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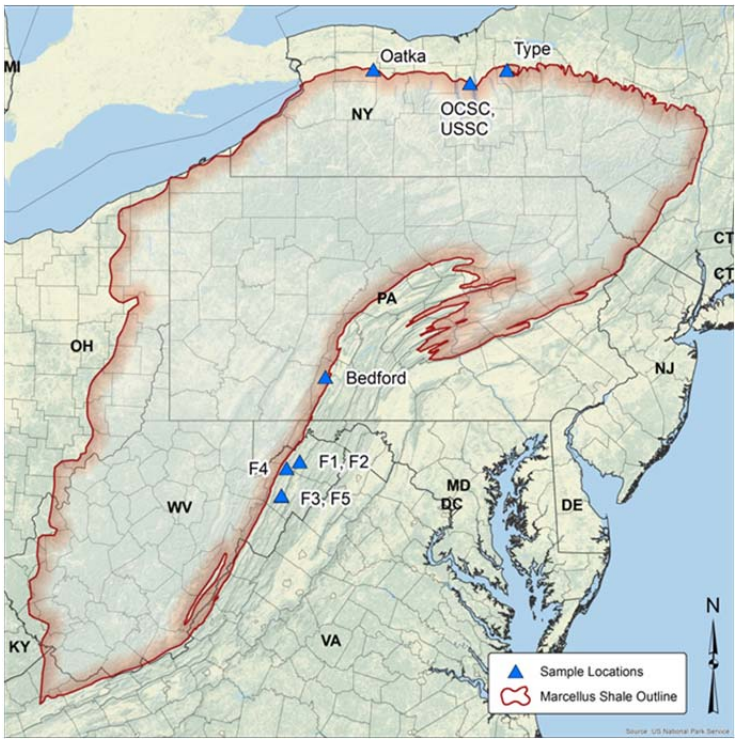

Experimental Characterization of Marcellus Shale Outcrop Samples, and their Interactions with Carbon Dioxide and Methane

6 February 2015

U.S. DEPARTMENT OF ENERGY

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Cover Illustration: Location map showing the sampling locations for the Industrial Carbon Management Initiative (ICMI) experimental characterization study.

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Experimental Characterization of Marcellus Shale Outcrop Samples, and their Interactions with Carbon Dioxide and Methane

Robert Dilmore[1], Kathy Bruner[2], Christopher Wyatt[3], Vyacheslav Romanov[1], Angela Goodman[1], Sheila Hedges[1], Dustin McIntyre[4], Dustin Crandall[4], Magdalena Gill[2], Corinne Disenhof [5], Jinesh Jain[6], Christina Lopano[1], Khashayar Aminian[7], Mehrdad Zamirian[7], Atoosa Mashayekhi[7], Sean Sanguinito[8], Thomas Mroz[4], Daniel Soeder[4]

[1] U.S. Department of Energy, Office of Research and Development, National Energy Technology Laboratory, 626 Cochrans Mill Road, Pittsburgh, PA 15236

[2] U.S. Department of Energy, National Energy Technology Laboratory, URS, 3610 Collins Ferry Road, Morgantown, WV 26507

[3] U.S. Department of Energy, National Energy Technology Laboratory, Sextant Technical Services, 3610 Collins Ferry Road, Morgantown, WV 26507

[4] U.S. Department of Energy, Office of Research and Development, National Energy Technology Laboratory, 3610 Collins Ferry Road, Morgantown, WV 26507

[5] U.S. Department of Energy, National Energy Technology Laboratory, URS, 1450 Queen Ave SW, Albany, OR 97321

[6] U.S. Department of Energy, National Energy Technology Laboratory, URS, 626 Cochrans Mill Road, Pittsburgh, PA 15236

[7] West Virginia University, Petroleum and Natural Gas Engineering, Benjamin M. Statler College of Engineering and Mineral Resources, Morgantown, WV 26506

[8] Oak Ridge Institute for Science and Education, 1299 Bethel Valley Road, Building SC-200, Oak Ridge, TN 37830

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NETL Contacts:

Robert Dilmore, Technical Coordinator

George Richards, ICMI Technology Director

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Acronyms, Abbreviations, and Symbols

Term	Description
AI	Artificial intelligence
ARRA	American Recovery and Reinvestment Act of 2009
ATR	Attenuated total reflectance
BET	Brunauer–Emmett–Teller method
BJH	Barrett-Joyner-Halenda analysis
CH_4	Methane
CO_2	Carbon dioxide
CT	Computed tomography
DOE	Department of Energy
EGR	Enhanced gas recovery
FTIR	Fourier transform infrared spectroscopy
GC	Gas Chromatograph
GIS	Geographic information systems
ICMI	Industrial Carbon Management Initiative
ICP-AES	Inductively coupled plasma atomic emission spectrometer
nd	Nanodarcy (nanodarcies)
NETL	National Energy Technology Laboratory
ORD	Office of Research and Development
PI	Principal investigators
PPAL	Precision Petrophysical Analysis Laboratory
Penn State or PSU	Pennsylvania State University
SRM	Surrogate reservoir models
TC	Total carbon
TIC	Total inorganic carbon
TOC	Total organic carbon
XRD	X-ray diffraction
WVU	West Virginia University
ZnSe	Zinc selenide

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EXECUTIVE SUMMARY

Organic-rich shale formations that have been depleted of hydrocarbon through a period of primary production have been proposed as candidates for geologic storage of carbon dioxide (CO_2) and beneficial utilization of CO_2 for enhanced hydrocarbon recovery (Nuttall, 2005). To evaluate the potential of such CO_2 utilization and storage scenarios, investigators working at the National Energy Technology Laboratory (NETL) and partner universities are conducting research through the Industrial Carbon Management Initiative (ICMI), funded by the American Recovery and Reinvestment Act of 2009 (ARRA). The research focuses on developing insights into important attributes of depleted organic shale reservoirs through experimental characterization, simulation of formation performance under CO_2 storage and enhanced gas recovery (EGR) scenarios, and a techno-economic assessment.

This report provides a detailed description of results of experimental work completed to date and a preliminary discussion of findings and insights. It fulfills a milestone requirement for the ICMI Carbon Storage in Depleted Shale task to report findings of initial experimental assessment of shale gas formation storage.

The set of analyses and experiments being performed are intended to improve the science base with respect to important shale matrix properties that may influence CO_2/shale interaction, measure CO_2 and CO_4 adsorptive capacity on shales to understand storage and EGR potential, and improve understanding of effective permeability/porosity in shales. Samples taken from ten outcrops of the Middle Devonian Marcellus shale formation have been designated as the base sample set for the ICMI and are thought to be representative of the range of rock properties across the Marcellus interval including, but not limited to, the organic- rich “main pay” interval that is a subset. Analyses performed to date include fourier transform infrared spectroscopy (FTIR), shale digestion/total metals analysis, semi-quantitative X-ray diffraction (XRD) mineralogical analysis, total organic and inorganic carbon analysis (TOC and TIC), high-resolution computed tomography (CT) imaging of shale cores/plugs, optical petrography, and petrophysical analysis of matrix effective porosity/permeability. It is intended that findings of this work will be applied to refine reservoir simulation of CO_2 storage in and EGR from shale and improve confidence in techno-economic screening that are also being developed in this ICMI task.

1. CARBON STORAGE IN DEPLETED SHALE

Organic shale formations are unique in the production of natural gas because the shale serves not only as the source for the gas, but also forms the reservoir. Natural gas formed by thermal maturation of organic matter in the shale is held in the shale reservoir as free gas in natural fractures and pore spaces, as adsorbed gas onto the surface of shale particles and organic matter, and as absorbed gas within the shale matrix. The shale reservoir rock has very low permeability; therefore, migration of the gas into conventional reservoirs does not occur. During well production, the free gas is released first very rapidly for a short period; adsorbed and absorbed gas is released more slowly producing steady small amounts of gas for decades.

Since the 1970s, the key to producing natural gas from shale has been fracture stimulation—fracturing the shale to provide open passages through which released gas will more easily move. Technological advances in drilling fluids and completion techniques, in particular, directional/horizontal drilling and hydraulic fracturing over the past 10 years, have allowed exceptionally rapid economic development of shale gas resources throughout the nation.

The Department of Energy (DOE) is looking beyond current production to the future when developed shale reservoirs are approaching depletion. The depleted reservoirs may be able to serve as storage reservoirs for carbon dioxide (CO_2) with the added benefit of enhanced gas, liquids, and condensate production as the CO_2 is injected. The Industrial Carbon Management Initiative (ICMI) was established as one initiative for accelerating the commercialization of carbon capture and storage technologies from the research phase to commercial development by industrial producers of CO_2, and is funded by the American Recovery and Reinvestment Act of 2009 (ARRA). The potential for CO_2 storage in, and enhanced gas recovery (EGR) from shale gas formations that have been depleted or partially depleted of natural gas through primary production is one part of the initiative. DOE's National Energy Technology Laboratory (NETL) and partner universities are collaborating on this funded project to develop technologies and simulation tools for carbon capture and storage from industrial sources.

Industrial carbon storage in depleted shale is considered to have two attractive features: an established network of fractured geology with an existing infrastructure (well fields) that could be adapted to CO_2 gas injection; and the potential to use injected CO_2 to enhance production of remaining gas, liquids, and condensate through mechanisms similar to those used in enhanced coalbed methane (CH_4) production. This could offset the cost of CO_2 disposal.

The initiative is focused on three areas of research:

1. Experimental–Laboratory analyses and experiments to discover and document key geological and reservoir parameters in shale, with particular interest in reactions to CO_2 exposure. Samples of the Lower Devonian Marcellus shale from the Appalachian outcrop belt are being used for analyses.
2. Modeling–The experimental results, broadly in the category of mass of CO_2 retained versus mass of fractured shale, will be entered into well field simulators that consider permeability and other factors to arrive at potential injection rates and final CO_2 capacity from single or multiple well systems.

3. Economic assessment–Typical CO_2 injection well field arrays deemed necessary by the simulators will be placed into a larger cost model that compares the depleted shale option to other subsurface storage options, such as saline aquifers.

1.1 EXPERIMENTAL CHARACTERIZATION

The primary objective is to characterize CO_2/shale interactions to help evaluate the potential for management of CO_2 from industrial sources. Associated with this research is the additional opportunity for exploring the potential for enhanced gas recovery (EGR). Results from the experimental (and analytical) characterization will be used to refine simulation of reservoir performance, which will then be used in assessing the economic viability of these CO_2 utilization and geologic storage options.

Scientific evidence suggests that CO_2 adsorbs more strongly than CH_4 to shale, and CO_2 adsorption is higher on shales than it is on coal (Chareonsuppanimit et al., 2012). Therefore, while storing the CO_2, it may be possible to sweep shale reservoirs with CO_2 to displace CH_4 from adsorption sites, to enhance natural gas production. In addition, emplacement of CO_2 may improve permeability by re-opening fractures that had closed as a result of removing the gas during shale gas production. Removal of gas from the pore system increases effective stress on voids in the rock resulting in reduced porosity and permeability; the larger CO_2 molecule may be able to reverse some of the effect.

The experimental characterization team consists of researchers from the NETL Office of Research and Development (NETL-ORD), URS, partner universities, and contractors. Experimental areas, team roles, and facilities are summarized in Table 1. The experimental plan, including types and number of tests, is summarized in Figures 1 and 2 for powdered shale samples and shale core/plug samples, respectively.

Table 1: ICMI Storage in Shale Experimental Team and Facilities

Researcher Entity	Role	Testing Method	Facilities
NETL-ORD	Geochemical and adsorptive properties of various shale lithotypes to CH_4 and CO_2 powdered samples	FTIR	**Carbon Storage Laboratory** Volumetric, gravimetric, and infrared characterization of CO_2 adsorption on coal, clay, shale, other sedimentary rocks
NETL-ORD	Geochemical and adsorptive properties of various shale lithotypes to CH_4 and CO_2 core samples	CO_2 adsorption isotherms	**Weatherford (contracted laboratory)**
NETL-ORD	Optical petrographic and CT scan evaluations of pores and flowpaths	CT scans	**Industrial Computed Tomography (CT) Scanner** X-ray CT scanner capable of 5 micron resolution
WVU Petroleum Engineering	Petrophysical properties of various shale lithotypes in the laboratory with N_2, CH_4, and CO_2 under representative net stress conditions. Investigate hysteresis in shale gas permeability from stress cycling	Core testing	**Precision Petrophysical Analysis Laboratory (PPAL)** Determine porosity, permeability, and effects of net stress under representative pressures
URS & NETL-ORD	Shale chemistry, bulk shale, elemental analysis and detailed clay mineralogy	XRD	**Albany XRD, URS-NETL Pittsburgh, and Micromeritics (contracted laboratory)**

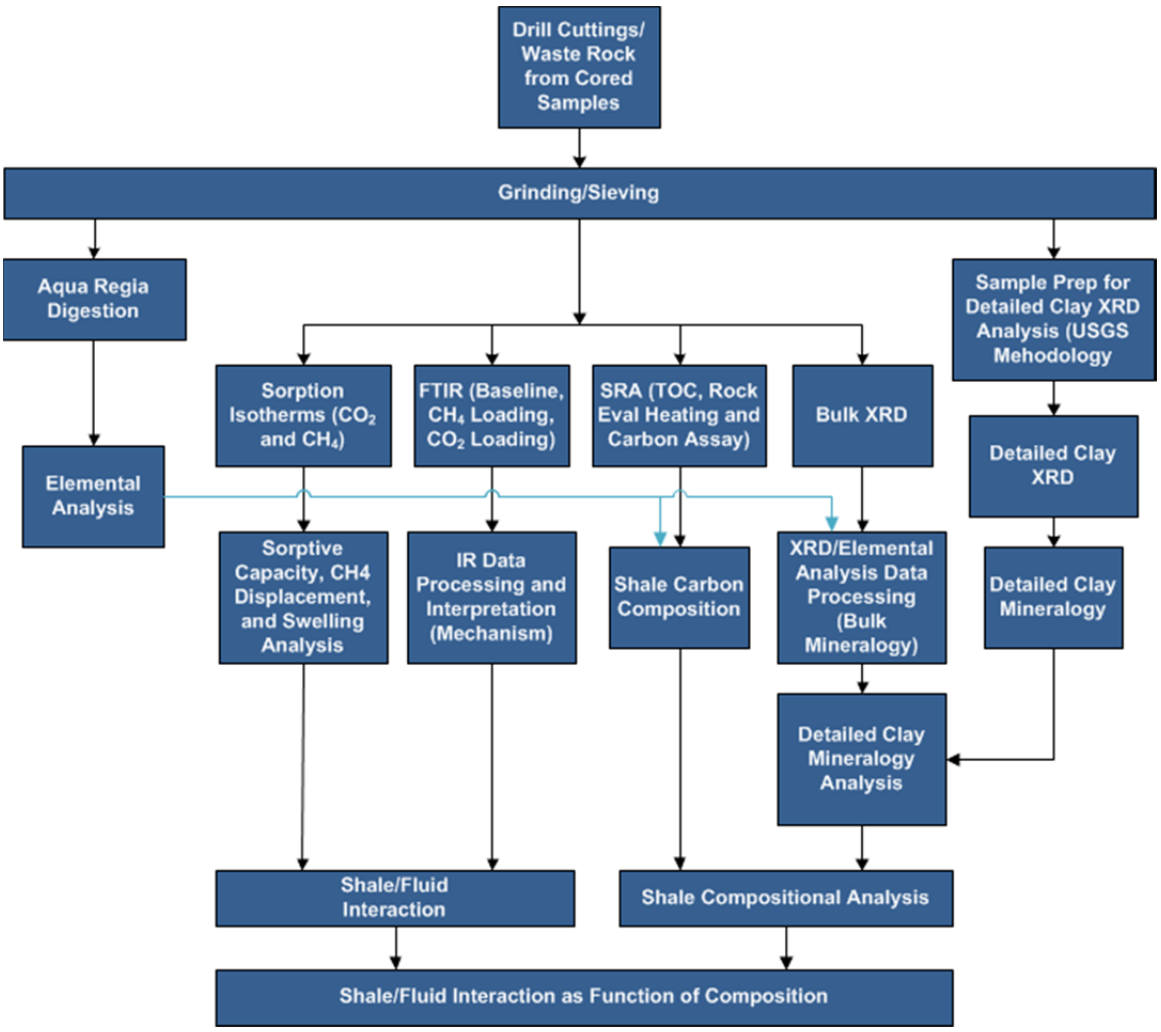

Figure 1: Experimental plan: powder samples.

The laboratory experiments and analyses are designed to characterize key physical and chemical properties of organic-rich shales, with emphasis on determining permeability in shale, documenting retention and permanence of CO_2 in shale matrix, and improving understanding of mechanisms of CH_4 displacement and CO_2 adsorption. Results will be used to explain what occurs when CO_2 passes through the sample, to determine the amount of CO_2 the shale can retain, and how permanent is the retention.

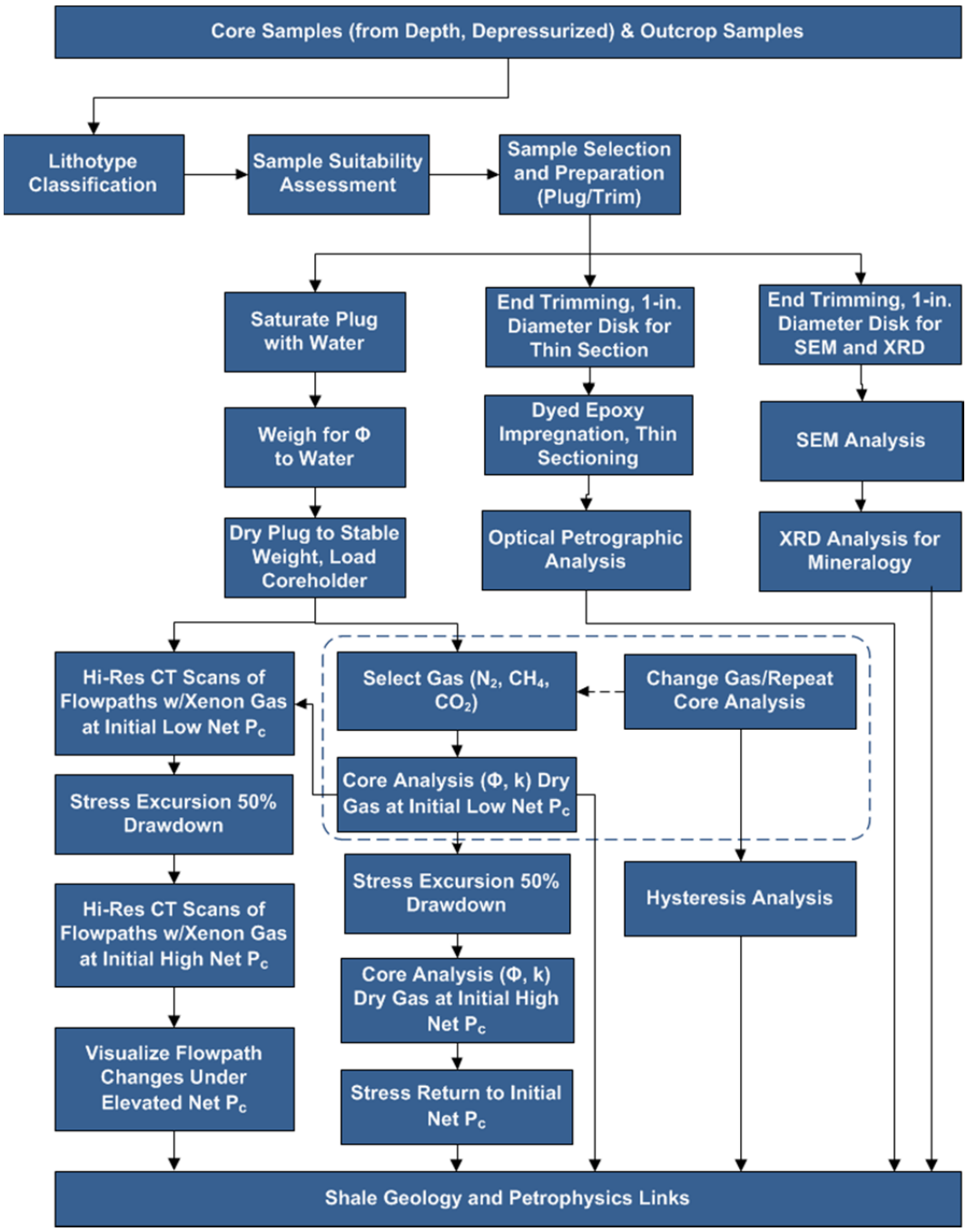

Figure 2: Experimental plan: intact core plugs.

The laboratory experiments will characterize key physical/chemical properties of organic rich shales (X-Ray diffraction [XRD], total organic carbon [TOC]); as well as CO_2 storage capacity of shales, via description of the effective porosity and permeability to CO_2 as a function of confining stress, and a preliminary assessment of potential for CO_2 EGR. This characterization will then be used to explain what occurs during experiments that pass CO_2 through fractured and depleted shale samples to determine the amount of CO_2 the shale can retain, the permanence of the retention, and the mechanisms and locations within the structure, and components of the shale where displacement (filling) and adsorption occur.

2. EXPERIMENTAL/CHARACTERIZATION PROGRESS: POWDERED SAMPLES

2.1 SAMPLE COLLECTION

Samples were collected from seven geographic locations in West Virginia, Virginia, Pennsylvania, and New York with surface exposures of the Middle Devonian Marcellus shale (Table 2). Figure 3 is a map of the Appalachian Basin showing sample locations. The samples were divided into three parts for powder analyses, physical tests, and core tests. Powdered analyses included XRD, fourier transform infrared spectroscopy (FTIR), elemental analyses of metals, TOC and total inorganic carbon (TIC) percent, and adsorption isotherms for CO_2 and CH_4. Physical tests consisted of grain density, bulk density, porosity, pore size distribution, and micropore surface area.

Table 2: Shale Samples for Testing

Sample Suffix	Sample ID (Lat:Long:Suffix)	Formation	Type	Geographic Location
F5	390011790800F5	Marcellus	Bulk	Petersburg, WV
F3	390041790754F3	Marcellus	Bulk	Petersburg, WV
F4	391610790358F4	Marcellus	Bulk	Whip Gap, WV
F1	392005785407F1	Marcellus	Bulk	Burlington, WV
F2	392005785407F2	Marcellus	Bulk	Burlington, WV
Bedford	400817783501BD	Marcellus	Bulk	Bedford, PA
OCSC	425120764726OC	Oatka Crk	Bulk	Canoga, NY
USSC	425120764726US	Union Spr	Bulk	Canoga, NY
Type	425828762002TS	Marcellus	Bulk	Marcellus, NY
Oatka	425843775918OC	Oatka Crk	Bulk	Le Roy, NY

Figure 3: ICMI sample locations map for testing.

Table 3 is a list of all samples and identifies the various experimental and analytical tests performed on each sample. The table is organized by sample location (1–10), lithology, sample suffix from Table 2 (latitude, longitude, suffix), experimental and analytical tests, and geographic location. The sample suffix is used for sample identification in the remainder of this document. An expanded table showing sample subsets and specific tests performed is included in Appendix A.

Table 3: Study Samples and Analyses

			Powdered Samples							Intact Cores and Plugs		
Sample Location Number	Litology/Source	Sample Suffix	X-ray Diffraction	Fourier Transform Infrared Spectroscopy (FTIR)	Elemental Analysis of Metals	Organic/Inorganic Carbon	Sorption Capacity/Isotherms for CO_2	Physical Testing [1]	Petrophysical Analysis (Porosity and Permeability)	Petrography	X-ray Computed Tomography (CT)	Geographic Location
1	**WV facies 5; silty gray shale**	**F5** *Subsamples F5HA and F5HB*	√	√	√	√	√	√	√	√	√	Petersburg, WV
2	**WV facies 3: calcareous black shale**	**F3**	√	√	√	√	√	√		√	√	Petersburg, WV
3	**WV facies 4: non-calc black shale**	**F4**	√	√	√	√	√	√		√	√	Whip Gap, WV
4	**WV facies 1: calc gray shale**	**F1**	√	√	√	√	√	√		√	√	Burlington, WV
5	**WV facies 2: shaly limestone**	**F2** *Subsamples F2HA and F2HB*	√	√	√	√	√	√	√	√	√	Burlington, WV
6	**F4 slab oriented plugs, WV facies 4: non-calc black shale**	**Bedford** *Subsamples F4HA, F4HB, F4V3, and F4V4*	√	√	√	√	√	√	√	√		Bedford, PA
7	**Oatka Creek member basal black shale, gray shale above**	**OCSC** *Subsample OS*	√	√	√	√	√	√		√		Canoga, NY
8	**Union Springs member black shale**	**USSC** *Subsample US*	√	√	√	√	√	√		√		Canoga, NY
9	**Black shale**	**Type** *Subsamples OCNY and TS*	√	√	√	√	√	√		√	√	Marcellus, NY
10	**Oatka Creek member basal black shale, gray shale above**	**Oatka** *Subsample OC*	√	√	√	√	√	√		√		Le Roy, NY

[1] ***Physical Testing suite includes: grain dessity, bulk density, porosity, pore size distribution, and micropore surface area.***

2.2 BULK AND DETAILED CLAY XRD

Shale samples were characterized for essential mineral content and elemental composition through XRD analyses, an analytical technique used to identify crystalline material. The characteristic atomic structure of a given crystalline material diffracts an X-ray beam into a unique pattern that is recorded by the instrument. By matching the diffraction pattern of an unknown material to a database of patterns generated by known materials, the crystalline components can be identified.

Samples were crushed and separated into two groups—one for bulk analyses and the second for clay analyses (Figure 4).

Figure 4: Bulk shale and powdered shale (after grinding).

The fraction for bulk analysis was ground to powder using a Spex SamplePrep Shatterbox swing mill for 15 s in a tungsten carbide container. The powders were analyzed in aluminum sample holders on a Rigaku Ultima-III X-ray diffractometer using Cu K-alpha radiation from 3 to 90°two-theta (2θ). Mineral identification was performed using JADE 9 software and the International Centre for Diffraction Data PDF4+ database. Weight percent estimates were obtained using JADE 9.3's Whole Pattern Fitting software. Due to the nature of the analysis, the weight percentages reported are semi-quantitative.

Table 4 shows the results for the bulk XRD analyses. Quartz ranges from 17 to 88%. Clays, primarily illite with some chlorite, range from 12–36% in eight of the samples. Two samples, identified as non-calcareous black shale (Bedford) and shaly limestone (F2), are composed of less than 10% clays. Calcite ranges from 3% (F5 silty shale) to 74% in the shaly limestone (F2).

Table 4: X-Ray Diffraction Results for ICMI Shale Bulk Powder Samples

		Semi-Quantitative Weight Percent [1]							
Sample Suffix	Description & Location	Quartz SiO_2	Calcite $CaCO_3$	Illite/ Muscovite $KAl_2(AlSi_2O_{10})(OH)_2$	Chlorite $(Mg,Al,Fe)_6(Si,Al)_4O_{10}(OH)_8$	Pyrite FeS_2	Dolomite $CaMg(CO_3)_2$	Smectite $Ca(Al,Mg)_2Si_3O_{10}(OH)_2 \cdot H_2O$	Other Phases
F5 [2]	F5 Marcellus Shale, WV facies 5: silty gray shale, bulk outcrop sample, Petersburg (west), WV	52	3	26	12	1	7		
F3 [2]	F3 Marcellus Shale, WV facies 3: calcareous black shale, bulk outcrop sample, Petersburg (north), WV	35	37	16	6		6		Gypsum (in clay fraction) - $CaSO_4 \cdot 2H_2O$
F4	F4 Marcellus Shale, WV facies 4: non-calcareous black shale, bulk outcrop sample, Whip Gap, WV	88		12					Possible unidentified trace
F1 [2]	F1 Marcellus Shale WV facies 1: calcareous gray shale, bulk outcrop sample, Burlington, WV	44	14	32	10				Possible unidentified mixed-layer clay
F2	F2 Marcellus Shale, WV facies 2: shaly limestone, Burlington, WV; bulk outcrop sample (slab) from which oriented plugs were cut	17	74	6					Barite $(Ba(SO_4))_3$
Bedford	Bedford Marcellus Shale, WV facies 4: silica-rich, non-calcareous black shale from Bedford, PA; bulk outcrop sample (slab) from which oriented plugs were cut	74	16	7		1	3		
OCSC	OCSC Oatka Creek Member of Marcellus Shale; bulk outcrop sample from fresh exposure in Seneca Quarry, Canoga, NY	26	51	14		4	4		
USSC	USSC Union Springs Member of Marcellus Shale; bulk outcrop sample from fresh exposure in Seneca Quarry, Canoga, NY	35	32	27	5	2			
Type [2]	Type Marcellus Shale type section, Marcellus, NY; bulk outcrop sample	49	4	35	7	6			
Oatka	Oatka Oatka Creek Member of Marcellus Shale from type locality in Oatka Creek, Le Roy, NY; bulk outcrop sample (hydrocarbon odor on fresh surfaces)	49	6	36	3	7			

Notes on analyses:

[1] Weight percent estimates were obtained using MDI Jade 9.3's Whole Pattern Fitting program. Numbers are estimates only and error is not known.

[2] Ethylene glycol treatment was performed on these samples to differentiate chlorite and illite from possible similar-structured swelling clays (including smectite). No evidence of swelling clay was found, except where noted in F1.

Chemical analyses are needed to determine precise chemistries of the phases present in the samples. Chemistries may vary from the listed general formula.

Clay Identification

Many clay minerals have similar structures, making them difficult to differentiate by bulk XRD analysis. Samples were prepared following preparation techniques outlined by Poppe et al. (2001) in order to distinguish the clay minerals from each other by expanding, collapsing, or destroying the atomic structure. Exposure to ethylene glycol expands the structure of any swelling clays and changes the measured diffraction pattern.

Four samples (F1, F5, F3, and Type) were chosen as being representative of compositional variability in collected samples for identification of clay minerals. The initial splits of crushed rock were ground to powder using a mortar and pestle to avoid potential destruction of clays. The powders were then separated via gravity settling to obtain a sample with particles less than 5 microns. The resulting clay slurries were dried on glass slides in a low-temperature oven (~50°C) and allowed to cool. XRD scans were conducted after drying. Clay slides were analyzed from 3 to 30° 2θ on the same instrument as the bulk samples. After the first analysis, each slide was saturated with ethylene glycol by exposure to vapor for at least 16 hrs. A second XRD analysis with the same instrument settings was performed immediately after removal from the ethylene glycol.

Table 4 also shows the results of clay analyses. Ethylene glycol tests confirmed no smectite-group clays are identifiable in the samples. Illite and chlorite are the dominant clays. Illite ranges from 6 to 36%, and chlorite ranges 3 to 12%. Glycolation caused a shift in several peaks in F1 that may indicate mixed-layer clay, although further analysis is needed to confirm this.

2.3 FOURIER TRANSFORM INFRARED SPECTROSCOPY (FTIR)

Infrared spectroscopy deals with longer wavelength and lower frequency than visible light. The infrared part of the electromagnetic spectrum covers the range from roughly 300 GHz (1 mm) to 400 THz (750 nm). Infrared light is absorbed by molecular vibrations in areas where the different atoms in a molecule vibrate around their equilibrium positions. FTIR was utilized to probe the interaction of CO_2 and CH_4 with powdered samples of organic-rich Marcellus shale.

FTIR experiments were conducted using two attenuated total reflectance (ATR) cells from Spectra Tech (Figure 5). Two stainless steel cells were connected in tandem via 0.16 cm stainless steel tubing so that each cell experienced the same pressure. The cells can accommodate pressures up to 136 atm. A cylindrical zinc selenide (ZnSe) ATR crystal was placed inside of each cell. The length of the ATR crystal was 2.8 cm, the diameter of the ATR crystal was 0.6 cm, the incidence angle is 45° and the number of reflections was eleven.

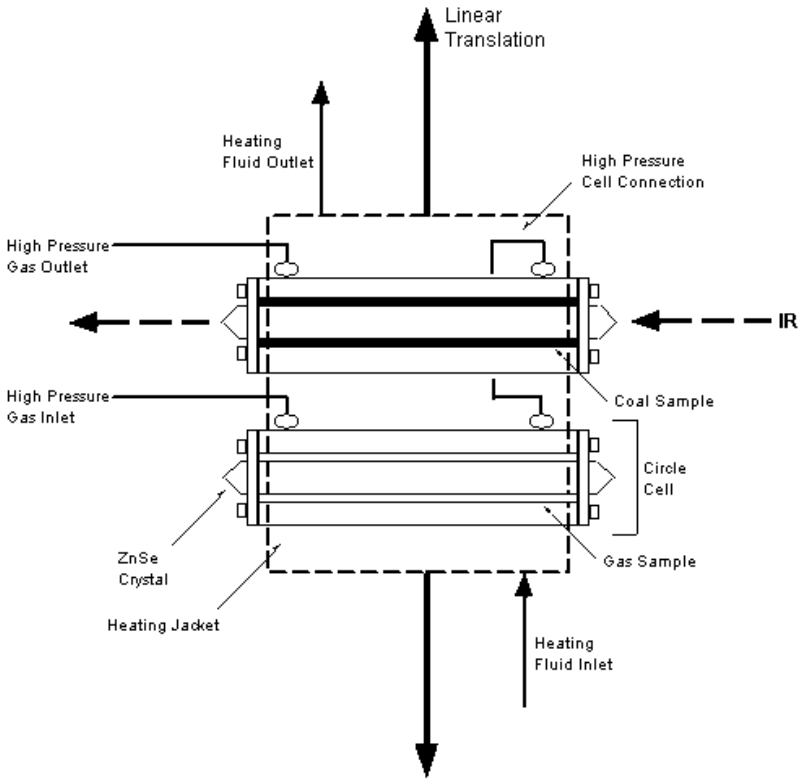

Figure 5: Schematic of the modified ATR-FTIR cell assembly.

Analyses were performed on six of the ten samples outlined in Table 2. Samples F5, F4, and Type were taken from the Marcellus formation in Petersburg, WV; Whip Gap, WV; and Marcellus, NY respectively. XRD analyses indicate their primary mineral content is quartz with illite/muscovite as secondary components. XRD analyses for sample F2, taken from the Marcellus formation in Burlington, WV, and sample OCSC, part of the Oatka Creek Member taken in Conoga, NY, indicate a primary mineral content of calcite with quartz as a minor constituent. Sample Oatka was collected from the Oatka Creek Member of the Marcellus shale in Le Roy, NY. Its XRD analysis shows quartz as the primary mineral constituent followed by illite/muscovite.

One cell contained a ZnSe ATR crystal with no sample present and the other cell contained a ZnSe ATR crystal coated with a shale sample. Both cells were exposed to CH_4 and/or CO_2 as a function of increasing pressure from 0 to ~10 MPa. Two spectra were recorded: one from the cell containing either CH_4 or CO_2 and the sample, and one from the cell containing CH_4 or CO_2. By calculating the difference between the two spectra, an absorption spectrum of CH_4 or CO_2 adsorbed on the sample was obtained.

Infrared spectra were first collected of the shale samples prior to introduction of CH_4 or CO_2. Figure 6 shows this initial spectra as well as a spectra collected at a high CO_2 pressure. The significant peak difference seen around wavelength 2,349 cm^{-1} represents adsorbed CO_2 onto the shale samples.

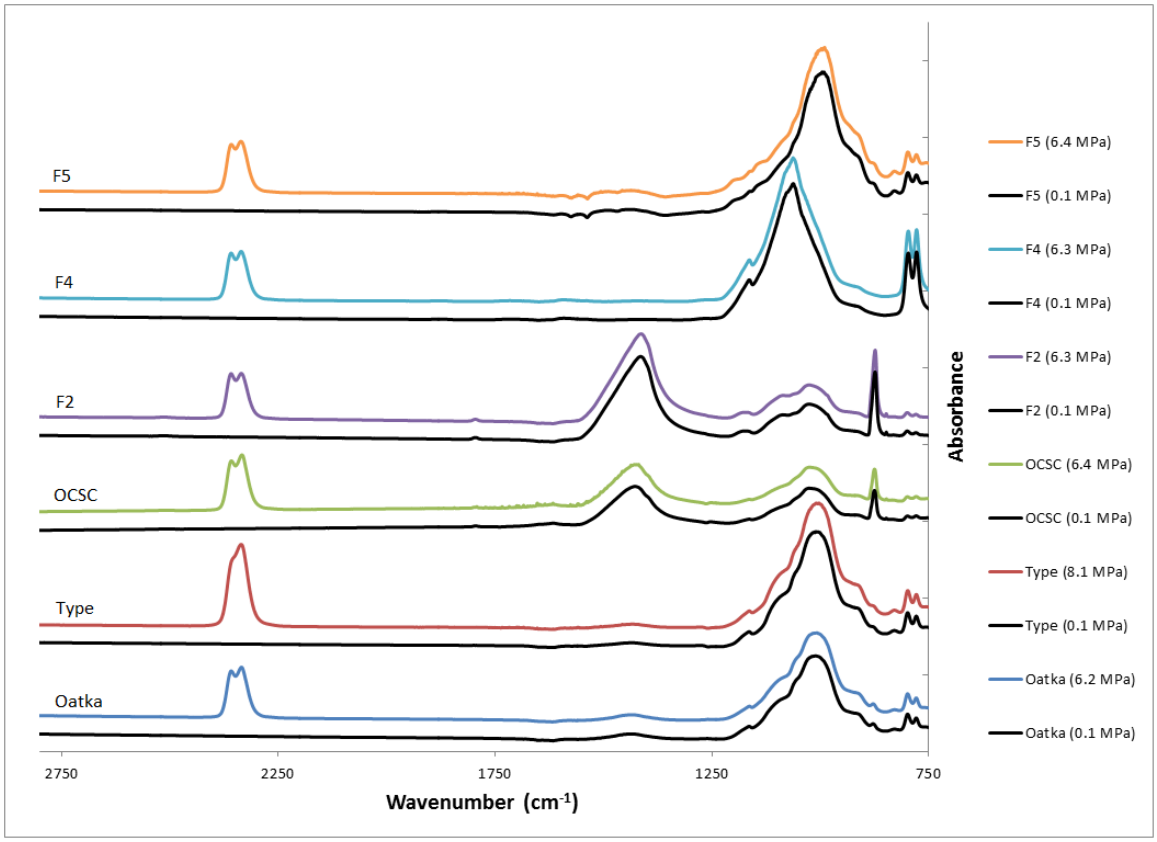

Figure 6: Infrared spectra of the shale samples exposed to CO_2 at low and high pressures.

Figure 7 shows the spectra of the Type shale and provides an example of components typically found in shale samples. Quartz at 1,164, 798, 778, and 694 cm^{-1}; illite at 825 and 750 cm^{-1}; carbonate ion at 1,433, 875, and 704 cm^{-1}; and chlorite at 3,675, 3,575, 3,428, 988, 761, 662, and 448 cm^{-1} were identified in the shale sample.

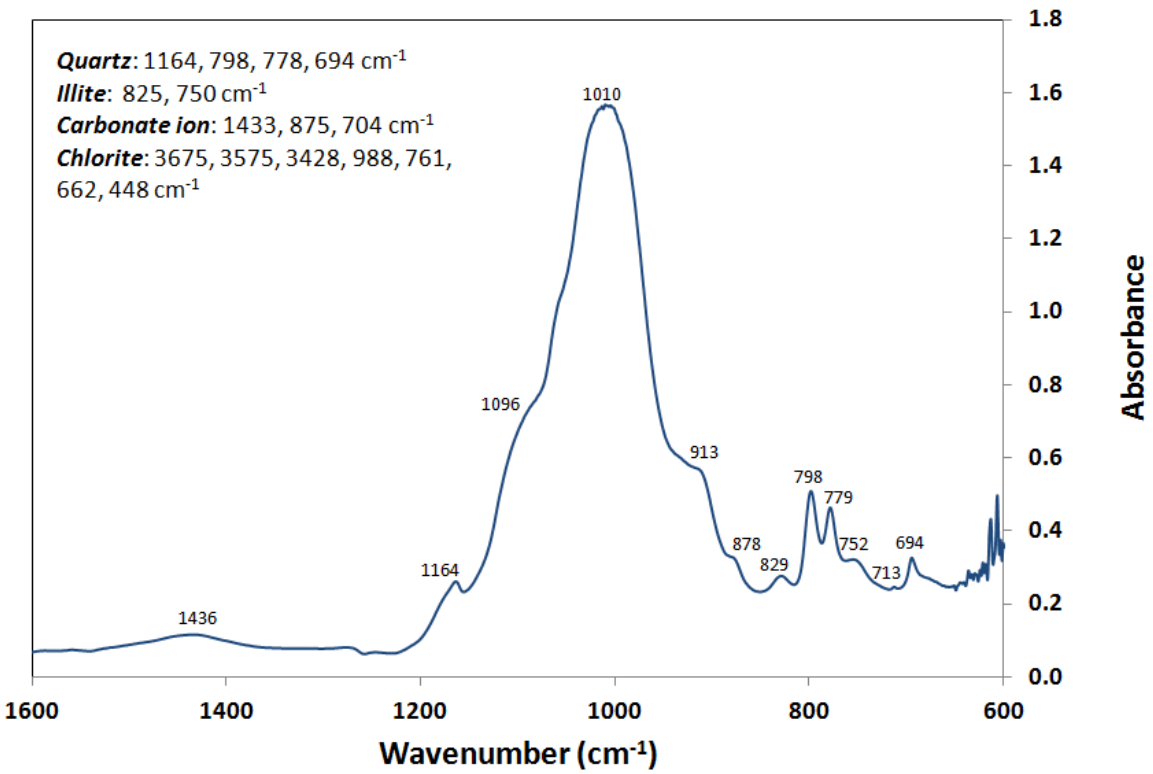

Figure 7: An infrared spectrum of the shale sample was taken before exposure of CH_4 and CO_2. Quartz, illite, carbonate, and chlorite were identified in the Type (425828762002TS) shale sample.

The shale samples were then exposed to CH_4 and CO_2 at 50°C. Three CH_4 pressures were examined at 0.79, 3.53, and 9.64 MPa for the 425828762002TS shale. Gaseous CH_4 absorption peaks were weak and located at 3,013 and 1,302 cm^{-1} for both the blank (no shale present) and sample (shale) chambers. Sorption peaks were not discerned upon spectral subtraction of the gaseous CH_4 from the shale sample due to the weak absorbance of CH_4 in the infrared (Figure 8). CH_4 experiments were not conducted for the other shale samples due to inadequate detection of CH_4 gas with ATR-FTIR.

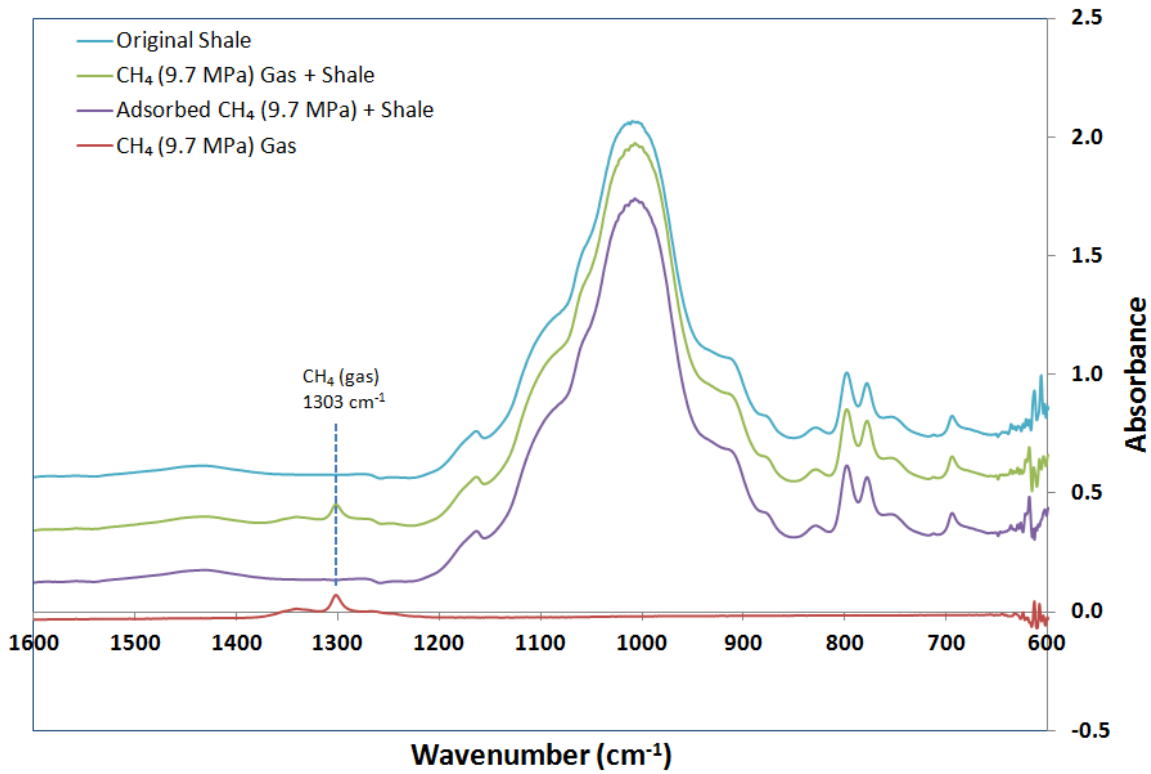

Figure 8: Exposure of the shale sample to CH_4 at 0.79, 3.53, and 9.64 MPa.

The shale samples were exposed to CO_2 at 50°C between 0.1 and 8.1 MPa. A CO_2 absorption peak was located at 2,349 cm^{-1} for both the blank (no shale present) and sample (shale) chambers. Spectral subtraction of the gaseous CO_2 from the CO_2 and shale revealed adsorption of CO_2 onto the shale sample at near 2,343 and 2,331cm^{-1} (Figure 9).

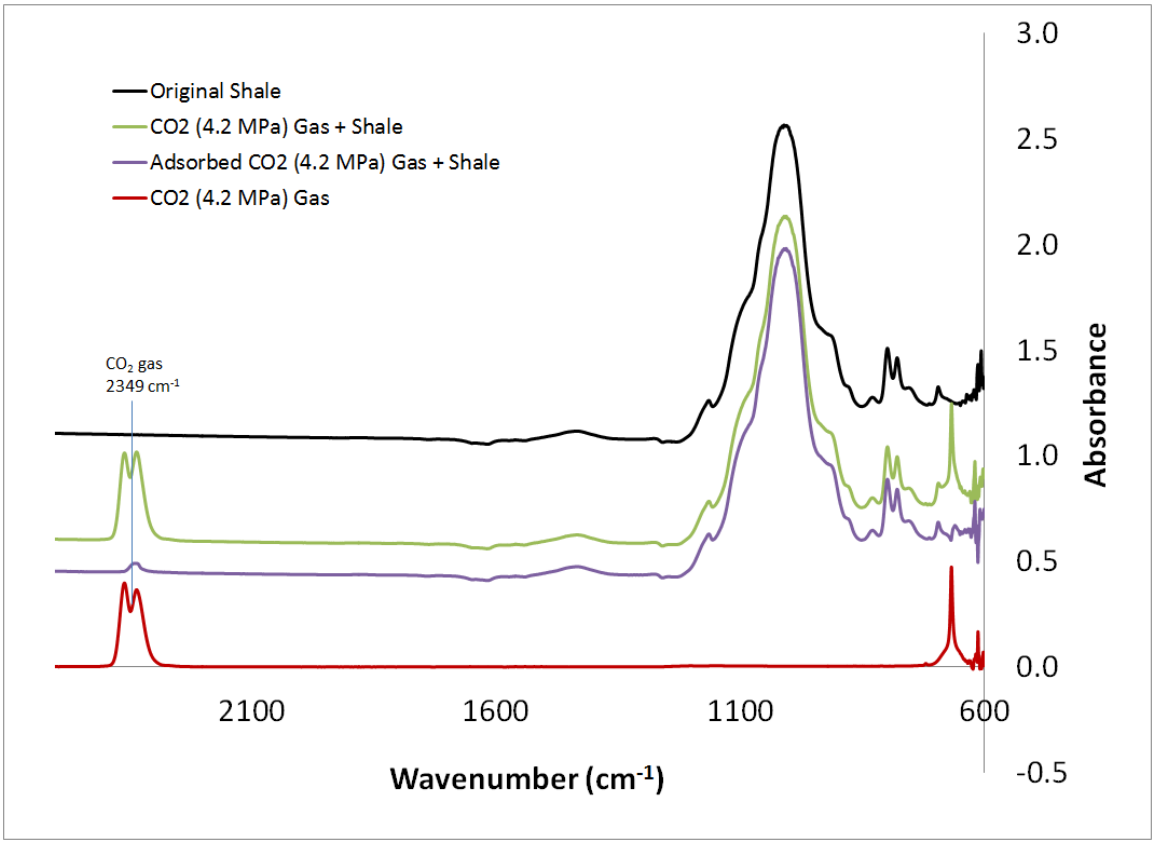

Figure 9: ATR-FTIR spectra of shale with gaseous CO_2 (top spectrum) and adsorbed CO_2 at 50°C as a function of CO_2 pressure at 0.66, 2.08, 4.14, and 6.24 MPa.

The absorption bands near 2,343, 2,331, and 659 cm^{-1} have been observed previously and are indicative of physical adsorbed CO_2. CO_2 is a linear molecule with two infrared-active absorption bands at 2,349 cm^{-1} (ν_3 anti-symmetric stretching mode) and 667 cm^{-1} (ν_2 bending mode). The ν_2 CO_2 bending mode is doubly degenerate. Upon adsorption of CO_2, the degeneracy of the ν_2 bending mode can be lost because of a change in symmetry. The ν_2 band can split into two features: an in-plane bend (lower frequency) and an out-of-plane bend (higher frequency). When CO_2 physically interacts with a surface, the resulting absorption band frequencies shift slightly from the gas phase values. In this study, the observed absorptions band at 2,343 and 2,331 cm^{-1} corresponded to the ν_3 anti-symmetric CO_2 stretching mode of physical adsorbed CO_2 and the absorption bands 659 cm^{-1} corresponded to the ν_2 CO_2 bending mode.

Figure 10 shows all six shale samples with their spectra from exposure to CO_2 at increasing pressures.

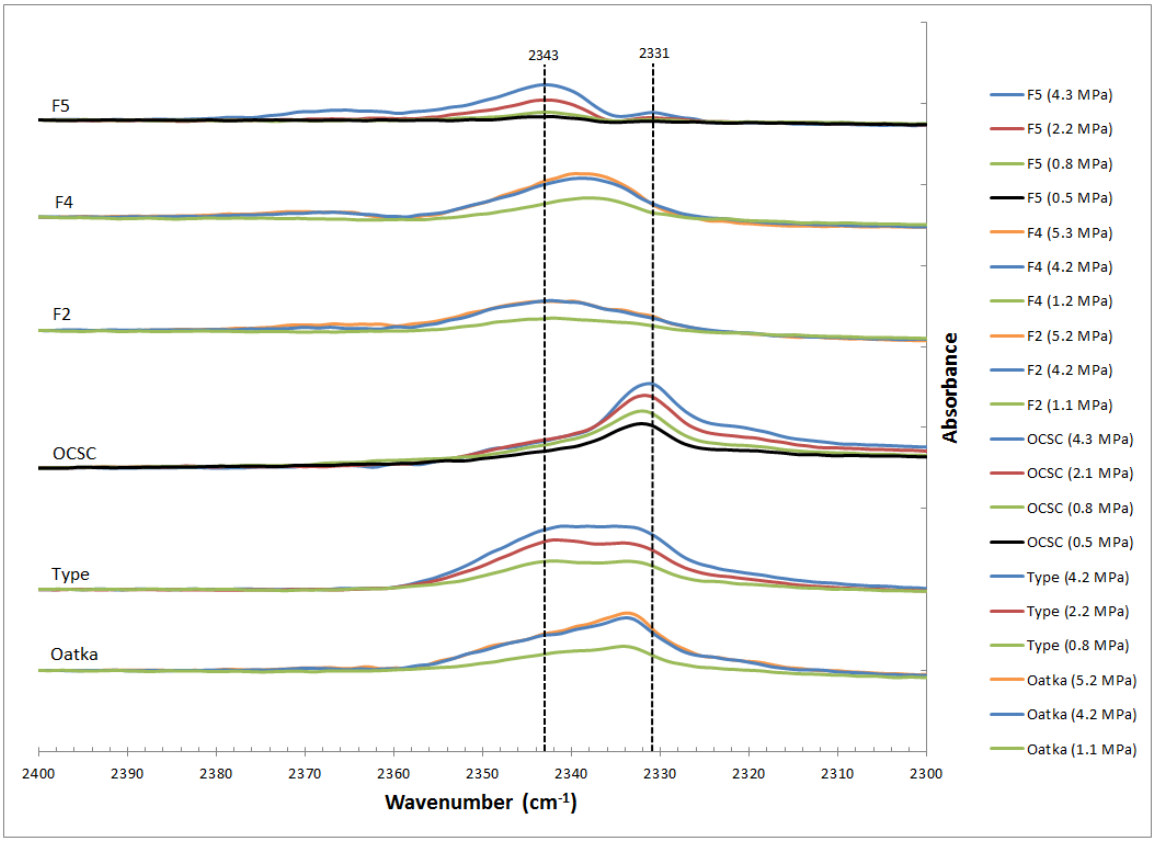

Figure 10: ATR-FTIR spectra of Marcellus shale samples with adsorbed CO_2 at 50°C as a function of CO_2 pressure.

Two sorbed peaks at 2,343 and 2,331 cm^{-1} indicate that there are two distinct adsorption environments available for CO_2 interaction with the shale. The peak at 2,343 is indicative of inorganic adsorption and represents adsorption of CO_2 onto the interlayers of clays. The peak at 2,331 is indicative of organic adsorption and represents adsorption of CO_2 in the interpore spaces of kerogen.

In summary, the ATR-FTIR technique was applied to measured contributions from CO_2 interactions with shale samples. The technique does not capture CH_4 adsorption due to its weak absorption cross-section in the infrared, and traditional manometric isotherm techniques should be used to quantitatively assess CH_4 sorption onto shale. The ATR-FTIR technique did reveal that CO_2 is adsorbing physically onto the shale. Two sorption peaks at 2,343 and 2,331 cm^{-1} indicate that there are two distinct adsorption mechanisms contributing to CO_2 interaction with shale matrix. Inorganic adsorption onto clays at 2,343 cm^{-1} and organic adsorption onto kerogen at 2,331 cm^{-1} is corroborated by the shale samples. Sample OCSC contained the highest concentration of TOC of all evaluated samples (representing kerogen content), and had the largest 2,331 cm^{-1} peak. Samples low in TOC, such as F5 and F2, displayed much smaller peaks at 2,331 cm^{-1}. Clay content was not measured quantitatively but in general samples with higher clay content display more prominent peaks at 2,343 cm^{-1}.

2.4 ELEMENTAL ANALYSIS

Elemental analysis is useful to study CO_2-shale interaction. Geochemical reactions between shale and CO_2 may potentially alter the clay mineralogy, elemental composition, and consequently affect the porosity and permeability of the formations. As the CO_2 diffuses into the shale matrix, dissolution of minerals may lead to leaching of cations from the shale matrix. The leaching could be significant to increase porosity as the exposure time progresses (Liu et al., 2012; Shukla et al., 2010). The elemental data will also aid in better interpretation of XRD results.

Ten powdered Marcellus samples (Table 5) were digested using lithium metaborate fusion and were analyzed for multi-elements using the inductively coupled plasma atomic emission spectrometer (ICP-AES) technique.

Sample Digestion

Approximately 0.1 g of powdered sample was mixed with 0.9 g of lithium metaborate in a platinum crucible and fused in a muffle furnace at 1000°C for 30 min. The crucible, containing molten mass, was cooled and immersed in a beaker containing 5% HNO_3. The beaker was placed on a hot plate and stirred at a moderate rate until contents of the crucible were dissolved. The resulting solution was transferred to a volumetric flask and made up to 100 ml by the addition of 5% HNO_3.

Sample Analysis

A Perkin Elmer model Optima 3000 XL ICP-AES was used for all data acquisition. Samples were introduced using a peristaltic pump at 1.0 ml per minute in conjunction using an auto sampler. Analysis was performed using an external calibration procedure, and internal standards were included to correct for matrix effects and instrumental drift correction. A reference material (BIR-1) was included for quality control purposes and procedural blanks were analyzed to check for any contribution from the reagents.

Results

The concentrations of 30 elements for each sample are shown in Table 5. The BDL indicates that those elements were not detected because of their concentration in the samples is below detection limit of the ICP-AES. Comparison of these data with future analysis of Marcellus shale samples after CO_2 exposure will provide useful information to understand the CO_2-shale interaction. Figure 11 shows the relative abundance of elements in each sample.

Table 5: ICMI Results of Elemental Analyses

		Sample Suffix (units in ug/g)									
Element	Detection Limit (ug/g)	F5	F3	F4	F1	F2	Bedford	OCSC	USSC	TYPE	Oatka
Ag	0.80	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Al	19.0	8,913	4,746	2,125	8,469	1,404	2,171	2,974	6,389	7,915	7,001
As	1.20	3.61	2.78	2.12	3.89	3.15	3.45	5.40	3.03	5.07	6.39
Ba	1.60	80.2	58.7	36.4	86.0	2989	21.7	19.3	42.1	44.0	32.7
Be	0.32	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Ca	51.0	1,540	13,459	BDL	4,057	25,722	6,630	17,178	9,971	1,135	1,564
Cd	0.32	0.83	0.38	BDL	0.57	0.50	BDL	0.33	0.48	0.57	0.72
Ce	11.0	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Co	1.70	2.22	BDL	BDL	1.86	BDL	BDL	BDL	BDL	2.62	2.61
Cr	0.70	14.6	11.9	13.8	15.4	8.65	7.63	13.2	12.4	17.1	13.9
Cu	4.00	BDL	BDL	4.4	BDL	BDL	14.7	26.9	5.7	7.56	14.4
Fe	46.0	4,649	2,133	707	3,703	1,689	968	2,235	2,075	4,677	4,260
K	188	3207	1882	864	3359	589	892	1808	3119	3675	3243
Mg	6.00	1,123	933	123	874	403	384	609	882	947	851
Mn	0.60	55.4	29.4	2.3	43.5	48.1	12.6	12.9	26.9	20.9	15.3
Mo	0.20	1.19	1.92	10.9	2.48	3.89	8.77	11.5	2.54	9.83	13.6
Na	72.0	500	385	125	414	219	235	291	234	222	369
Ni	2.30	14.0	9.91	6.30	9.96	6.31	14.5	41.0	24.6	15.1	21.5
P	18.0	34.4	28.6	BDL	57.0	24.2	42.3	40.0	29.2	44.1	33.8
Pb	0.80	BDL	1.24	4.64	BDL	BDL	2.65	2.41	BDL	2.53	3.72
S	161	646	548	BDL	BDL	1333	213	518	524	998	651
Sb	13.0	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Se	14.0	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Si	60.0	24,688	16,579	35,481	22,450	5,582	28,738	10,708	18,054	24,757	20,482
Sn	3.20	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Sr	0.60	10.5	29.4	4.70	12.9	56.6	17.7	33.1	25.1	8.74	9.56
Ti	0.05	497	311	105	452	96	104	173	345	406	259
Tl	1.20	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
V	0.29	13.6	8.76	40.8	14.2	3.74	32.0	43.0	14.0	20.0	28.8
Zn	9.00	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

Notes: BDL = Below detection limits.
For the elements indicated in red, there is less confidence in data. These could be best analyzed by ICP-MS if needed. The quality of data for rest of the elements is good.

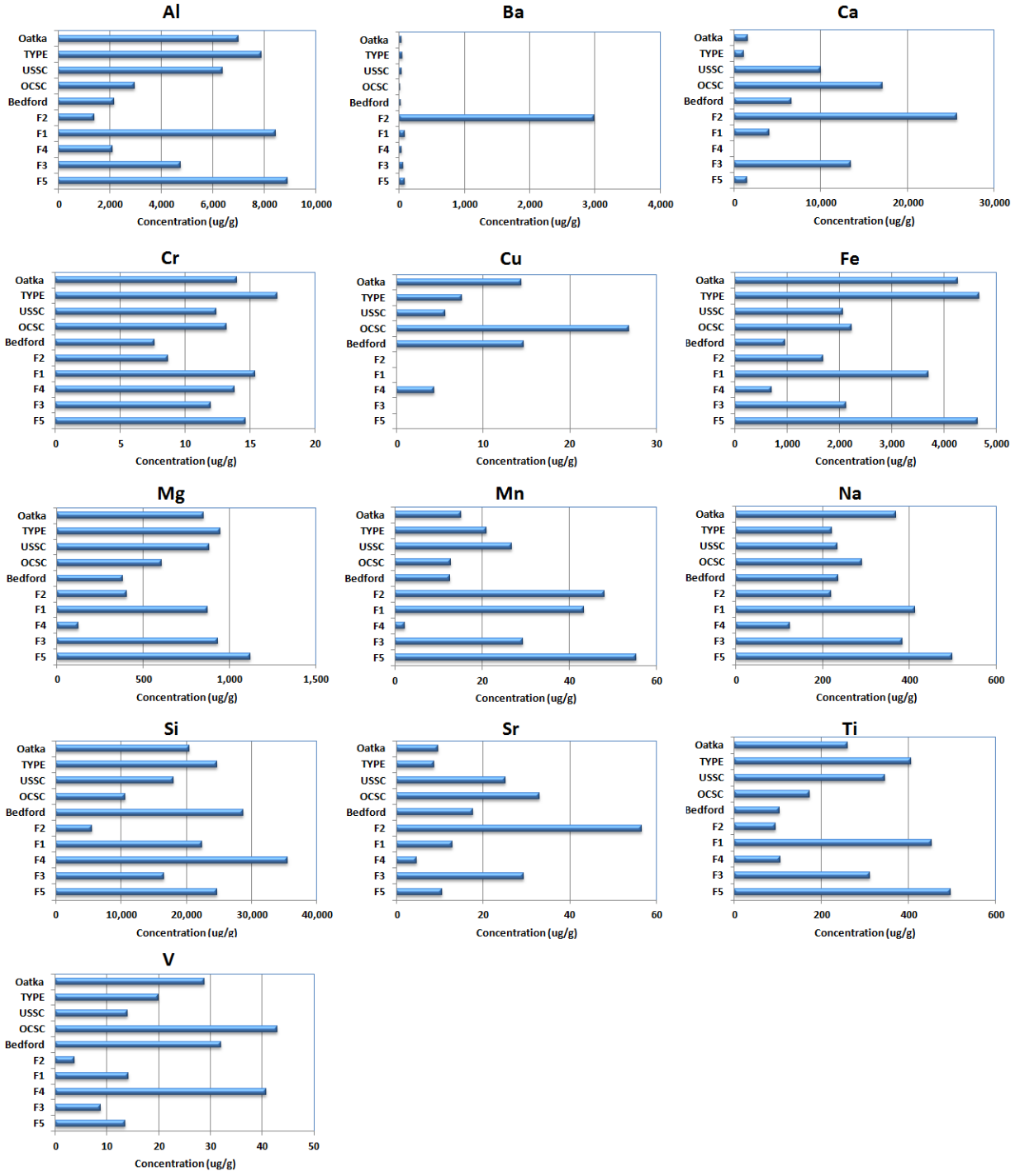

Figure 11: Sample concentrations by element and sample.

2.5 TOTAL ORGANIC CARBON/TOTAL INORGANIC CARBON (TOC/TIC)

Organic carbon in sedimentary rocks occurs in the preserved remnants of plants and animals. The organic carbon is degraded during burial by increases in temperatures and pressures to form kerogen (insoluble) and bitumen (soluble), a process known as maturation. Kerogen forms the basic component from which oil and gas are derived. TOC is the measure of the organic richness of a rock; it is the quantity of organic carbon (both kerogen and bitumen) in a rock sample. Laboratory measurements of TOC are commonly used to assess the quality of source rocks and to evaluate shale reservoirs which serve as both source and reservoir. The amount of organic carbon in shale determines not only if the shale can serve as source rock, but also provides sites for adsorption of natural gas which contributes to the storage capacity of the shale reservoir. An added advantage is that the same adsorption capacity for CH_4 has been shown to be stronger for CO_2 in organic rich shales. The organic matter also acts as a molecular sieve allowing more CO_2 to reside in small pores than other naturally-occurring gases. Inorganic carbon is also present in source rocks in the form of carbonate minerals, most notably calcite, dolomite, and siderite. Because these minerals produce CO_2 during maturation (high temperatures), their presence must be corrected in order to determine the organic carbon content.

The analysis of carbon was performed using a CM5015 Carbon Dioxide Coulometer (UIC, Inc.) equipped with both acidification module and furnace assembly. The working range of the UIC CO_2 coulometer is from less than one microgram carbon (µg C) up to 10,000 micrograms for a single sample with 1000–3000 µg C being the optimal carbon concentration. However, actual quantization limits for the analysis also depend on reproducibility of sample blanks, sample size, effective removal of potential interfering species, and process parameters such as adequate CO_2 release and titration times for each sample type. Sample sizes for the individual Marcellus shale samples tested were adjusted so that the determinations were performed within the optimal range whenever possible. NETL's largest available sample boat could only handle ~ 1 g of the powdered shale. Blank reproducibility with current cleaning procedures is estimated to be ± 10–15 µg C which implies a quantization limit of ~ 15 ppm for these tests.

TIC, i.e. carbon from the carbonate mineral content, was determined by acidification of the sample (reaction with excess 2 N $HClO_4$) followed by electrochemical titration of the released CO_2 in the coulometer cell. Three replicate TIC determinations were performed for each shale sample. Total carbon (TC) was determined by burning the sample at 900°C in pure oxygen in the furnace apparatus followed by electrochemical titration of the released CO_2. Four replicate TC determinations were performed for each shale sample. TOC was determined by subtraction of the average TIC content for each shale sample from its corresponding average total carbon. Results are presented in the Table 6.

Table 6: Carbon Analysis of ICMI Marcellus Shale Samples

	Total Inorganic Carbon		Total Carbon		Total Organic Carbon	
Sample Suffix	Average % Carbon	Standard Deviation	Average % Carbon	Standard Deviation	Average % Carbon	Standard Deviation
F5	0.749	0.00	1.127	0.01	0.378	0.01
F3	4.82	0.01	5.91	0.11	1.08	0.11
F4	< DL	N/A	4.02	0.15	4.02	0.15
F1	1.29	0.00	1.51	0.02	0.22	0.02
F2	8.63	0.10	9.43	0.04	0.8	0.11
Bedford	2.33	0.00	7.58	0.14	5.25	0.14
OCSC	5.82	0.07	14.73	0.06	8.9	0.10
USSC	3.37	0.02	6	0.06	2.63	0.06
Type	0.319	0.00	3.56	0.05	3.24	0.05
Oatka	0.567	0.01	8.12	0.21	7.55	0.21

TOC for the samples ranges from 0.2–9 wt %. A TOC of 1.0 wt. % is generally considered as a minimum value for defining potential source rocks. TOC content for the Marcellus shale has reported ranges from 2–12 wt % (Bruner and Smosna, 2011).

2.6 ADSORPTION CAPACITY AND ADSORPTION ISOTHERMS FOR CO_2

Effective adsorption capacity of shale cores as a function of net stress was compared to maximum adsorption capacity as determined through CO_2 isotherm development for powdered samples. The first step in this work was to determine the maximum adsorption capacity for the shale samples. Figure 12 presents an example CO_2 adsorption isotherm for sample F5.

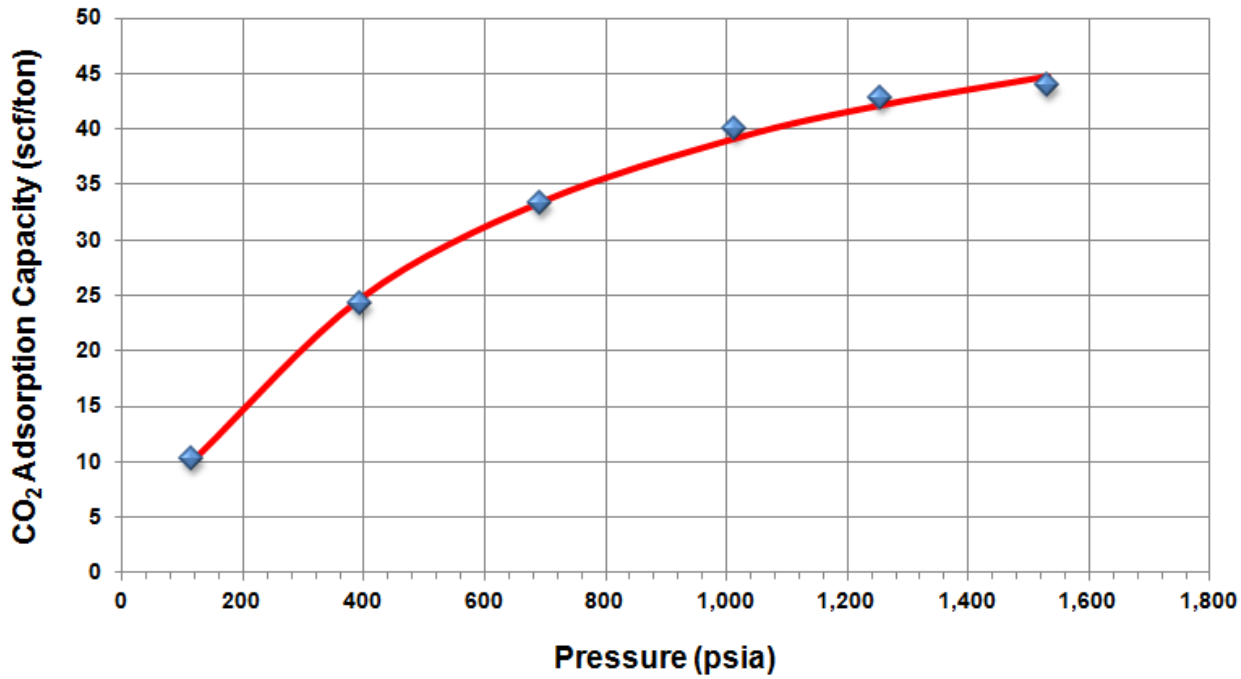

Figure 12: Example CO_2 adsorption isotherm for Sample F5.

The objectives of this effort were to estimate the pure-gas Langmuir parameters for CH_4 and CO_2 adsorption on representative powder samples to support modeling efforts, and to verify the key correlations between organic carbon content, micropore structure, and the maximum gas adsorption capacities. These evaluations may provide initial insight into possible reservoir EGR performance; mixed-gas isotherms can provide different results from the behavior expected based on the pure-gas isotherms and should be considered in the future (Mohammad et al., 2012; Sudibandriyo et al., 2011).

The measurements were performed by Weatherford Laboratories. Data for CH_4 and CO_2 isotherms and details of the analyses by Weatherford can be found in Appendix B. A standard manometric adsorption isotherm setup was utilized except for downstream plumbing modifications for gas chromatography measurements. The plumbing of the sample cell was modified to expand the volume aliquot into a larger volume of tubing in order to reduce pressure sufficiently for introduction into the gas chromatograph (GC) and to ensure that disturbance to adsorption equilibrium is small.

The following procedure was used for adsorption isotherm studies.

1. Set temperature to 169°F (76.1°C).
2. Purge with helium (He) and pull vacuum on entire system.
3. Conduct void volume determination.
4. At the end of each pressure step expand gas to termination.
5. Calculate sample cell void volumes in sample and reference cells.

6. Pull final vacuum on sample cell and modified plumbing. (The plumbing modifications are filled with low pressure He for subsequent gas sampling).
7. Conduct a six step CH_4 isotherm to final equilibrium pressure of 4,000–4,500 psia.
8. Run CH_4 desorption pressure steps targeting pressures of 3,000, 1,500, and 500 psia. (Pressure bleed-off upstream to reference cell).
9. Purge the reference cell and manifold with CO_2. Load reference with the sufficient CO_2 pressure to obtain the first sample cell target pressure of 3,000 psia.
10. Expand CO_2 into sample cell but isolate the sample cell ~200 psia above total pressure distribution from the reference cell to ensure no upstream mixing of CH_4 and CO_2 in the reference cell. Allow sample cell to come to pressure and temperature equilibrium.
11. Expand a small aliquot of sample cell gas into Stage 1. (Stage 1 is to be submerged in the oil bath to maintain temperature and avoid phase change.) Leave the valve open until pressure equilibrium is achieved.
12. Isolate the sampling stages and expand the capture gas volume aliquot into Stage 2. Leave the valve open for approximately 20 min to ensure equilibrium is obtained.
13. Close the valve and carefully disconnect the sampling system from the isotherm instrument.
14. Connect the sampling system to the GC using a Swagelok fitting, and then run the sample through the GC.
15. Disconnect the sampling device from the GC, purge, evacuate, and reconnect to the isotherm instrument. Once connected pull a final vacuum to remove the air in the dead space.
16. Repeat steps 6–12 targeting a final sample cell pressure of 5,000 psia using CO_2.
17. Pure CO_2 adsorption isotherm measurements targeting a final sample cell pressure of 2,000 psia were performed for quality assurance.

The results of the pure-gas adsorption isotherms are shown in Table 7.

Table 7: Pure-Gas Adsorption Isotherm Parameters

			CH_4 Measurement Gas		CO_2 Measurement Gas	
Sample Suffix	Measurement Temperature (°F)	Crushed Density (g/cc)	Langmuir Adsorption Capacity (scf/ton)	Langmuir Pressure (psia)	Langmuir Adsorption Capacity (scf/ton)	Langmuir Pressure (psia)
F5	169.0	2.781	20.37	3,088.98	61.65	582.52
F3	169.0	2.686	32.37	1,344.01	135.83	1,346.22
F4	169.0	2.522	113.96	7,436.49	163.87	1,350.30
F1	169.0	2.681	37.23	3,426.14	89.22	897.67
F2	169.0	2.728	22.88	4,252.19	84.23	2,748.78
Bedford	169.0	2.536	124.32	1,036.23	236.33	700.91
OCSC	169.0	2.492	244.04	872.25	329.76	364.75
USSC	169.0	2.646	86.35	1,191.44	163.14	635.05
Type	169.0	2.679	103.61	1,339.80	138.11	415.88
Oatka	169.0	2.455	197.41	2,935.45	259.81	1,095.67

Notes: STP = 14.696 psia, 519.67°R (or 60°F). Ton = short U.S. ton, or 2,000 lbs

The reported storage capacities for both CH_4 and CO_2 adsorption appear to be well correlated with TOC (Figures 13 and 14). The correlation between the physical properties is shown in Table 8.

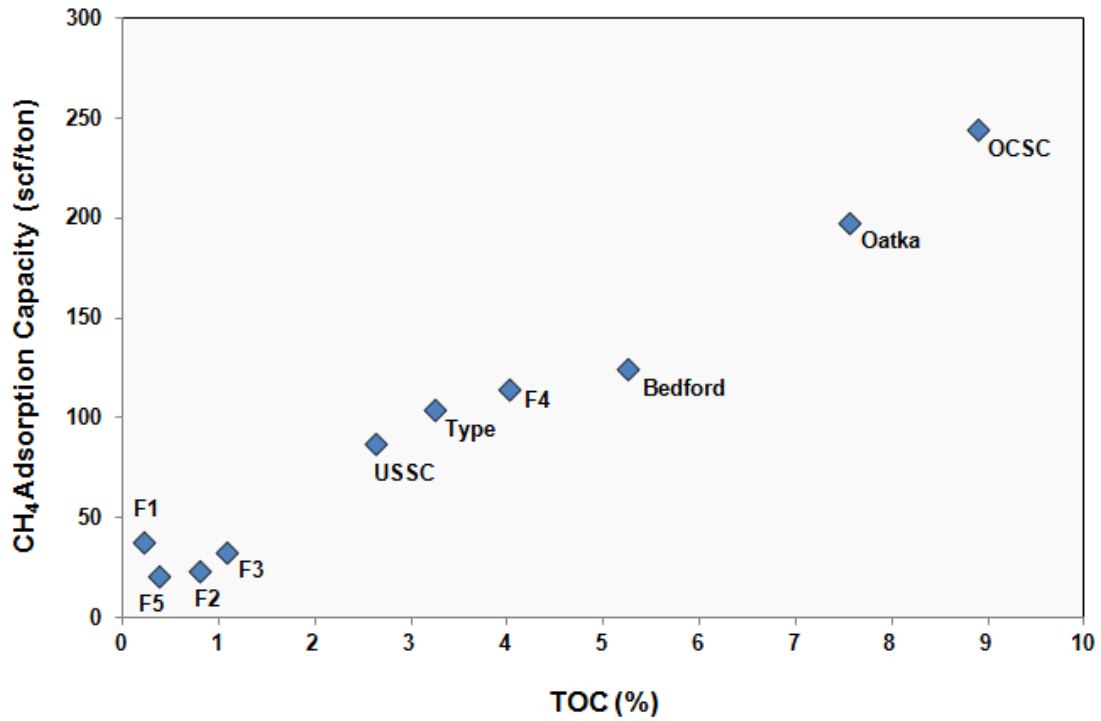

Figure 13: CH_4 adsorption capacity as a function of TOC.

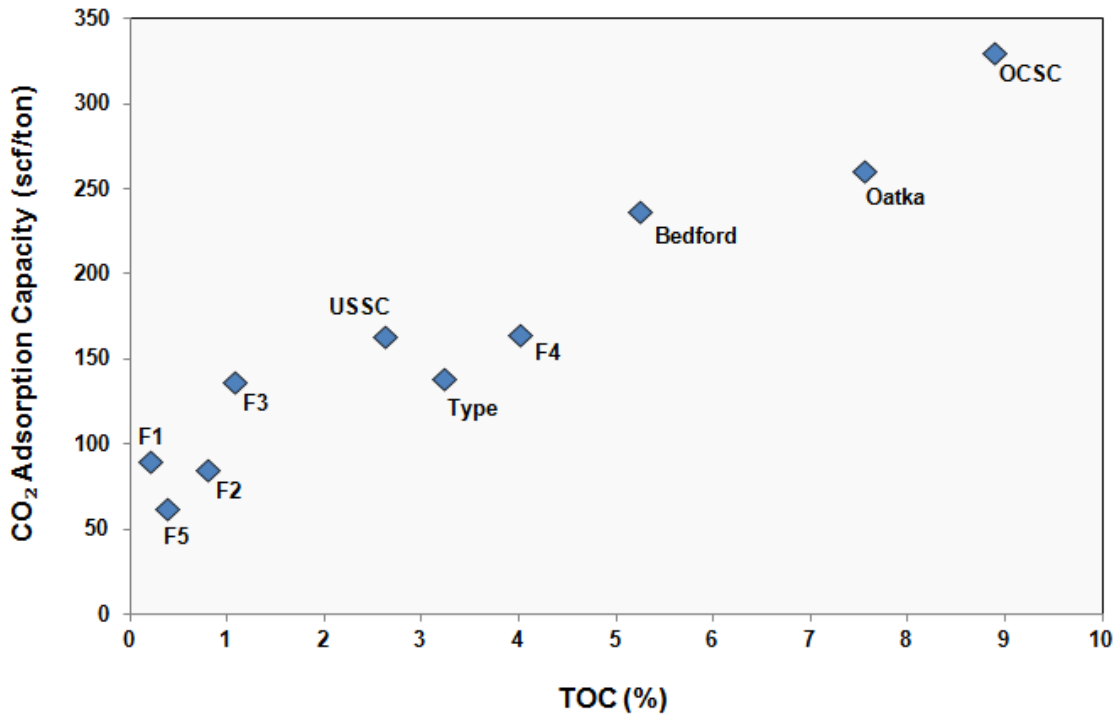

Figure 14: CO_2 adsorption capacity as a function of TOC.

Table 8: Correlation of Adsorption and Physical Properties

Sample Suffix	BET Surface Area [1] (m^2/g)	CH_4 Adsorption Capacity [2] (scf/ton)	CO_2 Adsorption Capacity [2] (scf/ton)	CO_2:CH_4 Ratio [2]	Grain Density [1] (g/cc)	Bulk Density [1] (g/cc)	Crushed Density [2] (g/cc)
F5	10.4	20.37	61.65	3.03	2.79	2.76	2.78
F3	10.3	32.37	135.83	4.20	2.73	2.79	2.69
F4	8.1	113.96	163.87	1.44	2.54	1.97	2.52
F1	16.6	37.23	89.22	2.40	2.75	2.54	2.68
F2	5.7	22.88	84.23	3.68	2.79	2.67	2.73
Bedford	23.5	124.32	236.33	1.90	2.56	2.46	2.54
OCSC	33.8	244.04	329.76	1.35	2.55	2.38	2.49
USSC	18.1	86.35	163.14	1.89	2.71	2.50	2.65
Type	20.4	103.61	138.11	1.33	2.75	2.29	2.68
Oatka	7.3	197.41	259.81	1.32	2.57	2.43	2.46

Notes: [1] Data from Micomeritics
[2] Data from Weatherford

The storage capacities for CH_4 (Figure 15) and CO_2 (Figure 16) correlate well with Brunauer–Emmett–Teller (BET) surface area data reported by Micromeritics (Table 8, see Section 3.1) except for the samples F4 and, especially, Oatka which had the highest TOC values. This may suggest increased micropore volume accessibility at high pressures compared to relatively low pressures applied during the BET surface area measurements. The BET method is widely used in surface science for the calculation of surface areas of solids by extension of the Langmuir theory to infinite multi-layer physical adsorption of gas molecules; the information can help predict storage capacity of a sorbent Detailed BET analyses from Micromeritics can be found in Appendix C.

BET surface area ranges from 5.7 to 33.8 m^2/g. This compares favorably with Fischer and Gaupp's (2005) measurements on blacks shales, which reported BET surface areas ranging from 6-24 m^2/g. Fischer and Gaupp's study also showed a linear decrease in BET surface area as organic matter oxidized during weathering of black shales. Consistent with that study, samples F1, F2, F3, and F5 that contain low TOC also show corresponding low BET surface areas (6–17 m^2/g).

Six out of ten samples, Oatka, Type, OCSC, F4, USSC, and Bedford, show relatively low CO_2:CH_4 storage capacity ratios ranging from 1.3 to 1.9, while the four samples with the lowest TOC content show higher ratios ranging from 2.4 to 4.2. The low TOC samples, F1, F2, F3 and F5, have high grain densities, between 2.75 and 2.79, due to high mineral contents (Figure 17). This may suggest that the presence of organic matter in shale creates more favorable conditions for CH_4 rather than CO_2 sorption, thereby decreasing the molar CO_2/CH_4 storage capacity ratio compared to sorption on the mineral surfaces. Further evaluation of this phenomenon would be required to support this observation.

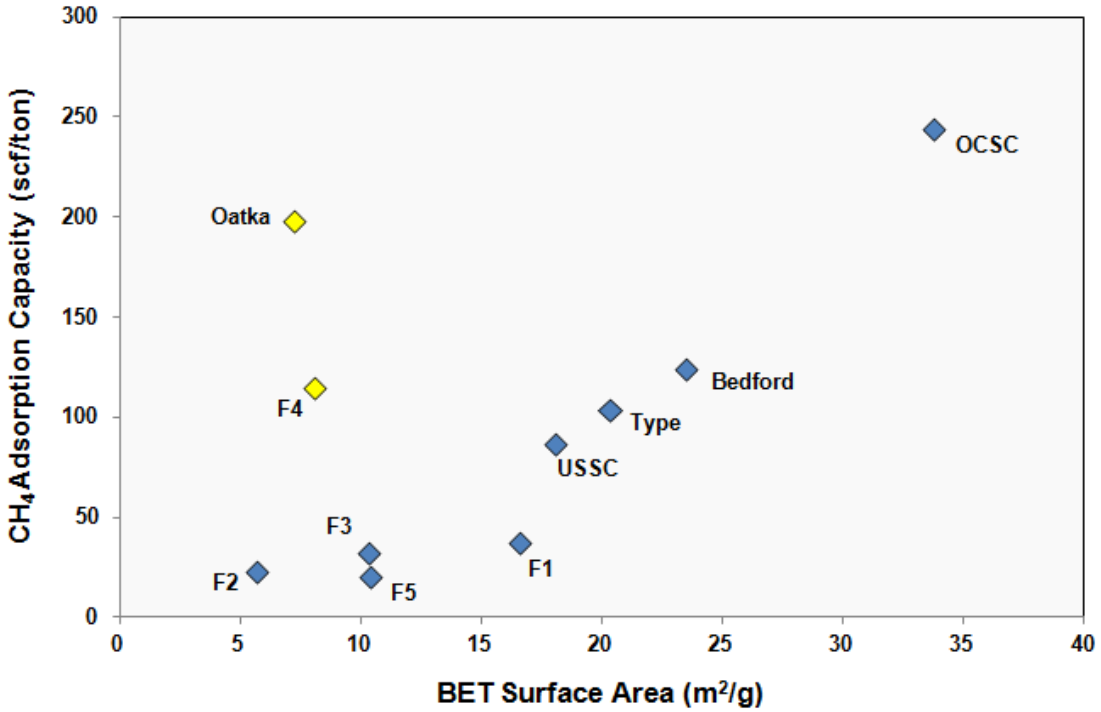

Figure 15: CH4 adsorption density.

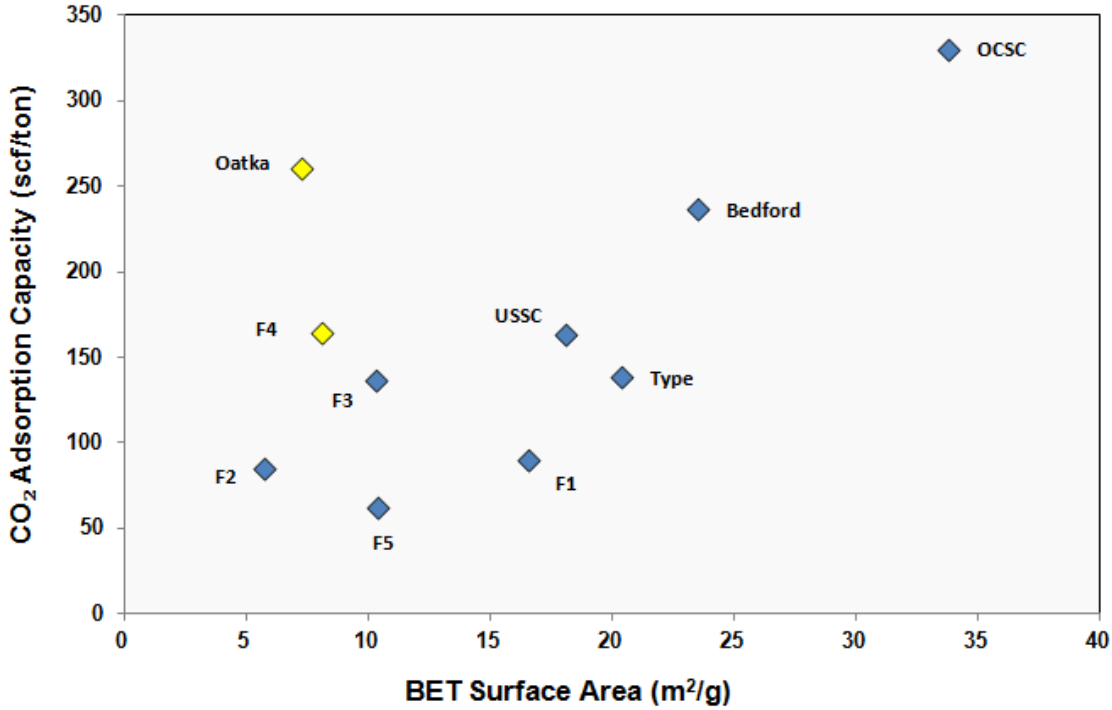

Figure 16: CO_2 adsorption density.

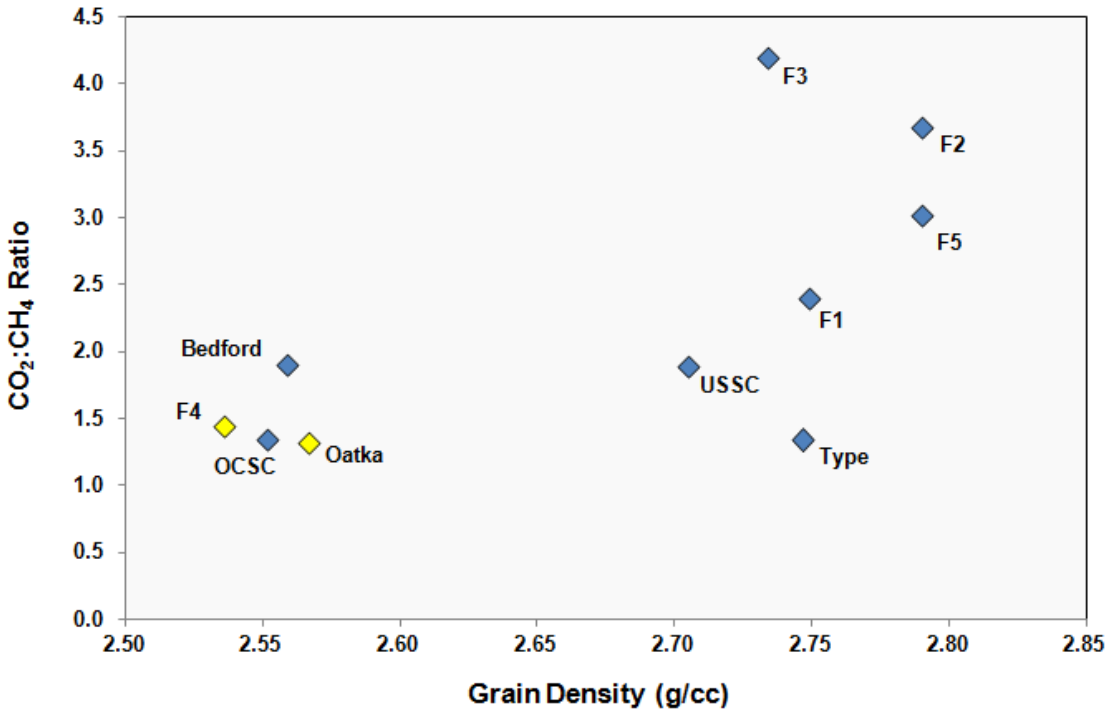

Figure 17: Gas adsorption ratio vs. grain density.

3. EXPERIMENTAL CHARACTERIZATION: PHYSICAL TESTS

Economic and efficient shale gas production enhanced by CO_2 injection is dependent on understanding key properties of reservoir rock. Accurate porosity and permeability measurements, structural analyses, and comparison of the bulk and grain physical properties provide a complete picture of the potential equilibrium fluid saturation conditions as well as kinetic parameters of the associated adsorption-desorption processes. Such analyses are especially important in shale reservoirs because of the vertical and lateral heterogeneity of the rocks. This information can be used to better estimate the reservoir gas storage capacity, to calibrate log and seismic measurements, and to assist in well and completion design, well placement, and various aspects of reservoir production modeling.

Grain density describes the density of solid or mineral grains of the rock. In log and core analysis, the term “grain” refers to all the solid material in the rock, because no effort is made to distinguish mineral grains from other solid material when interpreting the measurements. Grain density suggests the mineralogy of the rock, because the density varies with the mineral composition of the rock and the state of hydration of the minerals.

Bulk density is the total volume of the sample including particle volume, inter-particle void volume, and internal pore volume. It is the mass of many particles of the material divided by the total volume they occupy. A combination of grain and bulk density measurements can be used to calculate the total porosity in a sample.

Surface area, porosity, and permeability can greatly influence the gas flow rate and gas storage in reservoir rock. Micropore volume and micropore surface area are the key physical parameters that determine adsorption capacity.

The term "porosity" is often used to encompass the measurements of pore size distribution, pore volume, density, and other porosity-related characteristics of a material. Gas adsorption, permeability, strength, density are influenced by porosity and are key parameters in modeling gas flow and storage in geological formations.

Summary data for this work is contained in Table 9. Pore size distribution curves (unsmoothed) for the ICMI shale samples are shown in Figures 18 through 27.

3.1 SUMMARY OF TECHNIQUE

The grain density, porosity and micropore surface area were tested using Micromeritics Instrumentation. Micromeritics Analytical Services specializes in the physical characterization of materials and manufactures the equipment used to perform these types of measurements. Total porosity was estimated by two methods: 1) mercury porosimetry of an in-tact sample; and 2) comparison of the powder grain density and the bulk density of an in-tact sample.

Table 9: Physical Testing Results for ICMI Shale Samples

Sample Suffix	Grain Density (g/cc)	Bulk Density (g/cc)	Median Pore Diameter - Volume (µm)	% Porosity (Hg porosimeter, ISO 15901-1)	% Porosity (from Bulk Volume, USP <616> method II)	Micropore Surface Area (m^2/g)
F5	2.790	2.8	5.226	1.98	1.18	2.3
F3	2.734	2.8	0.136	7.92	-2.01	3.2
F4	2.536	2.0	0.314	25.52	22.20	1.7
F1	2.749	2.5	0.114	14.82	7.49	4.3
F2	2.790	2.7	0.009	6.73	4.23	0.8
Bedford	2.559	2.5	0.312	2.4	4.03	15.2
OCSC	2.552	2.4	0.022	2.53	6.58	31.8
USSC	2.705	2.5	0.010	3.84	7.54	8.6
Type	2.747	2.3	0.023	3.35	16.67	7.8
Oatka	2.567	2.4	0.004	3.37	5.38	0 [1]

Notes: [1] Could not fit a positive t-plot micropore area
Pore size distribution is illustrated in the individual sample plots

Grain Density (ISO 12154) - AccuPyc II 1340 (Helium Displacement Density Analyzer)

Grain density is the density of the solid material of a rock sample minus any pore space. It is also known as matrix density and is measured in gm/cm^3. Grain densities of the samples were measured using an AccuPyc II 1340 Series Pycnometer which produces high-precision volume measurements and density calculations.

Bulk Density (USP <616> method II) - VanKel (Varian) Autotap (Tapped Density Analyzer)

Bulk density (mass per unit volume) is the total volume of the sample including particle volume, inter-particle void volume, and internal pore volume. A combination of grain and bulk density measurements can be used to calculate the total porosity in the sample. The Marcellus shale samples were measured using a dry powder pycnometer attachment for the Autotap and either a coarse or fine pycnometric powder, according to the scale of pore size and surface features under test. The tapped density of powdered, granular, or flakey material is highly dependent on the manner in which the particles are packed together. During tapping, particles gradually pack more efficiently, the powder volume decreases and the tapped density increases. Under controlled conditions of tapping rate, tap force (i.e. drop) and cylinder diameter, this condition of maximum packing efficiency is highly reproducible. Tapped density measurement (sometimes referred to as tapped bulk density, or just tap density) is formalized in a number of international standards to which both Autotap models conform.

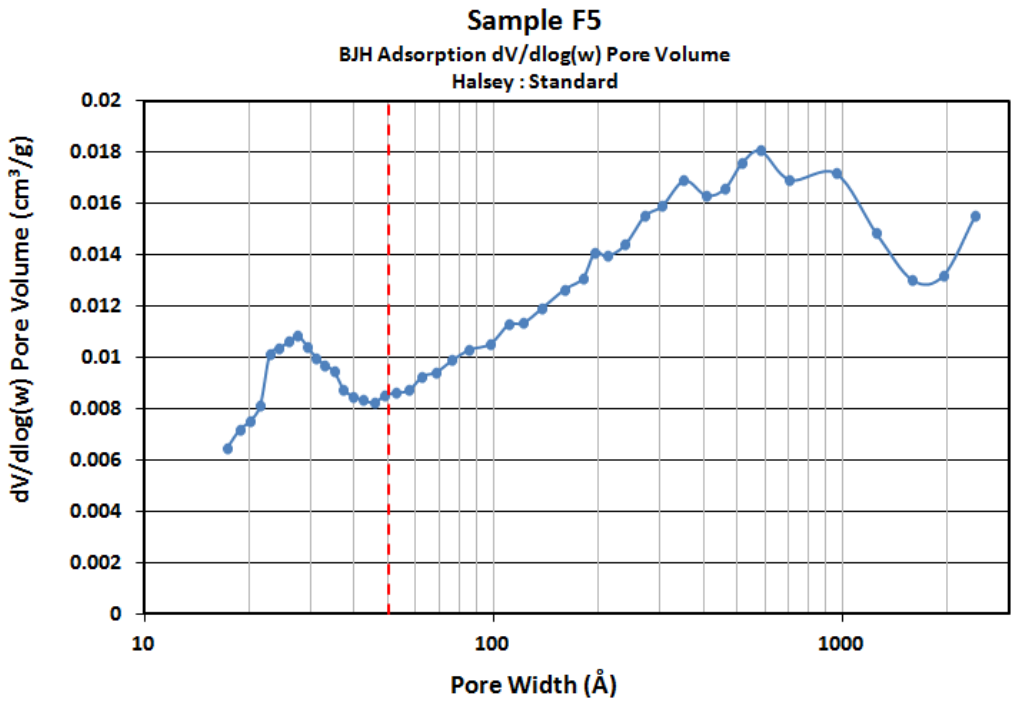

Figure 18: Pore size distribution for ICMI sample F5.

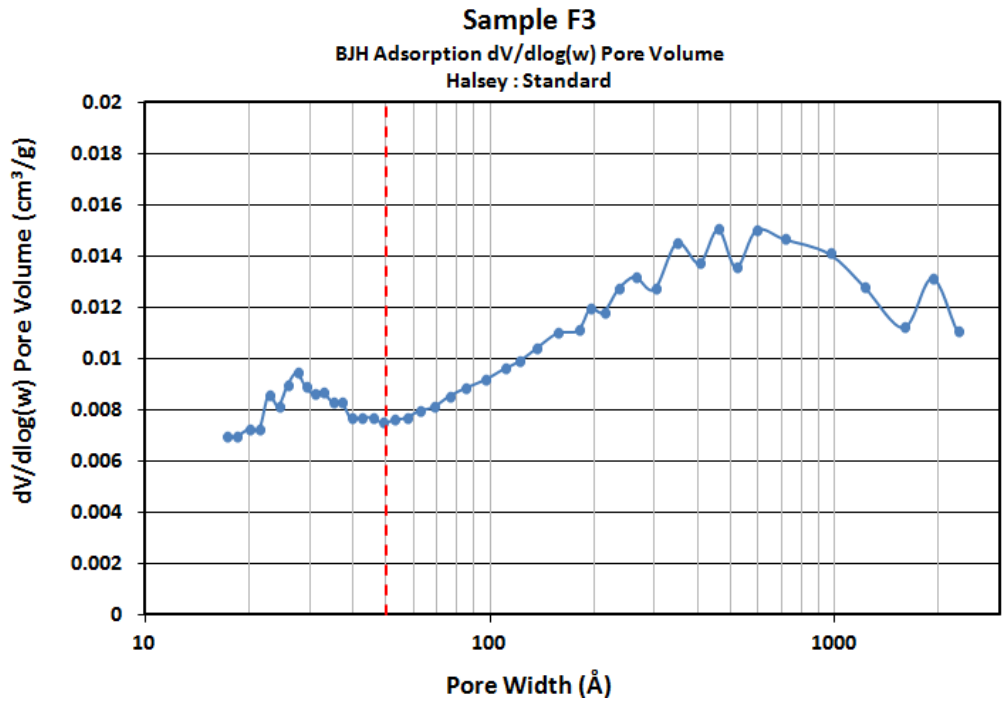

Figure 19: Pore size distribution for ICMI sample F3.

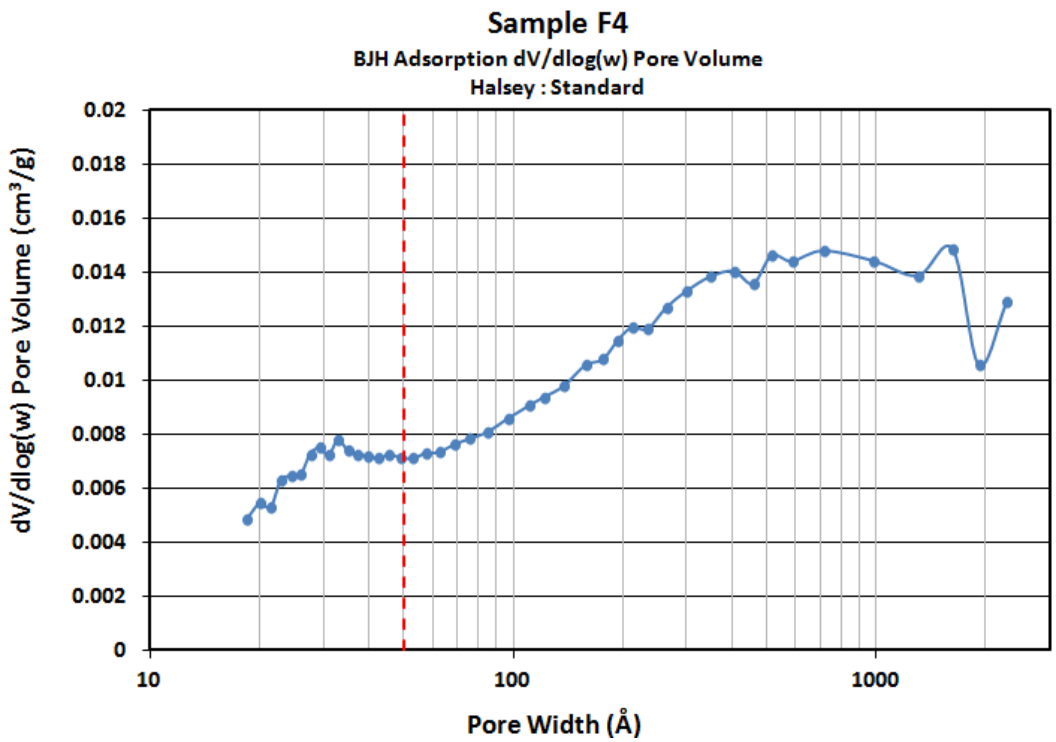

Figure 20: Pore size distribution for ICMI sample F4.

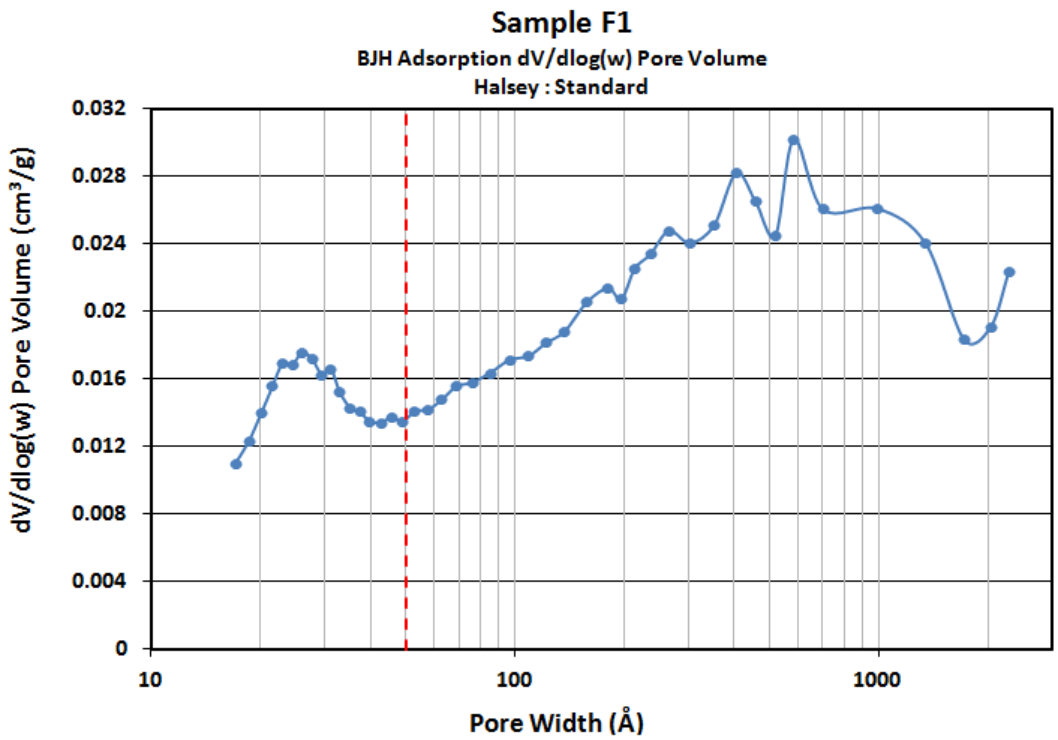

Figure 21: Pore size distribution for ICMI sample F1.

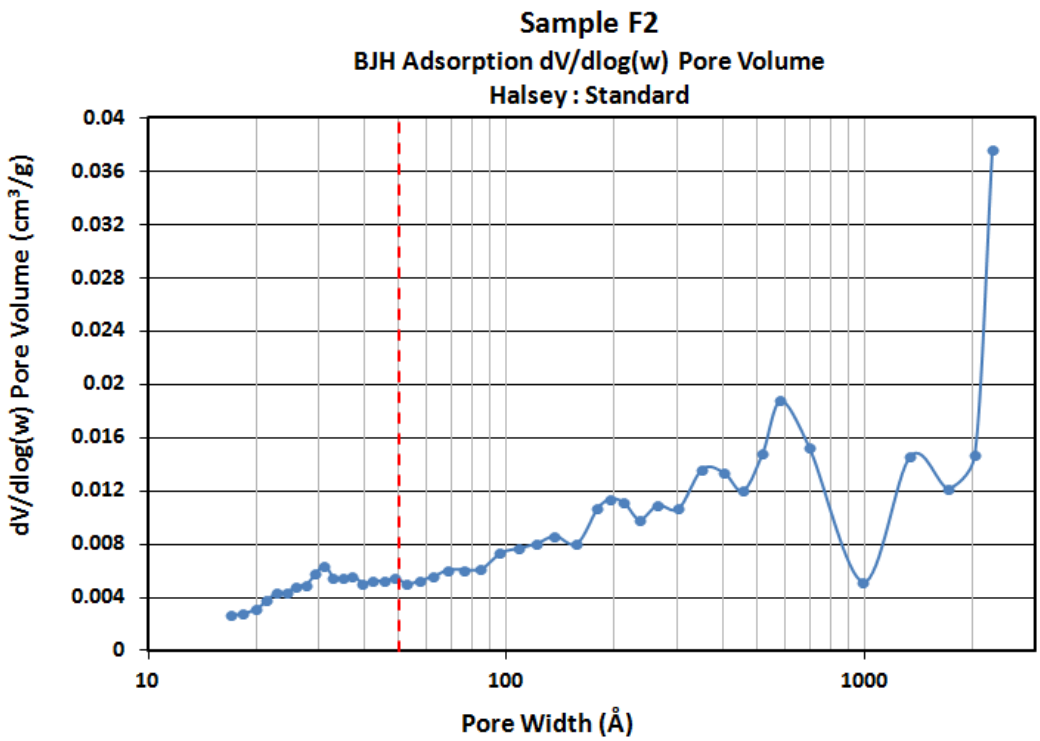

Figure 22: Pore size distribution for ICMI sample F2.

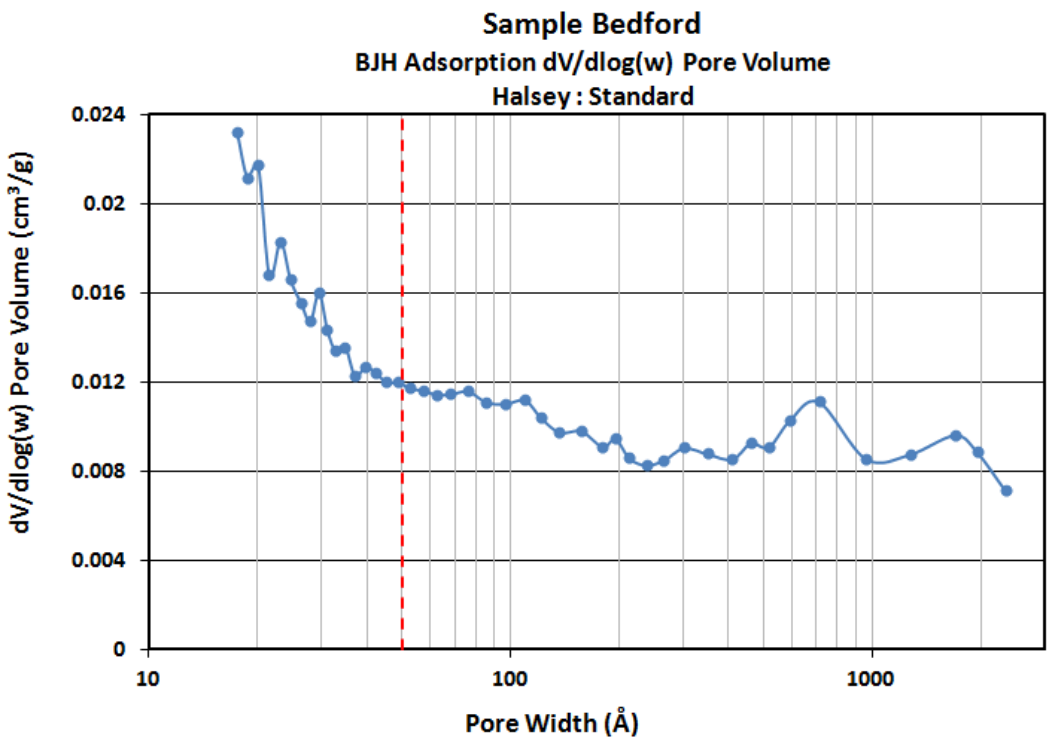

Figure 23: Pore size distribution for ICMI sample Bedford.

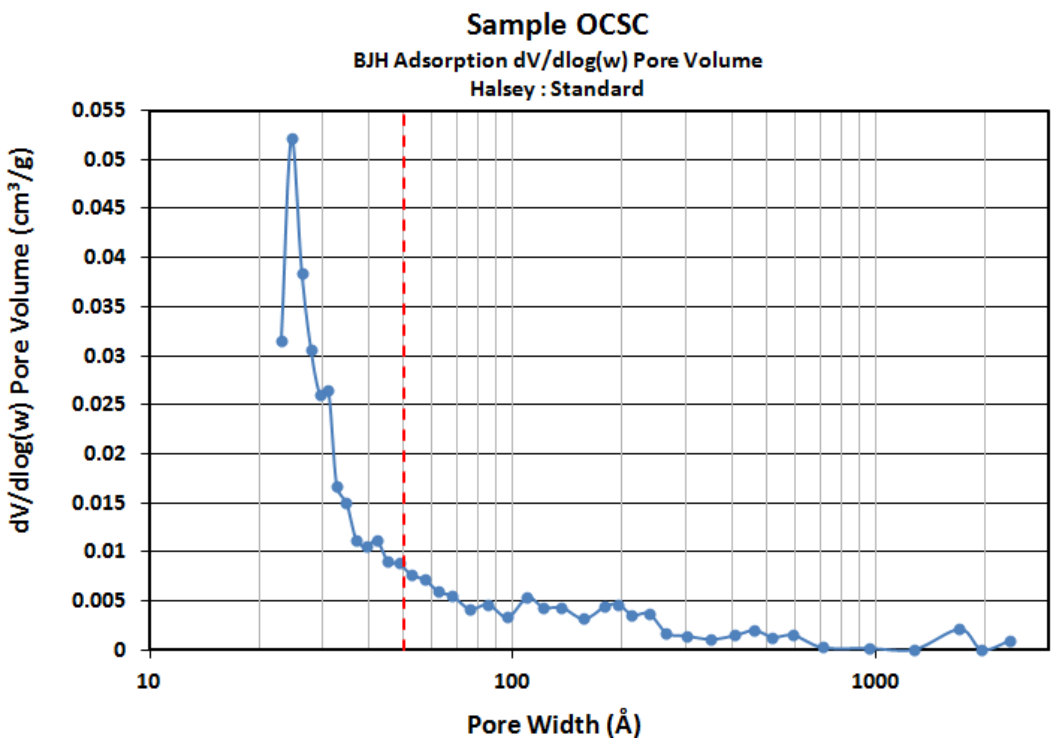

Figure 24: Pore size distribution for ICMI sample OCSC.

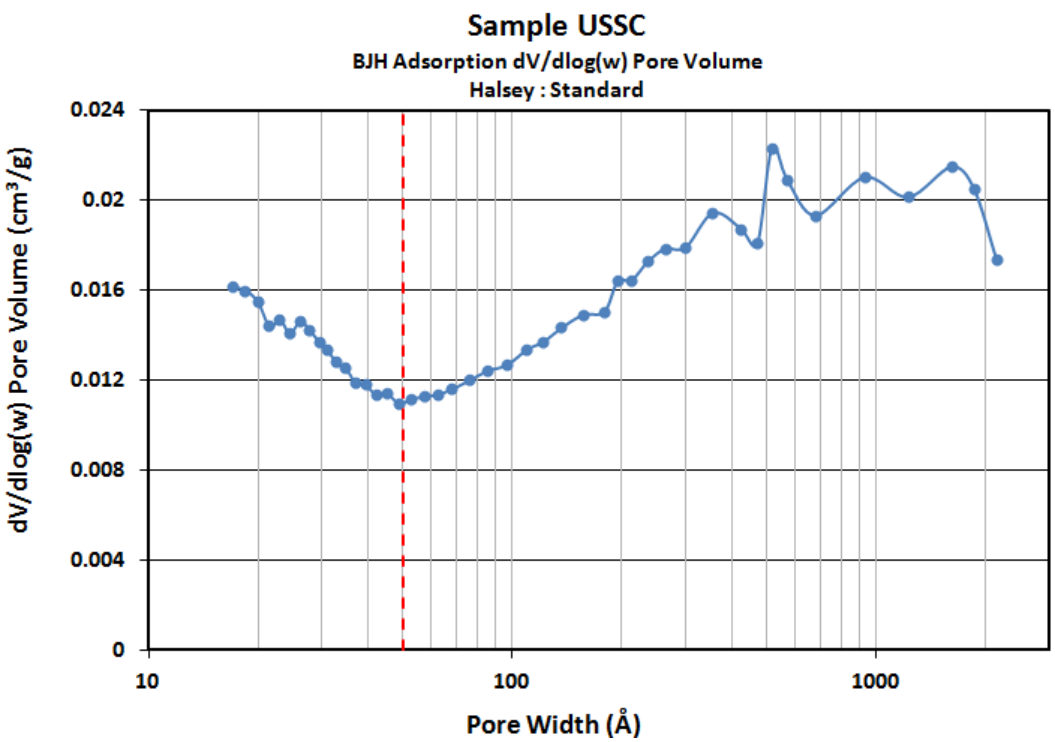

Figure 25: Pore size distribution for ICMI sample USSC.

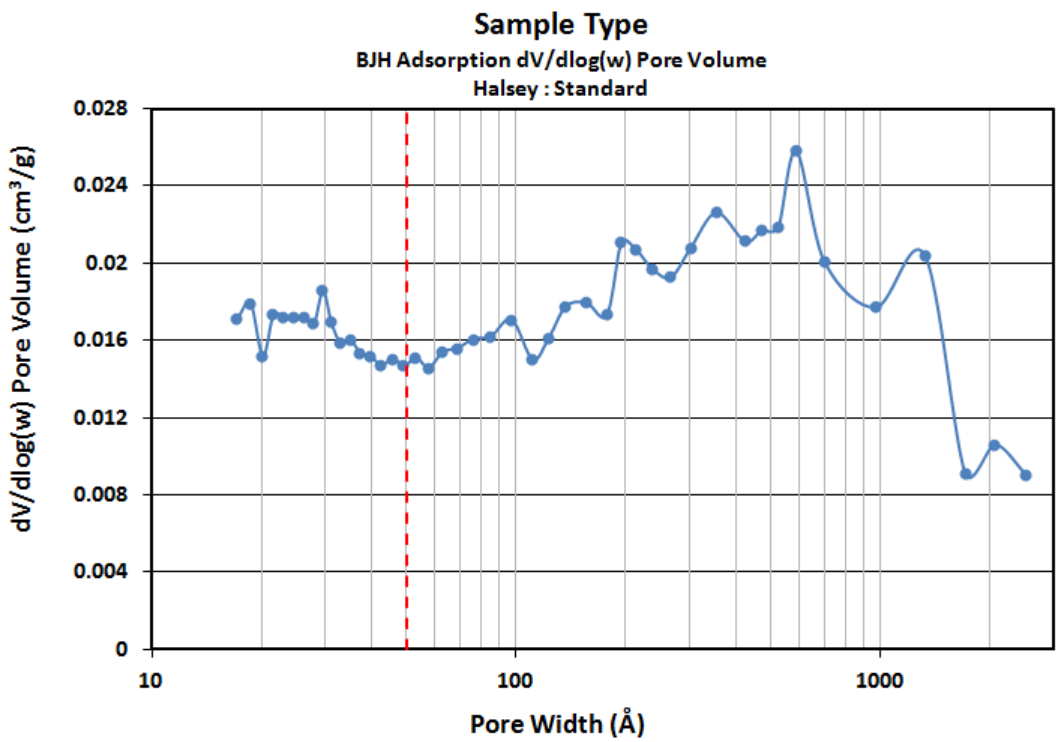

Figure 26: Pore size distribution for ICMI sample Type.

