Flowrates/Frictional Loss/Pump Charts
11TH August 2008

I have been given the task of producing charts for the pump bays of the appliances, at first glance this may seem straightforward but there are a number of important factors that need to be taken into account and the service will need to decide the way forward. The following report will highlight these points and give my recommendations:

Flowrates

I recently carried out a number of tests to establish exactly the frictional losses encountered through our hoselines for various flowrates (45mm/70mm and the 52mm hose we have on trial, all terminating in a Delta H500-65f Hand Controlled Branch), the test results are attached. Interestingly, the test results have shown that the fireground formula for frictional loss has proved to be more accurate than Angus Fire's hose calculator, their calculator results in the need for a higher figure to be added per length.

It can be seen from the charts that at the different pump settings there's not a dramatic change in flowrates, these tests just go to show that the H500-65f's branch there is no significant increase in flowrate with an increase of pressure at the pump. It must be remembered that these results reflect seriously low flowrates and could place our crews in serious danger! In the next part of this report I shall go on to explain and provide proof to justify such a statement.

H500-65f Branches

We tested a further four branches and the results are very similar to our previous tests (see attached test results). The branch would require an inlet pressure at the branch of between 9-11 bars to achieve flow rates in the region of 450-500 l/min.

Recommendation 1:

The service use the fireground formula for calculating frictional loss through our hoselines. This formula is available to everyone (it can be used on the fireground, although lengthy hydraulic calculations and pump operating at the same time should be avoided and the provision of the pump charts should on most occasions alleviate this problem).

A margin for error is included into the figures produced in the pump charts because of kinking, snaking etc of the hose.

All crews are made aware of the benefits of keeping hoselines as straight as possible where practicable.

Efficiency Factors

A compartment fire may only burn with an efficiency factor of approx 50% and the actual amount of HRR (Heat Release Rate) occurring inside the compartment may not be as high for the fire loading as if it were 100% efficient (if it were we would be looking at using even higher flowrates). But to understand the need to flow our hoselines correctly, the firefighter needs to appreciate that firefighting streams are never 100% efficient. It is estimated that solid streams are about 50% efficient and fog patterns are approx 75% efficient in their ability to control and suppress fires. Therefore, only 250 l/min will have any effect on a fire when using a 500 l/min solid stream.

Critical Flow Rate V's Tactical (Safe Flow Rate)

Critical Flow Rates are those that are working right on the limits. They are bordering on being unsafe and yet they may well suppress the fire with success if the conditions are right, but of course it would be difficult for the firefighters on scene to predict or foresee this success. The Tactical Flowrate is that which is calculated with an inbuilt safety margin for error (Grimwood's formula), it is perhaps twice that of the CFR but it takes account of the unpredictability of a compartment fires progress through the stages of 'growth' and 'development' towards steady state burning. It also accounts for the dynamic movements of energy release that may be encountered inside compartment fires. **Critical Flow Rates are not a target to meet but a target to BEAT!**

Recommendation2:

The service adopts (as also recommended in the 'Branches report') Paul Grimwood's simple 'rule-of -thumb' formula for calculating the 'ideal' tactical flow requirements for compartments with 2.5m ceilings. This is based on the need for a single attack line operating from an interior position in compartments with floor spaces between 50m^2 to 600m^2 the formula recommends a minimum and safe flowrate from the primary attack line equal to:
Ax4 = Litres Per Minute (LPM)
Where A = Area in m^2 (based on 2.5m ceilings)
4 = for normal/average fire loads (and should be increased to 6 for heavier fire loading or fires involving structural members or is wind assisted creating forced draughts).
The *tactical flowrate* is for fire suppression during the growth-phases of development, or in post-flashover *steady state* enclosure fires before the decay-phase has been reached. This flowrate will allow for attacks in both the fuel phase and gaseous phases of combustion being the two basic types of combustion that firefighters may face in almost every compartment/structure fire, namely-

Fuel-Phase Fire – *Two-dimensional* fuel bed or surface fire.

