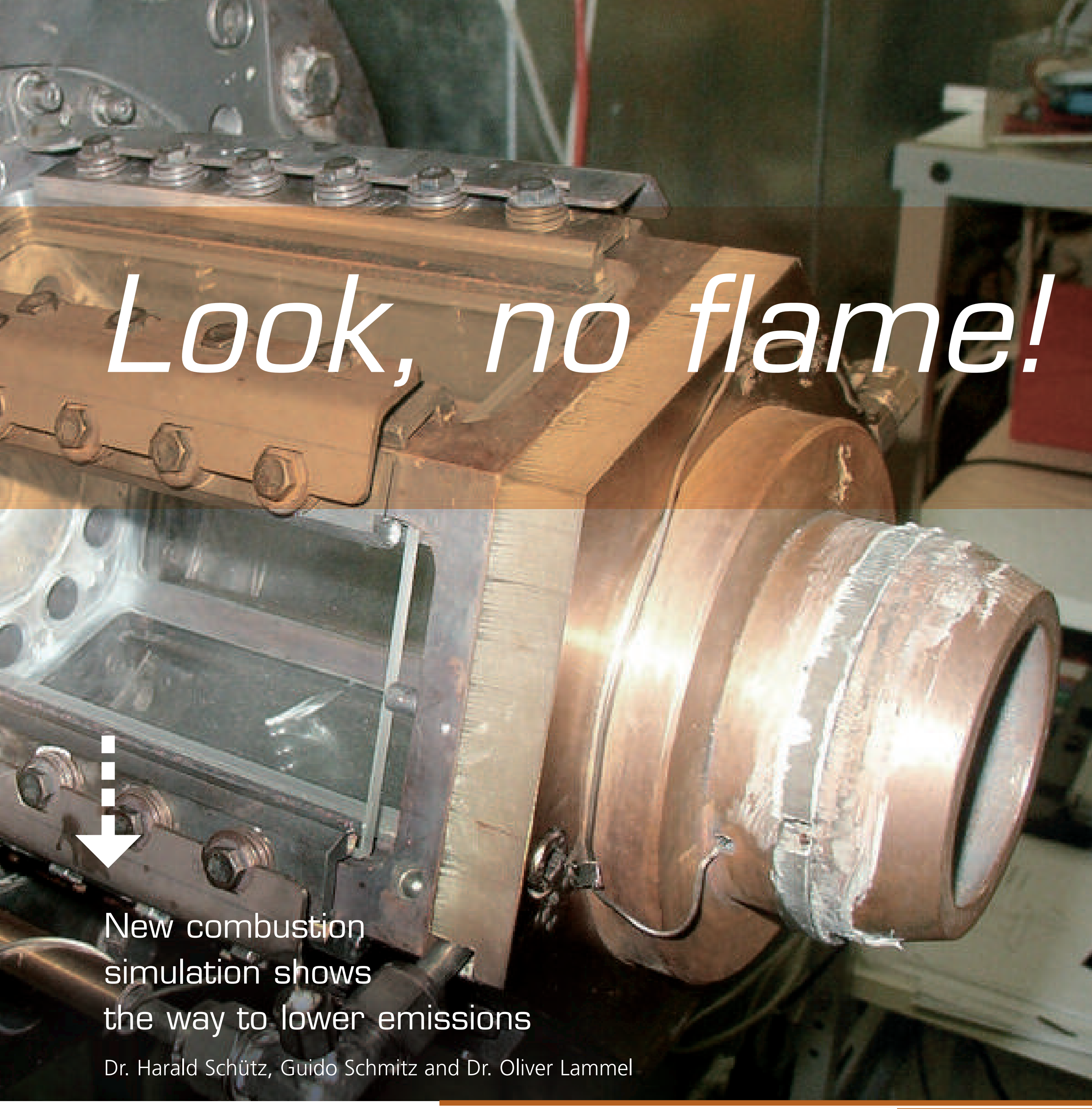


Look, no flame!

New combustion simulation shows the way to lower emissions

Dr. Harald Schütz, Guido Schmitz and Dr. Oliver Lammel

One major aspect in the optimisation of technical combustion processes is the reduction of pollutant emissions. The main focus here is on the emission of nitric oxide (NO), nitrogen dioxide (NO_2) and carbon monoxide (CO) from fossil fuels. Understanding the mechanisms that govern the formation of these substances is greatly facilitated by computer simulation.

