

QUIZZ 

BACK  
TO THE FUTURE  
OF FFFF 

**BACK TO THE FUTURE**

**OF FFF** 

*Dear Friends*

*The history of the FFF is made up of so many major events, players and places that it's impossible for us to cover them all in just a few minutes.*

*That's why I'd like to sincerely apologize to all of you for any events, places or people I may have forgotten to mention...*

 **WHO IS WHO?**

**SEE PART 2 TO ANSWER...**

# Who is this famous FFF researcher: Q1

- A : Steve Williams
- B : John Calvin Giddings
- C : Marcus Myers



# Who is this famous FFF researcher: Q1

A : Steve Williams

B : John Calvin Giddings

C : Marcus Meyers



# Who is this famous FFF researcher: Q1

A : Steve Williams

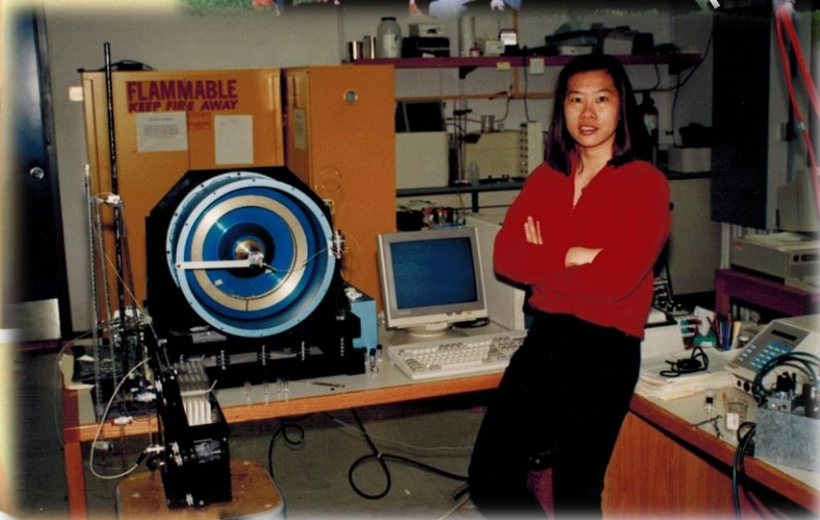
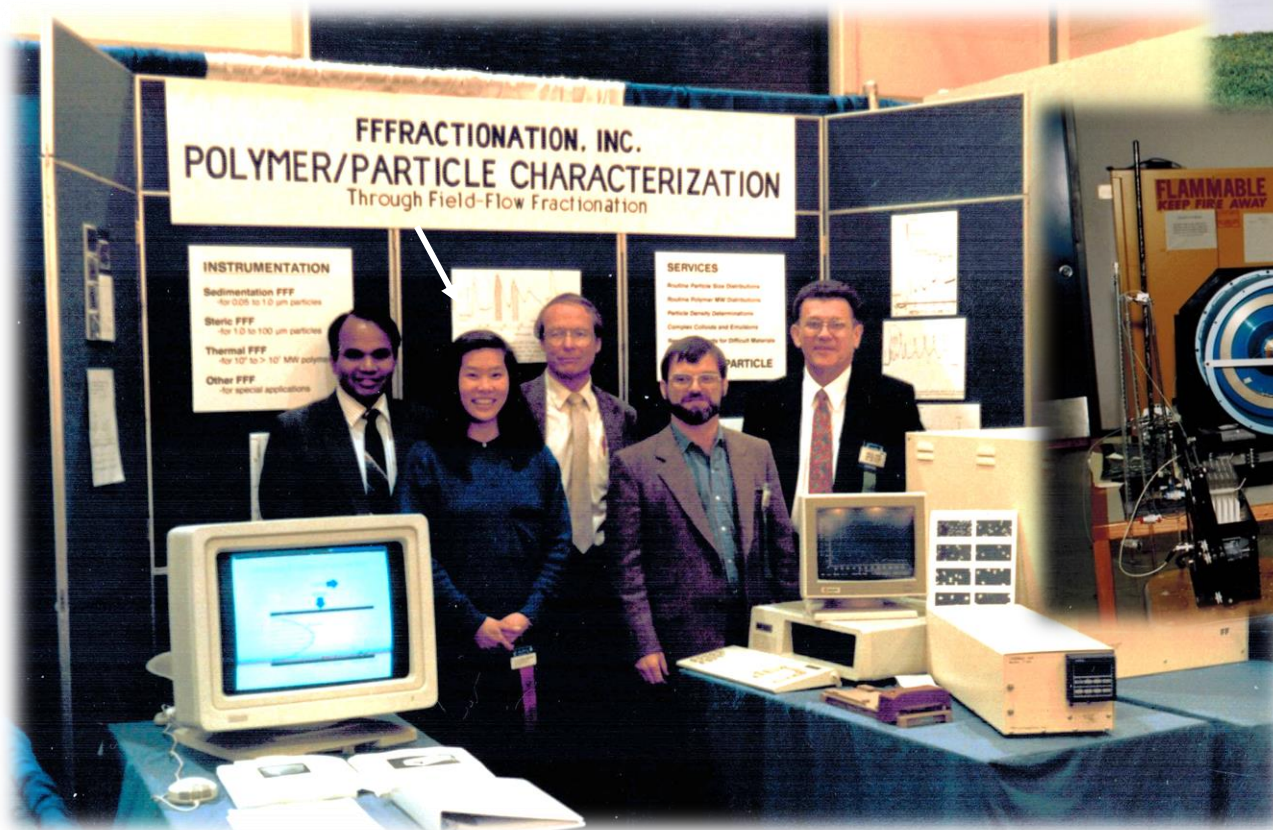
B : John Calvin Giddings

C : Marcus Meyers



# Who is this famous FFF researcher: Q2

- A : Karin Caldwell
- B : Kim Williams
- C : Marcia Hansen



With the Giddings' Lab...  
what a nice concentration  
of brilliant people

With a small SdFFF



## Who is this famous FFF researcher: Q2

- A : Karin Caldwell
- B : Kim Williams
- C : Marcia Hansen



With George  
Karaiskakis on her left



With Luigi Reshiglian and  
Seungho Lee on her right



With Catia Contado on her left



## Who is this famous FFF researcher: Q2

A : Karin Caldwell

B : Kim Williams

C : Marcia Hansen



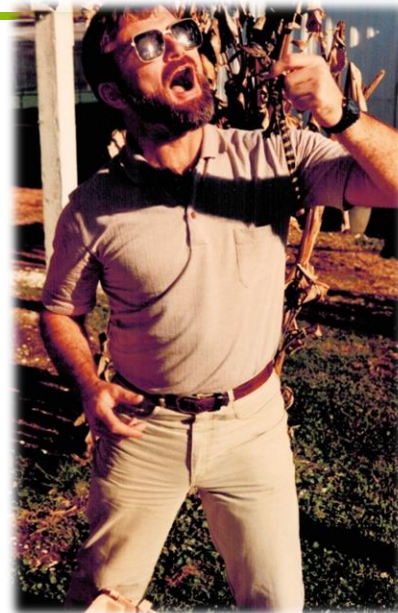
With Albena Lederer, Suzanne  
Boye, William Smith, Frédérique  
Violleau ....



With Soheyl Tadjiki, Mauricio Hoyos and  
many other famous FFF members....

And now...Who is this famous FFF researcher: **Q3**

- A : Martin Schimpf
- B : Karl-Gustav Wahlund
- C : Ron Beckett



With John Calvin and  
Karl-Gustav who think  
about A4F?



To the left of Kim in the foreground

And now...Who is this famous FFF researcher: **Q3**

A : Martin Schimpf

B : Karl-Gustav Wahlund

C : Ron Beckett



With Francesco Dondi on his left



With Mauricio Hoyos on his left



And now...Who is this famous FFF researcher: **Q3**

A : Martin Schimpf

B : Karl-Gustav Wahlund

C : Ron Beckett



With Francesco Dondi with two other friends, including two next persons to discover

And now...Who is this famous FFF researcher: **Q4**

- A : Karin Caldwell
- B : Karin Fromell
- C : Marcia Hansen



With Ron on her left...

With Soheyl on her right...



With a special guest chef!  
Marcus Myers...

And now...Who is this famous FFF researcher: **Q4**

A : Karin Caldwell

B : Karin Fromell

C : Marcia Hansen



With Karl Gustav...

# And now...Who is this famous FFF researcher: **Q5**

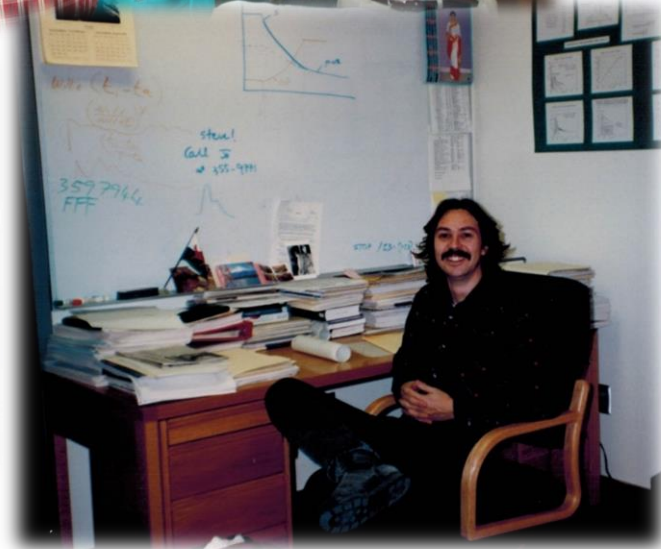
- A : Mauricio Hoyos
- B : Steve Williams
- C : Josef Chmelik



Now, as you know Ron, Karin, Francesco, who his the last guy on the picture...? He started with FFF a long time ago... with a famous moustache!



With Luigi, Kim and Seungho!...



And the power programmed field decay!...



And Kim in Amsterdam...

And now...Who is this famous FFF researcher: **Q5**

- A : Mauricio Hoyos
- B : Steve Williams
- C : Josef Chmelik



To the left of Maciej Zborowski...



To the left of Carmel, and  
with Ron, Mauricio...



To the left of Catia Contado...



With Karl-Gustav and the next *FFFFFR*\*! \*Famous French FFF Researcher



And now...Who is this famous FFF researcher: **Q5**

A : Mauricio Hoyos

B : Steve Williams

C : Josef Chmelik



To the left of Carmel, and  
with Ron, Mauricio...



To the left of Maciej Zborowski...



To the left of Catia Contado...



With Karl-Gustav and the next *FFFFFR*\*! \*Famous French FFF Researcher

And now...Who is this famous FFF researcher: **Q6**

- A : Mauricio Hoyos
- B : Michel Martin
- C : Marcus Myers



With Steve and Maciej ...



With Francesco and Ron...



In Paris at the Observatory for  
G4F meeting



And now...Who is this famous FFF researcher: **Q6**

A : Mauricio Hoyos

B : Michel Martin

C : Marcus Myers



With Lee Moore on the left of the picture...

# And now...Who is this famous FFF researcher: **Q6**

A : Mauricio Hoyos

B : Michel Martin

C : Marcus Myers



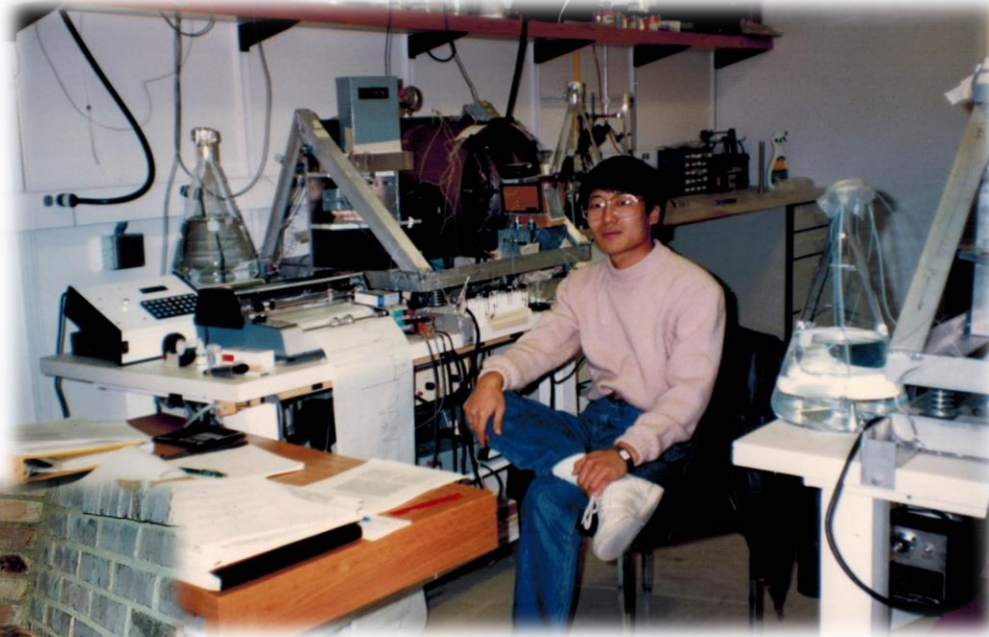
With Lee Moore on the left of the picture...