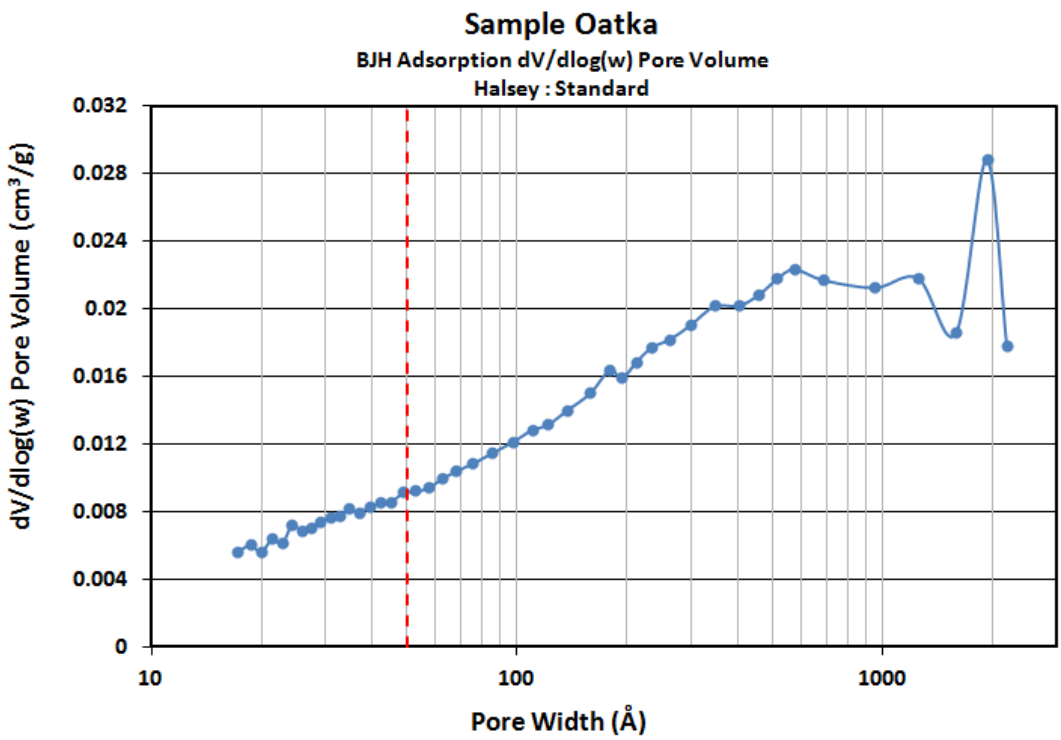

Figure 27: Pore size distribution for ICMI sample Oatka.

Mercury Intrusion Porosimetry and Pore Volume and Size Distribution (ISO 15901-1) - AutoPore IV 9500 (Automated Mercury Porosimeter)

Mercury intrustion porosimetry is a technique that provides quantifiable characterization of pore structure. The technique involves injecting non-wetting mercury into the sample using a porismeter; the pressure required is inversely proportional to the size of the pores. The resulting data set is used to calculate pore area and volume distributions according to size, total pore volume, total pore surface area, median pore diameter, and sample densities (bulk and skeletal). Micrometerics AutoPore IV Pore Size Analyzer provided an accurate data set for calculations.

The porosity of a material affects its physical properties and, subsequently, its behavior in its surrounding environment. The adsorption and permeability, strength, density, and other factors influenced by a substance's porosity determine the manner and fashion in which it can be appropriately used. Micrometerics AutoPore IV Pore Size Analyzer provided an accurate data set for calculations.

Micropore Surface Area Characterization (ISO 15901-2) - TriStar II 3020 (Surface Area Analyzer)

The Tristar® II 3020 uses the technique of gas adsorption to measure surface area and porosity measurements. Measurements on the Marcellus samples were performed using nitrogen adsorptive at 77.3°K.

3.2 SUMMARY OF RESULTS

The results of preliminary physical properties characterization by Micromeritics were of direct importance for planning the adsorption isotherm experiments awarded to the Weatherford Laboratories.

Grain densities of the samples range from 2.5 to 2.8. The higher density samples, F5-silty shale, F3-calcareous shale, F1-calcareous shale, F2-shaly limestone, reflect compositions higher in silicates and carbonates. Pyrite appears to be contributing to the high density of the Type sample as shown by relatively high sulfur and iron concentrations in the elemental analyses (Table 5).

Large meso- and macro-porosity (Figures 18 through 27) and large, >3 m^2, external surface areas (complementary results of the micropore surface area characterization, Table 9) were present in most of the sample powders from the < 100 mesh size samples. Accordingly, Weatherford used a more coarsely ground powder (>60 mesh as a general rule) for each sample to better represent the adsorption that could occur on grains of an intact sample. The micropore surface area and the grain density data are expected to be verified by the Weatherford Laboratories, which are complementary outcomes of the CO_2 adsorption isotherm and the helium void volume measurements respectively.

Comparison of the total porosity estimated from mercury (Hg) porosimetry (Table 9) and from combined grain/bulk density measurements (Figures 18 through 27) show differences for samples F1, F2, F3, F4, and F5. This suggests that the percent porosity calculated using the grain/bulk density data may introduce potential error in the bulk density measurements caused by slow equilibration in the relatively large in-tact samples used for this test. Other potential root causes of inconsistencies between the powder and in-tact sample data may include unrepresentative sample compaction of the particles and erroneous bulk volume data for the in-tact samples. In such cases, the percent porosity measured by Hg, is a better value to use.

Additional useful information provided by the Micromeritics Analytical Services (separate reports for each test) includes BJH[1] surface area of pores between 1.7 and 300-nm width, total volume of pores with <300-nm width, and the average pore size. However, the median pores size appears to be skewed by significant presence of large pores; a small shift in the large pore sizes can lead to potentially erroneous results.

[1] Barrett-Joyner-Halenda (BJH) Analysis - a pore size distribution determination method, which is typically applied to nitrogen desorption data measured at 77°K on mesoporous materials.

4. EXPERIMENTAL/CHARACTERIZATION PROGRESS: INTACT CORES AND PLUGS

4.1 PETROPHYSICAL ANALYSES – POROSITY, PERMEABILITY

Using the recently designed and built Precision Petrophysical Analysis Laboratory (PPAL) at West Virginia University (WVU), shale core samples were analyzed under steady-state conditions with representative reservoir net stress applied using a tri-axial core holder to apply confining stress on all three axes. The PPAL analysis unit is shown in Figure 28.

Figure 28: Precision Petrophysical Analysis Laboratory (PPAL).

Figure 29 is a schematic showing the layout of the PPAL components and their assembly. The core holders are the most essential components. The solid stainless steel core holders are positioned in the center of the unit to allow for even warming and to maintain a constant temperature. Core samples measuring approximately 1-in. diameter by 2.5-in. length must be placed in a sleeve made of Viton Synthetic Elastomer to protect them from the water that is used to apply confining pressure tri-axially; this is accomplished by one of the end caps of the core holder that floats and compresses the sample axially. An air-driven liquid pump (Haskel 4B Series) is used to pressure the water up to a maximum of 10,000 psi. The calibrated positive displacement pump is used for displacing gas into the system for volume measurements. Two tanks are used to store gas at upstream and downstream pressure. A number of control valves, electric actuators, and sensitive pressure and pressure differential transducers are utilized to automatically control the flow and monitor the pressures. The compact electric heaters,

programmable temperature controller, and circulation fans are mounted on the system to maintain a stable temperature within the PPAL enclosure. Data acquisition system, solenoid valves, relays, and a computer with the necessary software (LabView) are used to operate the system and collect the data.

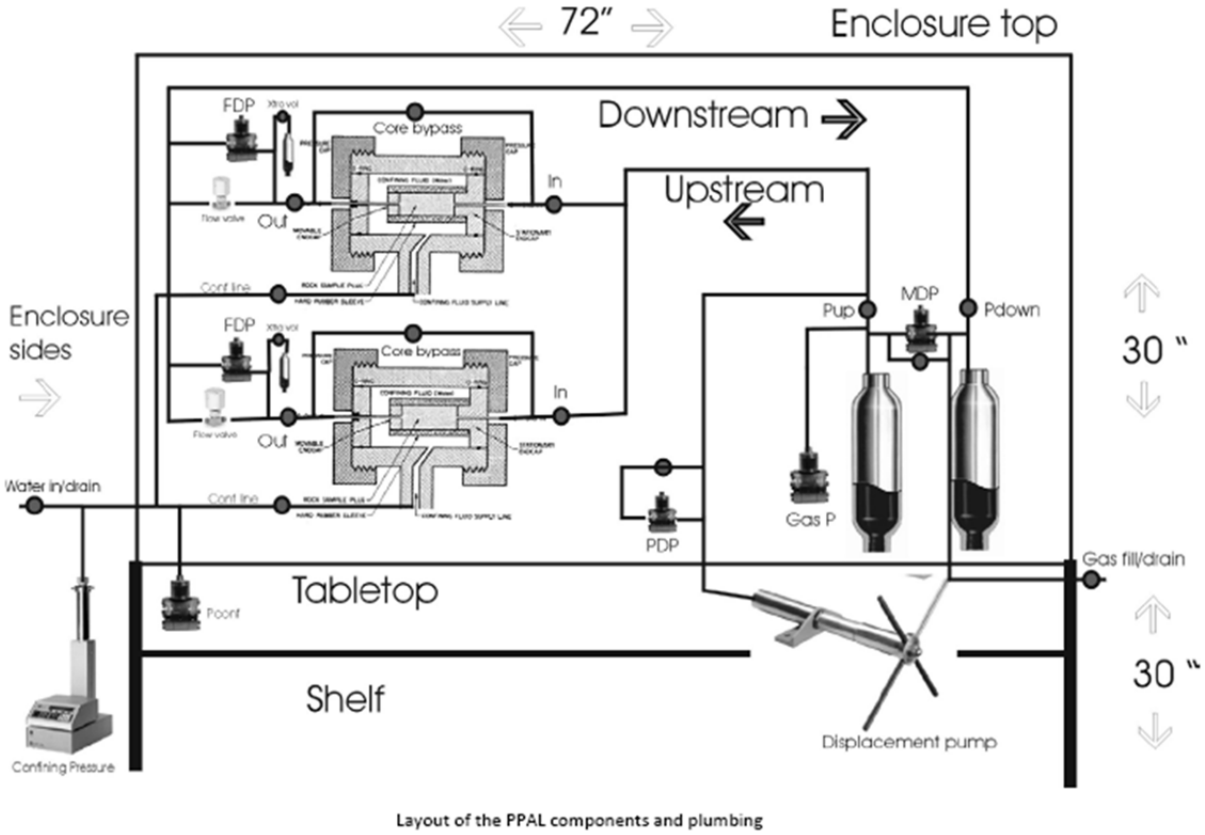

Figure 29: PPAL layout.

PPAL Operation

Initially, the blank steel core is placed in the core holder. The confining side is pressurized first. The water line is opened to allow water to pass through the confining pump and into the bottom of the core holders. The valves on top of the core holders are open until all the air is bled out. The top valves are then closed and the liquid pump is used to increase the confining pressure. Once the desired confining pressure is achieved, the valve downstream of the liquid pump is closed. This separates the pump from the cores, locking the confining pressure in the cores and transducer. The gas is then introduced into the reservoir tanks and to the rest of the system. The entire system is brought up to the desired downstream pressure. Then the valve between the two tanks is closed and the upstream tank is pressured up to the desired value (a maximum pressure differential of 30 psi). The PPAL unit is then enclosed. The heaters are turned on and the desired operating temperature is set. The unit is left un-interrupted for several days until the temperature stabilizes. Once brought up to the desired operating temperature, the gas pressures can be fine-tuned and adjusted back to the desired set points.

Leak Test

Because the PPAL is capable of measuring extremely small flow rates, it is imperative that the lines do not leak and are sealed tight. Snoop leak testing liquid was used to identify and repair leaks from 100 to 1,500 psi at 300 psi increments prior to sample testing.

Line Volume Measurements

Before any testing can begin, the line volumes must be measured. The volumes of the different sections can be measured using Boyle's Law and the sensitive differential pressure transducer. The entire gas line will be pressured to a desired pressure (600 psi). Then the valve at the start of the line is closed and the upstream and downstream tanks are isolated. The downstream tank is then bled off until 15 to 30 psi is observed on the main differential transducer between the tanks. The line is now at lower pressure. The last valve is then closed, isolating the line from the downstream tank. At this time the sensitive transducer is evenly pressured with the upstream pressure. The sensitive differential valve is then closed locking the high pressure on one side of the transducer. The valve at the start of the line is then opened releasing the high pressure into the line. The sensitive transducer will be reading full scale. Now the calibrated gas pump is used to pump gas back into the line on one side of the sensitive transducer. Once the sensitive transducer is back to zero, the volume of the displaced gas is the same as the volume of the line. This process can be repeated for each section of the line. This method, similar to that of the porosity measurement, uses steel blank cores installed in the core holders.

Core Preparation

The core samples were cut, trimmed, and smoothed to a size of 1-in. diameter by 2-in. length. The diameter and length of the samples were measured with the caliper. The plug was weighed. The samples were then placed into a relative humidity dryer at 60°C with 45% humidity in order to reach a baseline of water saturation. The samples were removed from the chamber often and weighed to track the changes over time. Over the course of a few days the samples reach a stable weight and are placed in sealed containers.

Loading the Core Sample

First, the fixed end of the core holder is removed. The solid end and the large rubber O-ring are lubricated with a thick, clean, petroleum jelly. The supplied rubber Viton sleeve is fit over the greased end. The core sample is then removed from the sealed container and placed in the Viton sleeve. Then, the floating end of the core holder is inserted into the Viton sleeve such that it comes in contact with the core sample. This assembly is then fitted into the core holder body. Both ends of the core holder can be screwed in completely. If necessary, a core holder wrench can be used to help seat the O-ring. Once the sample is loaded into the holders, the gas lines can be connected.

Porosity Measurement

The porosity of core samples is measured under in-situ conditions. The core sample is loaded into the cores holder and the system is pressurized to achieve the desired confining and gas pressure; then the system is enclosed to achieve the desired temperature. The core sample is at the upstream pressure. The core is then separated from the upstream side and the pressure is released from the lines to the downstream tank. The change in pressure can be observed on the sensitive differential pressure transducer. The volume of gas that has been released is the upstream line volume and the core pore volume. Then the calibrated gas pump is used to pump gas back into the lines and core until the sensitive transducer is once again balanced. Since the pump is calibrated the exact volume gas displaced back into the lines and core can be determined. The core pore volume can be determined by subtracting the line volume from the pumped volume.

Permeability Measurement

The permeability of the core sample is measured by introducing a pressure difference across the core sample to allow the gas to flow. Gas flows from the upstream tank, through the core, and into the small downstream line, which is separated from the downstream tank by an automated bellow valve. Over time, the pressure in the line builds up. The pressure difference between the line and the downstream tank is measured with an extremely sensitive pressure transducer. The transducer has a maximum differential limit of 0.5 psi. Once the pressure differential reaches 80% of transducer's full scale, or 0.4 psi, the automated bellow valve opens by a computer signal. This valve stays open just long enough for the line and downstream reservoir tank to reach pressure equilibrium (5 to 10 s). The valve is then closed and the pressure buildup is started over. PPAL is capable of measuring extremely low flow rates accurately. The flow rate is determined based on the previously measured volume of the section of the line. The data acquisition system records the pressure buildup in the line over time and the results are used to determine the permeability of the sample under the set conditions (temperature, confining pressure, pore pressure) and these can be averaged for a precise measurement.

Measurement Results

Marcellus shale outcrop core plugs were obtained for analysis. Table 10 summarizes the information on the core plugs. The porosity of all the samples was measured first. Table 11 summarizes the results of the porosity measurements. Of all the samples, only F2HA and F5HB had measurable permeability. Sample F5HB was fractured and accurate measurements could not be performed. Sample F2HA was utilized for detailed analysis. The permeability was measured first by increasing the net stress and then by decreasing the net stress. The results for permeability measurements on F2HA are summarized in Table 12. It should be noted that each run included at least 10 cycles. The value of permeability was calculated for each cycle and the minimum, maximum, and average values of permeability for each are tabulated. Figure 30 illustrates the impact of net stresses on the average permeability of Sample F2HA. The impact of net stress on porosity was also investigated. The results are summarized in Table 13 and are illustrated in Figure 31. In addition, the permeability of the sample to gas was measured under constant net stress for different gas pressures. The results are summarized in Table 14. The results were then utilized to perform the Klinkenberg analysis. Figures 32 and 33 illustrate the results of the Klinkenberg and modified Klinkenberg analyses, respectively (Klinkenberg, 1941).

Table 10: Core Plug Information

Sample	Location	Description
F2HA	Burlington, WV	WV facies 2: shaly limestone, horizontal plug
F2HB	Burlington, WV	WV facies 2: shaly limestone, horizontal plug
F4HA	Bedford, PA	WV facies 4: non-calc black shale, horizontal plug
F4HB	Bedford, PA	WV facies 4: non-calc black shale, horizontal plug
F4V3	Bedford, PA	WV facies 4: non-calc black shale, vertical plug
F4V4	Bedford, PA	WV facies 4: non-calc black shale, vertical plug
F5HA	Petersburg, WV	WV facies 5: silty gray shale, horizontal plug
F5HB	Petersburg, WV	WV facies 5: silty gray shale, fractured horizontal plug

Table 11: Porosity Measurement Results

Sample	Porosity (%)
F2HA	4.83
F2HB	0.33
F4HA	0
F4HB	0
F4V3	0
F4V4	0
F5HA	0.30
F5HB	3.87

Table 12: Sample F2HA Permeability Measurement Results

Run	Net Stress, psi			Permeability, nD		
	MIN	MAX	AVG	MIN	MAX	AVG
1	629.93	645.31	637.0	61.5	82.0	74.2
2	2534.1	2544.5	2538.6	52.3	61.2	56.8
3	3048.1	3072.1	3057.2	48.2	54.7	51.7
4	3567.4	3586.6	3575.9	46.0	51.4	48.5
5	4016.0	4033.1	4025.4	40.7	46.1	43.6
6	4557.7	4572.8	4564.7	37.8	44.2	40.3
7	3491.3	3498.6	3496.5	40.7	46.8	42.8
8	2468.2	2477.0	2472.9	42.5	48.7	44.5
9	2028.7	2041.2	2034.7	43.5	50.5	46.4
10	1516.9	1525.2	1520.6	46.6	53.2	50.0
11	1048.9	1058.4	1054.5	46.8	60.9	51.7

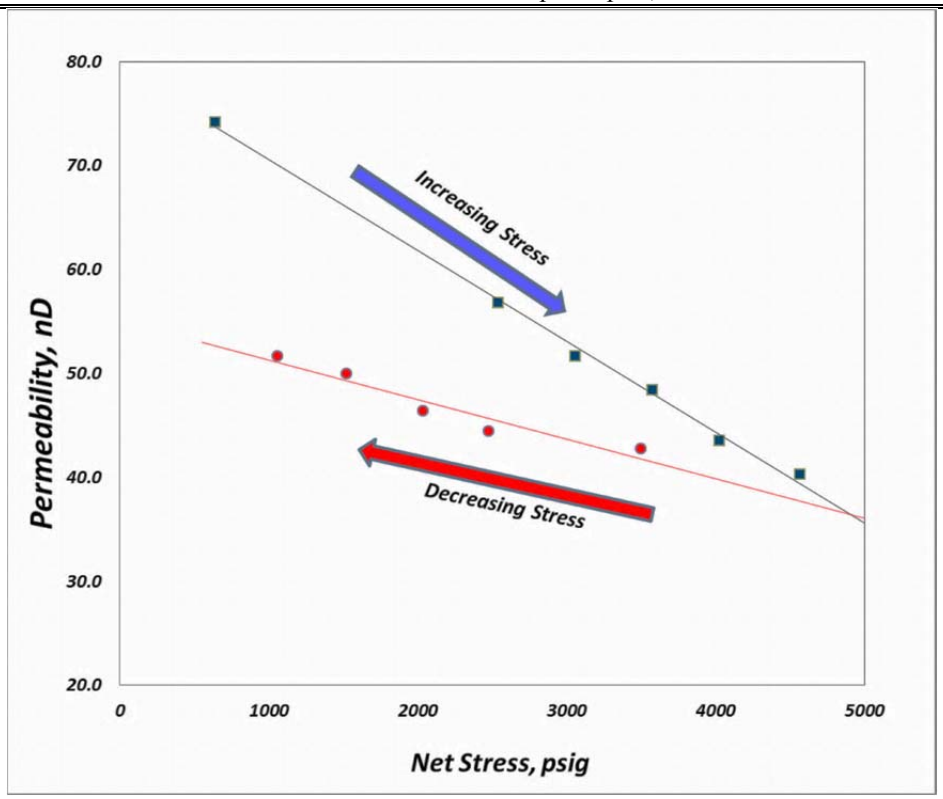

Figure 30: Effect of Net Stress on the average permeability of Sample F2HA.

Table 13: Sample F2HA Net Stress Effect on Porosity

Temperature °F	Net Stress psi	Porositypercent
83.6	613.1	4.83
84.0	3566.1	4.06
83.5	4574.4	3.84
83.6	3498	4.16
83.6	2469.23	4.32
83.6	2039.4	4.67
83.6	665.0	4.83

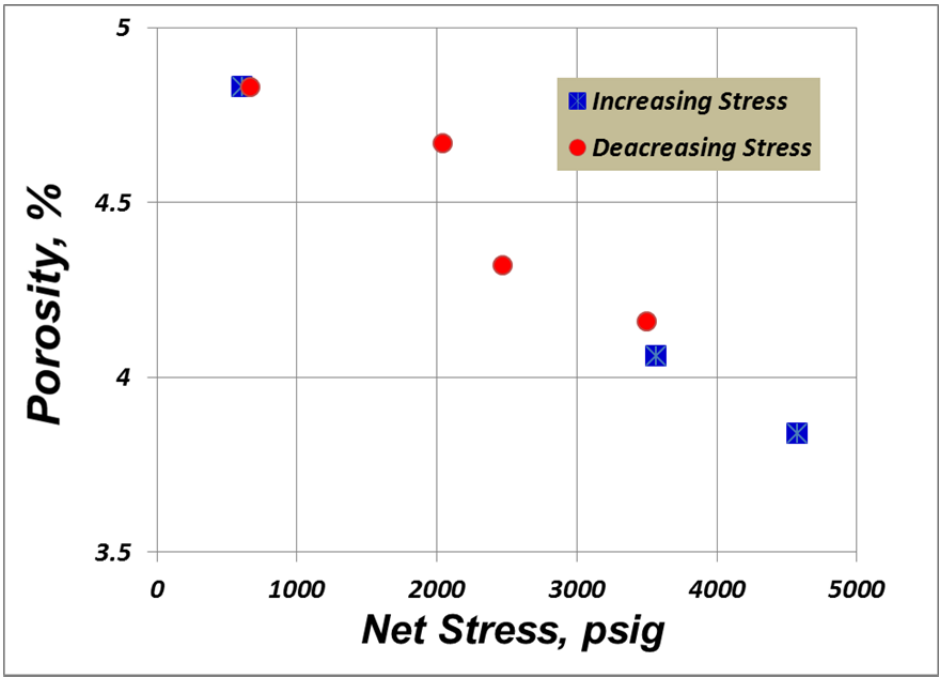

Figure 31: Effect of Net Stress on the Porosity of Sample F2HA.

Table 14: Sample F2HA Permeability Measurement Results for Different Pressures

Average Net Stress psi	Average Gas Pressure psia	Inverse of Pressure $psia^{-1}$	Average Permeability nD
3496.5	465.8	0.002146846	42.5
3503.4	520.3	0.001921821	36.6
3518.4	574.5	0.001740715	32.9
3497.5	636.2	0.001571798	29.9
3510.0	807.8	0.001237897	24.0
3525.3	1187.6	0.000842029	16.1

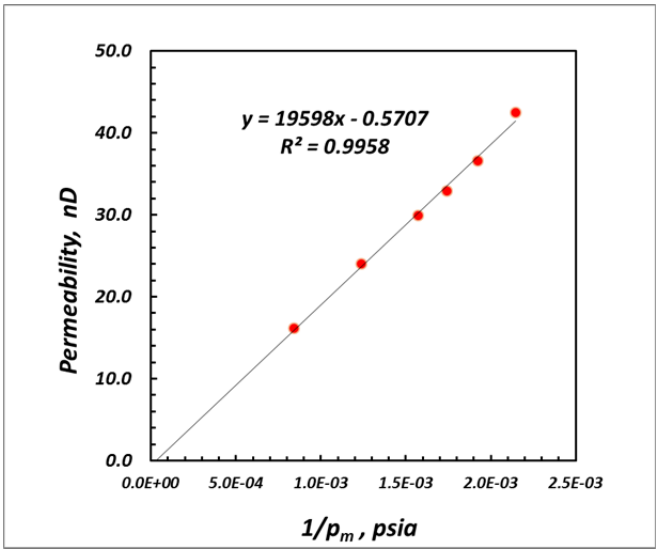

Figure 32: Traditional Klinkenberg Analysis for Sample F2HA.

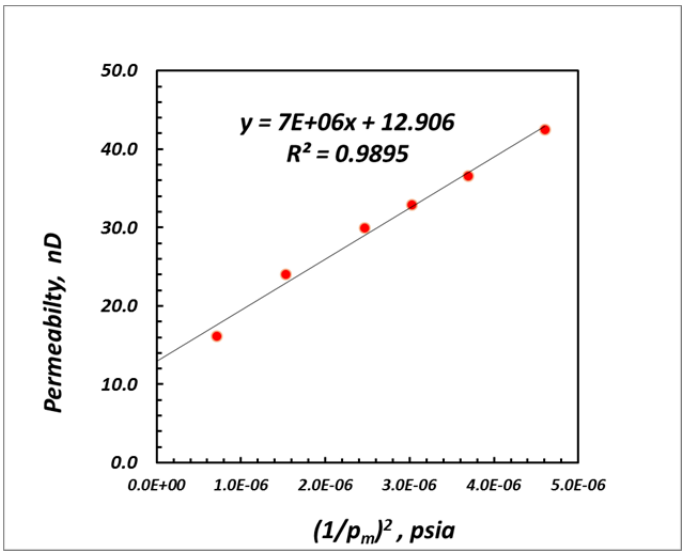

Figure 33: Modified Klinkenberg Analysis for Sample F2HA.

Summary

The results of permeability measurements demonstrate increasing net stress reduces permeability (Table 12, Figure 30). Increased stress has a smaller effect on porosity; an increase of ~4,000 psi results in a 1% porosity decrease. A reduction in stress results in only partial restoration of the permeability from 57 nanodarcies (nd) to 45 nd at ~ 2,500 psi, a reduction of 21% (Table 12, Figure 30). Porosity, however, is fully restored as net stress is removed. It can be postulated that the flow takes place through very small capillaries, or fractures, which do not contribute to porosity significantly.

The Klinkenberg analysis, as illustrated in Figure 32, results in a negative absolute permeability. This is not an uncommon result for shales and ultra-low permeability media. This result is

attributed to failure of Klinkenberg assumptions when the gas flows in extremely low permeability media. The revised analysis technique, as illustrated in Figure 33, provides more reasonable results. However, additional investigation is necessary to confirm these results.

4.2 PETROGRAPHY

Petrography is the microscopic examination of rocks that provides information on mineralogy, texture, and diagenetic (changes that occur as sediment becomes rock) features. A Nikon Optiphot-Pol® polarizing petrographic microscope was used for visual examination of the shale samples. The microscope was equipped with a Paxit® camera and software for digital photomicrograph documentation. Oblique reflectance and fluorescent microscopy was performed using the Leica M165® stereo microscope using the Leica Application Suite® software.

Polarized light petrography uses rock samples prepared into *thin sections*, thin slices that allow light to be transmitted through the sample. A thin sliver of the shale sample was cut with a diamond saw and ground optically flat. It was then mounted on a glass slide and ground smooth using progressively finer abrasive grit until the sample is 30 µm thick. The thin sections were then wedged, ground from 30 µm on one end to a feather edge on the other end, to allow for better light transmission though the clays. Thin sections were partially stained with Alizarin Red S and potassium ferricyanide to identify calcite, dolomite, and iron-rich carbonates.

Twenty-one thin section chips were cut from outcrop samples and were sent for sectioning for petrographic analysis (Table 15). Petrographic descriptions, mineralogy, and textural data were integrated with other analyses being performed on the samples.

Table 15: Thin Section Identification

Sample Suffix	Location	Thin Section ID	Lithology
F5	Petersburg, WV	F5HA, F5HB	Silty shale, dark gray to black, laminated
F3	Petersburg, WV	Marc3-A, Marc3-B	Calcareous black shale, laminated
F4	Whip Gap, WV	Marc4-A	Black shale
F1	Burlington, WV	Marc1-A, Marc1-B	Calcareous gray shale
F2	Burlington, WV	F2HA, F2HB, Marc2-A, Marc2-B	Shaly limestone, fossils
Bedford	Bedford, PA	F4HA, F4HB, F4V3, F4V4	Black shale
OCSC	Canoga/Seneca, NY	OatkaS-A, OatkaS-B	Black shale, laminated, fossils
USSC	Canoga/Seneca, NY	UnionS-A, UnionS-B	Black shale, fossils
Oatka	Le Roy, NY	OatkaL-A, OatkaL-B	Black shale, fossils

The following is a summary of the samples selected for thin sections and characteristic photomicrographs. All thin sections were made from field samples. Thin sections billets F5HA, F5HB, F4HA, F4HB, F4V3, F4V4, F2HA and F2HB were taken from core plugs drilled from field samples. Lithologic observations and descriptions were done using a standard hand lens.

Samples F5HA and F5HB

The rock is a dark gray to black silty shale with a moderate organic content. It is laminated, bioturbated, and contains pyrite, small fossils, and fossil fragments (Figures 34 through 36).

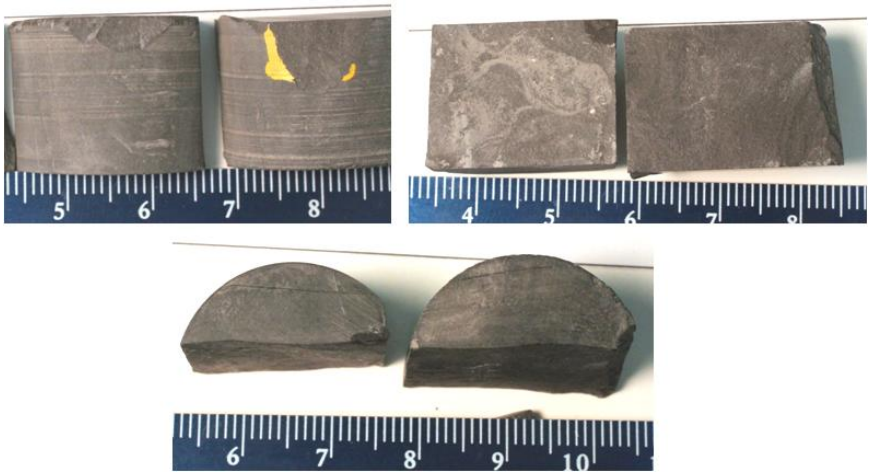

Figure 34: Views of remnant pieces of Core F5HA (scale in centimeters).

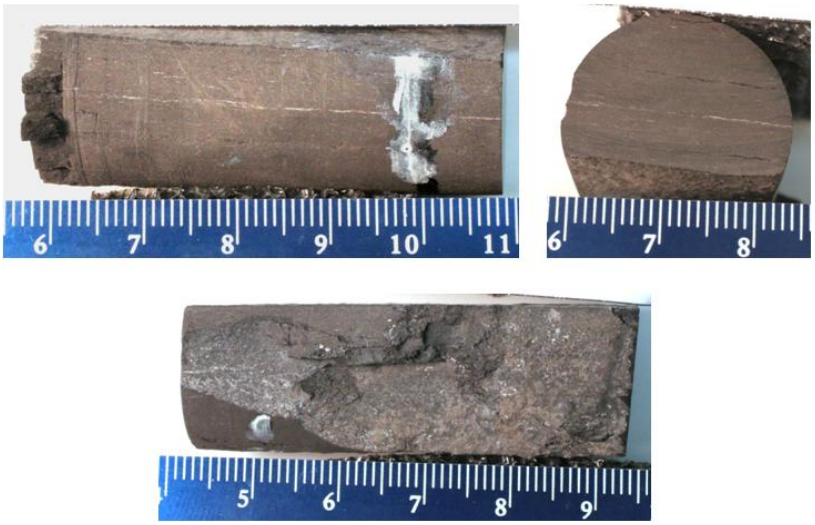

Figure 35: Views of remnant piece of Core F5HB (scale in centimeters).

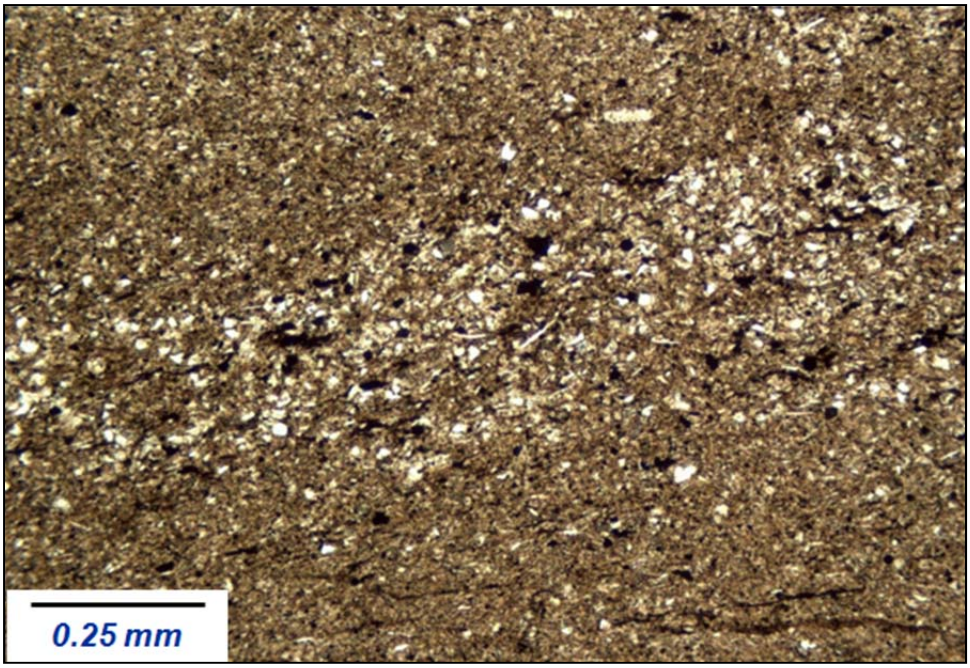

Figure 36: Silty shale, Petersburg, WV. Quartz silt is scattered in the sample and concentrated as lamine. Opaques are organic matter (thin, discontinuous, wavy) and pyrite (dots).

Samples F4HA, F4HB, F4V3, and F4V4

Samples F4HA, F4HB, F4V3, and F4V4 are non-calcareous black shales (Figures 37 through 41). The samples are laminated and contain silt and fine-grained, disseminated pyrite. Red and yellow weathering oxides are observed on the surface. A subvertical fracture filled with oxides and carbonate was observed in sample F4HB. Samples F4V3 and F4V4 are slightly fossiliferous.

Figure 37: Remnant piece of Core F4HA (scale in centimeters).

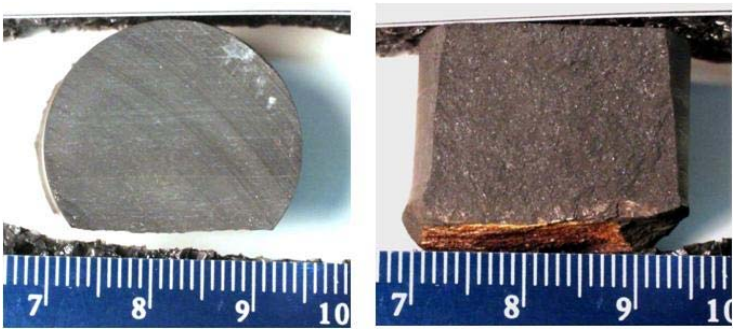

Figure 38: Remnant piece of Core F4HB (scale in centimeters).

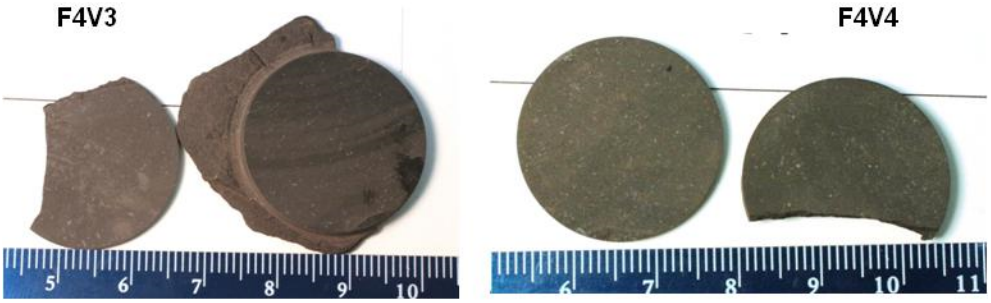

Figure 39: Remnant pieces of Cores F4V3 and F4V4 (scale in centimeters).

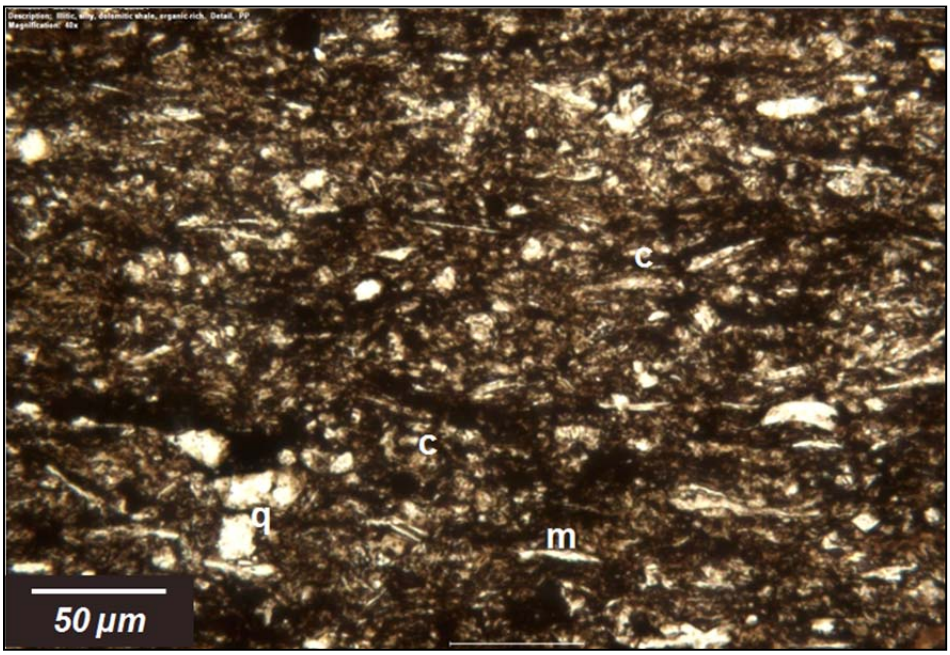

Figure 40: Black shale, Bedford, PA. Black shale with scattered quartz silt, fossil fragments, and pyrite. Bioturbation has redistributed organic matter. Micas (m), quartz (q).

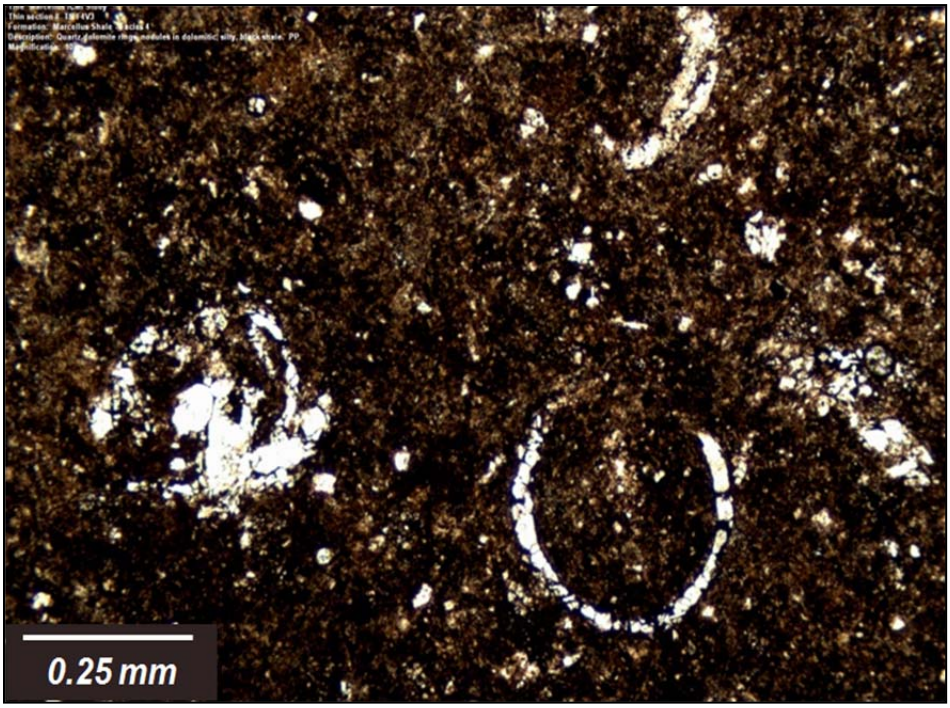

Figure 41: Black shale, Bedford, PA. Slightly fossiliferous black shale. Siliceous fossils, quartz silt, organic matter, and pyrite.

Samples F2HA and F2HB

Cores F2HA and F2HB are shaly limestones with low organic content (Figures 42 through 44). F2HA is a gray to yellowish laminated, crystalline, silty to shaly limestone with small amounts of disseminated pyrite. Fractures are filled with carbonate. F2HB is from the same sample and is a fossiliferous shaly limestone. Pyrite is concentrated as laminae and has replaced fossils.

Figure 42: Remnant pieces of core F2HA (scale in centimeters).

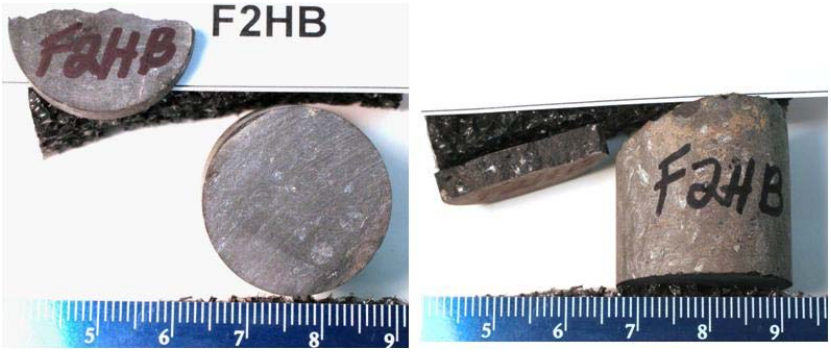

Figure 43: Remnant pieces of Core F2HB (scale in centimeters).

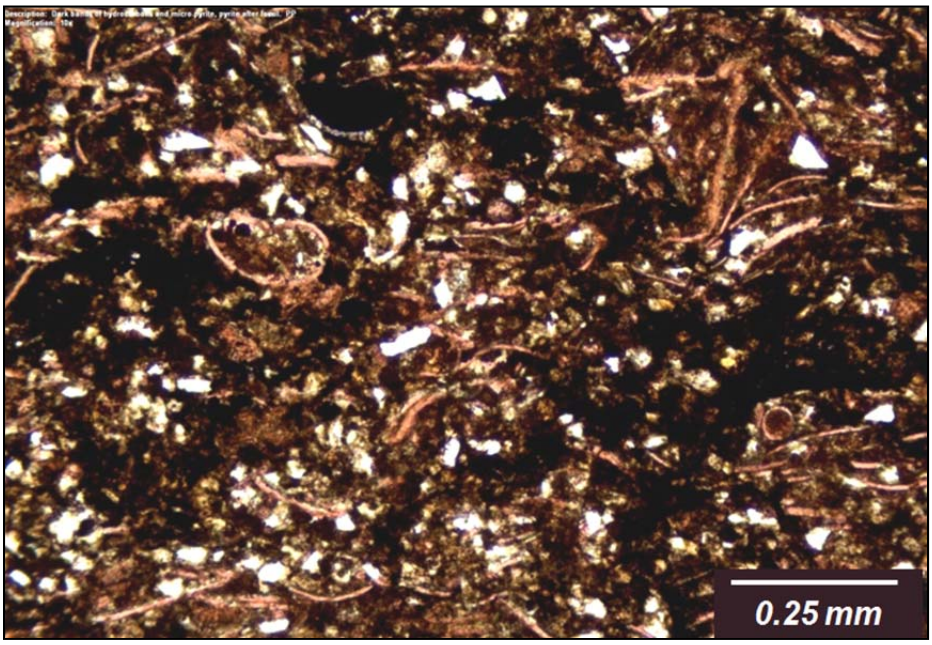

Figure 44: Shaly limestone, Burlington, WV. Fossil fragments in a matrix of quartz silt, pyrite, and organic matter. Random fossil orientation and concentrations of organic matter suggests bioturbation. Sample stained with Alizarin Red S.

Sample OCSC

Sample OCSC is a fossiliferous, dark gray to black, calcareous shale displaying large molds of brachiopod shells and shell fragments of brachiopods and other fossils (Figures 45 and 46). Laminae are lenticular and wavy. Pyrite is concentrated along laminae.

Figure 45: Sample of the Oatka Creek Member from the Seneca Quarry, New York.

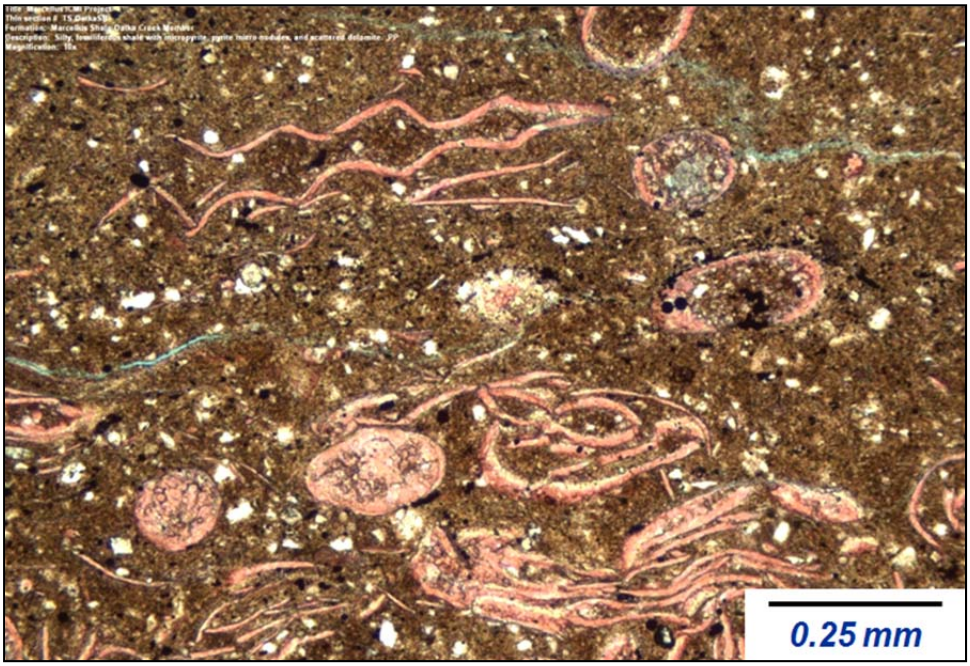

Figure 46: Fossiliferous black shale, Canoga/Seneca, NY. Abundant fossil fragments disseminated in shale matrix. Sample stained with Alizarin Red S.

Sample USSC

Sample USSC (US Union Sp – Seneca) is a very dark gray to black fossiliferous calcareous shale. The rock is thinly laminated and contains disseminated pyrite (Figures 47 and 48).

Figure 47: Sample of the Union Spring Member from the Seneca Quarry, New York.

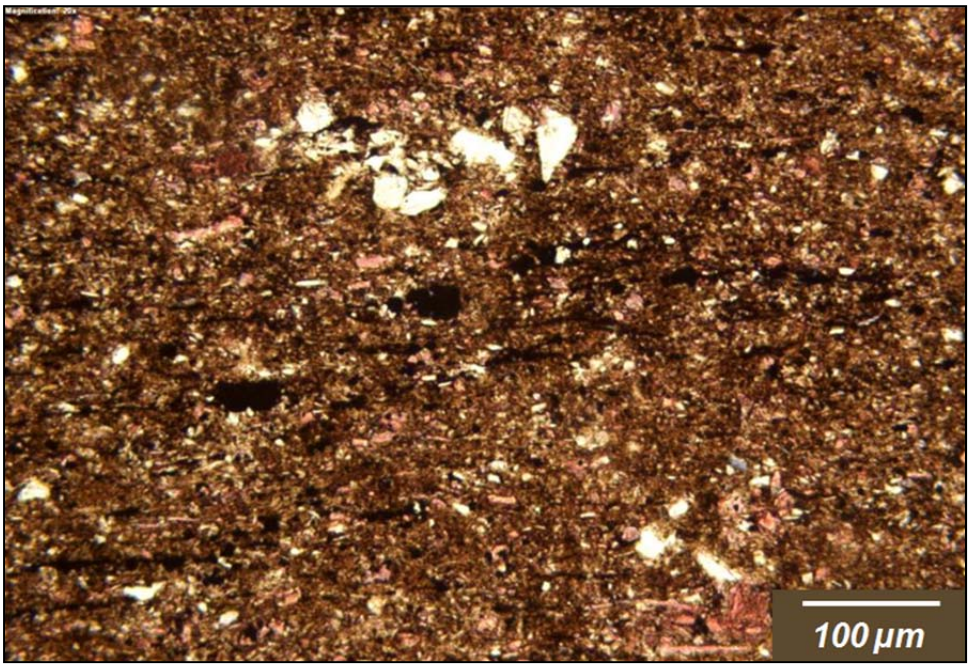

Figure 48: Calcareous black shale, Canoga/Seneca, NY. Disseminated, finely crystalline calcite and shell debris gives the sample a red tint. Opaques are organic matter and pyrite. Concentration of quartz silt (top center). Sample stained with Alizarin Red S.

Sample Oatka (OC Oatka Ck – Leroy)

Sample Oatka (OC Oatka Ck – Leroy) is a black to dark gray, non-calcareous, pyritic shale, thinly laminated, with abundant spots of a black mineral. Limonite is present on a fracture surface along laminae (Figures 49 and 50).

Figure 49: Samples of the Oatka Creek Member from Leroy, NY (scale in centimeters).

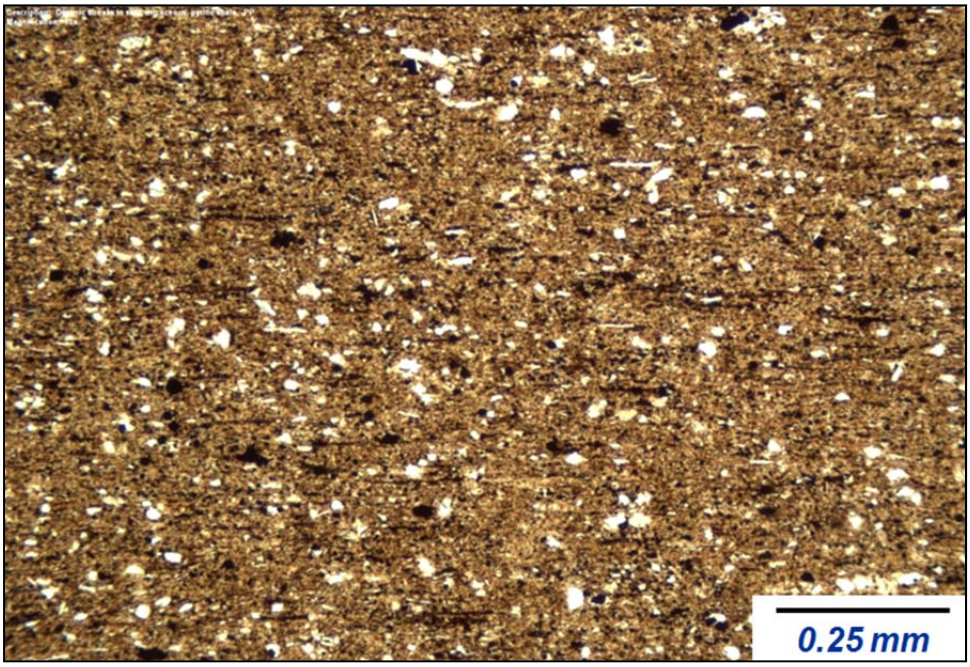

Figure 50: Non-calcareous shale. Disseminated quartz silt (white) and opaques (organic matter - thin stringers, pyrite - black spots) in a clay matrix.

Photo-documentation

Photographs of hand samples and core plugs were taken with incandescent light; many have a reddish hue and photo-enhancing often left a blue background in shadows. No attempt was made to re-photograph the samples. A more complete set of these photographs are available upon request.

4.3 X-RAY COMPUTED TOMOGRAPHY (CT)

Computed tomography (CT) scanning is the process of obtaining large numbers of two-dimensional images of an object and reconstructing the images into a three-dimensional digital representation of that object. The internal structure of the object is shown by variations of X-ray attenuation, which closely relates to density and atomic composition. In reservoir core analyses X-ray CT is commonly used in the study of porosity because it images the high contrast between

solid materials and liquids or gases. In addition, because the imaging is non-destructive, it is ideal for collaborative studies because the same sample can be analyzed with a different technique. X-ray CT results are generally combined with traditional techniques, such as optical microscopy and scanning electron microscopy for interpretation.

CT scans were performed on a North Star Imaging Industrial scanner using North Star Imaging's efX CT software. Exported raw data were converted to 16 bit tif images, and analyzed using the National Institutes of Health software ImageJ. The volume pixel (voxel) resolution of the reconstructed images is 31.2 µm. However, the pore space within the shales studied is far below this detection threshold. Thus, the analyses focuses on "large scale" variations within the cores such as changes in the bulk CT number (a proxy for changes in density), presence of minerals within the shale, and the location and orientation of fractures and bedding planes.

One-inch diameter core plugs were drilled in pre-determined directions perpendicular and parallel to bedding. Figures 48 through 85 are photos of outcrop samples from which core plugs were taken and their corresponding CT scans. Eight representative core plugs from three facies were CT scanned to obtain an understanding of the internal geometry of these shales. The unscanned samples were similar to the scanned samples, and while there would be small differences between natural samples from the same facies, it was decided that duplicating the effort of scanning multiple sub-cores would not yield a substantial extra amount of useful information. Samples F5, F4, and F2 were scanned and results are summarized below.

4.3.1 Sample F5 - Silty gray shale

Field samples showing core plug locations (Figure 51).

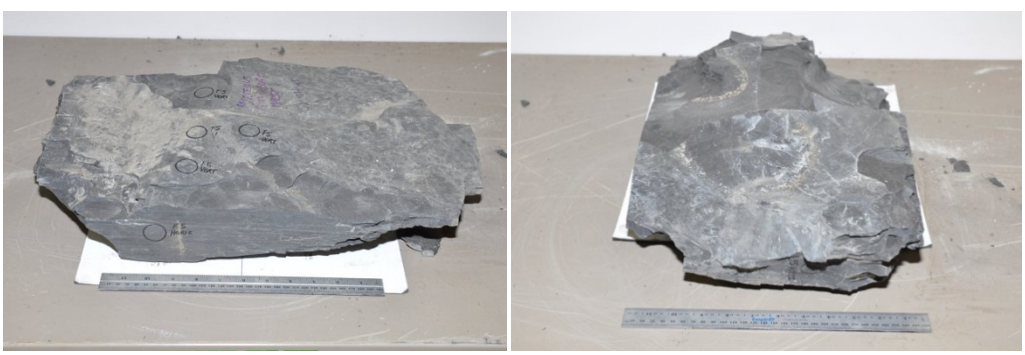

Figure 51: F5 Silty gray shale prior to coring.

Sample F5HA – Sub-perpendicular to bedding

Figures 52, 53 and 54 are false color CT scan images with core orientation sub-perpendicular to bedding. Purple, red, and orange indicate lower density constituents. Yellow and white indicate higher density constituents. This is a silty gray shale. XZ slices show indeterminate, irregular, lower density areas. XY slices display discontinuous, subhorizontal, wavy, lower density, sharply defined lines, which may indicate laminae or partings.

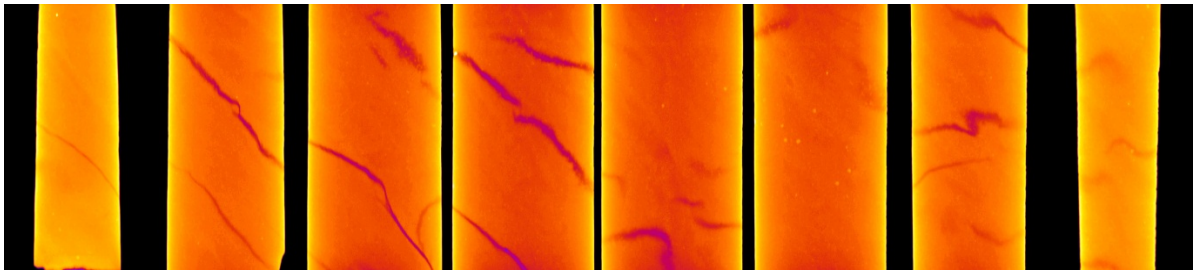

Figure 52: Montage of XZ slices through F5HA.

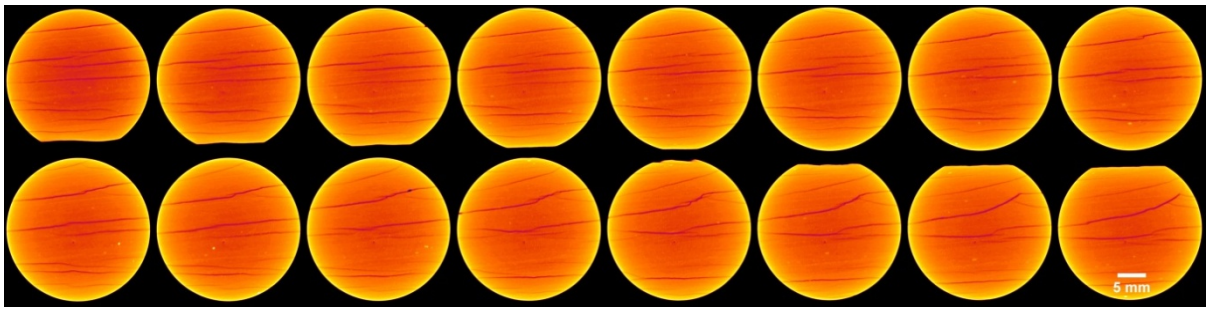

Figure 53: Montage of XY slices through F5HA.

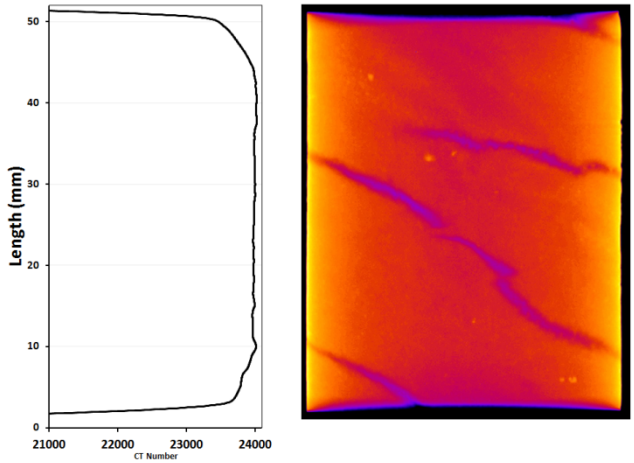

Figure 54: Bulk CT number log for F5HA. The highly consistent density profile is partially due to the bedding being at a steep angle to the length of core.

Sample F5HB – Sub-parallel to bedding

Figures 55, 56, and 57 are resultant scans of the silty, non-calcareous, gray shale and are false color CT scan images. Core orientation is sub-parallel to bedding. Purple, red, and orange indicate lower density constituents. Yellow and white indicate higher density constituents.

Laminae of lower density material are discontinuous, distorted, and irregular in XZ slices. The darkest purple area may indicate void space such as a fracture. Sub-parallel fractures, oriented at

approximately 50° are filled with higher density material. XY slices show low density, discontinuous, wavy, and distorted laminae/partings.

XY slices display discontinuous, subhorizontal lower density, sharply defined lines which may indicate laminae or partings. Healed irregular fractures cut the bedding planes.

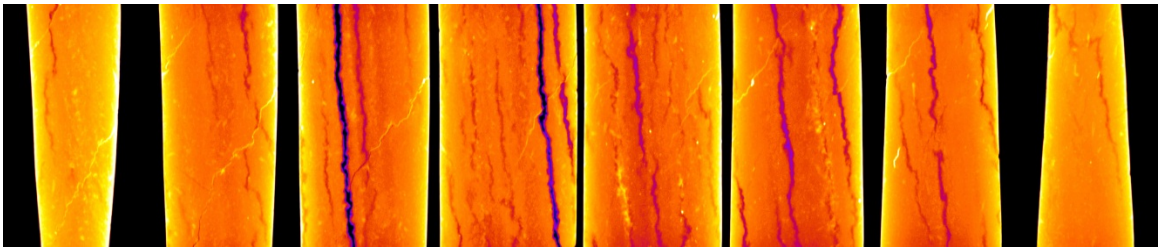

Figure 55: Montage of XZ slices through F5HB.

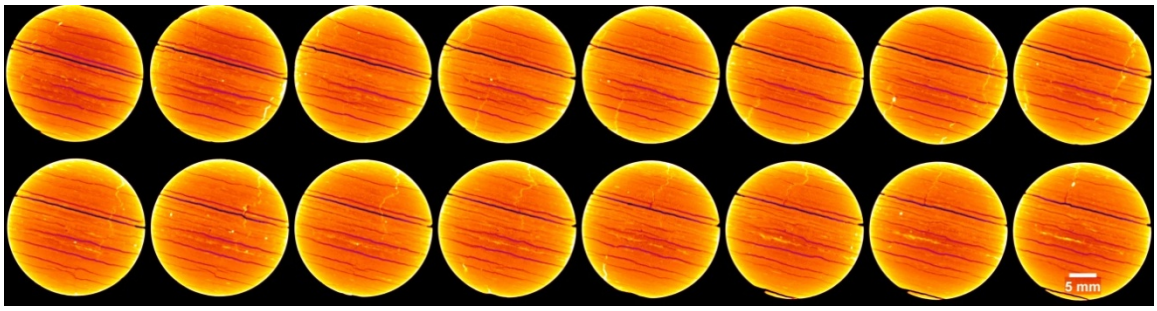

Figure 56: Montage of XY slices through F5HB.

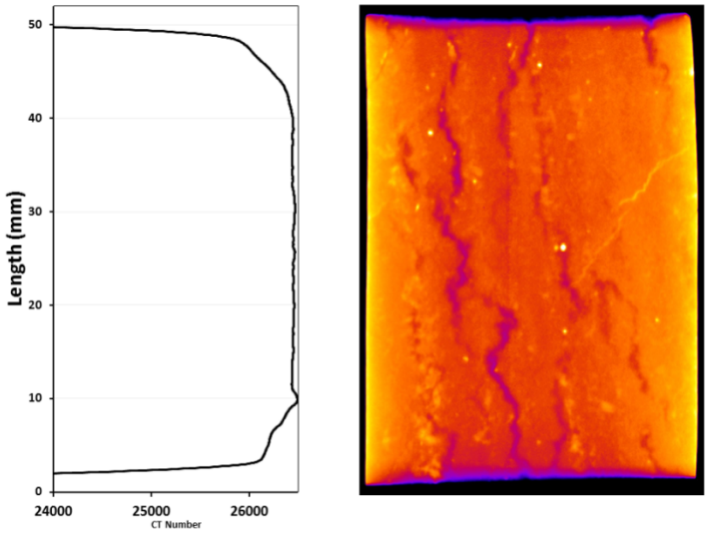

Figure 57: Bulk CT number log for F5HB. The highly consistent density profile is partially due to the bedding being vertical to the length of core.

4.3.2 Sample F4 – Non-calcareous black shale

Field samples showing core plug locations (Figures 58 and 59).

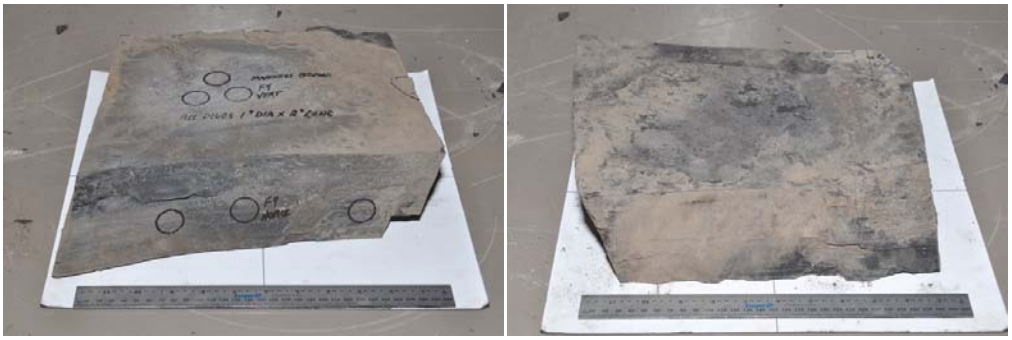

Figure 58: F4 Sample #1, Non-calcareous black shale prior to coring.

Figure 59: F4 Sample #2, Non-calcareous black shale prior to coring.

Sample F4HA - Parallel to bedding

Sample F4HA is a non-calcareous black shale. The core plug orientation occurs sub-parallel/parallel to bedding (Figure 60).

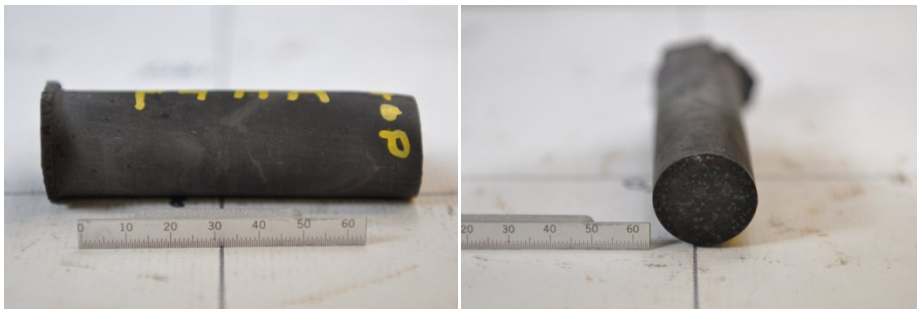

Figure 60: Photographs of F4HA prior to trimming on end.

Figure 61, 62 and 63 are resultant scans of a non-calcareous black shale and are false color CT scan images. Purple, red, and orange indicate lower density constituents. Yellow and white indicate higher density constituents.

Core plug orientation is parallel to bedding. Purple lines in both the XZ and XY slices indicate lower density materials that form the laminae. Small accumulations of denser materials are shown as bright dots that may be aligned with laminae. The sample is very lithologically homogenous. The darker purple band running through the middle of the core is a lower-density lamina.

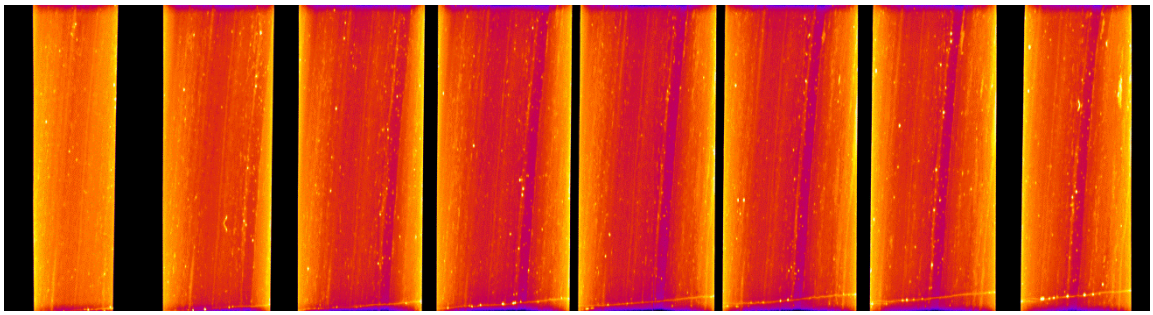

Figure 61: Montage of XZ slices through F4HA.

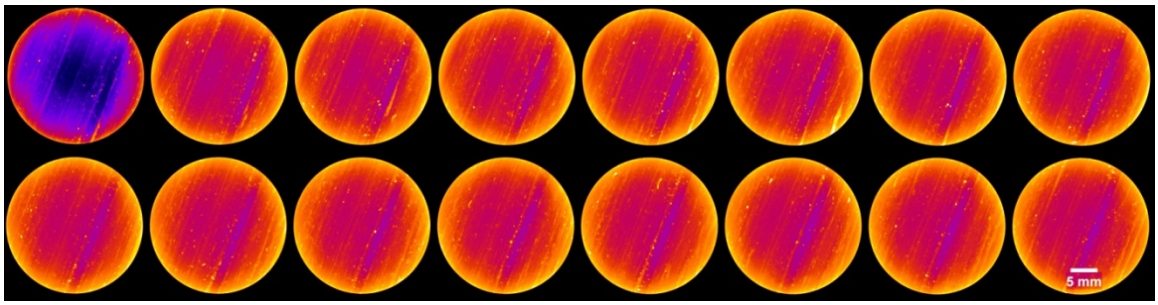

Figure 62: Montage of XY slices through F4HA.

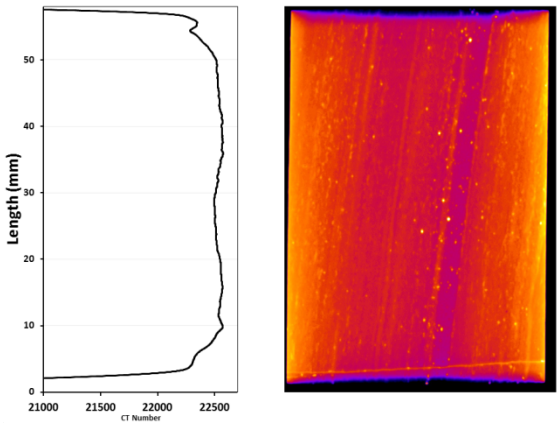

Figure 63: Bulk CT number log for F4HA. The homogenous nature of the sample.

Sample F4HB - 45 degree angle to bedding

Sample F4HB is a non-calcareous black shale, with core plug orientation approximately at a 45 degree angle to the bedding planes (Figure 64)

Figure 64: Photographs of F4HB prior to trimming on end.

Figure 65, 66, and 67 are false color CT scan images. Purple, red, and orange indicate lower density constituents. Yellow and white indicate higher density constituents. XY slices clearly display laminations of alternating lower and higher density materials. Higher density white spots are scattered and concentrated slightly along laminae.

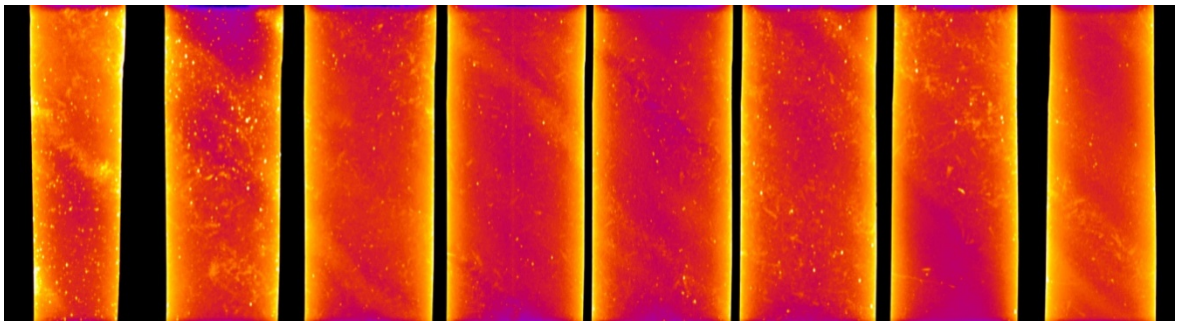

Figure 65: Montage of XZ slices through F4HB.

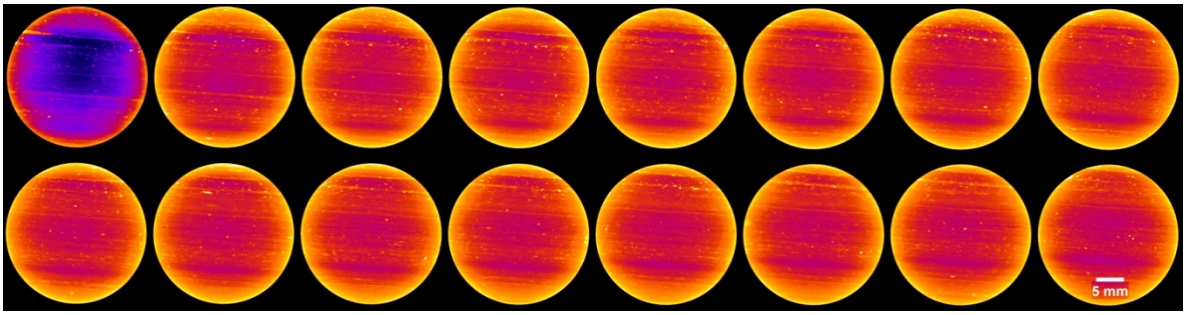

Figure 66: Montage of XY slices through F4HB.

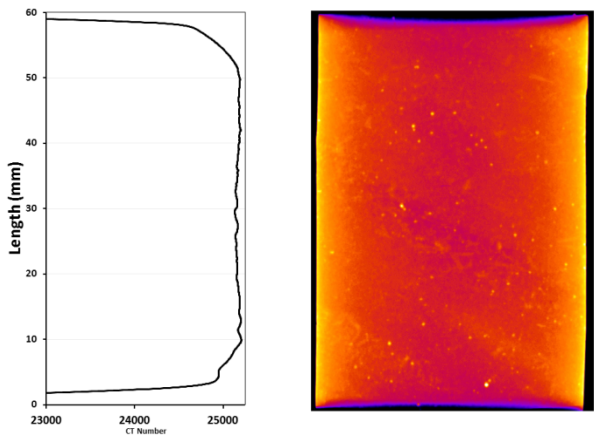

Figure 67: Bulk CT number log for F4HB, XZ slice. Scattered heavy mineral grains, high angle bedding, and a very uniform density profile.

Sample F4V3 – Perpendicular to bedding

Sample F4V3 is non-calcareous black shale with core plug orientation perpendicular to the bedding (Figure 68).

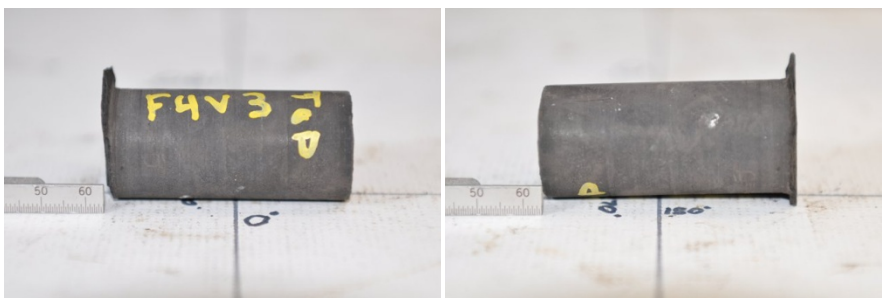

Figure 68: Photographs of F4V3 Non-calcareous black shale prior to trimming on end.

Figures 69, 70 and 71 are false color CT scan images. Purple, red, and orange indicate lower density constituents. Yellow and white indicate higher density constituents. Laminae with small concentrations of higher density material are shown.

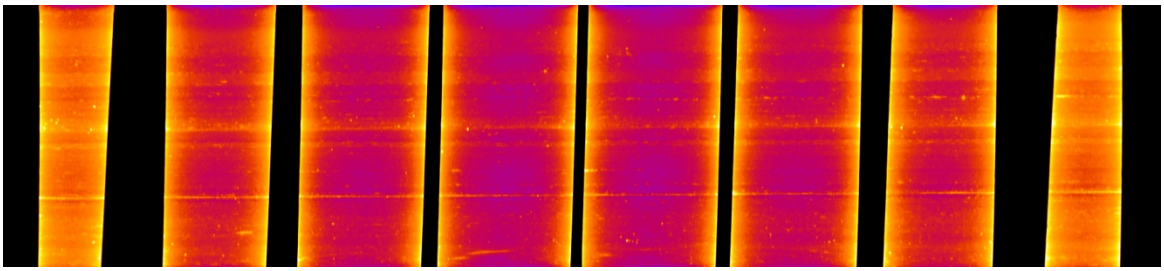

Figure 69: Montage of XZ slices perpendicular to bedding.

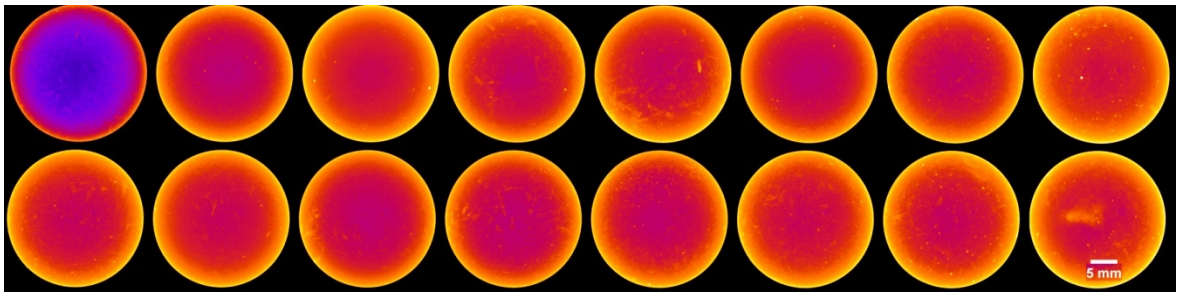

Figure 70: Montage of XY slices parallel to bedding planes.

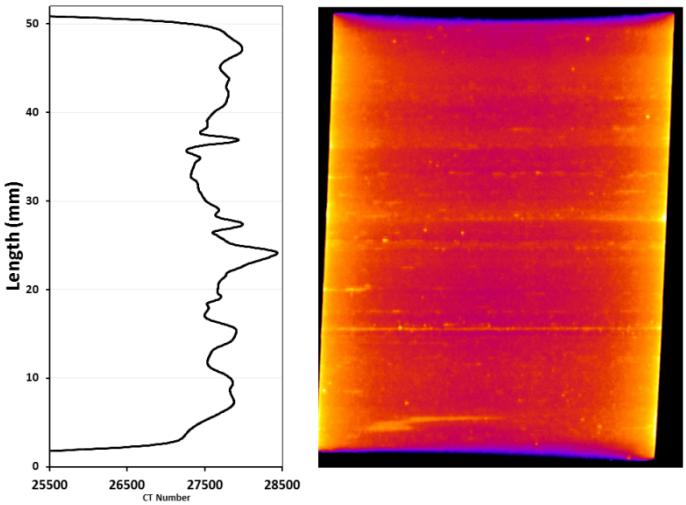

Figure 71: Bulk CT number log for F4V3, XZ slice. Bedding is horizontal. Accumulations of heavy minerals along bedding planes result in variable CT numbers.

Sample F4V4 – Perpendicular to bedding

Sample F4V4 is a non-calcareous, black shale (Figure 72).

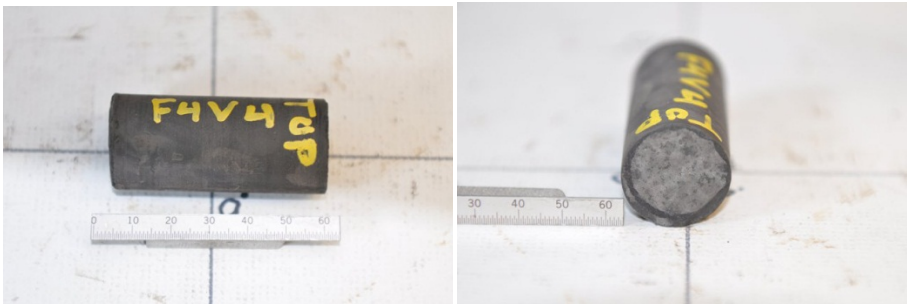

Figure 72: Photographs of F4V4 non-calcareous black shale after trimming on end.

Figures 73, 74, and 75 show false color CT scan images with core orientation perpendicular to the bedding. Laminae of alternating lower and higher denser constituents are clearly visible in XZ slices. XY slices, parallel to bedding, are homogenous.

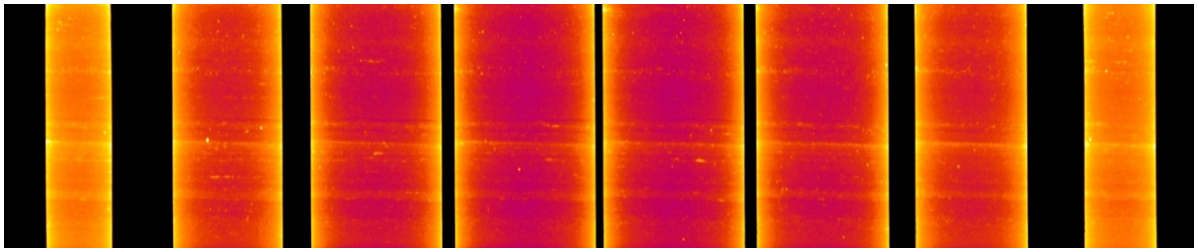

Figure 73: Montage of XZ slices. Orientation perpendicular to laminae.

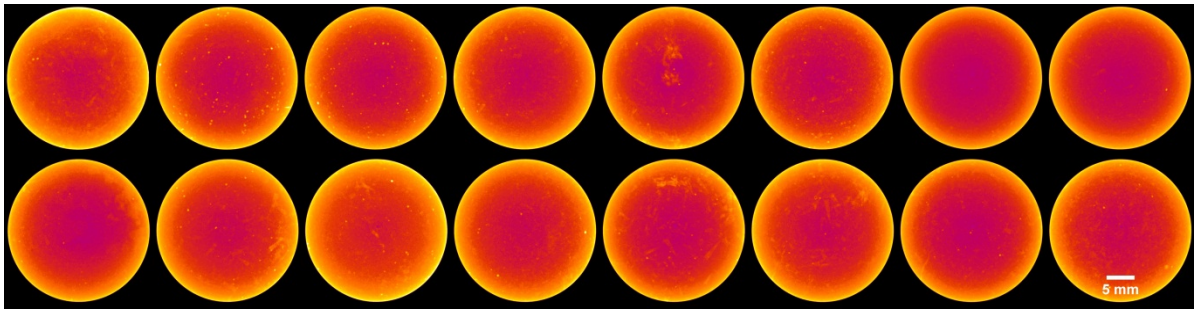

Figure 74: Montage of XY slices parallel to laminae.

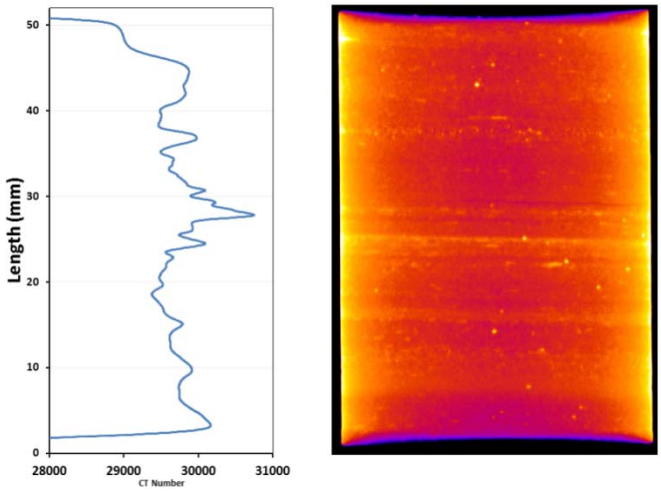

Figure 75: Bulk CT number log for F4V4, XZ slice. Due to the bedding being almost exactly perpendicular to the core length, the accumulations of heavy minerals along bedding planes result in variable CT numbers.

4.3.3 Samples F2HA, F2HB – Shaly limestone

Samples F2HA and F2HB are shaly limestone. Figures 76 and 77 indicate field samples with core plug locations.

Figure 76: F2 Sample #1 shaly limestone prior to coring.

Figure 77: F2 Sample #2 shaly limestone prior to coring.

Sample F2HA - Perpendicular to bedding

Sample F2HA below shows a core plug cut perpendicular to bedding from F2 (Figure 78).

Figure 78: Photographs of F2HA shaly limestone core plug prior to trimming on the end.

Figures 79, 80, and 81 indicate shaly limestone and are false color CT scan images. Purple, red, and orange indicate lower density constituents. Yellow and white indicate higher density constituents. Parallel orientation of the white (higher density) material suggests bedding. Small white dots are scattered throughout. In the Marcellus shale, clastic constituents and authigenic minerals of higher density than clays (2.6-2.8 gm/cm^3) and organic matter (<2.0) are feldspar (2.5–2.7), quartz (2.65) carbonate fossil fragments (~2.7), dolomite (2.8), siderite (3.9), and pyrite (5).

An open-centered ring is visible in the second of the XZ slices. The mottled appearance of orange and red areas (concentrations of lower density materials) is consistent with the concentration of clays and organics during reworking of sediments by burrowing organisms.

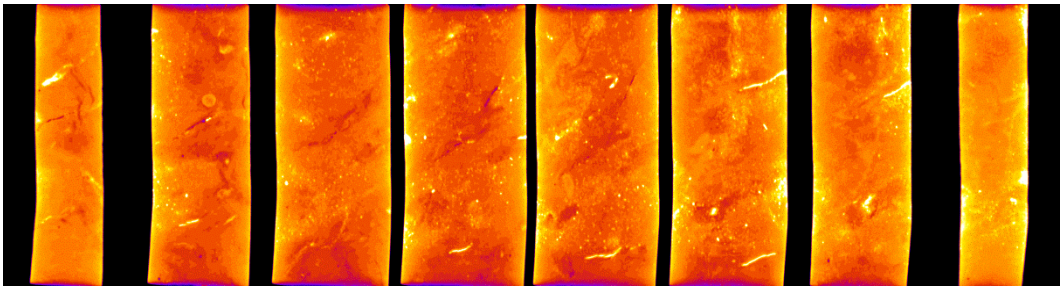

Figure 79: Montage of XZ slices through F2HA.

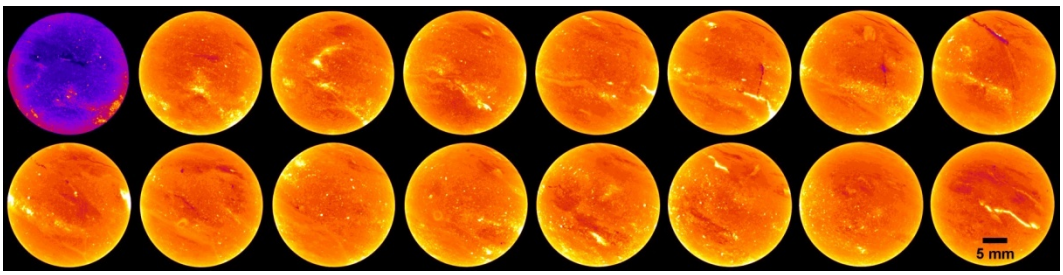

Figure 80: Montage of XY slices through F2HA.

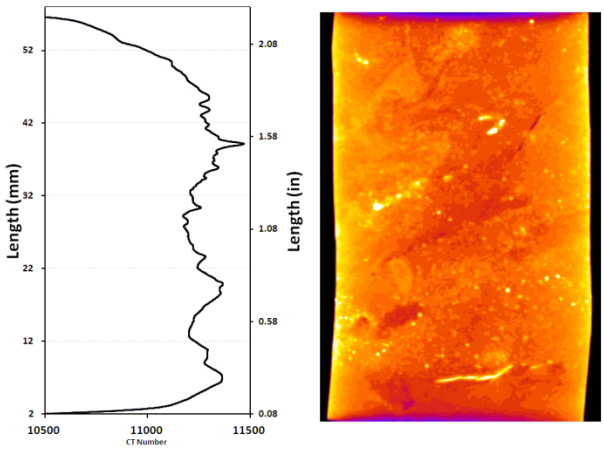

Figure 81: Bulk CT number log for F2HA, XZ slice. Variable density profile due to heterogeneities. High density lenses and accumulations of heavy minerals, and pockets of lower-density shale show up as bright and dark patches, respectively.

Sample F2HB – Parallel to bedding

Sample F2HB (Figure 82) is a core cut parallel to bedding from F2.

Figure 82: Photographs of F2HB shaly limestone prior to trimming on the end.

Figures 83, 84, and 85 are false color CT scan images. The core plug orientation is sub-parallel/parallel to bedding.

Purple, red, and orange indicate lower density constituents. Yellow and white indicate higher density constituents. Lamination is indicated by parallel lines of higher density material, particularly visible in the XY slices. White-rimmed, high-density constituents occur in both the XZ and XY slices. The brilliance of the white indicates the rim is composed of very high density material. Irregular patches of lower density materials are shown in red and purple.

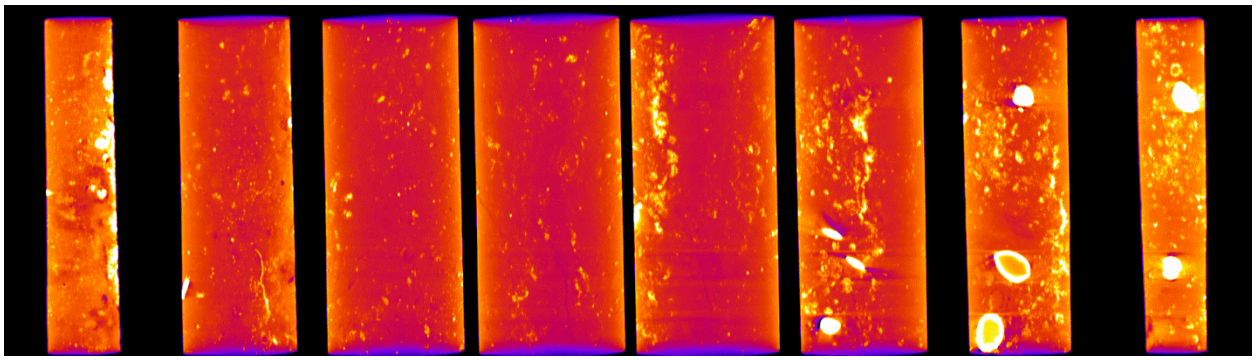

Figure 83: Montage of XZ slices through F2HB.

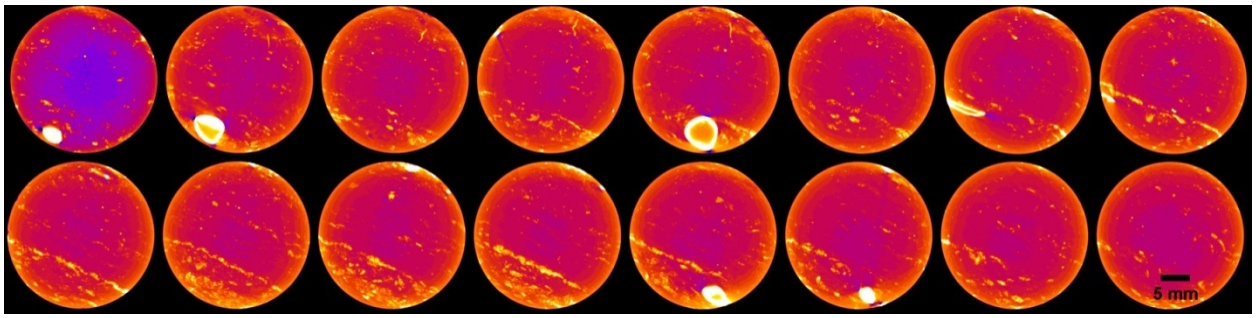

Figure 84: Montage of XY slices through F2HB.

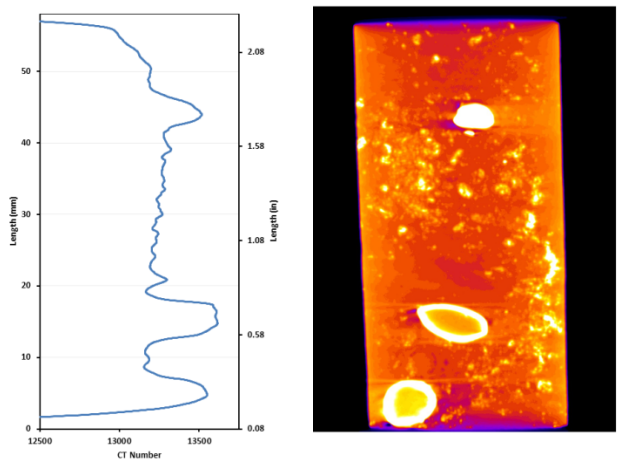

Figure 85: Bulk CT number log for F2HB, XZ slice. Peaks on the scan signature correspond to brilliant white particles of high density.

Table 16 is a summary of samples and CT scan results.

Table 16: Summary of Samples and CT Scan Results

Sample Number	Lithology	Location	Scanned Samples	CT Scan Results
F5HA F5HB	Silty gray shale	Petersburg West, WV	F5HA	Very uniform density. Lower density laminae is wavy and discontinuous.
			F5HB	Core orientation sub-parallel to bedding. Lower density lamine is wavy and discontinuous. Hairline fractures cutting laminae at ~ 50 degrees are filled with higher density material.
F4HA F4HB F4V3 F4V4	Noncalcareous black shale	Whip Gap, WV	F4HA	Uniform density profile. Core orientation sub-parallel to bedding. Laminae of lower density material. Higher density 'grains' disseminated along laminae.
			F4HB	Uniform density profile. Core orientation ~ 45 degrees to bedding. Laminae of alternating low and higher density materials. Higher density grains disseminated throughout.
			F4V3	Variable density profile. Core orientation perpendicular to bedding. Laminae of higher density materials.
			F4V4	Variable density profile. Core orientation perpendicular to bedding. Laminae of alternating higher and lower density materials.
F2HA F2HB	Shaly limestone	Burlington, WV	F2HA	Variable bulk density profile. Core orientation sub-parallel to bedding. Mottled appearance consistent with bioturbation. Higher density grains disseminated throughout.
			F2HB	Variable bulk density profile. Core orientation sub-parallel to bedding. Laminae defined by accumulations of high density minerals. Brilliance of fossil material may indicate replacement with hgih-density mineral.

4.4 SIMULATION MODEL DEVELOPMENT

The goal of this task is to model fluid flow in fractured shale to develop simulations of CO_2 storage in, and enhanced gas recovery from, organic-rich shale formations that are depleted through primary production. The model development task began in June 2010 with formation of a team having the capability to perform physics-based and surrogate reservoir models (SRM) of CO_2 injection in depleted shale. The research in this area follows the NETL-ORD/NETL-RUA

model, with the research team using professors as principal investigators (PIs) and research expertise already in place. Table 17 shows roles of the simulation team.

Table 17: Storage in Shale – Modeling Team

Research Entity	Role	Expertise
WVU	Develop behavioral patterns for swelling and fracture propping due to CO_2 injection	Coupled flow and geomechanics
PSU	Model CO_2 injection in fractured shale	Dual porosity flow modeling
WVU	Model CO_2 injection in fractured shale, develop and run surrogate reservoir models (SRM) for the economic assessment team	Numerical and artificial intelligence (AI) modeling
URS	Model reservoir performance (NFFLOW/FRACGEN) and link to geological properties of the rock	Modeling

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Appendix A
ICMI Experimental Study Samples and Subsets

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			Powdered Samples								Intact Cores and Plugs	
Sample Location Number	Litology/Source	Sample Suffix	X-ray Diffraction	Fourier Transform Infrared Spectroscopy (FTIR)	Elemental Analysis of Metals	Organic/Inorganic Carbon	Sorption Capacity/Isotherms for CO_2	Physical Testing[1]	Petrophysical Analysis (Porosity and Permeability)	Petrography	X-ray Computed Tomography (CT)	Geographic Location
1	WV facies 5; silty gray shale	F5	√	√	√	√	√	√		√	√	Petersburg, WV
1	WV facies 5; silty gray shale	F5HA							√	√		Petersburg, WV
1	WV facies 5; silty gray shale	F5HB							√	√		Petersburg, WV
2	WV facies 3: calcareous black shale	F3	√	√	√	√	√	√		√	√	Petersburg, WV
3	WV facies 4: non-calc black shale	F4	√	√	√	√	√	√		√	√	Whip Gap, WV
4	WV facies 1: calc gray shale	F1	√	√	√	√	√	√		√	√	Burlington, WV
5	WV facies 2: shaly limestone	F2	√	√	√	√	√	√		√	√	Burlington, WV
5	WV facies 2: shaly limestone	F2HA							√	√		Burlington, WV
5	WV facies 2: shaly limestone	F2HB							√	√		Burlington, WV
6	WV facies 4: non-calc black shale	F4HA							√	√		Bedford, PA
6	WV facies 4: non-calc black shale	F4HB							√	√		Bedford, PA
6	WV facies 4: non-calc black shale	F4V3							√	√		Bedford, PA
6	WV facies 4: non-calc black shale	F4V4							√	√		Bedford, PA
6	F4 slab oriented plugs	Bedford	√	√	√	√	√	√				Bedford, PA
7	Oatka Creek member basal black shale, gray shale above	OCSC	√	√	√	√	√	√				Canoga, NY
7	Oatka Creek member basal black shale, gray shale above	OS								√		Canoga, NY
8	Union Springs member black shale	US								√		Canoga, NY
8	Union Springs member black shale	USSC	√	√	√	√	√	√				Canoga, NY
9	Oatka Creek member basal black shale, gray shale above	OCNY									√	Marcellus, NY
9	Black shale	TS								√		Marcellus, NY
9	Black shale	Type	√	√	√	√	√	√				Marcellus, NY
10	Oatka Creek member basal black shale, gray shale above	Oatka	√	√	√	√	√	√				Le Roy, NY
10	Oatka Creek member basal black shale, gray shale above	OC								√		Le Roy, Ny

[1] *Physical Testing suite includes: grain dessity, bulk density, porosity, pore size distribution, and micropore surface area.*

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Appendix B
Detailed Analyses from Weatherford Laboratories

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Adsorption Isotherm Results
URS Energy & Construction, Inc.
Sequestration Isotherm Study

Appendix B Sample Crosswalk

NETL Sample Number	Weatherford Sample Number
F5	56793-10
F3	56793-7
F4	56793-9
F1	56793-5
F2	56793-6
Bedford	56793-8
OCSC	56793-1
USSC	56793-2
Type	56793-4
Oatka	56793-3

Methane Shale Adsorption Isotherm Parameters, Part 1

Parameter	Unit	56793-1	56793-2	56793-3	56793-4	56793-5
Sample Parameters						
Measurement Gas	-	methane	methane	methane	methane	methane
Measurement Temperature	°F	169.0	169.0	169.0	169.0	169.0
Crushed Density	g/cm^3	2.492	2.646	2.455	2.679	2.681
Langmuir Parameters						
Langmuir Storage Capacity, As-Received	scf/ton	244.04	86.35	197.41	103.61	37.23
Langmuir Pressure	psia	872.25	1,191.44	2,935.45	1,339.80	3,426.14

Methane Shale Adsorption Isotherm Parameters, Part 2

Parameter	Unit	56793-6	56793-7	56793-8	56793-9	56793-10
Sample Parameters						
Measurement Gas	-	methane	methane	methane	methane	methane
Measurement Temperature	°F	169.0	169.0	169.0	169.0	169.0
Crushed Density	g/cm^3	2.728	2.686	2.536	2.522	2.781
Langmuir Parameters						
Langmuir Storage Capacity, As-Received	scf/ton	22.88	32.37	124.32	113.96	20.37
Langmuir Pressure	psia	4,252.19	1,344.01	1,036.23	7,436.49	3,088.98

Carbon Dioxide Shale Adsorption Isotherm Parameters, Part 1

Parameter	Unit	56793-1	56793-2	56793-3	56793-4	56793-5
Sample Parameters						
Measurement Gas	-	carbon dioxide	carbon dioxide	carbon dioxide	carbon dioxide	carbon dioxide
Measurement Temperature	°F	169.0	169.0	169.0	169.0	169.0
Crushed Density	g/cm^3	2.492	2.646	2.455	2.679	2.681
Langmuir Parameters						
Langmuir Storage Capacity, As-Received	scf/ton	329.76	163.14	259.81	138.11	89.22
Langmuir Pressure	psia	364.75	635.05	1,095.67	415.88	897.67

Carbon Dioxide Shale Adsorption Isotherm Parameters, Part 2

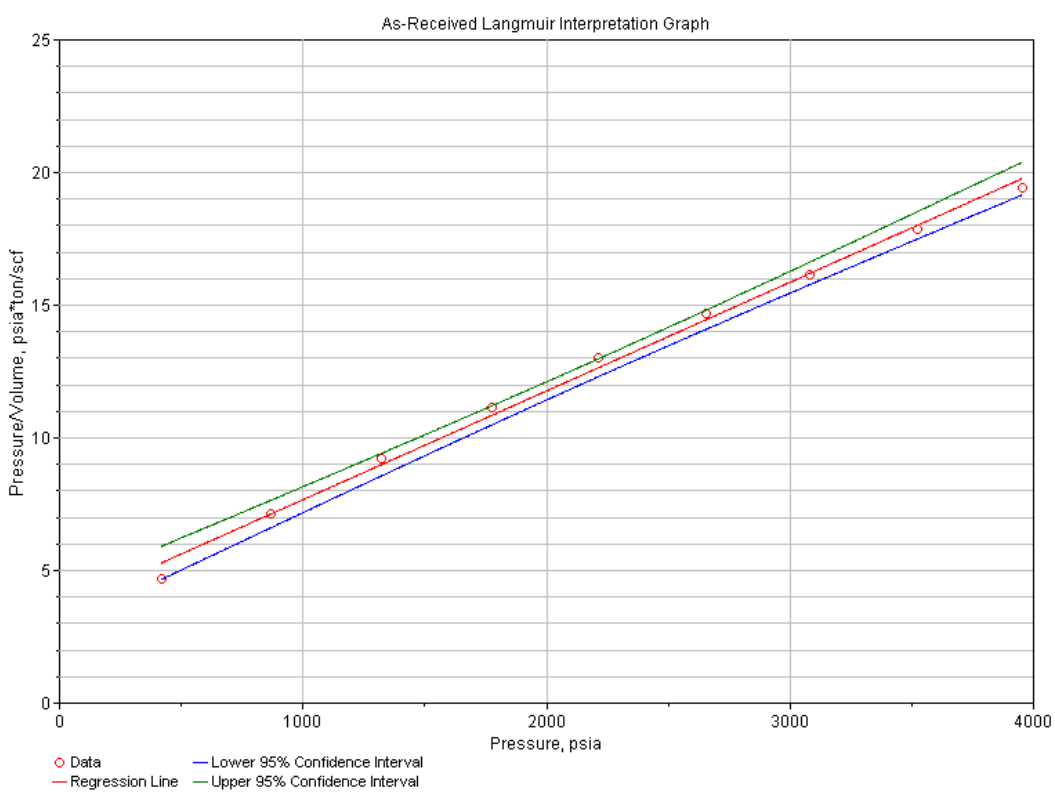
Parameter	Unit	56793-6	56793-7	56793-8	56793-9	56793-10
Sample Parameters						
Measurement Gas	-	carbon dioxide	carbon dioxide	carbon dioxide	carbon dioxide	carbon dioxide
Measurement Temperature	°F	169.0	169.0	169.0	169.0	169.0
Crushed Density	g/cm^3	2.728	2.686	2.536	2.522	2.781
Langmuir Parameters						
Langmuir Storage Capacity, As-Received	scf/ton	84.23	135.83	236.33	163.87	61.65
Langmuir Pressure	psia	2,748.78	1,346.22	700.91	1,350.30	582.52

Sample 56793-1 Methane Adsorption Isotherm Parameters

Parameter	Unit	Value
Sample Depth	ft	unknown
Sample Parameters		
Measurement Gas	-	methane
Measurement Temperature	°F	169.0
Crushed Density	g/cm^3	2.492
Langmuir Parameters		
Number of Points	-	9
Correlation Coefficient	-	0.9978
Langmuir Storage Capacity, As-Received	scf/ton	244.04
Langmuir Storage Capacity Range, As-Received	scf/ton	0.25
Langmuir Pressure	psia	872.25
Langmuir Pressure Range	psia	128.09

Sample 56793-1 Methane Adsorption Isotherm Data

Pressure	Storage Capacity, As-Received
psia	scf/ton
417.86	89.20
869.40	122.22
1,324.44	143.31
1,773.67	158.92
2,215.15	170.13
2,653.62	180.41
3,081.47	190.72
3,522.41	197.36
3,955.25	203.65



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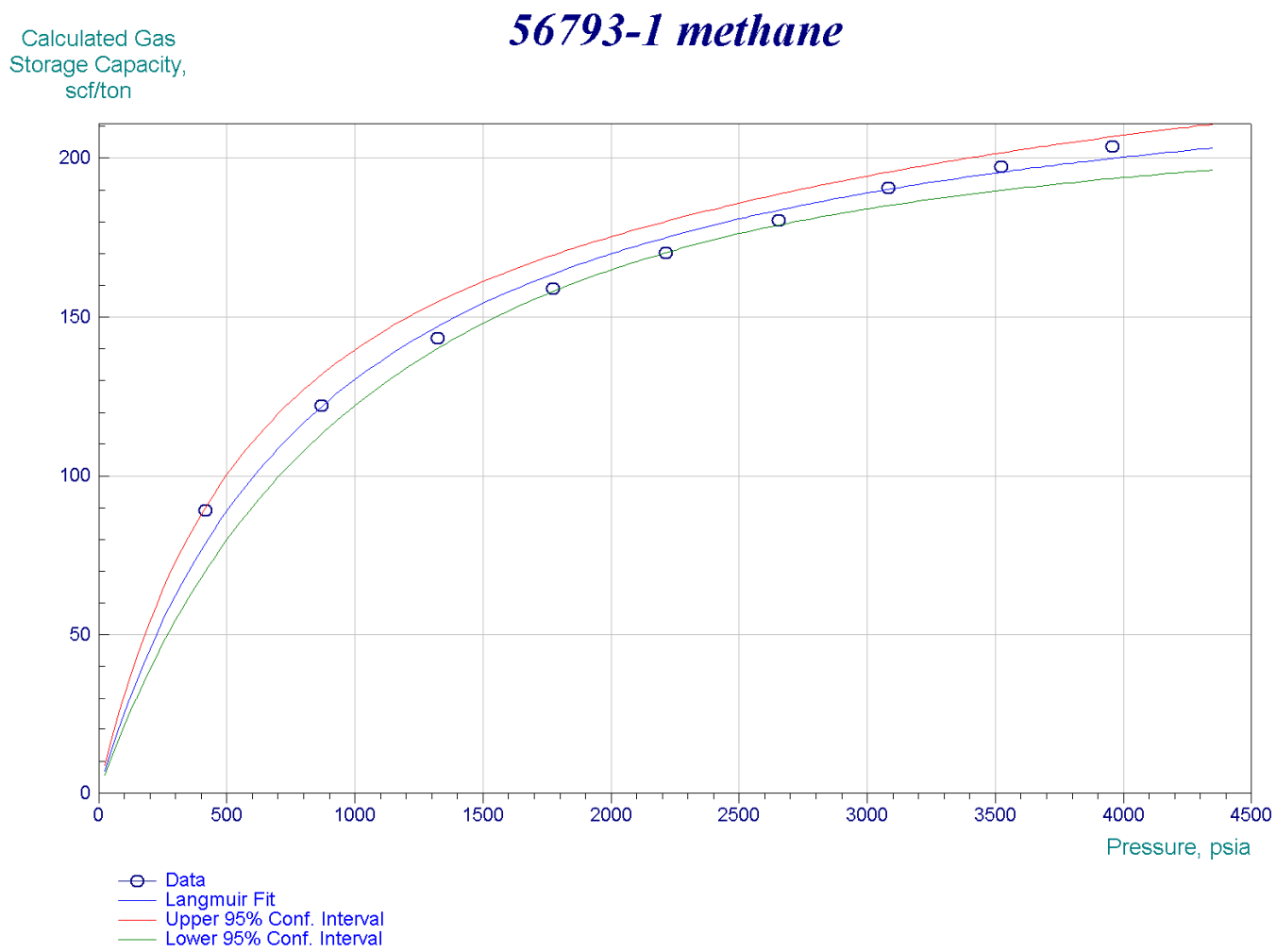

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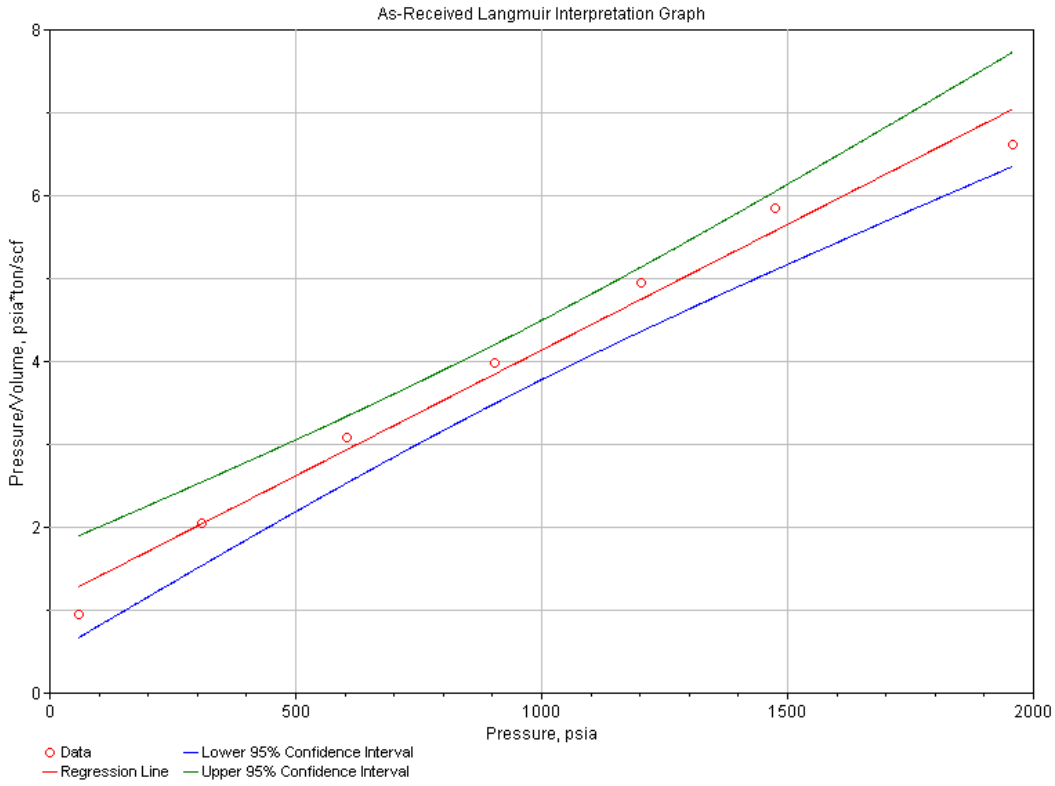
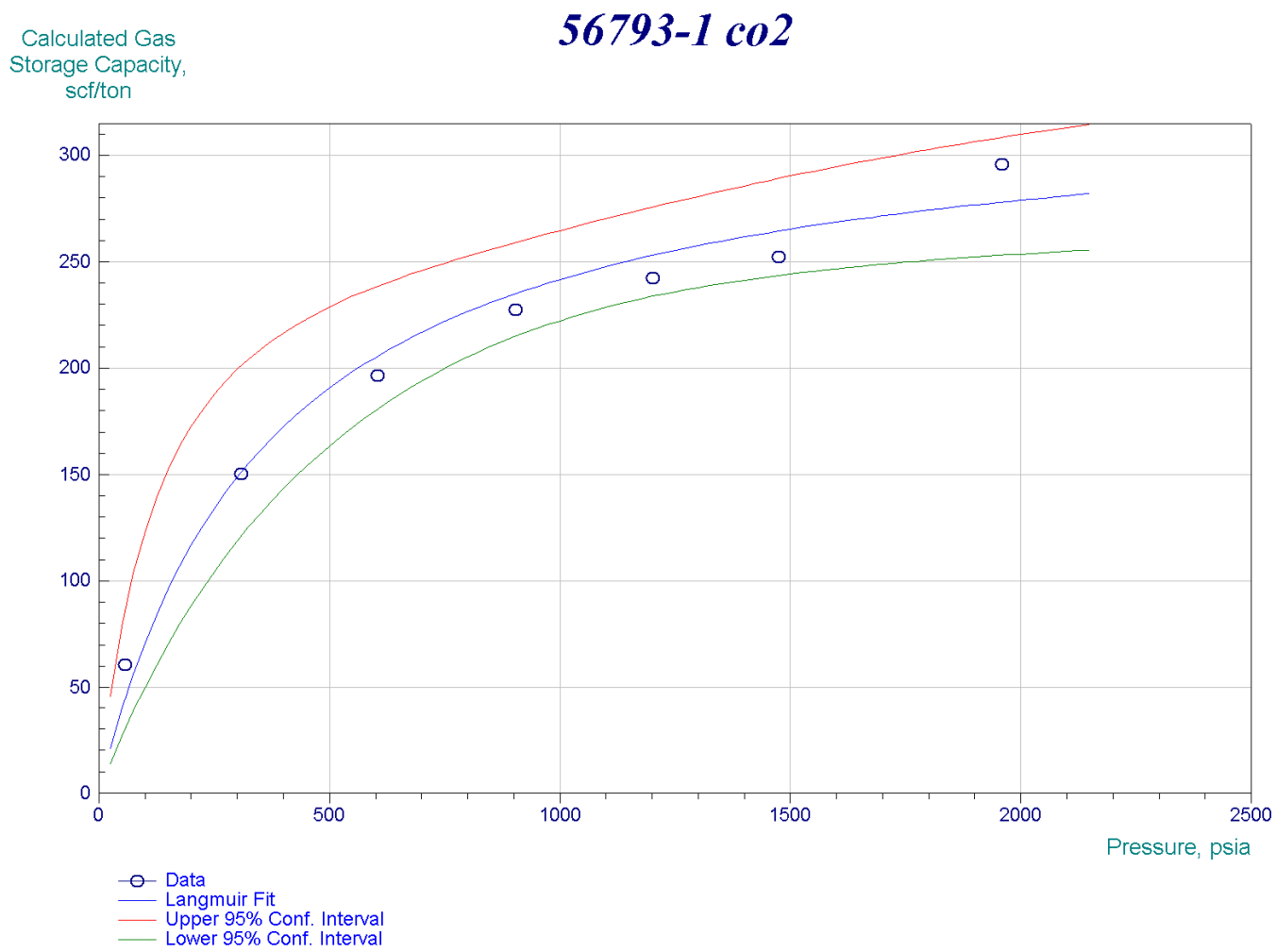
Sample 56793-1 Carbon Dioxide Adsorption Isotherm Parameters

Parameter	Unit	Value
Sample Depth	ft	unknown
Sample Parameters		
Measurement Gas	-	carbon dioxide
Measurement Temperature	°F	169.0
Crushed Density	g/cm^3	2.492
Langmuir Parameters		
Number of Points	-	7
Correlation Coefficient	-	0.9911
Langmuir Storage Capacity, As-Received	scf/ton	329.76
Langmuir Storage Capacity Range, As-Received	scf/ton	9.30
Langmuir Pressure	psia	364.75
Langmuir Pressure Range	psia	124.42

Sample 56793-1 Carbon Dioxide Adsorption Isotherm Data

Pressure	Storage Capacity, As-Received
psia	scf/ton
57.69	60.72
308.34	150.42
605.03	196.40
904.98	227.32
1,201.56	242.33
1,474.50	252.20
1,958.20	295.86





