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*“Experimental and numerical characterization of heating
domestic appliances for energetic efficiency improvement”*

Il Candidato

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Abstract

Every year 5 million of boilers for domestic heating are sold in the European Union (EU). Because heating contributes to more than 20% to the whole energy use in the EU strategies for energy saving are of great interest.

Currently in the European Union, efficiency requirements on boilers are becoming more and more stringent: following the common target of the energy reduction, European directives 2005/32/EC on the eco-design of energy-using products and 2009/125/EC on the energy-related products, oblige the labeling of boilers and water heaters in performance categories. Furthermore, EU policy is to phase out appliances with low performance, by no longer giving the right to be sold on the European market. The regulation on the Energy related products (Erp) which enters into force from 26th of September 2015 sets efficiency bans so that low efficiency boilers are going to be excluded from EU market. As a consequence, boilers manufacturers should face significant investments in terms of efficiency oriented product-development. Furthermore, robust measurements become necessary to establish correct performance categories and not generate conflicts with surveillance bodies.

In the present PhD thesis work, carried out at Ariston Thermo Group in Osimo R&D center, experimental and modeling activities have been performed and reported concerning domestic heating appliances.

A comprehensive analysis of energy fluxes has been carried out on domestic methane supplied gas boilers, different methods for efficiency estimation have been compared with related measurement uncertainties. The boiler energy balance closing problem has been undertaken through a novel statistical approach, subsequently, an uncertainty related risk analysis has been performed on space heating efficiency and water heating efficiency according to Erp regulation.

Afterward, appliances insulation testing methods have been set-up and compared, in particular an automated test rig has been constructed and thermal camera measurements have been performed. Using such methods, boilers and tank losses have been characterized.

Moreover, an experimental analysis has been carried out in order to identify maximum efficiency reachable by a standard boiler avoiding

condensation, in order to verify Erp compliance. The analysis has showed a borderline result which does not completely exclude the possibility of Erp-compliant non-condensing boilers.

Furthermore, because boiler modulation is an important parameter in order to minimize fuel consumption and the ratio currently available on the market is equal to 10, the convenience of adopting higher modulation ratios has been investigated.

Yet, high modulation ratio could improve efficiency by reducing cycling frequency, nevertheless would improve boiler operating times and electrical consumption. An annual consumption model, based on bin method, has been presented in order to simulate boiler behavior on field for different cities, buildings and plants and to investigate ultra-high modulating boilers.

Simulations show relevant potential for energy savings and environmental impact reduction that are to be more deeply examined. Energy and CO₂ saving potential is considerable and ranges from 8% for colder climates to 38% for milder climates and low emission buildings; savings could be further improved in some cases by adding an electrical resistance. A trade-off analysis shows that with the use of an ultramodulating boiler, electrical consumption increases due to higher operating time, but this has only a minor impact on overall primary energy savings. Furthermore, a relation between ultramodulation savings and the geographic location for different building losses have been identified, in order to approximately estimate CO₂ and money savings.

Further development should consist in performing a complete cost/benefit analysis, to deepen technical aspects of burner ultramodulation and perform long term cycling efficiency measurements both in the field and in laboratory environments.