FINE WATER SPRAY FIRE SUPPRESSION ALTERNATIVE TO HALON 1301 IN GAS TURBINE ENCLOSURES

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ABSTRACT

Although the highly effective cooling capability of water is well recognized in fire suppression scenarios, potential of its full effectiveness as a fire extinguishing agent in a fixed fire suppression system has not been fully explosred commercially until recently.

The impending phase out of halon gas as a fire extinguishant has refocused the attention on water as one of the many suitable alternatives to halon gas.

The effectiveness of water, in the form of a fine water spray and as an extinguishant has been recently demonstrated in full scale trials conducted at **SINTEF** laboratories in Trondheim, Norway. A full scale mock-up of an enclosed ABB Stal GT-35 gas turbine was used for the purposes of these tests.

At the heart of this technology is a patented twin fluid nozzle which combines water and air to produce controlled size water droplets which are readily transported into the base of the fire leading to a rapid extinguishment of large intense fires using limited quantities of water.

The system design, developed through extensive tests conducted at SINTEF and other facilities, features ease of new installation or retrofit, fire fighting efficiency, reliability, minimal maintenance and cost effectivenes.

A modular system has been developed consisting of self-contained air and water reservoirs which allow application in areas without on-site air or water service available. The air cylinder provides the necessary pressure to propel the water and the atomizing medium required to produce the controlled size water droplets.

1. INTRODUCTION

The use of fine water spray has been demonstrated in a variety of fire scenarios with success. Hydrocarbon fires ranging from light fuels (e.g., gasoline) to heavier black fuels were extinguished under various levels of ventilation, using very small amounts of water.

At the base of this technology is a twin fluid atomizing nozzle developed by *British* Petroleum ***Research*** (BP), which uses water and air operating at low pressure (60 *to* 90 psi). Compressed air (or gas) is used as the atomizing medium which when mixed with water within the nozzle produces controlled size droplets which are subsequently propelled to the fire source. (Papavergos, 1991)

This technology provides an ideal alternative *to* Halon 1301, in the protection of gas turbine enclosures. This type of installation presents a unique hazard in so far as it represents an environment operating at a high temperature, with potential fires originating from pools of fuel and oil resulting from leaks and fuel jets caused by the ruptured of high pressure fuel lines.

This paper will describe the application of fine water spray or water mist as an alternative to Halon 1301 in the fire protection of gas fired turbine enclosures.

2. BACKGROUND

The 1987 Montreal Protocol instigated a revolution in the fire protection industry, something never seen before. The abolition of the use of CFCs in the fire protection industry brought into focus the environmental issues directly related to the use of the different products, i.e., chemicals, gases, water, etc., being utilized for fire suppression purposes and forced the manufacturers of extinguishing agents to seek environmentally friendly alternatives.

This situation also prompted industry suppliers and end users to assess the situation and identify alternate methods of extinguishment to replace the more conventional total flooding systems such as Halon, CO_2 or the chemical based fire suppression systems. The direct result of this assessment was the development of a fire extinguishing method utilizing water combined with a propellant or atomizing medium such as compressed air or nitrogen. The twin fluid nozzle, so called because it utilizes both air and water, was developed and tested by British Petroleum (BP) in the United Kingdom. (Papavergos, 1991)

The'testing of the gas turbine enclosure fire suppression system using fine water spray was conducted at the laboratories of SINTEF (Trondheim, Norway), in 3 phases, using a full scale mock-up of an ABB STAL GT-35 Jupiter gas turbine. The tests were conducted under the supervision of BP officials and were carried out in accordance with ABBs recommendations in regards to the use of water on operating gas turbines. (Papavergos, 1993)

3. TECHNOLOGY

A lot of research has been done regarding the efficacy of water when applied in the form of a jet or as a fog for the purpose of extinguishing fires. Regardless of the form in which it is used, water extinguishes fires through its ability to absorb heat thus reducing or eliminating one of the elements required for a fire to take place. Firefighters have made extensive use of fog nozzles specially before entering an enclosed space. This has the effect of rapidly cooling the environment making it safer to enter the scene of the fire and subsequently extinguish the fire by applying the water jet. But where a firefighter can direct the spray or the jet to the source of the fire, a fixed fire suppression system must be designed to ensure total coverage and extinguishment regardless of the location of the fire within the boundaries delineated by the system design.

In the case of fixed fine water spray fire fighting systems, the question that is often raised is the amount of water or flow rate required to extinguish a fire. During Phase II of the testing programme it was confirmed that the water application rate of the fine water spray system is dependent on several factors such as the volume of the protected space, ventilation, products of combustion, etc. Furthermore, tested indicated that, unlike a Halon system, the fine water spray system is not sensitive to pressure drops in the piping system.

3.1 Low Pressure Twin Fluid Atomizing Nozzle

The Twin Fluid Atomizing Nozzle developed by BP consists of a two part arrangement designed to mix the water and the air in a mixing chamber, so as to form an optimum and controlled size water droplet. This process takes place at an operating pressure of 60 to 90 psi for both the air and the water. As the nozzle contains no moving parts the water

droplet is generated by the shearing effect of the air as the water is brought in contact with it within the mixing chamber of the nozzle. The combined air and water pressures have the effect of improving the penetrating effect of the water spray which is an essential element for effective fire suppression.
(Mawhinney, 1993) (Wighus, 1991)

