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University professor - Area 09 Industrial and Information Engineering
- Macrosettore 09/C Energy, thermo-mechanical and nuclear engineering -
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for the environment preservation - Settore scientifico disciplinare ING/IND
08 - **Energy Systems and Power Generation**

- Associate professor of “Fluid Machinery and Energy Conversion Systems” since December 2002 (University of Brescia)
- Researcher at the University of Brescia from 1986 to 2002
- PhD in Energy obtained in 1987 (Politecnico di Milano)
- Degree in Nuclear Engineering obtained in 1981 (Politecnico di Milano)
- ★ Harold Disney Prize 2008 (with G Angelino e P Iora) of the Institution of Mechanical Engineers. For the paper *Closed versus open cycle energy recovery from solid oxide fuel cells*, Proceedings of the Institution of Mechanical Engineers - Part A - Journal of Power and Energy, Vol. 222, 2008, pp. 371-379
- ★ Winner, in 1985, of the Prize “Giovanni Francia” reserved to studies and researches on the “Alternative Energies”
- Tenured professor of the following courses at the University of Brescia: (1) Renewable Energy Technologies; (2) Energy Conversion Systems
- Member of the Research Doctorate in Mechanical and Industrial Engineering (DRIMI) college, at the University of Brescia
- Member of the “Giunta del Dipartimento di Ingegneria Meccanica e Industriale” of the University of Brescia
- Member of the “Presidio della Qualità della Ricerca del DIMI (Mechanical and Industrial Engineering Department)” of the University of Brescia
- Member of many examination board for PhD thesis evaluation and for RTD-A (Italian researchers of “A type”)

Member of the “Technical Review Panel (TRP) for faculty evaluation” of the University of Engineering and Technology, Taxila, Pakistan (May 2017)

Research Interests – My research activity is mainly oriented to special energy systems, both in theoretical and experimental aspects. Basically, my scientific activities are currently devoted to the study of the thermodynamics and to the design of cycles and fluid machines for non-conventional heat engines: closed cycles using non-traditional working fluids or mostly operating in zones of the thermodynamic diagram characterised by strong real gas effects. Some examples, in summary:

1. thermodynamic analysis of advanced heat engines (engines, heat pumps and refrigerating machines) with non conventional working fluids (pure fluids or mixtures, in single- or two-phase conditions)
2. thermodynamic and technological aspects of (a) Rankine cycles with organic working fluids, (b) closed Brayton cycles, (c) Stirling engines. Typical applications of these type of engines can be in the field of heat recovery, in the exploitation of renewable energies (biomass combustion, the thermodynamic conversion of solar energy, the use of geothermal energy) or in the industrial and distributed cogeneration
3. thermodynamic and technological aspects of “binary cycles” (liquid metals and steam, or with organic working fluids, too) for high temperatures applications experimental evaluation of the thermochemical stability of working fluids

The main research results are reported in about eighty publications: about fifty published in international journals, one book and one (Italian) patent.

Since 2002, I coordinated research projects and agreements funded by the Ministry of University and Research (MURST) and by private companies and public companies. Reviewer of technical papers for many journals.

