The Strategic Petroleum Reserve

Policy Challenges in Managing the Nation's Strategic Oil Stock

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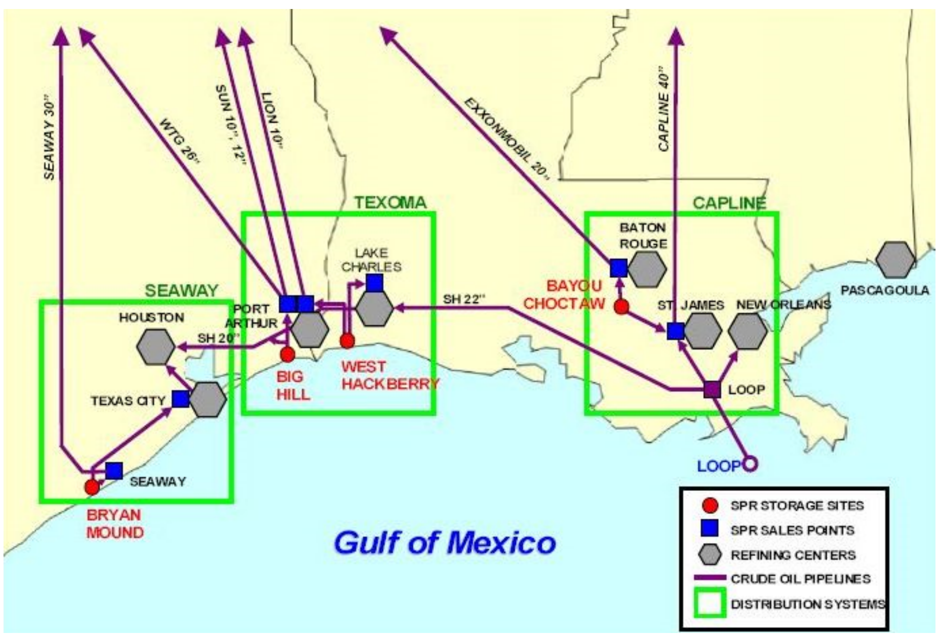
Introduction

U.S. energy policy, particularly those aspects directly related to oil and natural gas, largely was designed and implemented in the years immediately following the 1973-74 Arab oil embargo. It was an era of rapidly rising petroleum imports, declining domestic production, price volatility, price and allocation regulations, and expectations of long-term sustained growth in U.S. oil consumption.

A central concern among policy makers in the aftermath of the Arab oil embargo was the threat from growing reliance on expensive and insecure imports from production centers that might disrupt the flow of petroleum to the United States, either through an embargo, war, or political instability. In response to these concerns Congress authorized the construction and operation of the Strategic Petroleum Reserve (SPR) as part of the 1975 Energy Policy and Conservation Act (EPCA).[1] The legislation emphasized the importance of the SPR as an instrument to counter severe supply interruptions. Today the SPR consists of four storage sites (Figure 1), two in Louisiana and two in Texas, holding 692 million barrels of blended crude oils, categorized as either sweet or sour.

Figure 1. Storage Sites for U.S. Strategic Crude Oil Stocks



Source: U.S. Department of Energy, Sandia National Laboratories

[1] In 1971, two years before the Arab Embargo, EPRINC (then known as the Petroleum Industry Research Foundation, Inc.) recommended that the U.S. Government create a strategic reserve along the U.S. Gulf coast to avoid any sudden loss of supplies and disruption to the national economy. Senator Henry Jackson, chairman of the Senate Committee on Interior and Insular Affairs Committee picked up on that theme and lead the effort for including the SPR in the 1975 EPCA legislation. At that time the Senate Committee on Interior and Insular

The official storage capacity of the sites is 727 million barrels. All of the oil is stored underground and the surface facilities consist of massive motors, pumps, manifolds, pipelines and control facilities.

