Storage Tank Protection
High Flow Monitors

Large storage tank fires are very complex events and satisfactory extinguishment requires methodical planning and the effective use of resources. At this time, existing codes and standards do not provide guidelines for using high flow foam monitors for large tank fires. The existing codes and standards do however provide good recommendations for fixed fire protection systems. Full surface fires involving large diameter tanks have occurred around the world. Historically, extinguishment of such fires has not been totally successful. However, with the introduction of large capacity foam monitors, new varieties of foam concentrates and improvements in application techniques there have been some degree of success in achieving extinguishment.

The largest fully involved tank fire that has been successfully extinguished was 150 ft. (46 meter). The extinguishment was carried out with a large capacity monitor/cannon applying non-aspirated foam "over-the-top" onto the burning surface. It is believed that present fire fighting technology is capable of extinguishing fully involved tank fires up to 197 ft. (60 meters) in diameter. In theory it may be technically feasible to extinguish tank fires in excess of 200 ft. (61 meters) using the "over-the-top" method utilizing very large capacity mobile monitors with improved types of foam concentrates. The logistics for mounting such massive operations must be fully considered.

APPLICATION RATE

NFPA 11: Application Rate for Mobile Equipment is often interpreted as 0.16 gpm/ft^2. (6.5 L/min./m^2). The code also states that flammable liquids having a boiling point of less than 100ºF (37.8ºC) may require higher rates of application. In addition flammable liquids with a wide range of boiling points such as crude oil may require application rates of 0.2 gpm/ft^2. (8.1 L/min./m^2) or more. The application rate stated in the code is based on the assumption that all the foam solution reaches the burning surface.

Note: The rates are intended for liquid hydrocarbon fuels. Polar solvent liquids are destructive to regular foams and require the use of alcohol resistance foams. Chemguard should be consulted to determine the recommended application rate. Taking into consideration the above rates and practical experience gained from full surface fires involving large storage tanks, it would be more appropriate to consider 0.25 gpm/ft^2. (10.4 L/min./m^2). For burning crude oil tank a rate of 0.32 gpm/ft^2. (12.9 L/min./m^2) may be more appropriate.

The elevated application rates ensure a better chance of foam reaching the burning surface, thus increasing the probability of extinguishment. Consideration for such high rates should take into account fall out from the delivery system, losses due to strong thermal updraft; break down of foam as it travels through the flames to reach the burning fuel and destruction of the foam due to the hot fuel and any hot metal surface.

WATER/FOAM CONCENTRATE REQUIRED

Water supply in terms of pressure, flow rate and adequate amount of foam concentrate are among the most important factors in launching a successful extinguishing operation. Unless an adequate and uninterrupted supply is guaranteed, an attempt to extinguish a fully involved large tank fire is doomed to failure at the very onset of the operation. The amount of water and the flow rate needed to produce foam solution to fight a large tank fire can be found in *Table 1*. The quantity of 3% foam concentrate and the flow rate needed to produce foam solution to generate foam to fight a large tank fire can be found in *Table 2*.

COOLING INVOLVED TANK/PROTECTION OF ADJACENT TANKS FROM RADIATED HEAT SOURCES

With reference to existing guidelines, the amount of water needed to cool the involved tank shell is estimated by tank size:

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100 ft. (30 meter) diameter	750 gpm (3m^3/min)
120 ft. (36 meter) diameter	1000 gpm (4m^3/min)
160 ft. (48 meter) diameter	1250 gpm (5m^3/min)
220 ft. (67 meter) diameter	1500 gpm (6m^3/min)

Cooling water required to protect each adjacent tank not shielded from the tank on fire is 500 gpm (2 m^3 /min.).

In practice, water applied to the shell of a large tank on fire is ineffective in preventing it from buckling and deforming. In the late stages of extinguishment, cooling water applied on the area above the liquid level would help the foam stay in contact with the tank shell. The cooling streams should be stopped when foam attack has started to conserve water and to concentrate on extinguishment. The need for protecting adjacent tanks can best be illustrated with information and data published in a recent study done on large tank fires. Although not yet fully validated, it nevertheless provides valuable information for pre-fire planning purposes.

