

Curriculum Vitae A.N.R. (René) Bos

René Bos is currently *Team Lead* "Process Innovation" as well as *Theme Lead* "Methane to Products" at Shell Technology Centre, Amsterdam. Since June 2018 he is also part time guest professor "Industrial Reaction Engineering" at the Laboratory of Chemical Technology, Ghent University.

He received his chemical engineering degree from University Twente where he also obtained his PhD in 1992 on "Reactor and catalyst dynamics and stability - the hydrogenation of ethyne in ethene".

He joined Shell in September 1991 where he has had a variety of roles in Amsterdam, Pernis and Houston, mostly within research and technology but also at manufacturing sites as advising technologist. From 1991 to 2007 he worked as (senior) scientist on topics comprising ethylene oxide, ethylene glycol, DeNO_x, EpiChloroHydrin, Methanol To Olefins, catalytic oxidation of NH₃, Versatic Acids production, Butadiene Rubber, Carilon and Carilite, PIB/MALA production and SMPO (Styrene + Propylene Oxide). In January 2008 he became Principal Scientist and overall project lead for all Fischer-Tropsch / GTL exploratory and explanatory R&D, with an annual budget varying between 5 and 10 Million US\$/yr.

Since 2013 he is the team lead "Process Innovation" (~13 staff) within the department Emerging Technologies that focuses on lead generation, experimental proof of concept and subsequent process development mostly, but not exclusively, in the field of Gas to Chemicals (C1 – C3 to bulk chemicals) and the broader field of Methane to Products. His team works with a wide range of experimental equipment, including small pilot plants, many micro-flow reactors suitable for high pressures and temperatures (up to 1400 °C / 50 bar) and also a range of advanced analytical / surface science techniques. Next to his team lead role, he also runs the "Reactor Engineering skill network" and the advanced internal course "Industrial Reaction Engineering and Conceptual Process Design".

Externally from Shell, he has been several times invited lecturer for the post-graduate OSPT-course "Process Development and Scale-up" (University Amsterdam, 1993 – 1995), the graduate course "Scale-up of fixed and moving bed reactors" (University Twente, 2000 - 2005), the post graduate NIOK course "Advanced Catalysis Engineering" (TU Delft, 2009) and invited lecturer on Reactor Engineering (TU Eindhoven, 2015).

In 1998, with Prof. Marin (Ghent, but then TU Eindhoven) and representatives from DSM and DOW, he was one of the founding members of the consortium "EuroKin", which is still operative today. From 2005 to 2010 he also represented Shell as executive officer of the Dutch-Belgium branch of the American Institute of Chemical Engineers and from 2013 onwards as member of "College van Toezicht" of the Hogeschool Utrecht.

Overall he (co-) authored 33 published scientific publications in the open literature (next to >100 Shell internal research reports) and 36 Patent Applications, see the full list attached, with added some Oral contributions at international conferences.

Career

2018 – present Guest Professor Industrial Reaction Engineering, Ghent University
2013 – present Team Lead Emerging Technologies, Shell Technology Centre, Amsterdam (STCA)
2008 – 2013 Principal Scientist & Overall Project Lead GTL Exploratory/Explanatory, STCA
2003 – 2007 Senior Research Technologist SMPO (Styrene Monomer / Propylene Oxide), STCA
1999 – 2003 Senior Research Technologist Ethylene Oxide and Ethylene Glycols, STCA
1998 – 1999 Process Development Engineer EO/EG, Shell Oil Company, Houston, USA
1995 – 1998 Advising Technologist Versatic Acids Plant, Shell Nederland Chemie, Pernis
1991 – 1995 Reactor Engineer, Koninklijke Shell Laboratorium, Amsterdam (KSLA)

Education

1992 PhD in Chemical Engineering, University Twente, advisor Prof. K.R. Westerterp (Committee members included Prof. Van Swaaij, Prof. Eigenberger and Prof. Geus)
1987 Scheikundig Ingenieur (Master in Chemical Engineering), University Twente

Attached: List of publications in the open literature and patent applications

List of publications and patents of A.N.R. Bos, dd January 2018

[34] Kezheng Zhu, René Bos, Klaus Hellgardt, Activation of Catalysts in Commercial Scale Fixed-Bed Reactors: Dynamic Modelling and Guidelines for Avoiding Undesired Temperature Excursions, submitted for publication.