The original design of the U.S. Strategic Petroleum Reserve anticipated that the program would be a bridge to provide protection against oil interruptions until technological advances and demand modifications made the storage of strategic petroleum stocks unnecessary. There was a policy consensus in 1976 that the U.S. would require protection against an oil disruption for about 25 years and that it would be prudent to prepare for a major disruption, on average, every five years. Consequently, the cavern design of the SPR sites was optimized for 5 drawdown cycles.

Transitioning the U.S. economy to an alternative fuel mix proved more difficult than anticipated, and U.S. policy makers concluded that protection against oil supply disruptions would be needed for a longer time horizon. In addition, instead of planning only for periodic major disruptions, the U.S. would have to respond to more frequent but less severe disruptions.

In early 2010, officials managing the SPR program concluded that the engineering design of the storage facilities was not well matched to a policy of more frequent use. There are several reasons for the mismatch in design and use. First, the large number of small oil removals that occurred in the previous 20 years had caused several caverns to deviate from their ideal shape, and those caverns are now suffering damage due to salt falls and other geologic activity. Second, in order to remove excess natural gas from the oil inventory (a common problem in large scale storage of crude oil), the surface facilities are being used extensively at slow speeds rather than the high speed, short intervals for which they were designed, resulting in the degradation of the surface production facilities. Third, the underground storage caverns are shrinking due to continuous geologic pressure.

While the exact rate of cavern closure in any year is unknown, it is minimally in the range of 2 million barrels per year and may be significantly higher. As a consequence the SPR is at full capacity even though inventory is 692 million barrels, significantly below the authorized level of 727 million barrels, and shrinkage is increasing monthly. In addition to capacity loss, shrinkage in storage capacity may be damaging well casings, which are essential for pressure maintenance, leak prevention and production of the stored oil.

There are two known options for addressing the scope of these problems. The first is to have a second Life Extension Program (the first Life Extension Program was initiated in the 1990s) that would increase cavern capacity, address the impacts of equipment deterioration and well damage, and upgrade facilities to accommodate the smaller oil sales that have become the hallmark of the SPR over the past 20 years. The second option is to reduce the size and official capabilities of the SPR to fit within the diminishing capabilities. Recent sales and severe budget constraints suggest the SPR is being moved in the direction of the second option by default with little public discussion or policy debate.

Salt Domes as a Medium for Oil Storage

Salt has been considered an almost ideal medium for storing petroleum for many decades and has been used commercially in the United States and other countries. Along the U.S. Gulf Coast, naturally occurring oil is often found on the flanks of salt domes, and the first major oil find in Texas, Spindle Top, was named for the adjacent salt dome. Salt domes are massive plumes of salt that well up from a bed of salt deposited when an ancient sea evaporated. These plumes can be miles high and wide. Some come near the surface, but for purposes of oil storage the best domes have a significant layer of rock above the top of the salt. The salt domes are not static: at high temperatures and pressure salt is plastic. The existence of the domes is due to fissures in the covering rock layers that allowed the plastic salt to move up toward the surface. This phenomenon persists to this day.

In some ways plasticity makes salt domes an almost perfect storage medium. Salt does not react with oil and the oil can be stored indefinitely. From a structural perspective, the salt has the virtue of being self-healing. Conceptually, if a fault were to intersect a cavern, the salt would close in and over time reseal the fault. On the other side, salt plasticity presents unique maintenance challenges because artificially created caverns within the salt domes are under constant closure pressure, and the salt formation may shift relative to the covering cap rock. The SPR Office manages the closure phenomenon by leaving a significant bed of salt brine at the bottom of each cavern, and keeping the caverns under high pressure to slow the shrinkage. As the pressure increases to what is considered safe limits the cavern managers remove some of the salt brine from the bottom of the cavern, thereby decreasing the pressure. The rate of cavern shrinkage varies from cavern to cavern and site to site. Shrinkage even varies in individual caverns over time.

