250,000 barrels or 1,000,000 barrels. In addition, a given batch of product might be transported in multiple pipelines between its origin and its final destination and even within the same system might require a stop in breakout tanks, as noted above. Each segment of the journey generates additional interface.