APPENDIX 12 - CONCEPT SAFETY REVIEW

The Eggborough CCGT Project

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The Eggborough CCGT (Generating Station) Order

Land at and in the vicinity of the Eggborough Power Station site, near Selby, North Yorkshire, DN14 0BS

Concept Safety Review

The Planning Act 2008

The Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

Regulation 5(2)(q)

Applicant: Eggborough Power Limited
Date: November 2017

Eggborough Power Ltd

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GLOSSARY

Abbreviation	Description
AECOM	AECOM Infrastructure & Environment UK Limited
AGI	Above Ground Installation
BAT	Best Available Techniques
CCGT	Combined Cycle Gas Turbine
CCGT	combined cycle gas turbine
CCR	Carbon Capture Readiness
CFD	Computational Fluid Dynamics
COMAH	Control of Major Accident Hazards
DSEAR	Dangerous Substances and Explosive Atmospheres Regulations
eMARS	Major Accident Reporting System
EP	Environmental Permit
ES	Environmental Statement
HAC	Hazardous Area Classification
HAZID	Hazard Identification
HAZOP	Hazard and Operability
HSC	Hazardous Substances Consent
HSE	Health and Safety Executive
HV	high voltage
IChemE	Institute of Chemical Engineers
JIP	Joint Industry Project
kV	kilovolt
m	metres
MAH	major accident hazard
MAPP	Major Accident Prevention Policy
MATTE	Major Accident To The Environment
NFPA	National Fire Potation Association
NG	National Grid
NOx	nitrogen
NTS	National Transmission System
NYCC	North Yorkshire County Council
Order limits	The Proposed Development Site
PHR	Process Hazard Review
RR	Research Report

Abbreviation	Description
SCR	Selective Catalytic Reduction
SCR	Selective Catalytic Reduction
SDC	Selby District Council
SIL	safety integrity level
Site	Proposed Development Site
SMS	Safety Management System
SoS	Secretary of State
SRV	shut-off valve/pressure-regulating valve

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LIMITATIONS

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1.0 EXECUTIVE SUMMARY

The purpose of this study is to identify the potential major accident hazards associated with a new 2.5 GW gas-fired Combined Cycle Gas Turbine (CCGT) power station proposed to be installed on the site of the existing coal fired power station at Eggborough, near Goole in East Yorkshire. It also responds to the relevant representation submitted by the Health and Safety Executive (HSE), in which the HSE recommended that EPL consider the potential hazards from the Proposed Development.

There are many gas-fired power stations in operation around the UK and the world, and these have been safely operated for many years and many thousands of running hours without major incident. The design and operation of high efficiency gas-fired power stations and fuel pipelines such as that proposed by the Applicant is standard engineering practice that is closely regulated and carefully operated to avoid major incidents occurring. By adopting these standard practices during design, construction, commissioning and operation, the risk of accidents and incidents occurring is expected to be negligible.

As outlined in the National Policy Statement for Energy EN-1, the CCGT power station site may be regulated under the Control of Major Accident Hazards (COMAH) legislation as a Lower Tier site or require Hazardous Substances Consent (HSC) dependent on the quantities of specified dangerous substances which will be stored and used at the site. The specific quantities of these materials have not yet been fully determined and will be confirmed as the project design develops.

If it becomes a Lower Tier COMAH Site, a Major Accident Prevention Policy (MAPP) document must be prepared, the first stage of which is identification of potential major accidents. Part 1 of the COMAH 2015 Regulations defines a major accident as:

"…an occurrence such as a major emission, fire, or explosion resulting from uncontrolled developments in the course of the operation of any establishment to which these Regulations apply, and leading to serious danger to human health or the environment (whether immediate or delayed) inside or outside the establishment, and involving one or more dangerous substances".

This study has been undertaken as a desktop assessment using the current design documentation by an experienced safety professional (CV included in Appendix A). A review of accident databases has been undertaken to identify lessons learned which can be incorporated into the ongoing design of the facility. Applicable industry guidance published by the Institute of Chemical Engineers (IChemE) has also been reviewed.

The conclusions of this Concept Safety Review are that there are a number of potential major accident hazard (MAH) scenarios associated with the following materials and systems at the power station:

- Releases of natural gas and fuel oil;
- Failure of high voltage (HV) electrical equipment; and
- Reactions of hazardous chemicals used in water treatment.

Each of these is considered in turn within this report. Implementing inherent safety factors to the design such as substitution of hazardous materials for alternative, less harmful materials cannot be applied to the natural gas feed to the CCGT or the chemicals to be used; consequently, the site will incorporate safety systems proportionate to the level of risk. For example, higher risk equipment such as the gas turbine enclosures will be fitted with fixed fire suppression systems. Gas pipework will be welded where practicable and include isolation valves to segregate inventory.

There are MAH scenarios associated with the operation of electrical generators, transformers and in the electrical equipment rooms which contain equipment such as switchgear. Fixed fire suppression systems will be installed in these areas.

If a Selective Catalytic Reduction (SCR) system is required for abatement of NOx emissions and aqueous ammonia solution is stored on site, there is the potential for a Major Accident To The Environment (MATTE) through the loss of containment of the ammonia solution. However, from a safety perspective, it is preferable to use aqueous ammonia rather than anhydrous (gaseous) ammonia to reduce safety risks. If the eventual CCGT design does not require the installation of an SCR system, then the use of aqueous ammonia on site could be largely removed. A small quantity would remain which is used within water treatment systems.

Diesel, lubrication oils and transformer oils which will be used on site also have the potential to cause harm to the environment if their primary containment systems (storage tanks) are compromised. Secondary (bunding) and tertiary (site drains) containment will be installed to prevent this material from entering the environment. Tertiary containment systems shall be fitted with isolation valves such as penstocks to prevent the offsite release of material. All drains from areas subject to oil contamination will have EN 858 class 1 oil separator fitted. In addition, a class 1 oil separator is provided on the surface water discharge to Hansall dyke. As stated, the final discharge will be controlled via valves.

