MW1 C STATION TRAINING AND INCIDENT CASE STUDIES

FILE NO. SR / 02.

11th ALARM PORT KEMBLA ETHANOL BULK STORAGE TANK FIRE

"Learning from Excellence…
To Protect the Irreplaceable."

Cover photo: Numerous defensive master streams are in operation as firefighters establish protection of surrounding storage tanks.

Incident Videos (**Control + Click** on YouTube symbols to watch)

Incident Summary

On the morning of Wednesday 28th January 2004, workers were carrying out an upgrade of Tank 11, the largest storage tank onsite at the Flinders Street, Porta Kembla bulk flammable liquid storage tank complex. Tank 11 was approximately one third full, containing almost five million litres of ethanol. Shortly before 1000 hours, sparks from a welding rod ignited flammable vapour within a vertical pipe connected to the storage tank, resulting in a major explosion occurring that blew the 120-tonne fixed steel roof off the tank. The explosion was heard and felt over 25 kilometres away. The tank roof landed on the site firefighting foam protection system, destroying the equipment and rendering it inoperable. A major fire broke out, involving the full surface of Tank 11, producing extreme fire conditions that included 80-metre-high flames, an enormous smoke plume and extreme levels of radiant heat. The ethanol tank was burning fiercely. As bad as the situation was, it was already rapidly deteriorating. Numerous bulk flammable liquid storage tanks were located in close proximity to the involved ethanol tank and were under threat. Most seriously threatened was Tank 14, containing 14 million litres of heavy marine bunker fuel oil and beginning to buckle, glow red and vent smoke. Radiant heat from the blazing ethanol tank was causing the structures of nearby industrial sites, including fuel storage depots and factories to start to release pyrolysis gases. The enormous BlueScope Steel coke works were potentially under threat. This is the situation that confronted firefighters when they arrived on scene minutes after the first '000' call was received. The initial actions of the first arriving firefighters were absolutely critical and would ultimately decide the outcome of the incident. The first line was placed in operation and the stream directed onto exactly the right part of Tank 14 to prevent tank failure and catastrophe from happening. Throughout the day, firefighters would continue to place defensive lines around the fully involved ethanol tank, strengthening protection of tanks under threat, using ground monitors, appliance roof monitors and aerial master streams. Firefighters extinguished and saved multiple exposures that ignited due to the tremendous radiant heat being produced. Over the following 20 hours, firefighters fought an enormous tactical and strategic battle, under oppressive and horrendous conditions, to establish fire control and ensure all exposures remained protected. At the height of firefighting operations, 75 kilometre per hour wind gusts were driving horizontal flames onto the heavily threatened Tank 14. By daylight the next morning the fire was extinguished, all exposures were intact and a significant catastrophe had been averted. The best possible incident outcomes had been achieved, in the face of the strongest adversity, due to the determination, skill and courage of the responding firefighters and the sound leadership and strength of command of the fireground commanders. This was NSWFB at its best. The positive lessons to be shared from this incident will inspire and motivate firefighters for years to come. Those lessons are just as valid today as they were on the morning of 28th January 2004.

Key Learning Points

1. Firefighting Operations at Bulk Flammable Liquid Storage Tank Fires.

2. Fires Involving Bulk Stored Ethanol.

4. Exposure Protection.

5. Managing Large and Complex Fire Incidents.

6. The Importance of Pre Incident Planning Exercises.

7. The Hazards Presented by Radiant Heat.

Incident Type:

Flammable Liquid Bulk Storage Tank Fire - Full Surface Fire.

Station Training Program References

STP Drill 1 - Flammable Liquids and Gases
STP Drill 2 - Special Fires (Bulk Storage, Dust, Cladding, Plastics, Metal, and Rubber Fires)
STP Drill 4 - Psychological Preparedness
STP Drill 5 - Physical Preparedness
STP Drill 6 - Personal Safety and Risk Management
STP Drill 7 - Pumps/Pumping Operations
STP Drill 8 - Operational Entry and Use of Hoses and Branches
STP Drill 9 - Hose Handling, Branches and Portable Ladders
STP Drill 13 - Fire Behaviour
STP Drill 16 - Incident Management
STP Drill 17 - Incident Communications
STP Drill 18 - Fire Detection and Suppression Systems
STP Drill 22 - Hazardous Atmospheres – Self Contained Breathing Apparatus
STP Drill 26 - HAZMAT Theory and Practical
STP Drill 27 - HAZMAT Equipment
STP Drill 28 - Hazardous Materials
STP Drill 32 - Electricity and Fire Involving Electrical Hazards
STP Drill 33 - Methods of Construction and Structural Collapse

Abbreviations/Acronyms Used in this Report:

ARFF - Aviation Rescue Fire Fighting.
BA – Breathing Apparatus.
BLEVE – Boiling Liquid Expanding Vapour Explosion.
HMFO – Heavy Marine Fuel Oil.
IAP – Incident Action Plan.
IBC - Intermediate Bulk Container.
IC – Incident Commander.
ICC – Incident Command Centre.
ICP – Incident Command Point.
IMT – Incident Management Team.
NSWFB – New South Wales Fire Brigades.
PPC – Personal Protective Clothing.
SCBA – Self Contained Breathing Apparatus.
SFF – Senior Firefighter.
SO – Station Officer.
TIC – Thermal Imaging Camera.

Time, date and place of Call:

0951 hours on Wednesday 28th January 2004, Flinders Street, Port Kembla.

NSW Fire Brigades Response:

Super Pumpers 422 (Warrawong), 503 (Wollongong), 1 (City of Sydney) and 40 (Willoughby), Pumpers 474 (Unanderra), 488 (Shellharbour), 241 (Bulli), 277 (Dapto), 269 (Corrimal), 210 (Balgownie), 461 (Thirroul), 52 (Campsie), 49 (Cabramatta), 87 (Rosemeadow), 34 (Riverwood), 26 (Mascot), 48 (Mortdale), 29 (Rockdale), 72 (Merrylands), 54 (Cronulla), 56 (Matraville), 73 (Fairfield), 30 (Lidcombe), 17 (Drummoyne), 22 (Leichhardt), 23 (Gladesville), 15 (Concord), 65 (Rydalmere), 31 (Busby), 10 (Redfern), 85 (Chester Hill), 38 (Pyrmont), 14 (Ashfield), 258 (Coledale), 346 Bravo (Kiama), 241 (Bulli), Hydraulic Platform 21 (Kogarah), Ladder Platforms 503, 18 (Glebe) and 1 (City of Sydney), Aerial Pumper 92 (St Andrews), Heavy Rescue 503, Heavy HazMats 9 Charlie (Greenacre HazMat) and 488, Incident Control Vehicle Alpha (Alexandria Comms), Logistic Support Vehicle 503, Urban Search and Rescue 1 and FireAir 1 (Bankstown Airport).

In addition to above, numerous senior officers and specialist support staff responded to the incident over the following 48 hours for command and incident support purposes, including Commissioner NSW Fire Brigades (Greg Mullins), Operational Commander Wollongong, Senior Instructor South 3, Deputy Regional Commanders South, West and Wollongong, State Operations Liaison Officer, Hazmat 1 and 2, Manager Appliance Training, Regional Commander South, Zone Commanders South 1, South 2 and West 1, Principal Instructor South, Seach and Rescue 9, Community Risk Management Officer South, Assistant Director State Operations, Fire Investigations and Research Unit 2 and Manager Aerial Appliance Training.

Additional Agencies/Services in Attendance:

NSW Police, NSW Ambulance, NSW Rural Fire Service, District Emergency Management Officer (DEMO), Aviation Rescue and Firefighting Service, Environmental Protection Authority, Department of Environment and Conservation, Electricity Authority, Sydney Water, BlueScope Steel, Port Kembla Marine Fuels, Caltex, Shell, Manildra Park Petroleum, Port Kembla Ports Authority, Serco, Erickson Air-Crane Inc, Air Services Australia, WorkCover NSW, Sydney Water, Roads and Traffic Authority and Minister for Emergency Services The Honourable Tony Kelly.

Fireground Description:

The fireground was located at Lot 2, 5 Flinders Street, Port Kembla and consisted of an above ground dangerous goods/flammable liquids storage tank farm located on a 4.3-hectare site. There were originally 13 storage tanks at the site. Four of these had been removed, leaving nine tanks at the site on the occasion of the fire. These storage tanks had retained their original tank numbers. All storage tanks were located within a bunded area, secured by an impervious earth bund wall.[1]

The fire occurred in storage tank number 11, an above ground cylindrical steel, fixed roof vented storage tank, which measured approximately 14.450 metres high with a diameter of approximately 36.602 metres. The surface area of the tank was approximately 1052.63 metres squared. A 120-tonne tank roof of steel construction was fixed to the top of the storage tank. The tank capacity was 13 million litres of liquid product. The tank was licenced for the storage of petrol only.[1]

An additional eight storage tanks were located at the site.

-Tank 14 was located 18.2 metres to the west of Tank 11. Tank 14 was approximately 14.5 metres high with an outside diameter of approximately 36.6 metres and contained approximately 13,638,000 litres of marine fuel oil.[1]

-Tank 6 was located was approximately 21 metres to the east of Tank 11. Tank 6 was approximately 14.5 metres high with an outside diameter of approximately 22.0 metres. Tank 6 was being upgraded and as of 28 January 2004 was empty and a floating floor was being installed.[1]

-Tank 12 was located 27.0 metres to the east of Tank 11. Tank 12 was approximately 14.5 metres high with an outside diameter of approximately 22.0 metres and contained approximately 4,546,000 litres of ethanol.[1]

-There were a further five storage tanks on site. Four tanks contained marine fuel oil and one tank was empty.

The BlueScope Steel coal and coke handling plant was located 65 metres to the north of the involved storage tank. Two fuel distribution depots were located 45 metres to the south of the involved storage tank. A 4,400 m^2 industrial complex containing multiple factory units was located 70 metres to the south west of the involved storage tank.

1. This information is obtained from the transcript of judgement in NSW Industrial Court Matter IRC 6789 - 92 of 2005, as reported by His Honour J Marks in his final judgement delivered on Wednesday 28 February 2007.

Installed Fire Protection:

The site was fitted with an above ground 150 mm diameter ring main with twin headed attack hydrants fitted. There was no fire brigade booster assembly fitted to the ring main. Some tanks were fitted with manually operated external water drencher systems attached to the top of tank rims.

Several tanks (including Tank 11) were fitted with "foam box pourers", located on the rim of the tanks. Three foam box pourers were fitted to the tank rims, equally spaced apart. In the event of fire, a foam/water mixture would be pumped under pressure through the foam delivery pipe work to these foam box pourers where it is mixed with air to generate foam. Foam is forced through the foam box pourer, then is forced back from the deflector plate section onto the tank wall and surface of the tank contents, resulting in the foam moving centrally to the middle of the tank extinguishing the fire.[1]

A fire service diagram (site block plan) was affixed to the gate at the main entrance access to the site, specifying the content of Tank 11 was marine fuel oil. This information is contrary to the contents actually contained in the tank which was ethanol.[1]

1. This information is obtained from the transcript of judgement in NSW Industrial Court Matter IRC 6789 - 92 of 2005, as reported by His Honour J Marks in his final judgement delivered on Wednesday 28 February 2007.

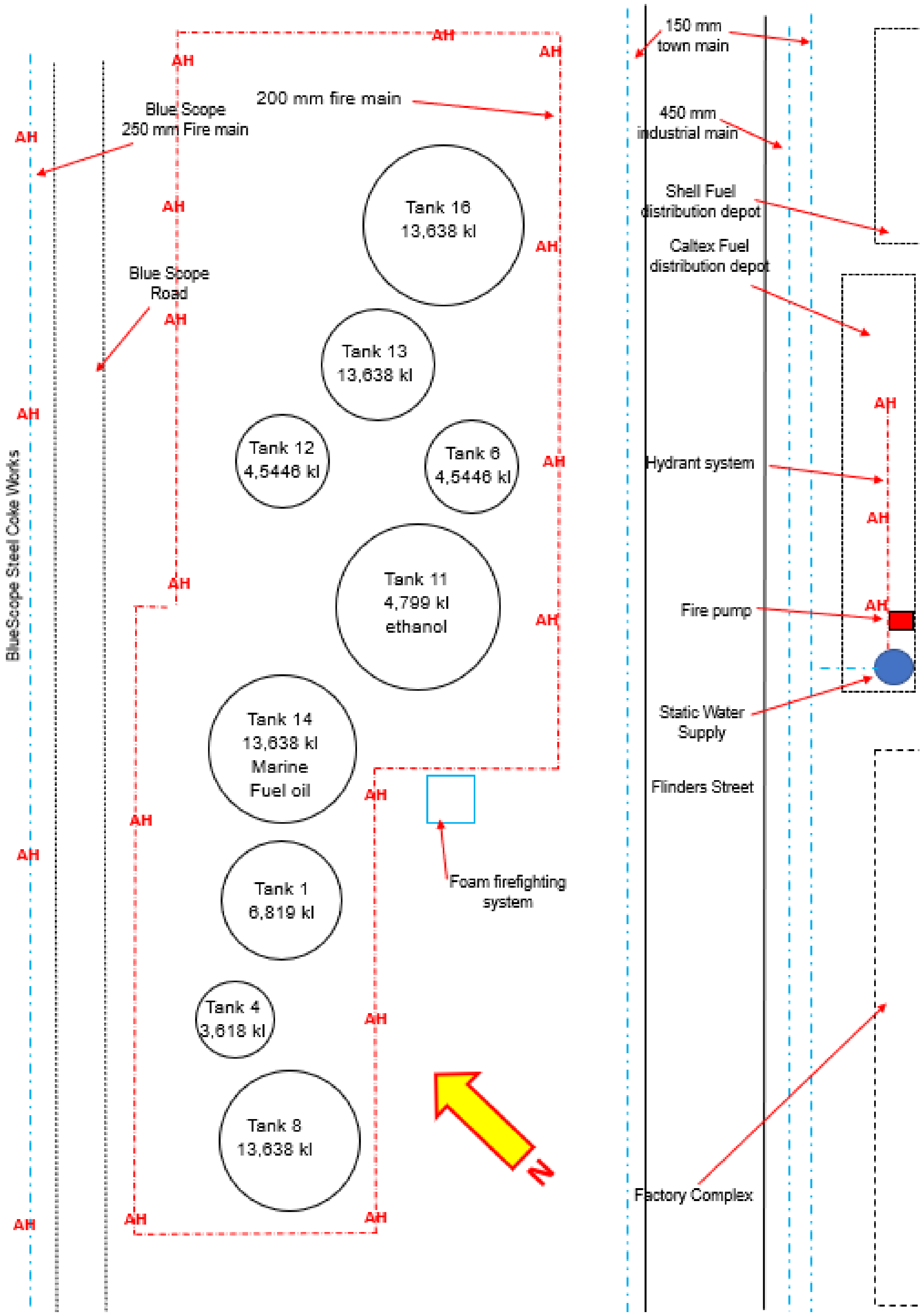
Three water mains were located in Flinders Street:

150 mm reticulated main on the eastern side of the road.
450 mm industrial supply main on the eastern side of the road.
150 mm reticulated main on the western side of the road.

N.B., the 450 mm industrial supply main was used to supply the BlueScope Steel plant and had large water volume however poor water pressure.

A 250 mm ring main was located within the BlueScope Steel coke works to the west of the fireground.

The Caltex fuel distribution depot contained a 150 mm fire main, with two twin headed attack hydrants fitted to the main. A 100,000-litre on-site static water supply tank supplied water to the fire main. An onsite fire pump increased water pressure within the fire main.



Port Kembla Fireground General Layout

Drawing not to scale

Weather at Time of Fire:

Temperature 26.0°C, relative humidity 59%, Winds West at 8km/h gusting to 11 km/h (a north east 24km/h wind change was recorded at 1500 hours), nil rain, cloud 3/8 and mean sea level pressure 1005.0 hPa recorded at Bureau of Meteorology Albion Park Aerodrome automatic weather station (approximately 14.5 km from the fireground).

Situation Prior to NSWFB Arriving on Scene:

On the occasion of the subject fire, Tank 11 contained approximately 4,799,119 litres of ethanol (denatured with 1% petrol). The tank was approximately 1/3 full.[1]

Several months prior to the fire, the tank owners had engaged contractors to commence an upgrade of Tank 11 by installing a water sprinkler system and a foam protection system. On the day of the subject fire, contractors were working on foam pipe work that ran from the manifold onto the tank base, then around the tank to supply the vertical pipe work connected to the foam box pourers, installed on Tank 11. Specifically, one of the contractors had been instructed to weld half-inch sockets onto five pipes located in the bund area, including a section of the foam delivery pipe work connected to Tank 11 at the base area of the tank.[1]

Immediately prior to the subject fire breaking out, a total of seven persons were present at the site. At approximately 9.30 am a worker was in the bunded area of the premises undertaking the installation of the sockets. The worker undertook grinding and welding on four separate foam pipes without incident (these pipes were not connected to Tank 11).[1]

The worker then commenced work on the fifth foam pipe, that was connected to Tank 11. He used a portable electrical angle grinder to grind the galvanized coating off the section of pipe work in order to perform the welding for the attachment of the half-inch socket. Once he had finished grinding he commenced to burn a hole in the pipe work using a welding rod connected to the hand piece of the welder. Shortly after he commenced welding there was a loud explosion from Tank 11 which blew the lid off the tank and was followed by a fire.[1]

As a result of the explosion, a worker located at ground level approximately eight metres from the storage tank was thrown several metres through the air, landing several metres away at the bund wall adjacent to Flinders Street and knocked unconscious. He sustained burns due to the radiant heat generated by the ethanol tank fire whilst he lay unconscious for approximately 15 minutes.[1]

As a result of the explosion, the 120-tonne steel lid of Tank 11 was propelled into the air, inverted and landed upside down onto a number of site ancillary buildings (no persons were in these buildings at the time). Part of the equipment destroyed by the impact of the tank lid included the electrical switchboard, which was necessary for the operation of fire protections systems at the site. **Essential equipment that formed part of the foam protection system for storage tanks at the site was also destroyed, rendering this equipment inoperable**.[1]

One of the seven workers at the site was standing outside the main access gate to the site having morning tea when he heard the explosion, saw the tank lid travelling through the air and observed flames and black smoke coming from Tank 11. This worker immediately telephoned 000 at 9.50 am to report the fire.[1]

Numerous persons located in the immediate area either heard or felt the explosion, observed large flames and black smoke coming from the site and telephoned ‘000’ to report the explosion and fire. It was reported that the explosion could be heard and felt for a distance up to 25 km from the site.

Plastic components on cars (brake light lenses, indicator lenses, number plate surrounds, etc) parked over 50 metres from the burning ethanol tank began to melt because of the radiant heat from the fire. The emergency response team from the Caltex fuel distribution depot began spraying foam over storage tanks at the depot to try and protect them from radiant heat. All staff at the adjoining BlueScope Steel coke works (approximately 200 workers) began to evacuate from the site.

1. This information is obtained from the transcript of judgement in NSW Industrial Court Matter IRC 6789 - 92 of 2005, as reported by His Honour J Marks in his final judgement delivered on Wednesday 28 February 2007.

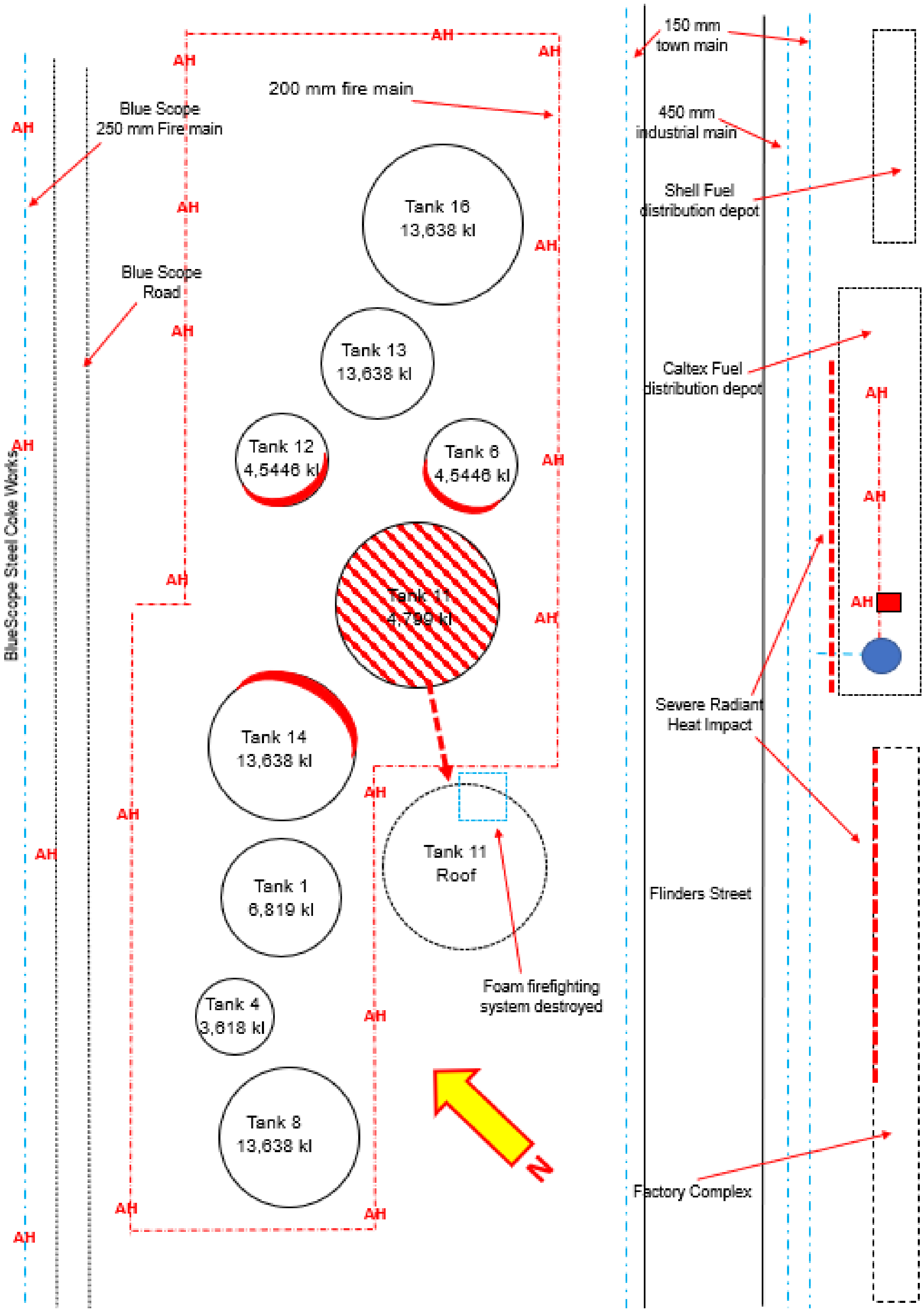
Initial Call and Response:

At 0951 hours on Wednesday 28th January 2004, NSW Fire Brigades Fire Communications received the first of numerous ‘000’ calls to reports of an explosion and fire involving a fuel storage tank at Flinders Street, Port Kembla. Super Pumpers 422 and 503 and Heavy Rescue 503 were initially assigned to the call.