1 Pubblicazioni

Contributo in rivista – Journal contribution

- [1] Angelino Gianfranco and Invernizzi Costante. General method for thermodynamic evaluation of heat pump working fluids. *International Journal of Refrigeration*, 11:16–25, 1988.
- [2] Angelino Gianfranco and Invernizzi Costante. Low temperature convector made from polymeric material for heat-pump applications. *International Journal of Refrigeration*, 15:247–254, 1992.
- [3] Angelino Gianfranco and Invernizzi Costante. Cyclic methylsiloxanes as working fluids for space power cycles. *Journal of Solar Energy Engineering*, 115:130–137, 1993.
- [4] Angelino Gianfranco and Invernizzi Costante. Supercritical heat pump cycles. *International Journal of Refrigeration*, 17:543–554, 1994.
- [5] Angelino Gianfranco and Invernizzi Costante. Prospects for real-gas reversed Brayton cycle heat pumps. *International Journal of Refrigeration*, 18:272–280, 1995.
- [6] Angelino Gianfranco and Invernizzi Costante. Potential performance of real gas Stirling cycle heat pumps. *International Journal of Refrigeration*, 19:390–399, 1996.
- [7] Angelino Gianfranco and Invernizzi Costante. Binary and ternary liquid metal-steam cycles for high-efficiency coal power stations. *Proceedings of the Institution of Mechanical Engineers. Part A, Journal of Power and Energy*, 220:195–205, 2006.
- [8] Angelino Gianfranco and Invernizzi Costante. Binary Conversion Cycles for Concentrating Solar Power Technology. *Solar Energy*, 82:637–647, 2008.
- [9] Angelino Gianfranco and Invernizzi Costante. Thermodynamic optimization of ejector actuated refrigerating cycles. *International Journal of Refrigeration*, 31:453–463, 2008.
- [10] Angelino Gianfranco, Invernizzi Costante, and Iora Paolo. Closed versus Open Cycle Energy Recovery from Solid Oxide Fuel Cells. *Proceedings of the Institution of Mechanical Engineers. Part A, Journal of Power and Energy*, 222 Part A:371–379, 2008. Harold Disney Prize 2008.

- [11] Angelino Gianfranco and Invernizzi Costante Mario. Carbon dioxide power cycles using liquid natural gas as heat sink. *Applied Thermal Engineering*, 29:2935–2941, 2009.
- [12] Angelino Gianfranco and Invernizzi Costante Mario. The role of real gas Brayton cycles for the use of liquid natural gas physical exergy. *Applied Thermal Engineering*, 31:827–833, 2011.
- [13] Bombarda Paola, Invernizzi Costante, and Gaia Mario. Performance Analysis of OTEC Plants With Multilevel Organic Rankine Cycle and Solar Hybridization. *Journal of Engineering for Gas Turbines and Power*, 135:042302–1–042302–8, 2012.
- [14] Bombarda Paola, Invernizzi Costante, and Pietra Claudio. Heat recovery from Diesel engines: a thermodynamic comparison between Kalina and ORC cycles. *Applied Thermal Engineering*, 30:212–219, 2010.
- [15] Bombarda Paola and Invernizzi Costante Mario. Binary liquid metal-organic Rankine cycle for small power distributed high efficiency systems. *Proceedings of the Institution of Mechanical Engineers. Part A, Journal of Power and Energy*, 229:192–209, 2015.
- [16] Bonalumi Davide, Bombarda Paola A., and Invernizzi Costante Mario. Zero Emission Geothermal Flash Power Plant. *Energy Procedia*, 126:698–705, September 2017.
- [17] Bonalumi Davide, Bombarda Paolo, and Invernizzi Costante Mario. Potential performance of environmental friendly application of ORC and flash technology in geothermal power plants. *Energy Procedia*, 129:621–628, September 2017.
- [18] Gómez Aláez S.L., Bombarda Paola, Invernizzi Costante, Iora Paolo, and Silva Paolo. Evaluation of ORC modules performance adopting commercial plastic heat exchangers. *Applied Energy*, 154:882–890, 2015.
- [19] Invernizzi Costante. Calcolo delle proprietà termodinamiche alla saturazione di alcuni idrocarburi aromatici alogenati. *La Termotecnica*, 4 aprile 1982:78–85, 1982.
- [20] Invernizzi Costante. Calcolo delle proprietà termodinamiche di alcuni idrocarburi aromatici alogenati. gas e liquido. *La Termotecnica*, aprile 1984:47–54, 1984.

