

[ACQUITY ADVANCED POLYMER
CHROMATOGRAPHY SYSTEM]

ACCELERATE INNOVATION
SMARTER, FASTER INSIGHT INTO
YOUR POLYMER STRUCTURE



Waters
THE SCIENCE OF WHAT'S POSSIBLE.™

THE NEXT STEP IN POLYMER INNOVATION:



ACQUITY Advanced Polymer Chromatography System.

MORE INFORMATION IN LESS TIME.

Advances in materials research have led to a growing demand for instrumentation that delivers faster, more detailed analytical information about polymer samples. Current GPC/SEC methods are limited by a lack of resolution for novel and complex polymeric entities, the time required to achieve satisfactory separation, and the volume of solvent consumed per analysis.

Waters™ ACQUITY™ Advanced Polymer Chromatography™ (APC™) System is at the forefront of separation technology, defining the ultimate in high-resolution, size-based chromatographic separations, delivering more information about your polymers faster than ever before. This means better characterization, improved asset utilization, greater analytical flexibility, and a superior solution for achieving your corporate innovation and sustainability goals.





OUR RICH HISTORY WITH GPC ENABLES US TO CREATE THE FUTURE WITH APC

GEL PERMEATION CHROMATOGRAPHY - ANALYSES IN HOURS NOT DAYS

In 1961, Waters Associates founder Jim Waters was approached by Dow Chemical Company to help develop an instrumental method of analyzing polymers in solution using gel columns. This collaboration resulted in the creation of the Gel Permeation Chromatography (GPC) technique.

For the last half-century, GPC has had tremendous scientific and business impact on the chemical industry, and continues to be an important component of Waters' product portfolio and engine for scientific innovation.

Today, chemical laboratories all over the world continue to utilize Waters liquid chromatographs, gel columns, and dedicated GPC software to help characterize polymers in solution. However, it is now clear that this traditional technique alone, is not always adequate to perform the analyses of increasingly complex emerging polymers.

ADVANCED POLYMER CHROMATOGRAPHY - COMPLEX ANALYSES IN MINUTES NOT HOURS

In 2009, Waters developed the APC, which revolutionized the analysis of low to mid molecular weight polymers. APC has become essential in efficiently providing superior polymer characterization to the polymer industry.

Since its introduction, the APC has streamlined the way scientists calibrate systems, optimize methods, utilize solvents, and successfully reduce the time it takes to analyze complex polymers from days to just hours.



THE ACQUITY APC SYSTEM:

- Low-dispersion chromatographic system with fluid paths, fully optimized for solvents typically used in the aqueous and organic analysis of polymers without lengthy calibrations.
- High-performance Refractive Index (RI) Detector is designed specifically to operate with low dispersion chromatographic systems and interface with a range of 3rd party detectors.
- Innovative sub 3- μ m hybrid-polymer column chemistries are optimized for the analysis of aqueous and organic polymer separations.
- Polymer Quantenary Solvent Manager (p-QSM) technology offers ultimate flexibility to analyze the most complex polymer blends and additives using standard polymer chromatography, GPEC, and reverse phase LC with a single system.
- Automated and efficient solvent switching makes method development easy.



ANALYTICAL SOLUTIONS THAT MEET YOUR BUSINESS DEMANDS

The ACQUITY APC System was developed with an array of key objectives in mind, reflecting the corporate, operational, and scientific challenges as defined by you.

CORPORATE OBJECTIVES

- Drive innovation and revenue
- Increase productivity
- Develop “green initiatives” and improve sustainability

OPERATIONAL OBJECTIVES

- Introduce innovative and advanced technologies to meet growth goals
- Improve laboratory efficiencies
- Reduce operating costs
- Reduce waste

SCIENTIFIC OBJECTIVES

- Protect intellectual property with in-depth characterization
- Improve the speed and quality of analysis
- Achieve scientific research leadership position
- Maintain ease-of-use and efficiency
- Better informed decisions through improved insight into polymer samples





GAIN AN UNPRECEDENTED DEGREE OF LABORATORY EFFICIENCY

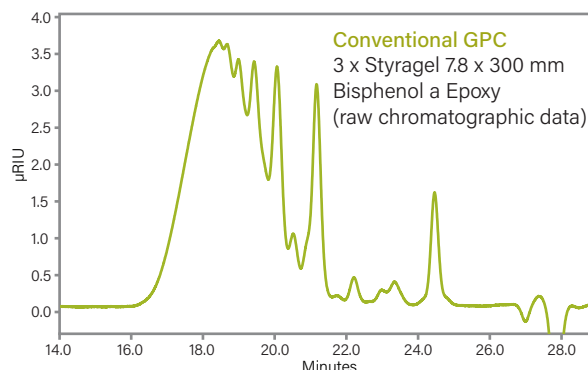
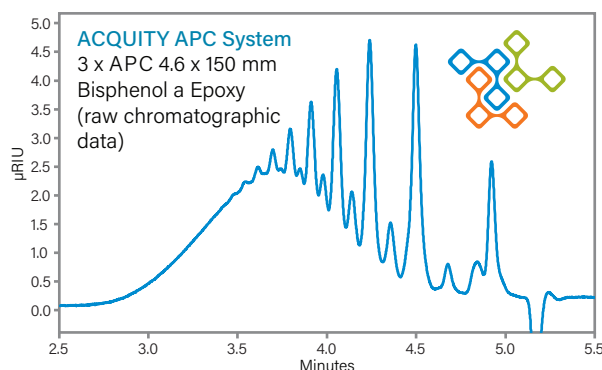
YOU ARE WORKING SMARTER AND FASTER – SO SHOULD YOUR LABORATORY

The ACQUITY APC System means that chromatographic polymer characterization is no longer synonymous with long run times. You can obtain accurate and repeatable polymer molecular weight information up to 5 to 20 times faster than before.

