TA Instruments

X3 DSC

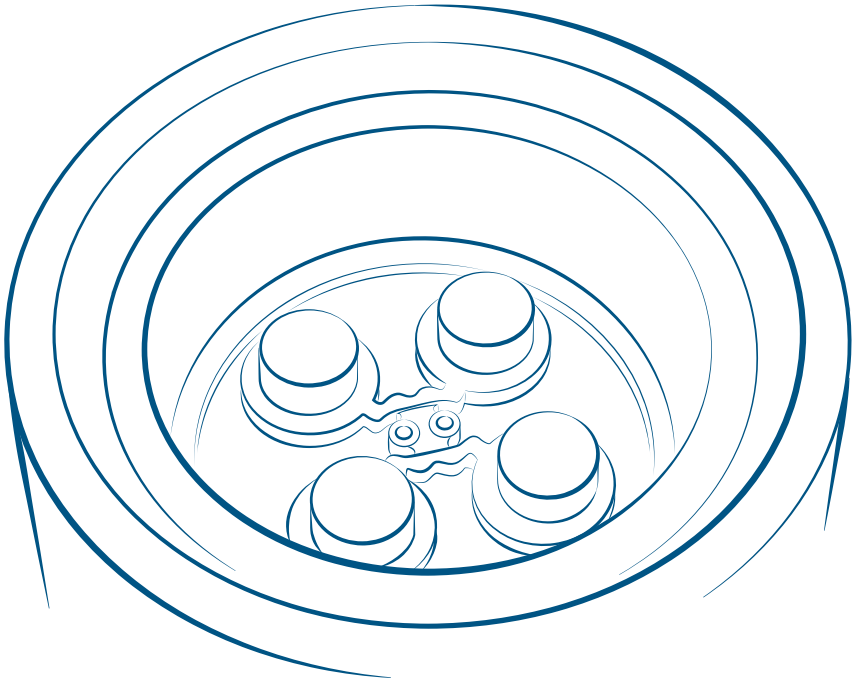
DIFFERENTIAL SCANNING CALORIMETER

Discover the **DSC** that **delivers**

Innovative Technology

Unmatched Productivity

Extraordinary Possibilities



DISCOVERY X3 DSC | DIFFERENTIAL SCANNING CALORIMETRY

TA Instruments invites you to Discover the possibilities with the Discovery X3 Differential Scanning Calorimeter featuring a multi-sample cell that delivers high quality heat flow data for up to three samples simultaneously. The Discovery X3 DSC combines industry-leading performance with the tools to increase productivity on every level of material research. TA Instruments' commitment to innovation enables scientists and engineers to reach their goals faster and make critical decisions with confidence.

Features and Benefits:

- Fusion Cell™ with patented technology provides unrivaled performance in baseline flatness, sensitivity, resolution, and reproducibility. Its superb technology enables detection of the weakest thermal transitions and the most accurate enthalpy and specific heat capacity measurements.
- Enhanced Tzero heat flow technology for the X3 guarantees temperature and enthalpy accuracy simultaneously on all three samples
- High-end performance with three sample calorimeters provide unmatched flexibility from replicate testing for statistical analysis to validation/verification against a control sample for the ultimate in certainty
- Modulated DSC® (MDSC®) for the most efficient separation of complex thermal events.
- One-Touch-Away™ User Interface enhances usability and access to data on the instrument.
- Reliable linear autosampler with 54 programmable tray positions for worry-free 24/7 operation, flexible programming of experiments, and automated calibration and verification routines.
- Widest range of refrigerated cooling options eliminates liquid nitrogen expense and ensures uninterrupted sub-ambient operation during extended autosampler routines.
- Tzero Press and pans for fast, simple, and reproducible sample preparation.
- Powerful software that delivers an exceptional user experience in a combined package for instrument control, data analysis, and reporting. Features such as automated calibration routines and real-time test method editing provide unmatched flexibility, while One-Click analysis and custom reporting raise productivity to new levels.
- Commitment to quality backed by the industry's ONLY five-year cell and furnace warranty for peace of mind.

