EBA Engineering Consultants Ltd.

Creating and Delivering Better Solutions

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EBA File: 1100052

Public Works and Government Services Canada
c/o Giant Mine Reclamation Project
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Attention: Mr. Mark Cronk

Subject: Results of Laboratory Measurement of the Thermal Properties of Arsenic Trioxide Giant Mine Reclamation Project

1.0 SUMMARY

EBA Engineering Consultants Ltd. (EBA) conducted a laboratory program to determine the thermal conductivity and unfrozen water content curve of two samples of arsenic trioxide dust from Giant Mine, NWT. The dust samples tested were labelled as B208-1 and C212-2. Due to the limited quantities of C212-2, SRK also authorized the use of dust from Barrel No. 10394-001 for thermal conductivity testing.

The unfrozen thermal conductivity of B208-1 material varied from 0.47 and 0.92 W m^{-1} K^{-1} for saturations between 53% and 100%; the frozen thermal conductivity varied between 0.59 and 1.9 W m^{-1} K^{-1} over the same saturations. The unfrozen thermal conductivity of C212-2 material varied from 0.89 and 1.02 W m^{-1} K^{-1} for saturations around 108%; the frozen thermal conductivity varied between 1.76 and 2.02 W m^{-1} K^{-1} for the same saturation. The unfrozen thermal conductivity of Barrel No. 10394-001 dust varied from 0.47 and 0.71 W m^{-1} K^{-1} for saturations between 42% and 90%; the frozen thermal conductivity varied between 0.67 and 1.43 W m^{-1} K^{-1} over the same saturations.

The unfrozen water content was inferred from the apparent dielectric constant using both the Topp et al. (1980) and the Smith and Tice (1988) empirical equations. Both equations indicated that the volumetric unfrozen water content did not decrease significantly below -2°C for both B208-1 and C212-2.

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2.0 INTRODUCTION

Public Works and Government Services Canada (PWGSC) retained EBA Engineering Consultants Ltd. to determine the thermal conductivity and unfrozen water content curve for arsenic trioxide dust from Giant Mine, NWT. Arsenic trioxide is classified as a hazardous material. PWGSC arranged to conduct the tests at SGS Lakefield Research where they had a containment booth set-up with the necessary engineering controls for testing this hazardous material. Under these circumstances, EBA proposed that test equipment be purchased for this program as our Edmonton equipment could not be moved to another laboratory. Furthermore, it was also understood that the equipment would likely be contaminated with arsenic trioxide dust and may not re-useable.

EBA's scope of work included the following:

1. Purchasing equipment required for both the needle probe thermal conductivity tests and the time domain reflectometry (TDR) unfrozen water content tests.
2. Mobilizing and transport of equipment to SGS Lakefield Research's laboratory at Lakefield, Ontario.
3. Conducting the test program by an EBA representative at SGS Lakefield over a period of 10 days.
4. Writing a report presenting the results of the test program and describing the test methods.

2.1 Test Methods

2.1.1 Specimen Preparation

Test specimens of arsenic trioxide from Giant Mine were obtained from two pails labelled as B208-1 and C212-2. B208-1 had an initial moisture content of 0.3% and there was sufficient material to prepare three specimens at three different water contents for both the unfrozen water content tests and the thermal conductivity tests. C212-2 had an initial water content of 27.8%; there was insufficient material to make six test specimens and so this material had to be oven dried and reconditioned at different water contents to complete the test program. Specimens were oven dried at 105 °C and allowed to cool prior to mixing with tap water and preparing the specimens at the desired water content to achieve saturations at approximately 50, 75 and 100%.

Due to time constraints, SRK authorized EBA to obtain thermal conductivity test specimens from dust in Barrel No. 10394-001. This was dust left over from a previous test program at SGS Lakefield (March 2004 feed). It was dry and was therefore moisture conditioned to get the desired saturations. Particle size distributions and Atterberg limits should be compared for these material as it was evident through preparation of the test specimens that this dust was different from C212-2 dust.

Two kinds of specimen containers were used: rectangular steel containers for the unfrozen water content specimens and cylindrical HDPE containers for the thermal conductivity specimens. The steel containers were fabricated with a rectangular cross-section that permitted six specimens to be immersed in the temperature control circulation bath (71 x 95 x 280 mm). The HDPE cylinders were 101.2 mm in diameter by 202.4 mm higher. Material was tamped into the specimen containers in five lifts and then struck off at the top of the container. Cuttings were retained for moisture content determination, and the initial specimen mass and volume were measured. After the test was completed, the specimen was removed and the final water content determined along with the final volume and mass. Due to time restrictions, the final water content and densities of unfrozen water content specimens 5 and 6 were not determined. A specific gravity of 3.17 for the solids, as given by SRK, was used to calculate the associated physical properties (void ratio, saturation, and volumetric water). The initial and final physical properties of the thermal conductivity and unfrozen water content test specimens are presented in Tables B-1 and B-2 and C-1 and C-2, respectively.

After testing, the specimens were bagged and placed in 20 litre HDPE pails for storage.

2.1.2 Thermal Conductivity

EBA used a thermal conductivity needle probe and power supply purchased from Geotherm Inc. and followed the ASTM D5334[1] test procedure. A 150 mm long probe consisting of a heating element and temperature sensor was inserted into the specimen and a known current and voltage were applied to the probe. The temperature rise is monitored over about 15 minutes. The thermal conductivity was determined from an analysis of the linear portion of the temperature versus time response. This procedure is based on a variation of the line source method where a needle probe with sufficient diameter to length ratio is chosen to simulate conditions for an

[1] ASTM 2004: D5334 Determination of Thermal Conductivity of Soil and Soft Rock by Thermal Needle Probe Procedure. Annual Book of ASTM Standards, Vol. 04.08, ASTM International, West Conshohocken, PA.

infinitely long specimen. The equipment and procedure were checked and calibrated in Edmonton by determining the thermal conductivity of ice (Appendix A).

Tests were conducted first on unfrozen specimens that were conditioned at room temperature (approximately 24 °C). Specimens were then placed in a chest freezer with the probe inserted and the leads extending outside of the freezer. These were left overnight and the thermal conductivity measurements conducted with the specimen left in the freezer with an average specimen temperature of -24.1°C. Specimens were removed from the chest freezer and allowed to thaw overnight before the needle probe could be removed and used in another specimen. The specimen thermal conductivity was determined on the thawed specimen as well.

Photograph D-1 in shows the equipment and set-up for this test.

2.1.3 Unfrozen Water Content by Time Domain Reflectometry

EBA purchased six 200 mm long three-wire transmission probes (or waveguides) and one TDR100 Time Domain Reflectometer for logging the waveform signal. The TDR100 was plugged into a laptop and PCTDR software was used to the plot the waveform, record the signal, and calculate the apparent dielectric constant. An Isotemp Model 3028 refrigerated circulator was purchased to condition the specimens at a constant temperatures of -8, -5, -3, -2, -.1.5, -1, and -0.5°C. The circulator work area was large enough to accommodate all six of the test specimens required for unfrozen water content testing (2 samples at 3 different saturation). The intent was to condition all of the specimens simultaneously since temperature equilibration can take between 4 to 16 hours; thereby extending the unfrozen water content conditioning time over 3 to 4 days. However, there was insufficient material from C212-2 to prepare all three specimens and a second batch of specimens were run through the temperature range once the first batch was completed. Temperature was monitored with two thermistor beads immersed in the work area glycol and a third thermistor installed in a sand specimen also immersed in the work area next to the test specimens. The TDR measurement was taken when the sand specimen temperature had stabilized near the desired temperature. The equipment and procedure were checked and calibrated in Edmonton by measuring the volumetric water content of sand specimens and comparing these with the gravimetric water content.

There is no standard method in North America for determining the unfrozen water content of soils by time domain reflectometry. Topp et al[2]. found that a reliable relationship could be established between the volumetric water content and the dielectric constant of soils. Studies by Patterson and Smith[3], Smith and Patterson[4] and Smith and Tice[5] have demonstrated that TDR provides a relatively accurate means of determining the unfrozen water content of soils.

After the specimens were prepared, the transmission probes were inserted and the volumetric water content determined at room temperature. The specimen was then frozen in an uncontrolled manner by either placing it in the chest freezer (approximately -25°C) or in the circulation bath set at -10°C. After initial freezing, the specimen was conditioned in the circulation bath at -8°C and allowed to stabilize. To take a measurement, the probe was connected to the TDR100 and laptop system (wave cable, wave generator, datalogger and recorder) and the waveform generated in the probes logged, recorded and Ka calculated. The circulation bath temperature was reset to the next temperature and the procedure repeated. Photographs D-2, D-3 and D-4 show the equipment set-up for these tests.

The logged waveform of amplitude versus time gives the time for the signal to travel down the probe and reflect back. The travel time of the signal depends on velocity, which in turn depends on the dielectric constant (Ka) of the medium surrounding the probe. The apparent dielectric constant (or relative permittivity) is an expression of the extent to which a material concentrates electric flux. The signal duration is related to Ka of the material surrounding the probe by the equation:

$$Ka = (c\ \Delta t/2\ L)^2$$

Where c is velocity of electromagnetic signals in free space, Δt is the signal transit time, and L is the probe length.

Two equations are commonly used to calculate the volumetric water content from the dielectric constant. Topp et al. developed empirical equations for volumetric water in unfrozen soil. Smith

[2] Topp, G.C., Davis, J.L., and Annan, A.P., 1980. Electromagnetic determination of soil water content: measurements in coaxial transmission lines. Water Resources Research, 16: 574-582.

[3] Patterson, D.E. and Smith, M.W. 1981. The measurement of unfrozen water content by time domain reflectometry: results from laboratory tests. Canadian Geotechnical Journal, 18: 131-144.

[4] Smith, M.W. and Patterson, D.E. 1984. Determining the unfrozen water content in soils by time-domain reflectometry. Atmosphere-Ocean, 22(2): 261-263.

and Tice developed a similar equation relating the unfrozen water content and the dielectric constant in frozen soils. Both equations were used to calculate the volumetric water content; they are provided below:

$$\theta_v = 8.14E-06Ka^3 - 7.38E-04Ka^2 + 3.18E-02Ka - 5.97E-02 \text{ Topp et al.}$$

$$\theta_v = 9.92E-06Ka^3 - 8.502E-04Ka^2 + 3.868E-02Ka - 0.14858 \text{ Smith and Tice}$$

Where (θ_v in m^3 of water per m^3 of specimen) is the volumetric water content and Ka is the apparent dielectric constant.

3.0 RESULTS

3.1 Thermal Conductivity Measurements

Results are presented in Table 1. The individual data sheets are presented in Appendix B.

Table 1
Measured Thermal Conductivities and Specimen Characteristics

Specimen No.	Bulk Density (g/cm^3)	Water Content (%)	Dry Density (g/cm^3)	Void Ratio	Saturation (%)	Volumetric Water	Thermal Conductivity $W\ m^{-1}\ K^{-1}$		
							Unfrozen	Thawed	Frozen
Sample B208-1									
1	1.999	27.8	1.565	1.03	85.8	43.5	0.89	0.80	1.61
2	1.950	42.4	1.369	1.31	102.3	66.4	0.92	0.88	1.90
3	1.773	18.8	1.492	1.13	53.1	29.5	0.49	0.47	0.59
Sample C212-2									
4	2.192	27.0	1.726	0.84	102.4	42.3	0.97	0.89	1.76
8	2.196	33.5	1.645	0.93	114.5	52.4	1.02	n/a	2.02
Sample Barrel Dust									
5	1.646	16.4	1.414	1.24	41.9	25.7	0.47	0.49	0.67
6	1.672	25.5	1.333	1.38	58.6	39.9	0.47	0.47	0.84
7	1.879	37.2	1.370	1.31	89.7	58.2	0.71	n/a	1.43

[5] Smith, M.W. and Tice, A.R. 1988. Measurement of the unfrozen water content of soils. Comparison of NMR and TDR methods. CRREL Report 88-18, 41p.

3.2 Unfrozen Water Content Measurements by TDR

Results are presented in Appendix C. The volumetric water content (based on the gravimetric water and density) for unfrozen specimens were compared with the volumetric water obtained from the TDR method. The results were comparable for B208-1 specimens at initial saturations of 75% and 102% and for C212-2 specimens at initial saturations of 89% and 68%. For both B208-1 and C212-2, the empirical equations under-predicted the volumetric water at the lowest saturations (49% for B208-1 and 60% for C212-2).

4.0 LIMITATIONS

The testing services reported herein have been performed by an EBA engineer to recognized industry standards, unless otherwise noted. No other warranty is made. These data do not include or represent any interpretation or opinion of specification compliance or material suitability. Should engineering interpretation be required, EBA will provide it upon written request.

Data presented herein are for the sole use of the stipulated client. EBA is not responsible, nor can be held liable, for use made of this report by any other party, with or without the knowledge of EBA.

5.0 CLOSURE

EBA Engineering Consultants Ltd. is pleased to provide you with these test results of the thermal properties of arsenic trioxide dust from Giant Mine. Please contact the undersigned if you have any questions.

Submitted by,
EBA Engineering Consultants Ltd.

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/kdb

APPENDIX A

CALIBRATION INFORMATION FOR THE THERMAL CONDUCTIVITY AND UNFROZEN WATER CONTENT BY TDR

Calibration of Thermal Conductivity Probes Using Ice

Apr. 13 to Apr. 19, 2004 Tests Conducted by GZ

Tested in	cold bath (-15.9)	cold bath (-15.0)
Test:	Probe No. 1, Test No.1	Probe No. 2, Test No.6
Date	Apr. 13, 2004	Apr. 19, 2004
Measured:		
Total Voltage V [Volt]	1.9	1.9
eater Resistance R (Ohm)	1.425	1.425
Resistance of Heater plus wires R_{total} [Ohms]	**1.51**	**1.51**
Probe Length, l [mm]	150	150
Current on Screen of DC Power Supply (Amp)	1.18	1.2
Current Measured (point connection) by Multimeter (Amp)	1.15	1.16
Calculate:		
$i = V/R_{total}$ [A]	1.258	1.258
Q = (Ri)*i [W]	2.256	2.256
q = Q/l [W/m]	1.504E+01	1.504E+01
K = q/(4PI*(T2-T1))*ln(t2/t1)		
Enter:		
T2 [°C]	-14.04	-14.09
T1 [°C]	-11.62	-10.2
t2 [sec]	10	1
t1 [sec]	1000	1000
K [W/m°C] =	**2.28**	**2.13**
Theoretical Value [W/m°C]	2.32	2.32
Error in Percentage (%)	-1.8	-8.4
water for ice	tap water ice	distilled water ice
freezing from	outside-in	bottom-up
initial freezing in	cold room (-7C)	cold bath (-15.2C)

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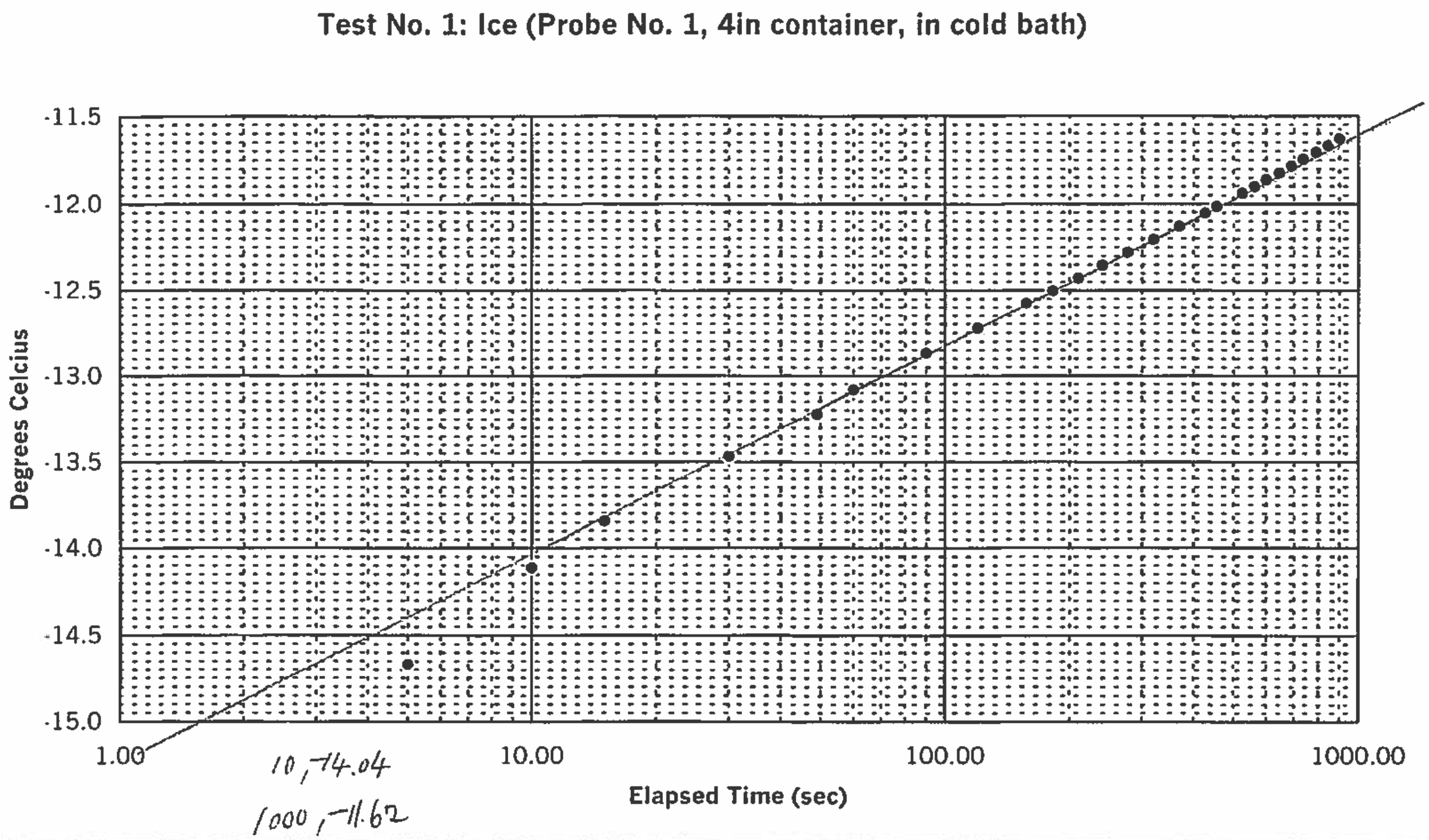
Thermal Conductivity Test



Total Volts: 1.9 Heater Resistance (Ohms): 1.43 Probe Length: 150.0 mm

Displayed Current on Screen of DC Power Supply (Amps): 1.18

Test_Ice_Thermconduct.xls

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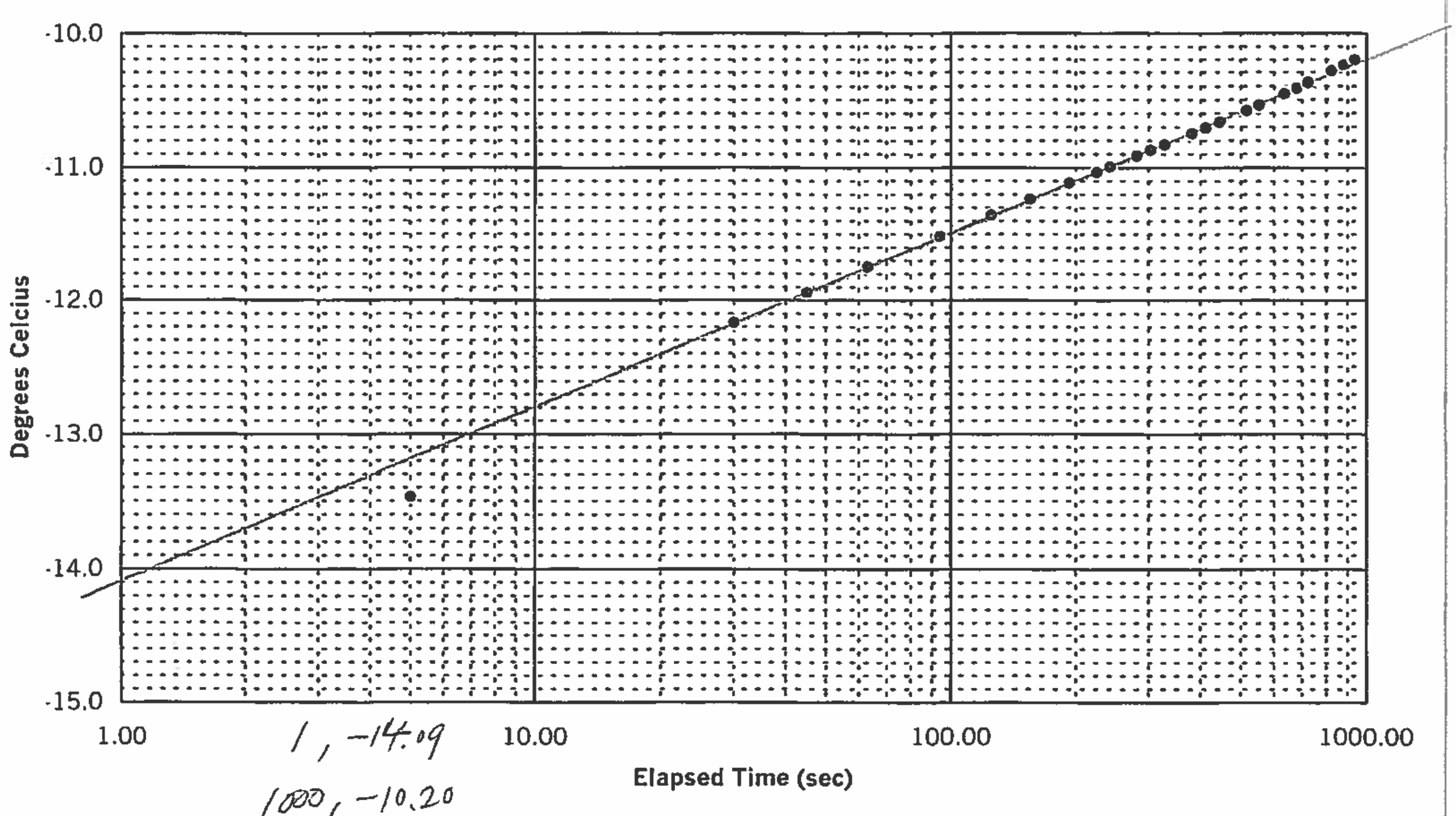
Thermal Conductivity Test

Test No. 6: Distilled Water Ice (Probe No. 2, 4in container, in cold bath)



Total Volts: 1.9 Heater Resistance (Ohms): 1.43 Probe Length: 150.0 mm

Displayed Current on Screen of DC Power Supply (Amps): 1.2

Material Properties - Material properties as densities, heat capacities for gases, fluids and solids ....