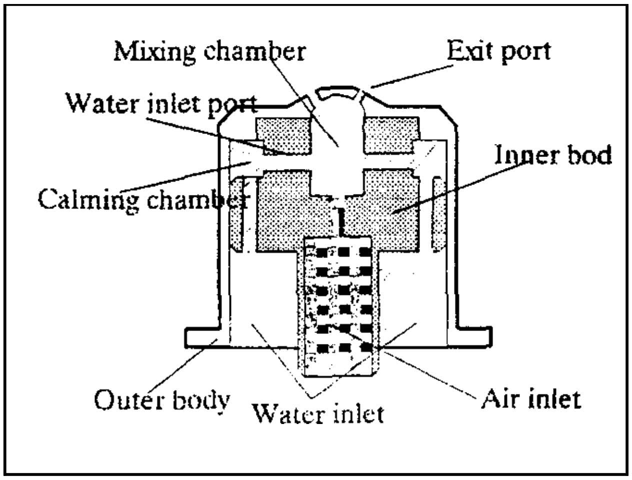

Fig.1
Fine **Water Spray Jetmist Nozzle**

3.2 Drop Size Distribution

The purpose of this paper is not to discuss the attributes or characterization of the fine water spray, drop size or distribution. The reader is invited to refer to William D. Bachalo's work in the subject. (Bachalo, 1993) For the purpose of this paper it is sufficient to indicate that BP's research established that a water droplet with a mean spherical diameter of 142µm is most effective in extinguishing hydrocarbon type fires. Water droplet measurements by means of an image Acquisition System using an AMS Optomax high speed camera, show that BP's nozzle produces water drops with an effective mean spherical diameter ranging from 80 to 200 µm. The efficacy of the mist using BP's twin fluid nozzle was confirmed and demonstrated by the tests conducted during the gas turbine test programme. It is important to note that the application of the fine water spray technology differs significantly from the application of a sprinkler system. Where a sprinkler system is installed on the basis of surface area coverage, testing indicated that the number of nozzles and flow rates are determined on the basis of the hazard, the volume of the space being protected and the fuels within the space. Since there are no engineering guidelines available to support a system design it was necessary to carry out full trial fire tests to confirm some of the assumptions made during the design phase such as coverage, distribution, flow rates, etc. (Papavergos, 1991)

In order to explain the effect of the drop size in the fire, the reader is asked to refer to Figure 3. Let us consider a pool of fuel and examine what happens when this fuel is ignited. The area of combustion takes place in an area directly above the surface area of the fuel as the result of the evaporation process. That means that if any extinguishment is to take place, it is important that the extinguishing agent enter in contact with the area of combustion. However, in the case of large, catastrophic fires (>2 Mw), nozzle placement and coverage are immaterial for efficient fire extinguishment. On the other hand, small fires, i.e., fires in the range of 1/4 to 1/2 Mw, require direct hit for extinguishment. In large catastrophic fires, wall or low mounted nozzles are more efficient than high or ceiling mounted nozzles and the best results are obtained with droplets with a diameter of 80 μm. Small fires, however, require a droplet with a higher kinetic energy in order to be able to reach the seat of the fire. The reason being that small fires do not generate sufficient air disturbance to cause the transportation of the water droplets to the seat **of** the fire.

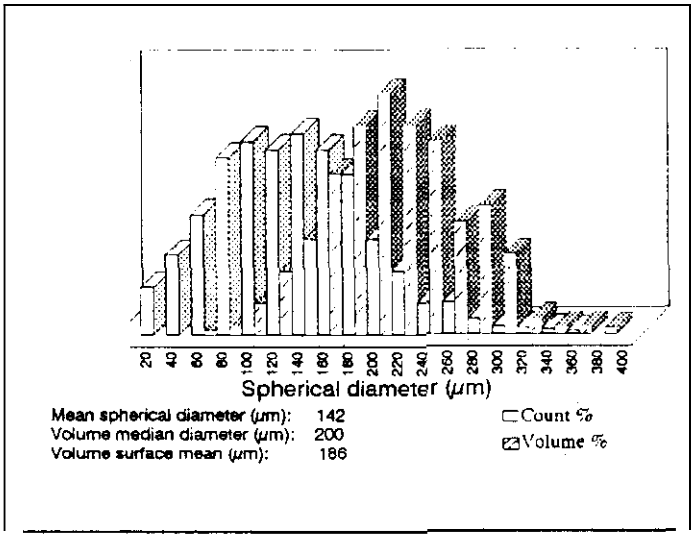

Fig. 2
Water Drop Distribution

With the adequate droplet size, the spray can be effectively directed at the combustion area. It should be noted that, by itself, the amount of water used could not realistically absorb the energy output of the fire. Nonetheless, the thermal reaction that takes place is essential for the extinguishment of hydrocarbon fires. The heat transfer effect causes the water to change from its liquid phase to its vapour phase, triggering an increase in volume by a factor of approximately 1700 times, which in turn causes the displacement of oxygen from the seat of the fire. (Papavergos, 1991)

