



Universidad de Valladolid

GRUPO DE INVESTIGACIÓN TERMOCAL



Grupo TERMOCAL
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Nuestra motivación

Necesidad de propiedades termofísicas exactas:

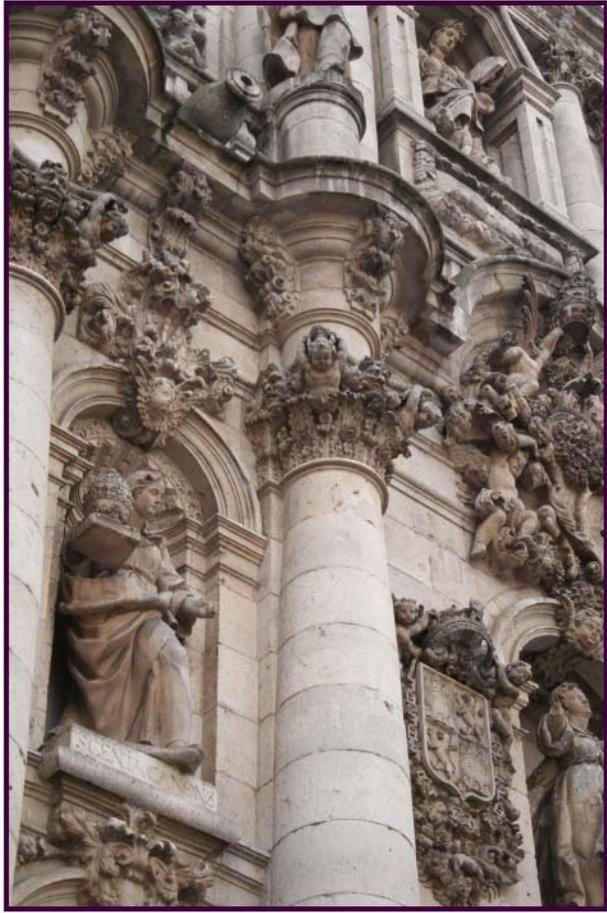
- Datos
- Modelos

Industria energética
Optimización de procesos
Ingeniería química

.....
....