[33] Christos Kalamaras, David Palomas, Rene Bos, Andrew Horton, Mark Crimmin, Klaus Hellgardt Selective Oxidation of Methane to Methanol over Cu- and Fe-exchanged Zeolites: The Effect of Si/Al Molar Ratio, *Catalysis Letters*, January 2016, pp 483–492.

[32] Zoi F. Makrodimitri, Andreas Heller, Thomas M. Koller, Michael H. Rausch Matthieu S.H. Fleys, A.N. René Bos, Gerard P. van der Laan, Andreas P. Fröba, Ioannis G. Economou, Viscosity of heavy n-alkanes and diffusion of gases therein based on molecular dynamics simulations and empirical correlations, *J. Chem. Thermodynamics* 91 (2015) 101–107.

[31] Andreas Heller, Thomas M. Koller, Michael H. Rausch, Matthieu S. H. Fleys, A. N. René Bos, Gerard P. van der Laan, Zoi A. Makrodimitri, Ioannis G. Economou and Andreas P. Fröba, Simultaneous Determination of Thermal and Mutual Diffusivity of Binary Mixtures of n-Octacosane with Carbon Monoxide, Hydrogen, and Water by Dynamic Light Scattering, *J. Phys. Chem. B*, 2014, 118 (14), pp 3981–3990.

[30] J.K.F. Buijink, Jean-Paul Lange, A.N.R. Bos, A.D. Horton and F.G.M. Niele, Propylene Epoxidation via Shell's SMPO Process: 30 Years of Research and Operation, in *Mechanisms in Homogeneous and Heterogeneous Epoxidation Catalysis*, ed. S. Ted Oyama, Elsevier 2008.

[29] A.N.R. Bos, J.P. Lange and G. Kabra, A novel reverse flow reactor with integrated separation, *Chemical Engineering Science* 62, 18-20, 2007, pp 5661-5663.

[28] P.A.A. Klusener, G. Jonkers, F. During, E.D. Hollander, C.J. Schellekens, I.H.J. Ploemen, A. Othman and A.N.R. Bos, Horizontal cross-flow bubble column reactors: CFD and validation by plant scale tracer experiments, *Chem. Engng Sci.* 62, 18-20, 2007, pp 5495-5502.

[27] A.K. Nayak, D. Lathouwers, T.H.J.J. van der Hagen, A.N.R. Bos, F.J.M. Schrauwen, A numerical study of a closed loop thermosyphon system, in: *Proceedings of the Third International Conference on Computational Heat and Mass Transfer (APM2003)*, 2003, pp. 1–10.

[26] Roel Westerterp, René Bos, Ruud Wijngaarden, Wout Kusters and Albert Martens, *Chem. Eng. Technol.* 25 (2002).

[25] Roel Westerterp, René Bos, Ruud Wijngaarden, Wout Kusters and A. Martens, Selective hydrogenation of acetylene in an ethylene stream in an adiabatic fixed bed reactor, *Inzynieria Chemiczna I Procesowa*, 2000, pp 7-28.

[24] A.N.R. Bos, Rules of thumb for Chemical Engineers – Book review, *Chem. Engng Journal* 73, 1999, pp 261.

[23] A.N.R. Bos, L. Lefferts, G.B. Marin, M.H.G.M. Steijns, Kinetic research on heterogeneously catalysed processes: A questionnaire on the state-of-the-art in industry, *Applied Catalysis A: General* (160)1 1997 pp. 185-190.

[22] A.N.R. Bos and E.H.P. Wolff, Dynamische modellering van molgewichtsdistributies bij polymerisatie reacties, NPT, June 1998.

[21] Wolff, E.H.P. and Bos, A.N.R., Modelling of polymer molecular weight distributions: Application to the case of polystyrene, *Ind. Engng Chem. Res.*, May 1997.

[20] Bos, A.N.R., Postma, R. and Menninga, L., Complex gedrag bij het ontwerp van een simpel catalytisch oxydatie proces, NPT December 1996.

[19] Bos, A.N.R., Postma, R. and Menninga, L., Dynamic and steady state behaviour of reactor and process for the catalytic oxydation of NH₃, *Proc. Symposium Dynamics and control in process design*, 13 March 1996.

