Jordi Labs

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Client Name.

Contact Name

Released by:
Mark Jordi, Ph.D.
President

Job Number: J8679

Case Study

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Dear Client,

Please find enclosed the test results for your samples described as:

1- Milk Jug
2- PE Rope
3- Unstabilized Resin
4- Clear PE Bag

The following tests were performed:

1. Differential Scanning Calorimetry-Oxidative Induction Time (DSC-OIT)

Objective

The goal of the analysis was to determine the relative abundance of thermal stabilizers in each sample using DSC-OIT. The unstabilized resin is known to contain no stabilizer, while the stabilizer content of each other resin is unknown.

Summary of Results

Milk Jug was analyzed at temperatures between 190 °C and 230 °C to determine an optimal temperature that provides an optimal balance of run time and resolution. The results of optimization can be found in **Table 1**.

195 °C was found to be an appropriate temperature, and all samples were analyzed at 195 °C. It was found that *Milk jug* showed the longest oxidative induction time. This indicates that *Milk Jug* possessed the most effective thermal stabilizer relative to the other samples. The effectiveness of the stabilizer in *PE Rope* and *Clear PE Bag* was compared relative to *Milk Jug*. Unstabilized resin was used as a baseline for minimum oxidation time of polyethylene as it did not possess stabilizer and was used to correct for the oxidation time of PE. Oxidation times of the samples can be found in **Table 2**.

Background

Differential Scanning Calorimetry-Oxidative Induction Time (DSC-OIT) is a thermal analysis method performed typically on stabilized polyolefins to determine the relative amount of antioxidant remaining in a material. DSC-OIT is therefore commonly used in two capacities: To investigate the current state of the thermal stabilizer as a quality control measure or to ensure

sufficient thermal stabilizer is present in a polymer formulation for a particular application. Both common applications are accomplished through comparison of the sample with a standard known to possess either sufficient or deficient amounts of thermal stabilizer relative to the unknown sample.

Individual Test Results

A summary of the individual test results is provided below. All accompanying data, including spectra, has been included in the data section of this report.

DSC-OIT

The samples were analyzed to determine their oxidation induction time. In this analysis, the sample is initially heated to a predefined temperature under nitrogen and then the atmosphere is switched to oxygen. The time for the onset of oxidation is then measured. A longer time for onset of oxidation generally indicates a higher level of stabilization is present in the polymer.

Results

Milk Jug was analyzed at temperatures between 190, 195, 200, 210, 220, and 230 °C to determine an optimal temperature that provides an optimal balance of run time and resolution. The results of optimization can be found in **Table 1**. Furthermore, an overlay of the thermograms acquired at each temperature can be found in **Figure 1**. It was also found that the reduction of oxidation time as a function of temperature exhibits an exponential decay curve with an R^2 value of 0.9906 as can be seen in **Figure 2**. Based on the exponential decay curve seen in **Figure 2**, 195 °C was selected as a temperature to analyze the remaining samples.

Table 1
DSC-OIT Oxidation Times of Plastic Milk Jug at Various Temperatures

Temperature (°C)	Run	Oxidation Time	Average Oxidation Time
230	**1**	1.56	1.58
	2	1.60	
220	**1**	2.83	3.16
	2	3.48	
210	**1**	7.09	7.29
	2	7.49	
200	**1**	13.56	13.86
	2	14.15	
195	**1**	28.34	27.68
	2	27.01	
190	**1**	N/A	N/A
	2	N/A	

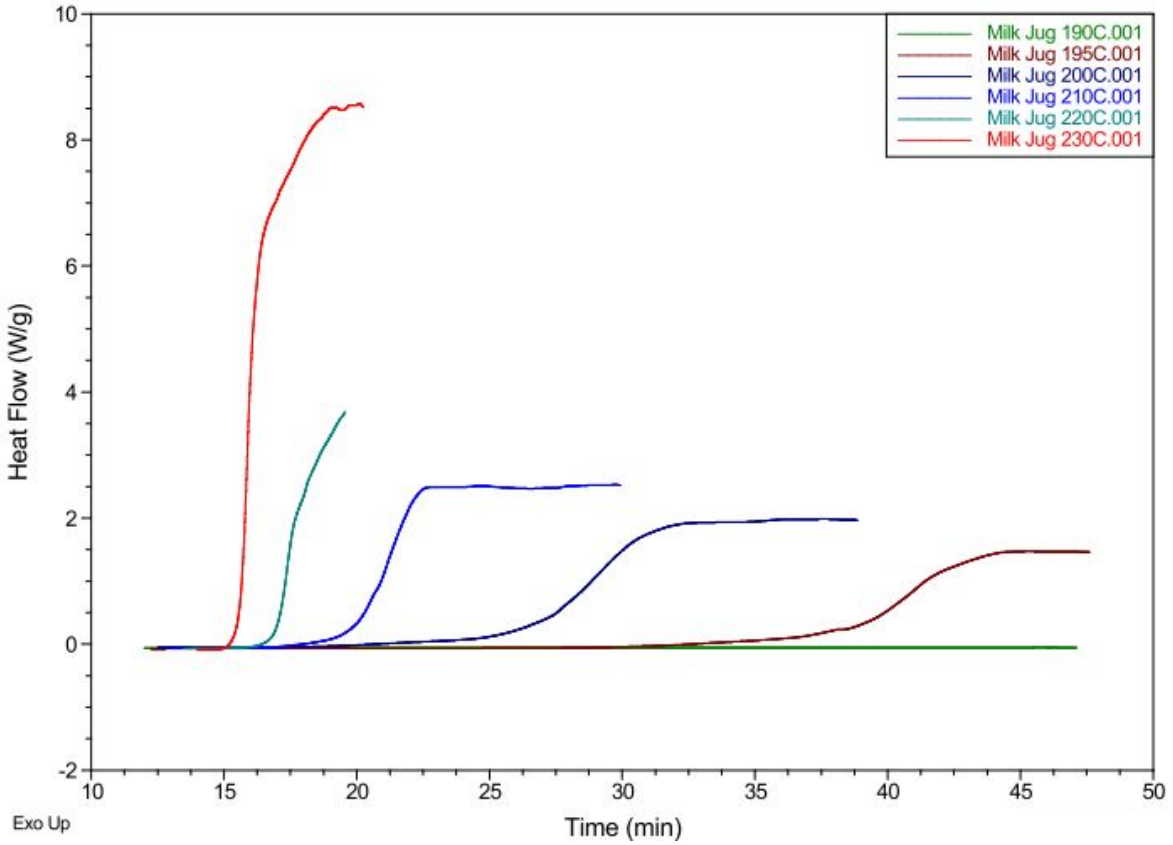

Figure 1: Overlay of thermograms of *Milk Jug* at various oxidation temperature of *Milk Jug*

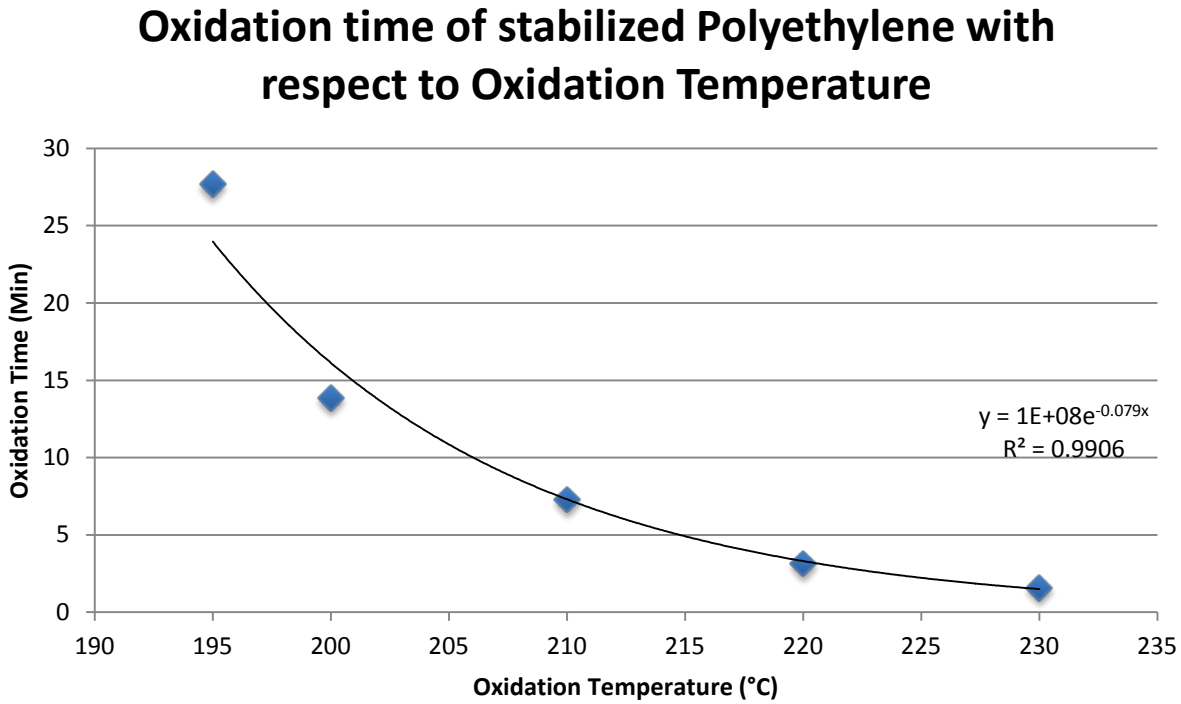

Figure 2: Graph of Oxidation Time as a Function of Oxidation Temperature of *Milk Jug*

An overlay of the thermograms for each sample can be found in **Figure 1**. It was found that *Milk jug* showed the longest oxidative induction time. This indicates that *Milk Jug* possessed the highest thermal stability relative to the other samples. The thermal stability of the *PE Rope* and *Clear PE Bag* relative to *Milk Jug* was determined. Unstabilized resin was used as a baseline for the minimum oxidation time of polyethylene. Oxidation times of the samples and their relative thermal stability can be found in **Table 2**.