TA Instruments has set the bar in the science of DSC where best-in-class performance is realized without the need for pre- and post-test data manipulation prevalent in competitive offerings. The Discovery Series DSC's provide both novice and advanced DSC users the highest confidence in generating superior data, while enhancing laboratory workflows and productivity.

Understanding a material's structure–property relationship is necessary when designing, processing, and utilizing a product. A range of thermal analysis techniques are used to measure the physical properties of a material with respect to temperature, time, and atmosphere. The most prevalent thermal analysis technique—Differential Scanning Calorimetry (DSC)—measures endothermic and exothermic processes and is widely used to characterize a broad range of materials including polymers, pharmaceuticals, foods, biologicals, organic chemicals, and inorganic materials.

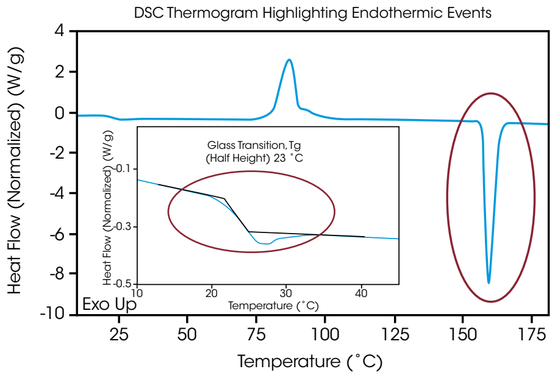
With DSC, easily measure thermal events such as the glass transition (Tg), melting, crystallization, cure reactions, onset of oxidation, and heats of transitions (enthalpy). Then expand upon the measurement of DSC Heat Flow to determine reaction kinetics, specific heat capacity, compatibility and stability of blends and alloys, effect of aging, impact of additives on crystallization, and much more.

The heat flux DSC consists of a single furnace in which the specimen and reference materials are heated or cooled together under a controlled temperature program. The sample is encapsulated in a pan (typically aluminum) and, along with an empty reference pan, sits on a thermoelectric disk surrounded by the furnace. As the furnace temperature is changed, typically at a constant rate, heat is transferred to the sample and reference. The differential heat flow to the sample and reference is measured by area thermocouples using the thermal equivalent of Ohm's law. A material's response in a DSC is best defined by the equation below, where the amplitude of heat flow is the sum of a heat capacity component and kinetic component of the test material.

$$q = Cp\ (dT/dt) + f\ (T,t)$$

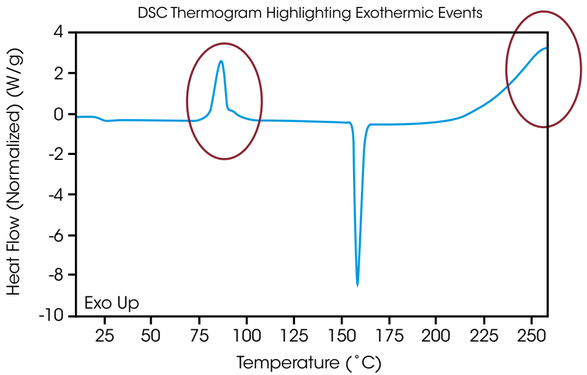
where: q = sample heat flow, Cp = sample specific heat capacity, dT/dt = heating rate, and f(T,t) = kinetic response at a specific temperature, time.

The heat capacity component of the equation, Cp (dT/dt), will express the specific heat capacity and changes in the heat capacity; this includes the glass transition observed in amorphous and semi-crystalline materials. Evaporation, cure reactions, crystallization, denaturation, and decomposition are expressed in the kinetic function, whereas melting, a latent heat, is an endothermic enthalpy change and may be expressed as the sum of both heat capacity and kinetic components within the melting temperature range of a material.