Response Increased to Structure Fire 2nd Alarm:

As appliances responded to the incident, firefighters were able to observe a large column of thick black smoke coming from the direction of Port Kembla. Rescue Pumper 241 under the command of S.O. Andrew Sefton had only just left the station doors when they observed a large column of black smoke from a distance of 15 kilometres from the fireground. Super Pumper 422, under the command of S.O. Don Pescud, was approximately one kilometre from the scene when firefighters observed large flames in the distance. When the appliance turned onto Flinders Street, Port Kembla, firefighters observed a storage tank heavily involved in fire. At 0957 hours S.O. Pescud sent a message requesting the response be increased to a Structure Fire 2nd Alarm.

N.B., By today’s standards, the initial request for a structure fire 2nd Alarm may not have appeared adequate for this fire. However, the Alarm Response Protocol system of response had only been in service for a very short time and most firefighters were still learning this system of assigning resources.



Port Kembla Fireground Following Initial Explosion and Outbreak of Fire

Drawing Not to Scale

First Crews Arrive on Scene:

After travelling for a short distance along Flinders Street, S.O. Pescud could see a storage tank heavily involved in fire. The entire surface of the tank was fully involved in fire. Fierce flames were rolling upwards, extending at least 60 metres into the air. The fire was producing a large plume of thick black smoke. A number of storage tanks within the tank farm were in close proximity to the involved tank and were in imminent danger. The scene was highly unstable, extremely dangerous and there was a significant danger a rapid and potentially catastrophic expansion of the incident could occur. The first priority of S.O. Pescud was the safety of firefighters.

As Super Pumper 422 approached the scene, S.O. Pescud ordered the crew to stop the appliance 200-300 metres before the site, to enable size-up to be conducted from a safe distance. S.O. Pescud's immediate objective was to gather accurate information, enabling him to transmit a detailed report to Wollongong Fire Communications of the incident situation. S.O. Pescud describes his observations and explains his objectives at that point;

"***The roof had completely come off the top of the tank and was on the ground. The tank was burning fiercely and numerous explosions were occurring. The entire surface area of the top of the tank was completely involved in fire. Flame height was at least 60 metres above the top of the tank. This was a situation that could have escalated greatly. We didn't rush in. We positioned the appliance at a safe distance from the incident. There was important information I needed to identify, including whether any persons were missing, what the product was that was alight and what the quantity of the product was, what hazards were associated with the product, how far the evacuation zone needed to be extended, what other tanks were at risk of catching alight. At that time, I needed to gather as much information as possible, so that we knew exactly what the situation was that we were dealing with.***"

At this time, S.O. Pescud assumed control of the incident and established a Control Point at Super Pumper 422. From initial observations of the scene, S.O. Pescud sent the following **RED** message at 0959 hours:

"WOLLONGONG COMMUNICATIONS SUPER PUMPER 422 RED! RED! RED! FROM FLINDERS STREET, PORT KEMBLA, WE HAVE A LARGE OIL STORAGE TANK TOTALLY INVOLVED IN FIRE. A NUMBER OF EXPOSURES ENDANGERED. FURTHER MANAGE TO FOLLOW, OVER".

Operational Safety Considerations

At this point in the incident, the following Operational Safety Considerations were of note:

1. The product type and quantity of product involved in fire were unknown to firefighters.

2. Risks and hazards associated with the involved product were unknown to firefighters; consequently, appropriate safety precautions could only be implemented in a limited manner.

Initial Scene Size-Up:

When Super Pumper 422 arrived at Flinders Street, numerous persons had already gathered on the road opposite the burning storage tank. A number of these persons approached S.O. Pescud and all began to give him information simultaneously, creating a chaotic scene. S.O. Pescud had to ascertain which of the people were from the site who would be able to provide him with the critical information he needed to fight the fire and which of the people had information that was less urgent in nature. From within this group of people S.O. Pescud was able to identify an employee who worked at the site. This person was able to provide S.O. Pescud with important information concerning the situation. S.O. Pescud describes his conversation with the site employee:

"I spoke to an employee at the site, who informed me the burning tank contained seven million litres of ethanol. He advised me the main exposure contained 14 million litres of marine fuel oil. Other nearby exposure tanks contained four million litres of ethanol and seven million litres of marine fuel oil. He also said there was a very real risk of the main exposure tank splitting or exploding. Based on this information alone, I was not prepared to commit crews onto the site at this time."

After making these initial investigations, S.O. Pescud sent the following **RED** informative message at 1006 hours:

"WOLLONGONG COMMUNICATIONS SUPER PUMPER 422 RED! WE HAVE A STORAGE TANK CONTAINING APPROXIMATELY 7 MILLION LITRES OF ETHANOL TOTALLY INVOLVED IN FIRE. EXPOSURES UNDER THREAT ARE A 7 MILLION LITRE ETHANOL TANK AND A 14 MILLION LITRE TANK OF MARINE FUEL OIL. THERE IS A HIGH RISK OF FURTHER EXPLOSIONS. ALL SURROUNDING BUILDINGS HAVE BEEN EVACUATED. THERE ARE NO CASUALTIES AT THIS TIME, OVER."

Operational Commander Wollongong Inspector Frank Murphy, assigned on the 2nd Alarm, was responding to the fire when he overheard S.O. Pescud's transmission. Inspector Murphy contacted Wollongong Communications and requested Logistics Support Vehicle 503 collect the foam trailer and respond to the Port Kembla fireground. Upon overhearing S.O. Pescud's radio message, Deputy Regional Commander Wollongong Chief Superintendent Hans Bootsma contacted Wollongong Fire Communications Centre and requested that all available foam stocks in Sydney be responded to the incident.

Operation of Tank Protection Drenchers:

Site staff informed firefighters that the valves for the operation of storage tank external drencher systems were still operable, however would have to be turned on manually from inside the site. Firefighters and site staff entered the site and located the valves for the drencher system. The drenchers were turned on, providing protection for Tanks 12, 13 and 16. Firefighters and site staff then withdrew from the area.

NSW Police Helicopter Provides Assistance:

NSW Police helicopter PolAir 1 was flying from Bankstown to Dapto and approaching Wollongong when the explosion occurred. At the same time S.O. Pescud was sending the above **RED** message at 1006 hours, PolAir 1 was overhead the fireground and sent a message to Police VKG that was the passed to NSWFB Fire Communications, advising that PolAir 1 was available to assist anyway they could. The Incident Controller accepted assistance from PolAir 1 and a short time later the Police helicopter landed on nearby open ground. Super Pumper 503 under the command of S.O. Gary Power had just arrived on scene. The I.C. requested S.O. Power conduct a reconnaissance flight in the Police helicopter to try to identify the full extent of the fire, further tanks that could be in imminent danger and the safest and most effective place to position appliances, deploy attack lines and commence firefighting.

From PolAir 1, S.O. Power observed 50-60 metre flame heights above the surface of the burning flammable liquid. S.O. Power as able to identify several exposures in immediate danger, consisting of Tanks 6, 12 and 14. S.O. Power was able to determine that water drenchers were operating on Tanks 12, 13 and 16. Tank 14 (containing 14 million litres of marine fuel oil) was identified as a high priority requiring protection. S.O. Power was able to observe large blistering of the paint on the side of Tank 14 and could see smoke venting from the tank. Throughout the flight, S.O. Power was relaying his observations to the I.C. via a hand-held transceiver on Fireground Channel 510. At the conclusion of the reconnaissance flight, which lasted approximately 3-5 minutes, the Police helicopter returned to the landing site.

Evacuations:

Two fuel distribution depots and a factory complex containing multiple industrial occupancies were located on the opposite side of the road to the storage tank fire. Intense radiant heat from the tank fire was beginning to impact these sites, causing plastic components of motor vehicles parked at the front of the sites to melt. Pyrolysis gases were starting to be released from the buildings. While S.O. Power was aboard PolAir 1, the I.C. directed two firefighters from Super Pumper 422 to conduct an evacuation of these sites. Firefighters went from premises to premises, clearing the sites of all persons as they went and directing these persons to go to the evacuation point several hundred metres to the southwest on Flinders Street.

Initial Incident Objectives Established:

Following completion of the aerial reconnaissance flight in the Police helicopter, S.O. Power met the I.C., where they conferred and discussed the initial firefighting plan. The situation was extremely unstable and both agreed the safety of firefighters was the utmost priority. S.O.'s Pescud and Power both agreed the fire could only be extinguished with foam, however there were insufficient quantities of foam present to conduct any sort of foam attack. They would require much greater quantities of foam stocks before a foam attack could even be considered.

The aerial reconnaissance confirmed Tank 14 containing 13 million litres of marine fuel oil was the storage tank most at risk. Tank 6 was also at risk (although this tank was empty, workers informed firefighters it contained 4.5 million litres of ethanol; firefighters had no reason to doubt this information). Both tanks were being heavily impacted by intense radiant heat. S.O. Power advised the external water drencher systems were operating effectively on Tank 12 (which contained 4.5 million litres of ethanol) as well as Tanks 13 and 16; these tanks were not an immediate priority because of the effective protection from the drencher systems already in operation. The initial objective of the I.C. was to establish protection of the most threatened tanks (Tanks 14 and 6) with the largest cooling streams possible.

Incident Controller's Firefighting Plan

At this time, the Incident Controller had developed the following Incident Objectives, Strategy and Tactics:

1. Evacuation of all persons from the site and surrounding exposures. This had been completed.

2. Establishment of large diameter streams to cool the external walls of storage tanks most at risk of ignition due to the radiant heat being produced from the storage tank fire.

3. Protection of other nearby exposures in danger, including Shell and Caltex fuel distribution depots and factory complex.

The I.C. directed the crew of Super Pumper 503 to commence protection of Tank 6, located to the northeast of the involved storage tank. Super Pumper 422 was tasked to protect Tank 14, located to the west of the ethanol tank.

A privately owned industrial firefighting pumping appliance (a former A.C.T Fire Service urban pumper) located at the BlueScope Steel plant, under the operation of Serco industrial firefighters arrived at Flinders Street, near the NSWFB appliances. The crew of the Serco pumper offered their services to the Incident Controller. This appliance was fitted with a roof monitor and a capacity to deliver 3,500 litres of water per minute. The I.C. directed this appliance to set up in a position just inside the driveway entrance to the site where the roof monitor stream could be directed onto the upper external wall of Tank 14.

Tank 14 (containing 13 million litres of marine fuel oil) was under imminent threat. Staff on site advised **the tank would fail when the external temperature of the tank's steel wall reached 600°C.** Tank failure would have catastrophic consequences, resulting in the release of large quantities of marine fuel oil, almost certain ignition and the involvement of 13 million litres of marine fuel oil in fire. Burning fuel would rapidly spread through the enclosed bunded area of the tank farm resulting in the ignition of all other tanks. It is highly likely the release of such a large volume of liquid could result in burning fuel overflowing and escaping from the bunded area, significantly endangering firefighters.

The I.C. noted a number of signs indicating Tank 14 was in serious danger of failing, including the following:

"The upper wall of the tank was glowing and buckling from the impact of radiant heat. Large sections of the external paint on the tank were blistering. Smoke was being released from the vent holes in the tank."

Operational Safety Considerations

At this point in the incident, the following Operational Safety Considerations were of note:

1. Tank 14 contained 13.6 million litres of heavy marine bunker fuel oil (a combustible liquid). The product was being heated (due to the impact of radiant heat from the ethanol tank fire) releasing flammable vapours into the tank vapour space. Ultimately, this could have led to a flammable atmosphere forming with the tank vapour space, resulting in a catastrophic explosion occurring.

Operational Commander Wollongong Arrives on Scene:

At the same time protection lines were being put in place to cool Tank 14, Operational Commander Wollongong, Inspector Frank Murphy arrived on scene as protection was being established for Storage Tanks 6 and 14. Inspector Murphy was monitoring the radio en-route to the call and advised the detailed informative messages from the scene enabled him to have an accurate understanding of the situation on his arrival. S.O. Pescud briefed Inspector Murphy on the fire situation and firefighting operations underway. Inspector Murphy commenced a further incident size-up, during which he made the following observations of Tank 14:

"The heat being produced by the ethanol tank was tremendous. The top of the marine fuel oil tank was glowing cherry red and was buckling. Smoke was pouring from the vent holes. This tank was in imminent danger of failure."

Inspector Murphy made contact with site management, who informed him of the contents and quantities of all tanks on site. Management also informed Inspector Murphy of the installed protection systems of the tanks on site and their operational status. Management staff informed Inspector Murphy that although Tank 6 was "empty", it is likely it had not been purged. A storage tank that has not been purged still contains significant quantities of flammable vapour and is at risk of explosion. Although the tank did not contain product, it was in immediate danger and required protection.

Operational Safety Considerations

At this point in the incident, the following Operational Safety Considerations were of note:

1. Tank 6 (located approximately 21 metres to the east of Tank 11) was reported to be "empty" and undergoing an upgrade. Even in an empty state, storage tanks can be extremely hazardous. Solid deposits accumulate on the inside surface of tanks or sludge can form in the base of the tank; this material can be just as dangerous as the original contents.

2. Substances not normally regarded as an explosion hazard can give off flammable vapours when heated, which can form an explosive or combustible atmosphere when mixed with air. The tank had contained ethanol; in its current state it was considered more dangerous than in its original form.

3. Site management were unsure whether Tank 6 had been purged (i.e. steamed and ventilated to remove all traces of flammable liquid). If this tank had not been completely purged, the vapour and air mixture could well have been within the flammable range. In this scenario, any product remaining in the tank could have been heated by the nearby burning storage tank, producing an atmosphere that was flammable and explosive (and additional toxic hazards) within the cavernous interior of Tank 6.

4. The situation could have been dangerous and a large explosion could have occurred. The Incident Controller rightfully erred on the side of caution and established protection of Tank 6.

5. It situations where an "empty" tank is being impacted by heat or direct flame impingement from an involved tank, should always be assumed that there is a risk of a violent explosion.

Burning Product Identified as a Polar Solvent:

Within a short time of Inspector Murphy arriving on scene, site management confirmed the product burning was ethanol, a polar solvent. Inspector Murphy immediately recognised the problems this was going to cause firefighters. Polar solvents are known to be extremely difficult to extinguish and require large quantities of Alcohol Type Concentrate (ATC) foam to extinguish. This was identified as a potential problem for the planned firefighting operation, as almost all of the NSWFB foam stocks in place consisted of AFFF (Aqueous Film-Forming Foam) foam solution. AFFF was unsuitable for use on polar solvent fires because of its poor resistance to polar solvents (polar solvents aggressively attack the foam by mixing with the water in the bubble structure). If AFFF is applied to a polar solvent fire, it must be applied in vastly greater quantities than a hydrocarbon fire to be effective.

Monitoring of Tank Temperatures:

Hazmat crews from 488 Station, under the command of S.O. Peter Jezzard arrived on scene and met with Inspector Murphy and site management staff. A major concern was the integrity of surrounding storage tanks due to the impact of extreme levels of radiant heat from the ethanol fire. If the tanks failed, in addition to the escalation in incident conditions, firefighters fighting the fire would be placed in immediate danger. S.O. Jezzard was tasked to use the hazmat Raytek laser thermometer to take continuous temperature readings of the tanks under threat, in particular Tank 14. After deploying the laser thermometer at Tank 14, firefighters measured temperatures of 200°C at the tank's upper external wall. Firefighters also observed that temperature readings on Tank 14 were rapidly rising. S.O. Jezzard was acutely aware of the dangers of the tank failing:

"The temperatures of the external steel wall of the storage tank containing the heavy marine fuel oil were rising rapidly. Once the external surface of the tank reached 600°C the steel would lose 80% of its strength, which was enough to cause the tank to fail. Tank 14 contained bunker oil. This is marine grade heavy fuel oil. The situation would have been catastrophic if this product had become involved in fire."

Protection of Threatened Exposures:

Exposures located on the eastern side of Flinders Street were being impacted by extreme levels of radiant heat. These exposures included two fuel distribution depots (containing above ground fuel storage tanks), numerous vehicles and a row of factory units. The buildings were at least 50 years old and formed of timber. Smoke was beginning to pour from the buildings due to pyrolysis occurring. The exposures were in imminent danger of becoming involved in fire. Operational Commander Wollongong Inspector Murphy describes the impact of the radiant heat caused by the ethanol tank fire to these exposures:

"The fire was producing extreme levels of radiant heat. Buildings and cars on the opposite side of the road were beginning to catch alight. There were flames coming from beneath the eaves of the buildings. Plastic was melting and smoke was starting to pour from cars parked at the front of these buildings."

Pumper 474, under the command of Captain Peter Quin was the third pumper to arrive on scene and commenced protection of the exposures under threat on the eastern side of Flinders Street. The Caltex fuel distribution depot contained an above ground 70,000 litre diesel fuel tank and an above ground 70,000 litre petroleum fuel tank. Captain Quin describes the situation that confronted him and the initial operations of Pumper 474 firefighters to protect the threatened exposures:

"We were directed to protect the exposures on the eastern side of Flinders Street. The Caltex fuel distribution depot was located directly opposite the fully involved ethanol tank fire and was in imminent danger. We began to set up protection around the Caltex depot using 38 mm lines. The building was made from very old timber. As we were setting up protection lines the eaves caught alight. We used two 38 mm lines to extinguish this fire. A third 38 mm line went into the building, which was made from very old timber and contained fuel drums. Smoke was starting to pour from the building timbers due to the radiant heat. The building kept re-igniting and we had to extinguish it three times. We used a 38 mm line to protect the fuel drums inside the building. We were also cooling the two above ground 70,000 litre fuel tanks. We continued to direct cooling steams onto the fuel depot."

Pumper 474 firefighters placed the installed fire pump that provided fire protection for the Caltex fuel distribution depot in operation, charging water within the site hydrant system. Two attack hydrants were connected to the hydrant system. A breaching and two 38 protection lines were connected to the first attack hydrant. One 38 mm line was operated by Pumpers 474 and 210 firefighters, the second 38 mm line was operated by trained Caltex staff. These lines were used to continuously cool the Caltex depot, including the building, storage tanks, motor vehicles at the front of the depot and firefighting appliances. Captain Quin deliberately left the second attack hydrant unused, in case fire broke out within the Caltex site, requiring additional firefighting water. Firefighters obtained water supplies for Pumper 474 from a hydrant located at the pump house. Water to the pump house was being supplied from an on-site static water tank. Plastic on vehicles parked at the front of the Caltex depot was melting and pyrolysis gases were pouring off the vehicles, indicating they were close to ignition. Pumper 210 firefighters, under the command of Captain Ken Lawrence, directed protective cooling streams onto these vehicles, preventing them from igniting. Pumper 210 firefighters also directed protective streams onto a pole mounted electrical transformer (containing quantities of transformer oil) located directly in front of the burning ethanol tank.

Firefighting Operations – Initial Protection of Storage Tanks most Under Threat:

At the same time Pumper 474 firefighters were protecting the threatened fuel storage depots and factories opposite the burning ethanol tank, Firefighters from Super Pumper 422, Rescue Pumper 241 and Pumper 269 began to place a ground monitor in position, on a hardstand area within the site between the involved tank and Tank 14. Firefighters wanted to direct the monitor stream onto the upper wall of the tank facing the burning ethanol tank.

This part of the tank (known as the tank “head space”) contained no product and therefore was most vulnerable to failure (product within the tank was acting as a “heat sink”, able to absorb the radiant heat protecting the tank steel. Steel near the head space did not have this protection). Initially, the ground monitor stream would not reach the storage tank with the diffuser nozzle fitted. Firefighters then replaced the diffuser nozzle on the ground monitor with a stack tip nozzle, resulting in a solid stream that projected across a greater distance. An advantage of the solid stream compared to the diffuser nozzle stream was its ability to remain intact and not break up. The solid stream was able to travel a much greater distance and was delivering more water onto the surface of the tank and therefore was a much more effective stream than a hollow core stream.