Table 2
DSC-OIT Oxidation Times of Samples at 195 °C

Temperature (°C)	Run	Oxidation Time	Average Oxidation Time	Thermal Stability Compared to *Milk Jug* (%)
Milk Jug	**1**	28.34	27.68	100
	2	27.01		
PE Rope	**1**	20.29	20.11	72.42
	2	19.92		
Clear PE Bag	**1**	17.24	17.59	63.24
	2	17.93		
Unstabilized Resin	**1**	0.22	0.23	0
	2	0.24		

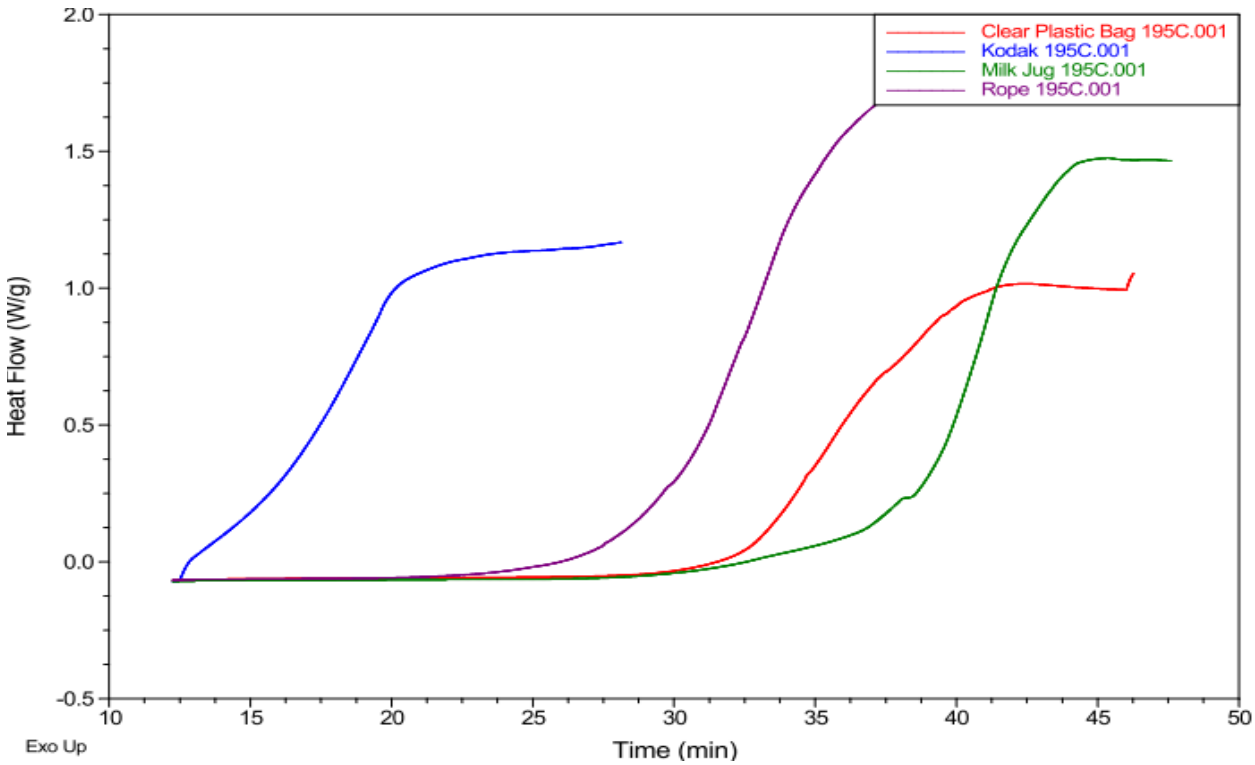

Figure 3: Overlay of thermograms of *Milk Jug* at various oxidation temperature of *Milk Jug*

Analysis Conditions

This section of a Jordi report provides information on the methods used including instrument type, temperatures, solvents, sample preparation, etc. The specific conditions have been removed for this case study.

Closing Comments

Deformulation of an unknown material is intended to provide a best estimate of the chemical nature of the sample. All chemical structures are supported by the evidence presented but are subject to revision upon receipt of additional evidence. Additional factors such as material processing conditions may also affect final material properties.

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Jordi Labs specializes in polymer testing and has 30 years experience doing complete polymer deformulations. We are one of the few labs in the country specialized in this type of testing. We will work closely with you to help explain your test results and solve your problem. We appreciate your business and are looking forward to speaking with you concerning these results.

Sincerely,

David York

David York, M.S.
Senior Chemist
Jordi Labs LLC

Mark Jordi

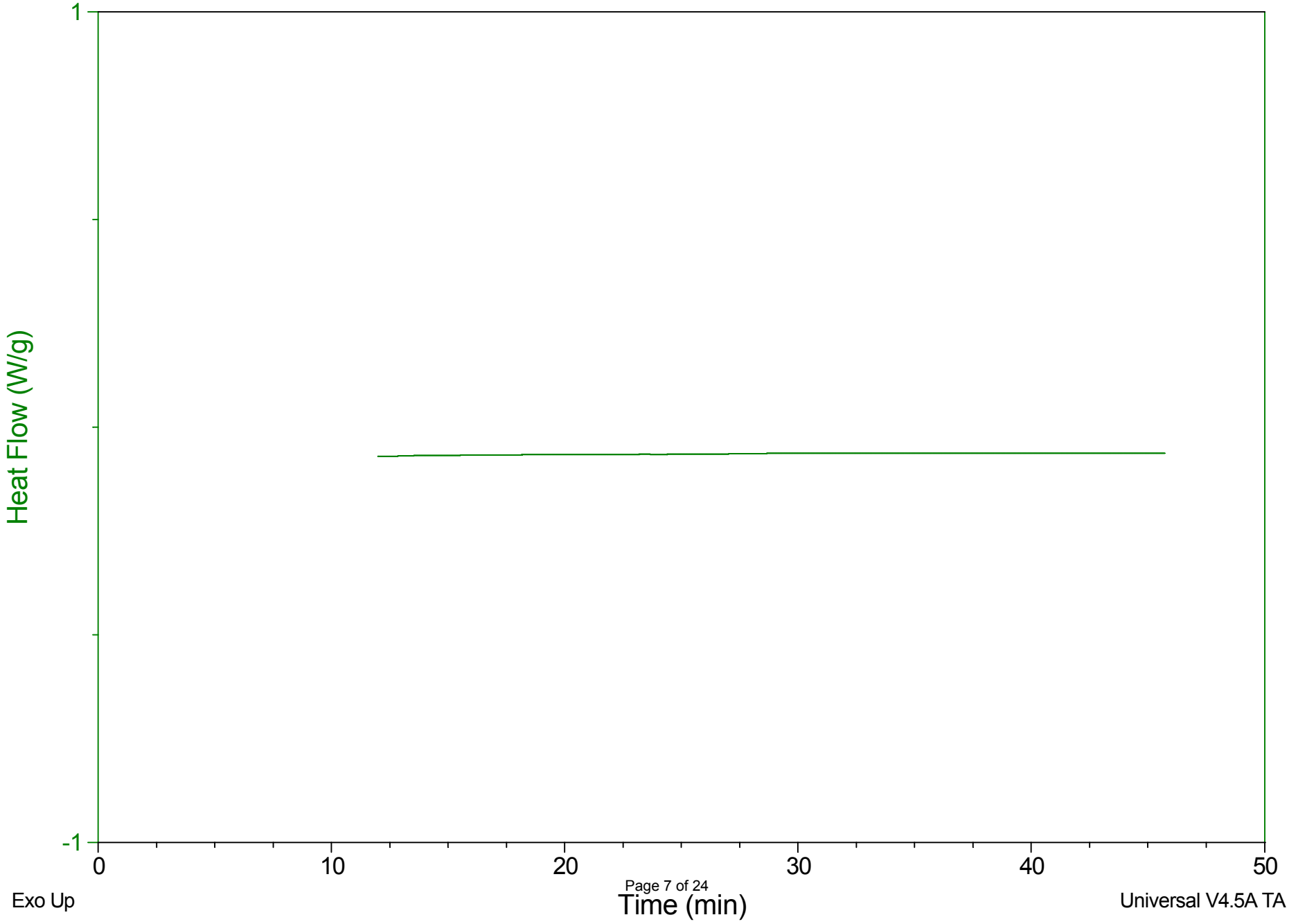
Mark Jordi, Ph. D.
President
Jordi Labs LLC

