Strategic Petroleum Reserve
Crude Oil Assay Manual

5th Edition
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U. S. Department of Energy
Assistant Secretary for Fossil Energy
Office of Petroleum Reserves
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PREFACE

This booklet provides detailed information on the specifications for crude oils to be acquired for storage in the Strategic Petroleum Reserve (SPR), procedures used to assess quality of the stored petroleum during protracted storage, and methods used in developing assays of the various streams that may be sold. Links to assays of the eight SPR streams are provided. This edition supersedes the fourth edition, March 2017, as revised August 2024.

Any questions regarding sampling practices, analysis procedures, or the assays themselves should be addressed to Crude Oil, Drawdown Readiness, and Cavern Integrity Division (CR-4622), Office of Petroleum Reserves, New Orleans, LA 70123, telephone +1 (504) 734-4749. This office should also be contacted for the latest edition of the SPR Crude Oil Specifications shown in Table I.

I. Acquisition and Storage of Crude Oils.

Recent technological advancements in drilling and completion techniques for the production of crude oil from shale formations, such as Hydraulic Fracturing (also hydrofracturing, hydrofracking, fracking, or fraccing) has increased the availability of light crude oil from the various domestic shale plays. The majority of the shale oil production currently is from the Bakken, Marcellus, Utica and Eagle Ford producing areas. The Wolfcamp area in the Midland Basin is expected to contribute an additional 20 billion barrels of shale-derived crude oil over its lifetime. These shale crude oils display higher API gravities than crudes typical for the SPR although most fall within the SPR Crude Oil Specifications listed in Table 1. These shale oils routinely show high bubble point pressures (BPP) and high gas-oil ratios (GOR) which present logistics and environmental concerns for the SPR.

The majority of this new shale production is in areas with very little oil processing capabilities or transportation infrastructure. As crude oil processing and transportation infrastructures are developed in each production area the SPR expects issues associated with high vapor pressures in crude oil will be mitigated over time. Increased vigilance by marketing, transportation, and environmental organizations will compel producers to resolve the challenges associated with the sale and shipment of these light crude oils.

The specifications for the acquisition of crude oil for storage in the Strategic Petroleum Reserve (SPR) were originally developed in 1976. At that time, six categories of crude oil were defined. These encompassed a large segment of crude oils– both domestic and foreign – being processed by U. S. refineries at that time and included projections of future runs based on new fields being developed such as those on the Alaskan North Slope and in the North Sea.

These categories included one medium-gravity, sour crude oil of nominal Arabian Light quality; four medium-gravity, sweet categories, covering North and West African streams and production coming on-stream in the North Sea; and a heavy, sour category specific to Alaskan North Slope production. Later, a seventh category was added to allow for acquisition of Mexican Maya crude oil.

For practical reasons related to drawdown logistics, it was not possible to segregate all these various categories in storage and essentially four segregations evolved. The two largest of these in terms of volume were a medium gravity, sour of nominal Mexican Isthmus quality, and a medium gravity, sweet of nominal Ninian/Forties quality. Another segregation comprised Alaskan North Slope crude commingled with medium gravity, sour crude oils, and the fourth segregation was Mexican Maya. Due to technical considerations unrelated to crude oil quality or drawdown logistics, the Alaskan North Slope segregation formerly stored in the Weeks Island Mine has been relocated and commingled with medium gravity, sour crude oils. The Maya segregation has now been disposed of and replaced by other crude oils. Today, only two specifications – one sweet and one sour, both of medium gravity – are used for acquiring crude oil for the SPR (Table I).

Member companies of the American Petroleum Institute (API), the American Fuel and Petrochemical Manufacturers Association (AFPMA), along with other industry groups and petroleum companies have reviewed these specifications as they have evolved over the past four

decades. Minor changes to the SPR's acceptance criteria have been made as the result of these informed suggestions. The SPR strives to acquire domestic and foreign crude types with the widest range of application in domestic refining.

