VessFire

The Leading Tool for Depressurization and Fire Safety of Process Facilities

VESSFIRE

A Computer Program for the Simulation of Thermo-mechanical Response of Pressure Vessels, Flow-lines to Flare, Pipework and Heat Exchangers to Fire

INTRODUCTION

VessFire is a computer program for the time-dependent non-linear analysis of thermo-mechanical response during blowdown of process segments with or without fire exposure. The program is based on a coupled solution of problems using a combined numerical and analytical approach to simulate:

- Heat transfer from a fire onto the surface of a process segment. The process segment may consist of vessels, flow lines, heat exchangers or pipework within shut valves. One may also include insulation as fire protective coating or thermal insulation
- Heat transfer through the fire protective coating or thermal insulation
- Heat conduction through the object shell
- Heat transfer from the inner object surface to the object content fluid, both liquid and gas phases
- Non-equilibrium thermodynamics of the content gas and liquid phases
- Variation of pressure in the segment due to depressurization counter-acted by the increase of the pressure due to evaporation, boiling and expansion of the segments contents
- Stress in the object shell
- Temperature in the depressurization pipe work for material selection
- Time to object failure/rupture.

VessFire may be used for the simulation of vessels, pipes or heat exchangers in a shutdown segment. Any time variation of the heat input from the fire may be simulated.

VessFire was developed in 1998 in response to requirements in the petrochemical industry. There was a demand for a computer tool that could rapidly simulate the thermo-mechanical response of pressurized systems exposed to accidental fires both offshore and onshore. Since its inception, the program has been applied in the design and analysis of a great number of pressurized objects and depressurizing systems in the oil & gas, refinery and chemical industries. *VessFire* is used to prevent fire escalation. The program complies with:

- what *API 521 (ISO 23521)* in relation to fire exposure names “more rigorous calculation” (Ref.5)
- the requirements outlined in *Guidelines for the Design and Protection of Pressure Systems to Withstand Severe Fires* (Ref. 1)
- the requirements outlined in *Guidance for the Protection of Pressurised Systems Exposed to Fire* (Ref. 2).

VessFire is under continuous development. Petrell AS, the supplier of *VessFire*, works with process safety and simulations tools for engineering, and is also engaged in related research. New capabilities are developed in *VessFire* as new requirements are identified and research findings are obtained. *VessFire* users may also have their own specific capabilities included in the program.

PROGRAM CAPABILITIES

VessFire solves the problem of heat transfer, conduction, thermodynamics of object contents and stress using the coupled approach. The following capabilities are included in the program, all simulated with respect to time:

Heat transfer from the fire onto the object surface or onto the surface of fire protection

VessFire uses an empiric flame model where the rate of heat released from the flame is expressed in the form of heat flux varying with time. The flame model supports the widely used fire modelling technique of peak and global loads. This gives the opportunity of defining a higher heat load for an area subjected to jet fire and a lower heat load for the remaining area that mainly is subjected to radiation.

Heat transfer from the fire onto the object is assumed to cover both radiation and convection. The specified heat flux is divided into radiation and convection based on initial conditions of the exposed object. Convection heat transfer coefficients are computed by the program based on flame velocity and fluid flow characteristics. Various areas of the object being analyses may have various values of heat input (jet fire effect).

Since this heat model treats energy transfer onto the segment, *VessFire* is ideally for analysis without fire exposure. In such cases the heat load can simply be set to zero.

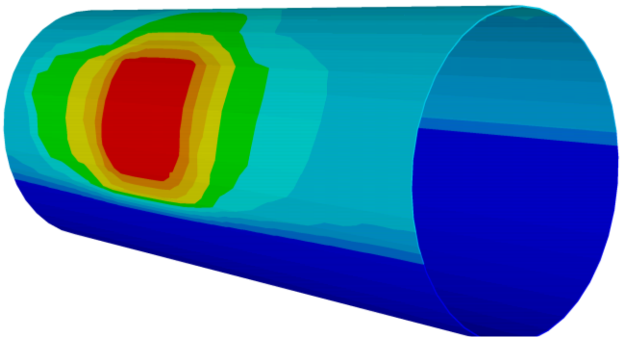

Figure 1 Illustration of gas and liquid filled vessel exposed to jet fire

Heat transfer through the object`s fire protection

VessFire includes models of various fire protective coatings. The thermal resistance of the object`s thermal protection can also be included in a *VessFire* analysis and made use of as a fire protection, provided that the sheet metal cladding that holds the thermal protection in place can survive the fire.