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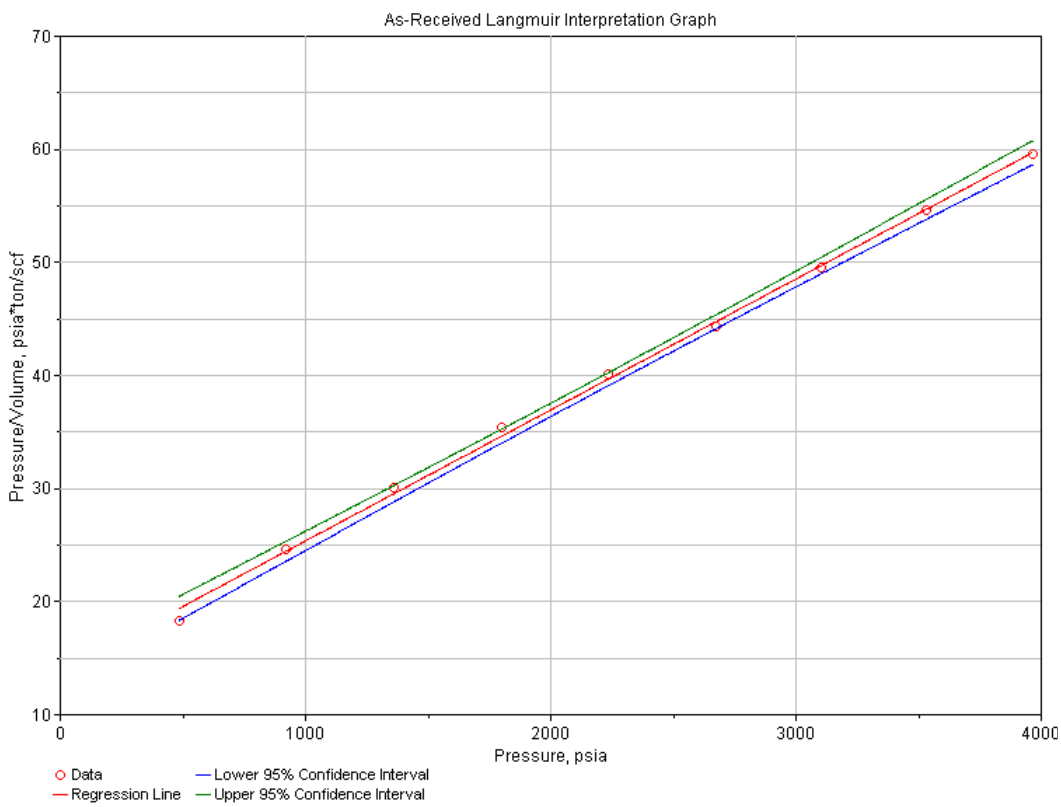
Sample 56793-2 Methane Adsorption Isotherm Parameters

Parameter	Unit	Value
Sample Depth	ft	unknown
Sample Parameters		
Measurement Gas	-	methane
Measurement Temperature	°F	169.0
Crushed Density	g/cm^3	2.646
Langmuir Parameters		
Number of Points	-	9
Correlation Coefficient	-	0.9991
Langmuir Storage Capacity, As-Received	scf/ton	86.35
Langmuir Storage Capacity Range, As-Received	scf/ton	0.10
Langmuir Pressure	psia	1,191.44
Langmuir Pressure Range	psia	80.43

Sample 56793-2 Methane Adsorption Isotherm Data

Pressure	Storage Capacity, As-Received
psia	scf/ton
483.86	26.41
919.44	37.26
1,361.54	45.23
1,799.18	50.80
2,235.45	55.70
2,671.68	60.27
3,105.30	62.75
3,530.59	64.67
3,966.53	66.56



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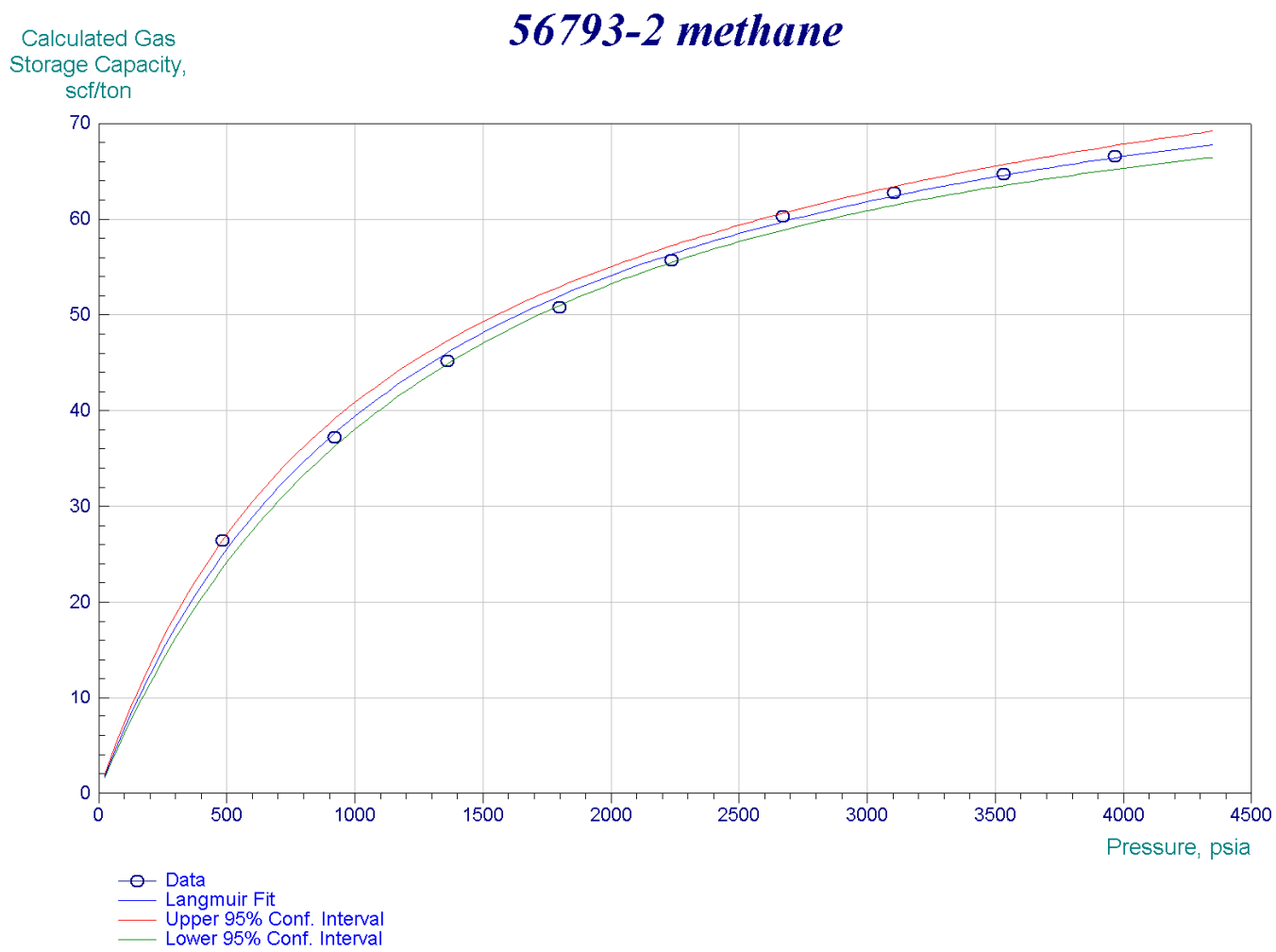
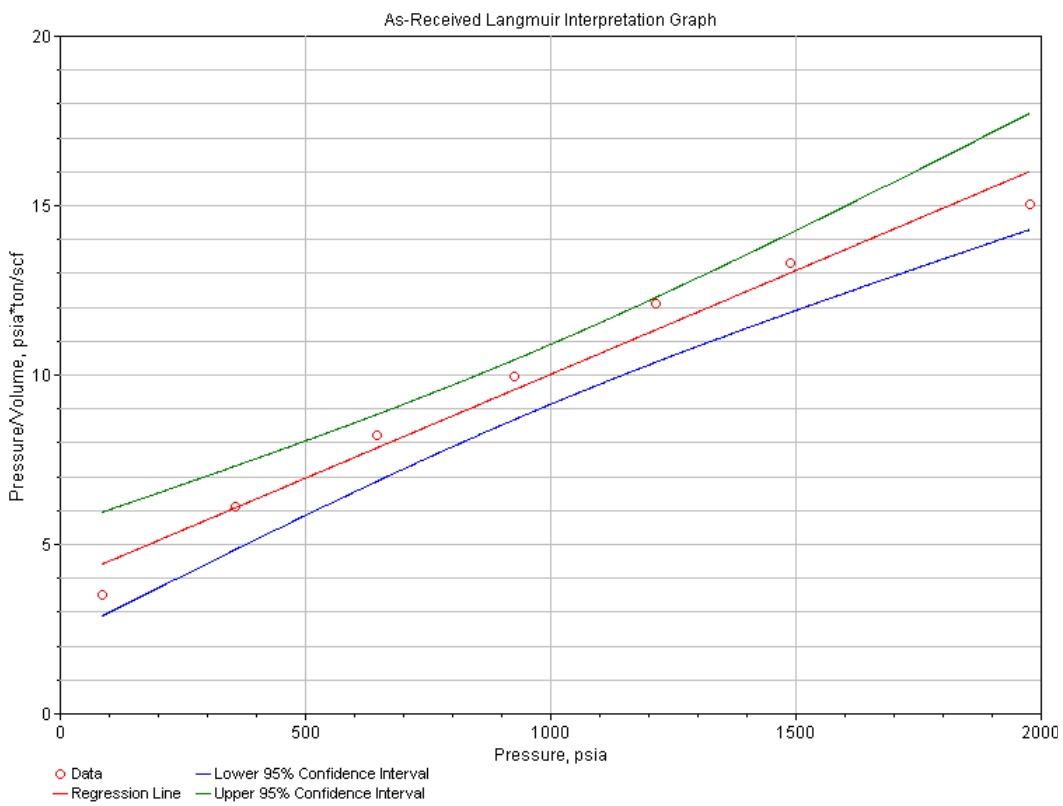

56793-2 methane
Calculated Gas Storage Capacity, scf/ton
70
60
50
40
30
20
10
0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Pressure, psia
Data
Langmuir Fit
Upper 95% Conf. Interval
Lower 95% Conf. Interval

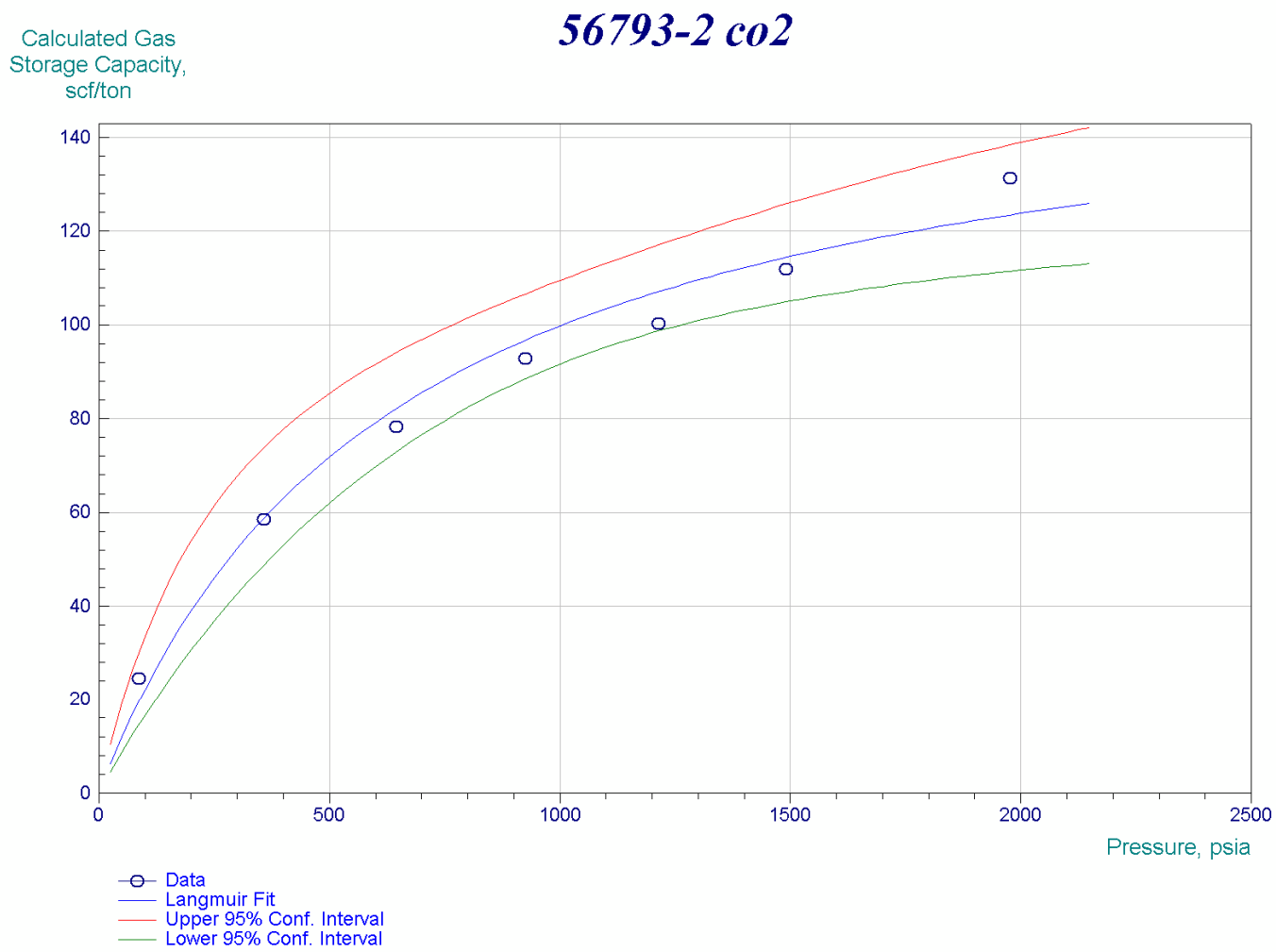
Sample 56793-2 Carbon Dioxide Adsorption Isotherm Parameters

Parameter	Unit	Value
Sample Depth	ft	unknown
Sample Parameters		
Measurement Gas	-	carbon dioxide
Measurement Temperature	°F	169.0
Crushed Density	g/cm^3	2.646
Langmuir Parameters		
Number of Points	-	7
Correlation Coefficient	-	0.9864
Langmuir Storage Capacity, As-Received	scf/ton	163.14
Langmuir Storage Capacity Range, As-Received	scf/ton	5.07
Langmuir Pressure	psia	635.05
Langmuir Pressure Range	psia	150.30

Sample 56793-2 Carbon Dioxide Adsorption Isotherm Data

Pressure	Storage Capacity, As-Received
psia	scf/ton
86.18	24.51
357.21	58.45
644.47	78.28
925.08	92.78
1,213.51	100.39
1,489.71	111.94
1,976.92	131.36





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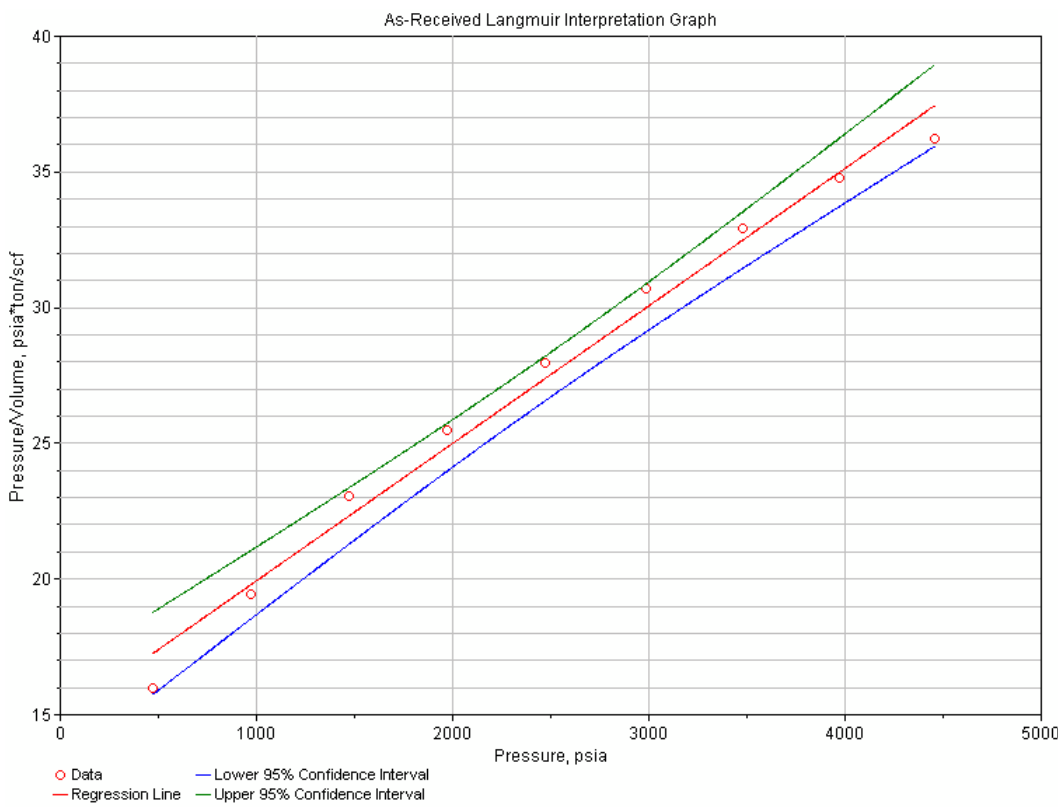
Sample 56793-3 Methane Adsorption Isotherm Parameters

Parameter	Unit	Value
Sample Depth	ft	unknown
Sample Parameters		
Measurement Gas	-	methane
Measurement Temperature	°F	169.0
Crushed Density	g/cm^3	2.455
Langmuir Parameters		
Number of Points	-	9
Correlation Coefficient	-	0.9932
Langmuir Storage Capacity, As-Received	scf/ton	197.41
Langmuir Storage Capacity Range, As-Received	scf/ton	0.24
Langmuir Pressure	psia	2,935.45
Langmuir Pressure Range	psia	253.12

Sample 56793-3 Methane Adsorption Isotherm Data

Pressure	Storage Capacity, As-Received
psia	scf/ton
473.55	29.60
972.62	49.99
1,469.94	63.77
1,969.18	77.30
2,470.69	88.40
2,988.13	97.26
3,481.14	105.69
3,972.85	114.26
4,459.85	123.13



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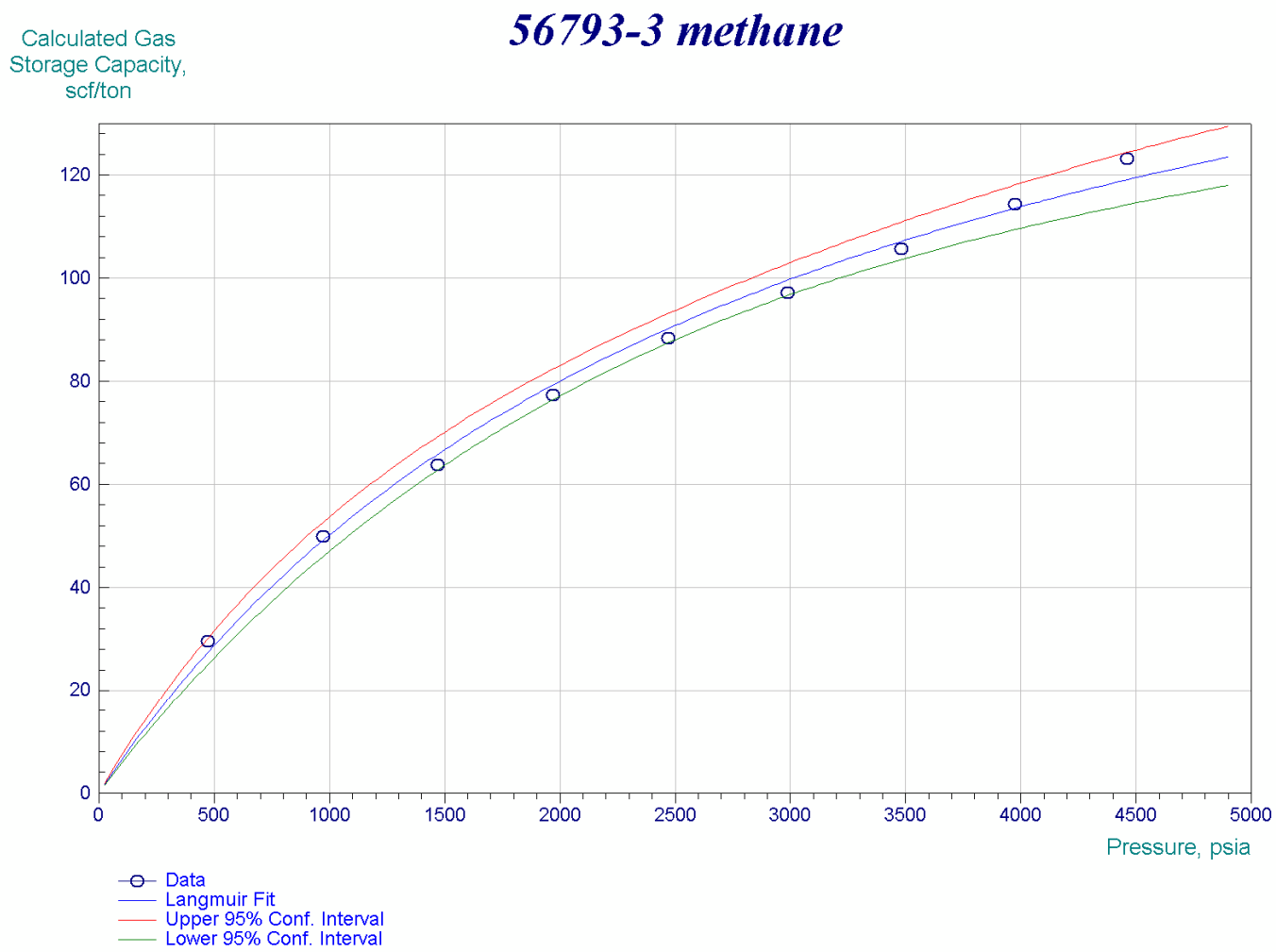

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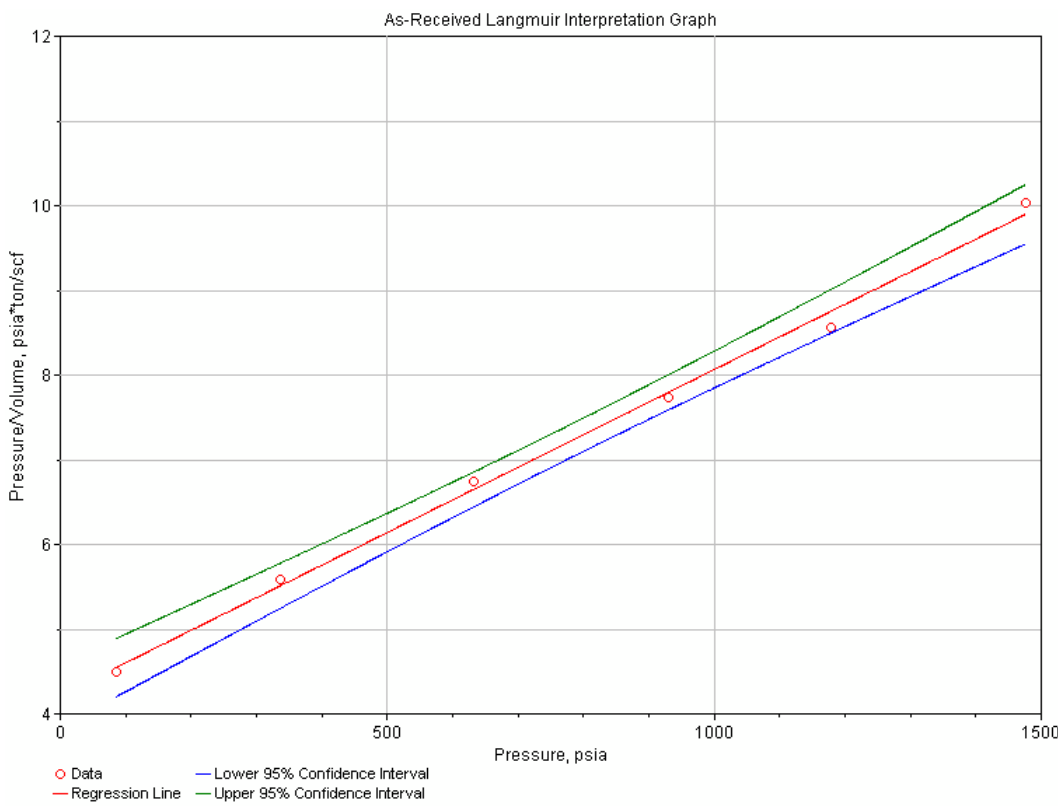
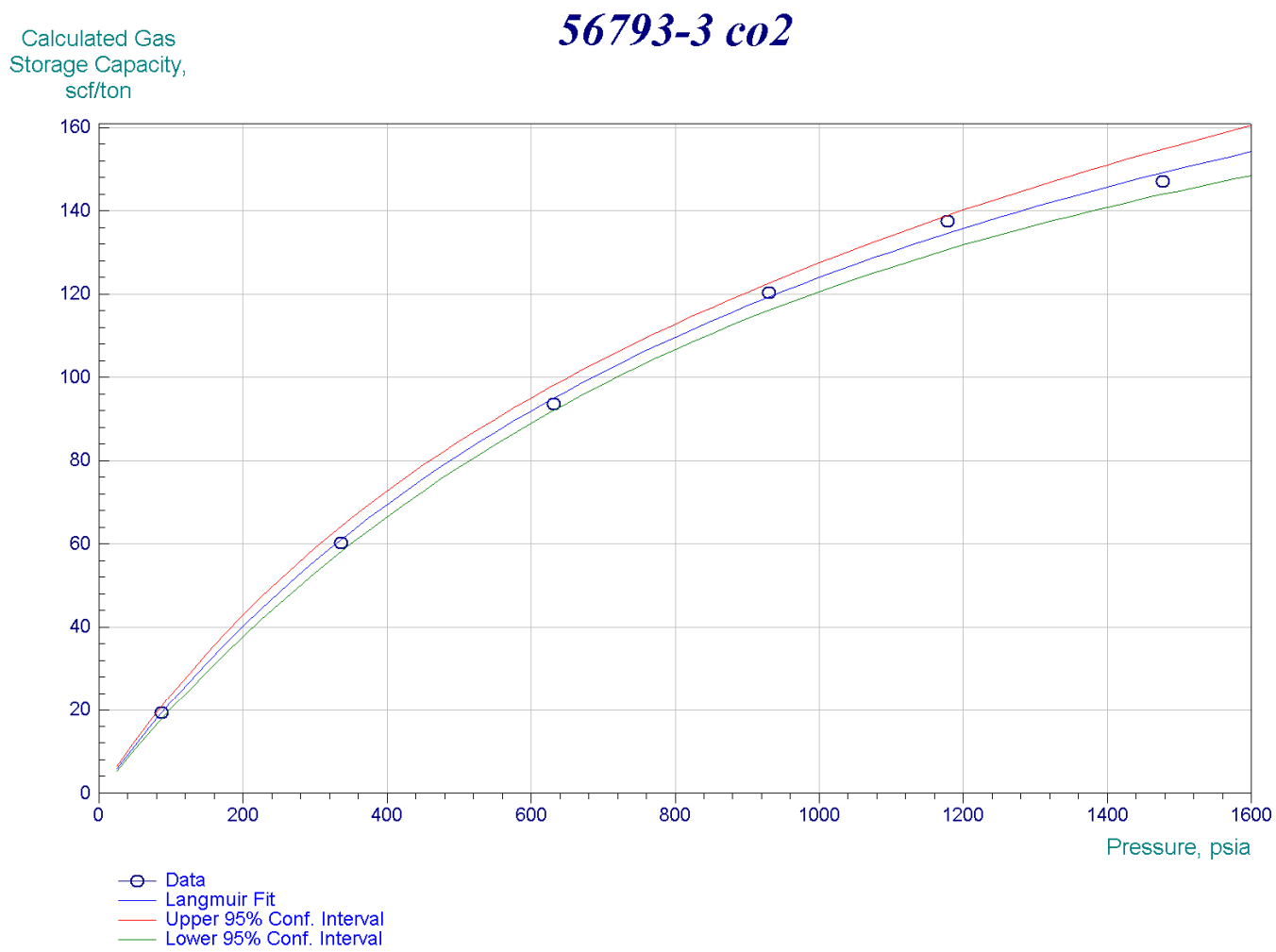
Sample 56793-3 Carbon Dioxide Adsorption Isotherm Parameters

Parameter	Unit	Value
Sample Depth	ft	unknown
Sample Parameters		
Measurement Gas	-	carbon dioxide
Measurement Temperature	°F	169.0
Crushed Density	g/cm^3	2.455
Langmuir Parameters		
Number of Points	-	6
Correlation Coefficient	-	0.9981
Langmuir Storage Capacity, As-Received	scf/ton	259.81
Langmuir Storage Capacity Range, As-Received	scf/ton	1.47
Langmuir Pressure	psia	1,095.67
Langmuir Pressure Range	psia	61.46

Sample 56793-3 Carbon Dioxide Adsorption Isotherm Data

Pressure	Storage Capacity, As-Received
psia	scf/ton
86.76	19.30
336.26	60.19
631.53	93.60
929.54	120.26
1,178.75	137.59
1,476.22	147.14





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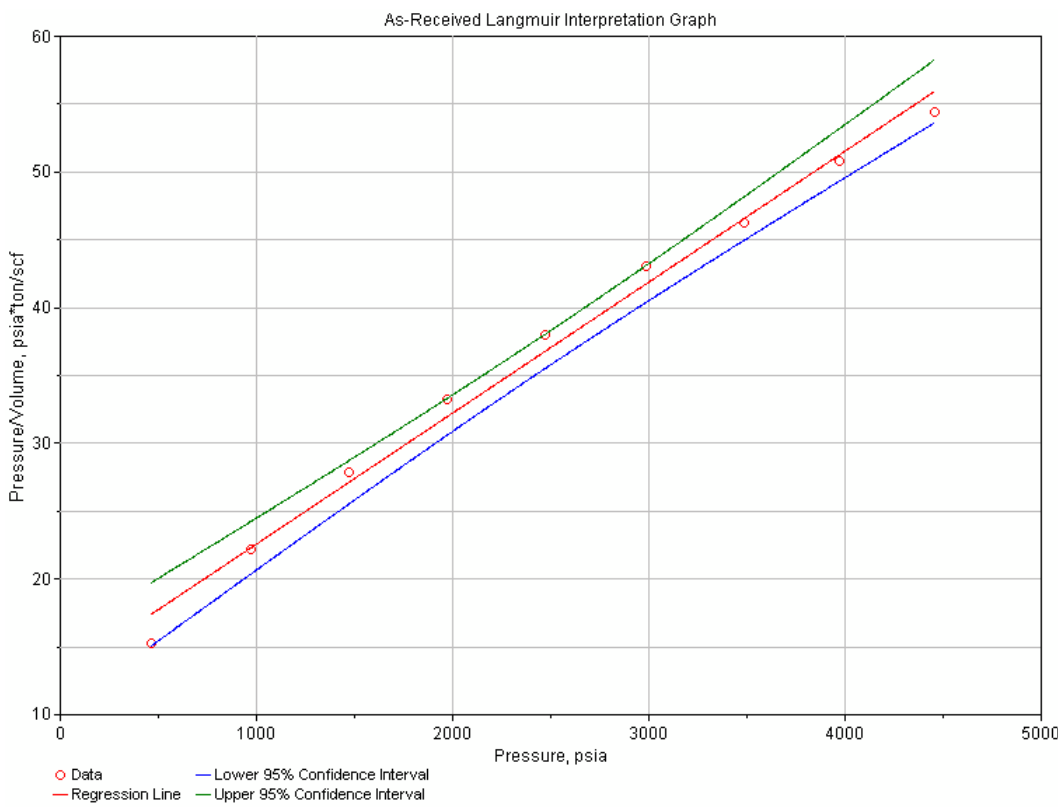
Sample 56793-4 Methane Adsorption Isotherm Parameters

Parameter	Unit	Value
Sample Depth	ft	unknown
Sample Parameters		
Measurement Gas	-	methane
Measurement Temperature	°F	169.0
Crushed Density	g/cm^3	2.679
Langmuir Parameters		
Number of Points	-	9
Correlation Coefficient	-	0.9956
Langmuir Storage Capacity, As-Received	scf/ton	103.61
Langmuir Storage Capacity Range, As-Received	scf/ton	0.10
Langmuir Pressure	psia	1,339.80
Langmuir Pressure Range	psia	202.49

Sample 56793-4 Methane Adsorption Isotherm Data

Pressure	Storage Capacity, As-Received
psia	scf/ton
464.50	30.47
969.69	43.74
1,473.79	52.95
1,971.40	59.25
2,468.20	65.03
2,986.33	69.43
3,484.34	75.27
3,968.65	78.05
4,454.30	81.86



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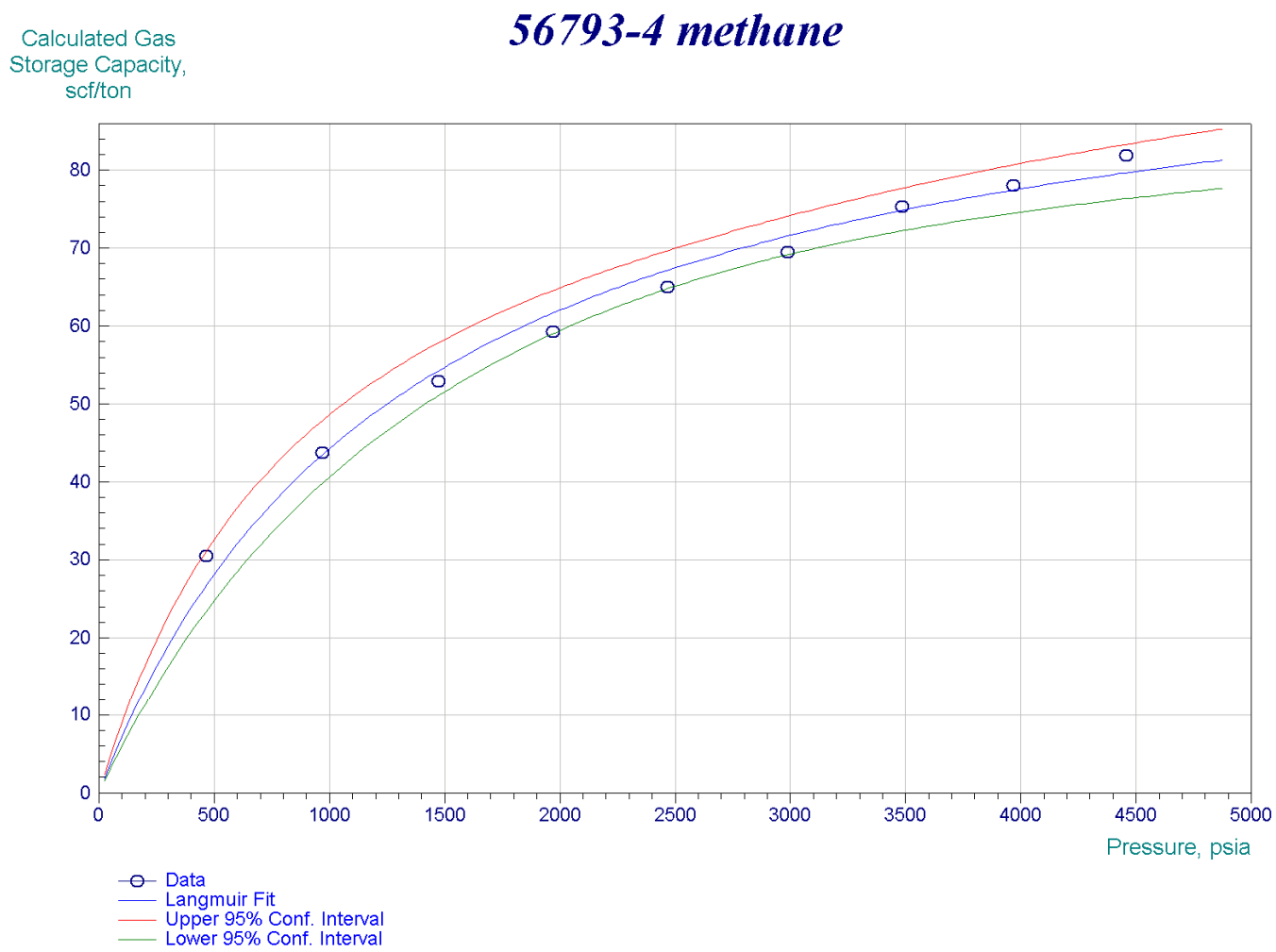

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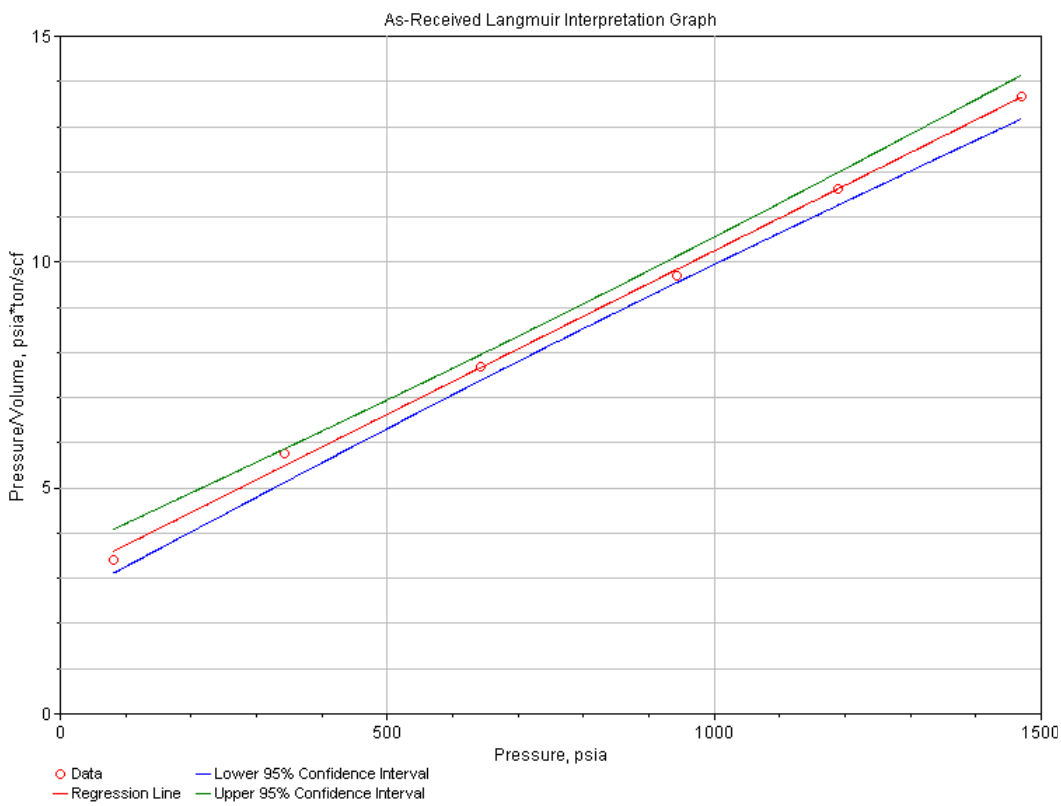
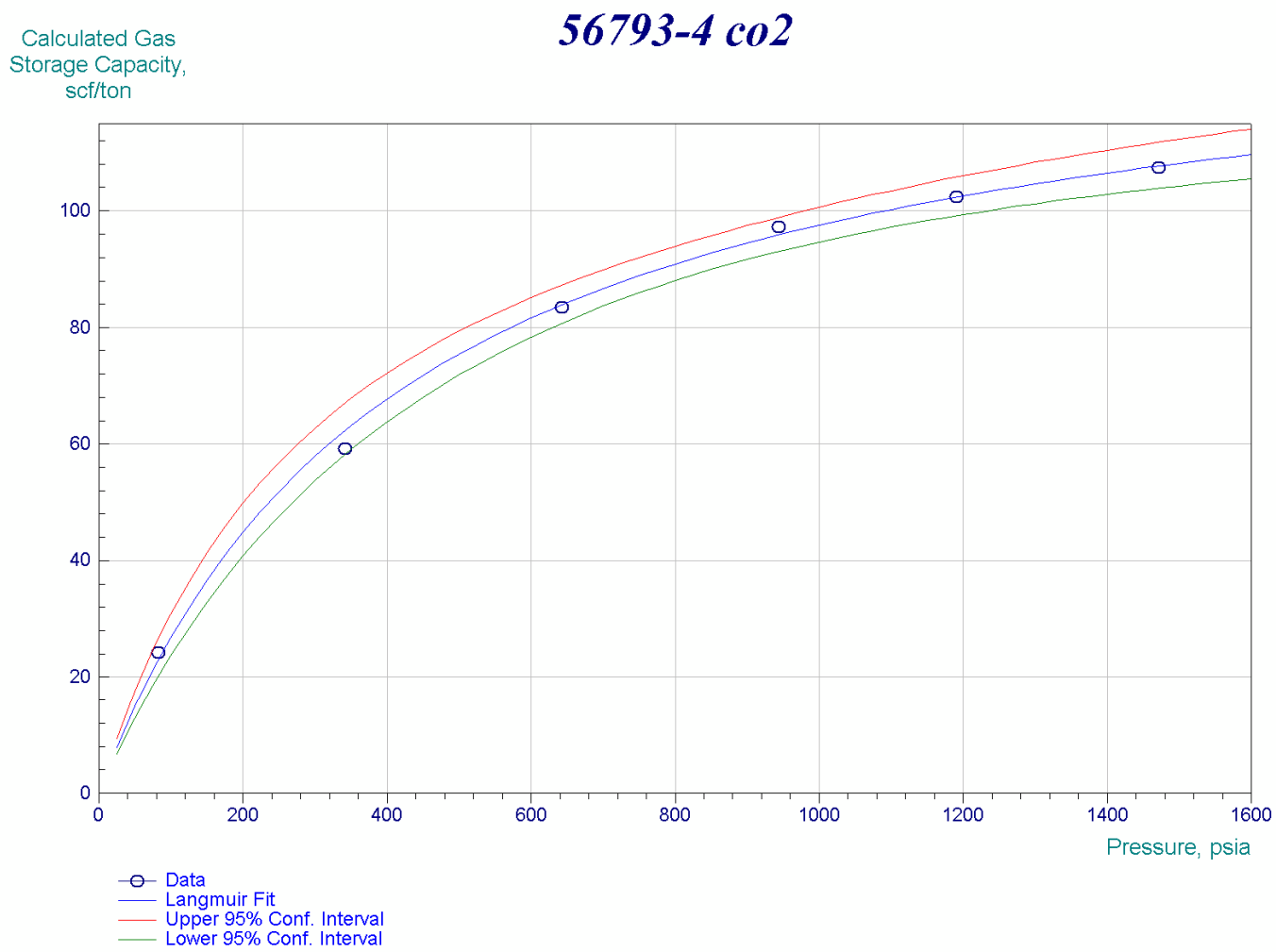
Sample 56793-4 Carbon Dioxide Adsorption Isotherm Parameters

Parameter	Unit	Value
Sample Depth	ft	unknown
Sample Parameters		
Measurement Gas	-	carbon dioxide
Measurement Temperature	°F	169.0
Crushed Density	g/cm^3	2.679
Langmuir Parameters		
Number of Points	-	6
Correlation Coefficient	-	0.9990
Langmuir Storage Capacity, As-Received	scf/ton	138.11
Langmuir Storage Capacity Range, As-Received	scf/ton	0.48
Langmuir Pressure	psia	415.88
Langmuir Pressure Range	psia	49.42

Sample 56793-4 Carbon Dioxide Adsorption Isotherm Data

Pressure	Storage Capacity, As-Received
psia	scf/ton
82.42	24.21
342.05	59.18
642.30	83.44
943.60	97.27
1,190.04	102.36
1,470.71	107.49





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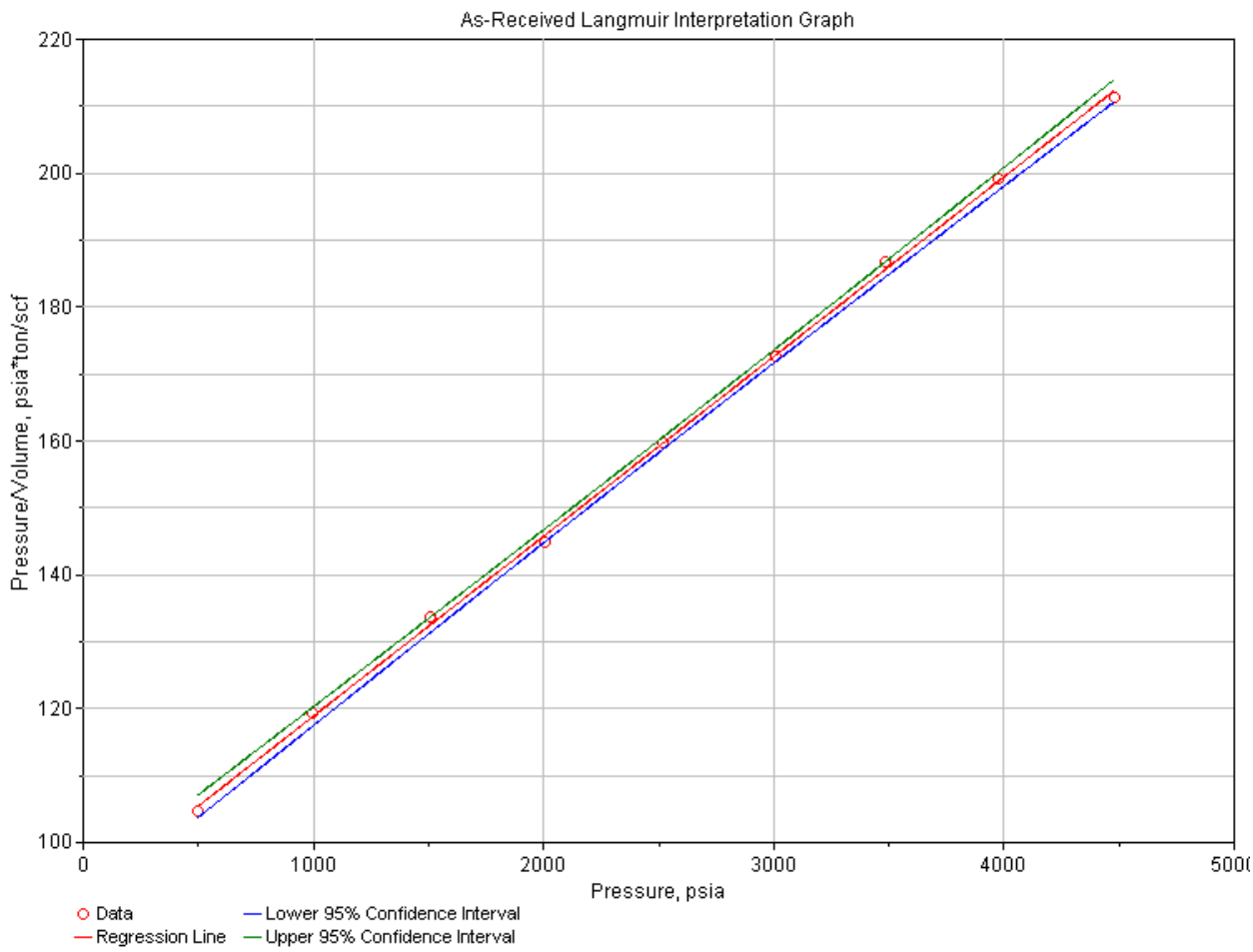
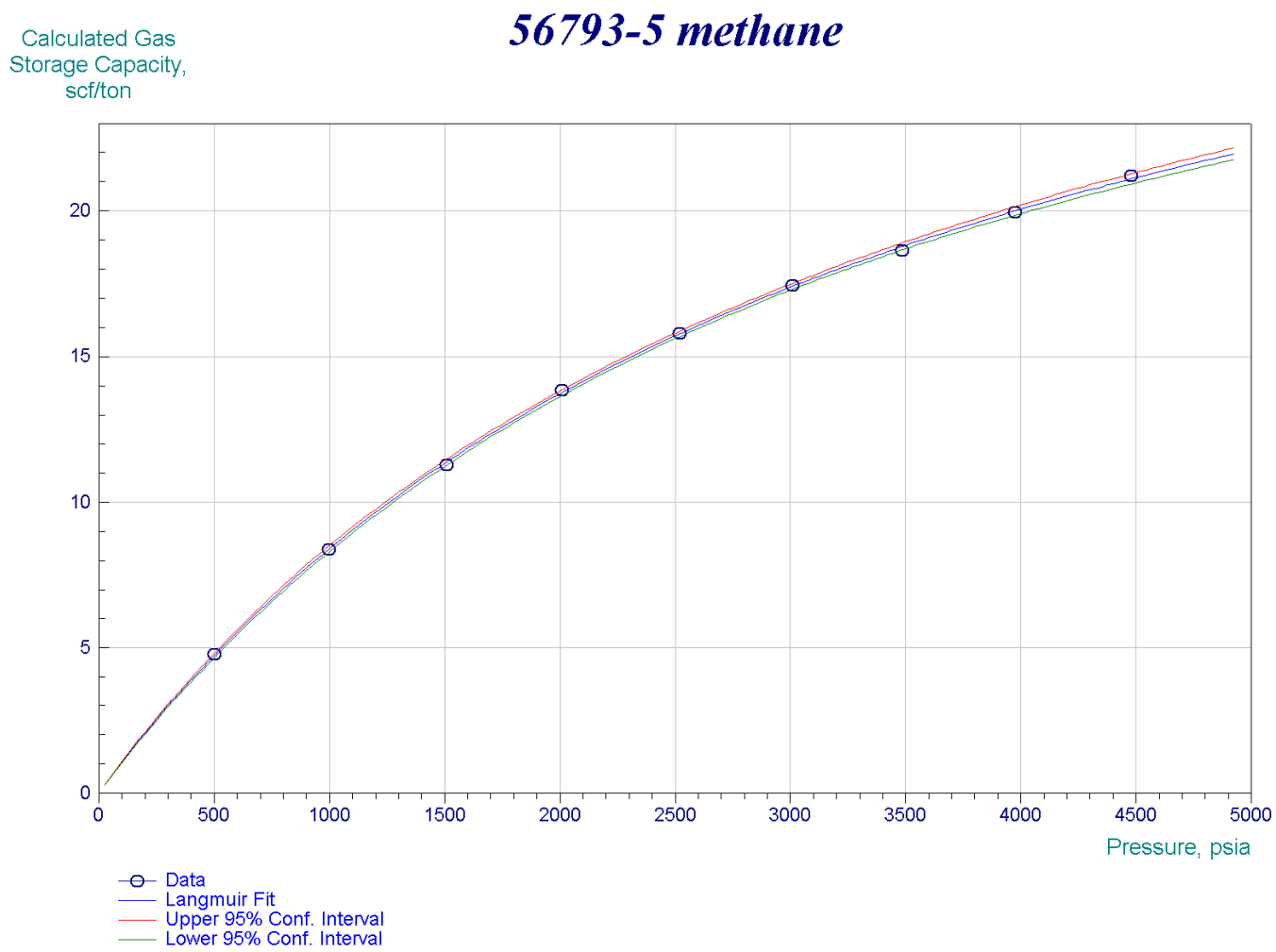
Sample 56793-5 Methane Adsorption Isotherm Parameters

Parameter	Unit	Value
Sample Depth	ft	unknown
Sample Parameters		
Measurement Gas	-	methane
Measurement Temperature	°F	169.0
Crushed Density	g/cm^3	2.681
Langmuir Parameters		
Number of Points	-	9
Correlation Coefficient	-	0.9997
Langmuir Storage Capacity, As-Received	scf/ton	37.23
Langmuir Storage Capacity Range, As-Received	scf/ton	0.02
Langmuir Pressure	psia	3,426.14
Langmuir Pressure Range	psia	54.29

Sample 56793-5 Methane Adsorption Isotherm Data

Pressure	Storage Capacity, As-Received
psia	scf/ton
500.85	4.79
998.20	8.37
1,508.60	11.28
2,006.69	13.85
2,520.13	15.79
3,009.50	17.44
3,485.31	18.65
3,973.49	19.94
4,478.32	21.20


As-Received Langmuir Interpretation Graph
Pressure/Volume, psia*ton/scf
220
200
180
160
140
120
100
0
1000
2000
3000
4000
5000
Pressure, psia
Data
Regression Line
Lower 95% Confidence Interval
Upper 95% Confidence Interval



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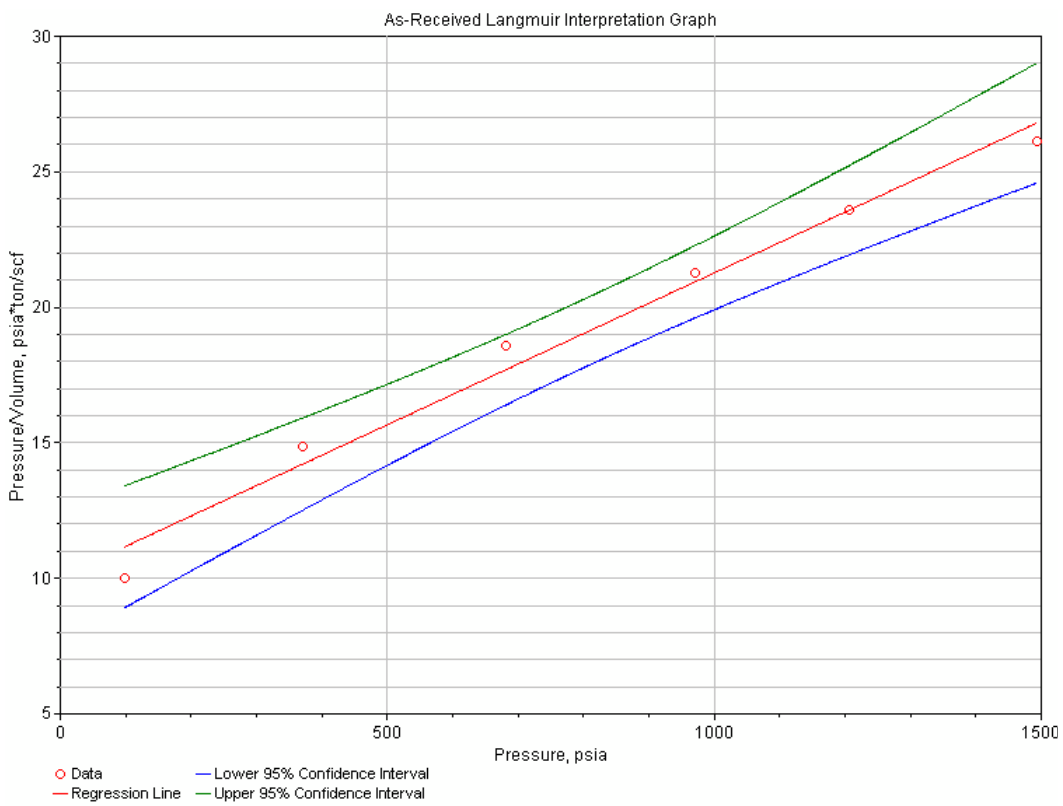
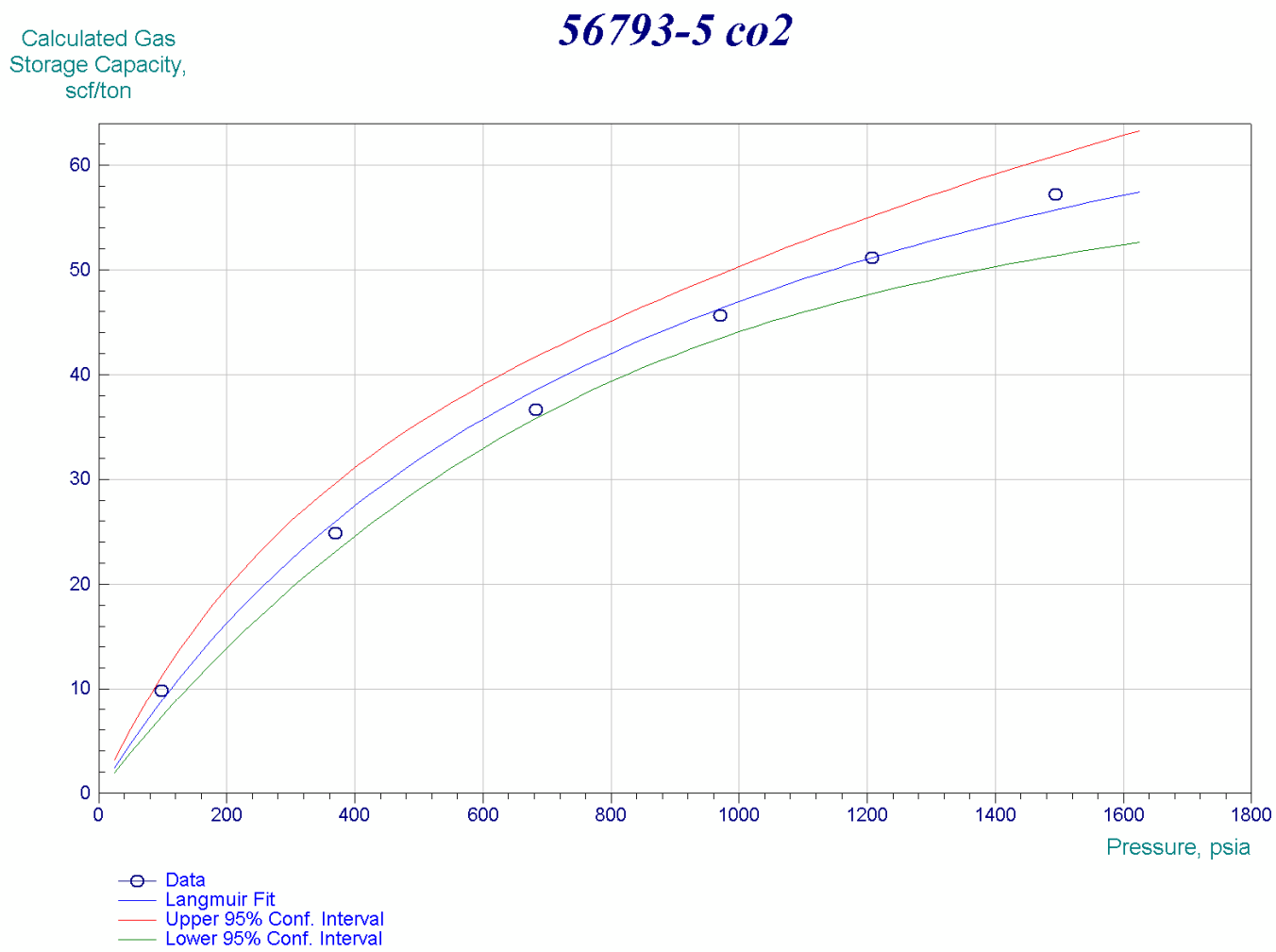
Sample 56793-5 Carbon Dioxide Adsorption Isotherm Parameters

Parameter	Unit	Value
Sample Depth	ft	unknown
Sample Parameters		
Measurement Gas	-	carbon dioxide
Measurement Temperature	°F	169.0
Crushed Density	g/cm^3	2.681
Langmuir Parameters		
Number of Points	-	6
Correlation Coefficient	-	0.9910
Langmuir Storage Capacity, As-Received	scf/ton	89.22
Langmuir Storage Capacity Range, As-Received	scf/ton	0.55
Langmuir Pressure	psia	897.67
Langmuir Pressure Range	psia	149.34

Sample 56793-5 Carbon Dioxide Adsorption Isotherm Data

Pressure	Storage Capacity, As-Received
psia	scf/ton
98.50	9.84
369.82	24.89
682.16	36.70
970.79	45.68
1,207.06	51.14
1,494.34	57.22



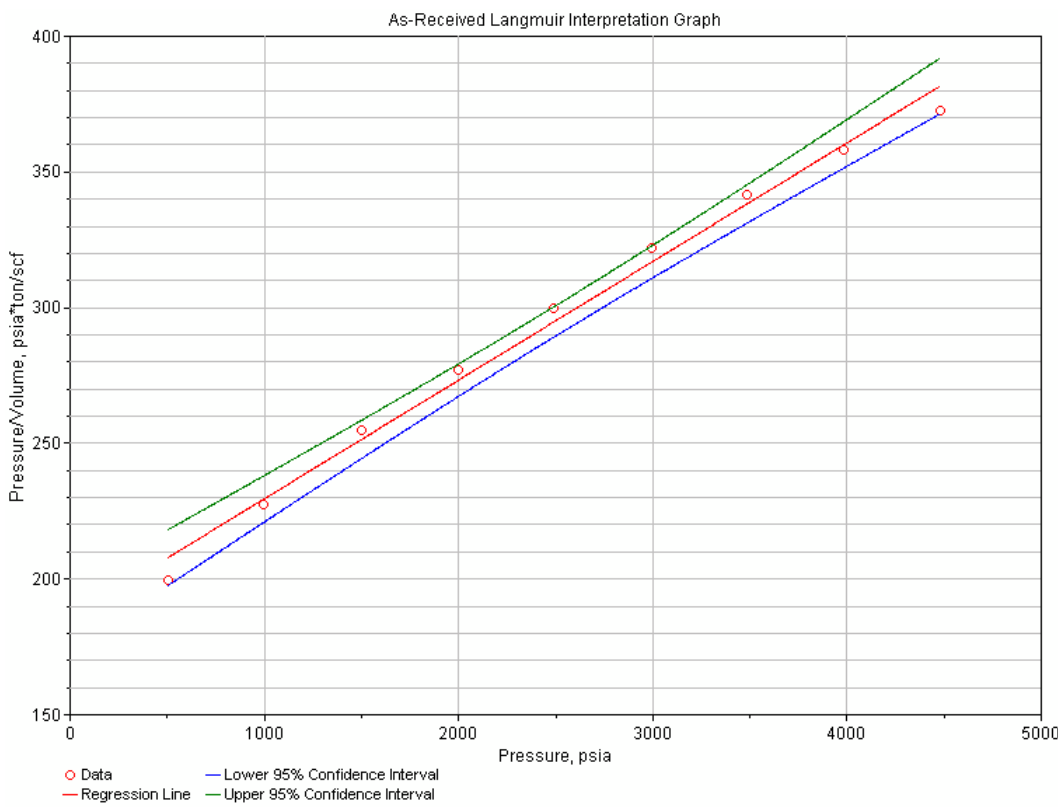

56793-5 co2
Calculated Gas Storage Capacity, scf/ton
0
10
20
30
40
50
60
0
200
400
600
800
1000
1200
1400
1600
1800
Pressure, psia
Data
Langmuir Fit
Upper 95% Conf. Interval
Lower 95% Conf. Interval

Sample 56793-6 Methane Adsorption Isotherm Parameters

Parameter	Unit	Value
Sample Depth	ft	unknown
Sample Parameters		
Measurement Gas	-	methane
Measurement Temperature	°F	169.0
Crushed Density	g/cm^3	2.728
Langmuir Parameters		
Number of Points	-	9
Correlation Coefficient	-	0.9957
Langmuir Storage Capacity, As-Received	scf/ton	22.88
Langmuir Storage Capacity Range, As-Received	scf/ton	0.03
Langmuir Pressure	psia	4,252.19
Langmuir Pressure Range	psia	204.18

Sample 56793-6 Methane Adsorption Isotherm Data

Pressure	Storage Capacity, As-Received
psia	scf/ton
502.68	2.52
995.23	4.38
1,503.69	5.90
1,996.93	7.20
2,491.09	8.32
2,994.76	9.30
3,484.90	10.20
3,983.25	11.12
4,477.70	12.01



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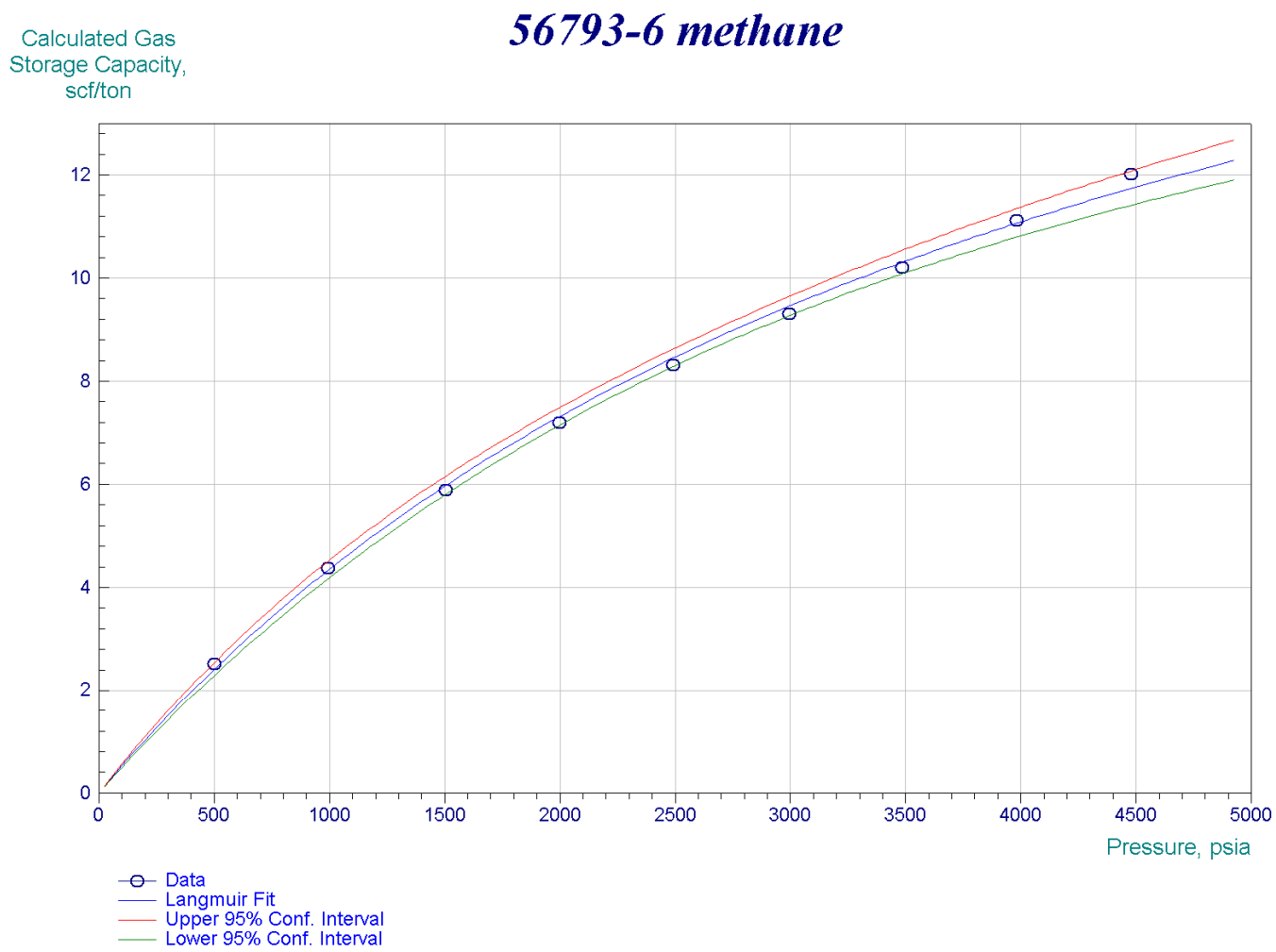

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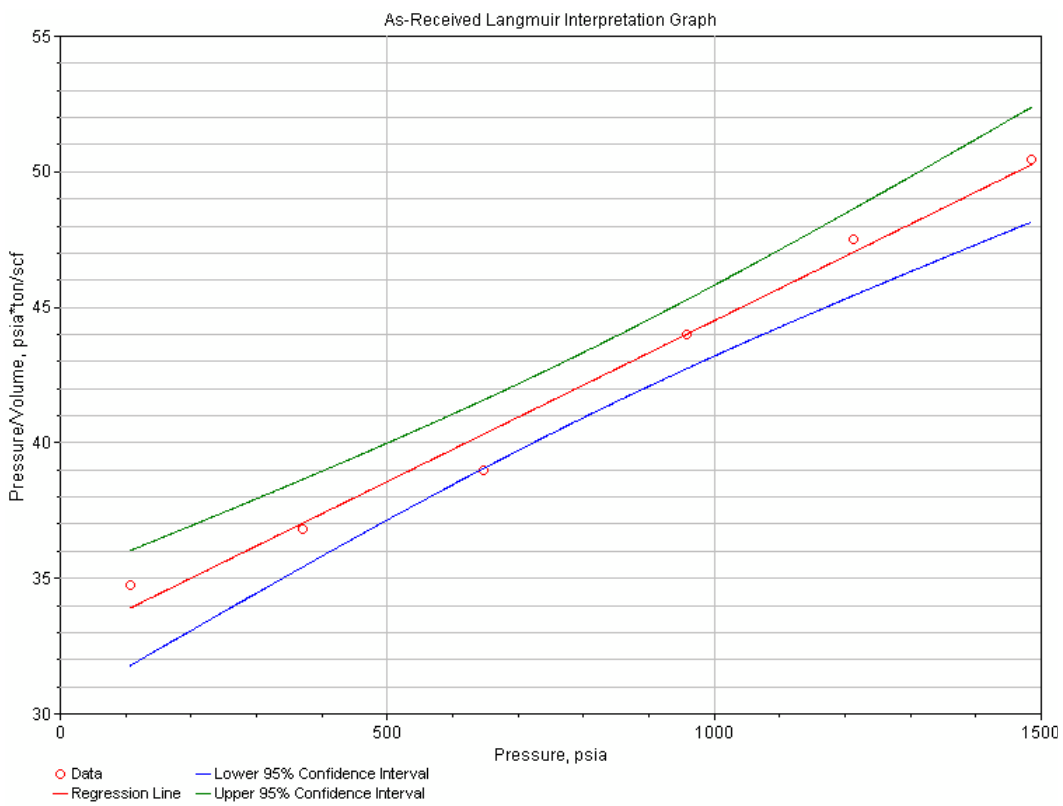
Sample 56793-6 Carbon Dioxide Adsorption Isotherm Parameters

Parameter	Unit	Value
Sample Depth	ft	unknown
Sample Parameters		
Measurement Gas	-	carbon dioxide
Measurement Temperature	°F	169.0
Crushed Density	g/cm^3	2.728
Langmuir Parameters		
Number of Points	-	6
Correlation Coefficient	-	0.9926
Langmuir Storage Capacity, As-Received	scf/ton	84.23
Langmuir Storage Capacity Range, As-Received	scf/ton	0.51
Langmuir Pressure	psia	2,748.78
Langmuir Pressure Range	psia	122.53

Sample 56793-6 Carbon Dioxide Adsorption Isotherm Data

Pressure	Storage Capacity, As-Received
psia	scf/ton
106.75	3.07
369.71	10.04
648.21	16.62
958.05	21.79
1,211.99	25.50
1,485.98	29.45



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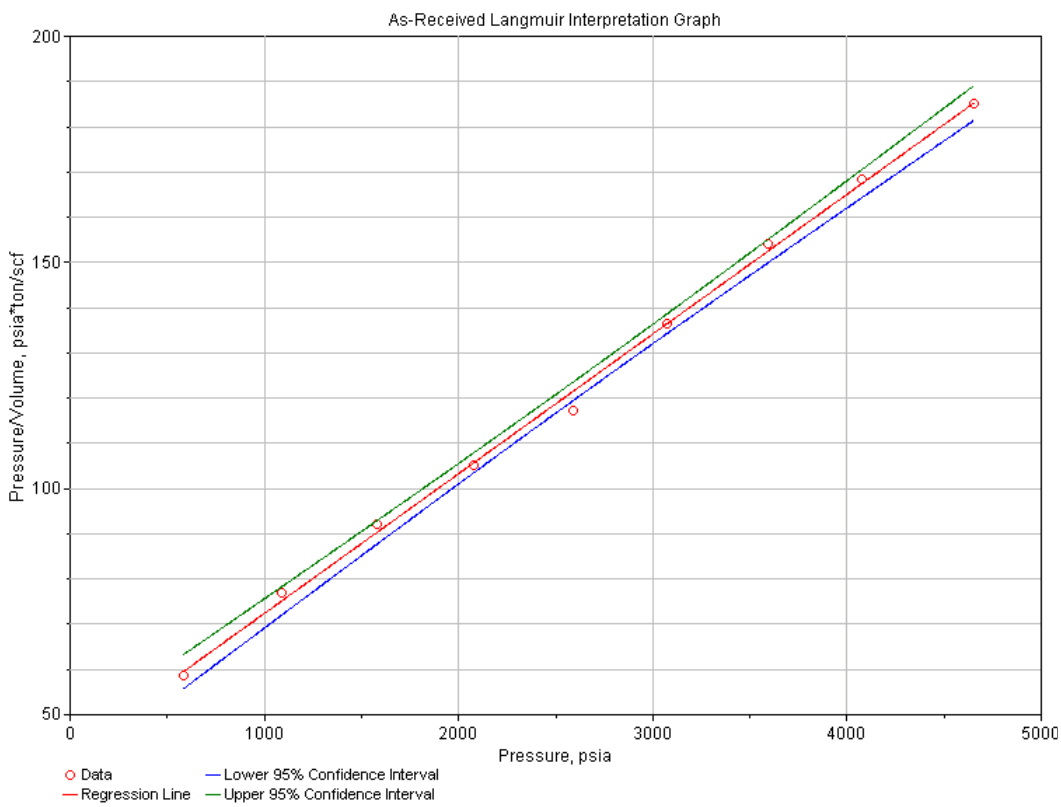
Sample 56793-7 Methane Adsorption Isotherm Parameters

Parameter	Unit	Value
Sample Depth	ft	unknown
Sample Parameters		
Measurement Gas	-	methane
Measurement Temperature	°F	169.0
Crushed Density	g/cm^3	2.686
Langmuir Parameters		
Number of Points	-	9
Correlation Coefficient	-	0.9989
Langmuir Storage Capacity, As-Received	scf/ton	32.37
Langmuir Storage Capacity Range, As-Received	scf/ton	0.02
Langmuir Pressure	psia	1,344.01
Langmuir Pressure Range	psia	105.42

Sample 56793-7 Methane Adsorption Isotherm Data

Pressure	Storage Capacity, As-Received
psia	scf/ton
587.77	10.04
1,088.40	14.12
1,579.29	17.12
2,078.02	19.76
2,592.60	22.14
3,074.76	22.53
3,595.72	23.32
4,078.52	24.22
4,656.80	25.16



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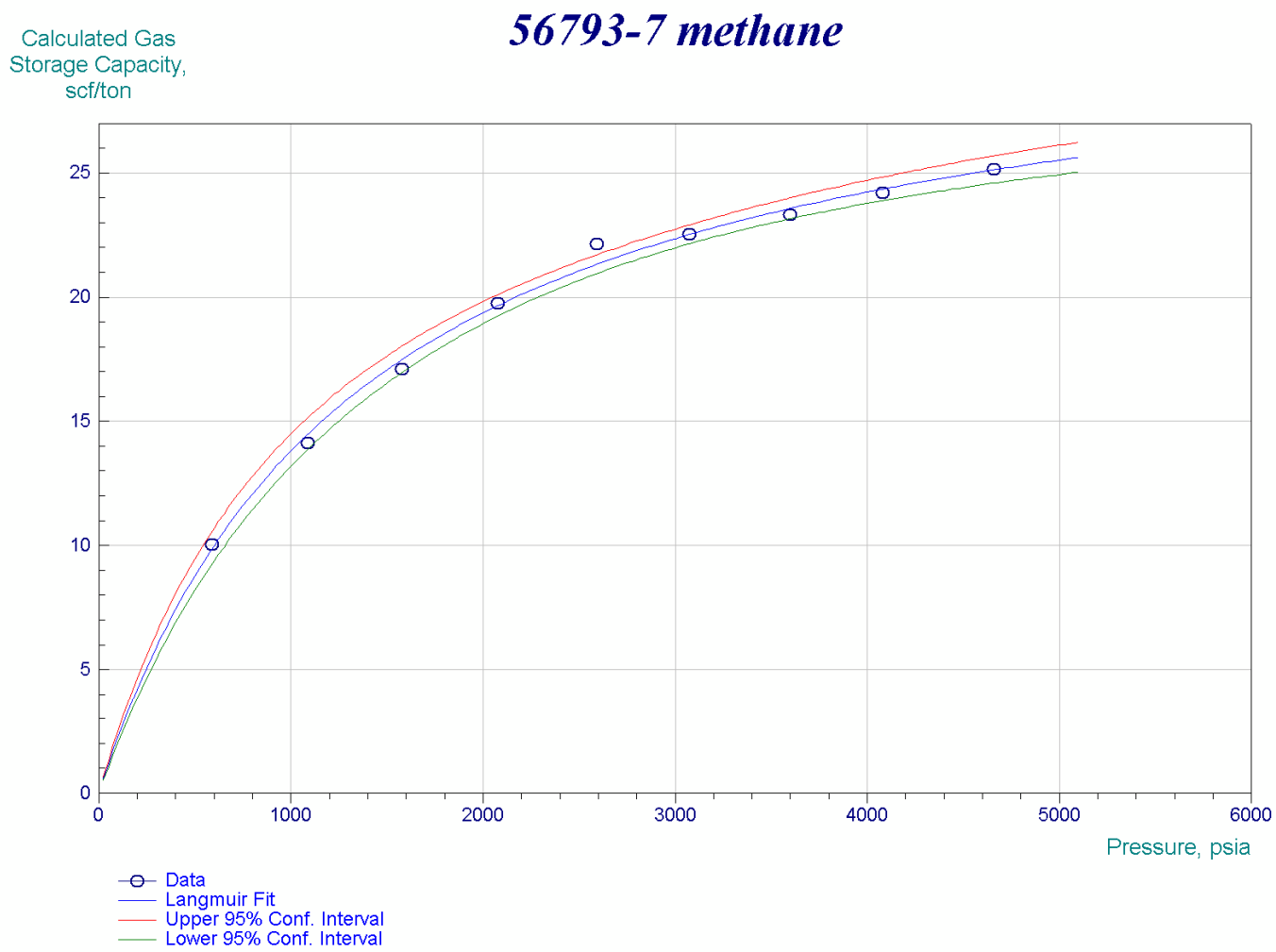

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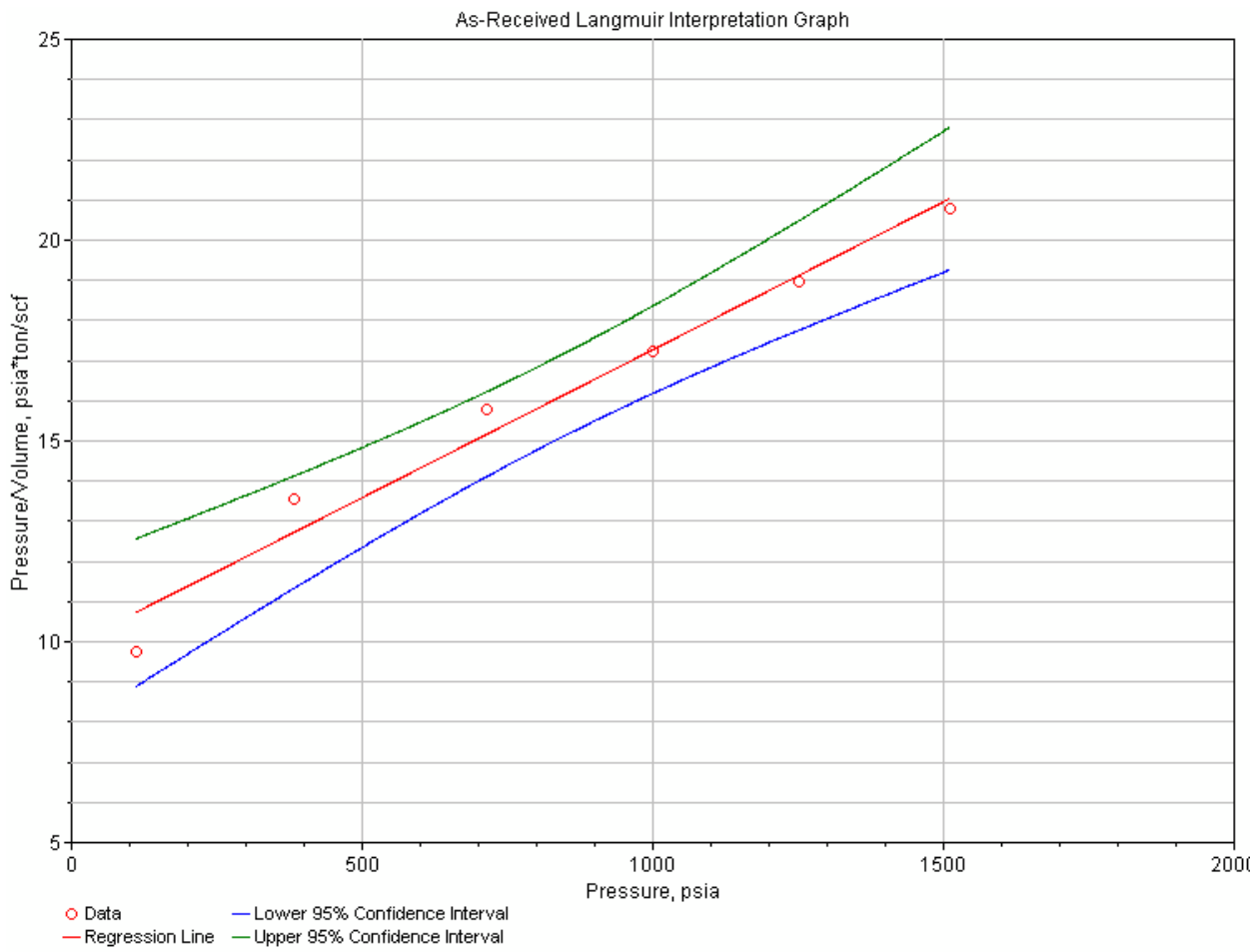
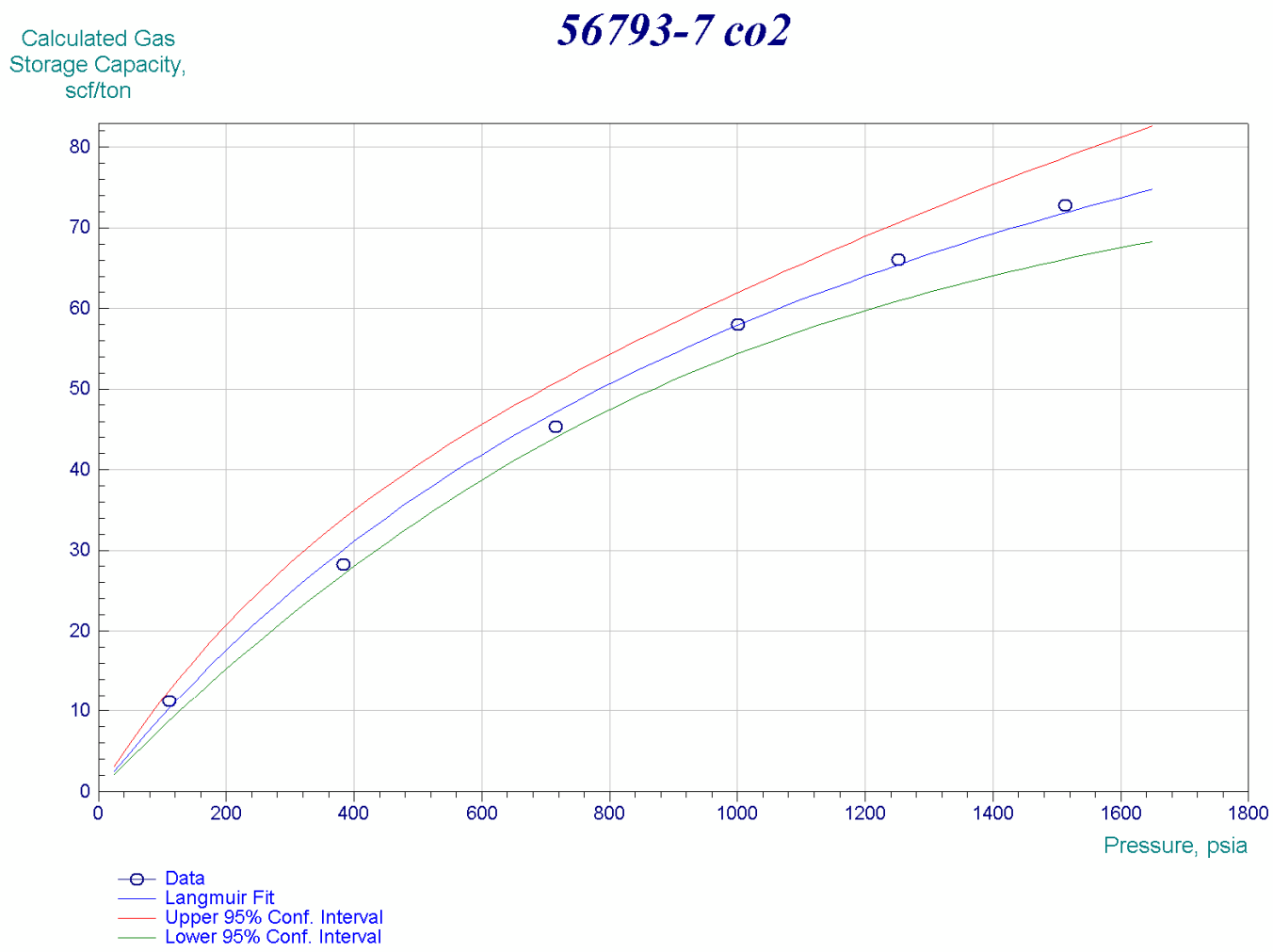
Sample 56793-7 Carbon Dioxide Adsorption Isotherm Parameters

Parameter	Unit	Value
Sample Depth	ft	unknown
Sample Parameters		
Measurement Gas	-	carbon dioxide
Measurement Temperature	°F	169.0
Crushed Density	g/cm^3	2.686
Langmuir Parameters		
Number of Points	-	6
Correlation Coefficient	-	0.9867
Langmuir Storage Capacity, As-Received	scf/ton	135.83
Langmuir Storage Capacity Range, As-Received	scf/ton	0.15
Langmuir Pressure	psia	1,346.22
Langmuir Pressure Range	psia	195.75

Sample 56793-7 Carbon Dioxide Adsorption Isotherm Data

Pressure	Storage Capacity, As-Received
psia	scf/ton
110.33	11.30
383.53	28.27
715.62	45.35
1,001.21	58.06
1,252.22	66.04
1,512.62	72.76


As-Received Langmuir Interpretation Graph
Pressure/Volume, psia*ton/scf
25
20
15
10
5
0
500
1000
1500
2000
Pressure, psia
Data
Regression Line
Lower 95% Confidence Interval
Upper 95% Confidence Interval



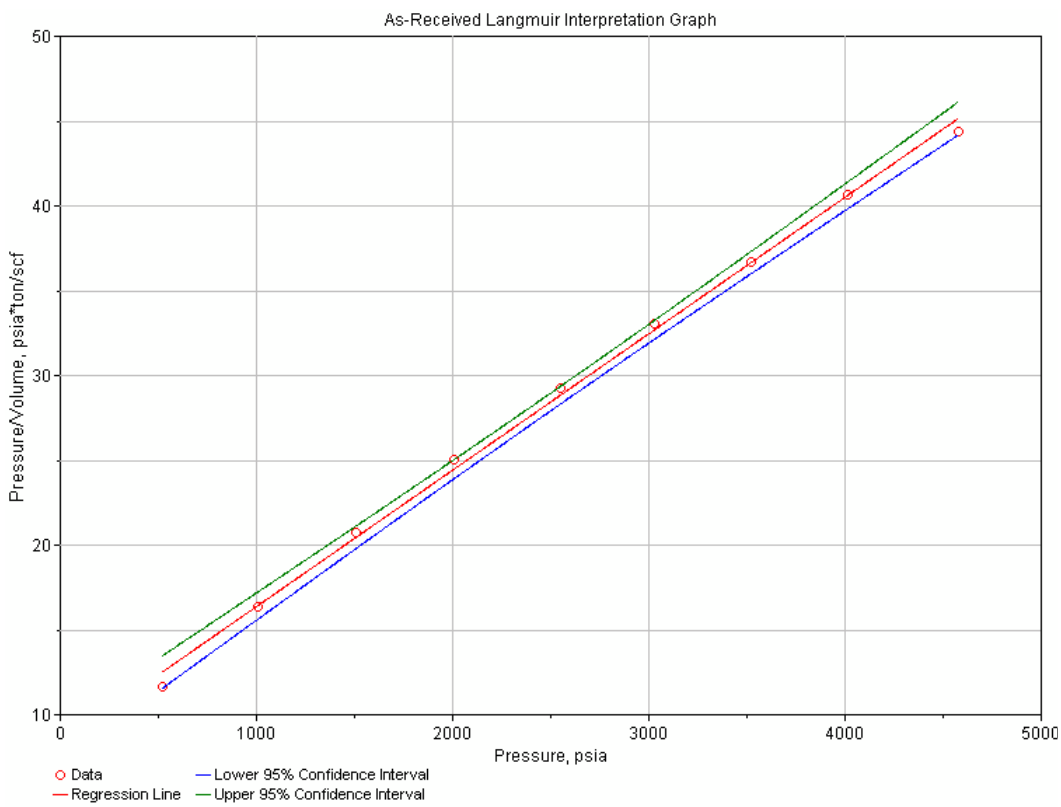
Weatherford LABORATORIES

Sample 56793-8 Methane Adsorption Isotherm Parameters

Parameter	Unit	Value
Sample Depth	ft	unknown
Sample Parameters		
Measurement Gas	-	methane
Measurement Temperature	°F	169.0
Crushed Density	g/cm^3	2.536
Langmuir Parameters		
Number of Points	-	9
Correlation Coefficient	-	0.9989
Langmuir Storage Capacity, As-Received	scf/ton	124.32
Langmuir Storage Capacity Range, As-Received	scf/ton	0.02
Langmuir Pressure	psia	1,036.23
Langmuir Pressure Range	psia	100.03

Sample 56793-8 Methane Adsorption Isotherm Data

Pressure	Storage Capacity, As-Received
psia	scf/ton
521.36	44.86
1,006.53	61.47
1,508.01	72.59
2,009.49	80.12
2,547.36	87.00
3,028.97	91.74
3,522.62	96.11
4,012.30	98.66
4,575.82	103.06



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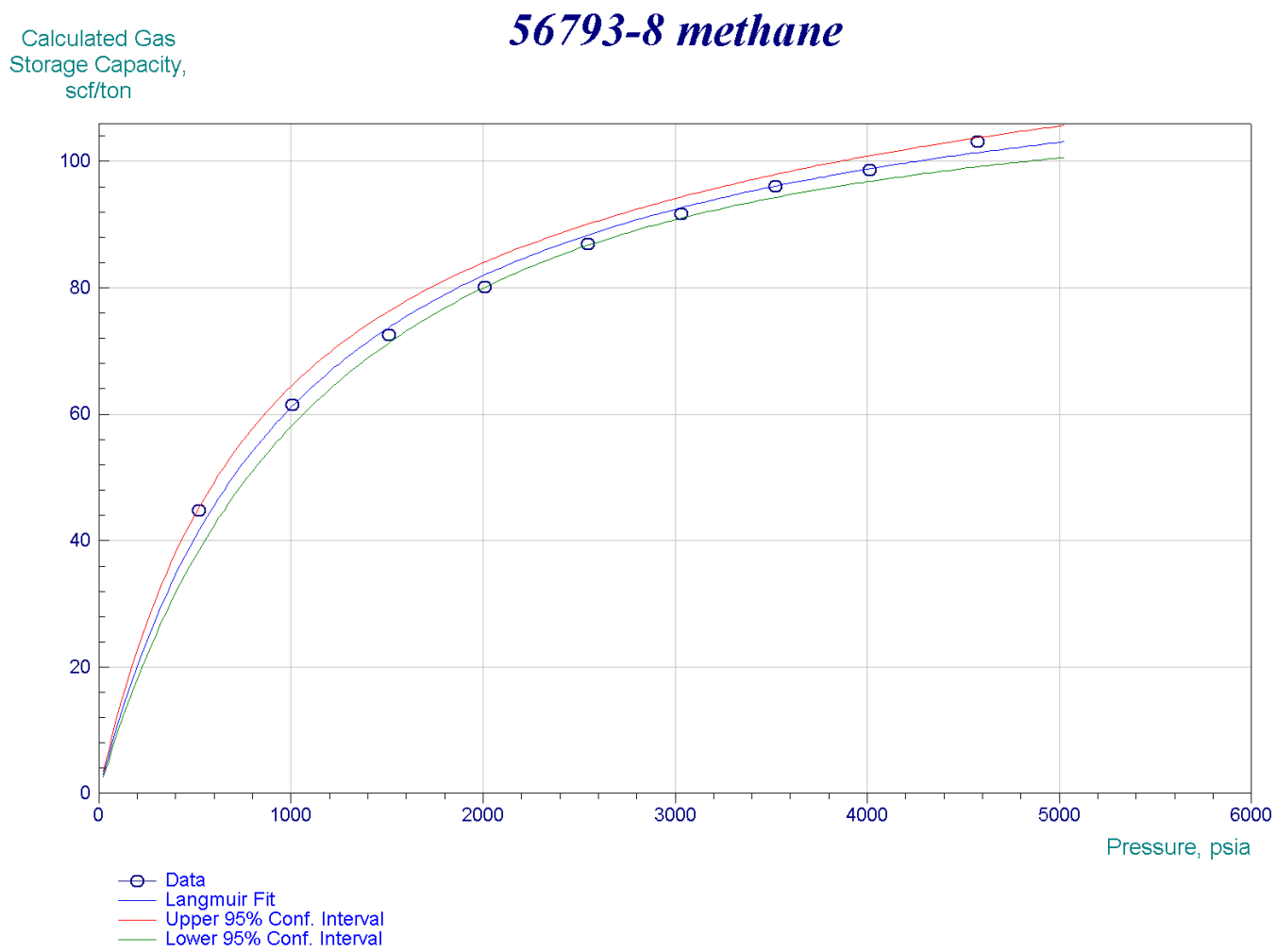

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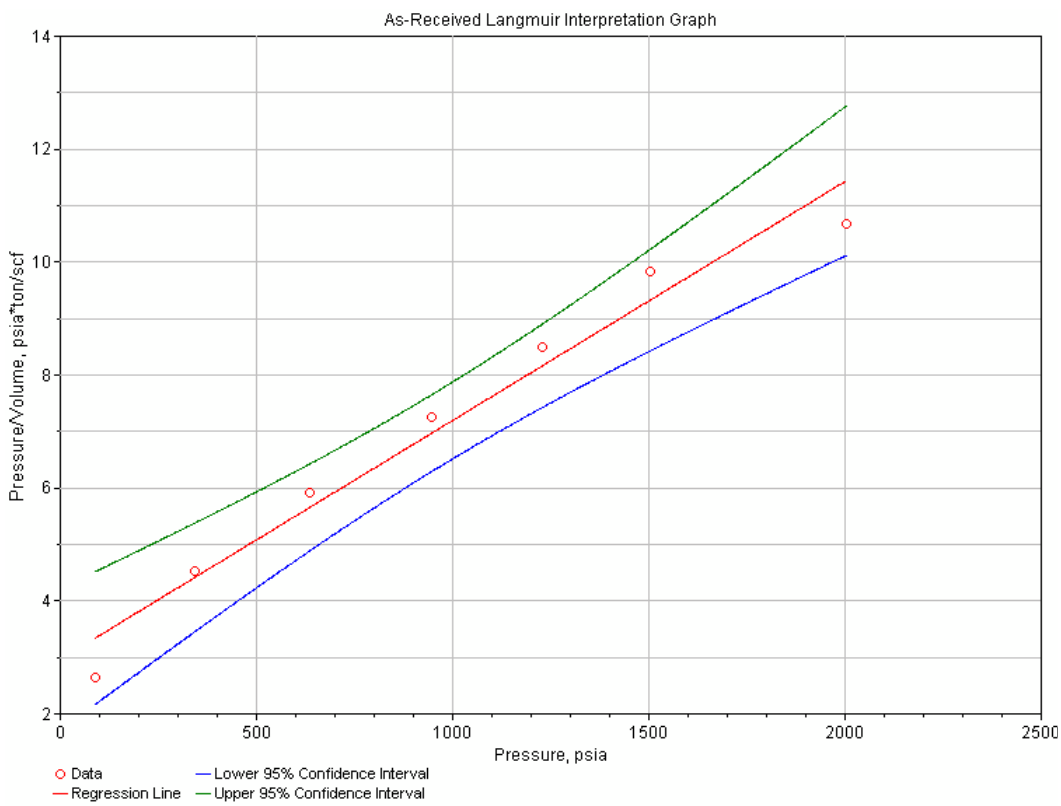
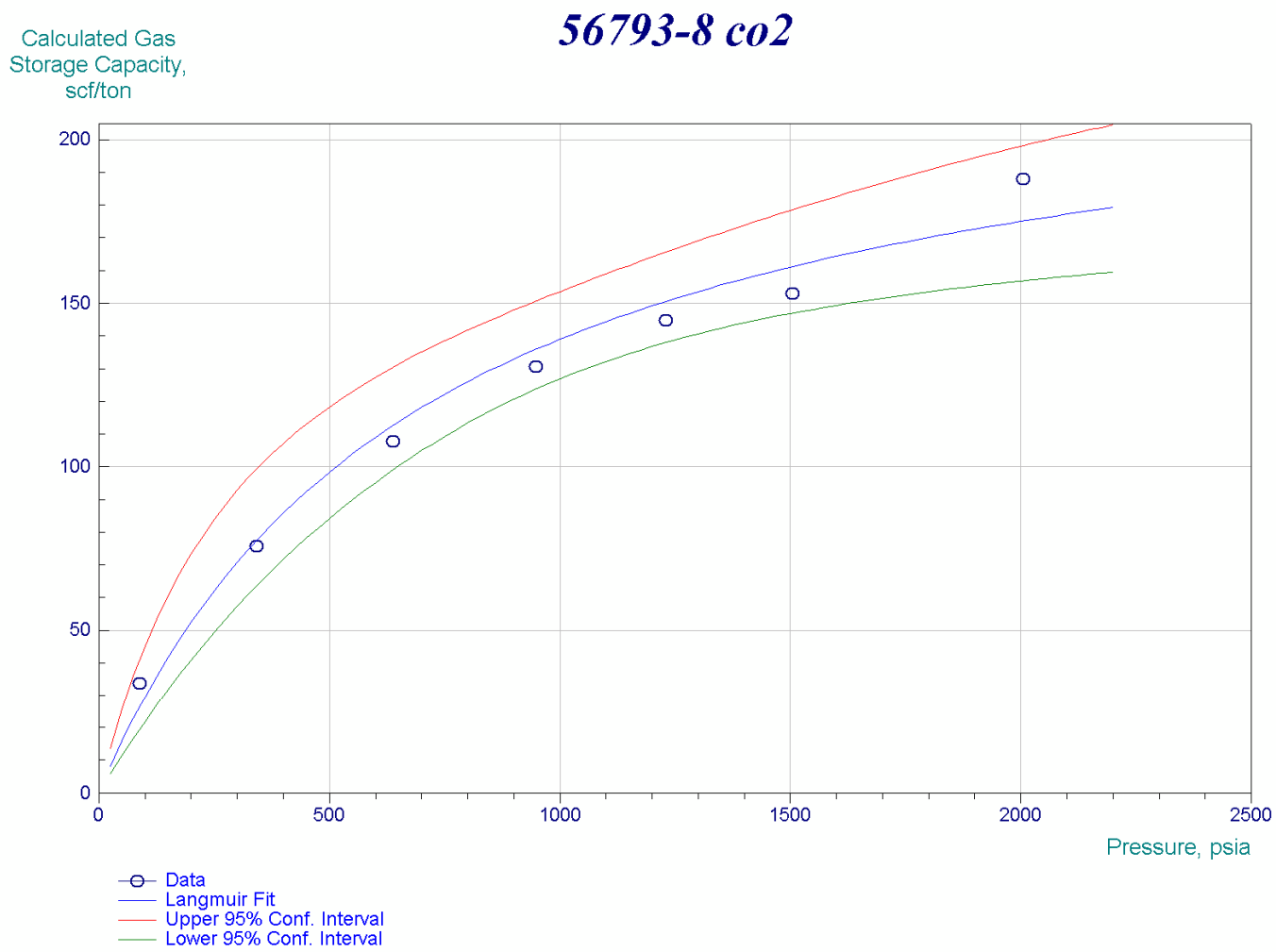
Sample 56793-8 Carbon Dioxide Adsorption Isotherm Parameters

Parameter	Unit	Value
Sample Depth	ft	unknown
Sample Parameters		
Measurement Gas	-	carbon dioxide
Measurement Temperature	°F	169.0
Crushed Density	g/cm^3	2.536
Langmuir Parameters		
Number of Points	-	7
Correlation Coefficient	-	0.9837
Langmuir Storage Capacity, As-Received	scf/ton	236.33
Langmuir Storage Capacity Range, As-Received	scf/ton	8.36
Langmuir Pressure	psia	700.91
Langmuir Pressure Range	psia	163.91

Sample 56793-8 Carbon Dioxide Adsorption Isotherm Data

Pressure	Storage Capacity, As-Received
psia	scf/ton
89.31	33.75
343.29	75.75
637.46	107.72
947.35	130.67
1,230.26	144.75
1,504.62	152.90
2,004.90	187.95





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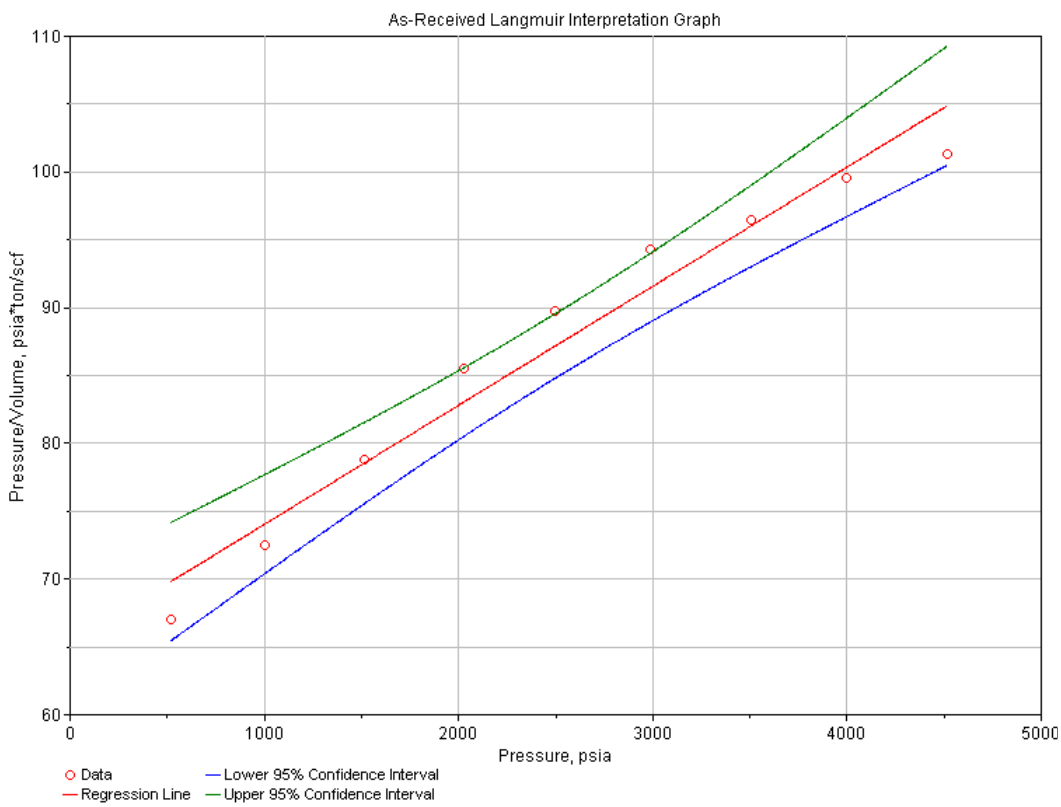
Sample 56793-9 Methane Adsorption Isotherm Parameters

Parameter	Unit	Value
Sample Depth	ft	unknown
Sample Parameters		
Measurement Gas	-	methane
Measurement Temperature	°F	169.0
Crushed Density	g/cm^3	2.522
Langmuir Parameters		
Number of Points	-	9
Correlation Coefficient	-	0.9814
Langmuir Storage Capacity, As-Received	scf/ton	113.96
Langmuir Storage Capacity Range, As-Received	scf/ton	0.26
Langmuir Pressure	psia	7,436.49
Langmuir Pressure Range	psia	436.48

Sample 56793-9 Methane Adsorption Isotherm Data

Pressure	Storage Capacity, As-Received
psia	scf/ton
517.37	7.72
1,000.96	13.81
1,516.24	19.24
2,024.17	23.67
2,496.02	27.82
2,986.36	31.68
3,508.33	36.36
3,994.49	40.11
4,515.64	44.55



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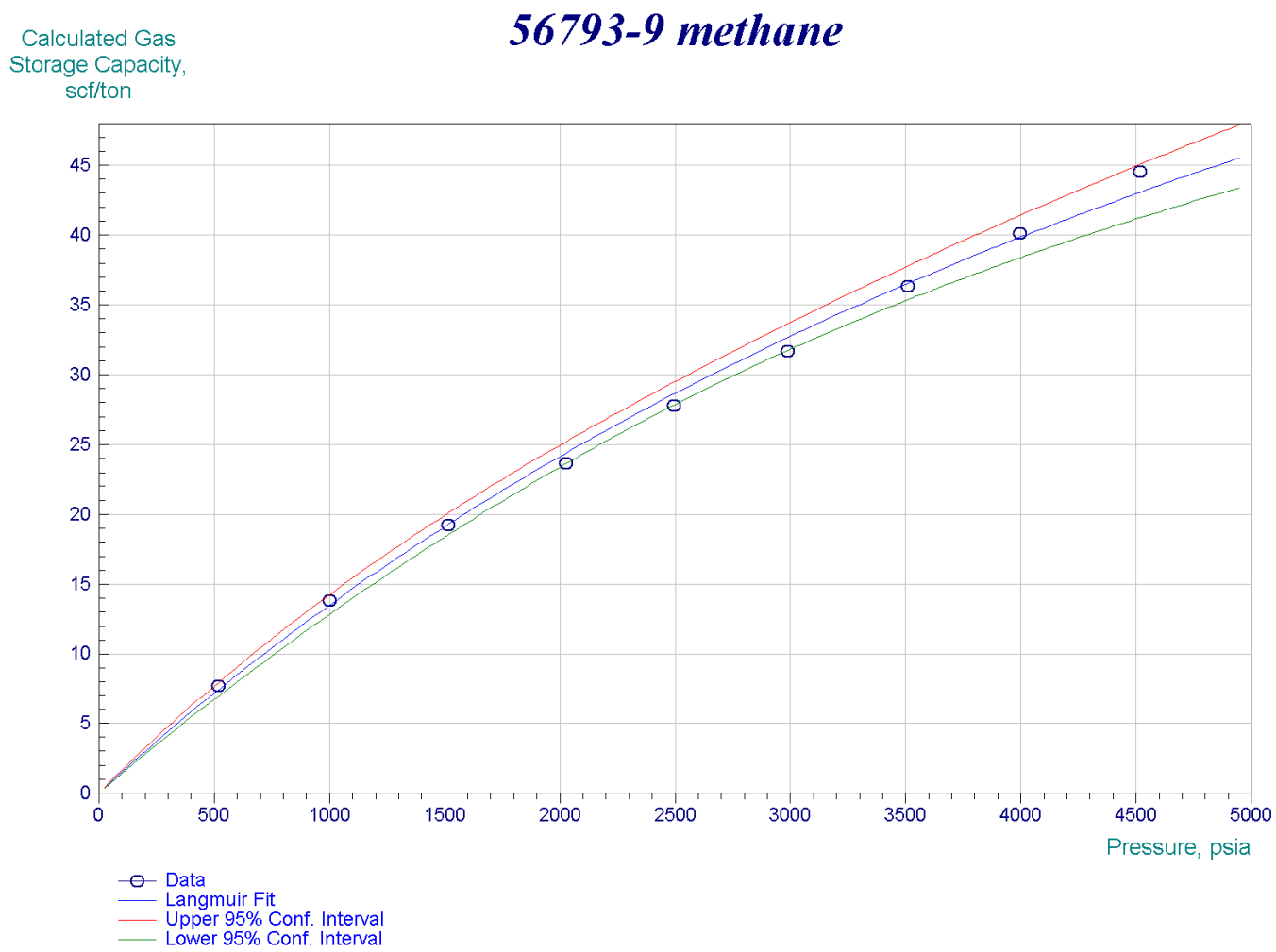

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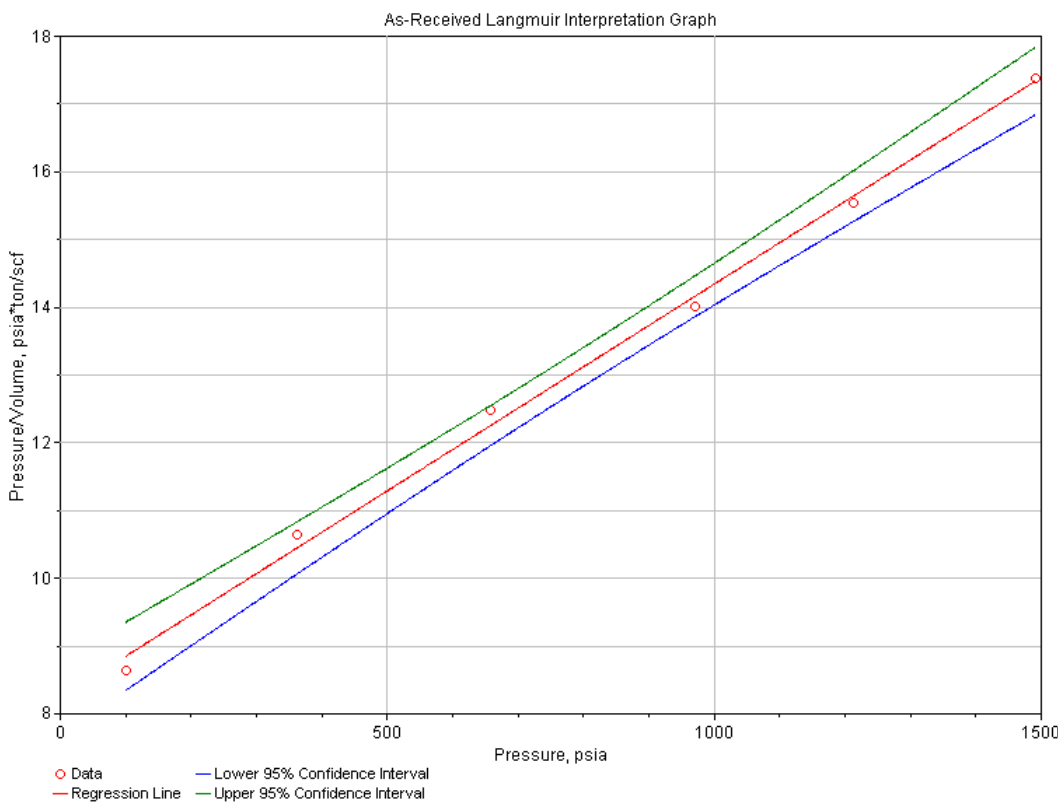
Sample 56793-9 Carbon Dioxide Adsorption Isotherm Parameters

Parameter	Unit	Value
Sample Depth	ft	unknown
Sample Parameters		
Measurement Gas	-	carbon dioxide
Measurement Temperature	°F	169.0
Crushed Density	g/cm^3	2.522
Langmuir Parameters		
Number of Points	-	6
Correlation Coefficient	-	0.9985
Langmuir Storage Capacity, As-Received	scf/ton	163.87
Langmuir Storage Capacity Range, As-Received	scf/ton	0.47
Langmuir Pressure	psia	1,350.30
Langmuir Pressure Range	psia	59.83

Sample 56793-9 Carbon Dioxide Adsorption Isotherm Data

Pressure	Storage Capacity, As-Received
psia	scf/ton
99.70	11.54
362.50	34.09
658.69	52.76
970.37	69.23
1,212.51	77.98
1,491.12	85.81



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Sample 56793-10 Methane Adsorption Isotherm Parameters

Parameter	Unit	Value
Sample Depth	ft	unknown
Sample Parameters		
Measurement Gas	-	methane
Measurement Temperature	°F	169.0
Crushed Density	g/cm^3	2.781
Langmuir Parameters		
Number of Points	-	9
Correlation Coefficient	-	0.9864
Langmuir Storage Capacity, As-Received	scf/ton	20.37
Langmuir Storage Capacity Range, As-Received	scf/ton	0.06
Langmuir Pressure	psia	3,088.98
Langmuir Pressure Range	psia	376.44

Sample 56793-10 Methane Adsorption Isotherm Data

Pressure	Storage Capacity, As-Received
psia	scf/ton
567.23	3.54
1,074.99	5.33
1,577.50	6.69
2,101.62	7.87
2,582.05	8.91
3,081.79	9.80
3,586.72	11.00
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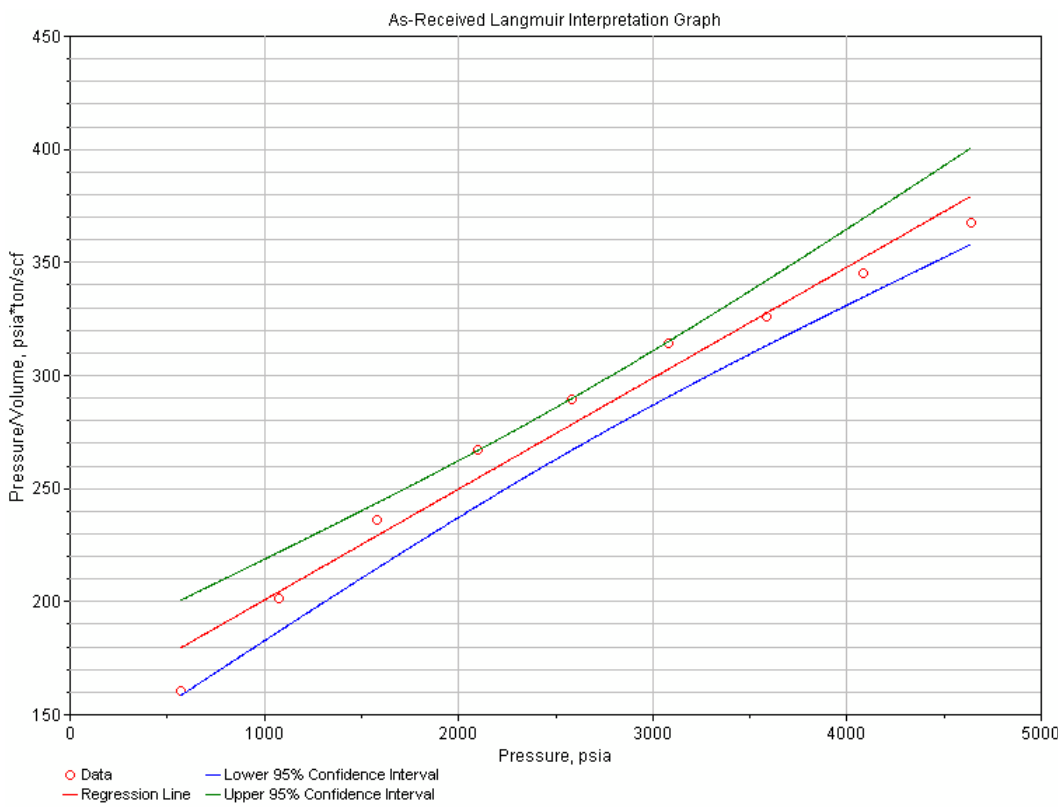
4,636.31	12.62



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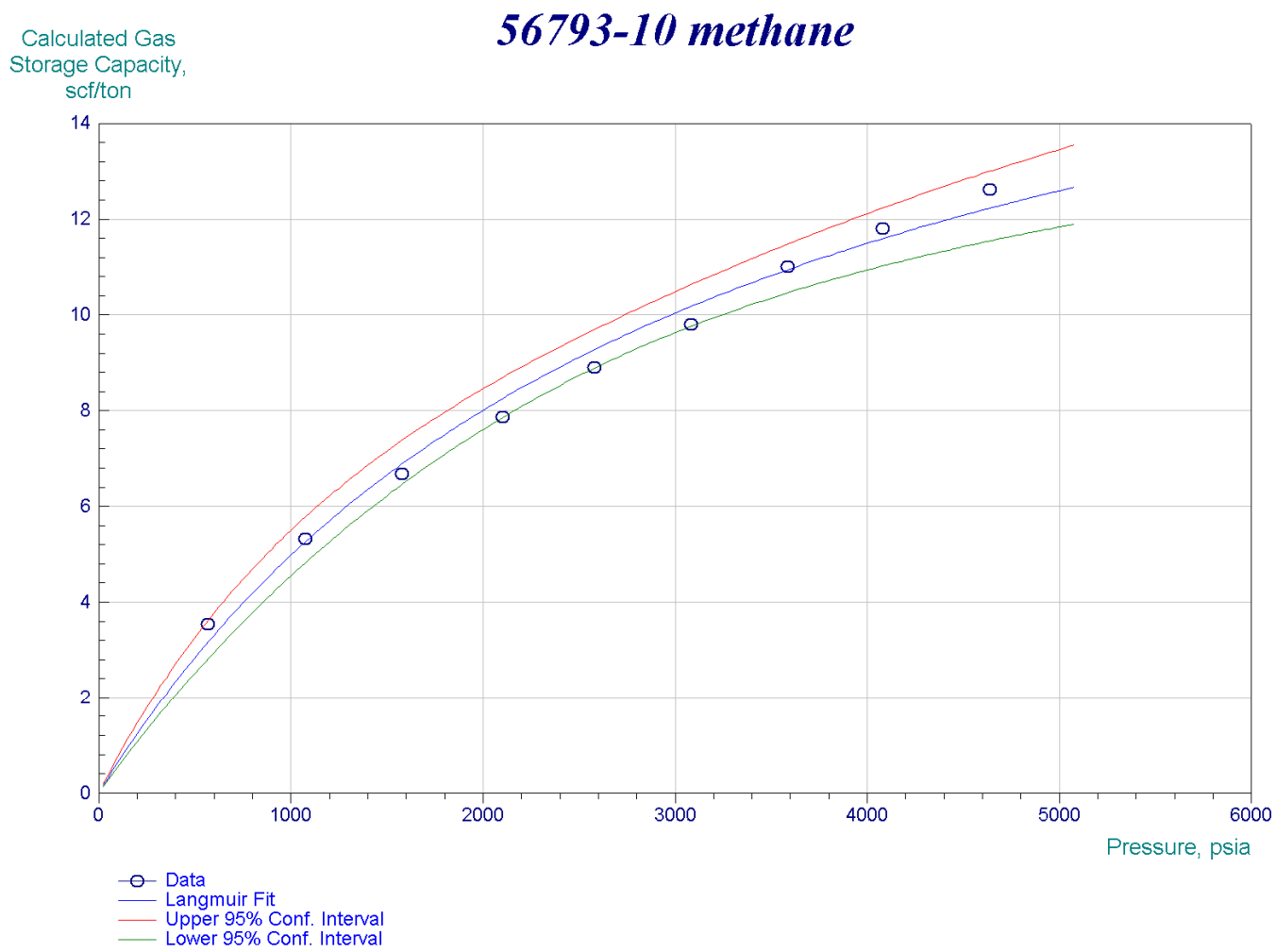

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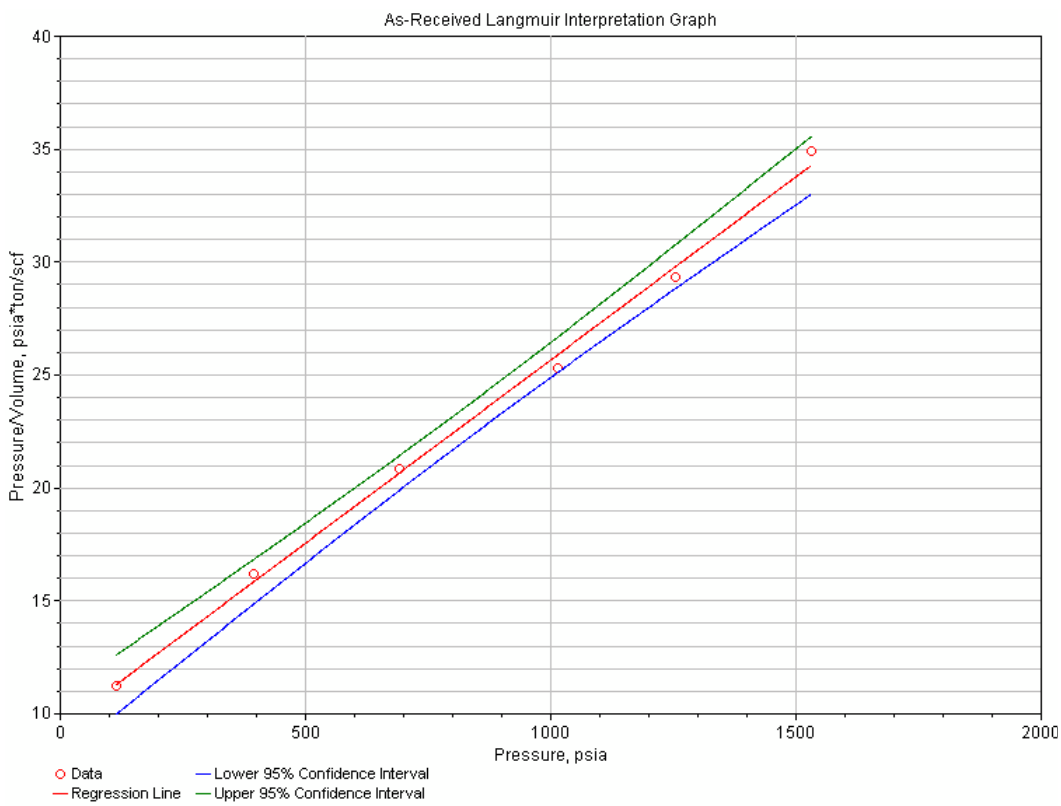
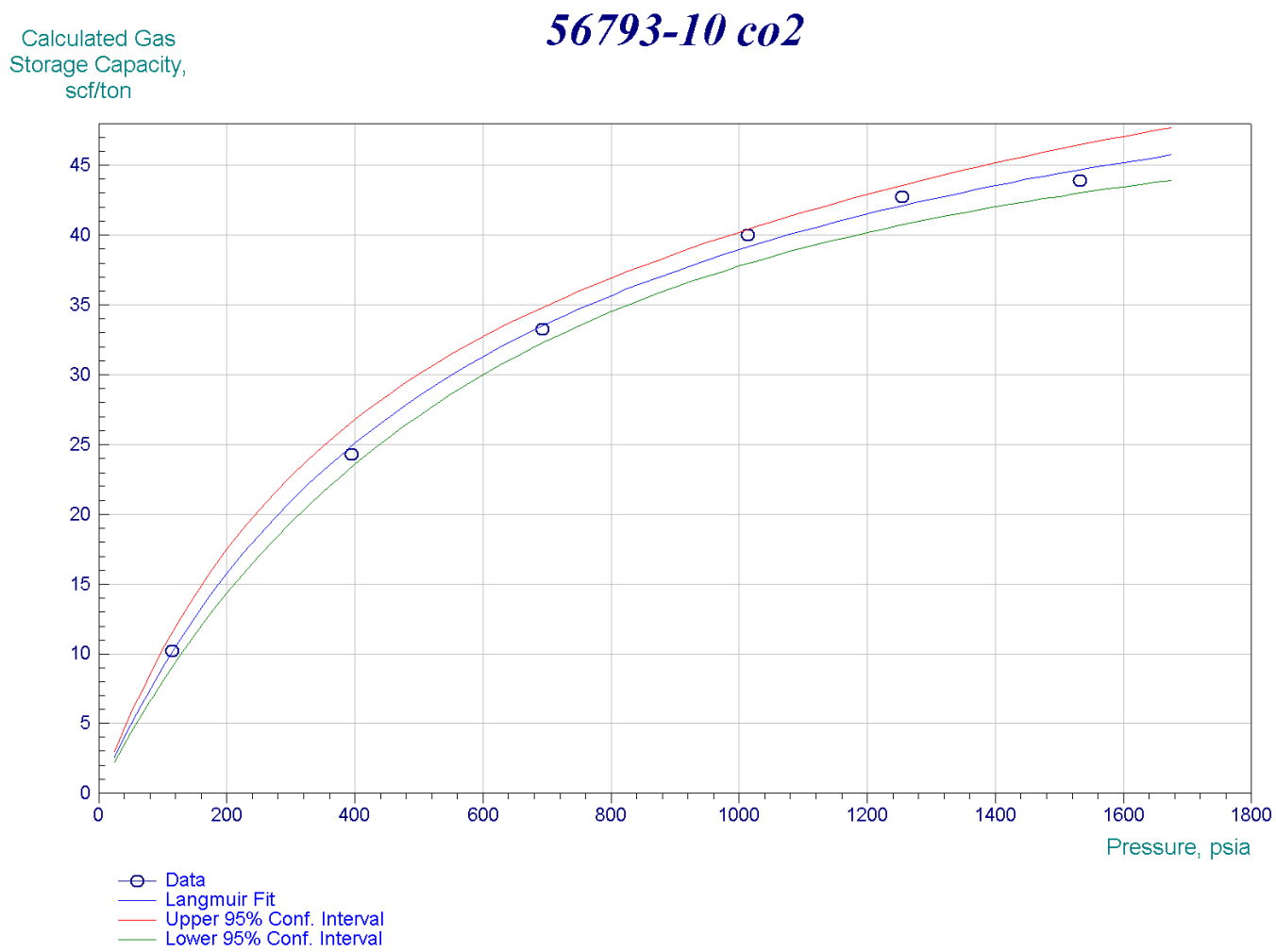
Sample 56793-10 Carbon Dioxide Adsorption Isotherm Parameters

Parameter	Unit	Value
Sample Depth	ft	unknown
Sample Parameters		
Measurement Gas	-	carbon dioxide
Measurement Temperature	°F	169.0
Crushed Density	g/cm^3	2.781
Langmuir Parameters		
Number of Points	-	6
Correlation Coefficient	-	0.9986
Langmuir Storage Capacity, As-Received	scf/ton	61.65
Langmuir Storage Capacity Range, As-Received	scf/ton	0.07
Langmuir Pressure	psia	582.52
Langmuir Pressure Range	psia	62.77

Sample 56793-10 Carbon Dioxide Adsorption Isotherm Data

Pressure	Storage Capacity, As-Received
psia	scf/ton
114.66	10.22
394.28	24.32
692.68	33.23
1,013.63	40.01
1,254.53	42.78
1,531.77	43.90





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Appendix C

Detailed Analyses from Micromeritics

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CALCULATIONS

Saturation Pressure (Po)

Po method is selected by the user on the Po and Temperature Options dialog box. It may be entered, measured, or calculated from temperature.