Gaseous- Phase Fire – *Three-dimensional* gaseous-phase fire.

The *tactical flowrate* is suitable for the three methods of fire suppression, using water, that may be applied by choice to deal with the above two 'types' of fire-

Direct Attack – *Direct straight-stream to deal with the fuel- phase fire.*

Indirect Attack- *The use of indirect fog attack should be considered under certain conditions.*

3D (three-dimensional)
Offensive Water-fog – *A 3D offensive application of water-fog to tackle the gaseous-phase combustion.*

Recommendation 3:

Any literature we produce relating to this subject that refers to gas cooling, places the term '3D' in front of it (the '3D' refers to the *volumetric* mechanisms of combustion in the gaseous-phase). I believe this will assist our firefighters to understand the hazards encountered in the gaseous-phase and will therefore help them in choosing and understanding the correct water application method ('3D Offensive Water-Fog') and the science behind it. It will also enable them to understand the differences between '3D' and 'Indirect Attack's' and to ensure that their '3D Attack' doesn't turn into an un-intentional 'Indirect Attack' with its associated hazards.

This 'Indirect' Fog application may create a problem caused by the 'piston' effect of the expanding steam, (striking hot surfaces within the compartment results in a sudden transition to super-heated steam), which would push smoke, heat and occasionally fire into relatively unaffected parts of the structure. The thermal balance within the compartment may be subjected to an 'envelope' effect, whereby the indirect application of water would again push heat towards the far wall before moving upwards and across the ceiling and then returning down to surround the advancing fire-fighters! In 'real' fire situations the 'perfect' application is difficult to achieve and a small amount of water may strike hot surfaces within the compartment. Therefore the nozzle operator should attempt a cooling ratio of 2:1, in favour of hot gases over surfaces, to prevent the application turning into an 'Indirect Attack'.

'3D Water-Fog' applications require a cone angle be around 60 degrees and this should be applied at approximately a 45degree angle to the floor.

Paul Grimwood suggests that in terms of tackling compartment fires in the gaseous-phase, the strategy of '3D Water-Fog Attack' is limited to a maximum compartment size of 70m² (this was not mentioned in the ODPM reports into firefighting in Highrise buildings). He has encouraged that where a transition between interior uses of pulsing 'Water-Fog' and 'Direct Attack' 'jet' streams lies and where gaseous/fuel-phase fire involvement beyond 70m² exists, 'Direct Attack' via high-flow 'jet' streams become the most effective means of suppression.

Recommendation 4:

We adopt the above policy and ensure this information is included in any operational procedures.

Air Track Management

If we asked the following question to most firefighters "At what stage does ventilation start at a compartment fire?" In the cold light of day they may ponder over this and come up with correct answer, but if they are honest and in the heat of the moment how many of us have opened up the front door to a premise and proceeded straight in to locate and tackle a fire! By opening the front door it may be an extremely influential action and have major effects on the fires development. This action may set in motion a 'gravity current' where air is sucked in at low level and smoke comes 'pushing' out with high velocity at the top of the compartment doorway. Where gravity current is allowed to progress unchecked, the fire will be dynamic in its progression and development towards some form of dangerous 'Event' associated with the phenomena of 'Rapid-Fire Progress'. The UK's firefighters experience an event; termed 'abnormal rapid fire development around 600 times every year and this alone should prompt a tactical approach that ensures a capable flowrate from the point of initial entry.

If this 'Air Track' (gravity current) was to go unmanaged, apart from what's described above, as the fire gases leave the compartment (assuming the compartment door is partially or fully open) there is a plentiful supply of oxygen and they may combust with some great ferocity. Therefore the greatest HRR will be as it gets near to the area of higher ventilation (the compartment doorway) thus requiring the nozzle operator to have the correct flowrate stream velocity, and nozzle tip pressure in advance (possibly needing even greater cooling capability in the firefighting stream at the door entry than that required inside the compartment itself).