The time required to create an escalation condition in an adjacent tank depends upon a number of factors including tank size, distance/separation, and type construction, initial boiling point of flammable liquid in the tanks, water-cooling, tank design, wind speed and direction.

For example, a full surface fire involving a 164 ft. (50m) diameter open top, floating roof naphtha tank fire could be expected to fully involve a neighboring identical tank in approximately 1.5 hours under the following conditions:

- 4 m/sec.(14 km/hr.) wind towards neighboring tank
- Intertank separation of 0.5 diameters (82 ft.)(25 m)
- Neighboring tank having pontoon roof and inadequate water spray protection

Altering any of the above conditions can change the time for ignition of the adjacent tank:

Base Case: 1.5 hrs.

CHANGE OF CONDITIONS

Calm (no wind condition): 2.8 hrs.
Intertank separation increased to 1.0 D(50m): 3.0 hrs.
Intertank separation increased to 2.0 D(100m): 17.0 hrs.
Water protection on side facing exposure: 2.8 hrs.
Double deck roof on exposed tank: 1.5 hrs.
Water protection on side facing exposure + double deck roof: 24.0+hrs.
Tank diameters only 30m but with 0.5 D separation: 0.5 hrs.
Neighboring tank contains kerosene, not naphtha: 22.0 hrs.

CONCLUSIONS DRAWN FROM THE RESULTS

- Escalation is likely for unprotected tanks of volatile material with normal separation unless the original fire is extinguished quickly.
- Calm conditions only delay the escalation potential.
- Increased separation alone only delays the escalation potential.
- Water spray protection or roof insulation alone does prevent escalation.
- Water spray and roof insulation together are effective.
- Smaller diameter tanks at normal separation are at greater risk of escalation than larger diameter tank.
- Lower volatility fuels provide more response time for fire fighter.

Cooling of adjacent tanks is best achieved with fixed systems that are designed to provide effective water film coverage of all exposed metal surfaces. A cooling water rate of 0.05 gpm/ft^2. (2.0 L/min./m^2) is sufficient to absorb 90% of incoming radiant heat. Any increase in the cooling water rate does not increase the cooling effect significantly. The figure of 10.2 L/min./m^2 by NFPA 15 relates mainly to the protection of pressurized vessels such as LPG tanks subject to direct flame impingement.

OVER THE-TOP-APPLICATION TECHNIQUE WITH LARGE CAPACITY FOAM MONITORS

A present concept in extinguishing large tank fires is to employ large capacity non-aspirated foam monitors to apply foam "over-the-top" of the involved tank onto the burning fuel surface. Although they are normally known as non-aspirated monitors, these monitors are capable of producing foam with an expansion ratio of about 3.1 to 4.5 when used with alcohol resistance type foam concentrates.

Chemguard has large capacity foam monitors currently available with capacities ranging from 2,000 to 4,000 gpm (7,570 L/min.). The equipment operates at inlet pressure between 100 to 130 psig (690 to 890 kPa) and has a range of about 250 to 300 feet (61-99 meter).

AR-AFFF type foam concentrate is preferred and it should be transported in bulk totes or trailers having large capacities. The logistics for transporting foam in 5-gallon pails or 55-gallon drums to the fire scene should not be considered, for obvious reasons.

Large diameter hose should be used to supply the flow required for large volume foam attack. The use of 5" (125 mm) diameter hose is preferred due to low frictional loss and ease of utilization. It must be remembered that it is extremely difficult to move the hose once it is charged with water. For quick estimation, provide one 5" (125 mm.) hose line for every 1,000 gpm (3.8 m 3 /min.) flow requirement. At this flow rate the friction loss is 8.0 psig (55 kPa) for every 100 feet (30.5 m). Table 3 provides information on friction loss of some large diameter hoses.

The “over-the-top” foam technique attacks the burning tank with either a very large capacity monitor that meets the required application rate or combines several monitors to form a mass stream discharging with the wind to concentrate on a selected landing zone within the tank.