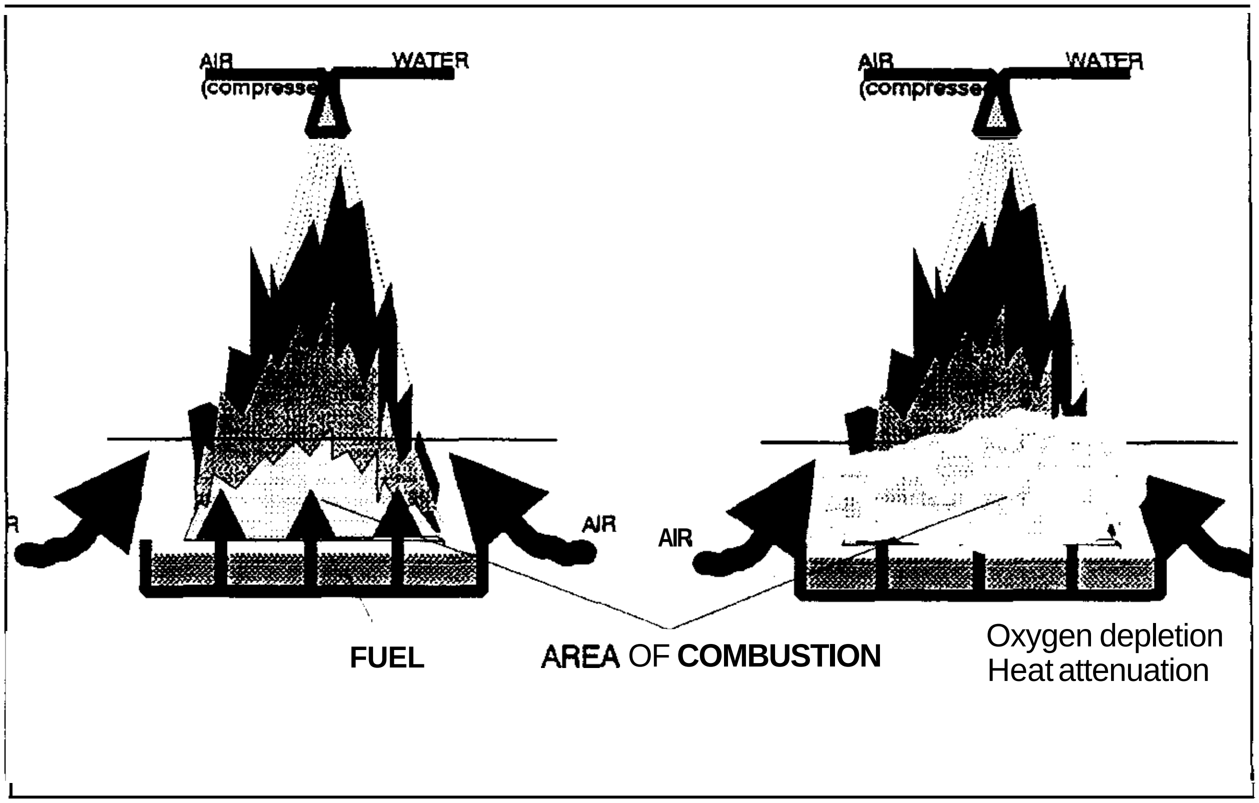

Fig. 3
Fire Suppression with Fine Water **Spray**

3.3 Atomizing Medium

As mentioned before, the twin fluid nozzle requires both air and water. During the test programme, compressed air stored at a pressure of 2150 psi was selected. It should be noted that nitrogen can also be used without any effect on the operation of the system. The required pressure at the nozzle is 75 psi (±20%). Hence it is required to reduce the storage pressure from 2150 to *75* psi by means of a pressure reducing mechanism as illustrated in Figure 7. Storing the air under high pressure reduces the need for large holding tanks. The volume of air required is directly related to the volume of water used. The ratio between water and air varies depending on the flow rate of the nozzle. This ratio could be as much as 20 volumes of air for 1 volume of water at atmospheric pressure. However at a pressure of 2150 psi the ratio becomes 0.13 to 1. (Girard, 1992)

3.4 Water Quality

Unlike high pressure systems the quality of the water is not required to be strictly controlled. As the water droplet is mostly generated inside the nozzle, the diameter of the nozzle orifices can be in excess of 2 millimetres. This makes it possible to use saline water or fresh water directly from fire mains available on site. In order to minimize blockage by rust particles or other foreign objects, it is important to use a strainer at the inlet to the fine water spray system distribution piping. This will not be necessary if the piping and the water reservoir are made of non-corrosive materials and the water supply is relatively clean of foreign objects. In the case of self-contained systems, and since it is required to store the water in reservoirs for long periods of time, it is recommended to treat the water to prevent contamination. In addition the water should be flushed regularly. (Girard, 1992)

4. FIRE SCENARIOS

A fire can be fuelled by any of the hydrocarbons present either alone or in combined fire scenarios. ABB Stal, in their report clearly define the maximum allowable natural gas and diesel fuel leakage under the forced circulated air conditions in the turbine hood. Diesel fires could occur under any of the following conditions:

1. Pool fires originating from dripping fuel onto hot metal surfaces;
2. Spray of jet fires produced from escaping fuel caused by a possible fuel line rupture or flange gasket failure;
3. Combination of 1 and 2; and
4. Smouldering fires caused by overheated fuel soaked insulation mats that result in large fires.

Hydraulic fires are normally slow burning but once established are difficult to extinguish and are prone to re-ignition. With respect to natural gas leakages it was stated that '...the concentration of any escaped gas in the generator room will not reach the LEL of methane, at the worst scenario, to cause an explosion." This means that there is no need to address the inert (or non-inert) characteristics of the fine water spray. ABBs report also addressed the potential rupture of the high pressure fuel lines to the burners. These lines operate at a pressure of 600 psi with a supply from the high pressure pumps of 146 l/min at full load. Therefore, the types of fires to be considered and actually simulated in the test programme were pool fires and jet fires. Pools with diesel and lubricating oil were strategically located directly underneath the turbine mock-up and fuel lines, operating at a pressure of 600 psi, were also positioned to simulate ruptured fuel lines. (Papavergos, 1993)

5. TEST PROGRAMME

The test programme at SINTEF was carried out in three phases. Phase I was designed *to* determine the correct type of nozzle, in terms of flow rate and angle of aperture and *to* define key parameters that would later be applied in the full scale mock-up. During this phase individual fires of propane, diesel and lubricating oil were established and analyzed. These fires were of a magnitude of 1 Megawatt and were carried out in an enclosed environment so as to simulate the enclosed conditions of the gas turbine enclosure. For this purpose one single overhead nozzle was used, directed at the pool or spray fire in a downward arrangement.