Recommendation 5:

'Air Track Management' is taught and practiced and forms part of our Dynamic Risk Assessment and Operational Procedures.

I will refer back to 'Air Track Management' at a later date.

Primary Attack Lines

It is in this next statement where the service needs to decide on its flowrates for its primary attack hoselines.

There have been several international research studies into the ideal *base-line flow* for a primary low-pressure attack hoselines and these have been fairly consistent in their approval for the 51mm hoseline flowing 450-560 l/min. This research takes into account such relevant issues as (a) optimal flowrates; (b) manoeuvrability and manual handling; (c) nozzle reaction; and (d) stowage and tactical deployment issues. Such hoselines are fast becoming established as ideal attack tools, for a primary offensive advancement by two firefighters into most compartment/structural fires where the fire area is contained within 100m². In situations where a defensive mode of attack is necessary, or where any particular fire front is rapidly escalating through an established heavy fire loading, extensive structural fire involvement, or wind gusts (for example), the higher flows will be necessary. However, be aware that flows up to 950 l/min from a 51mm hoseline are generally perfectly manageable by a team of two firefighters in a defensive or offensive 'holding position' (the nozzle reaction would be too powerful to advance such a line whilst flowing).

Needed Flowrates For Various Tactical Applications (Grimwood)

Solid Stream (Direct) Fire Attack-**CFR (2 l/min/m²); TFR (4 l/min/m²)**

Water-Fog (3D) Fire Attack-**CFR (3.25 l/min/m²); TFR (8.13 l/min/m²)**

Water-Fog (Indirect)-**CFR (0.3 l/min/m²); TFR (2.5 l/min/m²)**

If we accept the above as I believe we should, it can be seen from my earlier statement with reference to the test result and them producing seriously low flowrates that we are potentially committing crews armed with under flowed hoselines. And with some pump operators setting their pumps with seriously low pressures e.g. 4bars (no matter how many lengths of hose are in the attack line), resulting in flowrates heading towards hosereel rates but at seriously low pressures (See 'Go With The Flow' report page 3 paragraph 3).

There are several factors that go to making an effective interior firefighting stream including nozzle pressure, stream velocity, flowrate, nozzle reaction, application pattern, technique and design and most importantly of all, the skill of the nozzle operator. If we go back to Critical Flowrates it can be seen that some of these pump settings will be close to the minimum flowrate required which for any stream is around 200 l/min (using either high or low-pressure) and allowing for the losses due to the efficiency of straight streams (**50%**) and fog patterns (**75%**), to ensure our firefighters are correctly armed and avoid them having to try and play 'catch up' as the fire escalates, we must address the low flowrates through our branches.

I have discussed the possibility with Ian Gardner from DeltaFire with reference to flowrates through the Delta H500-65f Branch and I asked if they could alter the flowrate through the branch i.e. 500 l/min @ 7 bars. He said this could be done; he also informed me of their new branches, the 'Attack 500' which is supposed to flow 500 l/min and has a dial collar to give adjustable flowrates. They also supply an 'Attack 750'; of which he is sending me some details. I also asked him about pressure losses through their branches (this is because in my understanding of the correct '3D Fog

Attack', it requires a nozzle tip pressure of 7 bars) he could not answer my question there and then but said he would find out and come back to me.

I also discussed with him hand controlled smooth bore jet/spray (fog) and 'A' type nozzles for High-rise fire fighting. He said they may have something suitable.

Recommendation 6:

The service explores the above and the possibility of other suitable branches available from other manufacturers. To include, a suitable fog/jet combination smoothbore nozzle with flow control handle and pistol grip for High-rise firefighting, providing a minimum flowrate of 500 l/min at a branch inlet pressure of 4 bars. Also a suitable solid stream smoothbore nozzle with flow control handle and pistol grip, providing flowrates of 470 l/min at a branch pressure of 2 bars also for High-rise firefighting. Also contact other Services to see what they use/recommened.