Three dimensional heat conduction through the object shell

Three dimensional heat conduction through the object`s shell is computed using temperature-dependent specific heat and thermal conductivity, which are included in the program for various construction materials. Temperature gradients are simulated in the radial, axial and circumferential directions.

Heat transfer from the inner surface of the object shell to the object contents

Both radiation and convection are included in the simulation of heat transfer from the object inner wall surface to the contents of the object in the liquid space and the vapour space. Commonly used emissivities are used for the radiative component whilst the convection heat transfer coefficients are calculated based on dimensionless flow numbers.

Thermodynamics of the object contents

The thermodynamic behaviour of the inventory is simulated to represent evaporation, condensing, boiling, vapour expansion and pressure, as the liquid and vapours/gas are progressively heated-up from the object shell. The simulation includes a full representation of vapour /steam tables. Multiphase fluids are included.

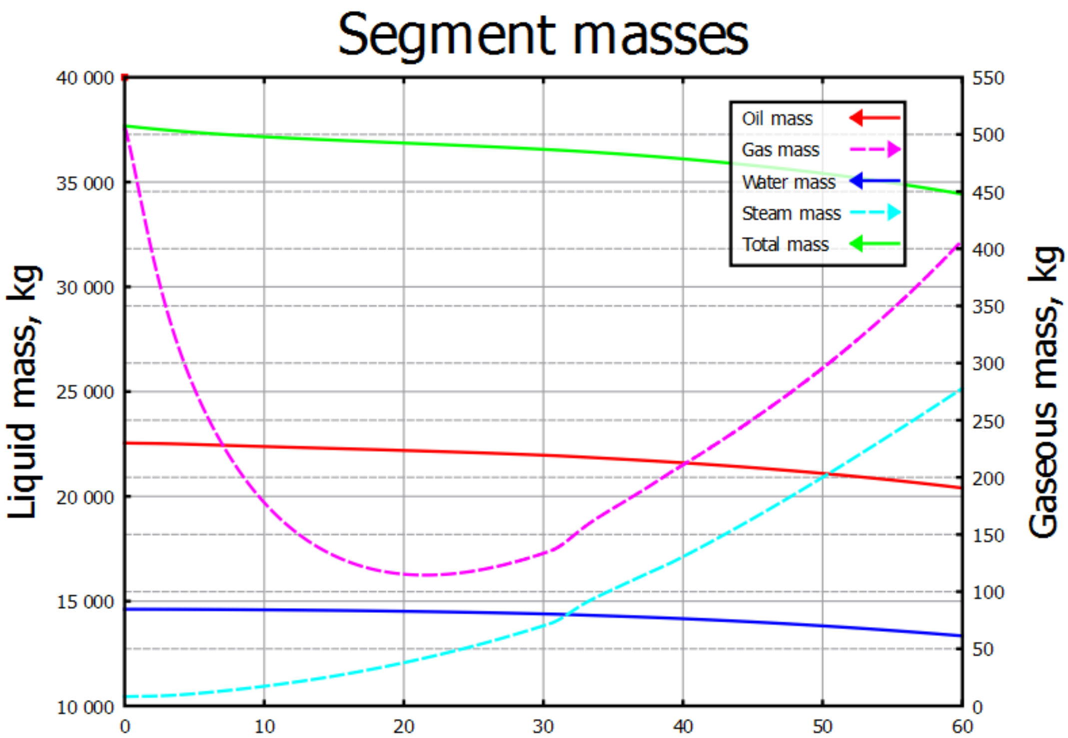

Figure 2 Illustration of the thermodynamically calculated phase-transitions

Depressurisation
Based on the given orifice size, *VessFire* calculates pressure reduction in the object caused by the blowdown process. The action of process safety valves (PSVs) is also included. The various PSV characteristics are incorporated in the program.