In Phase II the actual full scale mock-up scenario was examined. Figure 4 illustrates the set up and the location of the nozzles in relation to the gas turbine mock-up. The gas turbine mock-up consisted of a full scale shell of a GT-35 Jupiter gas turbine which was heated to the normal operating temperatures of a working turbine. In order to ensure that the conditions with the turbine enclosure were as close to reality as possible, experienced personnel from the offshore industry were invited to provide their input. Operating conditions were closely simulated including the ventilation system which consisted of a forced air arrangement regulated by air dampers.

One of the major concerns regarding the use of water as a fire extinguishing agent in gas turbine enclosures is the potential damage to the casing of the turbine. Clearly, it was essential to follow the manufacturer's recommendations as described in Section 6 of this paper. Nonetheless, in order to gain a higher degree of confidence and to accelerate the process of "thermal-shock" of the casing of the mock-up, it was decided to select a "...thinner metal with inferior metallurgical properties, as far as the development of metal deformation and cracks are concerned...". (Papavergos. 1993) ABB's report provides full details on the mechanical physical properties of the metal used for the mock-up casing as well as that of the actual **GT-35** turbine.

The test programme included pool and spray fires. All fuels, i.e., those encountered in the turbine hood environment, as described above, were tested individually and in combination of fires.

The scope of work, as submitted to test laboratory, was clearly defined as the requirement to test the fine water spray technology applied in large engine rooms which would be cluttered with obstruction objects with the final objective to develop sound design criteria for FWS system applications. The purpose of the tests were the following:

To find the minimum water application rate necessary to extinguish a worst case fire in a gas turbine enclosure of pre-defined dimensions.
To find the effect of nozzle position versus fire location in the turbine enclosure.
To find the effect of fire retardants when used in conjunction with water on burning insulation mats, with regards to re-ignition when same are soaked with diesel oil.
Find effect of cold water on hot turbine casing.
Determine the effectiveness of the fine water spray as a fire extinguishant in gas turbine enclosures.
Develop design parameters for the application of fine water spray in gas turbine enclosures.

During Phase II of the test programme, approximately 20 tests were conducted. In most cases the tests were conducted with the turbine casing unheated. It was important to observe the effectiveness of the fine water spray under these conditions. It was observed that the fine water spray is more effective under high temperature conditions. However, extinguishment was still achieved under "cold" conditions.

In Phase III, the laboratory was requested to validate some of the design methods formulated during Phase I and Phase II of the test programme.

6. MANUFACTURER'S RECOMMENDATIONS

As pointed out earlier, one of the major concerns of turbine manufacturers is the potential damage resulting from the application of water on superheated turbine casings. **ABB** Stal was requested to outline the operating parameters of their GT-35 gas turbine unit and to clearly define the potential fire scenarios, fire hazards, types of fuel, and the possible limitations on the use of water. In the report **ABB** carried out a full detail analysis on the effects of fine water spray to the metal surfaces ***of*** the GT-35 gas turbine and of the types of fuels and fire hazards present in the turbine enclosure. The sections of concern, which constituted the elements of **ABB's** analysis and their mechanical and physical properties are listed in Tables 1 and *2* respectively. Table **2** lists the material of the actual turbine while Table 3 describes the material of the mock-up used during the test programme at SINTEF laboratory. (Papavergos, 1993)

In order *to* establish the impact of the water on the turbines **ABB** considered two water application rates in the calculations. The two rates considered were: 5 $l/min/m^2$ and 10 $l/min/m^2$. **As** a result of this analysis **ABB** established that there would be no damage to the sections of the turbine that were considered critically sensitive, provided that the period of application of spray on the turbine fall within the parameters shown in Table **4.**

SECTION	MATERIAL	DIMENSIONS
Conical shell housing Combustor Chamber	2216-04 and 2216-94	Radius: 600 mm Thickness: 20 mm
Cylindrical shell housing: Compressor Turbine	2218-04	Radius: 600 mm Thickness: 10 mm Length: 325 mm
Flange between above two sections	2216 and 2218	Radius: 600 mm Height: 80 (50)mm Width: 80 mm

PROPERTIES	VALUE									
	221664	2218-04	2216-04	2218-04	2216-04	2218-04	2216-04	2218-04	2216-04	221864
T (°C)	100		200		300		400		500	
E(GPa)	205		195		185		175		165	
c(J/Kg°C)	510		534		572		616		662	
ρ(Kg/m³)	----7850----									
α(1/°C)[x10⁻⁶]	12.5	13.0	13.2	13.5	13.6	13.7	14.0	13.8	14.2	113.9

T= Metal temperature; E = Modulus of elasticity; c = Heat capacity of metal; ρ = Density of metal; k = Thermal conductivity of metal; *a* = Thermal expansion

PROPERTIES	VALUE				
T (°C)	100	200	300	400	500
E(GPa)	204	196	185	177	164
c(J/Kg°C)	510	534	572	616	662
ρ(Kg/m^3)	7850				
k(W/(m/°C)	53	50	48	44	41
α(1/°C)[x10^{-6}]	12.5	13.1	13.6	14.0	14.2
Plate Thickness	10 mm across the whole mock-up casing				
Composition	Carbon (max.) 0.17%; Phosphorous (max.): 0.05%; Sulphur (max.) 0.05%: Other (max.): 0.009%; no traceable Cr, Mo or Ni.				
Tensile Strength	340 - 470 MPa				
Yield Point (minimum)	235 MPa				
Elongation (minimum)	25%				

Table 4.
Period (z) of Spray w.r.t. Water Application Rate

APPLICATION RATE	INITIAL SPRAY	SUBSEQUENT SPRAYS
	τ [seconds)	τ [seconds]
5 l/min/m^2	< 10	< 10*
10 l/min/m^2	< 8	< 10*

τ = Period of application of fine water spray

* This period is recommended to avoid cyclic plastic deformation at repeated cooling cycles. Calculations show that for the 5 l/min/m^2 application rate this could be extended to 20 seconds.