How would shorter run times and higher sample throughput improve your laboratory operations?

- **Reduce laboratory turnaround times for polymer samples** – Get answers to your development labs, your manufacturing operations teams, and your customers, faster.

- **Drive innovation** – With faster results, your entire operation responds more rapidly, decreasing development times and accelerating time to market.
- **Improve polymer characterization** – Meet the challenge of increasing development demands to get more, higher resolution information in a world of ever more complex polymer samples (shorter run times = more samples = more information = better characterization).
- **Streamline process monitoring** – Ensure that batches are in control with the agility to make decisions “on-the-fly” about process optimization.
- **Dramatically reduce the analysis cost per sample** – Reduce solvent consumption and waste disposal volumes.



Faster analysis times and better resolution of a Bisphenol a Epoxy using the ACQUITY APC System compared to conventional GPC.

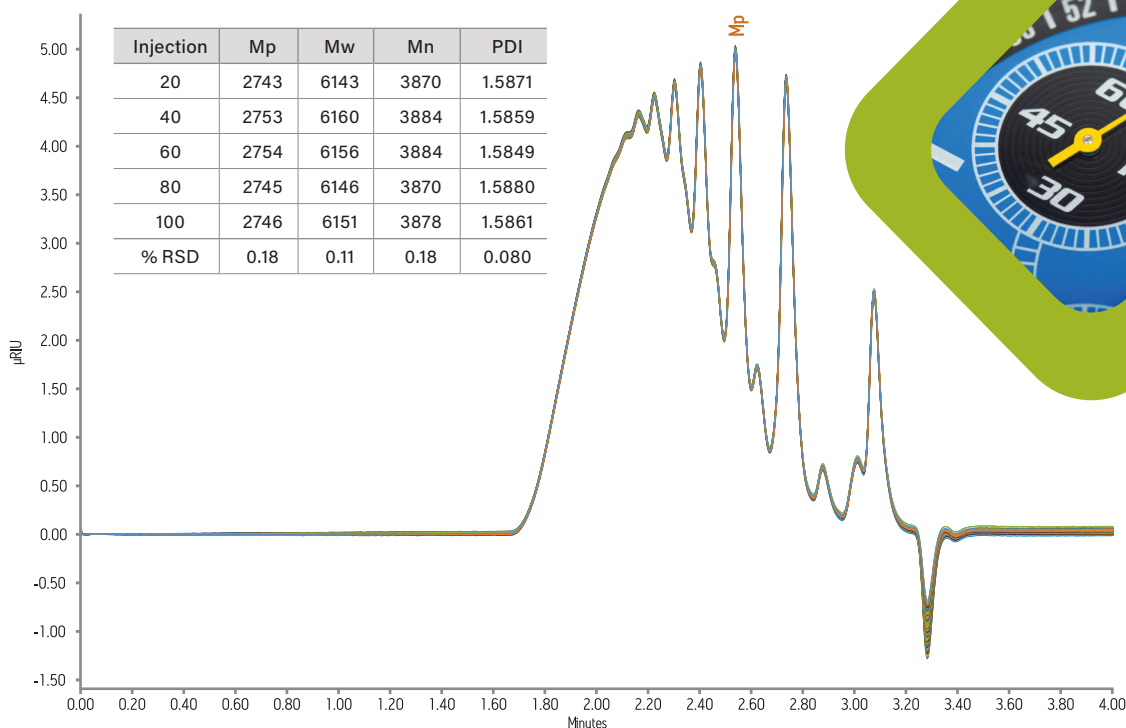
FASTER ANALYSIS SPEEDS WITHOUT SACRIFICING RESOLUTION

Decreasing the time it takes to get molecular weight information about your polymer shouldn't compromise the quality of data, as this is the current state of high-speed GPC – speed with less information. The ACQUITY APC System was designed to provide you with both fast analysis and quality data, so you can achieve high-resolution results smarter and faster.

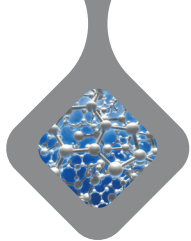
ENSURE DATA QUALITY WITH OPTIMUM STABILITY

Improving laboratory efficiency is not only about cost containment per sample; it's about streamlining overall workflows to improve the quality of data that supports your research and development pipeline. Therefore, improving efficiency cannot come at the cost of data quality. Data quality in size-based chromatographic separations relies on accurate molecular weight measurements, which in turn hinge on a stable system.