This Concept Safety Review has been undertaken at an early stage in the project, with the engineering design and plant layout at a preliminary stage. A number of recommendations have been made for consideration by the design team with a number of further studies and safety risk assessments to be undertaken at the appropriate time as the project progresses, including Hazard Identification (HAZID) and Hazard and Operability (HAZOP) studies.

2.0 INTRODUCTION

2.1 Proposed Development

The main components of the Proposed Development are summarised below:

- The 'Proposed Power Plant' (Work No. 1) - an electricity generating station with a gross output capacity of up to 2,500 MW located on the main coal stockyard area of the existing coal-fired power station, comprising:
  - Work No. 1A - a combined cycle gas turbine ('CCGT') plant, comprising up to three CCGT units, including turbine hall and heat recovery steam generator buildings, emissions stacks and administration/control buildings;
  - Work No. 1B - a peaking plant and black start plant fuelled by natural gas with a combined gross output capacity of up to 299 MW, comprising a peaking plant consisting of up to two open cycle gas turbine units or up to ten reciprocating engines and a black start plant consisting of one open cycle gas turbine unit or up to three reciprocating gas engines, including turbine buildings, diesel generators and storage tanks for black start start-up prior to gas-firing and emissions stacks;
  - Work No. 1C - combined cycle gas turbine plant cooling infrastructure, comprising up to three banks of cooling towers, cooling water pump house buildings and cooling water dosing plant buildings; and
  - Ancillary buildings, enclosures, plant, equipment and infrastructure connections and works.
- The 'Proposed Electricity Connection' (Work No. 3) - electrical connection works, comprising:
  - Work No. 3A - up to 400 kilovolt ('kV') underground electrical cables to and from the existing National Grid ('NG') 400 kV substation;
  - Work No. 3B - works within the NG substation, including underground and over electrical cables, connection to busbars and upgraded or replacement equipment.
- The 'Proposed Cooling Water Connections' (Work No. 4) - cooling water connection works, comprising works to the existing cooling water supply and discharge pipelines and intake and outfall structures within the River Aire, including, as necessary, upgraded or replacement pipelines, buildings, enclosures and structures, and underground electrical supply cables, transformers and control systems cables.
- The 'Proposed Ground and Towns Water Connections' (Work No. 5) - ground and towns water supply connection works, comprising works to the existing groundwater boreholes and pipelines, existing towns water pipelines, replacement and new pipelines, plant, buildings, enclosures and structures, and underground electrical supply cables, transformers and control systems cables.
- The 'Proposed Access and Rail Works' (Work No. 10) - rail infrastructure and access works, comprising alterations to or replacement of the existing private rail line serving the existing coal-fired power station site, including new rail lines, installation of replacement crossover points and ancillary equipment and vehicular and pedestrian access and facilities.
- The 'Proposed Surface Water Discharge Connection' (Work No. 9) - surface water drainage connection works to Hensall Dyke to the south-east of the main coal stockyard, comprising works to install or upgrade drainage pipes and works to Hensall Dyke.

- The 'Proposed Gas Connection' (Work No. 6) - gas supply pipeline connection works for the transport of natural gas to Work No. 1, comprising an underground high pressure steel pipeline of up to 1,000 millimetres (nominal bore) in diameter and approximately 4.6 kilometres in length, including cathodic protection posts, marker posts and underground electrical supply cables, transformers and control systems cables, running from Work No. 1 under the River Aire to a connection point with the National Transmission System ('NTS') for gas No. 29 Feeder pipeline west of Burn Village.
- The 'Proposed AGI' (Work No. 7) - an Above Ground Installation ('AGI') west of Burn Village, connecting the gas supply pipeline (Work No. 6) to the NTS No. 29 Feeder pipeline, comprising:
  - Work No. 7A - a compound for National Grid's apparatus; and
  - Work No. 7B - a compound for EPL's apparatus.
- The 'Proposed Construction Laydown Area' (Work No. 2A) - an area for temporary construction and laydown during the construction phase, including contractor compounds and facilities.
- The 'Proposed Carbon Capture Readiness ('CCR') Land' (Work No. 2B) - an area of land to be reserved for carbon capture plant should such technology become viable in the future. It is proposed that this 'reserve' land is provided on part of the area to be used for temporary construction and laydown.
- The 'Proposed Retained Landscaping' (Work No. 8) - encompassing the existing mature tree and shrub planting along the northern side of Wand Lane and to the eastern boundary of the existing coal-fired power station site, including that on the embankment around the eastern, southern and western boundaries of the main coal stockyard.

The 'associated development', for the purposes of section 115 of the PA 2008 comprises Work Nos. 2 to 10 of the Proposed Development.

It is anticipated that subject to the DCO having been made by the Secretary of State (SoS) and a final investment decision by EPL, construction work on the Proposed Development would commence in early 2019. The overall construction programme is expected to last approximately three years, although the duration of the electrical and water connection and gas supply pipeline connection works would be significantly less. The construction phase is therefore anticipated to be completed in 2022 with the Proposed Development entering commercial operation later that year.

A more detailed description of the Proposed Development is provided at Schedule 1 'Authorised Development' of the draft DCO and Chapter 4 'The Proposed Development' of the ES Volume I (Application Document Ref. 6.2) and the areas within which each of the main components of the Proposed Development are to be built is shown by the coloured and hatched areas on the Works Plans (Application Document Ref. 4.4).

The Plant incorporates a number of chemical dosing systems. These include systems for boiler water conditioning, cooling and waste water treatment. Chemicals used will include biocides, amines, corrosion and scale inhibitors.

Exhaust gases from the power plant may need to be treated using a Selective Catalytic Reduction (SCR) system to reduce emissions of oxides of nitrogen (NOx), typically using a 35% solution of aqueous ammonia. Whether this is required or not will be determined by a Best Available Techniques (BAT) justification. The need for the installation of SCR emissions treatment system, and hence the need for aqueous ammonia to be present on site is currently under review as part of the site's Environmental

Permit (EP) application. Emissions to air from the CCGT units will be released via a 90m stack, with one stack installed per unit.