Endothermic Events

- Glass Transition
- Melting
- Evaporation/Volatilization
- Enthalpic Recovery
- Polymorphic Transitions
- Some Decompositions



Exothermic Events

- Crystallization
- Cure Reactions
- Polymorphic Transitions
- Oxidation
- Decomposition
- Freezing

At the core of every Discovery DSC is the NEW TA Fusion Cell™, which incorporates design concepts that "FUSE" together the best features of the world's bestselling Q Series™ and first generation Discovery DSC, patented Tzero® technology, and new proprietary manufacturing processes. Unlike competitive designs, the Discovery DSC delivers optimum performance with a single sensor, eliminating the need to exchange sensors to optimize a specific performance aspect. The result is an innovative new DSC with unrivaled performance in baseline flatness, sensitivity, resolution, and reproducibility.

FusionCell™ Features and Benefits:

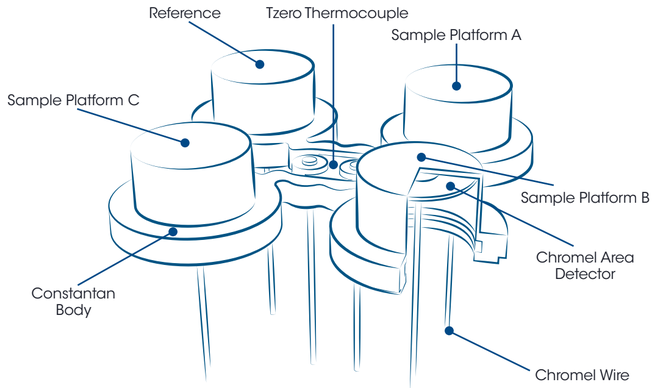
- A multi-sensor adaptation of TA's ground-breaking Discovery DSC Fusion Cell.
- Patented Tzero technology measures the cell resistance and capacitance (ability to store energy) characteristics. It delivers a fundamentally more accurate heat flow measurement with incomparable baseline performance, while eliminating the need for baseline corrections prevalent in all other competitive offerings.
- Fixed X3 sensor provides a stable configuration with a well-defined and reproducible heat flow path.
- Rugged uniblock silver furnace with long-life windings ensures superior temperature control and uniformity.
- Unique cooling rods and ring design produce superior cooling performance over a wide temperature range, higher cooling rates, and more responsive heating to cooling operation.
- Temperature-controlled electronics ensure the utmost in stability and repeatability of measured signals.
- Innovative gas delivery manifold provides gas switching and a consistent, repeatable atmosphere.

The Fusion Cell delivers the most absolute heat flow measurement possible. Additionally, lengthy pre- and post-test manipulations such as baseline subtractions or de-smearing routines required by competitive designs are never necessary.

Traditionally, DSC heat flow measurements have been based on the principle that ASSUMES contributions by the sample and reference sensors to the total measured heat flow simply cancel each other out. If this assumption was true, all DSCs would have perfectly flat baselines. In reality, they do not. The fact is that each sensor's resistance and capacitance produce imbalances in the heat flow, resulting in deviations from baseline flatness and impaired resolution and sensitivity. ONLY TA Instruments, with patented Tzero Technology®, can measure this imbalance. Tzero Technology eliminates complicated pre- and post-test manipulations, such as baseline subtraction, deconvolution or other mathematical treatments competitive designs must use to improve baseline performance, sensitivity and resolution.

Patented Tzero Technology* measures the resistance and capacitance of the sensors and utilizes these values in the four-term heat flow equation to give the most accurate real-time determination of heat flow available on any DSC. TA engineers have taken this one step further by also including the contributions of the DSC pans. The Enhanced TZero Technology developed for the X3 DSC provides superior heat flow performance on each of the three sample sensors that give any researcher confidence in the results.

Schematic of the Discovery X3 DSC Fusion Cell™



Tzero Heat Flow Equation

$$q = -\frac{\Delta T}{R_r} + \Delta T_0\left(\frac{1}{R_s} - \frac{1}{R_r}\right) + (C_r - C_s)\frac{dT_s}{dt} - C_r\frac{d\Delta T}{dt}$$