Currently the SPR has a sweet and a sour segregation at each of its four sites. The approximate crude oil makeup of each of these eight segregations is summarized in Appendix A. To maintain overall homogeneity for an assigned crude classification only crude oils of similar composition are commingled in storage. The composition of the crude oil mixture in the SPR caverns conforms to one of the two specifications in Table I. Consideration has been given to the increase in domestic oil production. Bakken and other tight oils in the Gulf coast oil market are high BPP-GOR oils that have significant impacts on long term storage and the existing SPR oil inventory with respect to light ends composition. As a result, the SPR Crude Oil Specifications were revised to address this issue.

II. Crude Oil Quality Assessment Program.

Cavern sampling is the collection of multi-level series of samples for laboratory analysis. Newly filled or refilled storage caverns are initially sampled after the completion of purchase cycle(s). Caverns are typically resampled at approximately eight-to-twelve-year intervals. Some cavern maintenance activities provide opportunities for collecting representative samples at shorter intervals than described above. An inspection analysis (Table II) of each cavern sample is performed to ascertain if there is any stratification or differentiation of the crude oil mixture. If none is evident, a composite sample is made of the individual oil samples and a comprehensive crude assay is performed. The specific test schedule for this analysis is listed in Table III.

Extensive studies of crude oil stockpiles held in cavern storage have shown convective mixing, induced by the natural geothermal gradient in the cavern, results in commingled crude oils becoming well mixed when stored in large underground caverns such as those of the SPR. While no deleterious changes in quality are known to occur to crude oil stored in solution-mined caverns in salt, a relatively small volume of dense, viscous, and waxy material containing emulsified water may accumulate in some caverns. This "sludge or rag layer" appears to be a natural phenomenon and not the result of incompatibility between various crude oils commingled in storage. This layer is not removed from a cavern during a drawdown and does not become a component of the stream that is sold.

III. Laboratory Procedures.

All whole crude oil samples and distillation fractions are analyzed using current ASTM-International standard test methods. All test results are reported in accordance with the respective ASTM test method's most current instructions. Many of the listed procedures have been adopted by other international standards organizations and given numerical designations unique to that standards body. Table III specifically notates when current equivalent methods are performed in lieu of ASTM. As an example, ASTM Test Designation D5853 is identical in all aspects to IP Test Designation 441/23 and will be accepted as such. ASTM analogues for many petroleum tests are published by IP, ISO, ANSI, UOP and API.

Acid Number tested in accordance with ASTM D664 *Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration. ASTM D8045 Standard Test Method for Acid Number of Crude Oils and Petroleum Products by Catalytic Thermometric Titration.*

Aniline Point tested in accordance with ASTM D611 *Standard Test Method for Aniline Point of Petroleum Products and Hydrocarbon Solvents.*

API Gravity tested in accordance with ASTM D1298 *Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method*, ASTM D5002 *Standard Test Method for Density and Relative Density of Crude Oils by Digital Density Analyzer*, ASTM D4052 *Density, Relative Density, and API Gravity of liquids by Digital Density Meter.* All are acceptable test methods for the determination of API gravity.

Asphaltenes tested in accordance with ASTM D6560 *Standard Test Method for Determination of Asphaltenes (Heptane Insolubles) in Crude Petroleum and Petroleum Products*. Used for determining their content in the whole crude and in the atmospheric and vacuum residuum fractions.

Atmospheric and Light Vacuum Distillation tested in accordance with ASTM D2892 *Standard Test Method for Distillation of Crude Petroleum (15-Theoretical Plate Column)*. Subsequent distillation of the residuum is performed using ASTM D5236 *Standard Test Method for Distillation of Heavy Hydrocarbon Mixtures (Vacuum Potstill Method)*. Distillation fractions are measured on a mass percent basis in both procedures, with volume percent values calculated using the specific gravity of each fraction. (See also High Temperature Simulated Distillation).

Boiling Point Distribution tested in accordance with ASTM D2887 *Standard Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography,* restricted to petroleum fractions in the range of 55 - 538°C or n-C_{43}.