And now...the last but not the least...Who is this F FFF R: **Q7**

A : Mauricio Hoyos

B : Seungho Lee

C : Myeong Hee Moon



With Karen...

The Korean Team with Francesco...



From the left with Ron, Philippe Cardot and George Karaiskakis...

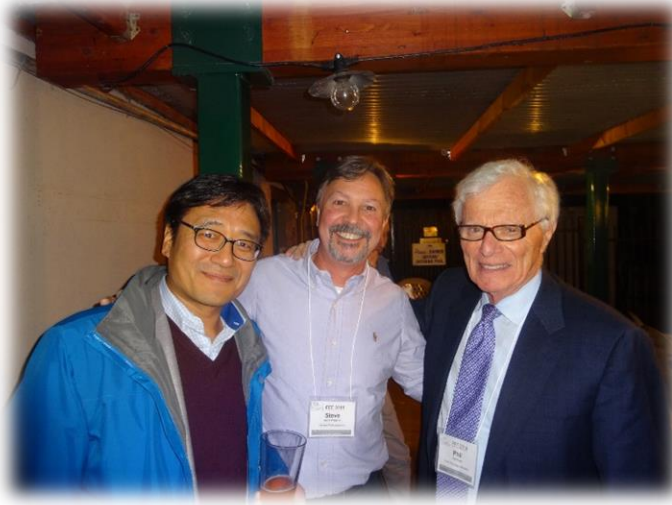


And now...the last but not the least...Who is this F FFF R: **Q7**

A : Mauricio Hoyos

B : Seungho Lee

C : Myeong Hee Moon



With Steve and Phil Wyatt...



With Lars Nielsen and Frédérique Violleau...



With Andrea Zattoni  
and Luigi Reshiglian...



With Josef Chmelik...



And now...the last but not the least...Who is this F FFF R: **Q7**

A : Mauricio Hoyos

B : Seungho Lee

C : Myeong Hee Moon



From the left...  
Mauricio, Michel,  
Bruce, Kim, Wenwan,  
Mohammed and  
Myeong Hee...

And now a special thanks also to MARCUS



From the left... Steve, Martin,  
MARCUS, and Catia...

From the left... Myeong Hee, Steve, Seungho, Luigi, Martin, MARCUS, Kim, Michel and  
Ron...



A stylized arrow icon with a red-to-yellow gradient and a white outline, pointing to the right. It has a segmented tail.

**WHERE?**

**SEE PART 3 TO ANSWER...**

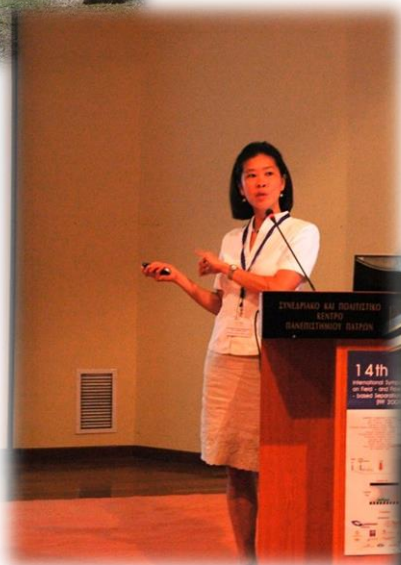
# The place to be : Q1

- A : Patras in 2009
- B : Columbia in 2018
- C : Brno in 2005



# The place to be : Q1

- A : Patras in 2009
- B : Columbia in 2018
- C : Brno in 2005

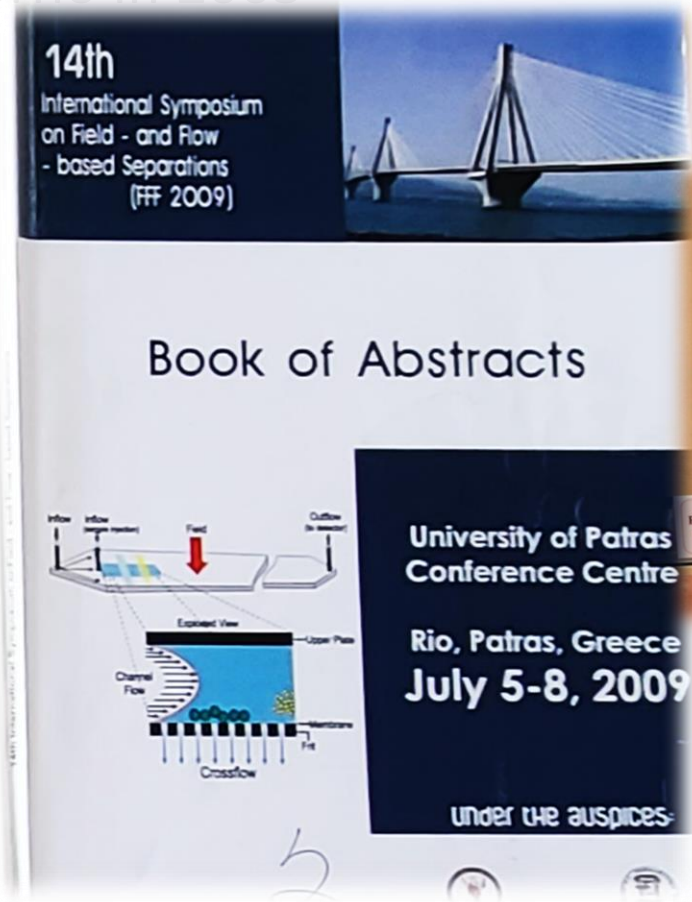


The place to be : **Q1**

A : Patras in 2009

B : Columbia in 2018

C : Brno in 2005



Chair : George Karaiskakis

# The place to be : Q2

- A : Vienna in 2020
- B : Salt Lake City in 2014
- C : Dresden in 2016



# The place to be : Q2

- A : Vienna in 2020
- B : Salt Lake City in 2014
- C : Dresden in 2016



Chair : Albena Lederer

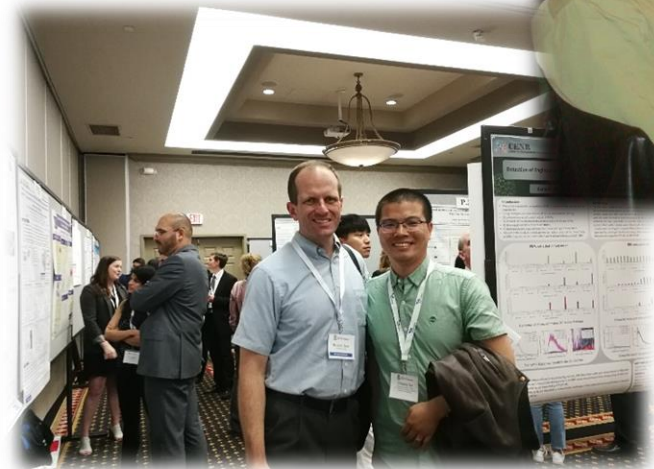


The place to be : **Q3**

A : Salt Lake City in 2007

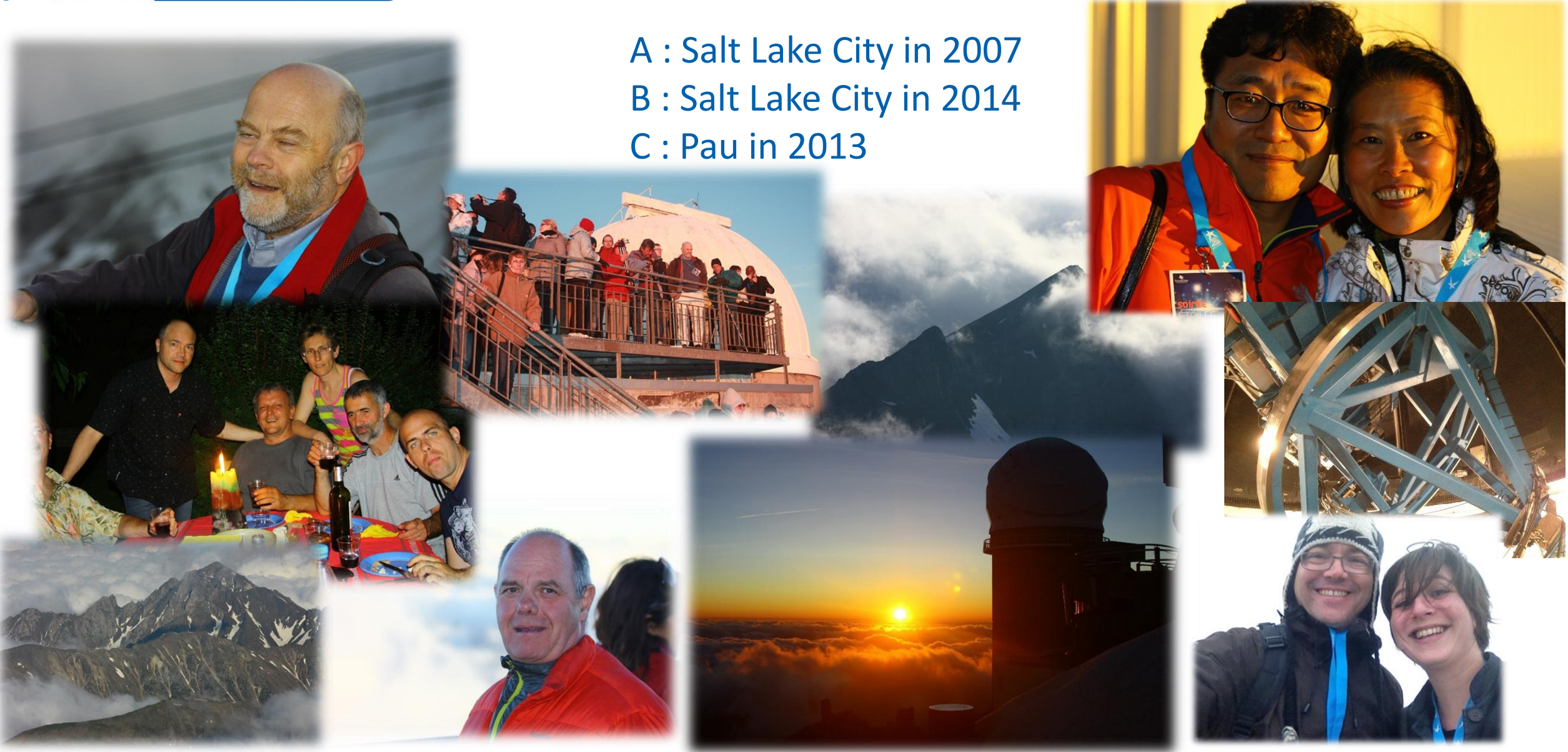
B : Salt Lake City in 2014

C : Pau in 2013



# The place to be : Q3

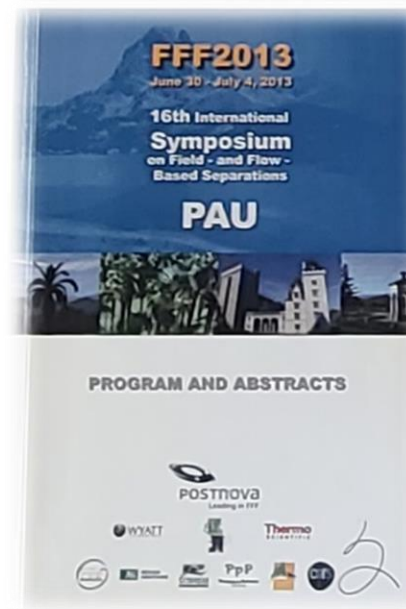
- A : Salt Lake City in 2007
- B : Salt Lake City in 2014
- C : Pau in 2013