It should be noted that these recommendations were for the thicker shell of the actual GT-35 gas turbine. The same guidelines were applied to the thinner (10 mm) shell of the turbine mock-up. Following ABBs recommendations, the mock-up was subjected to at least 25 cooling cycles during the test programme.

ABBs report also defined the need for a post fire examination of the material of the turbine mock-up to determine whether cracks were caused by the fine water spray. The mock-up material was examined prior to the test program and after the fire tests. ABB's report includes details of the test procedure for metal crack inspection using a test process known as "Penetrant". Since ABB predicted no deformation of the material, testing of the mock-up material to that effect was not carried out. (Papavergos, 1993)

7. GENERAL ARRANGEMENT OF TEST SITE

Figure 4 and Figure 5 show the general arrangement of the fire tests set-up including the location and number of nozzles, the location of the turbine with respect to the floor and ceiling areas and the location of the fire sources, i.e., fuel pools and jet or high pressure hoses. The inner dimensions of the enclosure are as follows:

Length	5.5 m
Width	3.5 m
Height	> 3.9 m

The arrangement is designed to simulate as close as possible a realistic GT-35 gas turbine installation including obstructions such as the pipe work. The turbine mock-up is internally heated to 400 °C to simulate normal operating temperatures. The enclosure is mechanically ventilated with realistic air change rates.

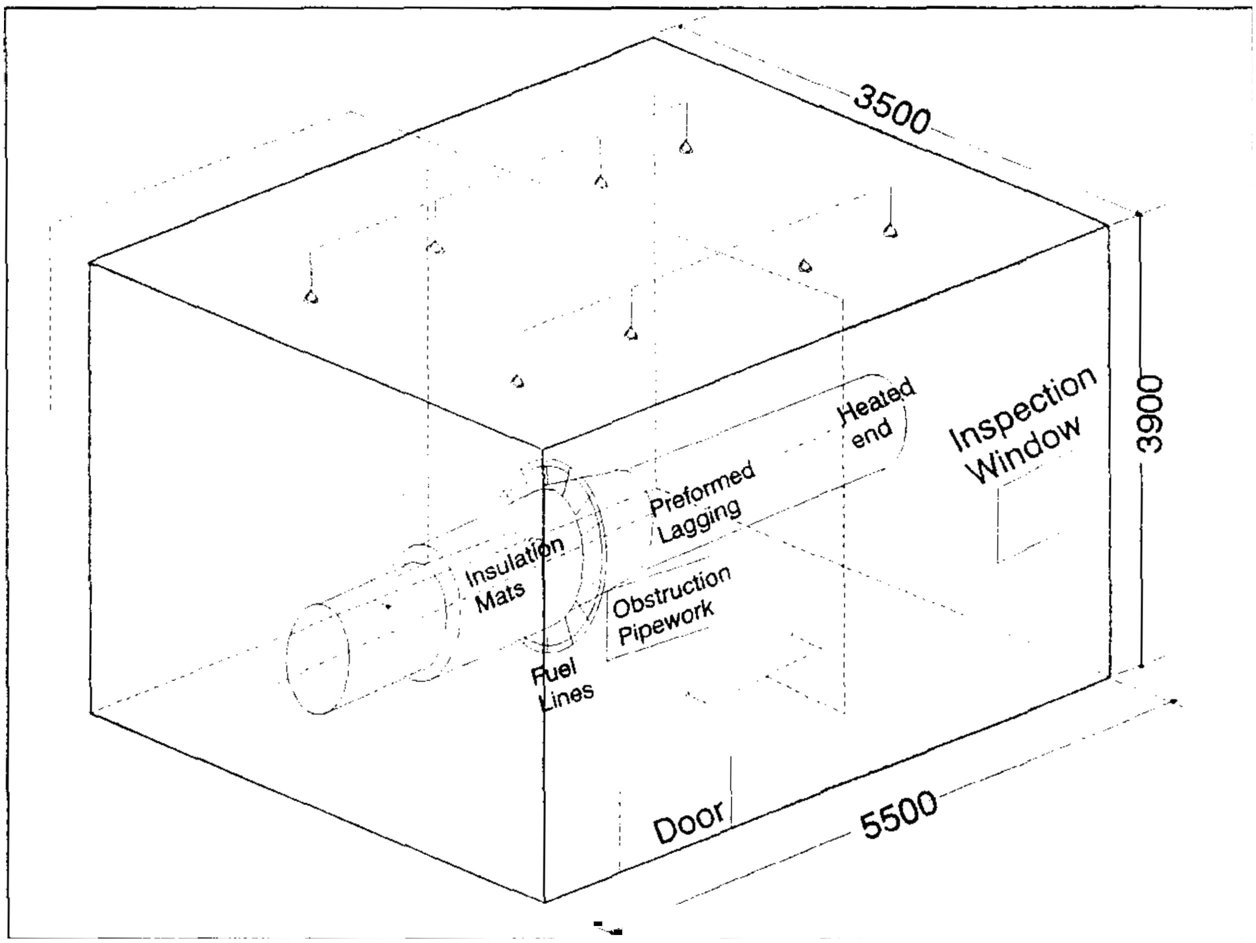

Fig. 4
Gas **Turbine Enclosure** Layout

In order to obtain the necessary performance characteristics of the fire suppression system, temperature profile and fire control performance were continually monitored by means of two racks of thermocouples and two total heat flux meters located in the short wall. In addition, ventilation air flow rate, smoke outlet temperature, compartment pressure, air and water pressure to the spray system and water flow rate were continually monitored and recorded. Finally, local temperature of the metal surface of the turbine mock-up was also measured and recorded. A fixture with lamps and a flame detector (not electrically connected) were located in the enclosure. Both units were inspected for water intrusion or damage after the fire tests. (Papavergos, 1993)

