ALIGN Working in partnership with HS2

HS2 C1 - Vehicle Fire in Tunnel

AFTES

14th February 2023

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Sub-Surface Construction Director for Align JV on the C1 section of HS2 (Chiltern Tunnels)

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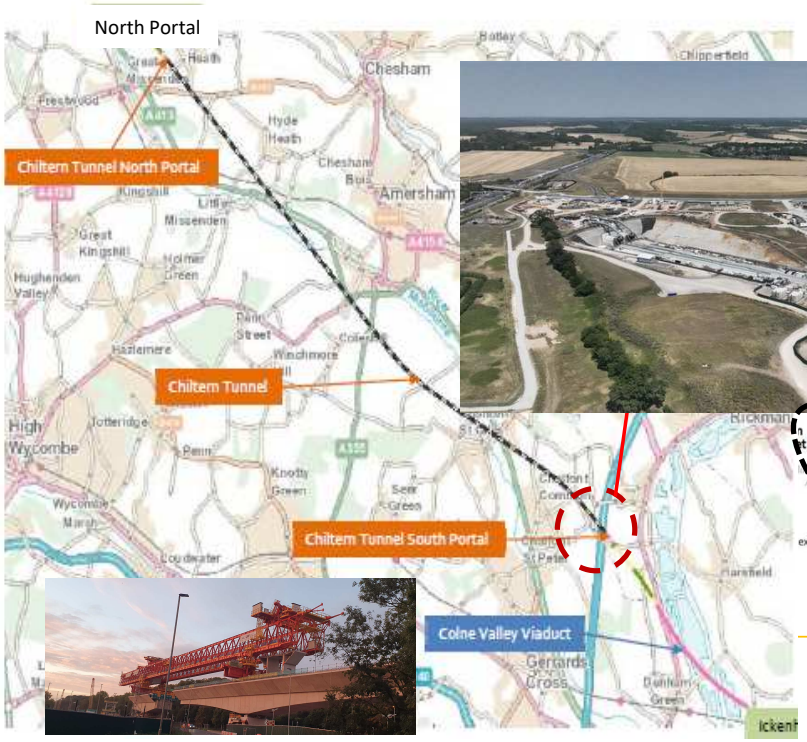
AGENDA

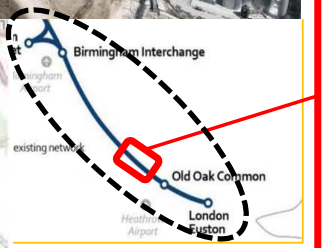
- ❑ **Project introduction**
- ❑ **Fire, Emergency Requirements & Arrangements**
- ❑ **Fire on 10th May 2022, Tunnel configuration, Evacuation,…**
- ❑ **Investigations & Key Outcomes**
- ❑ **Conclusions & Further Thoughts for the industry**

High Speed 2 - Phase 1 & C1 section

C1 section consists of 21.6km of high speed rail infrastructure

- 3.4km viaduct,
- 2.1 km of embankment
- 16.1km twin-bored tunnels, 5 shafts. (The excavation started in May & July 2021)





C1 section of HS2

Department for Transport

HS2

ALIGN

BOUYGUES TRAVAUX PUBLICS

VolkerFitzpatrick

Sir Robert McALPINE

ALIGN-D

ALIGN

JACOBS

INGEROP

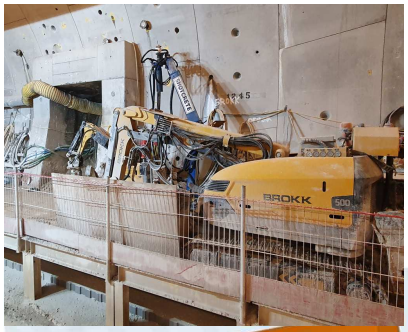
inventing for tomorrow

The Phase 1 length is 230 km, the full network will provide 530 km of new high speed line