Sample: Milk Jug 190C
Size: 5.2460 mg
Method: Oxygen induction time

DSC

File: R:...\Milk Jug 190C.002

Run Date: 15-Aug-2014 14:04
Instrument: DSC Q2000 V24.11 Build 124



Exo Up

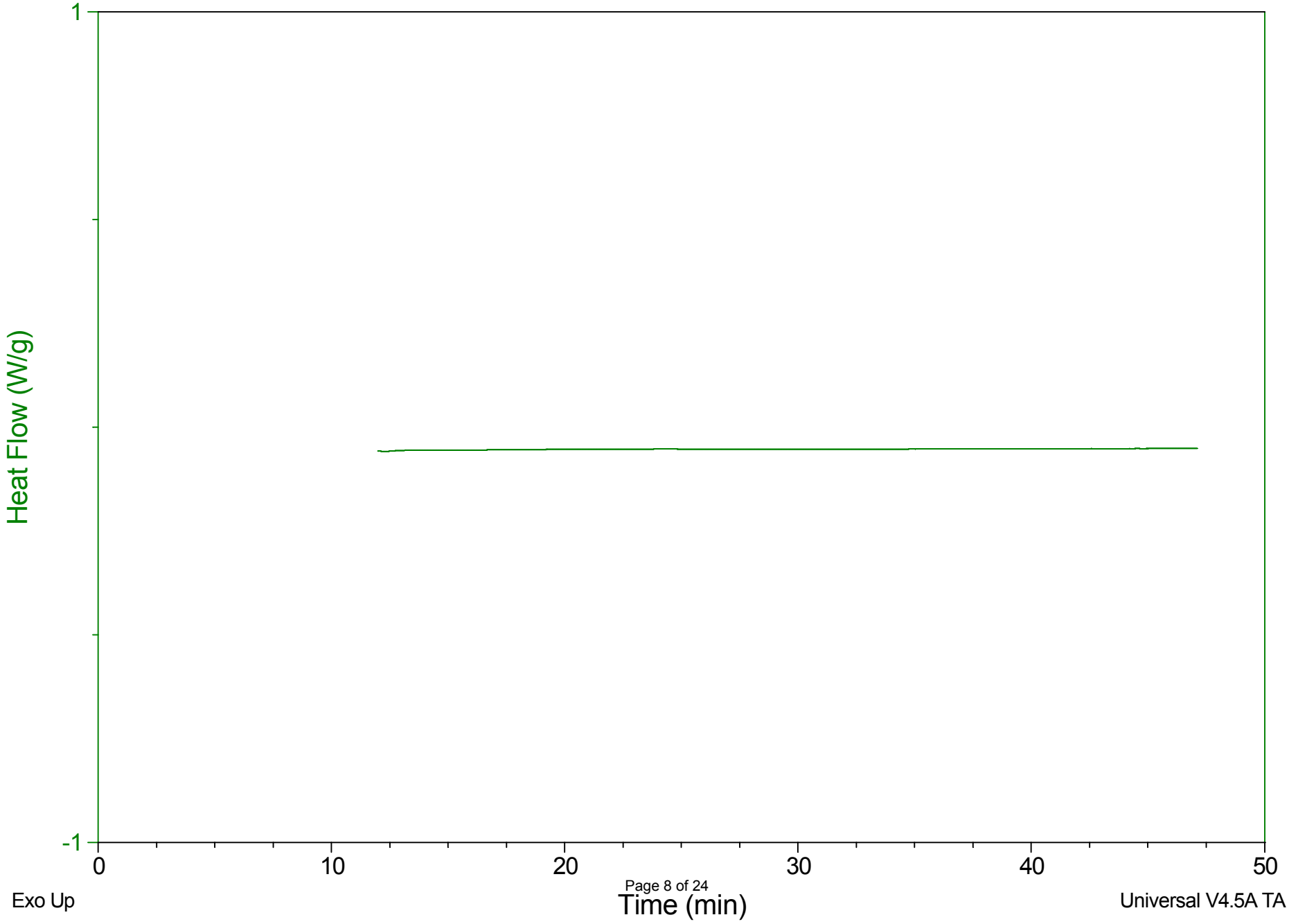
Universal V4.5A TA Instruments

Sample: Milk Jug 190C
Size: 5.0580 mg
Method: Oxygen induction time

DSC

File: R:...\Milk Jug 190C.001

Run Date: 06-Aug-2014 11:32
Instrument: DSC Q2000 V24.11 Build 124



Exo Up

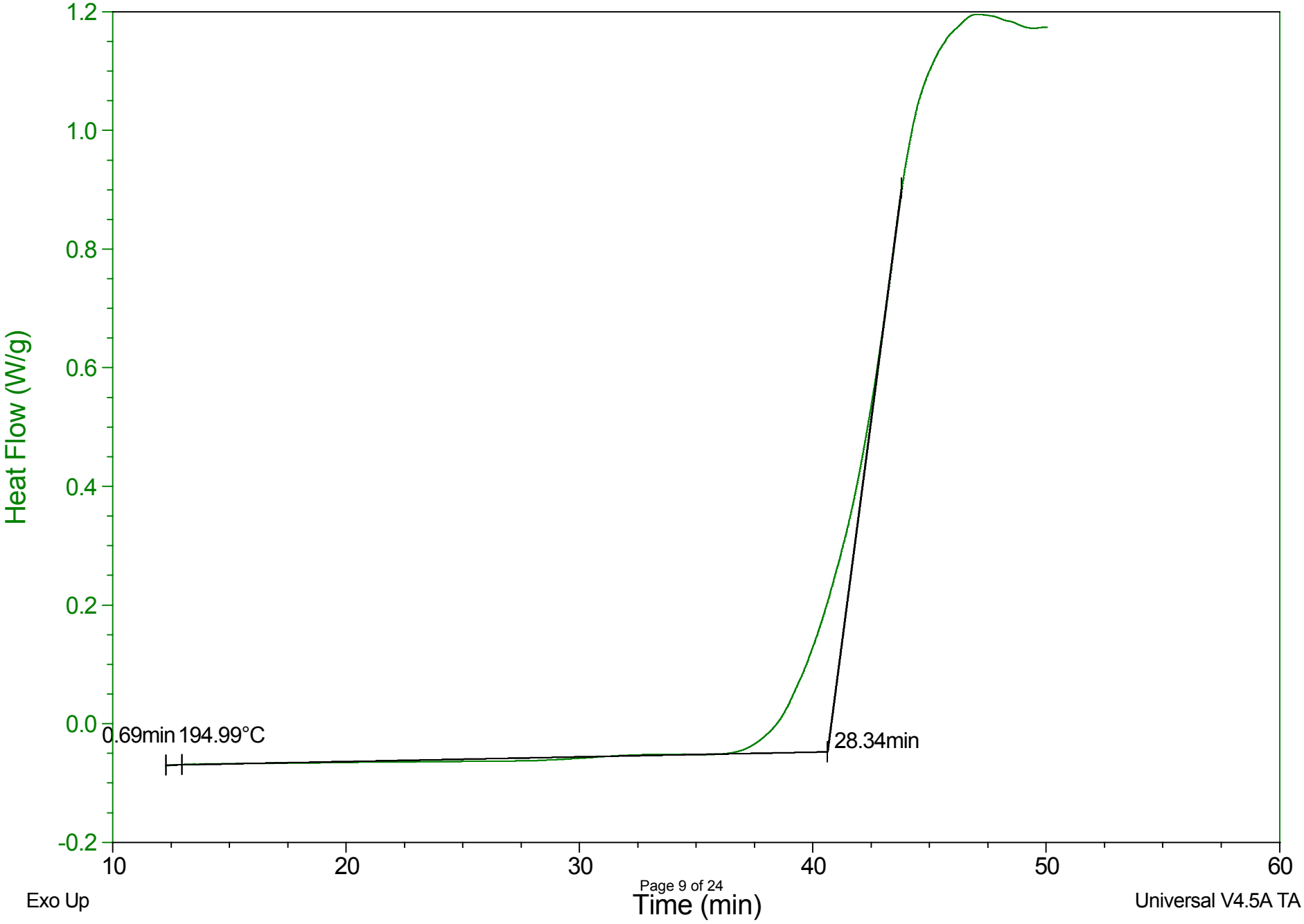
Universal V4.5A TA Instruments

Sample: Milk Jug 195C
Size: 5.2100 mg
Method: Oxygen induction time

DSC

File: R:...\Milk Jug 195C.002

Run Date: 12-Aug-2014 13:02
Instrument: DSC Q2000 V24.11 Build 124



Exo Up

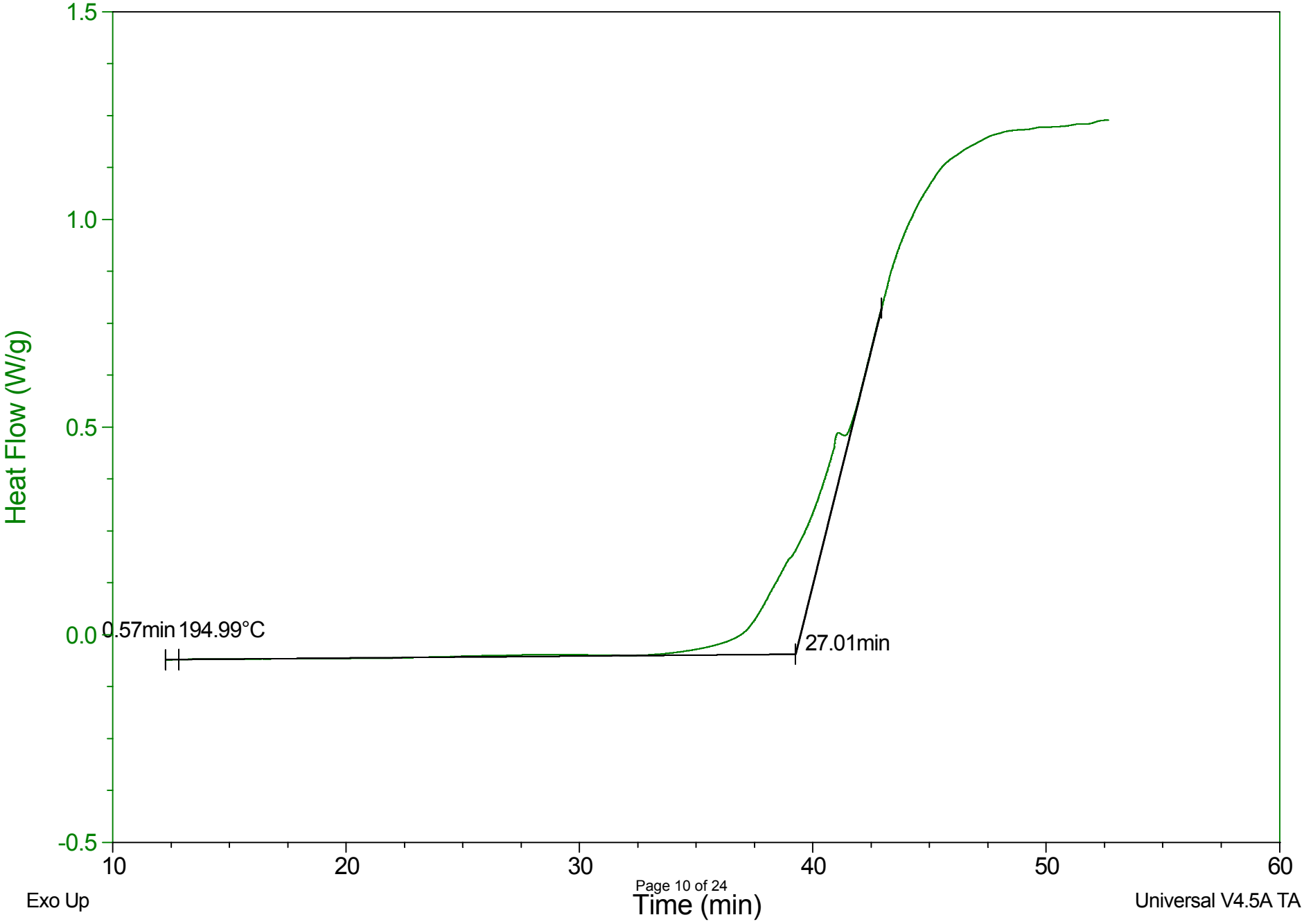
Universal V4.5A TA Instruments