Calculated Cetane Index tested in accordance with ASTM D976 *Standard Test Method for Calculated Cetane Index of Distillate Fuels.*

Cloud Point tested in accordance with ASTM D2500 *Standard Test Method for Cloud Point of Petroleum Products.*

Freeze Point tested in accordance with ASTM D2386 *Standard Test Method for Freezing Point of Aviation Fuels.*

High Temperature Simulated Distillation (HTSD) tested in accordance with ASTM D7169 *Standard Test Method for Boiling Point Distribution of Samples with Residues Such as Crude Oils and Atmospheric and Vacuum Residues by High Temperature Gas Chromatography*. Due to limitations of the method procedure, D7169 yields incomplete separation of C_{4-} $C_{9.}$ ASTM D7169 is often merged into one boiling point distribution with ASTM D7900 *Standard Test Method for Determination of Light Hydrocarbons in Stabilized Crude Oil by Gas Chromatography,* to determine the light end fraction of the crude oil more accurately through $C_{9.}$ (See also Light Ends in Crude Oil). Data obtained according to ASTM D7169 and D7900 is permissible in conditionally accepting a crude oil for storage, however, data obtained by ASTM D2892 and D5236 are still required for final certification of a crude oil's acceptability.

Hydrocarbons in Liquefied Petroleum Gas tested in accordance with ASTM D2163 *Standard Test Method for Determination of Hydrocarbons in Liquefied Petroleum Gases by Gas Chromatography.*

Hydrocarbon Types tested in accordance with ASTM D1319 *Standard Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption.*

Hydrogen Sulfide. The hydrogen sulfide (H2S) values reported for distillation fractions represent evolved (potential) gas resulting from decomposition of thermally unstable sulfur compounds as well as H2S carried over during distillation. ASTM D5705 *Standard Test Method for Measurement of Hydrogen Sulfide in the Vapor Phase* and UOP163 *Hydrogen Sulfide and Mercaptan Sulfur in Liquid Hydrocarbons by Potentiometric Titration* is used for determination of hydrogen sulfide in **liquid**. Alternative methods available for use are ASTM D7621-*Standard Test Method for Determination of Hydrogen Sulfide in Fuel Oils by Rapid Liquid Phase Extraction- Appendix X1 and* a modified version of ASTM D6021 *Standard Test Method for Measurement of Total Hydrogen Sulfide in Residual Fuels by Multiple Headspace Extraction and Sulfur Specific Detection.*

Hydrogen and Carbon Percent tested in accordance with ASTM D5291 *Standard Test Method for Instrumental Determination of Carbon, Hydrogen and Nitrogen in Petroleum Products and Lubricants.* Results can be used to estimate the processing and refining yields.

K Factor tested in accordance with UOP375 *Characterization Factor*. Helpful in determining the chemical characteristic of a crude oil, i.e. Aromatic, Paraffinic.

Kinematic Viscosity tested in accordance with ASTM D445 *Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)* is used as the primary test procedure for viscosity determinations at the temperatures listed. Samples that exhibit non-newtonian flow may be analyzed using ASTM D7042 *Standard Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity).*

Light Ends in Crude Oil tested in accordance with ASTM D7900 *Standard Test Method for Determination of Light Hydrocarbons in Stabilized Crude Oils by Gas Chromatography*. Functionally this test method is essentially the same as the Intertek Light Ends method (ITM6008) and AmSpec Light Ends Method (ATM-048).

Metals tested in accordance with ASTM D5708 Method B *Standard Test Method for Determination of Nickel, Vanadium, and Iron in Crude Oil by Inductively Coupled Plasma (ICP) Atomic Emission Spectrometry (AES).* ICP/AES allows for linear calibration over an elemental range. Thus is an acceptable technique for metals analysis not directly listed in method description.

Micro Carbon Residue tested in accordance with ASTM D4530 *Standard Test Method for Determination of Carbon Residue.*

Naphthalene is tested in accordance with ASTM D1840 *Standard Test Method for Naphthalene Hydrocarbons in Aviation Turbine Fuels by UV Spectrophotometry.* Used to assess combustibility of aviation fuels.

Nitrogen tested in accordance with ASTM D5762 *Standard Test Method for Nitrogen in Liquid Hydrocarbons and ASTM D4629 Standard Test Method for Trace Nitrogen in Petroleum Hydrocarbons by Oxidative Combustion and Chemiluminescence Detection.*

Octane tested in accordance with ASTM D2699 *Standard Test Method for Determination for Research Octane Number of Spark-Engine Fuel and* ASTM D2700 *Standard Test Method for Determination for Motor Octane Number of Spark-Engine Fuel.*

Organic Chlorides. To monitor for possible contamination by improperly disposed cleaning solvents or other forms of organically bound chlorine, all shipments of crude oil received for storage in the SPR are routinely analyzed for organic chlorides. ASTM D4929 *Standard Test Method for Determination of Organic Chloride Content in Crude Oil* Procedure B or C is used for this determination.

