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Water Curtain Design using Numerical Simulation for Offshore Rigs in South Pars Field Development

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Abstract
Offshore drilling operations have been done worldwide using several types of rigs. All activities and practices should be optimized to follow the important challenge which is rig costs optimization while offshore field development. Regarding South Pars water depth which is shallow, consequently jack up rigs are used to develop oil and gas reservoirs. Safety parameters are absolutely important especially in offshore practices. An artificial water curtain system is composed of a network of spray water cooling system. This system is utilized to limit the heat and noise radiation of burner and flare flowing on the rig. Numerical simulator has been developed to evaluate the performance of water curtain under various assumptions on offshore rigs. These assumptions include water curtain length, spacing of nozzles, water flow rate and pressure and etc. Simulations including heat radiation modeling and performance evaluation.
Results show heat radiation is strongly affected by the spacing of water curtain and structure of the nozzles. The installed burner booms and flares varies with different types of offshore rigs, which suggest that the distribution of water curtain pipes along the rig is also variable. Nozzles and water curtains should be located where maximize the cooling system efficiency to improve rig lifetime in field development period. Our results provide a significant consideration to design cooling system and select proper structure of offshore rigs.

Keywords : Water Curtain System, Offshore Rig, Heat Radiation Analysis, Numerical Simulation

Research Highlights
- Designing optimized water curtain in offshore rigs is a necessary parameter using numerical simulation
- To save riglife and improvement, heat radiation effects on rigs should be analyzed
- Performance of water curtain systems depends on various conditions such as water curtain length, spacings of nozzles, water rate and pressure, etc.

1. Introduction

The water curtains have been utilized for the safe and economical protection of offshore rigs and burner booms. Water curtains are an array of nozzles that are installed parallel to each other along and around the sidewalls of the offshore rigs.[4] With a water curtain, the heat radiation around burner booms can be decreased sufficiently to prevent thermal damages by creating significant spray water cooling systems. The idea is to make water continuously flow toward burner booms so that the heat can never escape out of the water curtains.

The water curtains must be sited adequate to ensure that the heat radiation in offshore rigs around the burner booms is always less than critical amount. The water flow rate and pressure is maintained by injecting sea water into the pipe lines to spray a stable cooling system with maximum efficiency.[2] The effectiveness of cooling system is strongly dependent on the water flow rate and pressure around the burner booms. Thus, it is essential that all cooling systems are filled with sea water during the operation of clean up or testing.

Despite the success of earlier implementations of water curtains, some practical problems remain to be solved. For example, the influence of the spacing of water curtain, the influence of nozzles structure is poorly understood. Therefore, we have designed a set of tests to evaluate the performance of a water curtain system in offshore rigs of gas condensate fields in Persian Gulf. The key point of our experiment is to add and modify water curtains along two different kinds of offshore rigs to improve the seal ability of the cooling systems.[1] We will present construction details for the water curtain and cooling system designs of following offshore rigs to investigate thermal effects, advantageous and disadvantageous of these different rigs and significant consideration to select proper structure of offshore rigs.

The primary function of the burner boom in addition to supporting the burner is to limit the heat radiation and noise on the rig to an acceptable level. Occasionally, offshore drilling rigs come equipped with their own burner booms. However, generally this is not the case and early consideration of the booms for the test should take place.[4] Consideration must be given to the length of boom required as a variety of lengths exist between 60' and 90' long. The choice of boom will be driven by a number of factors: expected flow rates, king post loadings, requirements of the drilling contractor and availability.[2]

Offshore testing/clean up operations use two burner systems, one on each side of the rig (port side & STBD side). This enables combustion of hydrocarbons from either one side of the rig or the other depending on the prevailing wind direction and also sometimes in the case of high flow rate based on wind condition both burner boom will be used.[3] The burner system includes a burner boom, air compressors, an ignition system, super green burner heads for the oil and an open pipe for the gas (flare), with a water deluge system.

