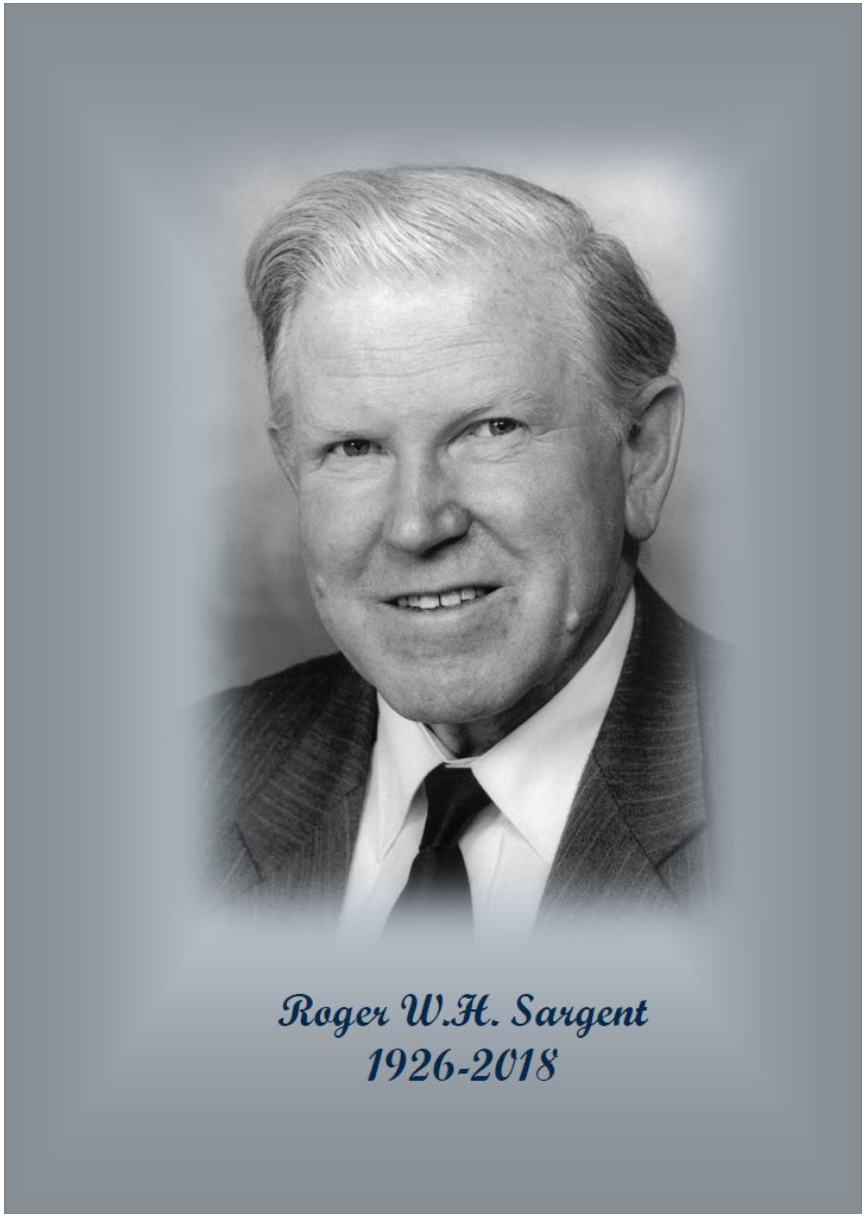
SESSION IN HONOR OF PROFESSOR ROGER SARGENT



SESSION IN HONOR OF PROFESSOR ROGER SARGENT

Sponsored by Process Systems Enterprise, Ltd.