C1 Tunnels

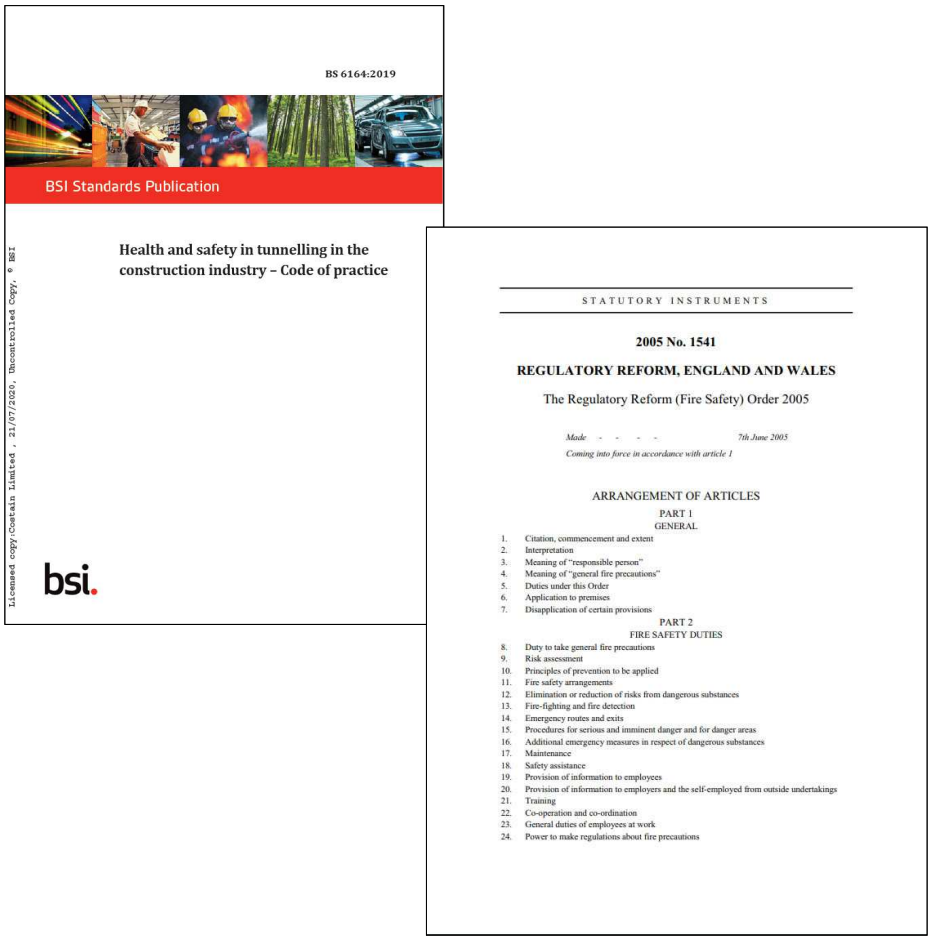
- **9.1 m ID, 4 adits & 38 XP excavation**
- **2x TBM's –**Florence & Cecilia (S1205/1206) Actually both at 8.9 km (in 20mths)
- Stage 1 Concrete of Track Invert just behind
- Multiple Slurry booster pumps
- Logistic with Multiple MSV's types & PSV's
  - MSV Production - TBM
  - MSV Concrete – Stage 1 Invert
  - MSV HiAb & Side Loaders – CP & Support team
  - PSV's – Operative Transport
- Services pipes , walkways, 2*22kV's cables + Lighting & Comms along tunnel

(MSV = Multi Service Vehicle)
(PSV = Personal Service Vehicle)



C1 Tunnels Fire & Emergency Requirements

- **Legislation / Regulation**
  - The Health & Safety at Work Act 1974
    - Gives the Health & Safety Executive (HSE) the ability to Investigate, Enforce & Sanction
  - Confined Spaces Regulation 1997
    - Management of CS work & specifically the need to have an emergency plan
  - (Regulatory Reform (Fire Safety) Order 2005)
    - Fire Risk Assessment, Training & Competency to check adequate provisions in place
- **Codes of Practice**
  - British Standard 6164 – Health and safety in tunnelling in the construction industry
    - Code of practice for all tunnelling works in the United Kingdom & widely used around the world
  - British / European Standard 16191 – Tunnelling machinery. Safety requirements