If entered, Po = user entered value

If measured, Po = equilibrated pressure reading after saturating Po tube

If calculated from temperature, interpolate Po from the Psat vs Temperature table on the Po and Temperature Options dialog box, given the analysis bath temperature

Relative Pressure

If Po was measured:

For points taken before the previous Po measurement,

$$Po_I = Po_1 + \frac{(Po_2 - Po_1) \times (T_I - To_1)}{(To_2 - To_1)}$$

For points taken after the previous Po, use the previous Po:

$$Po_I = Po_I$$

If Po was entered, use the entered Po:

$$Po_I = Po_E$$

If Po was calculated, use the calculated Po:

$$Po_I = Po_C$$

Calculate relative pressure for the Ith data point:

$$P_{rel_1} = \frac{P_1}{Po_I}$$

where

Po_I	=	saturation pressure for the Ith data point (mmHg)
Po_1	=	most previous measured saturation pressure before I^{th} data point (mmHg)
Po_2	=	first measured saturation pressure after the Ith data point (mmHg)
Po_C	=	calculated Po
Po_E	=	entered saturation pressure (mmHg)
T_I	=	time when the Ith data point was taken (minutes)
To_1	=	time when Po_1 was measured (minutes)
To_2	=	time when Po_2 was measured (minutes)
P_{rel_I}	=	relative pressure for the Ith data point (mmHg)
P_I	=	absolute pressure for the Ith data point, taken at equilibrium (mmHg)

Free Space

Free-space volumes are calculated using the following equations:

$$V_{FW} = \frac{V_{LOW}}{T_1} \times \left[\frac{P_1}{P_2} - 1\right] \times T_{STD}$$

$$V_{FC} = \frac{V_{LOW}}{T_2} \times \left[\frac{P_1}{P_3} - 1\right] \times T_{STD}$$

$$V_{ABT} = \frac{V_{FC} - V_{FW}}{1 - \frac{T_{ABT}}{T_{RM}}}$$

where:\

P_1	=	system manifold pressure before dosing helium onto sample (mmHg)
P_2	=	system manifold pressure after dosing helium onto sample (mmHg)
P_3	=	sample pressure after raising Dewar and equilibrating with helium (mmHg)
T_{STD}	=	standard temperature (273.13 K)
T_{RM}	=	approximate room temperature (298 K)
T_1	=	system manifold temperature before dosing helium onto sample (K)
T_2	=	system manifold temperature after raising Dewar and equilibrating with helium (K)
V_{LOW}	=	lower manifold volume (cm^3)
V_{FC}	=	volume of free space, cold (cm^3 at standard temperature)

V_{FW} = volume of free space, warm (cm^3 at standard temperature)
V_{ABT} = portion of cold free space at analysis bath temperature: used in non-ideality correction (cm^3 at standard temperature)
T_{ABT} = analysis bath temperature (K), from the Po and Temperature Options dialog box

Volume Adsorbed

For the Ith dose:

$$Ngas_I = Ngas_{I-1} + V_{LOW} \times \left[\frac{Psys1_I}{Tsys1_I} - \frac{Psys2_I}{Tsys2_I}\right] \times \frac{T_{STD}}{P_{STD}}$$

$$Nads_I = Ngas_I - Psam_I \div P_{STD} \times (V_{FC} + Psam_I \times V_{ABT} \times C)$$

$$V_I = \frac{Nads_I}{Wsam}$$

where:

C = non-ideality correction factor, user-entered on Adsorptive Properties dialog box
$Ngas_I$ = total amount of gas dosed into sample tube after I^{th} dose (cm^3 STP)
$Nads_I$ = amount of gas adsorbed after equilibrating I^{th} dose (cm^3 STP)
P_{STD} = standard pressure (760 mmHg)
$Psys1_I$ = system manifold pressure before I^{th} dose of gas onto sample (mmHg)
$Psys2_I$ = system manifold pressure after I^{th} dose of gas onto sample (mmHg)
$Psam_I$ = sample pressure after equilibrating I^{th} dose of gas onto sample (mmHg)
$Tsys1_I$ = system manifold temperature before I^{th} dose of gas onto sample (K)
$Tsys2_I$ = system manifold temperature after I^{th} dose of gas onto sample (K)
Wsam = weight of sample (g)
V_I = amount of gas adsorbed per gram of sample (cm^3/g STP)

Equilibration

Equilibration is reached when the pressure change per equilibration time interval (first derivative) is less than 0.01% of the average pressure during the interval. Both the first derivative and average pressure are calculated using the Savitzky-Golay[1] convolution method for polynomial functions. The equations below are those used to compute weighted average and first derivative, respectively, for the 6th point of an 11-point window.

$$P_{AVG} = \frac{-36(P_{11}+P_1)+9(P_{10}+P_2)+44(P_9+P_3)+69(P_8+P_4)+84(P_7+P_5)+89(P_6)}{429}$$

$$P_{CHG} = \frac{5(P_{11}-P_1)+4(P_{10}-P_2)+3(P_9-P_3)+2(P_8-P_4)+(P_7-P_5)}{110}$$

where the numerical constants are from the Savitzky-Golay convolution arrays, and

P_{AVG} = average pressure (mmHg)
P_{CHG} = change in pressure (mmHg)
P_I = I^{th} pressure reading taken at equilibrium intervals (mmHg)

After equilibration has been reached, if the user-entered minimum equilibration time from the Low Pressure Options dialog box has not elapsed, the equilibration continues until the entered time has elapsed.

If the user entered a non-zero maximum equilibration time from the Low Pressure Options dialog box, and this time period has elapsed before equilibration has been reached, the equilibration ends as if equilibration had been reached, and the point is collected.

If a non-zero value that is too small is entered for the maximum equilibration time, the points are collected before equilibration is reached.

If P_{AVG} is greater than 0.995 times the current Po, equilibration will not take place until the *Minimum equilibration delay for P/Po 0.995* has expired, in addition to the standard equilibration criteria.

Thermal Transpiration Correction

During data reduction, thermal transpiration correction is applied to the data if the user selected **Thermal transpiration correction** from the Report Options dialog box. Starting with the first collected pressure, the following calculations are performed until the pressure ratio (PC/P) is greater than or equal to 0.99.

$$Y = \frac{P \times SD \times MD^2}{2.33 \times T} \times 10^3$$

$$\mu = \frac{1 + G \times Y}{1 + H \times Y}$$

$$F = \frac{1}{(\alpha \times Y^2) + (\beta \times Y) + \mu}$$

$$PC = \left\{ 1 - \left[F - \left(F \left(\frac{T_{ABT}}{T_{RM}} \right)^{0.5} \right) \right] \right\} \times P$$

where:

P	=	equilibrated collected pressure measured by gauge at temp T_{RM} (mmHg)
SD	=	inside diameter of sample tube (mm), from the Report Options dialog box
MD	=	thermal transpiration hard sphere diameter of gas (Å), from the Adsorptive Properties dialog box
T	=	average temperature $[T_{ABT} + T_{RM}] / 2$ (K)
α	=	Weber's coefficient, 0.033
β	=	Weber's coefficient, 0.245
G	=	Weber's coefficient, 2.5
H	=	Weber's coefficient, 2
T_{ABT}	=	analysis bath temperature (K), from the Po and Temperature Options dialog box
T_{RM}	=	room temperature (298 K)
PC	=	corrected equilibrated pressure at temperature T_{ABT} (mmHg)
F, Y, μ	=	intermediate values for subsequent calculations

BET Surface Area

For each point designated for surface area calculations, the BET[2] transformation is calculated as follows:

$$B_1 = \frac{P_{rel_1}}{(1.0 - P_{rel_1}) \times N_{ads_1}}$$

where B_I is in units of g/cm^3 STP.

A least-squares fit is performed on the (P_{relI} ,B_I) designated pairs where P_{relI} is the independent variable and B_I is the dependent variable. The following are calculated:

a. Slope (S g/cm^3 STP)

b. Y-intercept (Y_{INT} g/cm^3 STP)

c. Error of the slope (S_{ERR} g/cm^3 STP)

d. Error of the y-intercept (YI_{ERR} g/cm^3 STP)

e. Correlation coefficient (Cc)

Using the results of the above calculations, the following can be calculated:

BET Surface Area (m^2/g):

$$SA_{BET} = \frac{CSA \times (6.023 \times 10^{23})}{(22414\ cm^3\ STP) \times (10^{18}\ nm^2/m^2) \times (S + Y_{INT})}$$

where

CSA = analysis gas molecular cross-sectional area (nm^2), user-entered on the Adsorptive Properties dialog box

BET C value:

$$C = \frac{S + Y_{INT}}{Y_{INT}}$$

Volume of the Monolayer (cm^3/g STP):

$$V_M = \frac{1}{C \times Y_{INT}} = \frac{1}{S + Y_{INT}}$$

Error of the BET Surface Area (m^2/g):

$$BET_{ERR} = \frac{SA_{BET} \times (S_{ERR}{}^2 + YI_{ERR}{}^2)^{0.5}}{Y_{INT} + S}$$

Langmuir Surface Area

For each point designated for surface area calculations, the Langmuir[3] transformation is calculated as follows:

$$L_I = \frac{P_{rel_I}}{N_{ads_I}}$$

where L_I is in units of g/cm^3 STP

A least-squares fit is performed on the (P_{relI} ,L_I) designated pairs where P_{relI} is the independent variable and L_I is the dependent variable. The following are calculated:

a. Slope (S g/cm^3 STP)

b. Y-intercept (Y_{INT} g/cm^3 STP)

c. Error of the slope (S_{ERR} g/cm^3 STP)

d. Error of the y-intercept (YI_{ERR} g/cm^3 STP)

e. Correlation coefficient (Cc)

Using the results of the above calculations, the following can be calculated:

Langmuir Surface Area (m^2/g):

$$SA_{LAN} = \frac{CSA \times (6.023 \times 10^{23})}{(22414\ cm^3\ STP) \times (10^{18}\ nm^2/m^2) \times S}$$

where

CSA = analysis gas molecular cross-sectional area (nm^2), user-entered on the Adsorptive Properties dialog box

Volume of the Monolayer (cm^3/g STP):

$$V_M = \frac{1}{S}$$

Langmuir b Value:

$$b = (Y_{INT})(V_M)$$

Error of the Langmuir Surface Area (m^2/g):

$$LAN_{ERR} = \frac{SA_{LAN} \times S_{ERR}}{S}$$

t-Plot

For each point designated for t-Plot[4] calculations, the following calculations are done:

Thickness for the Ith point (Å):

$$t_I = HP1 \times \left[\frac{HP2}{\ln(P_{rel_I})}\right]^{HP3} \qquad \text{(Halsey[5])}$$

or

$$t_I = \left[\frac{HJP1}{HJP2 - \log(P_{rel_I})}\right]^{HJP3} \qquad \text{(Harkins and Jura[6])}$$

where:

t_I	=	thickness for I^{th} point
HP1	=	Halsey parameter #1
HP2	=	Halsey parameter #2
HP3	=	Halsey parameter #3
HJP1	=	Harkins and Jura parameter #1
HJP2	=	Harkins and Jura parameter #2
HJP3	=	Harkins and Jura parameter #3
P_{relI}	=	relative pressure for the Ith point (mmHg)

A least-squares analysis fit is performed on the (t_I, N_{adsI}) data pairs where t_I is the independent variable and $Nads_I$ is the dependent variable. Only the values of t_I between t_{MIN} and

t_{MAX}, the minimum and maximum thickness, are used. The following are calculated:

a. Slope (S cm^3/g-Å STP)

b. Y-intercept (Y_{INT} cm^3/g STP)

c. Error of the slope (S_{ERR} cm^3/g-Å STP)

d. Error of the Y-intercept (YI_{ERR} cm^3/g STP)

e. Correlation coefficient (Cc)

Using the results of the above calculations, the following can be calculated:

External Surface Area (m^2/g):

$$SA_{EXT} = \frac{(S\ cm^3/g - A\ STP) \times (10^{10}\ A/m) \times (D\ cm^3\ liquid/cm^3\ STP)}{F \times (10^6\ cm^3/m^3)}$$

where

F = surface area correction factor, user-entered on the t-Plot Report Options dialog box

D = density conversion factor, user-entered on the Adsorptive Properties dialog box

Micropore Surface Area (m^2/g):

$$SA_{\mu P} = SA_{TOT} + SA_{EXT}$$

where SA_{TOT} is the BET surface area if the user enabled the BET report exclusively, or Langmuir surface area if the user enabled the Langmuir report exclusively. If neither report has been selected, SA_{TOT} is the BET surface area value calculated using a set of default parameters.

Micropore Volume (cm^3 liquid/g):

$$V_{\mu P} = (Y_{INT}\ cm^3/g\ STP) \times (D\ cm^3\ liquid/cm^3\ STP)$$

BJH Pore Volume and Area Distribution

For adsorption data, the relative pressure and volume adsorbed data point pairs collected during an analysis must be arranged in reverse order from which the points were collected during analysis. All calculations are performed based on a desorption model, regardless of whether adsorption or desorption data are being used.

The data used in these calculations must be in order of strictly decreasing numerical value. Points which do not meet this criterion are omitted. The remaining data set is composed of relative pressure (Pr), volume adsorbed (Va) pairs from (Pr_1, Va_1) to (Pr_N, Va_N) where (Pr_N = 0, Va_N = 0) is assumed as a final point. Each data pair represents an interval boundary (or desorption step boundary) for intervals i=1 to i=N-1 where N = total number of (Pr, Va) pairs.

Generally, the desorption branch of an isotherm is used to relate the amount of adsorbate lost in a desorption step to the average size of pores emptied in the step. A pore loses its condensed liquid adsorbate, known as the core of the pore, at a particular relative pressure related to the core radius by the Kelvin[7] equation. After the core has evaporated, a layer of adsorbate remains on the wall of the pore. The thickness of this layer is calculated for a particular relative pressure from the thickness equation. This layer becomes thinner with successive decreases in pressure, so that the measured quantity of gas desorbed in a step is composed of a quantity equivalent to the liquid cores evaporated in that step plus the quantity desorbed from the pore walls of pores whose cores have been evaporated in that and previous steps. Barrett, Joyner, and Halenda[8] developed the method (known as the BJH method) which incorporates these ideas. The algorithm used on the ASAP 2020 is an implementation of the BJH method.

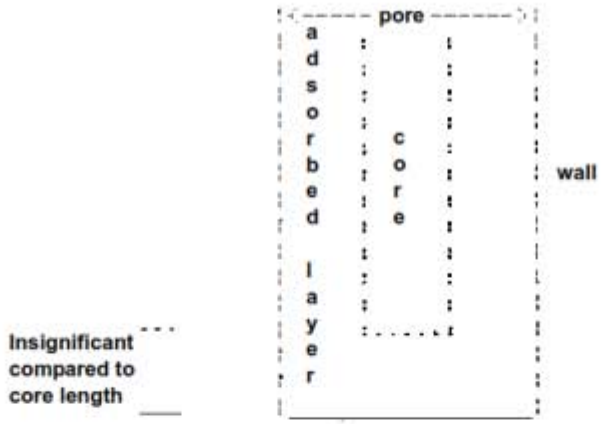
Explanation of Terms

A pore filled with condensed liquid nitrogen has three zones:

a. The ***core*** - evaporates all at once when the critical pressure for that radius is reached; the relationship between the core radius and the critical pressure is defined by the Kelvin equation.

b. The ***adsorbed layer*** - composed of adsorbed gas that is stripped off a bit at a time with each pressure step; the relationship between the thickness of the layer and the relative pressure is defined by the thickness equation.

c. The ***walls of the cylindrical pore*** - the diameter of the empty pore is required to determine the pore volume and pore area. End area is neglected.



Calculations

The volumes adsorbed (Va) are converted to the liquid equivalent volumes (V1, cm^3/g):

$$VI_l = (Va_l)(D)$$

where D is the Density Conversion Factor from the Adsorptive Properties dialog box.

The relative pressure (Pr_l) is assumed to be close to unity so that substantially all the pores in the sample are filled.

The corresponding Kelvin core radius is calculated. Only pores smaller than this size will be included:

$$Rc_l = \frac{-A}{(1+F)[\ln(Pr_l)]}$$

where

A	=	adsorbate property factor (the BJH Adsorptive Options dialog box)
F	=	fraction of pores open at both ends (from the BJH Adsorption Report Options dialog box or the BJH Desorption Report Options dialog box); assumed to be zero for desorption

This radius will be adjusted for the thickness of the adsorbed layer during subsequent calculation steps.

The thickness of the remaining adsorbed layer at this relative pressure is calculated:

$$Tw_1 = HP1\left[\frac{HP2}{\ln(Pr_1)}\right]^{HP3}$$

where

HP1, HP2, and HP3 are Halsey Parameters 1, 2, and 3 (respectively) from the Halsey Thickness Equation dialog box.

These calculations illustrate the use of the Halsey thickness equation. If the Harkins/Jura equation was selected, substitute the following wherever the thickness equation appears:

$$Tw_1 = \left[\frac{HJ1}{HJ2 - \log(Pr_1)}\right]^{HJ3}$$

where

HJ1, HJ2, and HJ3 are Harkins-Jura Parameters 1, 2, and 3 (respectively) from the Harkins-Jura Thickness Equation dialog box.

The following calculations (a-c) are made for each relative pressure interval based on the increment of volume desorbed during that interval. The variable I refers to the interval number, that is I=1 for the first interval from Pr_1 to Pr_2, and so on. J refers to each previous interval during which new pores were found. K refers to the total number of intervals in which new pores have been found. K is also the number of lines reported on the BJH table for collected data.

a. The thickness of the adsorbed layer at the end of the interval is calculated as follows:

$$Tw_{I+1} = HP1\left[\frac{HP2}{\ln(Pr_{I+1})}\right]^{HP3}$$

(For the last pressure interval from the lowest Pr_I to zero relative pressure, $Tw_{I+1} = 0$.)

For the first pressure interval, there are no previously opened pores so the volume desorbed from walls of previously opened pores is zero ($Vd_1 = 0$), and the remainder of Step a is skipped.

The change in thickness of the wall layer due to desorption from preivously opened pores is calculated:

$$\Delta Tw = Tw_1 - Tw_{I+1}$$

The annular cross-sectional area of the wall layer desorbed is calculated for all previously opened pores:

$$CSA_J = \pi[(Rc_j + \Delta Tw)^2 - Rc_j{}^2](10^{-16}\ cm^2/A^2)$$

The total volume of gas desorbed from walls of previously opened pores is calculated:

$$Vd_I = \sum(Lp_J)(CSAa_J) \text{ for all previously opened pores}$$

where LP_J = length of previously opened pores as calculated in Step b(2).

b. The physical processes occurring for this pressure interval are determined as follows:

(1) If Vd_I is greater than the current increment of volume desorbed (Vl_I - Vl_{I+1}), desorption from walls only is occurring. Total surface of walls exposed thus far (cm^2/g) is calculated as follows:

$$SA_W = \sum\pi(LP_J)(D_{avg_J})(10^{-8}\ cm/A) \quad \text{for all previously opened pores}$$

where

D_{avgJ} = weighted average pore diameter calculated below in Step b(2).

A new layer thickness (ΔTw) that will not overcompensate for the actual volume desorbed in this interval is calculated:

$$\Delta Tw = \frac{(V1_I - V1_{I+1})(10^8\ A/cm)}{SAw_I}$$

Since no cores are evaporated in this pressure interval, no new pores are revealed. Thus no ending Kelvin radius and average pore diameter are calculated for this interval. Note that this means the report may have fewer tabulated intervals on the collected data report than experimental pressure intervals.

(2) If Vd_I is less than the volume increment desorbed during this interval, the remaining volume is due to new pores with core evaporation taking place in this interval. K, the number of intervals with new pores exposed, is increased by 1. (For the interval from the lowest to zero relative pressure, no new pore volume is calculated and the rest of Step b is skipped.)

The volume desorbed from newly opened pores in this interval is calculated as follows:

$$Vc_I = (VI_I - VI_{I+1}) - Vd_I$$

The Kelvin radius for the end of the interval is calculated as follows:

$$Rc_{K+1} = \frac{-A}{(1+F)[\ln(Pr_{I+1})]}$$

All new pores opened in this interval are represented by one pore having a length-weighted average pore diameter and a corresponding length sufficient to account for the required volume of adsorbate. The weighted average pore diameter is calculated as follows:

$$D_{avg_K} = \frac{(2)(Rc_K + Rc_{K+1})(Rc_K)(Rc_{K+1})}{Rc_K{}^2 + Rc_{K+1}{}^2}$$

D_{avgK} is the diameter of a pore which would have a surface area that is the average of the areas for pores with radius and , if its length was the mean of the lengths at those radii.

The relative pressure corresponding to is calculated as follows:

$$P_{avg_K} = \ln^{-1}\left[\frac{-2A}{(1+F)(D_{avg_K})}\right]$$

The thickness of the adsorbed layer at this pressure is calculated as follows:

$$Tw_{avg_K} = HP1\left[\frac{HP2}{\ln(P_{avg_K})}\right]^{HP3}$$

The decrease in thickness of the wall layer by desorption from the walls of new pores during the lower portion of the pressure interval is calculated as follows:

$$\Delta Td = Tw_{avg_K} - TW_{I+1}$$

The cross-sectional area of the newly opened pores is calculated as follows:

$$CSAc_K = \left[\frac{Davg_K}{2} + \Delta Td\right]^2 (10^{-16}\ cm^2/A^2)$$

The length of the newly opened pores is calculated as follows:

$$LP_K = \frac{Vc_I}{CSAc_K}$$

c. Pore diameters and radii are adjusted for the change in thickness of the adsorbed wall layer during this interval. If new pores were opened during this interval, the average diameter is adjusted by the change in layer thickness during the second portion of the desorption interval as follows:

$$D_{avg_{Knew}} = D_{avg_{Kold}} + 2(\Delta Td)$$

The layer thickness change during the whole interval is added to diameters of previously opened pores as follows:

$$D_{avg_{Jnew}} = D_{avg_{Jold}} + 2(\Delta Tw)$$

(not including D_{avgK})

The layer thickness change desorbed during this interval also is added to the radii corresponding to the ends of the pressure intervals as follows:

$$Rc_{Jnew} = Rc_{Jold} + \Delta Tw$$

for all except Rc_{K+1}.

Steps a to c are repeated for each pressure interval.

After the above calculations have been performed, the diameters corresponding to the ends of the intervals are calculated as follows:

$$Dp_J = 2(rc_J)$$

for all Rc_J including Rc_{K+1}.

The remaining calculations are based on $DP_{(I)}$, $D_{avg(I)}$, and $LP_{(I)}$. These calculations are only done for values that fall between the Minimum BJH diameter and the Maximum BJH diameter specified by the operator on the BJH Adsorption Report Options dialog box or the BJH Desorption Report Options dialog box.

1) Incremental Pore Volume (Vp_I, cm^3/g):

$$Vp_I = \pi(Lp_I)\left[\frac{D_{avg_I}}{2}\right]^2 10^{16}\ cm^2/A^2$$

2) Cumulative Pore Volume ($Vp_{CUM(1)}$, cm^3/g):

$$VP_{CUM_{(1)}} = \sum Vp_J\ for\ (J \leq 1)$$

3) Incremental Surface Area (SA_I, m^2/g):

$$SA_I = \pi(LP_I)(10^{-2}\ m/cm)(D_{avg_I})(10^{-10}\ m/A)$$

4) Cumulative Surface Area ($SA_{CUM(I)}$, m^2/g):

$$SA_{CUM_{10}} = \sum SA_J\ for\ J \leq 1$$

5) dV/dD pore volume (dV/dD_I, cm^3/g-A):

$$dV/dD_I = \frac{VP_I}{Dp_I - Dp_{I+1}}$$

6) dV/dlog(D) pore volume ($dV/dlog(D)_I$, cm^3g):

$$lDv/d\log(D)_I = VP_I/\log\left(\frac{Dp_I}{Dp_{I+1}}\right)$$

7) dA/dD pore area (dA/dD_I, m^2/g-A):

$$dA/dD_I = \frac{SA_I}{Dp_I - Dp_{I+1}}$$

8) dA/dlog(D) pore area [$dA/dlog(D)_I$, m^2/g]:

$$dA/d\log(D)_I = SA_I/\log\left(\frac{Dp_I}{Dp_{I+1}}\right)$$

For fixed pore size tables (if selected), the following calculations are performed:

1) Average Fixed Pore Size (DF_{avgJ}, A):

$$DF_{avg_J} = \frac{Dp_{F_J} + Dp_{F_{J+1}}}{2}$$

calculated for all intervals in the fixed pore size table.

For the intervals with between the Minimum BJH diameter and the Maximum BJH diameter.

2) Cumulative Pore volume (VpF_{CUMI}, cm^3/g):

$$VpF_{CUM_I} = INTERP(DpF_{I+1})$$

where INTERP(x) is the value interpolated from the function $X = Dp_{J+1}$ and $Y = VP_{CUMJ}$, using an AKIMA semi-spline interpolation.

3) Incremental Pore Volume (VpF_I, cm^3/g):

$$VpF_I = VpF_{CUM_I} - VpF_{CUM_{I-1}}$$

where $VpF_{CUM0} = 0$.

4) Cumulative Surface Area (SAF_{CUMI}, m^2/g):

$$SAF_{CUM_I} = INTERP(DpF_{I+1})$$

where INTERP(x) is the value interpolated from the function $X = Dp_{J+1}$ and $Y = SA_{CUMJ}$.

5) Incremental Surface Area (SAF_I, m^2/g):

$$SAF_I = SAF_{CUM_I} - SAF_{CUM_{I-1}}$$

where $SAF_{CUM0} = 0$.

6) dV/dD pore volume ($dV/dDpF_I$, cm^3/g-A)):

$$dV/dDpF_I = INTERP(DpF_{I+1})$$

where INTERP(x) is the value interpolated from the function $X = D_{avgJ}$ and $Y = dV/dD_J$.

7) dV/dlog(D) pore volume [$dV/dlog(DpF)_I$, cm^3/g]:

$$dV/d\log(DpF_I) = INTERP(DpF_{I+1})$$

where INTERP(x) is the value interpolated from the function $X = D_{avgJ}$ and $Y = dV/dlog(D)_J$.

8) dA/dD pore area ($dA/dDpF_I$, m^2/g-A):

$$dA/dDpF_I = INTERP(DpF_{I+1})$$

where INTERP(x) is the value interpolated from the function $X = D_{avgJ}$ and $Y = dA/dD_J$.

9) dA/dlog(D) pore area [$dA/dlog(DpF_I)$, m^2/g]:

$$dA/d\log(DpF_I) = INTERP(DpF_{I+1}$$

where INTERP(x) is the value interpolated from the function $X = D_{avgJ}$ and $Y = dA/dlog(D)_J$.

Compendium of Variables

Va	=	quantity adsorbed expressed as a volume (cm^3/g STP)
Vl	=	liquid equivalent volume of volume adsorbed (cm^3/g)
D	=	density conversion factor from the Adsorptive Properties dialog box (cm^3/cm^3 STP)
Pr	=	relative pressure
Dp	=	pore (or core) diameter (A)
Rc	=	Kelvin radius (A) of core
A	=	adsorbate property factor; from the BJH Adsorptive Options dialog box
F	=	fraction of pores open at both ends; from the BJH Adsorption Report Options dialog box or the BJH Desorption Report Options dialog box
ΔTw	=	thickness of adsorbed layer desorbed during interval (A)
Tw	=	thickness of remaining adsorbed wall (A)

HP1, HP2, and HP3 are Halsey Parameters from the Halsey Thickness Equation dialog box.

HJ1, HJ2, and HJ3 are Harkins and Jura Parameters from the Harkins/Jura Thickness Equation dialog box.

Vd	=	volume of gas desorbed from walls of previously opened pores (cm^3/g)
Davg	=	average pore diameter (A)
CSAa	=	annular cross-sectional area of the desorbed layer (cm^2)
CSAc	=	cross-sectional area of opening of newly opened pores (cm^2)
SAw	=	total surface area of walls exposed (cm^2/g)
ΔTd	=	thickness of layer desorbed from walls of newly opened pores (A)
Vc	=	volume desorbed from cores of newly opened pores (cm^3/g)
Lp	=	length of pore (cm/g)

Horvath-Kawazoe

A relative pressure lower limit is determined such that L-d_0 never equals zero. All pressure points less than this limit are discarded. For each collected relative pressure point, values of L are chosen in an iterative manner, and the relative pressure (P/Po) determined by solving one of the following equations:

- Slit Pore Geometry (original Horvath-Kawazoe)
- Cylinder Pore Geometry (Saito/Foley)
- Sphere Pore Geometry (Cheng/Yang)

Slit Pore Geometry (original HK)

When you use the original Horvath-Kawazoe[9] method, the following equation is solved for each value of P. The value of L is determined when the solved-for relative pressure is within 0.1% of the collected absolute pressure.

$$\ln\frac{P}{Po} = \frac{K}{RT}\times\frac{IP\times 10^{32}\ JA^4/J\ cm^4}{\sigma^4\times(L-2\times d_0)}\times\left[\frac{\sigma^4}{3\times(L-d_0)^3}-\frac{\sigma^{10}}{9\times(L-d_0)^9}-\frac{\sigma^4}{3\times d_0^3}+\frac{\sigma^{10}}{9\times d_0^9}\right]$$

where

K = Avogadro's number (6.023×10^{23})

R = gas constant (8.31441×10^7 ergs/mole K)

T = analysis bath temperature (K), from an entered or calculated value on the Po and Temperature Options dialog box

σ = gas solid nuclear separation at zero interaction energy (Å), $\frac{Z_S + Z_A}{2}$

where:

Z_S = sample equilibrium diameter at zero interaction energy (Å) from the Horvath-Kawazoe Physical Properties dialog box

Z_A = zero interaction energy diameter from the Horvath-Kawazoe Physical Properties dialog box

d_0 = $\frac{D_A + D_S(A)}{2}$

where:

D_A = molecular diameter (Å) from the Horvath-Kawazoe Physical Properties dialog box

D_S = diameter of sample atom (Å) from the Horvath-Kawazoe Physical dialog box

L = pore width (nucleus to nucleus) (Å)
P = equilibrium pressure (mmHg)
Po = saturation pressure (mmHg)
IP = interaction parameter (10^{-43} ergs-cm^4) from the Horvath-Kawazoe Report Options dialog box

Cylinder Pore Geometry (Saito/Foley)

When you use the Saito-Foley[10] method, the following equation is solved for each value of P. The value of L is determined when the solved-for relative pressure is within 0.1% of the collected absolute pressure.

$$\ln\left(\frac{P}{Po}\right) = \frac{3}{4}\frac{\pi K}{RT} \times \frac{IP \times 10^{32}\ JA^4/J\ cm^4}{d_0{}^4} \times \sum_{k=0}^{\infty}\left[\frac{1}{k+1}\left(1-\frac{d_0}{r_p}\right)^{2k} \times \left\{\frac{21}{32}\alpha_k\left(\frac{d_0}{r_p}\right)^{10} - \beta_k\left(\frac{d_0}{r_p}\right)^4\right\}\right]$$

where

K = Avogadro's number (6.023×10^{23})
R = gas constant (8.31441×10^7 ergs/mole K)
T = analysis bath temperature (K), from an entered or calculated value on the Po and Temperature Options dialog box
L = pore width (nucleus to nucleus) (Å)
P = equilibrium pressure (mmHg)
Po = saturation pressure (mmHg)
IP = interaction parameter (10^{-43} ergs-cm^4) from the Horvath-Kawazoe Report Options dialog box

$d_0 = \frac{D_A + D_S(A)}{2}$

where:
D_A = molecular diameter (Å) from the Horvath-Kawazoe Physical Properties dialog box
D_S = diameter of sample atom (Å) from the Horvath-Kawazoe Physical dialog box

$\alpha_k = \left(\frac{-4.5-k}{k}\right)^2 \alpha_{k-1}, \alpha_0 = 1.0$

$\beta_k = \left(\frac{-1.5-k}{k}\right)^2 \beta_{k-1}, \beta_0 = 1.0$

r_p = radius of the cylindrical pore, $\frac{L}{2}$

Sphere Pore Geometry (Cheng/Yang)

When you use the Cheng/Yang[11] method, the following equation is solved for each value of P. The value of L is determined when the solved-for relative pressure is within 0.1% of the collected absolute pressure.

$$n\left(\frac{P}{Po}\right) = \frac{6(N_1\varepsilon^*_{12} + N_2\varepsilon^*_{22})L^3 \times 10^{32}\ J\ A^4/J\ cm^3}{RT(L-d_0)^3}$$

$$\left[-\left(\frac{d_0}{L}\right)^6\left(\frac{1}{12}T_1 + \frac{1}{8}T_2\right) + \left(\frac{d_0}{L}\right)^{12}\left(\frac{1}{90}T_3 + \frac{1}{80}T_4\right)\right]$$

where

R = gas constant (8.31441 x 10^7 ergs/mole K)

T = analysis bath temperature (K), from an entered or calculated value on the Po and Temperature Options dialog box

d_0 = $\frac{D_A + D_S(A)}{2}$

where:

D_A = molecular diameter (Å) from the Horvath-Kawazoe Physical Properties dialog box

D_S = diameter of sample atom (Å) from the Horvath-Kawazoe Physical dialog box

L = pore width (nucleus to nucleus) (Å)

P = equilibrium pressure (mmHg)

Po = saturation pressure (mmHg)

N_1 = $4\pi L^2 N_S$, where N_S = number of sample atoms/cm^2 at monolayer

N_2 = $4\pi (L - d_0)^2 N_A$, where N_s = number of gas molecules/cm^2

$$\varepsilon^*_{12} = \frac{A_S}{4d_S{}^6}, \quad \text{where } A_S = \frac{6 \times MC^2 \times \alpha_S \times \alpha_A}{\frac{\alpha_S}{\chi_S} + \frac{\alpha_A}{\chi_A}}$$

$$\varepsilon^*_{22} = \frac{A_A}{4D_A{}^6}, \quad \text{where } A_A = \frac{3 \times MC^2 \times \alpha_A \times \chi_A}{2}$$

$$T_1 = \frac{1}{(1-S)^3} - \frac{1}{(1+S)^3}$$

$$T_2 = \frac{1}{(1+S)^2} - \frac{1}{(1-S)^2}$$

$$T_3 = \frac{1}{(1-S)^9} - \frac{1}{(1+S)^9}$$

$$T_4 = \frac{1}{(1+S)^8} - \frac{1}{(1-S)^8}$$

$$\text{where } S = \frac{L - d_0}{L}$$

Cheng/Yang Correction

This factor corrects for the nonlinearity of the isotherm. It adds an additional term to the equations for the different geometrics:

$$\ln\left(\frac{P}{Po}\right) = G(L) - \left[1 - \frac{1}{\theta}\ln\left(\frac{1}{1-\theta}\right)\right]$$

where

G(L) = one of the Horvath-Kawazoe equations given above

θ = degree of void filling; θ is estimated by first computing the monolayer capacity (V_m) with the Langmuir equation over the range of data points from relative pressure 0.02 to 0.2 or the maximum relative pressure included in the Horvath-Kawazoe analysis. θ is computed as the volume adsorbed over V_m.

Interaction Parameter

The interaction parameter (IP) results from the following calculations:

The Kirkwood-Muller dispersion coefficients -

$$A_S = \frac{6 \times MC^2 \times \alpha_S \times \alpha_A}{\frac{\alpha_S}{\chi_S} + \frac{\alpha_A}{\chi_A}}$$

$$A_A = \frac{3 \times MC^2 \times \alpha_A \times \chi_A}{2}$$

where

MC^2 = kinetic energy of electron (0.8183×10^{-6} erg)

α_S = polarizability of sample atoms (cm^3)

α_A = polarizability of gas molecule (cm^3)

χ_S = diamagnetic susceptability of sample atom (cm^3)

χ_A = diamagnetic susceptability of gas molecule (cm^3)

$$IP = (N_A \times A_A) + (N_S \times A_S)$$

where:

N_A = number of gas molecules/cm^2 at monolayer from the Horvath-Kawazoe Physical Properties dialog box

N_S = number of sample atoms/cm^2 from the Horvath-Kawazoe Physical Properties dialog box

Refer to **Interaction Parameter Components** later in this Appendix for recommended values.

Additional Calculations

Based on the previous calculations, the following can be calculated:

Adjusted Pore Width (Å):
(Shell to Shell)

$$AL_I = L_I - DS$$

Cumulative Pore Volume (cm^3/g):

$$V_{CUM_I} = V_I \times D$$

where

D = density conversion factor (cm^3 liquid/cm^3 STP) on the Adsorptive Properties dialog box

dV/dD Pore Volume (cm^3/g-Å):

$$\frac{dV}{dD_I} = \frac{V_{CUM_I} - V_{CUM_{I-1}}}{AL_I - AL_{I-1}}$$

Median Pore Width (Å):

$$V_{HALF} = \frac{V_{CUM_N}}{2}$$

$$D_{MED} = 10\left[\log(D_L) + [\log(V_{HALF}) - \log(V_L)] \times \frac{\log(D_G) - \log(D_L)}{\log(V_G) - \log(V_L)}\right]$$

where

V_{CUMN} = total cumulative pore volume (V_{CUMI}) for points designated for Horvath-Kawazoe calculations
V_{HALF} = 50% of total cumulative pore volume
V_L = cumulative pore volume (V_{CUMI}) for first point less than V_{HALF}
V_G = cumulative pore volume (V_{CUMI}) for first point greater than V_{HALF}
D_L = pore width (L_I) that corresponds to V_L
D_G = pore width (L_I) that corresponds to V_G

Interaction Parameter Components

Table C-1. Interaction Parameters

Gas	Bath Temperature (K)	Sample Type	Interaction Parameter Calculated Value*
Argon	87.3	Carbon (Ross/Olivier value) Carbon (Horvath/Kawazoe value) Zeolite	2.61 5.89 3.19
Carbon Dioxide	298.15	Carbon (Ross/Olivier value) Carbon (Horvath/Kawazoe value) Zeolite	4.20 9.20 5.08
	273.15	Carbon (Ross/Olivier value) Carbon (Horvath/Kawazoe value) Zeolite	4.34 9.35 5.22
	194.65	Carbon (Ross/Olivier value) Carbon (Horvath/Kawazoe value) Zeolite	4.72 9.72 5.60
Nitrogen	77.15	Carbon (Ross/Olivier value) Carbon (Horvath/Kawazoe value) Zeolite	2.84 6.53 3.49

*The interaction parameter is entered in the Horvath-Kawazoe Report Options dialog in the following field:

Interaction parameter: (calculated value) x 10^{-43} ergs-cm^4

The following values were used to calculate the values in Table C-1.

Carbon-Graphite

$D_S = 3.40$
$N_S = 3.845 \times 10^{15}$
$\chi_S = 1.05 \times 10^{-29}$ (Ross/Olivier)
13.5×10^{-29} (Horvath/Kawazoe, implicit)
$\alpha_S = 1.02 \times 10^{-24}$

Zeolite

$D_S = 3.04$
$N_S = 3.75 \times 10^{15}$
$\chi_S = 1.94 \times 10^{-29}$
$\alpha_S = 0.85 \times 10^{-24}$

Nitrogen

$D_A = 3.00$
$N_A = 6.71 \times 10^{14}$
$\chi_A = 3.6 \times 10^{-29}$
$\alpha_A = 1.76 \times 10^{-24}$

Argon

$D_A = 2.95$
$N_A = 7.608 \times 10^{14}$
$\chi_A = 3.22 \times 10^{-29}$
$\alpha_A = 1.63 \times 10^{-24}$

Carbon Dioxide

$D_A = 3.23$
$N_A = 4.567 \times 10^{14}$ (25 °C)
5.45×10^{14} (0 °C)
7.697×10^{14} (−78 °C)
$\chi_A = 5.0 \times 10^{-29}$
$\alpha_A = 2.7 \times 10^{-24}$

D_A values are from van der Waal's constant.
N_A values are from liquid densities.
χ and α values are derived from data found in Ross and Olivier[12].

The physical parameters referenced in Saito/Foley are as follows:

Aluminophosphate

$D_S = 2.60$
$N_S = 1.48 \times 10^{15}$
$\chi_S = 1.3 \times 10^{-29}$
$\alpha_S = 2.5 \times 10^{-24}$

Aluminosilicate

$D_S = 2.76$
$N_s = 1.31 \times 10^{15}$
$\chi_S = 1.3 \times 10^{-29}$
$\alpha_S = 2.5 \times 10^{-24}$

Dubinin-Radushkevich

The Dubinin-Radushkevich[13] equation is as follows:

$$\log(V) = \log(Vo) - \frac{B \times T^2}{\beta} \times \left[\log\frac{Po}{P}\right]^2$$

where:

V	=	volume adsorbed at equilibrium pressure (cm^3/g STP)
Vo	=	the micropore capacity (cm^3/g STP)
Po	=	saturation vapor pressure of gas at temperature T (mmHg)
P	=	equilibrium pressure (mmHg)
B	=	a constant
β	=	the affinity coefficient of analysis gas relative to Po gas (for this application β is taken to be 1)
T	=	analysis bath temperature (K), from the Po and Temperature Options dialog box

For each point designated for Dubinin-Radushkevich calculations, the following calculations are done:

$$LV = log\ (V)$$

$$LP = \log\left(\frac{Po}{P}\right)^2$$

The intercept, log(Vo) can be found by performing a least-squares fit on the (LP,LV) designated pairs where LP is the independent variable and LV is the dependent variable. Assuming the adsorption of gas is restricted to a monolayer, Vo is the monolayer capacity. Based on this assumption, the following are calculated:

a. Slope (S cm^3/g STP)

b. Y-intercept (YI cm^3/g STP)

c. Error of the slope (S_{ERR} cm^3/g STP)

d. Error of the y-intercept (YI_{ERR} cm^3/g STP)

e. Correlation coefficient (Cc)

Using the results of the above calculations, the following can be calculated:

Monolayer Capacity (cm^3/g STP):

$$Vo = 10^{YI}$$

Error of Monolayer Capacity (cm^3/g STP):

$$Vo_{ERR} = Vo \times (10^{YI_{ERR}} - 1.0)$$

Micropore surface area (m^2/g):

$$SDP = \frac{\sigma \times Vo \times (6.023 \times 10^{23})}{22414\ cm^3 \times (10^{18}\ nm^2/m^2)}$$

where

σ = molecular cross sectional area of gas (nm^2) from the Adsorptive Properties dialog box

Dubinin-Astakhov

The Dubinin-Astakhov equation is a follows:

$$\log(V) = \log(Vo) - \left[\frac{RT}{\beta E_0}\right]^N \times \left[\log\frac{Po}{P}\right]^N$$

where

V	=	volume adsorbed at equilibrium pressure (cm^3/g STP)
Vo	=	the micropore capacity (cm^3/g STP)
Po	=	saturation vapor pressure of gas at temperature T (mmHg)
P	=	equilibrium pressure (mmHg)
T	=	analysis bath temperature (K)
R	=	the gas constant (0.0083144 kJ/mol)
E_0	=	characteristic energy (kJ/mole)
N	=	Astakhov exponent, may be optimized or user entered from the Dubinin Report Options dialog box
β	=	the affinity coefficient of the analysis gas relative to the Po gas, from the Dubinin Adsorptive Options dialog box

For each point designated for Dubinin-Astakhov calculations, the following calculations are done:

$$LV = log(V)$$

$$LP = \left[\log\frac{Po}{P}\right]^N$$

A least-squares fit is performed on the (LP,LV) designated pairs where LP is the independent variable and LV is the dependent variable. If the user selected **yes** for the Optimize Astakhov Exponent prompt, a systematic search for the optimum value of N is conducted by recalculating the linear regression and selecting the value of N that gives the smallest standard error of the y-intercept. The exponent N is optimized to within 10^{-4}. If the optimum value for N is not found in this range, an exponent of 2 is used. The following are calculated:

a. Slope (S cm^3/g STP)

b. Y-intercept (YI cm^3/g STP)

c. Error of the slope (S_{ERR} cm^3/g STP)

d. Error of the y-intercept (YI_{ERR} cm^3/g STP)

e. Correlation coefficient (Cc)

f. Optimized Astakhov exponent (N)

Using the results of the above calculations, the following can be calculated:

Monolayer Capacity (cm^3/g STP):

$$V_0 = 10^{YI}$$

Micropore Volume (cm^3/g):

$$W_1 = (V_1 \, x \, D)$$

where

D = density conversion factor (cm^3 liquid/cm^3 STP) from the Adsorptive Properties dialog box

Limiting Micropore Volume (cm^3/g):

$$W_0 = (V_0 \, x \, D)$$

where

D = density conversion factor (cm^3 liquid/cm^3 STP) from the Adsorptive Properties dialog box

Error of Limiting Micropore Volume (cm^3/g):

$$W_{0ERR} = W_0 \, x \, (10YI_{ERR} - 1.0)$$

Characteristic Energy (KJ/mole):

$$E = \frac{2.303 \times R \times T}{\beta(2.303 \times S)^{1/N}}$$

Modal Equivalent Pore Width (nm):

$$w_{mode} = 2 \times \left\{ \left[\frac{3N}{3N+1} \right]^{1/N} \times \left[\frac{k}{E_0} \right] \right\}^{1/3}$$

where

k = the interaction constant for benzene, 8.969 kJ•nm^3/mol

Maximum Differential Pore Volume (cm^3/g-nm):

This value is also known as *frequency of the mode*[11]

$$\frac{dV}{dw_{mode}}Max = 0.5 \times (3N+1) \times W_o \times \left[\frac{3N+1}{3N}\right]^{1/3N} \times \left[\frac{E_0}{k}\right]^{1/3} \times \exp\left(-\left[\frac{3N+1}{3N}\right]\right)$$

Mean Equivalent Pore Width (nm):

$$w_{mean} = 2 \times \frac{\left[\frac{k}{E_0}\right]^{1/3}}{\Gamma\left(\frac{3N+1}{3N}\right)}$$

Micropore surface area (m^2/g):

$$SDA = 1000 \times 2.0 \times W_0 \times \left[\frac{E_0}{k}\right]^{1/3} \times \Gamma\left(\frac{3N+1}{3N}\right)$$

Γ is calculated by a polynomial approximation[10] over the domain $0 \le x \le 1$ as follows:

$$\Gamma(x+1) = 1+b_1x + b_2x^2 + b_3x^3 + b_4x^4 + b_5x^5 + b_6x^6 + b_7x^7 + b_8x^8 + \varepsilon(x) \quad |\varepsilon(x)| \le 3 \times 10^{-7}$$

where

b_1 = -0.57719 1652
b_2 = 0.98820 5891
b_3 = -0.89705 6937
b_4 = 0.91820 6857
b_5 = -0.75670 4078
b_6 = 0.48219 9394
b_7 = -0.19352 7818
b_8 = 0.03586 8343

and where

$$x+1 = \left(\frac{3N+1}{3N}\right)$$

Equivalent Pore Width (nm):

$$w_i = 2 \times \left[\frac{-\left(\frac{k}{E_0}\right)^N}{\ln(W_i) - \ln(W_0)} \right]^{1/3N}$$

dV/dw Pore Volume (cm³/g-nm):

$$\frac{dV}{dw_i} = 0.5 \times W_0 \times 3N \times \left[\frac{k}{E_0}\right]^N \times \left(\frac{w_i}{2}\right)^{-(3N+1)} \times \exp\left[-\left(\frac{k}{E_0}\right)^N \times \left(\frac{w_i}{2}\right)^{-3N}\right]$$

MP-Method

For each point designated for MP-method[14] calculations, the following calculations are done:

Thickness for the Ith point (Å):

$$t_I = HP1 \times \left[\frac{HP2}{\ln(P_{rel_I})}\right]^{HP3} \qquad \text{(Halsey[6])}$$

or

$$t_I = \left[\frac{HJP1}{HJP2 - \log(P_{rel_I})}\right]^{HJP3} \qquad \text{(Harkins and Jura[7])}$$

where:

t_I	=	thickness for Ith point
HP1	=	Halsey parameter #1
HP2	=	Halsey parameter #2
HP3	=	Halsey parameter #3
HJP1	=	Harkins and Jura parameter #1
HJP2	=	Harkins and Jura parameter #2
HJP3	=	Harkins and Jura parameter #3
$P_{rel I}$	=	relative pressure for the Ith point (mmHg)

With the (t_I,V_I) data pairs, the Akima semi-spline interpolation method is used to interpolate volume adsorbed values based on thickness values that are evenly spaced 0.2 Angstrom apart starting at the first outlier point. Outliers are defined as those points have the maximum instantaneous slope within an iteratively shrinking subset of all points. The remaining pore

surface area calculation result is the slope of the line defined by two consecutive interpolated points. The slopes of each pair of consecutive points from the origin to the last point must be monotonically decreasing and non-negative. With the interpolated points set the following can be calculated:

Average pore hydraulic radius (Å):

$$R_I = \frac{t_I + t_{I-1}}{2}$$

Remaining pore surface area for the Ith point (m^2/g):

$$S_I = \frac{(V_I - V_{I-1}) \times (D \times 10^{-6}\ m^3/cm^3)}{(t_I - t_{I-1}) \times 10^{-10} m/A}$$

where

D = density conversion factor (cm^3 liquid/cm^3 STP) on the Adsorptive Properties dialog box

Incremental pore surface area occluded for the Ith point (m^2/g):

$$S_{INC_I} = S_{I-1} - S_I$$

Cumulative pore surface area occluded for the Ith point (m^2/g):

$$S_{CUM_I} = S_{INC_I} + S_{INC_{I-1}} + \ldots + S_{INC_1}$$

dA/dR pore surface area for the Ith point (m^2/g-Å):

$$\frac{dA}{dR_I} = \frac{S_{INC_I}}{t_I - t_{I-1}}$$

Incremental pore volume occluded for the Ith point (cm^3/g):

$$V_{INC_I} = (S_{INC_I} \times 10^4\ cm^2/m^2) \times (R_I \times 10^{-8}\ cm/\text{Å})$$

Cumulative pore volume occluded for the Ith point (cm^3/g):

$$V_{CUM_I} = V_{INC_I} + V_{INC_{I-1}} + \ldots + V_{INC_1}$$

dV/dR pore volume for the Ith point (cm³/g-Å):

$$\frac{dV}{dR_I} = \frac{V_{INC_I}}{t_I - t_{I-1}}$$

Freundlich Isotherm

The Freundlich isotherm has the form:

$$\frac{Q}{Q_S} = CP^{1/m}$$

where

Q	=	quantity of gas adsorbed
Q_S	=	quantity of gas in a monolayer
C	=	temperature-dependent constant
m	=	temperature-dependent constant

The pressure is absolute; typically, m > 1. In terms of quantity adsorbed,

$$Q = Q_S C P^{1/m}$$

Taking the log of both sides yields:

$$\log Q = \log Q_S C + \frac{1}{m} \log P$$

Temkin Isotherm

The Temkin isotherm has the form,

$$\frac{Q}{Q_S} = \frac{RT}{q_0\alpha} \ln(A_0 P)$$

where

Q	=	quantity of gas adsorbed
Q_S	=	quantity of gas in a monolayer
q_0	=	the differential heat of adsorption at zero surface coverage
A_0	=	$a_0 \exp\{-q_0/RT\}$, where α_0 and a_0 are adjustable constants

In terms of quantity adsorbed,

$$Q = \frac{RTQ_S}{q_0\alpha}\left[\ln A_0 + \ln\left(\frac{P}{Po}\right)\right]$$

Thus, the plot of the natural log of absolute pressure vs. quantity adsorbed yields a straight line with slope RTQ_S/q_0 and intercept $(\ln A_0)\ RTQ_S/q_0\alpha$.

DFT (Density Functional Theory)

The adsorption isotherm is known to convey a great deal of information about the energetic heterogeneity and geometric topology of the sample under study. The data of physical adsorption have been used for many years as the basis for methods to characterize the surface area and porosity of adsorbents. Real solid surfaces rarely approach ideal uniformity of structure. It is accepted that in general, the surface of even a nonporous material presents areas of greater or lesser attraction for adsorbed molecules.

This energetic heterogeneity greatly affects the shape of the adsorption isotherm with the result that simple theories such as the Langmuir and BET formulas can, at best, give only approximate estimates of surface area. Porous solids virtually are never characterized by a single pore dimension, but instead exhibit a more or less wide distribution of sizes. The observed adsorption isotherm for a typical material is therefore the convolution of an adsorption process with the distribution of one or more properties which affect that process. This was first stated mathematically by Ross and Olivier[12] for the case of surface energy distribution and has become known as the integral equation of adsorption.

The Integral Equation of Adsorption

In a general form for a single component adsorptive, the integral equation of adsorption can be written as

$$Q(p) = \int da\ db\ dc \ldots q(p, a, b, c \ldots)\ f(a, b, c \ldots) \qquad (1)$$

where

Q(p)	=	the total quantity adsorbed per unit weight at pressure p,
a,b,c,...	=	a set of distributed properties,
f(a,b,c,...)	=	the distribution function of the properties, and
q(p,a,b,c,...)	=	the kernel function describing the adsorption isotherm on unit surface of material with fixed properties a,b,c,...

Equation (1), a Fredholm integral of the first kind, is a member of a class of problems known as ill-posed, in that there are an infinite number of functional combinations inside the integral that will provide solutions. Even when the kernel function is known, experimental error in the data can make solving for even a single distribution function a difficult task. Solving for multiple distribution functions requires more data than provided by a single adsorption isotherm.

Application to Surface Energy Distribution

Under certain conditions, an energetically heterogeneous surface may be characterized by a distribution of adsorptive energies. The conditions are that the sample is not microporous, i.e., that adsorption is taking place on essentially a free surface with no pore filling processes at least to about 0.2 relative pressure. Secondly, that each energetically distinct patch contributes independently to the total adsorption isotherm in proportion to the fraction of the total surface that it represents. This condition is satisfied if the patches are relatively large compared to an adsorptive molecule, or if the energy gradient along the surface is not steep. In mathematical terms, this concept is expressed by the integral equation of adsorption in the following form.

$$Q(p) = \int d\varepsilon\ q(p, \varepsilon)\ f(\varepsilon) \qquad (2)$$

where

Q(p)	=	the experimental quantity adsorbed per gram at pressure p,
q(p,e)	=	the quantity adsorbed per unit area at the same pressure, p, on an ideal free surface of energy e, and
f(e)	=	the total area of surface of energy e in the sample.

The exact form of the energy-dependent term depends on the form of the model isotherms expressed in the kernel function and is provided in the model description (refer to Appendix G for model descriptions).

Application to Pore Size Distribution

Similarly, a sample of porous material may be characterized by its distribution of pore sizes. It is assumed in this case that each pore acts independently. Each pore size present then contributes to the total adsorption isotherm in proportion to the fraction of the total area of the sample that it represents. Mathematically, this relation is expressed by

$$Q(p) = \int dH\, q(p, H)\, f(H) \qquad (3)$$

where

Q(p)	=	the experimental quantity adsorbed at pressure p,
q(p,H)	=	the quantity adsorbed per unit area at the same pressure, p, in an ideal pore of size H, and
f(H)	=	the total area of pores of size H in the sample.

Numerical values for the kernel functions in the form of model isotherms can be derived from modern statistical mechanics such as density functional theory or molecular simulations, or can be calculated from one of various classical theories based on the Kelvin equation. Several types are found in the models library.

Performing the Deconvolution

The integrations in equations (2) and (3) are carried out over all surface energies or pore sizes in the model. The functions q(p,e) and q(p,H), which we call the kernel functions, are contained in numeric form as model isotherms. Because, in general, there is no analytic solution for equation (1), the problem is best solved in a discrete form; the integral equation for any distributed property Z becomes a summation:

$$Q(p) = \sum_i q(p, Z_i)\, f(Z_i) \qquad (4)$$

Given a set of model isotherms, q(p,Z), from a model chosen from the models library and an experimental isotherm, Q(p), contained in a sample information file, the software determines the set of positive values f(Z) that most nearly, in a least squares sense, solves equation (4). The distributed property, surface energy or pore size, is then displayed on the Report Options dialog box as a selection of tables or graphs.

Regularization

DFT allows a selectable regularization (also referred to as smoothing) constraint to be applied during the deconvolution process to avoid over-fitting in the case of noisy data or ill-fitting models. The method used is based on co-minimization of the second derivative of the distribution. The relative weight given to this term is determined by the value of the regularization parameter, which is set on the DFT Pore Size or Surface Energy dialog box and also is shown

in the header of reports. The value of the regularization parameter varies from zero (for no second derivative constraint) to ten (indicating a weight equal to minimizing the residuals), or even larger. When the distribution and residuals obtained change little with the value of the regularization parameter, it indicates that the chosen model provides a good representation of the data. Conversely, a large sensitivity to the regularization parameter might indicate inadequate data or a poor choice of model to represent the data.

Summary Report

The following calculations and the results of previous calculations (as noted) are used to generate the summary report:

a. BET Surface Area

See BET Surface Area Calculations

b. Langmuir Surface Area

See Langmuir Surface Area Calculations

c. Single Point Surface Area (m^2/g)

$$S_{1PT} = \frac{[Va \times (1 - Pr)] \times CSA \times (6.023 \times 10^{23})}{22414\ cm^3\ STP \times 10^{18}\ nm^2/m^2}$$

where

Pr = pressure closest to 0.3 of the relative pressure points designated for surface area calculations.

Va = volume corresponding to Pr

d. Micropore Area

See t-Plot calculations.

e. Micropore Volume

See t-Plot calculations.

f. Horvath-Kawazoe Maximum Pore Volume

See Horvath-Kawazoe Calculations

g. Horvath-Kawazoe Median Pore Diameter

See Horvath-Kawazoe Calculations

h. Dubinin-Radushkevich Micropore Surface Area

See Dubinin-Radushkevich Calculations

i. Dubinin-Radushkevich Monolayer Capacity

See Dubinin-Radushkevich Calculations

j. Dubinin-Astakhov Micropore Surface Area

See Dubinin-Astakhov Calculations

k. Dubinin-Astakhov Micropore Volume

See Dubinin-Astakhov Calculations

l. MP-Method Cumulative Surface Area of Pores

$MPS_{TOT} = S_{CUMI}$, (see MP-method Calculations) for the last collected data point used in the MP-method Calculations, and the range of hydraulic pore radii over which the cumulative surface area was computed.

m. MP-Method Cumulative Pore Volume of Pores

$MPV_{TOT} = V_{CUMI}$, (see MP-method Calculations) for the last collected data point used in the MP-method Calculations, and the range of hydraulic pore radii over which the cumulative pore volume was computed.

n. Average Pore Hydraulic Radius (A)

$$MP_{DAVER} = \frac{MPV_{TOT}}{MPS_{TOT}} \times 10^{-6} m^3/cm \times 10^{10}\ \text{Å}/m$$

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Sample: Powder 390011790800 F5 V10
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200801_005-50_Run1.SMP

Started:	2/22/2012 12:01:48 PM	Analysis Adsorptive:	N2
Completed:	2/22/2012 10:42:10 PM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:38:10 PM	Thermal Correction:	No
Sample Mass:	2.1701 g	Warm Free Space:	7.2941 cm³ Measured
Cold Free Space:	20.5003 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Summary Report

Surface Area

Single point surface area at p/p° = 0.260331921:	10.2149 m²/g
BET Surface Area:	10.3730 m²/g
t-Plot Micropore Area:	2.2943 m²/g
t-Plot External Surface Area:	8.0787 m²/g
BJH Adsorption cumulative surface area of pores between 17.000 Å and 3,000.000 Å width:	10.174 m²/g

Pore Volume

Single point adsorption total pore volume of pores less than 2,573.502 Å width at p/p° = 0.992441205:	0.027941 cm³/g
t-Plot micropore volume:	0.001046 cm³/g
BJH Adsorption cumulative volume of pores between 17.000 Å and 3,000.000 Å width:	0.028207 cm³/g

Pore Size

Adsorption average pore width (4V/A by Langmuir):	70.9546 Å
BJH Adsorption average pore width (4V/A):	110.900 Å

Sample: Powder 390011790800 F5 V10
Operator: AG
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Cold Free Space:	20.5003 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Tabular Report

Relative Pressure (p/p°)	Absolute Pressure (mmHg)	Quantity Adsorbed (cm³/g STP)	Elapsed Time (h:min)	Saturation Pressure (mmHg)
			01:04	734.648926
0.002593720	1.901696	1.5105	02:10	733.192322
0.004954884	3.631354	1.7016	02:26	732.883606
0.007548798	5.528779	1.8208	02:48	732.405212
0.010156684	7.436388	1.8988	03:08	732.166870
0.020172039	14.757892	2.0664	03:40	731.601379
0.030313473	22.174816	2.1706	04:03	731.516846
0.041154889	30.105967	2.2555	04:18	731.528320
0.049144774	35.937515	2.3087	04:27	731.258118
0.080235379	58.650127	2.4716	04:41	730.975891
0.115761979	84.601318	2.6260	04:56	730.821289
0.139543790	101.984451	2.7198	05:03	730.841919
0.169683082	123.994949	2.8322	05:09	730.744324
0.199803118	145.990982	2.9440	05:15	730.674194
0.229942823	168.000824	3.0577	05:21	730.619995
0.260331921	190.166367	3.1724	05:26	730.476563
0.290896924	212.404007	3.2889	05:32	730.169312
0.321425595	234.709152	3.4069	05:37	730.213013
0.352380376	257.155365	3.5240	05:42	729.766418
0.378797271	276.472046	3.6252	05:47	729.868103
0.408929528	298.436890	3.7388	05:52	729.800293
0.438611508	320.105286	3.8512	05:57	729.815063
0.468629848	341.982574	3.9663	06:02	729.749878
0.498638088	363.818024	4.0829	06:06	729.623413
0.528336120	385.437775	4.2041	06:11	729.531372
0.558457188	407.331665	4.3328	06:16	729.387451
0.588049902	428.958679	4.4689	06:21	729.459656
0.617948307	450.723816	4.6183	06:26	729.387573
0.647992775	472.522430	4.7818	06:32	729.209412
0.677391864	493.928894	4.9631	06:37	729.162720
0.707529833	515.780396	5.1693	06:43	728.987488
0.736708351	537.087952	5.3996	06:49	729.037415
0.770440005	561.831665	5.7122	06:58	729.234802
0.800972412	583.937439	6.0478	07:07	729.035645
0.818083698	596.415771	6.2735	07:13	729.040039
0.837392807	610.525391	6.5589	07:20	729.078857
0.860042530	626.884338	6.9621	07:29	728.899231
0.880269188	641.628662	7.4111	07:41	728.900513
0.889637981	648.417236	7.6561	07:47	728.855164

Sample: Powder 390011790800 F5 V10
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200801_005-50_Run1.SMP

Started:	2/22/2012 12:01:48 PM	Analysis Adsorptive:	N2
Completed:	2/22/2012 10:42:10 PM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:38:10 PM	Thermal Correction:	No
Sample Mass:	2.1701 g	Warm Free Space:	7.2941 cm³ Measured
Cold Free Space:	20.5003 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Tabular Report

Relative Pressure (p/p°)	Absolute Pressure (mmHg)	Quantity Adsorbed (cm³/g STP)	Elapsed Time (h:min)	Saturation Pressure (mmHg)
0.897913842	654.478516	7.9087	07:54	728.887878
0.907176221	661.115967	8.2164	08:01	728.762451
0.920641490	670.615906	8.7428	08:15	728.422424
0.928461433	676.264526	9.1205	08:23	728.371155
0.938115839	683.347534	9.6674	08:31	728.425537
0.947111750	689.938538	10.3013	08:40	728.465820
0.953994025	695.081421	10.8523	08:49	728.601440
0.958741684	698.615356	11.2935	08:56	728.679443
0.963580207	702.175964	11.8325	09:05	728.715637
0.968067776	705.474487	12.4191	09:13	728.744934
0.976951538	711.772461	13.7958	09:29	728.564758
0.982488326	715.698730	14.9930	09:46	728.455200
0.986601364	718.744995	16.0141	10:00	728.505981
0.988870621	720.373718	16.6429	10:09	728.481262
0.991349575	721.902588	17.5129	10:24	728.201843
0.992441205	722.585999	18.0638	10:35	728.089478
0.990938704	721.289368	17.9604	10:39	727.884949

Sample: Powder 390011790800 F5 V10
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200801_005-50_Run1.SMP

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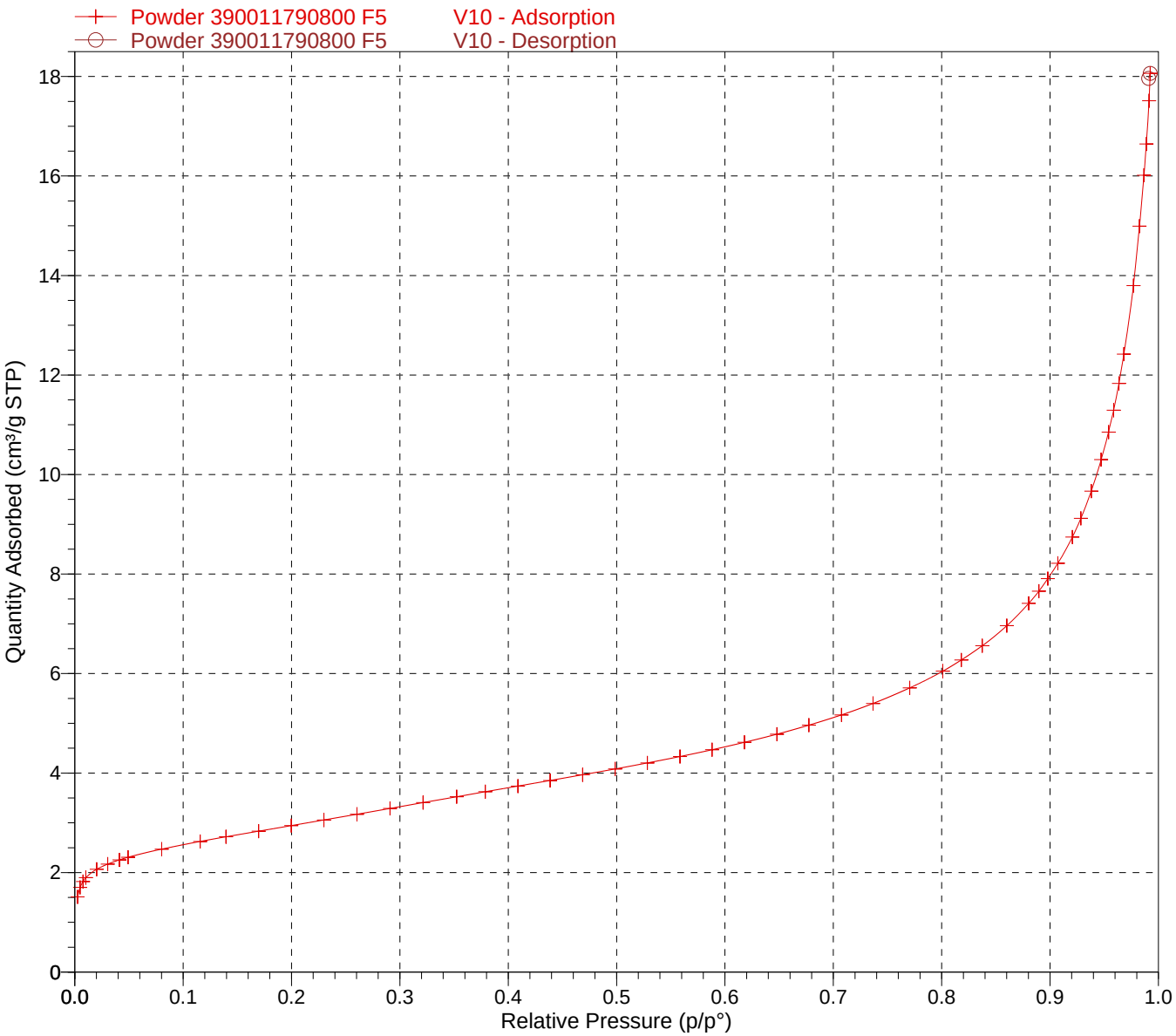
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Linear Plot



Sample: Powder 390011790800 F5 V10
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200801_005-50_Run1.SMP

Started:	2/22/2012 12:01:48 PM	Analysis Adsorptive:	N2
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Cold Free Space:	20.5003 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BET Surface Area Report

BET Surface Area: 10.3730 ± 0.0441 m²/g
Slope: 0.418113 ± 0.001759 g/cm³ STP
Y-Intercept: 0.001552 ± 0.000299 g/cm³ STP
C: 270.468062
Qm: 2.3829 cm³/g STP
Correlation Coefficient: 0.9999469
Molecular Cross-Sectional Area: 0.1620 nm²

Relative Pressure (p/p°)	Quantity Adsorbed (cm³/g STP)	1/[Q(p°/p - 1)]
0.049144774	2.3087	0.022387
0.080235379	2.4716	0.035295
0.115761979	2.6260	0.049854
0.139543790	2.7198	0.059626
0.169683082	2.8322	0.072155
0.199803118	2.9440	0.084813
0.229942823	3.0577	0.097658
0.260331921	3.1724	0.110943

Sample: Powder 390011790800 F5 V10
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200801_005-50_Run1.SMP

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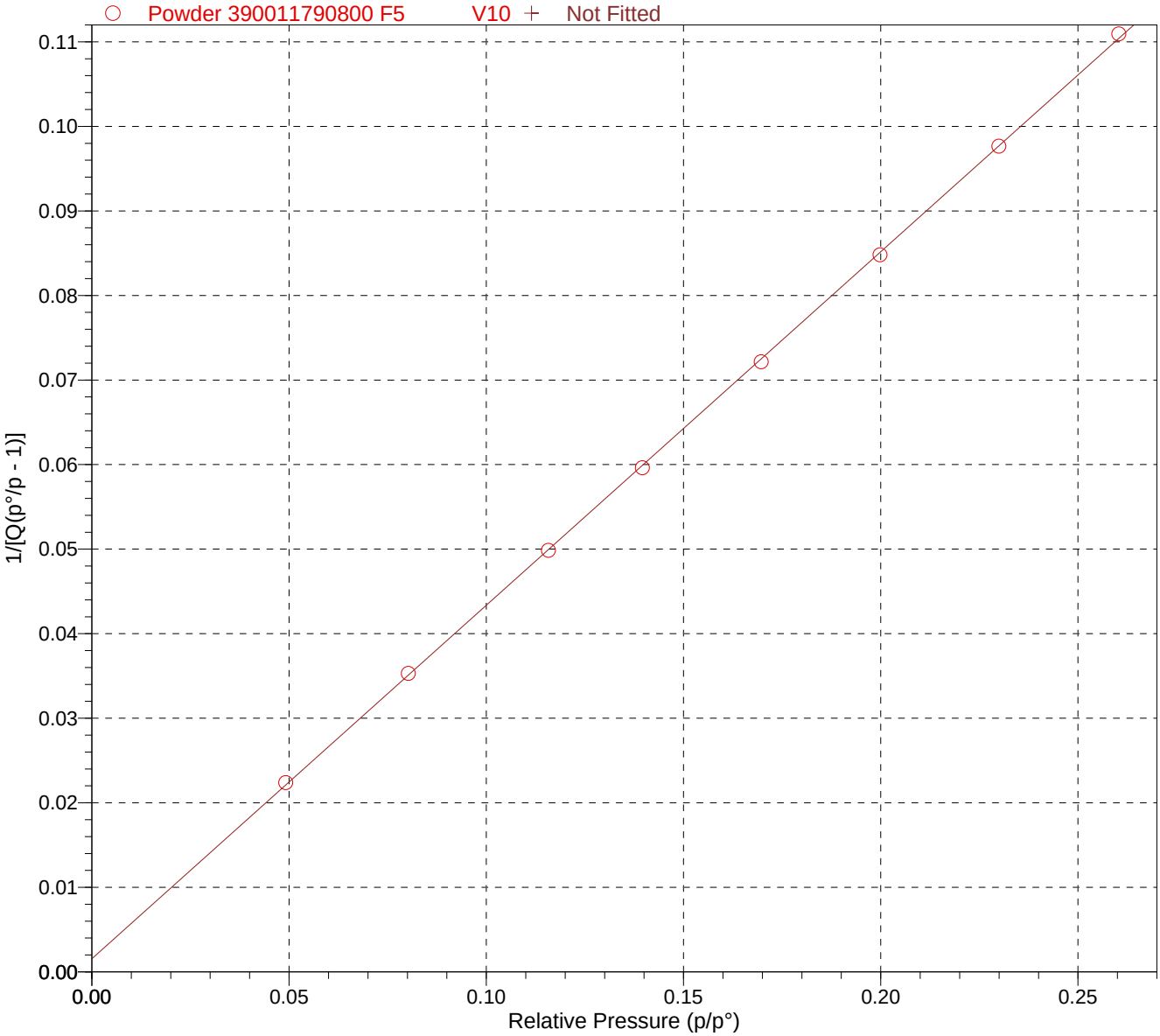
Cold Free Space:	20.5003 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BET Surface Area Plot



Sample: Powder 390011790800 F5 V10
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200801_005-50_Run1.SMP

Started:	2/22/2012 12:01:48 PM	Analysis Adsorptive:	N2
Completed:	2/22/2012 10:42:10 PM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:38:10 PM	Thermal Correction:	No
Sample Mass:	2.1701 g	Warm Free Space:	7.2941 cm³ Measured
Cold Free Space:	20.5003 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot Report

Micropore Volume:	0.001046 cm³/g
Micropore Area:	2.2943 m²/g
External Surface Area:	8.0787 m²/g
Slope:	0.522285 ± 0.003313 cm³/g·Å STP
Y-Intercept:	0.676131 ± 0.023608 cm³/g STP
Correlation Coefficient:	0.999457
Surface Area Correction Factor:	1.000
Density Conversion Factor:	0.0015468
Total Surface Area (BET):	10.3730 m²/g
Thickness Range:	3.2144 Å to 11.8910 Å
Thickness Equation:	Harkins and Jura

Thickness Curve

t = [13.99 / (0.034 - log(p/p°))] ^ 0.5

t-Plot Report - Data

Relative Pressure (p/p°)	Statistical Thickness (Å)	Quantity Adsorbed (cm³/g STP)	Fitted
0.002593720	2.3107	1.5105	
0.004954884	2.4457	1.7016	
0.007548798	2.5473	1.8208	
0.010156684	2.6270	1.8988	
0.020172039	2.8443	2.0664	
0.030313473	3.0020	2.1706	
0.041154889	3.1393	2.2555	
0.049144774	3.2281	2.3087	*
0.080235379	3.5192	2.4716	*
0.115761979	3.7969	2.6260	*
0.139543790	3.9663	2.7198	*
0.169683082	4.1705	2.8322	*
0.199803118	4.3676	2.9440	*
0.229942823	4.5614	3.0577	*
0.260331921	4.7561	3.1724	*
0.290896924	4.9530	3.2889	*
0.321425595	5.1527	3.4069	*
0.352380376	5.3598	3.5240	*
0.378797271	5.5414	3.6252	*
0.408929528	5.7554	3.7388	*
0.438611508	5.9746	3.8512	*
0.468629848	6.2066	3.9663	*
0.498638088	6.4506	4.0829	*

Sample: Powder 390011790800 F5 V10
Operator: AG
Submitter: URS Corporation
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Completed:	2/22/2012 10:42:10 PM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:38:10 PM	Thermal Correction:	No
Sample Mass:	2.1701 g	Warm Free Space:	7.2941 cm³ Measured
Cold Free Space:	20.5003 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot Report - Data

Relative Pressure (p/p°)	Statistical Thickness (Å)	Quantity Adsorbed (cm³/g STP)	Fitted
0.528336120	6.7060	4.2041	*
0.558457188	6.9817	4.3328	*
0.588049902	7.2715	4.4689	*
0.617948307	7.5869	4.6183	*
0.647992775	7.9307	4.7818	*
0.677391864	8.2983	4.9631	*
0.707529833	8.7136	5.1693	*
0.736708351	9.1608	5.3996	*
0.770440005	9.7469	5.7122	*
0.800972412	10.3586	6.0478	*
0.818083698	10.7437	6.2735	*
0.837392807	11.2230	6.5589	*
0.860042530	11.8588	6.9621	*
0.880269188	12.5106	7.4111	
0.889637981	12.8453	7.6561	
0.897913842	13.1612	7.9087	
0.907176221	13.5401	8.2164	
0.920641490	14.1462	8.7428	
0.928461433	14.5332	9.1205	
0.938115839	15.0527	9.6674	
0.947111750	15.5848	10.3013	
0.953994025	16.0285	10.8523	
0.958741684	16.3555	11.2935	
0.963580207	16.7085	11.8325	
0.968067776	17.0554	12.4191	
0.976951538	17.8056	13.7958	
0.982488326	18.3225	14.9930	
0.986601364	18.7348	16.0141	
0.988870621	18.9738	16.6429	
0.991349575	19.2450	17.5129	
0.992441205	19.3679	18.0638	

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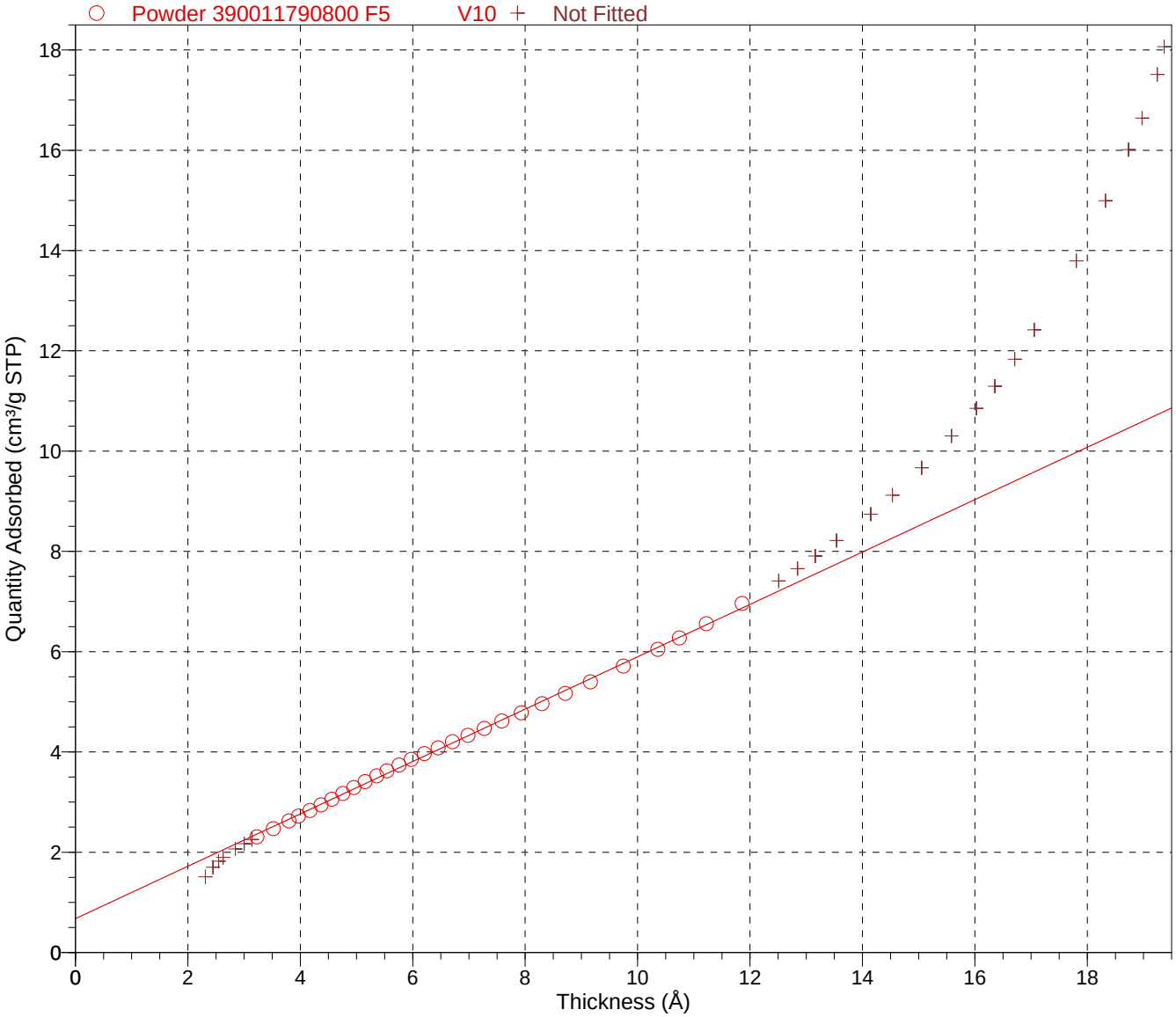
Cold Free Space:	20.5003 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot

Harkins and Jura



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Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200801_005-50_Run1.SMP

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Cold Free Space:	20.5003 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Pore Distribution Report

Standard
Halsey
t = 3.54 [-5 / ln(p/p°)] ^ 0.333

Width Range: 17.000 Å to 3,000.000 Å
Adsorbate Property Factor: 9.53000 Å
Density Conversion Factor: 0.0015468
Fraction of Pores Open at Both Ends: 0.00

Pore Width Range (Å)	Average Width (Å)	Incremental Pore Volume (cm³/g)	Cumulative Pore Volume (cm³/g)	Incremental Pore Area (m²/g)	Cumulative Pore Area (m²/g)
2573.5 - 2252.6	2391.5	0.000896	0.000896	0.015	0.015
2252.6 - 1757.1	1943.5	0.001423	0.002319	0.029	0.044
1757.1 - 1463.7	1583.4	0.001032	0.003352	0.026	0.070
1463.7 - 1125.3	1250.0	0.001692	0.005044	0.054	0.125
1125.3 - 859.7	956.6	0.002007	0.007051	0.084	0.208
859.7 - 625.2	705.2	0.002340	0.009391	0.133	0.341
625.2 - 550.0	582.6	0.001004	0.010395	0.069	0.410
550.0 - 487.1	514.6	0.000927	0.011322	0.072	0.482
487.1 - 438.2	459.9	0.000762	0.012084	0.066	0.548
438.2 - 382.7	406.5	0.000959	0.013043	0.094	0.643
382.7 - 328.6	351.3	0.001118	0.014161	0.127	0.770
328.6 - 285.5	303.9	0.000971	0.015132	0.128	0.898
285.5 - 258.3	270.5	0.000674	0.015806	0.100	0.998
258.3 - 221.9	237.2	0.000948	0.016754	0.160	1.158
221.9 - 202.4	211.2	0.000557	0.017311	0.105	1.263
202.4 - 187.7	194.5	0.000461	0.017773	0.095	1.358
187.7 - 173.5	180.0	0.000447	0.018220	0.099	1.457
173.5 - 149.1	159.3	0.000832	0.019051	0.209	1.666
149.1 - 128.9	137.4	0.000753	0.019805	0.219	1.885
128.9 - 115.6	121.4	0.000536	0.020341	0.177	2.062
115.6 - 105.9	110.2	0.000429	0.020769	0.156	2.217
105.9 - 92.0	97.8	0.000643	0.021412	0.263	2.480
92.0 - 80.3	85.3	0.000608	0.022021	0.285	2.766
80.3 - 72.3	75.8	0.000450	0.022471	0.238	3.003
72.3 - 65.5	68.5	0.000404	0.022875	0.236	3.239
65.5 - 59.9	62.4	0.000359	0.023234	0.230	3.469
59.9 - 55.0	57.2	0.000323	0.023557	0.226	3.695
55.0 - 50.8	52.7	0.000297	0.023854	0.225	3.920
50.8 - 47.2	48.9	0.000272	0.024127	0.223	4.143
47.2 - 43.9	45.4	0.000259	0.024385	0.228	4.371
43.9 - 41.0	42.4	0.000247	0.024632	0.233	4.604

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Operator: AG
Submitter: URS Corporation
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Completed:	2/22/2012 10:42:10 PM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:38:10 PM	Thermal Correction:	No
Sample Mass:	2.1701 g	Warm Free Space:	7.2941 cm³ Measured
Cold Free Space:	20.5003 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Pore Width Range (Å)	Average Width (Å)	Incremental Pore Volume (cm³/g)	Cumulative Pore Volume (cm³/g)	Incremental Pore Area (m²/g)	Cumulative Pore Area (m²/g)
41.0 - 38.4	39.6	0.000241	0.024873	0.243	4.848
38.4 - 36.0	37.1	0.000245	0.025118	0.264	5.112
36.0 - 33.9	34.9	0.000246	0.025365	0.283	5.394
33.9 - 31.9	32.8	0.000256	0.025620	0.312	5.706
31.9 - 30.2	31.0	0.000237	0.025857	0.306	6.012
30.2 - 28.4	29.2	0.000278	0.026135	0.380	6.392
28.4 - 26.7	27.5	0.000290	0.026425	0.422	6.814
26.7 - 25.1	25.9	0.000285	0.026710	0.441	7.255
25.1 - 23.6	24.3	0.000277	0.026987	0.456	7.711
23.6 - 22.2	22.8	0.000269	0.027256	0.471	8.183
22.2 - 20.7	21.4	0.000247	0.027503	0.462	8.645
20.7 - 19.3	20.0	0.000228	0.027731	0.457	9.102
19.3 - 18.2	18.7	0.000183	0.027915	0.392	9.494
18.2 - 16.4	17.2	0.000292	0.028207	0.680	10.174

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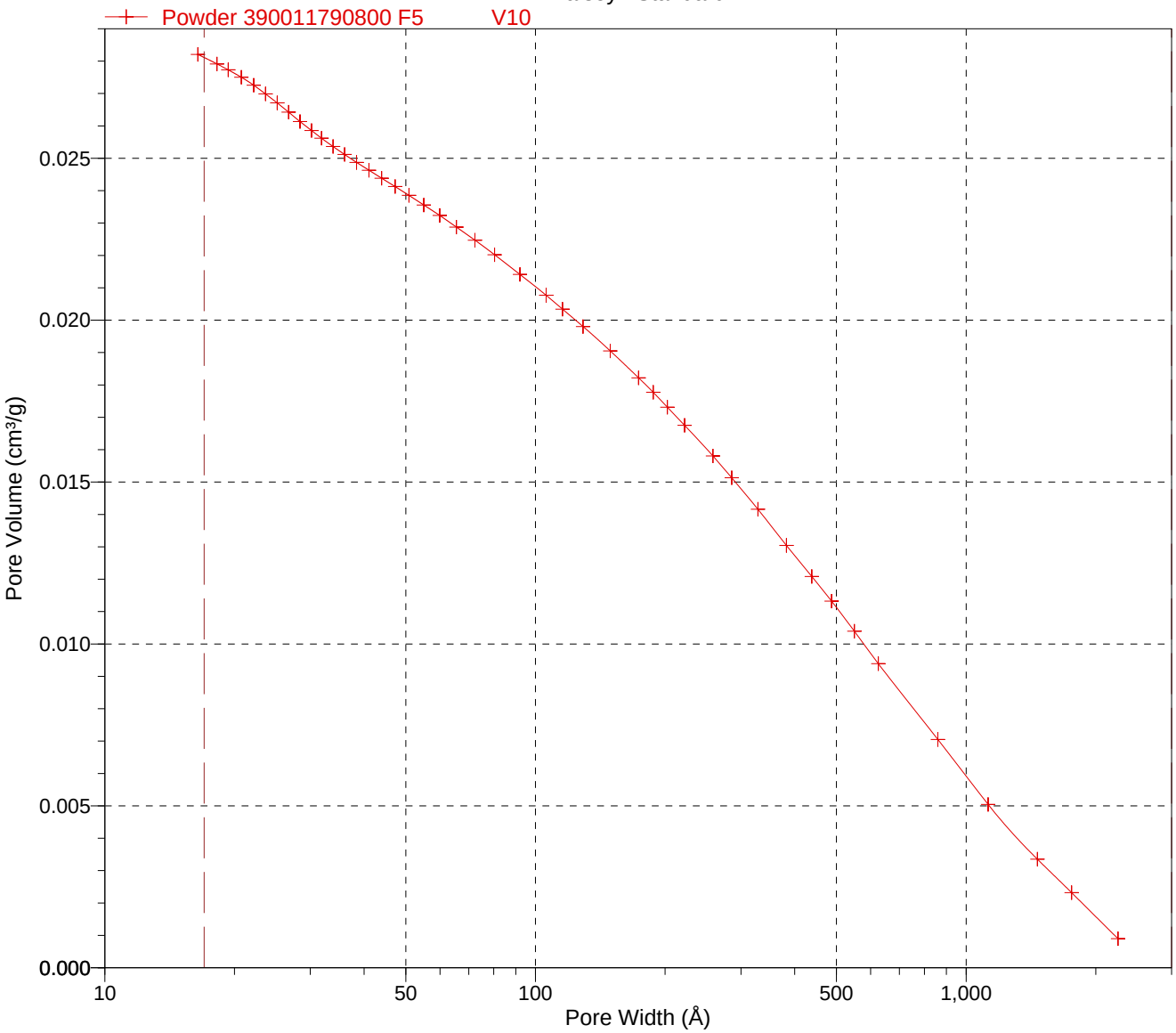
Cold Free Space:	20.5003 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Cumulative Pore Volume (Larger)

Halsey : Standard



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Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200801_005-50_Run1.SMP

Started:	2/22/2012 12:01:48 PM	Analysis Adsorptive:	N2
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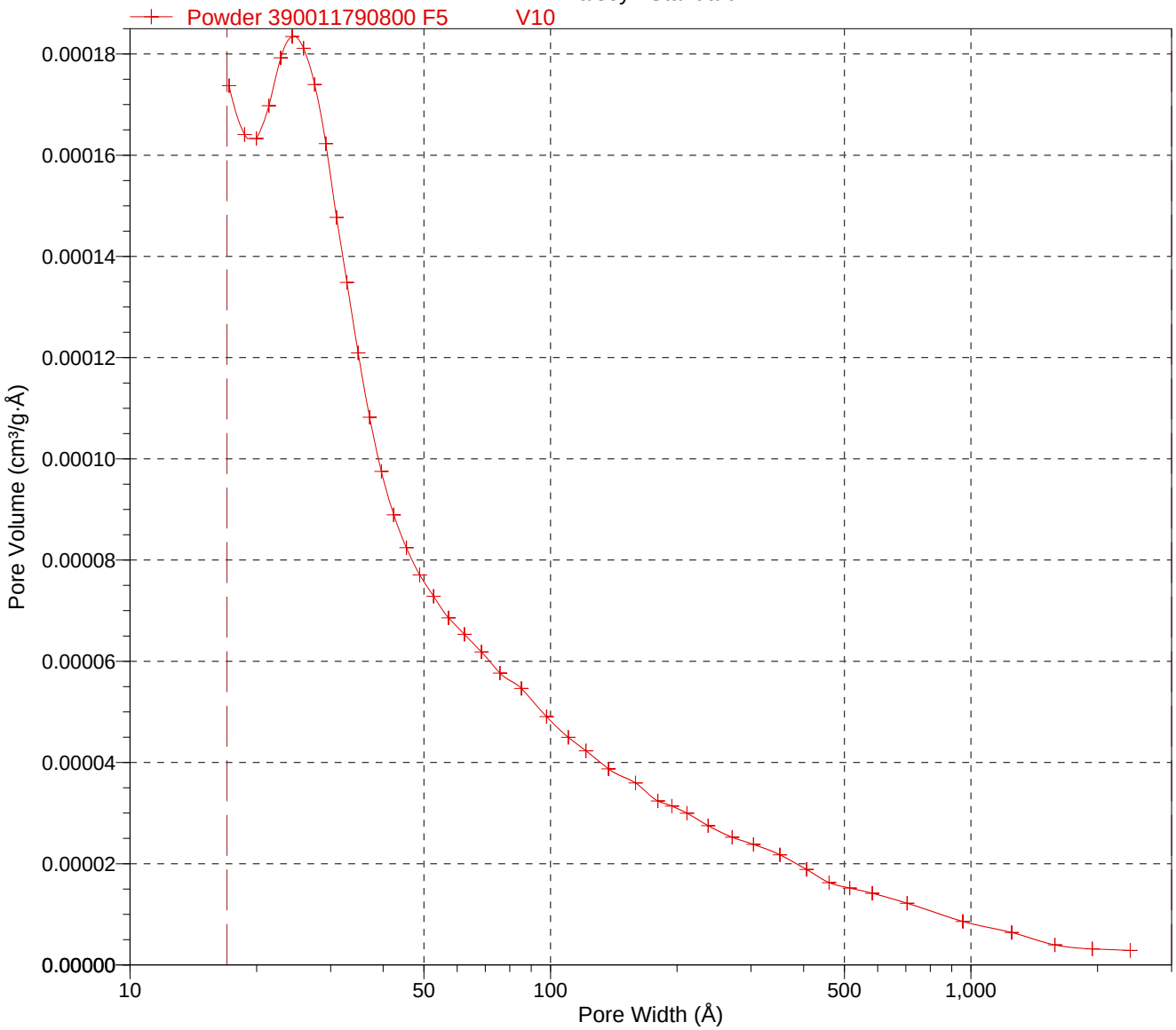
Sample Mass:	2.1701 g	Warm Free Space:	7.2941 cm³ Measured
Cold Free Space:	20.5003 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dV/dw Pore Volume

Halsey : Standard



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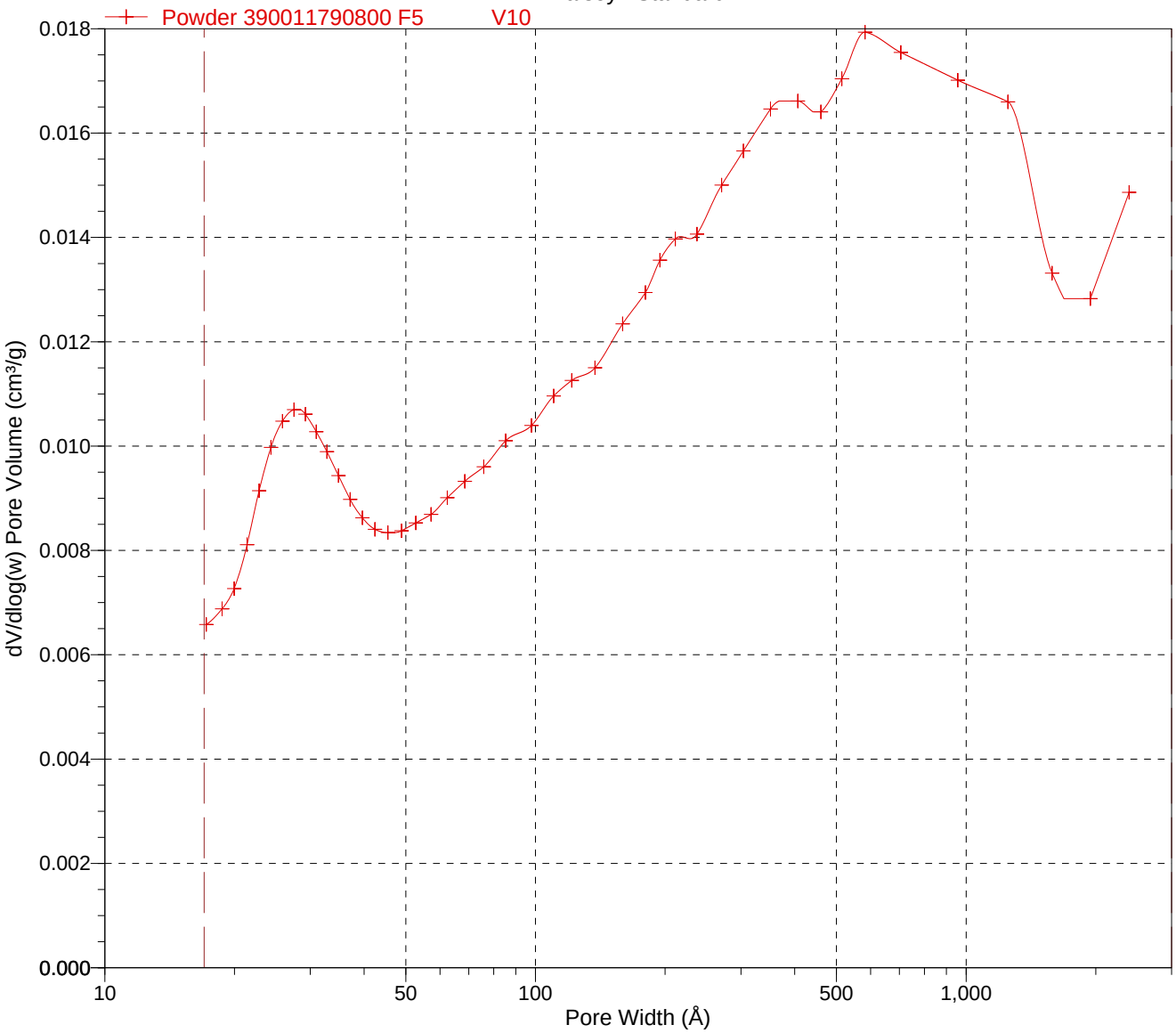
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200801_005-50_Run1.SMP

Started:	2/22/2012 12:01:48 PM	Analysis Adsorptive:	N2
Completed:	2/22/2012 10:42:10 PM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:38:10 PM	Thermal Correction:	No
Sample Mass:	2.1701 g	Warm Free Space:	7.2941 cm³ Measured
Cold Free Space:	20.5003 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dV/dlog(w) Pore Volume

Halsey : Standard



Sample: Powder 390011790800 F5 V10
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200801_005-50_Run1.SMP

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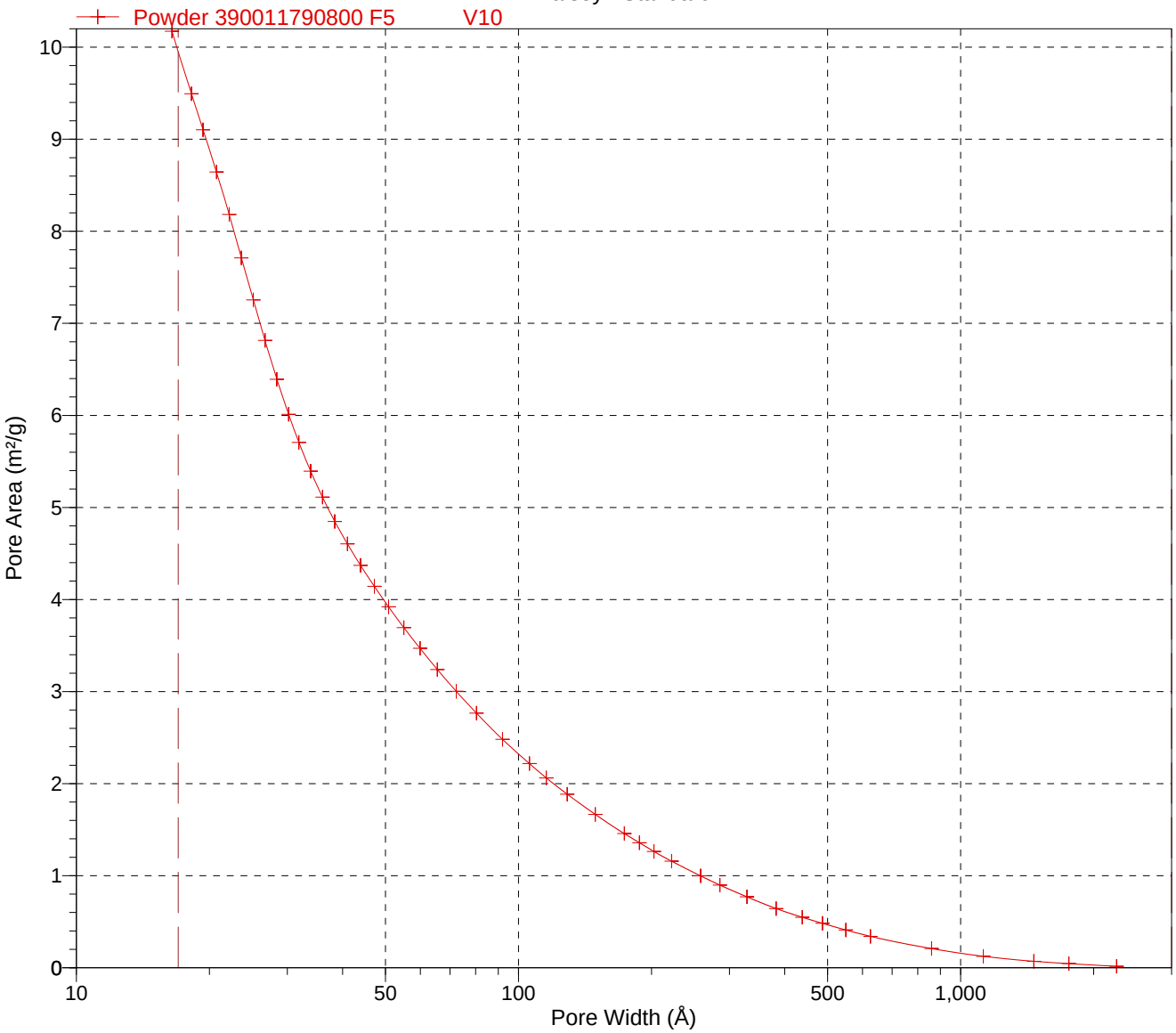
Sample Mass:	2.1701 g	Warm Free Space:	7.2941 cm³ Measured
Cold Free Space:	20.5003 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Cumulative Pore Area (Larger)

Halsey : Standard



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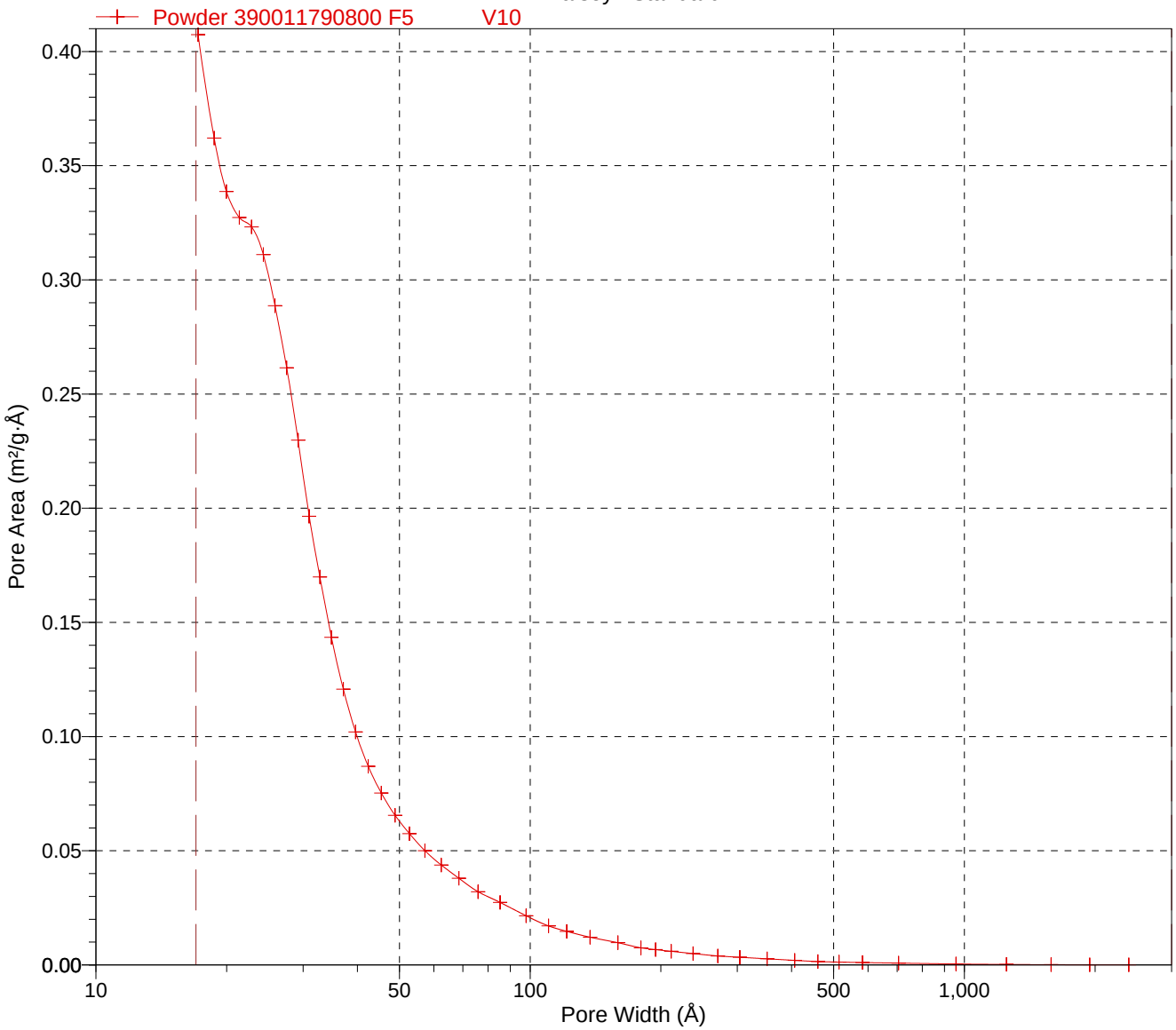
Sample Mass:	2.1701 g	Warm Free Space:	7.2941 cm³ Measured
Cold Free Space:	20.5003 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dA/dw Pore Area