# The place to be : Q3

- A : Salt Lake City in 2007
- B : Salt Lake City in 2014
- C : Pau in 2013



Chair : Gaëtane Lespès



# The place to be : Q4

- A : Riverside in 2022
- B : Salt Lake City in 2014
- C : Columbia in 2018



# The place to be : Q4

- A : Riverside in 2022
- B : Salt Lake City in 2014
- C : Columbia in 2018



# The place to be : Q4

- A : Riverside in 2022
- B : Salt Lake City in 2014
- C : Columbia in 2018



Chair : Mohammed Baalousha

# The place to be : Q5

A : Patras in 2009

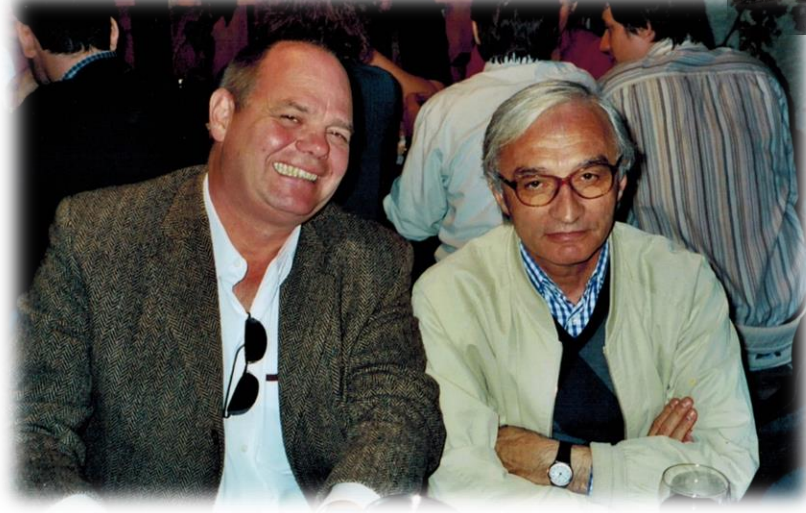
B : Salt Lake City in 2014

C : Brno in 2005

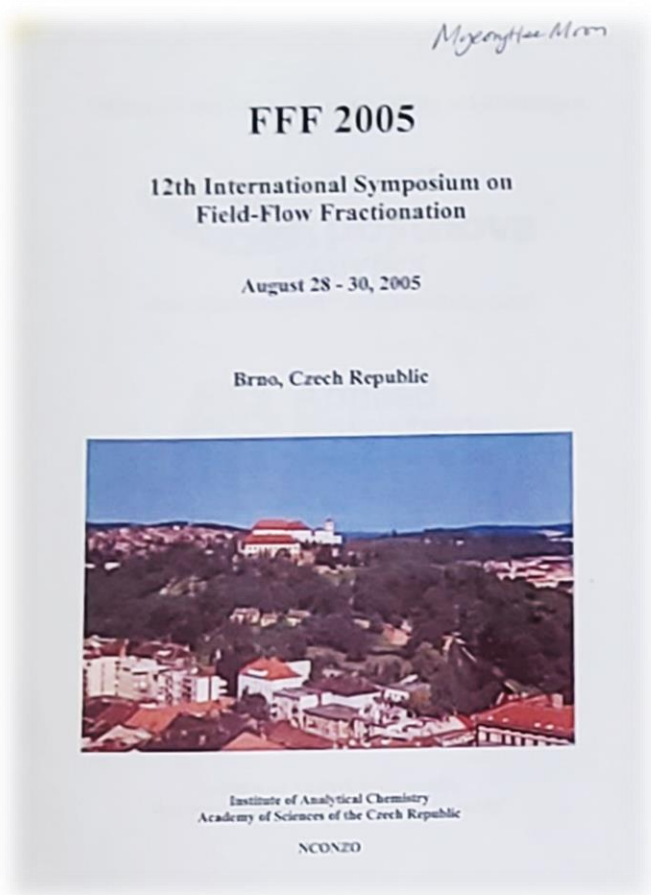


# The place to be : Q5

- A : Patras in 2009
- B : Salt Lake City in 2014
- C : Brno in 2005



# The place to be : Q5



A : Patras in 2009

B : Salt Lake City in 2014

C : Brno in 2005



Chair : Josef Chmelik

# The place to be : Q6

- A : Amsterdam in 2002
- B : Vienna 2020
- C : Columbia in 2018





# The place to be : Q6

A : Amsterdam in 2002

B : Vienna 2020

C : Columbia in 2018



# The place to be : Q6



A : Amsterdam in 2002

B : Vienna 2020

C : Columbia in 2018



Chair : Frank von der Kammer



**FFF2020**

**20th International Symposium on Field- and Flow-Based Separations**

23–27th February 2020

University of Vienna



# The place to be : Q7

- A : Salt Lake City in 2014
- B : Salt Lake City in 2007
- C : Paris in 1999



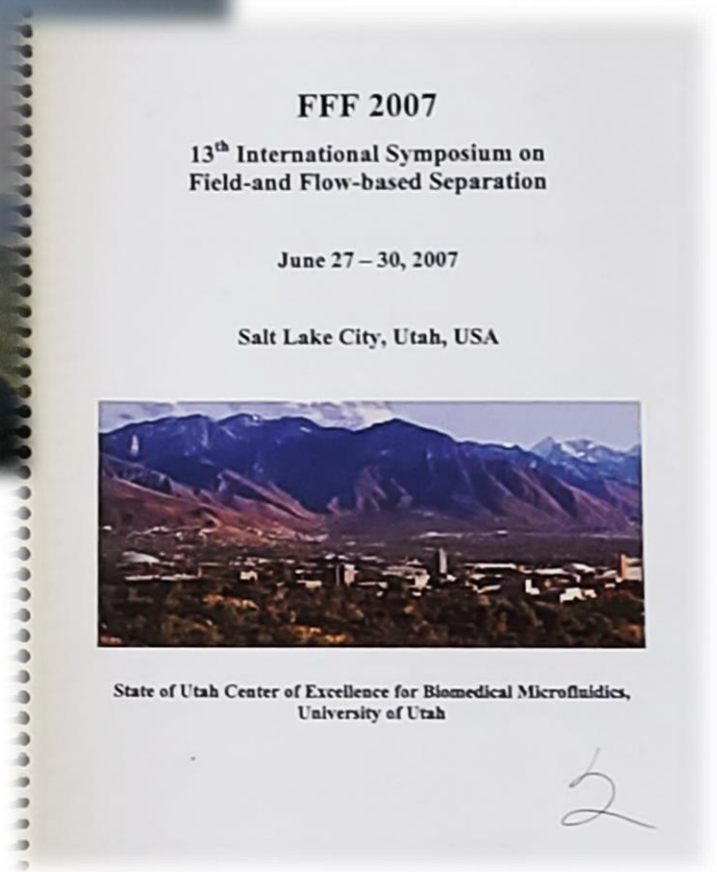
# The place to be : Q7

- A : Salt Lake City in 2014
- B : Salt Lake City in 2007
- C : Paris in 1999



The place to be : Q7

- A : Salt Lake City in 2014
- B : Salt Lake City in 2007
- C : Paris in 1999



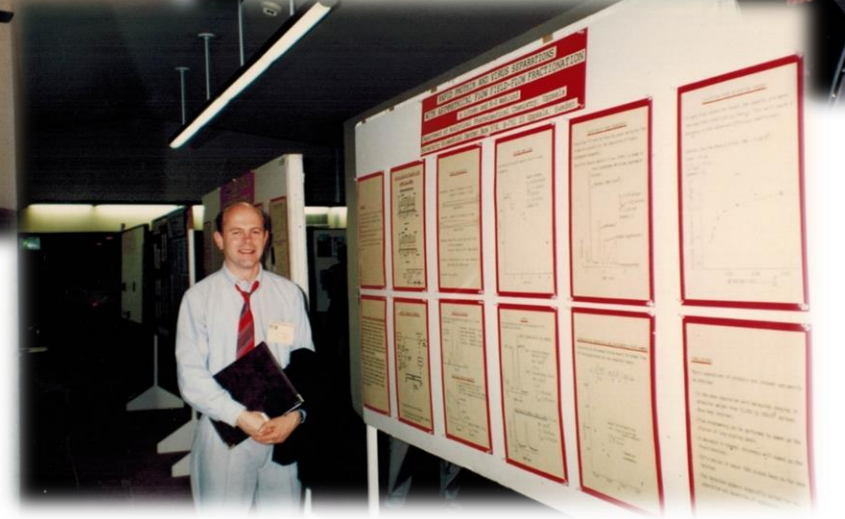
Chair : Bruce Gale

# The place to be : Q8

A : Park City 1989

B : Salt Lake City in 2007

C : Ferrara in 1996



The place to be : Q8

A : Park City 1989

B : Salt Lake City in 2007

C : Ferrara in 1996

# The First International Symposium on Field-Flow Fractionation

Sharon Kraus  
Rohm and Haas Company Research  
Laboratories  
727 Northmen Road  
Spring House, PA 19477

The First International Symposium on Field-Flow Fractionation (FFF), sponsored by the University of Utah's Field-Flow Fractionation Research Center, covered June 15 and 16 in Park City, UT. The meeting attracted 80 academic and industrial scientists from Europe, Asia, Australia, and the United States. Representing diverse interests in FFF technology, the group ranged from researchers working on the theory and fundamental developments of techniques to those applying FFF to the characterization and separation of polymers, biological materials, and particulates.

During these busy two days, the mood of the participants reflected the excitement of being involved in an emerging technology. According to Jack Kirkland of Du Pont, the current state of FFF development is comparable to the early days of high-performance liquid chromatography. Coincidentally, the 23 papers presented at this symposium equaled the number presented at the First International Symposium on Chromatography in 1963.

Reports on the theoretical developments and applications of sedimentation field-flow fractionation (SdFFF) were predictably more abundant, be-

cause SdFFF is the best understood of all the FFF techniques and is commercially available. Mark Schure of Rohm and Haas presented an elaborate computer modeling of secondary flow in the SdFFF channel. This secondary flow is the result of the Coriolis Force, which arises when a fluid flows relative to a rotating frame of reference. He described the effect as a wave in the flow stream, which causes a dispersion of the zones. The result is that some of the retained material elutes too soon. Schure suggested that experimentalists look for solute in the void volume peak. As his model confirmed and experimentalists determined, this effect can be minimized by using thin rectangular separation channels with high-aspect ratios.

In another session devoted to wall effects and perturbations at the accumulation wall, Dominique Maes, from Limburgs Universitair Centrum in Diepenbeek, Belgium, described theoretically the fundamental characteristics of particles flowing in an FFF channel. Edward Schmach of Du Pont, focusing on an application, provided an analytical solution for steric relaxation effects for FFF particles in a SdFFF channel.

Nonideal retention behavior in SdFFF from particle-wall interactions was discussed by Marcia Hansen of Procter & Gamble. She showed that the electrostatic interactions between sample particles and the FFF channel wall were a function of carrier strength and sample size as well as other parameters such as field strength and the

channel wall material. Perturbations to standard retention behavior were theoretically treated by including the electrostatic forces in the retention equation. Peak shape in SdFFF as a function of various experimental parameters was studied by Francesco Donati of the University of Ferrara, Italy. Donati used peak shape analysis to quantify overloading effects and to discriminate between overloading and other nonideal effects.

Applications of SdFFF continue to become more diverse. For instance, FFF is finding a special niche in environmental studies. Methodologies to fractionate and size colloidal particles extracted from river waters using SdFFF were presented by Ron Beckett of the Chisholm Institute of Technology in Australia and Pierluigi Reaching of the University of Ferrara. Howard Taylor, from the U.S. Geological Survey in Denver, CO, used inductively coupled plasma mass spectrometry as a detector for inorganic materials separated by SdFFF. Although this particular system is expensive, the idea of connecting various detectors to an FFF system could greatly extend the applications. In general, environmental analyses present some difficult applications for which the separation capabilities of FFF methods—both SdFFF and Flow FFF—are shown to be uniquely suited.