The plant will be fully automated, with around 50 people working full time when operational. There may however be a large number of temporary workers involved with the decommissioning and demolition of the existing power station, increasing the numbers of people nearby significantly for the period of demolition works, and depending on the timing of the two projects.

2.2 Site Location

The Proposed Development Site (the 'Site' or the 'Order limits') is located at and in the vicinity of the existing coal-fired power station approximately 8 kilometres south of Selby.

The existing coal-fired power station is bound to the north by Wand Lane, with the River Aire located approximately 650 metres ('m') further to the north and the A19 Selby Road immediately to the west. Eggborough Village is located approximately 750 m to the south-west.

The entire Site lies within the administrative boundaries of Selby District Council ('SDC') and North Yorkshire County Council ('NYCC').

The existing coal-fired power station was officially opened in 1970 and comprises four coal-fired boilers units, which together are capable of generating up to 2,000 MW of electricity. The existing coal-fired power station also includes a turbine hall and boiler house, an emissions stack (chimney) of approximately 198 m in height, eight concrete cooling towers of approximately 115 m in height, an administration and control block, a coal stockyard and a dedicated rail line for the delivery of coal, in addition to ancillary buildings, structures and infrastructure and utility connections.

The Site itself extends to approximately 102 hectares and comprises land within the operational area of the existing coal-fired power station for the new gas-fired generating station and electrical and groundwater supply connections; corridors of land to the north of the existing coal-fired power station for the cooling water connections and gas supply pipeline; an area of land to the south-east of the main coal stockyard for surface water discharge connections; and corridors of land to the west and south of the operational area of the existing coal-fired power station for ground and towns water supply connections and access.

The land required for the generating station and electrical and groundwater connections is owned by EPL, as well as the majority of the land for the cooling and towns water and surface water discharge connections. The majority of the land required for the gas supply pipeline is not owned by EPL.

The area surrounding the Site is predominantly flat and for the most part comprises agricultural land interspersed with small settlements and farmsteads. The area is however crossed by transport infrastructure, notably the A19 and railway lines, including the East Coast Mainline, in addition to overhead electricity lines associated with the existing coal-fired power station and other power stations within the wider area.

There is one lower tier COMAH site located 400m to the north of the proposed development which is operated by Air Liquide who manufacture industrial and medical gases.

The site is located on a Principal Aquifer having high groundwater vulnerability and is within a Groundwater Source Protection Zone. Consequently, the containment systems on site including bunds and drains must be appropriately designed to prevent releases reaching and causing harm to the environment.

Surface water falling onto the site is intended to be discharged to a local water course, Hensall Dyke, which is on the south eastern boundary of the site. The River Aire is located approximately 650m north of the site, from which water is abstracted for cooling water purposes.

A more detailed description of the Site is provided at Chapter 3 'Description of the Site' of the Environmental Statement ('ES') Volume I (Application Document Ref. 6.2). Each part of the site is shown on Figure 1.

2.3 HSE Relevant Representation

The HSE submitted a Relevant Representation to the Planning Inspectorate for the DCO examination which states:

HSE has made the suggestion earlier in the consultation process that it would be beneficial if the submission for the Eggborough CCGT Project included information on the extent and severity of hazards from the proposed generating station, with the potential to impact on local populations, and/or the adjacent major hazard installation. The loss of fuel gas containment may give rise to vapour cloud explosion or flash fire hazards. These may in turn escalate to impact adjacent plant. This would allow the applicant to take public safety implications of the project into account by carrying out a high level risk assessment.

On 15/2/17 we provided our advice in a letter emailed to Dalton Warner Davis (on behalf of the Applicant) when consulted under Section 42 of The Planning Act 2008. In reply to their subsequent request for future involvement in a Statement of Common Ground, we advised on 24/2/17 that HSE was not able to engage further on this matter. It is for the applicant themselves to be satisfied (using external expertise if necessary) that their design and operation will meet the requirements of relevant health and safety legislation as the project progresses. It is not HSE's role to 'approve' risk or hazard assessments in these particular circumstances. We only do this in limited circumstances covered by specific regulations in sectors such as; explosives, off-shore oil and gas and on shore chemicals where threshold levels of dangerous substances are exceeded.

HSE's response was a reminder to ensure that any safety implications of the proposed project were not overlooked at this early stage.

This review therefore is intended to address the comments made by the HSE through their relevant representation.

3.0 METHODOLOGY

The objective of this study is to assess the concept design for the Proposed Power Plant to identify potential MAH. Following identification, the principles of inherent safety and hierarchy of risk controls can be considered to mitigate hazards. This study is undertaken at an early stage in the design, such that changes can be implemented with the minimum of impact to the project, and taking into account the relevant representation submitted by the Health and Safety Executive to the Planning Inspectorate.

The concept safety review process used is as follows:

1. Review process operations to be undertaken at the site.
2. Identify dangerous substances which could be present on site, taking into consideration the conditions in which they are stored and/or used such as pressure and temperature.
3. Identify the combinations of process and substance with the potential for a major accident hazard which could result in significant harm to people, both onsite and offsite, or the environment.
4. Review previous incidents which have occurred on similar facilities and on sites using similar materials.
5. Review relevant information published by the Health and Safety Executive.
6. Review the proposed mitigation systems and identify any required changes and/or recommendations for consideration to reduce risk.
7. Describe the next steps in the design risk assessment process for the project.

4.0 MATERIALS AND PROCESS OPERATIONS

4.1 Site Layout and Overview of Process Operations

The conceptual site layout is presented in Figure 2, which is based on a single shaft layout. Should a multi-shaft layout be selected, this would not alter the conclusions of this safety review.

In the summary process description below, the numbers shown in brackets correspond to the areas identified in Figure 2.

Gas is received on site (9) via a new pipeline connection from the NTS at the north-eastern boundary of the site. The reception facilities on site include dehydration, filtration and pigging facilities for pipeline management.

Gas is treated (30) and enters the Turbine Hall (1) via distribution pipework. The peaking plant (24) would also be connected to the gas supply.