Competitive Measurement

Heat Flow: Principal Heat Flow

Thermal Resistance Imbalance

Thermal Capacitance Imbalance

Heating Rate Imbalance

TA Measurement

*U.S. Patent No. 4,488,406 , 6,431,747 , 6,561,692

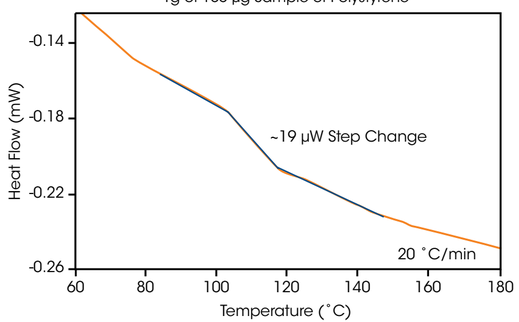
DISCOVER more Accurate Data with patented Tzero® Technology

Tzero Features and Benefits:

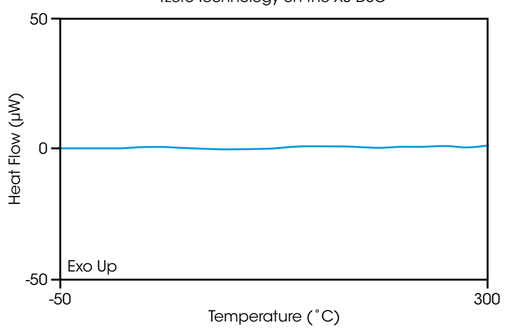
- Flattest baselines available compared to any competitive DSC, resulting in the most absolute measured data without manipulation or subtraction.
- Superb technology that enables detection of the weakest thermal transitions and the most accurate enthalpy and specific heat capacity.
- Highest resolution and sensitivity, without ever needing lengthy pre- and post-test manipulations as required by competitive designs.

By improving every aspect of performance, the Discovery DSC delivers data you can trust in all applications, all the time.

The High Level of Sensitivity on the X3 DSC Easily Shows the Tg of 100 µg Sample of Polystyrene



Absolute Zero Heat Flow Baseline Obtained with Tzero Technology on the X3 DSC



Gain confidence in data interpretation with the help of MDSC®. Through deconvolution of the Total Heat Flow signal, events such as a glass transition masked under an evaporation peak, or the simultaneous occurrence of a cold crystallization with a melt, are easily revealed.

In TA's patented MDSC*, a sinusoidal temperature oscillation is overlaid on the traditional linear ramp. The net effect is that heat flow can be measured simultaneously with, and independently of, changes in heat capacity. The Total Heat Flow signal contains the sum of all thermal transitions, just as in standard DSC.

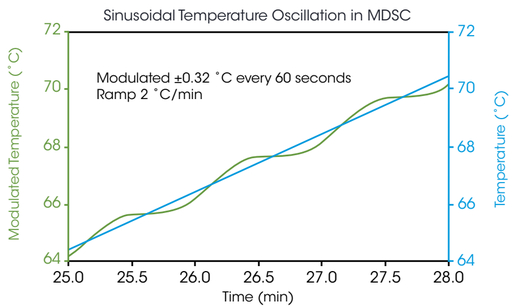
Modulated DSC separates the Total Heat Flow into the Reversing and Non-Reversing Heat Flow signals. The Reversing Heat Flow, comprised of the heat capacity component, contains glass transition and melting transitions. The Non-Reversing Heat Flow, the kinetic component, contains events like curing, volatilization, melting, and decomposition. TA invented MDSC and understands it like no other company. Modulated DSC is a standard feature on EVERY Discovery DSC model.

$$q = Cp\,(dT/dt) + f\,(T,t)$$

Reversing Heat Flow — Non-Reversing Heat Flow

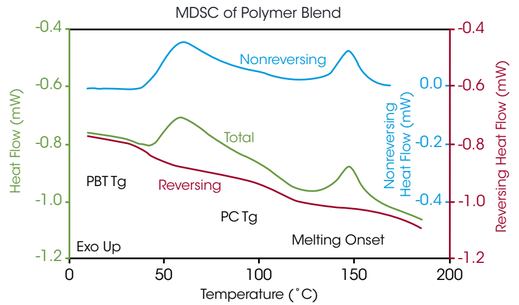
Features and Benefits of MDSC include:

- Separation of complex and overlapping transitions into more easily interpreted components.
- Increased sensitivity for detecting weak transitions.
- Increased resolution without loss of sensitivity.
- More accurate measurement of initial crystallinity.
- Direct determination of heat capacity.