Propiedades
Termodinámicas de
fluidos

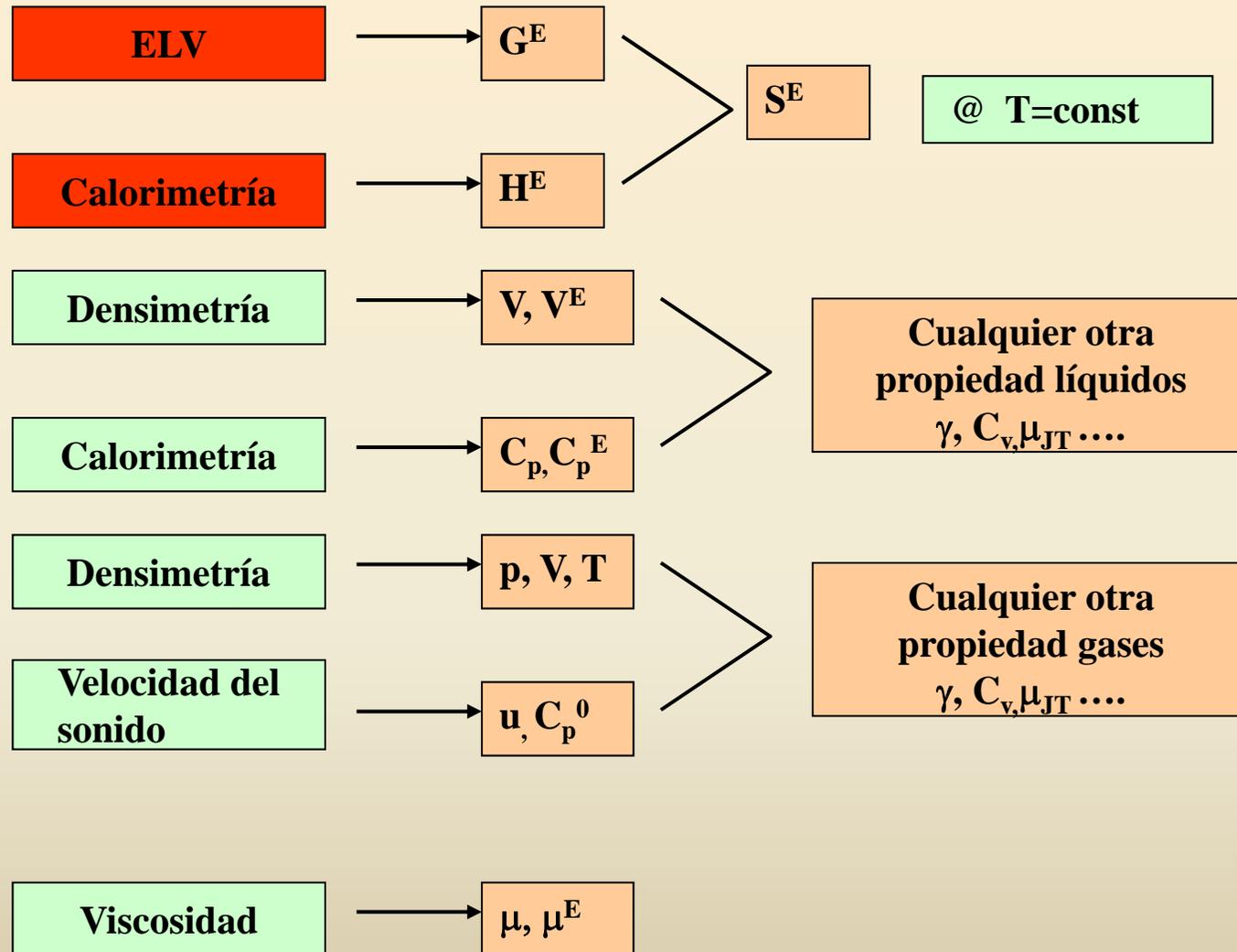




¿Termodinámica?

Ingeniería termodinámica

$$dG = -SdT + Vdp + \sum \mu_i dn_i$$



**PROPIEDADES TERMODINAMICAS Y DE
TRANSPORTE**

**PRESIÓN DE VAPOR
EQUILIBRIO DE FASES**

DENSIDAD

CAPACIDAD CALORÍFICA

ENTALPÍA

COEFICIENTE JOULE THOMSON

VELOCIDAD DEL SONIDO

VISCOSIDAD

GASES, LÍQUIDOS, PUROS Y MEZCLAS



¿Qué hay más allá de la Termodinámica?

FLUID PROPERTIES IMPORTANCE

Thermophysical Properties are fundamental to understanding and solving the world's great problems

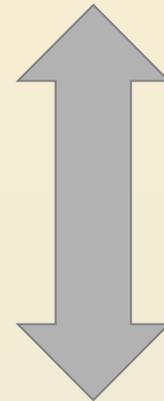
*“ Based on the total amount of money spent for **fluid properties research** in joint industry project and the cost saving attributed directly to the data obtained from these projects, it is conservatively estimated that for **every dollar spent, 12 dollars** in cost **savings** were achieved by the **industry** ”*

D.G. Elliot, J.J. Chen, T.S. Brown, E.D. Sloan, and A.J. Kidnay.

FLUID PHASE EQUILIBRIA 116 (1996) 27-38.

GRUPO TERMOCAL

OBJETIVOS



The science of measurement - metrology - is important for scientific research, industry and our everyday lives, as the demand for measurements with high accuracies and low uncertainties continues to increase.