Properties of Ice

A table with thermal and thermodynamic properties - density, conductivity and specific heat - ice.

Temperature (癈)	Density (kg/m^3)	Thermal conductivity (W/mK)	Specific heat (kJ/kgK)
0	916.2	2.22	2.050
-5	917.5	2.25	2.027
-10	918.9	2.30	2.000
-15	919.4	2.34	1.972
-20	919.4	2.39	1.943
-25	919.6	2.45	1.913
-30	920.0	2.50	1.882
-35	920.4	2.57	1.851
-40	920.8	2.63	1.818
-50	921.6	2.76	1.751
-60	922.4	2.90	1.681
-70	923.3	3.05	1.609
-80	924.1	3.19	1.536
-90	924.9	3.34	1.463
-100	925.7	3.48	1.389

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Calibration of New Probes
(20cm long)

When probe offset factor of 0.11 is used. ✓
we the following results were obtained.

Topp equation

in water in 3"x4" steel container
Measured volumetric content = 0.99 ~ 1.004 ✓

in sand in 3"x4" steel container
Measured volumetric content = 7.4% ✓

~~Calculated from lab moisture content (micro-wave)~~
~~wet soil = 702.7 − 24.7 = 678.0 g~~
dry soil = 669.2 − 24.7 = 644.5 g m_w 5.2%
~~water = 33.5 g~~

Volume of water $= \frac{33.5}{678.0} \times (4695.8 - 2345.6)$
$= 116.1 g = 116.1 cm^3$

~~Total volume = 7.1 × 9.47 × (27 − 2.8) = 1627.1~~

∴ Volumetric ~~wc~~ $= \frac{116.1}{1627.1} = 7.13\%$

NOTES	Project Number: 11000f2 Page: 1 of 1 Date: May 12, '04 By: Gordon Zhang

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APPENDIX B

THERMAL CONDUCTIVITY TEST RESULTS

Table B-1
Initial Physical Properties of Thermal Conductivity Test Specimens

Specimen No.	Mass (g)	Volume (cm^3)	Bulk Density (g/cm^3)	Water Content (%)	Dry Density (g/cm^3)	Void Ratio	Saturation (%)	Volumetric Water (%)
Sample B208-1								
1	3246.7	1623.9	2.00	27.8	1.565	1.03	85.8	43.5
2	3180.5	1630.7	1.95	42.4	1.369	1.31	102.3	66.4
3	2897.6	1634.4	1.77	18.8	1.492	1.13	53.1	29.5
Sample C212-2								
4	3576.8	1631.4	2.19	27.0	1.726	0.84	102.4	42.3
8	2663.8	1213.2	2.20	33.5	1.645	0.93	114.5	52.4
Sample Barrel Dust								
5	2696.9	1638.5	1.65	16.4	1.414	1.24	41.9	25.7
6	2734.6	1635.4	1.67	25.5	1.333	1.38	58.6	39.9
7	3068.4	1632.7	1.88	37.2	1.370	1.31	89.7	58.2

Table B-2
Final Physical Properties of Thermal Conductivity Test Specimens

Specimen No.	Mass (g)	Volume (cm^3)	Bulk Density (g/cm^3)	Water Content (%)	Dry Density (g/cm^3)	Void Ratio	Saturation (%)	Volumetric Water (%)
Sample B208-1								
1	3239.7	1623.9	2.00	26.8	1.574	1.01	83.6	41.9
2	3161.4	1630.7	1.94	40.2	1.383	1.29	98.6	62.9
3	2896.5	1605.1	1.80	19.2	1.801	1.09	55.6	30.0
Sample C212-2								
4	3571.0	1610.4	2.22	27.1	1.745	0.82	105.2	42.4
8	2656.4	1192.5	2.23	33.5	1.669	0.90	118.0	52.4
Sample Barrel Dust								
5	2693.5	1638.5	1.64	16.4	1.412	1.24	41.8	25.7
6	2730.8	1635.4	1.67	25.5	1.331	1.38	58.5	39.9
7	2711.4	1433.7	1.89	37	1.380	1.30	90.5	57.9

Thermal Conductivity Measurements

Test No.	1	2	3	4
Date	6/9/2004	6/10/2004	6/10/2004	6/10/2004
Sample No.	B208-1	B208-1	B208-1	C212-2
Specimen No.	1	2	3	4
Initial Specimen Temp (C)	21	20.8	21.2	21.5
Bulk Density (g/cm3)	2.000	1.950	1.773	2.192
Water Content (%)	27.8	42.4	18.8	27
Saturation (%)	85.8	102	53	103
Dry Density (g/cm3)	1.565	1.369	1.492	1.726
Void Ratio	1.03	1.31	1.13	0.84
Measured:				
Probe No.	2	1	1	2
Total Voltage V [Volt]	1.87	1.87	1.87	1.87
Heater Resistance R (Ohm)	1.425	1.425	1.425	1.425
Resistance of Heater plus wires R_{total} [Ohms]	**1.51**	**1.51**	**1.51**	**1.51**
Probe Length, l [mm]	150	150	150	150
Current on Screen of DC Power Supply (Amp)	1.2	1.2	1.2	1.2
Current Measured (point connection) by Multimeter (Amp)	n/a	n/a	n/a	n/a
Calculate:				
$i = V/R_{total}$ [A]	1.238	1.238	1.238	1.238
Q = (Ri)*i [W]	2.185	2.185	2.185	2.185
q = Q/l [W/m]	1.457E+01	1.457E+01	1.457E+01	1.457E+01
K = q/(4PI*(T2-T1))*ln(t2/t1)				
Enter:				
T2 [°C]	20.818	20.454	21.331	21.38
T1 [°C]	29.8450546	29.1715872	36.2952703	29.3135569
t2 [sec]	1	1	1	1
t1 [sec]	1000	1000	1000	1000
K [W/m°C] =	**0.89**	**0.92**	**0.54**	**1.01**

Thermal Conductivity Measurements

Test No.	5	6	7	8
Date	6/11/2004	6/11/2004	6/12/2004	6/12/2004
Sample No.	B208-1	B208-1	B208-1	B208-1
Specimen No.	1	2	1	2
Initial Specimen Temp (C)	-23.6	-22.9	22.9	23.3
Bulk Density (g/cm3)	2.000	1.950	2.000	1.950
Water Content (%)	27.8	42.4	27.8	42.4
Saturation (%)	85.8	102	85.8	102
Dry Density (g/cm3)	1.565	1.369	1.565	1.369
Void Ratio	1.03	1.31	1.03	1.31
Measured:				
Probe No.	2	1	2	1
Total Voltage V [Volt]	2.01	2.01	1.44	1.44
Heater Resistance R (Ohm)	1.425	1.425	1.425	1.425
Resistance of Heater plus wires R_{total} [Ohms]	**1.51**	**1.51**	**1.51**	**1.51**
Probe Length, l [mm]	150	150	150	150
Current on Screen of DC Power Supply (Amp)	n/a	n/a	0.86	1.2
Current Measured (point connection) by Multimeter (Amp)	n/a	n/a	n/a	n/a
Calculate:				
$i = V/R_{total}$ [A]	1.331	1.331	0.954	0.954
Q = (Ri)*i [W]	2.525	2.525	1.296	1.296
q = Q/l [W/m]	1.683E+01	1.683E+01	8.640E+00	8.640E+00
K = q/(4PI*(T2-T1))*ln(t2/t1)				
Enter:				
T2 [°C]	-22.3732	-21.9117	22.6519	23.0287
T1 [°C]	-16.6086782	-17.0368971	28.5967142	28.416
t2 [sec]	1	1	1	1
t1 [sec]	1000	1000	1000	1000
K [W/m°C] =	**1.61**	**1.90**	**0.80**	**0.88**

Thermal Conductivity Measurements

Test No.	9	10	11	12
Date	6/12/2004	6/12/2004	6/13/2004	6/13/2004
Sample No.	B208-1	C212-2	B208-1	C212-2
Specimen No.	3	4	3	4
Initial Specimen Temp (C)	20.3	20.8	-24.4	-24.3
Bulk Density (g/cm3)	1.773	2.192	1.773	2.192
Water Content (%)	18.8	27	18.8	27
Saturation (%)	53	103	53	103
Dry Density (g/cm3)	1.492	1.726	1.492	1.726
Void Ratio	1.13	0.84	1.13	0.84
Measured:				
Probe No.	1	2	1	2
Total Voltage V [Volt]	1.44	1.44	1.96	1.96
Heater Resistance R (Ohm)	1.425	1.425	1.425	1.425
Resistance of Heater plus wires R_{total} [Ohms]	**1.51**	**1.51**	**1.51**	**1.51**
Probe Length, l [mm]	150	150	150	150
Current on Screen of DC Power Supply (Amp)	0.88	0.9	1.23	1.26
Current Measured (point connection) by Multimeter (Amp)	n/a	n/a	n/a	n/a
Calculate:				
$i = V/R_{total}$ [A]	0.954	0.954	1.298	1.298
Q = (Ri)*i [W]	1.296	1.296	2.401	2.401
q = Q/l [W/m]	8.640E+00	8.640E+00	1.601E+01	1.601E+01
K = q/(4PI*(T2-T1))*ln(t2/t1)				
Enter:				
T2 [°C]	19.171	20.6406	-25.6628	-23.499
T1 [°C]	29.917	25.767	-10.748	-18.509
t2 [sec]	1	1	1	1
t1 [sec]	1000	1000	1000	1000
K [W/m°C] =	**0.44**	**0.93**	**0.59**	**1.76**

Thermal Conductivity Measurements

Test No.	13	14	15	16
Date	6/14/2004	6/14/2004	6/15/2004	6/15/2004
Sample No.	B208-1	C212-2	Barrel Dust	Barrel Dust
Specimen No.	3	4	5	6
Initial Specimen Temp (C)	30.4	28	27.1	26.8
Bulk Density (g/cm3)	1.773	2.192	1.646	1.672
Water Content (%)	18.8	27	16.4	25.5
Saturation (%)	53	103	41.9	58.6
Dry Density (g/cm3)	1.492	1.726	1.414	1.333
Void Ratio	1.13	0.84	1.20	1.38
Measured:				
Probe No.	1	2	1	2
Total Voltage V [Volt]	1.49	1.49	1.32	1.32
Heater Resistance R (Ohm)	1.425	1.425	1.425	1.425
Resistance of Heater plus wires R_{total} [Ohms]	**1.51**	**1.51**	**1.51**	**1.51**
Probe Length, l [mm]	150	150	150	150
Current on Screen of DC Power Supply (Amp)	0.91	0.92	0.79	0.82
Current Measured (point connection) by Multimeter (Amp)	n/a	n/a	n/a	n/a
Calculate:				
$i = V/R_{total}$ [A]	0.987	0.987	0.874	0.874
Q = (Ri)*i [W]	1.388	1.388	1.089	1.089
q = Q/l [W/m]	9.250E+00	9.250E+00	7.260E+00	7.260E+00
K = q/(4PI*(T2-T1))*ln(t2/t1)				
Enter:				
T2 [°C]	29.035	28.12	25.99	25.84
T1 [°C]	39.887	33.85	34.41	34.26
t2 [sec]	1	1	1	1
t1 [sec]	1000	1000	1000	1000
K [W/m°C] =	**0.47**	**0.89**	**0.47**	**0.47**

Thermal Conductivity Measurements

Test No.	17	18	19	20
Date	6/16/2004	6/16/2004	6/16/2004	6/16/2004
Sample No.	Barrel Dust	Barrel Dust	Barrel Dust	C212-2
Specimen No.	5	6	7	8
Initial Specimen Temp (C)	-24.3	-24	23.8	24.6
Bulk Density (g/cm3)	1.646	1.672	1.879	2.196
Water Content (%)	16.4	25.5	37.2	33.5
Saturation (%)	41.9	58.6	89.7	114
Dry Density (g/cm3)	1.414	1.333	1.370	1.645
Void Ratio	1.20	1.38	1.31	0.93
Measured:				
Probe No.	1	2	1	2
Total Voltage V [Volt]	2	1.62	1.1	1.1
Heater Resistance R (Ohm)	1.425	1.425	1.425	1.425
Resistance of Heater plus wires R_{total} [Ohms]	**1.51**	**1.51**	**1.51**	**1.51**
Probe Length, l [mm]	142	141	150	137
Current on Screen of DC Power Supply (Amp)	1.25	1.02	0.64	0.65
Current Measured (point connection) by Multimeter (Amp)	n/a	n/a	n/a	n/a
Calculate:				
$i = V/R_{total}$ [A]	1.325	1.073	0.728	0.728
Q = (Ri)*i [W]	2.500	1.640	0.756	0.756
q = Q/l [W/m]	1.760E+01	1.163E+01	5.041E+00	5.520E+00
K = q/(4PI*(T2-T1))*ln(t2/t1)				
Enter:				
T2 [°C]	-25.70	-24.21	23.38	24.444
T1 [°C]	-11.17	-16.60	27.26	27.426
t2 [sec]	1	1	1	1
t1 [sec]	1000	1000	1000	1000
K [W/m°C] =	**0.67**	**0.84**	**0.71**	**1.02**

Thermal Conductivity Measurements

Test No.	21	22	23	24
Date	6/17/2004	6/17/2004	6/17/2004	6/17/2004
Sample No.	Barrel Dust	C212-2	Barrel Dust	Barrel Dust
Specimen No.	7	8	5	6
Initial Specimen Temp (C)	-24.7	-24.4	25	25
Bulk Density (g/cm3)	1.879	2.196	1.646	1.672
Water Content (%)	37.2	33.5	16.4	25.5
Saturation (%)	89.7	114	41.9	58.6
Dry Density (g/cm3)	1.370	1.645	1.414	1.333
Void Ratio	1.31	0.93	1.20	1.38
Measured:				
Probe No.	1	2	1	2
Total Voltage V [Volt]	2	2	1.32	1.32
Heater Resistance R (Ohm)	1.425	1.425	1.425	1.425
Resistance of Heater plus wires R_{total} [Ohms]	**1.51**	**1.51**	**1.51**	**1.51**
Probe Length, l [mm]	150	137	150	150
Current on Screen of DC Power Supply (Amp)	1.26	1.29	0.79	0.81
Current Measured (point connection) by Multimeter (Amp)	n/a	n/a	n/a	n/a
Calculate:				
$i = V/R_{total}$ [A]	1.325	1.325	0.874	0.874
Q = (Ri)*i [W]	2.500	2.500	1.089	1.089
q = Q/l [W/m]	1.667E+01	1.825E+01	7.260E+00	7.260E+00
K = q/(4PI*(T2-T1))*ln(t2/t1)				
Enter:				
T2 [°C]	-24.08	-23.410	23.89	24.18
T1 [°C]	-17.69	-18.441	31.98	32.61
t2 [sec]	1	1	1	1
t1 [sec]	1000	1000	1000	1000
K [W/m°C] =	**1.43**	**2.02**	**0.49**	**0.47**

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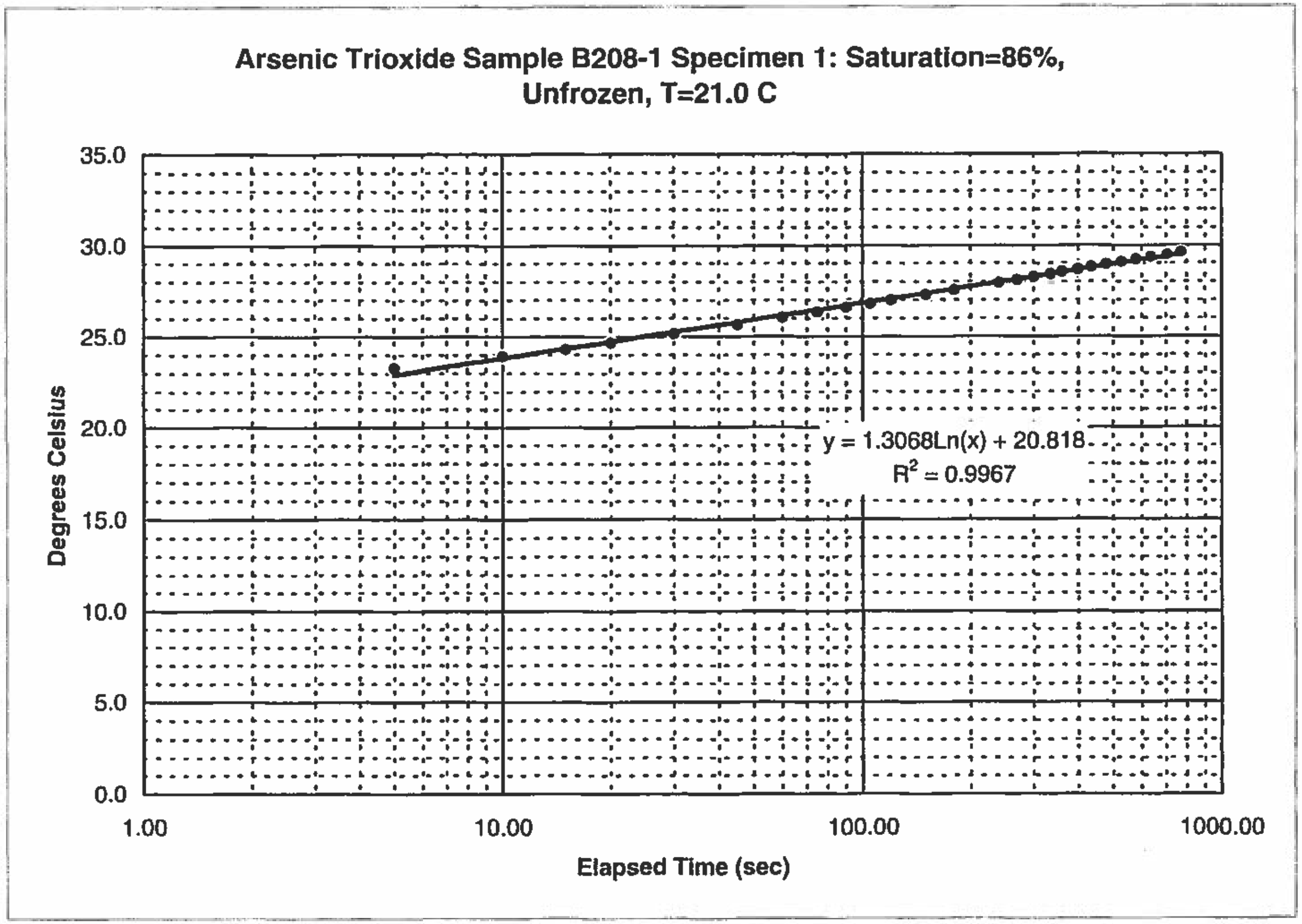
Thermal Conductivity Test No. 1