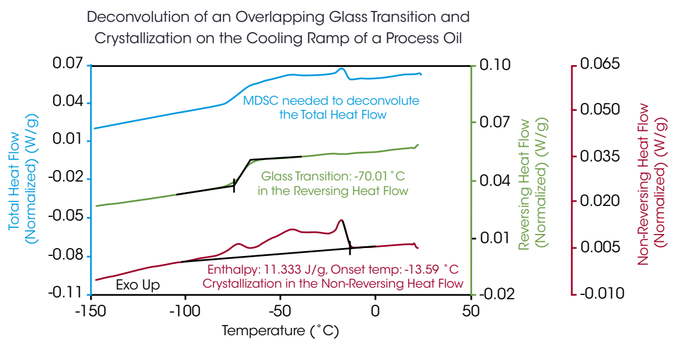


*U.S. Patent No. 6,561,692

DISCOVER more about your MATERIALS with MDSC®



The plot shows MDSC results for a thermoplastic alloy blend of polycarbonate (PC) and polybutylene terephthalate (PBT). This material exhibits a variety of overlapping transitions, and interpretation of the Total Heat Flow is complicated. MDSC effectively separates the crystallization of the PBT component into the Non-Reversing Heat Flow, thereby allowing for accurate determination of the glass transition temperatures of each polymer in the Reversing Heat Flow.



This process oil exhibits a variety of overlapping transitions, making interpretation of the Total Heat Flow complicated. On the cooling ramp from 25 to -150 °C, MDSC effectively separates crystallization into the Non-Reversing Heat Flow and the glass transition into the Reversing Heat Flow. Gain confidence in data interpretation with the help of MDSC!

It's hard to believe we could improve on the most reliable DSC autosampler on the market, but we did! The new linear autosampler is designed to be even more rugged and simple to use than ever before, while offering maximum testing flexibility.

Autosampler Features and Benefits:

- New Linear X-Y-Z design with integrated auto lid reduces sample loading time for increased throughput and reliability.
- The integrated auto lid gives consistent and repeatable cell closure, further improving the reproducibility of measurements.
- New laser positioning system enables one-touch automatic calibration and pan location verification.
- Scheduled and unattended calibrations and verifications gives scientists more time for research.
- TRIOS software makes it easier than ever to manage and run a large and diverse sample queue. The Design View and Running Queue allow for quick and efficient autosampler programming.
- Sample and reference pans may be assigned to any combination of the available 54 positions. Includes two quick-change trays for more convenient remote sample preparation.
- Convenient design allows you to unload pans back to the tray, or dispose of them, freeing space for continuous sample queuing.

The X3 DSC features TA's innovative touch screen, making operation easier than ever with enhanced One-Touch-Away™ functionality.

One Touch Away™

Touch Screen Features and Benefits:

- Ergonomic design for enhanced accessibility and productivity.
- Packed with functionality to simplify instrument operation.
- Resilient, responsive touch screen for an enhanced user experience.

The One-Touch-Away™ interface includes:

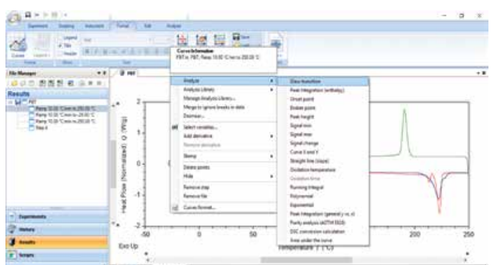
- Start/stop controls
- View active method
- Autosampler calibration
- System information
- Real-time signals and plot
- Advance to next step in method
- Load/unload pans
- Test and instrument status

Dramatically improve laboratory workflow and productivity with the One-Touch-Away™ interface, TA's powerful TRIOS software and the most robust, reliable DSC autosampler. These features enable automated calibration and verification routines that all work seamlessly for a simpler and more intuitive interaction.