Paraffin, **I**soparaffin, **A**romatic, **N**aphthene (PIAN) tested in accordance with ASTM D6733 *Standard Test Method for Determination of Individual Components in Spark Ignition Engine Fuels by 50-Metre Capillary High Resolution Gas Chromatography* used to identify naphtha components with a nominal end point of 225° C. *ASTM D5443 Standard Test Method for Paraffin, Naphthene, and Aromatic Hydrocarbon Type Analysis in Petroleum Distillates Through 200 °C by Multi-Dimensional Gas Chromatography* may be used for lighter naphtha having an endpoint below 200° C.

Pour Point tested in accordance with ASTM D97 *Standard Test Method for Pour Point of Petroleum Products* is the accepted test method for this property. ASTM D5853 *Standard Test Method for Pour Point of Crude Oils (Procedure A)* may be used as an acceptable alternate procedure.

Refractive Index tested in accordance with ASTM D1747 *Standard Test Method for Refractive Index of Viscous Materials.*

Salt Content tested in accordance with ASTM D6470 *Standard Test Method for Salt in Crude Oils (Potentiometric Method)* and ASTM D3230 *Standard Test Method for Salts in Crude Oil (Electrometric Method)* are used extensively for measuring salt content in crude oil.

Smoke Point tested in accordance with ASTM D6470 *Standard Test Method for Smoke Point of Kerosine and Aviation Turbine Fuel.*

Sulfur Content. Either ASTM D4294 *Standard Test Method for Sulfur in Petroleum and Petroleum Products by Energy Dispersive X-ray Fluorescence Spectrometry* or ASTM D2622 *Standard Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry, ASTM D5453 Standard Test Method for Determination of Total Sulfur in Light Hydrocarbons by Ultraviolet Fluorescence* is acceptable for measuring sulfur content in crude oil.

Vapor Pressure tested in accordance with ASTM D6377 *Standard Test Method for Determination of Vapor Pressure of Crude Oil: VPCRx (Expansion Method)* is the preferred test procedure for measuring the vapor pressure of crude oil.

Water and Sediment Content. There is some flexibility in which sediment and water procedures may be used to generate a reported value combining the two properties expressed as volume per cent. For water content either ASTM D4928 *Standard Test Method for Water in Crude Oils by Coulometric Karl Fischer Titration* or ASTM D4006 *Standard Test Method for Water in Crude Oil by Distillation* are the recommended methods. Results are to be reported as or converted to volume per cent as required. Sediment content is measured either by ASTM D473 *Standard Test Method for Sediment in Crude Oils or Fuel Oils by the Extraction Method* or ASTM D4807 *Standard Test Method for Sediment in Crude Oil by Membrane Filtration.* Sediment test results are converted to a volume per cent value. The volume per cent results for sediment and water are then combined to generate a single value for Water and Sediment, volume percent.

Wax tested in accordance with UOP46 *Paraffin Wax Content of Petroleum Oils and Asphalts* is used for determining mass % wax content of the whole crude and the light and heavy vacuum gas oil (VGO) fractions.

Quality Assurance. Laboratories providing crude oil analytical services for the SPR participate in the ASTM-International Interlaboratory Crosscheck Program for crude oil. Results from this program provide quantifiable evidence that the testing is performed to acceptable levels of precision and accuracy. Additionally, all laboratories have an established internal quality assurance program to ensure conformance to best industry laboratory practices and in meeting defined standards of quality at a stated level of performance.