As firefighters placed the ground monitor in position, the temperature of the tank upper wall continued to increase, rising to 300°C. Firefighters connected two 70 mm lines from Rescue Pumper 241 to the ground monitor and prepared to flow water from the appliance to the ground monitor. Firefighters began to charge the lines of the ground monitor, pumping water at 1800 kPa. Two 70 mm supply lines from the 150 mm main supplied water to the pumper. As water began to flow through the ground monitor and the stream started to reach the upper wall of the storage tank, the tank temperature was measured at 400°C and continuing to rise rapidly, reaching 450°C. However, as the stream began to reach the upper tank wall, the temperature being measured by Hazmat firefighters rapidly fell to 90°C. As water continued to be applied to the external surface of the storage tank, the temperature continued to fall until it stabilised at 50°C. Rescue Pumper 241 firefighters continued to monitor the stream, ensuring it was reaching the highest part of the tank where the greatest impact of radiant heat was occurring. On several occasions firefighters had to make adjustments to the monitor stream to ensure it continued to be projected onto the right part of the tank. On one occasion, firefighters repositioned the ground monitor 10 metres from its original position due to a strong wind change. S.O. Sefton describes the conditions firefighters were experiencing as they positioned the ground monitor:

“Conditions were very hot. We were encountering a large amount of radiant heat. We were protected from the radiant heat by wearing our firefighting gear, including our gloves and helmets with face shields down.”

The Serco industrial pumper was positioned on a hardstand area within the site near the displaced roof off the ethanol tank. Two 70 mm supply lines were connected from the installed 150 mm ring main to the Serco pumper. A further two 70 mm supply lines were relay pumped from Super Pumper 422 to the Serco pumper. The roof monitor of the Serco pumper was then placed in operation. The roof monitor stream was able to reach the top of the outer wall of Tank 14. The combined monitor streams from Rescue Pumper 241 and the Serco pumper were applying water (at a rate of approximately 5,500 litres per minute) to the hottest and most vulnerable part of Tank 14, resulting in significant reductions in the temperature of the surface of the tank wall and greatly reducing the risk of Tank 14 failing.

At the same time firefighters were establishing protection of Tank 14, operations were under way to protect Tank 6, which was reported by site staff to contain 4.5 million litres of ethanol. Super Pumper 503 positioned in Flinders Street on the north eastern side of the involved tank. Super Pumper 503 and Pumper 210 Firefighters obtained water supplies for the appliance from four 70 mm supply lines. Two of these lines were connected to the 150 mm site ring-main and two lines were connected to the Flinders Street 150 mm town main.

Once water supply had been secured, firefighters placed the roof monitor of Super Pumper 503 in operation and began to direct the monitor stream onto the upper wall of Tank 6. Super Pumper 503 water pressure was 1300-1500 kPa, enabling the roof monitor stream to reach the exposure tank. Firefighters initially used the diffuser nozzle fitted to the roof monitor, however the stream broke up and could not reach the storage tank. The stack tip nozzle was then fitted to the roof monitor, producing a solid jet that was able to reach the tank. The monitor stream was operated in a sweeping pattern on the side of the storage tank.

Pumper 277, under the command of S.O. Mark Wunsch, arrived on scene and was directed to position a second ground monitor within the tank storage yard between the involved ethanol tank and Tank 14 then direct the monitor stream onto the upper wall of Tank 14. Pumper 210 and 269 crews assisted to establish operation of this monitor. Firefighters obtained water supply with two 70 mm lines connected to the 150 mm main. Two 70 mm lines were connected to the ground monitor and the monitor stream was directed onto the upper tank wall in proximity to the tank head space, protecting the most vulnerable part of the tank from failure.

Operational Safety Considerations

At this point in the incident, the following Operational Safety Considerations were of note:

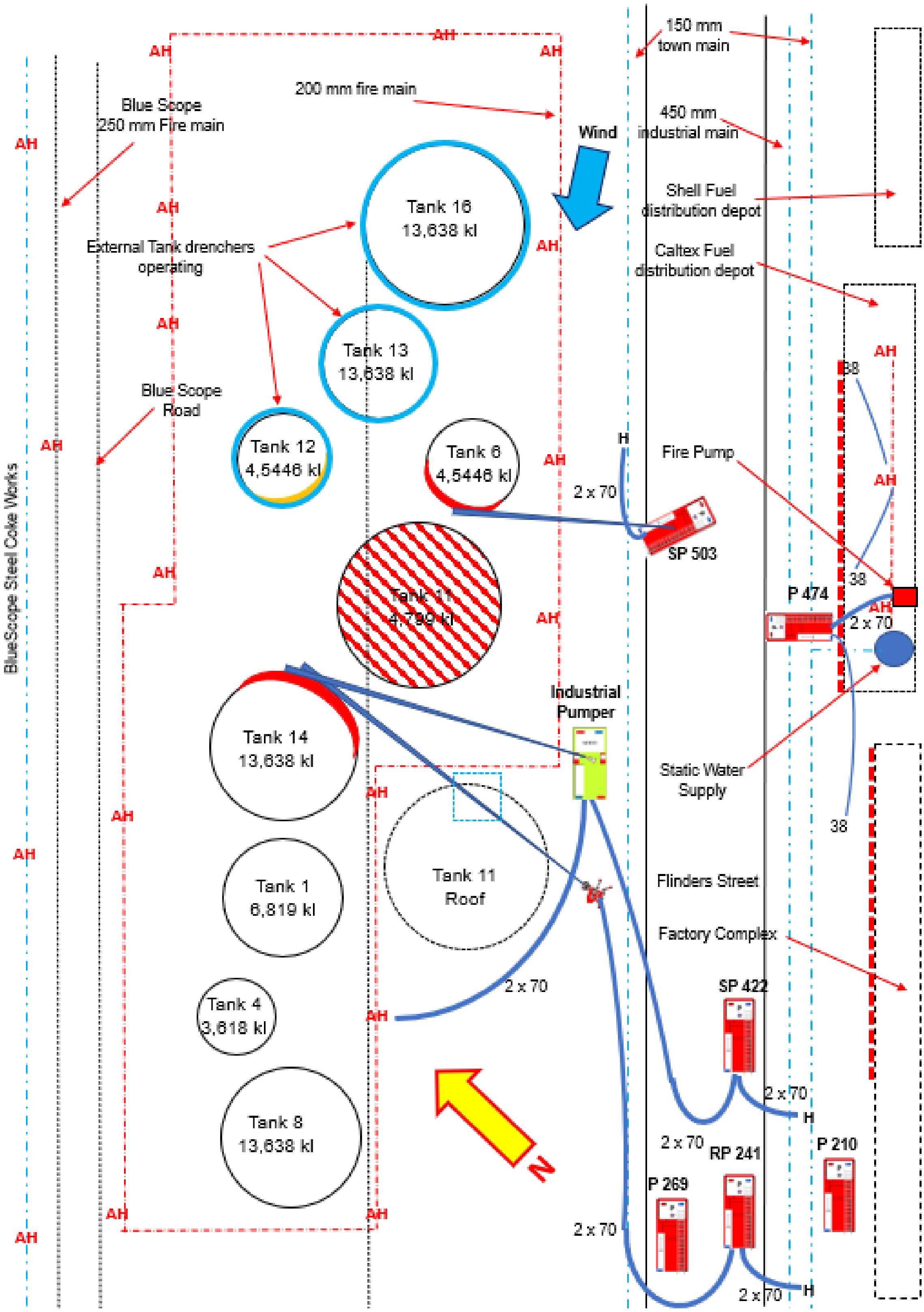
1. Radiant heat from the involved tank was extremely high. To protect against radiant heat, firefighters wore full structural PPC, flash-hoods and helmets with visors down.

2. Hazmat 488 S.O. Peter Jezzard observed that all firefighters were working in an area where the plastic on motor cars *behind* them had melted, indicating the high levels of radiant present in the area that firefighters were working.

3. Heat stress was a significant issue. Firefighters attempted to maintain rehydration as best they could by drinking bottled water.

4. Fireground operations of moving hose lines was extremely exhausting, particularly when combined with the impact of severe radiant heat.

5. An important factor to consider is to ensure large quantities of bottled drinking water are assigned to this type of incident as a matter of priority.



Fireground Drawing Initial Firefighting Operations

Drawing Not to Scale

Evacuation Radius Increased:

Operational Commander Wollongong Inspector Murphy liaised with site management and Police concerning product stored at the site. As a result of these discussions, Inspector Murphy requested Police evacuate all sites within a 500-metre radius of the involved storage tank. Inspector Murphy also requested staff be evacuated from the adjoining BlueScope Steel coke works.

Search for Missing Worker:

During the course of liaising with site management, staff advised a worker at the site was unaccounted for. Heavy Rescue 503 Senior Firefighters Glenn Rosetto and Glenn Edwards were tasked by the I.C. to conduct a search of the site, in particular the last known area the worker had been seen in, in an attempt to locate and rescue the missing person. Firefighters conducted a thorough search of the area, however could find no sign of the missing worker. It was later identified the worker (who had been knocked to the ground due to the force of the explosion, as described in the section "*Situation Prior to NSWFB Arriving on Scene*") had self-presented to Ambulance at the scene and had been conveyed to hospital.

Transfer of Incident Control and Establishment of Command Structure:

Deputy Regional Commander Wollongong Chief Superintendent Hans Bootsma arrived on scene and met with Inspector Murphy and S.O.s Pescud and Power. Following a briefing, Incident Control was transferred to Chief Superintendent Bootsma. The I.C. sectorised the incident into three sectors. S.O. Pescud was appointed as the Sector Commander on the southern side of the involved storage (Sector A) tank and tasked with protection of Tank 14. S.O. Power was appointed as the Sector Commander on the northern side of the involved storage tank (Sector C) and tasked with protection of Tank 6. Sector B was located directly in front of the involved ethanol tank and was being supervised by Inspector Murphy, with the objective of ensuring the tank walls remained as cool as possible through the application of cooling streams, to prevent the tank from failing. Incident Controller Superintendent Bootsma describes his objectives at this time:

"We needed to ensure that the two storage tanks most under threat were protected. It was critical to make sure the situation did not worsen. I also wanted to conduct a frontal attack on the involved storage tank, to try to cool the tank."

At 1014 hours the Incident Controller requested that all available foam stocks from Sydney be responded to the incident.

Hazmat Operations:

The hazardous material component of the incident was arguably equally as important as the firefighting operation. The potential for a major environmental disaster was extremely real due to the quantities and types of material involved. Hazmat operations were being undertaken under the command of Hazmat 488 S.O. Peter Jezzard and coordinated by Inspector Glenn Lord. By taking readings with laser thermometers, hazmat firefighters were able to determine the approximate level of ethanol within the involved storage tank by distinguishing between the gaseous and fluid states within the tank. Hazmat firefighters were taking readings of the surface of the ethanol storage tank. The upper tank wall had folded and was glowing red, showing readings of 800°C. Below the level of the burn line readings of 240°C were taken from the external tank surface. The instrument was only able to measure temperatures up to 900°C and at times tank surface temperatures could not be measured because they exceeded 900°C.

Using the onboard computers within the heavy hazmat appliance, hazmat firefighters were able to identify the properties and chemical characteristics of the burning ethanol within the storage tank, enabling an appropriate water run-off containment strategy to be implemented. Firefighters took samples of run-off water within the bunded area however could not detect any contamination. Hazmat crews conducted continuous inspections of the tank farm bund wall, however saw no signs that it was failing or water was escaping from it.

S.O. Jezzard advised the fuel bunker oil in Tank 14 was kept heated to prevent it from congealing. The 13 million litres of product stored within the tank were acting as a thermal barrier, providing protection against the impact of radiant heat.

As a precautionary measure in the event of any residual runoff associated with the stored marine fuel oil in Tank 14, firefighters placed primary and secondary containment booms around storm water drains. Hazmat firefighters made contact with and continued to liaise with EPA and Port Kembla Ports Authority. Firefighters identified the water run-off path led to Allans Creek before entering the Port Kemba waterway. Continued inspections of Allans Creek by hazmat crews over the duration of the incident identified minimal run-off with no traces of contaminant present.

Response of Incident Management Team:

As information of the unfolding incident was received, NSWFB Commissioner Greg Mullins was updated on incident developments. At 1035 hours Commissioner Mullins advised that an Incident Management Team from Sydney would be assembled consisting of himself, Assistant Director Specialised State Operations Chief Superintendent Jim Hamilton, Zone Commander South 1 Superintendent Doug Williams and Zone Commander South 2 Superintendent Michael Guymer and would be departing Alexandria at 1100 hours to travel via helicopter (FireAir 1) to Port Kembla to provide command assistance.

Response Increased to Structure Fire 4th Alarm:

Following handover and further incident size-up, at 1048 hours the I.C. increased the response to a structure fire 4th Alarm.

Further Aerial Reconnaissance of Fireground:

Police helicopter PolAir 1 landed at King George Oval, Military Road Port Kembla. PolAir 1 was used as an aerial reconnaissance platform by NSWFB Search and Rescue 9 Senior Firefighter Hart Peters to obtain photographs and draw a plan of the fireground. This proved to be highly advantageous, identifying a secondary access location for firefighting, via the BlueScope Steel coke works road to the northwest of the tank farm. This access was not clear from Flinders Street.

Water Supplies Improved:

Water service operators from Sydney Water attended the scene in Flinders Street and traced all of the water mains in the area of the fireground. The water service operators informed the I.C. of the locations of the two available 150 mm mains in Flinders Street. Water authority staff also informed the I.C. that water within the 450 mm industrial supply main was untreated and there were only two hydrants for this main on Flinders Street. Sydney Water crews opened all hydrants in Flinders Street to ensure they were all working properly. Sydney Water staff operated equipment to divert the flow of water from surrounding mains into the two 150 mm mains being operated by firefighters. These actions increased water supply and greatly assisted firefighting operations.

Direct Attack on Involved Storage Tank:

Sector Commander B Inspector Murphy discusses the initial strategies involving operations at the front of the tank:

"We attempted to dilute the ethanol with water, in the hope that this would reduce the ethanol flammability and subsequently reduce the intensity of the fire. However, the heat from the fire was tremendous and the water we were applying was unable to reach the surface of the burning ethanol. Once we realised that plan was not going to work, we concentrated on cooling the walls of the surrounding tanks and also cooling the walls of the burning ethanol tank, to prevent the tank from failing."

Ladder Platform 503, operated by firefighters Brent Wilkinson and Rodney Bland, was directed by the I.C. to set-up on Flinders Street and conduct a direct attack on the involved tank, with the intention of reducing fire intensity and cooling the steel wall of the tank to preserve the tank integrity and prevent the tank failing.

Pumper 488, under the command of S.O. Jeff Light supplied water to Ladder Platform 503. Firefighters were initially directing the aerial master stream onto the surface of the involved tank, in an attempt to create steam, lowering the available oxygen to the fire, however this was having little effect reducing the fire intensity.

Firefighters then attempted to attack the fire with foam pumped through the aerial appliance, however difficulties were encountered with the foam pick-up tube drawing foam concentrate, forcing this operation to be abandoned. Firefighters realised there was an insufficient quantity of foam concentrate on site to mount an effective attack. The I.C. made the decision to cease all foam applications and allow foam stocks to build up, until sufficient foam was present to mount a major attack. The major foam attack was planned for much later in the day.

Realising the aerial attack on the involved storage tank was having little effect, efforts were then concentrated on strengthening the protection of exposure Tank 6, which continued to be heavily impacted by radiant heat and remained under threat. From its current location, the aerial stream was unable to reach Tank 6. Ladder Platform 503 was then shut down and repositioned to a location where the aerial stream could reach Tank 6. After being repositioned, the aerial stream was much more effective.

Pumper 488 supplied Ladder Platform 503 water with four 70 mm lines. Water supply for Pumper 488 was via four 70 mm lines connected to hydrants located on the 150 mm mains. Pump operator Senior Firefighter Steve Rolls supplied water to the aerial appliance at 1500 kPa and reported a very good water supply with a compound reading of 500 kPa. The operators of Ladder Platform 503 directed a sweeping cooling stream onto Tank 6. Pumper 474 firefighters were using a 38 mm line to direct a cooling spray onto the working cage and as much of the Ladder Platform 503 boom as possible, to reduce the impact of severe radiant heat. At 1152 hours, the I.C. sent the following situation report:

"WOLLONGONG COMMUNICATIONS, DEPUTY REGIONAL COMMANDER WOLLONGONG BLUE. WE HAVE A FIRE IN A STORAGE TANK CONTAINING APPROXIMATELY 5 MILLION LITRES OF ETHANOL. THE INCIDENT HAS BEEN SECTORISED WITH SECTOR COMMANDERS IN EACH SECTOR. OPERATIONS IN SECTOR A ARE PROTECTING THE MAIN EXPOSURE CONTAINING 12.5 MILLION LITRES OF HEAVY FUEL OIL. SECTOR B OPERATIONS ARE ATTACKING THE FIRE. SECTOR C IS PROTECTING AN EXPOSURE TANK TO THE NORTH OF THE INVOLVED TANK. WE CURRENTLY HAVE 1 X LADDER PLATFORM AT WORK, 2 X ROOF MONITOR STREAMS AT WORK AND 3 X GROUND MONITOR STREAMS AT WORK, OVER."

Incident Management Team Arrive at Fireground:

The Incident Management Team aboard FireAir 1 were still 20 kilometres from Port Kembla when the fire became visible. Upon arrival at Port Kembla FireAir 1 overflew the fireground, enabling a full appreciation of incident conditions, operations underway and incident requirements to be more fully understood by the IMT. Commissioner Greg Mullins made the following observations of operations:

"The actions I was observing were textbook operations for a storage tank fire. Firefighters were protecting the exposures, keeping the exposures cool. Protection lines, roof monitor streams, aerial appliance streams and ground monitor streams were all in place and all exposures were covered. As the helicopter came in to land, I was extremely confident that we could successfully contain this fire."

Upon the arrival of the IMT at 1218 hours, Commissioner Mullins met the Incident Controller, Chief Superintendent Bootsma and was provided with a full situational briefing. Following this briefing, Commissioner Mullins advises of the following incident considerations:

"We needed polar solvent foam stock in the form of ATC, however most of our foam was AFFF. Our plan was to build up sufficient foam stocks so that we could mount a large foam attack later on. It was important to conserve our foam stocks until we had sufficient quantities of foam in place to mount a full attack. It was a large logistics challenge. We were attempting to source bulk foam stocks from various other plants and suppliers.

We were also developing an Incident Action Plan. Ultimately, we were planning on conducting a concerted foam attack. A major challenge for us would be projecting foam into the tank and onto the surface of the burning ethanol. In the meantime, we continued to protect the exposures that were under threat while we built up our foam stocks.

If the fire had spread to an adjoining storage tank, we would have had a domino effect within the tank farm, ultimately resulting in all of the tanks becoming involved in fire. We were working as hard as we could to ensure the fire remained contained and did not spread. It is important to emphasise how important the initial actions of the firefighters and commanders who arrived first on the scene were. They laid a strong foundation that remained in place and was built on for the duration of the incident."

Commissioner Mullins did not take control of the incident. Instead, he provided continuous briefings to numerous persons including the minister for emergency services (The Honourable Tony Kelly), Police Commander, representatives from industry and the assembled media.

Formation of Full Incident Management Team:

Regional Commander South, Assistant Commissioner Murray Kear arrived at the fireground and was provided a thorough briefing of the situation by Chief Superintendent Bootsma. At this point incident control was transferred to Assistant Commissioner Kear. Chief Superintendent Bootsma had a thorough understanding of operations and was appointed Operations Officer. Following transfer of command, Assistant Commissioner Kear accompanied by Commissioner Mullins and Chief Superintendent Bootsma conducted a walk around the fireground to carry out further size-up.

Sufficient officers were now in place for the establishment of a full Incident Management Team, consisting of the Incident Controller, Operations Officer, Safety Officer, Planning Officer, Logistics Officer and Media Officer, in addition to Division and Sector Commanders.

Establishment of Incident Divisions:

Reconnaissance from Search and Rescue 9 Senior Firefighter Peters had identified that the western side of the tank farm, accessible via the BlueScope Steel coke plant was suitable to conduct firefighting operations of the western side of the tank from. Upon receiving this information, the Incident Management Team decided to deploy firefighting crews to the western side of the tank farm. This location was remote from the area of operations on Flinders Street. To assist effective incident command, span of control and safe management of resources, the Incident Controller decided to establish two separate divisions at the incident:

Division A consisted of all operations based on the Flinders Street side of the incident and was formed by sectors A, B and C. Superintendent Michael Guymer was appointed Commander of Division A. Fire Safety Inspector Barry Waite was appointed Division A Safety Officer.

Division B consisted of all operations based on the BlueScope Steel side of the incident. Chief Superintendent Jim Hamilton was appointed Commander of Division B. The objectives of Division B were to increase the cooling of exposure storage tanks through the establishment of ground monitor streams. Inspector Gray Parkes was appointed Division B Safety Officer.

Establishment of two Division Commanders ensured the two Divisions were able to work closely together, enabling a coordinated firefighting attack. Tank 14 continued to show signs of severe heat impact and remained under threat of failure. Fire protection from Division B streams would enable the tank to be protected from the north side, which could not be reached from the Flinders Street side. The combined efforts of Divisions A and B enabled all storage tanks under threat to be protected.

After taking command of the incident, Assistant Commissioner Kear discusses his incident priorities, objectives and concerns:

"Safety of firefighters was our number one incident priority. There were a number of serious safety concerns that we were continually addressing. This was an extremely hot fire and we needed to manage issues associated with heat stress. The bund wall and the bunded area inside the bund wall remained a serious concern. The bund wall was quite old and we weren't sure how well it would perform if it was required to contain a major discharge from one of the storage tanks. We had to ensure that all firefighters understood the dangers associated with the bunded area and ensured that no firefighter entered the bunded area.

There were concerns that the extreme heat being applied to the storage tank could possibly result in a number of tank 'failure scenarios', including the tank buckling, the tank collapsing in on itself and the tank rupturing. Fuel storage tanks are designed to withstand fires and not collapse, however we were concerned there was always a risk the tank could fail, particularly because of the elevated temperatures associated with the burning ethanol (a product the storage tank had not been designed to store). We understood the risks. This dictated the positioning of appliances.

We were very aware of the surrounding risks. A major objective was to prevent the fire from spreading. We were also monitoring the impact on the environment very closely."