Halsey : Standard



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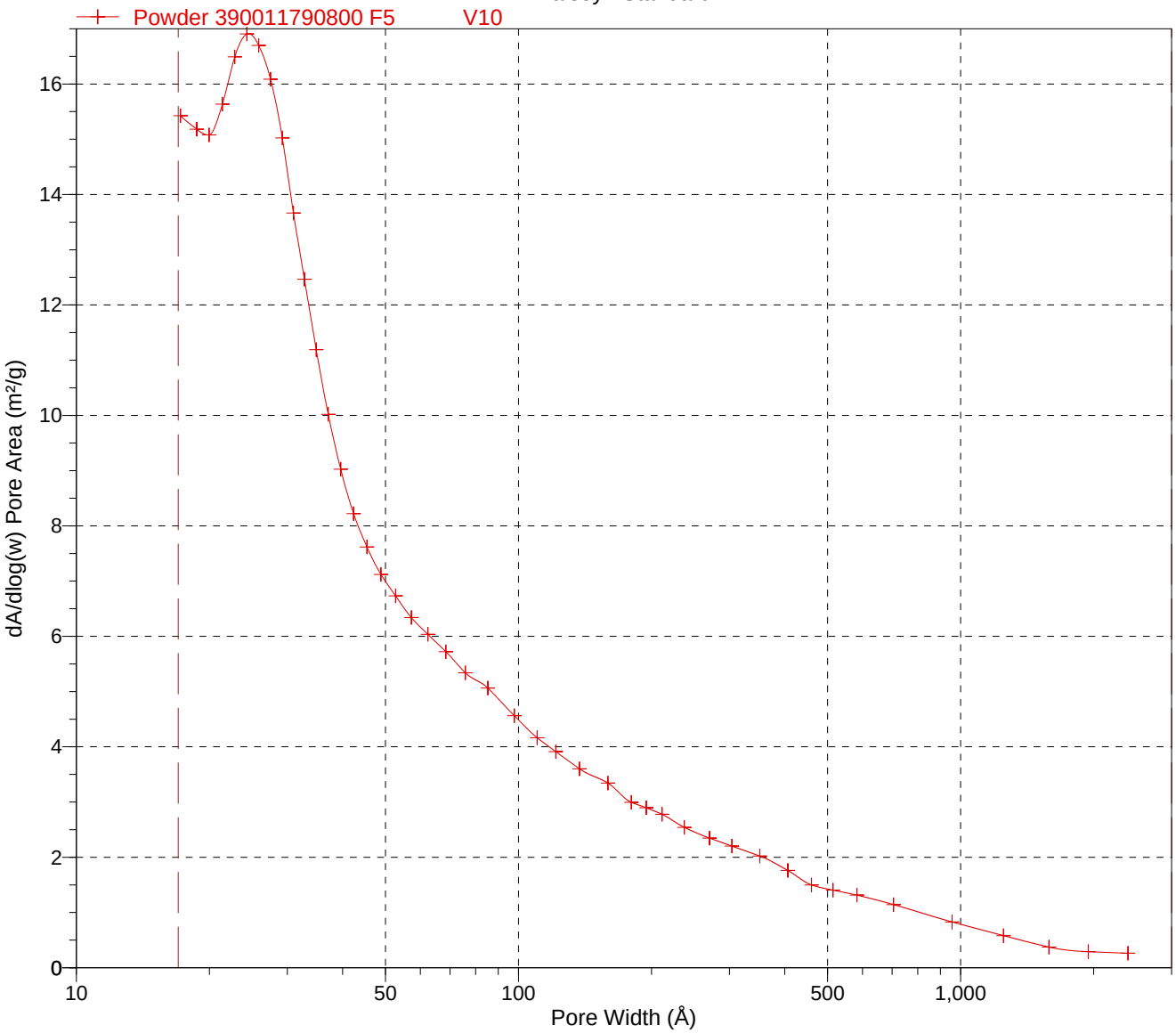
Sample Mass:	2.1701 g	Warm Free Space:	7.2941 cm³ Measured
Cold Free Space:	20.5003 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dA/dlog(w) Pore Area

Halsey : Standard



Sample: Powder 390041790754 F3 F2
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200798_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:22:18 PM	Thermal Correction:	No
Sample Mass:	2.2162 g	Warm Free Space:	7.3642 cm³ Measured
Cold Free Space:	20.7999 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Summary Report

Surface Area

Single point surface area at p/p° = 0.201923089:	10.1257 m²/g
BET Surface Area:	10.2807 m²/g
t-Plot Micropore Area:	3.2404 m²/g
t-Plot External Surface Area:	7.0404 m²/g
BJH Adsorption cumulative surface area of pores between 17.000 Å and 3,000.000 Å width:	8.946 m²/g

Pore Volume

Single point adsorption total pore volume of pores less than 2,515.365 Å width at p/p° = 0.992264307:	0.024331 cm³/g
t-Plot micropore volume:	0.001434 cm³/g
BJH Adsorption cumulative volume of pores between 17.000 Å and 3,000.000 Å width:	0.024071 cm³/g

Pore Size

Adsorption average pore width (4V/A by BET):	94.6681 Å
BJH Adsorption average pore width (4V/A):	107.630 Å

Sample: Powder 390041790754 F3 F2
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200798_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:22:18 PM	Thermal Correction:	No
Sample Mass:	2.2162 g	Warm Free Space:	7.3642 cm³ Measured
Cold Free Space:	20.7999 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Tabular Report

Relative Pressure (p/p°)	Absolute Pressure (mmHg)	Quantity Adsorbed (cm³/g STP)	Elapsed Time (h:min)	Saturation Pressure (mmHg)
			01:04	738.959595
0.002565297	1.892469	1.4700	02:21	737.719055
0.004989173	3.677027	1.6681	02:48	737.001282
0.007408512	5.453842	1.7925	03:32	736.158875
0.010228244	7.525640	1.8871	04:15	735.770447
0.019841095	14.578368	2.0680	05:20	734.756226
0.029793679	21.857626	2.1798	06:05	733.632996
0.041039489	30.090286	2.2692	06:29	733.203247
0.052260303	38.309105	2.3443	06:54	733.044067
0.083069647	60.880013	2.4957	07:14	732.879150
0.109406403	80.170113	2.6020	07:28	732.773499
0.140107696	102.663589	2.7132	07:40	732.747681
0.171454192	125.592163	2.8164	07:48	732.511475
0.201923089	147.912643	2.9146	07:55	732.519714
0.232468205	170.262131	3.0126	08:02	732.410400
0.263139938	192.647858	3.1108	08:09	732.111816
0.293563335	215.004593	3.2100	08:15	732.395935
0.323796286	237.117340	3.3090	08:21	732.304077
0.350711486	256.836121	3.3980	08:26	732.328796
0.380572292	278.697266	3.4966	08:31	732.310974
0.410316562	300.452850	3.5966	08:36	732.246460
0.440334901	322.455200	3.6979	08:41	732.295349
0.470059896	344.245026	3.8000	08:46	732.342896
0.499954582	366.164856	3.9055	08:51	732.396240
0.529867158	388.062592	4.0145	08:55	732.377136
0.559626897	409.877960	4.1285	09:00	732.412903
0.589488966	431.759399	4.2496	09:05	732.429993
0.619211866	453.532593	4.3796	09:10	732.435242
0.649004066	475.320770	4.5222	09:16	732.384888
0.678739510	497.004852	4.6800	09:21	732.246826
0.708473548	518.723022	4.8559	09:26	732.169922
0.737809241	540.149902	5.0556	09:32	732.099670
0.767440325	561.847961	5.2888	09:38	732.106384
0.800281043	585.845581	5.5986	09:47	732.049805
0.818990465	599.574951	5.8088	09:53	732.090271
0.837424893	613.039490	6.0470	09:59	732.053101
0.857088003	627.371155	6.3482	10:06	731.979858
0.880496945	644.508179	6.7931	10:18	731.982300
0.890322512	651.475403	7.0115	10:25	731.729675

Sample: Powder 390041790754 F3 F2
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200798_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:22:18 PM	Thermal Correction:	No
Sample Mass:	2.2162 g	Warm Free Space:	7.3642 cm³ Measured
Cold Free Space:	20.7999 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Tabular Report

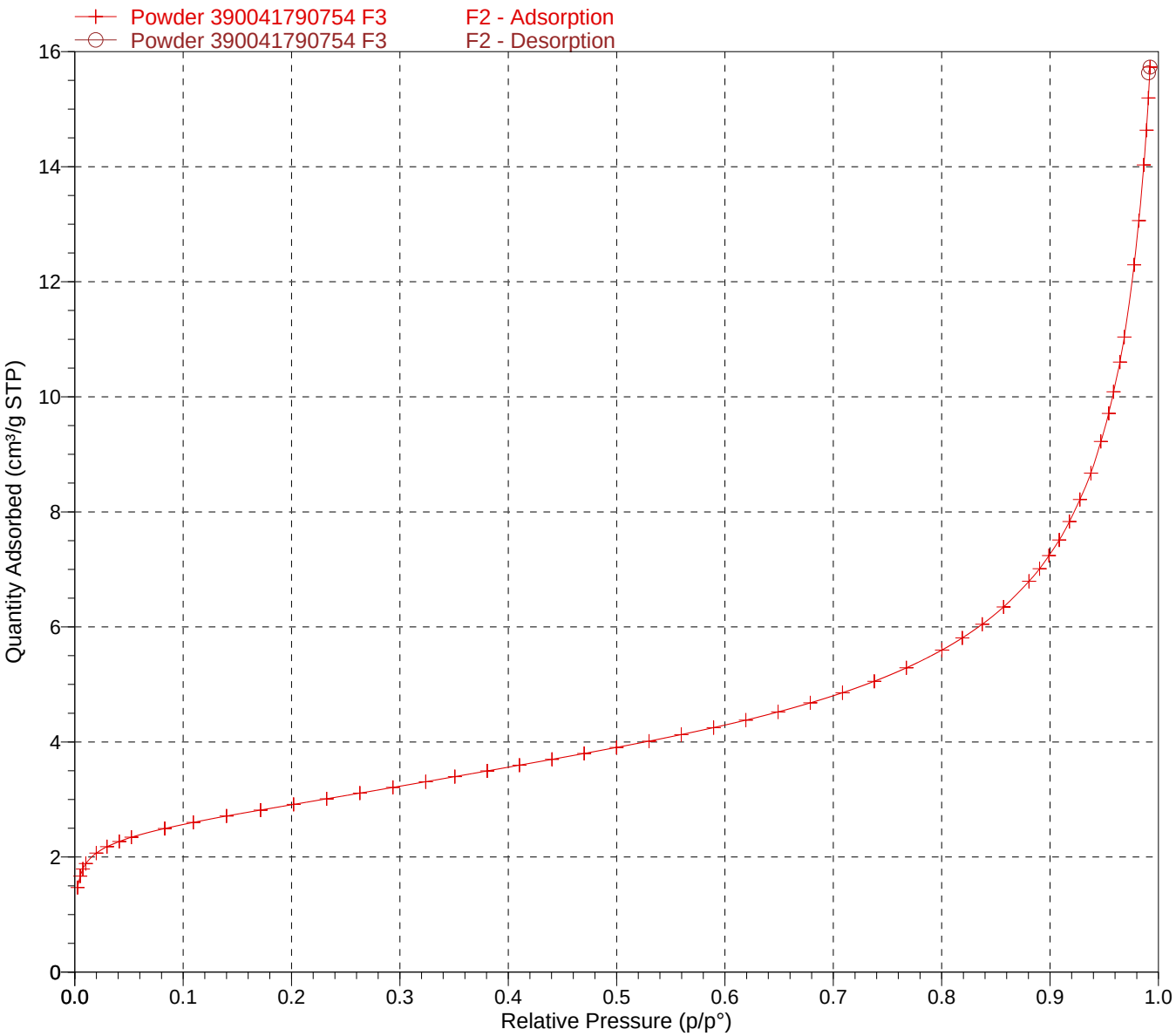
Relative Pressure (p/p°)	Absolute Pressure (mmHg)	Quantity Adsorbed (cm³/g STP)	Elapsed Time (h:min)	Saturation Pressure (mmHg)
0.899003356	657.721313	7.2388	10:31	731.611633
0.908541567	664.470947	7.5105	10:38	731.359985
0.917936513	671.313293	7.8312	10:45	731.328674
0.927516908	678.484619	8.2149	10:53	731.506470
0.937733835	685.680664	8.6742	11:01	731.210327
0.946873314	692.378052	9.2233	11:09	731.225647
0.954119432	697.519714	9.7108	11:18	731.061218
0.958587348	700.734314	10.0865	11:25	731.007263
0.964523915	704.908386	10.6035	11:33	730.835571
0.968424801	707.885193	11.0371	11:41	730.965576
0.977600149	714.944336	12.2933	11:57	731.325928
0.981926263	718.070618	13.0623	12:08	731.287720
0.986533703	721.478760	14.0301	12:21	731.327026
0.989051626	723.297607	14.6338	12:31	731.304199
0.990700686	724.624023	15.1947	12:41	731.425781
0.992264307	725.751526	15.7302	12:52	731.409485
0.990797193	724.573120	15.6305	12:55	731.303162

Sample: Powder 390041790754 F3 F2
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200798_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:22:18 PM	Thermal Correction:	No
Sample Mass:	2.2162 g	Warm Free Space:	7.3642 cm³ Measured
Cold Free Space:	20.7999 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Linear Plot



Sample: Powder 390041790754 F3 F2
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200798_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:22:18 PM	Thermal Correction:	No
Sample Mass:	2.2162 g	Warm Free Space:	7.3642 cm³ Measured
Cold Free Space:	20.7999 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BET Surface Area Report

BET Surface Area:	10.2807 ± 0.0564 m²/g
Slope:	0.422228 ± 0.002300 g/cm³ STP
Y-Intercept:	0.001205 ± 0.000313 g/cm³ STP
C:	351.364305
Qm:	2.3616 cm³/g STP
Correlation Coefficient:	0.9999406
Molecular Cross-Sectional Area:	0.1620 nm²

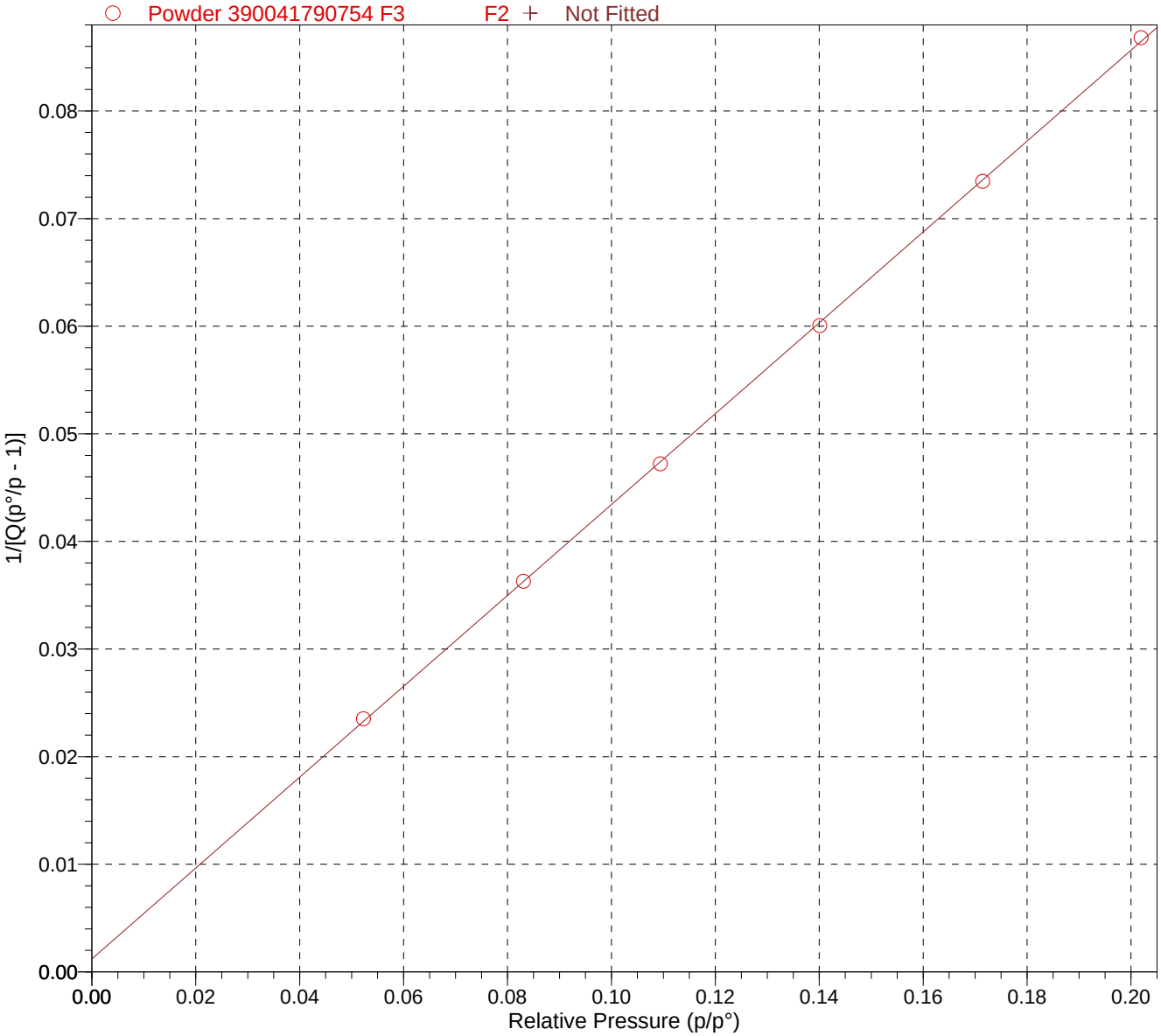
Relative Pressure (p/p°)	Quantity Adsorbed (cm³/g STP)	1/[Q(p°/p - 1)]
0.052260303	2.3443	0.023522
0.083069647	2.4957	0.036301
0.109406403	2.6020	0.047213
0.140107696	2.7132	0.060053
0.171454192	2.8164	0.073474
0.201923089	2.9146	0.086810

Sample: Powder 390041790754 F3 F2
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200798_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:22:18 PM	Thermal Correction:	No
Sample Mass:	2.2162 g	Warm Free Space:	7.3642 cm³ Measured
Cold Free Space:	20.7999 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BET Surface Area Plot



Sample: Powder 390041790754 F3 F2
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200798_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:22:18 PM	Thermal Correction:	No
Sample Mass:	2.2162 g	Warm Free Space:	7.3642 cm³ Measured
Cold Free Space:	20.7999 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot Report

Micropore Volume:	0.001434 cm³/g
Micropore Area:	3.2404 m²/g
External Surface Area:	7.0404 m²/g
Slope:	0.455156 ± 0.002783 cm³/g·Å STP
Y-Intercept:	0.927088 ± 0.019831 cm³/g STP
Correlation Coefficient:	0.999496
Surface Area Correction Factor:	1.000
Density Conversion Factor:	0.0015468
Total Surface Area (BET):	10.2807 m²/g
Thickness Range:	3.1494 Å to 11.9029 Å
Thickness Equation:	Harkins and Jura

Thickness Curve

t = [13.99 / (0.034 - log(p/p°))] ^ 0.5

t-Plot Report - Data

Relative Pressure (p/p°)	Statistical Thickness (Å)	Quantity Adsorbed (cm³/g STP)	Fitted
0.002565297	2.3086	1.4700	
0.004989173	2.4472	1.6681	
0.007408512	2.5425	1.7925	
0.010228244	2.6289	1.8871	
0.019841095	2.8384	2.0680	
0.029793679	2.9948	2.1798	
0.041039489	3.1379	2.2692	
0.052260303	3.2607	2.3443	*
0.083069647	3.5429	2.4957	*
0.109406403	3.7498	2.6020	*
0.140107696	3.9702	2.7132	*
0.171454192	4.1822	2.8164	*
0.201923089	4.3813	2.9146	*
0.232468205	4.5776	3.0126	*
0.263139938	4.7741	3.1108	*
0.293563335	4.9703	3.2100	*
0.323796286	5.1684	3.3090	*
0.350711486	5.3485	3.3980	*
0.380572292	5.5538	3.4966	*
0.410316562	5.7654	3.5966	*
0.440334901	5.9876	3.6979	*
0.470059896	6.2179	3.8000	*
0.499954582	6.4616	3.9055	*

Sample: Powder 390041790754 F3 F2
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200798_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:22:18 PM	Thermal Correction:	No
Sample Mass:	2.2162 g	Warm Free Space:	7.3642 cm³ Measured
Cold Free Space:	20.7999 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot Report - Data

Relative Pressure (p/p°)	Statistical Thickness (Å)	Quantity Adsorbed (cm³/g STP)	Fitted
0.529867158	6.7196	4.0145	*
0.559626897	6.9928	4.1285	*
0.589488966	7.2862	4.2496	*
0.619211866	7.6008	4.3796	*
0.649004066	7.9428	4.5222	*
0.678739510	8.3160	4.6800	*
0.708473548	8.7273	4.8559	*
0.737809241	9.1787	5.0556	*
0.767440325	9.6913	5.2888	*
0.800281043	10.3437	5.5986	*
0.818990465	10.7651	5.8088	*
0.837424893	11.2238	6.0470	*
0.857088003	11.7707	6.3482	*
0.880496945	12.5185	6.7931	
0.890322512	12.8707	7.0115	
0.899003356	13.2043	7.2388	
0.908541567	13.5985	7.5105	
0.917936513	14.0187	7.8312	
0.927516908	14.4850	8.2149	
0.937733835	15.0311	8.6742	
0.946873314	15.5701	9.2233	
0.954119432	16.0369	9.7108	
0.958587348	16.3446	10.0865	
0.964523915	16.7798	10.6035	
0.968424801	17.0839	11.0371	
0.977600149	17.8640	12.2933	
0.981926263	18.2681	13.0623	
0.986533703	18.7278	14.0301	
0.989051626	18.9932	14.6338	
0.990700686	19.1729	15.1947	
0.992264307	19.3478	15.7302	

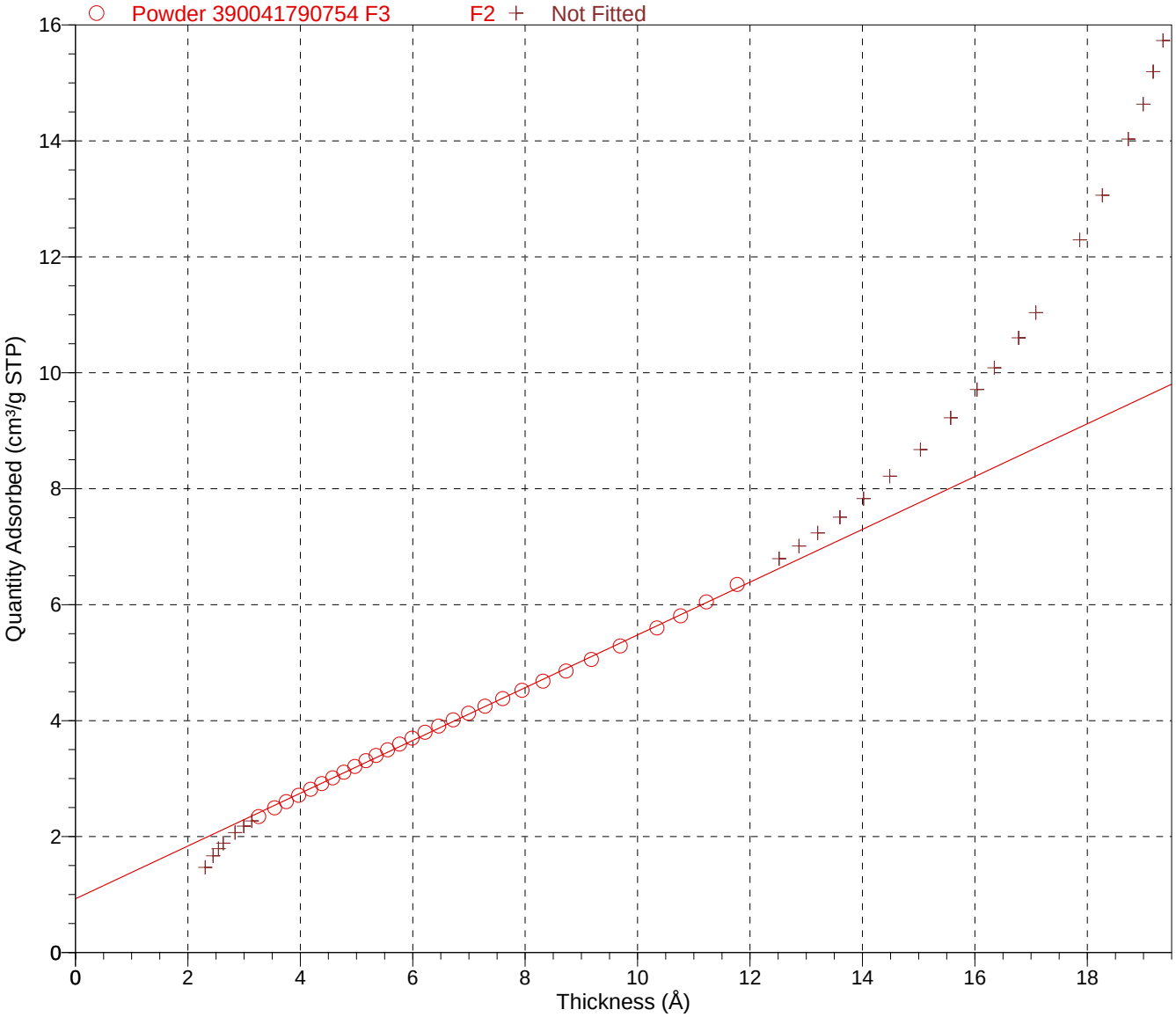
Sample: Powder 390041790754 F3 F2
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200798_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:22:18 PM	Thermal Correction:	No
Sample Mass:	2.2162 g	Warm Free Space:	7.3642 cm³ Measured
Cold Free Space:	20.7999 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot

Harkins and Jura



Sample: Powder 390041790754 F3 F2
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200798_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:22:18 PM	Thermal Correction:	No
Sample Mass:	2.2162 g	Warm Free Space:	7.3642 cm³ Measured
Cold Free Space:	20.7999 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Pore Distribution Report

Standard
Halsey
t = 3.54 [-5 / ln(p/p°)] ^ 0.333

Width Range: 17.000 Å to 3,000.000 Å
Adsorbate Property Factor: 9.53000 Å
Density Conversion Factor: 0.0015468
Fraction of Pores Open at Both Ends: 0.00

Pore Width Range (Å)	Average Width (Å)	Incremental Pore Volume (cm³/g)	Cumulative Pore Volume (cm³/g)	Incremental Pore Area (m²/g)	Cumulative Pore Area (m²/g)
2515.4 - 2097.4	2268.3	0.000873	0.000873	0.015	0.015
2097.4 - 1785.7	1916.2	0.000918	0.001791	0.019	0.035
1785.7 - 1456.5	1587.4	0.000992	0.002783	0.025	0.060
1456.5 - 1090.9	1221.1	0.001606	0.004389	0.053	0.112
1090.9 - 884.0	965.5	0.001287	0.005676	0.053	0.165
884.0 - 632.1	716.0	0.002136	0.007812	0.119	0.285
632.1 - 564.2	594.2	0.000741	0.008552	0.050	0.335
564.2 - 485.3	518.6	0.000887	0.009439	0.068	0.403
485.3 - 439.3	459.9	0.000651	0.010090	0.057	0.460
439.3 - 381.0	405.8	0.000849	0.010939	0.084	0.543
381.0 - 326.7	349.4	0.000970	0.011909	0.111	0.654
326.7 - 281.9	300.8	0.000814	0.012722	0.108	0.762
281.9 - 250.0	263.9	0.000688	0.013410	0.104	0.867
250.0 - 225.1	236.2	0.000579	0.013989	0.098	0.965
225.1 - 204.5	213.8	0.000492	0.014481	0.092	1.057
204.5 - 188.8	196.0	0.000415	0.014896	0.085	1.141
188.8 - 173.8	180.6	0.000399	0.015294	0.088	1.230
173.8 - 146.1	157.4	0.000829	0.016124	0.211	1.441
146.1 - 128.9	136.4	0.000565	0.016689	0.166	1.606
128.9 - 116.1	121.8	0.000449	0.017138	0.148	1.754
116.1 - 105.5	110.2	0.000399	0.017537	0.145	1.899
105.5 - 90.8	96.9	0.000597	0.018134	0.246	2.145
90.8 - 80.7	85.1	0.000453	0.018587	0.213	2.358
80.7 - 72.6	76.1	0.000391	0.018978	0.205	2.563
72.6 - 65.8	68.8	0.000346	0.019323	0.201	2.764
65.8 - 60.1	62.6	0.000313	0.019636	0.200	2.964
60.1 - 55.2	57.4	0.000284	0.019921	0.198	3.162
55.2 - 51.0	52.9	0.000261	0.020182	0.197	3.360
51.0 - 47.3	49.0	0.000245	0.020427	0.200	3.560
47.3 - 44.1	45.6	0.000234	0.020661	0.206	3.765
44.1 - 41.2	42.5	0.000227	0.020888	0.214	3.979

Sample: Powder 390041790754 F3 F2
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200798_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:22:18 PM	Thermal Correction:	No
Sample Mass:	2.2162 g	Warm Free Space:	7.3642 cm³ Measured
Cold Free Space:	20.7999 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Pore Width Range (Å)	Average Width (Å)	Incremental Pore Volume (cm³/g)	Cumulative Pore Volume (cm³/g)	Incremental Pore Area (m²/g)	Cumulative Pore Area (m²/g)
41.2 - 38.5	39.7	0.000225	0.021113	0.227	4.206
38.5 - 36.2	37.3	0.000222	0.021335	0.238	4.444
36.2 - 34.0	35.0	0.000226	0.021561	0.258	4.702
34.0 - 32.0	32.9	0.000229	0.021790	0.279	4.981
32.0 - 30.1	31.0	0.000229	0.022019	0.295	5.276
30.1 - 28.5	29.3	0.000211	0.022230	0.288	5.565
28.5 - 26.9	27.6	0.000237	0.022467	0.343	5.908
26.9 - 25.3	26.0	0.000239	0.022706	0.367	6.275
25.3 - 23.7	24.4	0.000231	0.022937	0.378	6.653
23.7 - 22.3	22.9	0.000227	0.023164	0.396	7.050
22.3 - 20.8	21.5	0.000219	0.023383	0.408	7.458
20.8 - 19.4	20.0	0.000219	0.023602	0.438	7.895
19.4 - 17.9	18.5	0.000243	0.023844	0.523	8.418
17.9 - 16.6	17.2	0.000227	0.024071	0.528	8.946

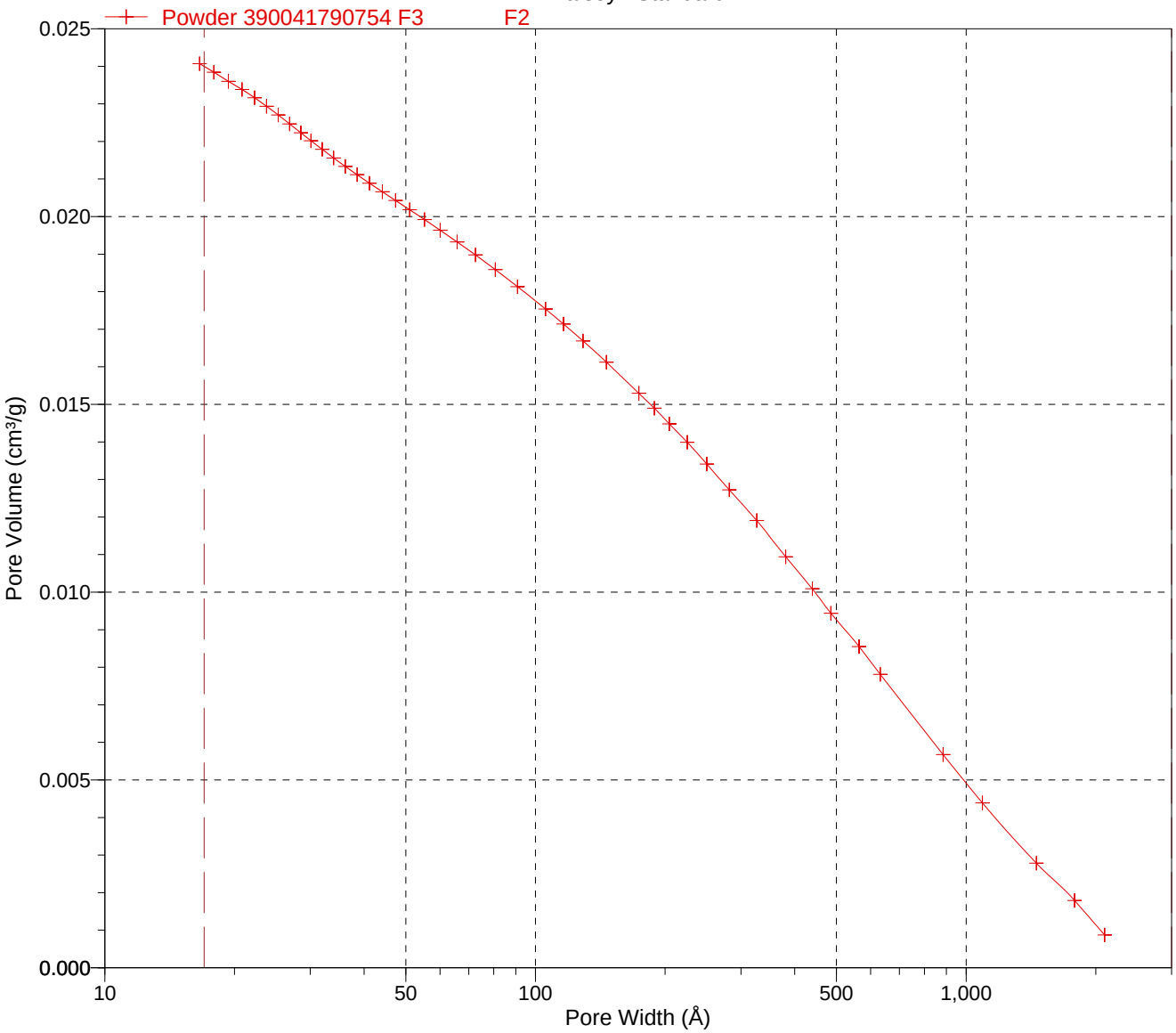
Sample: Powder 390041790754 F3 F2
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200798_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:22:18 PM	Thermal Correction:	No
Sample Mass:	2.2162 g	Warm Free Space:	7.3642 cm³ Measured
Cold Free Space:	20.7999 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Cumulative Pore Volume (Larger)

Halsey : Standard



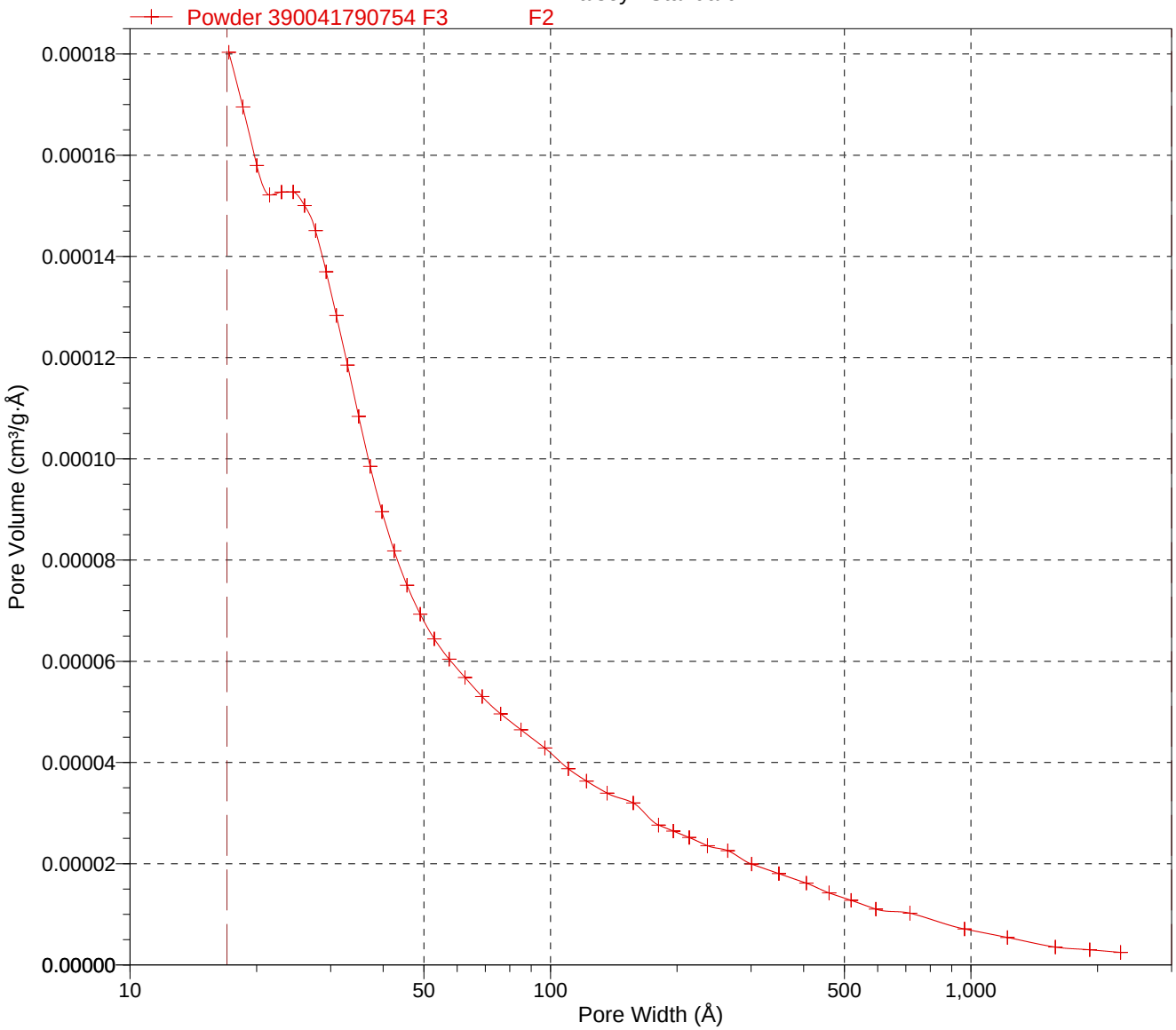
Sample: Powder 390041790754 F3 F2
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200798_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:22:18 PM	Thermal Correction:	No
Sample Mass:	2.2162 g	Warm Free Space:	7.3642 cm³ Measured
Cold Free Space:	20.7999 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dV/dw Pore Volume

Halsey : Standard



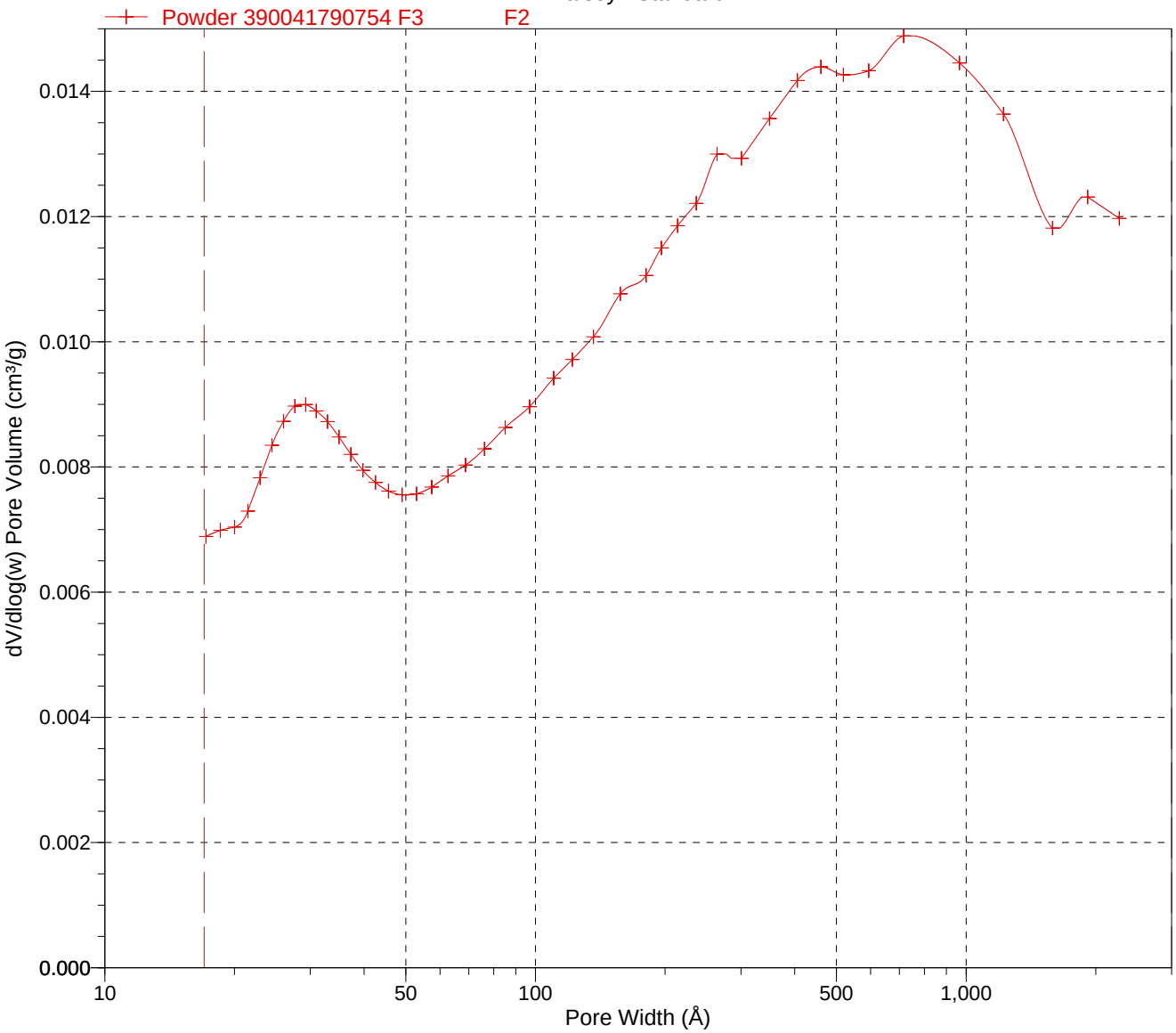
Sample: Powder 390041790754 F3 F2
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200798_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:22:18 PM	Thermal Correction:	No
Sample Mass:	2.2162 g	Warm Free Space:	7.3642 cm³ Measured
Cold Free Space:	20.7999 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dV/dlog(w) Pore Volume

Halsey : Standard



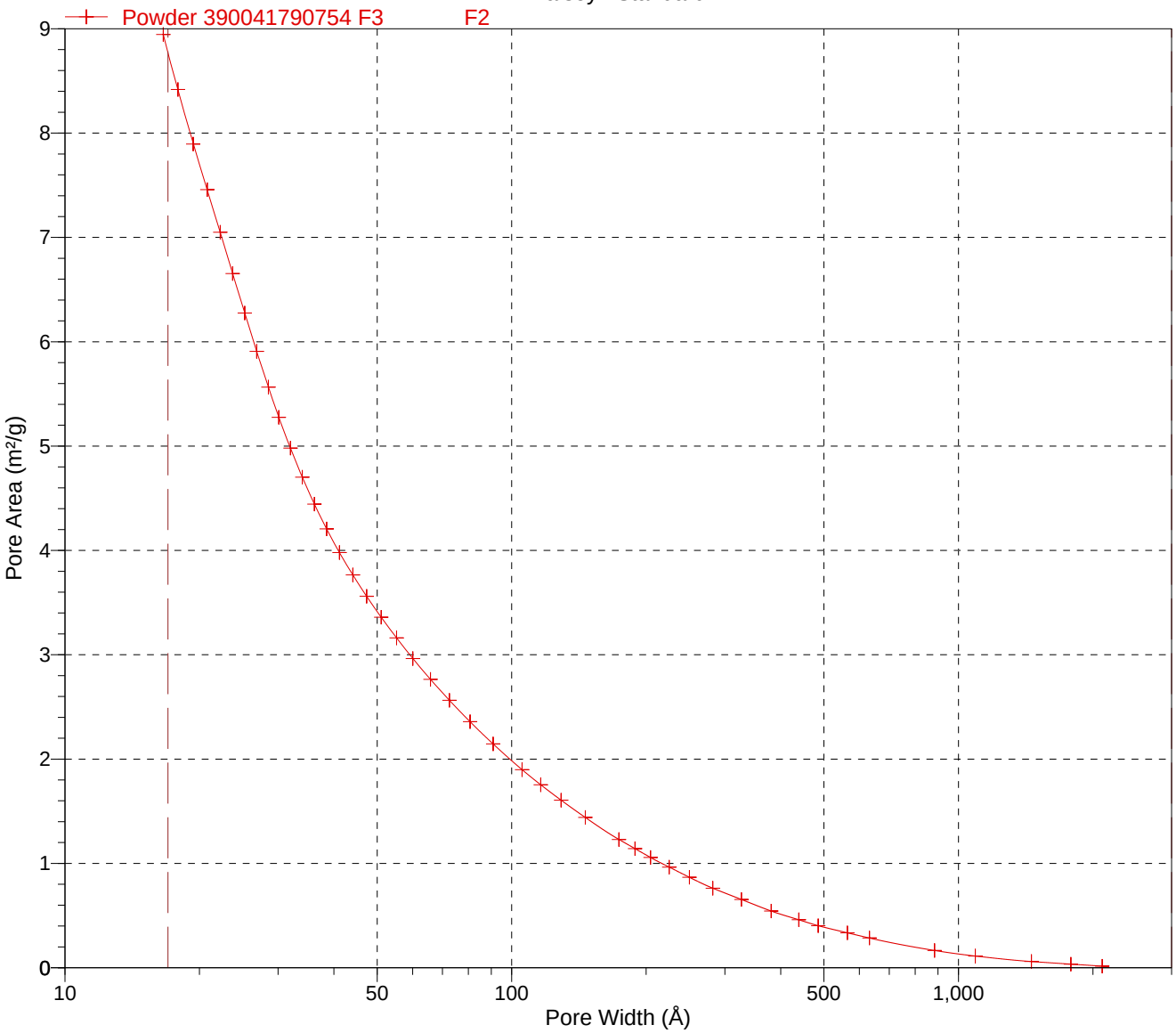
Sample: Powder 390041790754 F3 F2
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200798_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:22:18 PM	Thermal Correction:	No
Sample Mass:	2.2162 g	Warm Free Space:	7.3642 cm³ Measured
Cold Free Space:	20.7999 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Cumulative Pore Area (Larger)

Halsey : Standard



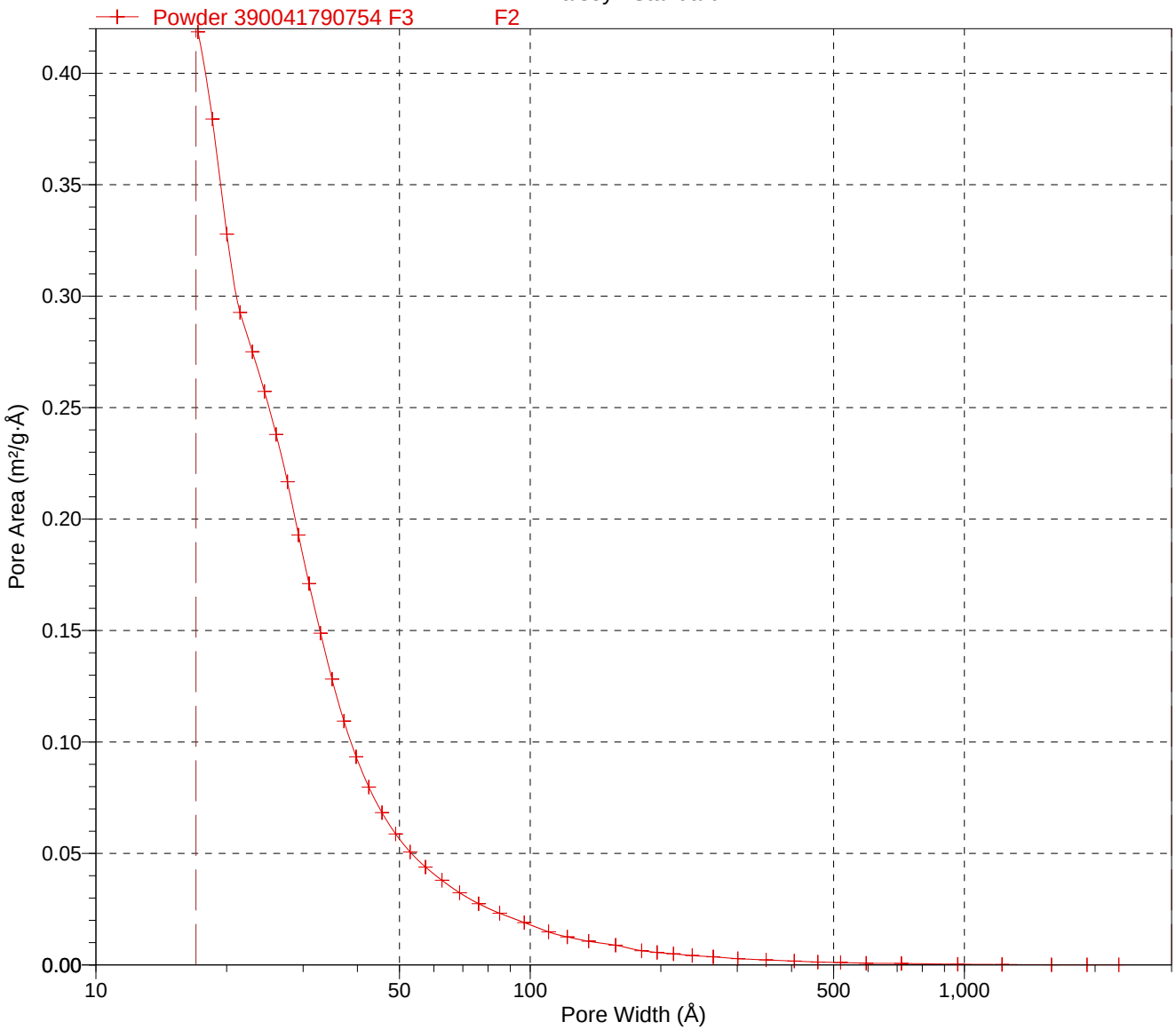
Sample: Powder 390041790754 F3 F2
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200798_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:22:18 PM	Thermal Correction:	No
Sample Mass:	2.2162 g	Warm Free Space:	7.3642 cm³ Measured
Cold Free Space:	20.7999 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dA/dw Pore Area

Halsey : Standard



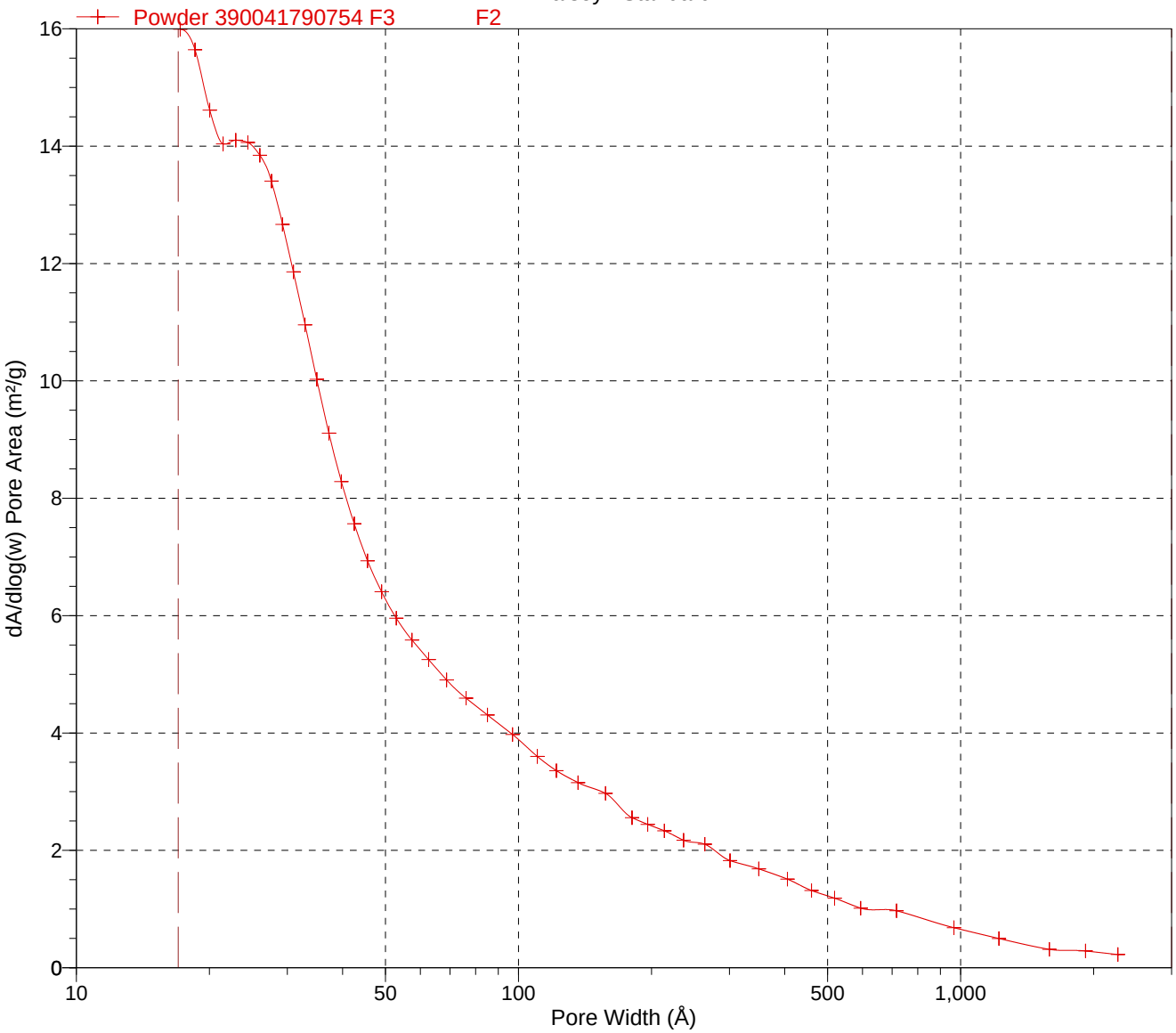
Sample: Powder 390041790754 F3 F2
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200798_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:22:18 PM	Thermal Correction:	No
Sample Mass:	2.2162 g	Warm Free Space:	7.3642 cm³ Measured
Cold Free Space:	20.7999 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dA/dlog(w) Pore Area

Halsey : Standard



Sample: Powder 391610790358 F4 L
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200800_005-50_Run1.SMP

Started:	2/22/2012 12:01:48 PM	Analysis Adsorptive:	N2
Completed:	2/22/2012 10:42:10 PM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:37:23 PM	Thermal Correction:	No
Sample Mass:	2.3131 g	Warm Free Space:	7.1469 cm³ Measured
Cold Free Space:	19.9883 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Summary Report

Surface Area

Single point surface area at p/p° = 0.232237335:	7.9871 m²/g
BET Surface Area:	8.1204 m²/g
t-Plot Micropore Area:	1.6931 m²/g
t-Plot External Surface Area:	6.4273 m²/g
BJH Adsorption cumulative surface area of pores between 17.000 Å and 3,000.000 Å width:	7.321 m²/g

Pore Volume

Single point adsorption total pore volume of pores less than 2,486.576 Å width at p/p° = 0.992173616:	0.023227 cm³/g
t-Plot micropore volume:	0.000752 cm³/g
BJH Adsorption cumulative volume of pores between 17.000 Å and 3,000.000 Å width:	0.023175 cm³/g

Pore Size

Adsorption average pore width (4V/A by BET):	114.4112 Å
BJH Adsorption average pore width (4V/A):	126.613 Å

Sample: Powder 391610790358 F4 L
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200800_005-50_Run1.SMP

Started:	2/22/2012 12:01:48 PM	Analysis Adsorptive:	N2
Completed:	2/22/2012 10:42:10 PM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:37:23 PM	Thermal Correction:	No
Sample Mass:	2.3131 g	Warm Free Space:	7.1469 cm³ Measured
Cold Free Space:	19.9883 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Tabular Report

Relative Pressure (p/p°)	Absolute Pressure (mmHg)	Quantity Adsorbed (cm³/g STP)	Elapsed Time (h:min)	Saturation Pressure (mmHg)
			01:04	734.648926
0.002567616	1.883427	1.0824	01:58	733.531616
0.005203209	3.815662	1.2644	02:13	733.328552
0.007465614	5.471159	1.3606	02:26	732.847717
0.010161205	7.441683	1.4393	02:48	732.362244
0.020072639	14.695697	1.5969	03:13	732.125793
0.030268920	22.146910	1.6923	03:33	731.671631
0.041319097	30.228180	1.7681	03:49	731.578918
0.049140095	35.949287	1.8125	03:59	731.567322
0.078377590	57.334351	1.9401	04:12	731.514587
0.107942540	78.960159	2.0415	04:20	731.501770
0.140919009	103.051300	2.1403	04:26	731.280334
0.171889084	125.667549	2.2270	04:32	731.096741
0.201764827	147.521774	2.3081	04:37	731.157043
0.232237335	169.770737	2.3898	04:42	731.022583
0.262559042	191.918304	2.4716	04:47	730.952942
0.293757383	214.696091	2.5571	04:51	730.861938
0.323336284	236.306290	2.6402	04:56	730.837524
0.354334787	258.940613	2.7298	05:01	730.779541
0.380477402	278.029449	2.8072	05:05	730.738403
0.409917244	299.569794	2.8961	05:09	730.805542
0.441263006	322.408234	2.9934	05:14	730.648682
0.469362012	342.960938	3.0837	05:18	730.695984
0.499133545	364.628479	3.1813	05:22	730.522888
0.528603455	386.134338	3.2827	05:27	730.480164
0.558711578	407.982147	3.3909	05:31	730.219604
0.590303195	431.065918	3.5127	05:36	730.244934
0.618469159	451.536957	3.6292	05:40	730.088074
0.648164688	473.142578	3.7628	05:45	729.972778
0.678076722	494.787750	3.9107	05:50	729.692871
0.707458413	516.272095	4.0753	05:55	729.756104
0.737209668	538.006653	4.2638	06:00	729.787842
0.766943823	559.563599	4.4818	06:05	729.601807
0.800618125	584.058350	4.7805	06:13	729.509277
0.818510614	597.007874	4.9707	06:19	729.383179
0.837511959	610.902100	5.2048	06:24	729.424927
0.860748640	627.623718	5.5468	06:34	729.160278
0.877083982	639.514404	5.8456	06:41	729.137024
0.888480602	647.732727	6.0866	06:47	729.034180

Sample: Powder 391610790358 F4 L
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200800_005-50_Run1.SMP

Started:	2/22/2012 12:01:48 PM	Analysis Adsorptive:	N2
Completed:	2/22/2012 10:42:10 PM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:37:23 PM	Thermal Correction:	No
Sample Mass:	2.3131 g	Warm Free Space:	7.1469 cm³ Measured
Cold Free Space:	19.9883 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Tabular Report

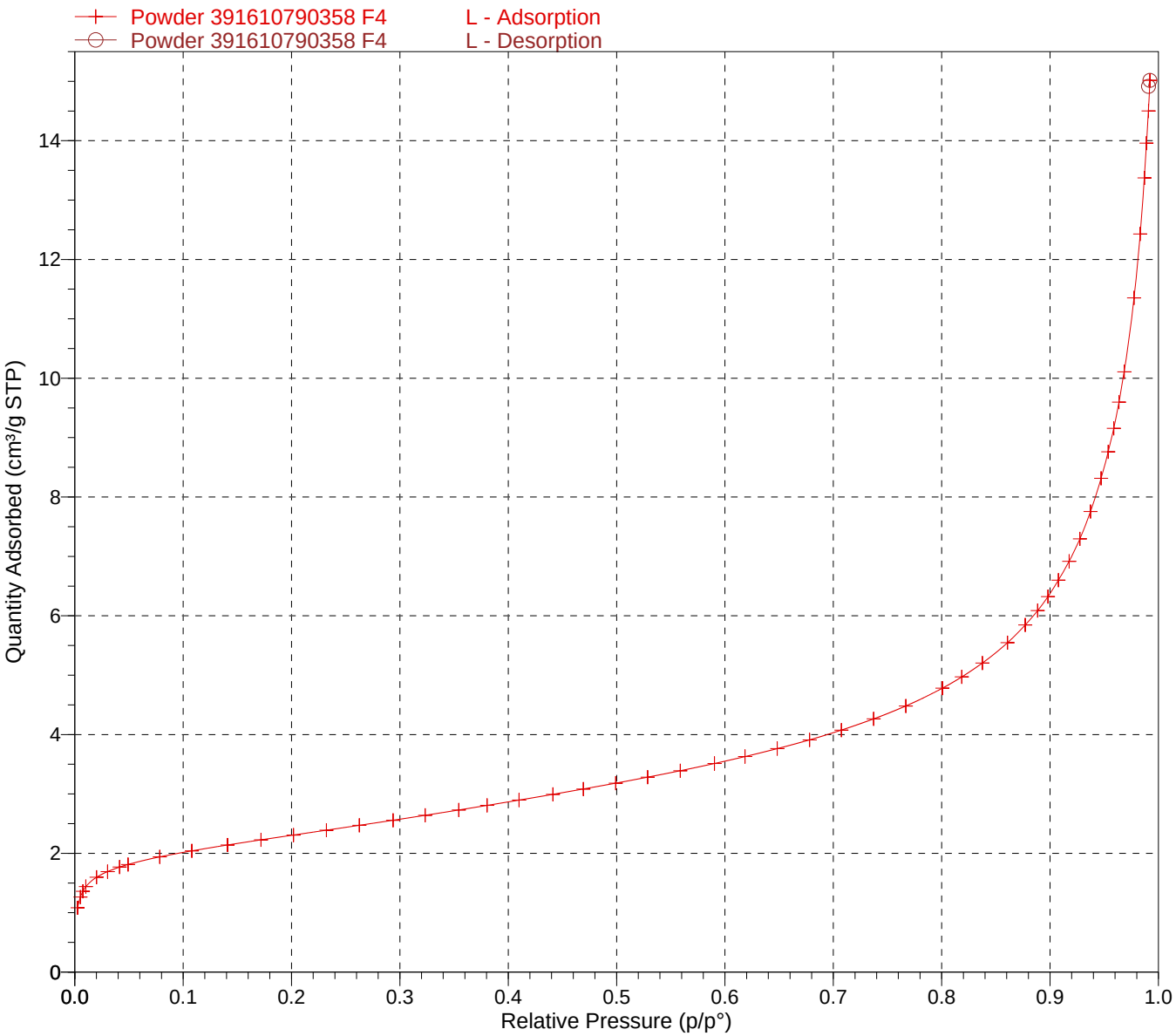
Relative Pressure (p/p°)	Absolute Pressure (mmHg)	Quantity Adsorbed (cm³/g STP)	Elapsed Time (h:min)	Saturation Pressure (mmHg)
0.898010208	654.716858	6.3229	06:53	729.075073
0.907739900	661.965942	6.6000	06:59	729.246277
0.917682626	669.084229	6.9182	07:05	729.101990
0.927494687	676.179688	7.2965	07:12	729.038879
0.937348977	683.375977	7.7561	07:20	729.051819
0.947084072	690.395386	8.3145	07:28	728.969482
0.953603845	695.217712	8.7614	07:36	729.042480
0.958800458	698.865112	9.1557	07:43	728.895264
0.963571061	702.406311	9.5983	07:50	728.961609
0.968415069	705.777344	10.1075	07:57	728.796326
0.977459487	712.209473	11.3534	08:11	728.633240
0.983197878	716.253113	12.4301	08:27	728.493347
0.987101811	719.180847	13.3747	08:40	728.578186
0.988916198	720.586548	13.9597	08:50	728.662903
0.990890161	722.031372	14.5013	08:59	728.669434
0.992173616	723.025085	15.0159	09:09	728.728394
0.990864784	722.105835	14.9146	09:12	728.763245

Sample: Powder 391610790358 F4 L
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200800_005-50_Run1.SMP

Started:	2/22/2012 12:01:48 PM	Analysis Adsorptive:	N2
Completed:	2/22/2012 10:42:10 PM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:37:23 PM	Thermal Correction:	No
Sample Mass:	2.3131 g	Warm Free Space:	7.1469 cm³ Measured
Cold Free Space:	19.9883 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Linear Plot



Sample: Powder 391610790358 F4 L
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200800_005-50_Run1.SMP

Started:	2/22/2012 12:01:48 PM	Analysis Adsorptive:	N2
Completed:	2/22/2012 10:42:10 PM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:37:23 PM	Thermal Correction:	No
Sample Mass:	2.3131 g	Warm Free Space:	7.1469 cm³ Measured
Cold Free Space:	19.9883 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BET Surface Area Report

BET Surface Area:	8.1204 ± 0.0453 m²/g
Slope:	0.534260 ± 0.002954 g/cm³ STP
Y-Intercept:	0.001823 ± 0.000452 g/cm³ STP
C:	293.997726
Qm:	1.8654 cm³/g STP
Correlation Coefficient:	0.9999236
Molecular Cross-Sectional Area:	0.1620 nm²

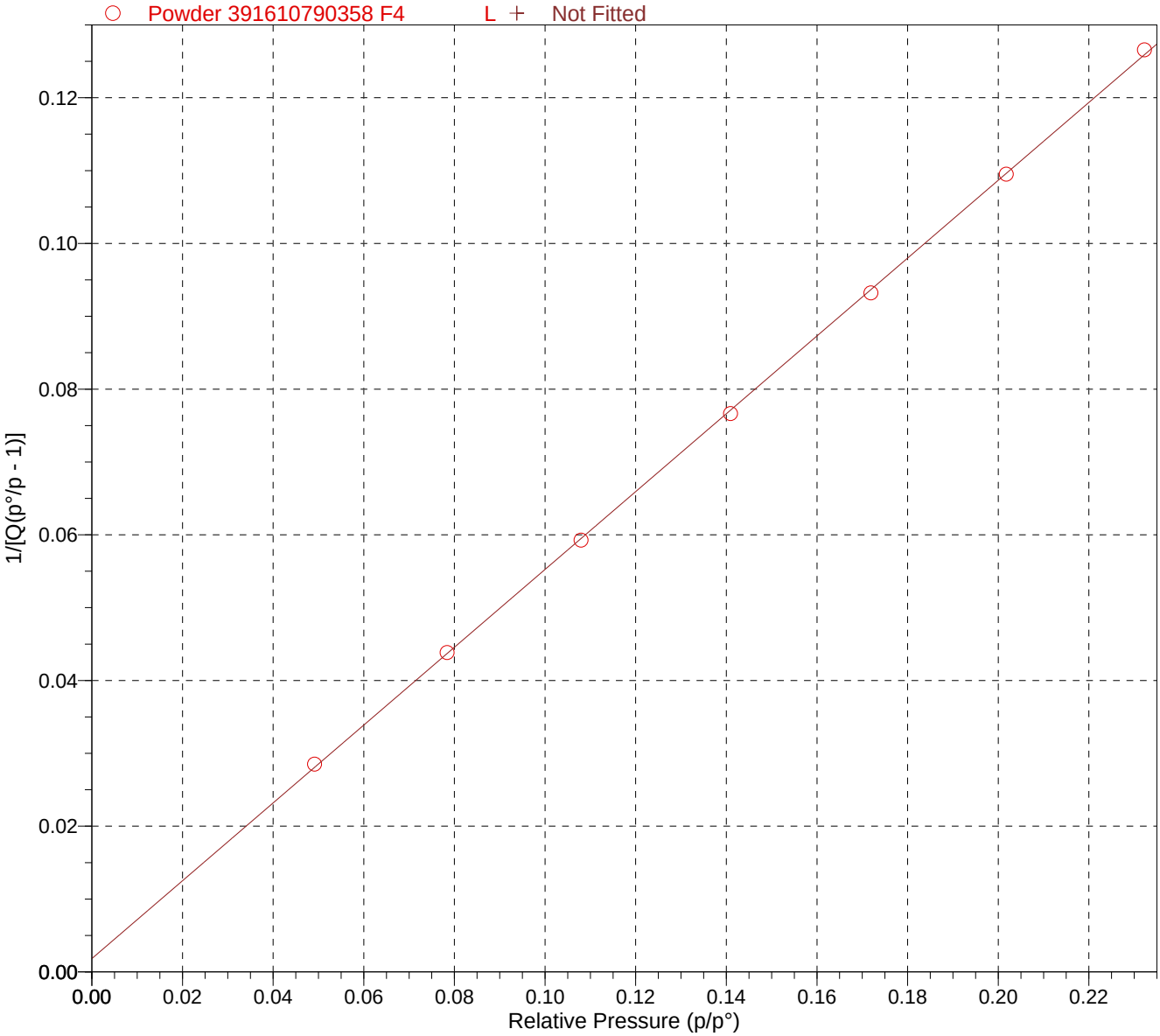
Relative Pressure (p/p°)	Quantity Adsorbed (cm³/g STP)	1/[Q(p°/p - 1)]
0.049140095	1.8125	0.028513
0.078377590	1.9401	0.043833
0.107942540	2.0415	0.059273
0.140919009	2.1403	0.076640
0.171889084	2.2270	0.093205
0.201764827	2.3081	0.109511
0.232237335	2.3898	0.126576

Sample: Powder 391610790358 F4 L
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200800_005-50_Run1.SMP

Started:	2/22/2012 12:01:48 PM	Analysis Adsorptive:	N2
Completed:	2/22/2012 10:42:10 PM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:37:23 PM	Thermal Correction:	No
Sample Mass:	2.3131 g	Warm Free Space:	7.1469 cm³ Measured
Cold Free Space:	19.9883 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BET Surface Area Plot



Sample: Powder 391610790358 F4 L
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200800_005-50_Run1.SMP

Started:	2/22/2012 12:01:48 PM	Analysis Adsorptive:	N2
Completed:	2/22/2012 10:42:10 PM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:37:23 PM	Thermal Correction:	No
Sample Mass:	2.3131 g	Warm Free Space:	7.1469 cm³ Measured
Cold Free Space:	19.9883 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot Report

Micropore Volume:	0.000752 cm³/g
Micropore Area:	1.6931 m²/g
External Surface Area:	6.4273 m²/g
Slope:	0.415523 ± 0.001515 cm³/g·Å STP
Y-Intercept:	0.485884 ± 0.010308 cm³/g STP
Correlation Coefficient:	0.999821
Surface Area Correction Factor:	1.000
Density Conversion Factor:	0.0015468
Total Surface Area (BET):	8.1204 m²/g
Thickness Range:	3.0087 Å to 11.8581 Å
Thickness Equation:	Harkins and Jura

Thickness Curve

t = [13.99 / (0.034 - log(p/p°))] ^ 0.5

t-Plot Report - Data

Relative Pressure (p/p°)	Statistical Thickness (Å)	Quantity Adsorbed (cm³/g STP)	Fitted
0.002567616	2.3088	1.0824	
0.005203209	2.4568	1.2644	
0.007465614	2.5444	1.3606	
0.010161205	2.6271	1.4393	
0.020072639	2.8426	1.5969	
0.030268920	3.0014	1.6923	
0.041319097	3.1412	1.7681	*
0.049140095	3.2281	1.8125	*
0.078377590	3.5034	1.9401	*
0.107942540	3.7388	2.0415	*
0.140919009	3.9758	2.1403	*
0.171889084	4.1851	2.2270	*
0.201764827	4.3803	2.3081	*
0.232237335	4.5761	2.3898	*
0.262559042	4.7704	2.4716	*
0.293757383	4.9716	2.5571	*
0.323336284	5.1654	2.6402	*
0.354334787	5.3731	2.7298	*
0.380477402	5.5531	2.8072	*
0.409917244	5.7625	2.8961	*
0.441263006	5.9947	2.9934	*
0.469362012	6.2124	3.0837	*
0.499133545	6.4547	3.1813	*

Sample: Powder 391610790358 F4 L
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200800_005-50_Run1.SMP

Started:	2/22/2012 12:01:48 PM	Analysis Adsorptive:	N2
Completed:	2/22/2012 10:42:10 PM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:37:23 PM	Thermal Correction:	No
Sample Mass:	2.3131 g	Warm Free Space:	7.1469 cm³ Measured
Cold Free Space:	19.9883 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot Report - Data

Relative Pressure (p/p°)	Statistical Thickness (Å)	Quantity Adsorbed (cm³/g STP)	Fitted
0.528603455	6.7084	3.2827	*
0.558711578	6.9841	3.3909	*
0.590303195	7.2945	3.5127	*
0.618469159	7.5926	3.6292	*
0.648164688	7.9328	3.7628	*
0.678076722	8.3073	3.9107	*
0.707458413	8.7126	4.0753	*
0.737209668	9.1690	4.2638	*
0.766943823	9.6821	4.4818	*
0.800618125	10.3509	4.7805	*
0.818510614	10.7537	4.9707	*
0.837511959	11.2261	5.2048	*
0.860748640	11.8801	5.5468	
0.877083982	12.4018	5.8456	
0.888480602	12.8027	6.0866	
0.898010208	13.1650	6.3229	
0.907739900	13.5641	6.6000	
0.917682626	14.0069	6.9182	
0.927494687	14.4838	7.2965	
0.937348977	15.0095	7.7561	
0.947084072	15.5831	8.3145	
0.953603845	16.0024	8.7614	
0.958800458	16.3597	9.1557	
0.963571061	16.7078	9.5983	
0.968415069	17.0831	10.1075	
0.977459487	17.8513	11.3534	
0.983197878	18.3918	12.4301	
0.987101811	18.7868	13.3747	
0.988916198	18.9787	13.9597	
0.990890161	19.1939	14.5013	
0.992173616	19.3376	15.0159	

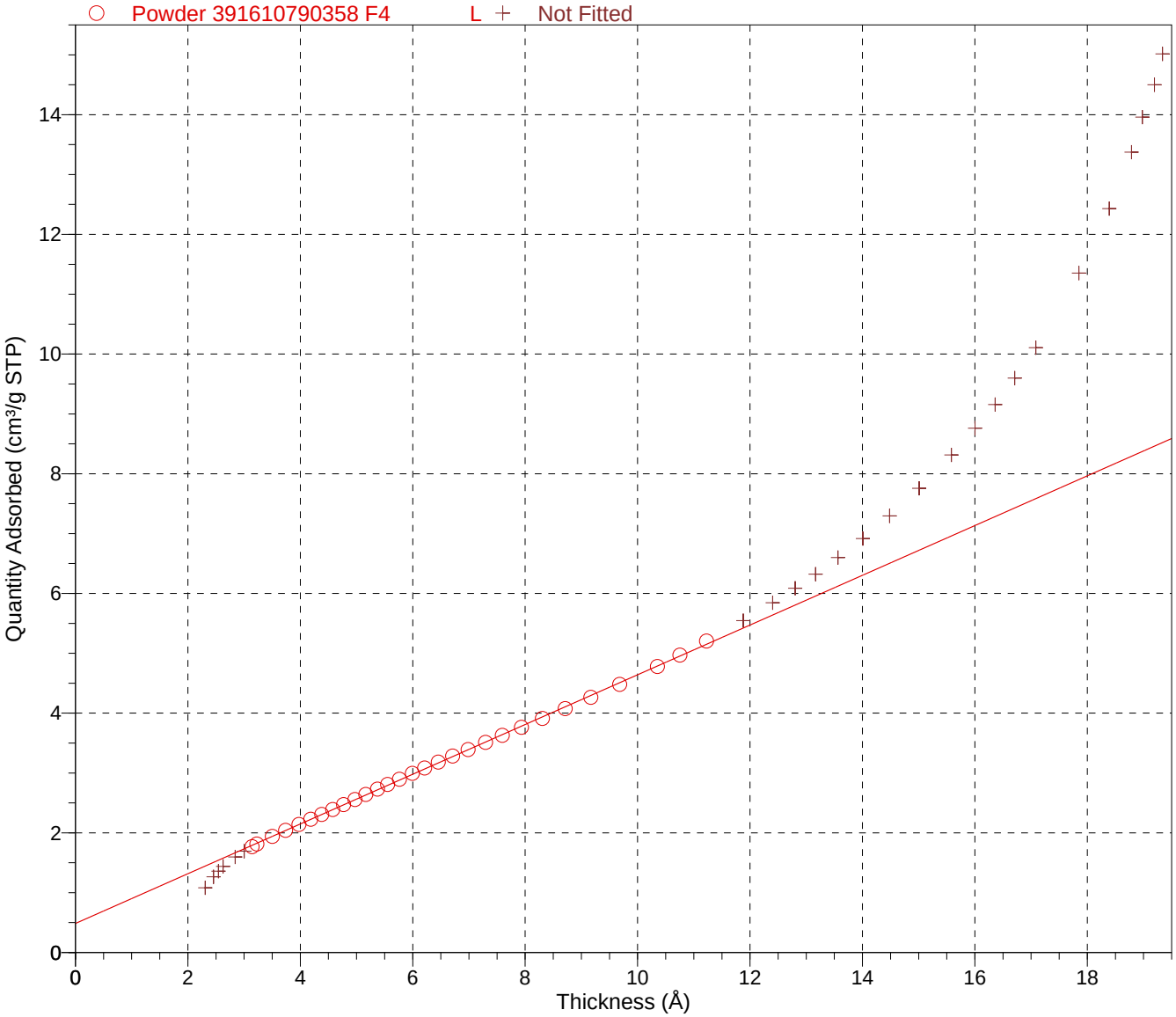
Sample: Powder 391610790358 F4 L
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200800_005-50_Run1.SMP

Started:	2/22/2012 12:01:48 PM	Analysis Adsorptive:	N2
Completed:	2/22/2012 10:42:10 PM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:37:23 PM	Thermal Correction:	No
Sample Mass:	2.3131 g	Warm Free Space:	7.1469 cm³ Measured
Cold Free Space:	19.9883 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot

Harkins and Jura



Sample: Powder 391610790358 F4 L
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200800_005-50_Run1.SMP

Started:	2/22/2012 12:01:48 PM	Analysis Adsorptive:	N2
Completed:	2/22/2012 10:42:10 PM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:37:23 PM	Thermal Correction:	No
Sample Mass:	2.3131 g	Warm Free Space:	7.1469 cm³ Measured
Cold Free Space:	19.9883 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Pore Distribution Report

Standard
Halsey
t = 3.54 [-5 / ln(p/p°)] ^ 0.333

Width Range: 17.000 Å to 3,000.000 Å
Adsorbate Property Factor: 9.53000 Å
Density Conversion Factor: 0.0015468
Fraction of Pores Open at Both Ends: 0.00

Pore Width Range (Å)	Average Width (Å)	Incremental Pore Volume (cm³/g)	Cumulative Pore Volume (cm³/g)	Incremental Pore Area (m²/g)	Cumulative Pore Area (m²/g)
2486.6 - 2140.5	2287.4	0.000839	0.000839	0.015	0.015
2140.5 - 1764.2	1915.8	0.000886	0.001724	0.018	0.033
1764.2 - 1519.6	1623.4	0.000962	0.002686	0.024	0.057
1519.6 - 1171.9	1300.6	0.001564	0.004250	0.048	0.105
1171.9 - 878.6	983.1	0.001802	0.006052	0.073	0.178
878.6 - 631.9	714.8	0.002116	0.008168	0.118	0.297
631.9 - 549.9	585.0	0.000869	0.009037	0.059	0.356
549.9 - 487.8	515.0	0.000760	0.009797	0.059	0.415
487.8 - 434.6	458.0	0.000680	0.010477	0.059	0.474
434.6 - 382.5	405.1	0.000778	0.011255	0.077	0.551
382.5 - 324.7	348.6	0.000983	0.012238	0.113	0.664
324.7 - 281.9	300.1	0.000816	0.013053	0.109	0.773
281.9 - 249.3	263.4	0.000676	0.013729	0.103	0.875
249.3 - 223.2	234.7	0.000571	0.014301	0.097	0.973
223.2 - 202.6	211.8	0.000502	0.014803	0.095	1.068
202.6 - 185.8	193.4	0.000430	0.015233	0.089	1.157
185.8 - 169.1	176.6	0.000440	0.015673	0.100	1.256
169.1 - 149.9	158.2	0.000552	0.016225	0.139	1.396
149.9 - 129.0	137.7	0.000637	0.016861	0.185	1.581
129.0 - 115.8	121.6	0.000439	0.017300	0.144	1.725
115.8 - 105.7	110.2	0.000358	0.017658	0.130	1.855
105.7 - 90.7	96.9	0.000570	0.018228	0.235	2.090
90.7 - 80.5	84.9	0.000418	0.018646	0.197	2.287
80.5 - 72.3	75.9	0.000365	0.019011	0.192	2.479
72.3 - 65.6	68.6	0.000321	0.019332	0.187	2.667
65.6 - 59.9	62.5	0.000289	0.019621	0.185	2.851
59.9 - 55.1	57.3	0.000264	0.019885	0.184	3.036
55.1 - 51.1	52.9	0.000232	0.020116	0.175	3.211
51.1 - 47.2	49.0	0.000246	0.020362	0.201	3.411
47.2 - 44.0	45.4	0.000220	0.020582	0.193	3.605
44.0 - 41.1	42.4	0.000210	0.020791	0.198	3.803

Sample: Powder 391610790358 F4 L
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200800_005-50_Run1.SMP

Started:	2/22/2012 12:01:48 PM	Analysis Adsorptive:	N2
Completed:	2/22/2012 10:42:10 PM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:37:23 PM	Thermal Correction:	No
Sample Mass:	2.3131 g	Warm Free Space:	7.1469 cm³ Measured
Cold Free Space:	19.9883 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Pore Width Range (Å)	Average Width (Å)	Incremental Pore Volume (cm³/g)	Cumulative Pore Volume (cm³/g)	Incremental Pore Area (m²/g)	Cumulative Pore Area (m²/g)
41.1 - 38.5	39.7	0.000204	0.020995	0.206	4.008
38.5 - 36.2	37.3	0.000194	0.021189	0.208	4.216
36.2 - 33.9	35.0	0.000211	0.021400	0.241	4.457
33.9 - 32.0	32.9	0.000195	0.021595	0.237	4.695
32.0 - 30.3	31.1	0.000171	0.021766	0.220	4.915
30.3 - 28.5	29.3	0.000199	0.021965	0.271	5.186
28.5 - 26.9	27.6	0.000182	0.022147	0.264	5.450
26.9 - 25.2	26.0	0.000184	0.022332	0.284	5.734
25.2 - 23.7	24.4	0.000172	0.022504	0.282	6.016
23.7 - 22.3	22.9	0.000166	0.022670	0.290	6.305
22.3 - 20.8	21.5	0.000160	0.022830	0.298	6.603
20.8 - 19.4	20.0	0.000164	0.022994	0.328	6.931
19.4 - 17.8	18.5	0.000181	0.023175	0.391	7.321

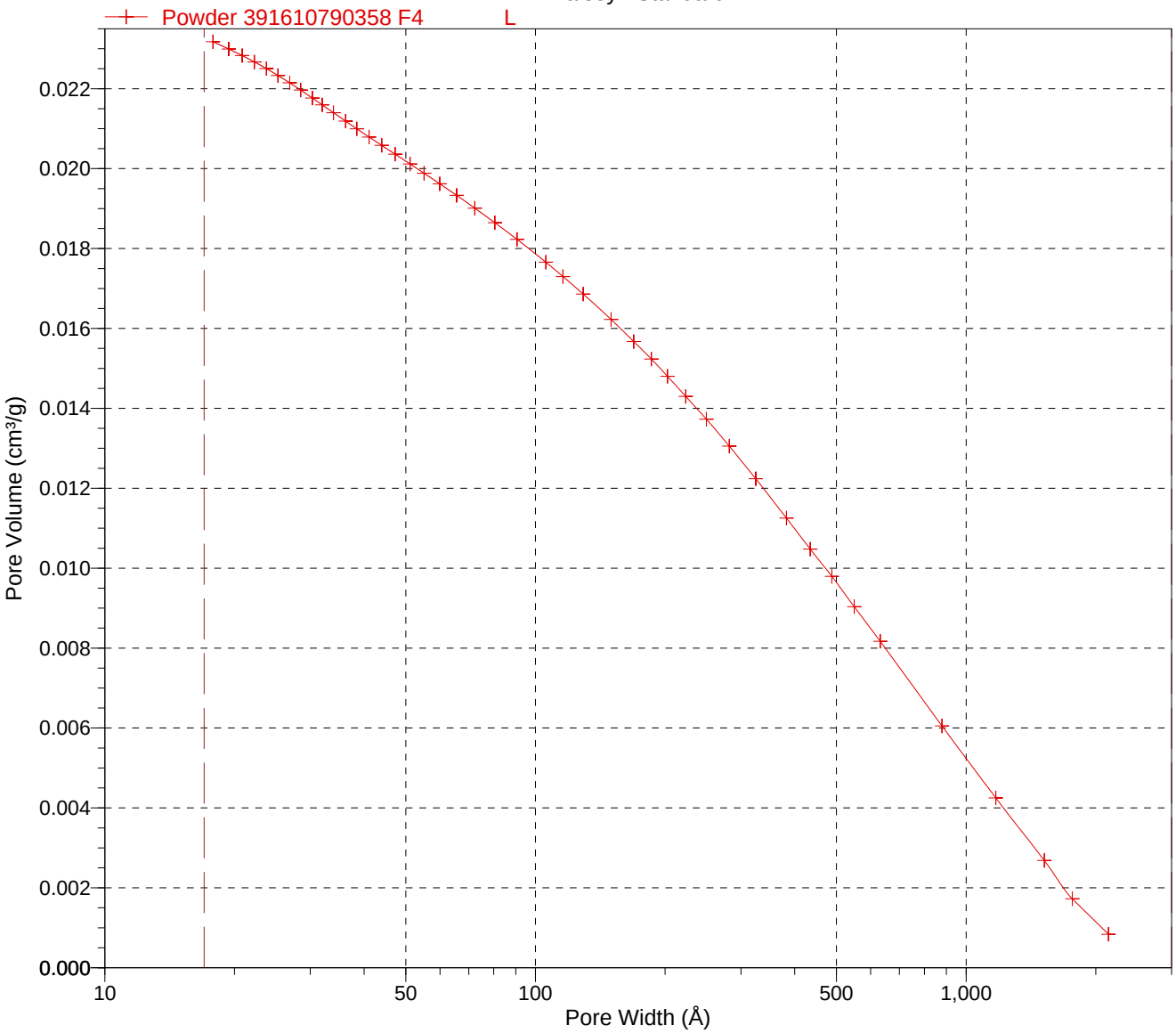
Sample: Powder 391610790358 F4 L
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200800_005-50_Run1.SMP

Started:	2/22/2012 12:01:48 PM	Analysis Adsorptive:	N2
Completed:	2/22/2012 10:42:10 PM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:37:23 PM	Thermal Correction:	No
Sample Mass:	2.3131 g	Warm Free Space:	7.1469 cm³ Measured
Cold Free Space:	19.9883 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Cumulative Pore Volume (Larger)

Halsey : Standard



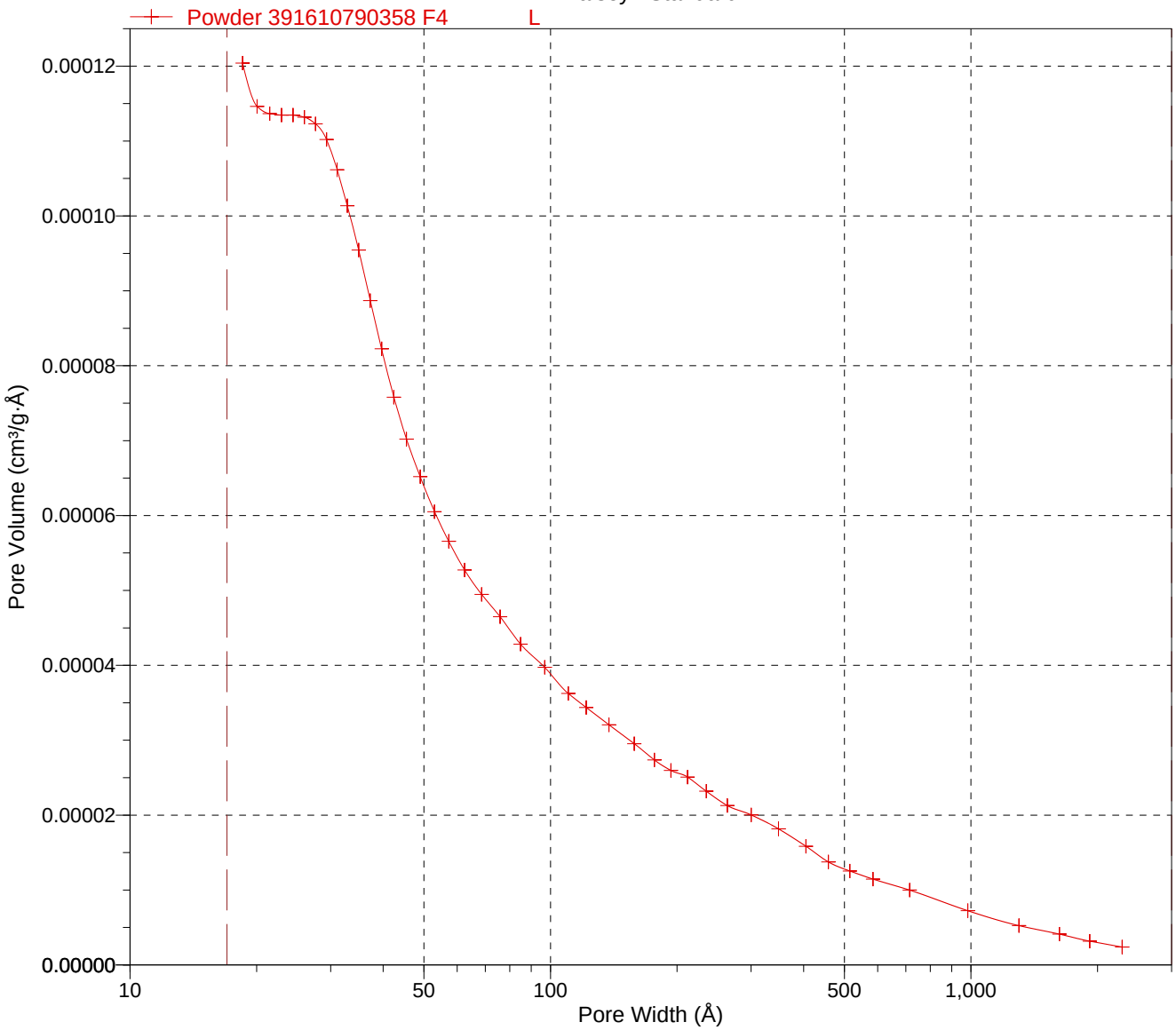
Sample: Powder 391610790358 F4 L
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200800_005-50_Run1.SMP

Started:	2/22/2012 12:01:48 PM	Analysis Adsorptive:	N2
Completed:	2/22/2012 10:42:10 PM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:37:23 PM	Thermal Correction:	No
Sample Mass:	2.3131 g	Warm Free Space:	7.1469 cm³ Measured
Cold Free Space:	19.9883 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dV/dw Pore Volume

Halsey : Standard



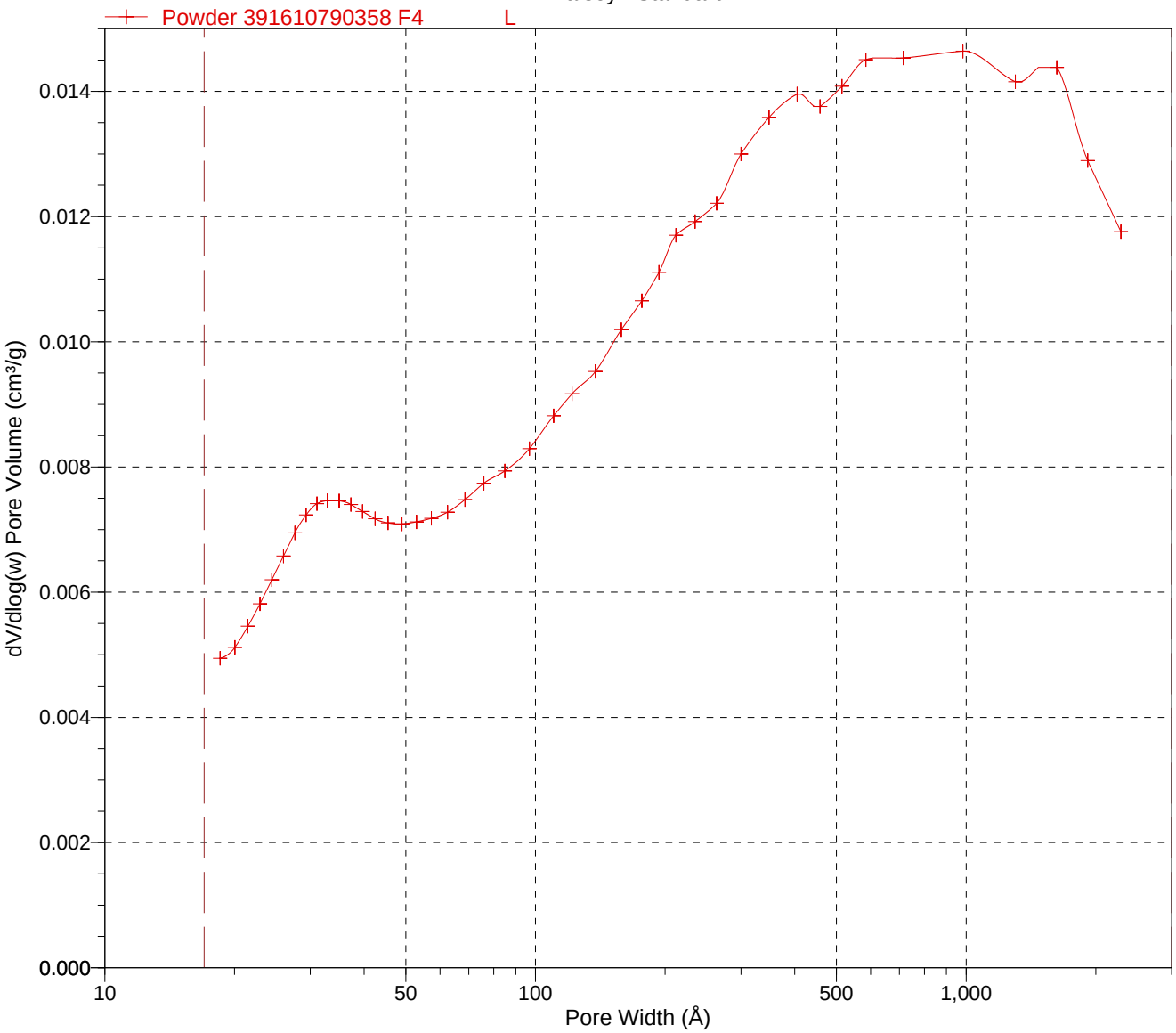
Sample: Powder 391610790358 F4 L
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200800_005-50_Run1.SMP

Started:	2/22/2012 12:01:48 PM	Analysis Adsorptive:	N2
Completed:	2/22/2012 10:42:10 PM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:37:23 PM	Thermal Correction:	No
Sample Mass:	2.3131 g	Warm Free Space:	7.1469 cm³ Measured
Cold Free Space:	19.9883 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dV/dlog(w) Pore Volume

Halsey : Standard



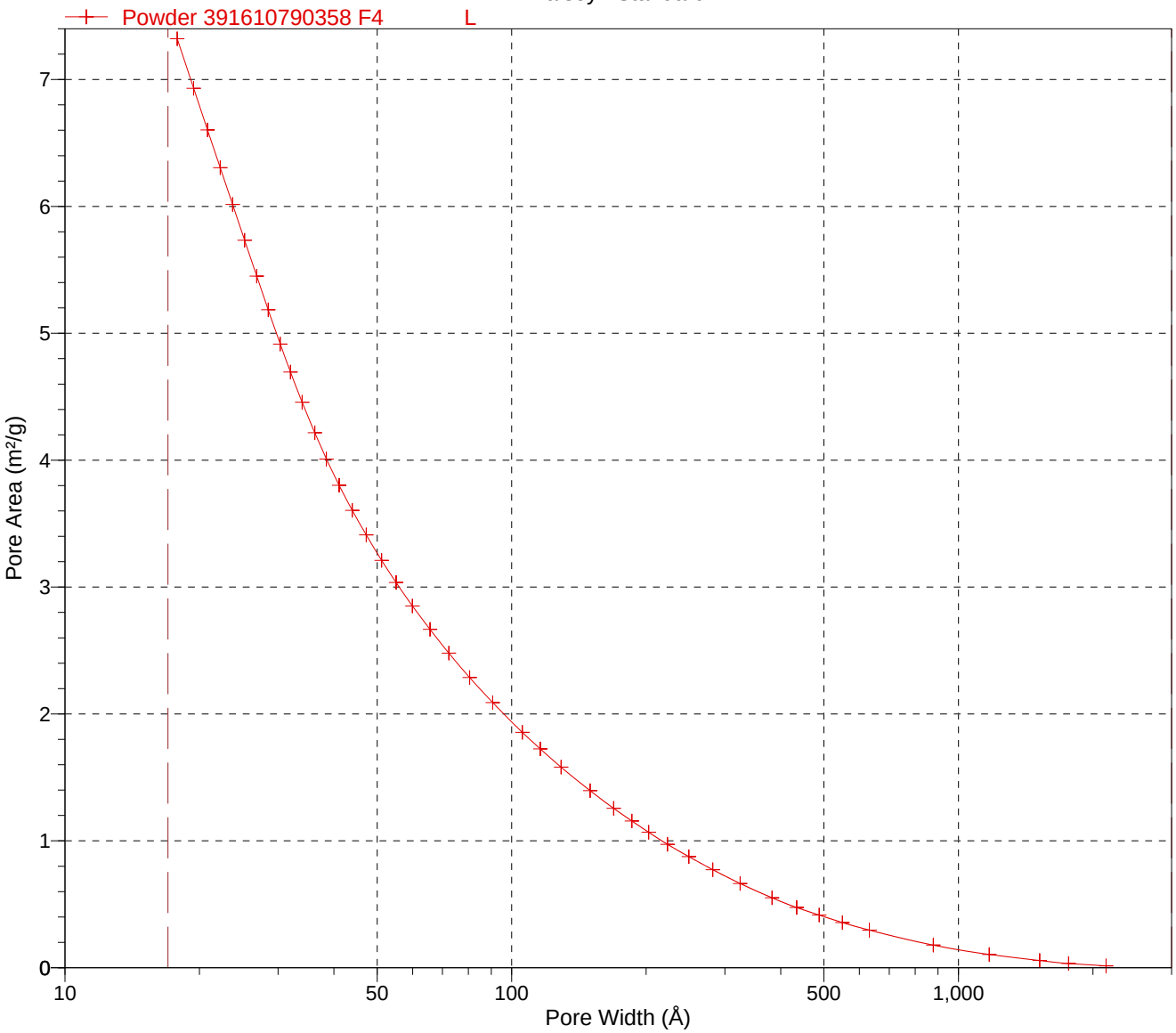
Sample: Powder 391610790358 F4 L
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200800_005-50_Run1.SMP

Started:	2/22/2012 12:01:48 PM	Analysis Adsorptive:	N2
Completed:	2/22/2012 10:42:10 PM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:37:23 PM	Thermal Correction:	No
Sample Mass:	2.3131 g	Warm Free Space:	7.1469 cm³ Measured
Cold Free Space:	19.9883 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Cumulative Pore Area (Larger)

Halsey : Standard



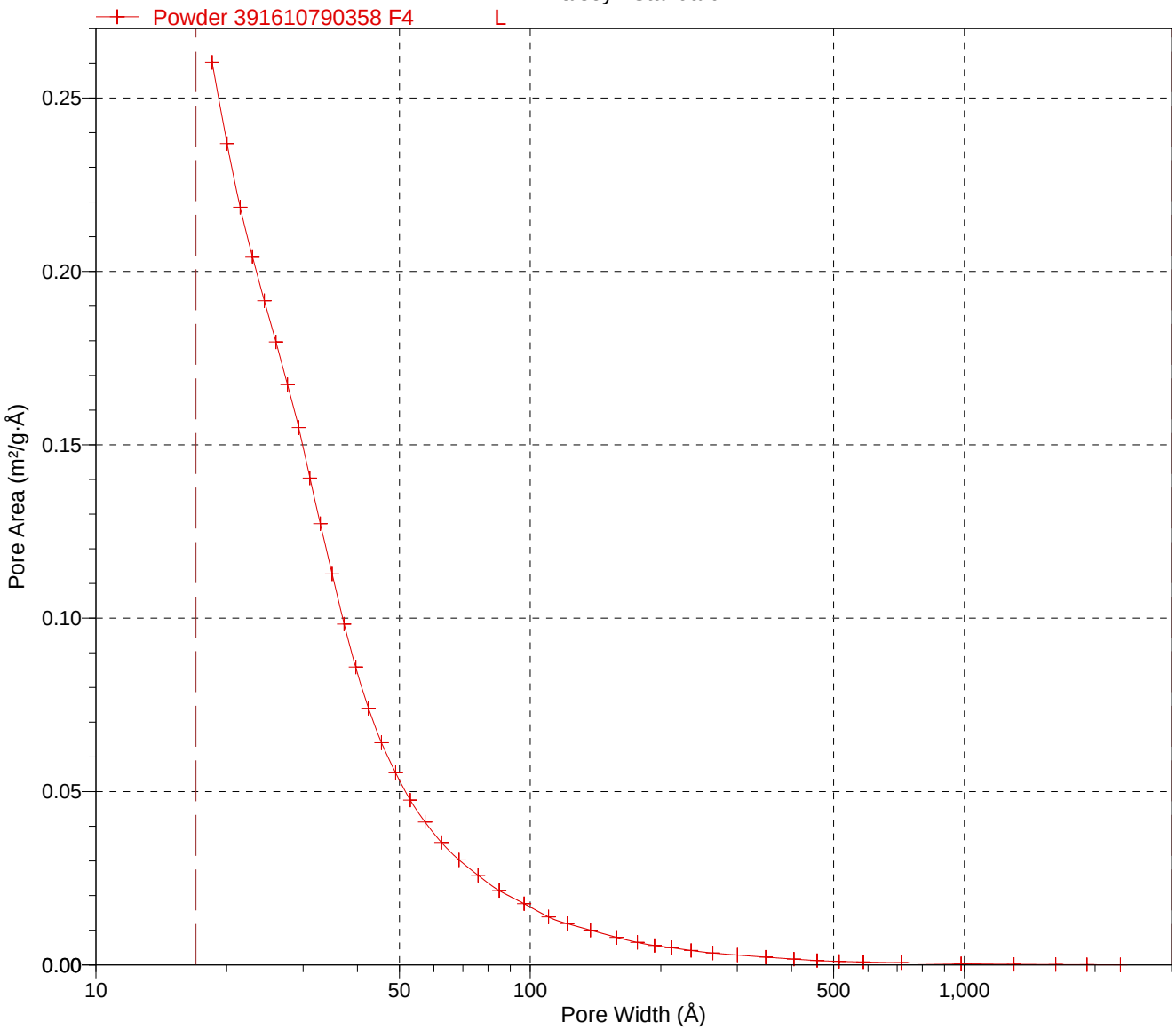
Sample: Powder 391610790358 F4 L
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200800_005-50_Run1.SMP

Started:	2/22/2012 12:01:48 PM	Analysis Adsorptive:	N2
Completed:	2/22/2012 10:42:10 PM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:37:23 PM	Thermal Correction:	No
Sample Mass:	2.3131 g	Warm Free Space:	7.1469 cm³ Measured
Cold Free Space:	19.9883 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dA/dw Pore Area

Halsey : Standard



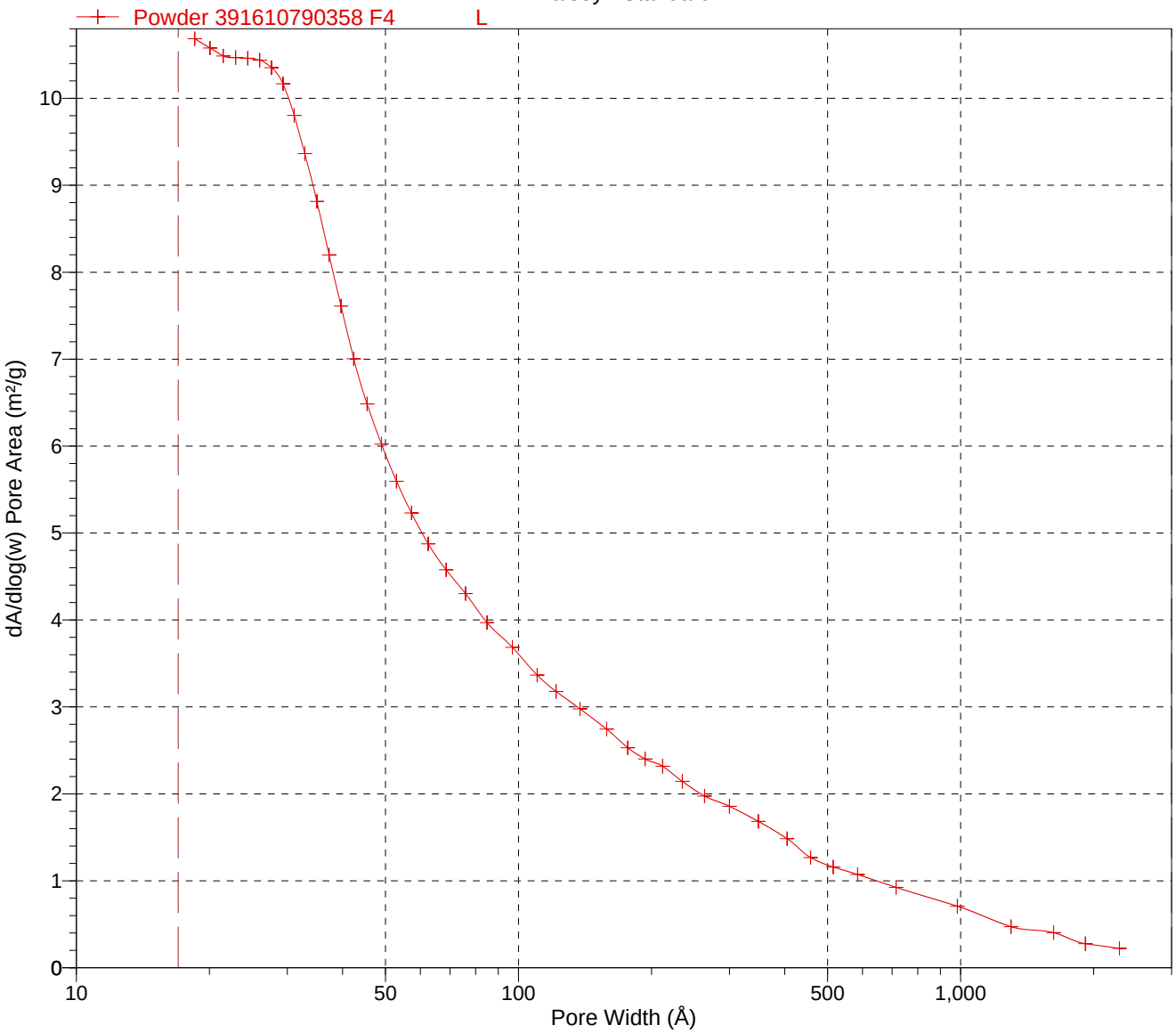
Sample: Powder 391610790358 F4 L
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200800_005-50_Run1.SMP

Started:	2/22/2012 12:01:48 PM	Analysis Adsorptive:	N2
Completed:	2/22/2012 10:42:10 PM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:37:23 PM	Thermal Correction:	No
Sample Mass:	2.3131 g	Warm Free Space:	7.1469 cm³ Measured
Cold Free Space:	19.9883 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dA/dlog(w) Pore Area

Halsey : Standard



Sample: Powder 392005785407 F1 D3
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200796_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:42:42 AM	Thermal Correction:	No
Sample Mass:	1.8213 g	Warm Free Space:	7.8819 cm³ Measured
Cold Free Space:	22.7997 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Summary Report

Surface Area

Single point surface area at p/p° = 0.292566825:	16.3000 m²/g
BET Surface Area:	16.5787 m²/g
t-Plot Micropore Area:	4.2891 m²/g
t-Plot External Surface Area:	12.2897 m²/g
BJH Adsorption cumulative surface area of pores between 17.000 Å and 3,000.000 Å width:	16.746 m²/g

Pore Volume

Single point adsorption total pore volume of pores less than 2,330.527 Å width at p/p° = 0.991642633:	0.043092 cm³/g
t-Plot micropore volume:	0.002182 cm³/g
BJH Adsorption cumulative volume of pores between 17.000 Å and 3,000.000 Å width:	0.043722 cm³/g

Pore Size

Adsorption average pore width (4V/A by BET):	103.9698 Å
BJH Adsorption average pore width (4V/A):	104.436 Å

Sample: Powder 392005785407 F1 D3
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200796_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:42:42 AM	Thermal Correction:	No
Sample Mass:	1.8213 g	Warm Free Space:	7.8819 cm³ Measured
Cold Free Space:	22.7997 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Tabular Report

Relative Pressure (p/p°)	Absolute Pressure (mmHg)	Quantity Adsorbed (cm³/g STP)	Elapsed Time (h:min)	Saturation Pressure (mmHg)
			01:11	740.482788
0.002479459	1.830503	2.3526	02:32	738.267029
0.005113809	3.773836	2.7061	02:53	737.969727
0.007548044	5.568312	2.8853	03:10	737.715881
0.009803201	7.228014	2.9946	03:28	737.311584
0.020275370	14.946322	3.2742	03:43	737.166443
0.029707483	21.893652	3.4304	03:56	736.974304
0.040906631	30.148109	3.5724	04:05	736.998108
0.049336114	36.356064	3.6644	04:14	736.905701
0.078652005	57.939232	3.9168	04:23	736.652954
0.107907963	79.497009	4.1284	04:31	736.711243
0.140761316	103.686569	4.3473	04:38	736.612671
0.171256873	126.115395	4.5390	04:45	736.410706
0.201409557	148.297424	4.7266	04:52	736.297852
0.232768547	171.355896	4.9221	04:58	736.164307
0.261959890	192.864883	5.1035	05:04	736.238220
0.292566825	215.387039	5.2929	05:09	736.197754
0.324750139	239.043396	5.4914	05:15	736.084045
0.355234740	261.445679	5.6746	05:21	735.980042
0.380255942	279.704193	5.8255	05:26	735.568237
0.411417044	302.537170	6.0132	05:32	735.354004
0.441197365	324.392517	6.1927	05:37	735.254883
0.470980165	346.124542	6.3767	05:43	734.902588
0.500961545	368.201599	6.5669	05:49	734.989746
0.530797754	390.101166	6.7617	05:55	734.933716
0.560426269	411.855774	6.9680	06:00	734.897339
0.588365612	432.326843	7.1760	06:06	734.792847
0.619889699	455.383179	7.4302	06:12	734.619690
0.649453968	477.065918	7.6933	06:19	734.564636
0.679248326	498.809723	7.9870	06:25	734.355469
0.707945562	519.934509	8.3092	06:32	734.427246
0.738005953	541.808350	8.6900	06:39	734.151733
0.767456333	563.476379	9.1249	06:47	734.212952
0.796652130	585.012817	9.6337	06:55	734.339111
0.817915980	600.465698	10.0632	07:03	734.141052
0.837794270	614.878967	10.5333	07:11	733.925964
0.857295183	629.304688	11.0783	07:19	734.058350
0.879581294	645.533752	11.8678	07:32	733.910278
0.889897827	653.070618	12.3064	07:41	733.871460

Sample: Powder 392005785407 F1 D3
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200796_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:42:42 AM	Thermal Correction:	No
Sample Mass:	1.8213 g	Warm Free Space:	7.8819 cm³ Measured
Cold Free Space:	22.7997 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Tabular Report

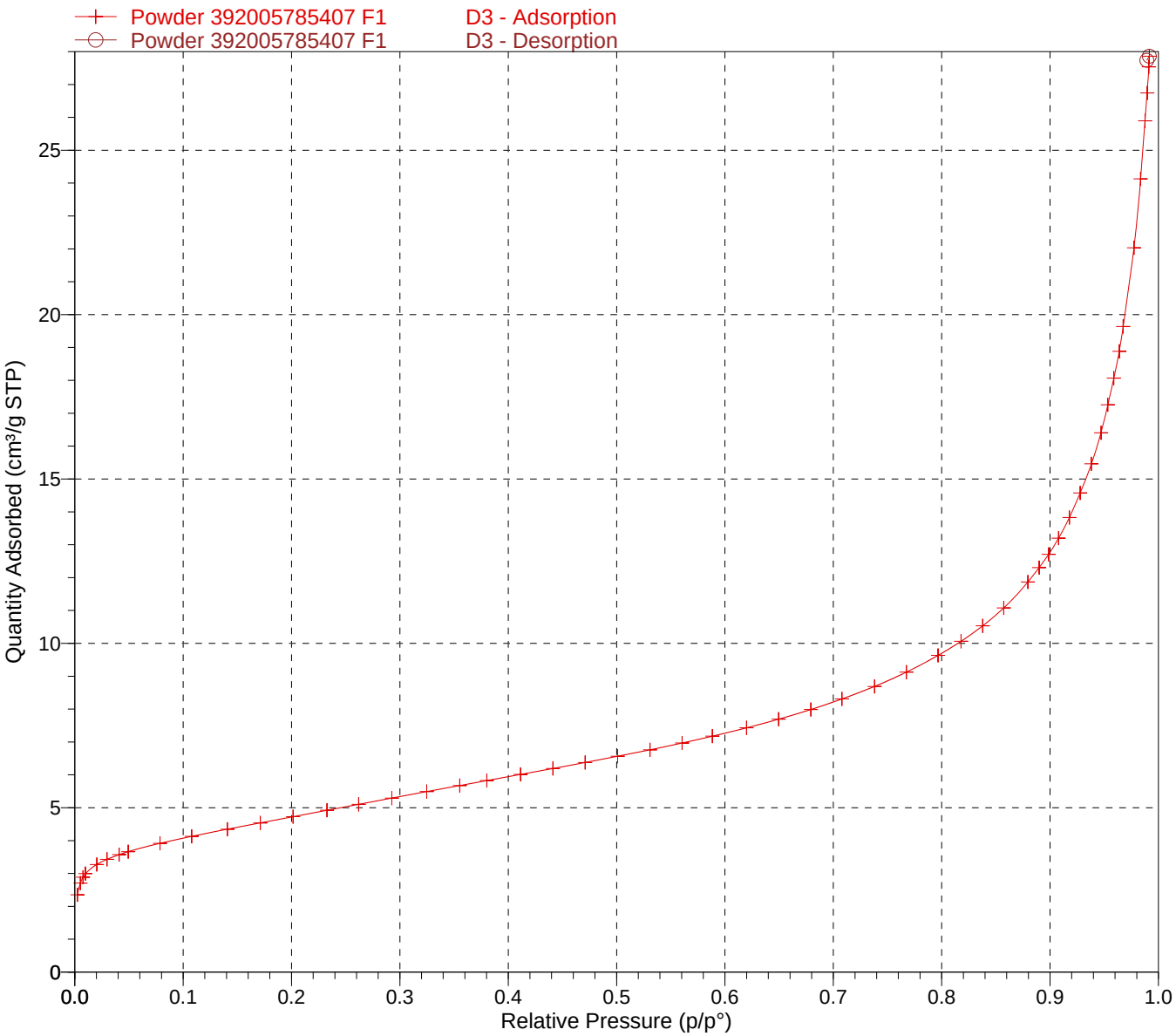
Relative Pressure (p/p°)	Absolute Pressure (mmHg)	Quantity Adsorbed (cm³/g STP)	Elapsed Time (h:min)	Saturation Pressure (mmHg)
0.898716524	659.504395	12.7095	07:48	733.829163
0.907776911	665.927002	13.1979	07:57	733.580017
0.917856144	673.130005	13.8299	08:06	733.372009
0.927761996	680.299377	14.5764	08:17	733.269287
0.938128572	687.830383	15.4613	08:27	733.194153
0.947100945	694.227478	16.4046	08:37	733.002625
0.953333899	699.127625	17.2573	08:47	733.350220
0.958820694	703.067505	18.0673	08:58	733.262756
0.964012022	706.950073	18.8831	09:07	733.341553
0.967478062	709.469543	19.6393	09:17	733.318481
0.977484398	716.693481	22.0311	09:38	733.201965
0.983584995	720.973145	24.1292	10:04	733.005432
0.987646446	723.726929	25.8930	10:25	732.779358
0.989661943	724.758423	26.7454	10:36	732.329285
0.991175980	725.648804	27.5391	10:45	732.108948
0.991642633	726.153015	27.8589	10:50	732.272888
0.989379472	724.669678	27.7380	10:54	732.448669

Sample: Powder 392005785407 F1 D3
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200796_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:42:42 AM	Thermal Correction:	No
Sample Mass:	1.8213 g	Warm Free Space:	7.8819 cm³ Measured
Cold Free Space:	22.7997 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Linear Plot



Sample: Powder 392005785407 F1 D3
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200796_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:42:42 AM	Thermal Correction:	No
Sample Mass:	1.8213 g	Warm Free Space:	7.8819 cm³ Measured
Cold Free Space:	22.7997 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BET Surface Area Report

BET Surface Area:	16.5787 ± 0.0885 m²/g
Slope:	0.261550 ± 0.001378 g/cm³ STP
Y-Intercept:	0.001027 ± 0.000259 g/cm³ STP
C:	255.660821
Qm:	3.8084 cm³/g STP
Correlation Coefficient:	0.9999029
Molecular Cross-Sectional Area:	0.1620 nm²

Relative Pressure (p/p°)	Quantity Adsorbed (cm³/g STP)	1/[Q(p°/p - 1)]
0.049336114	3.6644	0.014162
0.078652005	3.9168	0.021795
0.107907963	4.1284	0.029300
0.140761316	4.3473	0.037683
0.171256873	4.5390	0.045526
0.201409557	4.7266	0.053359
0.232768547	4.9221	0.061637
0.261959890	5.1035	0.069549
0.292566825	5.2929	0.078135