Sample: Milk Jug 195C
Size: 5.2620 mg
Method: Oxygen induction time

DSC

File: R:...\Milk Jug 195C.005

Run Date: 14-Aug-2014 09:06
Instrument: DSC Q2000 V24.11 Build 124



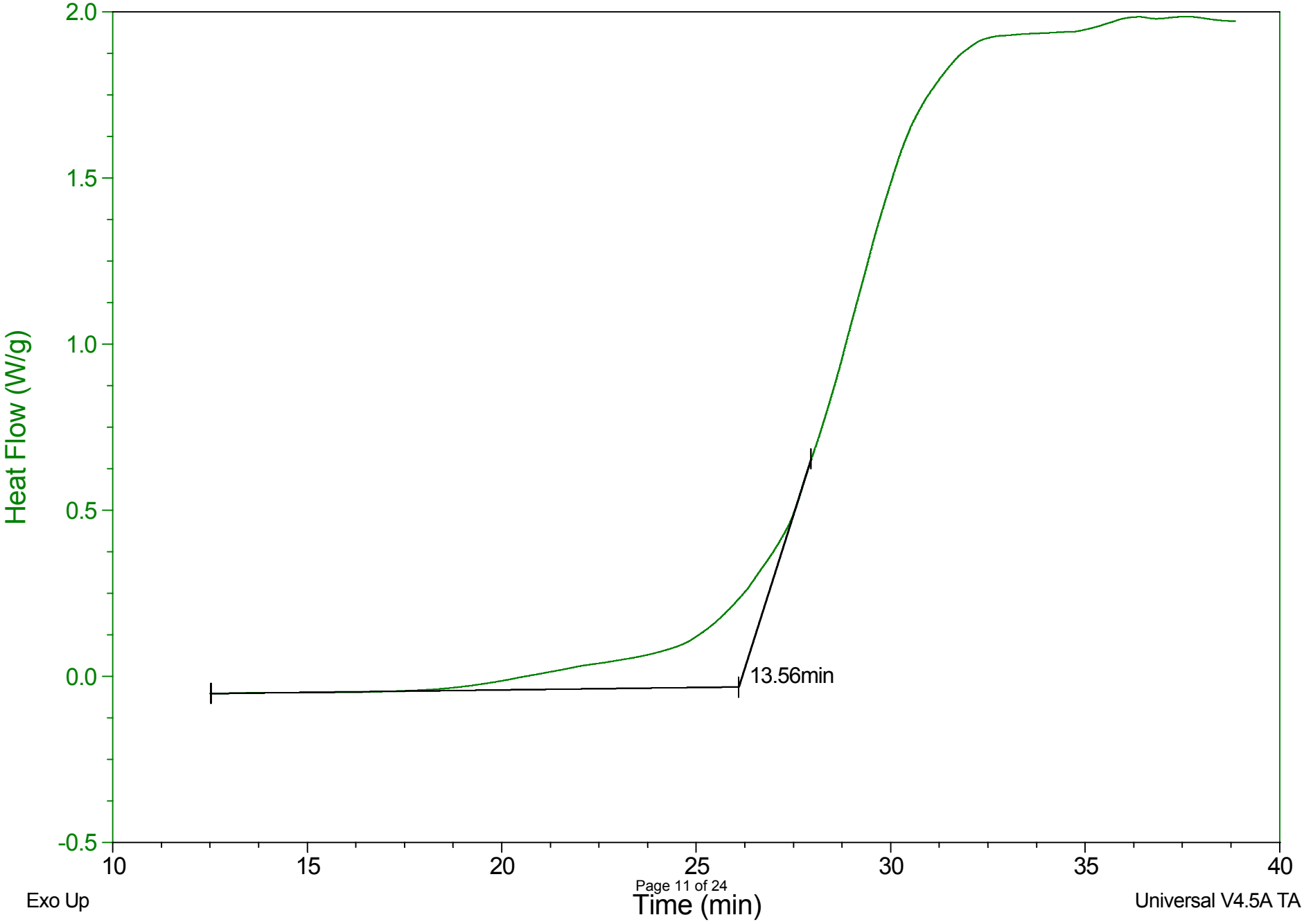
Universal V4.5A TA Instruments

Sample: Milk Jug 200C
Size: 5.1580 mg
Method: Oxygen induction time

DSC

File: R:...\Milk Jug 200C.001

Run Date: 06-Aug-2014 09:54
Instrument: DSC Q2000 V24.11 Build 124



Exo Up

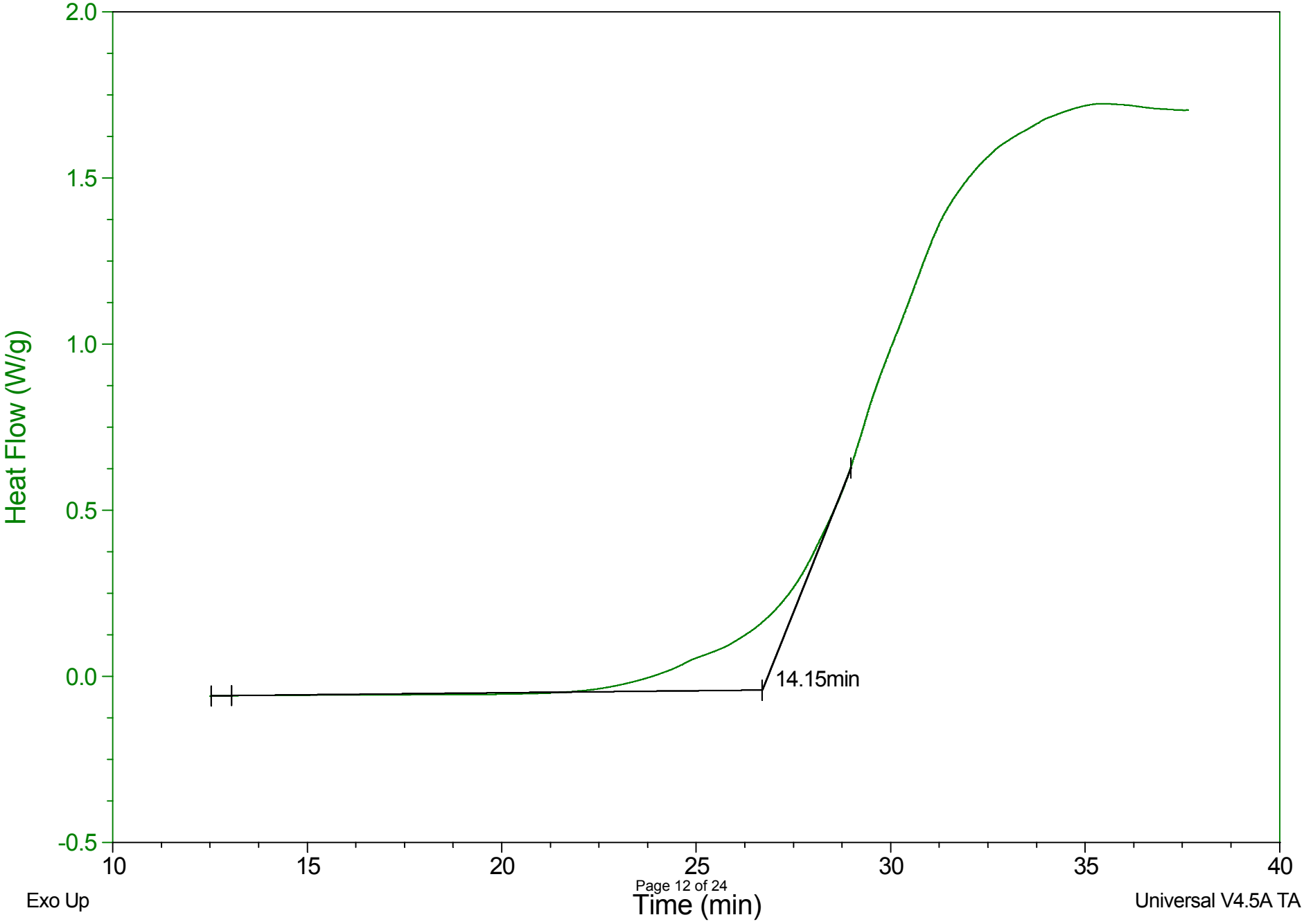
Universal V4.5A TA Instruments

Sample: Milk Jug 200C
Size: 5.3060 mg
Method: Oxygen induction time

DSC

File: R:...\Milk Jug 200C.003

Run Date: 08-Aug-2014 14:19
Instrument: DSC Q2000 V24.11 Build 124



Exo Up

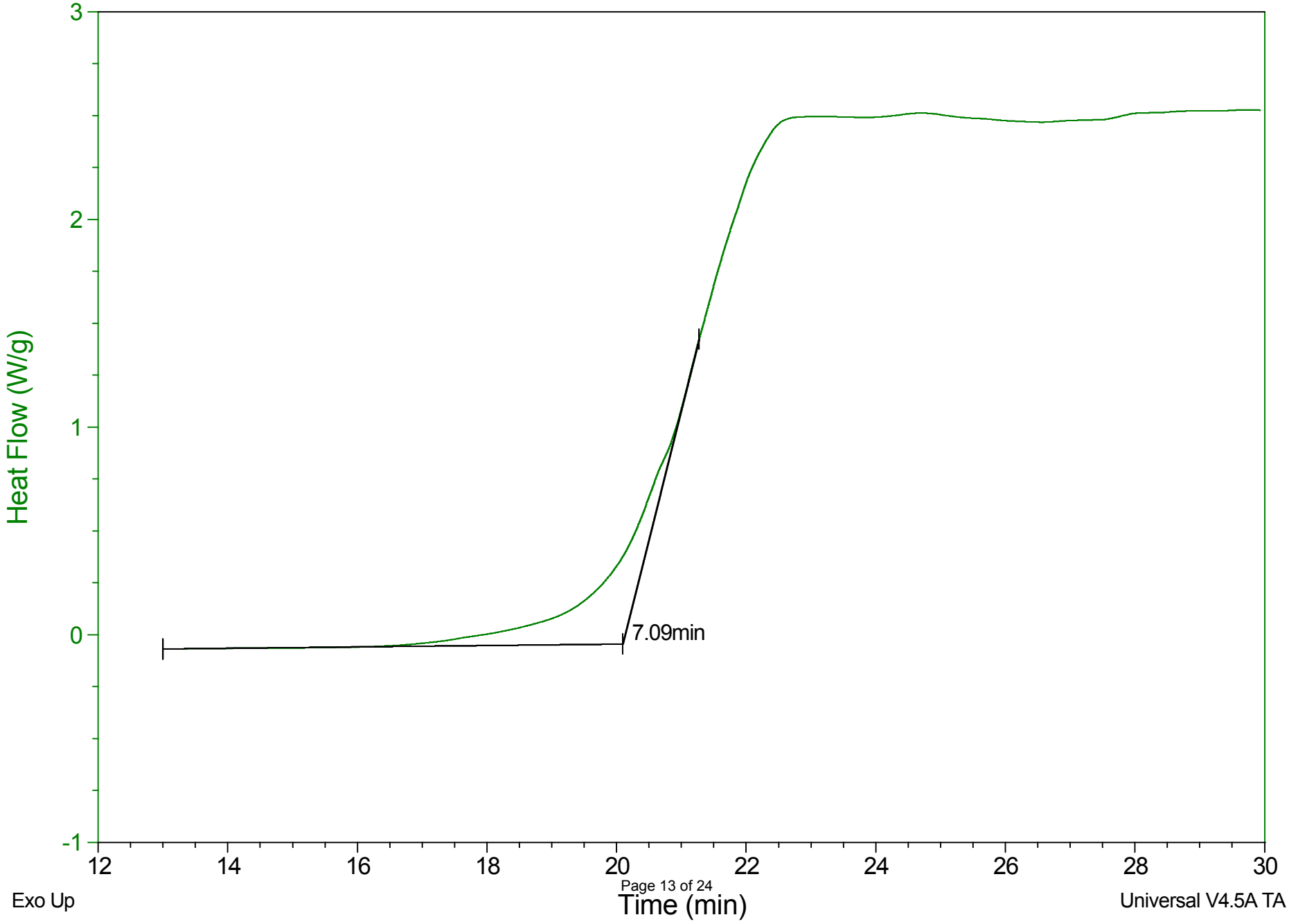
Universal V4.5A TA Instruments