Incident Controller's Firefighting Plan

At this time, the Incident Controller had developed the following Incident Objectives, Strategy and Tactics:

1. Maintain and increase cooling of exposures.

2. Build up foam stocks to a sufficient level that a foam attack can be successfully mounted.

3. Once sufficient foam stocks are in place commence foam attack.

Incident Control Point:

Incident Control Vehicle Alpha, under the control of S.O. Wayne Gregory and operated by Firefighters Marty Beudeker and Dave Finch arrived at the fireground at 1155 hours, enabling the Command Point to be established at the ICV. The ICV became the focal point for incident command, logging incident messages, managing staging and deployment of resources, organising additional foam stocks, managing incident logistics, sourcing specialised resources (such as foam monitors, LPG cylinders for forklifts), refuelling for appliances, obtaining weather reports and numerous other incident requirements.

The ICV was the command base for the incident management team, including operations, planning, logistics and safety cells. The ICV was able to facilitate the communications plan for the incident, involving the operation of three different radio channels (Tasking on 501, Tactical on 607 and Strategic on 301). The ICV facilitated meetings and briefings with members of supporting agencies and services, briefings with the Minister for Emergency Services and planning meetings with command staff. Liaison officers from various agencies and emergency services were present at the ICV. The ICV crew performed a critical and indispensable role in support of operations.

Local Emergency Management Arrangements:

Local Emergency Management Procedures were now in place. An Emergency Operations Centre had been established at Port Kembla Police Station. The Incident Controller was in direct communication with the Police Local Area Commander, Ambulance Superintendent, District Emergency Management Officer (DEMO) and representatives from numerous other agencies including the Environmental Protection Authority and Port Kembla Ports Authority. Establishment of these lines of communication ensured a coordinated and cohesive response to the incident.

Build-up of Foam Stocks:

The Incident Controller's ultimate objective was to attempt to extinguish the fire with a massed foam attack. Sufficient stocks of foam concentrate to mount a successful foam attack were not present at the fireground. Until sufficient foam was in place to complete extinguishment, any foam attack would be both ineffective and result in foam being unnecessarily wasted. A major priority of the Incident Management Team was to establish sufficient quantities of foam concentrate to enable an effective foam attack to take place.

State Communications activated the ***Emergency Foam Plan***, enabling bulk foam to be sourced from a number of locations. Community Risk Management Officer South S.O. Brad Smith was appointed the Foam Officer and was responsible for sourcing all available foam stocks and making arrangements for the foam to be transported to the fireground. Throughout the day foam stocks began to build up. Foam was being transported to the fireground from NSWFB Greenacre, Caltex refinery and Sydney airport. The Incident Controller was hopeful there would be sufficient foam stocks present to conduct a major massed stream foam attack at about 1700 hours.

Bulk foam stocks arrived on scene in 200 litre plastic drums. Moving the foam stocks to where they were needed was a major logistical challenge. Some of the foam was moved into position by fork-lift. Pumper 29 firefighters assisted to move foam to appliances in Division A. The site contained a 5,000-litre foam concentrate tank. Firefighters used a Davey portable pump and length of 38mm hose to transfer the foam into 200 litre hazmat bins.

Additional Foam Ground Monitors Sourced:

Firefighters needed as many foam ground monitors as they could locate to be brought to the Port Kembla fireground. Sydney Fire Communications began contacting foam stations in the Sydney Fire District (these included 19, 26, 35, 56 and 61) to source foam ground monitors. Once the locations of these ground monitors were identified, arrangements were made for them to be collected by Logistics Support Vehicle 85 and delivered to the Port Kembla fireground.

Division A Operations Increased:

As additional aerial appliances arrived at the Port Kembla staging area, they were deployed to Division A to increase the aerial master stream attack. Hydraulic Platform 21, operated by Senior Firefighters Dave Phillips and Jeff Wilson was tasked to set up and commence a master stream attack on the involved tank. Hydraulic Platform 21 positioned on Flinders Street, in line with the southern edge of the involved tank. Water supply to Hydraulic Platform 21 consisted of four 70 mm lines, being supplied by Pumper 49. Pumper 474 relayed two 70 mm lines to Pumper 49. An additional two 70 mm supply lines were connected to an attack hydrant fitted to the Caltex terminal pump house and laid to Pumper 49.

Initially, the Hydraulic Platform 21 aerial stream was used to cool the external steel wall of the storage tank in an effort to preserve the integrity of the tank and prevent possible failure and collapse of the tank. The cooling stream was then switched to protecting the upper wall of Tank 14. The Hydraulic Platform crew operated the aerial monitor remotely from the appliance pulpit. The hydraulic platform was being impacted by intense levels of radiant heat. The aerial nozzle was switched to a fog spray every 5-6 minutes to cool the aerial working cage.

Ladder Platform 18 was directed to position and set-up on Flinders Street to the southwest of Hydraulic Platform 21. The crew of Ladder Platform 18 were instructed to project an aerial cooling stream onto the upper side wall of Tank 14 to help cool the tank and maintain the tank integrity. Pumper 277 shut down lines going into the ground monitor and diverted water to Ladder Platform 18 via four 70 mm lines. Water was supplied to Pumper 277 from four 70 mm collector lines connected to hydrants on the Flinders Street 150 mm main. The working cage of Ladder Platform 18 was extended a significant distance towards the fire to improve the projection of the aerial stream. Consequently, on account of being closer to the tank fire, the working cage, boom and attached equipment of Ladder Platform 18 were exposed to very high levels of radiant heat.

The aerial stream of Hydraulic Platform 21 was used to cool the working cage and boom of Ladder Platform 18. Firefighters also observed the operations of Hydraulic Platform 21 acted as a windbreak for the aerial stream of Ladder Platform 18, allowing the aerial stream to project much further and operate with greater effectiveness because it was being broken up less by the impact of the wind. Pumper 210 firefighters using a 38 mm hose line were directing cooling streams onto the working cages of Ladder Platforms 18 and 503.

Division A Commander Superintendent Guymer advised maintaining the integrity of the burning tank was a priority. He stated this was achieved by the application of additional cooling streams.

Operational Safety Considerations

At this point in the incident, the following Operational Safety Considerations were of note:

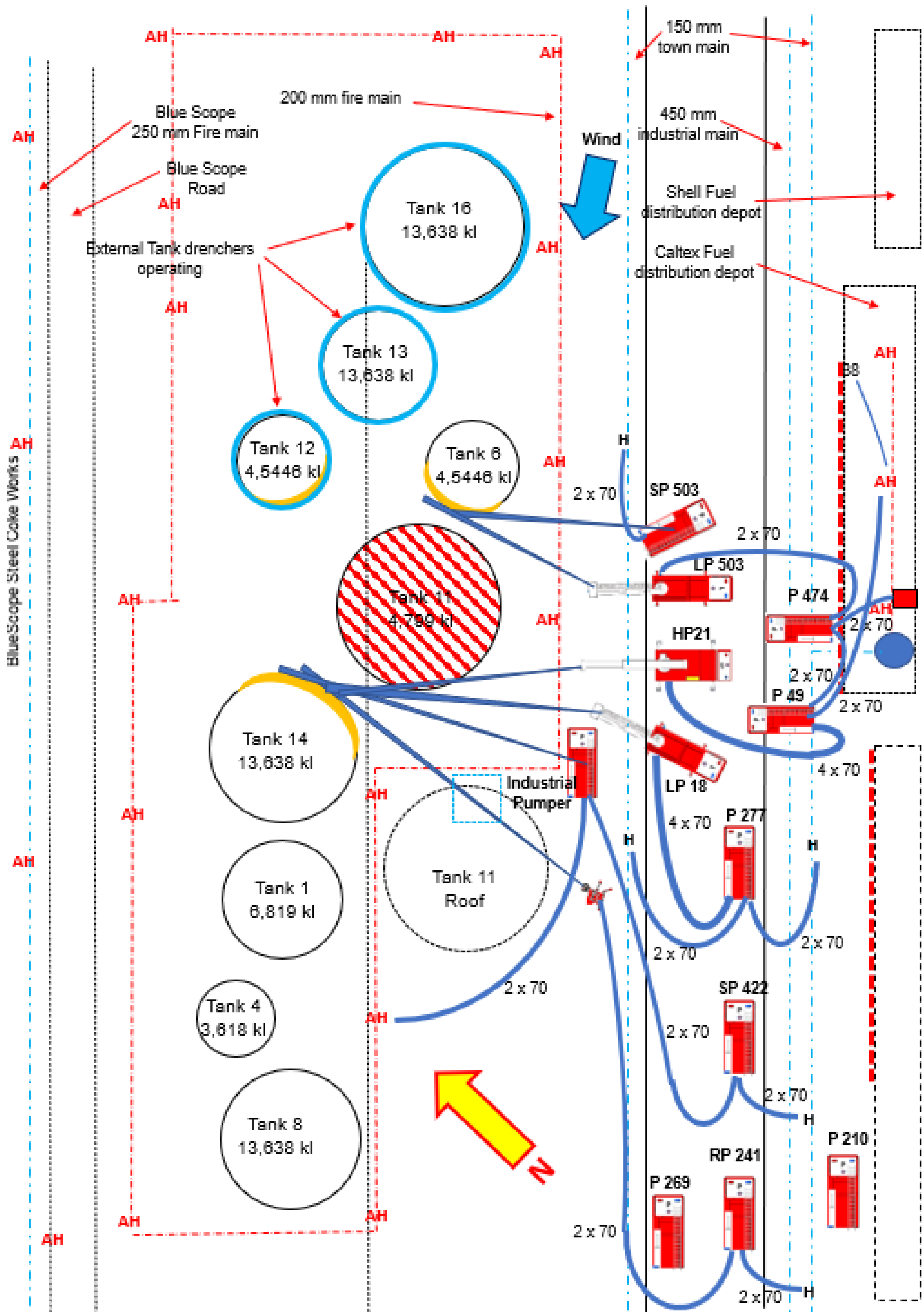
1. One of the measures to protect against radiant heat was the regular rotation of firefighters. A priority of the I.C. was to rotate firefighters every 10 minutes, to ensure crews were properly hydrated and were able to cool down and have a rest.

2. A rehabilitation area was established that was at a sufficiently remote location from the burning ethanol tank so that it was not being impacted by radiant heat.

3. Hazmat 488 crews were monitoring firefighters to ensure they were properly hydrated.

Appliance Self Protection:

The impact of radiant heat on firefighters, fire appliances and firefighting equipment was intense. Firefighters were operating high pressure hose reels on cooling spray patterns to protect their appliances from the impact of the intense radiant heat. When the hose reels were not being operated by hand to cool the appliances, they were secured and set on spray patterns to maintain continuous cooling of appliances.



Expanded Division A Operations

Drawing not to scale

Operations from the Western Side (Division B) of the Fireground:

At 1230 hours the I.C. directed Pumpers 461, 26 and 34 and one BlueScope Steel industrial pumper to deploy to Division B, on the western side of the storage tank farm (this area of potential operations had earlier been identified by Senior Firefighter Peters during an aerial reconnaissance). Inspector Murphy requested a BlueScope Steel industrial firefighting crew accompany the NSWFB crews, because of their expert knowledge of the steel works fire mains. Operations in Division B were carried out under the command of Divisional Commander Chief Superintendent Jim Hamilton and Sector Commander Superintendent Doug Williams. Access to the proposed area of operations was available via an internal road within the BlueScope Steel coke works. Additional ground monitors were being delivered to the scene aboard Logistics Support Vehicle 85.

From Division B, firefighters worked from the BlueScope Steel 200 mm fire main. All ground monitors placed in operation in Division B were fitted with stack tips, providing a solid water stream with the longest reach.

Operational Safety Considerations

At this point in the incident, the following Operational Safety Considerations were of note:

1. At an early stage in firefighting, the bund wall was identified as being quite old and not separated. Operations required firefighters to position and adjust ground monitors on the bund wall. The area inside the bund wall was extremely dangerous. Prior to conducting operations on the bund wall, all firefighters received a safety briefing concerning the hazards associated with the bunded area, firefighter PPE was checked, all operations were undertaken under the supervision of a Safety Officer and crews entered and left the bund wall as quickly as possible.

N.B., It is important to note that the area inside the bund wall (the bunded area) is extremely dangerous and should never be entered, except for essential operational requirements.

Pumper 26 initiated a water relay from the BlueScope Steel fire main. Pumper 26 obtained water from the fire main via four 70 mm supply lines. Pumper 26 then relay pumped four 70 mm lines to Pumper 34. Two 70 mm lines from Pumper 34 were used to supply water to a ground monitor positioned on top of the bund wall to the north of the burning ethanol tank, enabling a protective monitor stream to be directed onto the upper wall of Tank 14. A third 70 mm line from Pumper 34 was used to supply water to a second ground monitor positioned on the bund wall, which was also directed onto the upper wall of Tank 14.

Pumper 461 firefighters positioned a ground monitor on the bund wall in line with the northern end of Tank 14. The ground monitor received water supply from Pumper 461 via two 70 mm lines. Pumper 461 obtained water from BlueScope Steel ring main, via four 70 mm collector lines. Radiant heat near the bund wall was extreme. As firefighters were positioning the ground monitor, firefighters operating two 38 mm lines were creating a protective barrier from the radiant heat, directing cooling sprays between the firefighters working near the bund wall and the burning ethanol tank.

From Division B there were now three ground monitors in operation. All monitor streams were being directed onto the upper wall of Tank 14, which remained under severe threat. Fire conditions within the ethanol tank and associated impact to the surrounding storage tanks, in particular Tank 14, were constantly changing, in accordance with wind strength and direction. At around 1300 hours fire conditions intensified, causing the upper wall of Tank 14 to begin to show signs of failure. At 1306 hours, Division B Commander sent a message to Incident Control reporting:

"AT WORK ON SOUTHERN EXPOSURE OF TANK. THE TANK CONDITION IS DETERIORATING RAPIDLY".

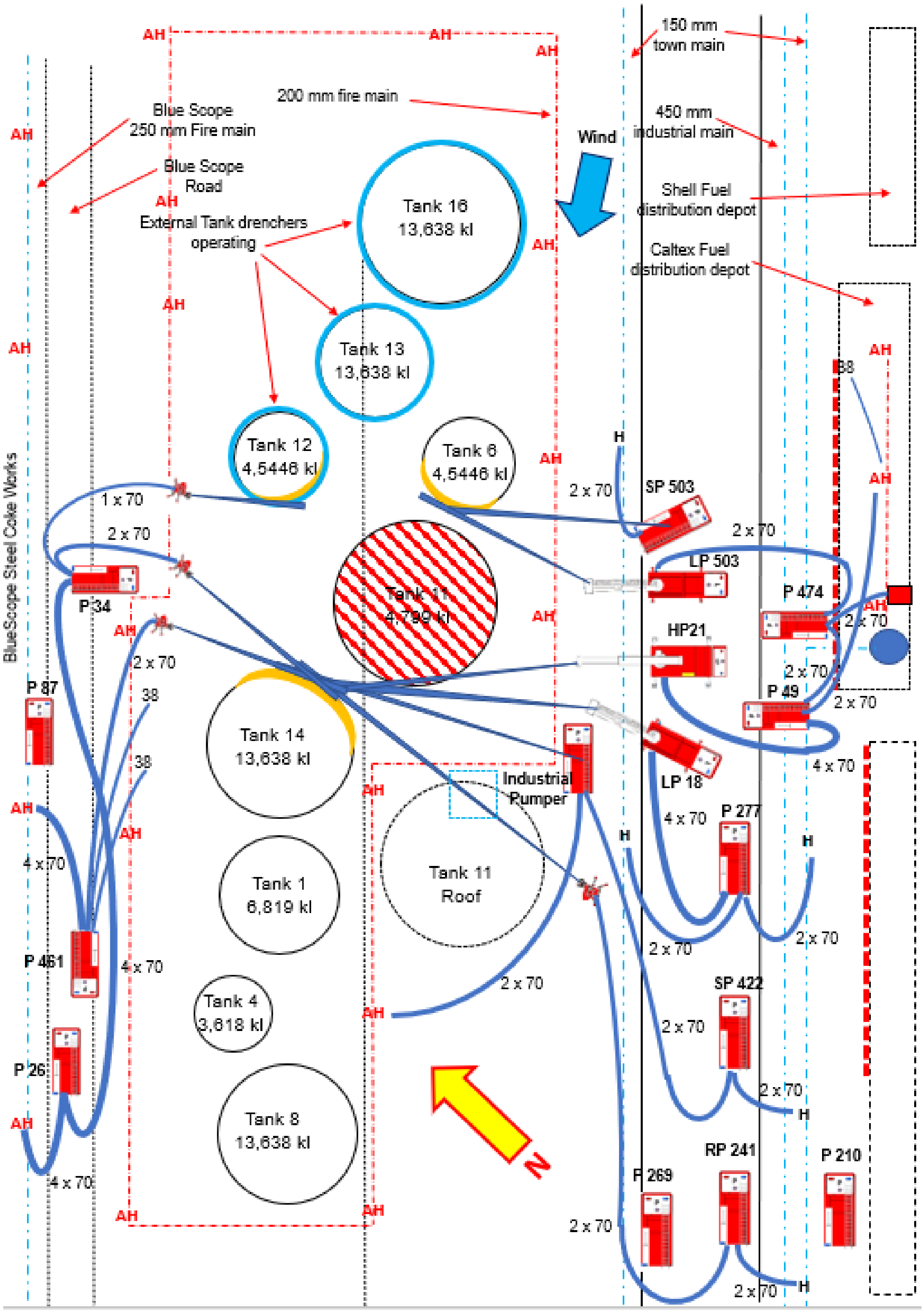
Firefighters entered the area of the bund wall and repositioned the monitor streams, to ensure the streams were reaching the upper wall of Tank 14, providing maximum cooling to the area greatest under threat. The stream of Ladder Platform 18 was also adjusted to ensure it was operating with maximum effect. These efforts successfully protected Tank 14 from further deterioration and potential failure.

Response Increased to an 11th Alarm:

At 1419 hours, the response was increased to an 11th Alarm. As the incident progressed, the Incident Management Team believed there were sufficient resources in place for effective firefighting operations, however the impact of severe radiant heat and heat stress to firefighters resulted in a plan to request the response be increased to an 11th Alarm, to enable firefighters to be rotated from the fireground to rehabilitation more regularly. Commissioner Mullins discusses his reasoning for this decision:

"It was a hot and humid day, operations were going to be of a protracted nature and therefore we were going to need a lot more resources. It was necessary to increase the response to an 8th alarm to fight the fire and a further 3rd alarm for relief purposes. Effectively, we were going to increase the response to an 11th Alarm. This included the incident management team as a component of the 11th Alarm Response.

This was a fireground with many hazards. The radiant heat was creating a significant heat stress issue. On occasions firefighters had moved in very close to the burning ethanol tank to put monitors in place. The area inside the bunded wall was extremely hazardous. We had to ensure that the safety of firefighters was maintained as our first priority."



Fireground Showing Initial Operations in Division B

Drawing not to scale

Plan For Use of Firefighting Aircraft:

During the course of the day, representatives of the aerial firefighting company "Erickson Air-Crane Inc" made an offer to Commissioner Mullins and the NSW Minister for Emergency Services The Honourable Tony Kelly, suggesting the Erickson Air-Crane water bombing helicopter could be used as a delivery platform for foam onto the surface of the burning ethanol, in conjunction with the planned major foam attack. The proposal was given much consideration by the IMT and by a number of persons with expertise in areas of foam and aerial firefighting. Following considerable discussion and evaluation, the Incident Controller made the decision to go ahead with the planned aerial attack. This decision was made only after aviation experts gave absolute assurances confirming the safety of the air crew and firefighters working on the ground would not be placed at risk.

Commissioner Mullins also believed that although there were some doubts as to whether foam could be applied to the surface of the burning ethanol, the application of a high volume of foam and water could result in the production of a large quantity of steam of sufficient size to exclude oxygen from the fire combustion area, potentially resulting in extinguishment or a significant lowering of fire intensity. This type of firefighting operation had never been attempted before; the view of the Commissioner was that providing safety could be assured, it was at least worth trying.

Planning for the Major Foam Attack:

The IMT were planning to conduct a major foam attack on the fire. Before the foam attack could take place and be successful, a number of critical factors needed to be taken into consideration. These included:

1. The diameter and surface area of the tank. This would determine the application required and the quantity of foam concentrate necessary to undertake the task.

2. The ability to apply the required quantity of foam at the necessary application rate onto the surface of the burning ethanol.

Foam stocks were being built up at the fireground. It was anticipated there would be sufficient foam concentrate at the fireground for a major foam attack to commence at 1700 hours.

The application of the foam consisted of three stages:

1. An attempt at aerial delivery of foam would be made using the 9,000-litre aerial firefighting helicopter.

2. At the conclusion of the aerial foam delivery, the Aviation Rescue and Fire Fighting (ARFF) fire appliance would commence to direct a foam stream onto the surface of the burning ethanol tank.

3. Foam would be directed onto the surface of the burning ethanol tank via aerial appliances already on scene and numerous foam ground monitors.

Preparation for the Major Foam Attack:

The wind at the fireground was 30 – 40 km/h from the northeast. Several appliances were tasked to reposition to the northeast of the burning ethanol tank on Flinders Street and establish foam ground monitors to take advantage of wind assistance when applying the foam.

Pumper 54 was tasked to set up a foam ground monitor on the bund wall at the front of the involved tank and direct a foam stream onto the fire. Firefighters entered the tank farm and positioned a ground monitor on the bund wall to the northeast of the burning ethanol tank. Firefighters encountered intense radiant heat as they positioned the monitor and connected two 70 mm lines from Pumper 54 to the monitor.

Foam supply for Pumper 54 consisted of Fluoroprotein foam concentrate, supplied in 200 litre drums. Firefighters connected the foam eductor to the delivery and the foam pick-up tube was placed in the opening of a 200-litre drum. Foam concentrate was proportioned at 3%. A single 70 mm foam line was connected from Pumper 54 to the ground monitor. A second 70 mm line consisting of water only was connected from Pumper 54 to the ground monitor. Pumper 488 relay pumped three 70 mm lines to Pumper 54 and obtained water from the 150 mm main and the 450 mm main in Flinders Street.