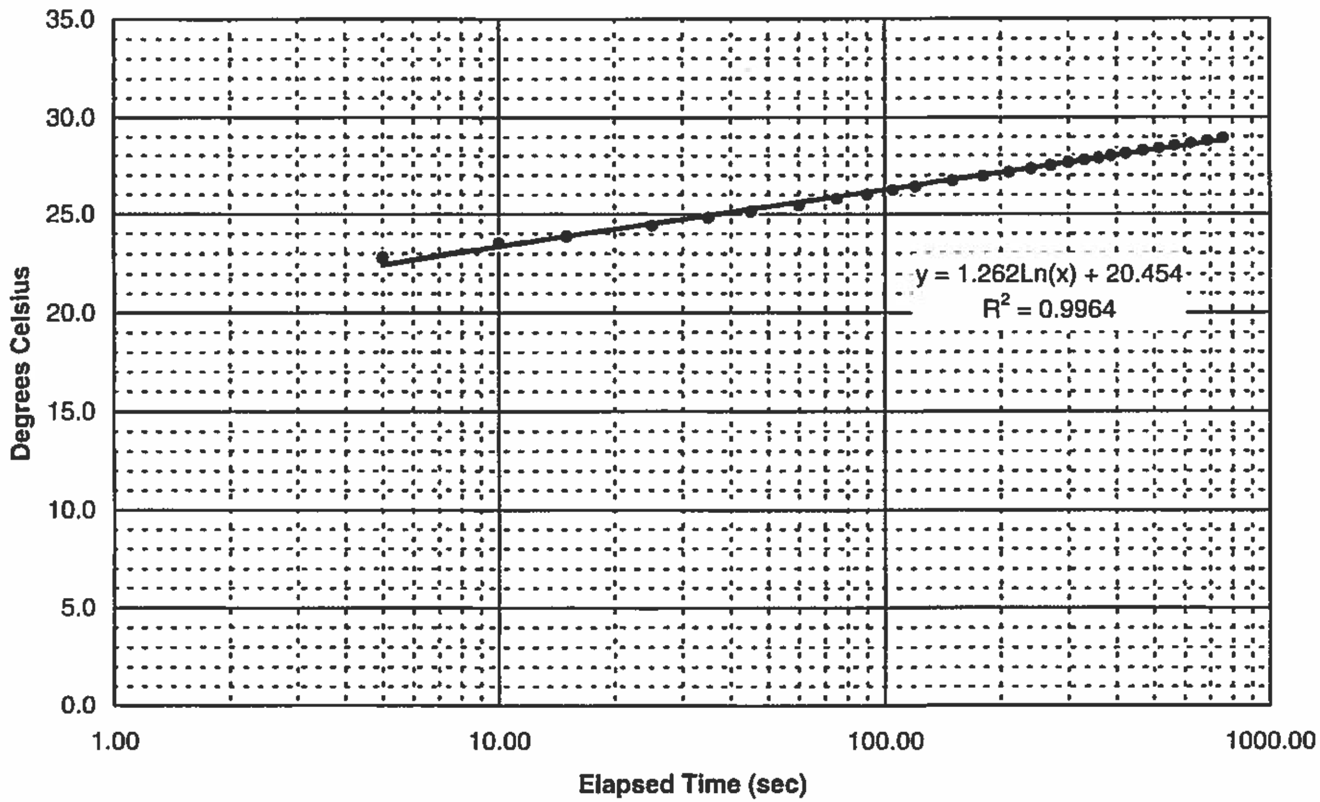
Total Volts: 1.870 Heater Resistance (Ohms): 1.43 Probe Length: 150.0 mm

Displayed Current on Screen of DC Power Supply (Amps): 1.2

EBA Engineering Consultants Ltd.

Thermal Conductivity Test No. 2

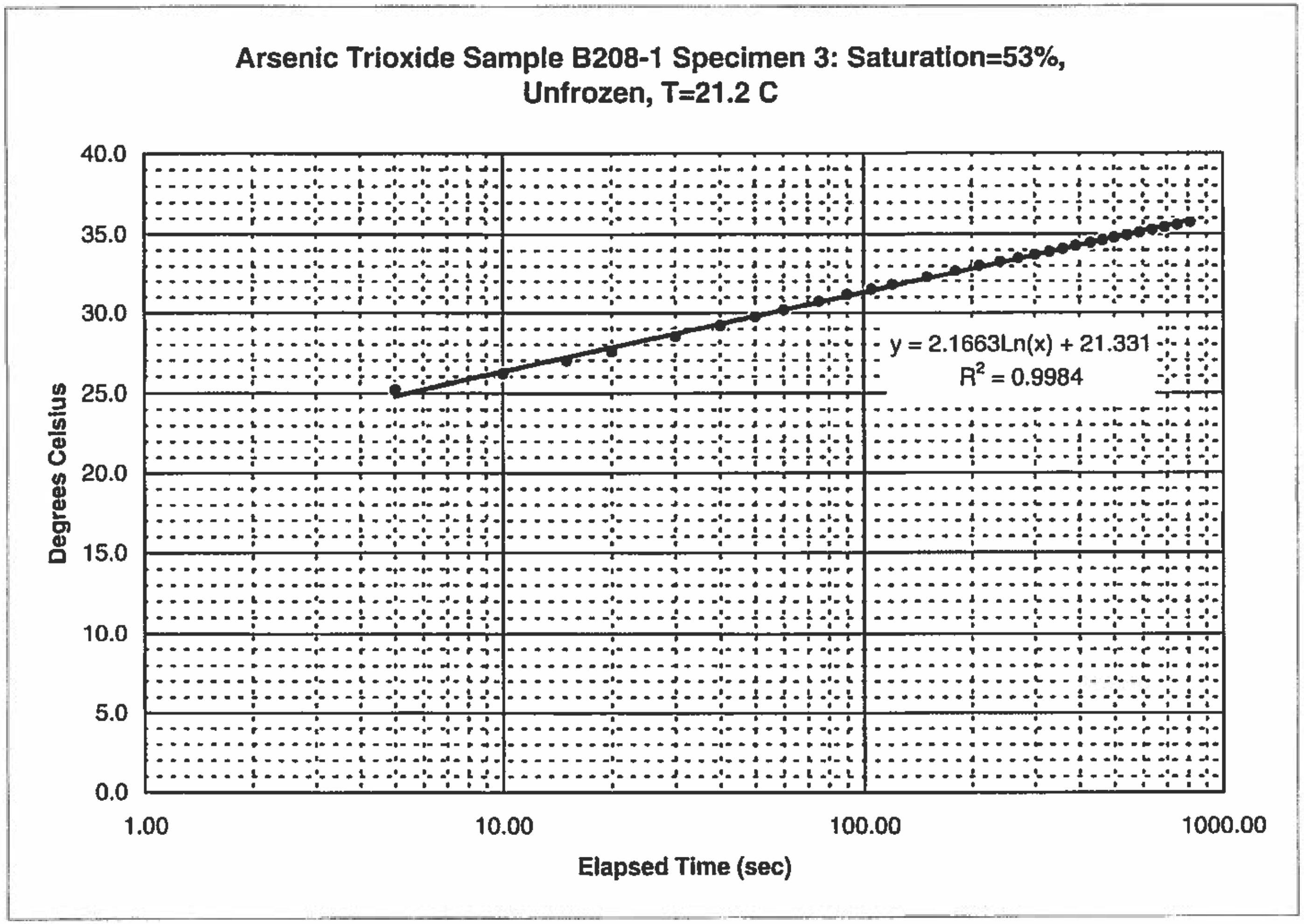
Arsenic Trioxide Sample B208-1 Specimen 2: Saturation=100%, Unfrozen, T=20.8 C



Total Volts: 1.870 Heater Resistance (Ohms): 1.43 Probe Length: 150.0 mm
Displayed Current on Screen of DC Power Supply (Amps): 1.2

EBA Engineering Consultants Ltd.

Thermal Conductivity Test No. 3

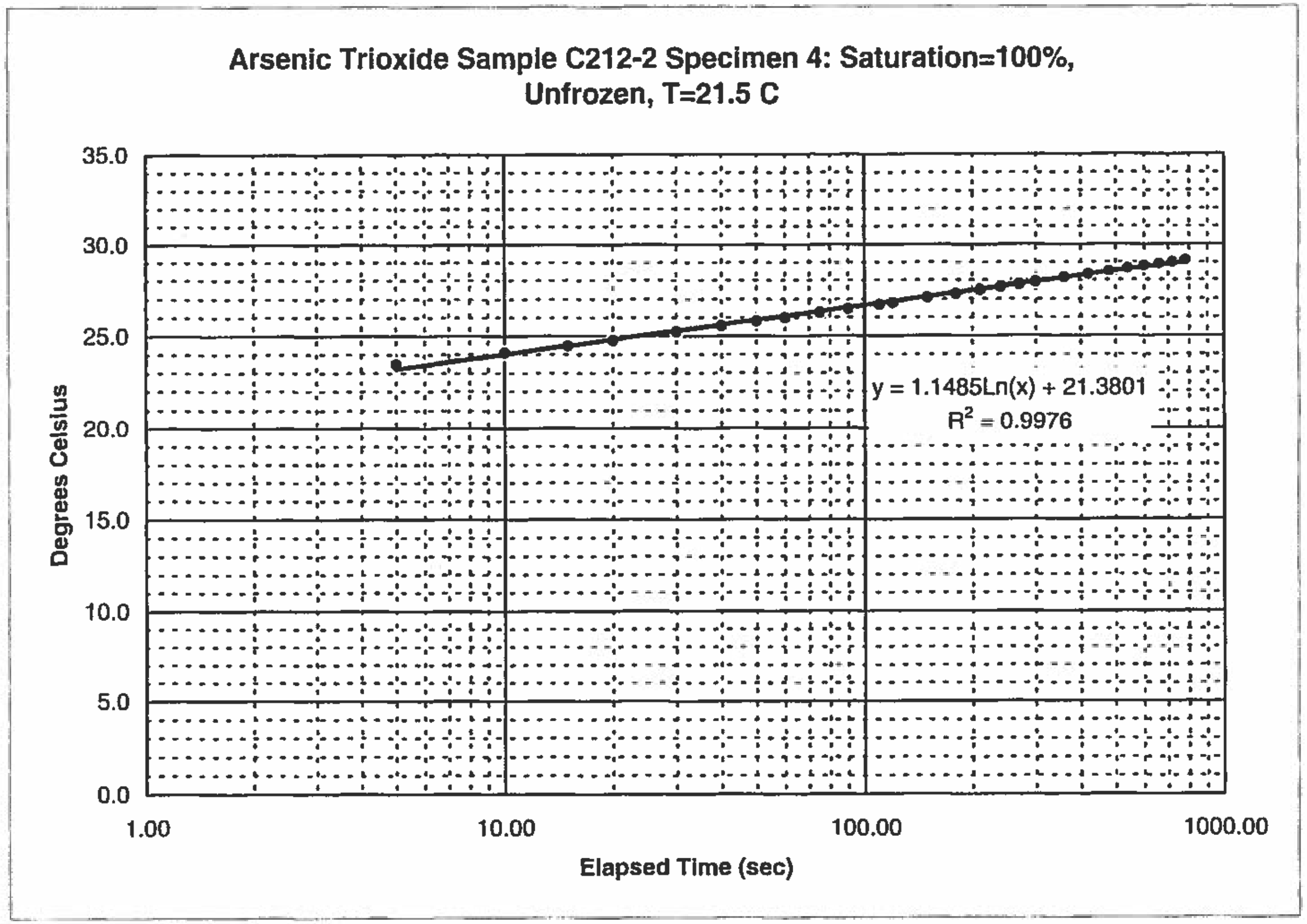


Total Volts: 1.870 Heater Resistance (Ohms): 1.43 Probe Length: 150.0 mm

Displayed Current on Screen of DC Power Supply (Amps): 1.2

EBA Engineering Consultants Ltd.

Thermal Conductivity Test No. 4

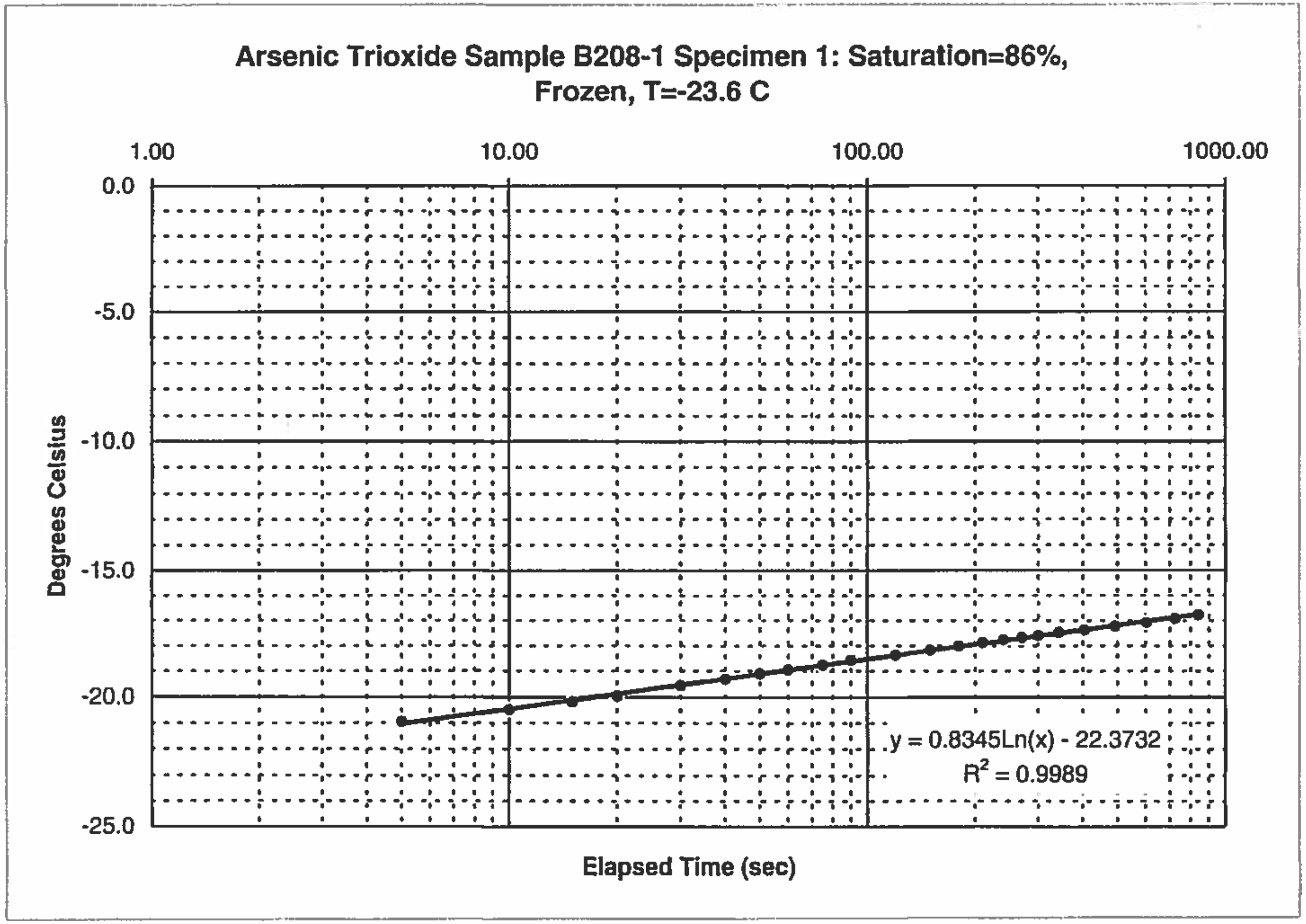


Total Volts: 1.870 Heater Resistance (Ohms): 1.43 Probe Length: 150.0 mm

Displayed Current on Screen of DC Power Supply (Amps): 1.2

EBA Engineering Consultants Ltd.

Thermal Conductivity Test No. 5



Total Volts: 2.010 Heater Resistance (Ohms): 1.43 Probe Length: 150.0 mm
Displayed Current on Screen of DC Power Supply (Amps): n/a

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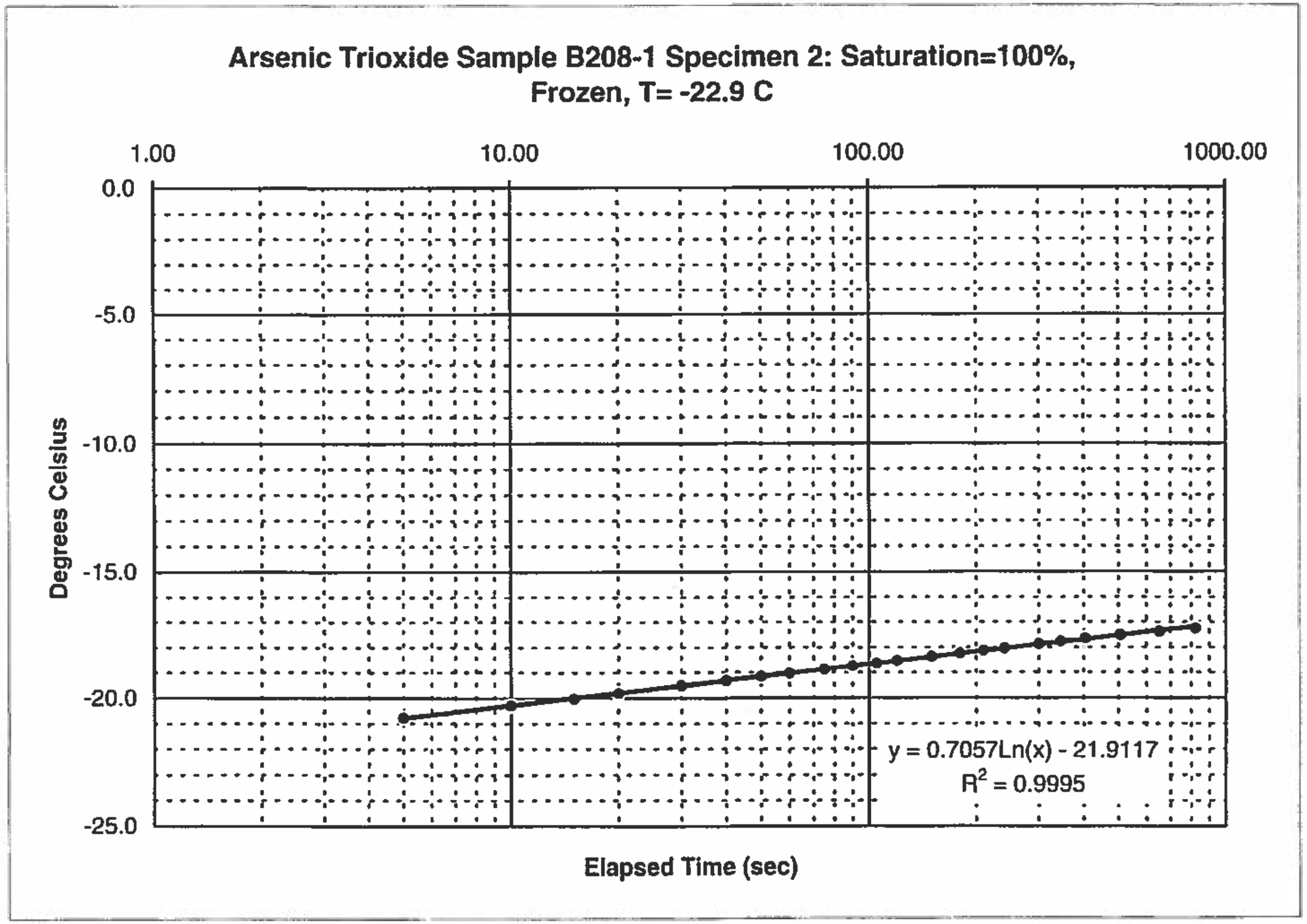
Thermal Conductivity Test No. 6