Recommendation 7:

Because of the high flows in the primary attack line we should return to 1800 litre tanks (see 'Go With The Flow' report).

Recommendation 8:

The supplementary water supply should be established where practicable before the primary attack team are committed.

High-Pressure Hose Reels

Most of the property fires we attend each year will be well within the capabilities of high-pressure hose reels be them 19mm or 25mm.The most frequent argument I encounter is "I've (or we've) always used (or got away with) using hose reels". To the firefighter who is posing this argument, it is difficult to convince them any different. But any firefighter that has or will experience a rapid-fire development progressing towards some form of dangerous 'Event' will question it no more! Any firefighter that enters a compartment fire with the correct equipment, flow rate and techniques will upon extinguishment leave the building and tell their friends (crew) about the 'job'. The same fire fighter if leaving the same 'job' but this time with the wrong equipment, flow rate and techniques, will leave the building and will want to tell **everybody**!! Fortunately, most firefighters in Hertfordshire will never experience the above during their career let alone each year but if they did we would have a lot of firefighters speaking out and the argument would be won.

If the Service decides that hose reels may be used (because of the limited tank supply), as a primary attack line at certain compartment fires then in my opinion the following should apply:

Recommendation 9:

25mm tubing is used guaranteeing a minimum flow rate of 200l/min (CFR).

Recommendation 10:

Only to be used for compartment up to 70m² with known low fire loadings, and the incident commander is sure that to tackle the fire it is well within the capabilities of the hose reel.

Recommendation 11:

The high-pressure side of the pump 'World Series Pump' or 'Prima' (for GM pumps see 'Hose Reel Branches And Frictional Loss' report Appendix1) needs to be set at 40 bars to ensure the minimum of 200 l/min (CFR) is available. This will also enable a high velocity '3D Fog Stream Attack' to take place to deal with combustion in both the gaseous-phase and fuel-phase in limited primary attack situations. This is not achievable with 19mm low flow tubing.

Tech1/35 is revised to reflect this.

Recommendation 12:

When in use, all of the tubing is removed from the drum and kept straight where practicable.

Reccomendation 13:

The nearside and offside tubing are not joined together when hosereels are used at compartment fires. Crews need to be taught the reasons why (high frictional losses dramatically reducing flowrates). If the hosereel tubing off one side of the appliance is not long enough then they should default to lay flat hose.

Recommendation 14:

A secondary (back up) low-pressure high flow lay flat hoseline is always laid out.

Pump Charts

If, as I believe, we should increase the flow through our lay flat attack lines. This will need to be reflected in the charts. The following will show examples of frictional lossess for higher flowrates through a single 25m length of 45, 52 &70mm hose:

1x45mm Hose	1x52 mm Hose	1x70mm Hose
350 l/min = 0.7 bar loss	350 l/min = 0.4 bar loss	350 l/min = 0.1 bar
400 l/min = 1.0 bar loss	400 l/min = 0.5 bar loss	400 l/min = 0.1 bar
450 l/min = 1.2 bar loss	450 l/min = 0.6 bar loss	450 l/min = 0.1 bar
500 l/min = 1.5 bar loss	500 l/min = 0.7 bar loss	500 l/min = 0.2 bar

It can be seen from the above that to achieve some of these flowrates through our 45mm hoselines, we will need to factor in higher pump pressures to counter these losses and achieve the flowrates required. The following gives examples of how we can reduce these losses, keeping the pump pressures lower:

For these examples we will use a nozzle inlet (not tip pressure) pressure of 7 bars producing a flowrate of 500 l/min