**FOCUS**

Applying FFF to latex and other emulsion polymers involves such parameters as particle size distribution, zeta potential, and particle growth. In an empirical approach to this problem, Kirkland studied retention effects in FFF over a range of experimental conditions and offered better definitions of the limitations of the method. He also presented techniques for combining more effective FFF experiments. Kirkland suggested that FFF has other potential applications that follow from determining Mark-Houwink constants for calculating the radius of gyration of molecules and intrinsic viscosity distributions.

For polymers with a known value of  $D_p$ , Yuhua Cao of Academia Sinica in Beijing, China, described a universal calibration procedure that holds for a single set of experimental conditions. Martin Schirmer, Bond Research, used TFFF as a method for determining  $D_p$  of polymers, and Marco Meyer of Utah's FFF Center pointed out that large errors in determined molecular weights can arise from incorrect  $D$  and  $D_p$  values.

Many researchers believe that applications for biological materials will be important to the future success of commercial SdFFF instrumentation because the number of potential users in the market could be greater than those for industrial applications. In one example, Samuel Mignani of the U.S. Department of Agriculture used SdFFF to determine the effect of sucrose and lactose on the size of osmium micelles. Most of the other biological applications rely on alternate fields or hybrid techniques. Examples include fractionation of liver blood cells by gravitational FFF, reported by Michel Martin from Institut Supérieur de Physique at Chimie Industrielle in Paris, and the separation of B and T immune system cells using a hybrid of cellular adhesion chromatography and FFF, presented by James Ripstein from the University of Vermont.

Flow FFF appears to be another promising subtechnique with a broad range of applications. Xian Hananath TFFF as a method for determining  $D_p$  of polymers, and Marco Meyer of Utah's FFF Center pointed out that large errors in determined molecular weights can arise from incorrect  $D$  and  $D_p$  values.

which has potential advantages over conventional based techniques. A novel approach to solving the problem of channel deformation in flow FFF was described by Earl Gasser, Wash State, and the University of Utah's School of Chemical Engineering. He used an experimental flow FFF channel with a single permeable wall. For the other wall, he used a porous medium that was prepared in a natural exponential flow FFF channel with a flow rate. The approach yielded rapid separations for a broad range of biological samples in shallow pressure vessels, plastics, and stainless steel tubes. Particular attention was given to the separation of yeast cells. The experimental results required for standard gel permeation chromatography (GPC) were obtained with the Utah FFF Center's newly developed subminiature chromatography and FFF system (UT-SCFC) from the University of Utah.

Flow FFF appears to be another promising subtechnique with a broad range of applications. Xian Hananath TFFF as a method for determining  $D_p$  of polymers, and Marco Meyer of Utah's FFF Center pointed out that large errors in determined molecular weights can arise from incorrect  $D$  and  $D_p$  values.

use of a novel experimental approach using SdFFF for the analytical study of very broad distributions and J. C. Giddings' construction of techniques to optimize the performance of FFF. Both researchers are associated with the University of Utah.

Optimization of FFF has broad implications for the future success of commercial SdFFF instrumentation. Giddings' objective was to optimize wide molecular weight distributions in FFF techniques, improve instrument availability, and identify limits of technology and throughput. As an example, Giddings compared SdFFF with flow FFF. SdFFF is used for particles  $< 1 \mu m$  and is sensitive to particle density, whereas flow FFF is applied to particles  $> 1 \mu m$  and is independent of particle density. Various forms of field programming, including the time-based exponential decay used by Du Pont and the power program developed at the University of Utah, were tested to the advantage. The flexibility of FFF techniques, and the wide variety of experimental parameters that can be varied within minimum, make it more than a niche technology, researchers claim and, consequently, researchers

The recent Park City FFF symposium and previous symposia have contributed to worldwide progress in commercial SdFFF instrumentation and applications. In addition, they should attract the important benefits of FFF technology to the international, academic, and industrial communities.

**FOCUS**

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**Pyrolysis Oils from Biomass**  
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Pyrolysis is a simple and necessary process for the most comprehensive method to upgrade by-products from biomass. Applications include: petroleum-derived fuels, solvents at the rate of 200 tons per day, the complete fuel cycle, increased biomass yields, and the production of a renewable fuel source. Presents the technology of pyrolysis of biomass, has other aspects of the oil, with 27 chapters, covers various types of characterization, biomass, and chromatographic techniques and concludes with seven chapters on upgrading pyrolysis oil to liquid fuels.

Series of collaborative effort to combat the long term use in CO<sub>2</sub> sequestration resulting from deforestation and the burning of fossil fuels. Specialists from the workshop contributed the results of their research. A must for anyone interested in the progress in progress of production as a long-term solution to the need for a renewable source of liquid transportation fuel.

Ed J. Soltes, Editor, Texas A&M University  
Thomas A. Miles, Editor, Solar Energy Research Institute  
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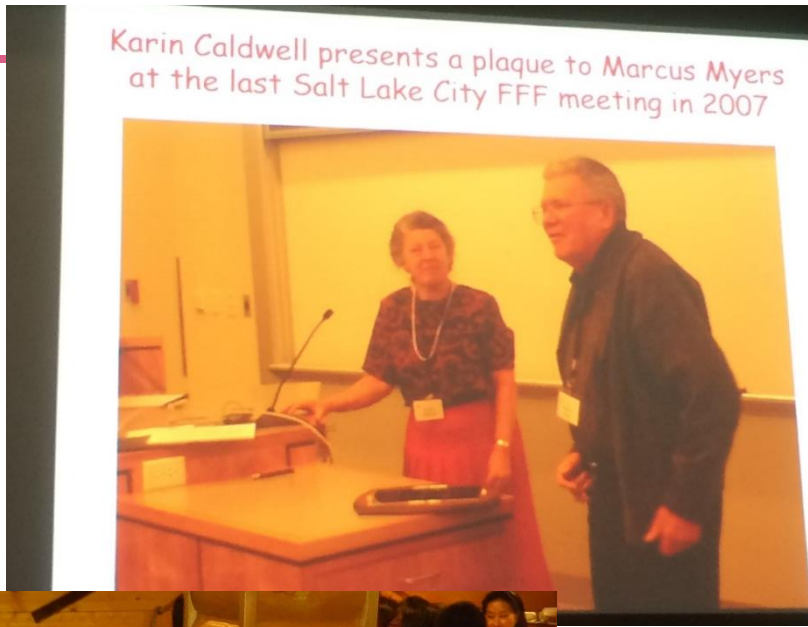
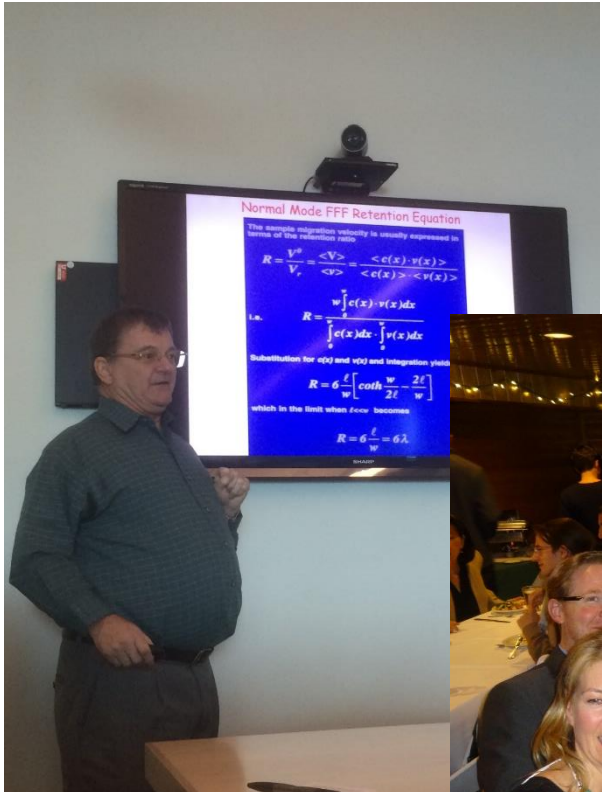
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TEL: 800-227-3558



Chair : John Calvin Giddings

# The place to be : Q9

- A : Riverside in 2022
- B : Salt Lake City in 2014
- C : Columbia in 2018





# The place to be : Q9

A : Riverside in 2022

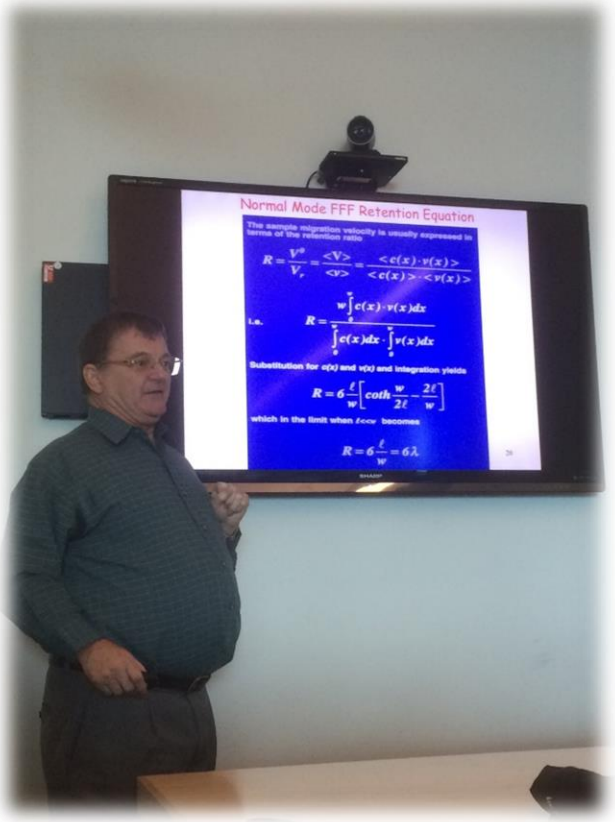
B : Salt Lake City in 2014

C : Columbia in 2018



# The place to be : Q9

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FFF 2014  
October 12-16, 2014

17th International  
Symposium On  
Field- and Flow- Based Separations

Salt Lake City, Utah, USA



Chair : Bruce Gale

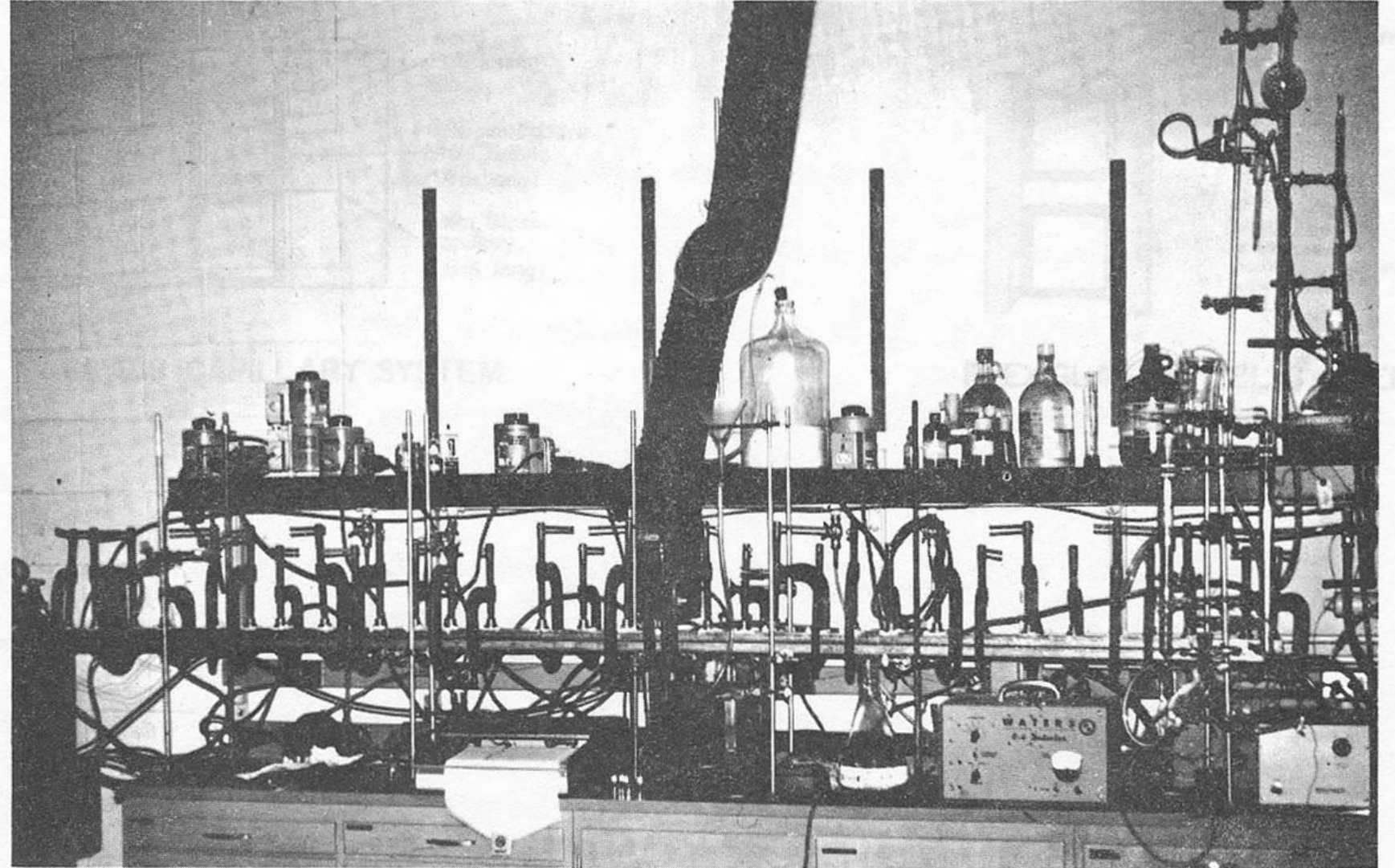
A stylized arrow icon with a gradient from red to yellow, pointing to the right.