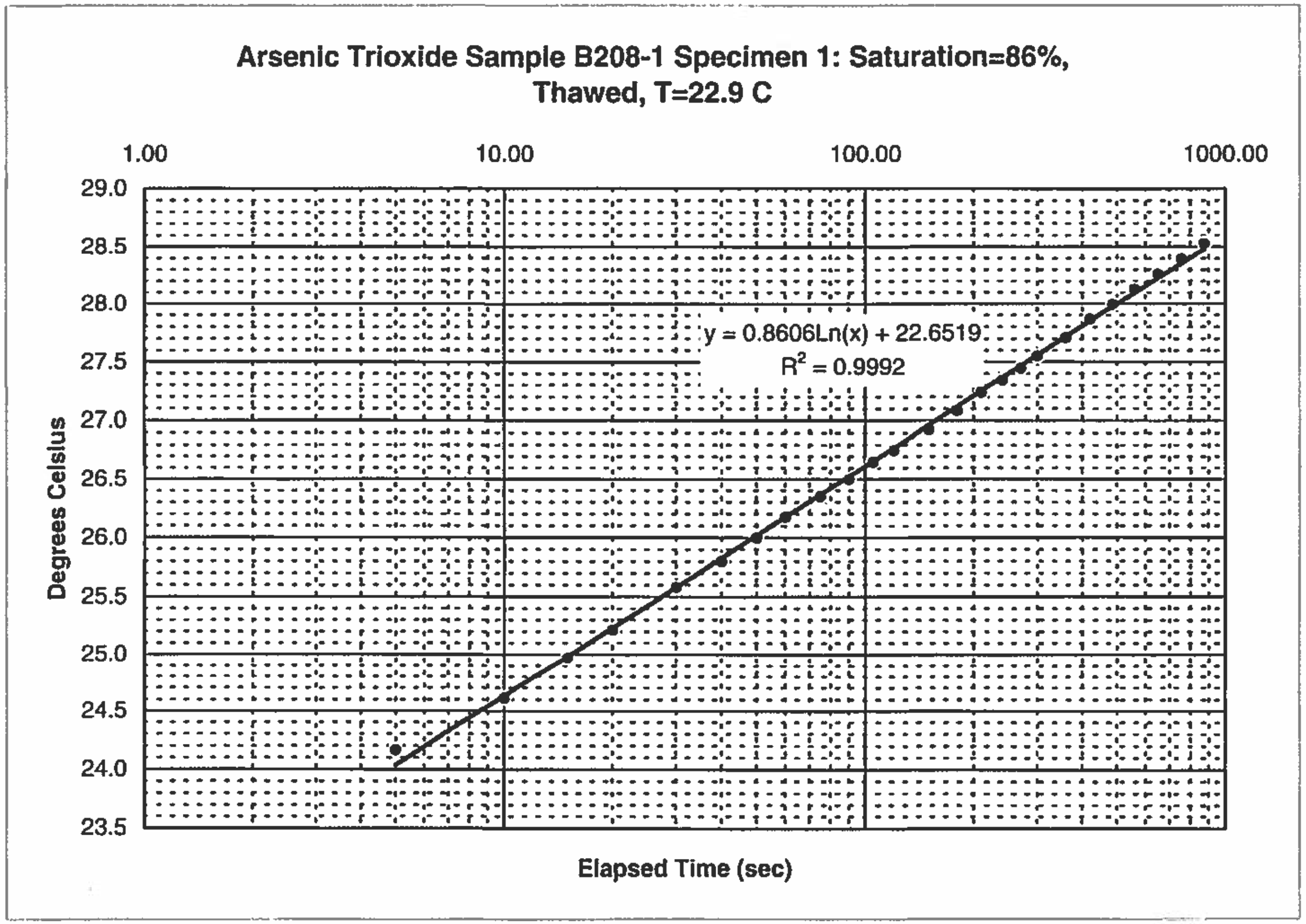


Total Volts: 2.010 Heater Resistance (Ohms): 1.43 Probe Length: 150.0 mm

Displayed Current on Screen of DC Power Supply (Amps): 1.2

EBA Engineering Consultants Ltd.

Thermal Conductivity Test No. 7

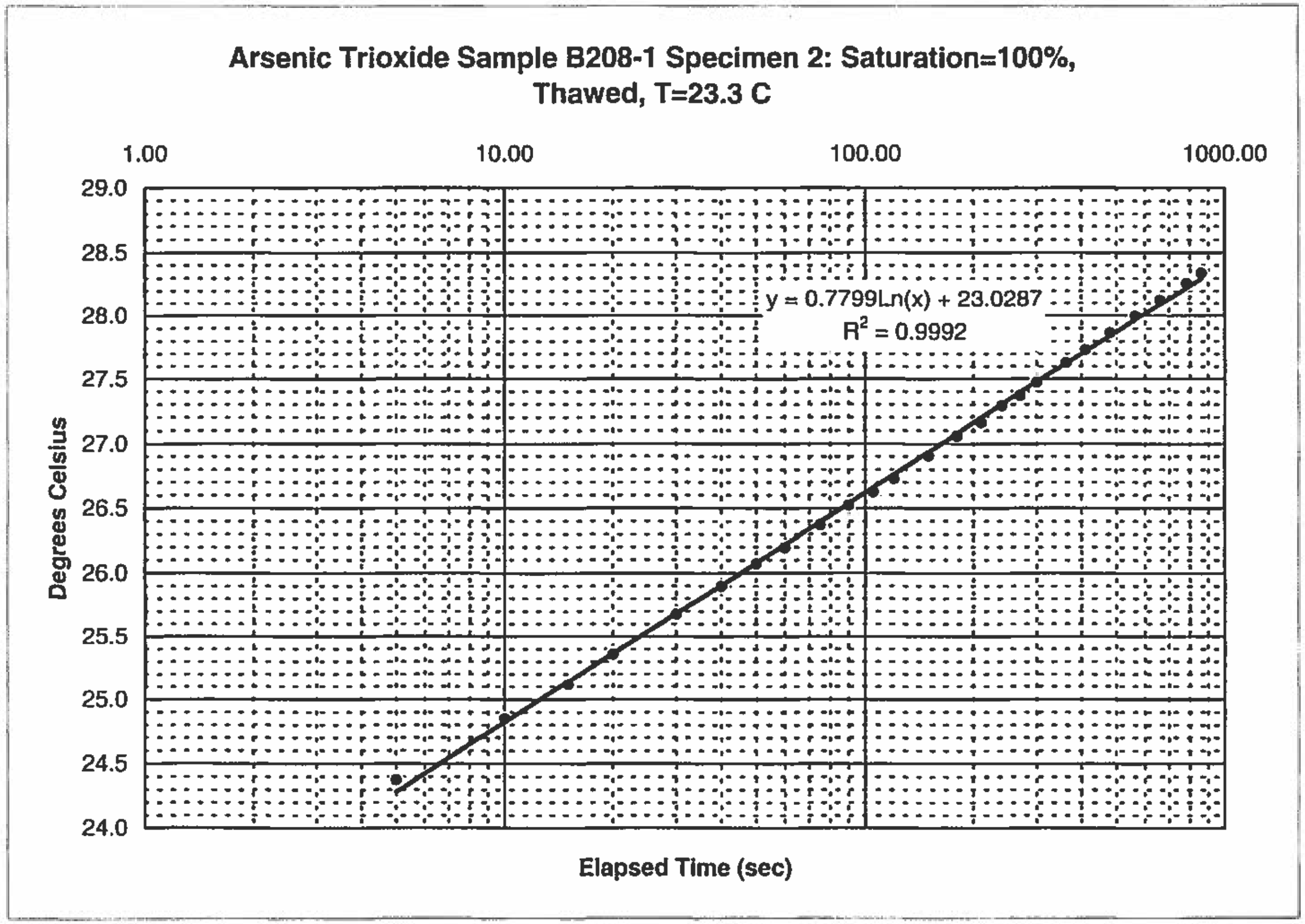


Total Volts: 1.440 Heater Resistance (Ohms): 1.43 Probe Length: 150.0 mm

Displayed Current on Screen of DC Power Supply (Amps): 0.86

EBA Engineering Consultants Ltd.

Thermal Conductivity Test No. 8

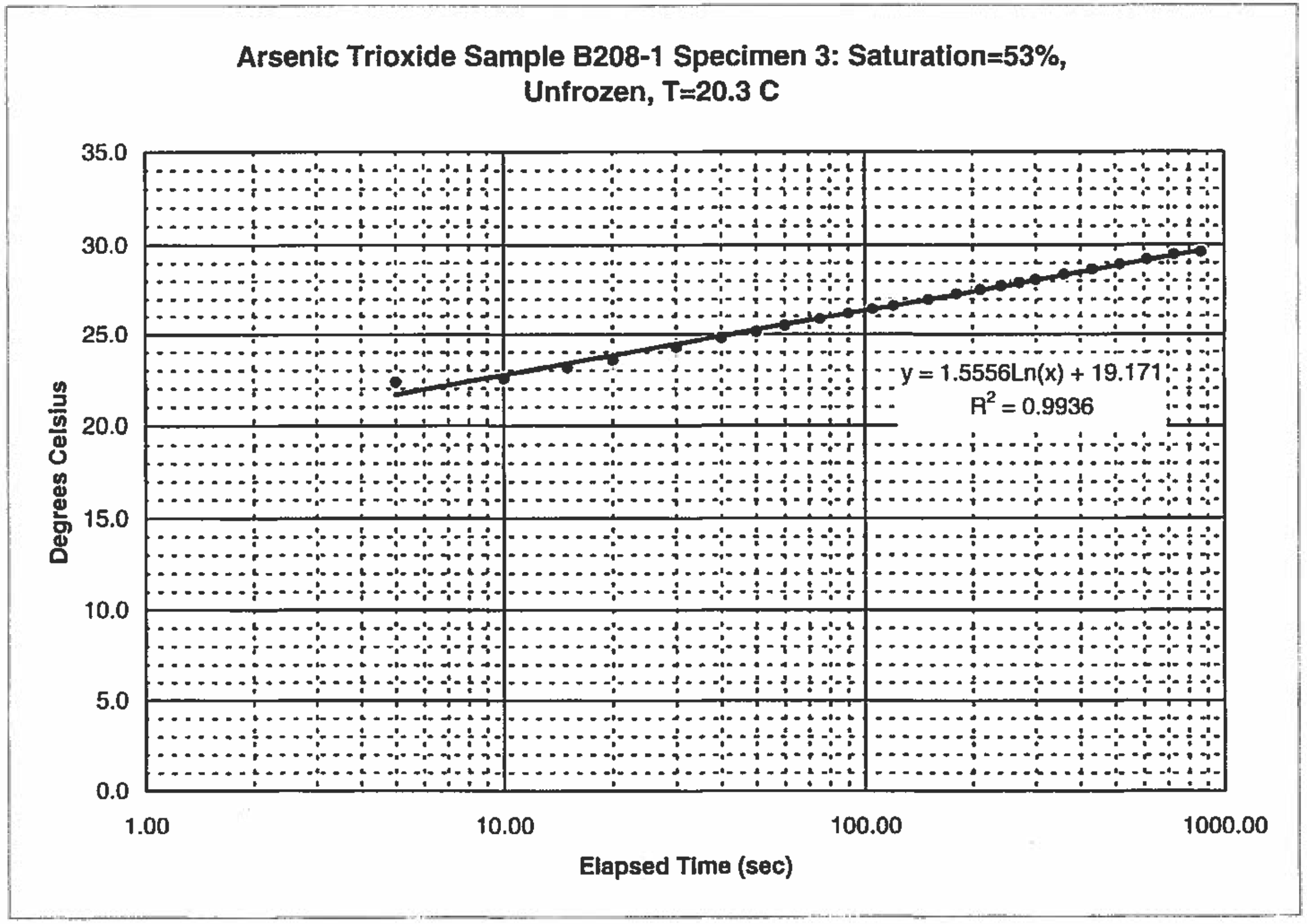


Total Volts: 1.440 Heater Resistance (Ohms): 1.43 Probe Length: 150.0 mm

Displayed Current on Screen of DC Power Supply (Amps): 0.86

EBA Engineering Consultants Ltd.

Thermal Conductivity Test No. 9



Total Volts: 1.870 Heater Resistance (Ohms): 1.43 Probe Length: 150.0 mm
Displayed Current on Screen of DC Power Supply (Amps): 1.2

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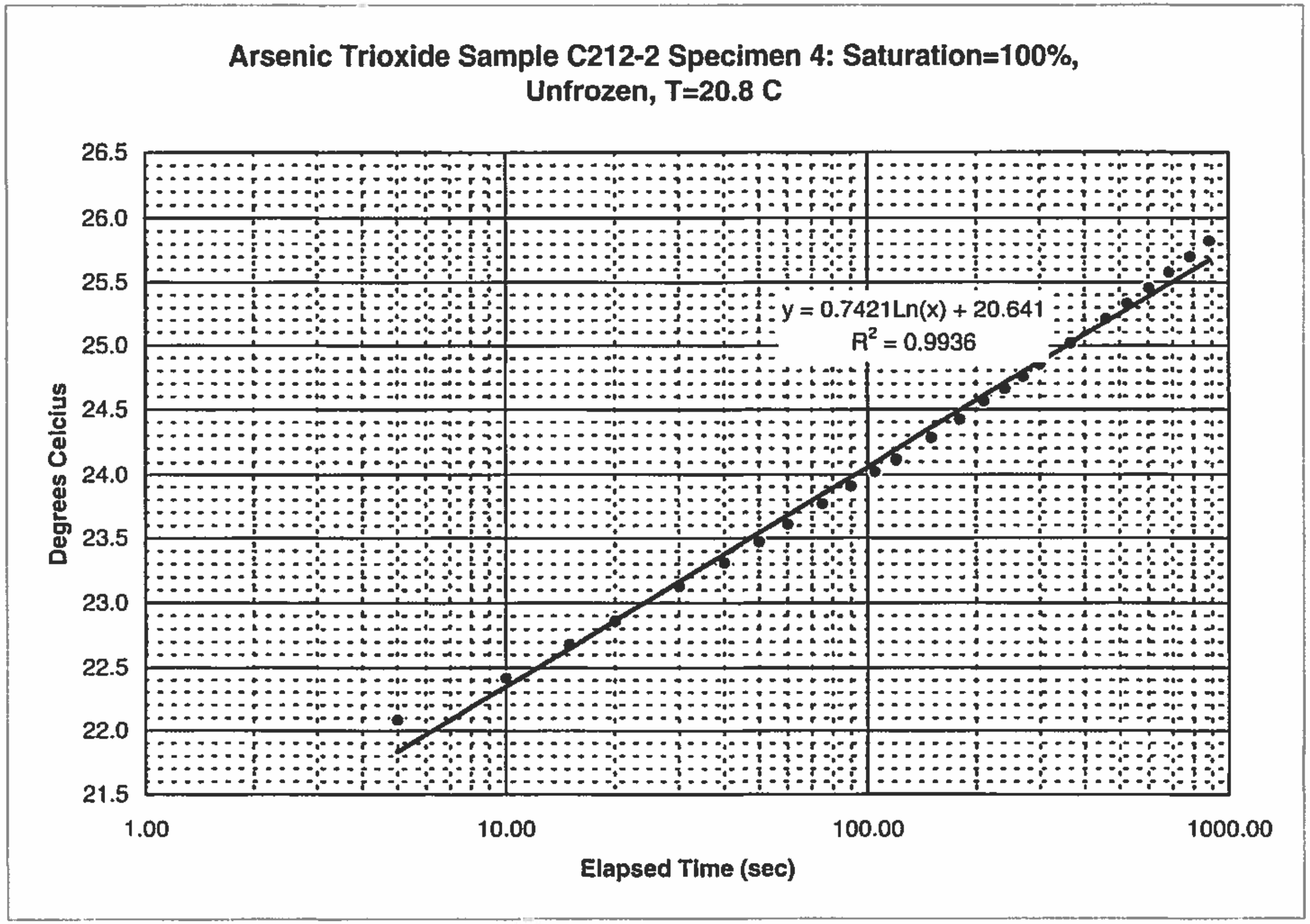
EBA Engineering Consultants Ltd.

Thermal Conductivity Test No. 10

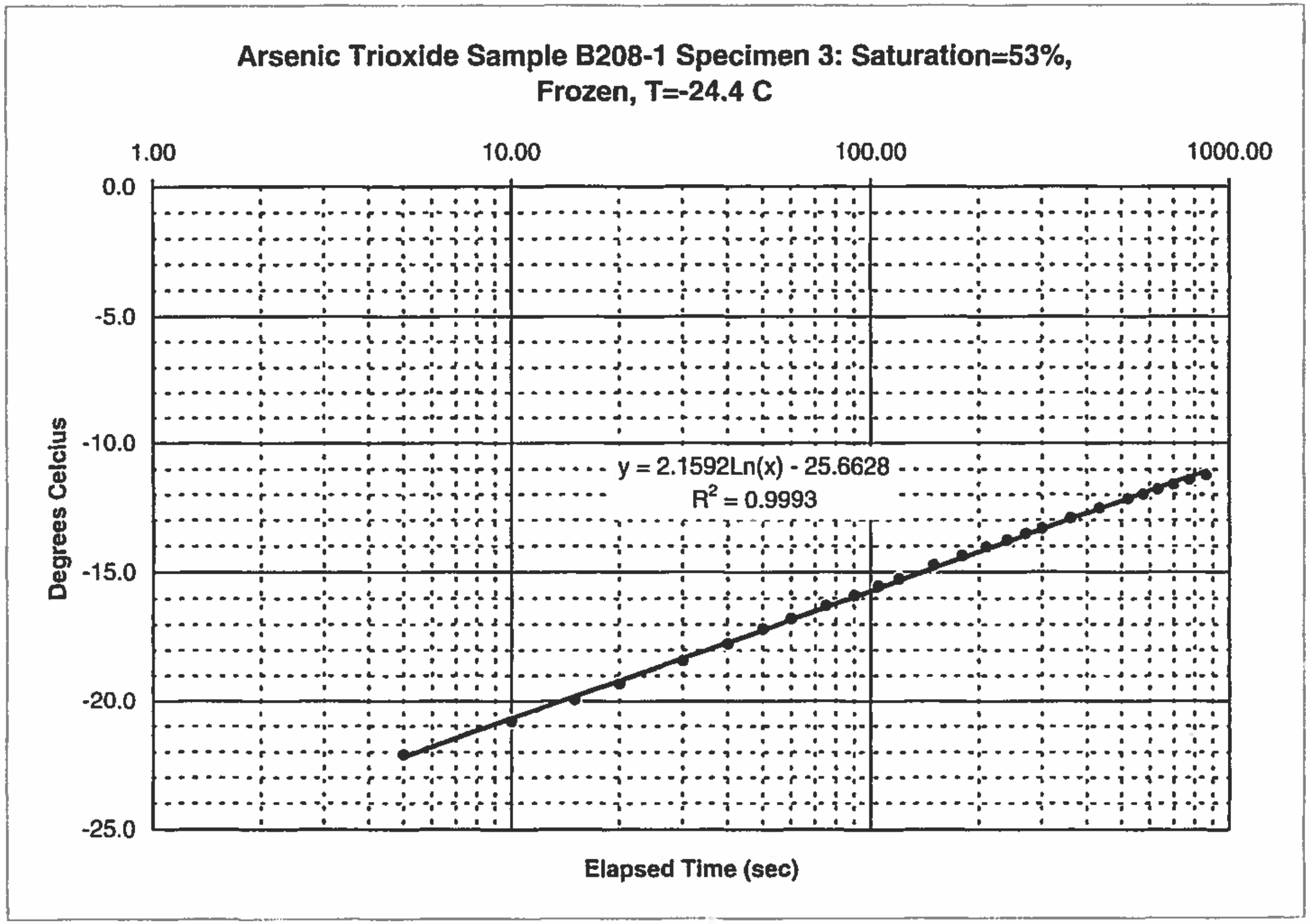


Total Volts: 1.440 Heater Resistance (Ohms): 1.43 Probe Length: 150.0 mm

Displayed Current on Screen of DC Power Supply (Amps): 0.9

EBA Engineering Consultants Ltd.