- Flow stability is the most important contributor to accurate molecular weight. Calibration of a bank of columns is based on the elution time of the polymers. The long-term flow stability of the ACQUITY APC System ensures your calibration will continue to give you the right molecular weight data for your polymer, even after hundreds of injections.
- Detector stability impacts the precision of integration and therefore the accuracy of your slice tables. All of the detector technologies for the ACQUITY APC System deliver outstanding baseline stability, giving you the confidence that high and low molecular weight slice data are accurate.
- The ACQUITY APC System also fully integrates with a series of third party detectors to deliver even more insight into the structure-property relationship of novel complex polymers.



Overlay of 100 injections of an epoxy resin sample in THF using two APC 4.6 x 150 mm Columns (125 Å and 45 Å) in series with ACQUITY RI detection. The exceptional stability of the ACQUITY APC System provides precise molecular weight determinations of repeated injections over time.



MEETING TOMORROW'S MATERIALS DEMANDS WITH TODAY'S TECHNOLOGY

YOUR INNOVATION SHOULD NOT BE LIMITED BY RESTRICTIVE GPC TECHNOLOGY

As the world's population increases, reducing carbon footprints is high on many companies list of priorities. This creates a demand for new and high-performance materials from sustainable sources to be manufactured and analyzed with a lower carbon footprint. The development of these materials often requires polymers with more complexity and with greater chemical functionality than ever before. Traditional GPC can't always meet the demands of innovation in polymer research – but ACQUITY APC dramatically advances polymer characterization providing more information, while supporting sustainable operations.

GREATER INSIGHT INTO LOWER MW POLYMERS AND OLIGOMERS

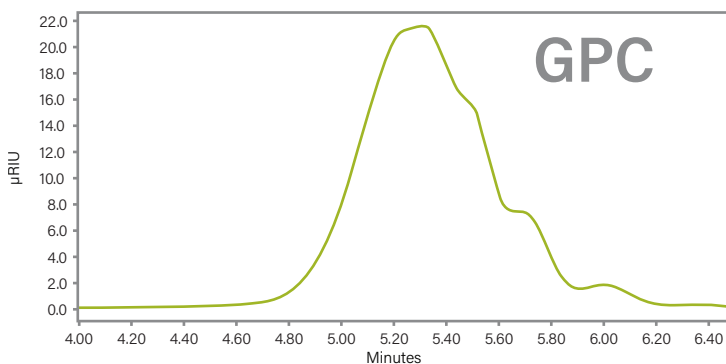
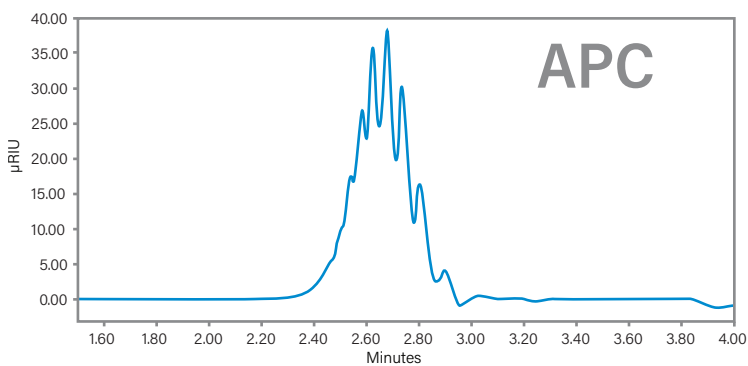
How well do you know your polymer? If you are analyzing innovative, lower molecular weight polymers, probably not as well as you would like.

GPC can be largely ineffective for low molecular weight polymers, offering limited insight into the polydispersity of your product.

Having the ability to characterize the presence of low molecular weight oligomers in your polymer is important to provide information for synthesis, process optimization, product formulation, and applications in end user markets.

The ACQUITY APC System is designed to take advantage of columns packed with small, rigid particles that deliver unprecedented resolution of low molecular weight oligomers – the result is more information about your high-performance polymers.

APC versus GPC with a narrow polystyrene standard, $M_p = 510$. Advanced Polymer Chromatography offers superior resolution of low molecular weight polymers and a better understanding of sample polydispersity due to reduced system dispersion.