On most designs of crude oil burner compressed air mixes with the oil in an atomizing chamber and the oil is converted into tiny droplets by the turbulent action of the air on the liquid oil. The oil is then easily ignited and depending on the flow rate the flame may be 75' - 100' long. At about 6ft from the burner focused jets of water enter the flame, where the water is evaporated and a water gas reaction occurs.[1] This reaction prevents the production of carbon black and the flame bums clean (yellow) and almost smokeless.

2. Methodology

Heat Radiation Analysis; while cleanup or testing operation, in order to analyze burner and flare heat radiation effect on offshore rigs and platforms it is highly recommended to simulate operation using one of the available industrial software packages for Heat Radiation Analysis.

Burning gas emits a large amount of heat by convection and radiation. To prevent any damages to painting, cables and personnel on offshore or platforms a heat radiation simulation should be performed. The Water Curtain is an *engineered radiant heat attenuation system* that is primarily used to reduce the hazardous effects of extreme heat during flaring operations associated with well testing and flow back projects. These activities are performed by drilling companies and their associated contractors in the upstream data acquisition phase to collect detailed information about offshore hydrocarbon reservoirs.

When a well is completed and tested, gas and oil is flared at different flow rates to receive an accurate assessment of the reservoir. The duration of this well test can be a few days to several months. During the testing, the radiant heat from the flare can reach extremely dangerous levels that pose threats to personnel as well as the offshore facility and equipment located on the deck. Without a proper Water Curtain, an oil company is subject to many hazard variables that can lead to shutting in the well test.

These variables include; shift in wind direction and speed, fluctuating well flow rates, and maximum heat exposure times for personnel and equipment. When a Water Curtain is commissioned, all of these variables are minimized, and the company has the abilities to flow the well at different flow rates.

In our calculations it is assumed that in all following heat radiation analysis related pictures north direction is the top of the picture. The following conditions entered to models as normal practice, Ideal practice and the worst case: (1) Flaring Rate for gas: 70-100 MMSCFD, (2) Flaring Rate for oil: 2500-4000 bbl/d. (3) Wind Speed: 5-25 knot, (4) Wind Orientation: parallel, opposite, perpendicular (5 different angles), (5) Water Curtain Efficiency: 50-100%.