Chair: Ignacio Grossmann, Carnegie Mellon University

8:00 a.m. to 8:05 a.m. *Session Introduction*

8:05 a.m. to 8:30 a.m. ***Roger Sargent: Intellectual Leader and Pioneer of Process Systems Engineering***
Ignacio Grossmann, Carnegie Mellon University

8:30 a.m. to 9:15 a.m. ***Process Modeling: From Sargent's Vision to its Current Directions***
Costas Pantelides, Imperial College London

9:15 a.m. to 9:40 a.m. ***Major Contributions by Roger Sargent in Nonlinear Optimization***
Ignacio Grossmann, Carnegie Mellon University

9:40 a.m. to 10:05 a.m. Refreshment Break

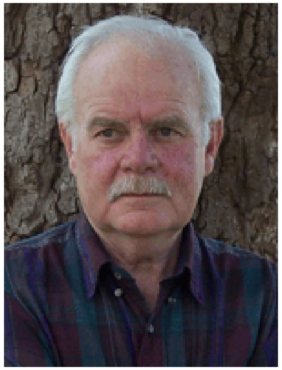
10:05 a.m. to 10:30 a.m. ***Distillation & Hybrid Separation: Modelling, Synthesis, Design & Operation***
Rafiqul Gani, PSE for SPEED

10:30 a.m. to 10:55 a.m. ***Scheduling in PSE: Before and After the State-Task Network***
Pedro Castro, University of Lisbon

10:55 a.m. to 11:20 a.m. ***Impact on Optimization, Control, and MPC***
Larry Biegler, Carnegie Mellon University

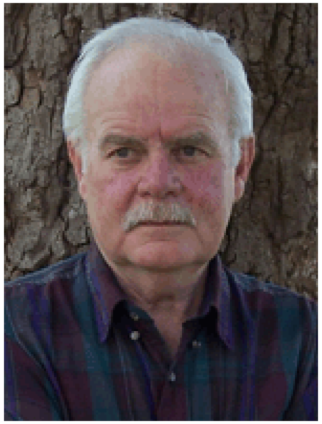
11:20 a.m. to 11:45 a.m. ***The Centre for Process Systems Engineering: Interactions and Integration***
Eva Sorensen, University College London

Major Losses for Process Systems Engineering



Dale F. Rudd (1935-2018)

Roger W.H. Sargent (1926-2018)



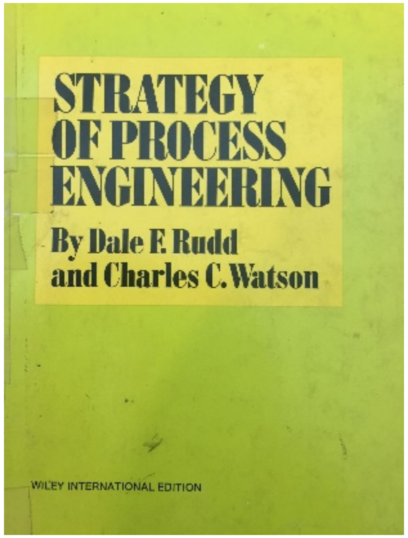
Dale F. Rudd

March 2, 1935, Minneapolis, Minn.

B.S. Chem. Eng. University Minnesota 1956
Ph.D. Chem. Eng. University Minnesota 1960

University of Michigan 1960-1962
University of Wisconsin, Madison 1962-
Slichter Professor Chemical Engineering

First textbook on PSE (1968)



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PART I. THE CREATION AND ASSESSMENT OF ALTERNATIVES
2. The Synthesis of Plausible Alternatives 11
3. The Structure of Systems 34
4. Economic Design Criteria 80
5. Cost Estimation 114

PART II. OPTIMIZATION
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12. Accounting for Uncertainty in Data 330
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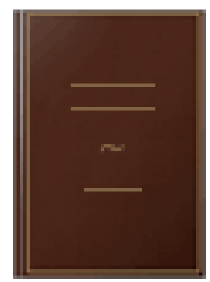
28 Ph.D. students supervised by Prof. Dale Rudd