MULTIPLE APPLICATIONS RUNNING SMOOTHLY ON A SINGLE SYSTEM

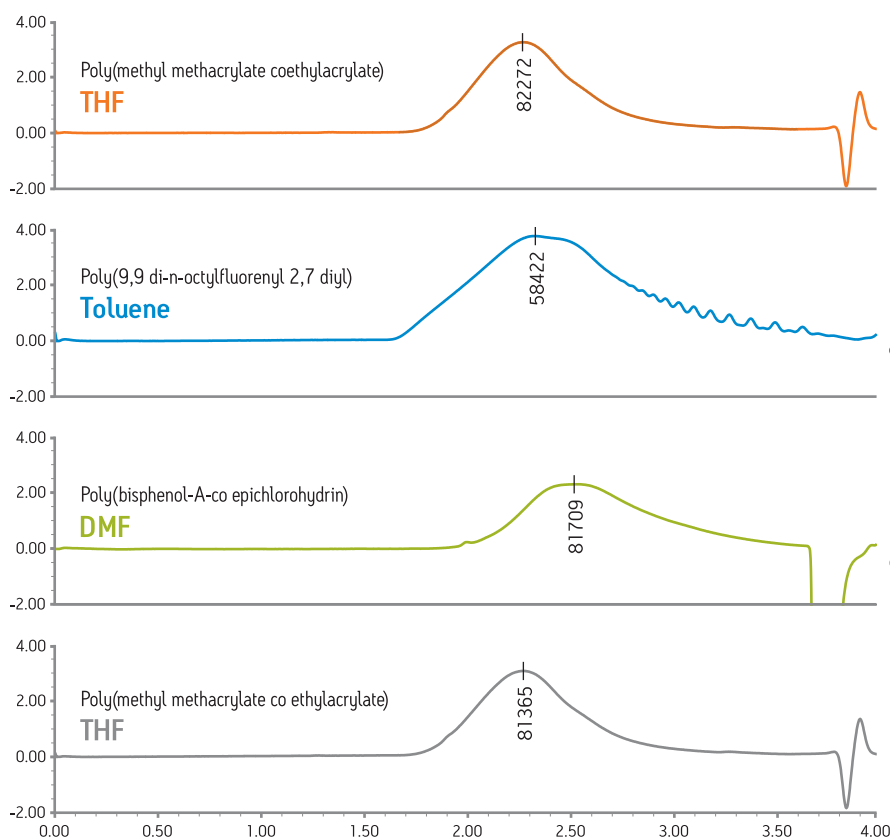
A wide range of polymers form part of our everyday world, yielding materials with critical functions based on properties such as strength, durability, electrical conductivity, heat, and chemical resistance. With so many different classes of polymers, the ability of a system to analyze the molecular weight of all of your different polymers is paramount.

The limitations of today's GPC systems and columns require either multiple systems to manage the different solvents and columns, or extensive system changeover times to accommodate all of these diverse applications on a single system. The column chemistries of the ACQUITY APC System are not polymeric gel-based materials, and they are not susceptible to swelling in the different solvents required for your diverse polymer analysis needs.

One system. One bank of columns.

Solvent flexibility.

The CM-30 column manager and streamlined method development allows for ultimate flexibility of both



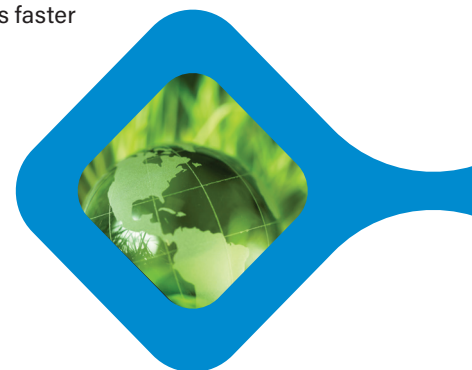
innovative APC and traditional GPC methods. Using APC with Polymer Quantenary Solvent Manager (p-QSM) technology provides polymer scientists with the ultimate flexibility to analyze the most complex polymer blends and additives using standard polymer chromatography, GPEC, and reverse phase LC with a single system.

What does this mean for your laboratory?

The ACQUITY APC System enables you to run all of your diverse polymer applications on a single system, automatically switching between multiple applications in a single day, regardless of the solvent or column you require.

What does this mean for your business?

By deploying the ACQUITY APC System, you will realize a reduction in the carbon intensity per sample analyzed, reduce the amount of solvent required, and gain the ability to arrive at reproducible results faster than with any GPC system.



Poly (methyl methacrylate co ethyl acrylate) in THF

	Before	After	% Change
Mp	82272	81365	1.1
Mw	78650	78953	0.4
Mn	49383	50110	1.5
PDI	1.59	1.58	0.6

Repeatable analysis of poly(methyl methacrylate co ethylacrylate) using the same two running ACQUITY APC 4.6 x 150 mm Columns (450 Å and 125 Å) in series after automated switching of the solvents from THF to toluene to DMF and back to THF.



ACQUITY APC: EXCEPTIONAL ATTENTION TO DETAILS

IT'S THE DETAILS THAT MATTER TO YOU - WE MAKE SURE YOU CAN FIND THEM

The ACQUITY APC System takes advantage of Waters' advancements in small particle column chemistries and low-dispersion system technology. Paying attention to every detail in our system designs gives you the highest quality data, enabling you to track the smallest changes in Mw, Mn, and polydispersity in your samples.

Precise solvent management

Be confident in your molecular weight results. The precise flow delivery of the isocratic solvent manager ensures that your calibrated system delivers accurate molecular weight data, day after day.

Low system dispersion

Maintaining the high resolution achieved on the sub-3- μm ACQUITY APC Columns depends on low system dispersion. Each module of the ACQUITY APC System has been optimized to deliver unprecedented resolution of your polymeric samples.

Compatibility with challenging solvents

Long-term reliability of systems with the harsh solvents associated with polymer analysis is a challenge for all instrumentation. The ACQUITY APC System was designed to operate in these challenging conditions, reliably. You can expect the highest performance with a wide variety of solvents.

Versatile column management

Column management hardware houses single or banked columns in a single, stable temperature environment. Integrated column pre-heating ensures that temperatures are consistent and stable across all columns. With a configurable capacity of up to two APC column banks and up to two GPC banks, the system can support a wide range of applications without manual intervention.