7.1 Fire Tests

Table 5 illustrates the fire types, fuel, heat output and environmental conditions for the tests carried out. Approximately 20 tests were conducted in all. Many of the tests were carried out with a cold turbine mock-up. This was done because testing showed that it is more difficult to extinguish a fire under these conditions, as the cold enclosure does not provide the heat required for the vaporisation process. Tests were conducted with open and closed door conditions, ventilation ON and OFF and with and without a pre-burn time of 10 seconds. In addition to the 3, 1 m^2 pans, four small boxes with a capacity of approximately 1 litre were located in the four corners of the enclosure.

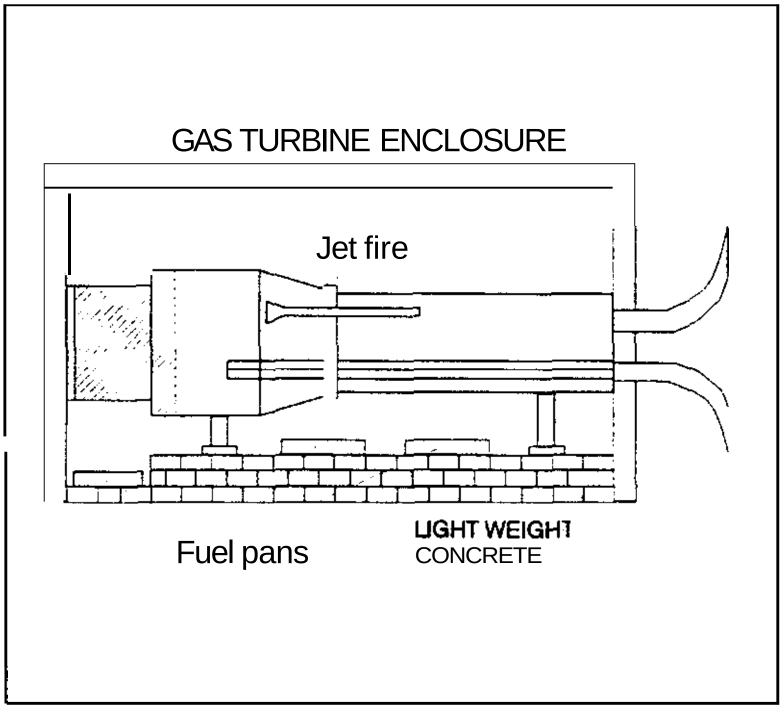

Fig. 5
Gas Turbine Enclosure, Side View

Table 5
Fire Tests Programme **Gas Turbine Enclosure**

FIRE TYPE	FUEL	HEAT OUTPUT	VENTILATION CONDITIONS			NOZZLE CONFIG. cell/other
					OFF	
JET Cold turbine	Propane	1 Mw	✓		30 s	8/4
Pool + spray	Diesel	2-4 Mw	✓	✓	-	8/4
			✓	✓		8/4
Pool + spray Cold turbine	Diesel	2-4 Mw	J	✓		8/4
3 pools + spray	Diesel	7-8 Mw	J	✓	-	814
3 pools + spray	~~Diesel~~	7-8 Mw	J		5 seconds after spray	8/4
3 pools + spray	/Lubricating oil	7-8 Mw	✓		5 seconds after spray	814
Critical fire			J		5 seconds before spray	8/4
Critical fire			J			8/4
Critical fire			J		15 seconds	814
Critical fire			J	J	15 seconds	8/4
Critical fire						
[Critical fire	Hot turbine, 3 pools + spray, diesel, 7-8 Mw of heat output.					

Tests were carried out on the insulation mats under different conditions. One section of the mat was covered with thin aluminium foil, another section was impregnated with 10 litres of fire retardant and the third was in the direct path of the horizontal diesel spray

7.2 Results of Fire Tests

Table 6
Test Data, Gas Turbine Enclosure Fire Trials

TYPE OF ARE	SIZE OF FIRE	VENTIL.		TIME TO EXTINGUISH [seconds]	VOLUME OF H_2O [litres)	DOORS & DAMPERS		NO. OF NOZZLES
		ON	OFF			OPEN	CLOS	
3 Pools Cold turbine	8 Mw		✓	15	Note 1		✓	-
3 Pools Cold turbine	8 Mw		✓	13	3		✓	2
3 Pools Cold turbine	8 Mw	✓		10	7	✓		4
2 Pools + 1 diesel spray Hot turbine	6 Mw		✓	< 10	2.5		✓	6
3 Pools + 1 diesel spray Hot turbine	8 Mw	✓		3.5	10	✓		12

Note 1. Extinguishment was attained by oxygen depletion

The final and official laboratory test report was not completed on time to permit the inclusion of the official test data in this paper. The test data presented in Table 6 is the result of preliminary test reports submitted during the test programme. The final report will be available in the near future. Table 6 includes information on some of the tests carried out during Phase II of the test programme. (Undheim. 1992)

The tests were carried out in strict accordance with **ABB** Stal's recommendation. The period of extinguishment, with a hot turbine operation, did not exceed 10 seconds. In the test cases where the insulation mats were either protected with fire retardant or sprayed with fuel, the following was observed:

Mat covered **with** aluminium foil:	The foil was displaced by the air turbulence and water. The fire was extinguished without any problems. However, since the diesel spray was also directed towards it, it became soaked and some degree of re-ignition was observed. **A** second discharge of 10 seconds successfully extinguished the reignited flames.
Mat soaked **with fire** retardant:	Extinguishment was immediate and no re-ignition was observed.
Mat soaked **with diesel fuel:**	The same conditions as those of the aluminium covered mat were observed. Here again, the second 10 second discharge was successful in extinguishing the fire.