Pumper 52, under the command of S.O. Jim Plater, was tasked to position a foam ground monitor on the bund wall at the front of the involved tank in preparation for the major foam attack. Firefighters positioned the ground monitor on the bund wall and connected two 70 mm delivery lines from Pumper 52 to the ground monitor. Water supply for Pumper 52 was obtained from three 70 mm lines connected to the 150 mm town main on both sides of the road. A foam eductor was fitted to one of the 70 mm delivery lines supplying water to the ground monitor. Firefighters from 52 and 54 stations awaited instructions to commence pumping foam.

Adverse Weather Forecast Received:

At approximately 1530 hours the Port Kembla Incident Management Team received information that severe thunderstorm activity was building up in the area. This was likely to impact firefighting operations due to forecast winds in excess of 75 km/h, rain and constant changes in wind direction.

Aviation Rescue Firefighting Appliance Arrives at Fireground:

In conjunction with the planned massed foam attack, the I.C. had earlier made a request for an Aviation Rescue and Fire Fighting (ARFF) fire appliance to assist in the application of foam. As a result of this request, an ARFF contingent under the command of ARFF Senior Fire Commander S.O. Ken Duncan, consisting of one Rosenbauer Ultra-large Mk5 Fire Vehicle, one ground fire command vehicle and one mechanical logistics support vehicle (including a mechanic), responded from Sydney International Airport to the Port Kembla staging area, arriving at 1600 hours. After arriving at the staging area, the Aviation Rescue and Firefighting crew received a briefing from the Incident Controller and were assigned Pumper 277 S.O. Mark Wunsch as NSWFB Liaison Officer.

Following the briefing, the aviation firefighters conducted a reconnaissance of the fireground to identify the best location to position the aviation firefighting appliance. The aviation fire appliance was most effective when conducting a foam attack from an upwind position. After taking into consideration wind direction, ARFF Senior Fire Commander S.O. Duncan believed the most effective means of attack would be from a position on Flinders Street, to the northeast of the involved tank. S.O. Duncan was hopeful the foam stream could be projected over the top of the tank rim and onto the tank wall, allowing foam to build up against the wall and then begin to spread across the surface of the ethanol.

At the conclusion to the site reconnaissance, ARFF Senior Fire Commander S.O. Duncan and NSWFB Liaison Officer S.O. Wunsch had a meeting to discuss any specific needs to assist the ARFF foam attack operation. S.O. Duncan identified a need for water and foam resupply. Stocks of foam had been building up throughout the day and were being stored on Flinders Street to the northeast of the involved tank, a short distance from where the ARFF fire appliance would be operating. Pumper 29, under the command of S.O. Mark Fagan was detailed with assisting to replenish foam concentrate within the ARFF fire appliance when required. Pumper 49 was tasked to supply water to the ARFF appliance.

Firefighters identified that the hose connections on the ARFF fire appliance (BIC/British Instantaneous Couplings) were not compatible with NSWFB Storz fittings. Fortunately, a number of appliances on the Port Kembla fireground that had responded from Sydney included stations that work in close proximity to Sydney Airport (Pumpers 26 and 56) and therefore were equipped with BIC/Storz adaptors. The BIC/Storz adaptors were connected to the ARFF fire appliance, enabling Pumper 49 to supply the ARFF appliance with three 70 mm supply lines. Pumper 474 was also supplying water to the ARFF appliance. Water supply for both Pumpers 49 and 474 was obtained from the Caltex ring main (connected to the bulk water storage tank).

A large stock of ATC (Alcohol Type Concentrate) foam was located in 20 litre drums in proximity to the ARFF appliance. The ARFF Senior Fire Commander was in communication with the ARFF crews using normal airport fire radios and was able to communicate with NSWFB commanders via a HHT operating on NSWFB fireground radio channels.

Fire Conditions Worsen:

At 1542 hours Division B Commander sent a report to Incident Control reporting four monitors were at work protecting Tank 14 and the Division B *position was in hand*. Wind conditions were of moderate strength and flames were venting vertically from the burning ethanol tank.

Just 18 minutes later at approximately 1600 hours a severe weather change began to impact the fireground, consisting of light rain and 75 km/h wind gusts from the north-northeast. This had an immediate impact on fire conditions, resulting in a significant increase in fire intensity. The flame height of the burning ethanol doubled. The increased supplies of air to the fire area resulted in greatly increased combustion. The surface of the ethanol became extremely turbulent due to the increase in fire activity, worsening fire conditions. Fireball type fire behaviour began to violently roll upwards within the fire plume. Enormous flames were extending to the southwest, threatening Tank 14.

At 1607 hours Division B commander sent an urgent message to the Incident Control Vehicle, reporting Tank 14 was being impinged by flames, the tank wall was beginning to ripple and was in imminent danger. Division B Commander requested additional pumpers respond to Division B to assist firefighting operations. As a result of this message, additional pumpers were assigned from the staging area to Division B.

Increased Operations to Protect Tank 14:

Pumpers 17, 22, 48, 56 and 72 were deployed to Division B to assist the establishment of additional ground monitors to protect Tank 14 (containing 13.5 million litres of heavy marine bunker fuel oil), which was now being heavily impacted by direct flame impingement due to the weather change and was in severe danger of failure.

Pumper 22, under the command of S.O. Mick Wren was directed to place a ground monitor in operation on the pipe tracks above the bund wall and direct a cooling stream onto the upper wall of Tank 14 to help maintain the strength and integrity of the storage tank and prevent it from failing. Water was supplied to the ground monitor with two 70 mm lines connected to Pumper 48 (under the command of Captain Wayne Challinor). Water supply for Pumper 48 was obtained using four 70 mm supply lines connected to the BlueScope Steel fire main.

Pumper 34 was supplying water via a single 70 mm line to a ground monitor located on the bund wall, which was used to project a cooling stream onto the upper wall of Tank 14. Water supply to this ground monitor was increased with a second 70 mm line, supplied by Pumper 48.

Pumpers 17 and 72 were redeployed to Division B and tasked with placing a ground monitor in operation to direct a cooling stream onto the upper tank wall of Tank 14. Firefighters from 17 station set up the monitor on the bund wall. Firefighters from 72 station connected one 70 mm line from the 150 mm tank farm ring main and two 70 mm lines from the BlueScope Steel fire main to Pumper 72. Water to the ground monitor was supplied with two 70 mm lines from Pumper 72, pumping water at between 500 - 1,000 kPa.

The placement of these ground monitors to enable streams to be projected onto the upper wall of Tank 14 required firefighters to work directly in front of the involved tank and be exposed to very high levels of radiant heat. To protect crews positioning the ground monitors on the bund walls, 38 mm spray streams were directed between the firefighters positioning the monitor and the involved ethanol tank.

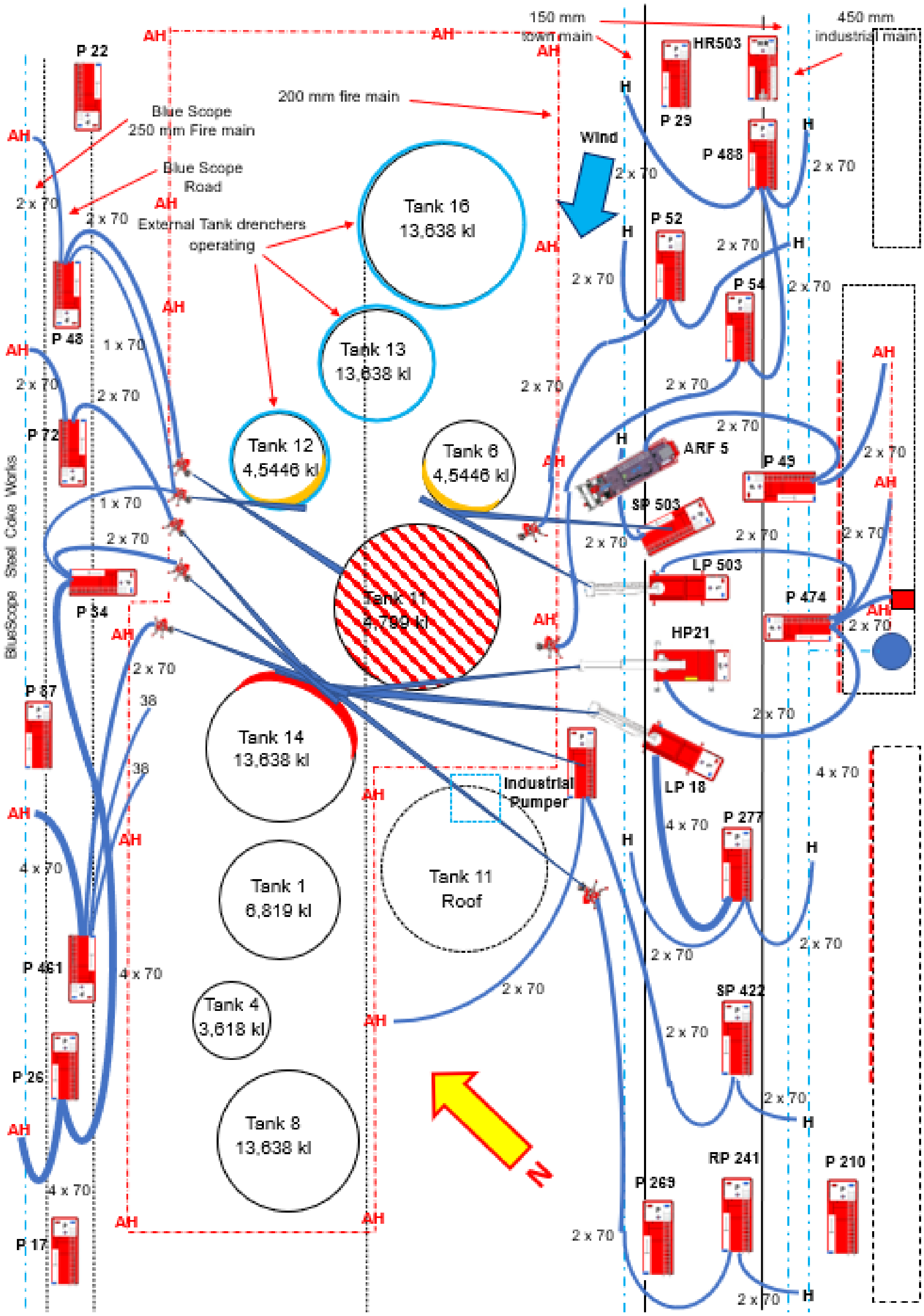
From Division B there were now five ground monitor streams being directed onto the upper wall of Tank 14. These monitors remained in operation overnight until the following morning, providing critical cooling. Firefighters worked continuously throughout the deployment of the ground monitors to adjust the positioning and direction of the monitor streams, to ensure the streams were being as effective as possible. Each time firefighters worked on the bund wall they operated under the protection of 38 mm cooling sprays. Despite the ferocity of the fire impact due to the extreme weather change, the cooling streams successfully protected the heavily threatened Tank 14.

Aerial Foam Attack:

The aircraft to be used in the aerial foam application was an Erikson Aircrane (Sikorsky S64F Skycrane) 178 "*Isabelle*" firefighting helicopter. Once all equipment was in place for the major foam attack, the I.C. gave instructions for stage 1 of the foam operation to commence, consisting of the aerial foam application from the Aircrane firefighting helicopter.

An air attack helicopter was providing guidance for the Aircrane. The air attack commander was in radio communications with the Incident Controller and the Aircrane crew. The Aircrane was carrying a load of 90 litres of foam concentrate (PF70+ FluoroProtein) mixed with 6,000 litres of water. The Aircrane approached from the north and dropped the water/foam load from a height of 800 feet (240 metres) upwind of the burning tank. The air attack commander, Ian Harris, made the following comments on the effectiveness of the attack:

"Flames were initially 60 to 70 metres high. After the initial attack, the flame height diminished. The water drop took the heat out of the centre of the fire. The attack produced a lot of steam and the flame height reduced by half. We were also hitting the northern side of the tank, where the tank had buckled, trying to cool the tank wall, to stop the tank from failing. There were nearby thunderstorms in the area and the drafts associated with these storms were starting to disrupt the water/foam drops."



Fireground Showing Additional Operations in Division B.
Crews in Division A are preparing for foam attack

Drawing not to scale

The Aircrane was unable to drop water/foam from a lower height because of the protruding towers and infrastructure at the steel works. After each drop, the Aircrane refilled using the sea-snorkel device from sea water within Port Kembla harbour. The Aircrane made a number of drops, however once it became apparent no further progress was going to be made, the Incident Controller made the decision to cease further Aircrane drops and move to the next phase of the foam attack.

Tank Structure Impeding Foam Attack:

The upper wall of the tank was beginning to buckle and fold inwards, creating a shield over burning ethanol near the tank wall that could potentially obstruct the application of foam. This was particularly concerning because the foam application plan involved directing foam onto the tank wall and letting it build up and then spread out against on the surface of ethanol. This would be problematic if the action of the folding tank wall hindered this process.

Aviation Rescue Firefighting Appliance Commences Foam Attack:

The ARFF appliance moved into position and began to project the foam monitor stream onto the fire. ARFF and NSWFB firefighters operating protection lines directed spray streams onto the ARFF appliance, to protect the appliance and crew from the impact of intense radiant heat. Firefighters maintained these protection sprays for the duration of operations of the ARFF appliance. As the ARFF crews were preparing to commence fire attack, there was a significant deterioration in weather conditions due to nearby thunderstorm cells, producing wind squalls that were impacting the fireground. The initial foam attack lasted for approximately two minutes, however there was little sign the foam attack had made any significant impact on the fire.

The ARFF appliance was replenished with foam concentrate and water and a further attack was made on the fire, from a slightly different angle. The gusting wind had a noticeable impact on the fire, resulting in greatly increased fire intensity. The wind strength was also impacting the projection of the foam stream. Again, there was little indication the foam application was having an impact on the fire. In an attempt to increase the effectiveness of the foam application, the security fence surround the site was cut by the crew of Rescue 503, allowing the ARFF appliance closer access to the tank. Winds continued to strengthen and swirl. Three further foam attacks were made with the ARFF appliance, however again no noticeable changes could be seen to fire conditions. At this time available foam stocks had been consumed and the decision was made not to continue the ARFF foam attack.

Rosenbauer Ultra-large Mk5 Data Sheet

Type of Appliance: Aviation Rescue and Firefighting Vehicle.
Water capacity: 7,000 litres
Foam capacity: 945 litres B Class AFFF
Monitor Capacity: 3,600 litres per minute at 1,100 kPa
Monitor Projection: 60 metres.
Pump: Rosenbauer 2 stage centrifugal

Major Foam Attack Operations:

At the same time the ARFF appliance began to attack the fire with the foam monitor stream, firefighters in Division A commenced a massed foam stream attack.

Pumper 52 firefighters directed the monitor stream over the tank wall and onto the surface of the burning ethanol. AFFF foam concentrate proportioned at 6% was used during the first stage of the foam attack. This was then changed to ATC foam concentrate. Water was supplied to the monitor at 1,100 kPa.

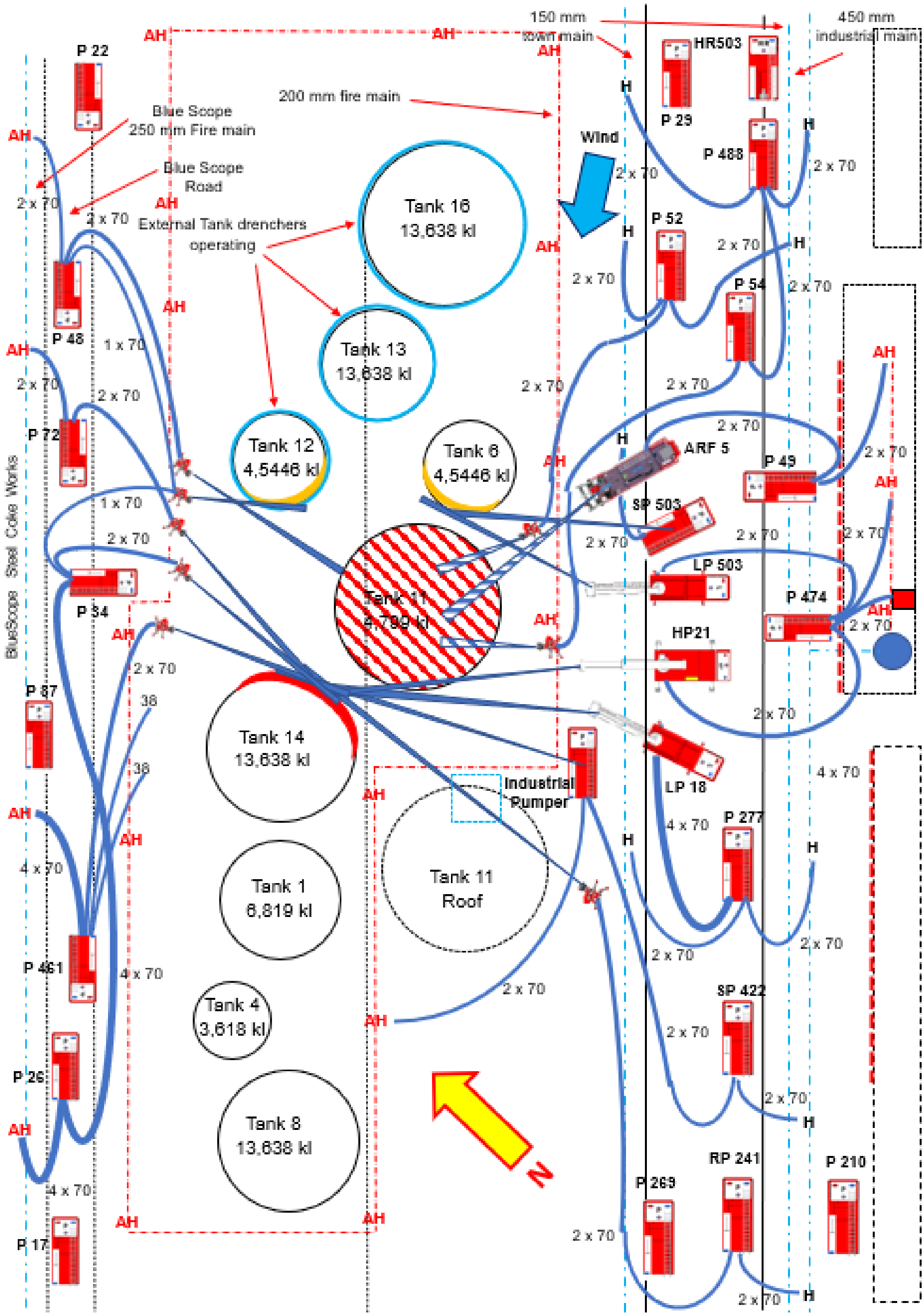
Super Pumper 503 were directing foam through the appliance roof monitor, being supplied by an eductor connected to the number 1 delivery, before switching to delivery 2. Firefighters were initially using AFFF (Aqueous Film-Forming Foam) solution before changing to ATC (Alcohol Type Concentrate) and Fluoro Protein foam concentrate. The foam stream was being severely impacted by high winds, and was having minimal impact on the fire.

Pumper 54 firefighters encountered difficulty projecting the foam stream over the tank wall because of the impact of the wind.

Hydraulic Platform 21 directed a foam stream into the burning ethanol tank. The aerial operators observed the thermal currents from the ethanol tank fire were breaking up the foam stream, reducing its effectiveness and preventing most of the foam from reaching the surface of the burning ethanol.

Despite the best efforts of a coordinated foam attack, too many variables were adversely impacting the attempted foam application, including strong winds that were breaking up foam streams, severe thermal turbulence above the tank due to intense fire activity resulting in foam streams being drafted upwards and away from the tank and the turbulent surface of the burning ethanol preventing what little foam did reach the surface from forming any sort of cover. Incident Controller Assistant Commissioner Kear advised there were a number of factors adversely affecting the application of foam:

"The fire was extremely hot. The thermal updraft from the burning ethanol was impacting the foam streams, lessening their ability to penetrate through to the surface of the burning ethanol. The heat intensity was so severe it was destroying the foam steams. A severe weather change impacted just as we were starting the foam attack. Strong winds were blowing the foam off course and causing foam streams to breakup. The burning ethanol was extremely turbulent, making it extremely problematic to lay a foam blanket on it. A further problem was the folding inwards of the upper wall of the ethanol tank, shielding fire from the foam streams."



Fireground Showing Major foam attack

Drawing not to scale

Revised Firefighting Strategy:

Commissioner Mullins advises on the changes to the firefighting strategy following the unsuccessful foam attack:

"Just as the foam attack commenced, a severe wind change impacted the fireground. The wind change had a severe impact on the foam streams and we couldn't get the type of foam cover onto the ethanol we were hoping for. That left us with several fallback options; either we could let the ethanol burn down to a level where it could be diluted which would result in extinguishment or we could just simply let it burn down until all of the product had burnt out. We decided to try and dilute the ethanol. Our operational priorities continued to be containment."

Incident Controller's Firefighting Plan

At this time, the Incident Controller had developed the following Incident Objectives, Strategy and Tactics:

1. Maintain cooling streams onto walls of threatened exposure tanks.

2. Maintain cooling streams onto wall of burning ethanol tank to preserve integrity of tank.

3. Prepare for Major Foam Attack at 0600 hours.

Breach of Bund Wall:

During the placement of ground monitors, firefighters had detected a breach of the earthen bund wall surrounding the involved tank. After the ARFF appliance had refilled with foam, this appliance was tasked to standby at a safe distance but within foam projection distance, to lay foam into the bund if the ethanol tank failed and a spill resulted.