Automated method change over

Select between up to six different solvents for your polymer analyses. The combination of column select valves, the solvent select valve, and Empower™ Software means you can run all your methods

unattended with automated switching, regardless of the column bank or solvent required.

Flexible detection techniques

The ACQUITY APC's Refractive Index (RI) Detector has been optimized for low dispersion but with the low noise and drift performance required for accurate integration, even at low polymer concentrations. In addition to RI detection, the system offers UV/Visible (UV/Vis), photodiode array (PDA), and evaporative light scattering (ELS) detection. For more complex characterization, the system is also compatible with third-party viscometry and multi-angle light scattering detectors.

Easy fraction collection

Waters in-line fraction collection, allows for automated and accurate isolation of specific sample components for secondary SEC analysis or further complimentary characterization.



ACQUITY APC System configured for automated column bank switching of both APC and GPC columns.

ACQUITY APC COLUMNS: ENABLING SUPERIOR SPEED AND RESOLUTION

ACQUITY APC Columns contain high-performance particles designed for rapid and accurate chromatographic characterization of synthetic polymer and macromolecular species. Based on innovative sub-3- μm Ethylene Bridged Hybrid (BEH) particles, ACQUITY APC Columns usher in a new era of polymer separation capabilities by outperforming conventional polymer-based columns and providing unmatched chromatographic efficiency, stability, and method flexibility. ACQUITY APC Columns deliver superior chromatographic performance for aqueous and organic soluble polymers up to a molecular weight of 2,000,000 g/mol.

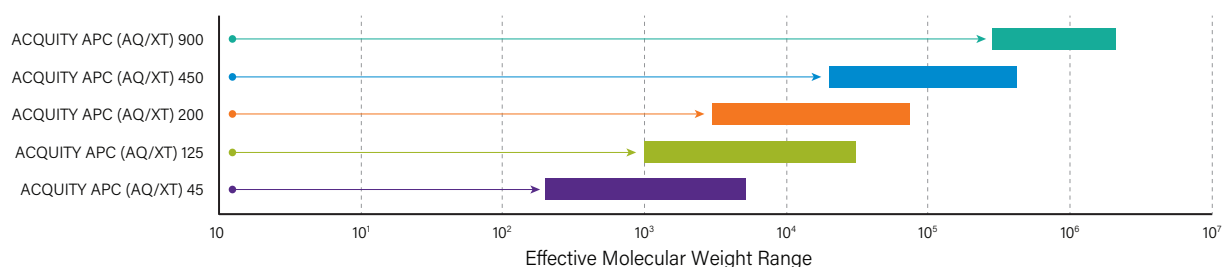
ONE COLUMN BANK FOR MULTIPLE SOLVENTS

The BEH particles used in ACQUITY APC Columns enable rapid solvent switching and the ability to use multiple conditions for the same bank of columns. Conventional polymeric stationary phases are dedicated to a single set of analytical conditions and solvent because the chromatographic bed is vulnerable to shrinking and swelling. By eliminating this undesirable behavior, ACQUITY APC Columns allow for maximum robustness and method development flexibility.

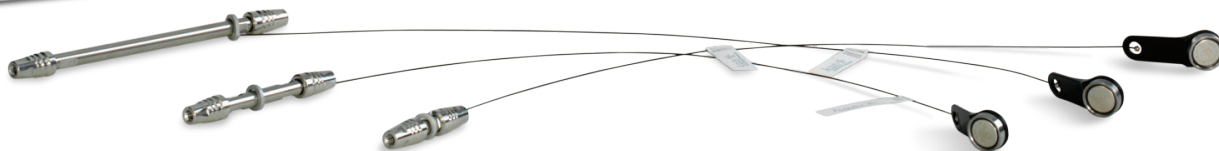
eCORD INTELLIGENT CHIP TECHNOLOGY

Attached to each ACQUITY APC Column is an eCord™ for electronic column usage management. It tracks the history of the column's performance and usage over the lifetime of the column. The smart and intuitive system software reads each column's eCord and keeps a record of the injection history on each column in your bank. Column information, including the molecular weight resolution range of the column used, is stored with every sample.

The ACQUITY APC (AQ and XT) Columns Selection Guide



ACQUITY APC XT Columns feature an extended temperature range (up to 90 °C) for organic solvent-based separations. ACQUITY APC AQ Columns are designed for aqueous-soluble polymer separations.