# HISTORY

*SEE PART 1 TO ANSWER...*

# What is it? Q1

- A : M. C. Escher artwork
- B : FFF instrument
- C : Lab storage bench

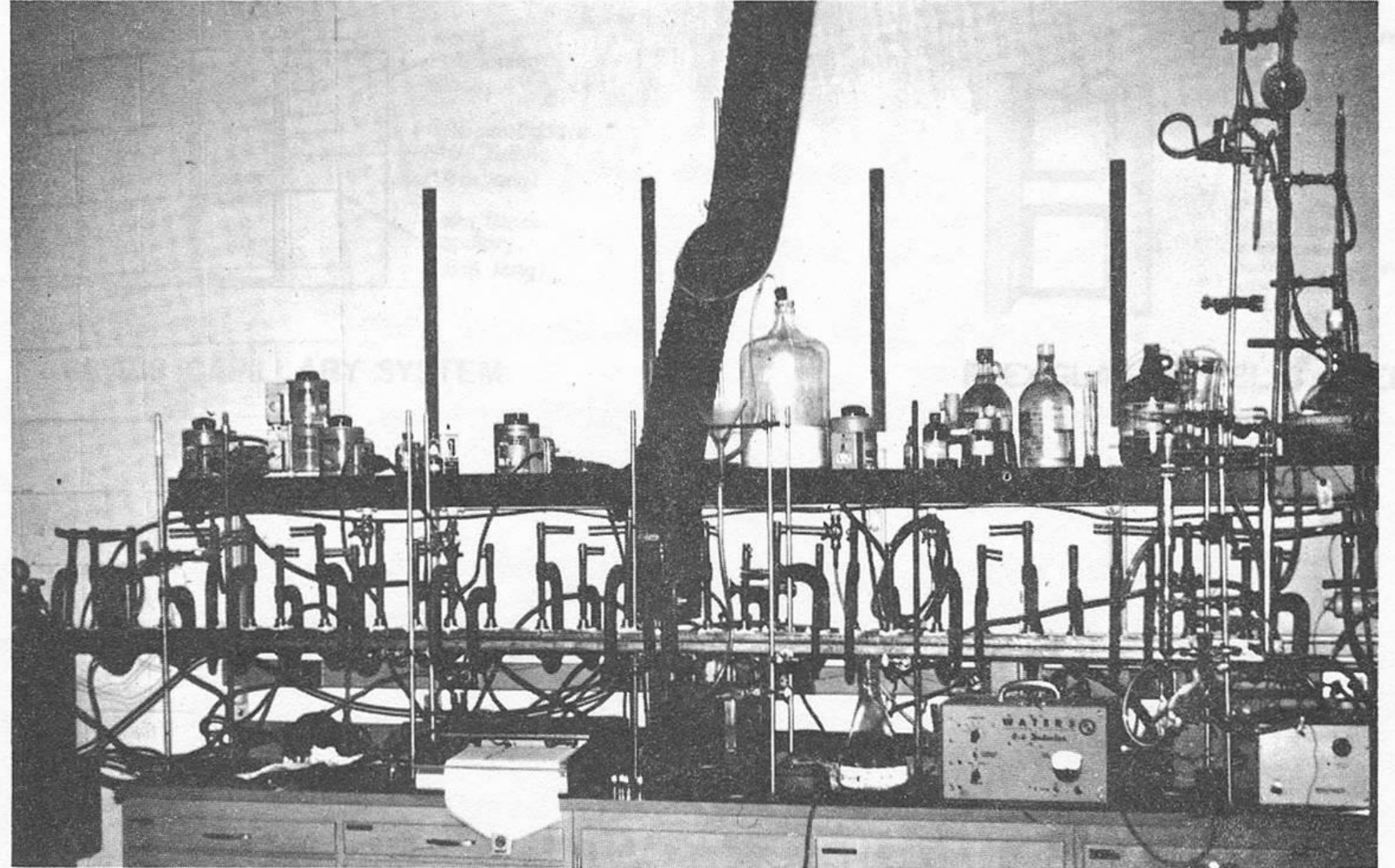


# What is it? Q1

A : M. C. Escher artwork

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# What is it? Q1

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C : Lab storage bench

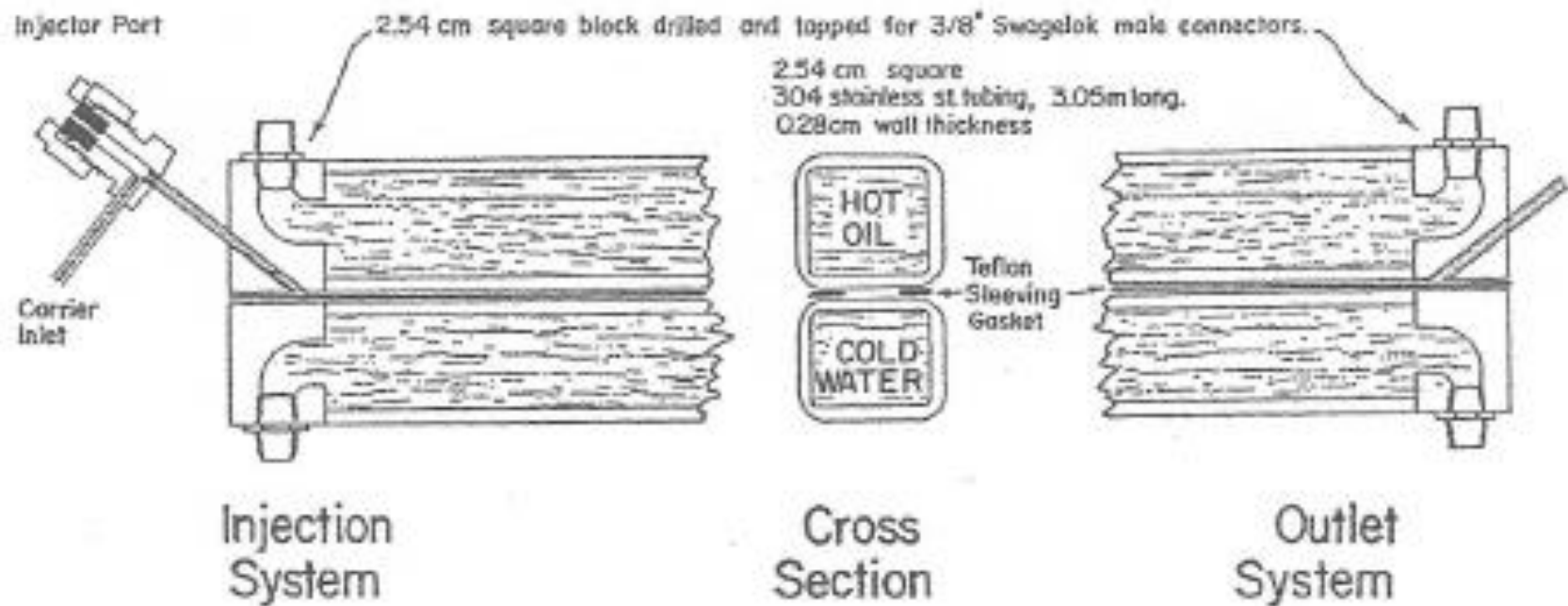
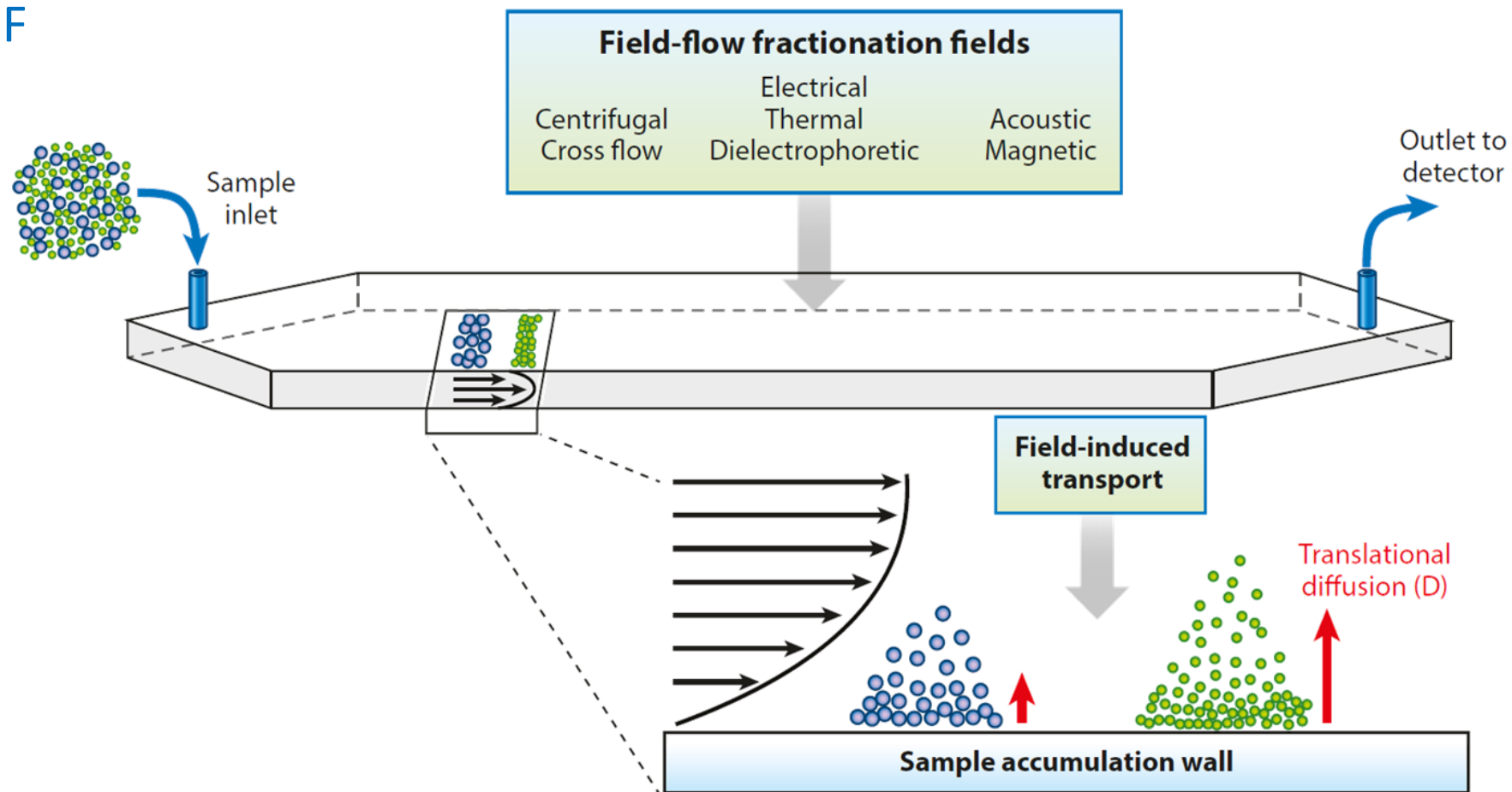