Incident Management Team Changeover:

At 1800 hours a change in the Incident Management Team took place. Following a handover, Incident Control was transferred from Assistant Commissioner Kear to Assistant Commissioner Ken Bryant. The replacement IMT consisted of the following persons:

Incident Controller: Assistant Commissioner Ken Bryant
Operations Officer: Superintendent Mark Brown.
Division A Commander: Superintendent Peter Stathis
Division B Commander: Superintendent Ray Kelly
Safety Officer Division A: Inspector Steve Baker
Safety Officer Division B: Inspector Jay Bland
Logistics Officer: Inspector Clinton Demkin
Staging Officer: S.O. Phil Collins

Firefighting Objectives and Strategies:

Following transfer of command, the Incident Management Team met aboard the ICV to redefine operational priorities and establish incident objectives and strategies. Assistant Commissioner John Benson was present during the briefing and describes some of the incident objectives and strategies discussed:

"The first priority was the safety of firefighters. We needed to ensure we had adequate resources in staging to facilitate crew rotation and firefighter rehabilitation because of the extreme levels of radiant heat from the fire. We also knew that as the product burned down, the lateral transfer of radiant heat was going to increase. Our plan was to rotate stations in and out of the site much more frequently, to reduce the levels of exposure to the heat. When the crews were exposed to heat they were also becoming fatigued and the chances of accidents happening increased. This required significant resource and logistics planning. This was a unique type of incident and the site contained numerous hazards. Ensuring firefighter safety was an enormous component of our firefighting plan. We had multiple Safety Officers deployed across the site. The role of the Incident Management Team wasn't just about managing the fire, it was about ensuring firefighter safety.

Due to the turbulence of the burning product, we had been unsuccessful in our initial attempts to lay a foam blanket on the surface of the ethanol. Therefore, at that time we couldn't extinguish the fire. Our priorities continued to be the protection of the surrounding tanks. We needed to ensure the monitor steams were all operating effectively and exposures were being adequately protected. Another concern was the bund wall. We needed to ensure the bund wall remained intact in case of tank failure. We continued to monitor the run-off of firefighting water. Our strategy was to continue to cool the tank until the product was at a sufficient level that it could be extinguished. We continued to monitor the temperature of the product. We needed additional resources kept in reserve, in case the tank failed, resulting in a spill and a major escalation of the incident."

The Incident Management Team meeting identified that the initial major foam attack had not been successful for a number of reasons, including the impact of severe winds, turbulence of the ethanol surface and the temperature of the ethanol tank. A new firefighting plan was formed, for a further foam attack at first light (0600 hours). At this time the winds would be at their calmest, the level of ethanol would have lowered and the tank temperatures would have significantly cooled. In the interim period, efforts would continue to protect exposure tanks and to cool the ethanol tank. From a safety perspective, the IMT made the decision to change over all firefighters and IMT staff every six hours, in an attempt to minimise the adverse effect of heat stress being caused by the severe radiant heat at the fireground.

Firefighting Operations into the Evening:

Following the 1800 hours changeover of the Incident Management Team, firefighting operations continued into the evening. At this time, firefighters were maintaining protection of the surrounding tanks with cooling streams and protection of the integrity of the burning ethanol tank, in support of the overall containment strategy, in preparation for a second planned foam attack at 0600 hours the following morning. Firefighting operations consisted of the following:

Division A: Three aerial master streams, two roof monitor streams and three ground monitor streams, providing cooling streams onto the surrounding tanks and the involved ethanol tank.

Division B: Five ground monitor streams providing cooling streams onto the surrounding tanks and the involved ethanol tank.

These operations continued over the following hours. The ethanol within the involved storage tank continued to burn fiercely. During the evening it was necessary for a number of appliance change overs to occur;

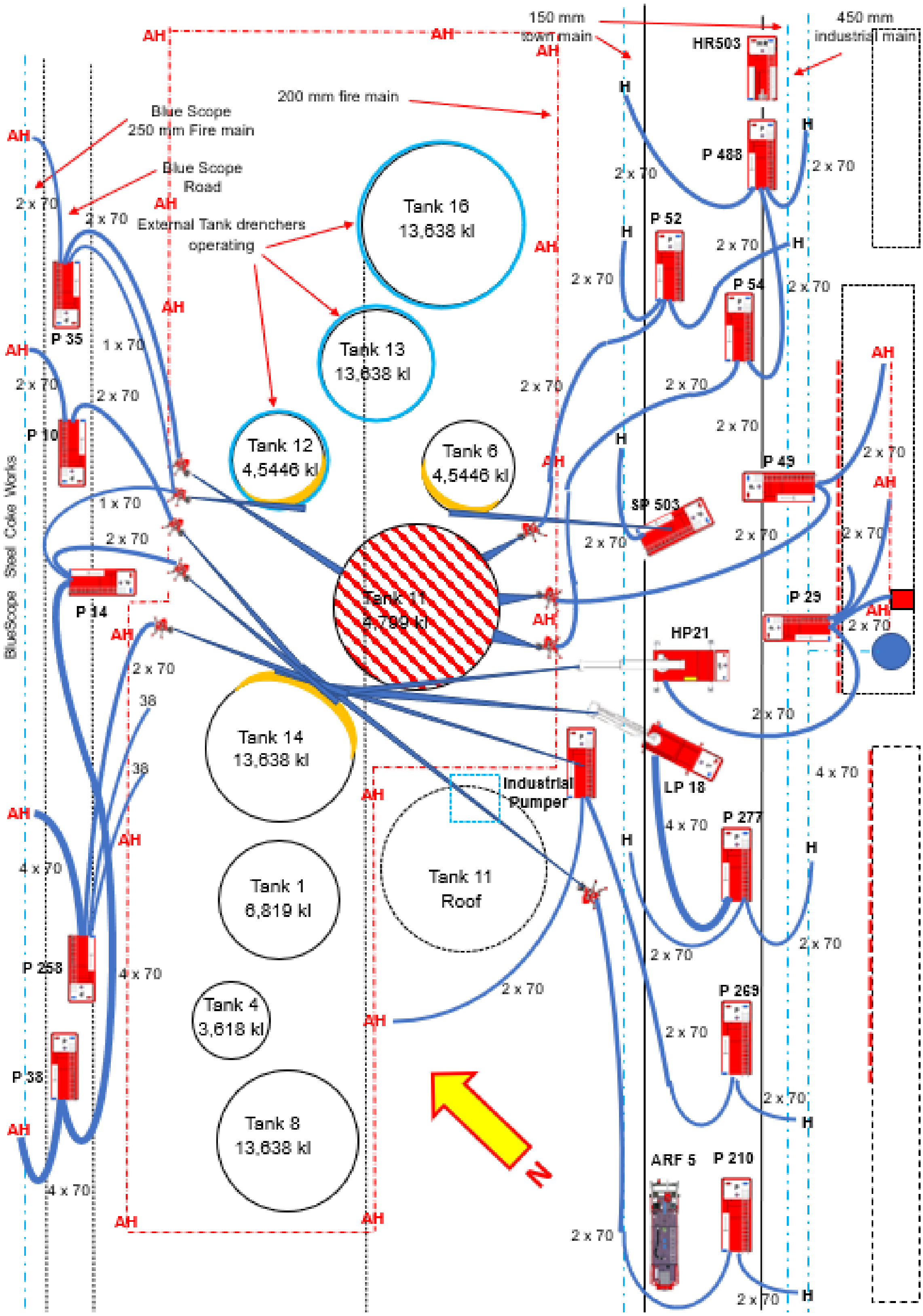
In Division A, Rescue Pumper 241 was shut down and replaced with Pumper 210, who continued to supply water to the ground monitor stream protecting Tank 14. Pumper 30 replaced Super Pumper 422, supplying two 70 mm lines to the Serco industrial pumper (continuing to direct a roof monitor stream onto the upper wall of Tank 14).

In Division B, Pumper 56 replaced Pumper 26 relay pumping to Pumper 34 and Pumper 22 replaced Pumper 48 supplying water to ground monitors. A crew change over on the Incident Control Vehicle occurred, consisting of oncoming S.O. Phil Collins and Firefighters Gail Marshall and Gary Munroe.

Firefighting Overnight:

At 0200 hours Incident Control was transferred from Assistant Commissioner Bryant to Chief Superintendent Roger Bucholz. The Incident Controller maintained the firefighting plan that was in place, which consisted of:

1. Maintaining cooling of storage tanks under threat.
2. Continue to cool the burning ethanol tank top maintain the integrity of the tank and prevent tank failure.
3. Continue to monitor the ethanol level within the tank and the temperature of the tank.
4. Prepare for a major foam attack once the ethanol level and tank temperatures had reached appropriate levels.



Fireground Showing Firefighting Operations Into the Evening

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The fireground command structure was re-organised to meet ongoing operational requirements. All divisions and sectors were removed. An Operations Officer and Logistics Officer were also appointed. The following fireground command reorganisation occurred:

Sector A located on Flinders Street, under the command of a Sector Commander and supported by a Safety Officer.

Sector B located within the BlueScope Steel coke works site, under the command of a Sector Commander and supported by a Safety Officer.

In accordance with the plan to rotate crews more frequently, a large rotation of firefighters also occurred. Pumpers 16, 65, 31, 10, 85, 38 and 14, Super Pumper 40, 9 Hazmat Charlie, Aerial Pumper 92 and Ladder Platform 1 were assigned to the incident at 0220 hours to replace all crews in place at the fireground.

By 0300 hours a complete change of crews had occurred. The firefighting strategy continued to be the protection of surrounding storage tanks under threat and cooling of the burning ethanol tank to maintain the integrity of the tank. Fireground operations were as follows:

Sector A operations were formed by Pumpers 16, 65, 31 and 85, Super Pumper 40, Aerial Pumper 92 and Ladder Platform 1. Firefighting operations in Sector A consisted of five ground monitors, one appliance roof monitor and one aerial appliance in operation, protecting Tank 14 and directing cooling streams onto the wall of the burning ethanol tank.

Sector B operations were formed by Pumpers 258, 10, 14, 38 and 35, pumping water to five ground monitors. Four monitor streams were being used to protect Tanks 12 and 14 and one monitor stream was being used to cool the wall of the burning ethanol tank.

Hazmat firefighters continued to take regular temperature readings of the burning ethanol tank. At 0200 hours the tank temperature was 600°C. Over the following hours the temperature of the tank was continuously falling. At 0600 hours the external temperature had fallen to 100°C.

Preparations for Second Major Foam Attack:

Throughout the night the level of ethanol within the burning tank and temperature of the external tank wall were continuously monitored. The temperature of the external tank wall was gradually falling at a rate of about 100°C per hour. The IMT estimated that by 0600 hours the ethanol would be at a level that a major foam attack could be mounted. A further advantage of a foam attack at this time of day was the stillness of the air, that would give foam the greatest chance of being projected onto the surface of the burning ethanol. The foam attack operation was being carried under the control of Sector A Commander Inspector Chris Shapter.

The ARFF appliance contained a full load (900 litres) of Alcohol Type Concentrate and was moved into position to commence an attack on the fire at the front of the involved tank on Flinders Street. 70 mm supply lines from two pumpers were connected to the ARFF appliance. Water supply for the pumpers was from 2 x 70 mm collector lines (each) connected to two hydrants within the Flinders Street 150 mm mains.

Ladder Platform 1 was positioned on Flinders Street, beside the ARFF appliance. Aerial Pumper 92 supplied four 70 mm delivery lines to Ladder Platform 1. 70 mm foam eductors were connected to each of the four 70 mm deliveries of Aerial Pumper 92. The pick-up tube connected to delivery # 1 was drawing foam concentrate from 20 litre drums. Pick-up tubes connected to deliveries 2, 3 and 4 were drawing foam concentrate from a 1,000 litre intermediate bulk container. All foam concentrate was Alcohol Type Concentrate (ATC). Water supply for Aerial Pumper 92 was from 4 x 70 mm collector lines connected to two hydrants within the Flinders Street 150 mm mains.

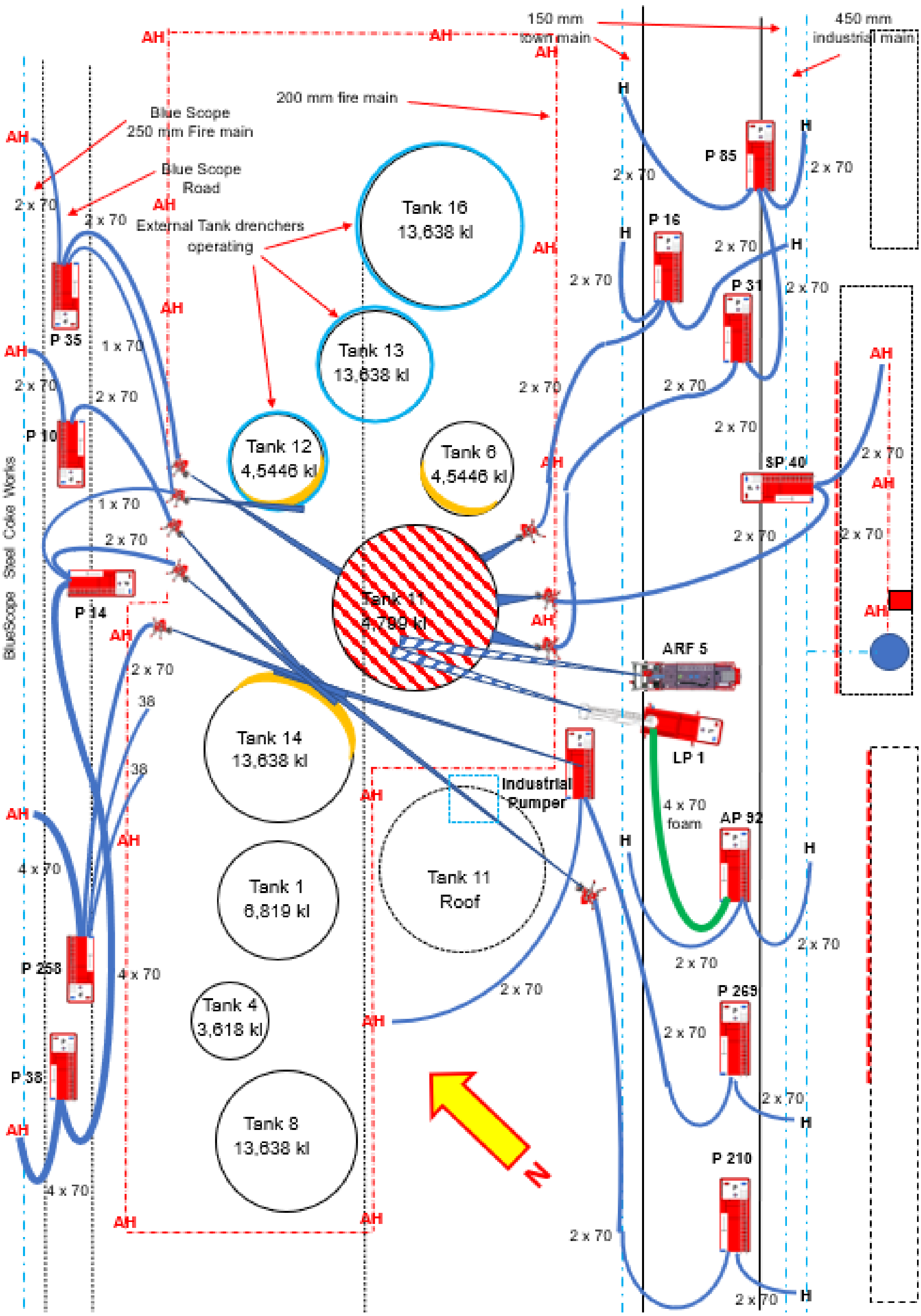
Ground monitors remained in place, directing cooling streams onto the sides of the ethanol tank. It was important to cool the tank as much as possible, to prevent the hot metal of the storage tank attacking and breaking up the applied foam. The I.C. planned to keep the cooling streams in place throughout the application of foam.

Fire Extinguished:

At 0614 hours Inspector Shapter gave orders for Aerial Pumper 92 to commence pumping foam to Ladder Platform 1. After approximately one and a half minutes Ladder Platform 1 began to project a 40-metre stream of finished foam solution onto the surface of the burning ethanol. Sector Commander A then gave instructions for the ARFF appliance to commence applying foam. Almost immediately the ARFF appliance began to project a foam stream onto the surface of the burning ethanol. The two foam streams were projected onto a single point of the ethanol, creating a “massing of streams” that then began to spread out across the surface of the ethanol, covering the ethanol within approximately ten minutes, resulting in extinguishment being achieved. Extinguishment was achieved using 500 litres of Alcohol Type Concentrate and 23,000 litres of water. Ground monitor cooling streams projected onto the external wall of the storage tank remained in place throughout the foam attack and after the foam attack had concluded, to ensure the hot steel of the storage tank did not cause the foam blanket to break down.

Following the initial application of foam, the blanket began to break-up after 20 minutes of initial application. Aerial Pumper 92 continued to pump foam to Ladder Platform 1, enabling the foam cover to be maintained. Following the second foam application, cooling streams continued to be applied to the sides of the ethanol tank, to reduce the possibility of a further breakdown of the foam blanket and re-ignition of the ethanol. Firefighters continued to apply foam onto the surface of the ethanol for a further four hours, ensuring the foam cover remained intact.

At 0630 hours, Sector Commander A reported a distinct decrease in heat emission from Tank 11 was being detected using a thermal imaging camera. At 0701 hours Hazmat officers reported the highest temperature reading they were recording was 53°C.



Fireground Showing Final Extinguishment Operations

Drawing not to scale

Post Fire Operations:

At 0730 hours transfer of Incident Control from Chief Superintendent Bucholtz to Chief Superintendent Bootsma occurred. Following extinguishment of the surface fire, a large quantity of ethanol remained within the tank and firefighters continued to cool the external walls of the ethanol tank. Firefighters were also directing water into the tank to dilute the ethanol, reducing the ethanol flammability. The objective of the Incident Controller was to reduce the temperature of the ethanol from 53°C to 20°C which was identified as the safe working temperature for ethanol.

At 1200 hours staff from Manildra wearing PPC and B.A. facemasks on extension lines, accompanied by firefighters wearing SCBA took a number of product samples from the tank. The samples were then the subject of chemical laboratory analysis to determine the level of dilution of the ethanol and the remaining flammability of the product within the tank. At 1517 hours analysis identified that liquid remaining within the tank consisted of 24.5% ethanol and the remainder water. On this basis, no further risk of ignition existed and all NSW Fire Brigades firefighting operations officially ceased at 1610 hours, after the last appliance left the scene.

Manildra clean-up teams working in conjunction with EPA and NSWFB Hazmat technicians developed a site clean-up plan, ensuring product remaining in the tank was safely removed for reprocessing and any fuel or contaminants within the bunded area were removed and properly treated.

Post Fire Scene Examination:

Following the fire, the site was inspected by officers from NSW Fire Brigades Fire Safety Division, who made the following observations[1]:

1. The tank farm bund walls were quite old, too shallow, did not separate the various tanks and contained a number of breaches.

2. Site block plan was not representative of what was at the site.

3. Foam control centre was too close to the storage tanks.

4. The control valves for the tank deluge systems had to be turned on manually.

5. The site fire main was not fitted with a fire brigade booster assembly.

6. The bunded area contained a work truck, work equipment and a 30,000-litre tanker.

1. This information is obtained from the transcript of judgement in NSW Industrial Court Matter IRC 6789 - 92 of 2005, as reported by His Honour J Marks in his final judgement delivered on Wednesday 28 February 2007.

Incident Outcomes:

The following incident outcomes were achieved:

1. All persons within the tank farm site were safely evacuated (with the exception of one person who was injured prior to the arrival of firefighters).

2. All persons within the immediate area of the burning tank were safely removed to an evacuation point and accounted for.

3. Surrounding tanks in severe danger of fire spread were protected.

4. The fire was successfully controlled and extinguished.

5. Contaminated water run-off, foam and tank product were contained to the site.

6. The fire and firefighting operations had a minimal impact on surrounding industry and business, which were able to resume normal operations within 24 hours of the fire occurring.

Bulk Flammable Liquid Storage Tank Fires – Full Surface Fire Firefighting Operations

There are a number of potential fire scenarios associated with bulk flammable liquid storage tanks. This section will examine the largest and most dangerous of these scenarios, a *full surface* fire. The following factors are important to take into consideration at firefighting operations involving bulk flammable liquid storage tank full surface fires:

Life Risk:

The following life risk factors should be taken into consideration:

a. Rescue - There may be persons trapped or injured who require rescue.

b. Evacuation – There may be a need to evacuate all persons from the site and adjoining sites.

c. Surrounding Area – There could be potential impact to the wider surrounding area, requiring either evacuation or advice given to residents/occupants.

An important lesson from the Port Kembla fire is that firefighters should not be committed onto the area of a bulk flammable liquid storage tank fire until it has been established that operations can be conducted safely.

Information Gathering and Size-up:

A storage tank fire is an extremely complex, difficult and dangerous firefighting scenario. The key to a successful incident outcome concerns the ability to develop an appropriate Incident Action Plan. The IAP will only be as good as the accuracy of the information that is used to develop it, which can only be obtained through the process of incident size-up. During the size-up process, critical information that the Incident Commander should attempt to obtain includes:

a. The product type and quantity within the burning storage tank.
b. The surface area of the storage tank (calculated from the tank diameter).
c. The distance to the closest exposure tanks and the nature of products within exposure tanks (this will assist in identifying which tanks will require protection).