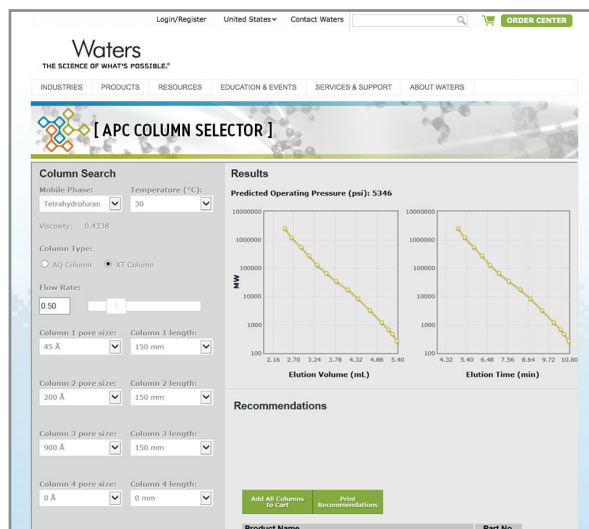


ACQUITY CALIBRATION STANDARDS: HAVE MORE CONFIDENCE IN YOUR RESULTS

Representing an industry first, APC Calibration Standards are specifically designed to match the molecular weight range of the ACQUITY APC Columns. They eliminate the need to manually prepare custom standard calibration mixes as ACQUITY APC Calibration Standards provide the right number of data points for the targeted MW range. In addition, the time to calibrate a bank of ACQUITY APC Columns is reduced by a factor of 3–5x compared to GPC columns. This significant reduction in run time allows you to perform more frequent calibrations, enabling higher confidence in the accuracy of your results.

The ACQUITY APC Standards are available in both polystyrene and polymethylmethacrylate configured into Low-, Middle- and High-Molecular Weight Calibration Kits. They are also available in convenient Method Development Kits which include the full suite of standards from all three different MW range kits.

- Simple and easy – add solvent and inject.
- Greater confidence in MW determination – shorter run times enable calibration standards to be included with each sample set.
- Reduce variances in analysis, increasing product quality.
- Improve process control.



APC COLUMN SELECTOR TOOL

The APC Column Selector Tool makes selecting the right ACQUITY APC Columns and Standards for your polymer separation fast and easy. The web-based tool allows users to visualize the calibration range for a configurable APC column bank.

- Simple and easy to navigate.
- Facilitates recommendations of the right pore size columns and calibration standards for analysis.
- Predicts operating pressure for various columns.
- Provides information regarding the predicted elution times required for analysis.

www.waters.com/apcselector

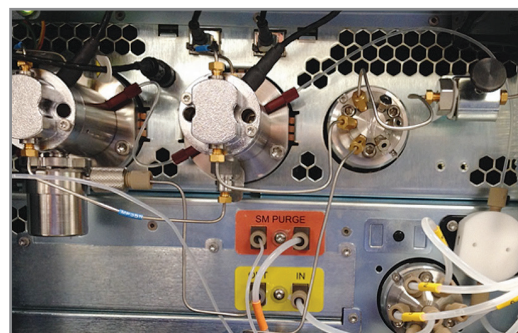


EFFICIENT METHOD DEVELOPMENT

It shouldn't take days or weeks to optimize your analytical methods. With the ACQUITY APC system's solvent select valve, scientists can streamline their method screening processes to advance from sample preparation to data collection faster and with greater insight into their results.

APC METHOD DEVELOPMENT SCREENING

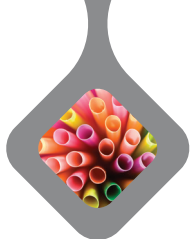
- Optional solvent select valve
- Fully compatible with the ACQUITY APC supported solvents
 - Aqueous and organic
 - 6 solvent lines
- Enables automated solvent switching on the ACQUITY APC System
 - Solvent resilient AQUITY APC hybrid particles not susceptible to swelling with solvent switching.



PROTOCOL - COMPLETED IN 4 HOURS

Plate/Well	Inj Vol (uL)	# of Injs	Sample Name	Function	Run Time (Minutes)	Method Set / Report Method	Processing
				Condition Column	45.00	APC AQ 40C S1 CAN 750	
				Purge Det	5.00	APC AQ 40C S1 CAN 750	
				Equilibrate	10.00	APC AQ 40C S1 CAN 750	
1:A,1	5.0	1	Blank	Inject Samples	5.00	APC AQ 40C S1 CAN 750	Normal
1:B,1	5.0	1	PEG 106 10% CAN 40C	Inject Narrow Standards	5.00	APC AQ 40C S1 CAN 750	Normal
1:B,2	5.0	1	PEG 202 10% CAN 40C	Inject Narrow Standards	5.00	APC AQ 40C S1 CAN 750	Normal
1:B,3	5.0	1	PEG 430 10% CAN 40C	Inject Narrow Standards	5.00	APC AQ 40C S1 CAN 750	Normal
1:B,4	5.0	1	PEG 633 10% CAN 40C	Inject Narrow Standards	5.00	APC AQ 40C S1 CAN 750	Normal
				Equilibrate	45.00	APC AQ 40C S2 MeOH 750	
				Purge Det	5.00	APC AQ 40C S2 MeOH 750	
				Equilibrate	10.00	APC AQ 40C S2 MeOH 750	
1:C,1	5.0	1	PEG 106 10% MeOH 40C	Inject Narrow Standards	5.00	APC AQ 40C S2 MeOH 750	Normal
1:C,2	5.0	1	PEG 202 10% MeOH 40C	Inject Narrow Standards	5.00	APC AQ 40C S2 MeOH 750	Normal
1:C,3	5.0	1	PEG 430 10% MeOH 40C	Inject Narrow Standards	5.00	APC AQ 40C S2 MeOH 750	Normal
1:C,4	5.0	1	PEG 633 10% MeOH 40C	Inject Broad Samples	5.00	APC AQ 40C S2 MeOH 750	Normal
				Equilibrate	45.00	APC AQ 40C S3 H2O 750	
				Purge Det	5.00	APC AQ 40C S3 H2O 750	
				Equilibrate	10.00	APC AQ 40C S3 H2O 750	
1:D,1	5.0	1	PEG 106 100% H2O 40C	Inject Narrow Standards	5.00	APC AQ 40C S3 H2O 750	Normal
1:D,2	5.0	1	PEG 202 100% H2O 40C	Inject Narrow Standards	5.00	APC AQ 40C S3 H2O 750	Normal
1:D,3	5.0	1	PEG 430 100% H2O 40C	Inject Narrow Standards	5.00	APC AQ 40C S3 H2O 750	Normal
1:D,4	5.0	1	PEG 633 100% H2O 40C	Inject Broad Samples	5.00	APC AQ 40C S3 H2O 750	Normal
1:A,1	5.0	1	Blank	Inject Samples	5.00	APC AQ 40C S3 H2O sd	Normal