Sample: Powder 392005785407 F1 D3
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200796_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
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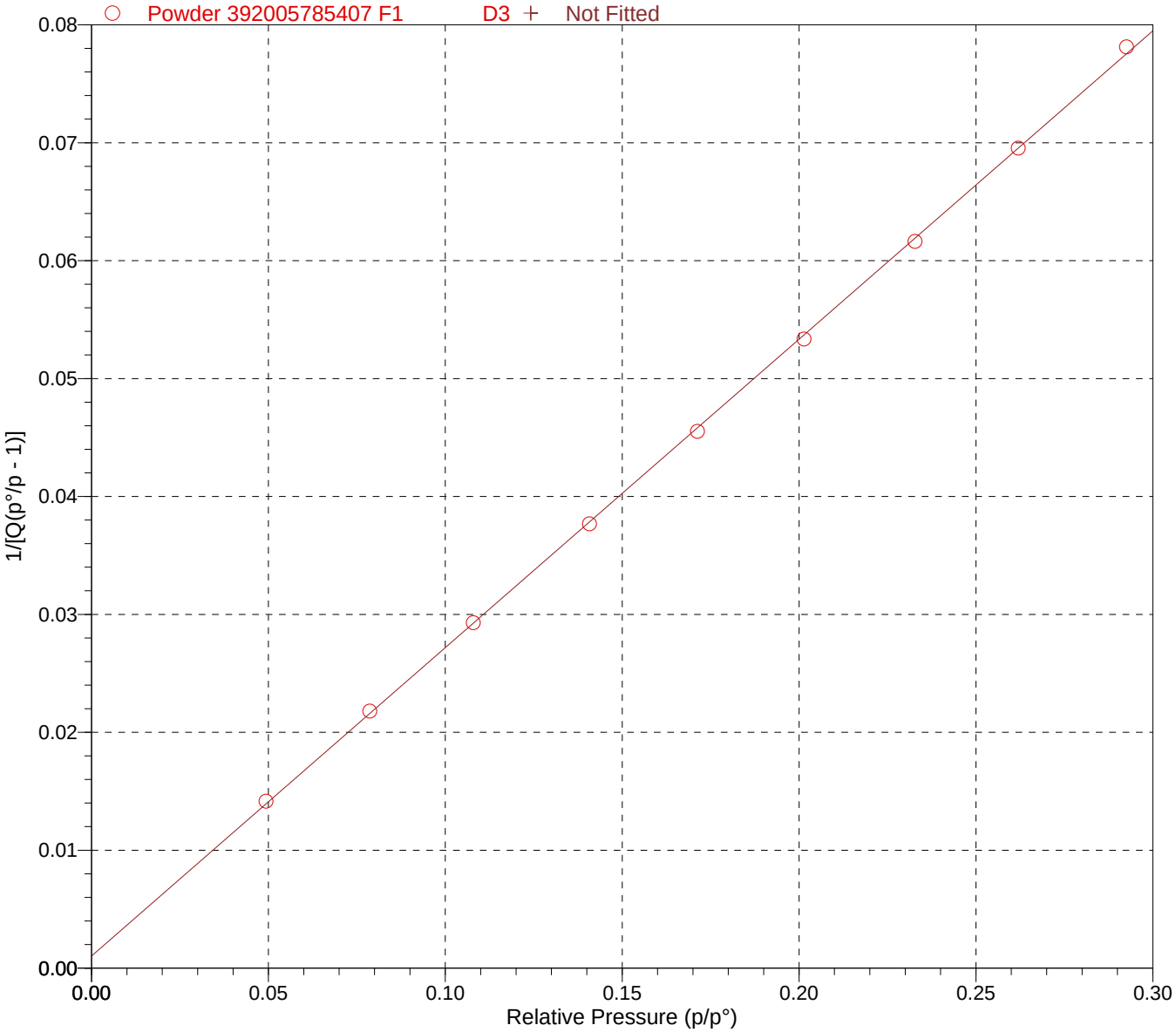
Sample Mass:	1.8213 g	Warm Free Space:	7.8819 cm³ Measured
Cold Free Space:	22.7997 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BET Surface Area Plot



Sample: Powder 392005785407 F1 D3
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200796_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:42:42 AM	Thermal Correction:	No
Sample Mass:	1.8213 g	Warm Free Space:	7.8819 cm³ Measured
Cold Free Space:	22.7997 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot Report

Micropore Volume:	0.002182 cm³/g
Micropore Area:	4.2891 m²/g
External Surface Area:	12.2897 m²/g
Slope:	0.794522 ± 0.005097 cm³/g·Å STP
Y-Intercept:	1.410772 ± 0.038995 cm³/g STP
Correlation Coefficient:	0.999733
Surface Area Correction Factor:	1.000
Density Conversion Factor:	0.0015468
Total Surface Area (BET):	16.5787 m²/g
Thickness Range:	5.5235 Å to 10.6022 Å
Thickness Equation:	Harkins and Jura

Thickness Curve

t = [13.99 / (0.034 - log(p/p°))] ^ 0.5

t-Plot Report - Data

Relative Pressure (p/p°)	Statistical Thickness (Å)	Quantity Adsorbed (cm³/g STP)	Fitted
0.002479459	2.3022	2.3526	
0.005113809	2.4529	2.7061	
0.007548044	2.5472	2.8853	
0.009803201	2.6171	2.9946	
0.020275370	2.8462	3.2742	
0.029707483	2.9936	3.4304	
0.040906631	3.1364	3.5724	
0.049336114	3.2301	3.6644	
0.078652005	3.5058	3.9168	
0.107907963	3.7386	4.1284	
0.140761316	3.9748	4.3473	
0.171256873	4.1809	4.5390	
0.201409557	4.3780	4.7266	
0.232768547	4.5795	4.9221	
0.261959890	4.7665	5.1035	
0.292566825	4.9639	5.2929	
0.324750139	5.1747	5.4914	
0.355234740	5.3792	5.6746	
0.380255942	5.5516	5.8255	*
0.411417044	5.7734	6.0132	*
0.441197365	5.9942	6.1927	*
0.470980165	6.2253	6.3767	*
0.500961545	6.4701	6.5669	*

Sample: Powder 392005785407 F1 D3
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200796_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:42:42 AM	Thermal Correction:	No
Sample Mass:	1.8213 g	Warm Free Space:	7.8819 cm³ Measured
Cold Free Space:	22.7997 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot Report - Data

Relative Pressure (p/p°)	Statistical Thickness (Å)	Quantity Adsorbed (cm³/g STP)	Fitted
0.530797754	6.7279	6.7617	*
0.560426269	7.0004	6.9680	*
0.588365612	7.2747	7.1760	*
0.619889699	7.6082	7.4302	*
0.649453968	7.9482	7.6933	*
0.679248326	8.3227	7.9870	*
0.707945562	8.7197	8.3092	*
0.738005953	9.1819	8.6900	*
0.767456333	9.6916	9.1249	*
0.796652130	10.2665	9.6337	*
0.817915980	10.7397	10.0632	
0.837794270	11.2335	10.5333	
0.857295183	11.7768	11.0783	
0.879581294	12.4869	11.8678	
0.889897827	12.8549	12.3064	
0.898716524	13.1930	12.7095	
0.907776911	13.5657	13.1979	
0.917856144	14.0149	13.8299	
0.927761996	14.4974	14.5764	
0.938128572	15.0534	15.4613	
0.947100945	15.5842	16.4046	
0.953333899	15.9844	17.2573	
0.958820694	16.3611	18.0673	
0.964012022	16.7410	18.8831	
0.967478062	17.0087	19.6393	
0.977484398	17.8536	22.0311	
0.983584995	18.4299	24.1292	
0.987646446	18.8438	25.8930	
0.989661943	19.0592	26.7454	
0.991175980	19.2256	27.5391	
0.991642633	19.2777	27.8589	

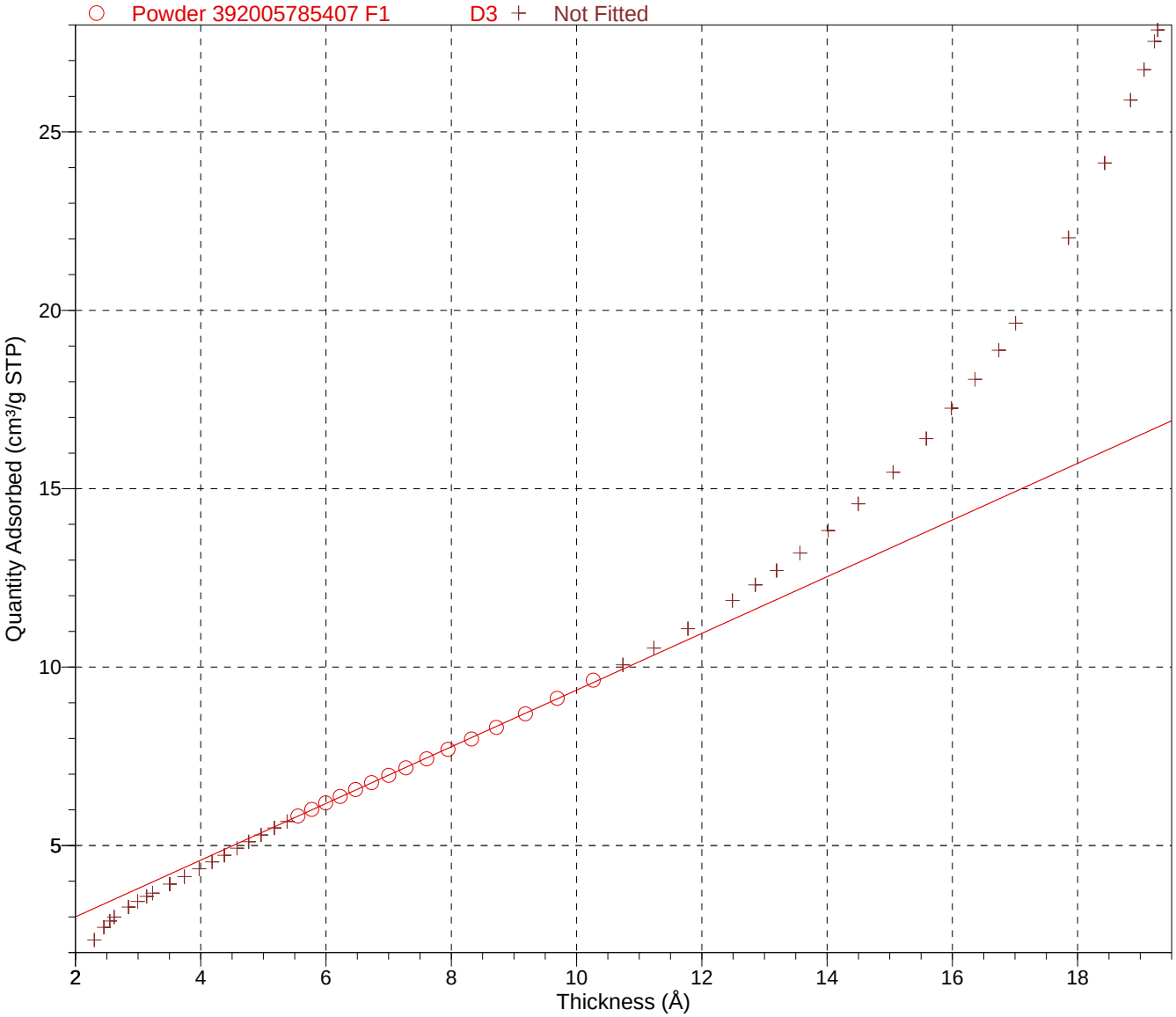
Sample: Powder 392005785407 F1 D3
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200796_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:42:42 AM	Thermal Correction:	No
Sample Mass:	1.8213 g	Warm Free Space:	7.8819 cm³ Measured
Cold Free Space:	22.7997 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot

Harkins and Jura



Sample: Powder 392005785407 F1 D3
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200796_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:42:42 AM	Thermal Correction:	No
Sample Mass:	1.8213 g	Warm Free Space:	7.8819 cm³ Measured
Cold Free Space:	22.7997 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Pore Distribution Report

Standard
Halsey
t = 3.54 [-5 / ln(p/p°)] ^ 0.333

Width Range: 17.000 Å to 3,000.000 Å
Adsorbate Property Factor: 9.53000 Å
Density Conversion Factor: 0.0015468
Fraction of Pores Open at Both Ends: 0.00

Pore Width Range (Å)	Average Width (Å)	Incremental Pore Volume (cm³/g)	Cumulative Pore Volume (cm³/g)	Incremental Pore Area (m²/g)	Cumulative Pore Area (m²/g)
2330.5 - 2208.8	2266.4	0.000521	0.000521	0.009	0.009
2208.8 - 1889.5	2024.0	0.001298	0.001819	0.026	0.035
1889.5 - 1585.5	1710.6	0.001399	0.003219	0.033	0.068
1585.5 - 1199.0	1338.5	0.002924	0.006142	0.087	0.155
1199.0 - 879.6	990.1	0.003518	0.009660	0.142	0.297
879.6 - 614.1	699.7	0.004074	0.013734	0.233	0.530
614.1 - 556.4	582.3	0.001297	0.015031	0.089	0.619
556.4 - 488.0	517.6	0.001399	0.016430	0.108	0.727
488.0 - 432.1	456.5	0.001404	0.017834	0.123	0.850
432.1 - 382.6	404.2	0.001493	0.019327	0.148	0.998
382.6 - 328.7	351.3	0.001659	0.020986	0.189	1.187
328.7 - 282.9	302.1	0.001571	0.022557	0.208	1.395
282.9 - 249.8	264.1	0.001342	0.023898	0.203	1.598
249.8 - 223.3	235.0	0.001142	0.025040	0.194	1.792
223.3 - 204.0	212.7	0.000887	0.025927	0.167	1.959
204.0 - 188.1	195.4	0.000732	0.026659	0.150	2.109
188.1 - 172.5	179.6	0.000806	0.027465	0.180	2.288
172.5 - 146.3	157.1	0.001474	0.028939	0.375	2.664
146.3 - 129.2	136.6	0.001019	0.029958	0.298	2.962
129.2 - 115.5	121.5	0.000886	0.030844	0.292	3.254
115.5 - 103.7	108.8	0.000815	0.031659	0.300	3.553
103.7 - 90.9	96.3	0.000983	0.032642	0.408	3.962
90.9 - 80.7	85.1	0.000848	0.033490	0.399	4.360
80.7 - 72.4	76.1	0.000747	0.034238	0.393	4.753
72.4 - 65.9	68.8	0.000638	0.034876	0.371	5.125
65.9 - 60.2	62.7	0.000582	0.035458	0.371	5.496
60.2 - 55.3	57.5	0.000525	0.035983	0.365	5.861
55.3 - 50.9	52.9	0.000509	0.036492	0.385	6.246
50.9 - 47.4	49.0	0.000419	0.036911	0.342	6.588
47.4 - 44.2	45.7	0.000418	0.037329	0.367	6.954
44.2 - 41.3	42.6	0.000397	0.037727	0.373	7.328

Sample: Powder 392005785407 F1 D3
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200796_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:42:42 AM	Thermal Correction:	No
Sample Mass:	1.8213 g	Warm Free Space:	7.8819 cm³ Measured
Cold Free Space:	22.7997 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Pore Width Range (Å)	Average Width (Å)	Incremental Pore Volume (cm³/g)	Cumulative Pore Volume (cm³/g)	Incremental Pore Area (m²/g)	Cumulative Pore Area (m²/g)
41.3 - 38.6	39.8	0.000398	0.038124	0.399	7.727
38.6 - 36.2	37.3	0.000393	0.038518	0.421	8.148
36.2 - 34.0	35.1	0.000391	0.038908	0.446	8.594
34.0 - 31.9	32.9	0.000423	0.039331	0.514	9.108
31.9 - 30.4	31.1	0.000348	0.039679	0.447	9.555
30.4 - 28.6	29.4	0.000432	0.040110	0.587	10.142
28.6 - 26.8	27.6	0.000487	0.040598	0.706	10.848
26.8 - 25.2	25.9	0.000471	0.041068	0.726	11.574
25.2 - 23.7	24.4	0.000451	0.041519	0.739	12.312
23.7 - 22.2	22.9	0.000482	0.042001	0.840	13.153
22.2 - 20.8	21.5	0.000442	0.042443	0.824	13.977
20.8 - 19.4	20.0	0.000424	0.042867	0.846	14.823
19.4 - 17.8	18.5	0.000462	0.043329	0.998	15.822
17.8 - 16.4	17.0	0.000393	0.043722	0.924	16.746

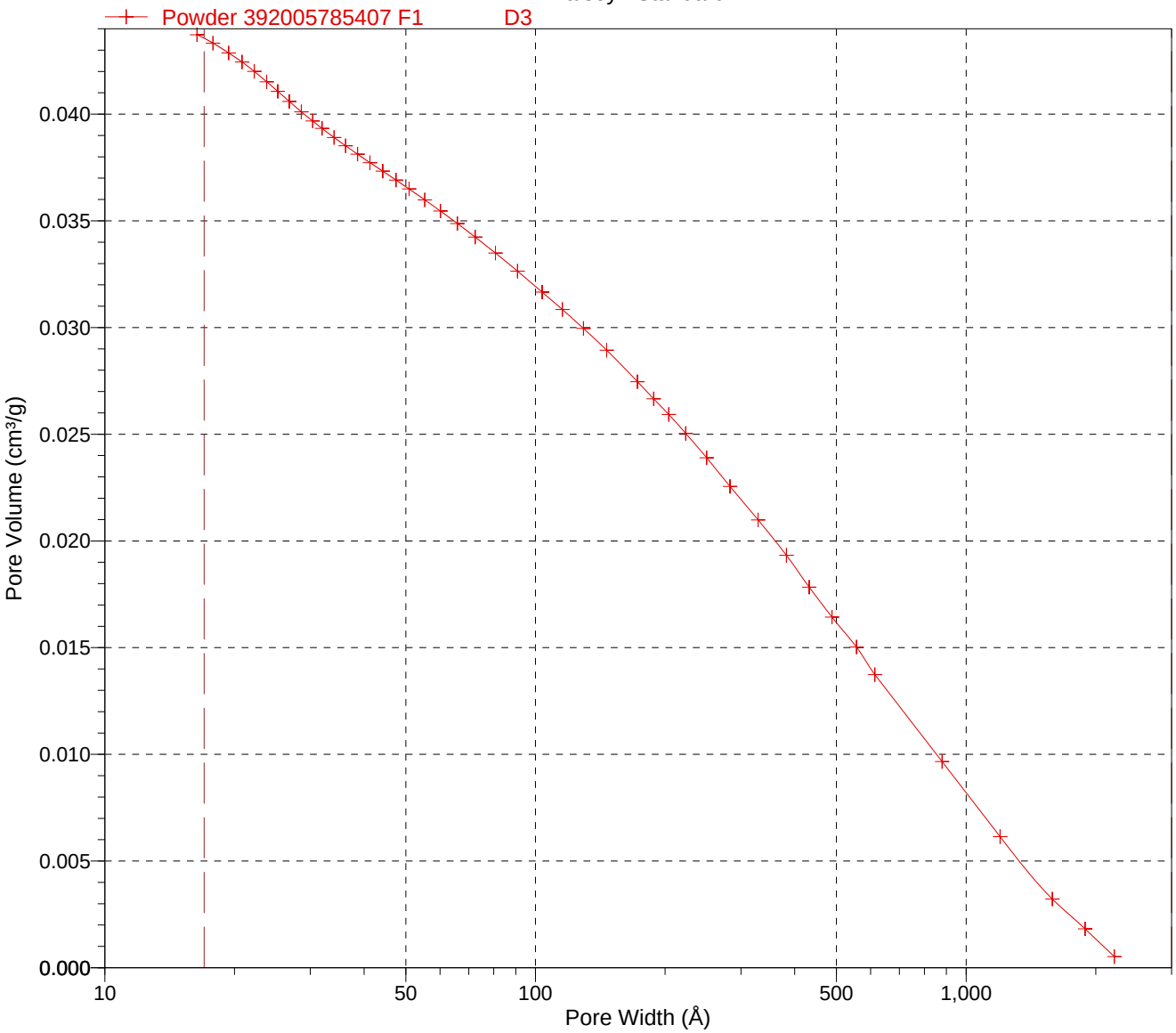
Sample: Powder 392005785407 F1 D3
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200796_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:42:42 AM	Thermal Correction:	No
Sample Mass:	1.8213 g	Warm Free Space:	7.8819 cm³ Measured
Cold Free Space:	22.7997 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Cumulative Pore Volume (Larger)

Halsey : Standard



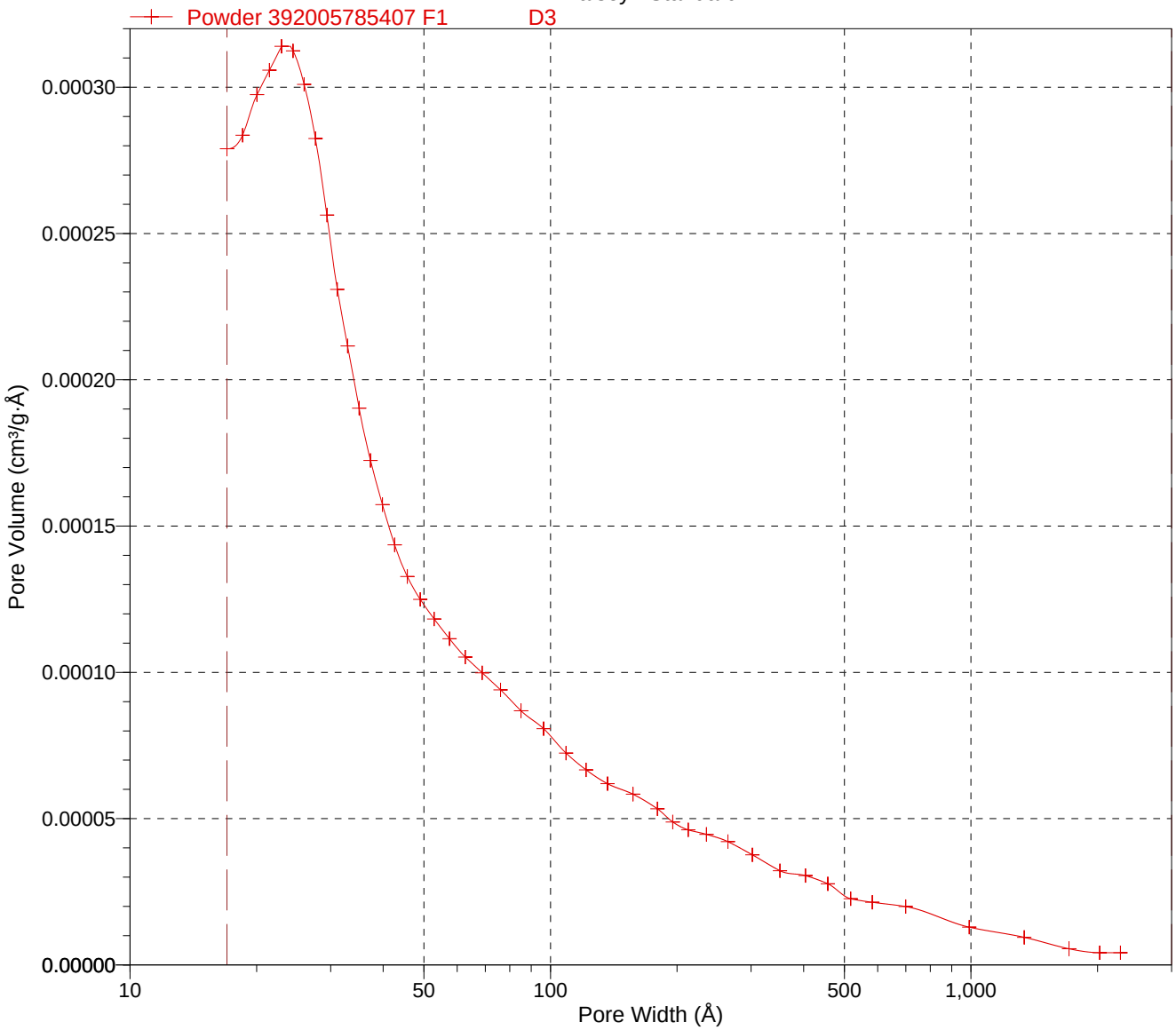
Sample: Powder 392005785407 F1 D3
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200796_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:42:42 AM	Thermal Correction:	No
Sample Mass:	1.8213 g	Warm Free Space:	7.8819 cm³ Measured
Cold Free Space:	22.7997 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dV/dw Pore Volume

Halsey : Standard



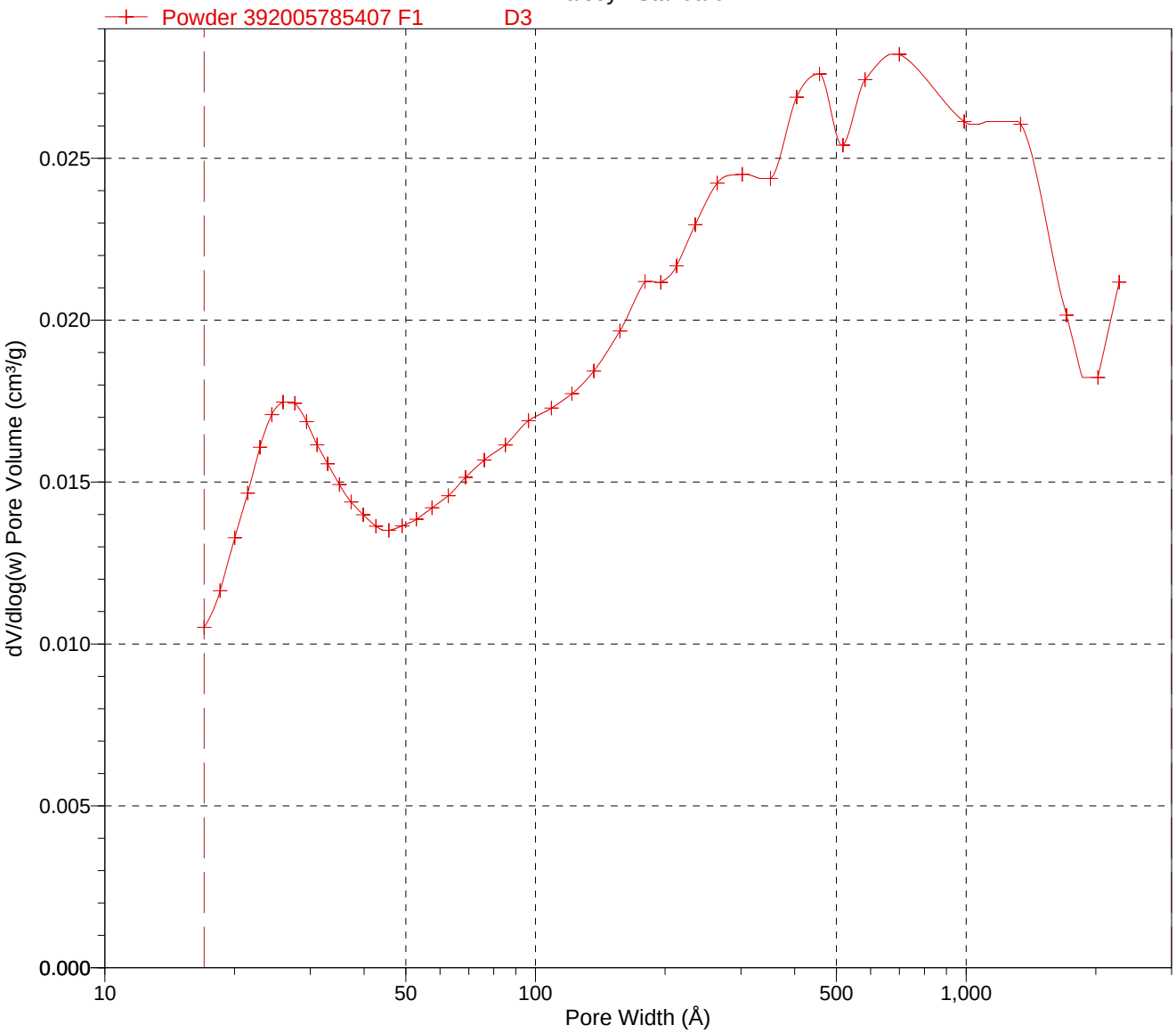
Sample: Powder 392005785407 F1 D3
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200796_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:42:42 AM	Thermal Correction:	No
Sample Mass:	1.8213 g	Warm Free Space:	7.8819 cm³ Measured
Cold Free Space:	22.7997 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dV/dlog(w) Pore Volume

Halsey : Standard



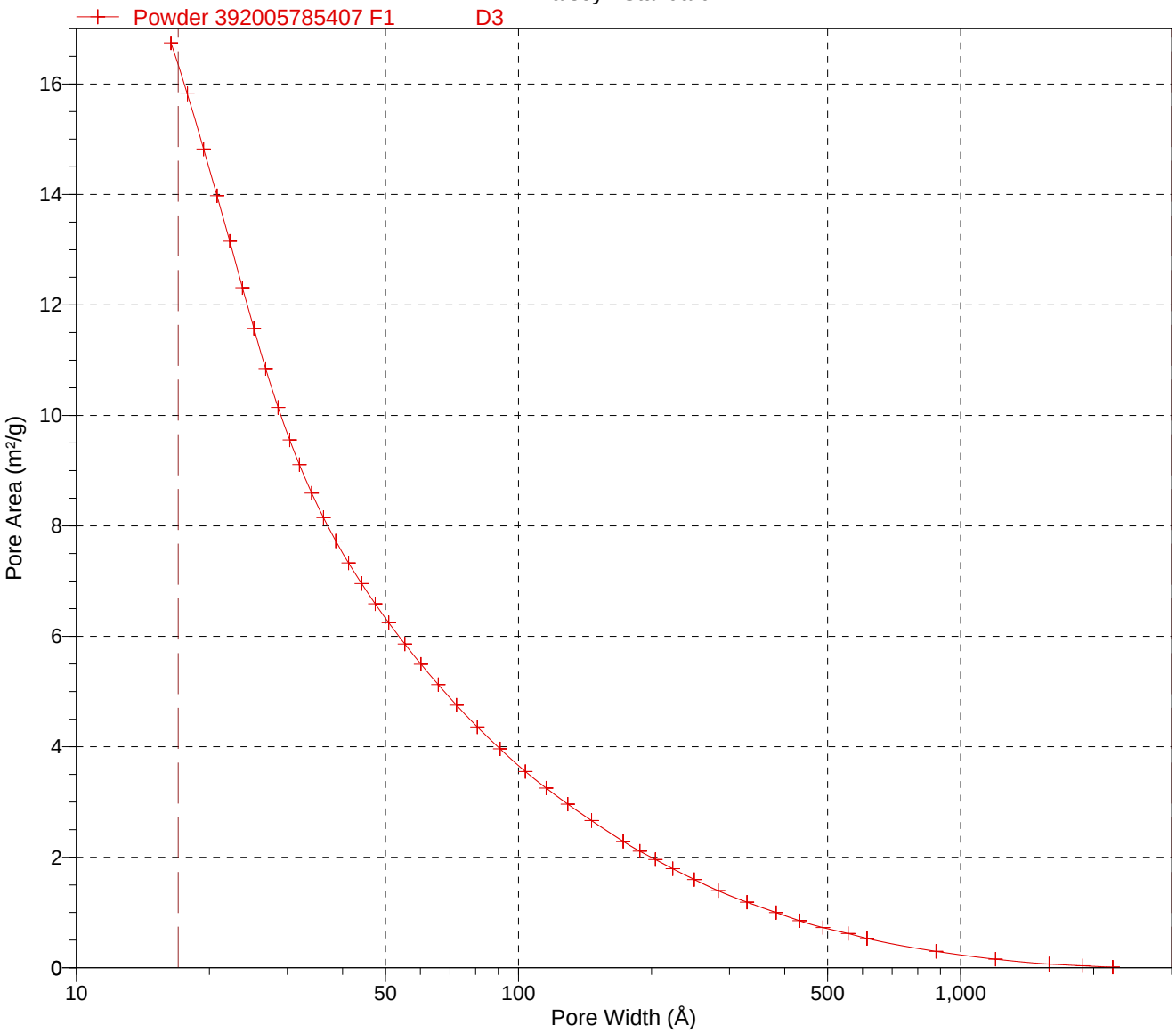
Sample: Powder 392005785407 F1 D3
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200796_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:42:42 AM	Thermal Correction:	No
Sample Mass:	1.8213 g	Warm Free Space:	7.8819 cm³ Measured
Cold Free Space:	22.7997 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Cumulative Pore Area (Larger)

Halsey : Standard



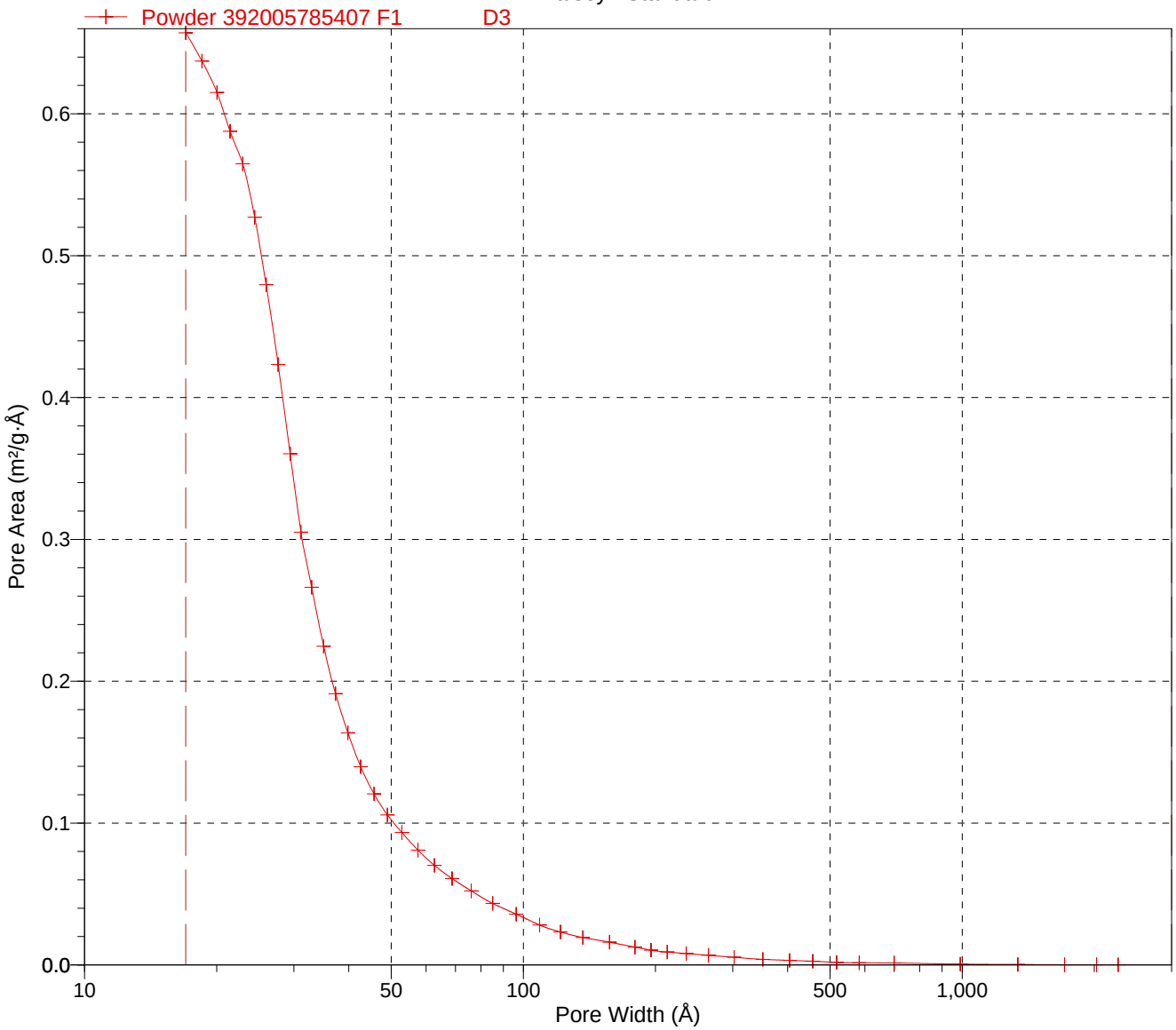
Sample: Powder 392005785407 F1 D3
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200796_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:42:42 AM	Thermal Correction:	No
Sample Mass:	1.8213 g	Warm Free Space:	7.8819 cm³ Measured
Cold Free Space:	22.7997 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dA/dw Pore Area

Halsey : Standard



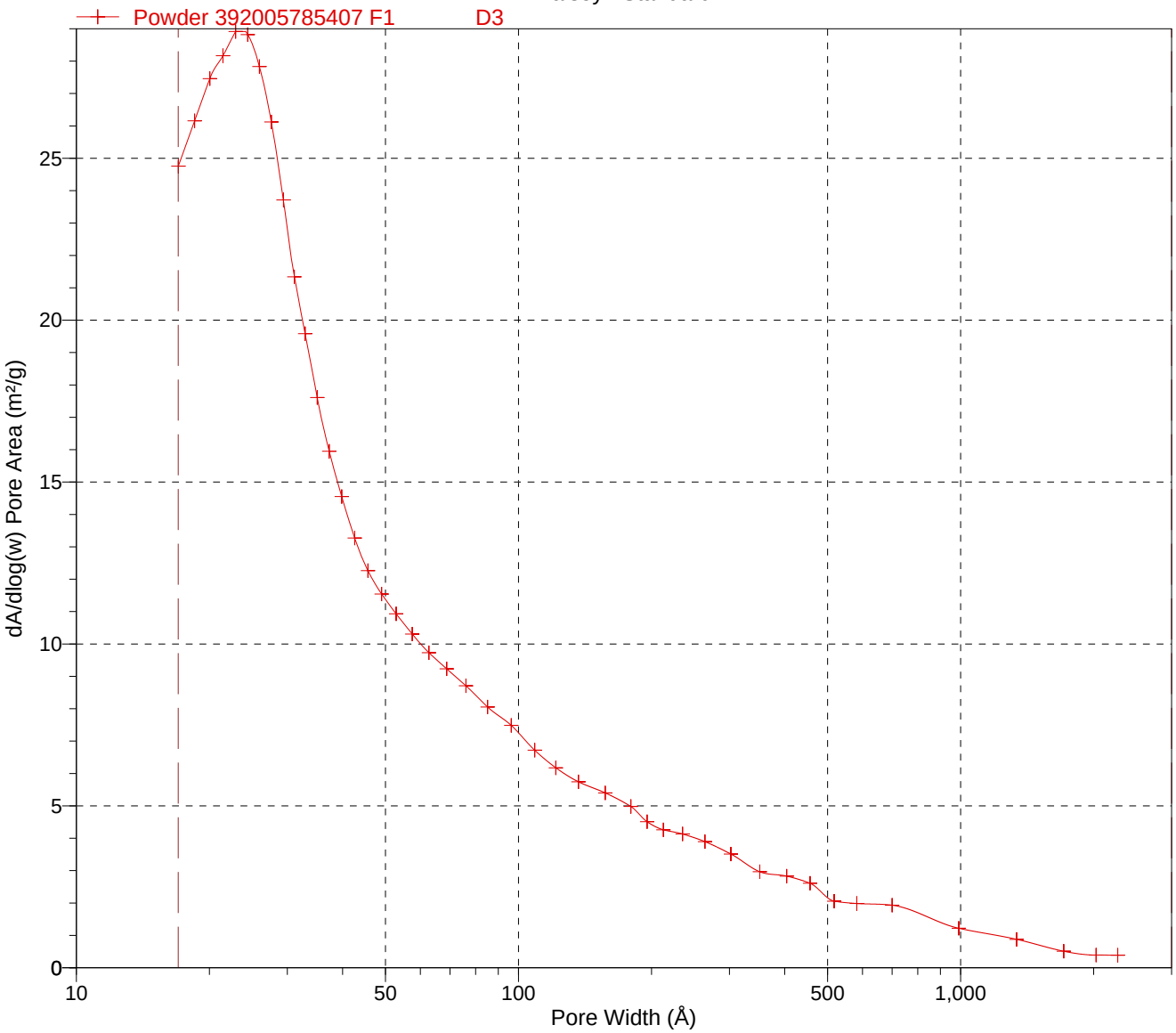
Sample: Powder 392005785407 F1 D3
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200796_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:42:42 AM	Thermal Correction:	No
Sample Mass:	1.8213 g	Warm Free Space:	7.8819 cm³ Measured
Cold Free Space:	22.7997 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dA/dlog(w) Pore Area

Halsey : Standard



Sample: Powder 392005785407 F2 E4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200797_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:50:04 AM	Thermal Correction:	No
Sample Mass:	2.3730 g	Warm Free Space:	7.7234 cm³ Measured
Cold Free Space:	22.0964 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Summary Report

Surface Area

Single point surface area at p/p° = 0.260184392:	5.6135 m²/g
BET Surface Area:	5.6989 m²/g
t-Plot Micropore Area:	0.8136 m²/g
t-Plot External Surface Area:	4.8853 m²/g
BJH Adsorption cumulative surface area of pores between 17.000 Å and 3,000.000 Å width:	5.768 m²/g

Pore Volume

Single point adsorption total pore volume of pores less than 2,608.168 Å width at p/p° = 0.992542899:	0.020131 cm³/g
t-Plot micropore volume:	0.000379 cm³/g
BJH Adsorption cumulative volume of pores between 17.000 Å and 3,000.000 Å width:	0.020400 cm³/g

Pore Size

Adsorption average pore width (4V/A by BET):	141.2954 Å
BJH Adsorption average pore width (4V/A):	141.460 Å

Sample: Powder 392005785407 F2 E4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200797_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:50:04 AM	Thermal Correction:	No
Sample Mass:	2.3730 g	Warm Free Space:	7.7234 cm³ Measured
Cold Free Space:	22.0964 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Tabular Report

Relative Pressure (p/p°)	Absolute Pressure (mmHg)	Quantity Adsorbed (cm³/g STP)	Elapsed Time (h:min)	Saturation Pressure (mmHg)
			01:11	740.482788
0.002579795	1.904884	0.7750	02:24	738.385803
0.005025726	3.709424	0.8902	02:46	738.087341
0.007602000	5.608329	0.9641	03:01	737.743835
0.010077636	7.434494	1.0115	03:11	737.722107
0.020633141	15.208190	1.1270	03:47	737.075867
0.030976955	22.827890	1.1908	04:06	736.931396
0.042100914	31.016556	1.2416	04:21	736.719299
0.049583650	36.523724	1.2707	04:31	736.608215
0.078920579	58.129063	1.3579	04:42	736.551392
0.108194371	79.676735	1.4282	04:51	736.422180
0.141623888	104.262886	1.5003	04:57	736.195618
0.169822669	125.026985	1.5584	05:03	736.220825
0.199909530	147.174911	1.6195	05:08	736.207581
0.232531565	171.140152	1.6855	05:13	735.986755
0.260184392	191.502716	1.7430	05:17	736.026917
0.290539163	213.839218	1.8064	05:21	736.008240
0.320706251	235.961914	1.8721	05:26	735.757141
0.353281062	259.795441	1.9443	05:30	735.378906
0.380642028	279.929779	2.0070	05:34	735.414795
0.411228749	302.360657	2.0787	05:38	735.261475
0.441005717	324.149323	2.1500	05:42	735.022949
0.472347139	347.148163	2.2265	05:46	734.942871
0.501860760	368.822968	2.3013	05:50	734.910950
0.531917911	390.859833	2.3803	05:54	734.812317
0.561850700	412.958618	2.4630	05:58	734.997070
0.591833279	434.914703	2.5514	06:02	734.860168
0.621606507	456.791321	2.6467	06:06	734.856079
0.651424622	478.654877	2.7505	06:11	734.781677
0.681056128	500.330170	2.8672	06:15	734.638672
0.710551473	521.971008	2.9987	06:20	734.599854
0.740129793	543.579346	3.1511	06:25	734.437866
0.767894487	563.811951	3.3196	06:30	734.231018
0.798001002	585.984497	3.5420	06:35	734.315491
0.819647328	601.763367	3.7348	06:41	734.173523
0.839385260	616.191162	3.9453	06:47	734.098145
0.858609603	630.427917	4.1949	06:53	734.242798
0.878418530	645.017944	4.5057	07:00	734.294556
0.890065011	653.395508	4.7263	07:06	734.098633

Sample: Powder 392005785407 F2 E4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200797_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:50:04 AM	Thermal Correction:	No
Sample Mass:	2.3730 g	Warm Free Space:	7.7234 cm³ Measured
Cold Free Space:	22.0964 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Tabular Report

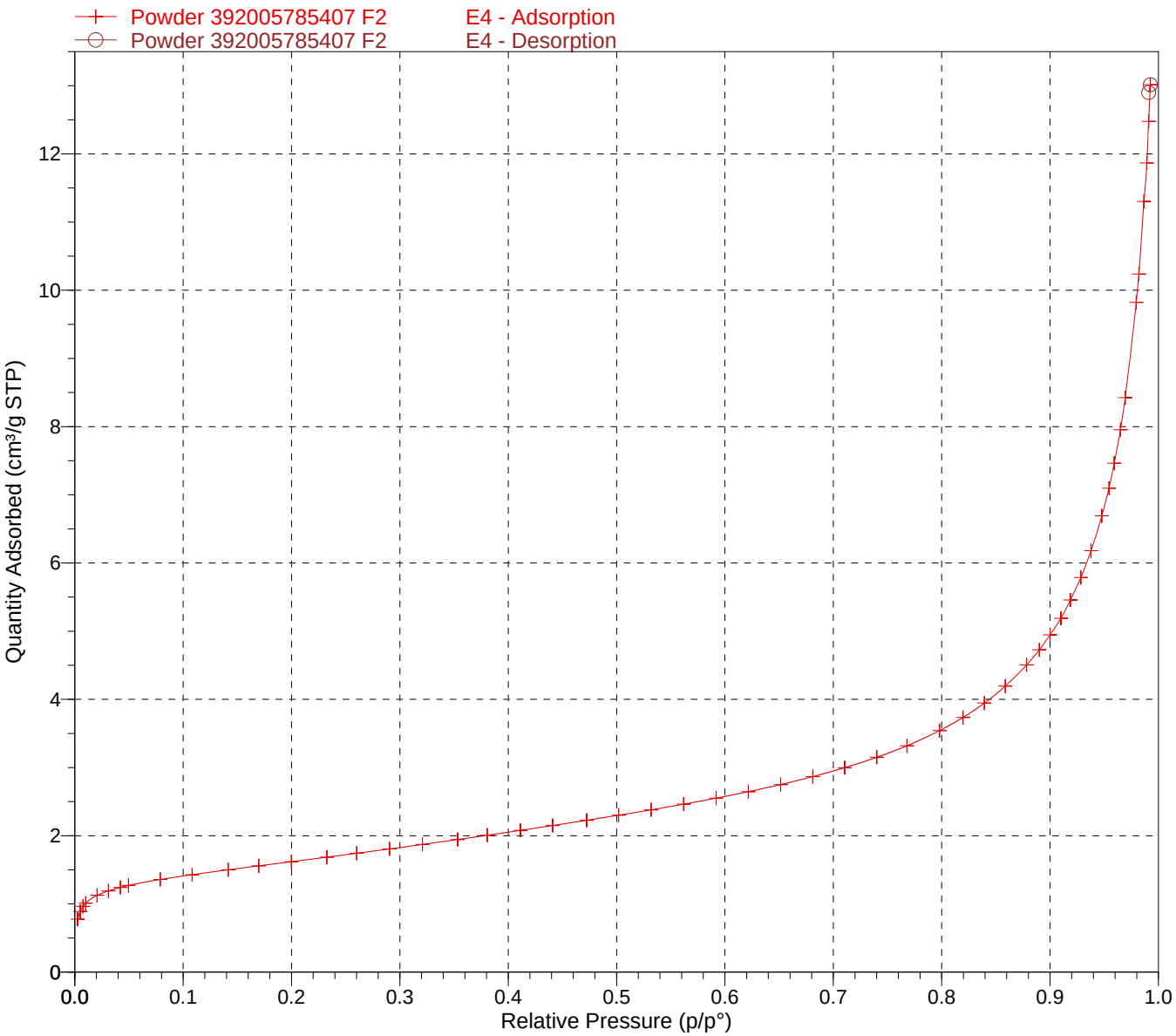
Relative Pressure (p/p°)	Absolute Pressure (mmHg)	Quantity Adsorbed (cm³/g STP)	Elapsed Time (h:min)	Saturation Pressure (mmHg)
0.899942819	660.605652	4.9471	07:12	734.052917
0.909980965	667.815613	5.1900	07:18	733.878662
0.918779669	674.382202	5.4568	07:25	733.997742
0.928451960	681.347961	5.7878	07:32	733.853760
0.937770439	688.215210	6.1797	07:39	733.884521
0.947749054	695.485779	6.6913	07:47	733.829041
0.954404430	700.370911	7.0978	07:54	733.830322
0.959149883	703.744263	7.4638	08:01	733.716675
0.964964589	707.628723	7.9549	08:09	733.320923
0.969334867	710.825256	8.4258	08:17	733.312378
0.979551322	718.233826	9.8233	08:35	733.227356
0.982039310	719.930237	10.2371	08:41	733.097168
0.986632144	723.562256	11.3023	08:54	733.365784
0.989357059	725.623657	11.8672	09:03	733.429504
0.991046645	726.774536	12.4761	09:13	733.340393
0.992542899	727.697693	13.0144	09:24	733.164978
0.991015778	726.604675	12.9008	09:27	733.191833

Sample: Powder 392005785407 F2 E4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200797_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:50:04 AM	Thermal Correction:	No
Sample Mass:	2.3730 g	Warm Free Space:	7.7234 cm³ Measured
Cold Free Space:	22.0964 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Linear Plot



Sample: Powder 392005785407 F2 E4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200797_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:50:04 AM	Thermal Correction:	No
Sample Mass:	2.3730 g	Warm Free Space:	7.7234 cm³ Measured
Cold Free Space:	22.0964 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BET Surface Area Report

BET Surface Area: 5.6989 ± 0.0257 m²/g
Slope: 0.761152 ± 0.003392 g/cm³ STP
Y-Intercept: 0.002717 ± 0.000576 g/cm³ STP
C: 281.103045
Qm: 1.3091 cm³/g STP
Correlation Coefficient: 0.9999404
Molecular Cross-Sectional Area: 0.1620 nm²

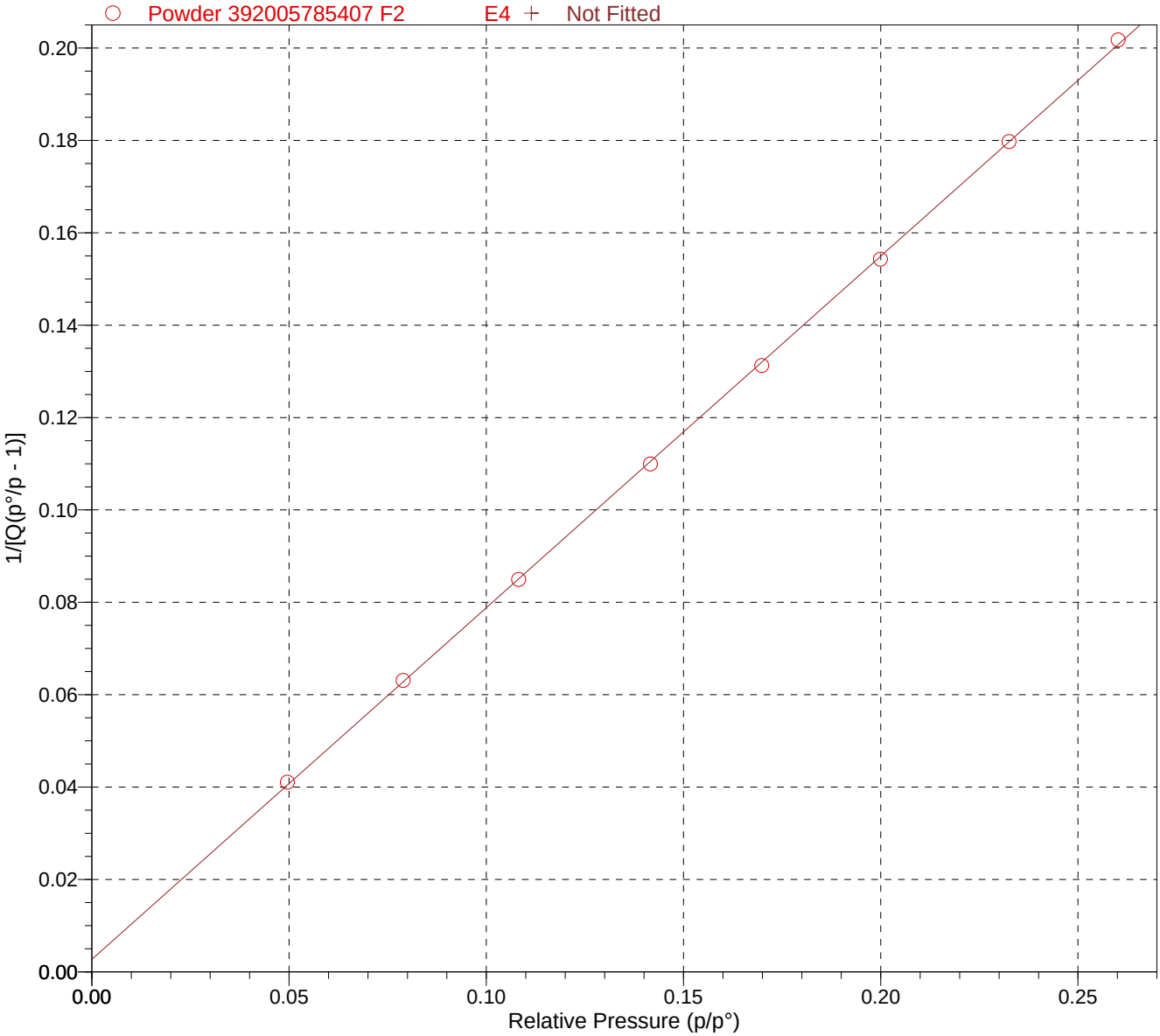
Relative Pressure (p/p°)	Quantity Adsorbed (cm³/g STP)	1/[Q(p°/p - 1)]
0.049583650	1.2707	0.041056
0.078920579	1.3579	0.063101
0.108194371	1.4282	0.084944
0.141623888	1.5003	0.109971
0.169822669	1.5584	0.131263
0.199909530	1.6195	0.154284
0.232531565	1.6855	0.179765
0.260184392	1.7430	0.201771

Sample: Powder 392005785407 F2 E4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200797_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:50:04 AM	Thermal Correction:	No
Sample Mass:	2.3730 g	Warm Free Space:	7.7234 cm³ Measured
Cold Free Space:	22.0964 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BET Surface Area Plot



Sample: Powder 392005785407 F2 E4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200797_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:50:04 AM	Thermal Correction:	No
Sample Mass:	2.3730 g	Warm Free Space:	7.7234 cm³ Measured
Cold Free Space:	22.0964 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot Report

Micropore Volume:	0.000379 cm³/g
Micropore Area:	0.8136 m²/g
External Surface Area:	4.8853 m²/g
Slope:	0.315832 ± 0.000826 cm³/g·Å STP
Y-Intercept:	0.244779 ± 0.004976 cm³/g STP
Correlation Coefficient:	0.999911
Surface Area Correction Factor:	1.000
Density Conversion Factor:	0.0015468
Total Surface Area (BET):	5.6989 m²/g
Thickness Range:	2.6681 Å to 10.1453 Å
Thickness Equation:	Harkins and Jura

Thickness Curve

t = [13.99 / (0.034 - log(p/p°))] ^ 0.5

t-Plot Report - Data

Relative Pressure (p/p°)	Statistical Thickness (Å)	Quantity Adsorbed (cm³/g STP)	Fitted
0.002579795	2.3097	0.7750	
0.005025726	2.4489	0.8902	
0.007602000	2.5491	0.9641	
0.010077636	2.6248	1.0115	
0.020633141	2.8524	1.1270	*
0.030976955	3.0111	1.1908	*
0.042100914	3.1502	1.2416	*
0.049583650	3.2328	1.2707	*
0.078920579	3.5080	1.3579	*
0.108194371	3.7407	1.4282	*
0.141623888	3.9807	1.5003	*
0.169822669	4.1714	1.5584	*
0.199909530	4.3683	1.6195	*
0.232531565	4.5780	1.6855	*
0.260184392	4.7551	1.7430	*
0.290539163	4.9507	1.8064	*
0.320706251	5.1480	1.8721	*
0.353281062	5.3659	1.9443	*
0.380642028	5.5543	2.0070	*
0.411228749	5.7720	2.0787	*
0.441005717	5.9927	2.1500	*
0.472347139	6.2361	2.2265	*
0.501860760	6.4776	2.3013	*

Sample: Powder 392005785407 F2 E4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200797_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:50:04 AM	Thermal Correction:	No
Sample Mass:	2.3730 g	Warm Free Space:	7.7234 cm³ Measured
Cold Free Space:	22.0964 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot Report - Data

Relative Pressure (p/p°)	Statistical Thickness (Å)	Quantity Adsorbed (cm³/g STP)	Fitted
0.531917911	6.7379	2.3803	*
0.561850700	7.0139	2.4630	*
0.591833279	7.3101	2.5514	*
0.621606507	7.6272	2.6467	*
0.651424622	7.9719	2.7505	*
0.681056128	8.3466	2.8672	*
0.710551473	8.7577	2.9987	*
0.740129793	9.2166	3.1511	*
0.767894487	9.6996	3.3196	*
0.798001002	10.2950	3.5420	
0.819647328	10.7806	3.7348	
0.839385260	11.2755	3.9453	
0.858609603	11.8159	4.1949	
0.878418530	12.4471	4.5057	
0.890065011	12.8611	4.7263	
0.899942819	13.2418	4.9471	
0.909980965	13.6607	5.1900	
0.918779669	14.0581	5.4568	
0.928451960	14.5327	5.7878	
0.937770439	15.0332	6.1797	
0.947749054	15.6245	6.6913	
0.954404430	16.0561	7.0978	
0.959149883	16.3845	7.4638	
0.964964589	16.8134	7.9549	
0.969334867	17.1570	8.4258	
0.979551322	18.0431	9.8233	
0.982039310	18.2790	10.2371	
0.986632144	18.7380	11.3023	
0.989357059	19.0262	11.8672	
0.991046645	19.2112	12.4761	
0.992542899	19.3795	13.0144	

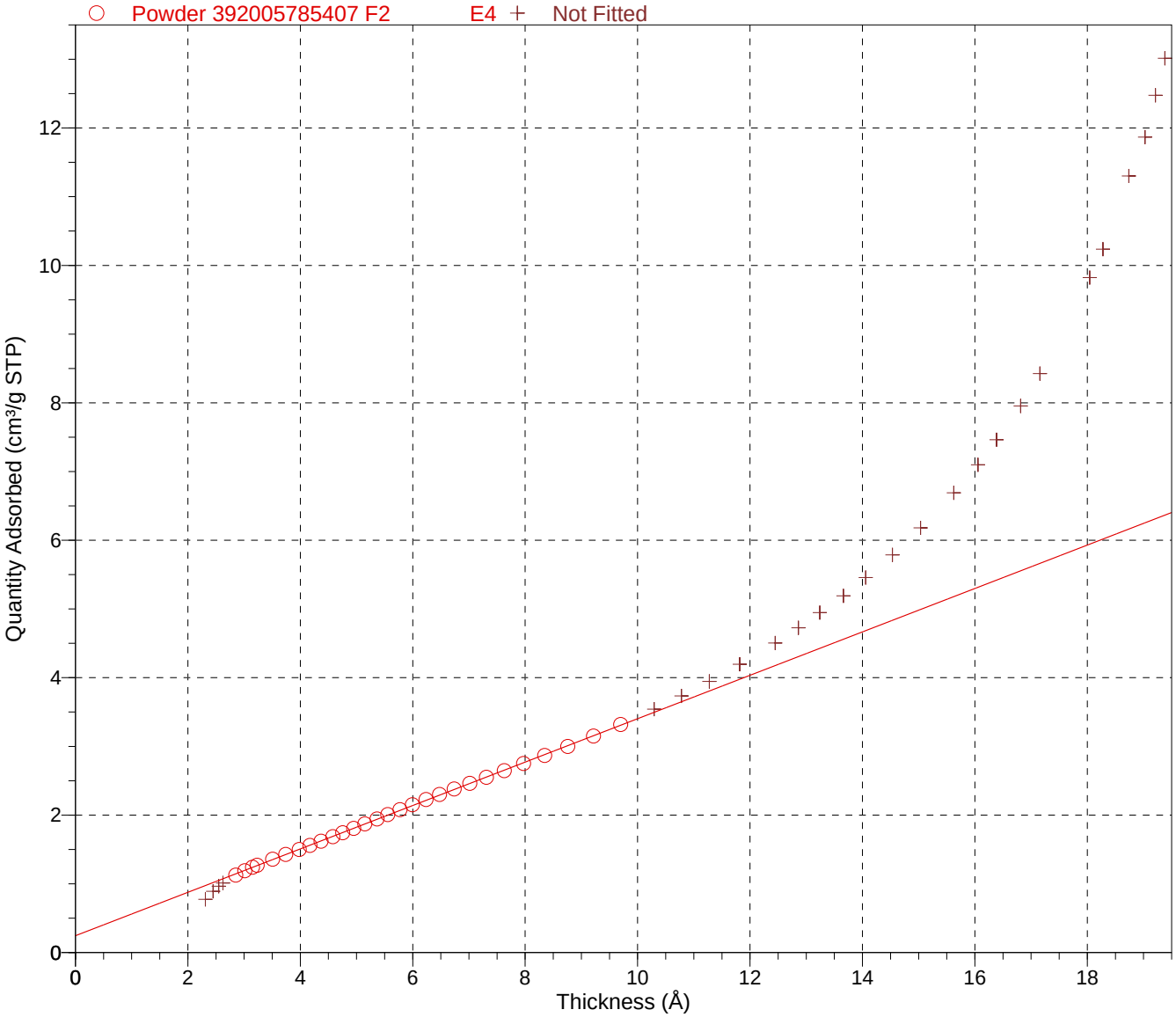
Sample: Powder 392005785407 F2 E4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200797_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:50:04 AM	Thermal Correction:	No
Sample Mass:	2.3730 g	Warm Free Space:	7.7234 cm³ Measured
Cold Free Space:	22.0964 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot

Harkins and Jura



Sample: Powder 392005785407 F2 E4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200797_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:50:04 AM	Thermal Correction:	No
Sample Mass:	2.3730 g	Warm Free Space:	7.7234 cm³ Measured
Cold Free Space:	22.0964 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Pore Distribution Report

Standard
Halsey
t = 3.54 [-5 / ln(p/p°)] ^ 0.333

Width Range: 17.000 Å to 3,000.000 Å
Adsorbate Property Factor: 9.53000 Å
Density Conversion Factor: 0.0015468
Fraction of Pores Open at Both Ends: 0.00

Pore Width Range (Å)	Average Width (Å)	Incremental Pore Volume (cm³/g)	Cumulative Pore Volume (cm³/g)	Incremental Pore Area (m²/g)	Cumulative Pore Area (m²/g)
2608.2 - 2177.4	2353.7	0.000876	0.000876	0.015	0.015
2177.4 - 1836.1	1977.5	0.000995	0.001872	0.020	0.035
1836.1 - 1467.1	1610.1	0.000926	0.002798	0.023	0.058
1467.1 - 1097.7	1229.1	0.001769	0.004567	0.058	0.116
1097.7 - 966.6	1023.6	0.000688	0.005255	0.027	0.143
966.6 - 650.4	747.2	0.002372	0.007627	0.127	0.269
650.4 - 571.2	605.5	0.000803	0.008430	0.053	0.323
571.2 - 491.8	525.4	0.000841	0.009271	0.064	0.387
491.8 - 442.0	464.1	0.000632	0.009903	0.054	0.441
442.0 - 387.2	410.8	0.000704	0.010607	0.069	0.510
387.2 - 326.8	351.7	0.000897	0.011504	0.102	0.612
326.8 - 285.5	303.2	0.000693	0.012197	0.091	0.703
285.5 - 252.5	266.9	0.000588	0.012785	0.088	0.791
252.5 - 228.6	239.3	0.000478	0.013264	0.080	0.871
228.6 - 206.4	216.3	0.000435	0.013698	0.080	0.952
206.4 - 188.4	196.5	0.000400	0.014099	0.081	1.033
188.4 - 170.9	178.7	0.000401	0.014499	0.090	1.123
170.9 - 147.7	157.4	0.000571	0.015070	0.145	1.268
147.7 - 130.5	137.9	0.000462	0.015533	0.134	1.402
130.5 - 116.6	122.6	0.000390	0.015923	0.127	1.529
116.6 - 104.3	109.7	0.000359	0.016281	0.131	1.660
104.3 - 91.0	96.7	0.000417	0.016699	0.173	1.833
91.0 - 81.4	85.6	0.000315	0.017013	0.147	1.980
81.4 - 73.1	76.7	0.000285	0.017298	0.148	2.128
73.1 - 66.3	69.3	0.000246	0.017544	0.142	2.270
66.3 - 60.5	63.1	0.000218	0.017762	0.139	2.409
60.5 - 55.6	57.8	0.000193	0.017956	0.134	2.543
55.6 - 51.3	53.3	0.000179	0.018135	0.135	2.677
51.3 - 47.6	49.3	0.000167	0.018302	0.136	2.813
47.6 - 44.3	45.8	0.000158	0.018460	0.138	2.951
44.3 - 41.3	42.7	0.000153	0.018614	0.144	3.094

Sample: Powder 392005785407 F2 E4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200797_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:50:04 AM	Thermal Correction:	No
Sample Mass:	2.3730 g	Warm Free Space:	7.7234 cm³ Measured
Cold Free Space:	22.0964 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Pore Width Range (Å)	Average Width (Å)	Incremental Pore Volume (cm³/g)	Cumulative Pore Volume (cm³/g)	Incremental Pore Area (m²/g)	Cumulative Pore Area (m²/g)
41.3 - 38.7	39.9	0.000148	0.018762	0.149	3.243
38.7 - 36.2	37.4	0.000154	0.018916	0.165	3.408
36.2 - 34.0	35.0	0.000147	0.019064	0.168	3.577
34.0 - 32.0	32.9	0.000151	0.019215	0.183	3.760
32.0 - 30.3	31.1	0.000133	0.019348	0.171	3.931
30.3 - 28.4	29.2	0.000153	0.019501	0.209	4.140
28.4 - 26.7	27.5	0.000139	0.019639	0.202	4.342
26.7 - 25.1	25.8	0.000128	0.019767	0.198	4.540
25.1 - 23.7	24.4	0.000115	0.019882	0.188	4.728
23.7 - 22.2	22.9	0.000123	0.020004	0.214	4.943
22.2 - 20.7	21.4	0.000106	0.020111	0.199	5.142
20.7 - 19.4	20.0	0.000093	0.020203	0.185	5.327
19.4 - 17.8	18.5	0.000103	0.020307	0.223	5.550
17.8 - 16.4	17.0	0.000093	0.020400	0.219	5.768

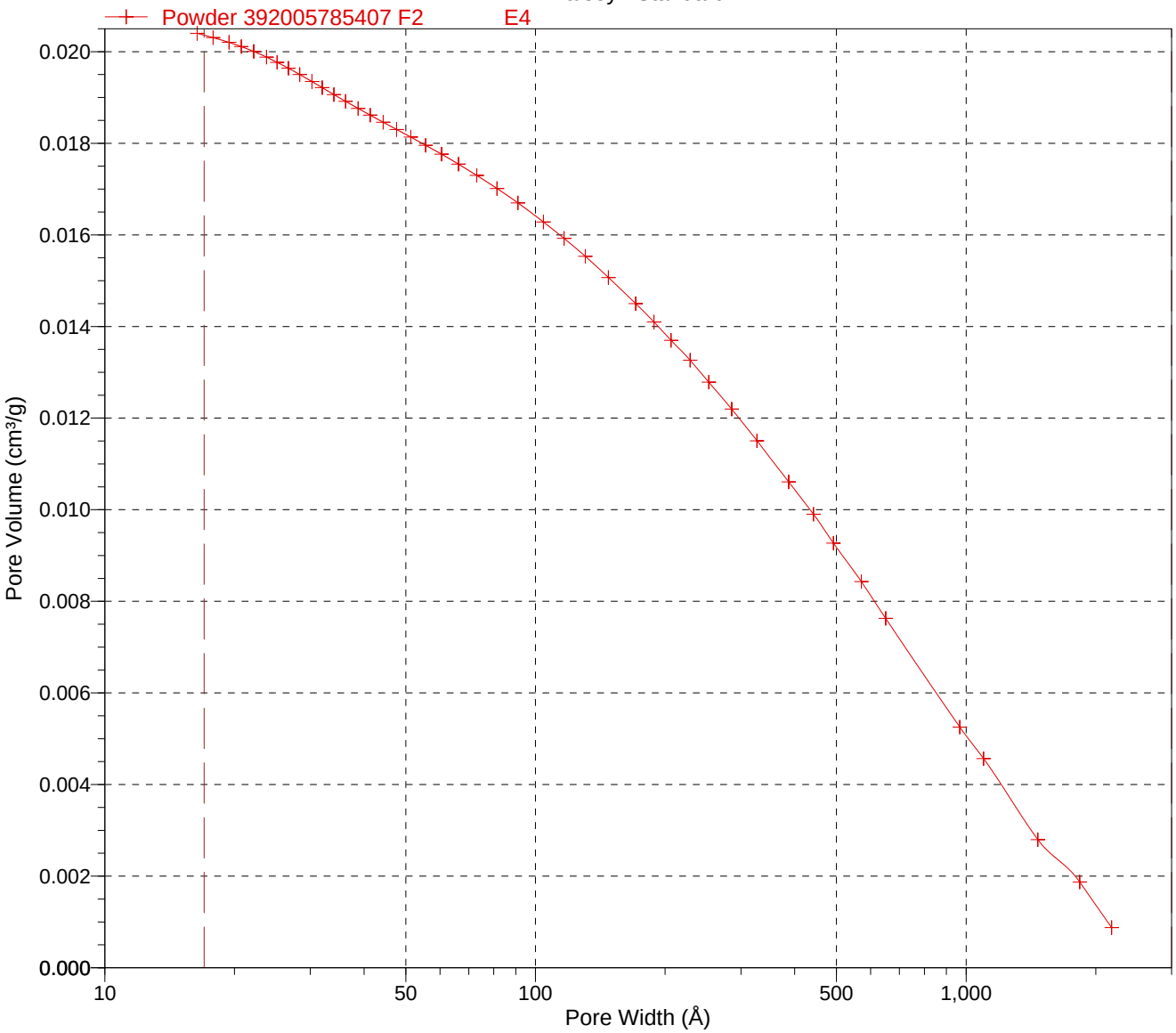
Sample: Powder 392005785407 F2 E4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200797_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:50:04 AM	Thermal Correction:	No
Sample Mass:	2.3730 g	Warm Free Space:	7.7234 cm³ Measured
Cold Free Space:	22.0964 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Cumulative Pore Volume (Larger)

Halsey : Standard



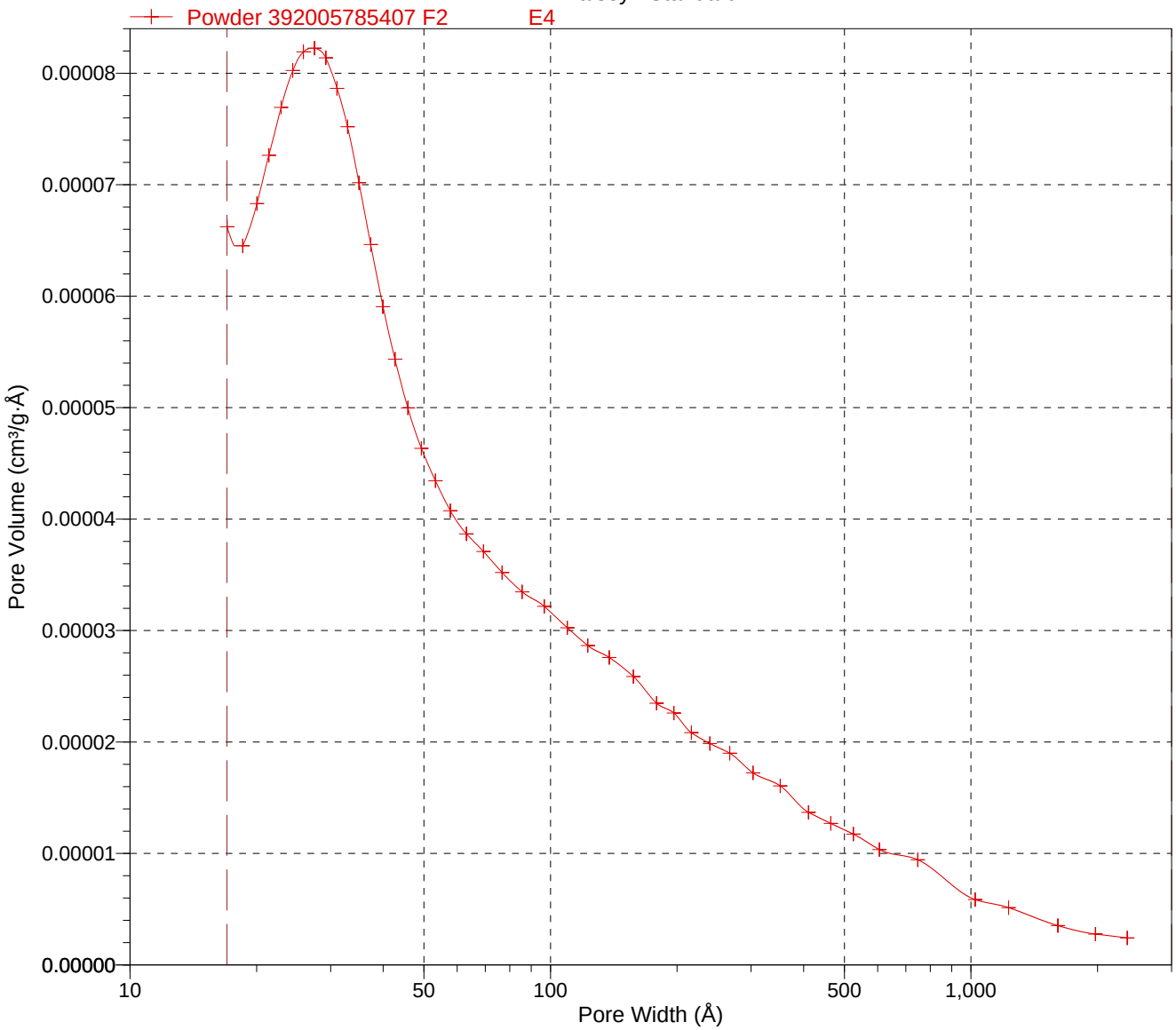
Sample: Powder 392005785407 F2 E4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200797_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:50:04 AM	Thermal Correction:	No
Sample Mass:	2.3730 g	Warm Free Space:	7.7234 cm³ Measured
Cold Free Space:	22.0964 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dV/dw Pore Volume

Halsey : Standard



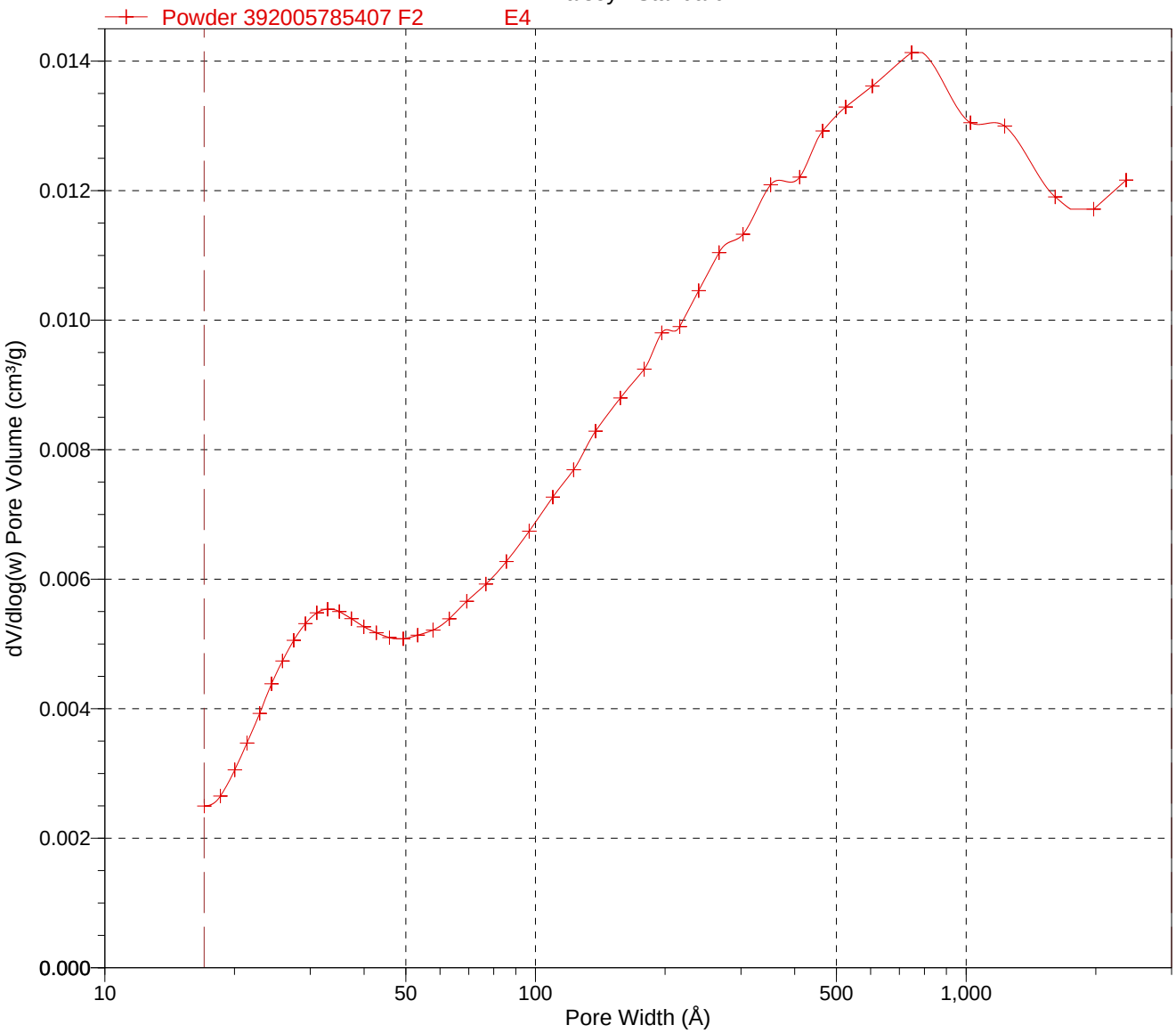
Sample: Powder 392005785407 F2 E4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200797_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:50:04 AM	Thermal Correction:	No
Sample Mass:	2.3730 g	Warm Free Space:	7.7234 cm³ Measured
Cold Free Space:	22.0964 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dV/dlog(w) Pore Volume

Halsey : Standard



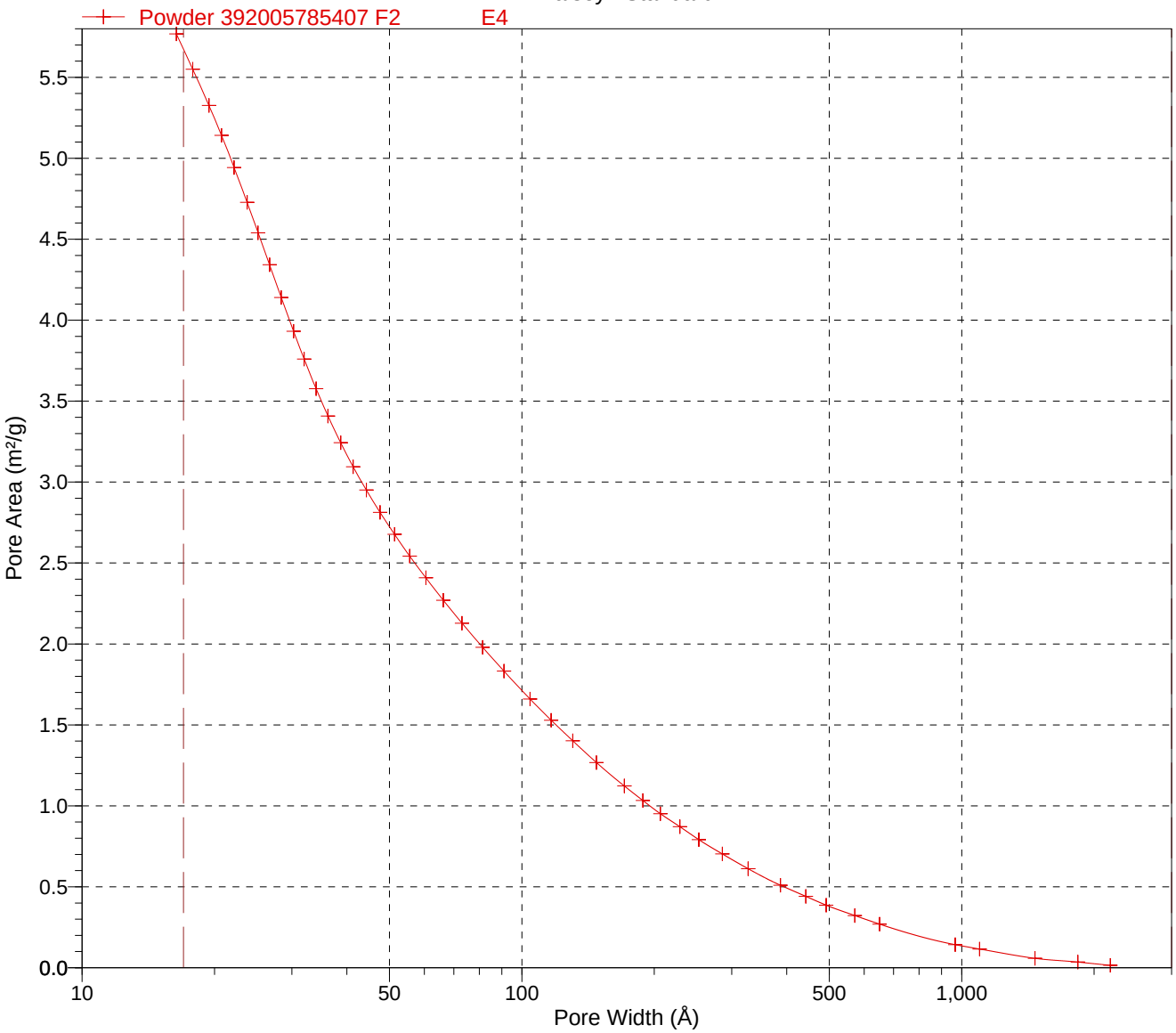
Sample: Powder 392005785407 F2 E4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200797_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:50:04 AM	Thermal Correction:	No
Sample Mass:	2.3730 g	Warm Free Space:	7.7234 cm³ Measured
Cold Free Space:	22.0964 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Cumulative Pore Area (Larger)

Halsey : Standard



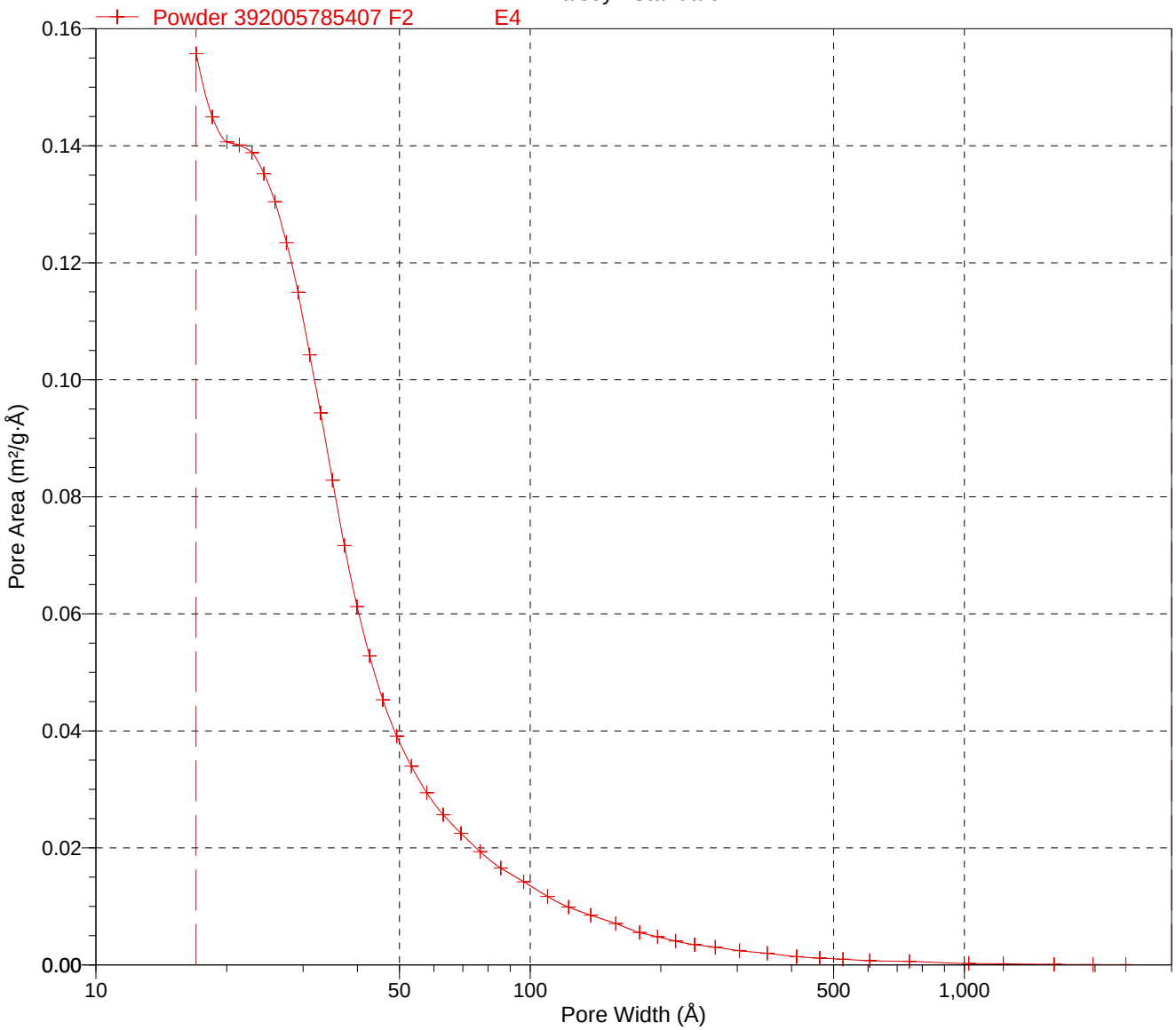
Sample: Powder 392005785407 F2 E4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200797_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:50:04 AM	Thermal Correction:	No
Sample Mass:	2.3730 g	Warm Free Space:	7.7234 cm³ Measured
Cold Free Space:	22.0964 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dA/dw Pore Area

Halsey : Standard



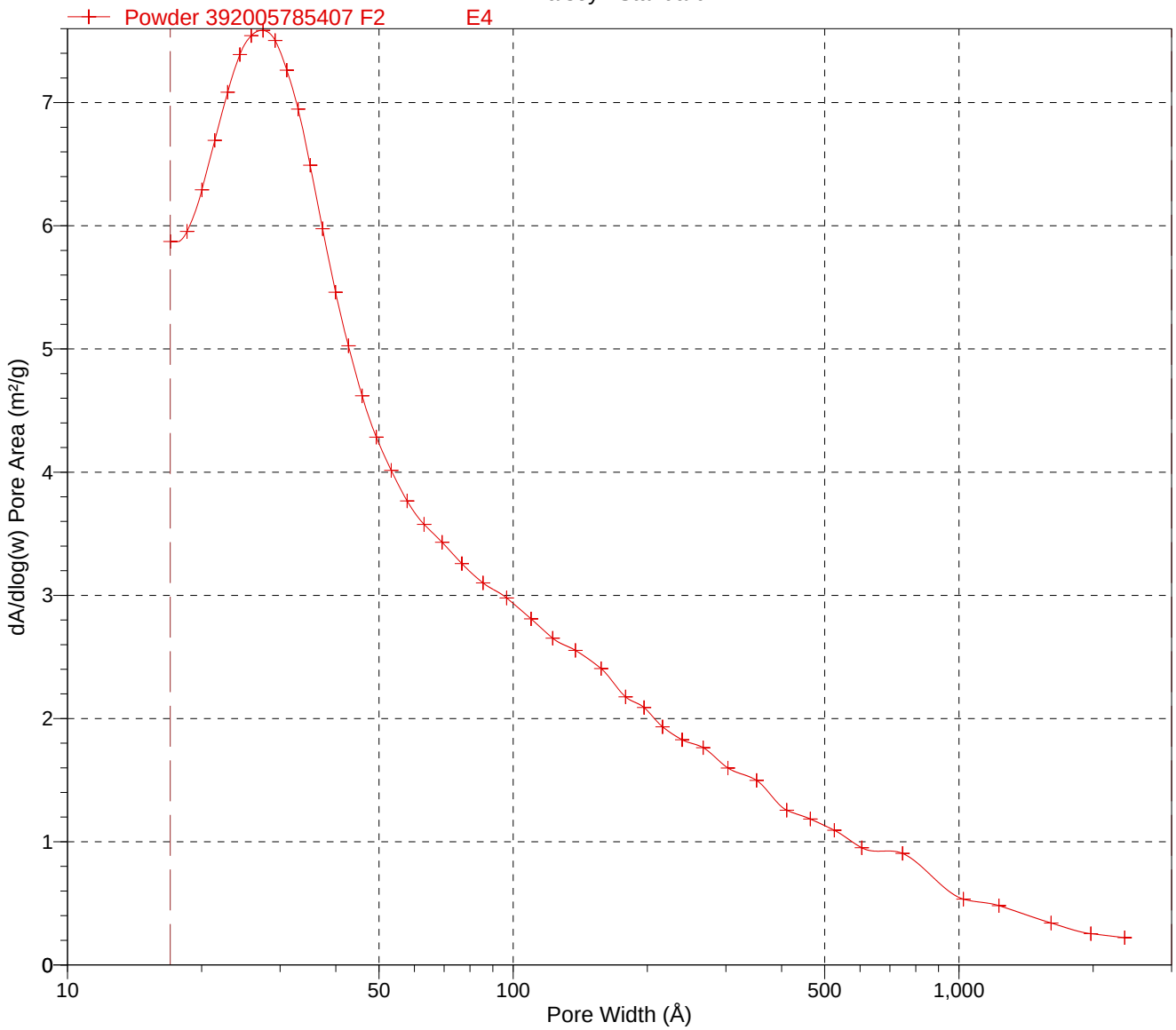
Sample: Powder 392005785407 F2 E4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200797_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:50:04 AM	Thermal Correction:	No
Sample Mass:	2.3730 g	Warm Free Space:	7.7234 cm³ Measured
Cold Free Space:	22.0964 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dA/dlog(w) Pore Area

Halsey : Standard



Sample: Powder 400817783501 BD N5
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200799_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:51:03 AM	Thermal Correction:	No
Sample Mass:	3.3250 g	Warm Free Space:	7.4010 cm³ Measured
Cold Free Space:	21.0952 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Summary Report

Surface Area

Single point surface area at p/p° = 0.140002794:	22.9952 m²/g
BET Surface Area:	23.5465 m²/g
t-Plot Micropore Area:	15.1526 m²/g
t-Plot External Surface Area:	8.3939 m²/g
BJH Adsorption cumulative surface area of pores between 17.000 Å and 3,000.000 Å width:	15.268 m²/g

Pore Volume

Single point adsorption total pore volume of pores less than 2,467.567 Å width at p/p° = 0.992112560:	0.026857 cm³/g
t-Plot micropore volume:	0.006953 cm³/g
BJH Adsorption cumulative volume of pores between 17.000 Å and 3,000.000 Å width:	0.023900 cm³/g

Pore Size

Adsorption average pore width (4V/A by BET):	45.6243 Å
BJH Adsorption average pore width (4V/A):	62.617 Å

Sample: Powder 400817783501 BD N5
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200799_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:51:03 AM	Thermal Correction:	No
Sample Mass:	3.3250 g	Warm Free Space:	7.4010 cm³ Measured
Cold Free Space:	21.0952 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Tabular Report

Relative Pressure (p/p°)	Absolute Pressure (mmHg)	Quantity Adsorbed (cm³/g STP)	Elapsed Time (h:min)	Saturation Pressure (mmHg)
			01:04	738.959595
0.002472843	1.820139	3.4500	03:45	736.051392
0.004927417	3.622587	3.8382	04:48	735.189758
0.008010461	5.876927	4.1329	06:15	733.656555
0.009839918	7.211277	4.2686	07:25	732.859436
0.020028774	14.663300	4.7064	09:37	732.111694
0.030144649	22.045216	4.9498	10:42	731.314392
0.039381977	28.803938	5.1423	12:07	731.398987
0.049918093	36.510429	5.3073	13:03	731.406738
0.087932473	64.253166	5.7369	14:50	730.710327
0.116405715	85.073494	5.9697	15:39	730.836060
0.140002794	102.295540	6.1423	16:16	730.667847
0.171740461	125.480820	6.3453	16:51	730.642151
0.204166472	149.188095	6.5254	17:12	730.717896
0.235407982	172.018219	6.6959	17:36	730.723816
0.267921848	195.780228	6.8591	17:52	730.736328
0.298511434	218.149857	7.0071	18:05	730.792297
0.328059375	239.739700	7.1490	18:18	730.781433
0.356276398	260.376007	7.2867	18:31	730.825867
0.379651488	277.461121	7.3994	18:42	730.831116
0.409136384	299.076599	7.5371	18:52	730.994873
0.438352792	320.413818	7.6765	19:01	730.949646
0.469053185	342.818817	7.8218	19:10	730.874084
0.498337796	364.216858	7.9648	19:17	730.863403
0.528021556	386.020691	8.1179	19:26	731.069946
0.558394444	408.209412	8.2783	19:34	731.041321
0.587637050	429.656403	8.4428	19:42	731.159485
0.618026850	451.803467	8.6203	19:49	731.041809
0.647071607	473.243347	8.8043	19:56	731.361633
0.676981251	495.135468	9.0087	20:04	731.387268
0.706819978	516.996277	9.2310	20:11	731.439819
0.740470256	541.680115	9.5166	20:23	731.535278
0.767381386	561.238831	9.7647	20:30	731.368835
0.799595702	584.943787	10.1030	20:39	731.549438
0.817617153	598.063293	10.3248	20:47	731.471069
0.838373377	613.303284	10.5921	20:53	731.539551
0.856971108	626.752808	10.8503	21:00	731.358154
0.879535735	643.416626	11.2204	21:11	731.541199
0.889829372	650.978455	11.4030	21:17	731.576721

Sample: Powder 400817783501 BD N5
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200799_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:51:03 AM	Thermal Correction:	No
Sample Mass:	3.3250 g	Warm Free Space:	7.4010 cm³ Measured
Cold Free Space:	21.0952 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Tabular Report

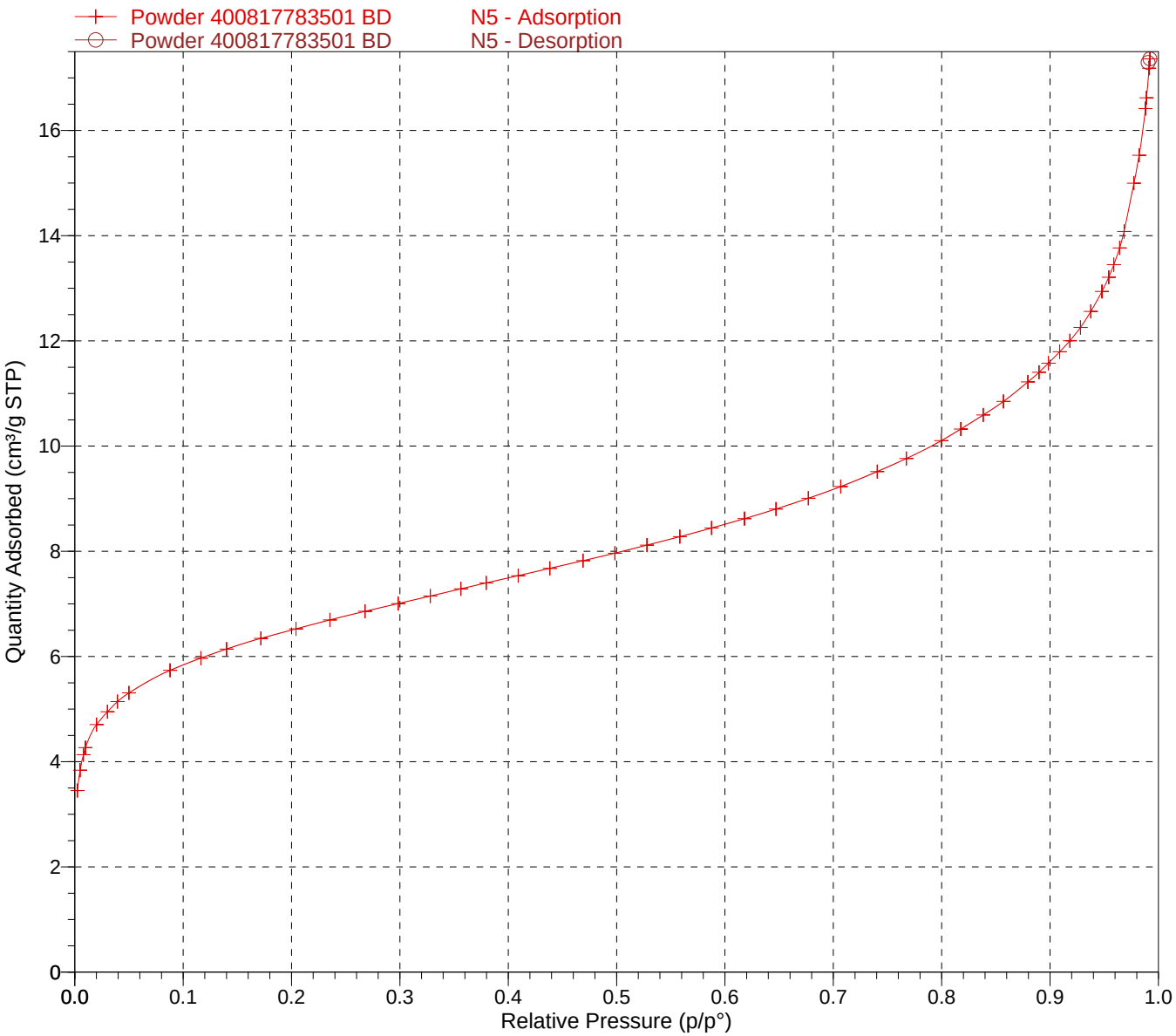
Relative Pressure (p/p°)	Absolute Pressure (mmHg)	Quantity Adsorbed (cm³/g STP)	Elapsed Time (h:min)	Saturation Pressure (mmHg)
0.898447344	657.418335	11.5770	21:24	731.727173
0.908928317	665.126160	11.7928	21:30	731.769653
0.918299893	671.872009	12.0024	21:37	731.647705
0.928046703	678.974182	12.2567	21:43	731.616394
0.937551084	686.042419	12.5597	21:50	731.738708
0.947840852	693.508667	12.9390	21:58	731.672058
0.954232859	698.229492	13.2112	22:04	731.718140
0.958795206	701.554443	13.4491	22:11	731.704163
0.964257971	705.579468	13.7685	22:18	731.733093
0.968372337	708.593750	14.0805	22:25	731.736877
0.977304083	715.118164	14.9993	22:44	731.725342
0.982207007	718.696106	15.5300	22:53	731.715515
0.988008896	722.712769	16.4186	23:09	731.484070
0.988938799	723.395935	16.6211	23:14	731.487061
0.991325322	725.125793	17.1854	23:27	731.471069
0.992112560	725.652466	17.3631	23:32	731.421509
0.990503710	724.483093	17.2930	23:35	731.428955

Sample: Powder 400817783501 BD N5
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200799_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:51:03 AM	Thermal Correction:	No
Sample Mass:	3.3250 g	Warm Free Space:	7.4010 cm³ Measured
Cold Free Space:	21.0952 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Linear Plot



Sample: Powder 400817783501 BD N5
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200799_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:51:03 AM	Thermal Correction:	No
Sample Mass:	3.3250 g	Warm Free Space:	7.4010 cm³ Measured
Cold Free Space:	21.0952 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BET Surface Area Report

BET Surface Area:	23.5465 ± 0.1266 m²/g
Slope:	0.184215 ± 0.000989 g/cm³ STP
Y-Intercept:	0.000662 ± 0.000103 g/cm³ STP
C:	279.199206
Qm:	5.4090 cm³/g STP
Correlation Coefficient:	0.9999712
Molecular Cross-Sectional Area:	0.1620 nm²

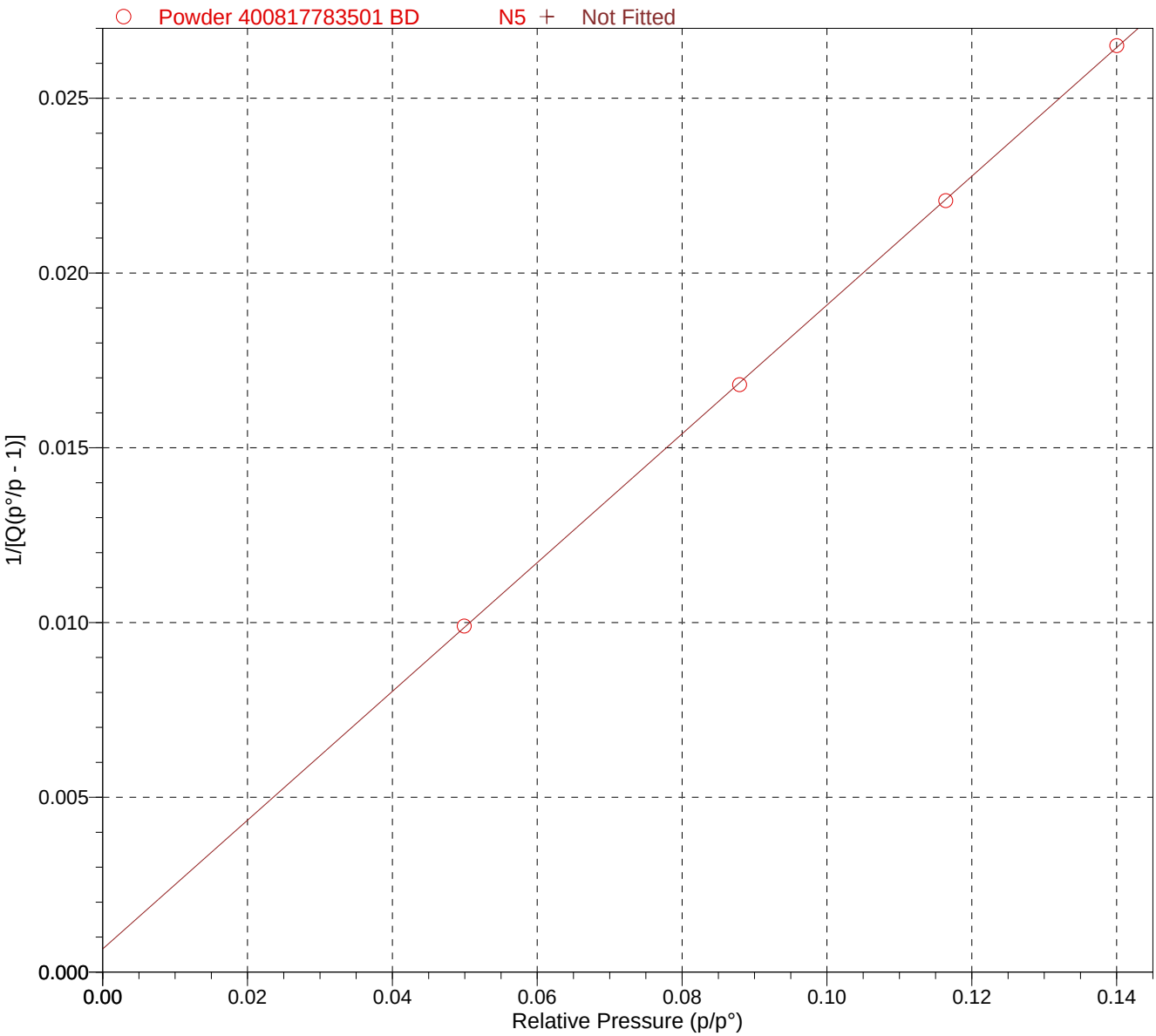
Relative Pressure (p/p°)	Quantity Adsorbed (cm³/g STP)	1/[Q(p°/p - 1)]
0.049918093	5.3073	0.009900
0.087932473	5.7369	0.016805
0.116405715	5.9697	0.022068
0.140002794	6.1423	0.026504

Sample: Powder 400817783501 BD N5
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200799_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:51:03 AM	Thermal Correction:	No
Sample Mass:	3.3250 g	Warm Free Space:	7.4010 cm³ Measured
Cold Free Space:	21.0952 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BET Surface Area Plot



Sample: Powder 400817783501 BD N5
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200799_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:51:03 AM	Thermal Correction:	No
Sample Mass:	3.3250 g	Warm Free Space:	7.4010 cm³ Measured
Cold Free Space:	21.0952 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot Report

Micropore Volume:	0.006953 cm³/g
Micropore Area:	15.1526 m²/g
External Surface Area:	8.3939 m²/g
Slope:	0.542663 ± 0.002539 cm³/g·Å STP
Y-Intercept:	4.494980 ± 0.022698 cm³/g STP
Correlation Coefficient:	0.999869
Surface Area Correction Factor:	1.000
Density Conversion Factor:	0.0015468
Total Surface Area (BET):	23.5465 m²/g
Thickness Range:	6.3159 Å to 12.0228 Å
Thickness Equation:	Harkins and Jura

Thickness Curve

t = [13.99 / (0.034 - log(p/p°))] ^ 0.5

t-Plot Report - Data

Relative Pressure (p/p°)	Statistical Thickness (Å)	Quantity Adsorbed (cm³/g STP)	Fitted
0.002472843	2.3017	3.4500	
0.004927417	2.4444	3.8382	
0.008010461	2.5626	4.1329	
0.009839918	2.6181	4.2686	
0.020028774	2.8418	4.7064	
0.030144649	2.9997	4.9498	
0.039381977	3.1183	5.1423	
0.049918093	3.2363	5.3073	
0.087932473	3.5828	5.7369	
0.116405715	3.8016	5.9697	
0.140002794	3.9695	6.1423	
0.171740461	4.1841	6.3453	
0.204166472	4.3958	6.5254	
0.235407982	4.5964	6.6959	
0.267921848	4.8048	6.8591	
0.298511434	5.0025	7.0071	
0.328059375	5.1967	7.1490	
0.356276398	5.3863	7.2867	
0.379651488	5.5474	7.3994	
0.409136384	5.7568	7.5371	
0.438352792	5.9727	7.6765	
0.469053185	6.2100	7.8218	
0.498337796	6.4481	7.9648	*

Sample: Powder 400817783501 BD N5
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200799_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:51:03 AM	Thermal Correction:	No
Sample Mass:	3.3250 g	Warm Free Space:	7.4010 cm³ Measured
Cold Free Space:	21.0952 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot Report - Data

Relative Pressure (p/p°)	Statistical Thickness (Å)	Quantity Adsorbed (cm³/g STP)	Fitted
0.528021556	6.7033	8.1179	*
0.558394444	6.9811	8.2783	*
0.587637050	7.2673	8.4428	*
0.618026850	7.5877	8.6203	*
0.647071607	7.9197	8.8043	*
0.676981251	8.2929	9.0087	*
0.706819978	8.7033	9.2310	*
0.740470256	9.2222	9.5166	*
0.767381386	9.6902	9.7647	*
0.799595702	10.3290	10.1030	*
0.817617153	10.7327	10.3248	*
0.838373377	11.2488	10.5921	*
0.856971108	11.7673	10.8503	*
0.879535735	12.4853	11.2204	
0.889829372	12.8524	11.4030	
0.898447344	13.1823	11.5770	
0.908928317	13.6151	11.7928	
0.918299893	14.0356	12.0024	
0.928046703	14.5120	12.2567	
0.937551084	15.0209	12.5597	
0.947840852	15.6302	12.9390	
0.954232859	16.0445	13.2112	
0.958795206	16.3593	13.4491	
0.964257971	16.7596	13.7685	
0.968372337	17.0797	14.0805	
0.977304083	17.8373	14.9993	
0.982207007	18.2952	15.5300	
0.988008896	18.8820	16.4186	
0.988938799	18.9811	16.6211	
0.991325322	19.2423	17.1854	
0.992112560	19.3306	17.3631	

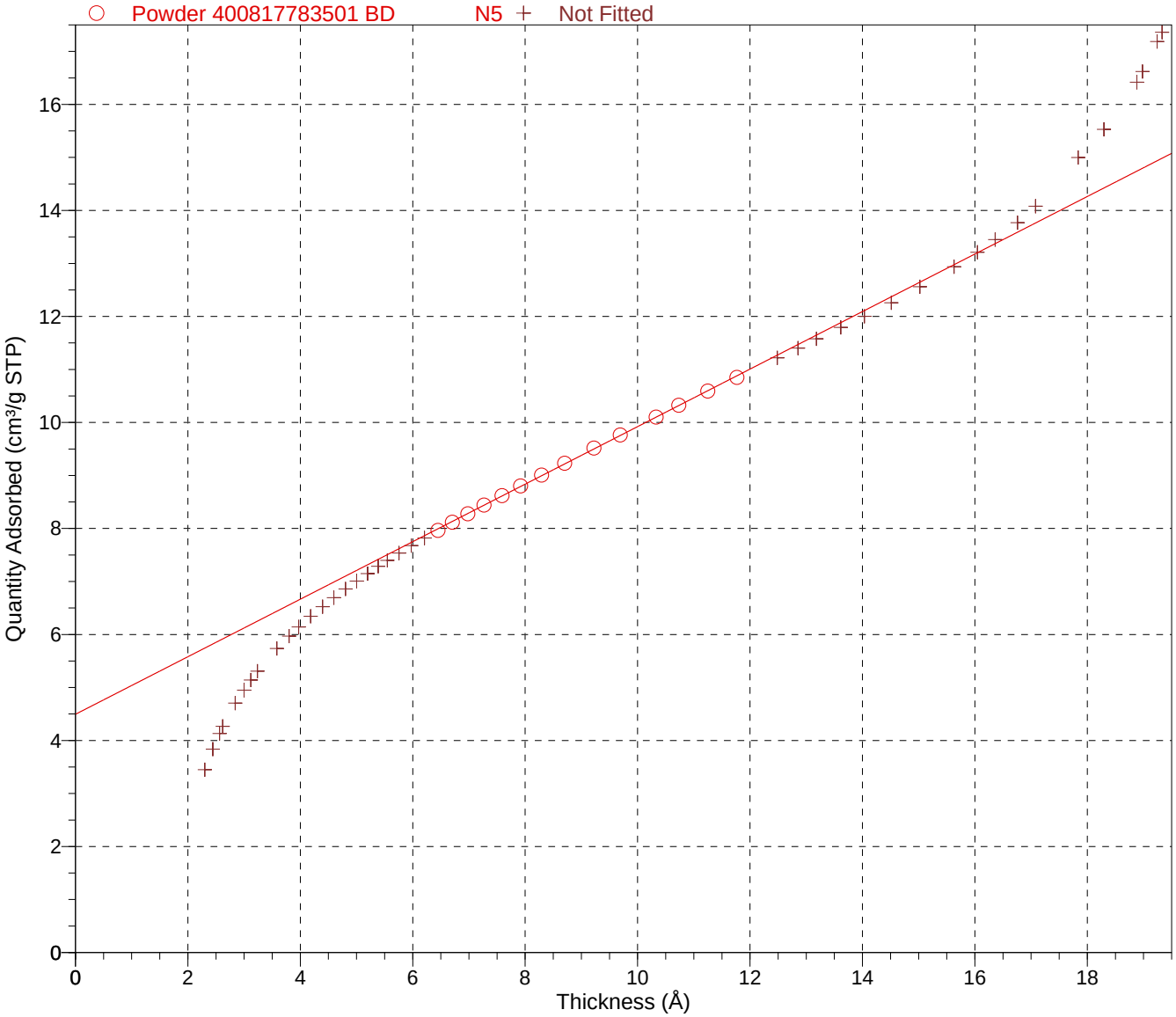
Sample: Powder 400817783501 BD N5
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200799_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:51:03 AM	Thermal Correction:	No
Sample Mass:	3.3250 g	Warm Free Space:	7.4010 cm³ Measured
Cold Free Space:	21.0952 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot

Harkins and Jura



Sample: Powder 400817783501 BD N5
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200799_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:51:03 AM	Thermal Correction:	No
Sample Mass:	3.3250 g	Warm Free Space:	7.4010 cm³ Measured
Cold Free Space:	21.0952 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Pore Distribution Report

Standard
Halsey
t = 3.54 [-5 / ln(p/p°)] ^ 0.333

Width Range: 17.000 Å to 3,000.000 Å
Adsorbate Property Factor: 9.53000 Å
Density Conversion Factor: 0.0015468
Fraction of Pores Open at Both Ends: 0.00

Pore Width Range (Å)	Average Width (Å)	Incremental Pore Volume (cm³/g)	Cumulative Pore Volume (cm³/g)	Incremental Pore Area (m²/g)	Cumulative Pore Area (m²/g)
2467.6 - 2246.4	2346.4	0.000290	0.000290	0.005	0.005
2246.4 - 1767.7	1949.8	0.000924	0.001213	0.019	0.024
1767.7 - 1632.6	1694.7	0.000332	0.001546	0.008	0.032
1632.6 - 1107.8	1271.3	0.001474	0.003020	0.046	0.078
1107.8 - 872.8	962.0	0.000886	0.003906	0.037	0.115
872.8 - 631.1	712.8	0.001565	0.005472	0.088	0.203
631.1 - 560.1	591.2	0.000532	0.006004	0.036	0.239
560.1 - 487.7	518.7	0.000547	0.006551	0.042	0.281
487.7 - 440.4	461.5	0.000410	0.006961	0.036	0.317
440.4 - 387.9	410.6	0.000471	0.007432	0.046	0.362
387.9 - 325.7	351.1	0.000666	0.008097	0.076	0.438
325.7 - 284.0	301.8	0.000538	0.008636	0.071	0.510
284.0 - 251.1	265.4	0.000454	0.009090	0.068	0.578
251.1 - 226.1	237.2	0.000377	0.009468	0.064	0.642
226.1 - 203.4	213.5	0.000394	0.009861	0.074	0.715
203.4 - 188.0	195.1	0.000323	0.010184	0.066	0.782
188.0 - 172.5	179.5	0.000340	0.010524	0.076	0.857
172.5 - 146.0	156.9	0.000710	0.011234	0.181	1.038
146.0 - 129.7	136.8	0.000501	0.011735	0.147	1.185
129.7 - 115.3	121.5	0.000531	0.012266	0.175	1.360
115.3 - 105.1	109.7	0.000450	0.012716	0.164	1.524
105.1 - 90.8	96.8	0.000700	0.013416	0.289	1.813
90.8 - 81.5	85.6	0.000521	0.013937	0.244	2.057
81.5 - 72.1	76.2	0.000617	0.014554	0.324	2.381
72.1 - 65.4	68.4	0.000485	0.015039	0.284	2.664
65.4 - 59.7	62.3	0.000453	0.015492	0.291	2.955
59.7 - 55.0	57.2	0.000414	0.015906	0.290	3.245
55.0 - 50.8	52.7	0.000404	0.016310	0.307	3.552
50.8 - 47.2	48.8	0.000383	0.016693	0.314	3.865
47.2 - 43.9	45.4	0.000377	0.017070	0.332	4.198
43.9 - 41.0	42.3	0.000369	0.017439	0.349	4.546