In addition to the above size-up factors, there are many more factors that will affect incident planning that the Incident Commander must try to identify. Some of these include:

a. Installed fire protections systems at the site and whether they are in operation.
b. Forecast weather including wind direction/strength and rain.
c. Available water supplies.
d. Environmental exposures.
e. Suitability of access for firefighters and firefighting equipment.
f. Exposures within the surrounding area.
g. Location of Command Point, Appliance Staging Area, Equipment Staging Area, Rehabilitation Area, Restricted Access Zones, media briefing points,

Firefighting Strategy:

Once sufficient information has been gathered, the Incident Commander can commence to determine a suitable firefighting strategy. The following considerations may be taken into account to determine an appropriate firefighting strategy:

1. In most situations, there are normally two strategies available to the I.C.:

a. A defensive strategy, where the tank is left to burn out and surrounding exposures are protected. This strategy is normally adopted if there are insufficient resources to mount an effective offensive attack or the I.C. has determined an offensive attack will be too unsafe.

b. An offensive strategy, where firefighters attempt to establish control of the fire. This can be undertaken with installed systems at the site or by carrying out firefighting operations with fire service resources. If the latter is chosen, firefighting operations will consist of a major foam attack.

2. In situations where multiple storage tanks are involved in fire, extinguishment prioritisation should commence with the tank that is easiest to extinguish or the tank that poses the greatest risk.

3. In the event a fire breaks out in the bunded area, the fire in the bunded area should be extinguished before the tank fire is extinguished.

4. In some situations, it may be possible to transfer product from the burning storage tank to another tank that is not in danger of becoming involved in fire. Prior to commencing the transfer of product from one tank to another, the operational status of the product transfer lines and pipe isolation valves must be considered.

Planning for a Major Foam Attack:

1. If firefighting operations at a full surface fire are to be successful, the Incident Commander will need to undertake detailed, methodical and meticulous planning. Based on the information obtained during the size-up, the Incident Commander will need to identify:

a. The **quantity and type of foam concentrate that is required to mount a successful foam attack**. This information is based on the surface area of the storage tank and the product type burning and can be calculated from data within NFPA 11, the international standard for foam application.

b. The **application rate that the foam must be applied at** and the minimum application time. This information can be calculated from data within NFPA 11, the international standard for foam application.

c. An effective foam delivery system (most likely a combination of ground monitors and aerial streams) that is going to be used to project the finished foam solution at the required application rate over the rim of the tank and onto the surface of the burning liquid.

d. A water supply that is capable of sustaining the required foam application rate.

2. If the minimum criteria as detailed within NFPA 11 for a successful foam attack cannot be met, a foam attack should not be attempted as the scientific data shows it will be unsuccessful and the foam will be wasted. More importantly, firefighters will be undertaking a very difficult and dangerous operation for little gain. In general terms the NFPA 11 application rate for foam is 10.4 litres/minute per square metre for 55 minutes (for a petroleum storage tank fire). Once the foam attack commences, the Incident Commander must ensure foam application is adequate and uninterrupted.

3. Incident logistics will be a major challenge, including:

a. The Equipment Logistics Officer will need to locate specialist equipment that can project foam over the storage tank rim and onto the surface of the burning liquid. This will most likely be through the use of aerial appliances and foam ground monitors.

b. The Foam Logistics Officer will need to identify where bulk foam (the correct type for the burning product) can be sourced, how the foam will be transported to the fireground and how the foam will be utilised by firefighting crews at the fireground.

Water supply:

There is a very large demand for water supply at a storage tank fire. Potential water sources may include town main supplies, natural static supplies (harbours, lakes, dams), bulk water storage tanks and industrial mains. The Hytrans Buk Water Transfer system is capable of transferring large quantities of water to the fireground from up to 1.5 kilometres away.

Protecting Exposures:

Fire spread from a burning storage tank to further storage tanks containing volatile contents is a very realistic possibility. An important goal of the Incident Commander at a storage tank fire is to prevent fire spread to further storage tanks, which would result in a major escalation of the incident to the point where the incident is uncontrollable. After any life risk has been dealt with, protection of exposures becomes the Incident Commander’s next priority. The following considerations relate to exposure protection at a storage tank fire:

1. The most effective means of protecting adjacent storage tanks to prevent the contents igniting is through cooling. Tanks can be cooled in the following manner:

a. Installed tank drencher systems. These can be either manually or remotely operated.
b. Installed monitors. These are generally designed to direct the correct volume of water onto the surface of the threatened tank. These can be either manually or remotely operated.
c. FRNSW equipment such as ground monitors or aerial streams.

2. Cooling streams should be applied to the side of the tank facing the involved tank. It is critical that the stream is directed onto the surface area of the external tank wall **between the liquid level and the roof** to protect the internal tank space. This area of the tank is vulnerable for the following reasons:

a. There is no liquid against the tank wall to act as a “heat sink”, protecting the steel. As the unprotected steel is heated, it will buckle and deform until integrity is lost and tank failure occurs. The tank will lose 80% of its tensile strength at 600°C.

b. Heating of combustible liquids can result in the tank vapour space filling with vapours that are within flammable range.

c. Heating of products with low flash points can result in an increase in tank pressure, causing flammable vapour to be expelled that could ignite, resulting in tank failure.

3. The liquid level of a tank can be identified with the use of remote heat measuring equipment such as a thermal imaging camera or specialist equipment carried aboard heavy hazmat appliances (laser thermometer).

4. The internal contents of a storage tank will act as a "heat sink" and provide protection to the tank shell in contact with the liquid. Any cooling streams directed onto an external tank shell below the liquid level will be of little or no value, resulting in valuable water being wasted unnecessarily.

5. In the event the tank is exposed to direct flame impingement, the tank roof (on fixed roof tanks only) and the area of flame contact should be cooled as quickly as possible, to maintain structural integrity of the tank and prevent tank failure. Any part of a tank that is impacted by flame should be cooled as a matter of priority.

6. Storage tanks containing lighter product are more vulnerable to ignition than tanks containing heavier product.

7. When directing cooling streams onto a threatened tank, the cooling streams should be kept moving (sweeping motion) to ensure all parts of the tank being impacted by radiant heat are being cooled. Distribute the largest quantity of water over the largest exposed area.

8. In situations where multiple storage tanks are threatened, the tank under greatest threat should be protected first.

9. Water curtains are ineffective at providing protection against radiant heat. Radiant heat will simply pass straight through a water curtain and continue to the surface of the exposure. To effectively protect an exposure against radiant heat, the cooling water streams must be applied directly to the surface being impacted by the radiant heat.

10. Cooling streams should not be directed onto the roofs of floating roof tanks, because of the potential danger of sinking the roof.

11. Cooling streams should also be directed onto storage tank equipment (including product pipe lines, product line valves and flanges) that is being exposed to flame or being impacted by high levels of radiant heat. As a consequence of exposure to high heat, bolts could expand and lengthen and gaskets could fail, resulting in the uncontrolled release of additional flammable product. This equipment should also be protected because it may need to be operated to move product between storage tanks as part of the firefighting operation. Cooling of this equipment should be undertaken in a coordinated manner with the overall firefighting operation.

12. Water supply is a critical issue at storage tank fires, because of the large volumes of water required to mount a successful extinguishment operation. Protection of exposures is important, however the Incident Commander should ensure that water is only applied to tanks requiring protection. Signs that indicate a storage tank may require protection include:

a. Blistering of paint, discolouration or scorching on the side of the tank.
b. When water is applied to the side of the tank it turns to steam.
c. Buckling of the tank.
d. Tank beginning to glow.
e. Visible release of smoke or vapours from vents.

13. Top pourer foam systems should be activated on floating roof tanks directly exposed to radiant heat and flame impingement, to suppress the release of flammable vapours within the seal area.

14. Installed firefighting equipment should be cooled and protected.

15. “Remote” exposures not located within the tank farm could be subject to intense radiant heat, resulting in pyrolysis and fire development occurring. Hose lines should be used to cool the heated surfaces of these exposures to prevent them from igniting.

16. Any storage tanks within 45 metres downwind of the involved storage tank are potentially under threat and may require protection.

Cooling The Burning Storage Tank:

The following factors are considerations associated with the direct application of cooling streams to the involved tank:

1. The shell of the involved tank will begin to buckle, deform and fold due to the impact of severe heat levels (the heat produced by the burning product is well in excess of 1,000°C, however the steel that forms the tank shell will lose 80% of its tensile strength at 600°C). The tank shell will begin to fold inwards, covering areas of burning liquid, preventing foam from reaching the entire surface of the burning fuel. If the foam cover is unable to reach 100% of the surface of the burning liquid, “burn back” will occur, destroying the foam blanket.

2. A number of measures, through the use of cooling streams, can assist the effective application of foam:

a. Cooling the tank exterior shell with water streams will cool the product, reducing the vapours being released and therefore lowering the fuel vapour available to burn. This will reduce heat within the thermal column, increasing the “survivability” of foam being applied onto the surface of the burning liquid (less foam will be lost to the thermal updraft).

b. As the foam settles on the surface of the flammable liquid it will come into contact with the metal tank shell, causing the foam to break up. Cooling the tank shell will reduce this effect.

c. Cooling the tank shell above the liquid level by applying large volumes of water will help to preserve the shape of the tank, reducing the inwards folding of the upper shell of the tank.

3. Cooling streams should not be directed into the burning tank. This could cause the tank to overflow, spilling burning fuel into the bunded area.

4. Firefighters must ensure cooling streams do not accidentally enter the storage tank during foam application. This will cause the foam blanket to break up. An option open to the Incident Commander is to cease operation of cooling streams during the application of foam if there is a danger of the cooling streams accidentally entering the tank.

5. When firefighters first arrive on scene, there may installed firefighting equipment (in particular foam pourers) located along the rim along the top of the burning tank. If this equipment cannot be operated immediately, cooling streams should be directed onto the equipment to protect it against the impact of flame and severe heat until it can be used.

Foam Application:

A foam attack using firefighting equipment to project foam onto the surface of a full surface tank fire is known as an "*over the top*" attack. The following critical factors are elements of firefighting operations that should be taken into consideration when a foam attack is being planned or conducted at a storage tank fire:

1. Prior to the foam attack commencing, the Incident Commander must be satisfied the follow requirements exist at the fireground:

a. There are adequate concentrates of foam concentrate present to mount and complete a successful attack.
b. There is suitable equipment available to project the foam onto surface of the fuel and form a foam layer
c. Water supply is sufficient to meet the demands of the foam application rate.

2. If the above criteria cannot be satisfied, it is highly unlikely a foam attack will be successful. If an attempt to conduct a foam attack is made under these circumstances, firefighters will be placed in danger unnecessarily, it is highly likely such an attack will fail and valuable and limited foam stocks will be wasted. Therefore, a foam attack should not be commenced until all of the above necessary components are in place.

3. Foam is made of an aerated solution of water and a small percentage of foam concentrate. Foam is used principally to form a cohesive floating blanket on the fuel surface that extinguishes the fire by smothering and cooling the fuel.

4. The purpose of a foam blanket is to provide a non-flammable layer between the surface of the fuel and the burning vapour above. The primary purpose of the foam layer is to create a barrier between the radiant heat emitted by the combustion zone, which heats the surface of the fuel, resulting in the release of flammable vapours, the fuel source for the flames. The secondary purpose of a foam layer is to restrict air supply and cooling of the liquid surface.

5. During the application of foam, the following techniques are the most effective:

a. Foam should be projected onto the tank wall on the opposite side of the tank and allowed to flow down to surface of the burning liquid and gently flow outwards over the burning surface of the fuel.

b. Foam should be projected smoothly in an upward arc, allowing foam to “feather” onto fuel surface (known as the “snowstorm effect”).

c. Foam streams should never be projected directly into surface of the burning liquid (known as “plunging”); this will cause turbulence and agitation of the liquid, increasing fire intensity and destroying the foam.

d. Attempts made to land the foam streams on the windward side of the tank, to protect the foam from flames.

6. An effective foam firefighting technique is known as “**massing of streams**”. This technique consists of several foam streams (ground monitor or aerial) projecting with the wind to a selected landing zone within the tank. The monitors and/or aerial appliances should be positioned near each other, to enable streams to be applied simultaneously (“massed”) and land as a single “**footprint**”. Massing of streams increases survivability of foam as it travels through the fire to the surface of the burning fuel, creating a foothold on a relatively small area on the burning fuel surface that can then be expanded by making adjustments to the mass stream. This allows the foam to establish itself on the liquid surface, reducing thermal updraft and heat breakdown.

7. When conducting major foam attack operations, firefighters should not attempt to use 20 litre foam drums. The constant removal and displacement of the foam pick-up tube will result in the foam “pick-up” being continuously lost and will result in the production of poor quality ineffective foam. Firefighters should use 200 litre hazmat bins whenever available, enabling an uninterrupted foam stream to be produced.

8. Once the foam attack commences, all water streams being applied in the area of foam application must be shut down, to prevent breakup of or dilution of the foam blanket.

9. During a foam attack on a storage tank there will be at least a 75% loss of foam. Foam is lost during application for the following reasons:

a. Thermal updraft, drawing the foam into the fire plume.
b. Foam that is blown away by the wind (the thermal updraft will create its own wind).
c. Foam that is broken down as it travels through flames to reach re surface of the burning fuel.

10. As the fire continues to burn, the upper walls of the storage tank will begin to buckle, resulting in the tops of the steel wall folding inwards. The folded steel will cover pockets of fire burning on the surface of the fuel that will be difficult for firefighting foam to reach.

11. Once a foam covering blanket has been formed, the foam must be continually monitored until a sealing cohesive foam blanket is established. Foam must be continually reapplied to ensure the integrity of the foam blanket is maintained. Some of the reasons foam blankets break down include:

a. Foam is destroyed upon making contact with the hot surface of the burning fuel.
b. The foam blanket is attacked and broken up when contact is made with hot metallic surfaces of the tank.
c. The foam blanket is gradually broken up due to evaporation and drainage.

12. Once the foam attack commences, it is essential that the foam application is continuous, at the required rate and for the necessary minimum application time. Any stoppage in the application of foam prior to the completion of the foam blanket will result in a rapid breakup of the foam blanket and all of the hard work will be lost.

13. Alcohol resistant foam (ARF) must be used on alcohol-based fires. Alcohol Resistant foam concentrate forms an insoluble barrier between the fuel surface and the foam blanket, allowing the foam blanket to form. If ordinary (non ARF) foam is used on an alcohol based fire, it is required to be applied at five times the normal application rate to enable a foam blanket to form.

Installed Firefighting Equipment:

Considerations relating to installed firefighting equipment at bulk flammable liquid storage tank facilities include:

1. There is a wide range of installed firefighting systems at bulk flammable liquid storage tank facilities. These systems vary from site to site. Some of these systems are extremely comprehensive, however some sites have minimal or no fire protection systems. It is critical that firefighters are familiar with the installed firefighting equipment and its operation at storage tanks in their area.

2. There are two types of installed fire suppression systems for bulk flammable liquid storage tanks:

a. Base foam injection systems. These are fitted to *some* fixed roof tanks. Foam is injected into the base of the tank, floats to the surface and spreads out, creating a blanket on the surface of the burning flammable liquid, effecting extinguishment.

b. Foam headers/top pourers on floating roof tanks. These are fitted along the rim of floating roof tanks. In the event of a fire, foam is pumped into the foam main and travels via a series of pipes to a number of locations along the top of the tank rim, where foam pourers are located. The foam is discharged from the pourers onto the fire burning below within the rim seal of the tank. N.B., these systems are not designed to be used on full surface fires.

Both of the above systems will usually require some level of manual intervention to enable their operation. These systems involve specialised operations and equipment and should be operated under the guidance of trained site staff. Not all storage tanks are fitted with these systems.

3. Some facilities are fitted with fixed and portable monitors. These fixed monitors have been installed in accordance with hydraulic engineering calculations to ensure all parts of the surface area of the exposure tank being protected receive an adequate of water to provide protection.

4. Some facilities contain external wall wetting drenchers fitted to storage tanks. Operation of these systems are designed to protect the external tank wall from the radiant of a storage tank fire from any direction.

5. Many sites are fitted with fire mains to supply water to the installed firefighting equipment on site. There is normally a very high demand for water to supply the installed firefighting equipment and fire main can easily be over-run. Some sites are fitted supplementary water sources including water storage tanks and drafting facilities to enhance water supplies.

6. It is not uncommon for sites to be fitted with above ground firefighting ring mains. In the event of a fire, it is possible this equipment could be damaged, particularly if a major explosion has occurred and large pieces of tank steel have landed on the ring main. In these situations, firefighters may be required to operate section isolation valves within the ring main. These operations result in the damaged section of the ring main being isolated (preventing the unnecessary loss of large quantities of much needed firefighting water) and still allow firefighters to use the undamaged section for firefighting.

7. Not all storage tanks have fire protection systems.

8. Where possible, firefighters should try to protect installed firefighting equipment being impacted by direct flame impingement or severe heat with cooling streams. This equipment may be needed later to assist firefighting operations.

9. Although not strictly part of the installed firefighting systems, firefighters should try to protect any product lines and pipe valves being impacted by direct flame impingement or severe heat with cooling streams. This equipment may be required at a later stage to assist with product transfer to achieve extinguishment.

10. It is not uncommon for installed systems to be damaged, disabled or destroyed due to explosions, direct flame or severe impingement or impact from explosion debris.

11. The most effective way of knowing what installed equipment is present at a site and the requirements for its safe and effective operation are through site visits. No two sites are the same and the operation of equipment will vary from site to site.

Bunded Area

Bulk flammable liquid storage tanks are required to be enclosed within a bunded area, to enclose any spilled liquid in the event of the unintended escape or release of product from a storage tank. Features of bunded areas include:

a. The bunded area should be 133% the size of the largest tank on site. It should also allow for the 20-minute operation of any installed firefighting equipment on the site that may result in firefighting water entering the bunded area.

b. A bund is an embankment or wall of brick, stone, concrete or other impervious material, Earth walls should not be used except when there is no other alternative.

c. During firefighting operations it is important the bund is monitored to ensure there are no breaches in the bund wall and/or escape of contaminated liquid from the bund.

d. The bunded area is an extremely dangerous location and should not be entered by firefighters except for urgent and/or essential operational purposes.

NFPA Foam Application Rates

The United States National Fire Protection Association (NFPA) Standard (11) for foam application makes the following recommendations for foam application rates:

a. Fixed Systems: Foam application rate of **4.1** litres per minute per metre^2.

b. Fire service equipment (monitors and aerial appliances): Foam application rate of **6.5** litres per minute per metre^2.

c. Alcohol fires (using alcohol resistant foam): Foam application rate of **6.5** litres per minute per metre^2.

Historically, full surface storage tank fires have only been successfully extinguished with a foam application rate of **8.0** litres per minute per metre^2.

Fire Behaviour Considerations

The following aspects of fire behaviour are relevant to bulk flammable liquid storage tank fires:

1. The size of the fire is directly proportional to the surface area of the tank contents (not the volume of the tank contents).

2. As the fuel temperature increases, flammable vapour released from the surface fuel increases.

3. The fire plume produces heat that is radiated downwards towards the fuel on the surface of the burning liquid, causing evaporation and resulting in more vapour being released. The released vapour mixes with air, drawn in from around the tank, before igniting.

4. Large flames associated with a full surface fire will produce powerful vertical updrafts.

5. The heat output from a full surface fire is estimated to be in the order of 1,000 megawatts.

6. Wind has a significant on effect on the fire plume. Flame inclination is influenced by wind, causing the flame to become elongated. The angle of inclination has a direct relationship with the wind speed. As wind speed increases and the angle of flame inclination increases, there will be a large redistribution of flame temperature within the fire plume in the downwind direction. Winds can deflect the flame column almost horizontal.

N.B., this was experienced at Port Kembla when the fireground was impacted by gusty 75 km/h north easterly winds, causing flames to become almost horizontal.

7. Most hydrocarbon products will burn downwards at a rate of approximately 30 cm per hour.

8. Most petrochemical products are flammable. Petrochemical products are a specific group of hydrocarbons, derived from crude oil. Hydrocarbon is a substance that has hydrogen and carbon.

9. Liquid within a storage tank (being impacted by radiant heat) acts as a “heat sink” and will provide a storage tank with some protection.

10. Vertical tanks are designed with a roof which has a weak seam which gives way under pressure build up to allow the fire to vent upward, which is in the least harmful direction. After separation, it is possible the tank roof will travel for a short distance.

11. Complete extinguishment will occur when the fuel surface can be cooled below its flash point, which is the temperature at which the fuel will give off enough vapour to support combustion.

12. Extinguishment of alcohol-based fuels can be achieved by adding sufficient volumes of water until a mixture is reached where the flash point has been raised to a level that flammable vapours are no longer emitted (dilution). This process is extremely slow and the very large volumes of water required to extinguish a storage tank fire cannot be practically achieved; a 75% water and 25% ethanol dilution is required to achieve a mixture that will not support combustion.

Pre-Incident Plans

The importance of site familiarisation, pre-incident planning, drills and regular site visits cannot be emphasised enough at storage tank facilities. The knowledge gained through these visits is invaluable and is often a critical factor in obtaining a safe and successful incident outcome. The following elements should be considered for inclusion within pre-incident plans for storage tanks:

1. Individually prepared plans that focus on each storage tank within a facility, providing all significant information relevant to firefighting operations, including:

a. Water supply, including locations for alternate water supplies.

b. Quantity of foam concentrate required for extinguishment.

c. Any fixed fire protection systems for the tank.

d. Exposures requiring imminent protection.

Learning Notes:

Significant learning notes from this incident include the following;

N.B.1, Specific detail relating to various aspects of firefighting operations, tactics and strategies at this fire is contained within the above section "*Bulk Flammable Liquid Storage Tank Fires – Full Surface Fire Firefighting Operations*".

N.B.2, Specific detail relating to foam application rates is contained within the above section "*NFPA Foam Application Rates*."

N.B.3, Specific detail relating to fire behaviour at bulk flammable liquid storage tank fires is contained within the above section "*Fire Behaviour Considerations"*

N.B.4, Numerous elements of firefighter operational safety are contained within the report, within highlighted boxes, in close proximity to the aspects of operations to which they relate, to ensure all elements of firefighter and incident safety are highlighted to maximum effect.