This extremely high “local application rate/density” promotes survivability of the foam journey through the fire to establish a foothold on a relatively small area of the burning surface. Once the foam blanket at the landing zone is established it can then be expanded by making adjustments to the mass stream. The added advantage of large volume application in a small area may help to reduce “local fuel temperature” and the associated actual vapor pressure, which in turn can help in lowering the fire severity. These factors require consideration because as the fuel temperature approaches the boiling point of water, it is difficult for the foam to survive. As fuel temperature increases the true vapor temperature will increase to overcome the effectiveness of the foam blanket.

Large volume foam attack should be launched as quickly as possible; however, it must be stressed that application must not be carried out until all equipment and logistic support are in place. The longer a tank is allowed to burn, the greater the danger of escalation. The fuel temperature increases making it more difficult to extinguish, and the exposed tank shell deforms (normally the exposed steel curls inwards to create nooks and crevices) making it difficult for foam to cover the entire burning surface. In the case of crude oil, the possibility of having a “boil over” increases with time.

The ability to deal with large tank fires depends on methodical pre-fire plan, regular training and exercises. The most important factor, however, rests on minimizing the risk of having a fully involved large tank fire through good engineering design, effective management and maintenance programs.

TABLE 1

WATER FLOW RATE TO PRODUCE 3% FOAM SOLUTION TO FIGHT FIRES IN TANKS

MINIMUM QUANTITIES

TANK DIAMETER		WATER FLOW RATE				TOTAL WATER REQUIRED TO SUSTAIN 65 MINUTES OF OPERATION			
		Application Rate				Application Rate			
Feet	Meter	0.16 gpm./ft^2	6.5 L/min./m^2	0.25 gpm./ft^2	10.4 L/min./m^2	0.16 gpm./ft^2 Gallon	6.5 L/min./m^2 Meter^3	0.25 gpm./ft^2 Gallon	10.4 L/min./m^2 Meter^3
100	30.5	1218	4598	1904	7357	79170	299	123760	478
110	33.5	1474	5563	2304	8902	95796	362	149750	579
120	36.6	1754	6621	2742	10594	114005	430	178214	689
130	39.6	2058	7770	3218	12433	133797	505	209154	808
140	42.7	2387	9012	3732	14420	155173	586	242570	937
150	45.7	2741	10345	4284	16553	176133	672	278460	1076
160	48.8	3118	11770	4874	18834	202675	765	316826	1224
170	51.8	3520	13288	5503	21262	226801	864	357666	1382
180	54.9	3946	14897	6169	23837	256511	968	400982	1549
190	57.9	4397	16598	6873	26558	285804	1079	446774	1726
200	61.0	4872	18391	7616	29425	316680	1195	495040	1913
210	64.0	5371	20276	8397	32444	349140	1318	545782	2109
220	67.1	5895	22253	9216	35606	383183	1446	598998	2315
230	70.1	6443	24322	10072	38916	418809	1581	654690	2530
240	73.2	7016	26483	10967	42376	456019	1721	712858	2754
250	76.2	7613	28736	11900	45981	494813	1868	773500	2989
260	79.2	8234	31081	12871	49733	535189	2020	836618	3233
270	82.3	8879	33518	13880	53632	577149	2179	902210	3486
280	85.3	9549	36047	14927	57679	620693	2343	970278	3749
290	88.4	10243	38667	16013	61872	665820	2513	1040822	4022
300	91.4	10962	41380	17136	66213	712530	2690	1113840	4304