3. Tables & Figures

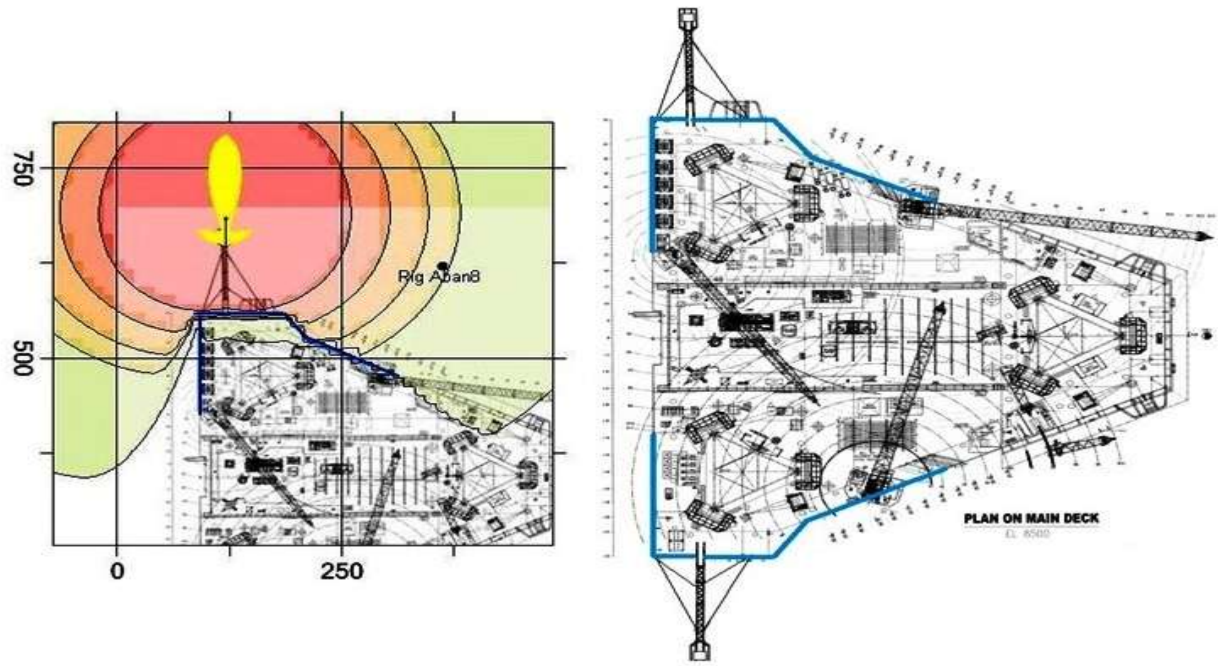

Fig.1. ABAN VIII Water curtains designed based on numerical simulation

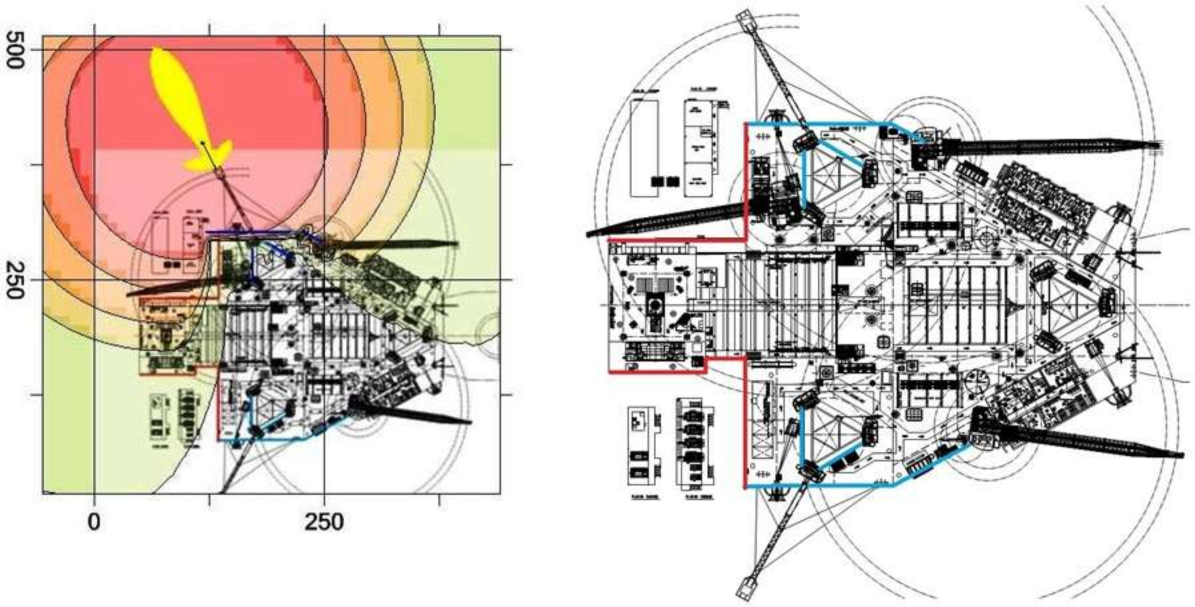

Fig.2. SAHAR II inappropraite water curtain desingned based on numerical simulation