Thermal Conductivity Test No. 11



Total Volts: 1.960 Heater Resistance (Ohms): 1.43 Probe Length: 150.0 mm

Displayed Current on Screen of DC Power Supply (Amps): 1.23

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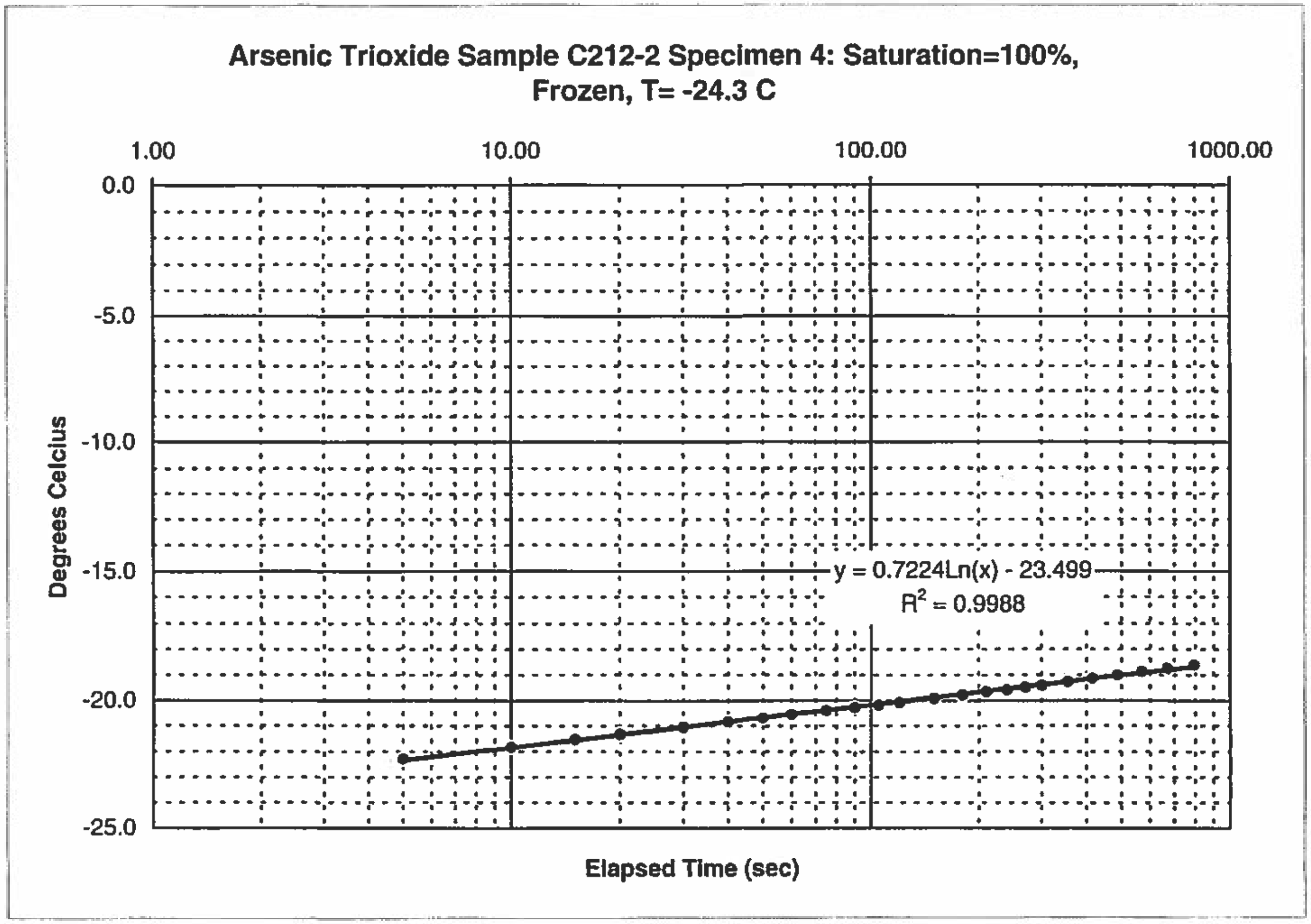
Thermal Conductivity Test No. 12



Total Volts: 1.960 Heater Resistance (Ohms): 1.43 Probe Length: 150.0 mm

Displayed Current on Screen of DC Power Supply (Amps): 1.26

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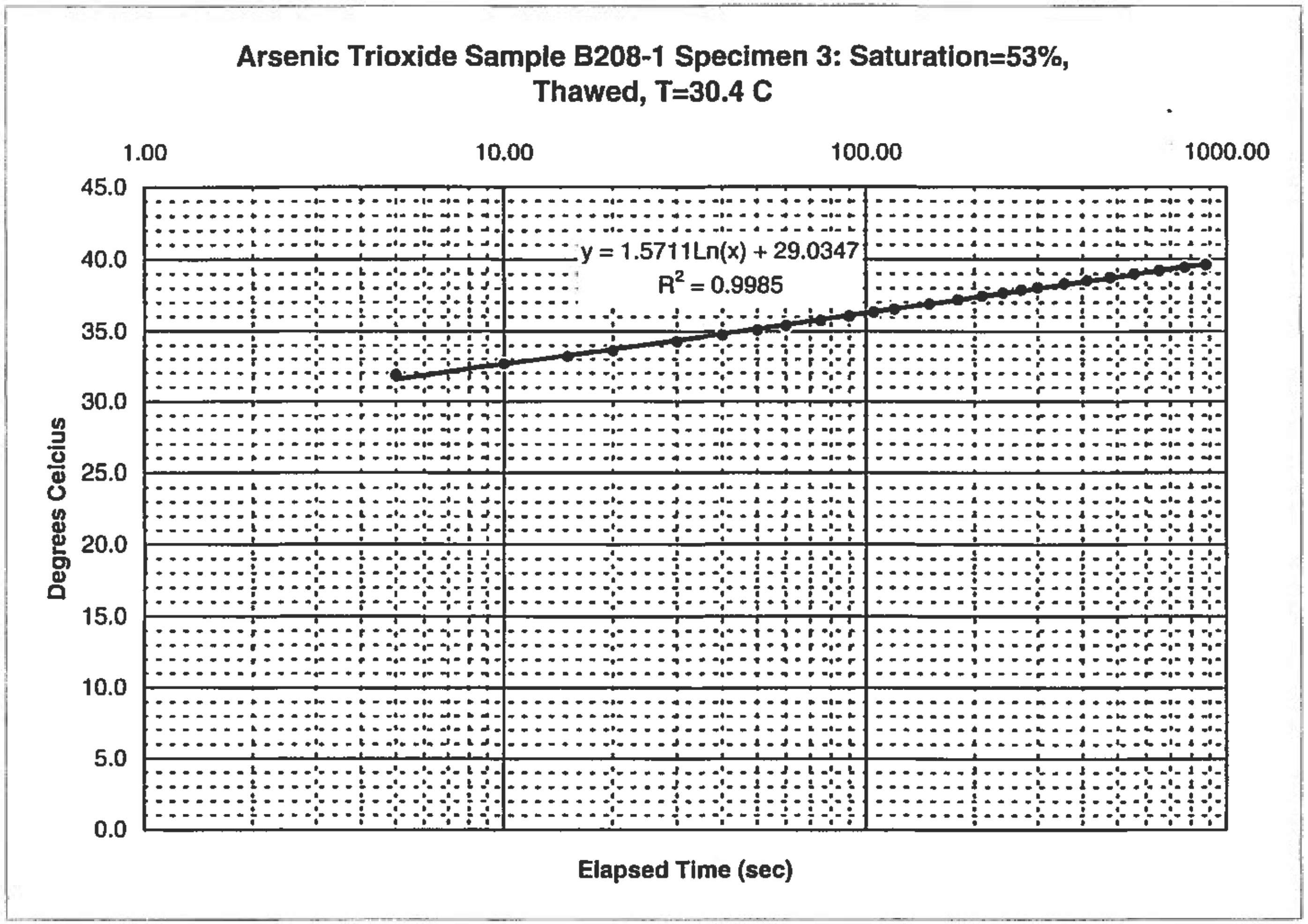
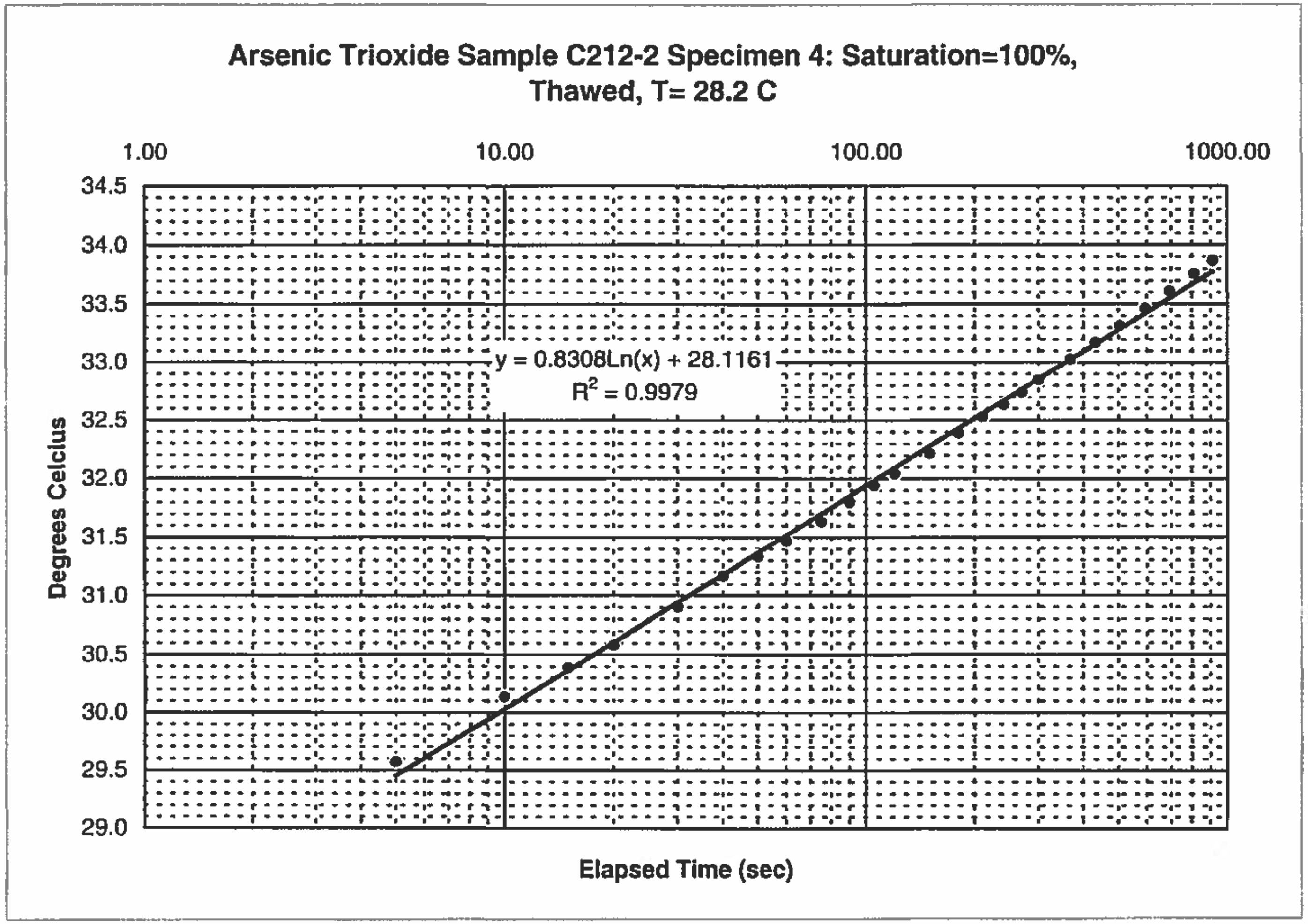
Thermal Conductivity Test No. 13



Total Volts: 1.490 Heater Resistance (Ohms): 1.43 Probe Length: 150.0 mm
Displayed Current on Screen of DC Power Supply (Amps): 0.91

EBA Engineering Consultants Ltd.

Thermal Conductivity Test No. 14

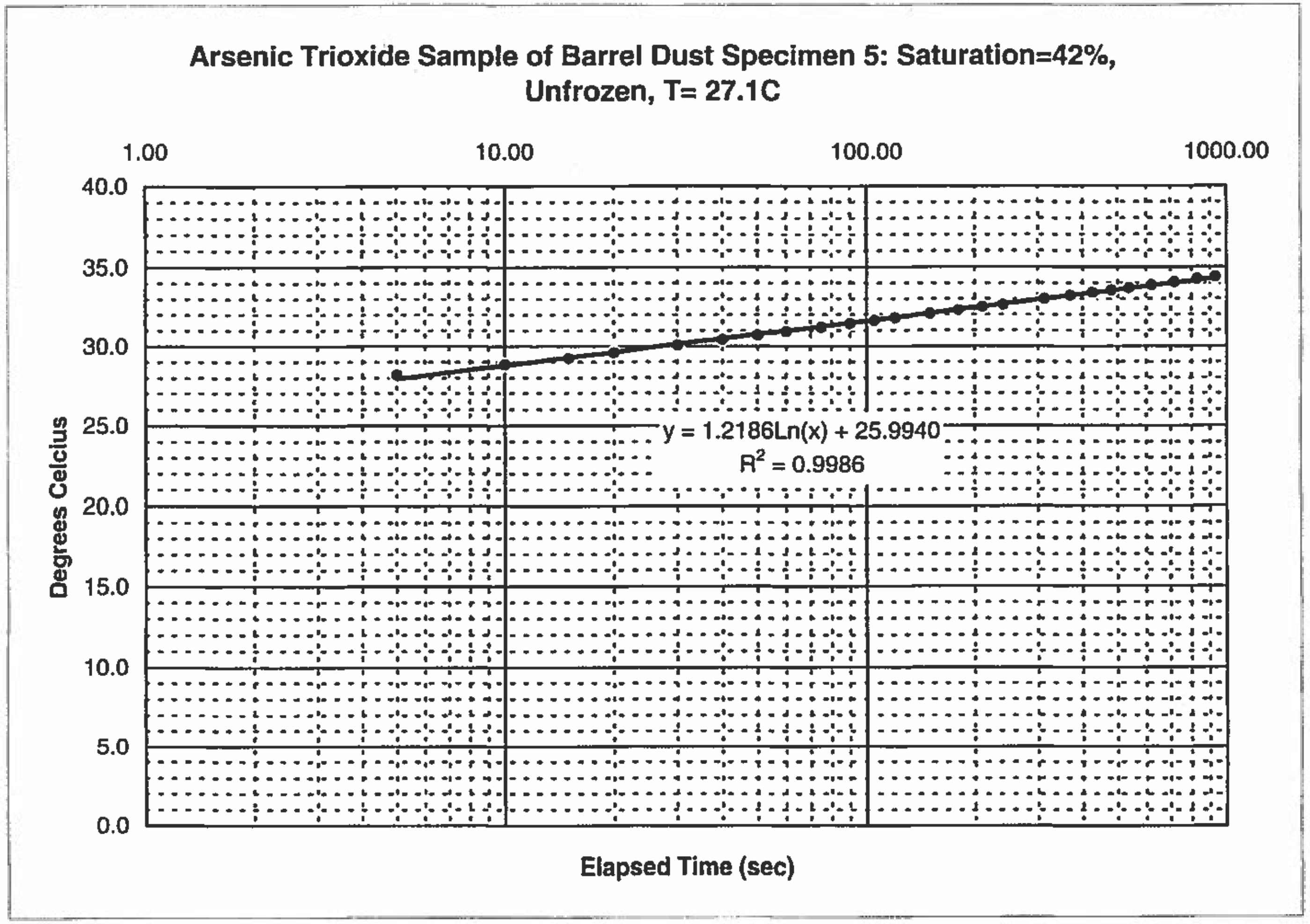


Total Volts: 1.490   Heater Resistance (Ohms): 1.43   Probe Length: 150.0 mm

Displayed Current on Screen of DC Power Supply (Amps): 0.92

EBA Engineering Consultants Ltd.

Thermal Conductivity Test No. 15

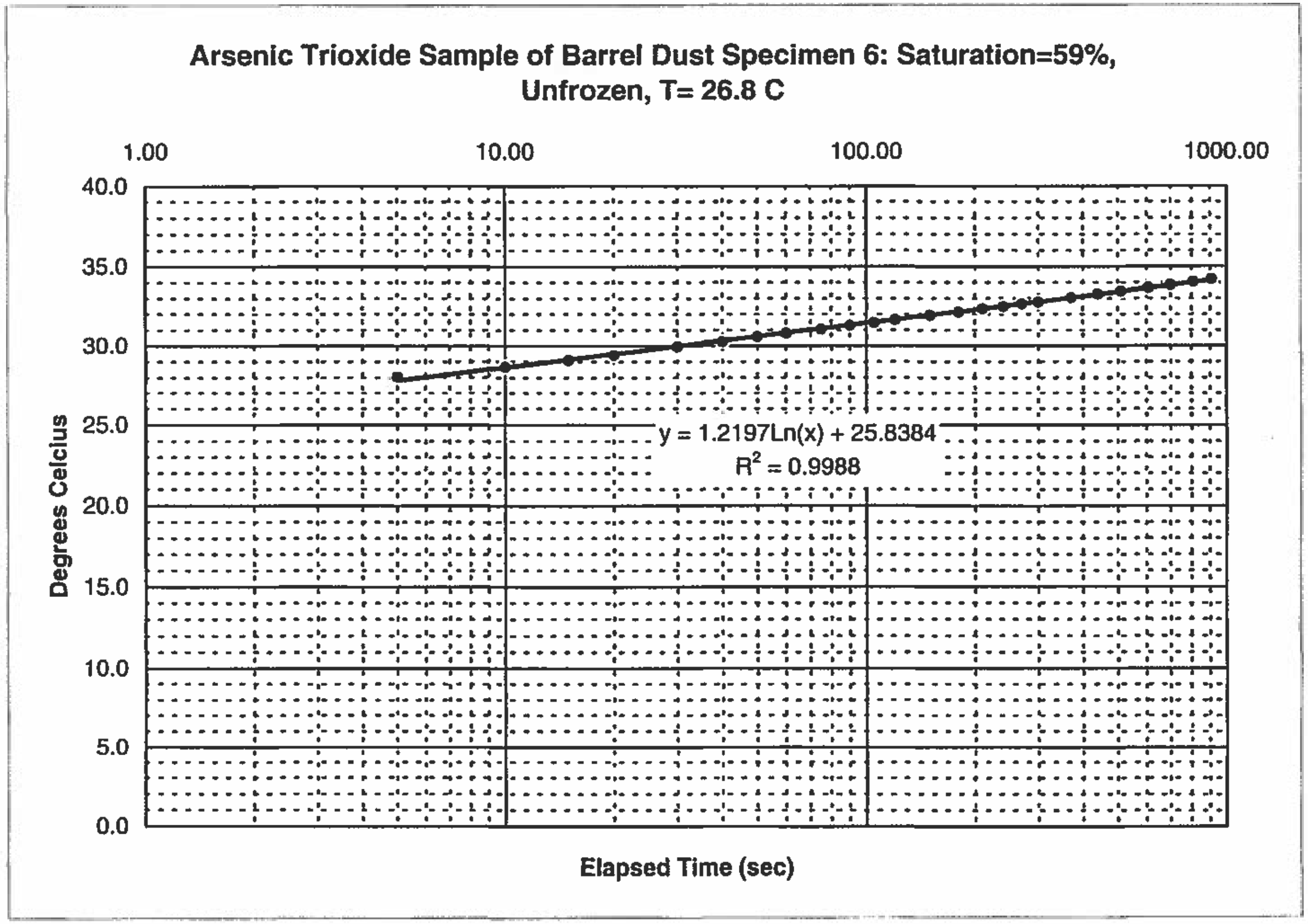


Total Volts: 1.320 Heater Resistance (Ohms): 1.43 Probe Length: 150.0 mm

Displayed Current on Screen of DC Power Supply (Amps): 0.79

EBA Engineering Consultants Ltd.