IV. Crude Oil Composition of SPR Streams.

Each SPR crude oil stream is comprised of crude oil stored in multiple caverns. The storage volume of individual caverns varies, with most being on the order of 10 million barrels (1.6 million m^3). Depending on the magnitude of a drawdown requirement of the SPR, one or more caverns comprising the segregation may be used to make up a delivery stream. The analyses published in Appendix B are weighted averages of test results for the caverns comprising a given SPR stream. Comparison of detailed assay data confirm there are only minor variations in the analytical profiles for the individual caverns in a given stream. In the majority of cases, the cavern-to-cavern variation of a specific test result is within the testing precision for the designated test protocol used. To minimize the impact of these minor variations in fluid properties, a proportional drawdown of caverns comprising a given stream is practiced to the extent practicable.

Analytical data for the crude oil composition of each storage cavern has been managed and archived using a commercial crude assay management system (e.g. Haverly Systems). Assay management systems can reproduce assay reports based on actual test data from individual source caverns. The management system also can generate predictive assay reports for any combination of cavern test data using advanced modeling algorithms. These are important capabilities in two respects. First, it allows a stream-specific assay to be developed for any combination of SPR caverns using any combination of analytical profiles. Second, changes in cavern quality resulting from deliveries between scheduled assay samplings can be monitored, calculated, and addressed. Some properties are not directly measured but are calculated by the modeling software and are not actual laboratory results. Crude oil assay management files are available upon request by contacting the Director, Operations and Readiness, as directed in the Preface.

TABLES I - III

Table I

STRATEGIC PETROLEUM RESERVE
CRUDE OIL SPECIFICATIONS [a]
(SPRO June 2023) [ε1]

CHARACTERISTIC	SOUR	SWEET	PRIMARY ASTM TEST METHOD [b]
API Gravity [°API]	30 Max	45 Max	D1298 or D5002
Total Sulfur [Mass %], max.	1.99	0.50	D4294 or D2622
Pour Point [°C], max.	-12	-12	D97
Salt Content [Mass %], max.	0.050	0.050	D6470
Viscosity			
[cSt @ 15.6°C], max.	32	32	D445
[cSt @ 37.8°C], max.	13	13	
Vapor Pressure			
[VPCR4 (100°F) psia (kPa)] [e], max.	9.0(62.1)	9.0(62.1)	D6377
Total Acid Number [mg KOH/g], max.	1.00	1.00	D664, or D8045
Water and Sediment [Vol. %], max.	1.0	1.0	D473, and D4006, or D4928
Yields [Vol. %]			D2892 and D5236[c]
Naphtha [28-191°C]	24-30	21-42	
Distillate [191-327°C]	17-31	19-45	
Gas Oil [327-566°C]	26-38	20-42	
Residuum [>566°C]	10-19	14 max.	
Light Ends [Vol. %] [d], max			
Methane (C_1)	0.01	0.01	D7900 or ITM 6008
Ethane (C_2)	0.1	0.1	
Propane (C_3)	1.0	1.0	

[ε1] This revision includes a limitation on light ends content (see Footnote [d]); a change to vapor pressure characteristic, limits and primary ASTM method (see Footnote [e])

[a] Marketable crude petroleum suitable for normal refinery processing and free of foreign contaminants or chemicals including, but not limited to, pour point depressants, chlorinated and oxygenated hydrocarbons, and lead.

[b] Alternate methods may be used if approved by the contracting officer.

[c] Merged data may be provided in requesting conditional acceptance of a Crude Oil via D7169 Appendix Section X1 Algorithm for Merging Boiling Point Distribution Results of D7900 and D7169. Distillation data according to D 2892 and D 5236 will still be necessary for final qualification of a Crude Oil's acceptance.

[d] Light ends content specifications are interim and will be superseded as industry standards for light ends evaluation are implemented.

e Vapor pressure changed to better reflect current domestic crude standards.

NOTE 1: The Strategic Petroleum Reserve reserves the right to refuse to accept any Crude Oil which meets these specifications but is deemed to be incompatible with existing stocks, or which has the potential for adversely affecting handling.

NOTE 2: The acceptability of any Crude Oil depends upon any assay typical of current production quality of the stream. Any Crude Oil offered to the Strategic Petroleum Reserve that meets these specifications may be subject to additional testing for acceptance.

NOTE 3: All Crude Oil shipments received by the SPR are tested to ensure they meet specifications.