- [21] Invernizzi Costante. Applicazione di una procedura generalizzata per il calcolo automatico di cicli di potenza ad alcuni idrocarburi aromatici alogenati. *La Termotecnica*, novembre 1987:53–65, 1987.
- [22] Invernizzi Costante. Valutazione della stabilità termica di fluidi di lavoro per cicli Rankine: apparato sperimentale e risultati di calibrazione. *La Termotecnica*, XLIV:69–76, 1990.
- [23] Invernizzi Costante. laboratori - Ed. Ambientale - ri-nuovo. *Scuola Italiana Moderna*, 1 Febbraio 2009 anno 116:70–72, 2009.
- [24] Invernizzi Costante. Università e ambiente: le esperienze del gruppo Energia della facoltà di ingegneria. *Brescia Ricerche*, marzo 2009 66 - anno XIX:52–54, 2009.
- [25] Invernizzi Costante and Angelino Gianfranco. General method for the evaluation of complex heat pump cycles. *International Journal of Refrigeration*, 13:31–40, 1990.
- [26] Invernizzi Costante and Angelino Gianfranco. Real gas Brayton cycles for organic working fluids. *Proceedings of the Institution of Mechanical Engineers. Part A, Journal of Power and Energy*, 215 Part A:27–38, 2001.
- [27] Invernizzi Costante and Angelino Gianfranco. Experimental investigation on the thermal stability of some new zero ODP refrigerants. *International Journal of Refrigeration*, 26:51–58, 2003.
- [28] Invernizzi Costante and Angelino Gianfranco. Ejector-Assisted Liquid Metal Topping Cycles. *Proceedings of the Institution of Mechanical Engineers. Part A, Journal of Power and Energy*, 218:111–121, 2004.
- [29] Invernizzi Costante, Angelino Gianfranco, and Molteni G. The potential role of organic bottoming Rankine cycles in steam power stations. *Proceedings of the Institution of Mechanical Engineers. Part A, Journal of Power and Energy*, 213:75–81, 1999.
- [30] Invernizzi Costante and Bombarda Paola. Thermodynamic performance of selected HCFS for geothermal applications. *Energy*, 22:887–895, 1997.
- [31] Invernizzi Costante and Iora Paolo. Heat recovery from a micro-gas turbine by vapour jet refrigeration systems. *Applied Thermal Engineering*, 25:1233–1246, 2005.

- [32] Invernizzi Costante and Iora Paolo. Il recupero di calore a bassa temperatura: una risorsa da valorizzare. *Nuova Energia*, anno X:42–45, 2012.
- [33] Invernizzi Costante, Iora Paolo, Preißinger Markus, and Manzolini Giampaolo. HFOs as substitute for R-134a as working fluids in ORC power plants: A thermodynamic assessment and thermal stability analysis. *Applied Thermal Engineering*, 103:790–797, 2016.
- [34] Invernizzi Costante, Iora Paolo, and Silva Paolo. Bottoming micro-Rankine cycles for micro-gas turbines. *Applied Thermal Engineering*, 27:100–110, 2007.
- [35] Invernizzi Costante, Iora Paolo, Zanoni Simone, and Zavanella Lucio. Anche le Piccole e Medie Imprese al centro dei nostri programmi. *Nuova Energia*, 6/2009:42–43, 2009.
- [36] Invernizzi Costante and Pasini Alberto. Prestazioni termodinamiche di un nuovo fluido di lavoro per cicli di potenza. *La Termotecnica*, Aprile 2000:87–92, 2000. working fluid, organic Rankine cycle, thermal stability, HFE-7100.
- [37] Invernizzi Costante Mario. Stirling engines using working fluids with strong real gas effects. *Applied Thermal Engineering*, 30:1703–1710, 2010.
- [38] Invernizzi Costante Mario. Ciclo Rankine, gli italiani fanno sempre scuola. *Nuova Energia*, 5.2013:58–61, 2013.
- [39] Invernizzi Costante Mario. Prospects of Mixtures as Working Fluids in Real-Gas Brayton Cycles. *Energies*, 10(10):1649, October 2017.
- [40] Invernizzi Costante Mario and Iora Paolo. The exploitation of the physical exergy of liquid natural gas by closed power thermodynamic cycles. an overview. *Energy*, 105:2–15, 2016. Special Issue - Practice and Innovations in the Regasification of LNG - contributo su invito.
- [41] Invernizzi Costante Mario, Iora Paolo, Bonalumi Davide, Macchi Ennio, Roberto R., and Caldera M. Titanium tetrachloride as novel working fluid for high temperature Rankine cycles: Thermodynamic analysis and experimental assessment of the thermal stability. *Applied Thermal Engineering*, 107:21–27, 2016.