EMRP

European Metrology Research Programme

■ Programme of EURAMET

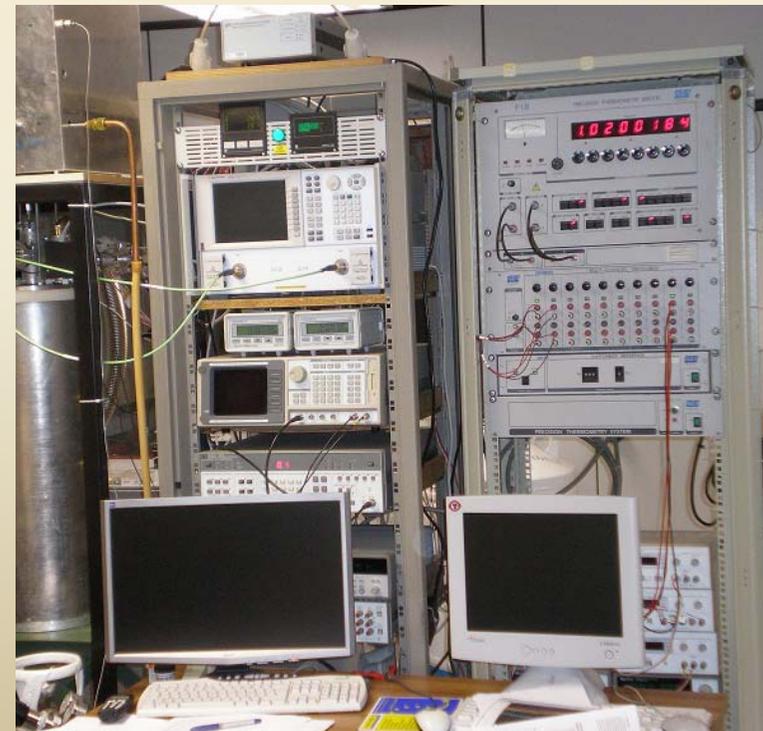


The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union

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Programme Structure

Call Year	Field	Status
iMERA-Plus		
2007	SI and Fundamental Health Length Electricity and Magnetism	Projects completed »
T1.J1.4	Boltzmann constant	Determination of the Boltzmann constant for the redefinition of the kelvin
		 Summary Project website Dr Joachim Fischer (PTB)



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EMRP Call 2009 - Energy

The aim of this call is to advance measurement science and technology by providing funding for Joint Research Projects (JRPs) and associated researcher grants in the field of:

- **Energy**

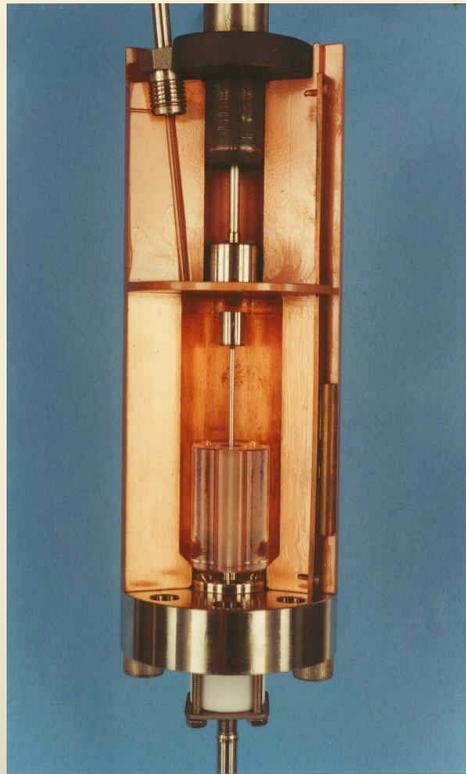
Focus is placed on technologies that enable greatly reduced greenhouse gas emissions, while also ensuring the security of Europe's energy supply.



Joint Research Projects (JRPs)

Number	Short Name	Full name	JRP Coordinator
ENG01	GAS	Characterisation of Energy Gases »	Dr Dai Jones (NPL)

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**Densímetro de Flotador con
Suspensión Magnética**



Resonador Esférica

EMRP Call 2011 - Health, SI Broader Scope & New Technologies

The aim of this call is to advance measurement science and technology by providing funding for Joint Research Projects and associated Researcher Grants in the following fields:

- **Metrology for Health »**
- **SI Broader Scope »**
- **Metrology for New Technologies »**

Number	Short Name	Full Name	JRP Coordinator
SIB01	InK	Implementing the new kelvin »	Graham Machin (NPL)

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EMRP Call 2013 - Energy & Environment

The aim of this call is to advance measurement science and technology by providing funding for Joint Research Projects (JRPs) and associated Researcher Grants in the following fields:

- **Metrology for Energy »**
- **Metrology for Environment »**



ENG54

Biogas

Metrology for biogas

Adriaan van
der Veen
(VSL)



Resultados

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SUBDIRECCIÓN GENERAL
DE PROYECTOS DE
INVESTIGACIÓN

REFERENCIA: ENE2009-14644-C02-01(subprograma CON)

INVESTIGADOR/A PRINCIPAL: JOSE JUAN SEGOVIA PURAS

ORGANISMO: UNIVERSIDAD DE VALLADOLID

CENTRO: DEPARTAMENTO INGENIERIA ENERGETICA Y FLUIDOM

TÍTULO: COMBUSTIBLES AMBIENTALMENTE SOSTENIBLES: CARACTERIZACION TERMOFISICA DE MEZCLAS ...