When equipped with BEH particle column technology, the APC system delivers fast and high resolution GPC separation, which allows rapid method development to obtain reproducible polymer molecular weight characterization results.



WATERS FRACTION MANAGER - ANALYTICAL: CAPTURE EVERY DROP

EASY FRACTION COLLECTION FOR FURTHER ANALYSIS

Innovation in the polymer industry is increasing demand for streamlined analysis, combining several analytical techniques, in order to piece together analysis and gain the full picture when characterizing complex polymer samples.

The Waters Fraction Manager - Analytical (WFM-A) was first developed following customer feedback. Customers faced many challenges in trying to control the several different aspects involved in the collection of small volume fractions (volume, flow, carryover, waste contamination).

WFM-A addressed these issues by easily integrating with the APC and its software, to maximize collection accuracy and efficiency, from the column, through the detector, to collection.

EASILY ISOLATE COMPONENTS IN A MIXTURE

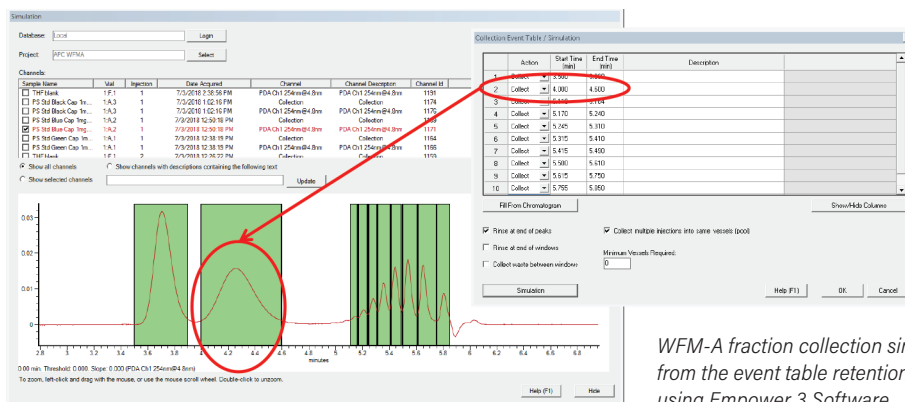
The WFM-A makes it easy to separate low molecular weight polymer solutions into well resolved and discreet fractions through high speed/high resolution size exclusion chromatography with the addition of in-line fraction collection, removing the need for lengthy purification/isolation, providing efficient collection for further analysis, using minimal resources and manpower. This can help streamline your analytical workflow, easily progressing from SEC to additional supporting characterization.

OPTIMIZED AND EFFICIENT COLLECTION

SEC and fraction collection can be achieved in two simple steps using a single vial of polymer. SEC analysis easily determines the collection times for each fraction, which are then collected repeatedly until your specified workable volume is achieved.



Waters Fraction Manager - Analytical.



WFM-A fraction collection simulation from the event table retention times using Empower 3 Software.

ADVANCED DETECTION: UNDERSTAND MORE ABOUT YOUR POLYMERS PROPERTIES

MORE INFORMATION IN A SINGLE RUN

The more complex a material, the more we need to know, particularly about a polymer's shape/structure/viscosity. Understanding how your polymer's structure gives rise to given properties is essential in driving high performance material innovation.

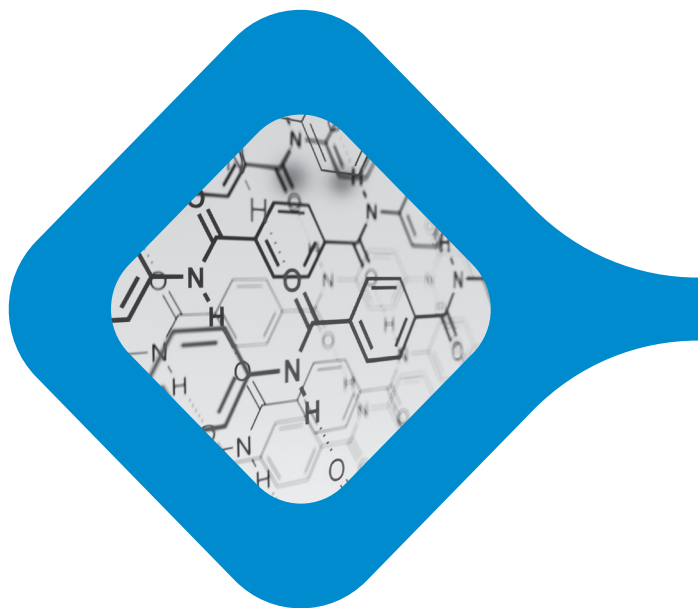
Coupling an APC or an SEC system with an advanced detection set-up allows for several analyses to be performed in tandem on a single sample, better informing your next iteration with minimal effort.