- [42] Invernizzi Costante Mario, Iora Paolo, Manzolini Giampaolo, and Lasala Silvia. Thermal stability of n-pentane, cyclo-pentane and toluene as working fluids in organic Rankine cycles. *Applied Thermal Engineering*, 121:172–179, 2017.
- [43] Invernizzi Costante Mario, Iora Paolo, and Sandrini Roberto. Biomass combined cycles based on externally fired gas turbines and organic Rankine expanders. *Proceedings of the Institution of Mechanical Engineers. Part A, Journal of Power and Energy*, 225:1066–1075, 2011.
- [44] Invernizzi Costante Mario and van der Stelt Teus. Supercritical and real gas Brayton cycles operating with mixtures of carbon dioxide and hydrocarbons. *Proceedings of the Institution of Mechanical Engineers. Part A, Journal of Power and Energy*, 226:682–693, 2012.
- [45] Iora Paolo, Bombarda Paola, Gómez Aláez S.L., Invernizzi Costante Mario, Rajabloo Talieh, and Silva Paolo. Flare gas reduction through electricity production. *Energy Sources. Part A, Recovery, Utilization, and Environmental Effects*, 38:3116–3124, 2016.
- [46] Iora Paolo, Chiesa Paolo, Invernizzi Costante, and Salogni Andrea. Incentivi al fotovoltaico in Europa. *Energia*, 4:86–93, 2006.
- [47] Iora Paolo, Di Marcoberardino Gioele, Invernizzi Costante Mario, Manzolini Giampaolo, Belotti Paolo, and Bini Roberto. Dynamic analysis of off-grid systems with ORC plants adopting various solution for the thermal storage. *Energy Procedia*, 129:216–223, September 2017.
- [48] Iora Paolo and Invernizzi Costante. Chi ci guadagna o ci perde con gli incentivi stanziati per gli impianti fotovoltaici. *Nuova Energia*, 1:74–77, 2006.
- [49] Keulen L., Landolina C., Spinelli A., Iora P., Invernizzi C., Lietti L., and Guardone A. Design and commissioning of a thermal stability test-rig for mixtures as working fluids for ORC applications. *Energy Procedia*, 129:176–183, September 2017.
- [50] Lasala Silvia, Invernizzi Costante Mario, Iora Paolo, Chiesa Paolo, and Macchi Ennio. Thermal Stability Analysis of Perfluorohexane. *Energy Procedia*, 75:1575–1582, 2015.
- [51] Pasetti Marco, Invernizzi Costante Mario, and Iora Paolo. Thermal stability of working fluids for organic Rankine cycles: An improved survey method and experimental results for cyclopentane, isopentane and n-butane. *Applied Thermal Engineering*, 73:762–772, 2014.

- [52] Rajabloo Talieh, Iora Paolo, and Invernizzi Costante Mario. Mixture of working fluids in ORC plants with pool boiler evaporator. *Applied Thermal Engineering*, 98:1–9, 2016.
- [53] Sala Fernando and Invernizzi Costante Mario. Low temperature Stirling engines pressurised with real gas effects. *Energy*, 75:225–236, 2014.
- [54] Sala Fernando, Invernizzi Costante Mario, Garcia David, Gonzalez Miguel-Angel, and Prieto Jesús-Ignacio. Preliminary design criteria of Stirling engines taking into account real gas effects. *Applied Thermal Engineering*, 89:978–989, 2015.
- [55] Scaccabarozzi Roberto, Tavano Michele, Invernizzi Costante Mario, and Martelli Emanuele. Thermodynamic Optimization of heat recovery ORCs for heavy duty Internal Combustion Engine: pure fluids vs. zeotropic mixtures. *Energy Procedia*, 129:168–175, September 2017.