The black-start diesel generator (26) will contain an inventory of diesel fuel within dedicated bunded tanks. Diesel will also be stored in the emergency generator day tanks (17) and fire pumps (12). A total of approximately 10 tonnes of diesel will be stored on site.

The hot exhaust gases exiting the gas turbine are converted into steam in the Heat Recovery Steam Generator (HRSG) (2) which drives steam turbines located in the Turbine Hall (1). Hydrogen and carbon dioxide is used within the generators, of which each has a dedicated electrical transformer (6) with electricity exported to the grid via a substation (16).

Raw water from boreholes is stored in a tank (13). Part of the tank contents is reserved exclusively for firefighting applications. Raw water is treated in the water treatment plant (12) to produce demineralised water for use in the steam circuit. The demineralised water is stored in a dedicated tank (14).

Water abstracted from the River Aire is also used for cooling (7) and is treated (29) with a number of conditioning chemicals.

The process is monitored from a Control Room (11) within an Administration Building and there is a dedicated maintenance workshop (10) onsite containing welding facilities including a small number of acetylene gas cylinders.

Any MAH has the potential to affect off site receptors including residential properties and the nearby Air Liquide Lower Tier COMAH installation, with the closest receptors over 400 m from the generating station and locations of bulk hazardous substance storage. Losses of hazardous substances to controlled waters or groundwater has the potential to create a MATTE. This is considered further below.

4.2 Assessment of Materials and Substances

The main feed material, natural gas, is not stored on site other than that contained within pipework and power generation equipment. The site will however use a number of substances which have the potential to initiate a MAH. The preliminary inventory of hazardous substances is shown in the following table and their properties are described in this section. Their corresponding main hazard category, flammable and/or combustible, toxic or harmful to the environment is subsequently described.

Table 1 - Hazardous Substance Inventory

Material	Estimate Inventory	Units
Diesel/Distillate Fuel Oil	200	Tonnes
Hydrogen	0.22	Tonnes
Carbon Dioxide	23	Tonnes
Aqueous Ammonia (if required)	74	Tonnes
Trisodium Phosphate	3.5	Tonnes
Carbohydrazide Solution	4	Tonnes
Sodium Hypochlorite	45	Tonnes
Hydrochloric Acid	45	Tonnes
Sulphuric Acid	45	Tonnes
Sodium Hydroxide	45	Tonnes
Lubrication Oils	150	Tonnes
Transformer Oils	300	Tonnes
Acetylene Gas	2	bottles
Nitrogen	12	bottles

Source: Hazardous Substance Consent Application

4.3 Flammable and Combustible Materials

The primary feed material on site is natural gas. A release of natural gas can result in a jet fire if immediately ignited or if ignition is delayed, there is the potential for a flash fire or vapour cloud explosion depending on the degree of confinement. Both of these scenarios would constitute a MAH with the potential to impact the environment or local populations.

A maximum total inventory of up to 200 tonnes of diesel is stored in several bunded tanks and delivered to site via road tanker for use in the Black Start Generator, Emergency Generators and Fire Pumps. Diesel is categorised as flammable, with a flash point of 55ºC. A loss of containment of diesel can result in a pool fire if ignited. A pressurised release of diesel can form an explosive mist under certain conditions and is a combustible liquid, and therefore diesel could initiate or escalate a MAH.

Gaseous hydrogen is used as a coolant within the electrical generation system in the turbine hall. An estimated quantity of 0.22 tonnes is supplied via compressed gas cylinders. The flammable and explosive range of hydrogen gas is very broad therefore there is the potential for a fire and/or explosion in the event of a loss of containment. Hydrogen gas has a ery low ignition energy, therefore uncontrolled releases always have the potential to initiate a fire and/or explosion. Hydrogen can also build up in oils used to seal the generator, and the oil/hydrogen mixture then becomes potentially explosive. Consequently, there are scenarios involving hydrogen which could constitute a MAH.

A small quantity of acetylene may be used on site for maintenance work during the operational phase of the site however this will be very infrequent.

4.4 Toxic Materials

A significant quantity of transformer oil is contained on site, estimated to be around 300 tonnes. This material is a light, paraffinic hydrocarbon and is not combustible at ambient temperature, but is toxic if inhaled. At temperatures above around 150ºC, this material becomes combustible and can generate toxic substances in the event of a fire. Transformer fires and explosions have rarely occurred at power stations, including an incident at Wilton on Teesside in 2003 when 3 fatalities occurred during maintenance on a transformer[1]. Consequently, there are potential MAH scenarios associated with transformers and the oil they contain.

Sulphur hexafluoride (SF6) by-products are produced if electrical arcing takes place inside SF6 filled compartments. The by products are highly toxic and strict handling procedures are required.

Carbon dioxide is stored under pressure within the generators and can cause asphyxiation in the event of a loss of containment which is not dispersed. A total of 23 tonnes is estimated to be present on site, some within the electrical generator systems for purging and the bulk is contained within the gas turbine enclosure for fire suppression. A typical scenario which could result in a loss of containment of carbon dioxide would be the failure of a pressure regulator valve; however it is unlikely that this would scenario would constitute a MAH.

Nitrogen will be used for purging gas systems which is supplied from compressed gas cylinders in bottle racks. A loss of containment of nitrogen into an area which is not well ventilated can cause asphyxiation. A typical quantity of nitrogen stored on site is around 12 bottles; therefore this material is unlikely to constitute a MAH.

Nitrogen and carbon dioxide are asphyxiants, therefore good natural ventilation will always be provided where compressed gas cylinders are stored and used.

Sodium hypochlorite will be used on site in water treatment systems. If used incorrectly, and mixed with acids, this material can liberate toxic chlorine gas and therefore has the potential for a MAH. A detailed risk assessment on the storage of chemicals is to be undertaken during the detailed design stage. It is envisaged that this will specify that the hypochlorite and any acids are stored within separate bunds to prevent accidental contact and the use of incompatible tanker couplings to prevent accidental loading of the wrong tanks.