APC COMPATIBLE DETECTION SYSTEMS

The APC has been designed to easily interface with a wide range of advanced detector systems, Waters have partnered with Wyatt and Malvern Panalytical to enhance SEC analysis, delivering more information in a single technique without sacrificing development speed or resolution.

Our advanced detection partners have developed low dispersion flow cells for their respective detectors which are fully compatible with the APC, further streamlining polymer analysis.

- **Light Scattering and Refractive Index** – Reduce column interactions “the context does not fit” and obtain the true molecular weight of a polymer
- **Viscometry** – Better understand structural differences between polymers



WYATT
TECHNOLOGY



**Malvern
Panalytical**
a spectris company

EMPOWER 3 SOFTWARE: POWERFUL DATA PROCESSING AND REPORTING

Empower 3 Software, our flagship chromatography data software (CDS), makes it easier than ever to run samples and produce meaningful results. Empower's switch-on functionality provides a convenient way to add advanced polymer analysis to your Empower installation as well as other separation techniques such as UPLC, UltraPerformance Convergence Chromatography (UPC²), and detection techniques, such as UV, ELS, and mass spectrometry.

MAXIMIZE LABORATORY EFFICIENCY

Empower 3's interface is designed to maximize your productivity, improving how you collect, process and print chromatography data. Capabilities include:

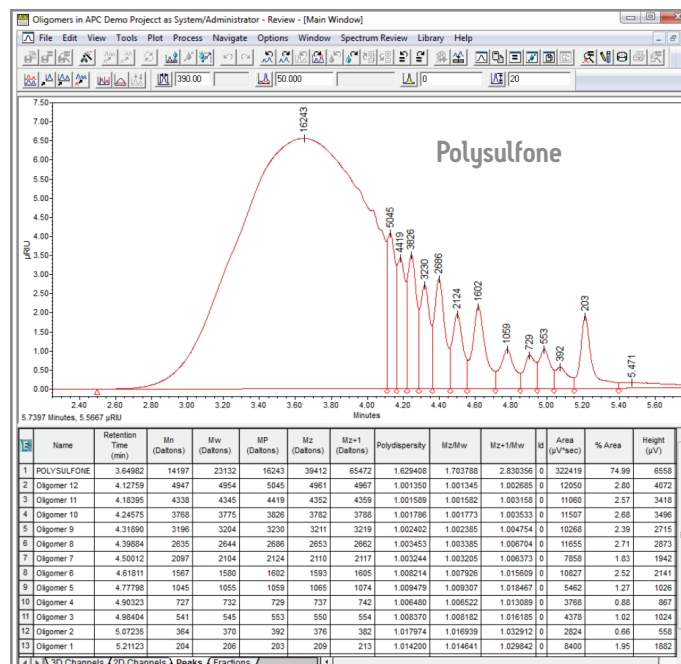
- Customizable data reports
- Integrated and automated custom calculations
- Relational database, so all your metadata is traceable back to the raw data
- Optimized workflow for different users and different analyses

Fits the way your lab works

Empower 3 Software is designed to fit into your corporate IT landscape. It provides advanced performance across your network and high availability deployment options to maximize your uptime.

Streamline polymer data analysis

Using Empower, you can quickly and easily review, compare, and report data from multiple injections of the same or different polymers.



Empower 3 Software with GPC option provides comprehensive data analysis capabilities specifically for polymers. Results reported are fully customizable and include molecular weight calculations such as number-average molecular weight (M_n), weight-average molecular weight (M_w), molecular weight of the highest peak (M_p), Z-average molecular weight (M_z) and polydispersity.

WATERS GLOBAL SERVICES.

Delivering world renowned service and support

Our team of experts will support your materials sciences success by providing you with tailored services to help maintain system peak performance, minimize down time, address scientific application challenges, and support stringent compliance requirements.



www.waters.com/APC

For your local sales
office, please visit
waters.com/contact



Waters

THE SCIENCE OF WHAT'S POSSIBLE.™

Waters Corporation
34 Maple Street
Milford, MA 01757 U.S.A.
T: 1 508 478 2000
F: 1 508 872 1990
www.waters.com

Waters, The Science of What's Possible, ACQUITY, Advanced Polymer Chromatography, APC, eCord, Empower, UPLC, UPC,² UltraPerformance Convergence Chromatography, and Waters Quality Parts are trademarks of Waters Corporation. All other trademarks are the property of their respective owners.

©2019 Waters Corporation. Printed in the U.S.A.
October 2019 720004570EN TC-SIG