A form of combustion that has attracted increasing interest in recent years because of its extremely low-pollutant emissions is "flameless" combustion – which, of course, sounds contradictory. But what the term actually means is that the flame, though present, is not at first visible. Such a low level of light emission is an indication of very low combustion temperatures of from 1,700 to 1,800 Kelvin (about 1,500 degrees Celsius), and this in turn meets one of the basic requirements for low pollutant formation rates. The relatively low temperatures required for this type of combustion are maintained by having an excess of combustion air in the process, which in effect cools the process from within.

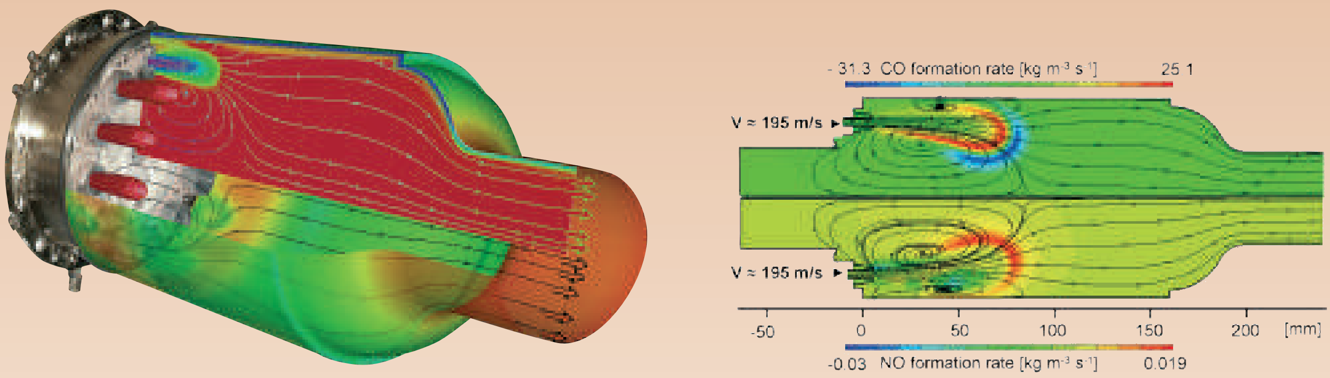
One important representative of flameless combustion is the FLOX® Burner (FLameless OXidation) produced by WS Wärmeprozesstechnik GmbH, one of DLR's cooperation partners. Besides its low emissions, the FLOX® burner is distinguished by its very simple and thus inexpensive construction. It works by a fuel-air mixture being injected axially and without spin into the cylindrical combustion chamber through twelve burners arranged in a concentric circle. The special feature of FLOX® combustion is that the injection is at a sufficiently high speed to ensure chemical imbalance effects will project the flame front far downstream into the combustion chamber and spread it over a relatively large area. This effect provides sufficient time for the turbulently diffusive mixing process of fuel and air to be virtually complete before the chemical reaction begins. The result is a very homogeneous distribution of low-level temperature in the combustion chamber.

The combustion process in general is defined as a complex sequence of chemical reactions in which the molecular conversion of the reactants follows a specific course related to temperature. The greater the number of chemical imbalance effects involved – as in FLOX® combustion – the more important it will be to take that point into account when carrying out numerical simulations. This is particularly relevant when trying to make precise predictions about pollutant formation. The simulations make use of DLR's IGNIS combustion code, which permits reaction schemata of any degree of complexity to be incorporated in the solution process. For the natural-gas-fuelled scenario discussed here, the so-called GRI3.0 mechanism is used. It covers 325 elementary reactions and 53 species. The coupled calculation involving both three-dimensional flow and an extensive chemical system imposes severe demands on the accuracy and stability of the simulation code, and DLR's experiment was actually the first time it had been carried out at this level of complexity

The FLOX® burner is still the subject of experimental and computational studies at DLR's Institute of Combustion Technology. Its suitability for use in high-pressure combustion in gas turbines has now been proved, and significant improvements and developments have been achieved on the basis of numerical simulation. To date, work in this area has led to the issuing of two patents.

Authors:

Dr. Harald Schütz, Guido Schmitz and Dr. Oliver Lammel are scientists at DLR's Institute of Combustion Technology in Stuttgart.



FLOX® combustion chamber: - Cylindrical chamber
- Twelve burners arranged on a concentric circle around the axis of the combustion chamber
- Axial, no-spin injection of fuel-air mixture through the burners
left: calculated distribution of flow and temperature
right: longitudinal section showing calculated CO and NO formation rates