Surface Facilities

The original design of site facilities in the 1970s accommodated both the creation of salt caverns and operations after sites were commissioned. Using pumps, pipes and manifolds for multiple purposes meant the surface facilities were complicated and very expensive to maintain after the initial cavern creation was complete. Beginning in 1994, after completion of all the storage sites, the Department of Energy (DOE) initiated a major rebuilding program, the Life Extension Program, which upgraded and replaced all major systems with modern technologies, streamlined piping, and standardized equipment. When the first Life Extension Program was finished in 2000, the SPR Office estimated that the facilities had a life span of 25 years with normal maintenance. While the Life Extension Program addressed surface facilities, the program's working assumption was that with routine maintenance storage capacity (cavern size) could be sustained until 2025.

Cavern Shrinkage

While the nominal size of the SPR in 2000 was 700 million barrels, in reality that size did not include the brine-filled capacity in the caverns designed to allow shrinkage and still have 700 million barrels of capacity in 2025. In 2004, the program revised this estimate of capacity and increased it to 727 million barrels based on sonic measurements of actual cavern size and estimates at the time of the rate of cavern closure, even though the actual rate of cavern closure was not uniform and subject to revision.

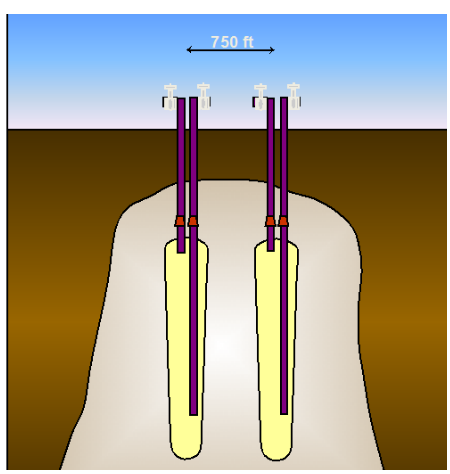
The salt leaching that occurs each time oil is sold or exchanged from the SPR periodically offsets this continuous shrinkage. Every time oil is removed from an SPR site, the oil is extracted by injecting fresh water into the bottom of caverns to push the oil out of the top. The water used for this purpose is either fresh water or unsaturated brine. The result is that more salt is dissolved and new space is created in the cavern. The rule of thumb estimate used by the SPR Office is that for every 100 barrels of oil removed from a cavern 15 barrels of salt are dissolved. In theory, oil sales should increase the total capacity of the Reserve, but in practice salt dissolution, especially during small movements, may create problems.

Cavern Design and Spacing

Rock salt engineers believe that the ideal shape for a large storage cavern is approximately cylindrical. Conceptually, having a narrow cylindrical shape should minimize rock falls that damage hanging pipes or compromise the cavern roof. For structural integrity the caverns are much taller than they are wide (Figure II): the target size is 200 feet in diameter and 2000 feet deep. A cavern this size will hold approximately 10 million barrels of oil. During cavern creation the engineering teams control cavern shape by continuously changing the length of pipe through which fresh water is injected into the solid salt formation to dissolve salt. The resulting cavern will be somewhat irregular but overall close to the ideal shape

Figure 2. Salt Dome Configuration for Oil Storage

- **10 to 12 Million Barrels**
- **Cylindrical shape**
  ~ 200 ft Diameter
  ~ 2000 ft Tall
- **Top >-2000 ft**
- **Bottom <-5000 ft**
- **Oil Injection (at Top)**
- **Water/Brine Injection (at Bottom)**



Source: U.S. Department of Energy

By design, once a cavern is complete, the brine is replaced by injecting oil until the desired amount of brine is displaced, and the oil floats on a remaining bed of brine. In the 1970's engineers anticipated large disruptions requiring large oil sales. They visualized caverns would have all or nearly all of their oil sold at one time. In that case, while a cavern would enlarge due to the cycling of fresh water the cavern would maintain its relative shape (near conical). One critical assumption was the amount of salt that would be maintained between caverns. The initial design called for about 550 feet of salt between adjacent caverns. This would allow for five cycles of the caverns with the separating salt being dissolved with each cycle so that after the fifth cycle the caverns would still have structural integrity with about 300 feet of salt still in place, but would be too close to neighboring caverns or to the edge of the dome to allow more cycles without the risk of the caverns coalescing or the caverns closest to the edge of salt reaching to rock that would allow oil to escape from the salt formation.