1. When firefighters arrive on scene at an incident of significant magnitude, it is quite possible they will be inundated by members of the public. This has the potential to greatly affect the ability of the I.C. to effectively perform his/her role. It is important to establish a restricted area for the I.C. to operate from as soon as possible. The most effective way to do this is with assistance of Police. This will allow persons to provide information to the I.C. in a controlled manner.

2. An early priority of the I.C. was to understand the nature of the incident before committing firefighters onto the site. The initial time taken to gather critical information concerning site hazards was essential to ensuring firefighters were operating as safely as possible. The I.C. ensured:

a. The product type and quantity burning were identified,
b. Hazardous conditions associated with the burning product were identified.
c. Special safety precautions required when operating near the burning product were identified.

3. Life risk was the first priority of firefighters. Commencing at the storage tank site, firefighters ensured that all persons at the site were accounted for. Firefighters then evacuated all persons from exposures in proximity to the tank farm complex.

4. Initial scene size-up was invaluable, identifying:

a. The storage tanks most at risk,
b. The storage tanks that did not require protection.
c. Locations that were suitable for the commencement of exposure protection.
d. Additional exposures requiring protection.

5. The first firefighting actions were to cool the exposure tanks most at risk with the largest streams possible with the resources that were available. These were Tanks 14 and 6. Tank 14 contained 13,638,000 litres of marine fuel oil. This tank was glowing red hot and beginning to buckle. Tank failure was imminent without intervention. If failure of Tank 14 had occurred, the entire tank farm would have been destroyed and the impact of the emergency would have been on an enormous scale.

6. As additional firefighting resources arrived on scene, the tank defences were strengthened. This was particularly critical at 1607 hours, when a severe weather change impacted the fireground, including winds gusting to 75 km/h, again placing Tank 14 in severe danger. At that time, firefighting defences of the highly vulnerable Tank 14 had been increased to include multiple ground monitor and aerial master streams, enabling the tank to survive this severe attack.

7. The use of ground monitors and remotely operated aerial master streams minimised firefighters to the enormous levels of radiant heat being generated by the fire.

8. From an early point in operations it was apparent that a large number of resources would be required to fight the fire. The I.C. established an appliance staging area, to avoid crowding and congestion of the fireground and enabling essential appliances to be tasked to the fireground when required in an orderly manner.

9. The fire was producing enormous levels of radiant heat. The levels of radiant heat were so high that plastic components of motor vehicles parked more than 60 metres from the burning storage tank were melting and timber structures were igniting. Firefighters were working inside this radiant heat zone. Some of the measures to protect firefighters from exposure to these severe levels of radiant heat included:

a. Establishment of a rehabilitation area remote from the area of radiant heat impact.
b. The number of responding stations was increased to enable frequent on-scene crew rotation.
c. A large number of additional supplies of bottled water was brought to the scene to maintain firefighter re-hydration.
d. Equipment was used that could be operated either remotely or unattended (ground monitors, aerial master streams).
e. A plan was put in place to rotate crews in and out of the site every two hours (instead of four hours) to minimise exposure to heat.
f. Personnel rotation included IMT members as well as fire station crews.
g. Wearing appropriate PPC to protect against heat.

10. The provision of meals for firefighters must also be accompanied by basic hygiene facilities.

11. Prior to any foam attack commencing, it is important to ensure a sufficient quantity of foam stocks are at the fireground. The following are important concerning foam stocks:

a. The quantity of foam stocks required to achieve extinguishment is directly related to the product burning and the surface area of the storage tank (calculated once the tank diameter is known).

b. It is critical that a Foam Supply Officer be appointed to source foam stocks. This is an enormous task and frees the I.C. to undertake other work. Historically, getting foam in the quantities required is not an easy task.

c. A foam logistics plan will assist firefighters to identify where foam can be sourced quickly. A further challenge is transportation of the foam to the fireground.

d. If a foam attack commences and there are insufficient foam stocks on site to complete extinguishment, the fire will simply "burn back" through the foam and all of the applied foam will be lost.

12. Stack tip solid core jet water streams were greatly more effective projecting water across long distances, compared to diffuser nozzle hollow core streams. Stack tip solid core jet water streams did not break up as much, had a greater range, were impacted as strongly by the wind and were able to deliver larger volumes of water onto the target surface.

13. It is important to protect firefighting equipment from radiant heat, through the use of cooling streams. Although the equipment stood up extremely well to the sustained levels of intense radiant heat, it was necessary for firefighters to continually direct cooling streams onto all firefighting equipment being impacted by radiant heat.

14. When arriving at a bulk flammable liquid storage tank fire, firefighters should be prepared for installed firefighting equipment that has been damaged or destroyed due to the effects of the fire or explosion.

15. Storage tanks that are "empty" are still a major risk and need to be protected.

16. Regular briefings with other services and agencies are extremely important. Briefings need to be conducted constantly and regular updates provided.

17. Pre-Incident Plans are an important component of the firefighting response to bulk flammable liquid storage tank facilities. Firefighters need to know where the tanks are located at a particular site, what installed systems are on site and how the installed systems work.

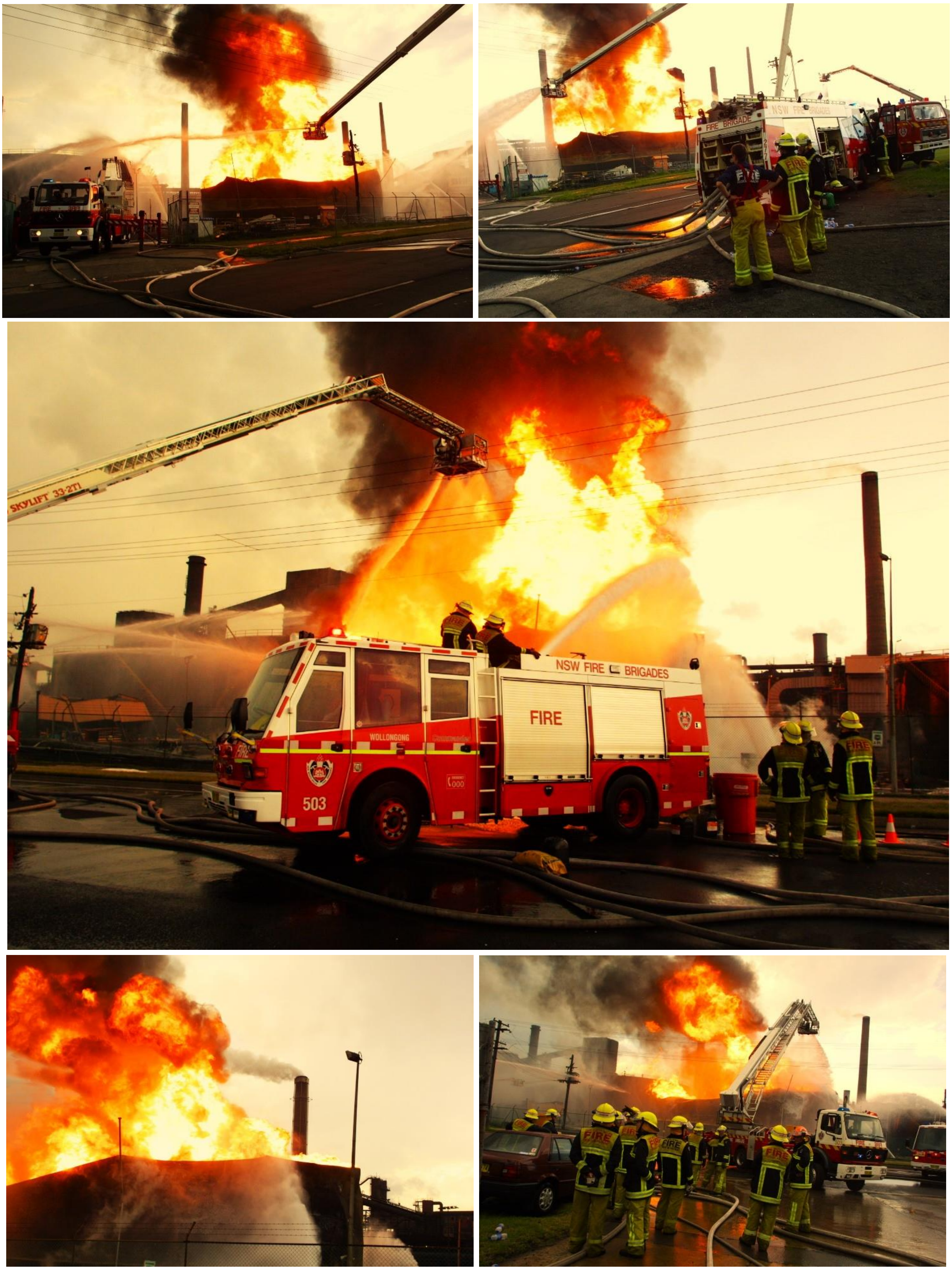
18. It is important that firefighters undertake regular drills involving the use of installed equipment at bulk flammable liquid storage tank facilities, with emphasis on understanding how installed equipment, particularly foam making and monitors operate. The NSWFB Principal Instructor who attended the incident reported the importance of firefighters maintaining proficiency in relay pumping, water supply, monitor operation and foam making.

Conclusion:

One of the greatest firefighting challenges for any fire service, anywhere in the world, is a full surface fire involving a bulk flammable liquid storage tank. The problem is infinitely worsened when the burning product is an alcohol-based fuel and is therefore enormously resistant to the application of normal firefighting foams. When the first firefighters arrived at the Port Kembla storage tank facility, the fire situation was extreme. The situation was rapidly deteriorating as numerous other high-risk exposures were being impacted by the tremendous radiant heat from the fire and were approaching ignition, including further storage tanks, petroleum distribution depots, factories and the steel works. If left unchecked, the situation would have worsened exponentially, with likely catastrophic outcomes. The initial responding crews were faced with a completely overwhelming situation. In an extremely controlled and considered manner, firefighters laid the foundation for firefighting operations by identifying as much information as they could about the fire situation, ensuring their initial actions would be both safe and effective.

There is an old saying in firefighting; "*As goes the first line, so goes the fire.*"
The first lines placed in operation by initial responding firefighters at Port Kembla proved to be the difference between establishing containment of the fire and uncontained and catastrophic fire spread. As the incident progressed, the defences around the fiercely burning storage tank were strengthened, enabling the protection of multiple exposures to be increased. There was never a point when firefighters could afford to relax; Seven hours into the incident strong gale force winds impacted the fireground, driving the flames from the burning tank horizontally towards a storage tank containing 14 million litres of heavy marine bunker fuel oil located metres away. The earlier work carried out by firefighters to establish protection streams around this particular tank ensured that when conditions rapidly and unexpectedly deteriorated, the threatened tank withstood the horrendous fire impact. To ensure exposures were protected firefighters had to go into hazardous locations to place equipment essential to firefighting operations in place, under the protection of operating hose streams.

Firefighters showed enormous dedication and commitment, working in arduous and at times dangerous conditions. The incident had many challenges, hazards and difficulties. The fireground commanders displayed exemplary leadership and the strategic and tactical decision making was to the highest standards. Every firefighter who responded to the Port Kembla ethanol tank fire contributed to the overwhelmingly successful incident outcomes. The potential for catastrophe was enormous. However, the professionalism of firefighters on the day, through the application of strong determination, courage and firefighting skill ensured that the best possible incident outcomes were achieved. The very positive lessons of the successful firefighting operations at Port Kembla on the 28th and 29th of January 2004 are just as valid today as they were in 2004.



Upper: Hydraulic Platform 21 and Ladder Platform 18 direct an aerial master stream onto the side of heavily threatened Tank 14 containing 13 million litres of heavy marine bunker fuel oil. Middle. Firefighters operating the Super Pumper 503 roof monitor direct a protective stream onto Tank 8. Lower: Flames erupt from the surface of the ethanol tank fire, creating enormous levels of radiant heat.

Upper: View from NSW Police helicopter Polair-1 shortly after fire broke out. Flame height is at least 80 metres above the top of the storage tank. Pyrolysis gases can be seen coming from the roof of the surrounding tanks. Lower: Multiple master streams are in place, protecting heavily threatened Tank 14 and cooling the steel wall of the burning ethanol tank.

From Division A Ladder Platform 503 and Super Pumper 503 firefighters direct master streams onto the wall of the burning ethanol tank, to cool the tank wall and maintain the integrity of the tank. Enormous flames erupt from the surface of the burning ethanol tank.

Hydraulic Platform 21 operated by Senior Firefighters Dave Phillips and Jeff Wilson alternated the aerial stream between Tank 14 and the wall of the burning ethanol tank.

Upper: Super Pumper 503 firefighters direct the roof monitor stream between the wall of the burning ethanol tank and threatened Tank 8. Lower: Pumper 49 supplies water to Ladder Platform 503 as fierce flames erupt from the burning ethanol tank.

The burning ethanol produced ferocious fire behaviour as large flames erupt above the storage tank. Firefighters directed cooling streams onto the ethanol tank and surrounding storage tanks for hours, containing the enormous fire.

Ladder Platform 503 firefighters direct the aerial master stream onto the wall of the involved ethanol tank, protecting the integrity of the steel wall of the tank. These operations assisted to prevent tank failure.

Fire activity from the burning ethanol was ferocious. The fire plume produced heat that was radiated downwards towards the fuel on the surface of the burning liquid, causing evaporation and resulting in more vapour being released. The released vapour mixed with air, drawn in from around the tank, before igniting.

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Upper: Pumper 49 supplies water to Ladder Platform 503. Lower: Ladder Platform 503 and Super Pumper 503 direct cooling streams onto the wall of the burning ethanol tank.

From Division A Firefighters operate multiple master streams, protecting heavily threatened Tank 14 and cooling the steel wall of the burning ethanol tank.

Foam Operations in Division A - Pumpers 52 and 54 supply foam to ground monitors positioned at the front of the storage tank. Firefighters were using ATC (Alcohol Type Concentrate) foam.

Upper: 20 litre drums of foam concentrate were being stockpiled at the scene. Middle and Lower: Foam operations in Division A. Firefighters move 200 litre drums of ATC (Alcohol Type Concentrate) foam to Pumpers 52 and 54, in preparation for the planned major foam attack.

Aviation Rescue and Fire Fighting (ARFF) firefighters commence to attack the fire with the appliance monitor foam stream, delivering 7,000 litres of finished foam solution onto the fire at a rate of 3,600 litres per minute. Just as the foam attack was commencing strong winds impacted the fireground, greatly intensifying fire conditions. Note fire activity on the right side of the tank in the middle photograph. These flames were impacting Tank 14. The ARFF crews provided extremely professional support to operations.

Upper and Middle: As the incident progressed additional protection streams were placed in operation, securing exposure tanks under threat. Lower: Ladder Platform 503 and Super Pumper 503 alternate master streams Between the burning tank wall and exposure tanks.


Upper: Firefighters direct master streams onto the wall of the burning storage tank.
Middle: The initial fire attack: Ground monitor and Blue Scope Steel appliance roof monitor stream used to protect Tank 14. Lower: 200 litre drums of foam are delivered to the site (left). Firefighters load alcohol type concentrate into the ARFF fire appliance.

Upper and middle right: Appliances at the northern end of Division A pump foam to ground monitors middle left: Pumper 277 supplies water to Ladder Platform 18. Lower: Pumper 49 (left) supplies water to the ARFF appliance (right).

Upper left: 210 Station firefighters direct a protective stream onto the cage of Hydraulic Platform 21 and a pole mounted electricity transformer. Ladder Platform 503 and Super Pumper 503 direct large diameter cooling streams onto the sides of the involved tank and Tank 8.

Fireground Command Staff: Upper – (left) Safety Officer Inspector Seve Baker and Incident Controller Assistant Commissioner Murray Kear. (right) Incident Controller Assistant Commissioner Murray Kear, Commissioner Greg Mullins and Operations Officer Chief Superintendent Hans Bootsma. Middle: Incident Controller Assistant Commissioner Murray Kear and Commissioner Greg Mullins. Lower: Incident Controller Assistant Commissioner Murray Kear briefs the Emergency Services Minister and senior Police.

Command staff aboard the Incident Control Vehicle. Top right: Off-going Incident Controller Assistant Commissioner Muray Kear briefs members of the oncoming command team.

Upper, Middle and lower right: Firefighters working in Division B direct multiple ground monitor streams onto the walls of threatened Tanks 12 and 14. Lower right: Firefighters reposition the roof monitor of the BlueScope Steel industrial appliance protecting Tank 14

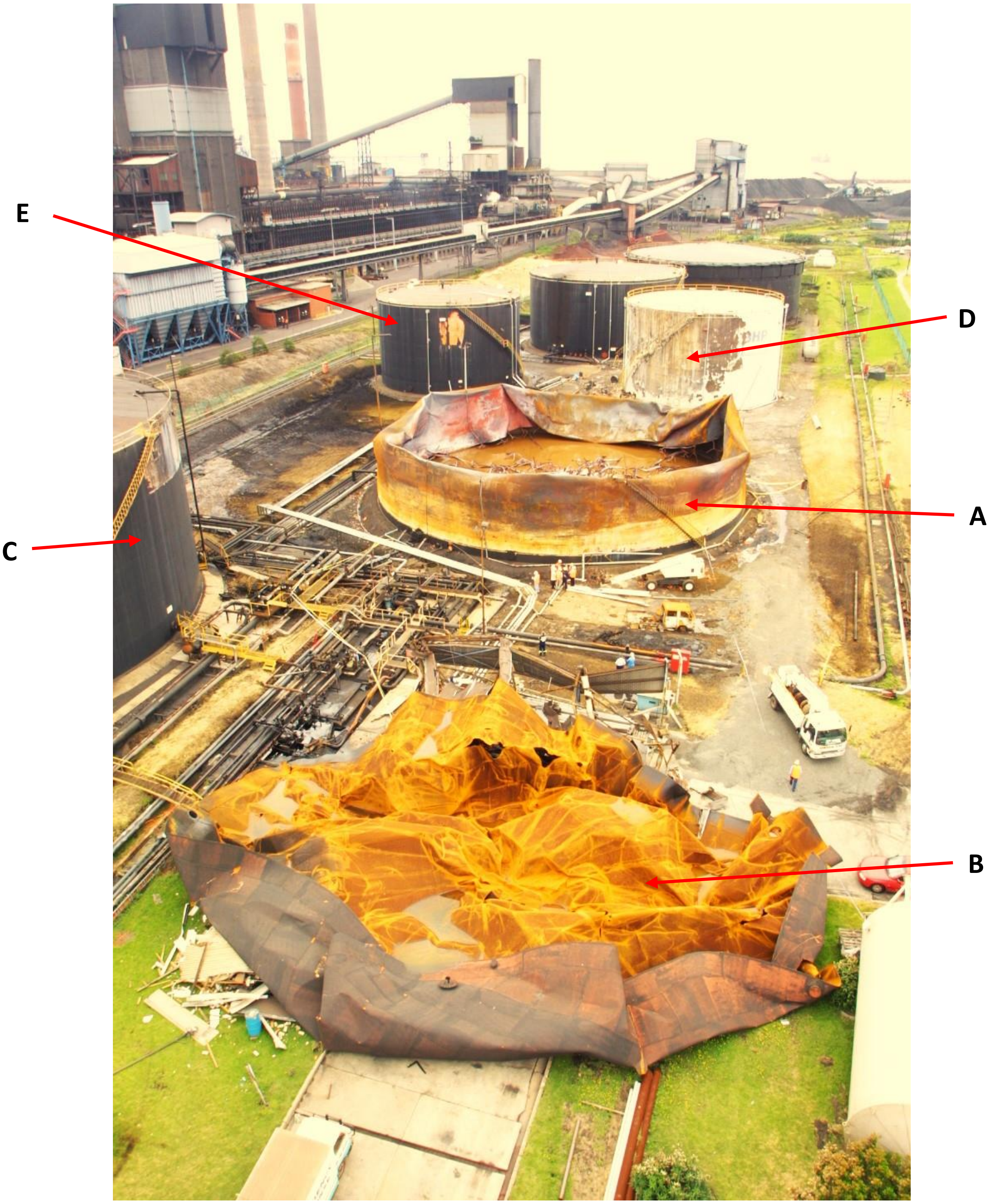
Firefighting operations go into the night. (Upper) Hydraulic Platform 21 continues to protect Tank 14. (Lower) Firefighters reposition a ground monitor at the front of the burning ethanol tank.

Evening Operations at the Port Kembla fireground. Firefighters continue to cool the walls of the exposure tanks. Hydraulic Platform 21 and Ladder Platform 18 are directing cooling streams onto Tank 14 in these views.

Top left: Changeover of fireground commanders - Superintendent Ray Kelly, Chief Superintendent Ken Bryant and Assistant Commissioner Murray Kear conduct a handover briefing as operations go into the evening. Top right: Hydraulic Platform 21 directs a cooling stream onto the wall of the burning ethanol tank. Lower: Firefighters working in Division A throughout the night were constantly moving and adjusting ground monitors, as the wind strength and direction fluctuated.

Overnight operations from Division A. Firefighters continued to cool the steel walls of the burning ethanol tank and direct master streams onto tanks under threat.

Some of the faces of the firefighters who fought the Port Kembla fire.



Post fire: **A** Ethanol tank (Tank 11), **B** Displaced lid of ethanol tank, **C** Tank 14, **D** Tank 6, **E** Tank 12.

The 120-tonne fixed steel roof was blown off the storage tank by the force of the explosion and landed on the foam fire suppression system, rendering the system inoperable.

Upper: Twin headed attack hydrants were fitted to the site 150 mm diameter ring main. Radiant heat made operation of the ring main impractical. Middle: The burning ethanol tank was located in proximity to several storage tanks that came under significant threat. Lower (left) Attack hydrants were located on the bund wall. (right) The ethanol storage tank following extinguishment.

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