Following the tests with the insulation mats, it was agreed that it was necessary to control the fine water spray system by means of a control unit that could provide the necessary cycling of the system. **ABB** recommended a waiting period ***of*** 60 seconds between each discharge. The use of retardant additives applied to the mats shows that its application can be highly effective as a fire prevention method and an enhancement to the fire fighting system. (Undheim, 1993)

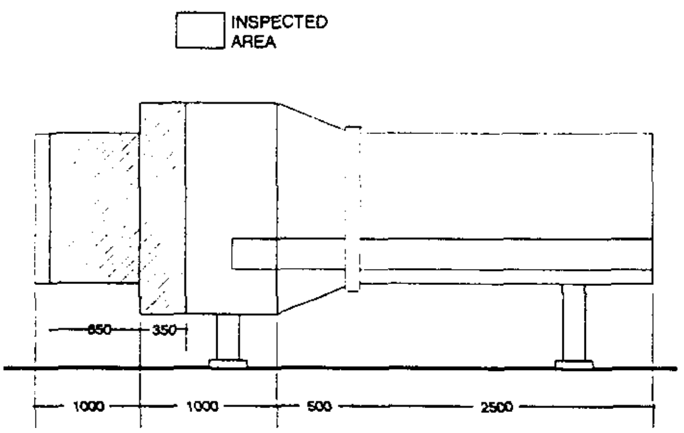

Fig. 6
Gas Turbine Mock-up, Penetrant Test Area

It was observed that total extinguishment can be attained with the doors open or closed and with the ventilation on or off. And it was further observed that the ambient conditions in the enclosure were well within safe margins shortly after extinguishment occurred. (data on GO, CO_2 and oxygen concentrations before, during and after the fire will be included in the laboratory's final report). This was an extremely important observation as it provided insight into the survivability of personnel in the case of an incident. Figure 8 is a typical representation of gas concentrations in an enclosure with a large fire (self-extinguished) and a medium size fire (extinguished by fine water spray). (Wighus, 1993) After extinguishment of a large fire (> 2 Mw) with 1 shot, the oxygen concentration in the enclosure remained below 15% for a period of 8 minutes. With repeated shots, this period was extended to approximatley 20 minutes.