Discover powerful TRIOS software that delivers exceptional user experience in a combined package for instrument control, data analysis, and reporting for thermal analysis and rheology. New features such as multiple calibration sets, real-time test method editing, and inter-laboratory data and test method sharing provide unmatched flexibility, while One-Click analysis and custom reporting raise productivity to new levels.

TRIOS Features:

- Control multiple instruments with a single PC and software package.
- Overlay and compare results across techniques including DSC, TGA, DMA, SDT and rheometers.
- One-Click analysis for increased productivity.
- Automated custom report generation including: experimental details, data plots and tables, control charts and analysis results.
- Convenient data export to plain-text, CSV, XML, Excel®, Word®, PowerPoint®, and image formats.
- Optional TRIOS Guardian with electronic signatures for audit trail and data integrity.



Ease-of-Use

TRIOS software makes calibration and operation of the entire line of Differential Scanning Calorimeters simple. Users can easily generate multiple calibration data sets under varying experimental conditions (e.g. different heating rates or gas selections) and seamlessly switch between them to match the experimental conditions used for sample testing. Real-time signals and the progress of running experiments is readily available, with the added capability of modifying a running method on the fly. TRIOS software offers a level of flexibility that is unmatched in the industry.

Complete Data Record

The advanced data collection system automatically saves all relevant signals, active calibrations, and system settings. This comprehensive set of information is invaluable for method development, procedure deployment and data validation.

The Most **VERSATILE CONTROL** and **ANALYSIS SOFTWARE!**

Complete Data Analysis Capabilities

A comprehensive set of relevant tools are available for real-time data analysis, even during experiments. Gain actionable insights into your material's behavior through a powerful and versatile set of features seamlessly integrated into TRIOS.

All Standard DSC Analyses:

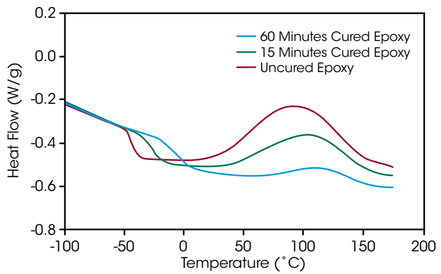
- Glass transition, step change analysis
- Peak integration
- 1st and 2nd derivatives
- Oxidative onset temperature
- Oxidative induction time
- Purity
- Running integral and conversion
- Peak height and area
- Temperature at peak maximum
- Onset and endset analyses
- Easily import and export DSC data with TRIOS

Advanced Analysis Capabilities (Standard Features):

- Deconvolution of the Total Heat Flow signal with MDSC® into Reversing and Non-Reversing Heat Flow signal.
- Advanced custom analysis and control charts with user-defined variables and models.
- Batch processing enables automated analysis, reporting, and control charting of large data sets.

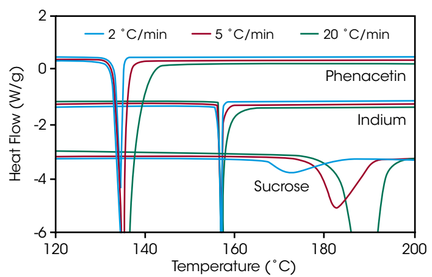
Degree of Cure

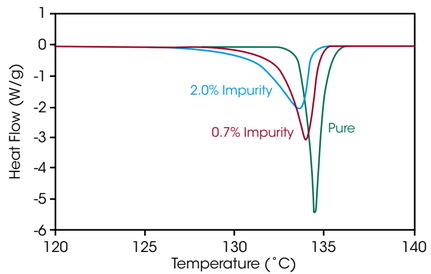
The degree of cure of a thermoset can dramatically affect the processing and end-use conditions. DSC is often used to investigate and quantify the degree of cure for epoxy and other thermosetting materials. This figure contains the data of three samples from the same thermoset material that have been cured under different conditions. By quantifying the residual cure, as well as comparing the glass transition temperature, the degree of cure is easily determined. The X3 DSC provides data on all three sample cure states simultaneously so that there is an absolute cure reference time comparison between the samples.



