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Ralph G. Scurlock

# Stratification, Rollover and Handling of LNG, LPG and Other Cryogenic Liquid Mixtures

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Ralph G. Scurlock
University of Southampton
Southampton, UK

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# Preface

My interest and experience in cryogenic engineering began in the early 1960s when we set up the first postgraduate training course on "Cryogenics and Its Applications". At that time, cryogenics meant LOX, LIN, LH2 and LHe. This course was developed to involve industry in the teaching and the hands-on demonstrations, together with a 3-month project in industry for all the students in participating companies.

Very soon, we found the project work was taking us into 3-year Ph.D. research programmes on a wide range of interdisciplinary topics, together with expanding into higher temperatures within the world of hydrocarbons, using a purpose-build LNG Safety Laboratory. This expansion was also taking us into the new territory of irreversible thermodynamics and the extraordinary properties of cryogenic liquid mixtures. LNG was one of these mixtures, but not the only one or the first one we met.

At that time (1960), LPGs with normal boiling points between −40 and −2 °C were being developed as an industrial fuel by liquefying the gas being flared off at refineries and oil wells. We were soon introduced to the problems of handling LPGs in bulk and surprised to find that our experience with colder cryogenic liquids such as LOX, LIN and LHe enabled us to begin solving the LPG problems very quickly.

At the same time, we began to find that liquid mixtures had unique properties of their own, which needed research programmes to gain an understanding of these properties, outside our experience with single component cryogenic liquids.

So, when the LNG rollover event happened at La Spezia in 1971, we were quickly involved in trying to understand what had happened. Subsequent research programmes, using the more sophisticated flow visualisation and measurement techniques we developed in the later 1970s, enabled us to reproduce and study rollover events between stratified layers of cryogenic liquid mixtures. In particular, we were able to visualise what happens in a rollover event using laser Doppler and photographic and video systems.

Continuing contact with the LNG industry, via contributions to the LNG cargo management courses at the Warsash Maritime School of Navigation, Southampton, led to 3- and 12-month Institute of Cryogenics training courses on LNG technology.

These courses at Southampton and Sonatrach Gas School, Boumerdes, Algeria, continued from the mid-1970s for many years.

Continuing research on cryogenic mixtures provided a firm base for developing the general features of cryogenic fluid dynamics as a new discipline for all cryogenic systems. As a consequence, a recommendation was made to redefine "cryogenics" with a broader base to cover all liquids boiling below 0 °C, the ice point.

This recommendation has not been accepted by everyone, but will be used for the purpose of this text, as a basis for learning to understand LNG and LPG rollovers. Our research findings have been published in some 150 papers scattered throughout various cryogenic and technical journals, cryogenic engineering conference proceedings and textbooks. Most of the material in this book is based on these findings, much of which comes from M.Sc. and Ph.D. theses of many of my students at Southampton University.

Southampton, UK Ralph G. Scurlock

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