The reality of SPR use has been very different from what the original designers had envisioned. The Reserve has never drawn down oil as a rate of more than 30 million barrels in a month or for any given event. Additionally, from 1996 through the test sale in 2014 there have been 14 instances of oil removals less than 10 million barrels. While removing one million barrels of oil from a cavern may seem inconsequential, repeating the process can have serious consequences for the shape of a cavern. This is because the dissolution of salt during a drawdown always begins at the bottom of the cavern and if the cavern is only partially emptied the shape of the cavern will become distorted with a bulge at the bottom, similar to the shape of a thermometer. Gravity then puts stress on the overhanging salt formation, and massive falls can occur. These falls often damage hanging steel tubulars, which are expensive and time consuming to replace. Cavern integrity may also be compromised by geologic activity. The Weeks Island site was decommissioned in 1997 due to water intrusion into the mine, and in 2013 the program decommissioned cavern 20 at Bayou Choctaw due to concerns that the cavern was too close to the edge of salt. Compounding the complexity of cavern maintenance, each time major work is conducted caverns must be depressurized. There is evidence that depressurizing caverns for even short periods allows the rate of shrinkage to increase rapidly, possibly creating new problems. There is also evidence that both the casing and hanging string problems at the Big Hill site should be addressed in several of the caverns, but due to budget constraints there is no comprehensive plan for restoring or replacing the suspect caverns.

Cavern Creep

In addition to the cavern shape problems, the natural geologic forces working on the salt have caused caverns to close faster than anticipated. In effect, SPR management has for several years been faced with the potential problem of having inventory exceed the capacity of the reserve, even at an inventory level of only 697 million barrels. In effect, the SPR program does not have the option of replacing the 30 million barrels of oil sold in 2011 to offset the loss of Libyan oil. The plan of action adopted to deal with this problem was referred to as a "mini leach". Effectively, fresh water was circulated through caverns to dissolve salt in a uniform pattern. While conceptually acceptable from a cavern perspective, the slow rate of water and brine circulation was driven by the motors and pumps designed to operate at higher speeds for shorter periods. This method of operation is putting an undue amount of wear and tear on surface facilities. Also, while the rate of salt dissolution offset shrinkage of total capacity while it was in effect, it appears that it has not increased the useable capacity of the caverns.

Nexus with Budget and Policy

In the absence of funding constraints, many of the SPR maintenance concerns might be addressed by a second Life Extension Program. In the current highly limited budget environment, the Department of Energy has examined programmatic alternatives on spending to maintain the official status quo of a 727 million barrel crude oil reserve, such as the creation of a large regional refined product component of the SPR, and a reduction in the crude oil capacity and inventory.

The urgency of addressing the capacity problem was temporarily mitigated by world events in 2011. That year, President Obama, in coordination with International Energy Agency member countries[2], made a finding of an energy supply emergency due to the revolution and supply disruption in Libya. The SPR sold 30 million barrels of light sweet oil, generating approximately $3 billion in revenue. By law, those revenues were automatically appropriated to the SPR Petroleum Account to be preserved for repurchasing the oil. However, the Administration was still considering a major refined product reserve as a component of the SPR, which might have been paid for with the funds in the SPR Petroleum Account, and did not replace the crude oil removed from the SPR in 2011. While the refined product reserve issue was being debated, Congress eliminated that programmatic option by rescinding the funds in the SPR Petroleum Account as part of the FY 2014 budget. A major refined product reserve was implausible without funding although consideration of such an option did not stop due to the loss of the SPR Petroleum Account balances. Super Storm Sandy, the attendant fuel shortages, and the perception that the Northeast remained vulnerable to a repeat of the disaster sharpened arguments in favor of taking action to at least partially mitigate the vulnerabilities. The administration determined that it would like to commit to a refined product reserve, albeit of small size, as part of the SPR, and other events would make some funding available for that purpose.