Impact of Experimental Conditions

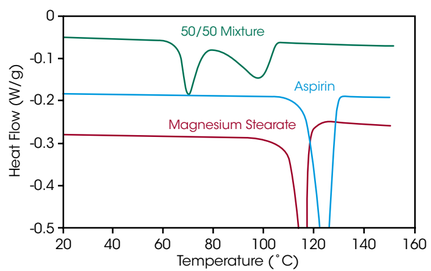
The conclusions that are formulated about the properties of materials from DSC data are certainly subject to the conditions of the experiment. Testing samples simultaneously under the exact same parameters eliminates any uncertainty method conditions may play in the results. The figure here shows that the onset of a true melting (thermodynamic) event in phenacetin and indium remains constant with a variable heating rate whereas the apparent melt (kinetic) event in sucrose shifts as the heating rate increases. Three different samples tested in the same environment provide a clear and correct interpretation of the types of transitions present in each of these materials.





Internal Standards

Impurities, even in small amounts, can impact the melting temperature and measured enthalpy of materials. The ability to compare results of an unknown sample with a known, highly pure material used as a standard can greatly improve the interpretation of the data. In this figure, two samples with small amounts of impurity are directly and easily compared with a third material that is known to be pure. Measuring and comparing samples that are tested simultaneously under the exact same test conditions provides even greater assurance of the interpretation.



Examine Material Compatibility

Material stability and compatibility are critical in many different applications across virtually every industry. Drug-excipient compatibility is extremely important during the formulation process to ensure that the properties of the active component of a drug remain unchanged over the lifetime of the released product. The experiment here contains a simultaneous study of individual components, aspirin and magnesium stearate (commonly used as a lubricant in the pharmaceutical industry), and a sample of 50/50 mixture of the two components. The significant change in the heat flow response in the mixture compared to the individual materials indicates some incompatibility between the selected materials.

Refrigerated Cooling Systems (RCS)

Take advantage of the convenient Refrigerated Cooling Systems (RCS) for unattended DSC and MDSC® operation over broad temperature ranges. The new RCS 120 provides enhanced safety and is the only liquid nitrogen-free system capable of conducting experiments down to -120°C.

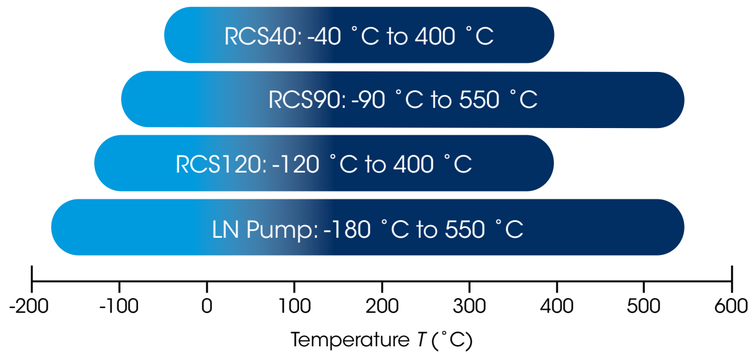
RCS Features and Benefits:

- One-, Two-, or Three-stage refrigeration systems that achieve temperature ranges down to -40 °C, -90 °C or -120 °C
- Sealed system eliminates the need for liquid nitrogen cooling
- Enables cycling, MDSC®, controlled, and ballistic cooling experiments
- Safe, convenient, and continuous cooling operation for your laboratory needs

Discovery Liquid Nitrogen Pump Accessory (LN Pump)

The LN pump provides the highest performance and greatest flexibility in cooling for the Discovery DSC. It facilitates the lowest operational temperature (to -180 °C), greatest cooling rate capacity (to 140 °C/min), fastest sub-ambient equilibration times, and an upper temperature limit of 550°C. Operating at ambient pressure, the LN Pump uses liquid nitrogen efficiently, thus reducing operating costs. It includes a 50-liter Dewar with auto-fill capability which allows the LN Pump to be automatically refilled from a larger source, even during a DSC experiment, for continuous DSC operation with no disruption.