Table II. TYPICAL SPR CAVERN SAMPLE INSPECTION ANALYSIS

Date Started 8/18/2021 Sample ID BMXYZi2021 Date Reported 8/30/2021

Sample Log No.	Bottle Label Date Collected	Depth (ft.)	Relative Density D 5002 at 60/60 F	Gravity °API	Pour Pt. D 97 °C	Nitrogen D5762 (Mass %)	Sulfur D4294 (Mass %)	Viscosity, cSt D445 at 77˚ F	Viscosity, cSt D445 at 100˚ F	Water D 4928 (Mass %)	Acid No. D 664 mg KOH/g	H2S UOP163 ppm Liquid	H2S D5705M ppmVapor
XYZ108i2021	EX210508-001 8-11-21	2459	0.8533	34.3	25	0.10	0.42	8.189	5.556	0.02	0.27	--	--
XYZ108i2021	EX210508-002 8-11-21	2793	0.8533	34.3	25	0.10	0.41	8.148	5.599	0.02	0.30	--	--
XYZ108i2021	EX210508-003 8-11-21	3128	0.8532	34.3	20	0.10	0.43	8.083	5.551	0.02	0.26	--	--
XYZ108i2021	EX210508-004 8-11-21	3462	0.8533	34.3	30	0.10	0.42	7.991	5.581	0.02	0.27	--	--
XYZ108i2021	EX210508-005 8-11-21	3796	0.8532	34.3	25	0.10	0.41	8.103	5.653	0.02	0.26	--	--
XYZ108i2021	EX210508-006 8-11-21	4130	0.8533	34.3	30	0.10	0.43	8.154	5.530	0.02	0.20	--	--
XYZ108i2021	EX210508-007 8-11-21	4175	0.8533	34.3	15	0.10	0.44	8.172	5.572	0.0	1.69	--	--
XYZ108i2021	EX210508-008 8-11-21	4179	0.8533	34.3	20	0.10	0.42	8.166	5.587	0.0	0.67	--	--
XYZ108i2021	EX210508-009 8-11-21	4182	0.8532	**34.30**	20	0.10	0.420	**Sludge**	--	0.02		--	--
XYZ108i2021	EX210508-010 8-11-21	4185	--	--	--	--	--	**Brine**	--	20		--	--

Data presented in chart is for informational purposes and not representative of any current cavern analysis.

Table III. SPR Crude Oil Comprehensive Assay Grid

Property	ASTM Representative Test Methods	Whole Crude	C_2-C_4 Gases	C_5-175°F Light Naphtha	175°-250°F Medium Naphtha	250375°F Heavy Naphtha	375-530°F Kerosine	530-650°F Distillate Fuel Oil	650850°F Light VGO	8501050°F Heavy VGO	650°F + Atmospheric Residuum	1050°F + Vacuum Residuum
Volume and mass % yields	D2892 & D5236		X	X	X	X	X	X	X	X	X	X
°API, density, specific gravity	D5002	X		X	X	X	X	X	X	X	X	X
Sulfur, total, mass %	D4294	X		X	X	X	X	X	X	X	X	X
Sediment, mass %	D473	X										
Water, volume %	D4928	X										
Salt, mass %	D6470	X										
Nitrogen, total, mass %	D5762	X					X	X	X	X	X	X
Micro. carbon residue, mass %	D4530	X							X	X	X	X
Pour Point	D5853	X					X	X	X	X	X	
Metals: Ni, V, Fe, Cu	D5708	X								X	X	X
Organic chlorides, total, ppm	D4929	X		X	X	X	X					
UOP "K" factor	UOP 375	X					X	X	X	X		X
Vapor Pressure, kPa@37.8°C	D323 or D6377	X										
Acid number, mg KOH/g	D664	X					X	X	X	X	X	X
H_2S and mercaptans, ppm	UOP 163	X		X	X	X	X					
Paraffins, Isoparaffins, Aromatics, Naphthenes (PIAN)	D5134 modified	B-T-E-X	X	X	X	X						