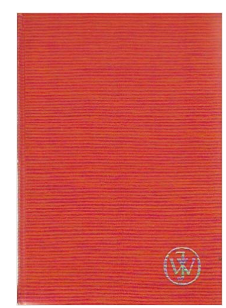
Lee, Woo-Young	1966	Kelly, Lloyd Ray	1972	Trevino, Andrés Antonio	1979
Christensen, James Henry	1967	Rivas, J. Roberto	1973	Brana-Mulero, Francisco Jose	1980
Park, Chang-Man	1967	Tedder, Daniel William	1975	Jiménez-Gutiérrez, Arturo	1982
Masso, Anthony Halim	1968	May, Dror	1976	Chavez, Octavio Emilio	1986
Bartman, Robert Verne	1969	Saidikowski, Ronald Martin	1976	Sigurdsson, Magnus	1986
Lee, Kwok-Fu	1969	Stadtherr, Mark Allen	1976	Tow, Daniel Stuart	1986
Engelstad, Donald George	1970	Lauerhass, Lance Norbert	1978	Bell, John Thornton	1990
Siirola, Jeffrey John	1970	Saxena, Ravindra Nath	1978	Biran, Yaacov	1990
King, Carl Fred	1971	Fathi-Afshar, Saeed	1979	Cisternas, Luis Alberto	1993
Powers, Gary James	1971				

61 publications, 2,042 citations h-index=22 (Web Science)

Rudd, Powers, Siirola,
***"Process Synthesis"* (1973)**

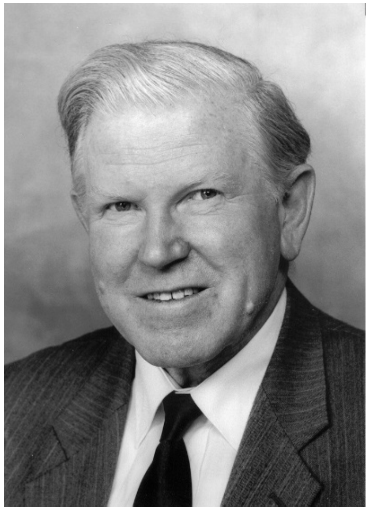


Rudd, Fathi-Afshar, Treviño, Stadtherr
***"Petrochemical Technology Assessment"* (1981)**



Intellectual Leader and Pioneer of Process Systems Engineering

Roger W.H. Sargent (1926-2018)



Roger W.H. Sargent

October 14, 1926, Bedford, England.

B.Sc. Chem. Eng. Imperial College, 1947
Ph.D. Chem. Eng. Imperial College, 1950

Air Liquide, Paris, 1951-58

Imperial College, 1958
Courtaulds Professor Chemical Engineering, 1962

President of the Institution of Chemical Engineers, 1973

Dean of the City and Guilds College, 1973-76
Head Department Chemical Engineering, 1975-88

Founding Fellow Royal Academy of Engineering, 1976

Founder and Director of the Centre for PSE (CPSE), 1989

Centre for
Process Systems Engineering

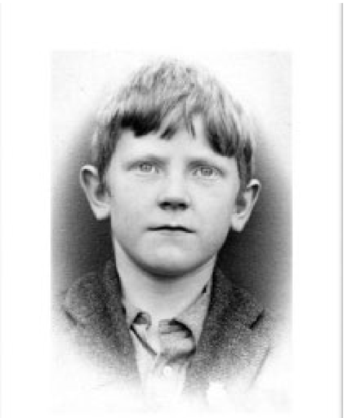
Promoted creation of
Process Systems Enterprise (PSE)

gPROMS

Roger W.H. Sargent

October 14, 1926, Bedford, England.

B.Sc. Chem. Eng. Imperial College, 1947
Ph.D. Chem. Eng. Imperial College, 1950



1931 - Roger 6 Years Old

1946 – B.S. graduation

1950 – PhD degree

THE DESIGN AND TESTING OF A FRACTIONATING COLUMN FOR THE SEPARATION OF AIR.