Changing Structure for the Movement of US Crude Oil

A current issue, which has gained headlines in the last two years, is the possibility that the private sector logistics systems can no longer accept and deliver the oil drawn from the SPR during a sale at the rates for which the SPR is designed (in excess of 4 million barrels per day). The origin of this concern is a massive increase in U.S. and Canadian oil production, which began flowing into the center of the country in the last decade. U.S. production alone has increased over 3 million barrels of oil per day in the last five years. This oil is satisfying refinery requirements through the entire interior of the country and is pushing south to the Gulf of Mexico. This phenomenon was highlighted in 2013 when the Seaway Pipeline system, which goes from the Gulf Coast to

[2] The International Energy Agency (IEA) is a Paris-based autonomous intergovernmental organization established in the framework of the Organization for Economic Co-operation and Development (OECD) in 1974 in the wake of the 1973 oil crisis. The IEA was initially dedicated to responding to physical disruptions in the supply of oil, as well as serving as an information source on statistics about the international oil market and other energy sectors.

Cushing, Oklahoma, was reversed. Responding to public expressions of concern, the DOE argued that other distribution channels were sufficient and emphasized moving oil over docks and into ships. While plausible, that option was viewed with some suspicion by observers for a variety of reasons including proscriptions against using foreign flag vessels to move the oil between U.S. ports and exporting the oil.

The Energy Policy and Conservation Act, which contains the organic legislation authorizing the SPR, provides the Secretary of Energy authority to conduct test sales of up to five million barrels of oil, and in the Spring of 2014, DOE undertook a 5 million barrel test sale to assess how industry would respond to a sale in terms of taking and distributing the oil. The sale generated about $500 million. Immediately following that sale DOE announced that it would create a one million barrel gasoline component of the SPR to be located in the Northeast. Given that the latter initiative could only be conducted with a funding source not requiring new appropriations, most observers believe that the test sale was conducted at least in part for the purpose of generating the revenues to enable creation of the gasoline component of the SPR.

Concluding Observations

One of the more important lessons from management of this important strategic stockpile is that the costs of a drawdown must include components for maintenance costs associated with cavern degradation, and opportunity costs associated with a smaller reserve inventory due to the likelihood that oil sales revenues will not be used to replace the oil sold.

Since 2011, three actions have effectively and permanently reduced the crude oil inventory in the SPR: the 30 million barrel Libyan sale, rescission of SPR Petroleum Account balances, and the 2014 test sale with the reallocation of funds to gasoline. The SPR crude oil inventory has dropped from 727 million barrels to 692 million barrels and neither the Administration nor the current Congress has committed to an inventory target. Meanwhile, the problems in adequately maintaining storage facilities remain and the effective maximum capacity has now been reduced to 700 million barrels. Even if Congress were to provide budget allocation for repurchase of drawn oil, the prior maximum size of the SPR is not achievable without additional spending on major maintenance.

Historically, the Energy Policy and Conservation Act provides overall guidance on SPR management, and that legislation requires that the SPR be expanded to one billion barrels. The funding for achievement of that target size has never been forthcoming. However, changes to the configuration or size of the SPR have always been guided either by legislation or conformance to a plan. Specifically, questions relating to the size and inventory of the SPR have been preceded by rigorous studies of optimum size. No such study has been conducted since 2006. Given the widespread changes in domestic petroleum development and ongoing instability in many of the world's major production centers, it remains important to address SPR policy with rigorous and systematic evaluations on optimal size and use, rather than ad hoc approaches.

If the current conflict in Iraq should lead to export disruptions, supply shortages, a price spike and a sale of significant inventories from the U.S. SPR and the inventories of other IEA members, what would then happen to the revenues generated? Should the inventories be replaced and would they be replaced? Like much of U.S. energy policy developed in much a different era, now is an appropriate time for a full-scale evaluation of the value and role of our strategic oil stocks.

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