3 x 45mm Hose = **7 Bar + 4.5** Bar FL = Pump Pressure Of **11.5** Bar Flowing

3 x 52 mm Hose = **7 Bar + 2.1** bar FL = Pump Pressure Of **9.1** Bar Flowing

1x45mm+2x70mm Hose = **7 Bar + 1.9** Bar FL = Pump Pressure Of **8.9** Bar Flowing

1x52mm+2x70mm Hose = **7 Bar + 1.1** Bar FL = pump pressure Of **8.1** Bar Flowing

It can clearly be seen from the above that if we configure our hose differently (break with tradition), then we can greatly reduce frictional losses, pump pressures and nozzle reactions. So for example, where a hoseline consisting of three lengths is laid to a

doorway and only one 25m length is to be taken in the building then by using 2x70mm hose as the first two lengths from the pump, we can reduce FL/pump pressures.
Neither the old manuals nor the new Fire Service Manual gives reference to configuring hose in this way. I think this is wrong and should be addressed and wherever hoselines are laid they should consist of the largest hose diameter available up until they reach the length or lengths where there are manual handling issues e.g. branch length.

Recommendation 15:

The service adopts the above practice and crews are taught the theory behind it and to adopt it where possible. Also for them to lay hoselines as straight as possible where practicable.

'Duraline' Hose Working Pressure

It can be seen from the result above that hose pressures may, will and do today on the fire ground exceed 10 bar pressure this is not a problem with 'Duraline' hose as its working pressure is 15 bar and its test pressure is 22.5 bar pressure. The service policy for testing hose is to test it to 10 bar pressure. We may not have the facilities to test our hose to 22.5 bar but we can test it to its working pressure of 15bar (see 'Branches, Hose lines And Fire fighting In High Rise Buildings' report).

Recommendation 16:

The service adopts the above policy to include any hose repair being capable of withstanding the 15 bar test pressure.

Prior To Entry Into A Compartment Fire

Any crew about to enter a compartment fire should be armed with knowledge above and be armed with the correct firefighting equipment. Prior to entry they should consider:

A – Air Track Management: When making any entry into a building, consider their actions and the effects of the'Air Track' (gravity current) and the control of it.

B – **Back Up (Flowrate):** Will the flow rate be adequate to carryout their objective and give them the back up should the fire escalate.

C – Cooling: Pulse some water droplets up into the overhead at the entrance doorway to the fire compartment just a second prior to opening the compartment door.

D – Door Entry Procedure: Carry out the correct 3D Firefighting door entry procedure including making use of the negative pressure below the 'interface' where air is being drawn towards the fire and a further amount of water-droplets are placed into this 'air-track' to maximise the effects of 3D techniques.

E – Extinguishment: Choosing the appropriate tactical methods from the three suppression techniques:
3D Offensive.
Direct Attack.
Indirect Attack.

The firefighter should continually reassess A B C D E in their minds throughout firefighting operations.

Pump Operators

At a building fire, the pump operator has the most important role because without him or her doing their job properly, everything else may fail. We have strict procedures for BAECO's and strict rules as to what they can and can't do. We should apply similar rules to pump operator and allow them to concentrate on the difficult role they have, providing and maintaining the correct flow of water.

Recommendation 17:

The pump operator has one role at a serious building/compartment fire.

Recommendation 18:

The pump operator has an assistant (a trained pump operator).

Recommendation 19:

The pump operator or his assistant is in radio contact with BAECO or the nozzle operator and vice versa to allow for any immediate action required or a change in circumstances e.g. increase in flowrate needed due to rapid fire development, or if there's a problem with the water supply etc.

Recommendation 20:

There is a JO appointed to run and control pumping operations (not to operate the pumps) their duties to include ensuring the pump operator gets what they require to carry out their duties. To calculate flowrates and to do any other Hydraulic calculations required e.g. calculation on hydrant supplies, open water sources, and water relays. Yes, I know the fireground is not the best place to carry out complicated calculations but this and management of the pumping operations would be their sole responsibility at a fire.