High pressure steam contains stored energy which can present a significant MAH onsite in the event of a loss of containment. This equipment and pipework will be designed and constructed in accordance with the appropriate design codes for pressure systems and with inspection and maintenance schedules produced to comply with the Pressure Systems Safety Regulations.

In addition to the substances identified above there may be further materials used and stored on site, which are categorised as corrosive, irritant and harmful, but the quantity is not considered sufficient for a loss of containment to result in a MAH. These materials include hydrochloric and sulphuric acids, sodium hydroxide and trisodium phosphate which are used in water treatment and conditioning systems.

4.5 Harmful to the Environment

If required, aqueous ammonia solution for exhaust gas treatment in the SCR would be delivered via a road tanker and stored in dedicated bunded tanks. The concentration of ammonia solution is expected to be 35%, which is categorised as acutely toxic to the aquatic environment and an inventory of 70 tonnes is estimated. In the event of a loss of containment where the material reaches an environmental receptor such as controlled waters or groundwater, this has the potential to create a MATTE. A smaller quantity of

[1] http://www.telegraph.co.uk/news/uknews/1422474/Ball-of-fire-killed-three-at-power-station.html

around 4 tonnes of 35% aqueous ammonia will be used in the boiler feed water treatment systems, which also has the potential for a MATTE.

Sodium hypochlorite (10-15% solution), stored in dedicated bunded tanks, is used as biocide in a cooling water system, and is also categorised as very toxic to aquatic life. An estimated quantity of 45 tonnes could be stored on site which has the potential to create a MATTE in the event of a failure of containment systems.

Lubricating oils are used in significant quantities at the site within rotating equipment such as the generators, compressors and pumps; with an estimated total inventory of circa 150 tonnes. The majority (circa 120 tonnes) will be located in the 3 gas turbine/steam turbine/generator lubrication systems. The remaining quantity however is widely distributed across the site in numerous locations, with several 200 litre drums contained within a storage area for maintenance top-ups. Lubricating oils are categorised as toxic and harmful to human health and are an acute and chronic aquatic toxin. This substance has the potential to create a MAH or MATTE.

Diesel fuel oil is harmful to the environment however again; the limited quantities on site are unlikely to result in a potential MATTE.

SF6 is used in switchgear as an insulation gas and interrupting medium in interrupters. A loss of containment of SF6 may cause equipment to fail. SF6 is a greenhouse with a global warming potential that is approximately 22,800[2] times that of CO2 and can also cause asphyxiation in the event of a leak. SF6 is heavier than air, so will sink to the lowest point; cable basement and cellars for example.

4.6 Major Accident Hazards by Material

A summary of the potential MAH scenarios by material, as identified in Section 3, are listed in the following Table.

Table 2. Summary of MAH Scenarios

Ref.	Material	Potential MAH
1	Natural Gas	Flash fire
2	Natural Gas	Vapour cloud explosion
3	Natural Gas	Jet fire (pressurised release)
4	Hydrogen	Fire and/or Explosion
5	Transformer Oil	Fire and/or Explosion
6	Aqueous Ammonia 35%	MATTE
7	Sodium Hypochlorite	Toxic release and MATTE
8	Lubrication oil	Fire

[2] https://climatechangeconnection.org/emissions/co2-equivalents/

5.0 LESSONS LEARNED AND BEST PRACTICE

5.1 Background

There have been a relatively small number of serious accidents which have occurred in power plants. In 2010, a Connecticut power plant explosion in the United States killed 6 people and injured 50, following a loss of containment of gas which was being used to clear pipework.

In the UK, three workers died at the Enron power plant on Teesside following an explosion in a transformer which occurred during routine maintenance[3].

There is a considerable volume of information available from accidents and incidents which have occurred in the power generation industry over the years. The learning from these events is recorded in databases and publications, a review of which has been undertaken as part of this study.

Major accidents in the UK from COMAH Regulated sites and across European Seveso sites are recorded in the electronic Major Accident Reporting System (eMARS) database. Results from a search of this database are contained in Section 5.2.

There has been a lot of work commissioned by the HSE on safety considerations in the use of gas turbines for power generation. A summary of this work is contained in Section 5.3.

Papers published by the IChemE as part of the annual Hazards symposia were also reviewed to identify lessons learned and best practise to prevent and mitigate major accident hazards. Key points from the Hazards papers reviewed are contained in Section 5.4.

The results of these reviews are contained in Section 5.5, including the learning points identified for consideration by the design and operations teams for the Eggborough CCGT.

5.2 eMARS Accident Database

The eMARS[4] was established in 1982 following implementation of the Seveso II Directive (96/82/EC). The purpose of eMARS is to facilitate exchange of lessons learned from accidents and near misses involving dangerous substances, in order to prevent accidents and mitigate their potential consequences.

This database contains around 900 accident reports and permits searchable by industry sector. A search of all recorded items for 'Power Supply and Distribution' generated 17 results. The most pertinent incidents to the Eggborough CCGT were as follows:

- Explosion within a recovery boiler of a generating station following start up. Malfunction of a gas turbine's shut-off valve/pressure-regulating valve (SRV) led to an accumulation of gas in the boiler during start-up, which exploded when the gas turbine was started. Significant damage costing over €2 million occurred. Following the incident, site procedures were reportedly amended to checks the actual position of regulating valves and carry out pressure checks during start-up. This was the only incident which specifically referenced 'CCGT' in the accident report.

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[3] http://www.gazettelive.co.uk/news/local-news/enron-the-tragic-facts-3850248
[4] https://minerva.jrc.ec.europa.eu/en/emars/content/

- Significant environmental harm was caused following the incorrect filling of a storage tank with an incompatible material followed by inadequate remedial actions. Tank filling procedures were amended following this incident.
- Leak at a natural gas storage facility from a 'dead leg' (closed) section of pipework located underground, which was subsequently ignited by electrical equipment. The learning from this accident was to remove dead legs, increase gas-tightness of electrical appliance rooms and install an increased number of gas detectors.
- Maintenance activities on a power generation process which resulted in a release of gas which ignited. The resulting fire caused significant damage to the plant. Modifications were made to install a safety valve for purging and additional training was provided to operations staff.