C1 Tunnels Fire & Emergency Arrangements

- **Fire Risk Assessment for Tunnelling:**
  - Tunnel Boring Machine Operations
    - Herrenknecht Assessment of TBM
  - Invert Concreting Operations
  - Cross Passage Construction
  - Tunnel Operations
    - Pumps, Transformers, lighting, etc.
    - General MSV Operations
  - Compressed Air Works

→ **Detailed Emergency Plan & Response Procedures**

- Fire Fighting Provisions on all Plant & in Tunnel, emergency box every 250m,…
- Refuge Chamber(s) on TBM's & in Tunnel to aid escape, self rescue mask,...etc
- Specific call-out arrangement with Police, Fire & Rescue Services

10th May 2022 – Fire @ Tunnel Shift Change

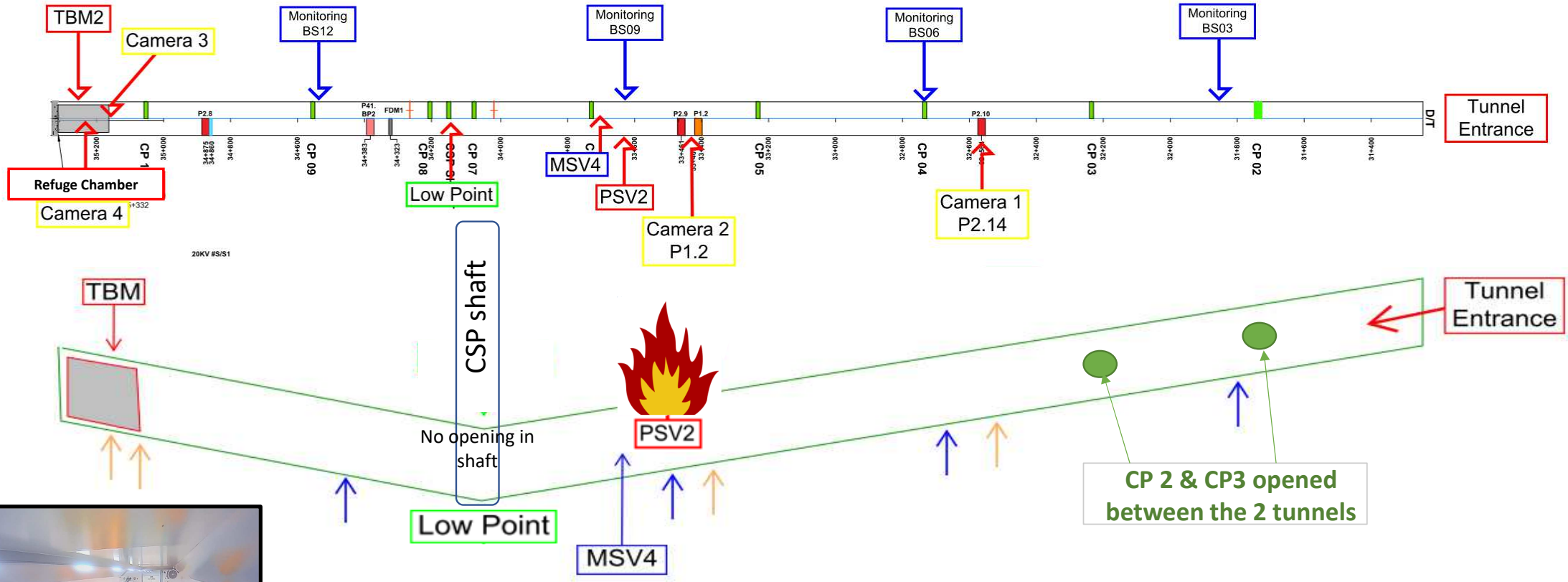
- Nightshift TBM Team on there way to TBM in PSV
- 3x Mechanical Operatives on TBM undertaking maintenance activities (during the shift changing)

- PSV stop a 2.6km to drop MSV Operator in tunnel

  In following minutes:
  - PSV stops functioning
  - Operator observes small flame inside power pack:
    - Handheld Extinguisher used – No Effect
    - PSV Fire Suppression Activated (see photo)
    - All Personnel begin to evacuate