TIPO DE PROYECTO: B

DURACIÓN: 3 AÑO/S



**MINISTERIO DE
ECONOMÍA
Y COMPETITIVIDAD**

SECRETARÍA DE ESTADO DE INVESTIGACIÓN,
DESARROLLO E INNOVACIÓN

SECRETARÍA GENERAL DE CIENCIA, TECNOLOGÍA
E INNOVACIÓN

DIRECCIÓN GENERAL DE INVESTIGACIÓN
CIENTÍFICA Y TÉCNICA

SUBDIRECCIÓN GENERAL DE PROYECTOS
DE INVESTIGACIÓN

COMUNICACIÓN SOBRE LA PROPUESTA DE RESOLUCIÓN PROVISIONAL Y TRÁMITE DE AUDIENCIA DE LA CONVOCATORIA 2013, MODALIDAD 1: PROYECTOS DE I+D+I, DEL PROGRAMA ESTATAL DE INVESTIGACIÓN, DESARROLLO E INNOVACIÓN ORIENTADA A LOS RETOS DE LA SOCIEDAD

Referencia:	ENE2013-47812-R
Investigador principal 1:	JOSE JUAN SEGOVIA PURAS
Investigador principal 2:	CESAR RUBEN CHAMORRIO CAMAZON
Entidad solicitante:	UNIVERSIDAD DE VALLADOLID
Centro:	ESCUELA DE INGENIERIAS INDUSTRIALES
Título:	GASES ENERGETICOS: BIOGAS Y GAS NATURAL ENRIQUECIDO CON HIDROGENO
Duración en años:	3



Contents lists available at ScienceDirect

J. Chem. Thermodynamics

journal homepage: www.elsevier.com/locate/jct



Accurate thermodynamic characterization of a synthetic coal mine methane mixture



R. Hernández-Gómez^a, D. Tuma^b, M.A. Villamañán^a, M.E. Mondéjar^a, C.R. Chamorro^{a,*}

^aGrupo de Termodinámica y Calibración (TERMOCAL), Dpto. Ingeniería Energética y Fluidomecánica, Escuela de Ingenierías Industriales, Universidad de Valladolid, Paseo del Cauce, 59, E-47011-Valladolid, Spain

^bBAM Bundesanstalt für Materialforschung und -prüfung, D-12200 Berlin, Germany

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Article history:

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Keywords:

Coal mine methane

Density measurements

Single sinker densimeter

GERG-2008 equation of state

ABSTRACT

In the last few years, coal mine methane (CMM) has gained significance as a potential non-conventional gas fuel. The progressive depletion of common fossil fuels reserves and, on the other hand, the positive estimates of CMM resources as a by-product of mining promote this fuel gas as a promising alternative fuel. The increasing importance of its exploitation makes it necessary to check the capability of the present-day models and equations of state for natural gas to predict the thermophysical properties of gases with a considerably different composition, like CMM. In this work, accurate density measurements of a synthetic CMM mixture are reported in the temperature range from (250 to 400) K and pressures up to 15 MPa, as part of the research project EMRP ENG01 of the European Metrology Research Program for the characterization of non-conventional energy gases. Experimental data were compared with the densities calculated with the GERG-2008 equation of state. Relative deviations between experimental and estimated densities were within a 0.2% band at temperatures above 275 K, while data at 250 K as well as at 275 K and pressures above 10 MPa showed higher deviations.