There were a number of major accidents listed in the eMARS 'Power Generation' search results which were associated with failures in gas storage systems and liquefied gas systems. These were not considered pertinent to the Eggborough CCGT facility.

5.3 HSE Guidance

The risk and hazardous consequences associated with the power generation gas turbines are high, with the basis of safety for these systems being based on the provision of dilution ventilation. Consequently, the HSE has been engaged for a number of years in the provision of guidance on their safe use for power generation both onshore and offshore, publishing a number of documents for reference by manufacturers and operators. These include:

- HSE guidance note PM84, "Control of safety risks for gas turbines used for power generation", provides advice on means of identifying and controlling hazards due to a gas leak.
- Summary report CM/04/09[5] describes the results of a Joint Industry Project (JIP) to assess safety questions raised on the use of gas turbines for power generation. This project commissioned a programme of Computational Fluid Dynamics (CFD) to assess dilution ventilation.
- Guidance on integrity and inspection of gas turbines is also provided by the HSE in Research Report (RR) 430, 'Offshore gas turbines (and major driven equipment) integrity and inspection guidance notes'.

5.4 IChemE Symposium Series

The IChemE annual Hazards conference series publish presentations on all aspects of process safety and risk management. From a search of their Symposium Series archive, the following two presentations were considered pertinent:

1. Hazards XIII Ref. 141 1997: Explosion hazards at CHP and CCGT plants, R C Santon, Health and Safety Executive[6].

This presentation concluded that following HSE investigations, the potential for fuel leaks in CHP and CCGT is considered to be high due to the complexity of pipework configurations and number of flanges and flexible connections. The ventilation systems associated with this equipment should be designed to

[5] http://www.hse.gov.uk/research/hsl_pdf/2004/cm04-09.pdf

[6] http://www.icheme.org/communities/special-interest-groups/safety%20and%20loss%20prevention/resources/hazards%20archive/hazards%20xiii.aspx

consider a release of fuel and dilute concentrations to reduce the risk of an explosion hazard. If dilution ventilation is not practicable, explosion relief panels should be fitted.

The risk of a fuel release and explosion should also be reduced by

- Avoiding the use of liquid fuels;
- Minimise pipework joints and use welded pipework;
- Fit manual valves at the fuel entry point to each combustion chamber;
- Consider a double containment fuel supply system;
- Fit safety shut off valves with proof of closure switches.

2. Hazards XXII Ref. 156 2011: Reducing the Potential for Major Accidents within the Power Generation Sector by Utilising Operational Experience, Graeme Ellis, ABB UK

This presentation contained the methodology and conclusions from a number of Process Hazard Review (PHR) studies which were carried out by the author on large power stations in the wake of the Texas City and Buncefield accidents. The PHR methodology was aimed at existing assets and used the experience of site operations personnel, providing an efficient means of identifying risks rather than undertaking full repeat HAZOP reviews. The key major accident hazards identified by the author at large power stations were:

- Releases of fuel leading to fire and explosion hazards;
- Sudden rupture of high pressure steam systems;
- Catastrophic failure of high speed machinery leading to projectiles;
- Electrical explosions involving high voltage equipment;
- Chemical reaction hazards involving water treatment systems, such as strong acids and alkalis;
- Blade failures on wind turbines; and
- Release of anhydrous ammonia from emissions abatement systems.

Application of the PHR technique identified a number of recommendations for improvement to reduce the risk of major accident hazards. These mainly included generic procedural controls for risk reduction such as fitting blank flanges to drain valves on hazardous lines and improvements in the inspection and testing of safety critical equipment.

It was recommended that PHR studies were repeated every 5 years to demonstrate continuous improvement in process safety.

5.5 Identification of Recurrent Themes in Power Generation Facility Accidents

The major accidents which have been identified in the assessments reviewed in Sections 5.2 - 5.4 were primarily associated with a loss of containment of natural gas which ignited resulting in a fire and/or explosion. The causes of these events were reviewed in order to identify any recurrent themes which should be considered in the ongoing development of the facility.

The recurrent themes are described in the following sections.

5.6 Integrity of Pipework

High pressure gas supply pipework should be designed to minimise the potential leak sources such as flanges and flexible connections, with welded pipework being used wherever practicable. The effects of vibration from equipment on pipework should be considered and integrity inspections carried out on a regular basis. Stress analysis is to be undertaken as part of the design process.

5.7 Ventilation

Dilution ventilation provided by mechanical systems is to be included where possible within buildings where gas is used.

5.8 Isolations

Positive isolations such as valves and blank flanges should be specified to a standard appropriate to the material and the hazard as part of the process engineering of the facility. Position indication for valves should be clearly shown. Isolations for plant and equipment will generally follow the guidance in HSG253.

The design will be subject to a comprehensive HAZOP at the appropriate time, during which the placement and specification of isolations will be reviewed. This is in addition to numerous further safety studies to be carried out during the design of the facility.

5.9 Maintenance

A number of accidents have been associated with poor planning and/or execution of maintenance activities including the explosion at Enron. Design risk assessments undertaken during the project including HAZID will consider maintenance in a structured review of the design. For example, access requirements, lifting, provision of spares, the requirement and availability of services such as compressed air and water.

Maintenance is listed as a risk reduction measure during HAZID studies therefore a planned, preventative, risk based system of inspection and maintenance should be established prior to operation.

5.10 Human Factors

The HSE attributes 80% of accidents to human error[7] and the review of incidents in this study has identified several common factors involved in major accidents associated with the behaviours of personnel. For example, filling the wrong tank with material, which resulted in a MATTE.

Managing human factors is essential in the prevention on major accidents therefore the design and design risk assessments undertaken during the project should consider this, particularly in the design of control rooms, and human computer interfaces.