Thermal Conductivity Test No. 16

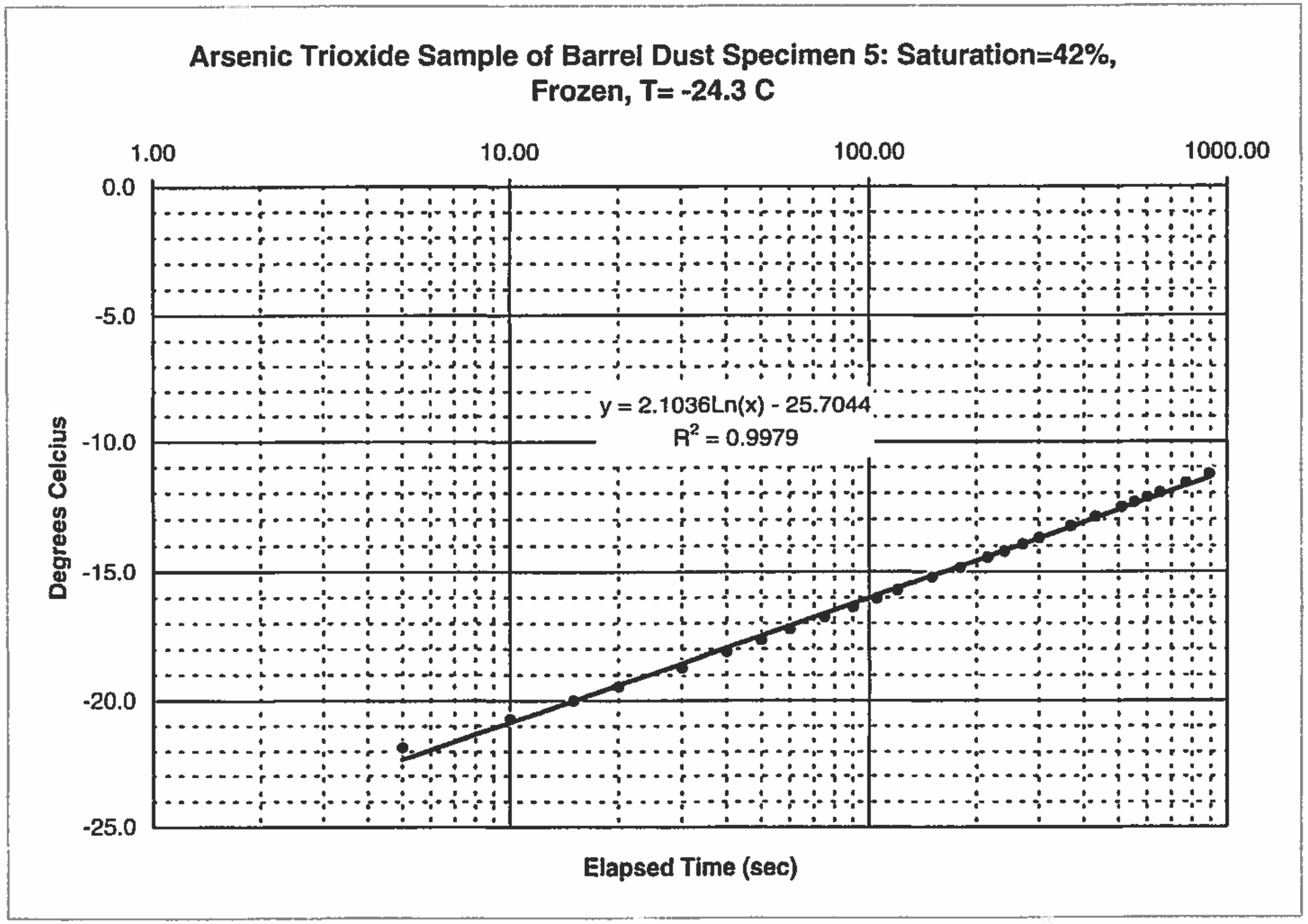


Total Volts: 1.320 Heater Resistance (Ohms): 1.43 Probe Length: 150.0 mm

Displayed Current on Screen of DC Power Supply (Amps): 0.82

EBA Engineering Consultants Ltd.

Thermal Conductivity Test No. 17

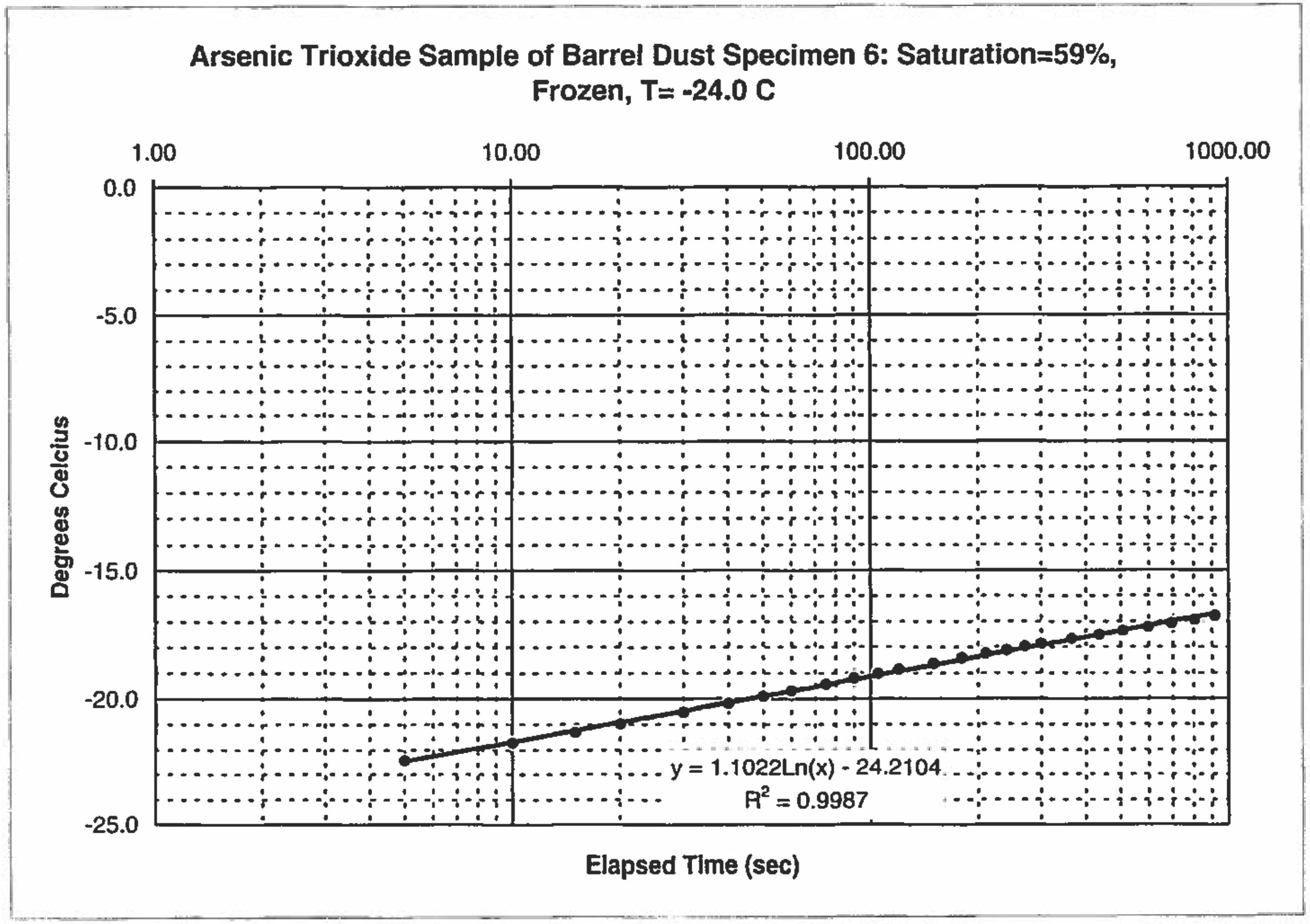


Total Volts: 2.000 Heater Resistance (Ohms): 1.43 Probe Length: 142.0 mm

Displayed Current on Screen of DC Power Supply (Amps): 1.25

EBA Engineering Consultants Ltd.

Thermal Conductivity Test No. 18

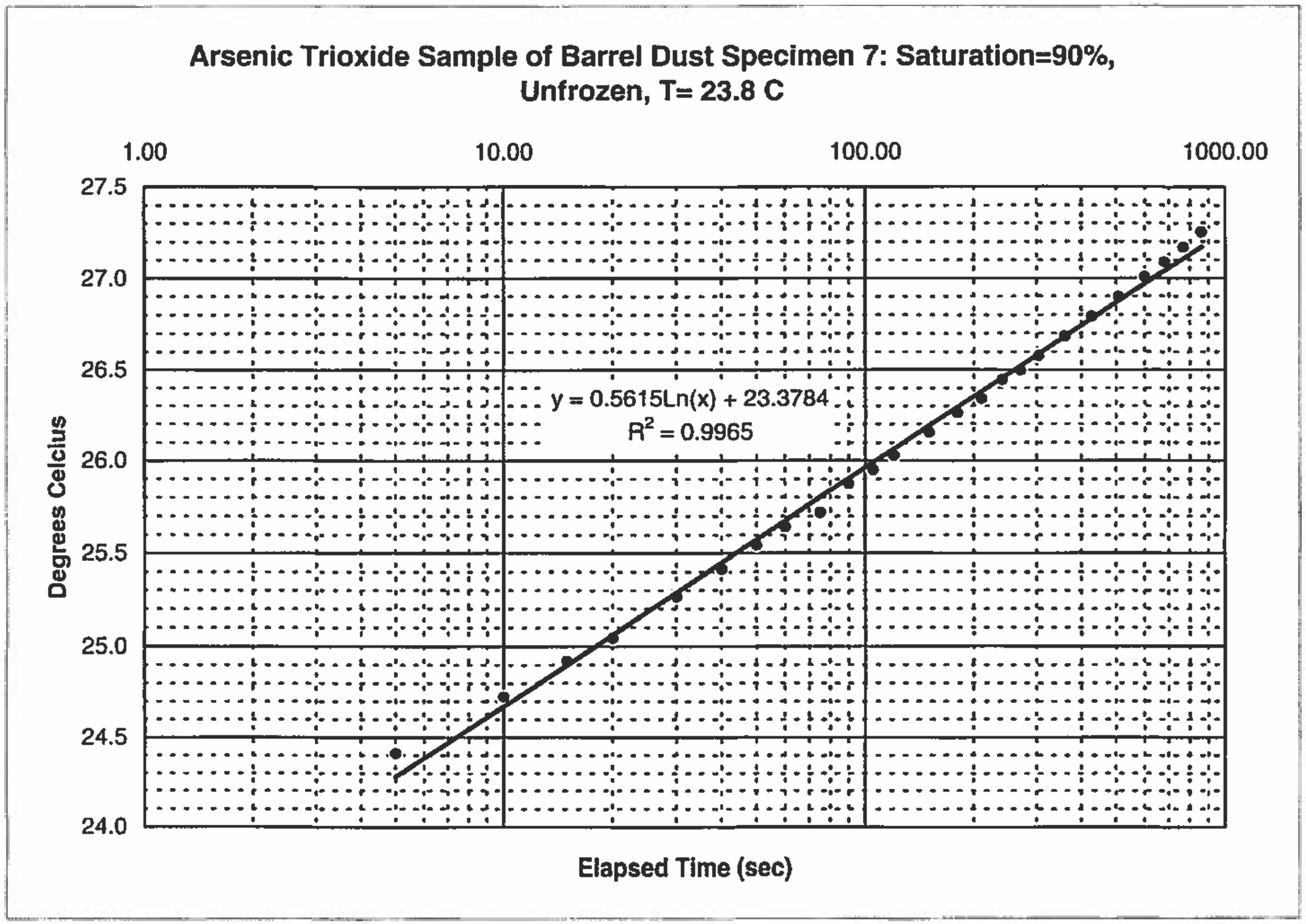


Total Volts: 1.620 Heater Resistance (Ohms): 1.43 Probe Length: 141.0 mm

Displayed Current on Screen of DC Power Supply (Amps): 1.02

EBA Engineering Consultants Ltd.

Thermal Conductivity Test No. 19



Total Volts: 1.100 Heater Resistance (Ohms): 1.43 Probe Length: 150.0 mm

Displayed Current on Screen of DC Power Supply (Amps): 0.64

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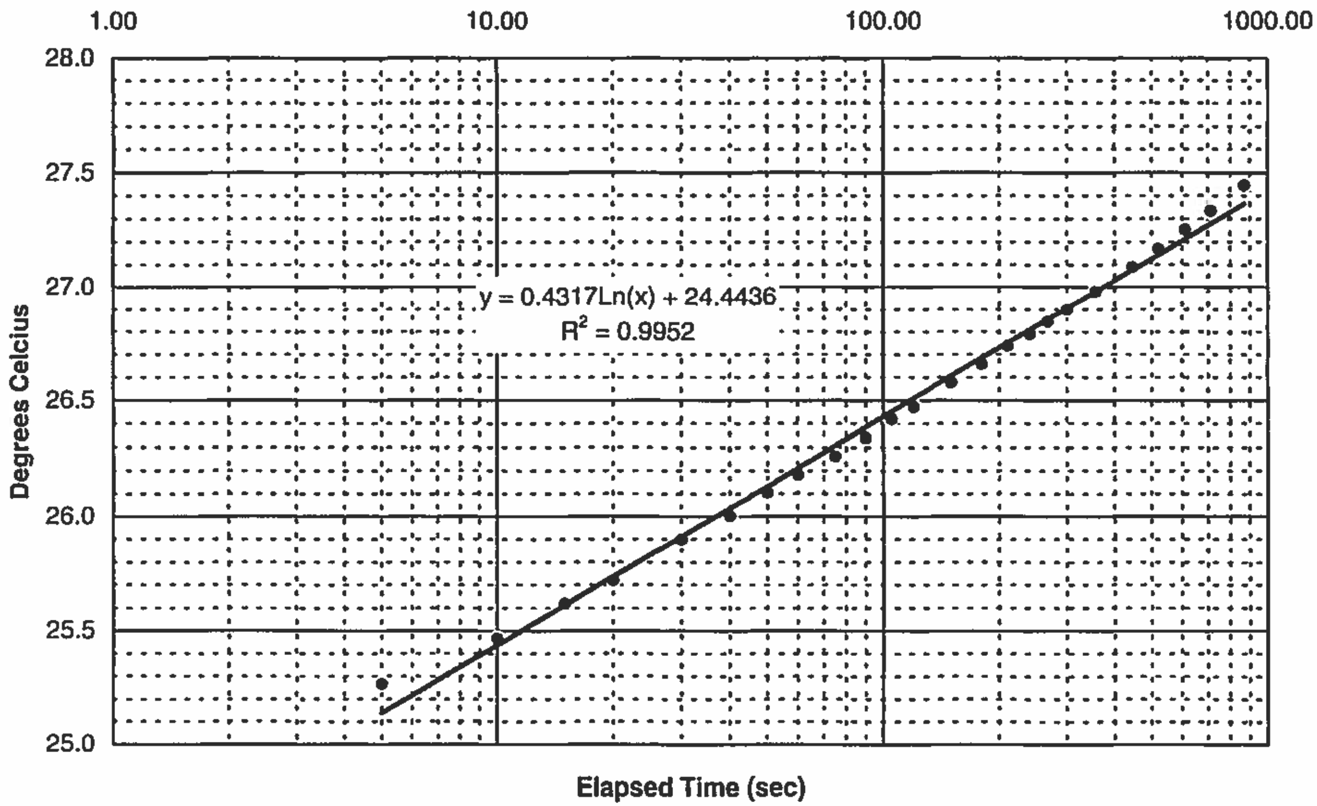
Thermal Conductivity Test No. 20

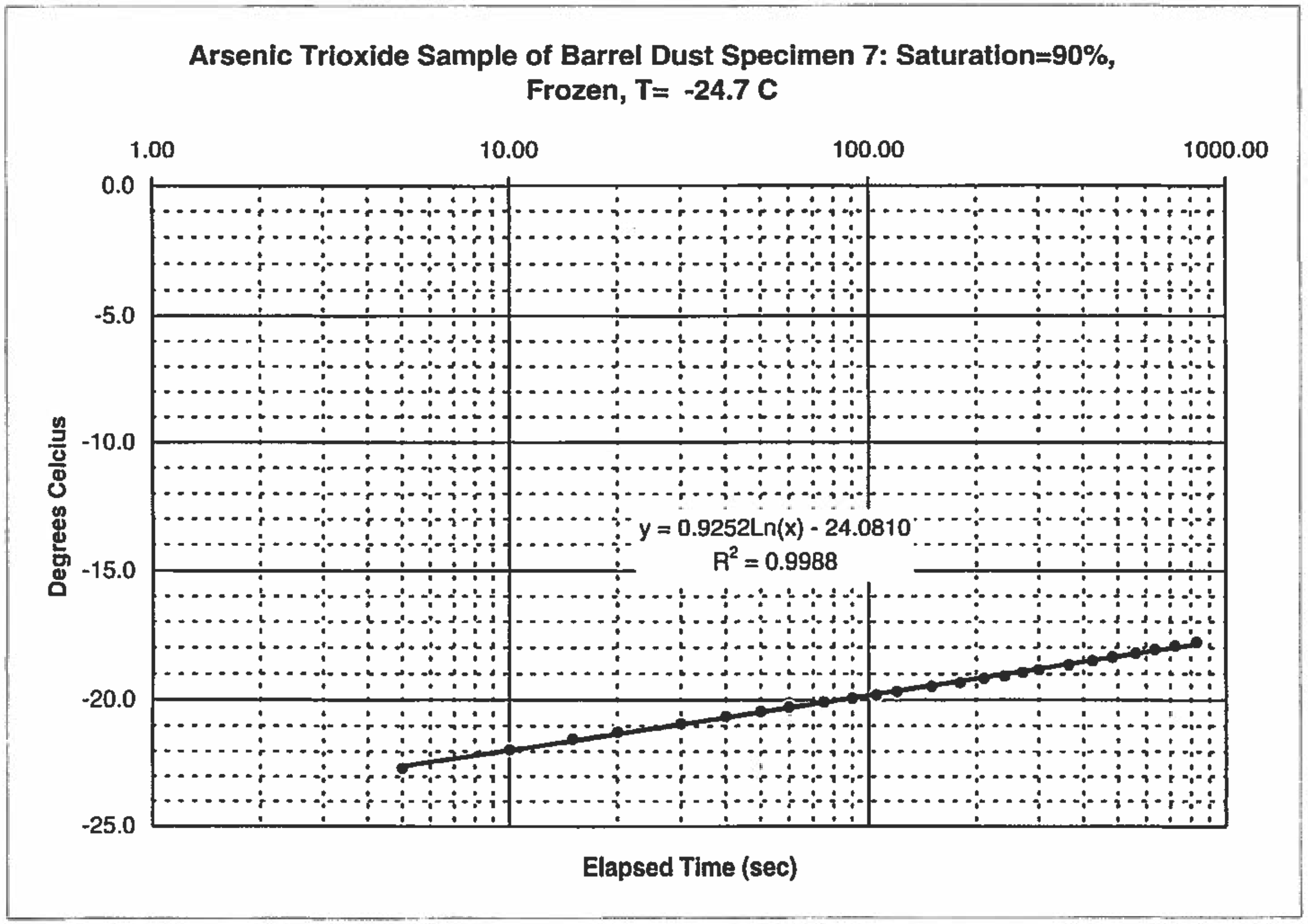
Arsenic Trioxide Sample C212-2 Specimen 8: Saturation=100%, Unfrozen, T= 24.6 C



Total Volts: 1.100 Heater Resistance (Ohms): 1.43 Probe Length: 137.0 mm
Displayed Current on Screen of DC Power Supply (Amps): 0.65

EBA Engineering Consultants Ltd.

Thermal Conductivity Test No. 21

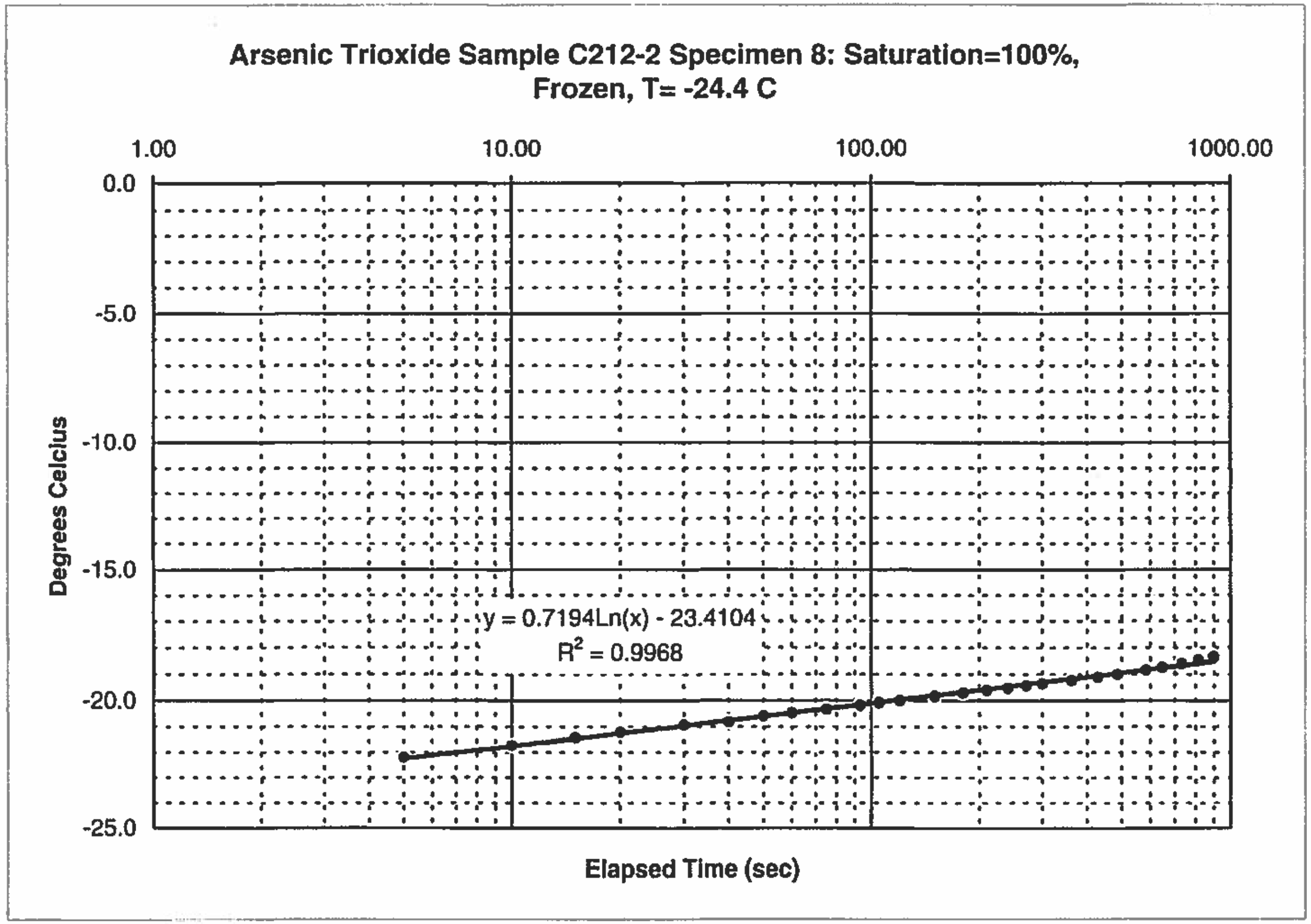


Total Volts: 2.000 Heater Resistance (Ohms): 1.43 Probe Length: 150.0 mm

Displayed Current on Screen of DC Power Supply (Amps): 1.26

EBA Engineering Consultants Ltd.