A Thesis presented for the Degree of

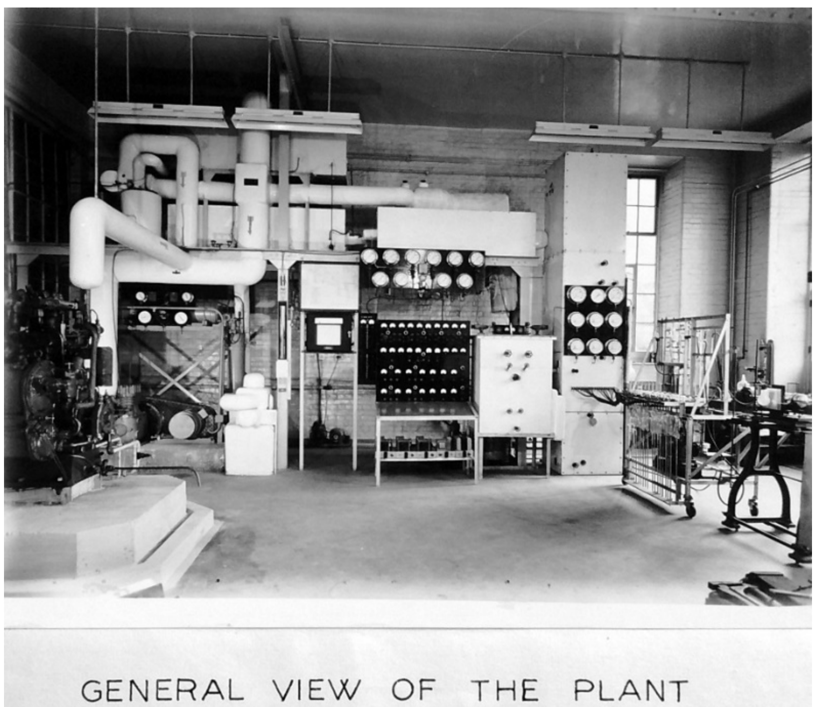
Doctor of Philosophy

of the University of London

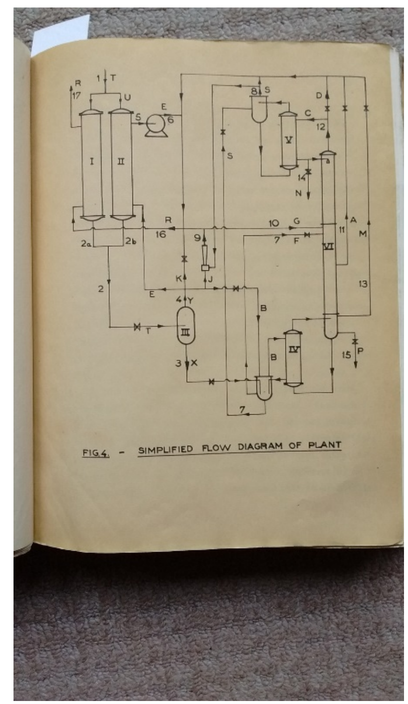
by

Advisor: Prof. Newitt

R.W.H. Sargent, B.Sc., A.C.G.I.



Pilot Plant Cryogenic Separation



Not a single equation!

Roger W.H. Sargent

October 14, 1926, Bedford, England.