- Few minutes later, fire started again while operatives started evacuation

Tunnel configuration



3 persons on TBM went into refuge chamber @ 4.1 km

- PSV2 (fire) Ring 1307
- MSV4 parked Ring 1320
- Low Point Ring 1453:
- Refuge Chamber in TBM Ring 2060:

- Gas Monitors: Rings 303 / 753 / 1203 / 1652
- Cameras: Rings 660 / 1082 / 2010 / 2060

Both tunnels evacuated, Ventilation stopped in tunnel with fire

Evening 10th May 2022 to 11th May morning

- Fire Service arrived on site, review similar vehicle configuration:

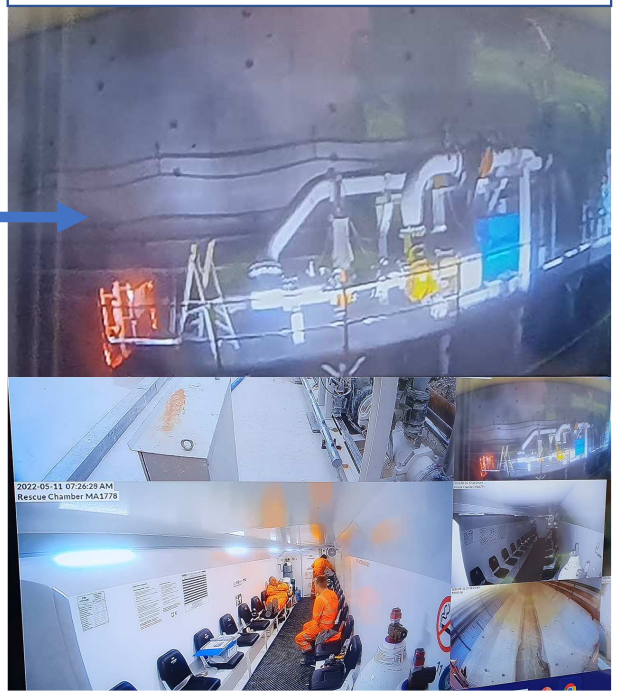
- Too much smoke in tunnel,
- Remaining workers in tunnel safely in refuge chamber and in constant contact with surface.

Photo from the camera at 2,1 km in tunnel (~450 m from fire)
1 h after fire (8:30 pm).

Ventilation stopped already

Same photo 11 h after

(ventilation still off)



→ *Decision was made to wait for the fire to die & smoke to fall before rescuing the team the next morning*

Morning 11th May 2022

- 3x Mechanical Operatives on TBM
  - Spent all night inside Refuge Chamber
  - Constant contact with surface
  - Left tunnel the following day at 10:00 am (using Breathable mask)

Burnt PSV location on 11th 10:00 am

(To be noted: Ventilation duct melted and not propagating fire as per specifications)

C1 Tunnel Fire Investigation & Findings

- **Collaborative Investigation**
  - Fire Service – *Later handed over to (HSE)*
  - The Health & Safety Executive
  - Align & Fire Expert (who reviewed Fire RA)
  - TMS (Machine supplier)
  - Ardent (Fire suppression system supplier)

- **2 Major Questions Raised:**
  - What is (are) the cause(s) of the fire?
  - Why & How did the fire reignite?

What caused the Fire and/or Re-Ignition

Fuel

- Diesel (or HVO in this case) ~ 100 Litres (HVO: Hydrotreated Vegetable Oil)
- Hydraulic Fluid ~ 100 Litres
- Other flammable materials in power pack (hoses, cables,…)