Contributo in volume e relazioni tecniche – Contribution in volume and technical reports

- [56] Angelino Gianfranco, Invernizzi Costante, and Calderazzi Ludovico. *Ottimizzazione Energetica Economica ed Ecologica dei Sistemi di Conversione dell'Energia*, volume unico, chapter Prospettive per l'impiego di cicli Brayton inversi a gas reale nelle pompe di calore. In Appendice: Prove di stabilità termica su fluidi organici per pompe di calore e cicli di potenza, pages 194–214. Progetto Leonardo, Bologna – ITA, 1996.
- [57] Angelino Gianfranco, Invernizzi Costante, and Macchi Ennio. *Modern Research Topics in Aerospace Propulsion*, volume unico, chapter Organic working fluid optimization for space power cycles, pages 297–326. Springer Verlag, New York – USA, 1991.
- [58] Ennio Macchi, Davide Bonalumi, Costante M. Invernizzi, and Paolo Iora. Risultati sperimentali relativi alla stabilità termica del ticl4, scelta dei materiali, approfondimento tecnico-economico. Technical Report Rds/PAR2013/269, ENEA, September 2014.
- [59] Ennio Macchi, Marco Astolfi, Davide Bonalumi, Antonio Giuffrida, Matteo C. Romano, Davide M. Turi, Costante M. Invernizzi, Roberta Roberto, V. Gerardi, and M. Caldera. Valutazione di cicli termodinamici innovativi per applicazioni con caldaia a sali fusi a biomassa legnosa. Technical Report RdS/2013/178, ENEA, September 2013.
- [60] Invernizzi Costante Mario and Bonalumi Davide. *Organic Rankine Cycle (ORC) Power Systems. Technologies and Applications*, volume Number 107, chapter Thermal stability of organic fluids for Organic Rankine Cycles systems, pages 121–148. Woodhead Publishing - Elsevier, Amsterdam, 2017.

Libro – Book

- [61] Invernizzi Costante Mario. *Closed Power Cycles. Thermodynamic Fundamentals and Applications*, volume 11. Springer - Verlag, London – GBR, 2013.

Contributo in atti di convegno – Contribution to conference proceedings

- [62] Angelino Gianfranco and Invernizzi Costante. Combined Binary Cycles using Combustion Gases, Alkali Metal and Steam as Working Fluid. In *Second International Conference on Clean Coal Technology for our Future*, volume unico, pages 1–16. CCT 2005, 2005.
- [63] Binotti Marco, Invernizzi Costante, Iora Paolo, and Manzolini Giampaolo. Innovative Fluids for Gas Power Cycles Coupled with Solar Tower Systems. SolarPACES, 2017.
- [64] Bombarda Paola, Invernizzi Costante, and Pasetti Marco. Stabilità termica di fluidi di lavoro e prestazioni termodinamiche del refrigerante HFC-245fa in cicli per applicazioni geotermiche. In *66° Congresso Nazionale ATI - Sommari delle memorie*, volume unico, pages 1–9, Cosenza – ITA, 5-9 settembre 2011. Barcello Editore.
- [65] Bonalumi Davide, Astolfi Marco, Roberto R., Caldera M., Romano M.C., Turi D.M., Silva Paolo, Giuffrida A., Invernizzi Costante, and Macchi Ennio. High efficiency ORC for high temperature molten salt boiler for biomass applications. ASME - ORC 2013, 2013.
- [66] Calderazzi Ludovico, Colonna Piero, and Invernizzi Costante. Apparecchiature per prove di stabilità termica su fluidi organici per cicli a fluido bifase. In *atti del congresso*, volume VOL. I, pages 563–573, ITA, 28 settembre -1 ottobre 1993. SGEditoriali, Padova.
- [67] de Marchi Desenzani Paola, Gaia Mario, and Invernizzi Costante. Modification of working fluid in geothermal organic rankine cycle engines. In *International Symposium on Geothermal Energy - International Volume*, volume International Volume, pages 447–452. Geothermal Resources Council, 1985.
- [68] Gaia Mario and Invernizzi Costante. Ciclo gas-vapore a pressione subatmosferica per l'utilizzazione di combustibili con umidità elevata. volume I, pages ID:45–ID:59. associazione termotecnica italiana, 18-21 settembre 1990.
- [69] Invernizzi Costante and Angelino Gianfranco. Real gas effects in Stirling engines. In *35th International Energy Conversion Engineering Conference*, volume UNICO, pages AIAA–2000–2811–1–AIAA–2000–281. American Institute of Aeronautical and Astronautic, July 2000.