B.Sc. Chem. Eng. Imperial College, 1947

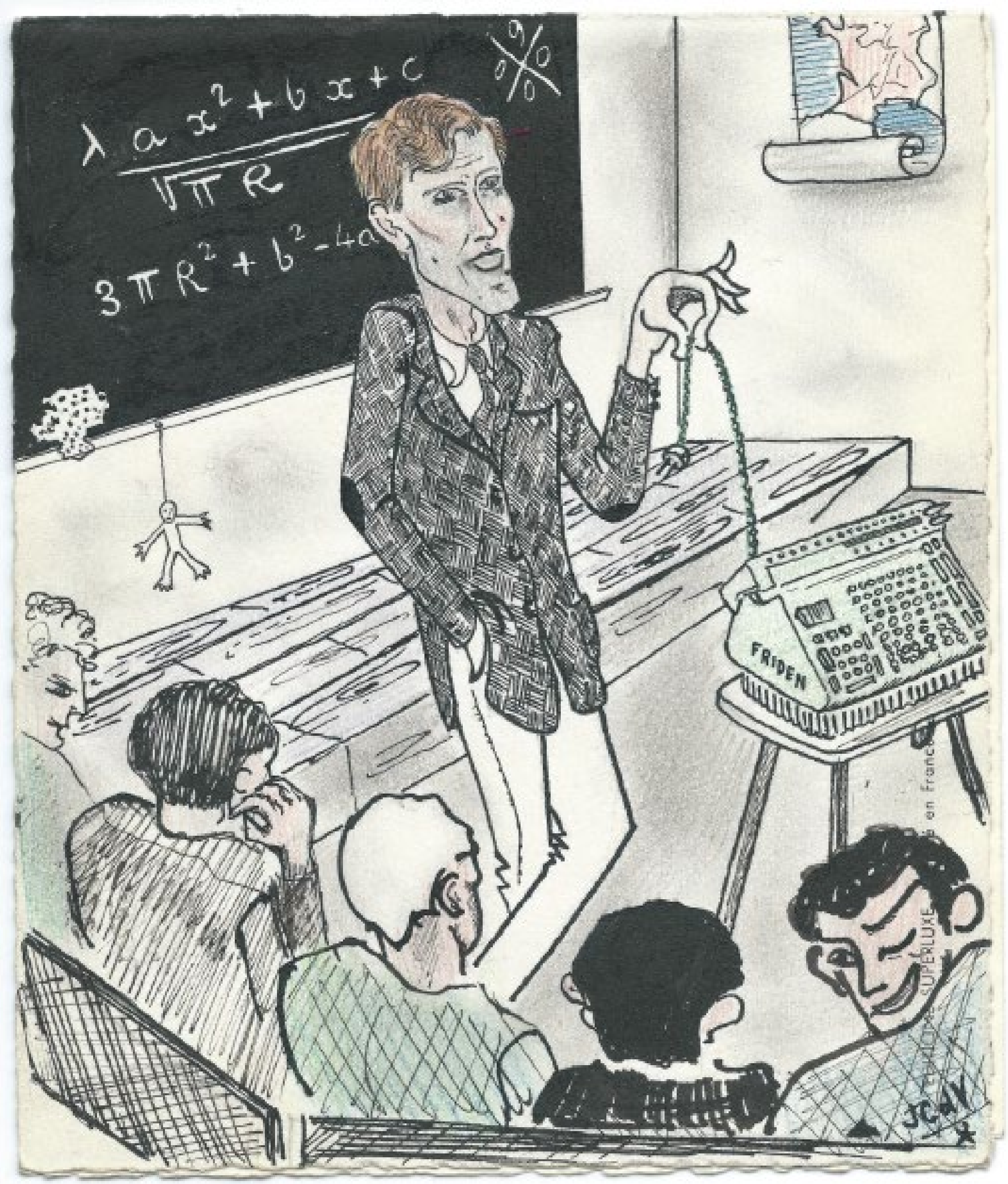
Ph.D. Chem. Eng. Imperial College, 1950


1931 - Roger 6 Years Old


1946 – B.S. graduation


1950 – PhD degree


Wife: Shirley 1951-58– Air Liquide, Paris



1956 Sketch of Roger W.H. Sargent at Air Liquide, Paris

1957 - Roger with Sons

Philip and Tony

Roger W.H. Sargent

October 14, 1926, Bedford, England.

B.Sc. Chem. Eng. Imperial College, 1947

Ph.D. Chem. Eng. Imperial College, 1950

1931 - Roger 6 Years Old

1946 – B.S. graduation

1950 – PhD degree

Wife: Shirley

1951-58– Air Liquide, Paris

1958– Senior Lecturer

1962 – Courtaulds Professor

Sargent RWH, Westerberg AW. SPEED-UP in Chemical Engineering Design.
Trans Inst Chem Eng. 1964;42:T190–T197.