[18] Bos, A.N.R. and Woldhuis, A.F., 1996, The Lateral Flow Reactor: a novel low pressure drop reactor for catalytic reactions. Modelling and design for the Shell Denox System, ISCRE-14

- [17] Westerterp, K.R., Bos, A.N.R. and Wijngaarden, R.J., 1995, Unsteady state processes in catalysis 2: proc. of the international conference, 10-13 September 1995.
- [16] Bos, A.N.R., Tromp, P.J.J. and Akse, H.N., 1995, The conversion of methanol to lower olefins. Kinetic modelling, reactor simulation and selection, *Ind. Eng. Chem. Res.* 34, pp 3808-3816.
- [15] Akse, H.N., Bos, A.N.R., and Tromp, P.J.J., 1994, Etheen uit methanol?, NPT, November, pp 25-29.
- [14] Borman, P.C., Bos, A.N.R. and Westerterp, K.R., 1994, A novel reactor for the determination of kinetics for solid catalyzed gas reactions, *AIChE. J.*, 3, pp 862-869.
- [13] Bos, A.N.R., Beld, L. van de, Martens, H.J. and Westerterp, K.R., 1993, Behaviour of an adiabatic packed bed reactor. part 2: Modelling, *Chem. Eng. Comm.*, 121, pp 55-80.
- [12] Bos, A.N.R., Beld, L. van de, Overkamp, J.B. and Westerterp, K.R., 1993, Behaviour of an adiabatic packed bed reactor, part 1: experimental study, *Chem. Eng. Comm.*, 121, pp 27-53.
- [11] Bos, A.N.R., Hof, E., Kuper, W. and Westerterp, K.R., 1993, The behaviour of a single catalyst pellet for the selective hydrogenation of ethyne in ethene, *Chem. Engng Sci.*, 48, 11, pp 1959-1969.
- [10] Bos, A.N.R., Bootsma, E.S., Foeth, F., Sleyster, H.W.J. and Westerterp, K.R., 1993, A kinetic study of the selective hydrogenation of ethyne and ethene on a commercial Pd/Al₂O₃ catalyst, *Chem. Engng Process.*, 32, pp 53-63.
- [9] Bos, A.N.R. and Westerterp, K.R., 1993, Mechanism and kinetics of the selective hydrogenation of ethyne and ethene. A review, *Chem. Engng Process.*, 32, pp 1-7.
- [8] K.R. Westerterp, A.N.R. Bos, J.G.H. Borkink, W.J.A. Wammes, *Technische Reaktionen und Technische Reaktionsführung, Chemie-Ingenieur-Technik*, 63, pp 286-288.
- [7] Bos, A.N.R. and Westerterp, K.R., 1991, The behaviour of an adiabatic packed bed reactor: the selective hydrogenation of acetylene and ethylene, *Chem. Ing. Techn.* 63, 3, pp 287.
- [6] Bos, A.N.R., Kuper, W. and Westerterp, K.R., 1991, The behaviour of a single catalyst pellet in the selective hydrogenation of acetylene and ethylene, *Chem. Ing. Techn.* 63, 3, pp 286.
- [5] Bos, A.N.R. and Westerterp, K.R., 1991, Comments on the behaviour of a fixed-bed reactor, *Chem. Engng Sci.* 46, pp 3330-3331.
- [4] Bos, A.N.R. and Westerterp, K.R., 1991, The mass balance for gas phase reactions in tubular reactors, *Chem.Eng.Comm.* 99, pp 139-153.
- [3] Bos, A.N.R. and Westerterp, K.R., 1990, The behaviour of an adiabatic packed bed reactor: the selective hydrogenation of acetylene and ethylene, *Unsteady state processes in catalysis: proc. of the international conference*, 5-8 June 1990, Novosibirsk, USSR, pp 599-605.
- [2] Bos, A.N.R., Kuper, W. and Westerterp, K.R., 1990, The behaviour of a single catalyst pellet in the selective hydrogenation of acetylene and ethylene, *Unsteady state processes in catalysis: proc. of the international conference*, 5-8 June 1990, Novosibirsk, USSR, pp 593-598.
- [1] Bos, A.N.R., Borman, P.C., Kuczynski, M. and Westerterp, K.R., 1989, The kinetics of the methanol synthesis on a copper catalyst. An experimental study. *Chem. Engng Sci.*, 44, 11, pp 2435-2449.