Figure 2. Diagram of the rectilinear channel system

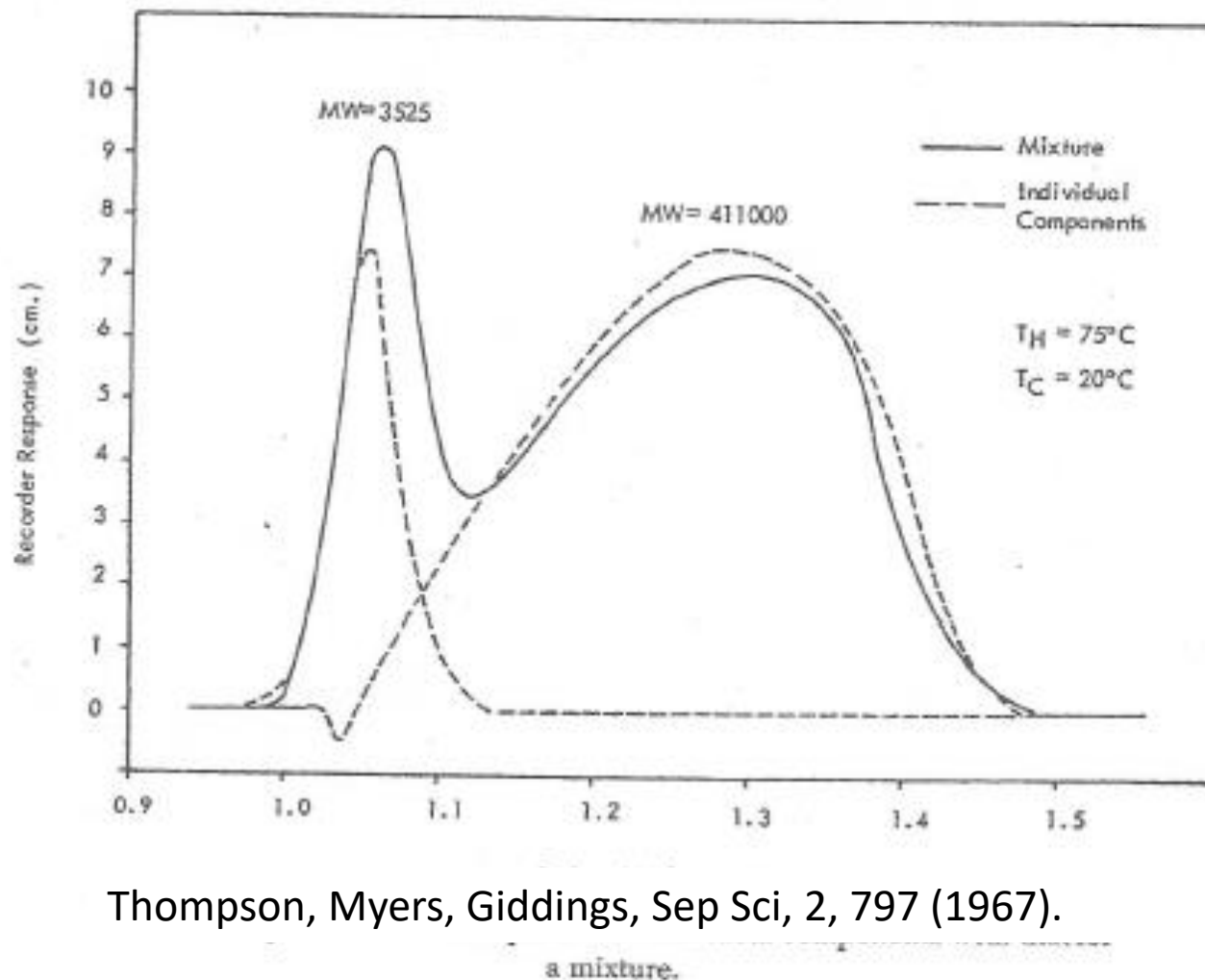
# Which FFF technique produced the first experimental results? Q2

- A : Flow FFF
- B : Centrifugal or SdFFF
- C : Thermal FFF
- D : Dielectrophoretic
- E : Magnetic
- F : Acoustic



# Which FFF technique produced the first experimental results? Q2

- A : Flow FFF
- B : Centrifugal or SdFFF
- C : Thermal FFF**
- D : Dielectrophoretic
- E : Magnetic
- F : Acoustic



Thompson, Myers, Giddings, Sep Sci, 2, 797 (1967).



## Properties of an Asymmetrical Flow Field-Flow Fractionation Channel Having One Permeable Wall

Karl-Gustav Wahlund<sup>1</sup> and J. Calvin Giddings\*

*Department of Chemistry, University of Utah, Salt Lake City, Utah 84112*

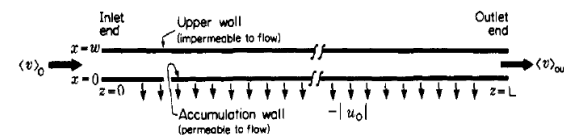
We describe here a flow field-flow fractionation channel having only a single permeable wall. This wall, serving as the accumulation wall, consists of a membrane/frit bilayer permeable to the carrier flow but impermeable to the sample. The opposite wall, impermeable to flow, is made of a glass plate, which renders the channel contents visible. In operation the channel has one incoming flowstream and two outgoing streams, one being the diffuse stream permeating the membrane. This design is technically simpler than conventional, more symmetrical designs where the upper wall is also permeable to flow. It is shown that the new design creates both longitudinal and transverse flow velocity gradients but retention, if sufficiently strong, can be interpreted in much the same way as with conventional channels. Theoretical expressions are obtained for velocity gradients, retention, and relaxation and focusing times. A fractionation of a mixture of proteins is shown in order to illustrate the potential for macromolecular separations.

Resolution in flow FFF, unlike that in other FFF sub-techniques, has been well below what theory predicts (4). This indicates that phenomena causing excessive zone broadening are operative in the channel. These might be associated with distorted flow profiles for axial and transverse flow and/or sample immobilization (e.g., by adsorption) at the accumulation wall. It is essential to develop new methodologies and concepts to help understand and overcome this deficiency.

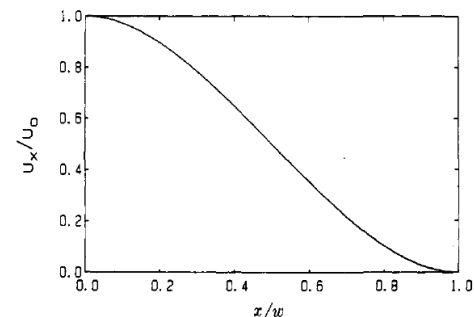
This paper presents a new design of the flow FFF channel which makes its construction technically simpler. The porous upper wall of the channel is replaced by a solid wall made of a glass plate. Thus the upper wall is impermeable to the carrier flow and the channel is left with only one source of carrier flow. This source is the channel inlet, located at one end of the channel. The carrier will exit the channel as two separate flowstreams, one a thin stream emerging from the outlet at the other channel end, and the other a diffuse stream passing through the accumulation wall.

This new “asymmetrical” design eliminates technical difficulties associated with the possible heterogeneity and uneven

- First paper: *Anal. Chem.*, **59**, 1332 – 1339 (1987).



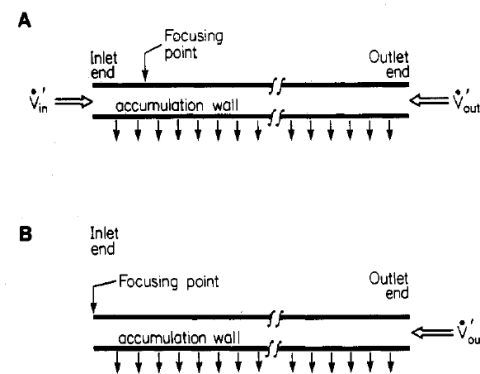
**Figure 1.** Schematic illustration of asymmetrical channel for flow field-flow fractionation. Flow velocities at designated locations are shown as  $\langle v \rangle_0$ ,  $\langle v \rangle_{out}$ , and  $u_0$  where the first two are the longitudinal flow velocities at the inlet and outlet ends, respectively, and  $u_0$  is the crossflow velocity at the accumulation wall.



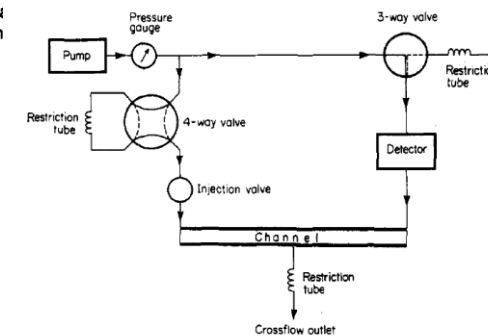
**Figure 2.** Crossflow velocity profile according to eq 1.

than the average longitudinal flow velocity, resulting in parabolic flow along the channel. Also the pressure drop along the channel is required to be much smaller than that across the accumulation wall in order to ensure a homogeneous permeation of the carrier. The transverse (crossflow) velocity distribution for our system according to this theory is

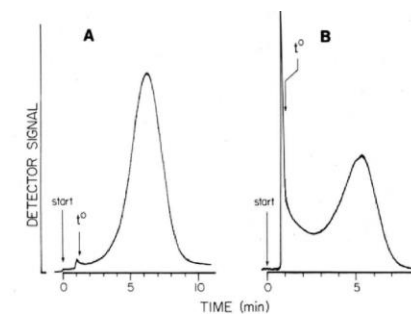
$$u_x = -|u_0| \left( 1 - \frac{3x^2}{w^2} + \frac{2x^3}{w^3} \right) \quad (1)$$



**Figure 5.** Schematic illustration of flow directions and focusing points for the two sample relaxation procedures. Part A illustrates opposing flow relaxation and B reverse flow relaxation.

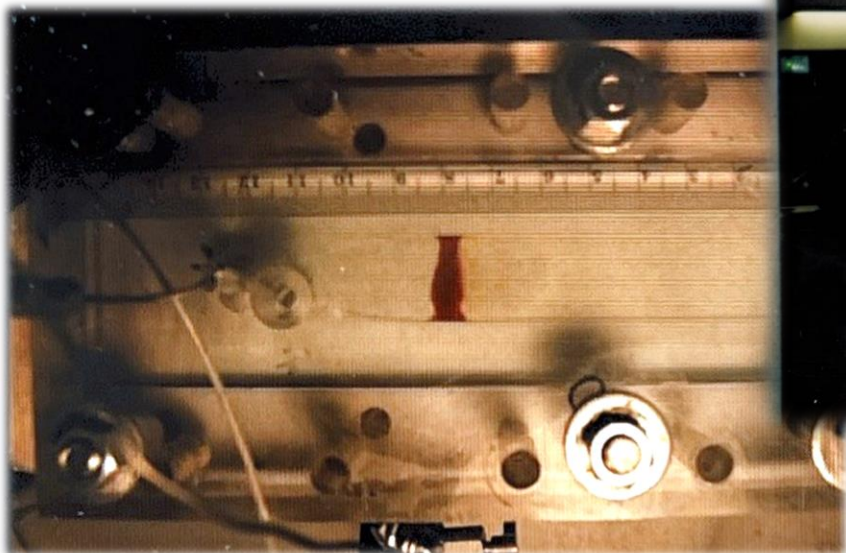


**Figure 6.** Illustration of flow system. The indicated flow direction and valve positions are for opposing flow relaxation and focusing. Dotted lines indicate valve positions during elution.