"SPEED-UP" IN CHEMICAL ENGINEERING DESIGN

By Professor R. W. H. SARGENT, B.Sc.(Chem.Eng.), Ph.D., D.I.C., A.C.G.I. (MEMBER),*
and A. W. WESTERBERG, B.Sc., M.Sc.*

SYNOPSIS

A description is given of a general-purpose computer programme (SPEED-UP) for the analysis and design of complex chemical engineering processes. In developing the programme the problem arose of finding an optimum order of computation for the units within the plant, and the paper presents two algorithms based on list-processing which together provide the solution. The first algorithm obtains a sequence of units such that only a forward feed of information occurs, whilst the second deals with ordering the units in a group so as to minimise a sum of numbers associated with feed-back links.

The use of this second algorithm in a possible learning process to accelerate the convergence for iteration loops is indicated.

Introduction

It has become commonplace for the chemical engineer to turn to the digital computer for the solution of routine problems in process design, and the literature abounds with computer programmes and techniques for such standard problems as the rating of heat exchangers and the determination of the number of plates in a distillation column. The capabilities of modern computers are such that the time required for these routine design calculations is determined in large measure by the speed of input and output of data, and this time in turn is in general small compared with the time for preparation of the input data and for interpretation of the results. There thus arises a need for more compact means of presentation of the data and results, preferably in the chemical engineer's own language rather than in terms oriented towards the needs of the computer.

In the design of complete processes these routine calculations are only a small part of the total design effort. The individual unit calculations are interlinked via the process streams, and in the past a final self-consistent design for the whole process has generally been achieved by an iterative procedure in which the successive corrections were left largely to the judgment and intuition of the designer. The convergence of such procedures is often slow, and much time and effort is required. If one is more ambitious and attempts an overall optimisation of the plant performance, the work is much more arduous and this traditional method of attack is usually quite impracticable.

Nowadays optimisation is usually treated as a separate problem, and is normally carried out using a greatly simplified model of the process. The parameters of this model must be fixed on the basis of the results of detailed design of the individual units and again an iterative procedure is necessary, which again involves an enormous task of data interpretation and transcription.

The present paper describes part of the logic for a general-purpose programme called SPEED-UP (Simulation Programme for the Economic Evaluation and Design of Unsteady-state Processes) which will provide for an integrated approach to the optimum design of complex processes, and thus eliminate much of the need for intervention by the designer in the intermediate stages.

* Department of Chemical Engineering, Imperial College of Science and Technology, London, S.W.7.

Scope of SPEED-UP

The programme is intended to provide the logical framework of the overall design procedure, and adopts the "simulation" approach. That is, it sets up a mathematical model of the process from the specification, which can be used as many times as required to evaluate the performance of the plant, either for different input conditions, or for different values of design parameters within the process. It can therefore be used equally well for design or for investigating behaviour of an existing plant if the appropriate data are available; for example, different methods of starting up the plant can be studied, or the model may be used for production optimisation.

The completed programme will consist of five main parts:

(1) Reading of the process description.

(2) Arrangement of units in order of computation.

(3) Specification of data.

(4) Computation of plant performance for fixed values of the inputs and plant parameters.

(5) Readjustment of the input and parameter values, and possibly also the structure of the plant, to obtain desired or optimum conditions.

The present paper deals mainly with the first two stages of the programme, but it is necessary to give some consideration to the methods of dealing with the other stages in order to make the requirements clear.

Data Specification

There are six main types of data required for the complete process calculation:

(1) The flow-diagram or process structure.

(2) Data on the nature and properties of the materials being processed (*e.g.* enthalpies, reaction rate data, particle size distribution).

(3) Data giving characteristics of individual plant units (*e.g.* number of plates in a column, pressure-drop correlations, lagging thickness).

(4) Data on feed-streams and other inputs to the plant.

(5) (*a*) The initial state of the plant, in the case of simulation of dynamic behaviour.

or (*b*) The performance specifications, in the case of design.