Viscosity, cSt, @ 77°F 100°F 130°F 180°F 210°F	**D445**	**X**					**X**					
		X					**X**	**X**				
								X	**X**	**X**	**X**	
									X	**X**	**X**	**X**
												X
High temp. simulated distillation	**D7169**	**X**										
Hydrogen and carbon, mass %	**D5291**					**X**	**X**	**X**	**X**	**X**	**X**	**X**
Refractive Index @ 60°C	**D1218**					**X**	**X**	**X**	**X**	**X**	**X**	**X**
Research and Motor Octane Numbers	**D2699 & D2700**								**X**	**X**		
Asphaltenes, mass %	**D 6560**			**X**	**X**	**X**						
Wax, mass %	**UOP-46**	**X**									**X**	**X**
Aniline Point	**D611**	**X**							**X**	**X**		
Cetane Index	**D976**					**X**	**X**	**X**	**X**	**X**		
Naphthalenes, volume %	**D1840**						**X**	**X**	**X**			
Aromatics, volume %	**D1319**					**X**	**X**	**X**				
Smoke Point, mm	**D1322**						**X**					
Freezing Point	**D2386**					**X**	**X**	**X**				
Freezing Point	**D5773**						**X**					
Cloud Point	**D2500**						**X**	**X**	**X**	**X**		

APPENDICES A - B

Appendix A. Approximate Crude Oil Composition of SPR Streams[1,2] (June 2024)

Bayou Choctaw Sweet

Crude Oil	Volume %
Girassol	17.5
HLS	16
LLS	14.5
Ninian	12
Es Sider	8
Brent & SLS	6 each
Cusiana and Forties	4 each
Kole, Oseberg, Qua Iboe, Sirtica, Bakken, & Zarzaitine	2 each

Bayou Choctaw Sour

Crude Oil	Volume %
Isthmus	35
Iranian Light	23
Alaskan North Slope	13
Maya	7
Arabian Light, Dubai, Gulf of Suez Blend, & Mars	4 each
Mandji, Mesa 30, Oman, & Upper Zakum	1.5 each
Thunderhorse & EIC	<1 each

Big Hill Sweet

Crude Oil	Volume %
Brent	28.5
Girassol, NPR CA Stevens Zone, & Zafiro	13 each
Oseberg	9
Es Sider, Kole, & Santa Barbara (Venezuela)	5.5 each
Forties	3.5
Azeri Light & Saharan	1.5 each

Big Hill Sour

Crude Oil	Volume %*
SGC & WTI Blend	28
Isthmus	11
SGC & Bakken Blend	9
Alaskan North Slope & Urals	7 each
SGC & Oklahoma Sour Blend	6
SGC & Eagle Ford Blend	4
SGC & Bakken & WTS Blend	5
SGC	4
Arabian Light, Lagotreco, Mars, & Mesa 30	2 each
SGC & Saddlehorn Blend	1.5
LSB	1.5
Dubai, Iranian Light, & Oman	1.5 each
Gulf of Suez Blend, Lagomedio, Mandji, & Maya	<1 each

*Volume percentages will adjust as additional crude is received through exchange returns and purchases.

Bryan Mound Sweet

Crude Oil	Volume %
Forties	34
Ninian	15
Brent and Es Sider	12.5 each
Domestic Sweet (DSW)	6
Bonny Light, Forcados, & Sirtica	4 each
Kole and Saharan	2 each
Santa Barbara (Venezuela), & Zafiro, Girassol, & Azeri Light	1 each

Bryan Mound Sour

Crude Oil	Volume %
Ishtmus	70
Urals	6.5
Oman	5.5
Arabian Light, Dubai, & Olmeca	4.5 each
HOOPS Blend	2.5
Forties	< 1

West Hackberry Sweet

Crude Oil	Volume %
Brent and Forties	20.5 each
Ninian	11
Saharan Blend, SLS, East Texas	8 each
Kole	6
Girassol	5
Bonny Light, Ekofisk, Es Sider, & Escravos	3 each
HLS	<1