Thermal Conductivity Test No. 22



Total Volts: 2.000 Heater Resistance (Ohms): 1.43 Probe Length: 137.0 mm

Displayed Current on Screen of DC Power Supply (Amps): 1.29

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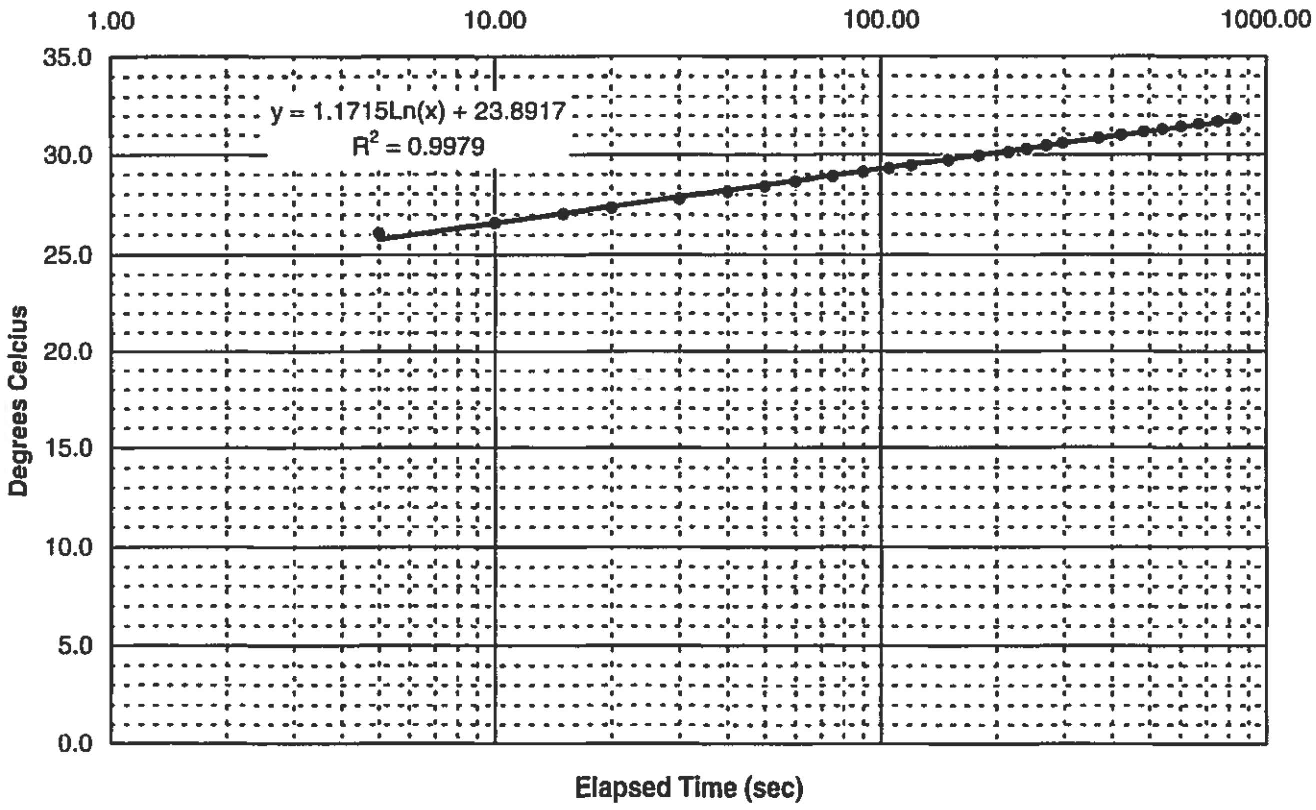
Thermal Conductivity Test No. 23

Arsenic Trioxide Sample of Barrel Dust Specimen 5: Saturation=42%, Thawed, T 25.0 C

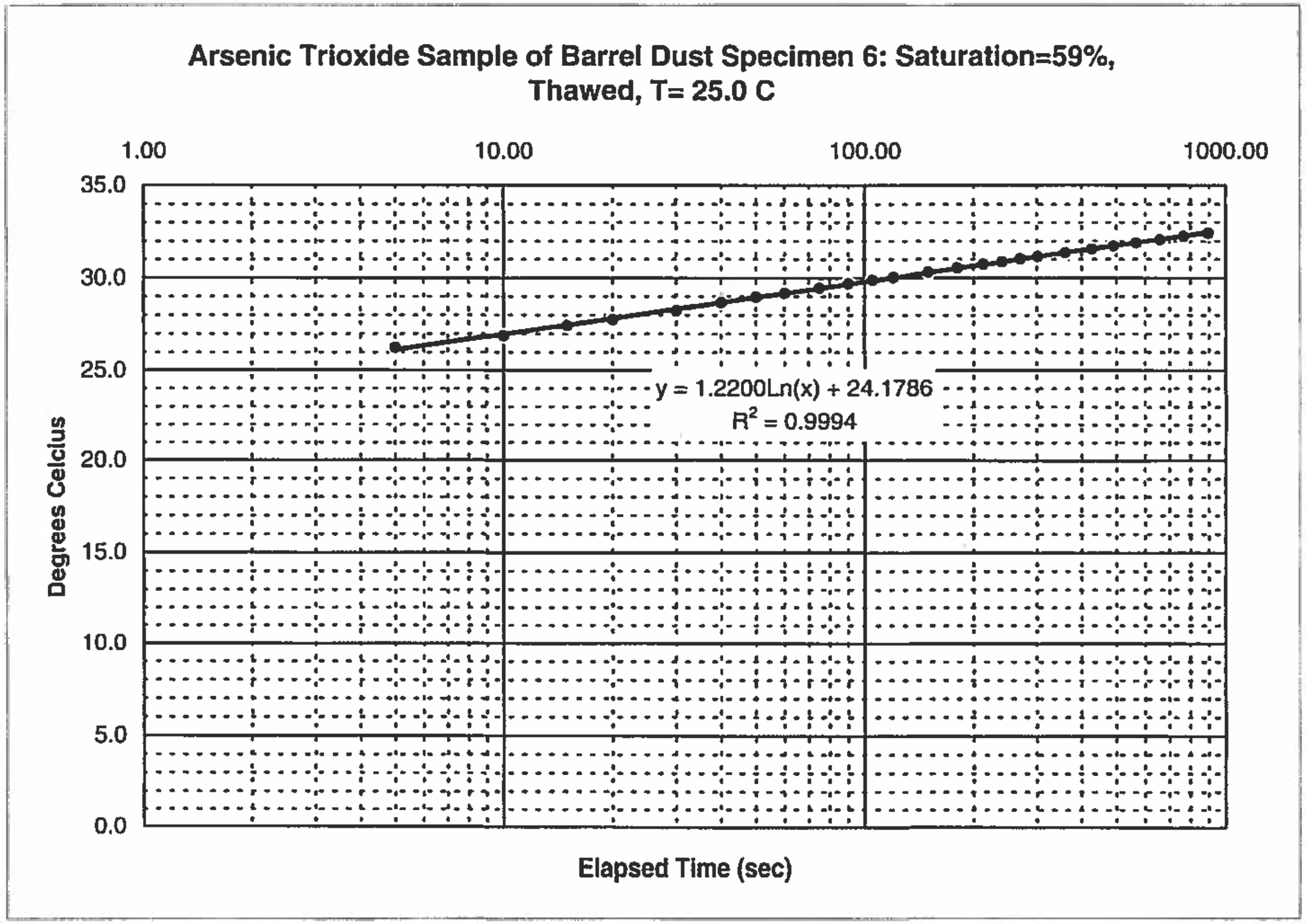


Total Volts: 1.320 Heater Resistance (Ohms): 1.43 Probe Length: 150.0 mm

Displayed Current on Screen of DC Power Supply (Amps): 0.79

EBA Engineering Consultants Ltd.

Thermal Conductivity Test No. 24



Total Volts: 1.320 Heater Resistance (Ohms): 1.43 Probe Length: 150.0 mm
Displayed Current on Screen of DC Power Supply (Amps): 0.81

APPENDIX C

UNFROZEN WATER CONTENT BY TDR TEST RESULTS

Table C-1
Initial Physical Properties of Unfrozen Water Content by TDR Test Specimens

Specimen No.	Mass (g)	Volume (cm^3)	Bulk Density (g/cm^3)	Water Content (%)	Dry Density (g/cm^3)	Void Ratio	Saturation (%)	Volumetric Water (%)
Sample B208-1								
1	3107.4	1663.8	1.868	27.8	1.462	1.17	75.3	40.6
2	3044.5	1564	1.947	42.4	1.367	1.32	101.9	58.0
3	2970	1755.1	1.692	18.8	1.424	1.23	48.7	26.8
Sample C212-2								
4	3661.5	1765.5	2.074	27.0	1.633	0.94	91.0	44.1
5	3473.9	1765.2	1.968	16.8	1.685	0.88	60.4	28.3
6	3172.9	1668.6	1.902	22.4	1.554	1.04	68.2	34.8

Table C-2
Final Physical Properties of Unfrozen Water Content by TDR Test Specimens

Specimen No.	Mass (g)	Volume (cm^3)	Bulk Density (g/cm^3)	Water Content (%)	Dry Density (g/cm^3)	Void Ratio	Saturation (%)	Volumetric Water (%)
Sample B208-1								
1	3107.4	1663.8	1.868	27.5	1.465	1.16	74.9	40.3
2	3044.5	1564	1.947	42.3	1.368	1.32	101.7	57.8
3	2970	1755	1.692	18.8	1.425	1.23	48.6	26.8
Sample C212-2								
4	3667.1	1771.4	2.070	25.0	1.656	0.91	86.7	41.4

Note: There are no final physical property data available for Specimens 5 and 6.

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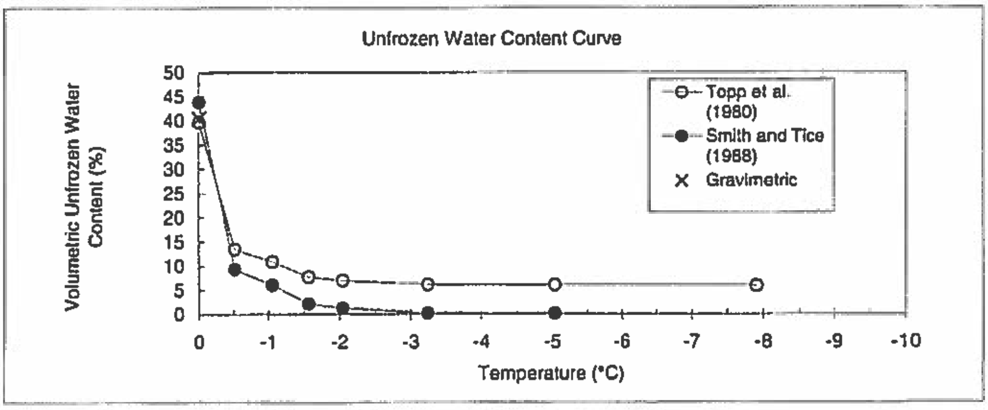
Unfrozen Water Content by Time Domain Reflectometry

Project : Arsenic Trioxide Thermal Properties
Project No.: 0101-1100052
Date Tested: June 11-14, 2004

Specimen No. B208-1
Test Number: TDR-1
Saturation (%): 75.1

Calibration Factor 1
Calibration Increment 0

Thermistor 4 Reading (kω)	Temp. (°C)	Ka^0.5	Ka	Volumetric Unfrozen Water Content (%) Smith and Tice (1988)	Topp et al. (1980)
7.53	15.85	5.06	25.61	45.39	40.74
24.7	-7.91	2.03	4.11	-0.05	5.91
21.2	-5.04	2.04	4.18	0.16	6.08
19.3	-3.25	2.05	4.21	0.26	6.16
18.13	-2.04	2.13	4.54	1.31	7.01
17.69	-1.57	2.20	4.82	2.19	7.73
17.23	-1.05	2.47	6.11	6.12	10.90
16.76	-0.52	2.69	7.24	9.33	13.48
unfrozen	0.00	4.96	24.56	43.8	39.7



Smith and Tice (1988): θ_L=-0.1458+0.03868*Ka-0.0008502*Ka^2+0.00000992*Ka^3)

Topp et al (1980): θ_L=-0.0597+0.0318*Ka-0.000738*Ka^2+0.00000814*Ka^3)

A. Pre-Test Properties

Volume (cm3)	Mass (g)	Mass (dry) (g)	Density (g/cm3)	Mass Water Content (% solids)	Volumetric Water Content (% solids)*	Volumetric Water Content (% total)	Saturation (%)
1664	3107.4	2431.9	1.87	27.8	88.1	40.6	75.3

B. Post-Test Properties

Volume (cm3)	Mass (g)	Mass (dry) (g)	Density (g/cm3)	Mass Water Content (% solids)	Volumetric Water Content (% solids)*	Volumetric Water Content (% total)	Saturation (%)
1664	3107.4	2437.3	1.87	27.5	87.2	40.3	74.9

Remarks:
*estimated using a specific gravity of 3.17

Average volumetric water content= 40.4

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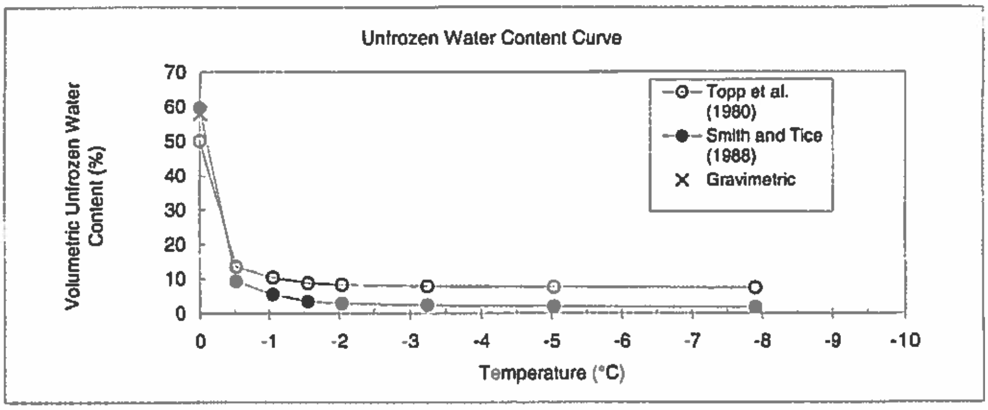
Unfrozen Water Content by Time Domain Reflectometry

Project : Arsenic Trioxide Thermal Properties
Project No.: 0101-1100052
Date Tested: June 11-14, 2004

Specimen No. B208-1
Test Number: TDR-2
Saturation (%): 101.8

Calibration Factor 1
Calibration Increment 0

Thermistor 4 Reading (kω)	Temp. (°C)	Ka^0.5	Ka	Volumetric Unfrozen Water Content (%) Smith and Tice (1988)	Topp et al. (1980)
7.13	17.02	3.11	9.68	15.79	18.63
24.7	-7.91	2.17	4.70	1.81	7.42
21.2	-5.04	2.19	4.78	2.07	7.63
19.3	-3.25	2.21	4.88	2.37	7.87
18.13	-2.04	2.25	5.06	2.93	8.33
17.69	-1.57	2.29	5.25	3.52	8.80
17.23	-1.05	2.43	5.93	5.57	10.46
16.76	-0.52	2.69	7.26	9.40	13.54
unfrozen	0.00	5.94	35.27	59.6	50.1



Smith and Tice (1988): θ_L=-0.1458+0.03868*Ka-0.0008502*Ka^2+0.00000992*Ka^3)

Topp et al (1980): θ_L=-0.0597+0.0318*Ka-0.000738*Ka^2+0.00000814*Ka^3)

A. Pre-Test Properties

Volume (cm3)	Mass (g)	Mass (dry) (g)	Density (g/cm3)	Mass Water Content (% solids)	Volumetric Water Content (% solids)*	Volumetric Water Content (% total)	Saturation (%)
1564	3044.5	2137.5	1.95	42.4	134.5	58.0	101.9

B. Post-Test Properties

Volume (cm3)	Mass (g)	Mass (dry) (g)	Density (g/cm3)	Mass Water Content (% solids)	Volumetric Water Content (% solids)*	Volumetric Water Content (% total)	Saturation (%)
1564	3044.5	2140.1	1.95	42.3	134.0	57.8	101.7

Remarks:
*estimated using a specific gravity of 3.17

Average volumetric water content= 57.9

eba

EBA Engineering Consultants Ltd.

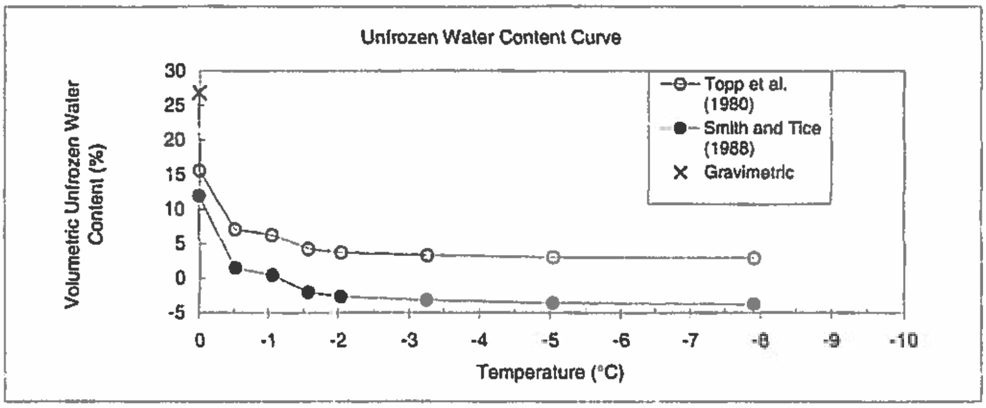
Unfrozen Water Content by Time Domain Reflectometry

Project : Arsenic Trioxide Thermal Properties
Project No.: 0101-1100052
Date Tested: June 11-14, 2004

Specimen No. B208-1
Test Number: TDR-3 First Cycle
Saturation (%): 48.7

Calibration Factor 1
Calibration Increment 0

Thermistor 4 Reading (kω)	Temp. (°C)	Ka^0.5	Ka	Volumetric Unfrozen Water Content (%) Smith and Tice (1988)	Volumetric Unfrozen Water Content (%) Topp et al. (1980)
8.94	12.2	2.82	7.96	11.33	15.09
24.7	-7.91	1.73	2.99	-3.76	2.89
21.2	-5.04	1.74	3.03	-3.62	3.00
19.3	-3.25	1.78	3.16	-3.17	3.37
18.13	-2.04	1.82	3.31	-2.68	3.77
17.69	-1.57	1.87	3.49	-2.06	4.27
17.23	-1.05	2.06	4.25	0.42	6.29
16.76	-0.52	2.14	4.58	1.45	7.12
unfrozen	0	2.86	8.19	12.0	15.6



Smith and Tice (1988): θ_L=-0.1458+0.03868*Ka-0.0008502*Ka^2+0.00000992*Ka^3)
Topp et al (1980): θ_L=-0.0597+0.0318*Ka-0.000738*Ka^2+0.00000814*Ka^3)

A. Pre-Test Properties

Volume (cm3)	Mass (g)	Mass (dry) (g)	Density (g/cm3)	Mass Water Content (% solids)	Volumetric Water Content (% solids)*	Volumetric Water Content (% total)	Saturation (%)
1755	2970	2499.0	1.69	18.8	59.7	26.8	48.7

B. Post-Test Properties

Volume (cm3)	Mass (g)	Mass (dry) (g)	Density (g/cm3)	Mass Water Content (% solids)	Volumetric Water Content (% solids)*	Volumetric Water Content (% total)	Saturation (%)
1755	2970	2500.0	1.69	18.8	59.6	26.8	48.6

Remarks: Average volumetric water content= 26.8
*estimated using a specific gravity of 3.17

eba

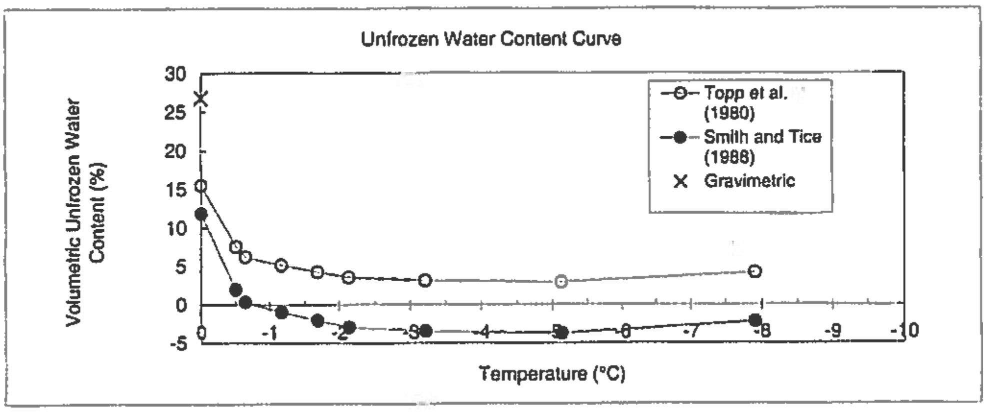
EBA Engineering Consultants Ltd.