(6) Information on the results required, their accuracy and the method of setting them out.

General purpose simulation program for chemical processes

Finding optimal sequence of computation of units to achieve fast convergence

Roger W.H. Sargent

CEP review

Integrated Design and Optimization of Processes

Although we are in sight of a truly integrated approach to the design of complete processes, a great deal of work remains to be done. With the need for more sophisticated analysis of larger complexes, it is more than ever necessary to join hands with those working in the fields of control engineering, operational research, numerical analysis, and computer science.

R. W. H. Sargent
Imperial College of Science and Technology, University of London, London, England

Visionary paper in 1967 on:

- *Process design and integration with control, reliability*
- *Process models: steady state, dynamics*
- *Strategy of process calculations*
- *Computational methods for optimization*

Sargent, R.W.H., "Integrated Design and Optimization of Processes," Chemical Engineering Progress, Volume: 63 Issue: 9, Pages: 71-78 (1967).

The PSE Faculty at Imperial College in 1974

Roger Sargent Lester Kershenbaum John Perkins

Roger W.H. Sargent

October 14, 1926, Bedford, England.

B.Sc. Chem. Eng. Imperial College, 1947
Ph.D. Chem. Eng. Imperial College, 1950


1931 - Roger 6 Years Old


1946 – B.S. graduation

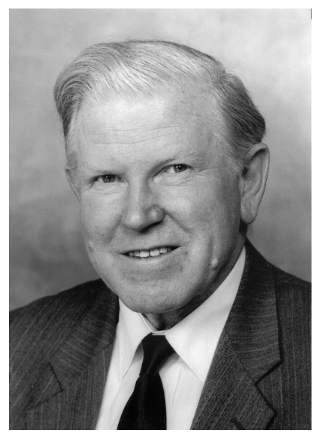

1950 – PhD degree


Wife: Shirley 1951-58– Air Liquide, Paris


1958– Senior Lecturer


1962 – Courtaulds Professor


1973 - President of IChemE


1975 – Department Head


1990 – Director CPSE


2008 – Sargent Lecture

Sargent's major contributions to PSE:

- **Process modeling**

  Equation oriented flowsheeting, DAEs dynamics

- **Optimization, distillation, control and scheduling**

  Nonlinear programming, optimal control

  Design, distillation columns, uncertainty

  Batch design and scheduling

PSE term used 1st time at: International Symposium of Process Systems Engineering, Kyoto, Japan (1982) ***Sargent-Takamatsu***

67 publications, 2,958 citations h-index=20 *(Web Science)*

A GENERAL ALGORITHM FOR SHORT-TERM SCHEDULING OF BATCH OPERATIONS . 1. MILP FORMULATION
Kondili, E; Pantelides, CC; Sargent, RWH
COMPUTERS & CHEMICAL ENGINEERING 17, 211-227 (1993) **695 citations**

COMPUTATIONAL EXPERIENCE WITH QUADRATICALLY CONVERGENT MINIMISATION METHODS
Murtagh, BA; Sargent, RWH
COMPUTER JOURNAL 13, 185 (1970) **335 citations**

48 Ph.D. students supervised by Professor Roger Sargent

R. S. H. Mah	S. F. Goldmann	Ignacio E. Grossmann	D. Juarez-Romero
W. P. Macmillan	B. A. Murtagh	R. Benveniste	E. Kondili
K. Chandrasekharan	B. L. Joffe	R. Hernandez-Sosa	D. M. Gritsis
L. O. Dworjaryn	M. J. Leigh	S. J. Byrne	Nilay Shah
R. H. Davies	R. J. Newell	Rafiqul Gani	R. Vasquez-Roman
Arthur W. Westerberg	D. J. G. Sebastian	S. Gomez-Gomez	J. L. Morales Perez
K. B. Wilson	G. D. D. Jackson	Ian T. Cameron	Vassilios S. Vassiliadis
G. P. Pollard	G. G. K. K. Gaminibandara	A. Eliceche	X. Zhang
Robert C. Schroter	John D. Perkins	B. Erik Ydstie	M. Ding
J. D .T. Bernard	R. J. Burkett	David W. Edwards	J. H. Cho
R. J. Young	D. J. Mellefont	K. R. Morison	M. Bell
C. J. Withford	G. R. Sullivan	Costas C. Pantelides	J. A. Barber

Academic Tree: over 2000 names!