Sample: Milk Jug 210C
Size: 5.3100 mg
Method: Oxygen induction time

DSC

File: R:...\Milk Jug 210C.001

Run Date: 05-Aug-2014 13:17
Instrument: DSC Q2000 V24.11 Build 124



Exo Up

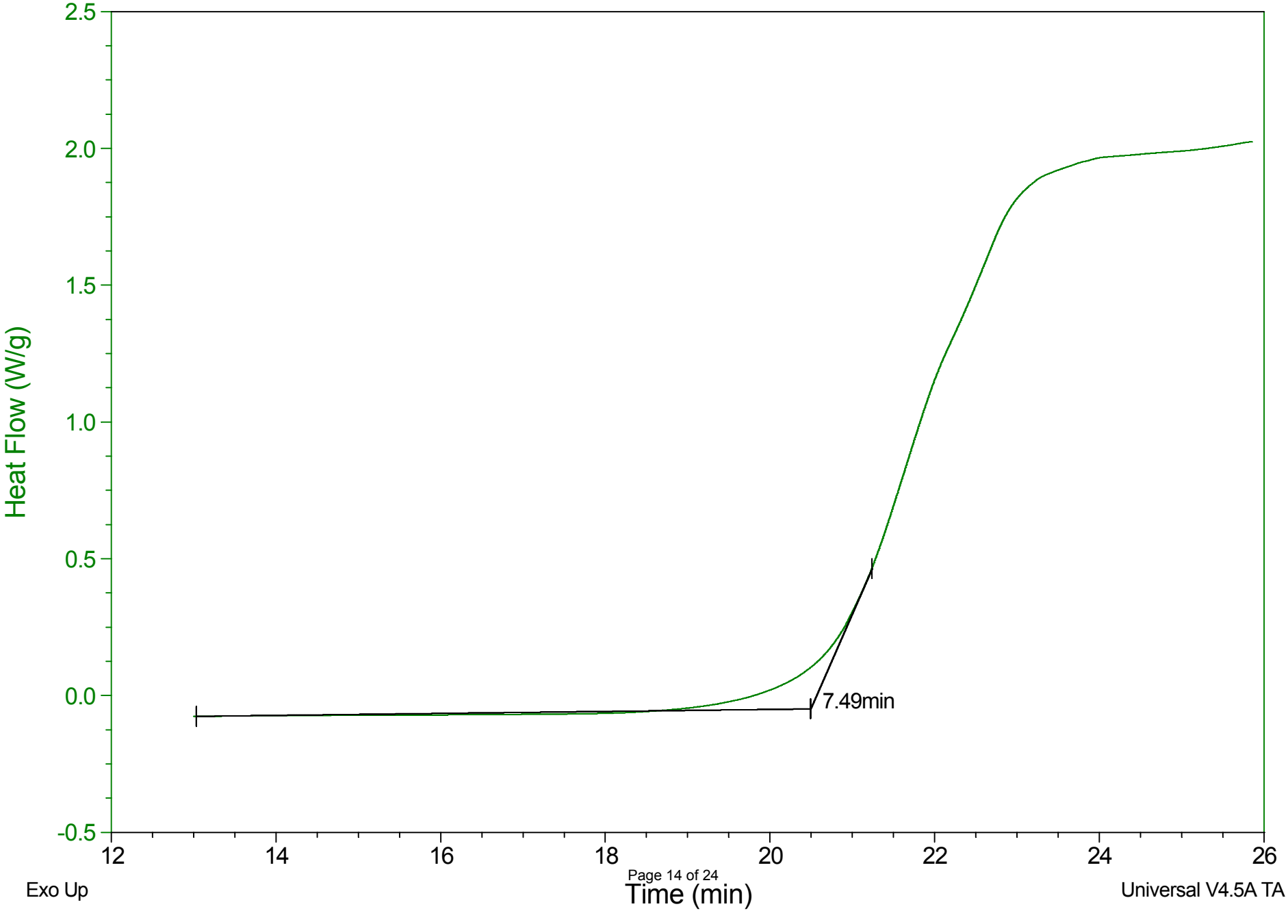
Universal V4.5A TA Instruments

Sample: Milk Jug 210C
Size: 5.1540 mg
Method: Oxygen induction time

DSC

File: R:...\Milk Jug 210C.002

Run Date: 07-Aug-2014 14:41
Instrument: DSC Q2000 V24.11 Build 124



Exo Up

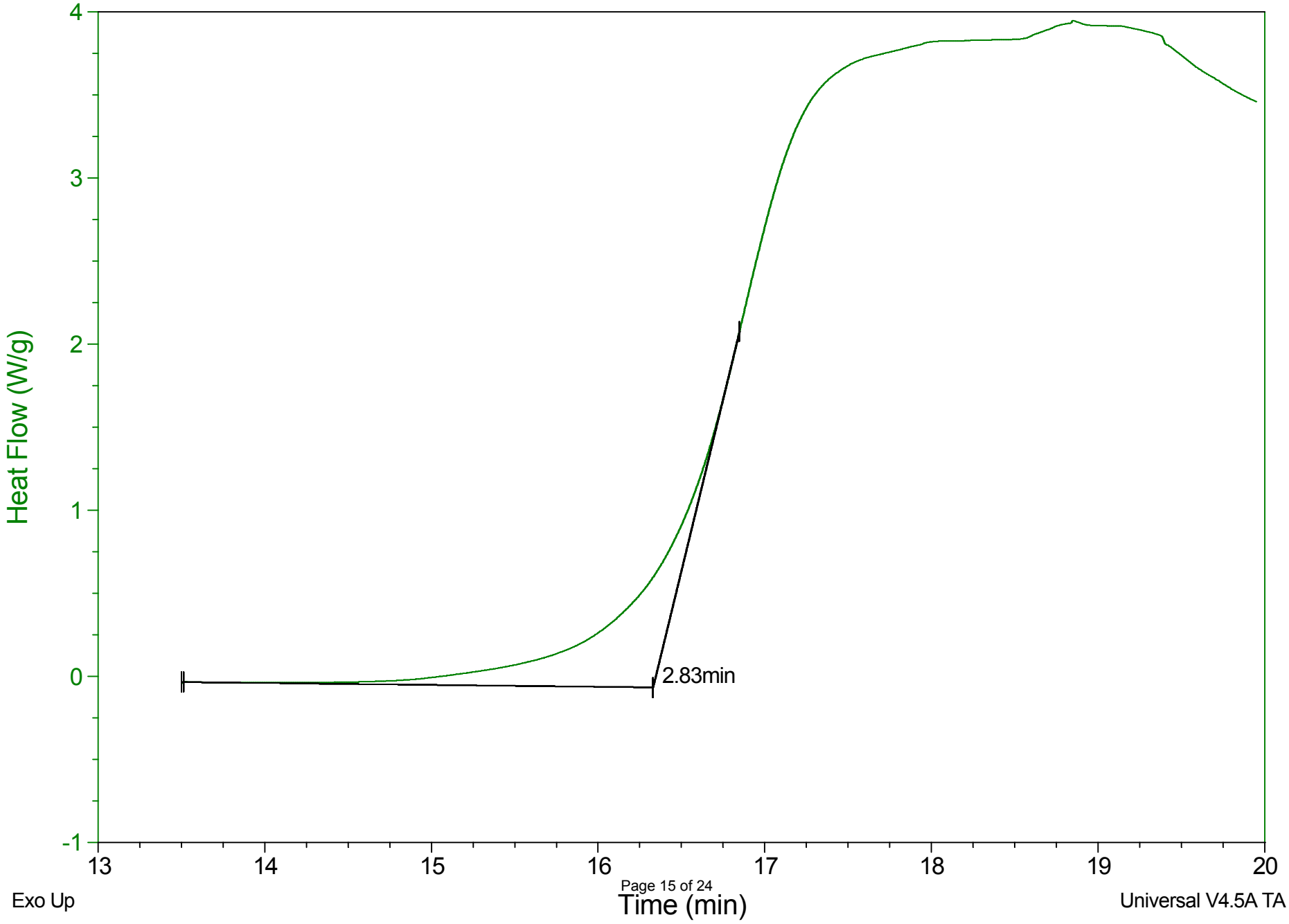
Universal V4.5A TA Instruments

Sample: Milk Jug 220C
Size: 5.2040 mg
Method: Oxygen induction time

DSC

File: R:...\Milk Jug 220C.002

Run Date: 05-Aug-2014 08:59
Instrument: DSC Q2000 V24.11 Build 124



Exo Up

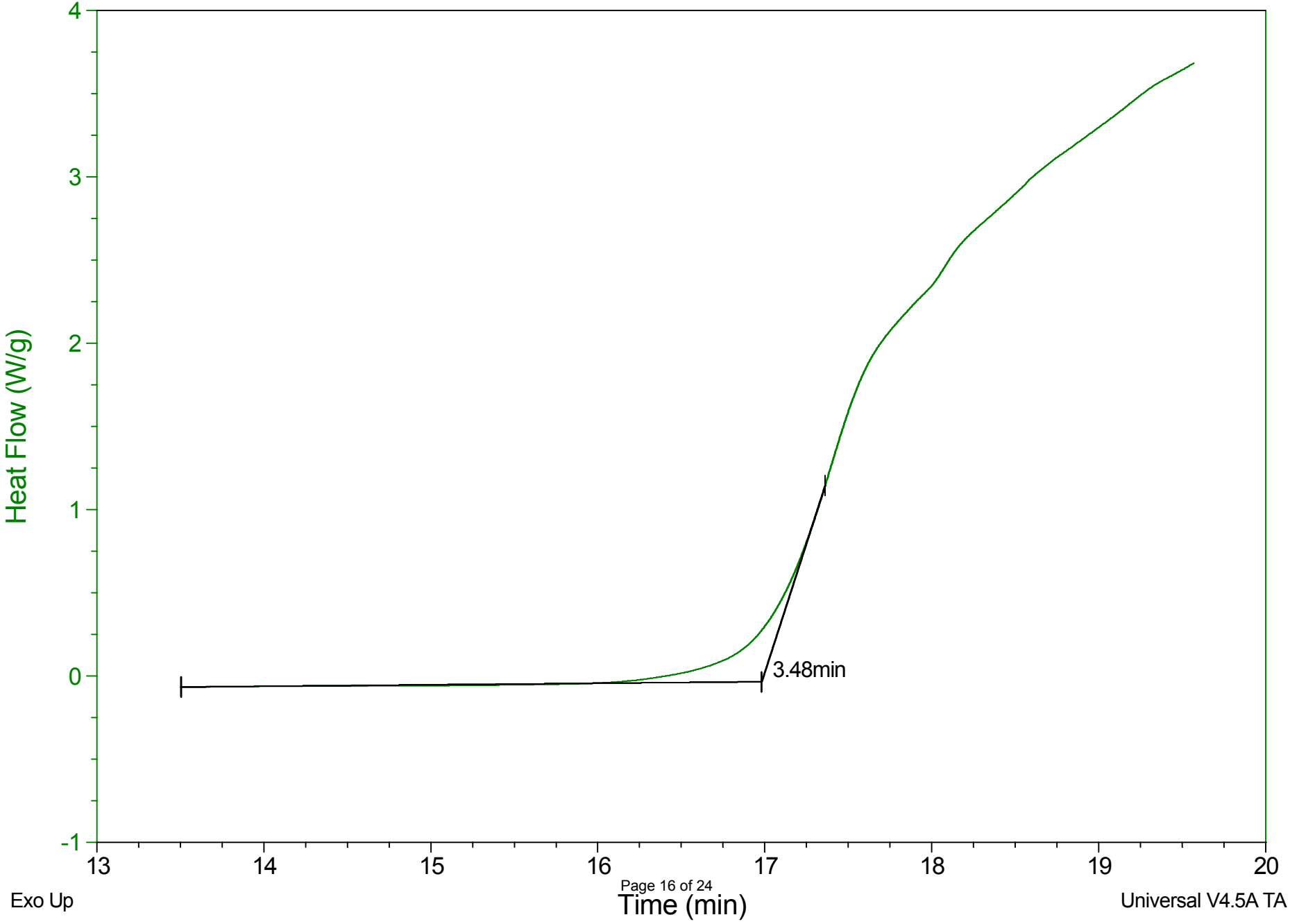