The program calculates the applied pressure resulting from depressurization counter-acted by the pressure rise due to the heating-up of the object's content, its expansion, evaporation, boiling and the expansion of vapours or gas in the object.

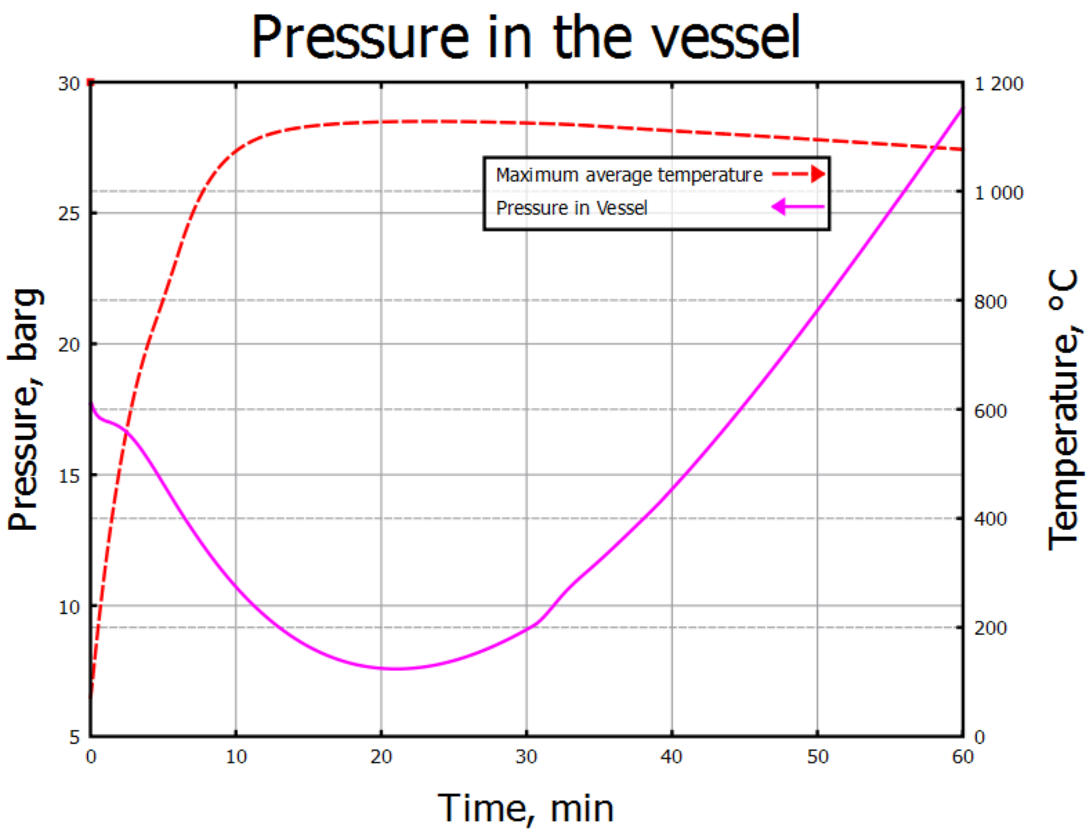

Figure 3 Illustration of a depressurization process where the pressure first decreases and then, due to boiling liquid an unsuitable flow orifice, increases again

Stress in the object shell VessFire

Based on the pressure in the object *VessFire* calculates stress components in the object shell and the combined stress. The resulting stress is compared with allowable stress where the material yield stress or the ultimate tensile strength varies with material temperature. *VessFire* contains a library of the most used steel materials and their mechanical properties. The user is also given the chance to define new material and material properties if the need arise