Unfrozen Water Content by Time Domain Reflectometry

Project :	**Arsenic Trioxide Thermal Properties**	**Specimen No.**	**B208-1**
Project No.:	**0101-1100052**	**Test Number:**	**TDR-3 Second Cycle**
Date Tested:	**June 14-18, 2004**	**Saturation (%):**	**48.7**

Calibration Factor 1
Calibration Increment 0

Thermistor 4 Reading (kω)	Temp. (°C)	Ka^0.5	Ka	Volumetric Unfrozen Water Content (%) Smith and Tice (1988)	Volumetric Unfrozen Water Content (%) Topp et al. (1980)
14.65	2.13	2.86	8.15	11.84	15.49
24.7	-7.91	1.85	3.44	-2.25	4.12
21.3	-5.13	1.73	2.98	-3.78	2.87
19.26	-3.21	1.75	3.07	-3.49	3.11
18.22	-2.14	1.80	3.22	-2.96	3.54
17.8	-1.69	1.868	3.49	-2.08	4.26
17.33	-1.17	1.956	3.82	-0.97	5.16
16.87	-0.64	2.059	4.24	0.36	6.24
16.75	-0.50	2.179	4.75	2.0	7.5
unfrozen	0.00	2.86	8.15	11.84	15.49



Smith and Tice (1988): θ_L=-0.1458+0.03868*Ka-0.0008502*Ka^2+0.00000992*Ka^3)

Topp et al (1980): θ_L=-0.0597+0.0318*Ka-0.000738*Ka^2+0.00000814*Ka^3)

A. Pre-Test Properties

Volume (cm3)	Mass (g)	Mass (dry) (g)	Density (g/cm3)	Mass Water Content (% solids)	Volumetric Water Content (% solids)*	Volumetric Water Content (% total)	Saturation (%)
1755	2970	2499.0	1.69	18.8	59.7	26.8	48.7

B. Post-Test Properties

Volume (cm3)	Mass (g)	Mass (dry) (g)	Density (g/cm3)	Mass Water Content (% solids)	Volumetric Water Content (% solids)*	Volumetric Water Content (% total)	Saturation (%)
1755	2970	2500.0	1.69	18.8	59.6	26.8	48.6

Remarks: Average volumetric water content= 26.8

*estimated using a specific gravity of 3.17

eba

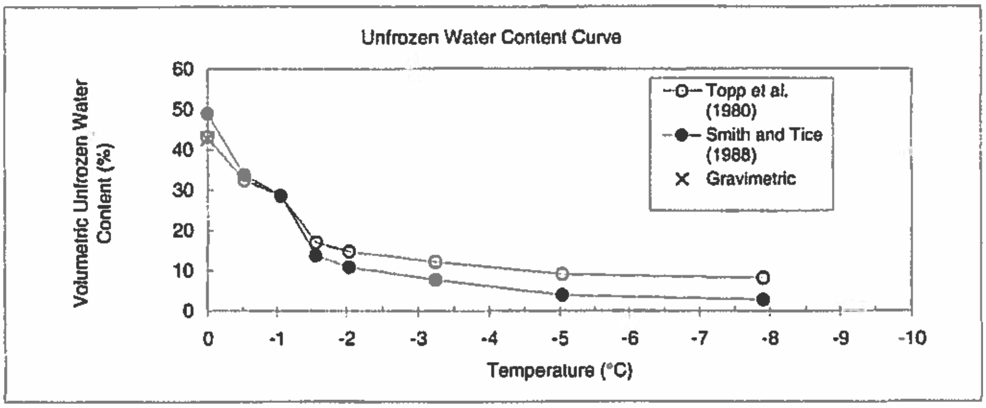
EBA Engineering Consultants Ltd.

Unfrozen Water Content by Time Domain Reflectometry

Project :	**Arsenic Trioxide Thermal Properties**	**Specimen No.**	**C212-2**
Project No.:	**0101-1100052**	**Test Number:**	**TDR-4**
Date Tested:	**June 11-14, 2004**	**Saturation (%):**	**88.9**

Calibration Factor 1
Calibration Increment 0

Thermistor 4 Reading (kω)	Temp. (°C)	Ka^0.5	Ka	Volumetric Unfrozen Water Content (%) Smith and Tice (1988)	Topp et al. (1980)
8.92	12.26	0.03	0.00	-14.58	-5.97
24.7	-7.91	2.23	4.97	2.66	8.11
21.2	-5.04	2.32	5.37	3.90	9.11
19.3	-3.25	2.58	6.64	7.66	12.14
18.13	-2.04	2.79	7.79	10.86	14.70
17.69	-1.57	2.98	8.87	13.74	17.01
17.23	-1.05	3.94	15.50	28.65	28.62
16.76	-0.52	4.28	18.28	33.77	32.47
unfrozen	0.00	5.30	28.08	49.0	43.2



Smith and Tice (1988): θ_L=-0.1458+0.03868*Ka-0.0008502*Ka^2+0.00000992*Ka^3)

Topp et al (1980): θ_L=-0.0597+0.0318*Ka-0.000738*Ka^2+0.00000814*Ka^3)

A. Pre-Test Properties

Volume (cm3)	Mass (g)	Mass (dry) (g)	Density (g/cm3)	Mass Water Content (% solids)	Volumetric Water Content (% solids)*	Volumetric Water Content (% total)	Saturation (%)
1766	3661.5	2882.4	2.07	27.0	85.7	44.1	91.0

B. Post-Test Properties

Volume (cm3)	Mass (g)	Mass (dry) (g)	Density (g/cm3)	Mass Water Content (% solids)	Volumetric Water Content (% solids)*	Volumetric Water Content (% total)	Saturation (%)
1771	3667.1	2933.1	2.07	25.0	79.3	41.4	86.7

Remarks: Average volumetric water content= 42.8

*estimated using a specific gravity of 3.17

EBA Engineering Consultants Ltd.

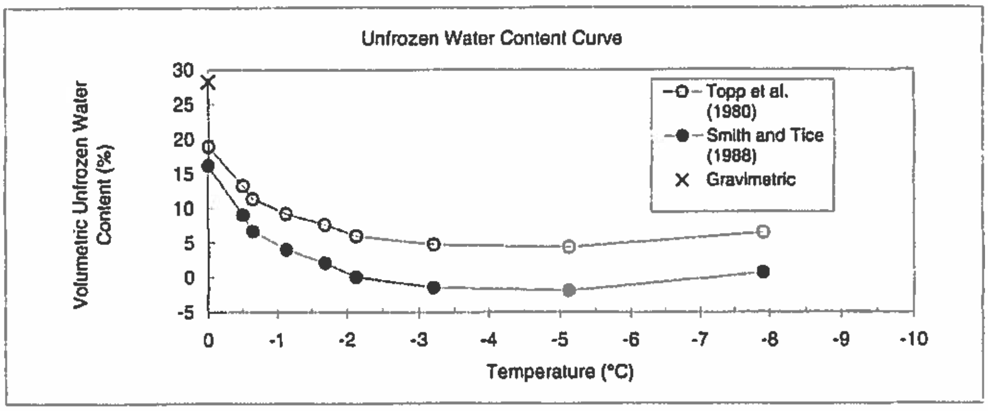
Unfrozen Water Content by Time Domain Reflectometry

Project : Arsenic Trioxide Thermal Properties
Project No.: 0101-1100052
Date Tested: June 14-18, 2004

Specimen No. C212-2
Test Number: TDR-5
Saturation (%): 30.2

Calibration Factor 1
Calibration Increment 0

Thermistor 4 Reading (kω)	Temp. (°C)	Ka^0.5	Ka	Volumetric Unfrozen Water Content (%) Smith and Tice (1988)	Volumetric Unfrozen Water Content (%) Topp et al. (1980)
24.7	-7.91	2.09	4.35	0.71	6.53
21.3	-5.13	1.88	3.54	-1.91	4.39
19.26	-3.21	1.92	3.67	-1.46	4.76
18.21	-2.13	2.03	4.14	0.05	5.99
17.8	-1.69	2.19	4.78	2.07	7.63
17.3	-1.13	2.33	5.43	4.07	9.25
16.87	-0.64	2.51	6.32	6.71	11.37
16.75	-0.50	2.67	7.14	9.07	13.28
unfrozen	0.00	3.14	9.85	16.2	19.0



Smith and Tice (1988): θ_L=-0.1458+0.03868*Ka-0.0008502*Ka^2+0.00000992*Ka^3)

Topp et al (1980): θ_L=-0.0597+0.0318*Ka-0.000738*Ka^2+0.00000814*Ka^3)

A. Pre-Test Properties

Volume (cm3)	Mass (g)	Mass (dry) (g)	Density (g/cm3)	Mass Water Content (% solids)	Volumetric Water Content (% solids)*	Volumetric Water Content (% total)	Saturation (%)
1765	3473.9	2974.6	1.97	16.8	53.2	28.3	60.4

B. Post-Test Properties

Volume (cm3)	Mass (g)	Mass (dry) (g)	Density (g/cm3)	Mass Water Content (% solids)	Volumetric Water Content (% solids)*	Volumetric Water Content (% total)	Saturation (%)
n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.0

Remarks:
*estimated using a specific gravity of 3.17

Average volumetric water content= 28.3

EBA Engineering Consultants Ltd.

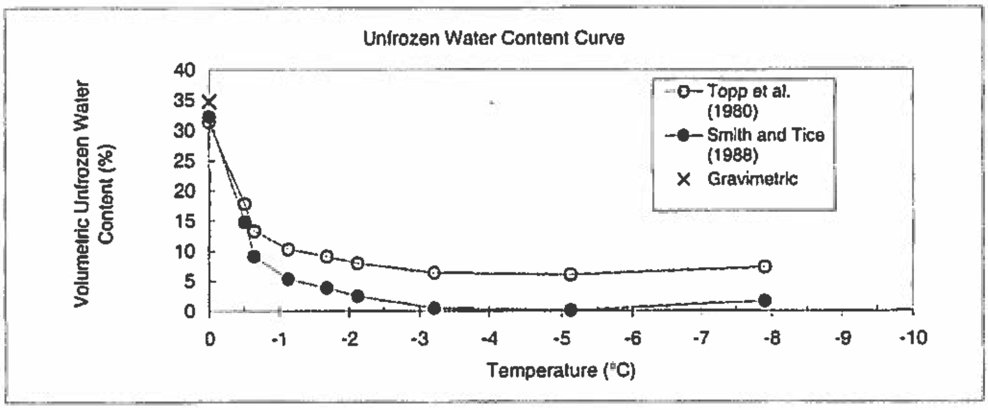
Unfrozen Water Content by Time Domain Reflectometry

Project : Arsenic Trioxide Thermal Properties
Project No.: 0101-1100052
Date Tested: June 14-18, 2004

Specimen No. C212-2
Test Number: TDR-6
Saturation (%): 68.2

Calibration Factor 1
Calibration Increment 0

Thermistor 4 Reading (kω)	Temp. (°C)	Ka^0.5	Ka	Volumetric Unfrozen Water Content (%) Smith and Tice (1988)	Topp et al. (1980)
24.7	-7.91	2.15	4.63	1.60	7.25
21.3	-5.13	2.04	4.15	0.08	6.01
19.27	-3.22	2.07	4.27	0.47	6.33
18.21	-2.13	2.22	4.91	2.48	7.96
17.8	-1.69	2.31	5.35	3.83	9.05
17.3	-1.13	2.42	5.86	5.36	10.29
16.87	-0.64	2.67	7.15	9.09	13.29
16.75	-0.50	3.05	9.29	14.80	17.85
unfrozen	0.00	4.18	17.44	32.3	31.4



Smith and Tice (1988): θ_L=-0.1458+0.03868*Ka-0.0008502*Ka^2+0.00000992*Ka^3)

Topp et al (1980): θ_L=-0.0597+0.0318*Ka-0.000738*Ka^2+0.00000814*Ka^3)

A. Pre-Test Properties

Volume (cm3)	Mass (g)	Mass (dry) (g)	Density (g/cm3)	Mass Water Content (% solids)	Volumetric Water Content (% solids)*	Volumetric Water Content (% total)	Saturation (%)
1669	3172.9	2592.2	1.90	22.4	71.0	34.8	68.2

B. Post-Test Properties

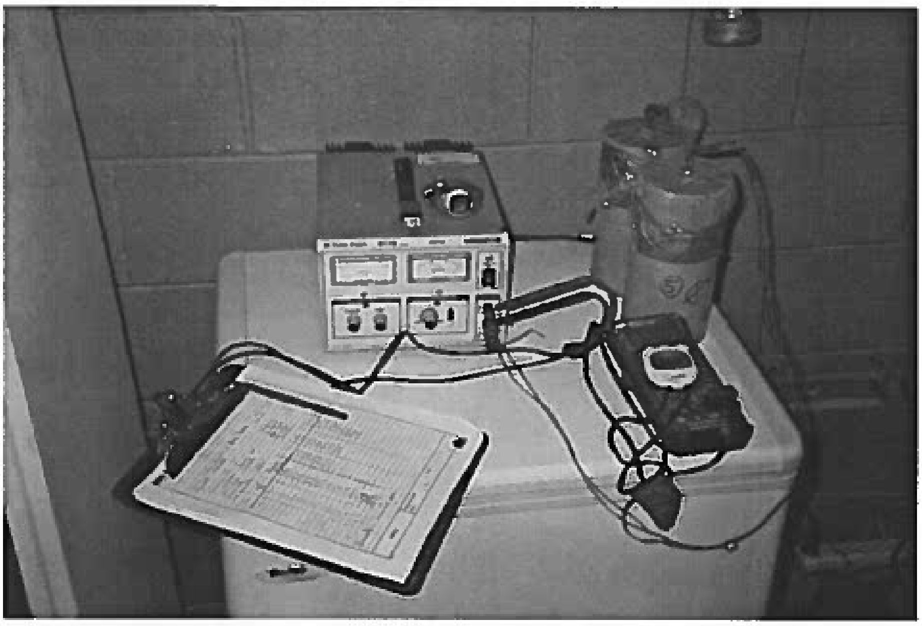
Volume (cm3)	Mass (g)	Mass (dry) (g)	Density (g/cm3)	Mass Water Content (% solids)	Volumetric Water Content (% solids)*	Volumetric Water Content (% total)	Saturation (%)
n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.0

Remarks: Average volumetric water content= 34.8

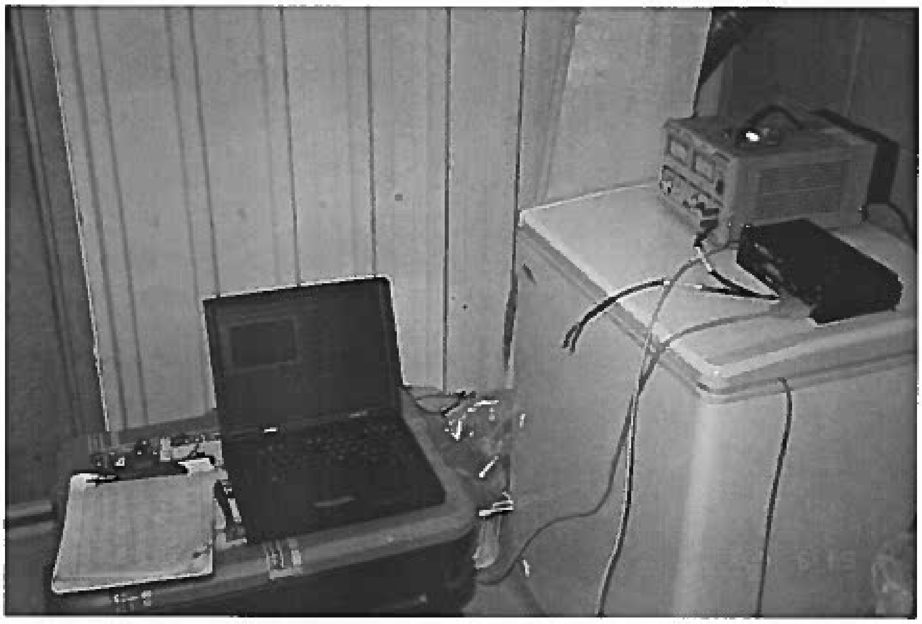
*estimated using a specific gravity of 3.17

APPENDIX D

PHOTOGRAPHS

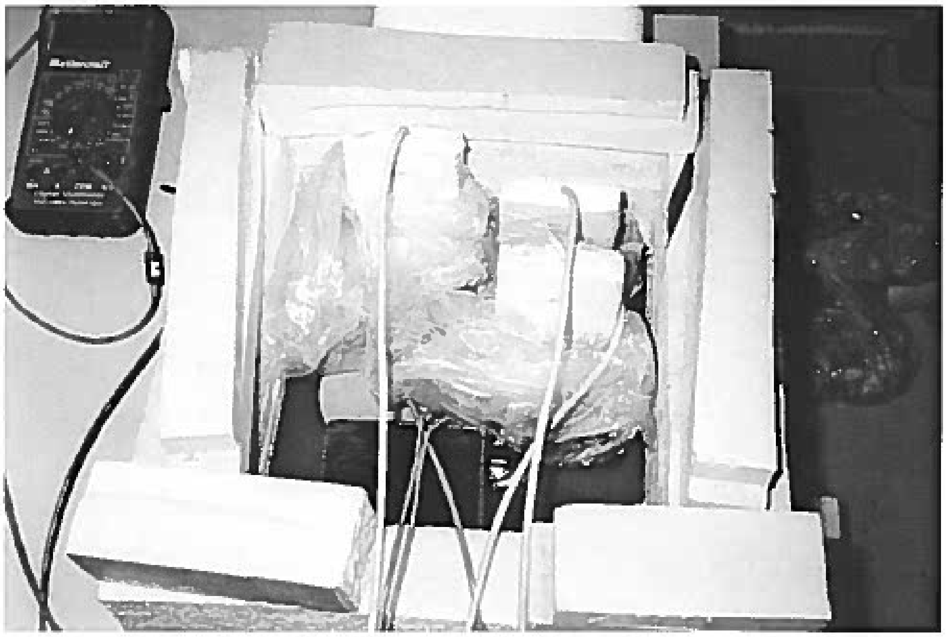


Photograph 1: Thermal conductivity test set-up: power supply, two specimens in HDPE cylinders with probes; stopwatch, and multi-meter for thermistor readings (all resting on chest freezer).



Photograph 2: TDR test set-up: TDR100 unit and power supply (upper right corner and sitting on chest freezer) connected to laptop and TDR probe.

Photograph 3: TDR test set-up: Isotemp 3028 circulation bath with specimens stored in work area beneath the Styrofoam insulation and probe leads extending to the TDR100 unit (background).



Photograph 4: TDR test set-up: View of circulation bath work area with specimens immersed in glycol and probe leads extending to TDR100.