Universal V4.5A TA Instruments

Sample: Milk Jug 220C
Size: 5.1220 mg
Method: Oxygen induction time

DSC

File: R:...\Milk Jug 220C.001

Run Date: 07-Aug-2014 13:28
Instrument: DSC Q2000 V24.11 Build 124



Exo Up

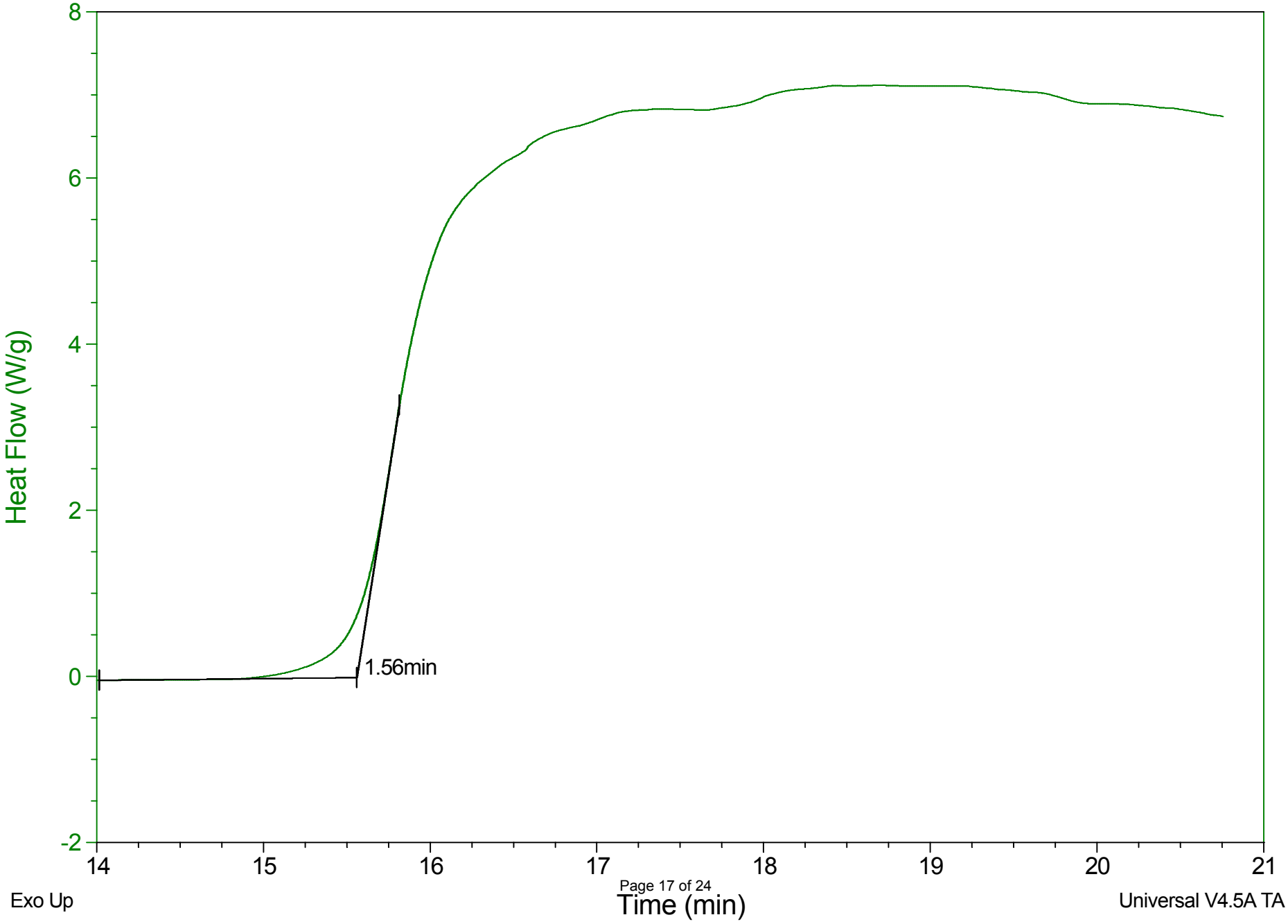
Universal V4.5A TA Instruments

Sample: Milk Jug 230C
Size: 5.1160 mg
Method: Oxygen induction time

DSC

File: R:...\Milk Jug 230C.003

Run Date: 05-Aug-2014 10:07
Instrument: DSC Q2000 V24.11 Build 124



Exo Up

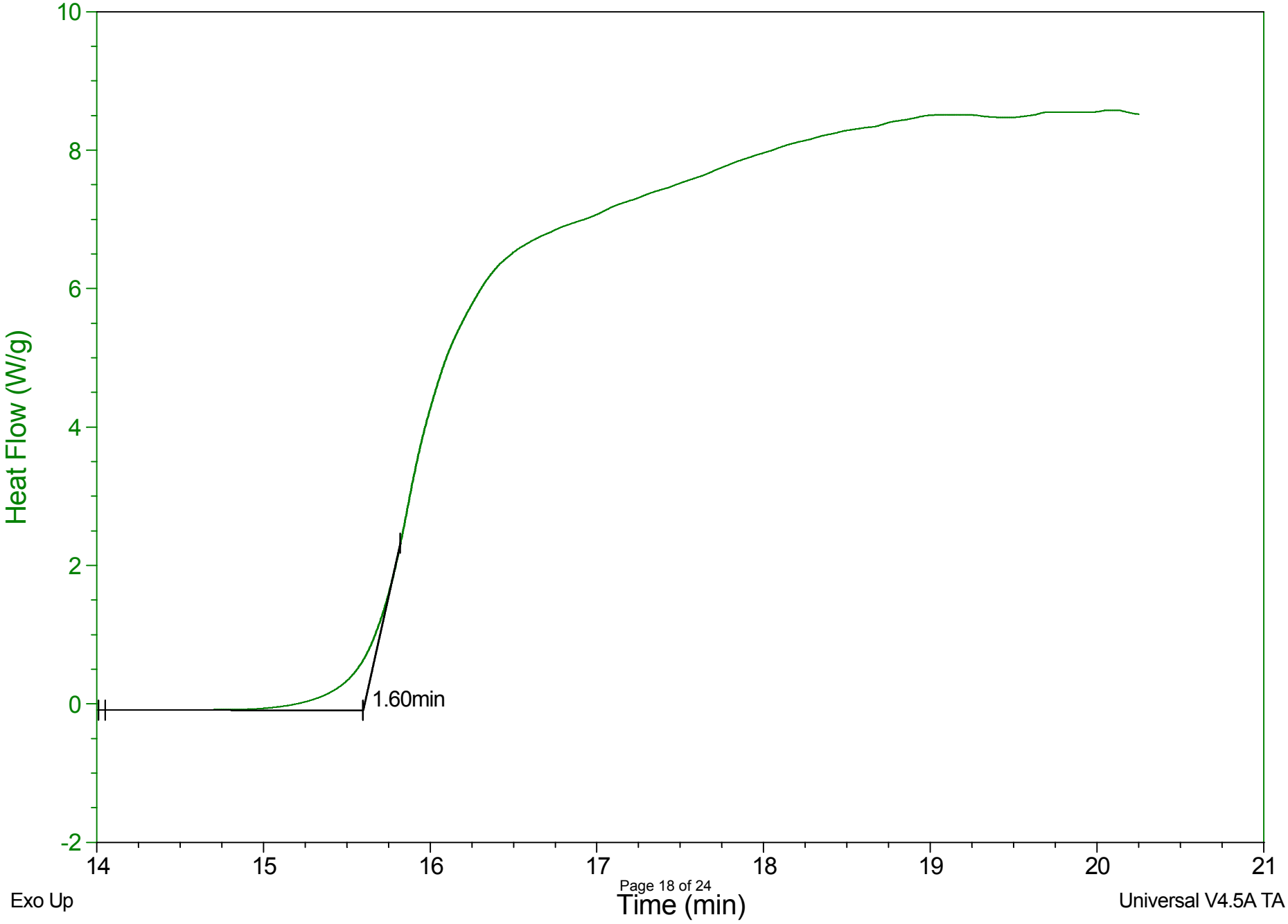
Universal V4.5A TA Instruments

Sample: Milk Jug 230C
Size: 5.1180 mg
Method: Oxygen induction time

DSC

File: R:...\Milk Jug 230C.001

Run Date: 07-Aug-2014 11:56
Instrument: DSC Q2000 V24.11 Build 124



Exo Up

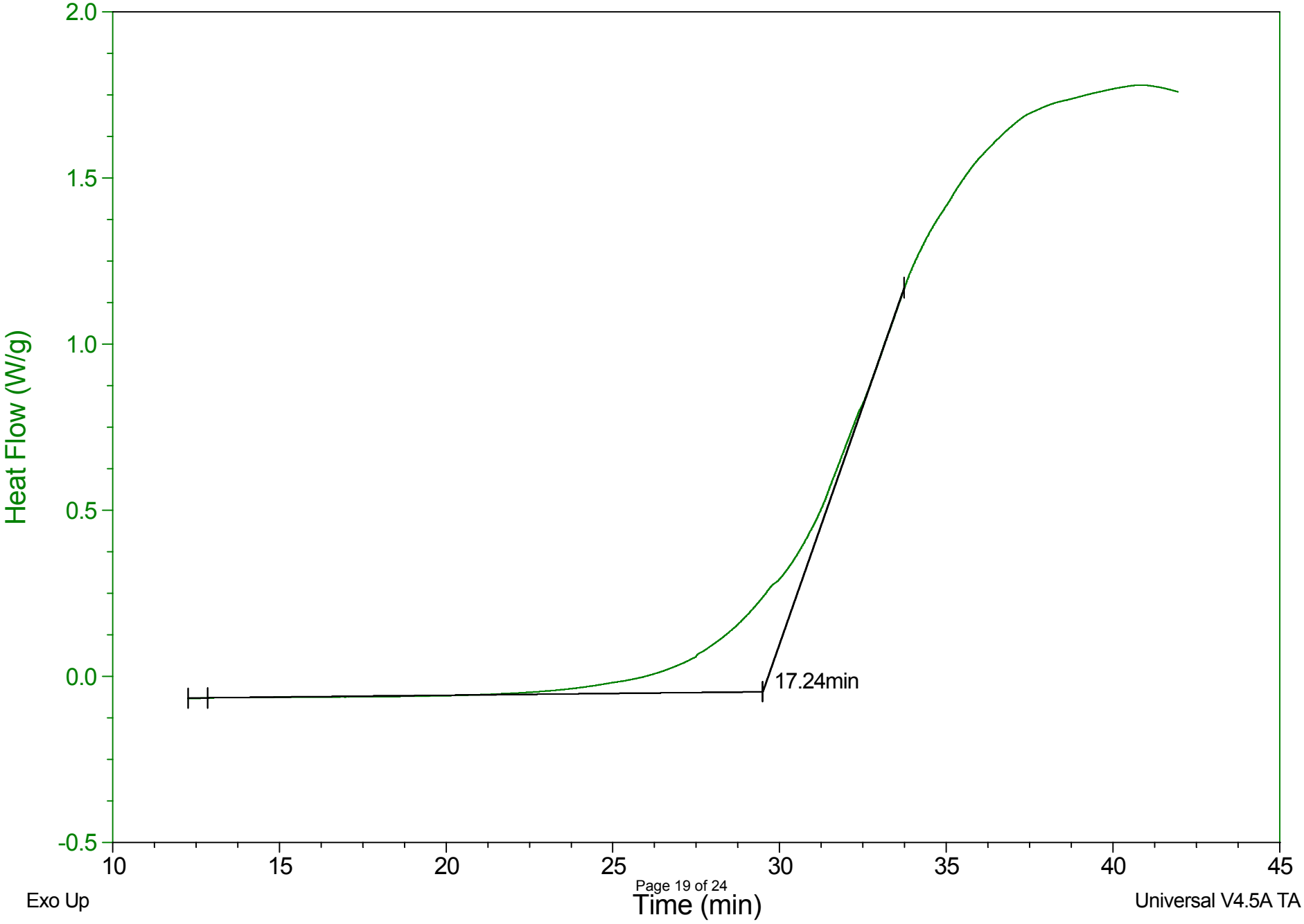
