Computer Models
For
Fire and Smoke

Model Name:	KAMELEON FIREEX KFX®
Version:	KAMELEON FIREEX KFX® Furcifer
Date:	February 14th, 2014
Classification:	Field model
Very Short Description:	KAMELEON FIREEX KFX® is an advanced Computational Fluid Dynamics (CFD) tool for three-dimensional, transient simulation of flares, gas dispersion, fire development and fire mitigation under realistic conditions in complex geometries as well as in open terrain. Detailed calculations of relevant physical quantities such as temperatures, thermal radiation, soot, smoke and gas concentrations are readily obtained. KFX™ includes powerful CAD import capabilities where electronic maps of terrain, buildings, modules, process plants, etc. are converted automatically into the calculation model. KFX™ is also interfaced with the finite element structure response codes FATHS/USFOS for non-linear dynamic structural response analysis.
Modeler(s), Organization(s):	Developed at Computational Industry Technologies AS (ComputIT), SINTEF Energy Research AS and the Norwegian University of Science and Technology (NTNU). Contact information can be found below.
User's Guide:	KFX™ Furcifer – User Manual, ComputIT Report No. R1344 (B. E. Vembe, R. N. Kleiveland, B. Grimsmo, N. I. Lilleheie, K. E. Rian, R. Olsen, B. Lakså, V. Nilsen, J. E. Vembe and T. Evanger)
Technical References:	KAMELEON FIREEX KFX® Theory Manual, ComputIT Report No. R0123 (B. E.. Vembe, K. E. Rian, J. K. Holen, N. I. Lilleheie, B. Grimsmo and T. Myhrvold)

Validation References:	KFX™ Validation Handbook, ComputIT Report No. R1345. (K. E. Rian, B. E. Vembe, T. Evanger, B. Grimsmo, R. N. Kleiveland and N. I. Lilleheie)
Availability:	User licenses can be obtained and purchased from Computational Industry Technologies AS (ComputIT), Trondheim, Norway, Tel: +47 73895900 Fax: +47 73895901 E-mail: computit@computit.no website: www.computit.no
Model Actively Supported?:	KAMELEON FIREEX KFX® is in daily use for a large number of industrial analyses around the world and is actively supported, developed and updated by ComputIT. A KFX™ license normally includes support by ComputIT's support desk, maintenance and upgrades of the code, an introductory training course, membership in the KFX™ User Group (User Group Meetings twice a year) and access to the KFX™ login on the ComputIT website. Trained specialists on the highest level, ranging from about 15 to 30 years of experience on CFD development, are actively developing KFX™. The majority of the KFX™ developers holds a PhD within computational fluid dynamics, turbulent flow and combustion, see www.computit.no for further details. The KFX™ developers are also using the KFX™ code in CFD analyses on a daily basis. Furthermore, the KAMELEON FIREEX KFX® tool is extensively validated, and the validation work is a continuously ongoing and very important activity in the development of the KFX™ simulation code. To ensure code quality, KFX™ releases are rigorously tested through ComputIT's comprehensive quality assurance program, and the release testing is documented in a release manual for each official code release.
Price:	Various types of licenses are available. For license price information, please contact ComputIT.
Necessary Hardware:	Any main stream Unix/Linux work station, including Intel PCs running Linux. Recommended RAM is > 2 GB.
Computer Language:	Fortran 77, Fortran 90 and C.

Size: 180 MB

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Detailed Description:

KAMELEON FIREEX KFX® is an advanced Computational Fluid Dynamics (CFD) tool for three-dimensional, transient simulation of flares, gas dispersion, fire development and fire mitigation under realistic conditions in complex geometries as well as in open terrain. KFX™ is developed by ComputIT/SINTEF/NTNU in Norway and it has been widely used for computational fire and smoke analyses of oil and gas installations for nearly 30 years. Presently, KFX™ is in daily use for a large number of industrial analyses around the world. Major partners in the development and industrialization of KFX™ are Statoil, Total, ENI, ConocoPhillips, Gassco, Gdf Suez, BP and Sandia National Laboratories, in addition to engineering companies, risk management companies and universities worldwide.

KFX™ solves the fundamental Reynolds-averaged governing partial differential equations for three-dimensional, transient, turbulent reacting flow using a finite-volume technique for a non-uniform Cartesian computational grid. The following quantities are determined from solving the governing transport equations:

- Momentum (three velocity components)
- Mass or continuity (pressure correction)
- Energy (total enthalpy)
- Species mass fractions
- Turbulence (extended k-ε model)
- Soot (equations for formation and combustion of nucleus and soot)
- Solid elements are rigorously treated and the consequences for mass, momentum and energy of the fluid are accounted for according to the physical processes involved. Objects less than the grid spacing are represented by volume and/or surface porosities which generate for instance restrictions to the flow field and radiation through such volumes, and are included when solving the governing equations. Thermal effects of the porosities are accounted for. KFX™ includes powerful CAD import capabilities (PDS, PDMS, IGES, Flacs macro and others) where CAD geometries are converted automatically into solid constructions or surface/volume porosities used by the KFX™ calculation model. Electronic maps of terrain, buildings, modules, process plants, etc. are readily handled, and porosities are automatically calculated on this basis.