**Figure 8.** Comparison of cytochrome c peaks obtained with two sample relaxation methods. Flowrates during elution are as follows:  $\dot{V}_{in} = 4.9$  mL/min (23 psi);  $\dot{V}_c = 3.19$  mL/min;  $\dot{V}_{out} = 1.75$  mL/min. (A) Opposing flow relaxation with  $z' = 4.1$  cm and cross flowrate ( $\dot{V}_{in} + \dot{V}_{out}$ ) = 3.4 mL/min (21 psi); relaxation/focusing time (preceding “start”), 17 min ( $\tau(95\%) = 10$  min). (B) Reverse flow relaxation using cross flowrate = 4.9 mL/min (36 psi) and relaxation/focusing time = 19 min ( $\tau(95\%) = 6$  min).

# The origins of AF4



And don't forget KG's students who did marvelous work over many years in Lund: Anne Litzen, Bengt Wittgren, Michael Nilsson, Mats Andersson, Cecilia Arfvidsson, Mats Leeman, Gustaf Modig, Lars Nilson, ....

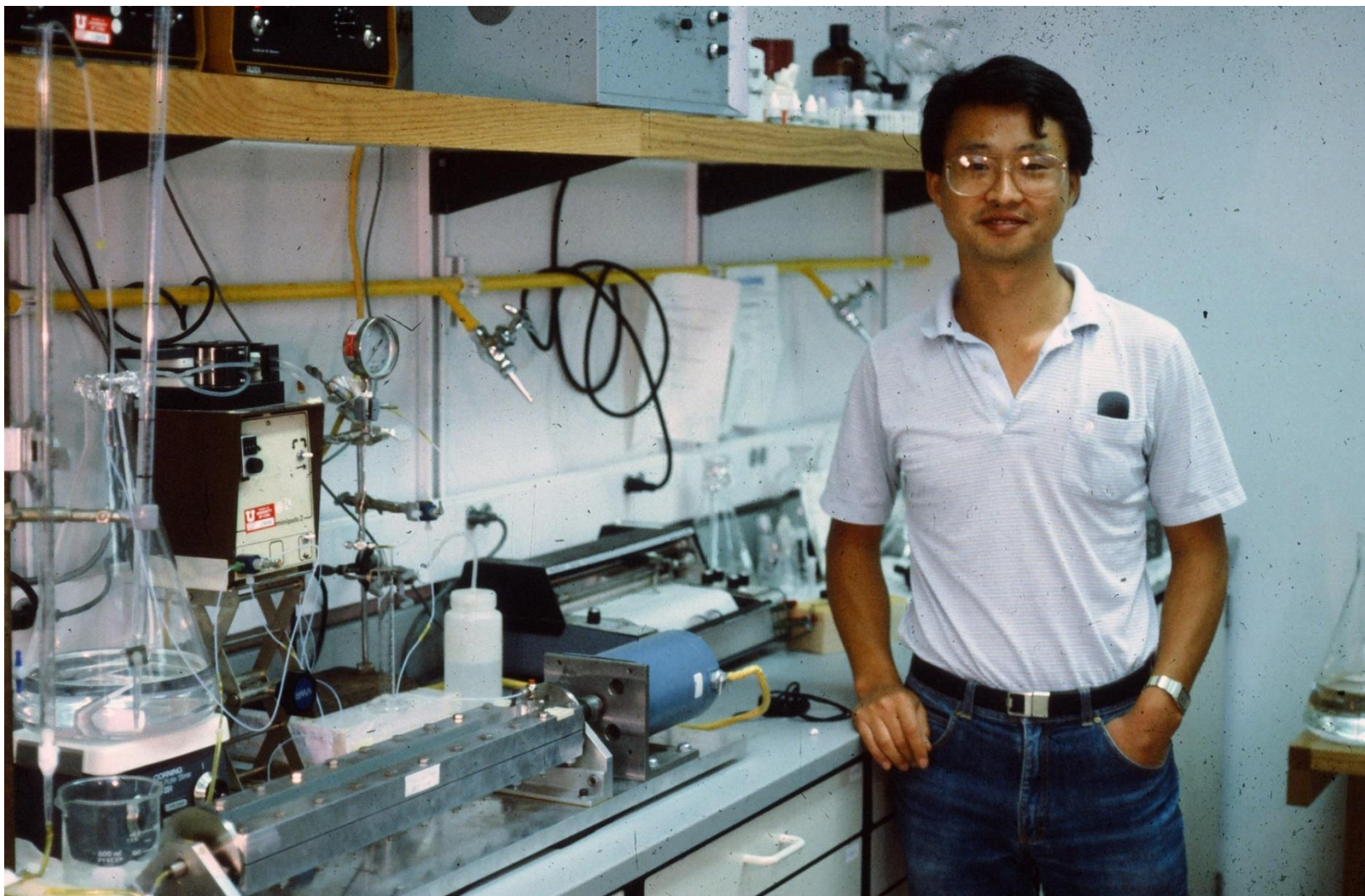
From the left, Enrica Alasonatti, Martin Schimpf.... **Lars Nilson** and Mauricio Hoyos

## What is Seungho Lee doing? Q3

A : Taking a break

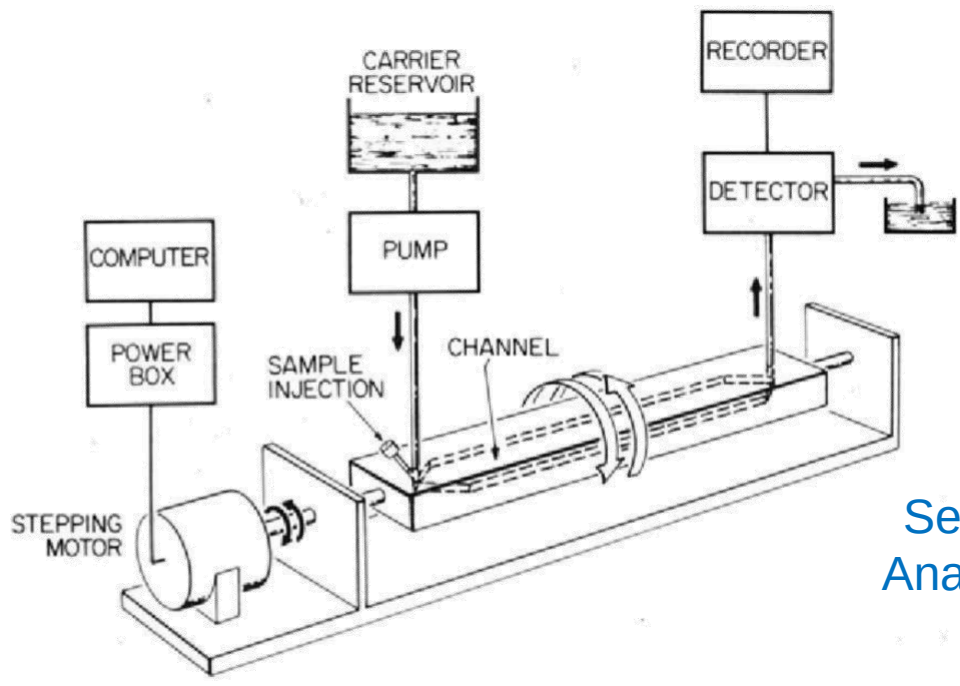
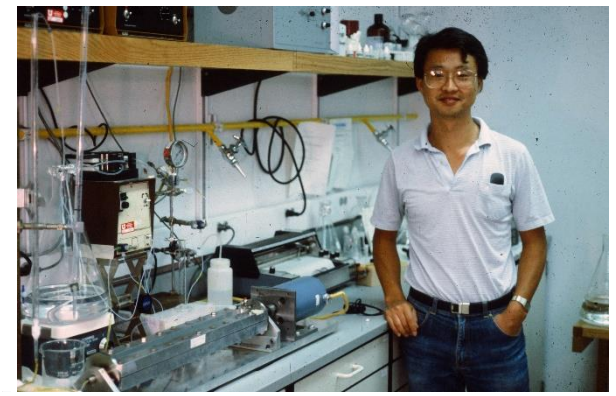
B : Watching a soccer match

C : Creating new FFF techniques

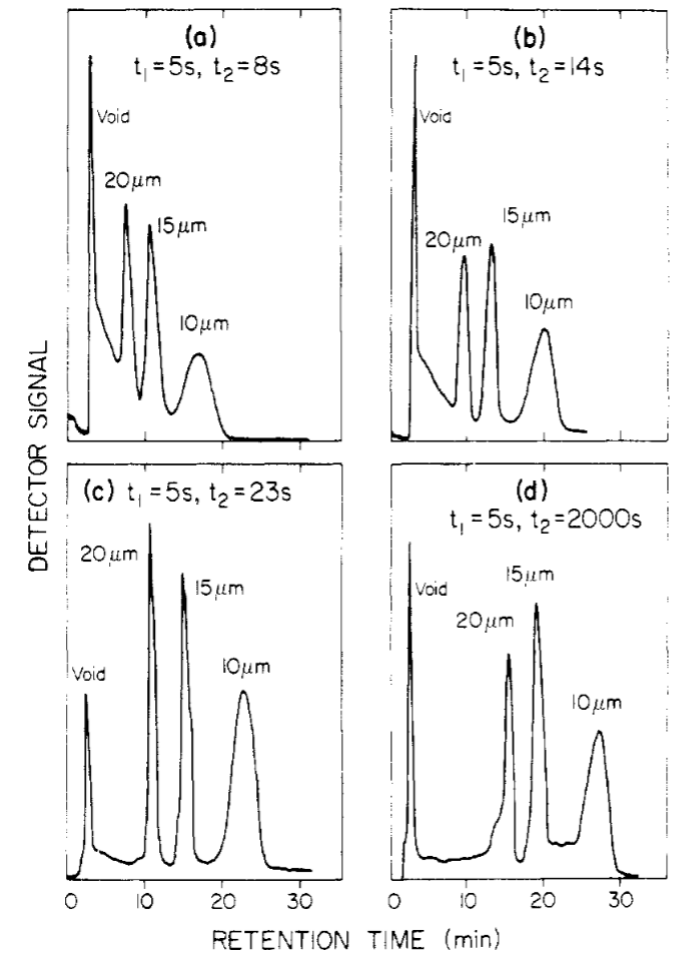


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- B : Watching a soccer match
- C : Creating new FFF techniques



Sedimentation/Cyclical FFF  
 Anal. Chem., 60, 1129 – 1135  
 (1988).



## What is it? Q4

- A : FFF instrument controller box
- B : White board with sticky notes
- C : Box of unknown origin found in  
Kim Williams research lab



A : FFF instrument controller box

B : White board with sticky notes

C : Box of unknown origin found in  
Kim Williams research lab



“Icki” box created by Dale Heisler (with  
Marcus Myers), University of Utah.