Sample: Powder 400817783501 BD N5
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200799_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:51:03 AM	Thermal Correction:	No
Sample Mass:	3.3250 g	Warm Free Space:	7.4010 cm³ Measured
Cold Free Space:	21.0952 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Pore Width Range (Å)	Average Width (Å)	Incremental Pore Volume (cm³/g)	Cumulative Pore Volume (cm³/g)	Incremental Pore Area (m²/g)	Cumulative Pore Area (m²/g)
41.0 - 38.5	39.6	0.000346	0.017786	0.349	4.896
38.5 - 36.0	37.1	0.000358	0.018143	0.385	5.281
36.0 - 33.9	34.9	0.000354	0.018497	0.406	5.687
33.9 - 31.9	32.8	0.000354	0.018851	0.431	6.118
31.9 - 30.4	31.1	0.000300	0.019151	0.385	6.503
30.4 - 28.8	29.5	0.000376	0.019526	0.509	7.012
28.8 - 27.1	27.9	0.000389	0.019915	0.558	7.570
27.1 - 25.5	26.3	0.000411	0.020326	0.627	8.196
25.5 - 23.9	24.6	0.000467	0.020794	0.759	8.956
23.9 - 22.4	23.1	0.000515	0.021309	0.894	9.850
22.4 - 20.8	21.5	0.000540	0.021849	1.003	10.853
20.8 - 19.4	20.0	0.000658	0.022507	1.316	12.168
19.4 - 18.2	18.7	0.000587	0.023094	1.252	13.420
18.2 - 16.8	17.5	0.000807	0.023900	1.848	15.268

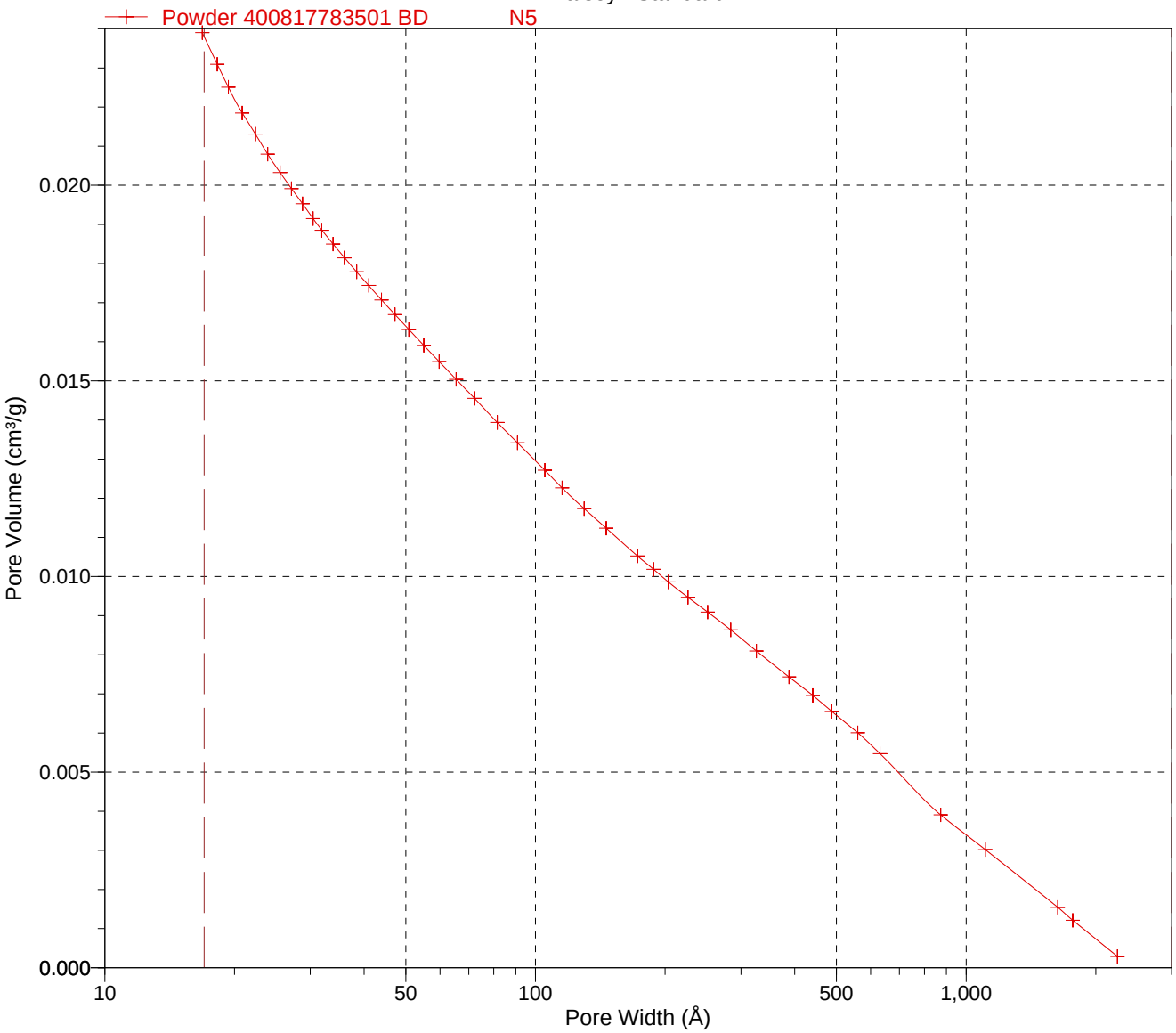
Sample: Powder 400817783501 BD N5
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200799_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:51:03 AM	Thermal Correction:	No
Sample Mass:	3.3250 g	Warm Free Space:	7.4010 cm³ Measured
Cold Free Space:	21.0952 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Cumulative Pore Volume (Larger)

Halsey : Standard



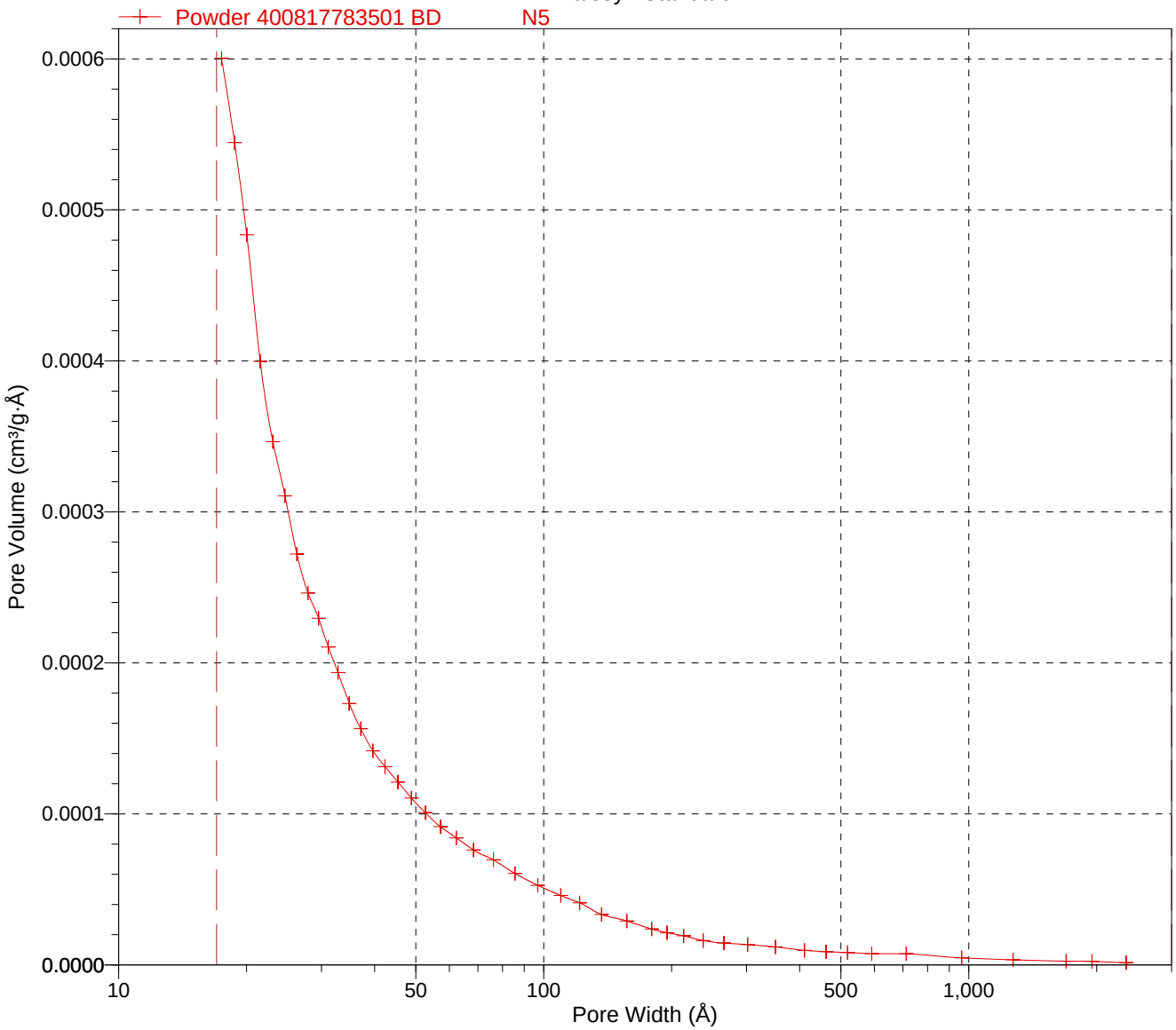
Sample: Powder 400817783501 BD N5
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200799_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:51:03 AM	Thermal Correction:	No
Sample Mass:	3.3250 g	Warm Free Space:	7.4010 cm³ Measured
Cold Free Space:	21.0952 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dV/dw Pore Volume

Halsey : Standard



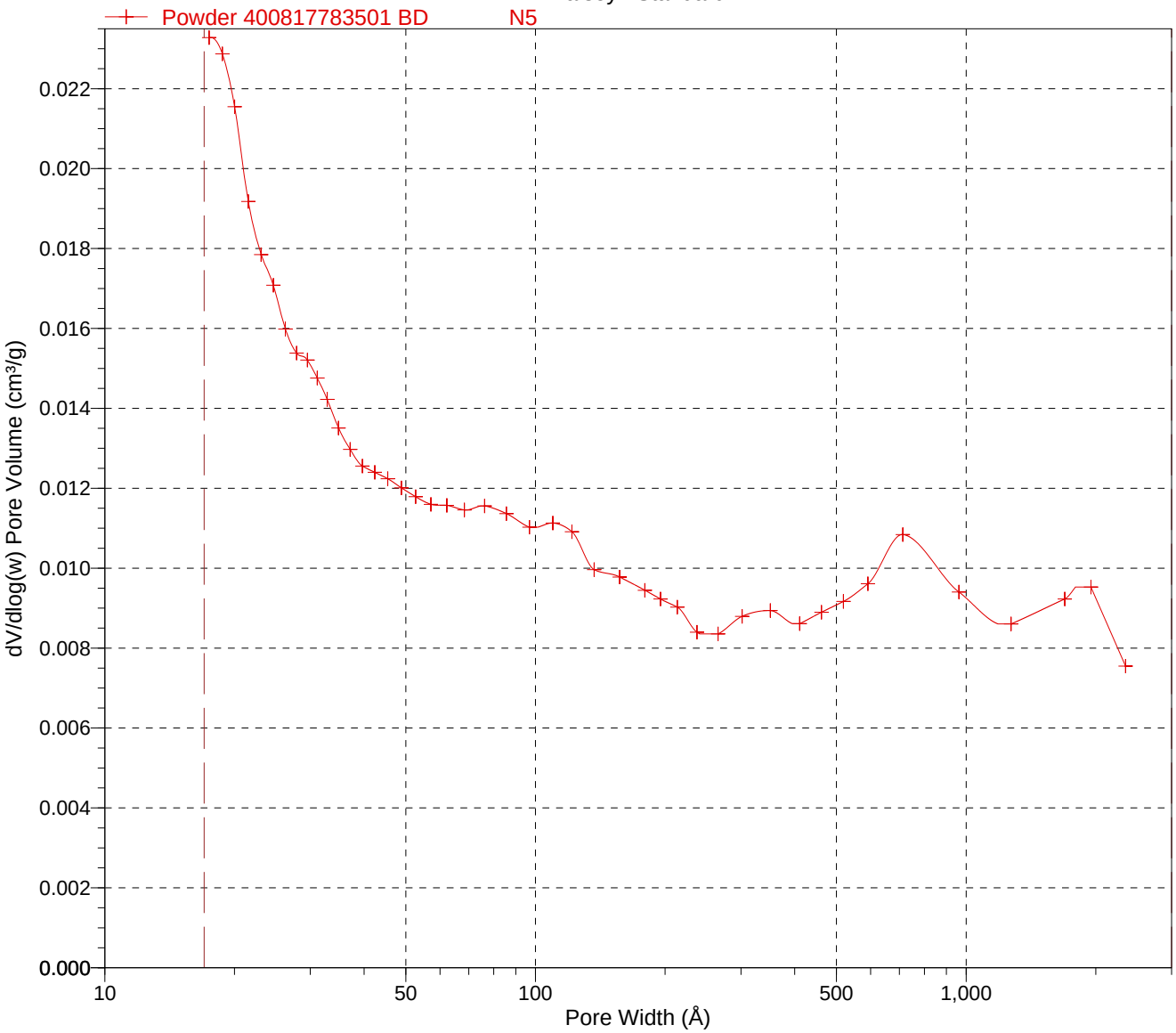
Sample: Powder 400817783501 BD N5
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200799_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:51:03 AM	Thermal Correction:	No
Sample Mass:	3.3250 g	Warm Free Space:	7.4010 cm³ Measured
Cold Free Space:	21.0952 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dV/dlog(w) Pore Volume

Halsey : Standard



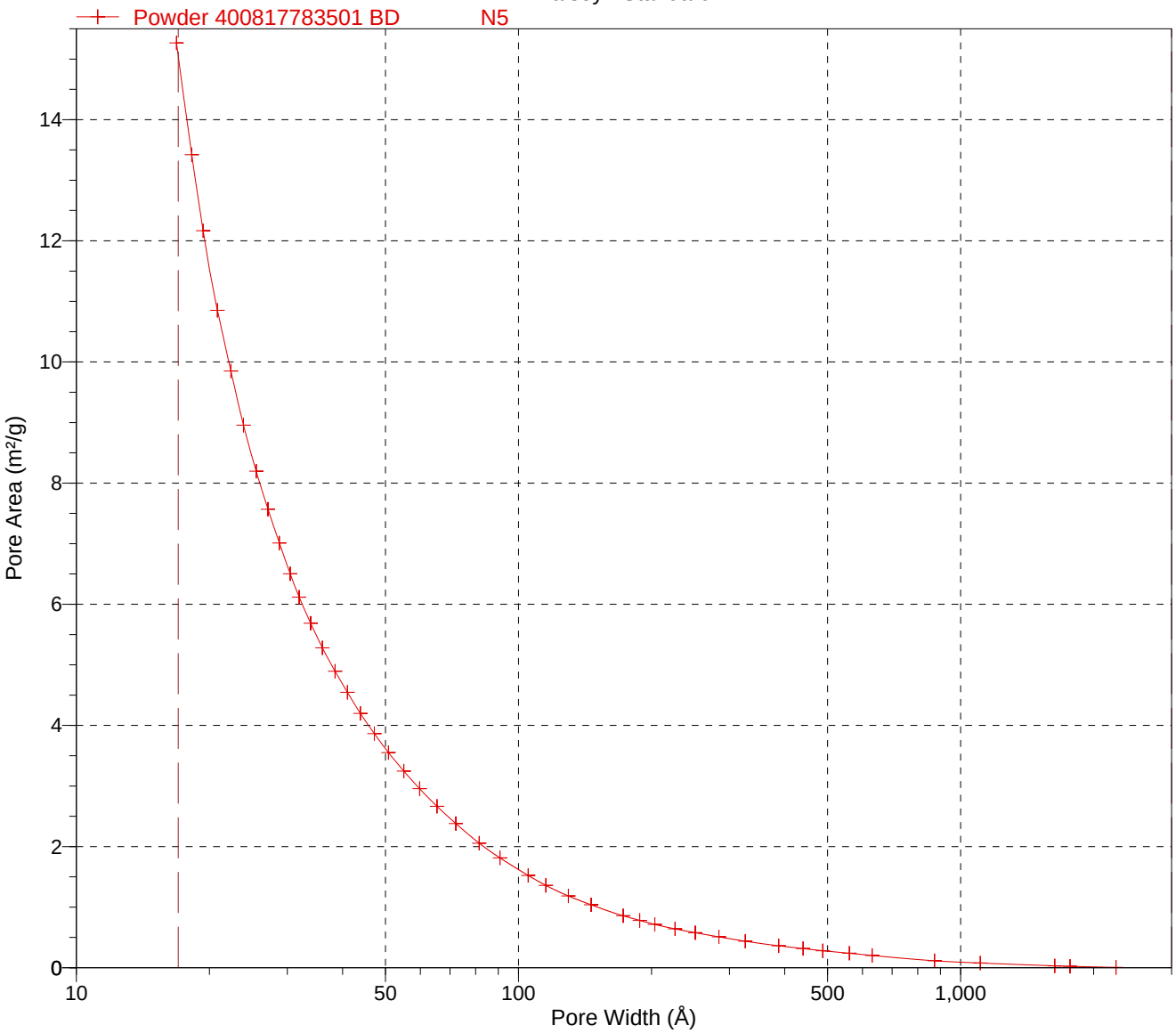
Sample: Powder 400817783501 BD N5
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200799_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:51:03 AM	Thermal Correction:	No
Sample Mass:	3.3250 g	Warm Free Space:	7.4010 cm³ Measured
Cold Free Space:	21.0952 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Cumulative Pore Area (Larger)

Halsey : Standard



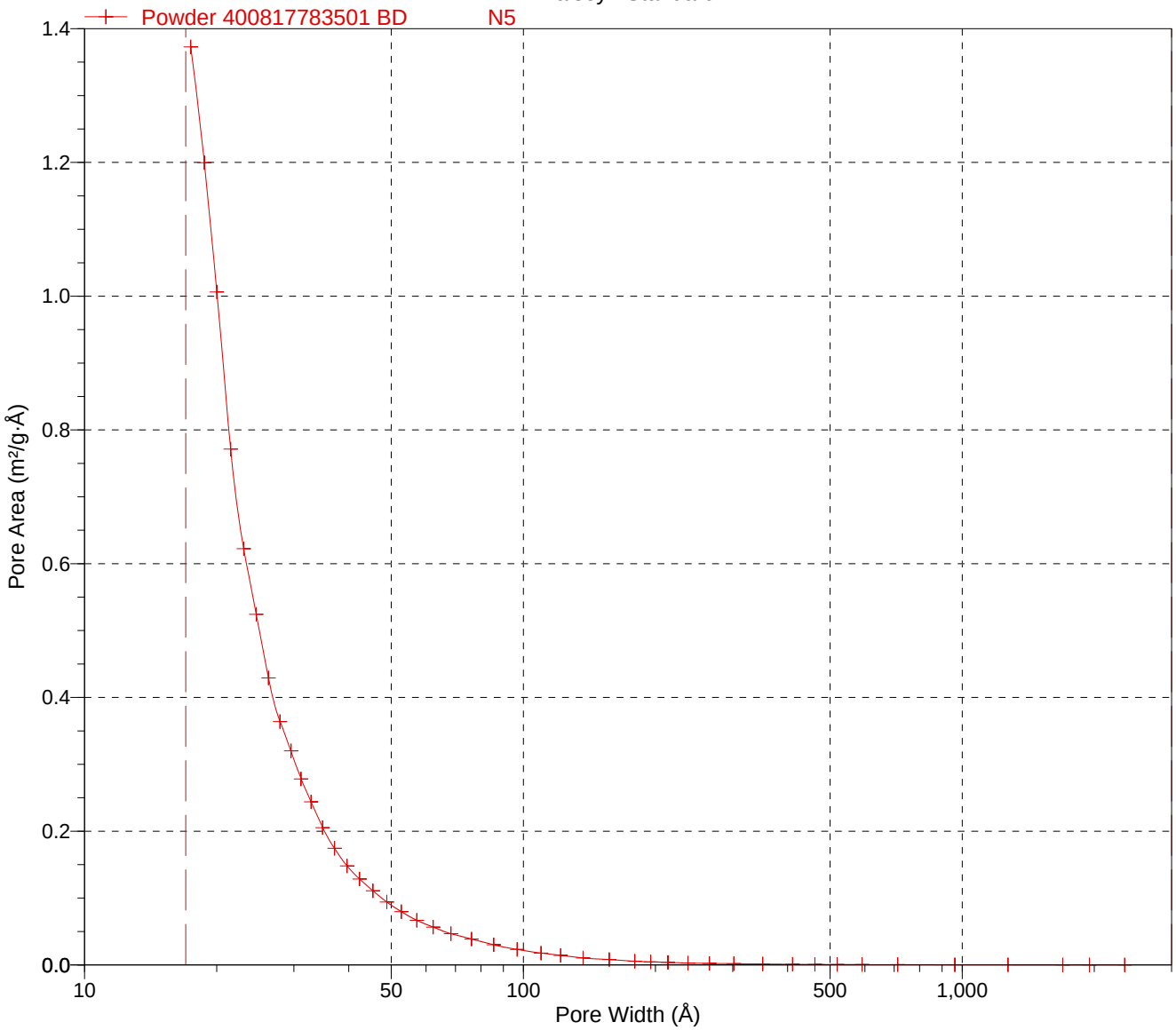
Sample: Powder 400817783501 BD N5
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200799_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:51:03 AM	Thermal Correction:	No
Sample Mass:	3.3250 g	Warm Free Space:	7.4010 cm³ Measured
Cold Free Space:	21.0952 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dA/dw Pore Area

Halsey : Standard



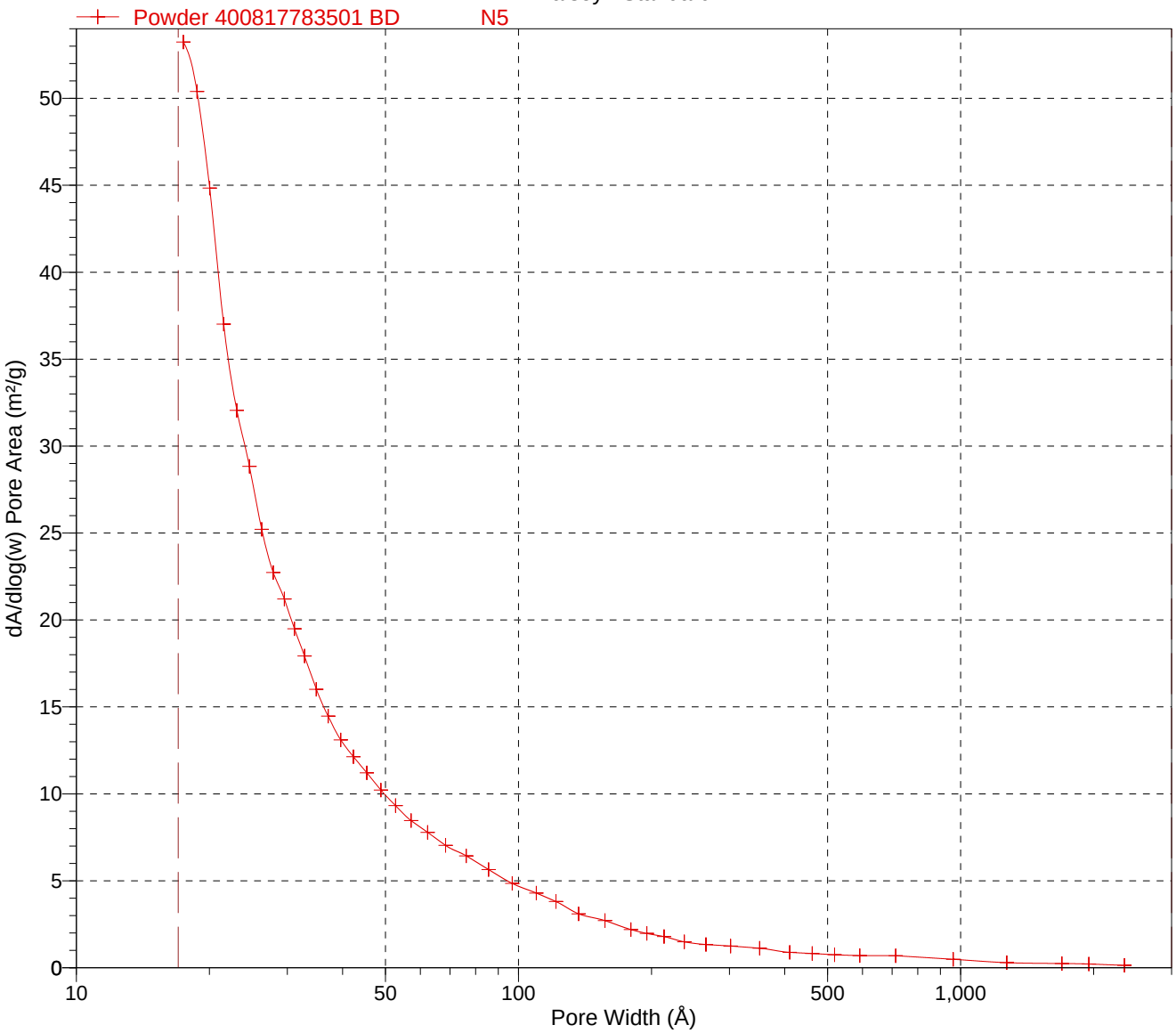
Sample: Powder 400817783501 BD N5
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200799_005-50_Run1.SMP

Started:	2/22/2012 12:01:38 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 11:38:52 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:51:03 AM	Thermal Correction:	No
Sample Mass:	3.3250 g	Warm Free Space:	7.4010 cm³ Measured
Cold Free Space:	21.0952 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dA/dlog(w) Pore Area

Halsey : Standard



Sample: Powder 425120764726 OC A6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200792_005-50_Run1.SMP

Started:	2/24/2012 12:10:11 PM	Analysis Adsorptive:	N2
Completed:	2/27/2012 7:56:55 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:52:54 AM	Thermal Correction:	No
Sample Mass:	2.7719 g	Warm Free Space:	7.3309 cm^3 Measured
Cold Free Space:	21.0573 cm^3	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm^3
Automatic Degas:	No		

Comments: Prepared the sample under nitrogen at 90 C for 960 minutes.

Summary Report

Surface Area

Single point surface area at p/p° = 0.137406735:	33.2251 m^2/g
BET Surface Area:	33.8044 m^2/g
t-Plot Micropore Area:	31.8358 m^2/g
t-Plot External Surface Area:	1.9686 m^2/g
BJH Adsorption cumulative surface area of pores between 17.000 Å and 3,000.000 Å width:	15.911 m^2/g

Pore Volume

Single point adsorption total pore volume of pores less than 3,904.644 Å width at p/p° = 0.995040862:	0.018660 cm^3/g
t-Plot micropore volume:	0.015556 cm^3/g
BJH Adsorption cumulative volume of pores between 17.000 Å and 3,000.000 Å width:	0.011614 cm^3/g

Pore Size

Adsorption average pore width (4V/A by Langmuir):	16.6909 Å
BJH Adsorption average pore width (4V/A):	29.196 Å

Sample: Powder 425120764726 OC A6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200792_005-50_Run1.SMP

Started:	2/24/2012 12:10:11 PM	Analysis Adsorptive:	N2
Completed:	2/27/2012 7:56:55 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:52:54 AM	Thermal Correction:	No
Sample Mass:	2.7719 g	Warm Free Space:	7.3309 cm³ Measured
Cold Free Space:	21.0573 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	No		

Comments: Prepared the sample under nitrogen at 90 C for 960 minutes.

Isotherm Tabular Report

Relative Pressure (p/p°)	Absolute Pressure (mmHg)	Quantity Adsorbed (cm³/g STP)	Elapsed Time (h:min)	Saturation Pressure (mmHg)
			01:03	734.050293
0.002445646	1.803773	4.8705	06:36	737.544373
0.004921125	3.644929	5.5508	10:10	740.669800
0.007322479	5.433289	6.0092	14:46	742.001282
0.009975931	7.407585	6.2568	16:33	742.545715
0.019687491	14.660878	6.9485	23:22	744.679871
0.030103251	22.362780	7.3409	26:56	742.869263
0.039316841	29.242889	7.6145	30:05	743.775146
0.048827510	36.391739	7.8402	32:41	745.312195
0.081502920	60.782101	8.3118	35:11	745.765930
0.108620882	81.050232	8.5422	35:46	746.175415
0.137406735	102.600403	8.8481	37:47	746.691223
0.171575541	128.140152	9.0901	38:54	746.843933
0.205818997	153.732056	9.2935	39:43	746.928406
0.240018382	179.298859	9.4600	40:12	747.021362
0.268926694	200.976761	9.6083	40:46	747.329163
0.297454078	222.322632	9.7334	41:09	747.418335
0.326567604	244.055786	9.8492	41:28	747.336182
0.355407350	265.678925	9.9512	41:41	747.533569
0.378264850	282.864349	10.0392	41:56	747.794434
0.410443656	307.001709	10.1464	42:09	747.975281
0.438381218	327.854889	10.2396	42:21	747.876221
0.469609664	351.291962	10.3359	42:32	748.050964
0.498441417	373.003967	10.4272	42:43	748.340637
0.529583869	396.365631	10.5196	42:52	748.447327
0.558937381	418.347504	10.6066	43:01	748.469360
0.589359620	441.082977	10.6947	43:09	748.410583
0.619132544	463.388702	10.7809	43:16	748.448303
0.649211931	485.878387	10.8679	43:22	748.412598
0.679197937	508.304291	10.9549	43:28	748.389038
0.708831491	530.549988	11.0453	43:34	748.485352
0.738878212	553.153931	11.1402	43:41	748.640198
0.768892796	575.663147	11.2378	43:46	748.691040
0.798527514	597.912292	11.3411	43:52	748.768555
0.820012220	614.017883	11.4186	43:56	748.791138
0.839759397	628.906494	11.4937	44:01	748.912720
0.859705269	643.967468	11.5729	44:05	749.056091
0.879907212	659.039063	11.6560	44:09	748.987000
0.890632467	667.108887	11.7016	44:13	749.028259

Sample: Powder 425120764726 OC A6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200792_005-50_Run1.SMP

Started:	2/24/2012 12:10:11 PM	Analysis Adsorptive:	N2
Completed:	2/27/2012 7:56:55 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:52:54 AM	Thermal Correction:	No
Sample Mass:	2.7719 g	Warm Free Space:	7.3309 cm³ Measured
Cold Free Space:	21.0573 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	No		

Comments: Prepared the sample under nitrogen at 90 C for 960 minutes.

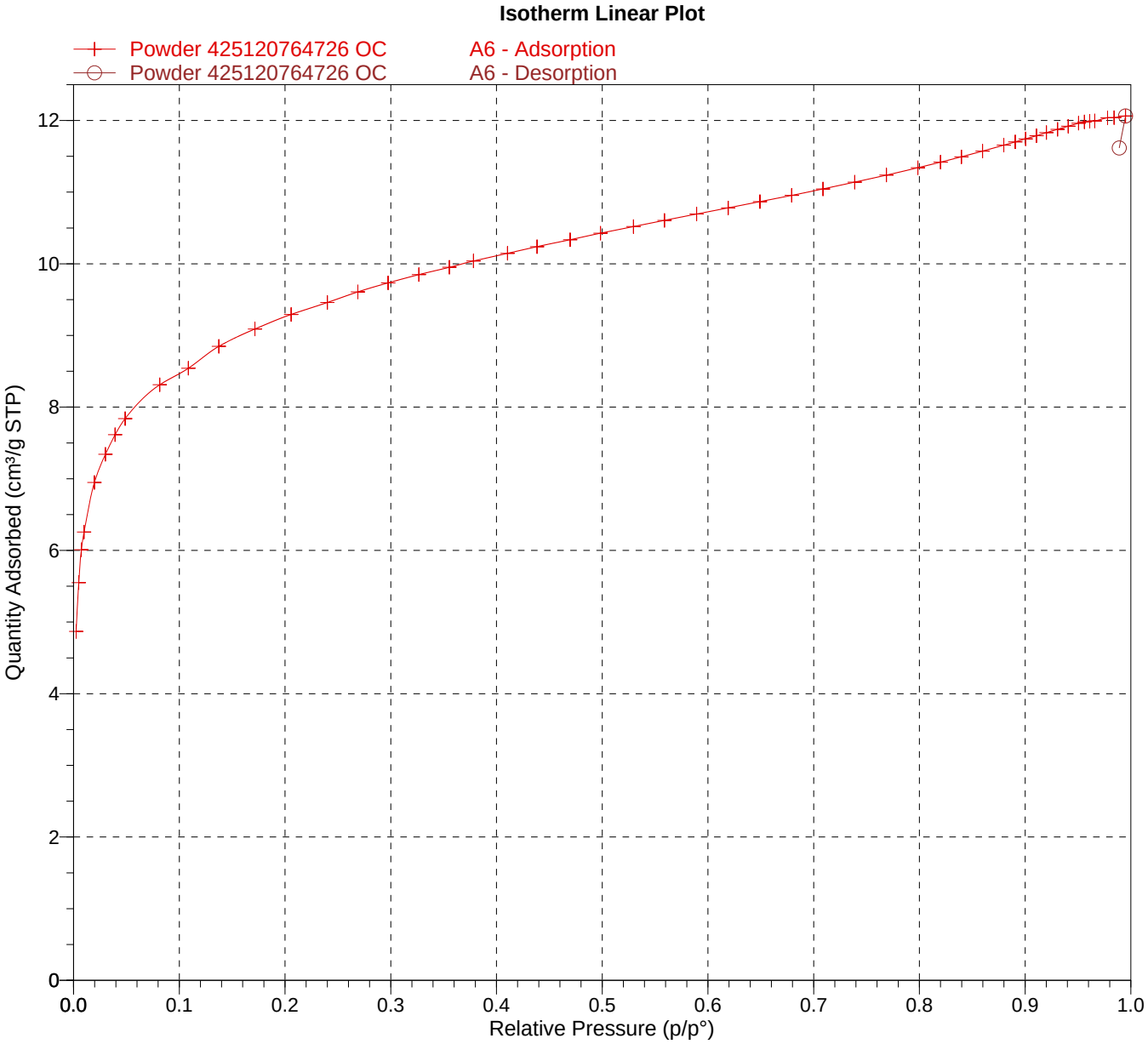
Isotherm Tabular Report

Relative Pressure (p/p°)	Absolute Pressure (mmHg)	Quantity Adsorbed (cm³/g STP)	Elapsed Time (h:min)	Saturation Pressure (mmHg)
0.900471356	674.569946	11.7446	44:16	749.129822
0.910752165	682.335144	11.7872	44:19	749.199585
0.920214308	689.442993	11.8303	44:22	749.220032
0.930764831	697.405090	11.8777	44:25	749.281738
0.940707638	704.880432	11.9202	44:28	749.308716
0.950521292	712.285522	11.9626	44:31	749.363037
0.956100526	716.480225	11.9814	44:34	749.377502
0.961078344	720.185852	11.9910	44:37	749.351868
0.965888754	723.841064	11.9955	44:40	749.404175
0.978002658	733.026184	12.0374	44:42	749.513489
0.984142404	737.560791	12.0395	44:45	749.445190
0.995040862	745.620667	12.0636	44:48	749.336731
0.989079493	741.355286	11.6173	45:07	749.540649

Sample: Powder 425120764726 OC A6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200792_005-50_Run1.SMP

Started:	2/24/2012 12:10:11 PM	Analysis Adsorptive:	N2
Completed:	2/27/2012 7:56:55 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:52:54 AM	Thermal Correction:	No
Sample Mass:	2.7719 g	Warm Free Space:	7.3309 cm³ Measured
Cold Free Space:	21.0573 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	No		

Comments: Prepared the sample under nitrogen at 90 C for 960 minutes.



Sample: Powder 425120764726 OC A6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200792_005-50_Run1.SMP

Started:	2/24/2012 12:10:11 PM	Analysis Adsorptive:	N2
Completed:	2/27/2012 7:56:55 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:52:54 AM	Thermal Correction:	No
Sample Mass:	2.7719 g	Warm Free Space:	7.3309 cm³ Measured
Cold Free Space:	21.0573 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	No		

Comments: Prepared the sample under nitrogen at 90 C for 960 minutes.

BET Surface Area Report

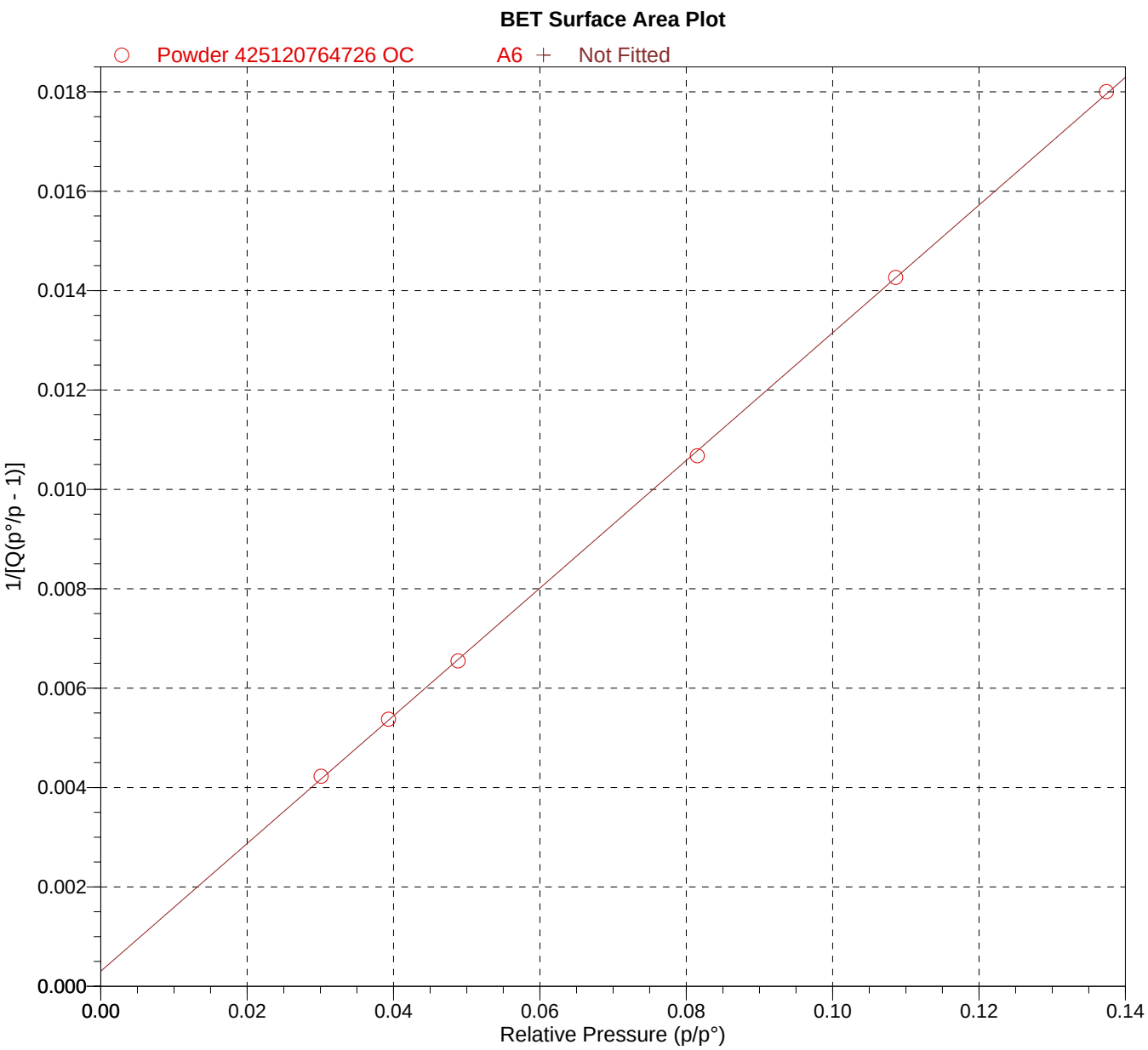
BET Surface Area: 33.8044 ± 0.1777 m²/g
Slope: 0.128472 ± 0.000675 g/cm³ STP
Y-Intercept: 0.000304 ± 0.000057 g/cm³ STP
C: 423.444193
Qm: 7.7654 cm³/g STP
Correlation Coefficient: 0.9999448
Molecular Cross-Sectional Area: 0.1620 nm²

Relative Pressure (p/p°)	Quantity Adsorbed (cm³/g STP)	1/[Q(p°/p - 1)]
0.030103251	7.3409	0.004228
0.039316841	7.6145	0.005375
0.048827510	7.8402	0.006548
0.081502920	8.3118	0.010676
0.108620882	8.5422	0.014265
0.137406735	8.8481	0.018003

Sample: Powder 425120764726 OC A6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200792_005-50_Run1.SMP

Started:	2/24/2012 12:10:11 PM	Analysis Adsorptive:	N2
Completed:	2/27/2012 7:56:55 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:52:54 AM	Thermal Correction:	No
Sample Mass:	2.7719 g	Warm Free Space:	7.3309 cm³ Measured
Cold Free Space:	21.0573 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	No		

Comments: Prepared the sample under nitrogen at 90 C for 960 minutes.



Sample: Powder 425120764726 OC A6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200792_005-50_Run1.SMP

Started:	2/24/2012 12:10:11 PM	Analysis Adsorptive:	N2
Completed:	2/27/2012 7:56:55 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:52:54 AM	Thermal Correction:	No
Sample Mass:	2.7719 g	Warm Free Space:	7.3309 cm³ Measured
Cold Free Space:	21.0573 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	No		

Comments: Prepared the sample under nitrogen at 90 C for 960 minutes.

t-Plot Report

Micropore Volume:	0.015556 cm³/g
Micropore Area:	31.8358 m²/g
External Surface Area:	1.9686 m²/g
Slope:	0.127268 ± 0.003659 cm³/g·Å STP
Y-Intercept:	10.056624 ± 0.045239 cm³/g STP
Correlation Coefficient:	0.997939
Surface Area Correction Factor:	1.000
Density Conversion Factor:	0.0015468
Total Surface Area (BET):	33.8044 m²/g
Thickness Range:	10.4392 Å to 13.9865 Å
Thickness Equation:	Harkins and Jura

Thickness Curve

t = [13.99 / (0.034 - log(p/p°))] ^ 0.5

t-Plot Report - Data

Relative Pressure (p/p°)	Statistical Thickness (Å)	Quantity Adsorbed (cm³/g STP)	Fitted
0.002445646	2.2996	4.8705	
0.004921125	2.4441	5.5508	
0.007322479	2.5395	6.0092	
0.009975931	2.6219	6.2568	
0.019687491	2.8357	6.9485	
0.030103251	2.9991	7.3409	
0.039316841	3.1176	7.6145	
0.048827510	3.2247	7.8402	
0.081502920	3.5298	8.3118	
0.108620882	3.7439	8.5422	
0.137406735	3.9515	8.8481	
0.171575541	4.1830	9.0901	
0.205818997	4.4064	9.2935	
0.240018382	4.6260	9.4600	
0.268926694	4.8113	9.6083	
0.297454078	4.9956	9.7334	
0.326567604	5.1868	9.8492	
0.355407350	5.3804	9.9512	
0.378264850	5.5377	10.0392	
0.410443656	5.7663	10.1464	
0.438381218	5.9729	10.2396	
0.469609664	6.2144	10.3359	
0.498441417	6.4490	10.4272	

Sample: Powder 425120764726 OC A6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200792_005-50_Run1.SMP

Started:	2/24/2012 12:10:11 PM	Analysis Adsorptive:	N2
Completed:	2/27/2012 7:56:55 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:52:54 AM	Thermal Correction:	No
Sample Mass:	2.7719 g	Warm Free Space:	7.3309 cm³ Measured
Cold Free Space:	21.0573 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	No		

Comments: Prepared the sample under nitrogen at 90 C for 960 minutes.

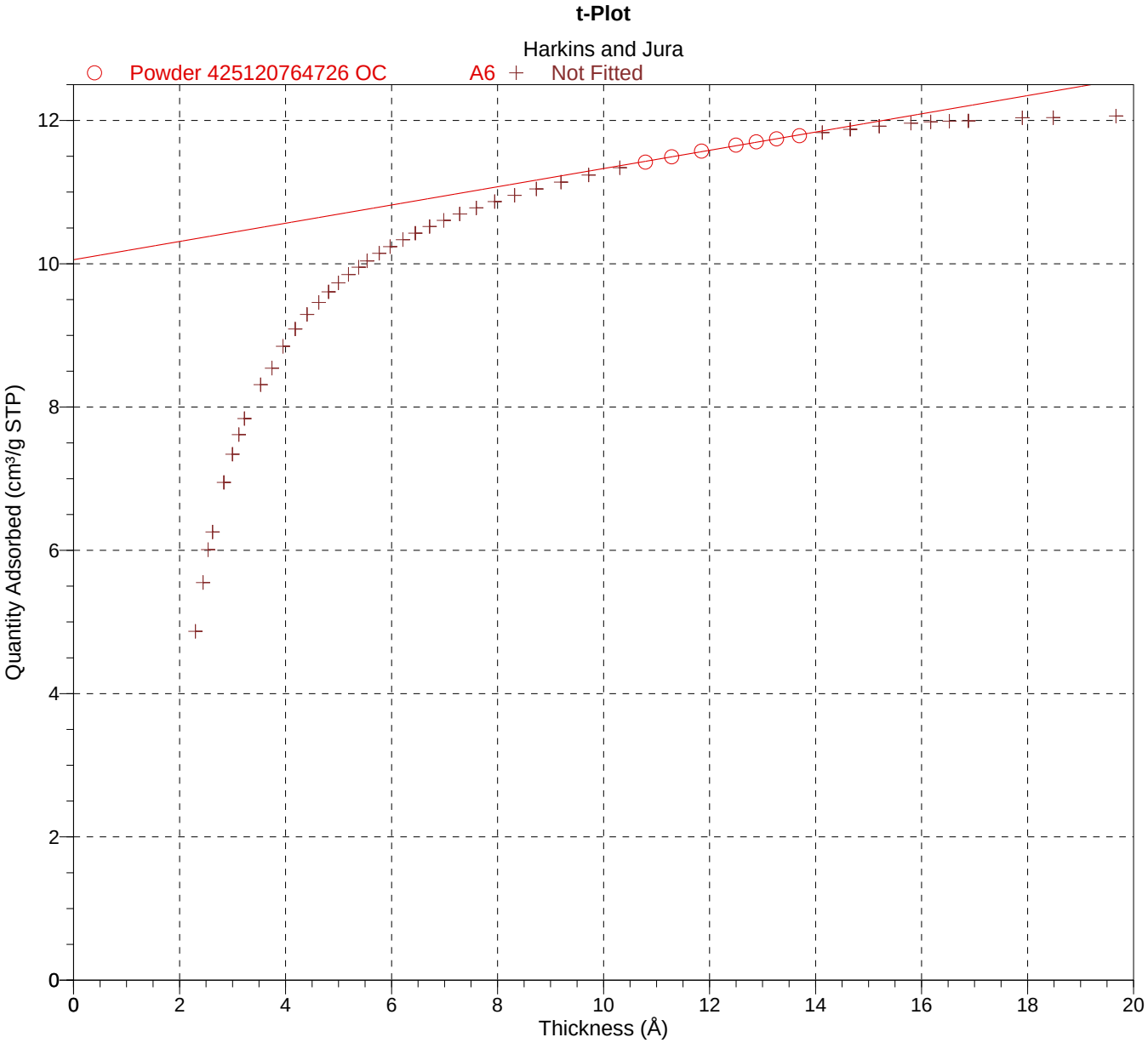
t-Plot Report - Data

Relative Pressure (p/p°)	Statistical Thickness (Å)	Quantity Adsorbed (cm³/g STP)	Fitted
0.529583869	6.7171	10.5196	
0.558937381	6.9862	10.6066	
0.589359620	7.2848	10.6947	
0.619132544	7.5999	10.7809	
0.649211931	7.9453	10.8679	
0.679197937	8.3220	10.9549	
0.708831491	8.7326	11.0453	
0.738878212	9.1961	11.1402	
0.768892796	9.7181	11.2378	
0.798527514	10.3062	11.3411	
0.820012220	10.7893	11.4186	*
0.839759397	11.2854	11.4937	*
0.859705269	11.8487	11.5729	*
0.879907212	12.4981	11.6560	*
0.890632467	12.8822	11.7016	*
0.900471356	13.2630	11.7446	*
0.910752165	13.6943	11.7872	*
0.920214308	14.1259	11.8303	
0.930764831	14.6527	11.8777	
0.940707638	15.2009	11.9202	
0.950521292	15.8004	11.9626	
0.956100526	16.1714	11.9814	
0.961078344	16.5234	11.9910	
0.965888754	16.8845	11.9955	
0.978002658	17.9006	12.0374	
0.984142404	18.4852	12.0395	
0.995040862	19.6698	12.0636	

Sample: Powder 425120764726 OC A6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200792_005-50_Run1.SMP

Started:	2/24/2012 12:10:11 PM	Analysis Adsorptive:	N2
Completed:	2/27/2012 7:56:55 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:52:54 AM	Thermal Correction:	No
Sample Mass:	2.7719 g	Warm Free Space:	7.3309 cm³ Measured
Cold Free Space:	21.0573 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	No		

Comments: Prepared the sample under nitrogen at 90 C for 960 minutes.



Sample: Powder 425120764726 OC A6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200792_005-50_Run1.SMP

Started:	2/24/2012 12:10:11 PM	Analysis Adsorptive:	N2
Completed:	2/27/2012 7:56:55 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:52:54 AM	Thermal Correction:	No
Sample Mass:	2.7719 g	Warm Free Space:	7.3309 cm³ Measured
Cold Free Space:	21.0573 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	No		

Comments: Prepared the sample under nitrogen at 90 C for 960 minutes.

BJH Adsorption Pore Distribution Report

Standard
Halsey
t = 3.54 [-5 / ln(p/p°)] ^ 0.333

Width Range: 17.000 Å to 3,000.000 Å
Adsorbate Property Factor: 9.53000 Å
Density Conversion Factor: 0.0015468
Fraction of Pores Open at Both Ends: 0.00

Pore Width Range (Å)	Average Width (Å)	Incremental Pore Volume (cm³/g)	Cumulative Pore Volume (cm³/g)	Incremental Pore Area (m²/g)	Cumulative Pore Area (m²/g)
3904.6 - 1240.4	1476.3	0.000040	0.000040	0.001	0.001
1240.4 - 899.9	1016.0	0.000003	0.000043	0.000	0.001
899.9 - 586.2	677.7	0.000073	0.000116	0.004	0.005
586.2 - 515.5	546.2	0.000007	0.000123	0.001	0.006
515.5 - 458.6	483.6	0.000017	0.000140	0.001	0.007
458.6 - 408.3	430.4	0.000034	0.000174	0.003	0.011
408.3 - 342.5	369.4	0.000077	0.000251	0.008	0.019
342.5 - 294.7	314.9	0.000078	0.000329	0.010	0.029
294.7 - 256.9	273.1	0.000089	0.000418	0.013	0.042
256.9 - 230.5	242.2	0.000082	0.000500	0.014	0.055
230.5 - 207.4	217.7	0.000082	0.000582	0.015	0.070
207.4 - 189.4	197.5	0.000084	0.000666	0.017	0.087
189.4 - 173.0	180.4	0.000090	0.000756	0.020	0.107
173.0 - 148.8	158.9	0.000168	0.000924	0.042	0.150
148.8 - 130.8	138.5	0.000163	0.001087	0.047	0.197
130.8 - 116.8	122.9	0.000158	0.001245	0.051	0.248
116.8 - 104.6	109.9	0.000166	0.001411	0.061	0.309
104.6 - 91.4	97.0	0.000228	0.001639	0.094	0.403
91.4 - 81.0	85.5	0.000221	0.001860	0.103	0.506
81.0 - 72.6	76.3	0.000221	0.002080	0.116	0.622
72.6 - 65.9	68.9	0.000215	0.002295	0.125	0.747
65.9 - 60.1	62.7	0.000211	0.002507	0.135	0.881
60.1 - 55.2	57.4	0.000217	0.002724	0.151	1.033
55.2 - 51.0	52.9	0.000221	0.002945	0.167	1.200
51.0 - 47.3	49.0	0.000232	0.003177	0.190	1.390
47.3 - 44.1	45.5	0.000236	0.003413	0.207	1.597
44.1 - 41.0	42.4	0.000256	0.003669	0.242	1.839
41.0 - 38.5	39.7	0.000262	0.003932	0.265	2.103
38.5 - 36.0	37.2	0.000281	0.004213	0.303	2.406
36.0 - 34.0	34.9	0.000283	0.004496	0.324	2.730
34.0 - 31.8	32.8	0.000331	0.004827	0.404	3.134

Sample: Powder 425120764726 OC A6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200792_005-50_Run1.SMP

Started:	2/24/2012 12:10:11 PM	Analysis Adsorptive:	N2
Completed:	2/27/2012 7:56:55 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:52:54 AM	Thermal Correction:	No
Sample Mass:	2.7719 g	Warm Free Space:	7.3309 cm³ Measured
Cold Free Space:	21.0573 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	No		

Comments: Prepared the sample under nitrogen at 90 C for 960 minutes.

Pore Width Range (Å)	Average Width (Å)	Incremental Pore Volume (cm³/g)	Cumulative Pore Volume (cm³/g)	Incremental Pore Area (m²/g)	Cumulative Pore Area (m²/g)
31.8 - 30.4	31.1	0.000287	0.005114	0.369	3.503
30.4 - 28.7	29.5	0.000327	0.005441	0.444	3.947
28.7 - 27.1	27.8	0.000392	0.005833	0.564	4.511
27.1 - 25.6	26.3	0.000441	0.006274	0.672	5.183
25.6 - 24.1	24.8	0.000554	0.006828	0.895	6.078
24.1 - 22.4	23.2	0.000611	0.007439	1.053	7.131
22.4 - 20.8	21.6	0.000806	0.008245	1.496	8.627
20.8 - 19.2	19.9	0.001015	0.009260	2.035	10.662
19.2 - 17.9	18.5	0.001466	0.010725	3.173	13.835
17.9 - 16.5	17.1	0.000888	0.011614	2.077	15.911

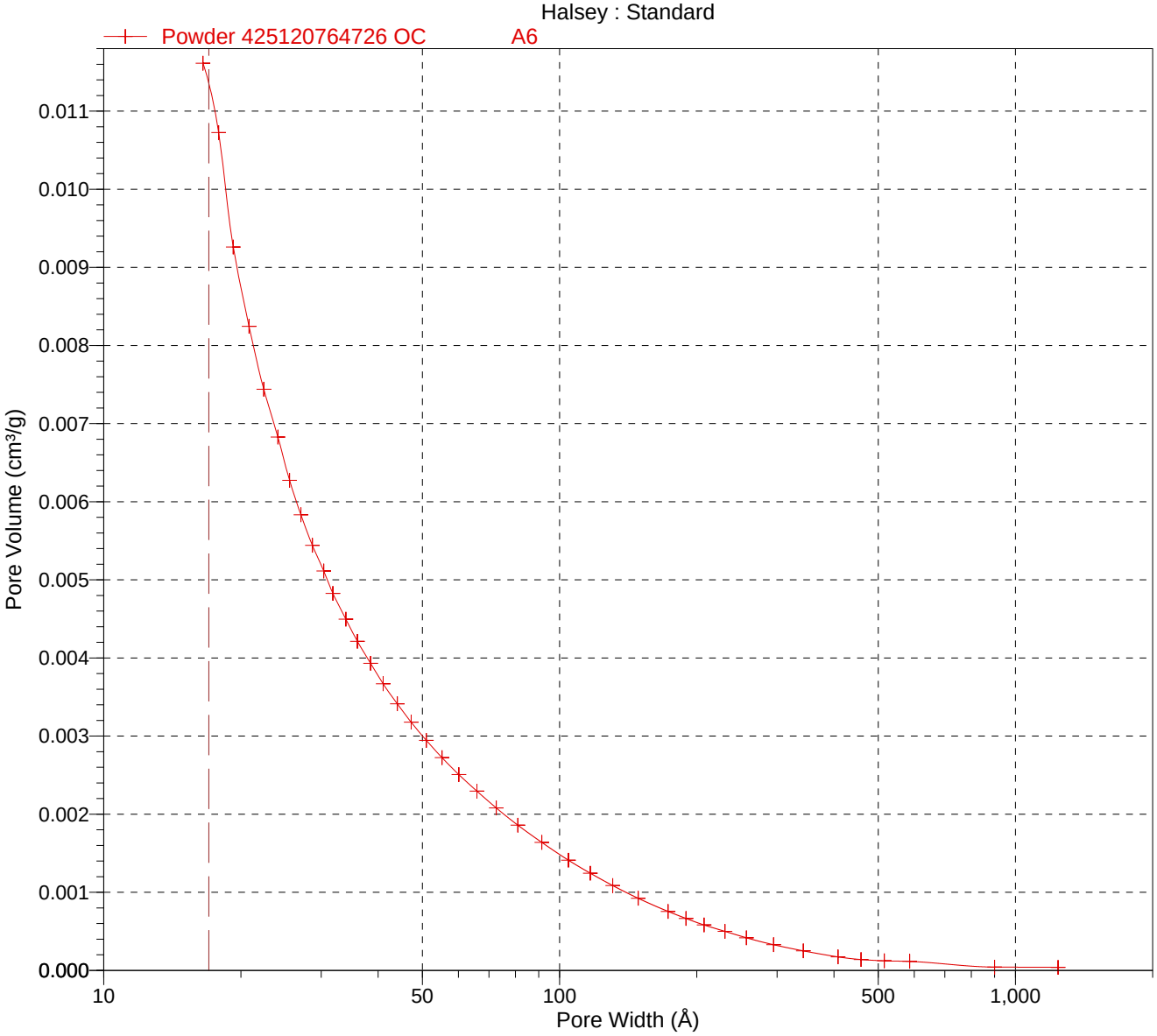
Sample: Powder 425120764726 OC A6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200792_005-50_Run1.SMP

Started:	2/24/2012 12:10:11 PM	Analysis Adsorptive:	N2
Completed:	2/27/2012 7:56:55 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:52:54 AM	Thermal Correction:	No
Sample Mass:	2.7719 g	Warm Free Space:	7.3309 cm³ Measured
Cold Free Space:	21.0573 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	No		

Comments: Prepared the sample under nitrogen at 90 C for 960 minutes.

BJH Adsorption Cumulative Pore Volume (Larger)

Halsey : Standard



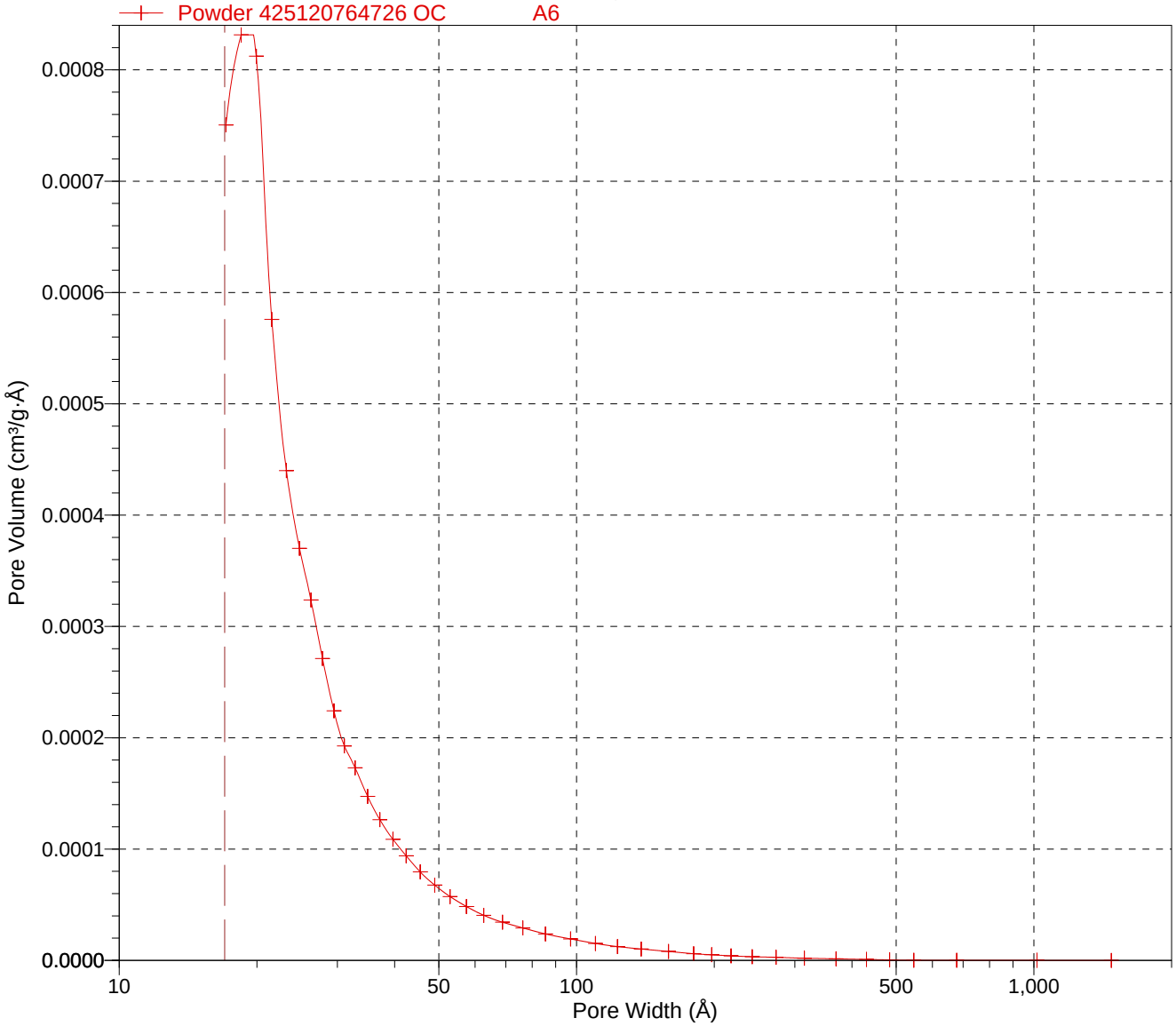
Sample: Powder 425120764726 OC A6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200792_005-50_Run1.SMP

Started:	2/24/2012 12:10:11 PM	Analysis Adsorptive:	N2
Completed:	2/27/2012 7:56:55 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:52:54 AM	Thermal Correction:	No
Sample Mass:	2.7719 g	Warm Free Space:	7.3309 cm³ Measured
Cold Free Space:	21.0573 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	No		

Comments: Prepared the sample under nitrogen at 90 C for 960 minutes.

BJH Adsorption dV/dw Pore Volume

Halsey : Standard



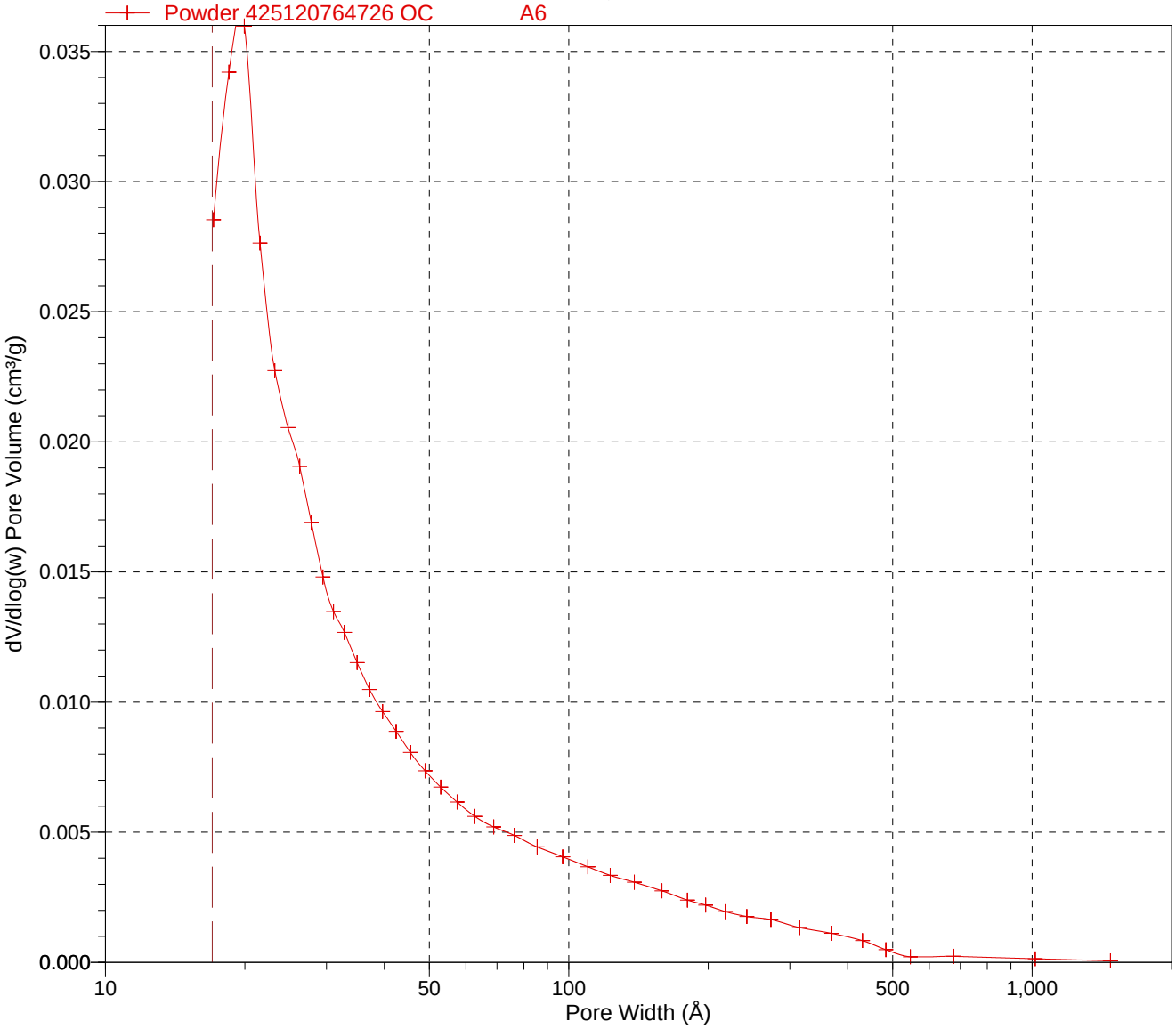
Sample: Powder 425120764726 OC A6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200792_005-50_Run1.SMP

Started:	2/24/2012 12:10:11 PM	Analysis Adsorptive:	N2
Completed:	2/27/2012 7:56:55 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:52:54 AM	Thermal Correction:	No
Sample Mass:	2.7719 g	Warm Free Space:	7.3309 cm³ Measured
Cold Free Space:	21.0573 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	No		

Comments: Prepared the sample under nitrogen at 90 C for 960 minutes.

BJH Adsorption dV/dlog(w) Pore Volume

Halsey : Standard



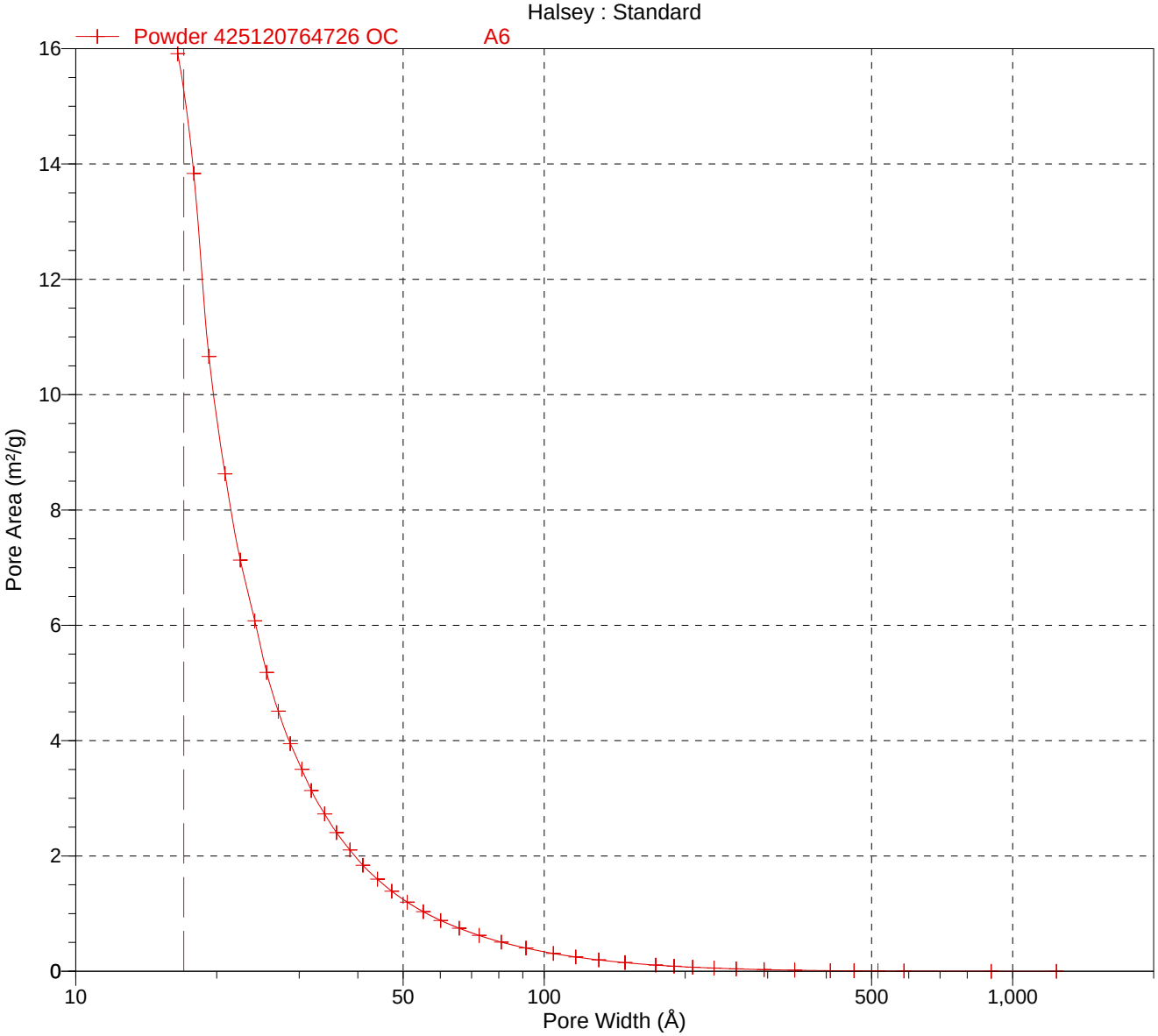
Sample: Powder 425120764726 OC A6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200792_005-50_Run1.SMP

Started:	2/24/2012 12:10:11 PM	Analysis Adsorptive:	N2
Completed:	2/27/2012 7:56:55 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:52:54 AM	Thermal Correction:	No
Sample Mass:	2.7719 g	Warm Free Space:	7.3309 cm³ Measured
Cold Free Space:	21.0573 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	No		

Comments: Prepared the sample under nitrogen at 90 C for 960 minutes.

BJH Adsorption Cumulative Pore Area (Larger)

Halsey : Standard



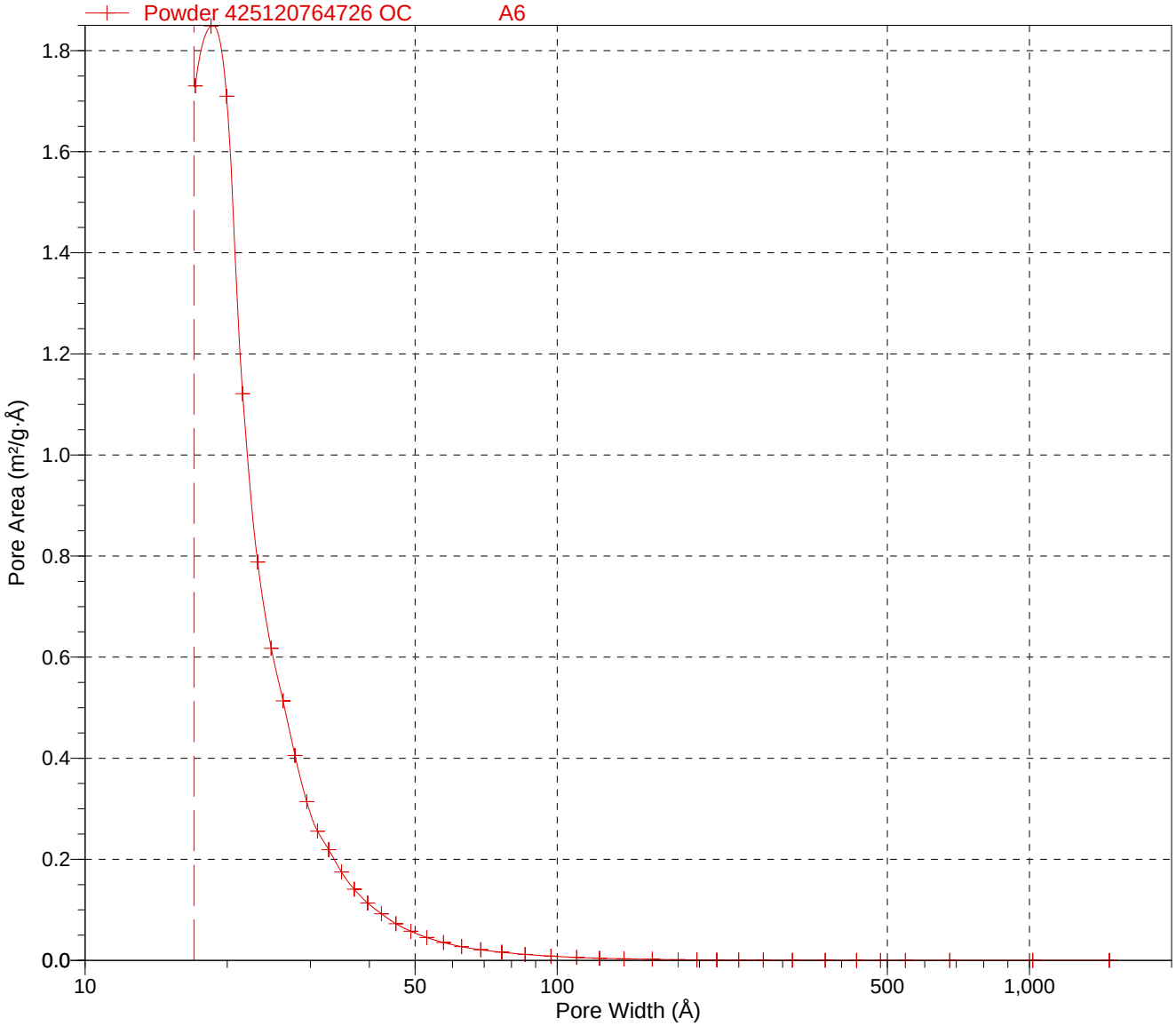
Sample: Powder 425120764726 OC A6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200792_005-50_Run1.SMP

Started:	2/24/2012 12:10:11 PM	Analysis Adsorptive:	N2
Completed:	2/27/2012 7:56:55 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:52:54 AM	Thermal Correction:	No
Sample Mass:	2.7719 g	Warm Free Space:	7.3309 cm³ Measured
Cold Free Space:	21.0573 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	No		

Comments: Prepared the sample under nitrogen at 90 C for 960 minutes.

BJH Adsorption dA/dw Pore Area

Halsey : Standard



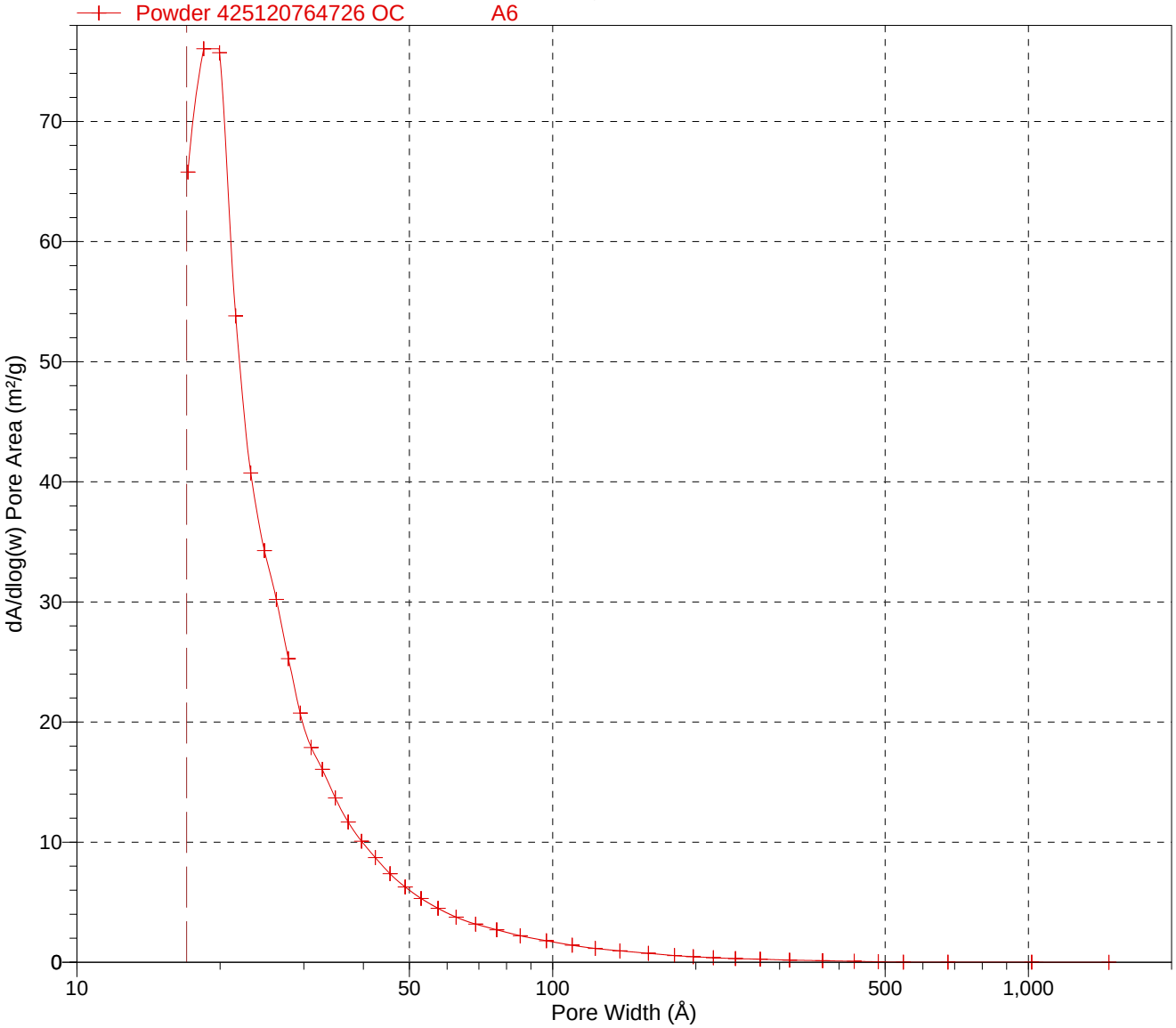
Sample: Powder 425120764726 OC A6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200792_005-50_Run1.SMP

Started:	2/24/2012 12:10:11 PM	Analysis Adsorptive:	N2
Completed:	2/27/2012 7:56:55 AM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:52:54 AM	Thermal Correction:	No
Sample Mass:	2.7719 g	Warm Free Space:	7.3309 cm³ Measured
Cold Free Space:	21.0573 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	No		

Comments: Prepared the sample under nitrogen at 90 C for 960 minutes.

BJH Adsorption dA/dlog(w) Pore Area

Halsey : Standard



Sample: Powder 425120764726 US B4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200793_005-50_Run1.SMP

Started:	2/22/2012 12:01:07 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 2:15:34 PM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:34:28 AM	Thermal Correction:	No
Sample Mass:	2.6690 g	Warm Free Space:	7.6892 cm³ Measured
Cold Free Space:	22.2270 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Summary Report

Surface Area

Single point surface area at p/p° = 0.202465262:	17.8214 m²/g
BET Surface Area:	18.1124 m²/g
t-Plot Micropore Area:	8.6155 m²/g
t-Plot External Surface Area:	9.4969 m²/g
BJH Adsorption cumulative surface area of pores between 17.000 Å and 3,000.000 Å width:	14.861 m²/g

Pore Volume

Single point adsorption total pore volume of pores less than 2,338.596 Å width at p/p° = 0.991671844:	0.036103 cm³/g
t-Plot micropore volume:	0.004082 cm³/g
BJH Adsorption cumulative volume of pores between 17.000 Å and 3,000.000 Å width:	0.035176 cm³/g

Pore Size

Adsorption average pore width (4V/A by BET):	79.7319 Å
BJH Adsorption average pore width (4V/A):	94.678 Å

Sample: Powder 425120764726 US B4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200793_005-50_Run1.SMP

Started:	2/22/2012 12:01:07 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 2:15:34 PM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:34:28 AM	Thermal Correction:	No
Sample Mass:	2.6690 g	Warm Free Space:	7.6892 cm³ Measured
Cold Free Space:	22.2270 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Tabular Report

Relative Pressure (p/p°)	Absolute Pressure (mmHg)	Quantity Adsorbed (cm³/g STP)	Elapsed Time (h:min)	Saturation Pressure (mmHg)
			01:05	738.750793
0.002508650	1.846007	2.5455	03:14	735.856750
0.004912003	3.612232	2.8950	04:01	735.388855
0.007448905	5.467378	3.1332	05:37	733.984131
0.009824976	7.206269	3.2597	06:10	733.464233
0.020245069	14.826100	3.6284	08:42	732.331421
0.029839633	21.846048	3.8232	10:08	732.115173
0.040952248	29.956095	3.9870	11:04	731.488403
0.050793868	37.159481	4.1088	11:45	731.574158
0.079027432	57.850468	4.3712	12:28	732.030212
0.108900309	79.717346	4.5897	12:58	732.021301
0.139924077	102.434570	4.7891	13:23	732.072510
0.171509624	125.530525	4.9673	13:40	731.915344
0.202465262	148.179733	5.1331	13:55	731.877319
0.233757684	171.072830	5.2938	14:07	731.838318
0.265115803	194.025528	5.4500	14:17	731.851990
0.296325275	216.855209	5.6041	14:26	731.814758
0.325572974	238.275024	5.7474	14:34	731.863647
0.355849138	260.431702	5.8962	14:42	731.859863
0.379136052	277.495239	6.0119	14:49	731.914673
0.408980099	299.311401	6.1573	14:56	731.848328
0.438354267	320.764130	6.3014	15:03	731.746338
0.468163213	342.547028	6.4511	15:09	731.682922
0.498032011	364.470398	6.6049	15:16	731.821228
0.527860811	386.333801	6.7630	15:22	731.885742
0.557723961	408.221771	6.9292	15:29	731.942322
0.587748617	430.255951	7.1041	15:35	732.040771
0.618281553	452.668854	7.2969	15:41	732.140320
0.647520665	474.073853	7.4958	15:48	732.137024
0.676881816	495.668854	7.7165	15:54	732.282715
0.707474905	518.060547	7.9718	16:01	732.267029
0.741022806	542.539368	8.2949	16:12	732.149353
0.766931921	561.590393	8.5825	16:19	732.255859
0.799953682	585.669800	9.0122	16:29	732.129639
0.818368611	599.131836	9.3020	16:36	732.105103
0.837507996	613.050537	9.6425	16:44	731.993652
0.856443417	627.032837	10.0419	16:51	732.135742
0.879681678	644.341003	10.6388	17:03	732.470642
0.889380457	651.323425	10.9300	17:10	732.333862

Sample: Powder 425120764726 US B4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200793_005-50_Run1.SMP

Started:	2/22/2012 12:01:07 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 2:15:34 PM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:34:28 AM	Thermal Correction:	No
Sample Mass:	2.6690 g	Warm Free Space:	7.6892 cm³ Measured
Cold Free Space:	22.2270 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Tabular Report

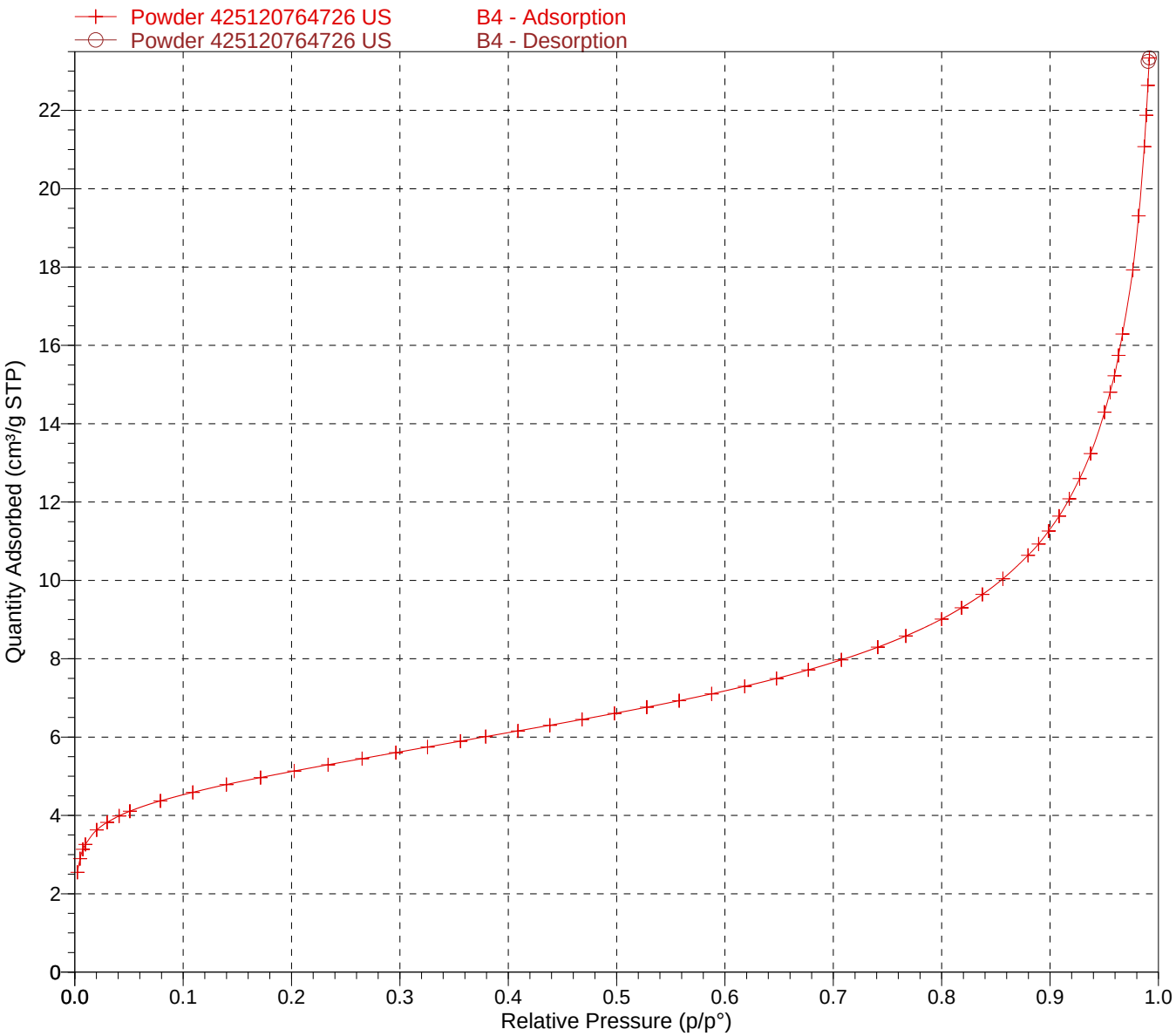
Relative Pressure (p/p°)	Absolute Pressure (mmHg)	Quantity Adsorbed (cm³/g STP)	Elapsed Time (h:min)	Saturation Pressure (mmHg)
0.898658338	658.138062	11.2612	17:17	732.356262
0.908296211	665.109436	11.6410	17:25	732.260498
0.917809158	672.212524	12.0821	17:33	732.409912
0.927321415	679.299500	12.5980	17:42	732.539429
0.937438792	686.657837	13.2356	17:51	732.482849
0.950214422	696.102356	14.2953	18:08	732.573975
0.955477273	699.932007	14.8046	18:16	732.546997
0.959475341	702.821777	15.2232	18:23	732.506348
0.963168427	705.634155	15.7457	18:31	732.617615
0.966837931	708.359558	16.2885	18:39	732.655945
0.976390119	715.514221	17.9259	18:55	732.815918
0.981785112	719.384705	19.3079	19:12	732.731323
0.987058494	723.492188	21.0735	19:34	732.978027
0.988794808	724.778870	21.8768	19:48	732.992188
0.990281088	726.186951	22.6388	19:59	733.313965
0.991671844	727.304260	23.3407	20:11	733.412231
0.990521802	726.446960	23.2517	20:15	733.398254

Sample: Powder 425120764726 US B4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200793_005-50_Run1.SMP

Started:	2/22/2012 12:01:07 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 2:15:34 PM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:34:28 AM	Thermal Correction:	No
Sample Mass:	2.6690 g	Warm Free Space:	7.6892 cm³ Measured
Cold Free Space:	22.2270 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Linear Plot



Sample: Powder 425120764726 US B4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200793_005-50_Run1.SMP

Started:	2/22/2012 12:01:07 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 2:15:34 PM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:34:28 AM	Thermal Correction:	No
Sample Mass:	2.6690 g	Warm Free Space:	7.6892 cm³ Measured
Cold Free Space:	22.2270 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BET Surface Area Report

BET Surface Area:	18.1124 ± 0.1288 m²/g
Slope:	0.239677 ± 0.001693 g/cm³ STP
Y-Intercept:	0.000666 ± 0.000230 g/cm³ STP
C:	360.776170
Qm:	4.1607 cm³/g STP
Correlation Coefficient:	0.9999002
Molecular Cross-Sectional Area:	0.1620 nm²

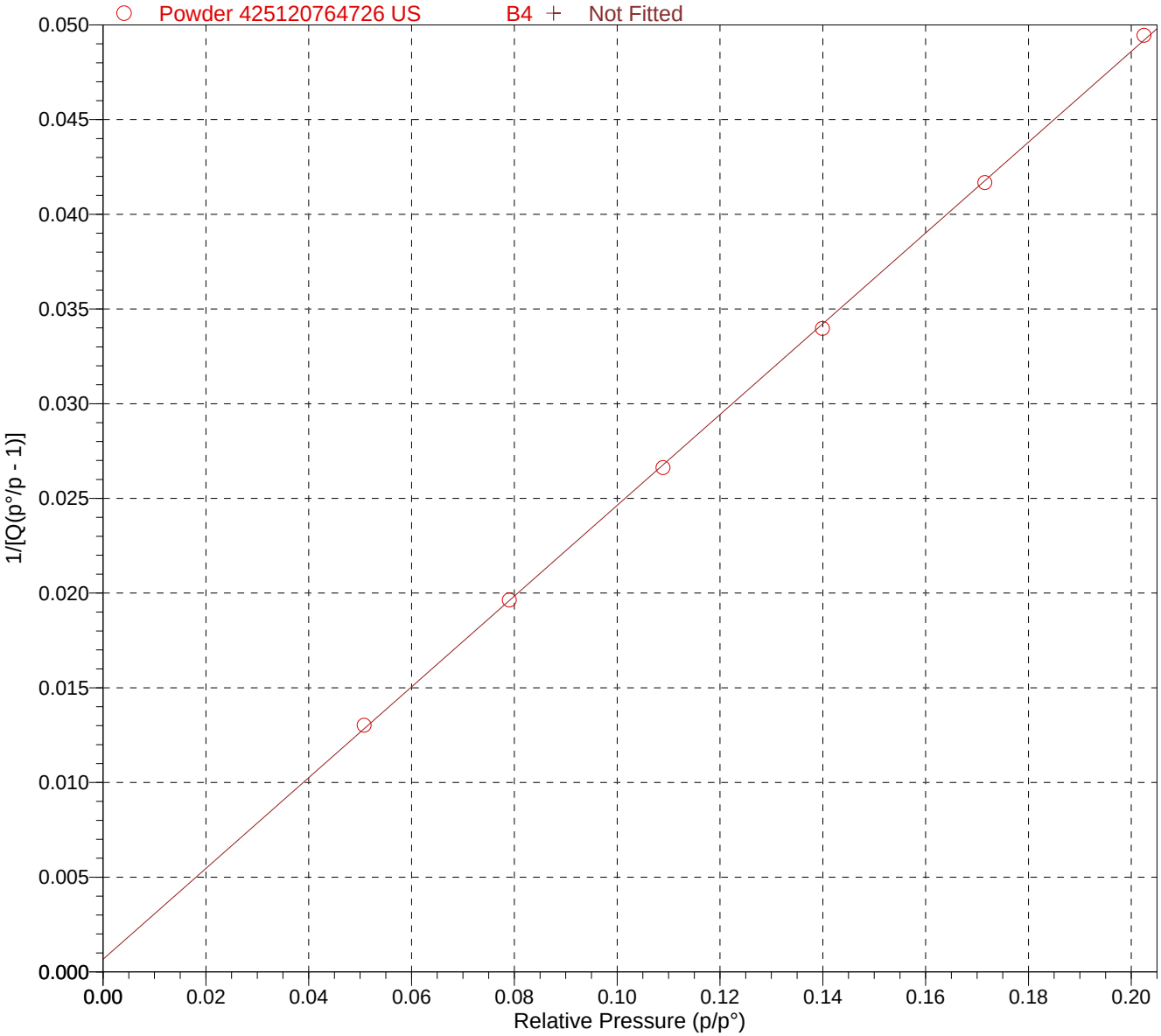
Relative Pressure (p/p°)	Quantity Adsorbed (cm³/g STP)	1/[Q(p°/p - 1)]
0.050793868	4.1088	0.013024
0.079027432	4.3712	0.019630
0.108900309	4.5897	0.026627
0.139924077	4.7891	0.033971
0.171509624	4.9673	0.041676
0.202465262	5.1331	0.049456

Sample: Powder 425120764726 US B4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200793_005-50_Run1.SMP

Started:	2/22/2012 12:01:07 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 2:15:34 PM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:34:28 AM	Thermal Correction:	No
Sample Mass:	2.6690 g	Warm Free Space:	7.6892 cm³ Measured
Cold Free Space:	22.2270 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BET Surface Area Plot



Sample: Powder 425120764726 US B4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200793_005-50_Run1.SMP

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Completed:	2/23/2012 2:15:34 PM	Analysis Bath Temp.:	77.300 K
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Cold Free Space:	22.2270 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot Report

Micropore Volume:	0.004082 cm³/g
Micropore Area:	8.6155 m²/g
External Surface Area:	9.4969 m²/g
Slope:	0.613972 ± 0.002559 cm³/g·Å STP
Y-Intercept:	2.638986 ± 0.020237 cm³/g STP
Correlation Coefficient:	0.999904
Surface Area Correction Factor:	1.000
Density Conversion Factor:	0.0015468
Total Surface Area (BET):	18.1124 m²/g
Thickness Range:	5.7721 Å to 10.4805 Å
Thickness Equation:	Harkins and Jura

Thickness Curve

t = [13.99 / (0.034 - log(p/p°))] ^ 0.5

t-Plot Report - Data

Relative Pressure (p/p°)	Statistical Thickness (Å)	Quantity Adsorbed (cm³/g STP)	Fitted
0.002508650	2.3044	2.5455	
0.004912003	2.4437	2.8950	
0.007448905	2.5438	3.1332	
0.009824976	2.6177	3.2597	
0.020245069	2.8456	3.6284	
0.029839633	2.9954	3.8232	
0.040952248	3.1369	3.9870	
0.050793868	3.2455	4.1088	
0.079027432	3.5090	4.3712	
0.108900309	3.7460	4.5897	
0.139924077	3.9690	4.7891	
0.171509624	4.1826	4.9673	
0.202465262	4.3848	5.1331	
0.233757684	4.5859	5.2938	
0.265115803	4.7868	5.4500	
0.296325275	4.9883	5.6041	
0.325572974	5.1802	5.7474	
0.355849138	5.3834	5.8962	
0.379136052	5.5438	6.0119	
0.408980099	5.7557	6.1573	
0.438354267	5.9727	6.3014	*
0.468163213	6.2029	6.4511	*
0.498032011	6.4455	6.6049	*

Sample: Powder 425120764726 US B4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200793_005-50_Run1.SMP

Started:	2/22/2012 12:01:07 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 2:15:34 PM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:34:28 AM	Thermal Correction:	No
Sample Mass:	2.6690 g	Warm Free Space:	7.6892 cm³ Measured
Cold Free Space:	22.2270 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot Report - Data

Relative Pressure (p/p°)	Statistical Thickness (Å)	Quantity Adsorbed (cm³/g STP)	Fitted
0.527860811	6.7018	6.7630	*
0.557723961	6.9748	6.9292	*
0.587748617	7.2685	7.1041	*
0.618281553	7.5905	7.2969	*
0.647520665	7.9251	7.4958	*
0.676881816	8.2916	7.7165	*
0.707474905	8.7128	7.9718	*
0.741022806	9.2313	8.2949	*
0.766931921	9.6819	8.5825	*
0.799953682	10.3367	9.0122	*
0.818368611	10.7504	9.3020	
0.837507996	11.2260	9.6425	
0.856443417	11.7517	10.0419	
0.879681678	12.4903	10.6388	
0.889380457	12.8358	10.9300	
0.898658338	13.1907	11.2612	
0.908296211	13.5879	11.6410	
0.917809158	14.0128	12.0821	
0.927321415	14.4750	12.5980	
0.937438792	15.0146	13.2356	
0.950214422	15.7806	14.2953	
0.955477273	16.1287	14.8046	
0.959475341	16.4077	15.2232	
0.963168427	16.6776	15.7457	
0.966837931	16.9584	16.2885	
0.976390119	17.7555	17.9259	
0.981785112	18.2545	19.3079	
0.987058494	18.7823	21.0735	
0.988794808	18.9657	21.8768	
0.990281088	19.1268	22.6388	
0.991671844	19.2810	23.3407	

Sample: Powder 425120764726 US B4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200793_005-50_Run1.SMP

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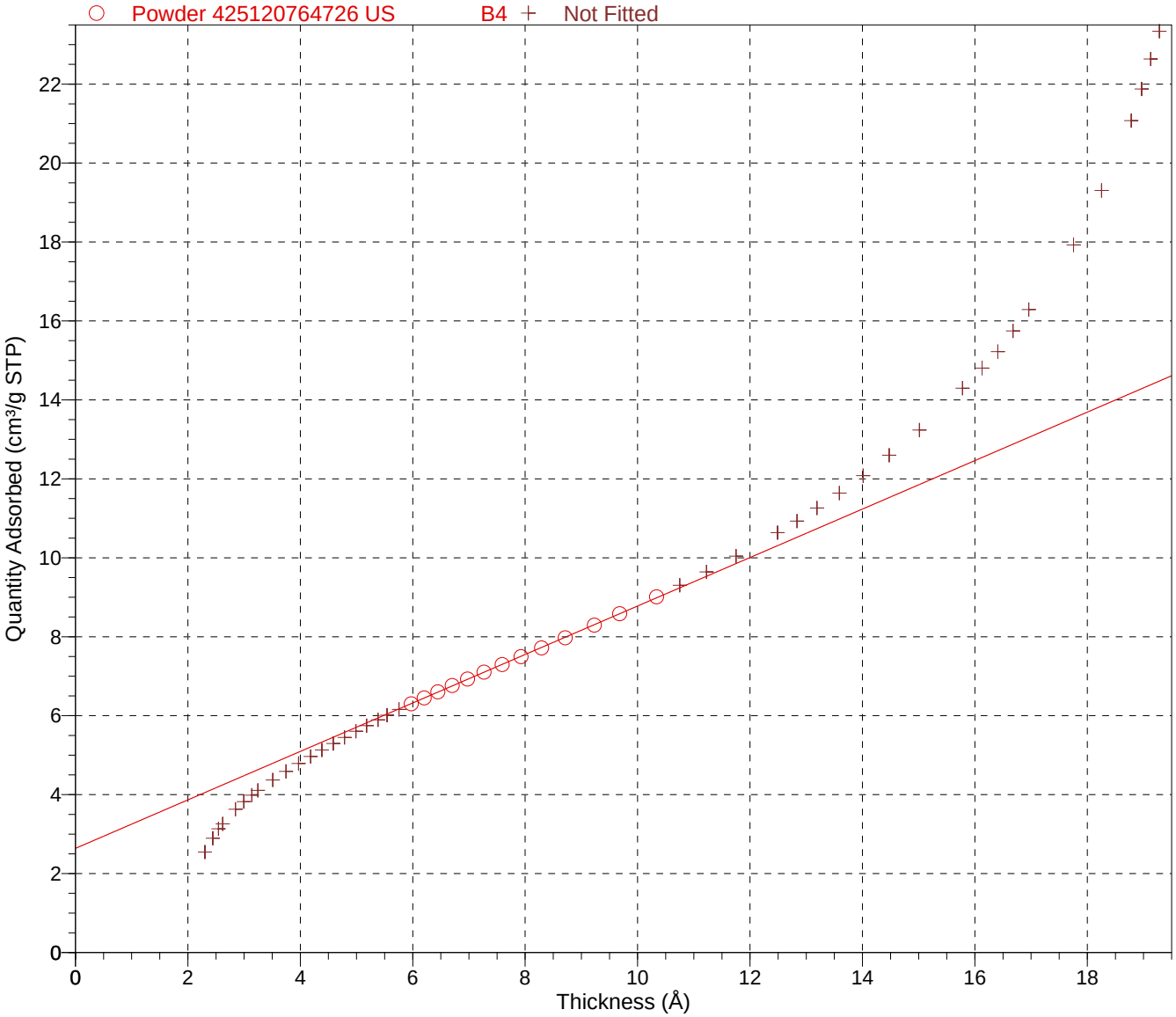
Completed:	2/23/2012 2:15:34 PM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:34:28 AM	Thermal Correction:	No
Sample Mass:	2.6690 g	Warm Free Space:	7.6892 cm³ Measured
Cold Free Space:	22.2270 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot

Harkins and Jura



Sample: Powder 425120764726 US B4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200793_005-50_Run1.SMP

Started:	2/22/2012 12:01:07 PM	Analysis Adsorptive:	N2
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Cold Free Space:	22.2270 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Pore Distribution Report

Standard
Halsey
t = 3.54 [-5 / ln(p/p°)] ^ 0.333

Width Range: 17.000 Å to 3,000.000 Å
Adsorbate Property Factor: 9.53000 Å
Density Conversion Factor: 0.0015468
Fraction of Pores Open at Both Ends: 0.00

Pore Width Range (Å)	Average Width (Å)	Incremental Pore Volume (cm³/g)	Cumulative Pore Volume (cm³/g)	Incremental Pore Area (m²/g)	Cumulative Pore Area (m²/g)
2338.6 - 2008.1	2148.0	0.001147	0.001147	0.021	0.021
2008.1 - 1745.3	1858.1	0.001249	0.002395	0.027	0.048
1745.3 - 1514.6	1613.4	0.001321	0.003717	0.033	0.081
1514.6 - 1082.6	1227.2	0.002933	0.006650	0.096	0.177
1082.6 - 839.7	930.1	0.002316	0.008966	0.100	0.276
839.7 - 602.6	681.9	0.002781	0.011747	0.163	0.439
602.6 - 544.0	570.2	0.000928	0.012675	0.065	0.504
544.0 - 495.7	517.5	0.000899	0.013574	0.070	0.574
495.7 - 452.3	471.9	0.000718	0.014292	0.061	0.635
452.3 - 405.8	426.4	0.000881	0.015173	0.083	0.717
405.8 - 325.2	356.2	0.001867	0.017040	0.210	0.927
325.2 - 281.2	299.8	0.001129	0.018170	0.151	1.078
281.2 - 249.6	263.4	0.000923	0.019092	0.140	1.218
249.6 - 224.5	235.7	0.000794	0.019886	0.135	1.353
224.5 - 203.9	213.1	0.000687	0.020573	0.129	1.481
203.9 - 187.3	194.8	0.000604	0.021177	0.124	1.606
187.3 - 172.7	179.3	0.000530	0.021707	0.118	1.724
172.7 - 145.5	156.6	0.001109	0.022816	0.283	2.007
145.5 - 129.0	136.2	0.000748	0.023564	0.220	2.227
129.0 - 115.8	121.6	0.000642	0.024206	0.211	2.438
115.8 - 105.3	110.0	0.000552	0.024758	0.201	2.639
105.3 - 90.6	96.7	0.000828	0.025586	0.342	2.981
90.6 - 81.7	85.6	0.000558	0.026144	0.261	3.242
81.7 - 72.3	76.3	0.000637	0.026781	0.334	3.575
72.3 - 65.4	68.4	0.000506	0.027286	0.296	3.871
65.4 - 59.8	62.3	0.000442	0.027728	0.284	4.154
59.8 - 55.1	57.2	0.000401	0.028129	0.280	4.435
55.1 - 50.8	52.7	0.000394	0.028523	0.299	4.734
50.8 - 47.1	48.8	0.000360	0.028883	0.295	5.029
47.1 - 43.9	45.4	0.000349	0.029232	0.308	5.337
43.9 - 41.0	42.3	0.000337	0.029570	0.319	5.656

Sample: Powder 425120764726 US B4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200793_005-50_Run1.SMP

Started:	2/22/2012 12:01:07 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 2:15:34 PM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:34:28 AM	Thermal Correction:	No
Sample Mass:	2.6690 g	Warm Free Space:	7.6892 cm³ Measured
Cold Free Space:	22.2270 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Pore Width Range (Å)	Average Width (Å)	Incremental Pore Volume (cm³/g)	Cumulative Pore Volume (cm³/g)	Incremental Pore Area (m²/g)	Cumulative Pore Area (m²/g)
41.0 - 38.4	39.6	0.000335	0.029905	0.339	5.995
38.4 - 36.0	37.1	0.000333	0.030238	0.360	6.354
36.0 - 33.9	34.9	0.000327	0.030566	0.375	6.730
33.9 - 31.9	32.8	0.000338	0.030904	0.412	7.142
31.9 - 30.4	31.1	0.000279	0.031182	0.358	7.500
30.4 - 28.6	29.5	0.000363	0.031546	0.493	7.994
28.6 - 27.0	27.8	0.000355	0.031901	0.512	8.505
27.0 - 25.4	26.1	0.000388	0.032289	0.594	9.100
25.4 - 23.8	24.5	0.000397	0.032686	0.648	9.748
23.8 - 22.3	23.0	0.000415	0.033101	0.723	10.471
22.3 - 20.8	21.5	0.000435	0.033536	0.810	11.281
20.8 - 19.4	20.0	0.000468	0.034004	0.935	12.215
19.4 - 17.9	18.5	0.000558	0.034562	1.205	13.420
17.9 - 16.4	17.0	0.000614	0.035176	1.441	14.861

Sample: Powder 425120764726 US B4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200793_005-50_Run1.SMP

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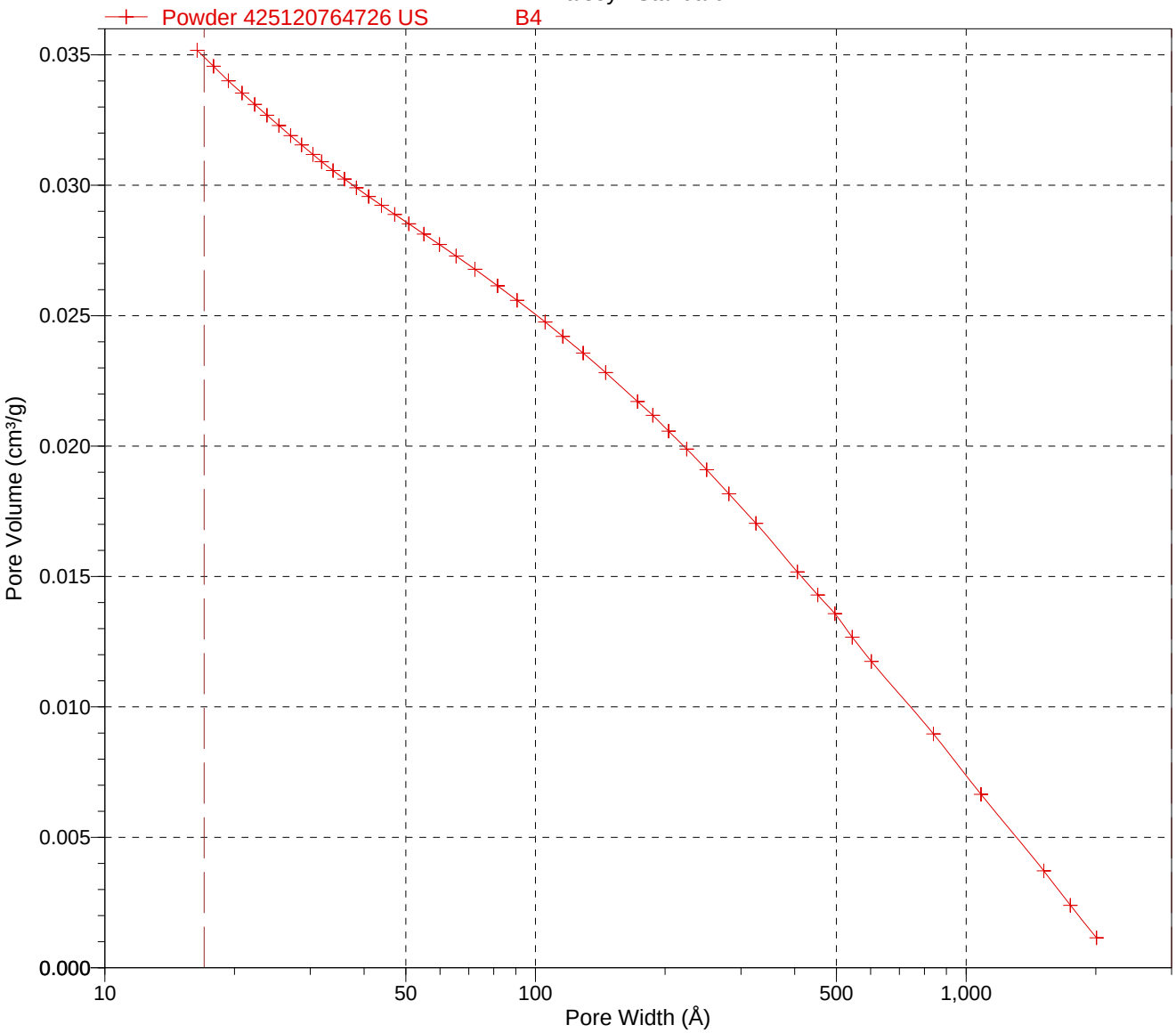
Cold Free Space:	22.2270 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Cumulative Pore Volume (Larger)

Halsey : Standard



Sample: Powder 425120764726 US B4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200793_005-50_Run1.SMP

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Completed:	2/23/2012 2:15:34 PM	Analysis Bath Temp.:	77.300 K
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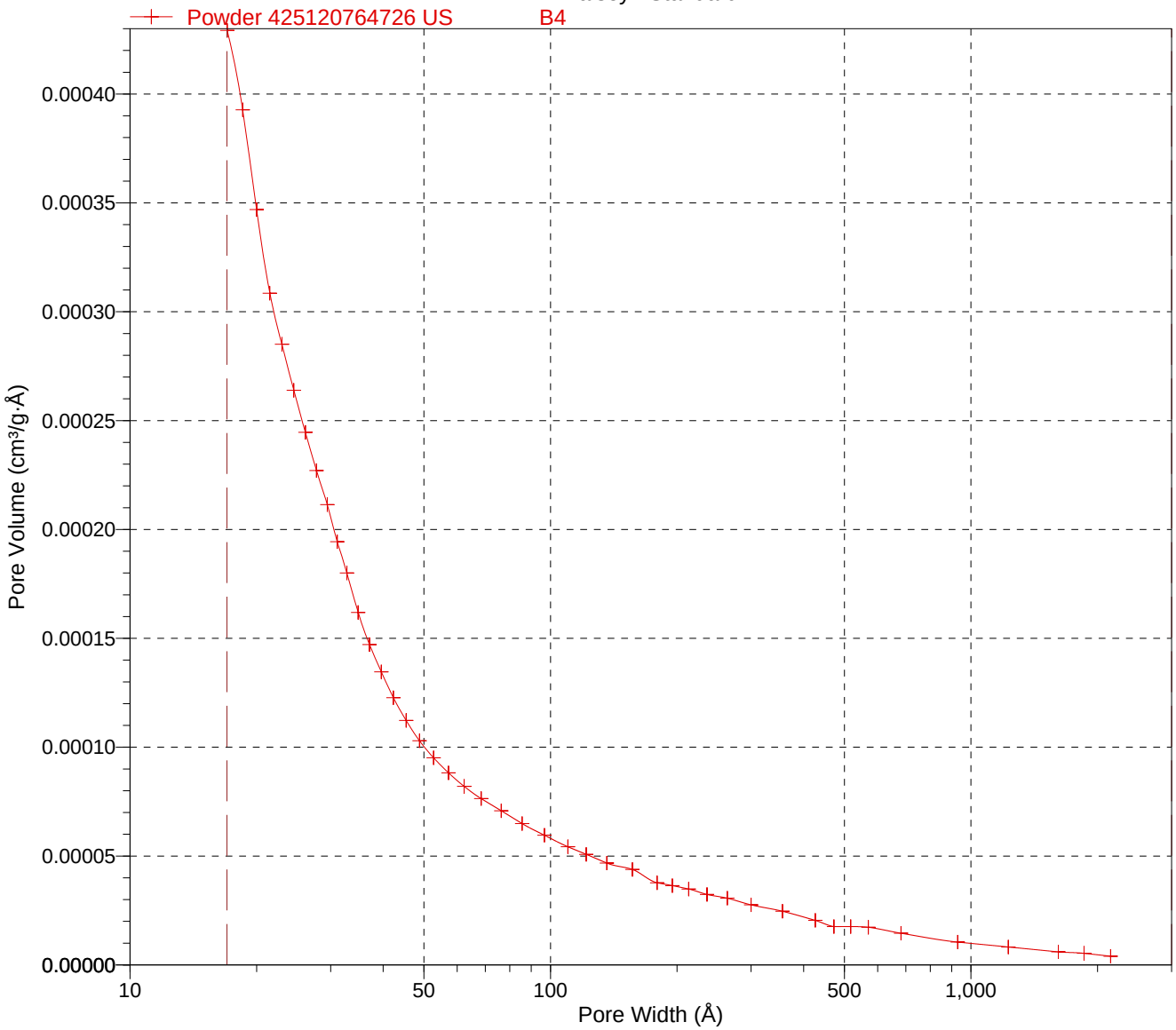
Sample Mass:	2.6690 g	Warm Free Space:	7.6892 cm³ Measured
Cold Free Space:	22.2270 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dV/dw Pore Volume

Halsey : Standard



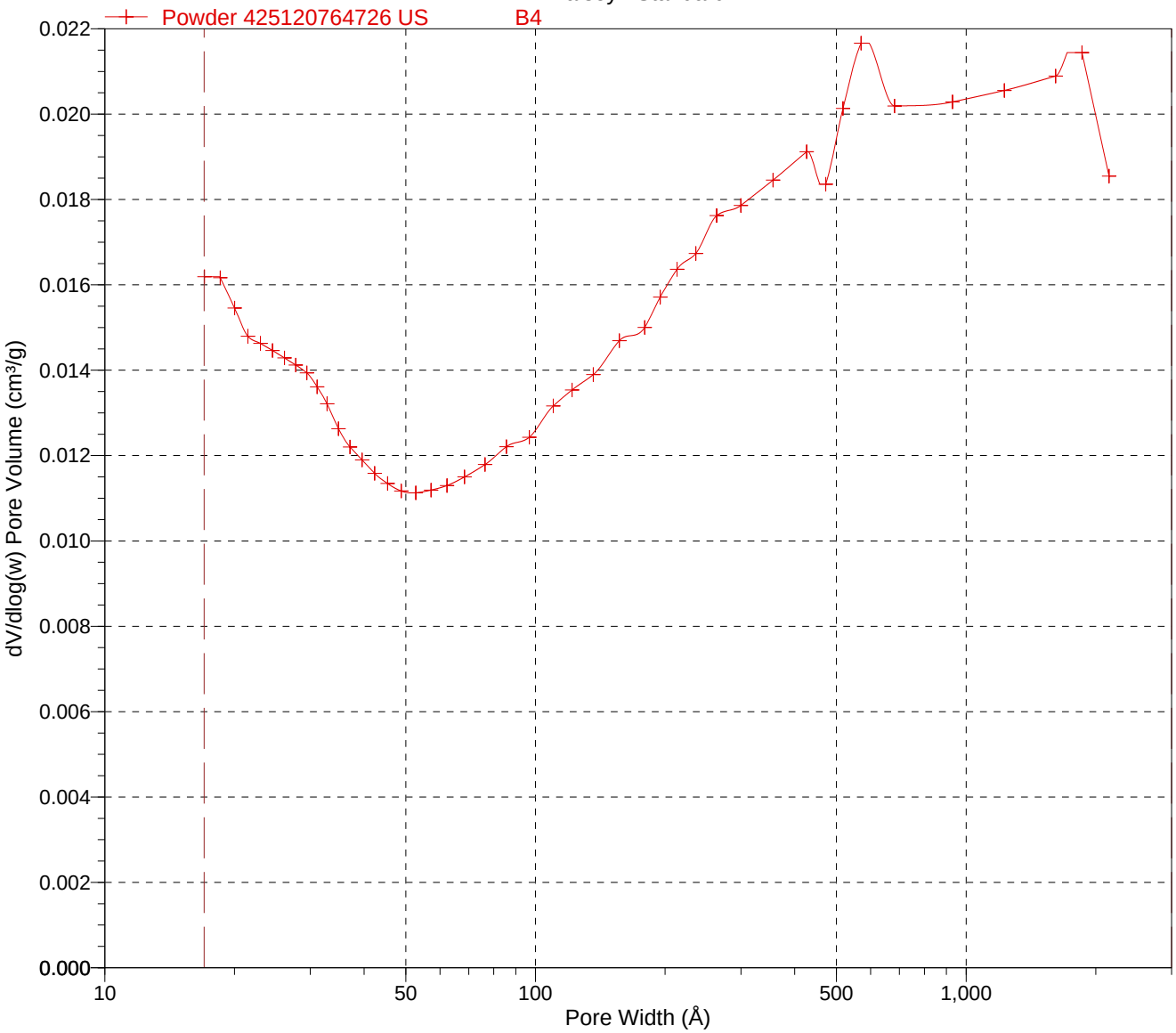
Sample: Powder 425120764726 US B4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200793_005-50_Run1.SMP