- [70] Invernizzi Costante, Incerti Giovanni, Lezzi Adriano Maria, Mazzú Angelo, Parmigiani S., Petrocelli Davide, Villa Valerio, and Zani D. Distributed electricity generation using an external combustion Ringbom-Stirling engine heated by agricultural wastes. In *Proceedings of the 28th UIT Transfer Congress*, volume unico, pages 469–472, Brescia – ITA, 21-23 Giugno 2010. Cartoleria Snoopy.
- [71] Invernizzi Costante, Incerti Giovanni, Parmigiani S., and Villa Valerio. Progettazione di un motore Ringbom-Stirling per la produzione di energia elettrica nei paesi in via di sviluppo. In *Atti del Primo Congresso del Coordinamento della Meccanica Italiana*, volume UNICO, pages 41–42, Palermo – ITA, 20-22 Giugno 2010.
- [72] Invernizzi Costante, Iora Paolo, Pietra Claudio, and Zaglio Maurizio. Sviluppo di un modello per cella a combustibile IR-SOFC per analisi di impianti ibridi a recupero con cicli a gas. volume 2, pages 893–898, SALERNO, 11-14 Settembre 2007. Cuzzolin Editore.
- [73] Joppolo Cesare Maria, Pasini Alberto, Pedrazzini F., and Invernizzi Costante. Simulazione termofluidodinamica di un impianto di riscaldamento a pavimento radiante a servizio di un locale di rilevante altezza. In *Convegno AICARR*, volume iv, pages 195–219, ITA, marzo 2002. AiCARR.
- [74] Parmigiani S., Zani D., Invernizzi Costante, Mazzú Angelo, Villa Valerio, and Lezzi Adriano Maria. A biomass powered Ringbom-Stirling engine for developing countries: a low-budget solution for distributed electricity generation. In *VIII International Conference on Renewable Energie and Power Quality (ICREPQ'10)*, volume UNICO, pages Paper 432–1–Paper 432–4. European Association for the Development of Renewa, 23 - 25 marzo 2010.
- [75] Pasetti Marco, Iora Paolo, Chiesa Paolo, Invernizzi Costante, and Salogni Andrea. Analysis of incentive systems for photovoltaic power plants in six countries of the european union. In *Proceedings of the ICREPQ'10*, volume unico, pages 1–6. ignoto, 23th to 25th March 2010.
- [76] Pasini Alberto, Silvestre Antimo, and Invernizzi Costante. Scambiatore di calore a bassa temperatura tipo Roll-Bond per il riscaldamento ambientale. volume VOL. I, pages 871–882, Padova – ITA, 11-15 settembre 1995. SGEditoriali.

- [77] Sala Fernando, Invernizzi Costante, Garcia D., Gonzales M.A., and Prieto J.I. Preliminary design criteria of Stirling engines taking into account real gas effects. In *Proceedings of 16th International Stirling Engine Conference*, volume 1, pages 521–534. ISEC - International Stirling Committee, 24-26 September 2014.

Brevetto – Patent

- [78] Angelino Gianfranco and Invernizzi Costante. Patent number 0001284448: Macchina Stirling a rendimento migliorato, 1997. Stirling engine, power engine, refrigerating engine, working fluid, real gas.