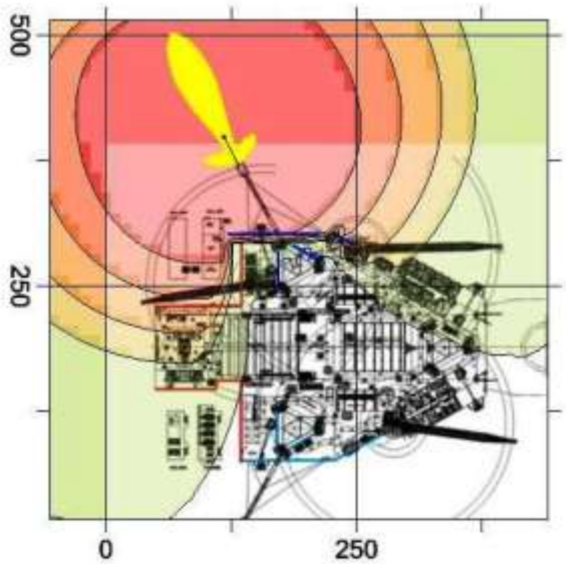

Fig.3. SAHAR II comrehesnsive water curtain desingned based on numerical simulation

Table 1. the heat flux on a contour color plot

>5000 BTU/ft^2/h	Heat intensity on structure and in areas where operations are not likely to be performing duties and where shelter from radiant heat is available (for example, behind equipment).
3000-5000 BTU/ft^2/h	Heat intensity at design flare release at any location to which people have access (at grade below the flare or a service platform of a nearby tower); exposure should be limited to a few seconds, sufficient for escape only.

2000-3000 $BTU/ft^2/h$	Heat intensity in areas where emergency actions lasting up to 1 minute may be required by personnel without shielding but appropriate clothing.
1500 -2000 $BTU/ft^2/h$	Heat intensity in areas where emergency actions lasting several minutes may be required by personnel without shielding but appropriate clothing.
500-1500 $BTU/ft^2/h$	Location where personnel with appropriate clothing may be continuously exposed.
0-500 $BTU/ft^2/h$	

4. Equations

The **minimum distance** from the center of the flare to the point of exposures estimated a follow:

$$D = (t * F* Q/4 \pi*K)^{0.5} \quad (1)$$

Where D is minimum distance from flame center [m],t is fraction of heat intensity transmitted (for a conservative analysis, t value is assumed as 1),F is fraction of heat radiated (Constant coefficient for each gas type), Q is heat release, [Kw], K is allowable radiation, [Kw/m^2] (Constant coefficient for each condition)

The **heat released** by the combustion is determined using the formula:

$$H = LHV * Q_{mass} \quad (2)$$

Where, H is heat released [watt], LHV is lower heat values [J/kg],Qmass is mass rate [kg/h]

The fraction of the radiated heat is computed by a Kent Method:

$$F = 0.2\ (50.M_w+900)^{0.5} \quad (3)$$

Where Mw is molecular weight [g/mol]. The formula Equation.3 is applicable for liquid and gas phase fluids.

Flame Length

It exists two distinct types of flame:

- The non-premixed flame: no air is injected in a combustion chamber. It is used for gas flare.
- The premixed flame: air is injected in a combustion chamber. It is used for oil burners, where air is injected.

Non-Premixed Flame (or Diffusion Flame)

Laminar

For a laminar diffusion flame, the length depends on the jet exit velocity:

$$L_f/d = 1/16\ R_e \quad (4)$$

Where, R_e is the Reynolds number taken at the jet diameter and d is the nozzle diameter.

Turbulent

For turbulent regime, the formula [Eq.5] is used for non-premixed flames. It concerns the flame at the gas flare where no air is injected.

$$L_f/d = 15/C_T\ (M_{air}/M_{gas})^{0.5} \quad (5)$$

Where, C_T is gas concentration in the stoichiometric mixture [-], d is Nozzle diameter [m], M_{gas} is molecular weight of gas [g/mol], M_{air} is molecular weight of air [g/mol]

Premixed Flame

No analytical forms are available for premixed flame lengths, even for one-dimensional flame. It follows that the flame length recommended by the British Department of Energy will be used.