Started:	2/22/2012 12:01:07 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 2:15:34 PM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:34:28 AM	Thermal Correction:	No
Sample Mass:	2.6690 g	Warm Free Space:	7.6892 cm³ Measured
Cold Free Space:	22.2270 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dV/dlog(w) Pore Volume

Halsey : Standard



Sample: Powder 425120764726 US B4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200793_005-50_Run1.SMP

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Completed:	2/23/2012 2:15:34 PM	Analysis Bath Temp.:	77.300 K
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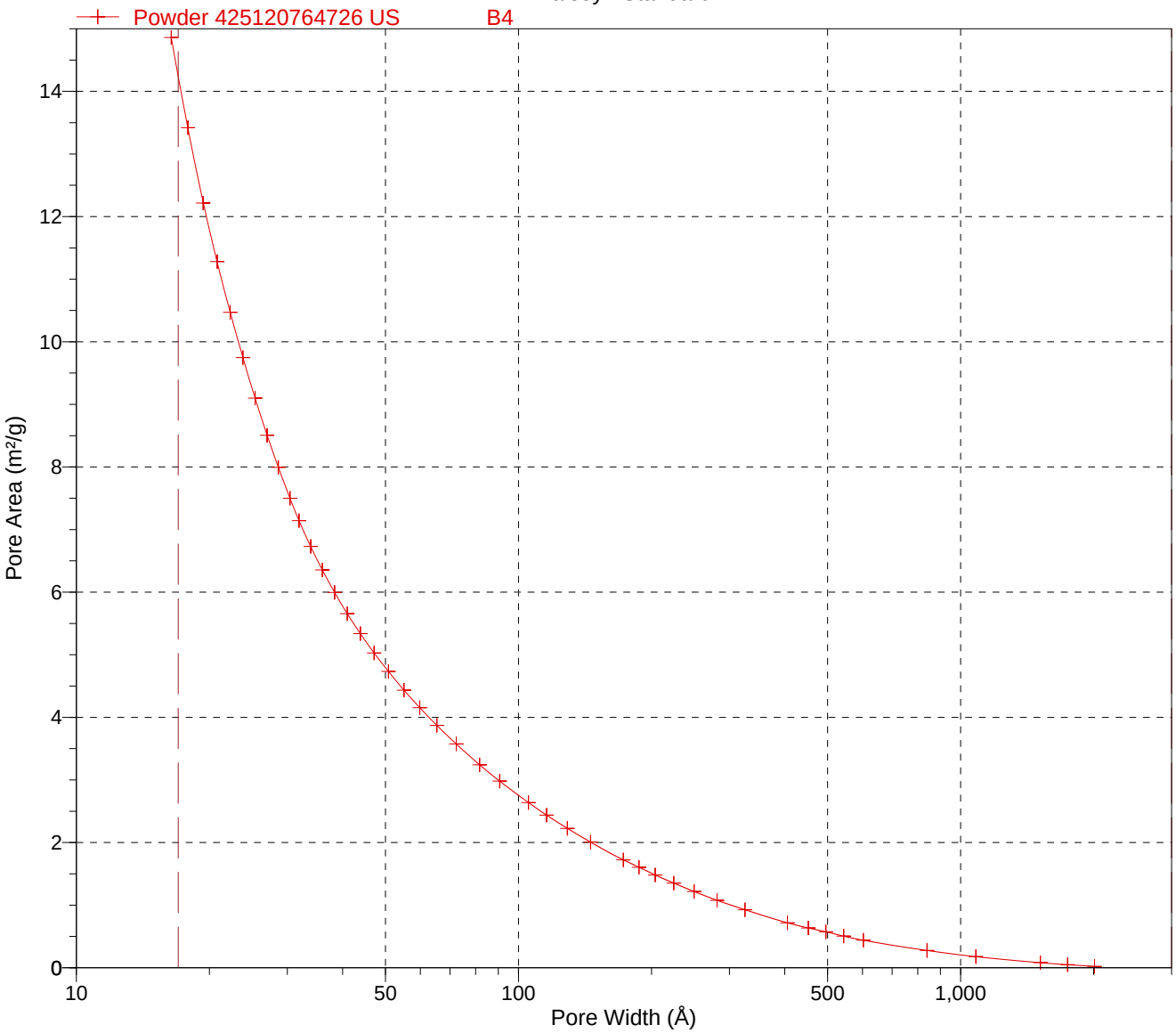
Sample Mass:	2.6690 g	Warm Free Space:	7.6892 cm³ Measured
Cold Free Space:	22.2270 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Cumulative Pore Area (Larger)

Halsey : Standard



Sample: Powder 425120764726 US B4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200793_005-50_Run1.SMP

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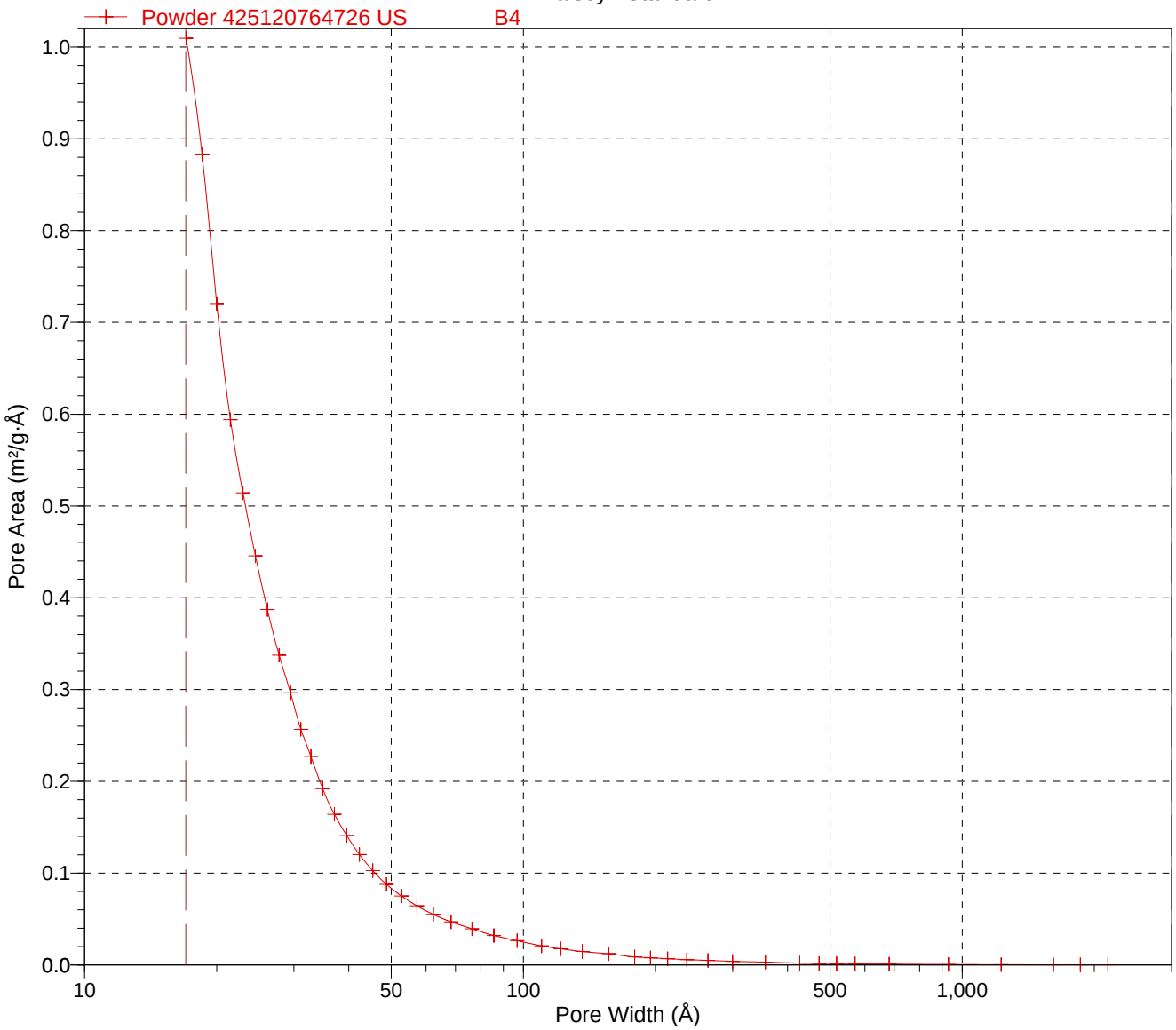
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dA/dw Pore Area

Halsey : Standard



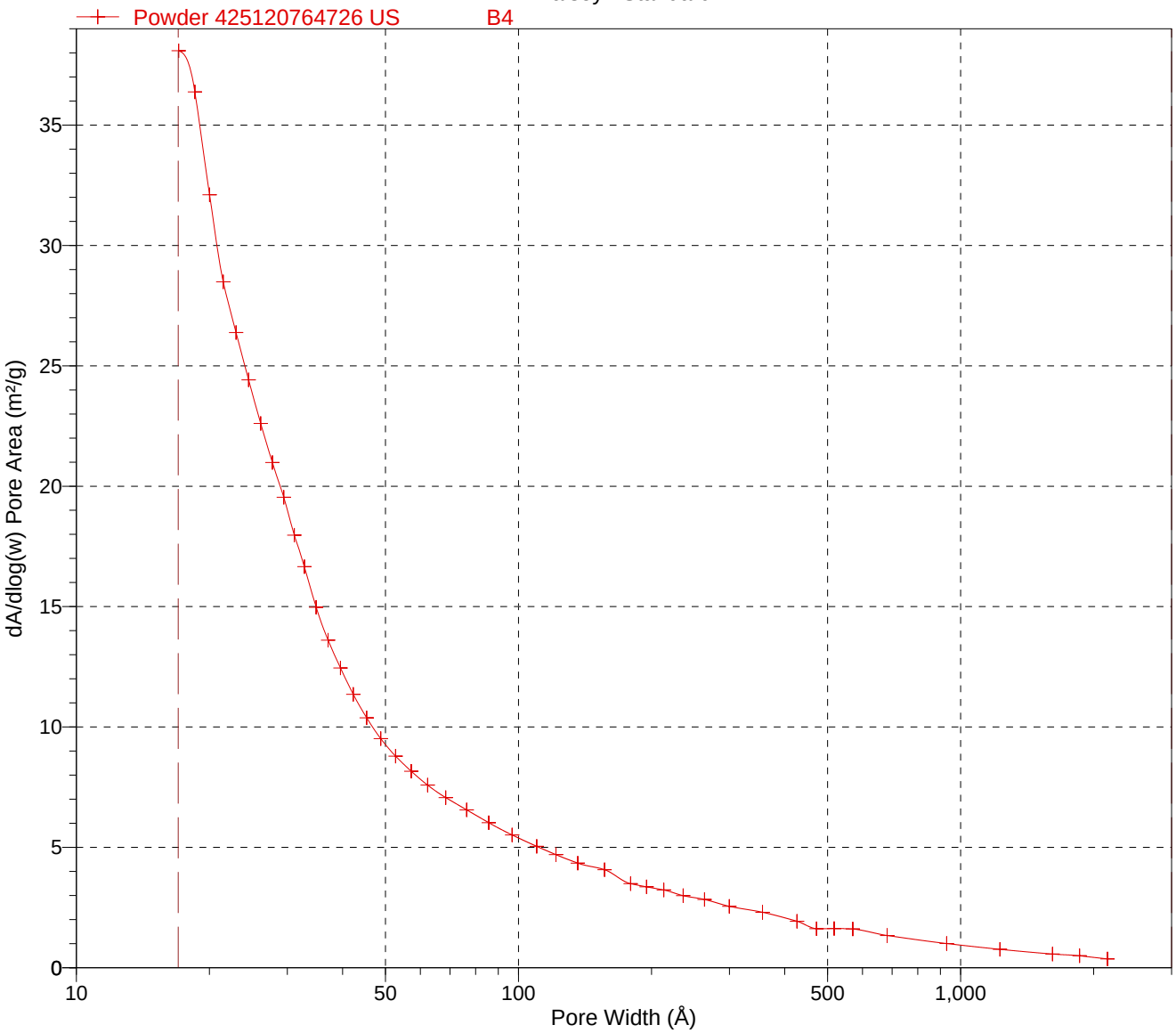
Sample: Powder 425120764726 US B4
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200793_005-50_Run1.SMP

Started:	2/22/2012 12:01:07 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 2:15:34 PM	Analysis Bath Temp.:	77.300 K
Report Time:	3/16/2012 11:34:28 AM	Thermal Correction:	No
Sample Mass:	2.6690 g	Warm Free Space:	7.6892 cm³ Measured
Cold Free Space:	22.2270 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dA/dlog(w) Pore Area

Halsey : Standard



Sample: Powder 425828762002 TS D1
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200795_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:19:46 PM	Thermal Correction:	No
Sample Mass:	2.0491 g	Warm Free Space:	7.9291 cm³ Measured
Cold Free Space:	23.0406 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Summary Report

Surface Area

Single point surface area at p/p° = 0.203405274:	19.9872 m²/g
BET Surface Area:	20.3681 m²/g
t-Plot Micropore Area:	7.7687 m²/g
t-Plot External Surface Area:	12.5994 m²/g
BJH Adsorption cumulative surface area of pores between 17.000 Å and 3,000.000 Å width:	17.698 m²/g

Pore Volume

Single point adsorption total pore volume of pores less than 2,703.675 Å width at p/p° = 0.992809457:	0.039239 cm³/g
t-Plot micropore volume:	0.003537 cm³/g
BJH Adsorption cumulative volume of pores between 17.000 Å and 3,000.000 Å width:	0.038667 cm³/g

Pore Size

Adsorption average pore width (4V/A by BET):	77.0593 Å
BJH Adsorption average pore width (4V/A):	87.395 Å

Sample: Powder 425828762002 TS D1
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200795_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:19:46 PM	Thermal Correction:	No
Sample Mass:	2.0491 g	Warm Free Space:	7.9291 cm³ Measured
Cold Free Space:	23.0406 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Tabular Report

Relative Pressure (p/p°)	Absolute Pressure (mmHg)	Quantity Adsorbed (cm³/g STP)	Elapsed Time (h:min)	Saturation Pressure (mmHg)
			01:11	740.482788
0.002472482	1.824217	2.7048	02:59	737.807739
0.004904258	3.615206	3.0934	03:53	737.156494
0.007347386	5.409485	3.3465	05:05	736.246216
0.009849714	7.234030	3.5289	06:24	734.440674
0.020011256	14.674663	3.9514	08:54	733.320435
0.030342907	22.210865	4.2040	10:41	731.995300
0.040834326	29.906132	4.3902	11:52	732.377258
0.050683766	37.125191	4.5522	13:15	732.486816
0.078975836	57.806446	4.8733	14:32	731.951050
0.110789250	81.083382	5.1397	15:11	731.870483
0.141335478	103.487366	5.3650	15:40	732.210815
0.172706991	126.482857	5.5689	15:57	732.355164
0.203405274	148.935516	5.7638	16:13	732.210693
0.234177627	171.461060	5.9555	16:28	732.183777
0.265177211	194.159973	6.1465	16:40	732.189514
0.296815963	217.328506	6.3336	16:49	732.199524
0.327011939	239.502853	6.5157	16:57	732.397888
0.351088325	257.183105	6.6685	17:06	732.531067
0.381621240	279.554352	6.8551	17:14	732.544006
0.410839317	300.911163	7.0331	17:22	732.430298
0.440531854	322.656860	7.2203	17:29	732.425720
0.470883928	344.923828	7.4107	17:36	732.502869
0.499992253	366.324066	7.6030	17:43	732.659485
0.530505047	388.648438	7.8090	17:49	732.600830
0.559887680	410.139801	8.0203	17:56	732.539429
0.590018470	432.260193	8.2466	18:02	732.621460
0.619174431	453.621307	8.4862	18:09	732.622803
0.649470997	475.833832	8.7509	18:15	732.648315
0.678422605	497.033875	9.0337	18:22	732.631653
0.708321046	518.987488	9.3594	18:29	732.700928
0.737544814	540.410889	9.7226	18:36	732.716003
0.767211486	562.257568	10.1412	18:43	732.858643
0.800513937	586.823669	10.7042	18:53	733.058655
0.820603801	601.453552	11.0612	18:59	732.940247
0.837753609	613.957581	11.4209	19:06	732.861755
0.856779001	627.914734	11.9111	19:14	732.878296
0.876841506	642.648132	12.5192	19:21	732.912537
0.889327103	651.870361	12.9426	19:28	732.992798

Sample: Powder 425828762002 TS D1
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200795_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:19:46 PM	Thermal Correction:	No
Sample Mass:	2.0491 g	Warm Free Space:	7.9291 cm³ Measured
Cold Free Space:	23.0406 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Tabular Report

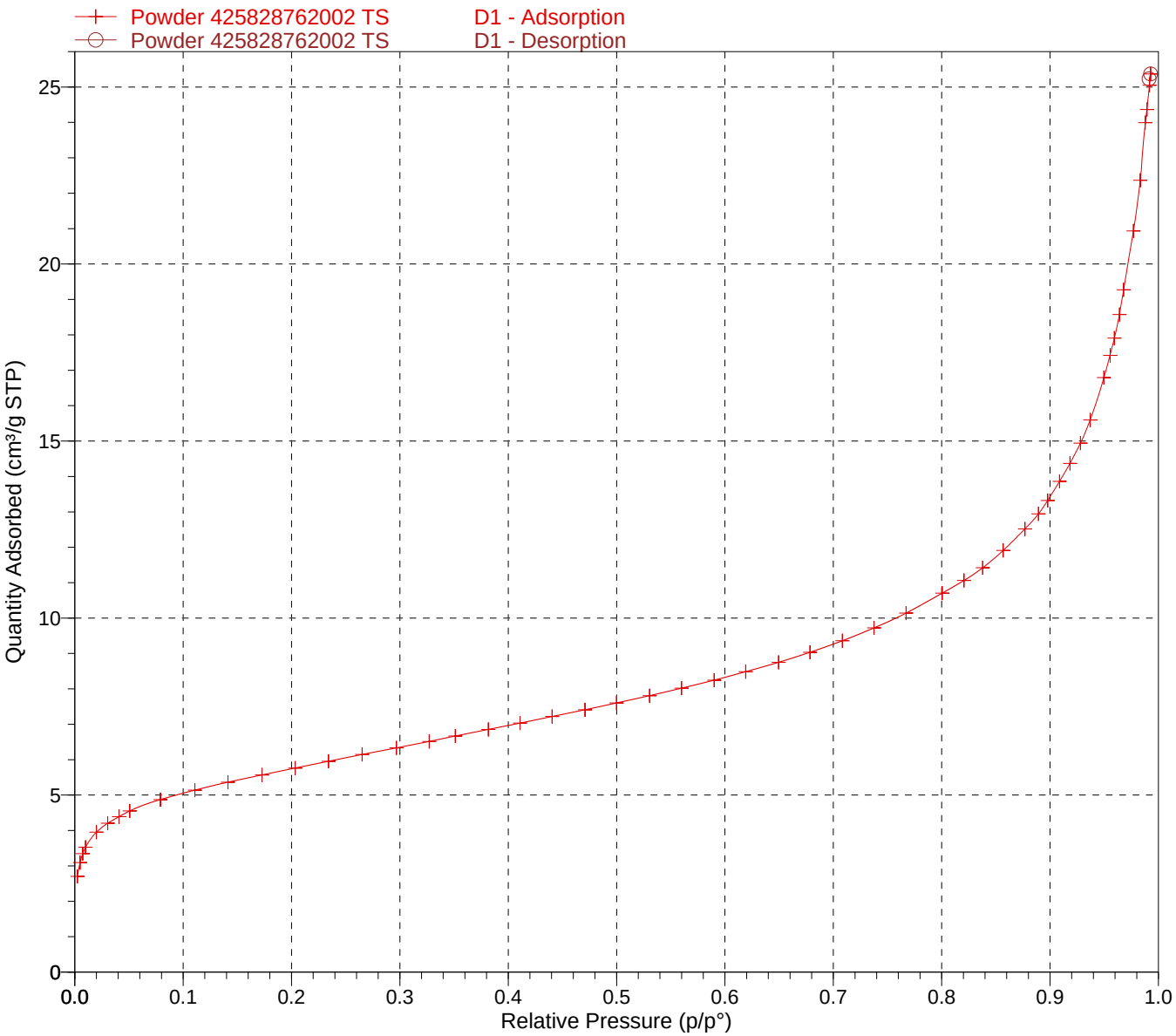
Relative Pressure (p/p°)	Absolute Pressure (mmHg)	Quantity Adsorbed (cm³/g STP)	Elapsed Time (h:min)	Saturation Pressure (mmHg)
0.897782974	658.062317	13.3231	19:37	732.985962
0.908795119	666.195801	13.8614	19:44	733.053894
0.918397274	673.271301	14.3701	19:52	733.093750
0.928048676	680.493958	14.9404	19:59	733.252441
0.937027301	687.122681	15.5944	20:08	733.300598
0.949636472	696.533081	16.7942	20:23	733.473389
0.955438878	700.841125	17.4208	20:31	733.527954
0.959380231	703.749023	17.9105	20:39	733.545471
0.964126225	707.247314	18.5751	20:47	733.562988
0.967847631	709.924744	19.2707	20:56	733.508789
0.976962652	716.759705	20.9348	21:11	733.661316
0.983239548	721.562561	22.3653	21:26	733.862427
0.987714030	724.931519	23.9942	21:47	733.948792
0.989491464	726.176697	24.3656	21:52	733.888794
0.991781757	727.913269	25.0498	22:01	733.945007
0.992809457	728.693237	25.3677	22:05	733.970886
0.991413216	727.687256	25.2320	22:09	733.989868

Sample: Powder 425828762002 TS D1
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200795_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:19:46 PM	Thermal Correction:	No
Sample Mass:	2.0491 g	Warm Free Space:	7.9291 cm³ Measured
Cold Free Space:	23.0406 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Linear Plot



Sample: Powder 425828762002 TS D1
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200795_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:19:46 PM	Thermal Correction:	No
Sample Mass:	2.0491 g	Warm Free Space:	7.9291 cm³ Measured
Cold Free Space:	23.0406 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BET Surface Area Report

BET Surface Area:	20.3681 ± 0.1336 m²/g
Slope:	0.212954 ± 0.001389 g/cm³ STP
Y-Intercept:	0.000773 ± 0.000190 g/cm³ STP
C:	276.551676
Qm:	4.6789 cm³/g STP
Correlation Coefficient:	0.9999149
Molecular Cross-Sectional Area:	0.1620 nm²

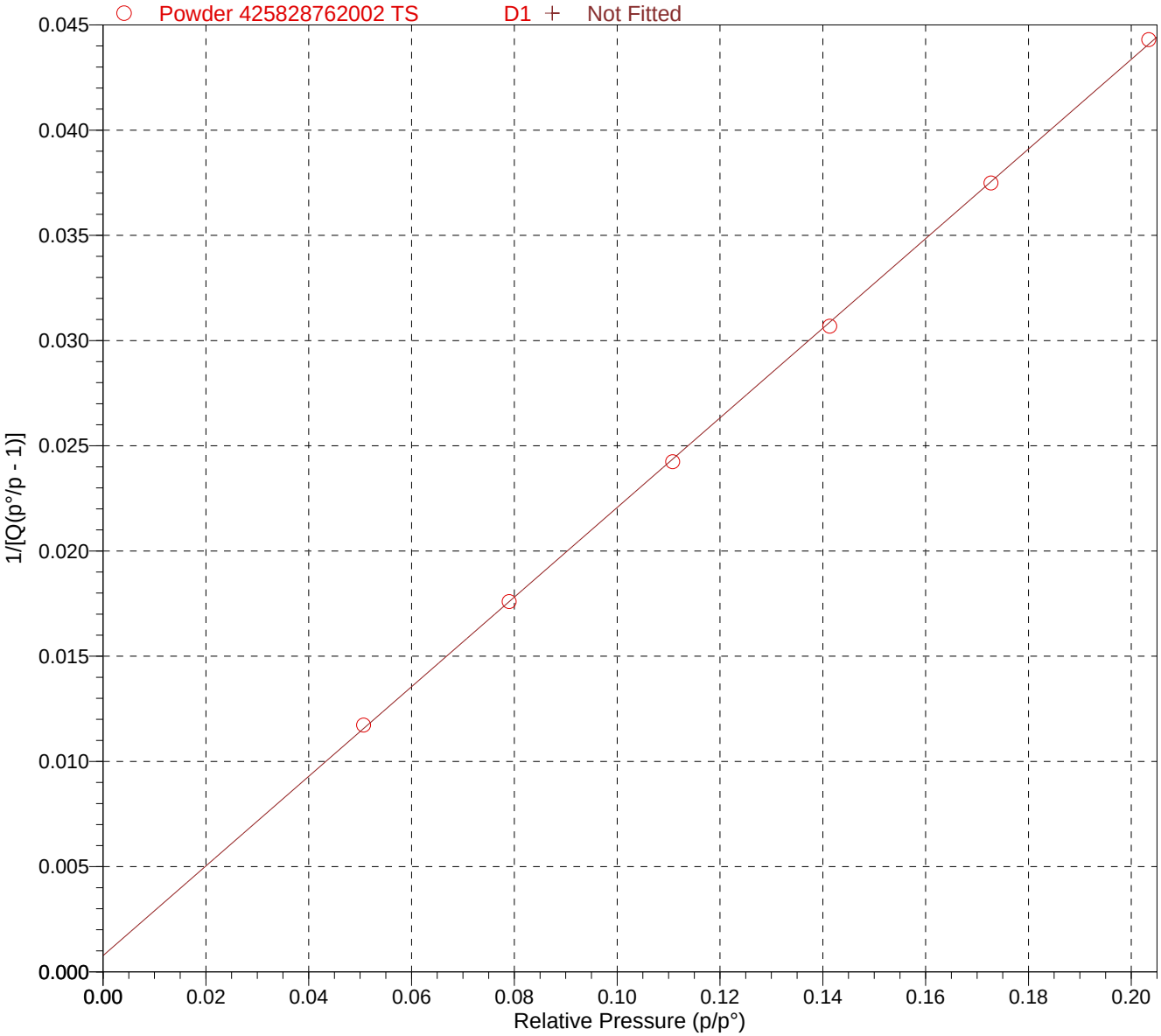
Relative Pressure (p/p°)	Quantity Adsorbed (cm³/g STP)	1/[Q(p°/p - 1)]
0.050683766	4.5522	0.011728
0.078975836	4.8733	0.017596
0.110789250	5.1397	0.024241
0.141335478	5.3650	0.030680
0.172706991	5.5689	0.037487
0.203405274	5.7638	0.044301

Sample: Powder 425828762002 TS D1
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200795_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:19:46 PM	Thermal Correction:	No
Sample Mass:	2.0491 g	Warm Free Space:	7.9291 cm³ Measured
Cold Free Space:	23.0406 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BET Surface Area Plot



Sample: Powder 425828762002 TS D1
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200795_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:19:46 PM	Thermal Correction:	No
Sample Mass:	2.0491 g	Warm Free Space:	7.9291 cm³ Measured
Cold Free Space:	23.0406 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot Report

Micropore Volume:	0.003537 cm³/g
Micropore Area:	7.7687 m²/g
External Surface Area:	12.5994 m²/g
Slope:	0.814544 ± 0.004016 cm³/g·Å STP
Y-Intercept:	2.286946 ± 0.030715 cm³/g STP
Correlation Coefficient:	0.999733
Surface Area Correction Factor:	1.000
Density Conversion Factor:	0.0015468
Total Surface Area (BET):	20.3681 m²/g
Thickness Range:	4.3124 Å to 11.8252 Å
Thickness Equation:	Harkins and Jura

Thickness Curve

t = [13.99 / (0.034 - log(p/p°))] ^ 0.5

t-Plot Report - Data

Relative Pressure (p/p°)	Statistical Thickness (Å)	Quantity Adsorbed (cm³/g STP)	Fitted
0.002472482	2.3016	2.7048	
0.004904258	2.4433	3.0934	
0.007347386	2.5403	3.3465	
0.009849714	2.6184	3.5289	
0.020011256	2.8415	3.9514	
0.030342907	3.0024	4.2040	
0.040834326	3.1355	4.3902	
0.050683766	3.2443	4.5522	
0.078975836	3.5085	4.8733	
0.110789250	3.7601	5.1397	
0.141335478	3.9787	5.3650	
0.172706991	4.1905	5.5689	
0.203405274	4.3909	5.7638	*
0.234177627	4.5886	5.9555	*
0.265177211	4.7872	6.1465	*
0.296815963	4.9915	6.3336	*
0.327011939	5.1897	6.5157	*
0.351088325	5.3511	6.6685	*
0.381621240	5.5611	6.8551	*
0.410839317	5.7692	7.0331	*
0.440531854	5.9891	7.2203	*
0.470883928	6.2245	7.4107	*
0.499992253	6.4619	7.6030	*

Sample: Powder 425828762002 TS D1
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200795_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:19:46 PM	Thermal Correction:	No
Sample Mass:	2.0491 g	Warm Free Space:	7.9291 cm³ Measured
Cold Free Space:	23.0406 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot Report - Data

Relative Pressure (p/p°)	Statistical Thickness (Å)	Quantity Adsorbed (cm³/g STP)	Fitted
0.530505047	6.7253	7.8090	*
0.559887680	6.9952	8.0203	*
0.590018470	7.2916	8.2466	*
0.619174431	7.6003	8.4862	*
0.649470997	7.9484	8.7509	*
0.678422605	8.3118	9.0337	*
0.708321046	8.7251	9.3594	*
0.737544814	9.1744	9.7226	*
0.767211486	9.6871	10.1412	*
0.800513937	10.3487	10.7042	*
0.820603801	10.8034	11.0612	*
0.837753609	11.2325	11.4209	*
0.856779001	11.7616	11.9111	*
0.876841506	12.3937	12.5192	
0.889327103	12.8338	12.9426	
0.897782974	13.1561	13.3231	
0.908795119	13.6094	13.8614	
0.918397274	14.0402	14.3701	
0.928048676	14.5121	14.9404	
0.937027301	14.9916	15.5944	
0.949636472	15.7436	16.7942	
0.955438878	16.1261	17.4208	
0.959380231	16.4009	17.9105	
0.964126225	16.7497	18.5751	
0.967847631	17.0379	19.2707	
0.976962652	17.8066	20.9348	
0.983239548	18.3959	22.3653	
0.987714030	18.8509	23.9942	
0.989491464	19.0407	24.3656	
0.991781757	19.2934	25.0498	
0.992809457	19.4099	25.3677	

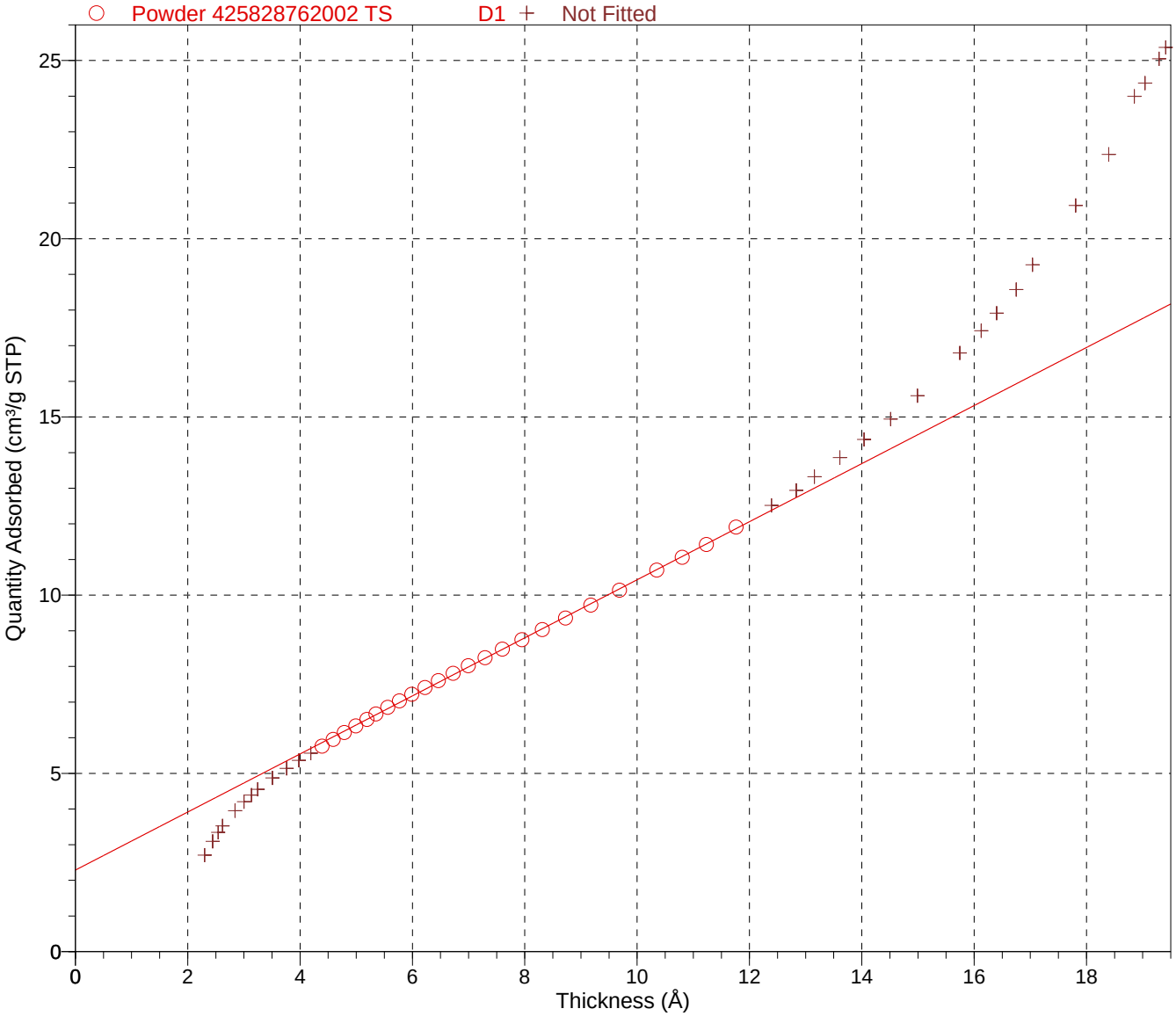
Sample: Powder 425828762002 TS D1
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200795_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:19:46 PM	Thermal Correction:	No
Sample Mass:	2.0491 g	Warm Free Space:	7.9291 cm³ Measured
Cold Free Space:	23.0406 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot

Harkins and Jura



Sample: Powder 425828762002 TS D1
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200795_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:19:46 PM	Thermal Correction:	No
Sample Mass:	2.0491 g	Warm Free Space:	7.9291 cm³ Measured
Cold Free Space:	23.0406 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Pore Distribution Report

Standard
Halsey
t = 3.54 [-5 / ln(p/p°)] ^ 0.333

Width Range: 17.000 Å to 3,000.000 Å
Adsorbate Property Factor: 9.53000 Å
Density Conversion Factor: 0.0015468
Fraction of Pores Open at Both Ends: 0.00

Pore Width Range (Å)	Average Width (Å)	Incremental Pore Volume (cm³/g)	Cumulative Pore Volume (cm³/g)	Incremental Pore Area (m²/g)	Cumulative Pore Area (m²/g)
2703.7 - 2369.5	2514.3	0.000516	0.000516	0.008	0.008
2369.5 - 1859.3	2052.7	0.001117	0.001634	0.022	0.030
1859.3 - 1594.1	1706.0	0.000608	0.002242	0.014	0.044
1594.1 - 1174.7	1321.0	0.002706	0.004947	0.082	0.126
1174.7 - 860.1	968.7	0.002397	0.007344	0.099	0.225
860.1 - 621.0	701.7	0.002835	0.010179	0.162	0.387
621.0 - 558.1	586.1	0.001197	0.011376	0.082	0.468
558.1 - 494.6	522.4	0.001145	0.012520	0.088	0.556
494.6 - 452.0	471.3	0.000848	0.013368	0.072	0.628
452.0 - 401.3	423.5	0.001092	0.014460	0.103	0.731
401.3 - 323.1	353.4	0.002130	0.016590	0.241	0.972
323.1 - 284.0	300.9	0.001165	0.017756	0.155	1.127
284.0 - 251.4	265.6	0.001021	0.018777	0.154	1.281
251.4 - 225.7	237.1	0.000921	0.019698	0.155	1.436
225.7 - 202.2	212.6	0.000989	0.020687	0.186	1.623
202.2 - 187.2	194.1	0.000706	0.021393	0.145	1.768
187.2 - 168.8	177.0	0.000778	0.022171	0.176	1.944
168.8 - 145.8	155.5	0.001142	0.023312	0.294	2.238
145.8 - 129.2	136.4	0.000932	0.024244	0.273	2.511
129.2 - 117.2	122.5	0.000682	0.024926	0.223	2.733
117.2 - 105.6	110.7	0.000679	0.025605	0.245	2.979
105.6 - 90.8	96.9	0.001120	0.026725	0.462	3.441
90.8 - 80.6	85.0	0.000839	0.027564	0.395	3.836
80.6 - 72.5	76.1	0.000739	0.028303	0.388	4.224
72.5 - 65.7	68.7	0.000667	0.028970	0.388	4.613
65.7 - 60.2	62.7	0.000585	0.029555	0.373	4.986
60.2 - 55.2	57.4	0.000549	0.030104	0.382	5.368
55.2 - 51.1	53.0	0.000506	0.030610	0.382	5.751
51.1 - 47.4	49.1	0.000479	0.031089	0.391	6.142
47.4 - 44.2	45.6	0.000457	0.031547	0.401	6.543
44.2 - 41.2	42.5	0.000448	0.031995	0.422	6.964

Sample: Powder 425828762002 TS D1
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200795_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:19:46 PM	Thermal Correction:	No
Sample Mass:	2.0491 g	Warm Free Space:	7.9291 cm³ Measured
Cold Free Space:	23.0406 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Pore Width Range (Å)	Average Width (Å)	Incremental Pore Volume (cm³/g)	Cumulative Pore Volume (cm³/g)	Incremental Pore Area (m²/g)	Cumulative Pore Area (m²/g)
41.2 - 38.6	39.8	0.000430	0.032425	0.432	7.397
38.6 - 36.2	37.3	0.000427	0.032852	0.458	7.855
36.2 - 34.0	35.0	0.000436	0.033288	0.498	8.353
34.0 - 32.0	32.9	0.000417	0.033705	0.506	8.859
32.0 - 30.1	31.0	0.000450	0.034155	0.580	9.439
30.1 - 28.7	29.4	0.000384	0.034538	0.523	9.962
28.7 - 27.0	27.8	0.000448	0.034987	0.645	10.606
27.0 - 25.4	26.1	0.000457	0.035444	0.700	11.306
25.4 - 23.8	24.5	0.000485	0.035929	0.792	12.098
23.8 - 22.3	23.0	0.000486	0.036415	0.844	12.942
22.3 - 20.9	21.5	0.000488	0.036902	0.905	13.848
20.9 - 19.4	20.1	0.000491	0.037393	0.977	14.825
19.4 - 18.0	18.6	0.000583	0.037976	1.254	16.079
18.0 - 16.4	17.1	0.000691	0.038667	1.619	17.698

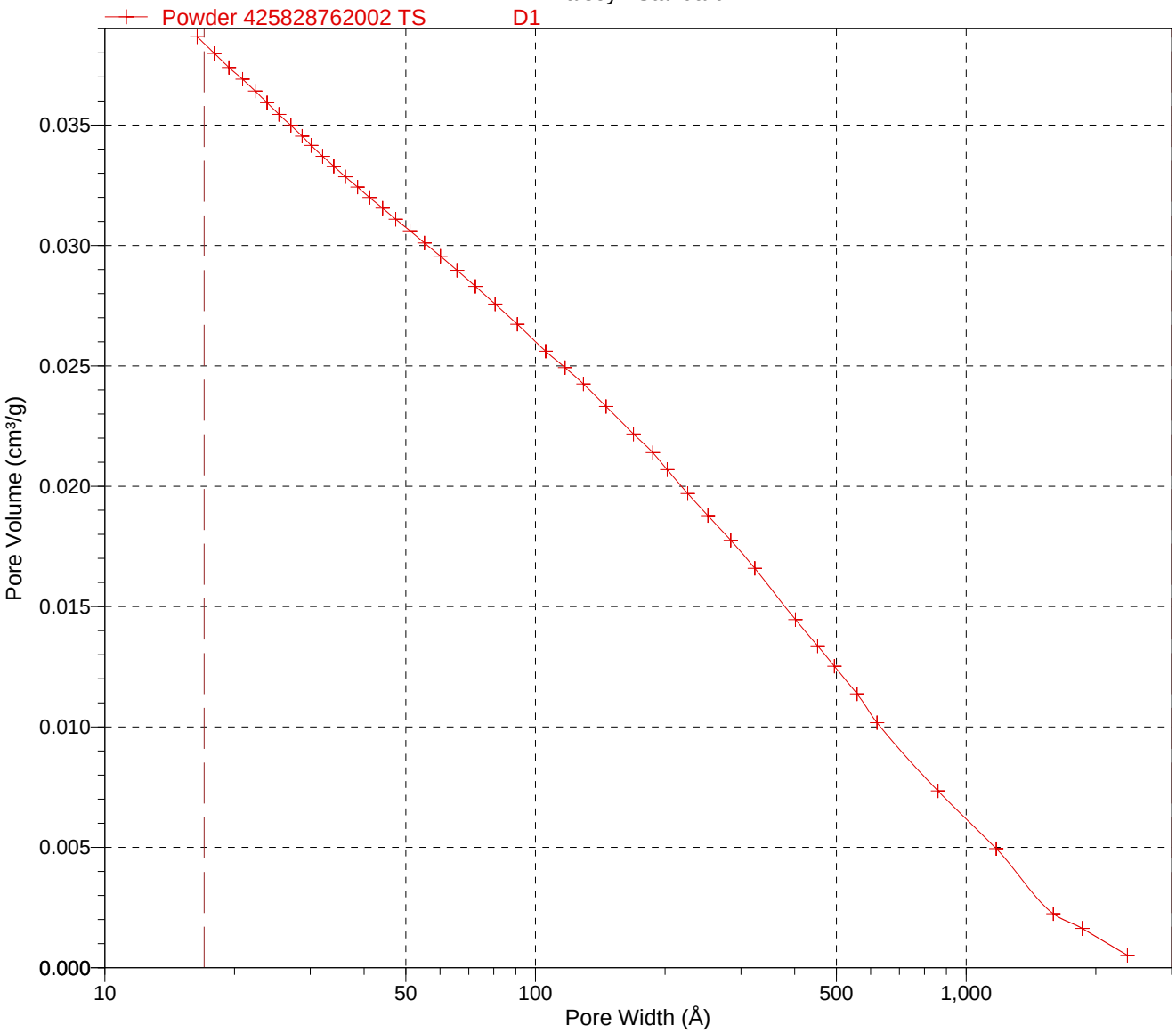
Sample: Powder 425828762002 TS D1
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200795_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:19:46 PM	Thermal Correction:	No
Sample Mass:	2.0491 g	Warm Free Space:	7.9291 cm³ Measured
Cold Free Space:	23.0406 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Cumulative Pore Volume (Larger)

Halsey : Standard



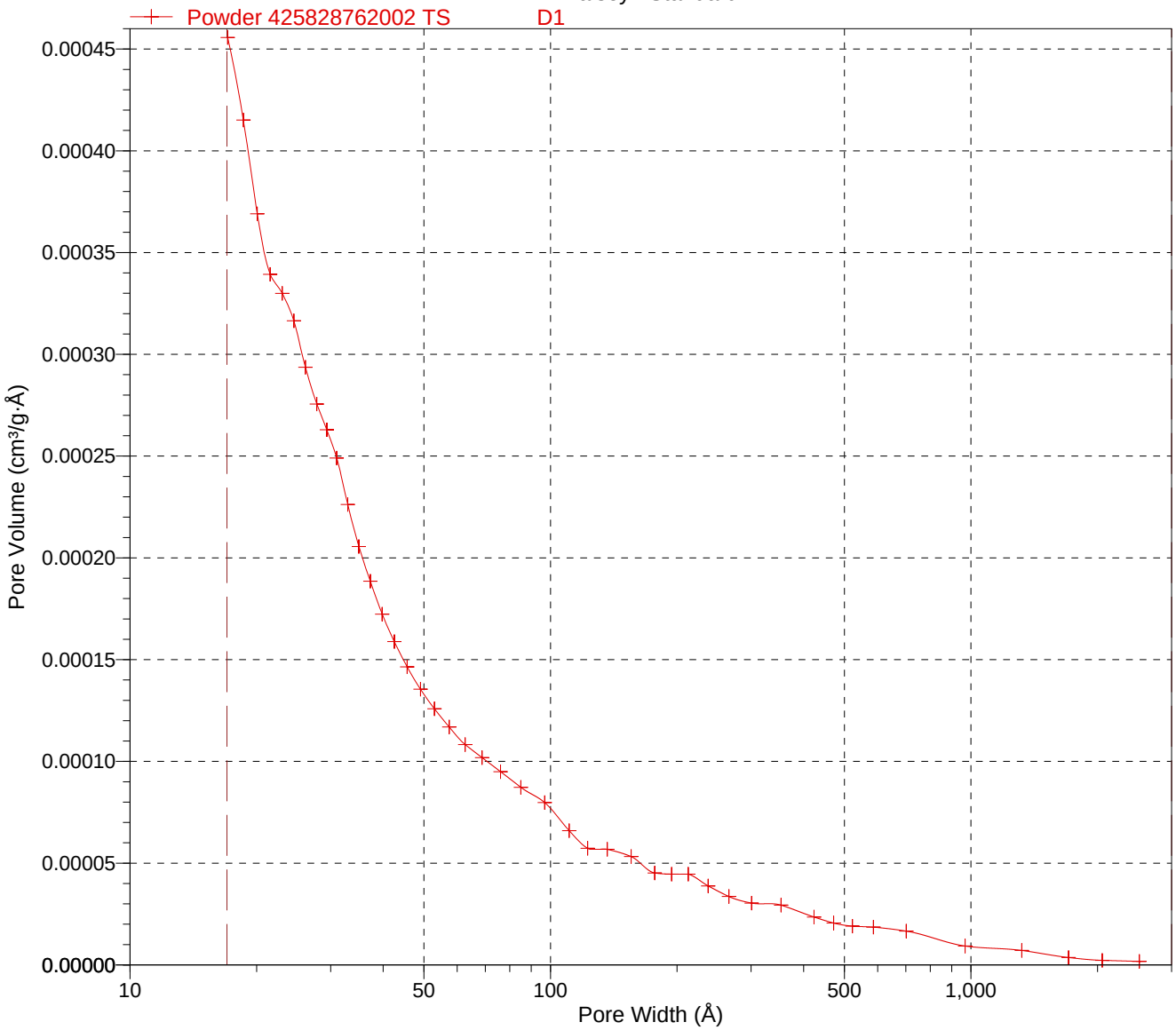
Sample: Powder 425828762002 TS D1
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200795_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:19:46 PM	Thermal Correction:	No
Sample Mass:	2.0491 g	Warm Free Space:	7.9291 cm³ Measured
Cold Free Space:	23.0406 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dV/dw Pore Volume

Halsey : Standard



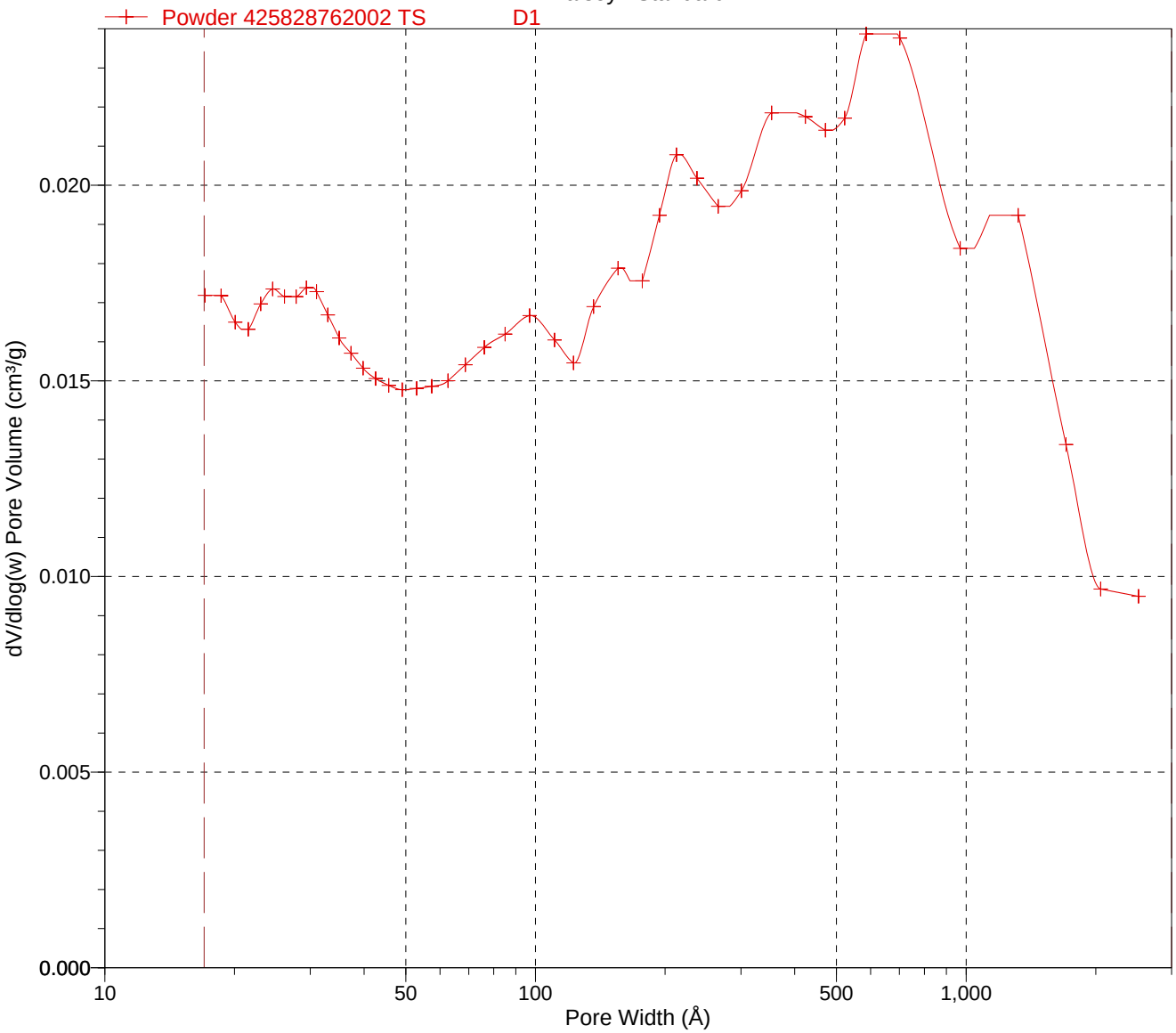
Sample: Powder 425828762002 TS D1
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200795_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:19:46 PM	Thermal Correction:	No
Sample Mass:	2.0491 g	Warm Free Space:	7.9291 cm³ Measured
Cold Free Space:	23.0406 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dV/dlog(w) Pore Volume

Halsey : Standard



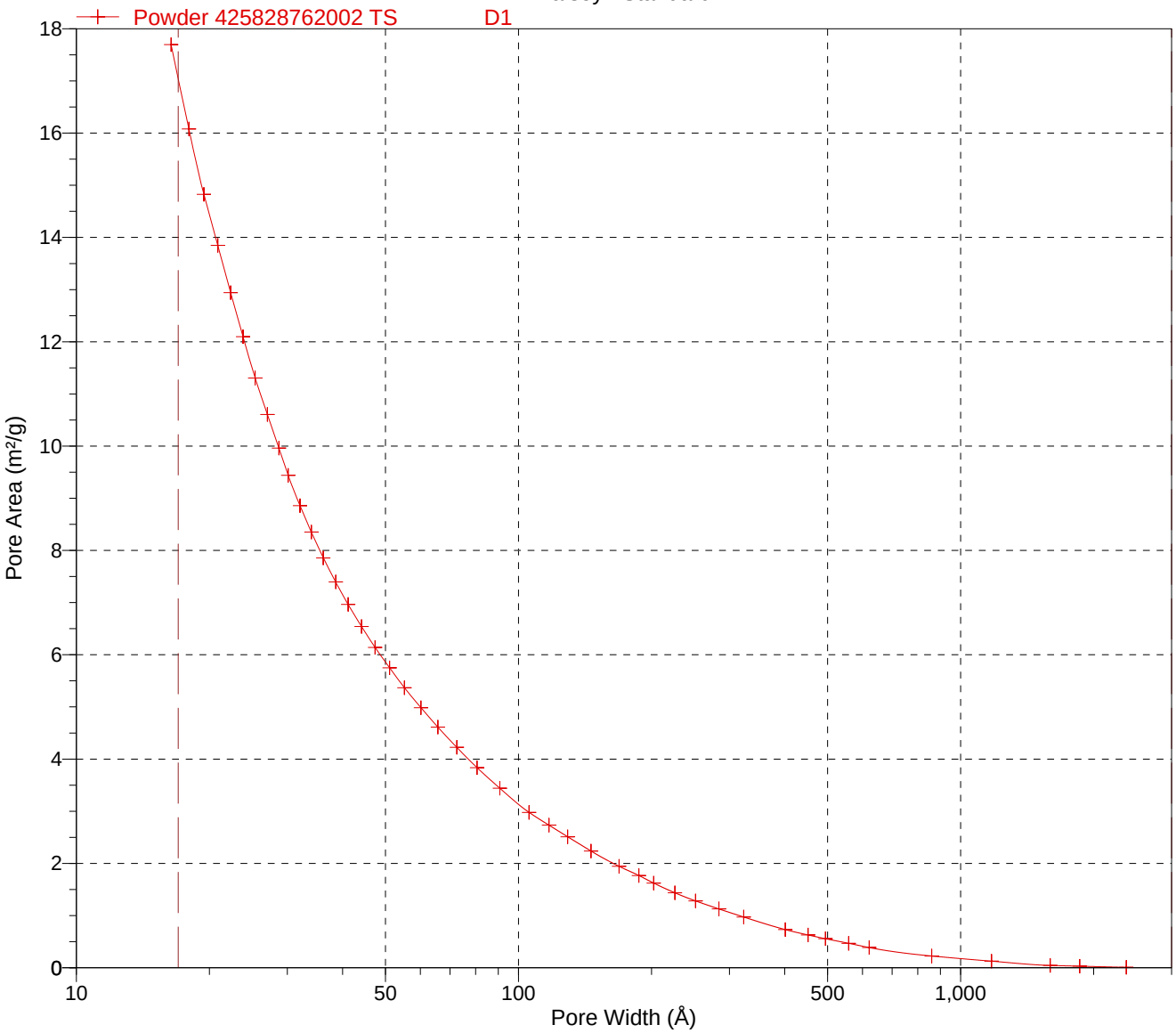
Sample: Powder 425828762002 TS D1
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200795_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:19:46 PM	Thermal Correction:	No
Sample Mass:	2.0491 g	Warm Free Space:	7.9291 cm³ Measured
Cold Free Space:	23.0406 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Cumulative Pore Area (Larger)

Halsey : Standard



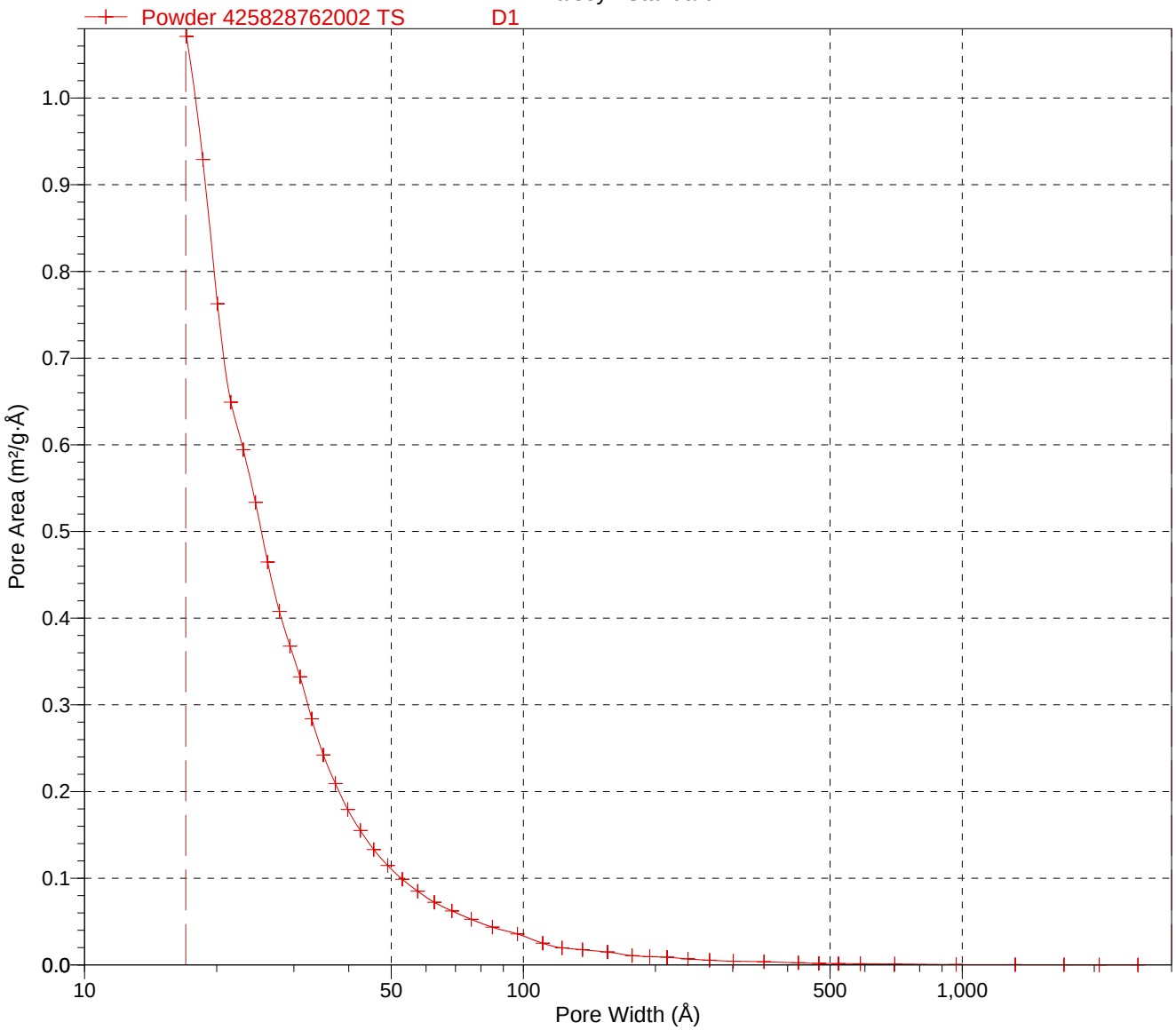
Sample: Powder 425828762002 TS D1
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200795_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:19:46 PM	Thermal Correction:	No
Sample Mass:	2.0491 g	Warm Free Space:	7.9291 cm³ Measured
Cold Free Space:	23.0406 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dA/dw Pore Area

Halsey : Standard



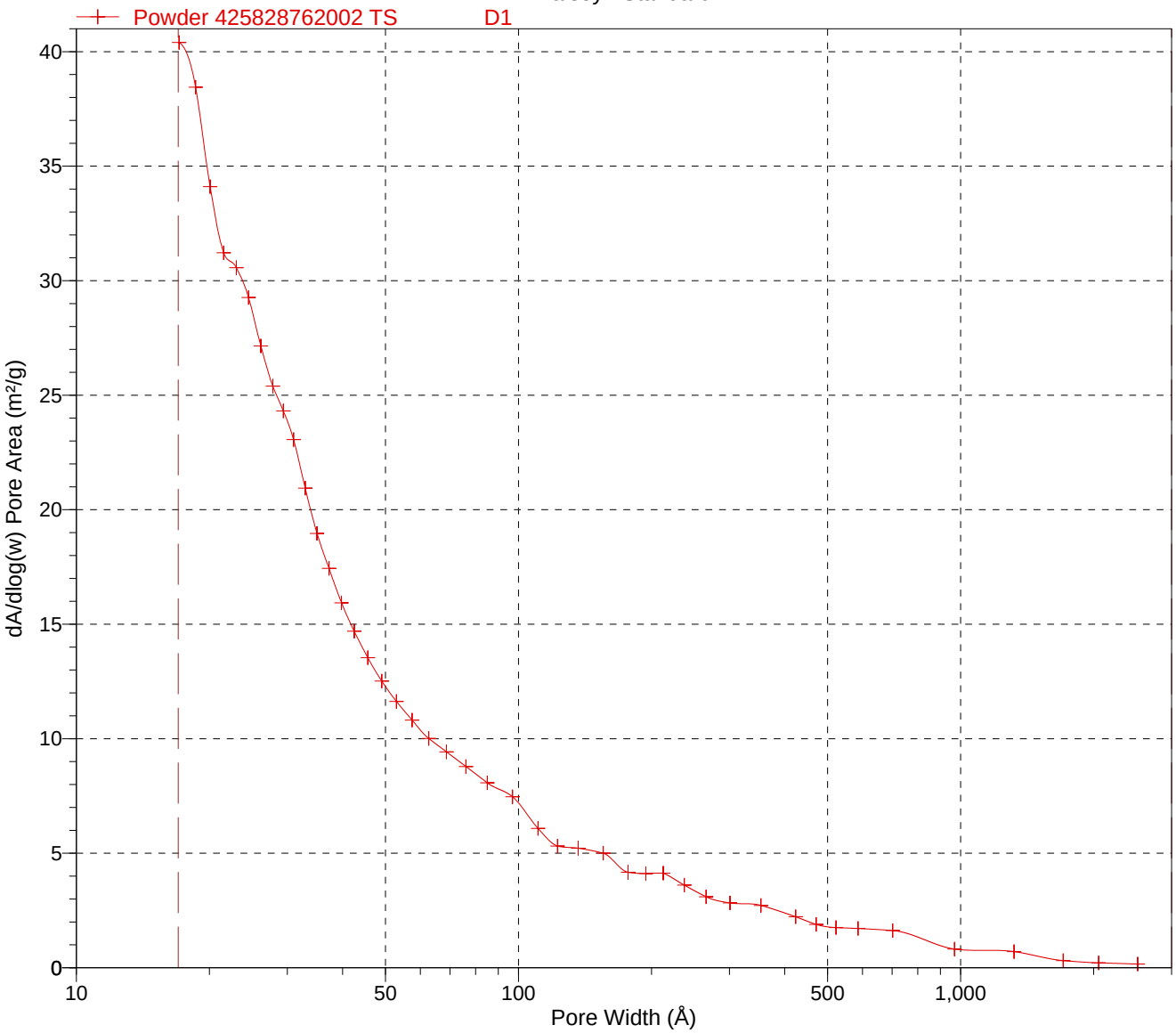
Sample: Powder 425828762002 TS D1
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200795_005-50_Run1.SMP

Started:	2/22/2012 12:01:23 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 10:12:06 AM	Analysis Bath Temp.:	77.300 K
Report Time:	2/28/2012 12:19:46 PM	Thermal Correction:	No
Sample Mass:	2.0491 g	Warm Free Space:	7.9291 cm³ Measured
Cold Free Space:	23.0406 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dA/dlog(w) Pore Area

Halsey : Standard



Sample: Powder 425843775918 OC B6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200794_005-50_Run1.SMP

Started:	2/22/2012 12:01:07 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 2:15:34 PM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:54:14 AM	Thermal Correction:	No
Sample Mass:	2.1991 g	Warm Free Space:	7.4690 cm³ Measured
Cold Free Space:	21.3080 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Summary Report

Surface Area

Single point surface area at p/p° = 0.291102740: 6.9734 m²/g

BET Surface Area: 7.2588 m²/g

t-Plot External Surface Area: 7.8124 m²/g

BJH Adsorption cumulative surface area of pores between 17.000 Å and 3,000.000 Å width: 9.541 m²/g

Pore Volume

Single point adsorption total pore volume of pores less than 2,401.620 Å width at p/p° = 0.991893182: 0.031498 cm³/g

t-Plot micropore volume: -0.000376 cm³/g

BJH Adsorption cumulative volume of pores between 17.000 Å and 3,000.000 Å width: 0.033056 cm³/g

Pore Size

Adsorption average pore width (4V/A by BET): 173.5690 Å

BJH Adsorption average pore width (4V/A): 138.586 Å

Sample: Powder 425843775918 OC B6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200794_005-50_Run1.SMP

Started:	2/22/2012 12:01:07 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 2:15:34 PM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:54:14 AM	Thermal Correction:	No
Sample Mass:	2.1991 g	Warm Free Space:	7.4690 cm³ Measured
Cold Free Space:	21.3080 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Tabular Report

Relative Pressure (p/p°)	Absolute Pressure (mmHg)	Quantity Adsorbed (cm³/g STP)	Elapsed Time (h:min)	Saturation Pressure (mmHg)
			01:05	738.750793
0.002581152	1.902074	0.6898	02:12	736.908936
0.005110740	3.764892	0.8233	02:30	736.662903
0.007481429	5.507967	0.9029	02:48	736.218506
0.009973057	7.340746	0.9631	03:03	736.057739
0.019722368	14.509241	1.1155	03:23	735.674377
0.030699701	22.578901	1.2261	03:37	735.476257
0.041299549	30.372534	1.3092	03:49	735.420471
0.049342205	36.284172	1.3627	03:57	735.357727
0.080207447	58.967674	1.5257	04:09	735.189514
0.115417576	84.851418	1.6716	04:17	735.168945
0.139389335	102.454666	1.7605	04:22	735.025146
0.170009519	124.982948	1.8661	04:28	735.152649
0.200493973	147.381866	1.9670	04:34	735.093750
0.230772859	169.608276	2.0646	04:39	734.957642
0.260834951	191.688217	2.1617	04:44	734.902344
0.291102740	213.881058	2.2597	04:49	734.727051
0.320858128	235.735489	2.3581	04:54	734.703186
0.350029971	257.149292	2.4561	04:58	734.649353
0.379358153	278.689178	2.5570	05:03	734.633423
0.409188460	300.625397	2.6635	05:07	734.686890
0.438762048	322.312286	2.7739	05:12	734.594727
0.468669407	344.253784	2.8899	05:16	734.534363
0.498464930	366.041229	3.0123	05:21	734.336975
0.528323987	387.975159	3.1432	05:26	734.350830
0.558285511	409.869751	3.2834	05:31	734.157959
0.588096096	431.667236	3.4343	05:36	734.007996
0.617917109	453.420929	3.5994	05:41	733.789246
0.647822287	475.219086	3.7811	05:46	733.563965
0.677179196	496.792694	3.9819	05:51	733.620728
0.706893118	518.640198	4.2118	05:56	733.689697
0.736723117	540.439331	4.4741	06:02	733.571838
0.770010205	564.812073	4.8230	06:10	733.512451
0.800549253	587.065674	5.2125	06:19	733.328613
0.818108674	599.880981	5.4809	06:25	733.253418
0.837375099	613.819458	5.8149	06:32	733.028076
0.859786331	630.140991	6.2870	06:41	732.904175
0.880404750	645.199280	6.8325	06:52	732.843933
0.889060793	651.774841	7.1155	06:58	733.104919

Sample: Powder 425843775918 OC B6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200794_005-50_Run1.SMP

Started:	2/22/2012 12:01:07 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 2:15:34 PM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:54:14 AM	Thermal Correction:	No
Sample Mass:	2.1991 g	Warm Free Space:	7.4690 cm³ Measured
Cold Free Space:	21.3080 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Tabular Report

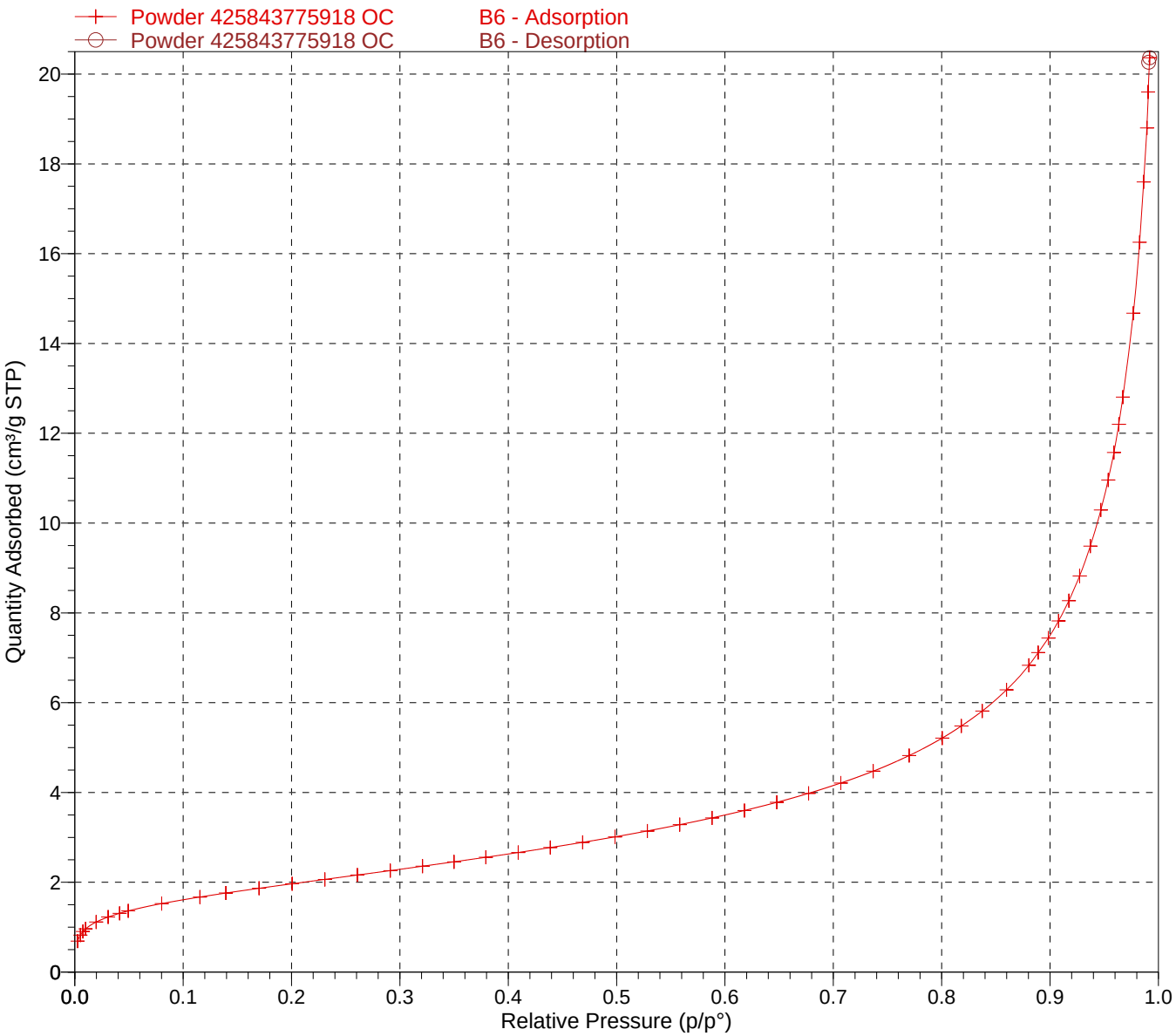
Relative Pressure (p/p°)	Absolute Pressure (mmHg)	Quantity Adsorbed (cm³/g STP)	Elapsed Time (h:min)	Saturation Pressure (mmHg)
0.898415360	658.414368	7.4406	07:05	732.861877
0.907829494	665.286255	7.8210	07:12	732.831726
0.917303504	672.281067	8.2720	07:20	732.888367
0.927303421	679.491882	8.8234	07:28	732.761108
0.937232312	686.768188	9.4882	07:36	732.761963
0.946873538	693.827942	10.2929	07:45	732.756714
0.953624987	698.581116	10.9585	07:53	732.553284
0.958908054	702.415894	11.5735	08:01	732.516418
0.963436406	705.524292	12.1993	08:10	732.299805
0.967239555	708.331299	12.8068	08:18	732.322510
0.976798521	715.251953	14.6727	08:35	732.241028
0.982686588	719.644348	16.2539	08:53	732.323364
0.986374648	722.569519	17.5982	09:08	732.550781
0.989384562	724.372375	18.8017	09:26	732.144409
0.990453848	725.456543	19.6009	09:39	732.448608
0.991893182	726.366150	20.3632	09:51	732.302795
0.990932343	725.554504	20.2625	09:54	732.193787

Sample: Powder 425843775918 OC B6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200794_005-50_Run1.SMP

Started:	2/22/2012 12:01:07 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 2:15:34 PM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:54:14 AM	Thermal Correction:	No
Sample Mass:	2.1991 g	Warm Free Space:	7.4690 cm³ Measured
Cold Free Space:	21.3080 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Isotherm Linear Plot



Sample: Powder 425843775918 OC B6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200794_005-50_Run1.SMP

Started:	2/22/2012 12:01:07 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 2:15:34 PM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:54:14 AM	Thermal Correction:	No
Sample Mass:	2.1991 g	Warm Free Space:	7.4690 cm³ Measured
Cold Free Space:	21.3080 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BET Surface Area Report

BET Surface Area: 7.2588 ± 0.0212 m²/g
Slope: 0.590231 ± 0.001722 g/cm³ STP
Y-Intercept: 0.009478 ± 0.000323 g/cm³ STP
C: 63.271456
Qm: 1.6675 cm³/g STP
Correlation Coefficient: 0.9999702
Molecular Cross-Sectional Area: 0.1620 nm²

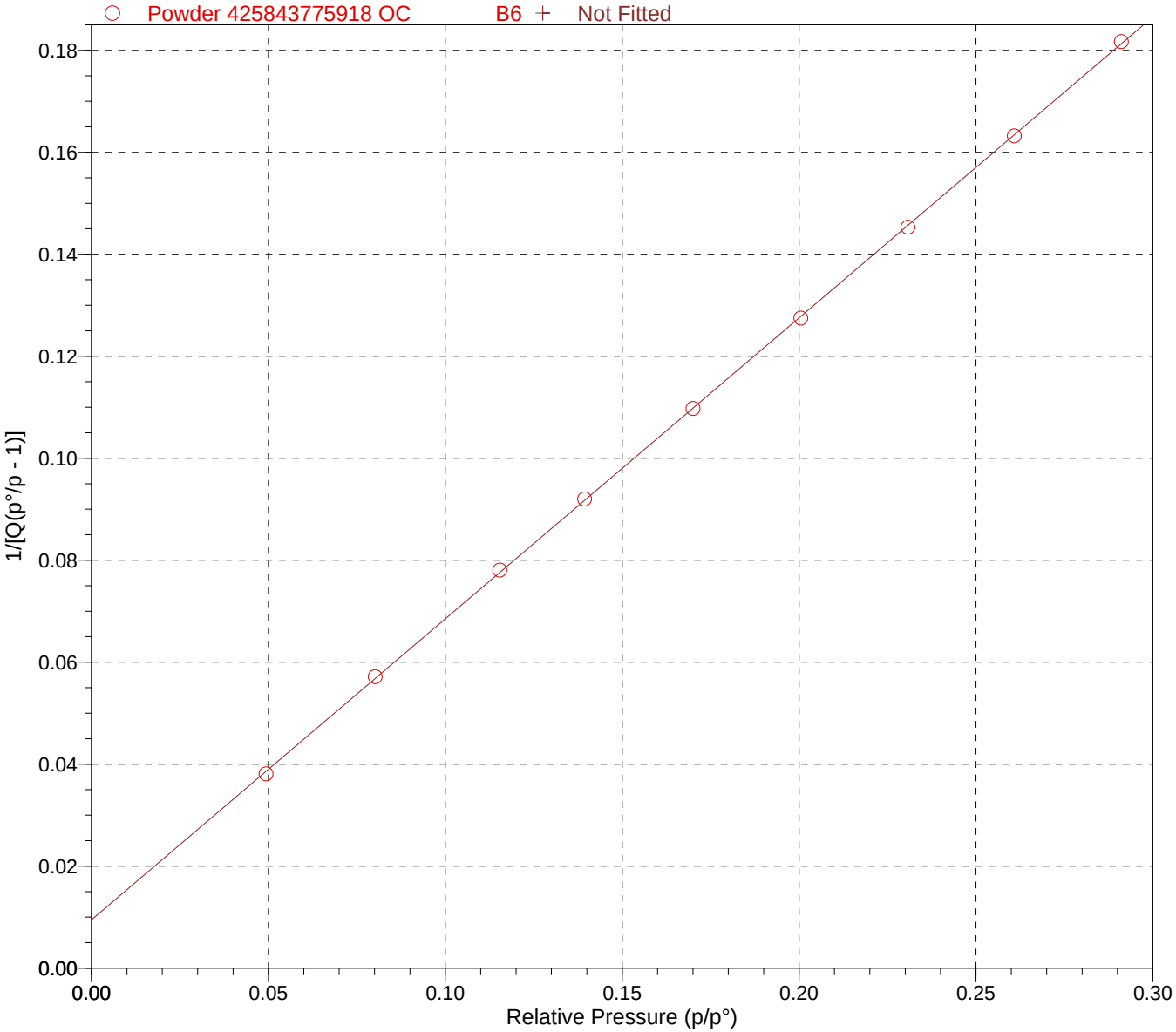
Relative Pressure (p/p°)	Quantity Adsorbed (cm³/g STP)	1/[Q(p°/p - 1)]
0.049342205	1.3627	0.038089
0.080207447	1.5257	0.057156
0.115417576	1.6716	0.078057
0.139389335	1.7605	0.092002
0.170009519	1.8661	0.109767
0.200493973	1.9670	0.127488
0.230772859	2.0646	0.145306
0.260834951	2.1617	0.163239
0.291102740	2.2597	0.181723

Sample: Powder 425843775918 OC B6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200794_005-50_Run1.SMP

Started:	2/22/2012 12:01:07 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 2:15:34 PM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:54:14 AM	Thermal Correction:	No
Sample Mass:	2.1991 g	Warm Free Space:	7.4690 cm³ Measured
Cold Free Space:	21.3080 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BET Surface Area Plot



Sample: Powder 425843775918 OC B6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200794_005-50_Run1.SMP

Started:	2/22/2012 12:01:07 PM	Analysis Adsorptive:	N2
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Cold Free Space:	21.3080 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot Report

Micropore Volume:	-0.000376 cm³/g
Micropore Area:	*
External Surface Area:	7.8124 m²/g
Slope:	0.505071 ± 0.000406 cm³/g·Å STP
Y-Intercept:	-0.242851 ± 0.002237 cm³/g STP
Correlation Coefficient:	0.999995
Surface Area Correction Factor:	1.000
Density Conversion Factor:	0.0015468
Total Surface Area (BET):	7.2588 m²/g
Thickness Range:	3.7221 Å to 7.3454 Å
Thickness Equation:	Harkins and Jura

Thickness Curve

t = [13.99 / (0.034 - log(p/p°))] ^ 0.5

t-Plot Report - Data

Relative Pressure (p/p°)	Statistical Thickness (Å)	Quantity Adsorbed (cm³/g STP)	Fitted
0.002581152	2.3098	0.6898	
0.005110740	2.4527	0.8233	
0.007481429	2.5450	0.9029	
0.009973057	2.6219	0.9631	
0.019722368	2.8363	1.1155	
0.030699701	3.0073	1.2261	
0.041299549	3.1410	1.3092	
0.049342205	3.2302	1.3627	
0.080207447	3.5189	1.5257	
0.115417576	3.7943	1.6716	*
0.139389335	3.9652	1.7605	*
0.170009519	4.1726	1.8661	*
0.200493973	4.3720	1.9670	*
0.230772859	4.5668	2.0646	*
0.260834951	4.7593	2.1617	*
0.291102740	4.9544	2.2597	*
0.320858128	5.1490	2.3581	*
0.350029971	5.3439	2.4561	*
0.379358153	5.5453	2.5570	*
0.409188460	5.7572	2.6635	*
0.438762048	5.9758	2.7739	*
0.468669407	6.2069	2.8899	*
0.498464930	6.4492	3.0123	*

Sample: Powder 425843775918 OC B6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200794_005-50_Run1.SMP

Started:	2/22/2012 12:01:07 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 2:15:34 PM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:54:14 AM	Thermal Correction:	No
Sample Mass:	2.1991 g	Warm Free Space:	7.4690 cm³ Measured
Cold Free Space:	21.3080 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot Report - Data

Relative Pressure (p/p°)	Statistical Thickness (Å)	Quantity Adsorbed (cm³/g STP)	Fitted
0.528323987	6.7059	3.1432	*
0.558285511	6.9801	3.2834	*
0.588096096	7.2720	3.4343	*
0.617917109	7.5865	3.5994	
0.647822287	7.9287	3.7811	
0.677179196	8.2955	3.9819	
0.706893118	8.7044	4.2118	
0.736723117	9.1611	4.4741	
0.770010205	9.7388	4.8230	
0.800549253	10.3495	5.2125	
0.818108674	10.7443	5.4809	
0.837375099	11.2225	5.8149	
0.859786331	11.8511	6.2870	
0.880404750	12.5153	6.8325	
0.889060793	12.8240	7.1155	
0.898415360	13.1810	7.4406	
0.907829494	13.5680	7.8210	
0.917303504	13.9893	8.2720	
0.927303421	14.4741	8.8234	
0.937232312	15.0030	9.4882	
0.946873538	15.5701	10.2929	
0.953624987	16.0038	10.9585	
0.958908054	16.3673	11.5735	
0.963436406	16.6977	12.1993	
0.967239555	16.9899	12.8068	
0.976798521	17.7919	14.6727	
0.982686588	18.3417	16.2539	
0.986374648	18.7114	17.5982	
0.989384562	19.0291	18.8017	
0.990453848	19.1457	19.6009	
0.991893182	19.3059	20.3632	

* The micropore area is not reported because either the micropore volume is negative or the calculated external surface area is larger than the total surface area.

Sample: Powder 425843775918 OC B6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200794_005-50_Run1.SMP

Started:	2/22/2012 12:01:07 PM	Analysis Adsorptive:	N2
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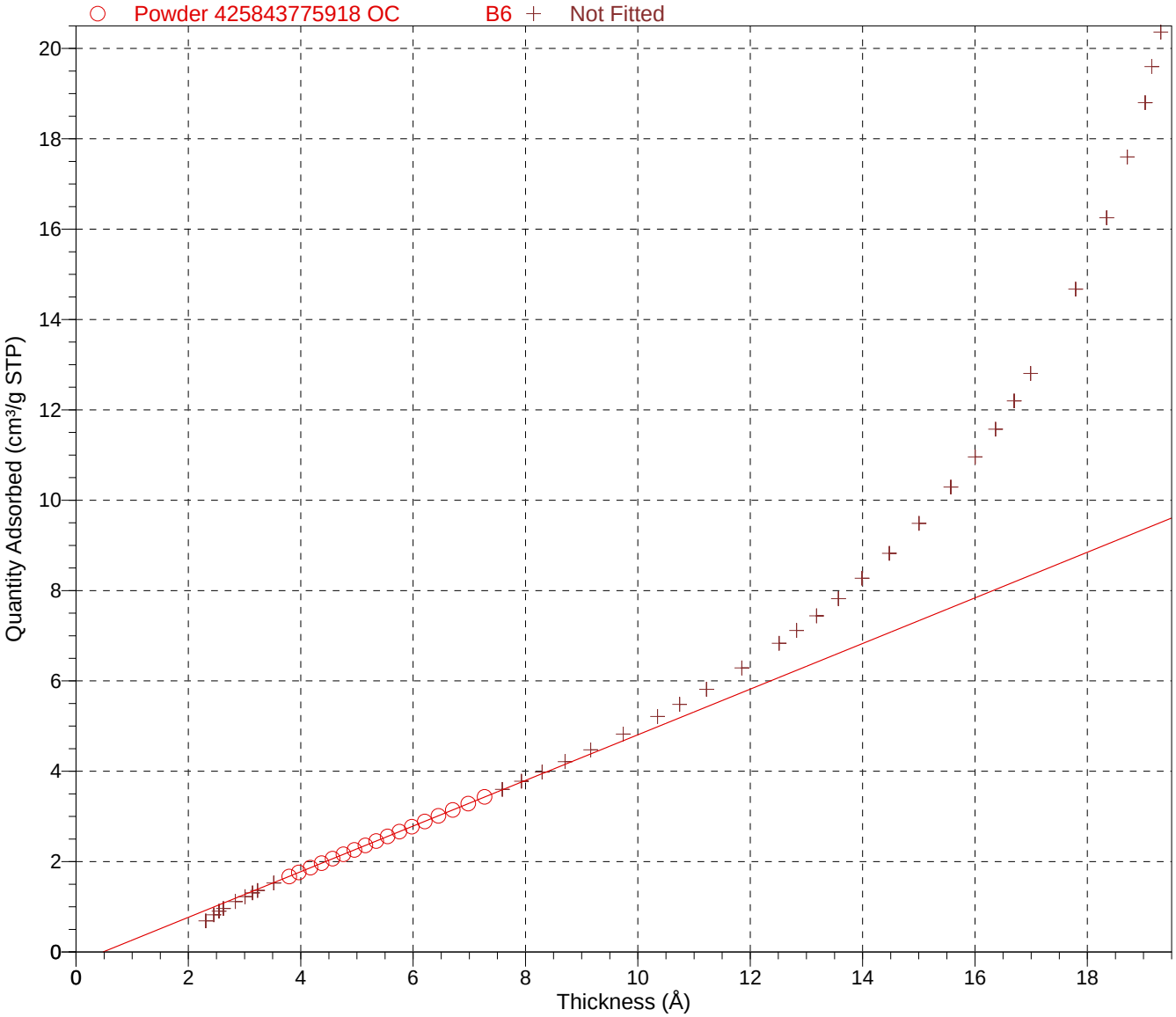
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

t-Plot

Harkins and Jura



Sample: Powder 425843775918 OC B6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200794_005-50_Run1.SMP

Started:	2/22/2012 12:01:07 PM	Analysis Adsorptive:	N2
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Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Pore Distribution Report

Standard
Halsey
t = 3.54 [-5 / ln(p/p°)] ^ 0.333

Width Range: 17.000 Å to 3,000.000 Å
Adsorbate Property Factor: 9.53000 Å
Density Conversion Factor: 0.0015468
Fraction of Pores Open at Both Ends: 0.00

Pore Width Range (Å)	Average Width (Å)	Incremental Pore Volume (cm³/g)	Cumulative Pore Volume (cm³/g)	Incremental Pore Area (m²/g)	Cumulative Pore Area (m²/g)
2401.6 - 2043.9	2193.7	0.001244	0.001244	0.023	0.023
2043.9 - 1840.8	1931.6	0.001309	0.002553	0.027	0.050
1840.8 - 1439.8	1591.1	0.001979	0.004531	0.050	0.100
1439.8 - 1137.9	1253.2	0.002228	0.006760	0.071	0.171
1137.9 - 854.1	955.3	0.002647	0.009407	0.111	0.281
854.1 - 609.8	691.0	0.003173	0.012580	0.184	0.465
609.8 - 547.9	575.4	0.001038	0.013617	0.072	0.537
547.9 - 489.0	515.0	0.001074	0.014692	0.083	0.621
489.0 - 434.8	458.6	0.001061	0.015753	0.093	0.713
434.8 - 381.0	404.2	0.001157	0.016910	0.114	0.828
381.0 - 324.1	347.8	0.001415	0.018324	0.163	0.991
324.1 - 281.1	299.4	0.001177	0.019502	0.157	1.148
281.1 - 248.2	262.5	0.000983	0.020485	0.150	1.298
248.2 - 223.4	234.4	0.000810	0.021295	0.138	1.436
223.4 - 203.4	212.4	0.000686	0.021981	0.129	1.565
203.4 - 186.8	194.3	0.000588	0.022569	0.121	1.686
186.8 - 173.7	179.7	0.000517	0.023086	0.115	1.801
173.7 - 148.9	159.2	0.001005	0.024091	0.252	2.054
148.9 - 128.9	137.3	0.000876	0.024967	0.255	2.309
128.9 - 115.6	121.4	0.000621	0.025588	0.205	2.513
115.6 - 105.6	110.1	0.000504	0.026092	0.183	2.696
105.6 - 91.8	97.7	0.000738	0.026830	0.302	2.999
91.8 - 80.3	85.2	0.000665	0.027495	0.312	3.311
80.3 - 72.2	75.7	0.000500	0.027995	0.264	3.575
72.2 - 65.5	68.4	0.000441	0.028436	0.258	3.833
65.5 - 59.9	62.4	0.000386	0.028822	0.248	4.081
59.9 - 55.0	57.2	0.000348	0.029170	0.244	4.324
55.0 - 50.8	52.7	0.000318	0.029488	0.241	4.565
50.8 - 47.2	48.8	0.000291	0.029779	0.238	4.803
47.2 - 43.9	45.4	0.000270	0.030049	0.238	5.041
43.9 - 41.0	42.4	0.000253	0.030302	0.239	5.280

Sample: Powder 425843775918 OC B6
Operator: AG
Submitter: URS Corporation
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Completed:	2/23/2012 2:15:34 PM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:54:14 AM	Thermal Correction:	No
Sample Mass:	2.1991 g	Warm Free Space:	7.4690 cm³ Measured
Cold Free Space:	21.3080 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

Pore Width Range (Å)	Average Width (Å)	Incremental Pore Volume (cm³/g)	Cumulative Pore Volume (cm³/g)	Incremental Pore Area (m²/g)	Cumulative Pore Area (m²/g)
41.0 - 38.4	39.6	0.000236	0.030538	0.238	5.518
38.4 - 36.0	37.1	0.000223	0.030761	0.240	5.758
36.0 - 33.9	34.9	0.000213	0.030974	0.245	6.003
33.9 - 31.9	32.8	0.000205	0.031179	0.250	6.253
31.9 - 30.1	30.9	0.000193	0.031372	0.250	6.503
30.1 - 28.4	29.1	0.000187	0.031559	0.257	6.759
28.4 - 26.7	27.5	0.000188	0.031747	0.273	7.033
26.7 - 25.1	25.9	0.000183	0.031930	0.283	7.316
25.1 - 23.7	24.3	0.000180	0.032110	0.295	7.611
23.7 - 22.2	22.9	0.000175	0.032285	0.306	7.918
22.2 - 20.8	21.4	0.000180	0.032464	0.335	8.253
20.8 - 19.3	20.0	0.000183	0.032648	0.367	8.620
19.3 - 18.2	18.7	0.000154	0.032802	0.330	8.949
18.2 - 16.4	17.2	0.000254	0.033056	0.591	9.541

Sample: Powder 425843775918 OC B6
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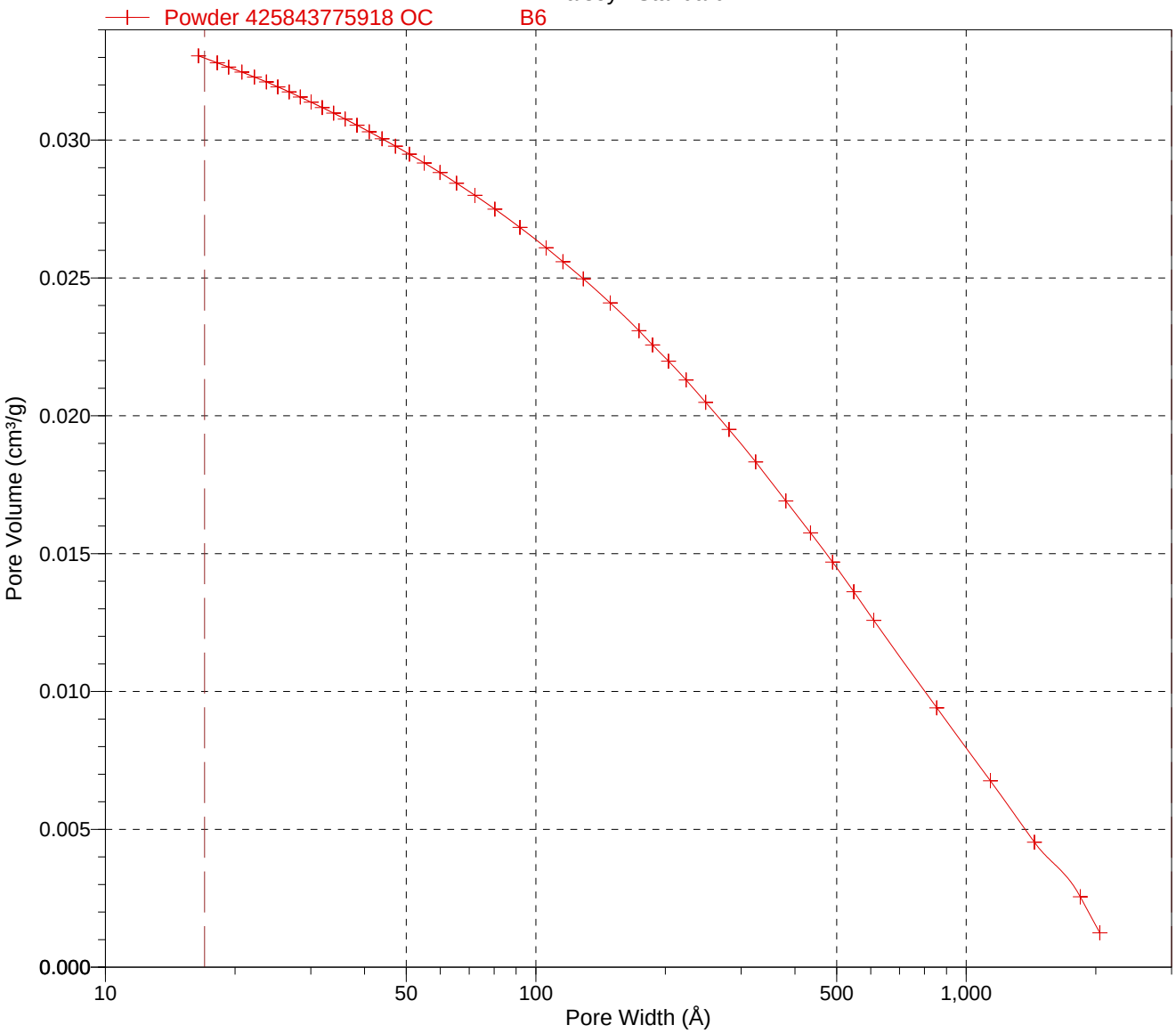
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Cumulative Pore Volume (Larger)

Halsey : Standard



Sample: Powder 425843775918 OC B6
Operator: AG
Submitter: URS Corporation
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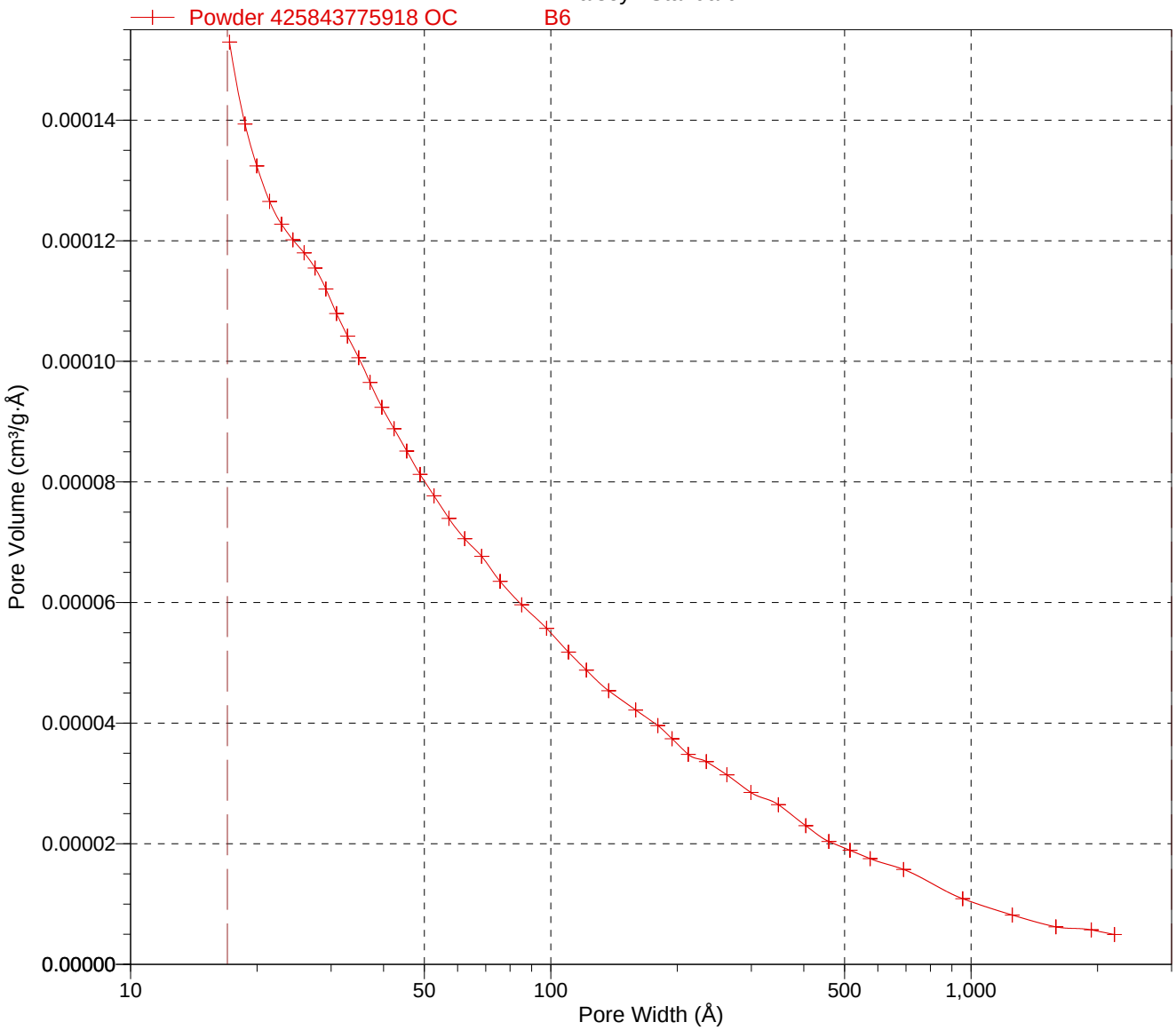
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dV/dw Pore Volume

Halsey : Standard



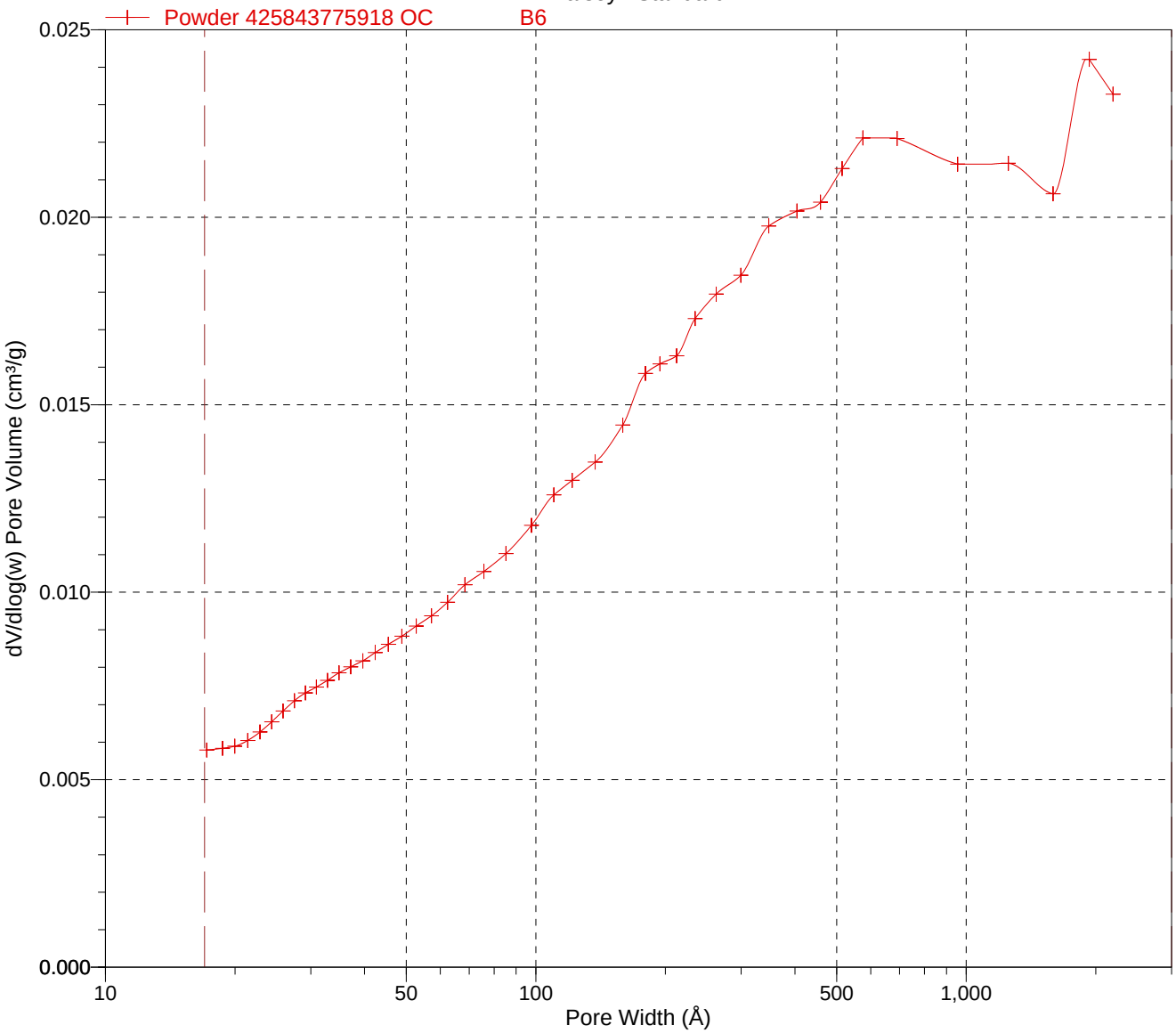
Sample: Powder 425843775918 OC B6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200794_005-50_Run1.SMP

Started:	2/22/2012 12:01:07 PM	Analysis Adsorptive:	N2
Completed:	2/23/2012 2:15:34 PM	Analysis Bath Temp.:	77.300 K
Report Time:	3/19/2012 8:54:14 AM	Thermal Correction:	No
Sample Mass:	2.1991 g	Warm Free Space:	7.4690 cm³ Measured
Cold Free Space:	21.3080 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dV/dlog(w) Pore Volume

Halsey : Standard



Sample: Powder 425843775918 OC B6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200794_005-50_Run1.SMP

Started:	2/22/2012 12:01:07 PM	Analysis Adsorptive:	N2
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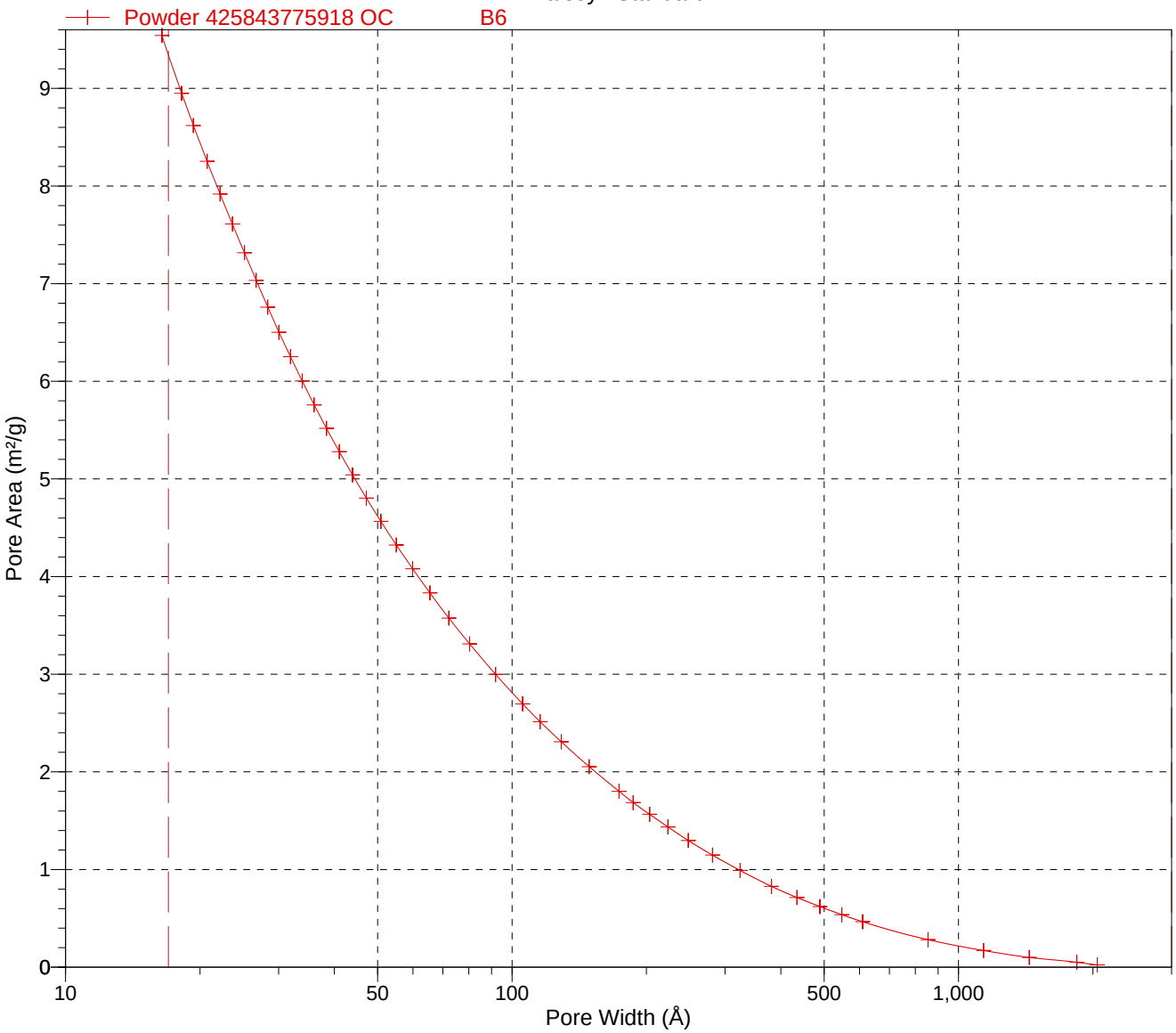
Sample Mass:	2.1991 g	Warm Free Space:	7.4690 cm³ Measured
Cold Free Space:	21.3080 cm³	Equilibration Interval:	15 s
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption Cumulative Pore Area (Larger)

Halsey : Standard



Sample: Powder 425843775918 OC B6
Operator: AG
Submitter: URS Corporation
File: C:\win3020\data\2012\02Feb\1200794_005-50_Run1.SMP

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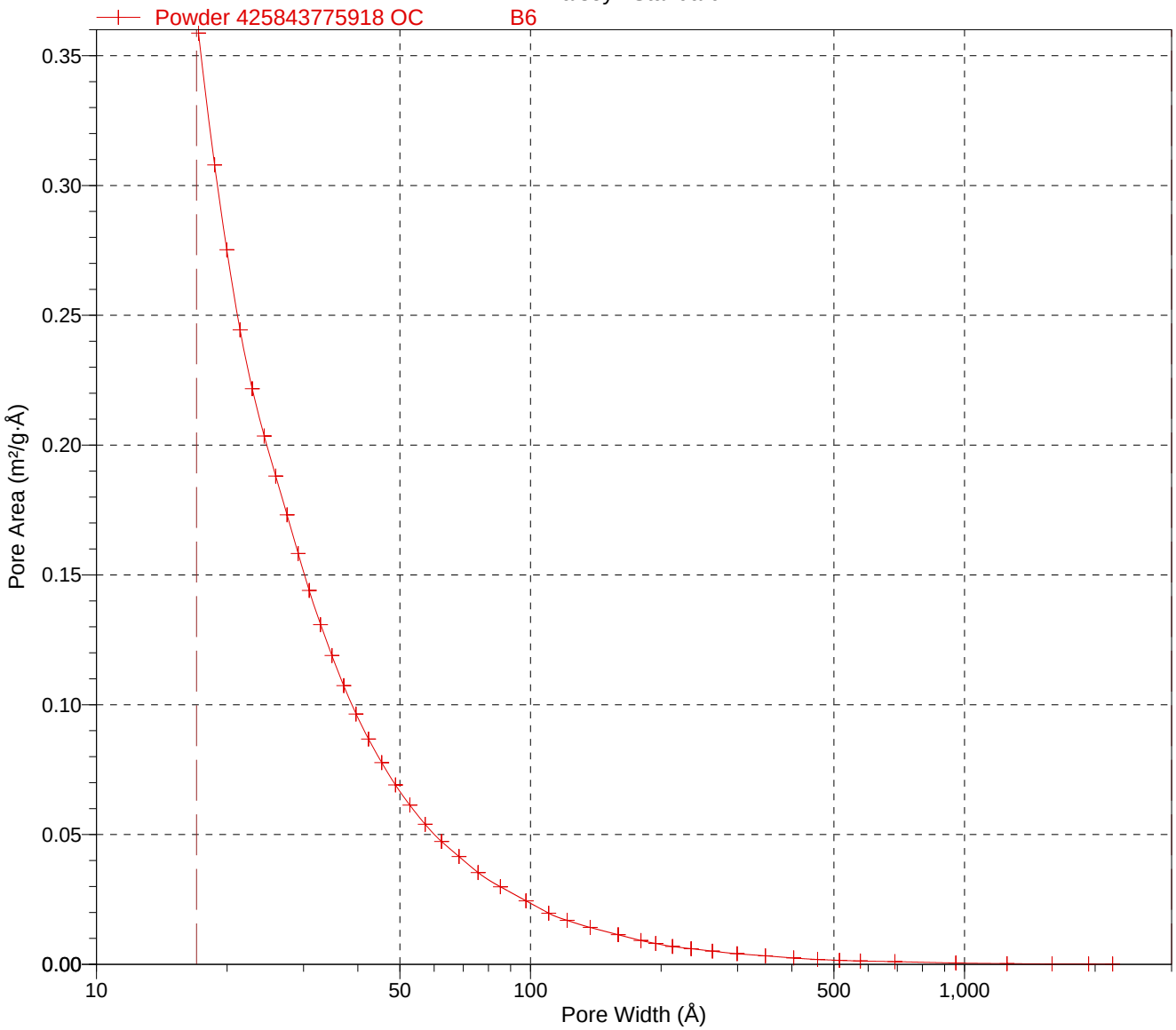
Low Pressure Dose:	None	Sample Density:	1.000 g/cm³
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dA/dw Pore Area

Halsey : Standard



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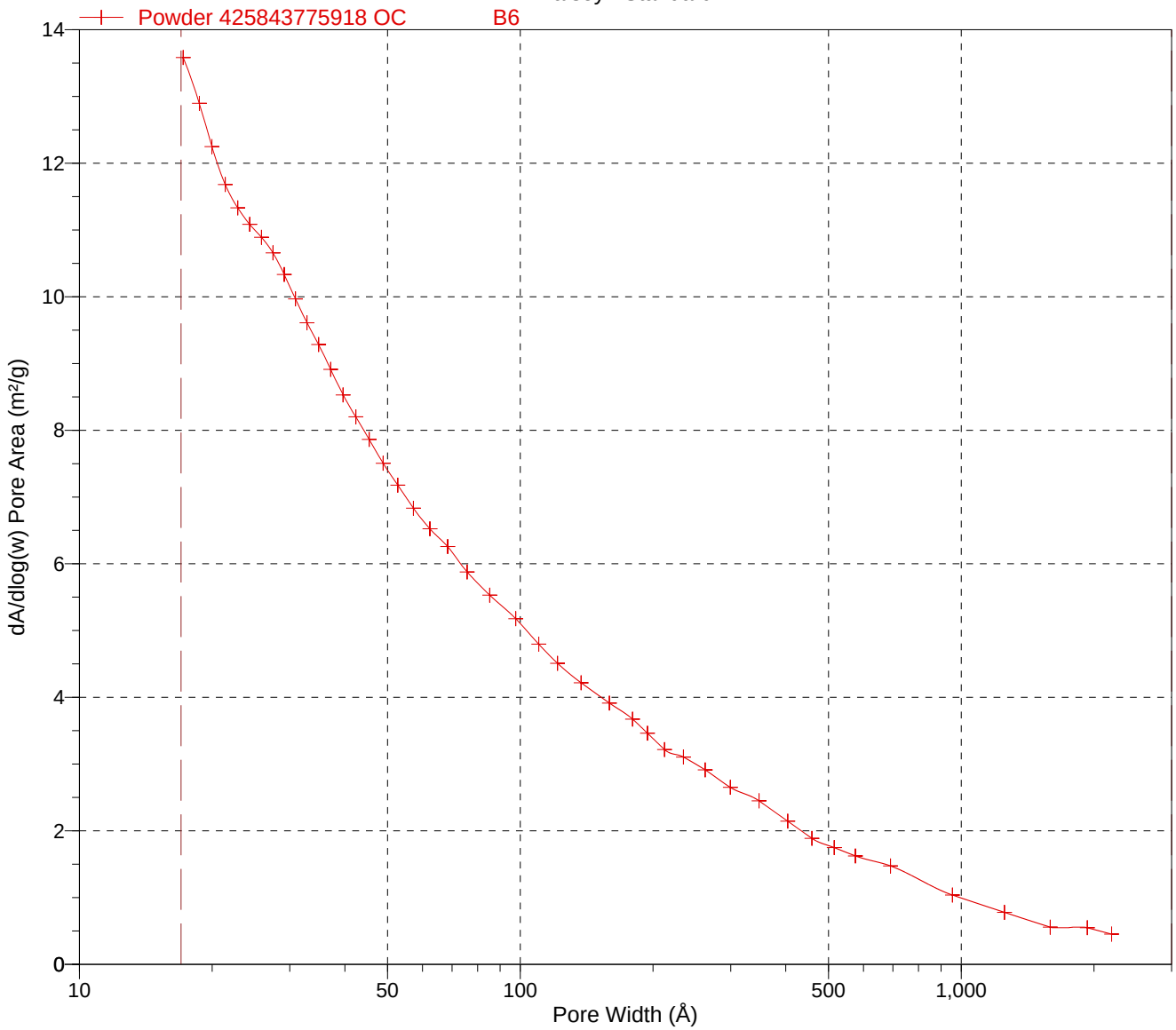
Automatic Degas:	Yes		

Sample Prep: Stage	Temperature ()	Ramp Rate (/min)	Time (min)
1	90	10	960

BJH Adsorption dA/dlog(w) Pore Area

Halsey : Standard



Sean Plasynski
Director
Strategic Center for Coal
National Energy Technology Laboratory
U.S. Department of Energy

Traci Rodosta
Sequestration Technology Manager
Strategic Center for Coal
National Energy Technology Laboratory
U.S. Department of Energy

Cynthia Powell
Director
Office of Research and Development
National Energy Technology Laboratory
U.S. Department of Energy

George Richards
Focus Area Lead
Energy Systems Dynamics
National Energy Technology Laboratory
U.S. Department of Energy

Angela Goodman
Technical Project Lead
Carbon Storage
Materials Characterization Division
National Energy Technology Laboratory
U.S. Department of Energy

Kevin Donovan
RES Program Manager
URS Corporation