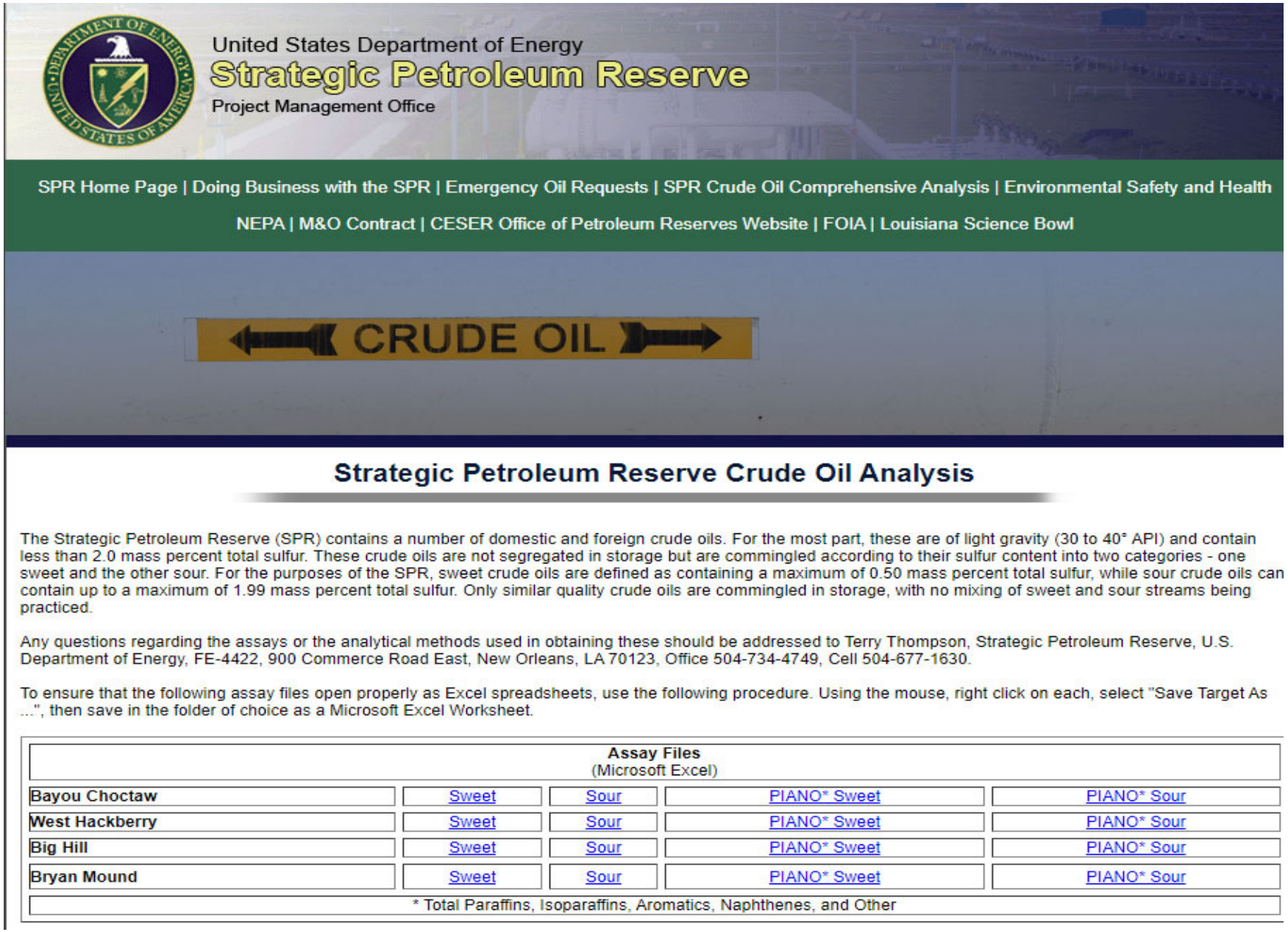
West Hackberry Sour

Crude Oil	Volume %
Isthmus	59
Mars	18
Arabian Light	9
Dubai	5
Iranian Light, & Oman	4 each
URALS	1

[1]Crude oils have unique chemical and molecular properties. A variety of physical and chemical factors such as geographical location, extraction techniques and blending can influence the quality characteristics of a given crude received by the SPR.

[2]Small quantities of crude oils other than those listed totaling less than 1 – 3% of overall volume may be present in a given stream. These, and rounding errors, may result to columns not adding to 100%.

Appendix B. SPR Crude Oil Assays



*Screenshot of Assay landing page

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