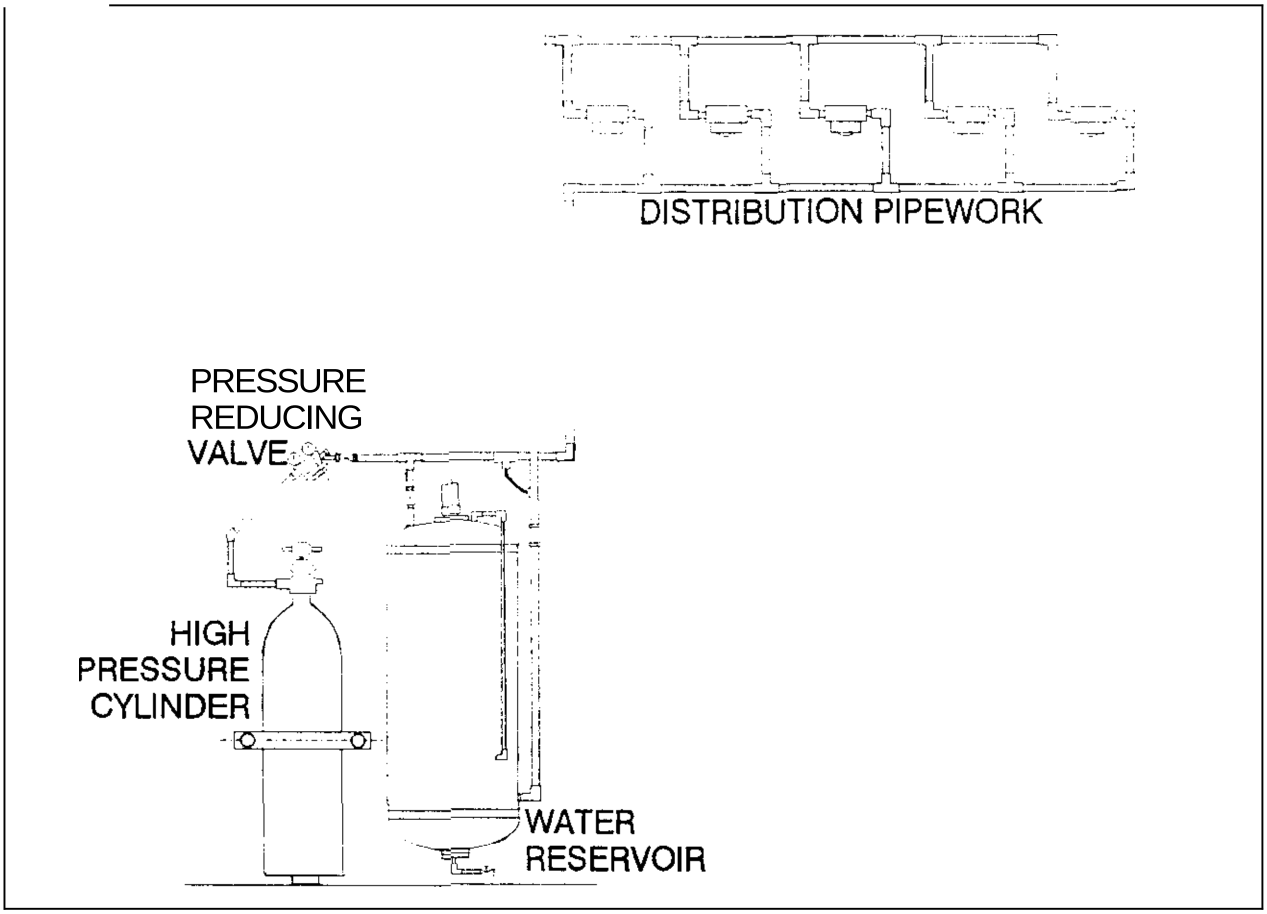

Fig. 7
Self-Contained Fine Water Spray system
(mechanical)

8. SELF-CONTAINED FINE WATER SPRAY SUPPRESSION SYSTEM

Following the test programme, the system recommended for the protection of gas turbine enclosures is a self contained unit and modular in configuration. In order to ensure sufficient water and air for two and even three possible discharges the following equipment is recommended:

1 200 litre water reservoir
2 67.5 litre high pressure cylinders

In addition, all the associated instrumentation, such as fire detection devices, monitoring sensors, control solenoids, actuator valves, etc. as well as the fire detection and control panel constitute an integral part of the system. It is important to note that the main objective of this set up is to replace an existing Halon 1301 installation. That means that the system must extinguish the fire in one shot as the Halon system would. By virtue of its modularity the system can be used to discharge one or more times. **As** in the case **of** Halon systems with reserve banks it is a matter **of** increasing the number of cylinders and the size of the water reservoir. The control system can be programmed for one or more discharges depending on the requirements. In **essence,** the detection/discharge control method is no different from that of a Halon or a **CO,** system except that in the case of a gas turbine the discharge of water can not be continued for periods longer than 10 seconds as recommended by the turbine manufacturer. (Berner, 1993).

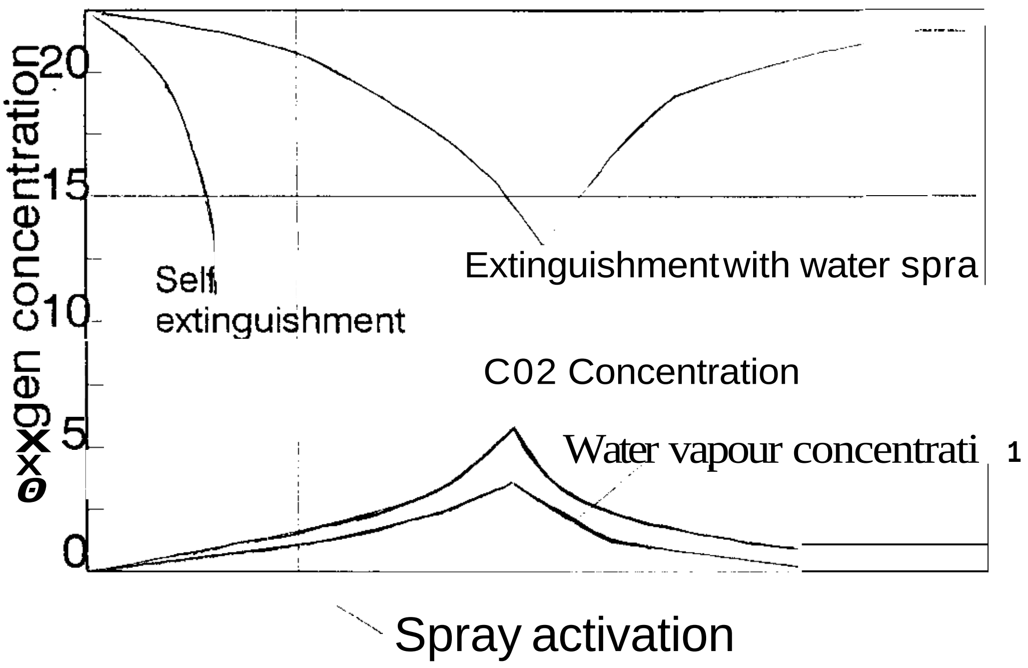

Fig. 8
Oxygen Levels in enclosed Space

9. DISCUSSION AND CONCLUSION

The end result of the test programme at SINTEF can be seen in a design document which will be submitted to North American fire protection regulatory agencies for analysis and appreciation. Subsequent testing was carried out to verify the design concepts and methods formulated during Phase II of the test programme.

The process was started with the purpose of finding a benign alternative to Halon 1301 in the protection of gas fired turbine enclosures. The ability of the fine water spray system to extinguish fires in gas turbine enclosures was demonstrated to meet the initial performance requirements with substantial built-in safety margins. Where the installation can be equipped with as much as 200 litres of water, only 10 litres were required to extinguish a large fire leaving ample room for additional discharges. The concerns regarding thermal shock and the hazardous environment within the gas turbine enclosure were dispelled.

As a final note it should be point out that the test programme served to reinforce the point that the fine water spray technology is not an ordinary fire suppression system. Until such time as organisations like NFPA have established standards and guidelines for fine water spray type systems, its application should be carried out under the supervision of qualified engineers familiar with this type of technology.

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