Universal V4.5A TA Instruments

Sample: Rope 195C
Size: 5.1880 mg
Method: Oxygen induction time

DSC

File: R:...\Rope 195C.001

Run Date: 20-Aug-2014 13:42
Instrument: DSC Q2000 V24.11 Build 124



Exo Up

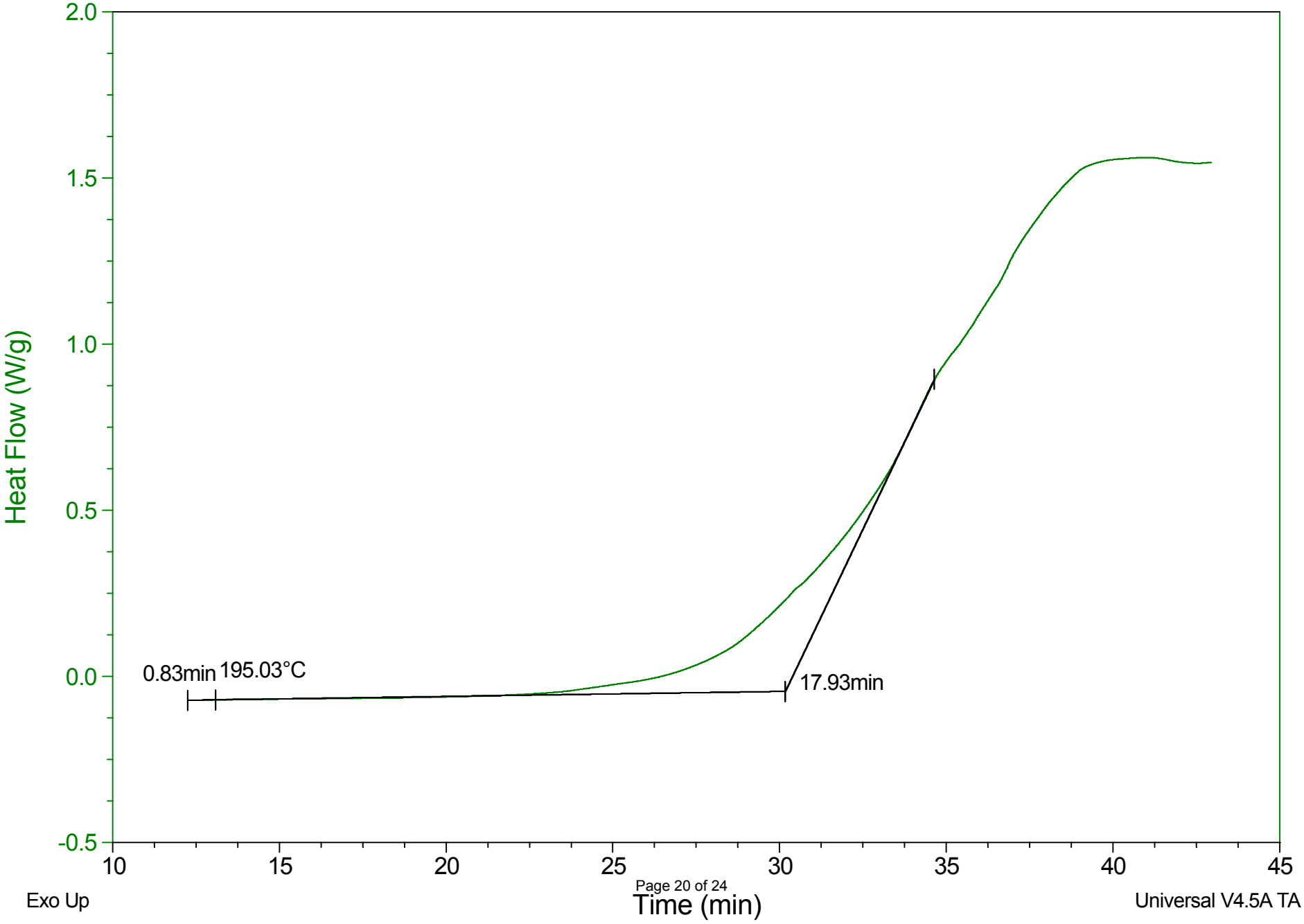
Universal V4.5A TA Instruments

Sample: Rope 195C
Size: 5.0160 mg
Method: Oxygen induction time

DSC

File: R:...\Rope 195C.002

Run Date: 21-Aug-2014 09:41
Instrument: DSC Q2000 V24.11 Build 124



Exo Up

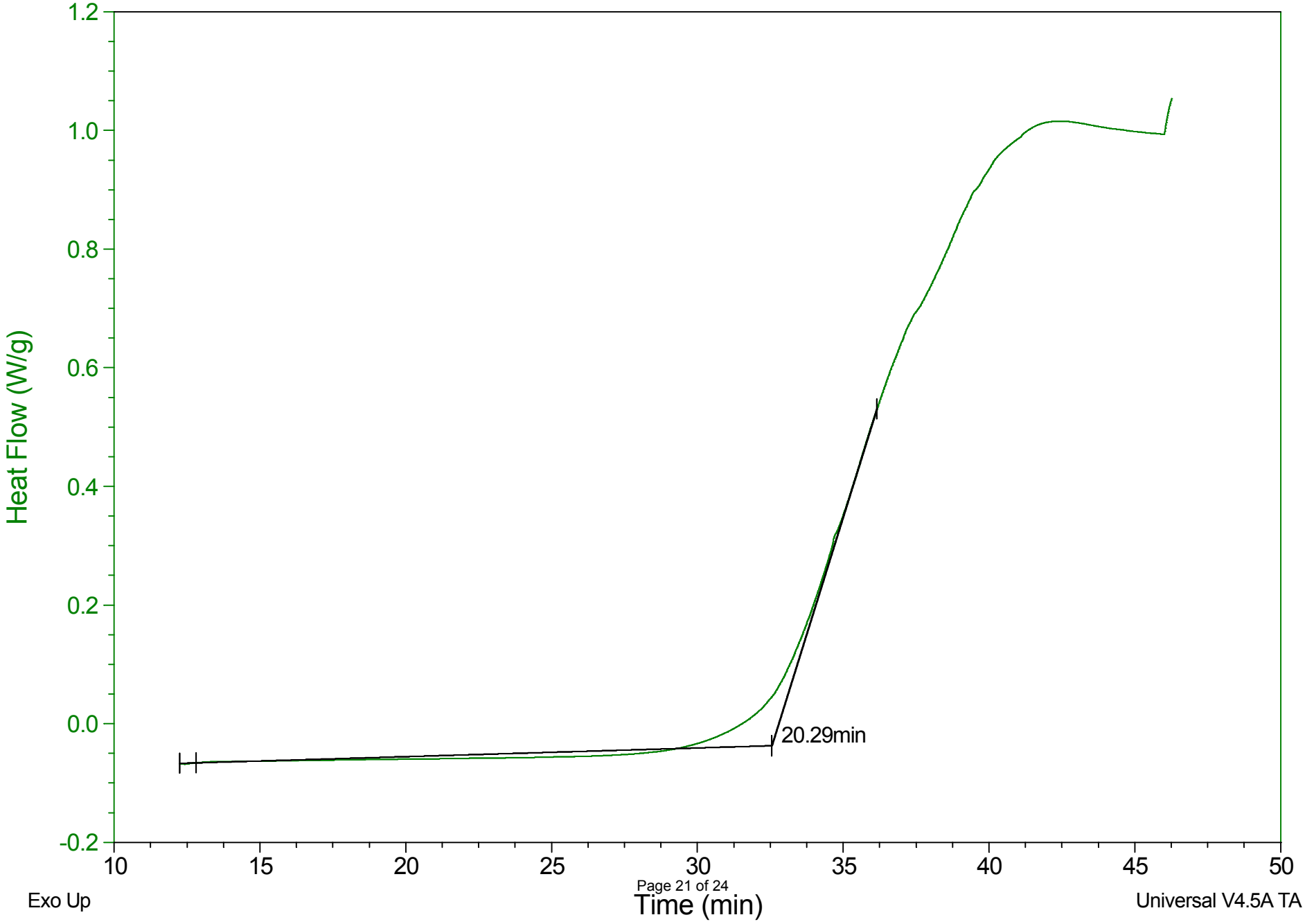
Universal V4.5A TA Instruments

Sample: Clear Plastic Bag 195C
Size: 4.9580 mg
Method: Oxygen induction time

DSC

File: R:...\Clear Plastic Bag 195C.001

Run Date: 19-Aug-2014 11:23
Instrument: DSC Q2000 V24.11 Build 124



Exo Up

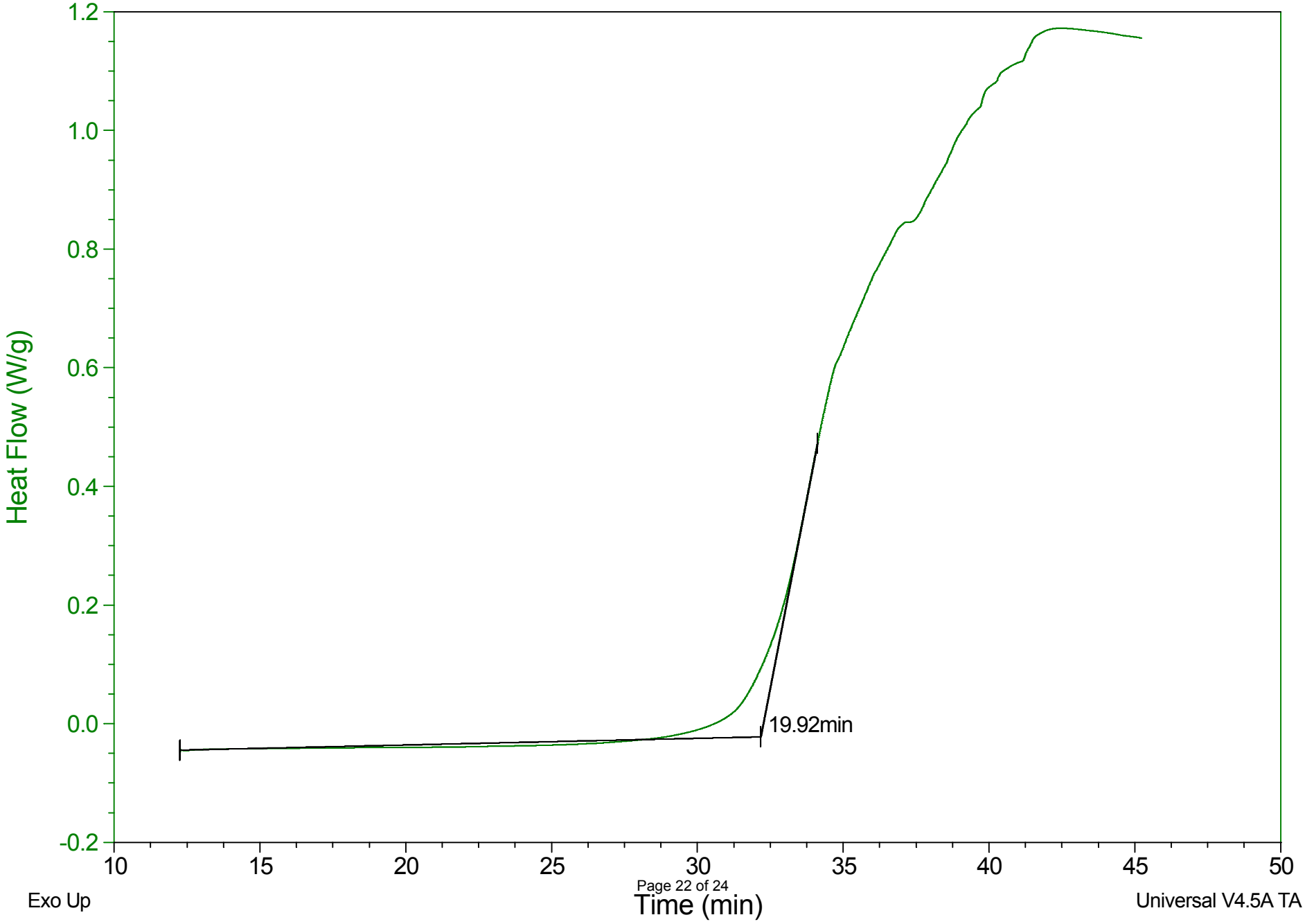