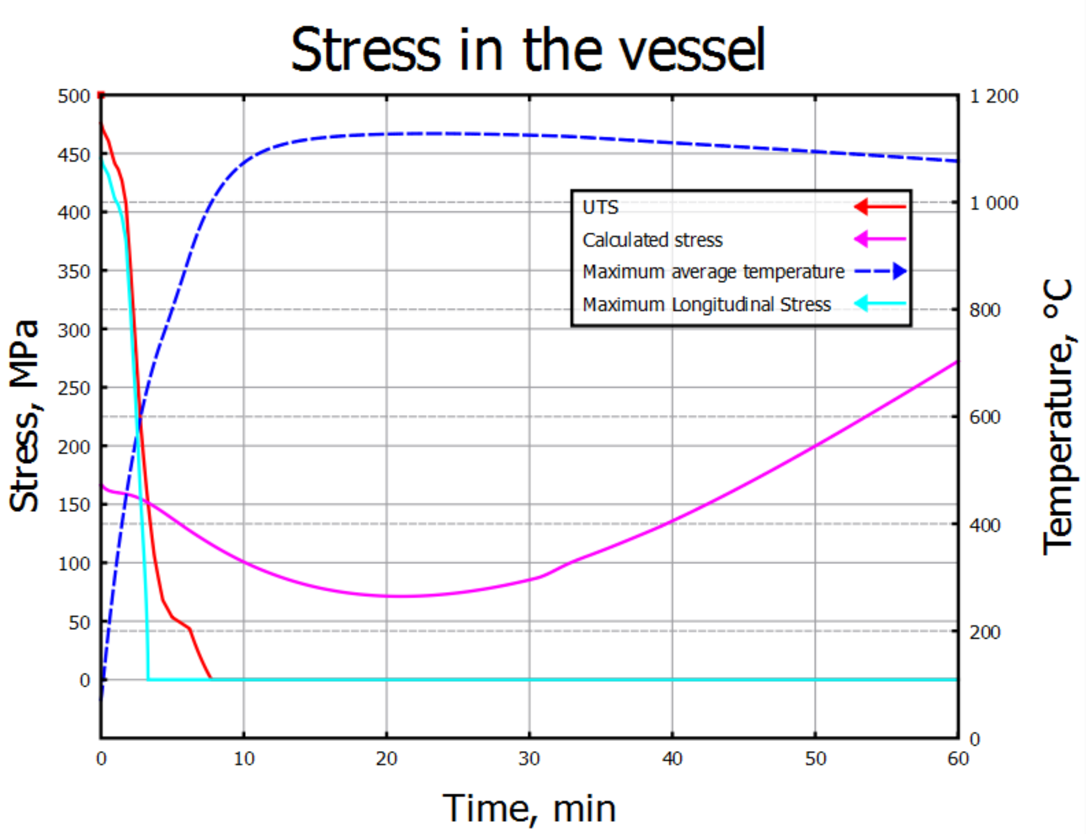

Figure 4 Presentation of vessel stress calculation. When the ultimate stress is weakened below the segment pressure the integrity of the vessel is no longer maintained and there is a rupture

Temperature of blowdown pipework

VessFire calculates the temperature of the pipework in the blowdown system. This is normally used for the selection of the pipework material as this temperature may reach very low levels due the sudden expansion of gas and the drop of the gas pressure in the system. The pipework material may get brittle if not properly selected for low temperature performance.