Recommendation 21:

The above to be taught and practiced on CMMI courses and for the JO's /Pump operators to be issued with pocket books/pump books.

Recommendation 22:

White boards to be fitted to pump bay doors to assist with the above, or this information could be available using the 'Tough Books'.

Recommendation 22:

Hoseline identification tallies to be provided in pump bays to enable them to be attached to hoselines to make them easily distinguishable (this is not as obvious as it sounds).

Water Relays

There is a real lack off understanding by many pump operators when it comes to relaying water over distances or passing water from pump to pump over short distances. This is evident in our lack of knowledge of frictional losses and (knowledge of which is essential and a key element for a water relay to be successful) and pump operating.

Recommendation 23:

Water relaying to be taught to all crews.

Recommendation 24:

Water relay charts sited in pump bays.

H.V.P.'s

High Volume Pumps and water relaying within the service, I shall refer back to this subject at a later date.

The Canterbury House Reports

Although I have not seen the reports and I am lead to believe there are some differences between the reports findings and my reports. I believe this is because of the following:

During the tests the figure used for pressure loss through static head would have probably been 0.0842 bar per metre and not the fire ground figure of 0.1 bar per metre. My fireground formula also allows for possible additional losses (1.0 bar) through additional riser pipe work and fittings and assumes that kinking or snaking of hose lines will take place (the ODPM's reports also addresses the possibity of losses through the riser pipe work and fittings). The fireground formula is a quick aid to the pump operator and incident commander at an incident, who may not have all the technical data for each premise to hand. It allows a small safety margin for the possible unknown losses and is intended to give an approximate figure for pressure available at the outlets for any given floor. The frictional losses through the relevant hoseline fitted with a pre-selected branch and the flowrate (it's the branch inlet pressure which determines its flowrate) could then be determined. This would enable the pump operator/oic to carry out a risk assessment to see if it's possible to carry out a safe attack of the fire. I used the formula to produce some examples of pump charts taking into account different notional storey heights.

The following examples may be more reflective of the Canterbury House results:

Assuming a Notional Storey Height of 3m and using an outlet on the 13th Floor.

13 x 3m = 39m 39x 0.0842 (Static Head) = 3.2838

10 bars (riser inlet pressure flowing) – 3.2838 = **6.7162 bars (6.7) outlet pressure on the 13th Floor.**

Assuming a Notional Storey Height of 3m and using an outlet on the 17th floor.

17 x 3m = 51m 51 x 0.0842 (Static Head) = 4.2942

10 bars (riser inlet pressure flowing) – 4.2942 = **5.7058 bars (5.7) outlet pressure on the 17th Floor.**

It must observed from both the above examples that even placing a branch directly into the landing outlet that a nozzle pressure of 7 bars is not achieved, therefore it would not be possible to carryout a '3D Offensive Fog Attack'.
As stated earlier, any '3D' application technique needs to be precise and relies heavily on suitable equipment, flowrates and training and where '3D Fog Offensive Attacks' at Low-rise fires (up to 70m²) are far superior to 'Straight Stream Attacks'. At High-rise fires when under flowed or where there is insufficient pressure the fog attack would fail to meet the requirements to make it effective. It would turn into a low-pressure fog attack with all the associated hazards previously described in this and my 'Go With The Flow' report. Therefore different firefighting techniques need to be employed.

It can also be observed that at certain floors we would be working close to or not achieving the Critical Flowrate of 200 l/min.

E.g. 17th Floor using 2 x45mm hose requiring a flowrate of **200 l/ min.**

The frictional loss for 200 l/ min through 2 x 45mm hose = **0.9 bars** (0.45 per length)

17th floor outlet pressure of 5.7 bars – 0.9 bars (FL) = **4.8 bars** (which would be the inlet pressure to the branch.)

Branch Four (see test charts) only flowed **190 l/min @ 5 bars** at the branch; this is below the Critical flowrate.