$L_f = 4.64 * (H/10^6)^{0.474}$ (6)

Incident Heat

When the burner equipment has more than one head, we compute:

- a single flame length Lf assuming Q/nHead as rate condition,
- the heat released by the equipment equal to (nHead * H_f), where H_f is the heat released by the flame.

The incident heat received by an observer is given by the integral [Eq.6] along the flame length:

$$K(x) = \frac{1}{\pi^2} \int_{\Gamma} f.E.\frac{\cos(\overrightarrow{\theta_\xi})}{||x-\xi||^2} d\xi, \qquad \xi \in \Gamma \quad (7)$$

Where K is incident heat received by an observer [watt/m2], E is heat radiated [watt], *f* is attenuation factor [-], $\cos(\theta_\xi)$ is view factor =1 if observer perpendicular to the flame [-]

The heat released by the flame sources can be attenuated by applying a factor *f* due to humidity and water screen.The **output frame** shows the heat flux on a contour color plot, with the contour values reported in Table-1. *These values are provided by the API-RP-521*.

6. Results and Discussion

By comparing and analyzing the results in two different types of offshore rigs in South Pars HPHT Field, It should be pointed out that the first parameter which plays a vital role in our discussion is angle of burner booms to rigs and their positions. In the most offshore rigs all port and STBD side burner booms are installed vertically which is the best design to keep away heat. However, in a few other offshore rigs burner booms are not installed vertically and have an angle less than 90. Actually, these designs make essential problems for rig if serious actions do not be taken.

In ABAN VIII rig calculations based on equation(1) emphasize that the minimum distance from the center of flare regarding 80-90 MMSCFD flowing rate is approximately 120 ft which is more than offshore standard burner booms length (60 and 90 ft.). Thus, the water curtain is utilized to cover and mitigate this deficiency. After input ABAN VIII rig map into the simulator as background of HRA plot and apply different assumptions and conditions, results was excellent. The ABAN VIII has a perfect water curtain to diminish the heat radiation and other reqiured 30 ft is compensated (Figure.1).

In SAHAR II the minimum distance regarding 80-90 MMSCFD flowing rate is obtained approximately 140 Ft. SAHAR II has not a scientific water curtain design and as shown in rig map, red line is shortages.

The incorrect water curtain designs around the PORT and STBD leg has no effect to diminish the heat radiation effect and make sever problem such as: slippery area, electrocution, etc. SAHAR II nozzles have less efficiency in comparison to ABAN VIII because of following reasons:

1. Low diameter
2. Low flow rate due to piping
3. Low height of Spraying

Which these reasons have important effect in 3D numerical analysis as Boundary & Initial Conditions.

It should be noticed that all equipment exposed to critical area and also rig components, regarding red line areas are influenced by extreme heat radiation effect for several month and lifetime will be decreased. So it is essential to pay attention to these factor in the first stages before testing/clean-up operations. Thus, we design a state of the art water curtain system to solve this conventional problem that exist in several available rigs in persian gulf. Simulation results show that a very cheap modification of equipment and using a numerical simulator could minimize and solve significantly the problems to prevent several expensive issues raise from that deficiency. As figure.3 shows a comprehensive designed water curtain avoid considerable problems in these area.

6. Conclusions

Based on the research performed in the course of this study, the following conclusions are presented.

1. It is highly recommended to design optimized water curtain using numerical simulators.
2. In the case of highly expensive rig costs and rig rental costs, proper designed water curtain could improve field development and production management.
3. Appropriate water curtain designs play a role for the safe and economical protection of offshore rigs and burner boom and limit the heat radiation and on the rig.
4. Performance of water curtain systems depends on various conditions ssuch as water curtain length, spacings of nozzles, water flow rate and pressure, nozzles location respect to burner head and etc.
5. The best offshore rigs to perform high rate clean up or testing operations should have burner booms which are installed vertically otherwise, a perfect water cooling system is required to cover all critical areas.

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