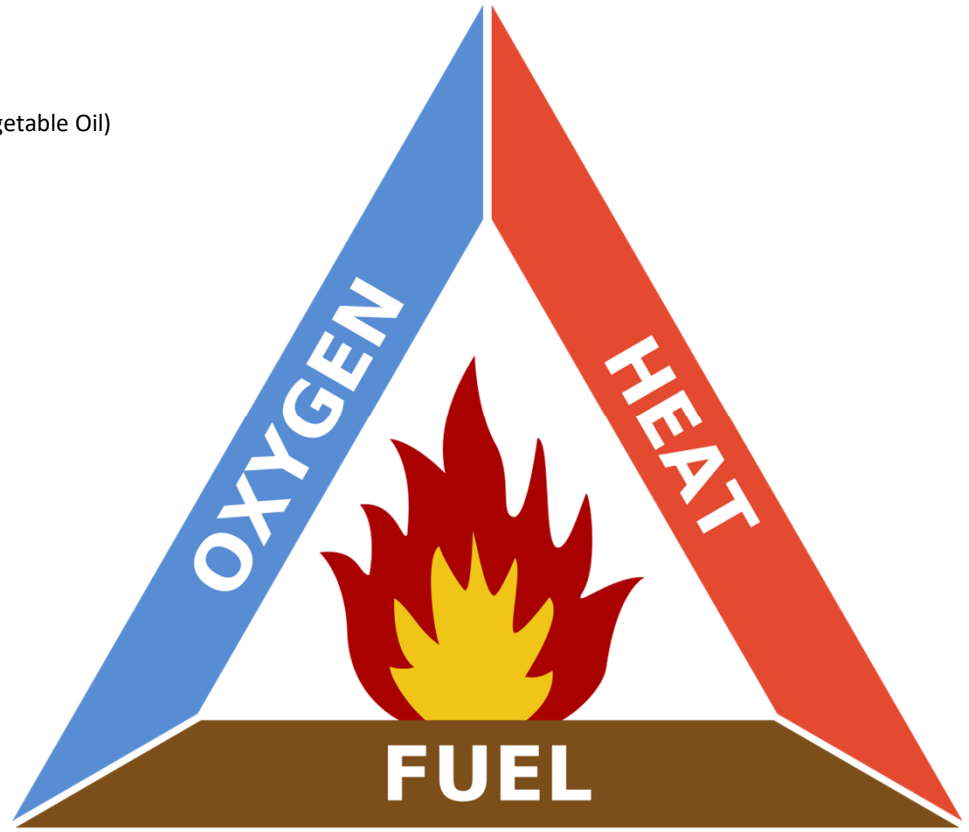
Oxygen: Air in tunnel

Source of Ignition (Heat)

- Spark from wiring?
- Heat from Engine?
- External source?

Re-Ignition

- Fire Suppression activated and it worked
- Was it sufficient? – **Usually; but not this time… Why?**



Fire investigation

Source of Ignition (Heat)

- Blackbox in PSV – Completely Destroyed
- Engine Damage so major, unable to find

But, Investigation of another PSV or MSV's

- Wiring and piping installation – kinks, strains and inappropriate grouping / taping
- Some Degradation of hoses & signs of wear due to rubbing
- Small hydraulic leak traces

Investigation Conclusion

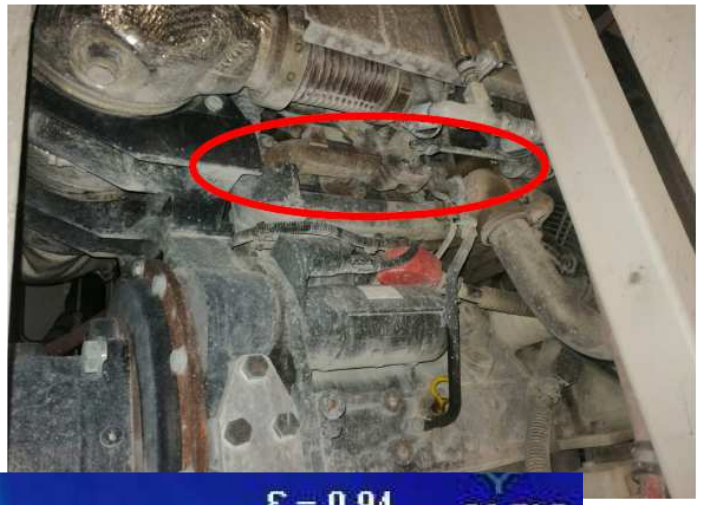
- No Evidence of Foul play
- 6Mths Ardant check (fire suppression) just completed.
- Source of ignition likely to be from spark due to damaged wiring and/or potential spray of fuel (HVO) onto hot engine component

(HVO: **Hydrotreated Vegetable Oil** is a second-generation, advanced renewable diesel alternative)

Is Engine temperature a potential cause of Fire?