[7] http://www.hse.gov.uk/humanfactors/introduction.htm

6.0 RISK REDUCTION

A number of hazard mitigation and risk reduction systems and equipment are to be installed at the facility, including the following:

- Gas turbine safety
- Gas turbine safety systems will be in line with relevant standards such as BS ISO 21789.
- Fire and Gas Detection and Alarm Systems

  The fire and gas detection and alarm systems will be designed in accordance with the relevant British Standard(s) and incorporate local automatic detectors, manual call points, audible sounders and visual beacons. A main fire alarm panel will be installed in the Central Control Room.

- Fire Suppression Systems & Passive Fire Protection

  The fire suppression systems and passive fire protection measures will be designed in accordance the relevant National Fire Potation Association (NFPA) and British Standard(s). The plant will be subject to a fire risk assessment as part of the design process.

  A dedicated fire suppression system employing water mist systems will be installed in the gas turbine enclosures.

  Inert gas suppression systems will be used in the electrical equipment rooms.

  Fixed water based fire suppression systems will be provided for oil filled transformers and turbine lubrication oil systems and other systems as determined by the fire risk assessment.

  The design of the firewater ring main and hydrants will be in accordance with the relevant British Standard(s). All buildings, structures and equipment shall be within reach of the hydrants located not more than 80m apart.

  The facility will include for a dedicated storage volume in the raw water tank. The drainage system will incorporate features to contain and store fire water runoff. The fire fighting pumping equipment will be housed in a dedicated building/container.

- ATEX Equipment

  A Hazardous Area Classification (HAC) assessment shall be undertaken to identify zoning requirements for the facility. Electrical and mechanical equipment within HAC zones shall by appropriately rated in accordance with the BS EN 60079 series standards to minimise the potential for ignition. This will be part of a risk assessment to be carried out in accordance with the Dangerous Substances and Explosive Atmospheres Regulations (DSEAR).

- SF6 Safety

  SF6 detection and alarms will be installed in cable basements and other at risk areas. Switchgear is usually fitted with SF6 gas indication on every SF6 filled compartment. Strict handling procedures, only staff trained to handle SF6 can fill and recover the gas from equipment. SF6 is covered by the EU regulations and the F (fluorinated) Gas Regulations. An IEC standard (IEC 62771 303 also covers SF6 use and handling of SF6).

- Safety Instrumented Systems

  Instrumented systems which fulfil a safety related function such as emergency shutdown are to be assessed to determine the required safety integrity level (SIL) for their functional safety lifecycle management in accordance with IEC 61508 and 61511. The SIL is the probability that the system will satisfactorily perform the required safety function under all stated conditions within a stated period of time when required to do so. This assessment is to be undertaken following the HAZOP and the required SIL incorporated into the equipment specification.

- Secondary containment of hazardous materials stored in bulk

  In accordance with Environment Agency guidance and to meet the requirements of any Environmental Permit for the power station, bulk storage of hazardous materials will require appropriate bunding, with bunds able to accommodate at least 110% of the stored volume, be impermeable to water and with no direct connection to drain.

The requirement for any further risk reduction systems and equipment in addition to those listed above is to be identified during the HAZID. ?

7.0 CONCLUSIONS

The conclusions of this Concept Safety Review are that high efficiency gas-fired power plants are routinely designed, built and operated safely across the UK and worldwide without major incident, the technology is mature and safety standards, controls and regulation are robust to minimise the risk of accidents occurring. Those working methods, designs and standards will be applied in the design, construction, commissioning and operation of the Proposed Development.

Notwithstanding the above, this desktop review has identified that there are a number of potential major accident hazard (MAH) scenarios associated with the materials and systems proposed for the Eggborough CCGT power station, including:

- Releases of natural gas, fuel oil and/or high pressure steam;
- Failure of high voltage (HV) electrical equipment, and
- Reactions of hazards chemicals used in water treatment.

A loss of containment of gas can result in a fire and/or explosion, with the potential for significant harm to people on site including fatalities and major damage to site infrastructure which could compromise its ongoing operation. The safety risks to offsite receptors such as residential properties and the neighbouring Air Liquide COMAH installation are considered to be very low based on the distances between areas of bulk hazardous material storage and the identified receptors.

Implementing inherent safety factors to the design such as substitution of hazardous materials for alternative, less harmful materials cannot be applied to the natural gas feed to the CCGT or the chemicals to be used; consequently, the site will incorporate safety systems proportionate to the level of risk, such as emergency isolations provided at each gas turbine and the main gas feed to the site. A further isolation will be installed between the site and the National Grid gas transmission system. During the design process, a risk assessment should be undertaken to determine if remote operation of these isolation valves is required.

Engineering design measures will include fire and gas detection, the use of welded joints in pipework and asset integrity management systems. Classification of hazardous areas will be undertaken to facilitate the appropriate selection of electrical and mechanical equipment.

The risk of fire and explosion within gas turbine enclosures is high due to the complex pipework configurations with a high leak potential and proximity to ignition sources. Consequently fixed fire suppression systems using carbon dioxide will be installed in gas turbine enclosures.

There are MAH scenarios associated with the operation of electrical transformers, and in the electrical rooms which contain equipment such as switchgear. Fixed fire suppression systems will also be installed in these areas. A chlorine leak could also constitute a MAH scenario and this will be prevented through separation of acids and alkalis and use of incompatible tanker couplings.

The potential major accidents to the environment (MATTE) identified for the facility include a loss of containment of aqueous ammonia solution, if this is required to be used in a Selective Catalytic Reduction (SCR) system for abatement of NOx emissions. However, use of aqueous ammonia solution is preferable from a safety perspective than the alternative SCR reagent, which would be to use anhydrous (gaseous) ammonia. If the final design of the CCGT does not require the installation of an SCR system, then the use of aqueous ammonia on site could be largely removed. This is subject to an ongoing design review and an assessment of Best Available Techniques (BAT) for the CCGT.

A review of major accidents occurring in the power generation and distribution industry has been undertaken which identified a number of common themes associated with failures of pipework and equipment leading to a loss of containment and ignition resulting in a fire and/or explosion. These themes include integrity management and control of maintenance activities.