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Int J Thermophys (2010) 31:1294–1309
DOI 10.1007/s10765-010-0746-4

An Apparatus Based on a Spherical Resonator for Measuring the Speed of Sound in Gases and for Determining the Boltzmann Constant

**J. J. Segovia · D. Vega-Maza · M. C. Martín ·
E. Gómez · C. Tabacaru · D. del Campo**

Received: 16 November 2009 / Accepted: 26 April 2010 / Published online: 13 May 2010
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Abstract The Spanish Metrology Institute and the Research Group TERMOCAL of the University of Valladolid are involved in a European project for which the main target is the determination of the Boltzmann constant k_B . We have set-up an acoustic

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J. Chem. Thermodynamics

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Speeds of sound in (0.95 N₂ + 0.05 CO and 0.9 N₂ + 0.1 CO) gas mixtures at $T = (273 \text{ and } 325) \text{ K}$ and pressure up to 10 MPa



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Accepted 24 July 2014

Available online 6 August 2014

ABSTRACT

The measurements of speed of sound for two mixtures of (N₂ + CO) are reported. The data have been obtained using a spherical resonator for two isotherms $T = (273.15 \text{ and } 325.15) \text{ K}$ and pressures up to 10 MPa. The uncertainty study is detailed and the total uncertainty of the speed of sound is not worse than 0.016%. The results have been compared with the GERG-2008 equation of state.

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Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement



Improvement of the measurement uncertainty of a high accuracy single sinker densimeter via setup modifications based on a state point uncertainty analysis

M.E. Mondéjar, J.J. Segovia, C.R. Chamorro *

Research Group TERMOCAL, Dpto. Ingeniería Energética y Fluidomecánica, Universidad de Valladolid, Paseo del Cauce 59, E-47071 Valladolid, Spain

ARTICLE INFO

Article history:

Received 11 February 2011

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Available online 23 July 2011

Keywords:

Density measurement

Uncertainty analysis

Single sinker densimeter

Monte Carlo method

ABSTRACT

The single sinker densimeter with magnetic suspension coupling is one of the state of the art methods for the accurate measurement of fluid densities. The uncertainties of experimental pressure, density and temperature data, measured with a single sinker densimeter, were thoroughly evaluated following the uncertainty propagation law. The main uncertainty sources of each magnitude were determined. Based on this statistical study, several modifications were performed to reduce the uncertainty associated to each magnitude. Firstly two new PTR-25 probes were added. Secondly a new pressure transducer for the low pressure range was added. Finally the sinker of the densimeter was replaced by a bigger one to improve the balance reading. After these modifications the uncertainty of each magnitude was evaluated and validated with a Monte Carlo simulation. Results yielded a significant reduction of 44% in temperature uncertainty, more than 92% on pressure below 2 MPa, and more than 22% on density.

Int J Thermophys
DOI 10.1007/s10765-014-1807-x

A European Roadmap for Thermophysical Properties Metrology

**J.-R. Filtz · J. Wu · C. Stacey · J. Hollandt ·
C. Monte · B. Hay · J. Hameury ·
M. A. Villamañan · E. Thurzo-Andras · S. Sarge**

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© Springer Science+Business Media New York 2014

Abstract A roadmap for thermophysical properties metrology was developed in spring 2011 by the Thermophysical Properties Working Group in the EURAMET Technical Committee in charge of Thermometry, Humidity and Moisture, and Thermophysical Properties metrology. This roadmapping process is part of the EURAMET (European Association of National Metrology Institutes) activities aiming to increase impact from national investment in European metrology R&D. The roadmap shows a shared vision of how the development of thermophysical properties metrology should

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Universidad de Valladolid

ESCUELA DE INGENIERÍAS INDUSTRIALES

DPTO. INGENIERÍA ENERGÉTICA Y FLUIDOMECÁNICA

PhD THESIS:

DEVELOPMENT OF AN ADVANCED TECHNIQUE BASED ON ACOUSTIC RESONANCE IN GASES
FOR DETERMINING RELEVANT THERMODYNAMIC CONSTANTS AND PROPERTIES

Submitted by

FERNANDO JOSÉ PÉREZ SANZ

Promotion von Maria Engracia Mondéjar Montagud

März 2012

Im Sommer 2010 hielt sich María Engracia Mondéjar Montagud für vier Monate für Forschungsarbeiten am Lehrstuhl für Thermodynamik auf. Jetzt konnte sie ihre Arbeit mit einer ausgezeichneten Promotion an ihrer Heimatuniversität, der Universität von Valladolid in Spanien, abschließen. Als Zweitbetreuer der Arbeit nahm Roland Span an der Promotionsprüfung teil.



COLABORACIÓN

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CENTROS DE INVESTIGACIÓN

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- ✓ **Publicaciones**
- ✓ **Tesis Doctorales**
- ✓ **Estancias de Investigadores**
- ✓ **.....**