Patents (excluding 4 recently filed applications for which the required 18 months after priority date have not been reached yet)

- [31] Oxidative dehydrogenation (ODH) of ethane, Schoonebeek, Ronald, Jan, van Rossum, Guus, Bos, Alouisius, Nicolaas, Renée, WO2018019760 (2018)
- [30] Alkane oxidative dehydrogenation, Bos, Alouisius Nicolaas Renée; Stephens, Ryan Mark, van Rossum, Guus; WO2018019761 (2018)
- [29] Process for the oxidative coupling of methane, Bos, Alouisius Nicolaas Renée; Dathe, Hendrik; Horton, Andrew David; Mesters, Carolus Matthias Anna Maria; Pekalski Andrzej Aleksander; Schoonebeek,

Ronald Jan, WO2017009449 (2017)

[28] Alkane oxidative dehydrogenation (odh), Bos, Alouisius Nicolaas Renée; Mitkidis, Georgios; Rossum van, Guus; San Roman Macia, Maria; Schoonebeek, Ronald Jan; Shah, Vatsal MukundlaL; Verhaak, Michael Johannes Franciscus Maria, WO2017046315 (2017)

[27] Alkane oxidative dehydrogenation, Bos, Alouisius Nicolaas Renée; Rossum Van, Guus; Schoonebeek, Ronald Jan; Verhaak, Michael Johannes Franciscus Maria, WO2017144584 (2017)

[26] Conversion of mixed methane/ethane streams, Bos, Alouisius Nicolaas Renée; Rossum Van, Guus; Schoonebeek, Ronald Jan; Verhaak, Michael Johannes Franciscus Maria, WO2017134164 (2017)

[25] Process for treating a hydrocarbon-containing feed, Joseph Broun Powell, Kuochen Tsai, Ryan Anthony Sothen, Ryan Mark Stephens, Shyamal K. BEJ, Nihar Phalak, Vikramaditya Chikyal; Alouisius Nicolaas Rene Bos, WO2016106228 (2016)

[24] Alkane oxidative dehydrogenation and/or alkene oxidation, Alouisius Nicolaas Rene Bos, Ronald Jan Schoonebeek, Frank Spies, Michiel Johannes Franciscus Maria Verhaak, WO 2016001111 (2016)

[23] A method for producing a syngas stream, Ronald Jan Schoonebeek, Alouisius Nicolaas Rene Bos, WO2016005317 (2016)

[22] Alkane oxidative dehydrogenation and/or alkene oxidation, Alouisius Nicolaas Rene Bos, Ronald Jan Schoonebeek, Frank Spies, Michiel Johannes Franciscus Maria Verhaak, WO 2015082602 (2015)

[21] Alkane oxidative dehydrogenation and/or alkene oxidation, Alouisius Nicolaas Rene Bos, Ronald Jan Schoonebeek, Michiel Johannes Franciscus Maria Verhaak, WO 2015082598 (2015)

[20] Stacked catalyst bed for Fischer-Tropsch Alouisius Nicolaas Rene Bos, Peter John Van Den Brink, Thomas Joris Remans, Erwin Roderick Stobbe, Dominik Johannes Michael Unruh, Ronald Vladimir Wisman US 8980194 B2 (2015)

[19] Methods and systems employing a horizontally configured digestion unit for hydrothermal digestion of cellulosic biomass solids, Joseph Broun Powell, Alouisius Nicolaas Rene Bos, Peter Anton August Klusener, Ingmar Hubertus Josephina Ploemen, WO 2014179306 (2014)

[18] Process for the production of ethylene glycol, Alouisius Nicolaas Rene Bos, Willem Derks, WO2011000830 (2011)

[17] Reverse flow reactor with integrated separation and process for the employing this reactor ANR Bos, GR Kabra, JP Lange, US patent US 2009/0101584 (2009)

[16] Reactor system and process for the manufacture of ethylene oxide, ANR Bos, LA Chewter, JM Kobe US Patent 2009/0234144 (2009)

[15] Process for the preparation of styrene and/or a substituted styrene, ANR Bos, P Koradia - US Patent App. US2009187055 (2009)

[14] Silver-containing catalysts, the manufacture of such silver-containing catalysts, and the use thereof, Matusz M, Richard MA, Lockemeyer JR, Bos ANR, Rekers DM, Reinalda D, Yeates RC, McAllister PM US Patent US 7,547,795 (2009)