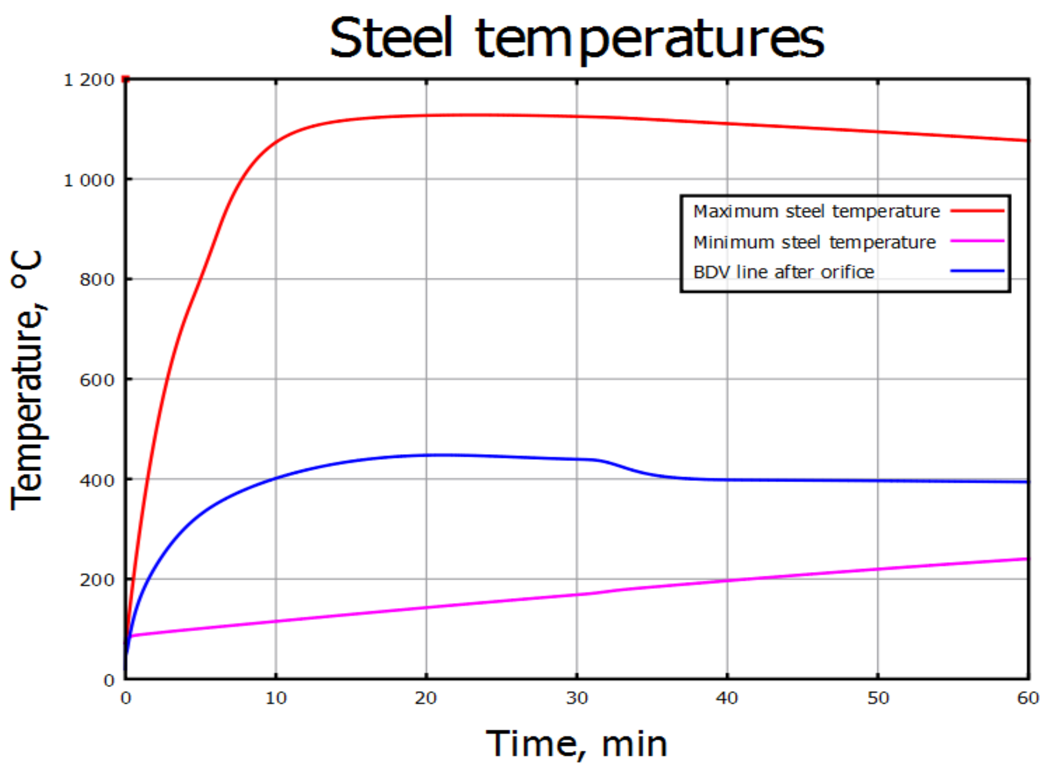

Figure 4 VessFire calculates the maximum and the minimum steel temperatures in the vessel (normally in a fire case found in respectively the gas and the liquid zones) and the steel temperature downstream the flow orifice

Time to object failure
All key results and data are displayed in the form of graphs throughout the whole history of the fire or for as long time as desired. The time to object failure is defined as the time from the start of the fire to the instant where the applied stress becomes equal to the allowable stress.

EASE OF USE OF VESSFIRE

VessFire is easy to use. The input data can be prepared in a general user interface (GUI) or by commandos in text-files. After the simulation is run, the program transfers the results of the simulation into the GUI where a set of graphs is automatically generated. In addition the simulation program generates text-files that allow the user to examine the results further, i.e. in a spread sheet.

The temperature-dependent thermal data for fire protection and the thermo-mechanical data for construction materials are not required for user input purposes as they are already built into the software. However, adding new materials is easily done.

ACCESS TO VESSFIRE

The capabilities of *VessFire* can be utilized either by

- Petrell personnel conducting engineering services for Clients
- Or by purchase of *VessFire* licenses from Petrell

For more commercial information, please contact Petrell.

DOCUMENTATION

VessFire User Manual (Ref. 3) is supplied together with a copy of the program, based on a License Agreement. The User Manual covers a general description of the program, instructions for the preparation of input data and running of the program. Documentation and validation on the program will be submitted on request. The manuals are written in English.

DEVELOPMENT

The commercial version of *VessFire* (VessFire 1.2) treats shutdown segments with an initial settle out pressure. Petrell`s proprietary CFD code Brilliant can handle further flow analysis, including multi-phase flow and local/dynamic back pressure. If this should be needed, please contact Petrell for more information.

REFERENCES

1. “Guidelines For The Design And Protection Of Pressure Systems To Withstand Severe Fires”, The Institute Of Petroleum, London. 2003
2. “Guidance for the Protection of Pressurised Systems Exposed to Fire”, Statoil, Hydro, Scandpower. 2004
3. VessFire User Manual. Geir Berge, Petrell as
4. VessFire Technical Manual. Geir Berge, Petrell as
5. “Pressure-reliving and Depressuring Systems”, API standard 521, 6th edition. 2014

CONTACT

For further information, please contact:

Tel: +47 73 80 55 00
Fax: +47 73 80 55 01
Mobile: +47 93 20 00 20
petrell@petrell.no
www.petrell.n
Olav Tryggvasons gate 40
NO-7011 Trondheim
Norway