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TABLE 2

FOAM CONCENTRATE (3%) TO PRODUCE 3% FOAM SOLUTION TO FIGHT FIRES IN TANK

MINIMUM QUANTITES

TANK DIAMETER		WATER FLOW RATE				TOTAL 3% FOAM CONCENTRATE REQUIRED TO SUSTAIN 65 MINUTES OF OPERATION			
		Application Rate				Application Rate			
Feet	**Meter**	**0.16 gpm./ft^2**	**6.5 L/min./m^2**	**0.25 gpm./ft^2**	**10.4 L/min./m^2**	**0.16 gpm./ft^2 Gallon**	**6.5 L/min./m^2 Meter^3**	**0.25 gpm./ft^2 Gallon**	**10.4 L/min./m^2 Meter^3**
100	30.5	38	142	59	228	2470	9.25	3835	14.79
110	33.5	46	172	71	275	2989	11.19	4640	17.89
120	36.6	55	205	85	328	3557	13.31	5522	21.30
130	39.6	64	240	100	385	4174	15.62	6481	24.99
140	42.7	74	279	116	446	4841	18.12	7617	28.99
150	45.7	86	320	133	512	5558	20.80	8629	33.27
160	48.8	97	364	151	582	6323	23.67	9818	37.86
170	51.8	110	411	171	658	7138	26.72	11063	42.74
180	54.9	123	461	191	737	8003	29.95	12425	47.92
190	57.9	137	513	213	821	8917	33.38	13844	53.39
200	61.0	152	569	236	910	9880	36.98	15340	59.16
210	64.0	168	627	260	1003	10893	40.77	16912	65.22
220	67.1	184	688	286	1101	11955	44.75	18561	71.58
230	70.1	201	752	312	1204	13066	48.91	20287	78.23
240	73.2	219	819	340	1311	14227	53.25	22090	85.18
250	76.2	238	889	369	1422	15438	57.78	23969	92.43
260	79.2	257	962	399	1538	15697	62.50	25925	99.97
270	82.3	277	1037	430	1659	18006	67.40	27957	107.81
280	85.3	298	1115	463	1784	19365	72.48	30068	115.94
290	88.4	320	1196	496	1913	20773	77.75	32252	124.37
300	91.4	342	1280	531	2048	22230	83.21	34515	133.10

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TABLE 3

FRICTION LOSS PER 100 FEET / 30.5 METERS

FRICTION LOSS IN WATER SUPPLY LINE EXPRESSED AS PSIG & kPa LOSS PER 100 FEET / 30.5 METERS OF HOSE

FLOW		4 INCH SUPPLY LINE		4-1/2 INCH SUPPLY LINE		5 INCH SUPPLY LINE		6 INCH SUPPLY LINE	
USGPM	L/MIN.	PSIG	kPa	PSIG	kPa	PSIG	kPa	PSIG	kPa
100	369	0.20	1	0.10	1	0.06	1	0.05	0.3
200	737	0.80	6	0.40	3	0.32	2	0.20	1
300	1106	1.80	12	0.90	6	0.72	3	0.45	3
400	1474	3.20	22	1.00	10	1.28	9	0.80	6
500	1843	5.00	34	2.50	17	2.00	14	1.25	9
600	2211	7.20	50	3.60	25	2.88	20	1.80	12
700	2580	9.80	68	4.90	34	3.92	27	2.45	17
800	2948	12.80	88	6.40	44	5.12	35	3.20	22
900	3317	16.20	112	8.10	56	6.48	45	4.05	28
1000	3685	20.00	138	10.00	69	8.00	55	5.00	34
1100	4054	24.20	167	12.10	83	9.68	67	6.05	42
1200	4422	28.80	199	14.40	99	11.52	79	7.20	50
1300	4791	33.80	233	16.90	117	13.52	90	8.45	58
1400	5160	39.20	270	19.60	135	1568	108	9.80	68
1500	5628	45.00	310	22.50	155	18.00	124	11.25	78
1600	5897	51.20	353	25.60	177	20.48	141	12.80	88
1700	6265	57.80	399	28.90	199	23.12	156	14.45	100
1800	6634	64.80	447	32.40	223	25.92	179	16.20	112
1900	7002	72.20	496	36.10	249	28.88	199	18.05	124
2000	7371	80.00	552	40.00	276	32.00	221	20.00	138
2100	7739	88.20	608	44.10	304	35.28	243	22.05	152
2200	8106	96.80	667	48.40	334	38.72	267	24.20	167
2300	8476	105.80	729	52.90	366	42.32	292	26.45	182
2400	8845	115.20	794	57.60	397	46.08	308	28.80	199
2500	9214	125.00	862	62.50	431	50.00	345	31.25	215

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