[13] Method of installing an epoxidation catalyst in a reactor, a method of preparing an epoxidation catalyst, an epoxidation catalyst, a process for the preparation of an olefin oxide or a chemical derivable from an olefin oxide, and a reactor suitable for such a process, Jeroen Willem Bolk, Alouisius Nicolaas Renee Bos, Wayne Errol Evans, John Robert Lockemeyer, Paul Michael Mc Allister, Bernardus Franciscus Josef Marie Ramakers, Dominicus Maria Rekers, Mathias Jozef Paul Slapak, US 20080154052 (2008)

[12] A method of preparing an epoxidation catalyst, an epoxidation catalyst, a process or the preparation of an olefin oxide or a chemical derivable from an olefin oxide, and a reactor suitable for such a process, JW Bolk, ANR Bos, WE Evans, JR Lockemeyer, PM McAllister, BFJM Ramakers, DMR Rekers, MJP Slapak, US Patent US2008154051 (2008)

[11] A method of preparing an epoxidation catalyst, an epoxidation catalyst, a process or the preparation of an olefin oxide or a chemical derivable from an olefin oxide, and a reactor suitable for such a process, JW Bolk,

ANR Bos, WE Evans, JR Lockemeyer, PM McAllister, BFJM Ramakers, DMR Rekers, MJP Slapak, US Patent US2008154052 (2008)

[10] Process for mixing an oxidant having explosive potential with a hydrocarbon, JW Bolk and ANR Bos, US Patent Appl. 2007/0203379 (2007)

[9] A process for the preparation of an olefin oxide or a chemical derivable from an olefin oxide, Jeroen Willem Bolk, Alouisius Nicolaas Rene Bos, Wayne Errol Evans, John Robert Lockemeyer, Paul Michael McAllister, Bernardus Franciscus Ramakers, Dominicus Maria Rekers, Mathias Jozef Paul Slapak, WO 2007076395 (2007)

[8] Silver-containing catalysts, the manufacture of such silver-containing catalysts, and the use thereof, Matusz M, Richard MA, Lockemeyer JR, Bos ANR, Rekers DM, Reinalda D, Yeates RC, US Patent US 7,259,129 (2007)

[7] Rod-shaped inserts in reactor tubes, Te Raa AJ, Slapak MJP, Bos ANR, US Patent 7,132,555 (2006)

[6] Process for selecting shaped particles, a process for installing a system, a Process for reacting a gaseous Feedstock in such a system, a computer Program, a computer program product, and a computer system, MA Richard, PM McAllister, AT Coleman, JLM Syrier, ANR Bos US Patent US 2006/0065064 (2006)

[5] Reactor system and process for the manufacture of ethylene oxide, PM McAllister, ANR Bos, MA Richard, DM Rekers, US 2005/0019235 (2005)

[4] Remediation process and apparatus, ANR Bos, DM Rekers, AWT Rots, US 2004/0175316 (2004)

[3] Reactor system and process for the manufacture of ethylene oxide PM McAllister, ANR Bos, MA Richard, DM Rekers, US 2004/0225138 (2004)

[2] Process for separating ethylene glycol, Baars HJ, Bos ANR, Kars J, US 6,525,229 (2003)

[1] Process for preparing styrene polymers, Binsbergen FL, Bos ANR, Santen A, US 5,587,438 (1996)

Some key conference presentations:

A.N.R. Bos and A. Hoek, Continuous improvement of Shell's GTL technology, Invited lecture WCCE-8, Montreal 2009.

A.N.R. Bos, Challenges in multi-phase reactor engineering, Invited key note lecture TU/e symposium Sustainable Energy and Resources, October 2011.

A.N.R. Bos, Challenges in multi-phase reactor engineering: An Industrial perspective, WCCE9: 9th World Congress of Chemical Engineering, August 2013.

A.N.R. Bos, Reaction Engineering through the Funnel of Innovation, ISCRE-23 Bangkok 2014

A.N.R. Bos and K. Zhu, Activation of Catalysts in Commercial Scale Fixed-Bed Reactors: Dynamic Modelling and Guidelines for Avoiding Undesired Temperature Excursions, keynote Lecture ISCRE-25 Florence 2018.