EXPLORE the full line of **INTERCHANGEABLE COOLING SYSTEMS**



Controlled Cooling Rate* (from upper limit of the accessory)	RCS 40 To Lower Temperature	RCS 90 To Lower Temperature	RCS 120 To Lower Temperature	LN Pump To Lower Temperature
100 °C/min	—	300 °C	—	200 °C
50 °C/min	175 °C	120 °C	130 °C	0 °C
20 °C/min	40 °C	-20 °C	-30 °C	-100 °C
10 °C/min	0 °C	-50 °C	-70 °C	-150 °C
5 °C/min	-15 °C	-75 °C	-75 °C	-165 °C
1 °C/min	-40 °C	-90 °C	-120 °C	-180 °C

* Performance may vary slightly, depending on laboratory conditions.

Proper sample preparation is of critical importance to the quality of data generated on a DSC. The Tzero sample encapsulation press and pans are designed to ensure simple and proper preparation for the highest data quality.

Tzero Pans

Tzero high-performance pans and lids are designed to maximize pan flatness and sample contact. Coupled with the unparalleled flatness and uniformity of the Fusion Cell™ sensor, the Tzero pans and lids provide the most direct, uniform heat flow path from the sample to the sensor. These pans are tolerant of many sample forms and are designed with lids that conform to the top of irregular specimens, efficiently transferring heat to and from the entire sample. Competitive pan designs that have non-flat bases are unable to achieve appropriate thermal contact with solid specimens. Fabricated using advanced technology and to extremely tight tooling specifications, the Tzero pans offer significant improvements in resolution and repeatability over any other pan design.

Tzero DSC Sample Encapsulation Press

The Tzero press takes sample encapsulation to a higher level of performance and convenience in conventional and hermetic sealing of a wide variety of materials. The press kit includes four die sets for Tzero aluminum and hermetic pans & lids. Optional die sets are available for high-volume DSC pans and Discovery TGA sealed pans. The die sets are magnetically attached with no tools or adjustments required. In addition, each die set is color-coded to the box containing the compatible Tzero or standard aluminum hermetic pans and lids.

Sample Cutting Kit

Samples for testing in the DSC come in all different forms, shapes, and sizes and typically require some type of manipulation before they can be loaded into a DSC pan. The sample cutting kit includes tools that will make it simple and easy to properly prepare samples for the ultimate repeatability and reliability of the results. A pliers-style sample cutter will provide a sample with a clean, flat surface to maximize sample to pan contact. A 4mm hole-punch and hammer will allow film samples to be cut into a consistent size perfect for Tzero pans. This tool kit is designed to help ensure that the high-level performance of the Fusion Cell and the Tzero pans is enhanced with the perfectly prepared sample.

Tzero® Powder Sample Preparation Kit

The task of loading powder samples into Tzero pans is now quicker and easier with the powder sample prep kit. Specifically designed to maximize the performance of Tzero Pans with powdered samples, the kit consists of a non-skid base and a three-part tool precision machined from high quality stainless steel. The lower tool has a precisely designed recess that holds the Tzero pan and supports and protects the bottom of the pan. The upper tool mounts over the pan, forming a funnel which directs the sample into the center of the pan, avoiding undesirable contamination of the outside surfaces of the pan. A steel rod is used to pack the sample firmly into the bottom of the pan, forming a packed layer of the powder while preserving the flatness of the bottom of the Tzero pan. Using this tool you can easily and effectively optimize the results of your DSC measurements of powdered samples.

DISCOVERY X3 DSC | FEATURES

Instrument Features	X3 DSC
Fusion Cell™	●
MDSC®	●
Enhanced Tzero Heat Flow	●
User Replaceable Cell	●
54-Position Autosampler	●
Dual Input Gas-Delivery Manifold	●
Color App-Style Touch Screen	●

Specifications

Baseline Flatness (-50 to 300 °C)[1]	≤10 µW
Baseline Repeatability (-50 to 300 °C)	<15 µW
Temperature Range	-180 °C to 550 °C
Temperature Accuracy	±0.025 °C
Temperature Precision	±0.005 °C
Enthalpy Precision	±0.08%

[1] No baseline subtractions

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