When were commercial FFF instruments first shown at Pittcon? **Q5**

- A : 1978
- B : 1988
- C : 1998
- D : 2008



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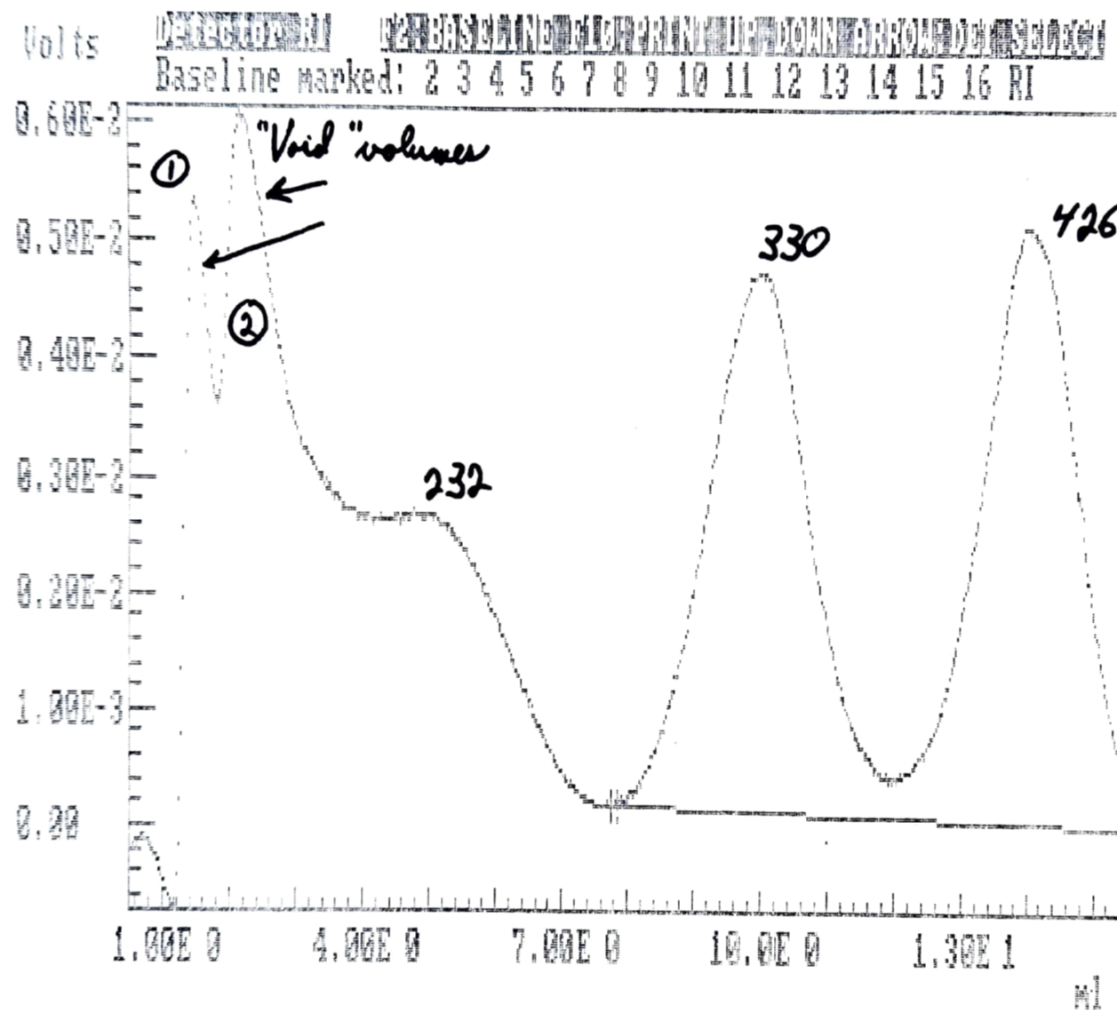


## When was FFF first coupled to MALS? Q6

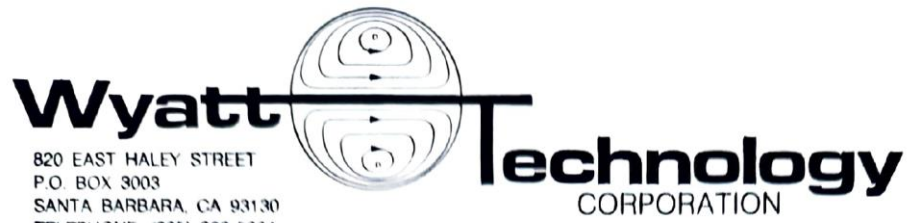
- A : 1979
- B : 1989
- C : 1999
- D : 2009

Who did this work? Q7

- A : Myeong hee Moon
- B : Phil Wyatt
- C : Marcus Myers
- D : Torsten Walter



UV detector



Except from letter

- A : 1979
- B : 1989**
- C : 1999
- D : 2009

- A : Myeong hee Moon**
- B : Phil Wyatt**
- C : Marcus Myers**
- D : Torsten Walter**

December 18, 1989

Professor Calvin Giddings  
Chemistry Department  
Henry Eyring Building, Room 2532  
University of Utah  
Salt Lake City, UT 84112

5. Finally, some results of my recent studies concerning Moon's measurements on SFFF of three latex "standards" of nominal diameter 232, 330, and 426 nm. Graph A presents the UV detector output and the designations of the peaks by Moon. On this basis, I normalized the detectors using the full Lorenz-Mie theory for the 330 nm results. The normalization coefficients were generated by comparing the measured results for 3 different slices in the peak at the scattering angles listed in Exhibit B. The lowest and highest angles (4.25° and 143.77°) were dropped. All numbers were relative to the values at 90°. The Lorenz data are shown attached to B also. Exhibit C lists the revised normalization coefficients for these experiments. Note that the booster amplifier gains had been set by me to 1X for detectors 3 through 9, and 21X for detectors 10 through 15.

WYATT TECHNOLOGY CORPORATION



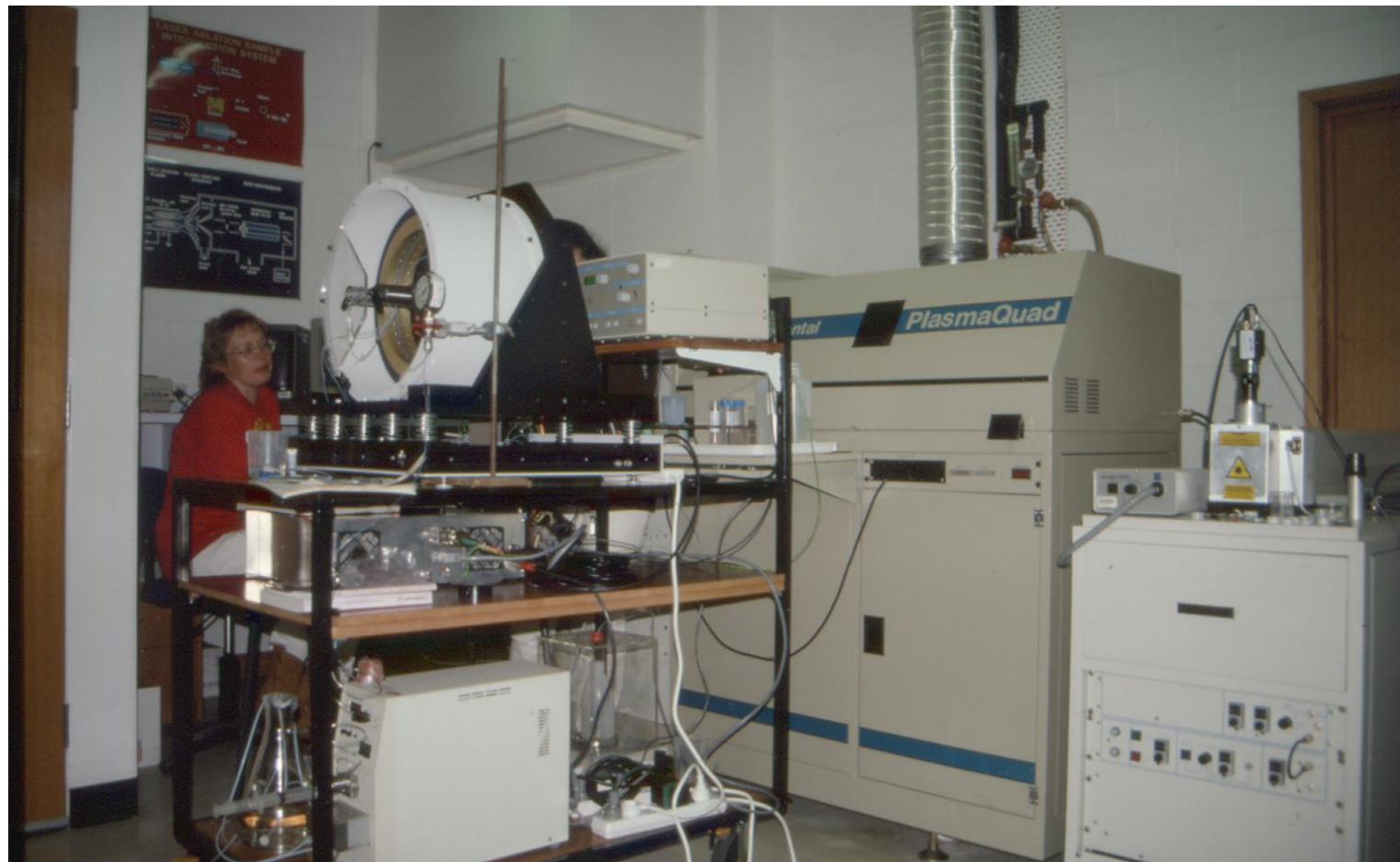
Philip J. Wyatt  
President  
PJW:hmb  
Enclosures

## When was FFF first coupled to ICP? **Q8**

- A : 1970s
- B: 1980s
- C: 1990s
- D: 2000s

## Who did this work? **Q9**

- A : Deidre Murphy
- B: Ron Beckett
- C: Atitaya Siripinyanond
- D: Raymond Barnes, Univ of Massachusetts

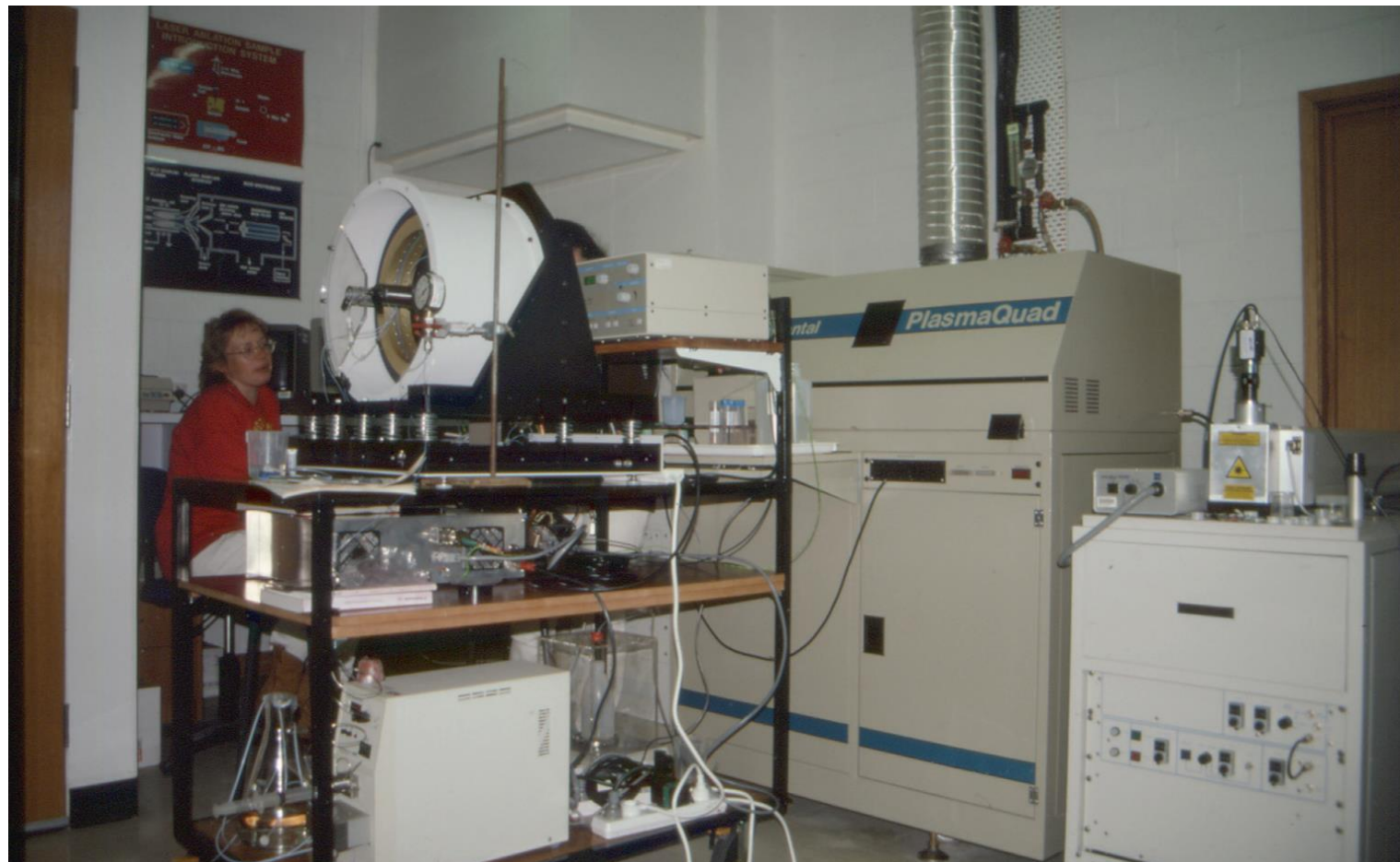


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*D.M. Murphy, et al., J. Chromatogr. 642, 459-467 (1993).*

How many times has France hosted the FFF symposium? **Q10**

- A : One
- B : Two
- C : Three
- D : Too many to remember



# How many times has France hosted the FFF symposium? Q10

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