This Concept Safety Review has been undertaken at an early stage in the project, with the engineering design and plant layout at a preliminary stage. Further risk and safety assessments will be undertaken at the appropriate time as the project progresses which are described in the following section, Next Steps.

8.0 NEXT STEPS

Following this study, the next steps for the ongoing management of major accident hazards in the design development are listed below.

1. A HAZID study is to be undertaken for the power station at the detailed design stage, involving the key members of the design and operations teams including Process, Civils, Mechanical and Instrumentation Engineers along with the Project Manager, operations and commissioning specialists. It would be beneficial to undertake the HAZID once the need for the SCR system for NOx abatement (and the associated storage and use of aqueous ammonia) has been determined, however this is not essential.
2. Following implementation of the HAZID actions and when design documentation such as Piping and Instrumentation Diagrams (P&IDs) are sufficiently developed, a HAZOP study is to be carried out. The HAZOP primarily requires Process and Instrumentation engineers supported by other relevant disciplines as required. Both HAZID and HAZOP will be led by an independent, experienced leader.
3. The Major Accident Prevention Policy (MAPP) is to be completed and approved by Senior Management personnel for the new facility.
4. The outline of the Safety Management System (SMS) is to be produced. This will establish the operating and management procedures required to deliver the MAPP, for example, Management of Change and Emergency Response, and will include operator training and competence requirements.
5. The design development shall include Hazardous Area Classification to identify the ATEX zoning requirements of mechanical and electrical equipment.
6. The design development shall include compliance with the Pressure Systems Safety Regulations, including the production of Written Schemes of Examination for pressure equipment.
7. The design development shall also include functional safety lifecycle management in accordance with IEC 61511 - Safety instrumented systems for the process industry sector[8].
8. A number of formal risk assessments will be undertaken by the EPC contractor as part of a defined schedule of reviews for each part of the plant prior to and during commissioning and start-up. The plant will then be handed over to the site operator.

[8] https://shop.bsigroup.com/ProductDetail/?pid=000000000030133733

Figure 1 -Site Location

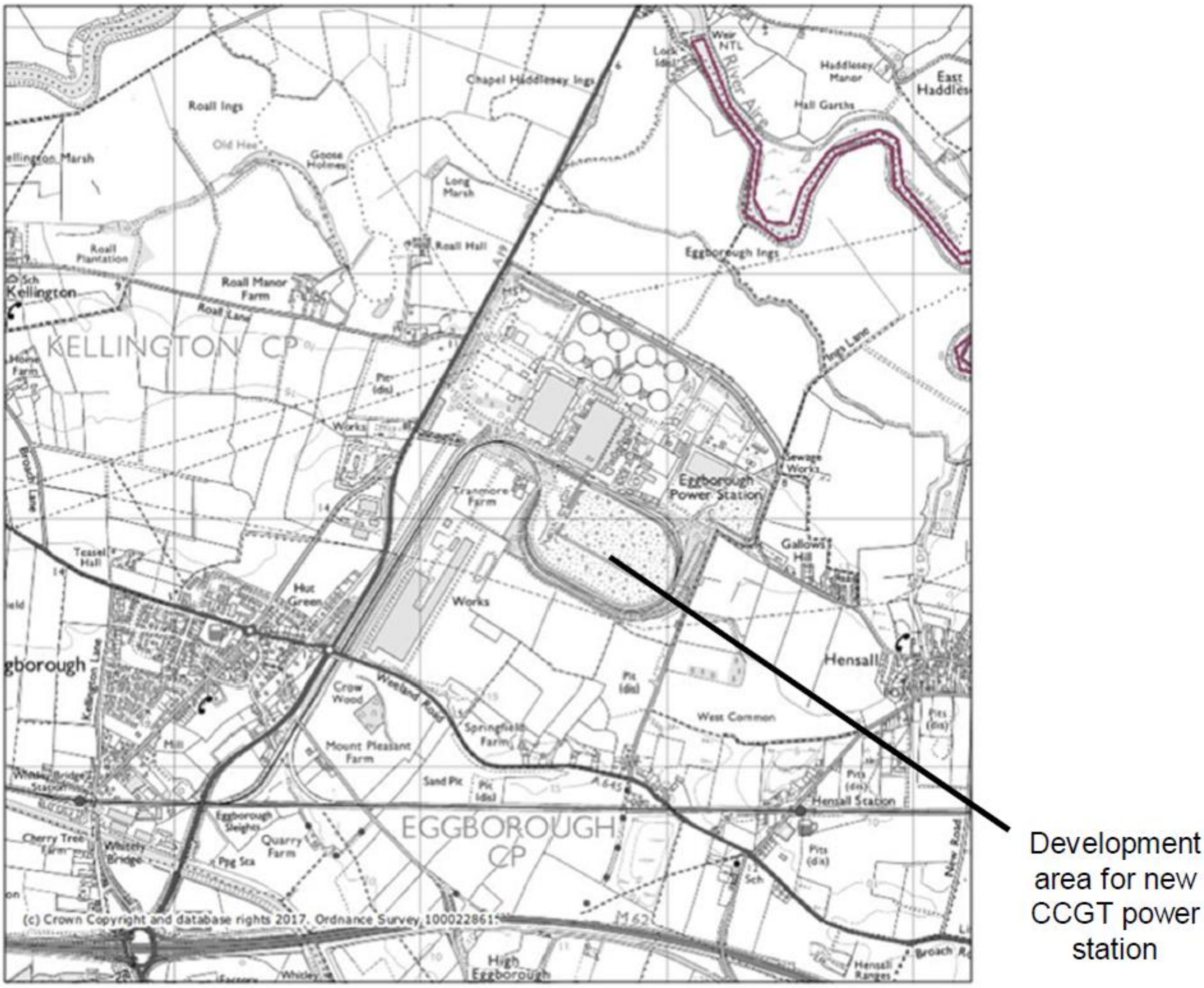

Figure 2 - Conceptual Site Layout