British Standard rising mains are generally designed to operate at a maximum pressure of 10 bars and the above examples are assuming there is a riser inlet pressure of 10 bars when an outlet is flowing. Because the riser is possibly only rated/tested to 10 bars then we need to set our pump at 10 bars static inlet pressure (no outlets flowing). If at 10 bars static a branch were to be opened up and the pump operator was to increase the throttle setting to bring the flowing inlet pressure back to 10 bars (the increase in throttle setting would be dependent on the amount of water being flowed) they would not be able to predict when the branch will be shut down and shutting the branch may result in the static pressure exceeding the maximum 10 bars. If more than one branch were to be got to work at the same time and the pump throttle was again increased to maintain a 10 bar riser inlet pressure this would result in an even higher static pressure if the branches were again closed. It can be seen from the above that if we take this into account it would actually result in lower outlet pressures on each floor so any figures used to calculate outlet pressures would need to allow for and reflect this. Yes, the pump operator could try to predict the above but it would require a high level of skill, concentration and communication between the nozzle operators and themselves. Pump operating at a High-rise already requires a high level of skill!

Another important factor we mustn't over look is 'Water Hammer', when many of these risers were installed firefighters would have tackled High-rise fires with high flow low pressure 'A' type branches (straight streams), but today with our modern branches and techniques, many of our firefighters would automatically 'pulse' resulting in the possibility of water hammer occurring. Unless the riser has a built in pressure relief valve then this could be a hazard. The following will explain:

Pulsing of nozzles can cause standing shock waves to travel back down the hoselines, riser and into the pump, if (as in Herts) a collecting head is fitted with non return valves and the pumps were being fed from a pressure fed supply. The pressure waves will have nowhere to go and could cause damage/rupture of the weakest component. Pulsing can cause pressure spikes, which may be higher than the nominal pressure. It is theoretically possible that the timing of the pulse (the closing of two branches at exactly the same time) may hit a natural frequency of reflected shock waves, which may result in a magnification of the pressure pulse. The 'World Series' / 'Prima' pumps have a built in Suction Pressure Relief Valve (SPRV) that begins to operate at 12 bars and unlike the

Anti-Surge Valves (ASV) on the high-pressure side of the pump (ASV's are fitted because the effects of water hammer is greater when pulsing high pressure hosereel branches), it may not offer the same protection. Although all of the previous statement is still true at a lowrise fire, the hose/pump may absorb much of the kinetic energy (or its conversion to pressure energy) in the water and may prevent the failure of the weakest part (often the collecting head, hoselines are possibly being able to absorb most of the kinetic energy in the water).We cannot be sure of any effects the increase above 10 bars or the effects of water hammer will have on the riser installation.

All of the above should be taken into account when planning equipment, techniques and training for High-rise firefighting. When calculating outlet pressures we need to ensure that crews realise the difference between 10 bar static and 10 bar flowing pressures.

I am sure if the test results for flowrates through our branches and hoselines contained within this report were compared to Canterbury House report then they would reflect very similar results. My formula was always meant to be for use on the fireground, but the best option is to have all our High-rise Buildings flow tested and the results recorded and available to the pump operator at an incident. The Service must decide the way ahead and take into account all of the above it will be then that I can produce the relevant pump charts. As I stated in my opening statement, "at first glance this may seem straight forward" but I hope I've proved it is far from it!

Recommendation 25:

All risers to be tested, to include hydrant testing and the recording of flowrates available at different times of the day.

Recommendation 26:

Investigate the possibility for the maximum working pressure for any given riser installation to be safely increased above 10 bars.

This report is in no way meant to offend anyone or contradict any safe practices; again it relies heavily on other people's knowledge and hard work for which I can take no credit. It is not the intention of this report to focus in on what we don't know but its aim is to help us find our way forward. My watch have been a great help in carrying out the flow tests and in compiling this report.

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