For complete academic tree see:

http://titan.engr.tamu.edu/Sargent_tree/

Awards

Fellow Royal Academy of Engineering (1976)
Silver Medal of the "Ville de Paris" (1986)
Doctor honoris causa Institut National Polytechnique de Lorraine (1987)
Doctor honoris causa of the University of Liège (1995)
US National Academy of Engineering (1993)
Fellow of the Royal Society of Arts
Computing in Chemical Engineering Award of AIChE (1990)
Nordic Process Control Award (2003)
MM Sharma medal by IChemE (2015)
Sir Frank Whittle Medal, Royal Academy of Engineering (2016)

1990 Computing in Chemical Engineering Award

CAST Division of AIChE, Miami, USA

Longest applause ever after Sargent's speech (3 min

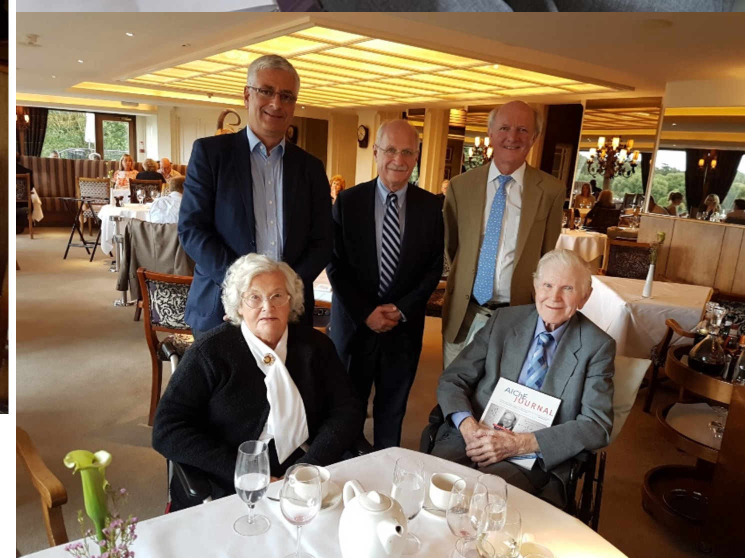
Founders Tribute Issue: September 2016

Doherty, M.F., I.E. Grossmann and C.C. Pantelides, "A tribute to professor Roger Sargent: Intellectual leader of Process Systems Engineering," *AIChE J.* 62, 2951-2958 (2016)

Roger Sargent's Family

Wife:* *Shirley

Sons:* *Philip, Tony



Reflections by Roger Sargent on PSE

Sargent, R.W.H..
"Special Issue on Process Systems Engineering-Critique"
Computers & Chemical Engineering **12**, R7-R11 (1988)

Sargent, RWH
"Introduction: 25 years of progress in process systems engineering"
Computers & Chemical Engineering, **28**, 437-439 (2004)

Sargent, R.W.H.
"Process systems engineering: A retrospective view with questions for the future", *Computers and Chemical Engineering* **29**, 1237–1241 (2005)

Sargent, R.W.H.
"My Contribution to Broadening the Base of Chemical Engineering,"
Annual Review of Chemical and Biomolecular Engineering, **2**, 1-7 (2011)

Roger W.H. Sargent (1926-2018)

Founder and pioneer of Process Systems Engineering

Brilliant researcher who had a tremendous impact in the field

He was a true inspiration to his students, a visionary scholar with very high standards who believed in the power of mathematical optimization.

He was a true gentleman, and above all, a very kind human being.

Roger W.H. Sargent
1926-2018