In addition several sub-models are included, mainly to model the source terms for the different governing equations:

- EDC model for turbulent reacting flow
  - Model for exothermal chemical conversion in turbulent flow
  - Generates source terms for the species mass fraction equations with emphasis on element and energy conservation
  - Developed by Professor Bjørn F. Magnussen at ComputIT/ NTNU
  - Widely used in commercial CFD codes, but the latest, most updated version of EDC will always be found in KFX™
- EDC soot model
  - Two-equation model for the formation and combustion of soot in turbulent reacting flows
  - Closely connected to the EDC model for turbulent reacting flow
  - Developed by Professor Bjørn F. Magnussen at ComputIT/ NTNU
  - Soot is the most important parameter for radiative heat exchange in luminous fires
- Standard k-ε model with extensions
  - Includes low-Reynolds number effects
  - Includes a buoyancy term to account for conditions of atmospheric stability
- Enhanced version of the Discrete Transfer Model of Lockwood and Shah for radiation heat transfer
  - A ray-based radiation model for predicting radiative heat exchange in participating medium and between solid objects
  - Models for radiation properties of various species (soot, CO_2, H_2O and others)
  - Defines source term for the energy equation
- Pool model for evaporation and spreading of oil and LNG leakage
  - Source terms for the continuity equation, the species mass fraction equations and the energy equation
- Spray model for simulation of fire mitigation by water systems, such as water mist systems, water curtains, deluge, monitors and sprinklers, as well as simulation of spray fires
  - Lagrangian description of discrete droplets
  - The spray model is fully coupled with the gas/vapor phase
  - Source terms for the continuity equation, the momentum equations, the species mass fraction equations and the energy equation
- Wall law for turbulent boundary layer
  - Based on turbulence boundary layer analysis, wall shear stress and convective heat transfer coefficients are calculated

   - Source terms in the momentum equations, turbulence equations and energy equation
- Well-defined obstacle handling
   - The different sides of an obstacle are treated individually, and hence detailed influence of wall effects is included
   - Affects all equations

Two important and unique features of KFX™ regarding fire mitigation and protection are the link to the finite element code FATHS/USFOS, which allows for detailed analysis of the dynamic non-linear structural response to fire including optimization of passive fire protection, and secondly the option for using water as active fire mitigation means as part of the simulations. An interface between KFX™ and FATHS/USFOS communicates necessary data from the fire simulations to the finite element code.

KFX™ comes with a powerful and efficient native KFX™ CAD format which can be used to build complete geometries from scratch or to modify existing geometries imported and converted from another supported CAD format. Furthermore, KFX™ includes efficient and user-friendly pre- and postprocessor capabilities, including options for animated graphical presentations of simulation results.

KFX™ applications include

- Simulation of all kind of fires; pool fires, jet fires, two-phase spray fires, flares, fires in enclosures, in complex geometries, in open space, in still air or in windy conditions. This includes detailed calculation of temperatures, radiation, smoke generation and dispersion, visibility, concentrations of species, toxic gases, noise, etc.
- Fire impact on structures and process equipment
- Simulations for scenario- and performance-based passive fire protection (PFP) design
- Fire temperature, radiation and smoke impact on humans
- Evaluation of escape routes
- Simulation and evaluation of fire mitigation by water systems; sprinklers, deluge, mist, curtains, monitors, etc.
- Flare simulations for improved operational safety & reliability and reduction of pollutant emissions; radiation, noise (not standard KFX™ version), detailed tip simulations, ignition, startup, dispersion of hot flare gases
- Simulation and analyses of cold vents
- Simulation of LNG dispersion and fire
- Simulation of fire development and fire mitigation in underground spaces, rail and traffic tunnels
- Simulation of fire development and smoke dispersion in buildings
- Dispersion of gases, including toxic, flammable, heavy/dense gases

- Calculation of explosive cloud sizes
- Simulations for positioning and optimization of gas and fire detection systems
- Combustion simulations of incinerators, furnaces, engines, burners and other combustion devices for improved energy efficiency and reduction of pollutant emissions
- HVAC (ventilation simulations)
- Turbulent flow simulations with respect to safe helicopter operation
- Dispersion simulations of hazardous CO_2 releases from vents and accidental leakages in connection with design and safe operation of Carbon Capture and Storage (CCS) facilities and infrastructure
- Fluid flow and combustion in general
- 3D visualization, animations and contour plot in real CAD geometries

KFX™ is extensively validated, and the validation work is a continuously ongoing and very important activity in the development of the KFX™ simulation code. KFX™ is validated for a multitude of gas dispersion, flare and fire scenarios, including fire mitigation scenarios using water-based systems. KFX™ is also validated at several levels:

- Comparisons to analytical solutions and scientific experiments with a high degree of accuracy, as well as comparisons to realistic full-scale experimental tests
- Sub-model tests and integrated tests
- Small-scale, medium-scale and large-scale tests
- Blind tests and “full-information” tests

The KFX™ validation work is performed

- through the KFX™ development projects
- through collaboration with internationally recognized laboratories
- through internal and external ComputIT projects
- by other companies and institutions using KFX™

The validation work is documented in the KFX™ Validation Handbook.