Universal V4.5A TA Instruments

Sample: Clear Plastic Bag 195C
Size: 5.0940 mg
Method: Oxygen induction time

DSC

File: R:...\Clear Plastic Bag 195C.003

Run Date: 20-Aug-2014 09:56
Instrument: DSC Q2000 V24.11 Build 124



Exo Up

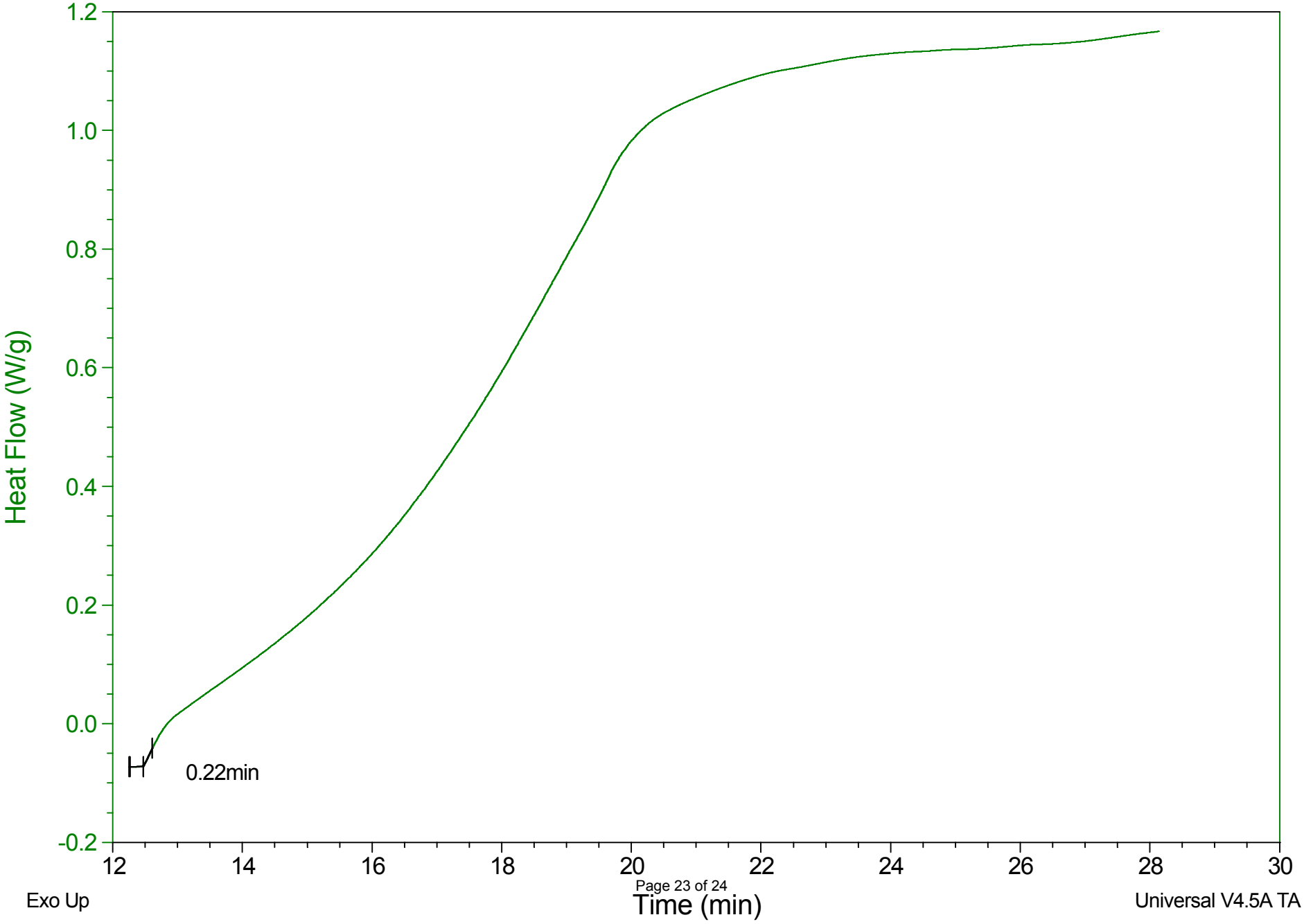
Universal V4.5A TA Instruments

Sample: Kodak
Size: 5.1640 mg
Method: Oxygen induction time

DSC

File: R:...\Kodak 195C.001

Run Date: 15-Aug-2014 15:39
Instrument: DSC Q2000 V24.11 Build 124



Exo Up

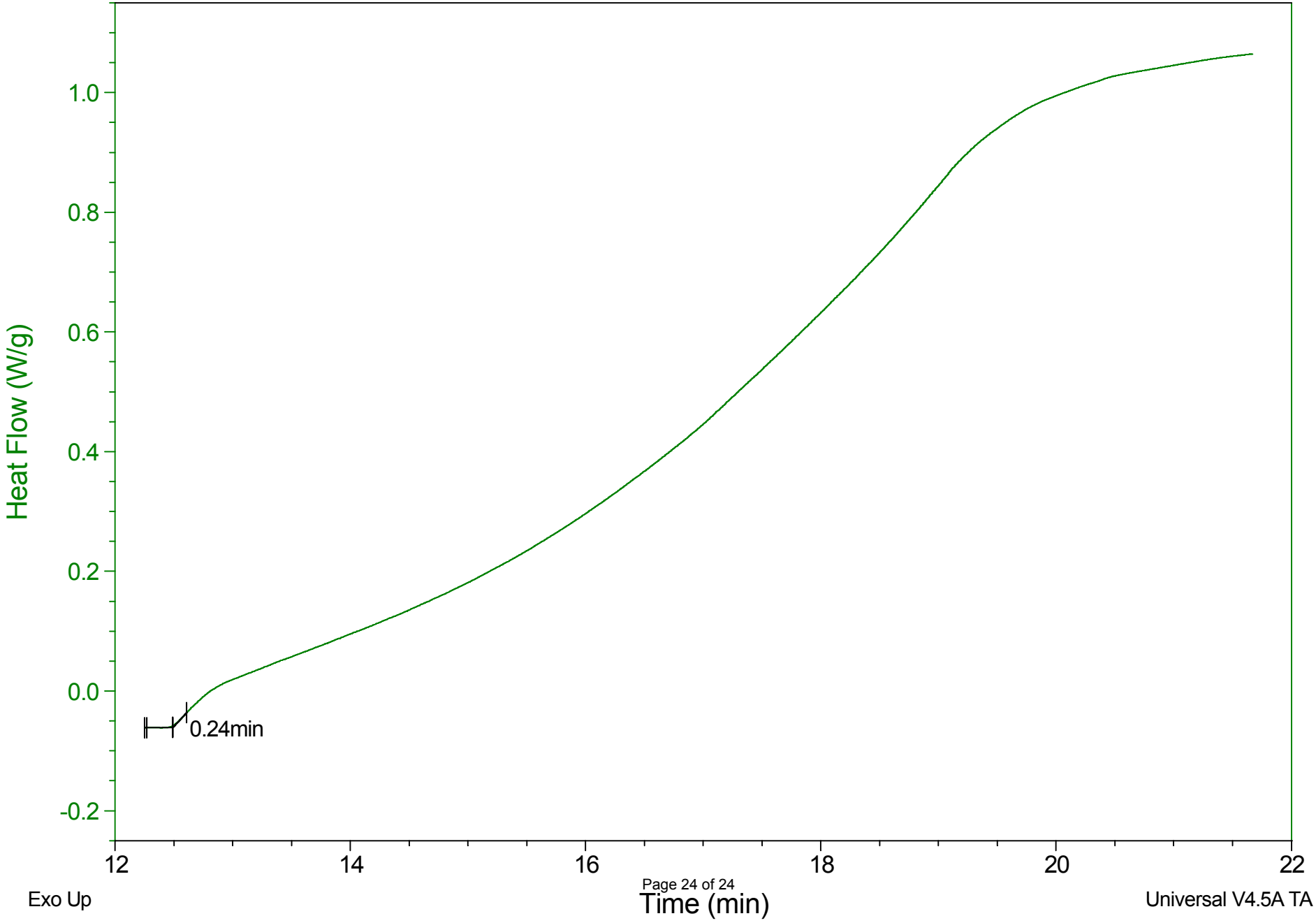
Universal V4.5A TA Instruments

Sample: Kodak
Size: 5.4060 mg
Method: Oxygen induction time

DSC

File: R:...\Kodak 195C.002

Run Date: 15-Aug-2014 16:52
Instrument: DSC Q2000 V24.11 Build 124



Exo Up

Universal V4.5A TA Instruments