HVO Fuel Vs Diesel

- Very similar properties to Diesel
- Improved sustainability properties
- Suppliers stated ok to use. (All plants on C1 project were moving to HVO use)
- Auto Ignition Properties:
  - Diesel – 250 Deg. C and above
  - HVO – 204 Deg. C and above



Temperature Analysis of PSV engine

- Exhaust & Engine – 160 Deg. C – OK
- Turbo – 238 Deg. C, >HVO ignition temp.

Conclusion

- Even if turbo temp > HVO ignition point, no clear cause identified as fire started in bottom of power pack

Is Fire fighting suppression system efficient enough?

Fire Fighting System design

- Align specified compliance to BS6164
- TMS / Ardent design:
  - ➢ Considered Cool & Quench, thought not required
  - ➢ Dry Powder Suppression
  - ➢ Believed Compliant to BS6164 & believed ‘fit for purpose’

Fire Fighting activation on 10th May

- Powder suppression worked & stopped the fire (supressing the flame)
- However, the dry powder may have not provided enough cooling effect and the heat within the power pack remained at or above 204 Deg. C & electrical supply not switch off automatically,

➢ Eventually, the Fire Re-Ignited

13.3.3 Fire suppression and smoke control systems

All mechanical plant and equipment identified in 13.1.8 should have fixed fire suppression systems covering the fire-risk areas of the machine. These should include the engine compartment and fuel storage, hydraulic pumps, motors and oil storage tanks, the cab, tyres, etc. Where the tyres cannot be covered by a fixed suppression system, an additional portable extinguisher of an appropriate size and type should be carried on the vehicle. The fixed fire suppression system should utilize appropriate extinguishants for the types of fire foreseeable on the machine. The need for cooling and quenching to prevent reignition should be considered.

NOTE 1 Fire suppression is a specific requirement of [illegible] in Reg 12(3) and Reg 28 [N4].

In addition, portable fire extinguishers confo[illegible]BS 5306-10 and to the appropriate part(s) of BS EN 3-10 should be provided. They sh[illegible]ed and installed in accordance with BS 5306-8 and maintained in accordanc[illegible]They should be sited so that they are readily accessible by personnel.

The [illegible]scount

“The Need for cooling and quenching to prevent reignition should be considered”

Table 5 — *Provision of fire extinguishing equipment*

Location of fire	Extinguishing medium				
	Water (jet)	Water (spray)	Foam	Inert gas	Powder
Tunnel – general	F		P	P	P
TBM – general			P	P	P
TBM – hydraulics			F		F
TBM – electrics				F	F
Diesel plant including locomotives			F		F
Battery plant including locomotives (lithium)				F	F
Battery plant including locomotives (lead acid)				P	P
Fuel store			P		P
Battery charging					P

“Foam or powder provision”

Other Contributing Factors

Design / Manufacture / Industry Considerations

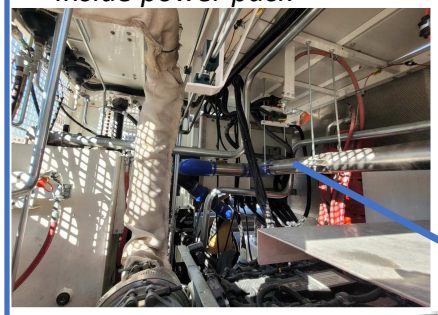
- "Retro Fit" Fire fighting system (not designed or installed as part of the Engine Unit manufacture) = complex Ardent system maintenance inside power pack
- Hot points protection covers (Turbo for ex.) implemented,
- No Jubilee clips & few re-engineering points on fuel Lines & electrical cables rooting or protections have been implemented,
- Electrical Systems isolations was manual, now in automatic.

Use of HVO to replace Diesel

- Use of HVO Fuel was approved by TMS & engine suppliers (Volvo, Deutz)
- No formal trials / investigations of its use were undertaken as replacement of diesel considering
  - ➢ HVO has limited Industry knowledge in U/G use
  - ➢ HVO not fully considered in Fire RA prior to use it

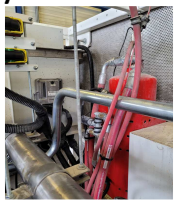
(Following the fire, the use of HVO was temporary suspended inside the tunnel only)

Inside power pack



Before fire:

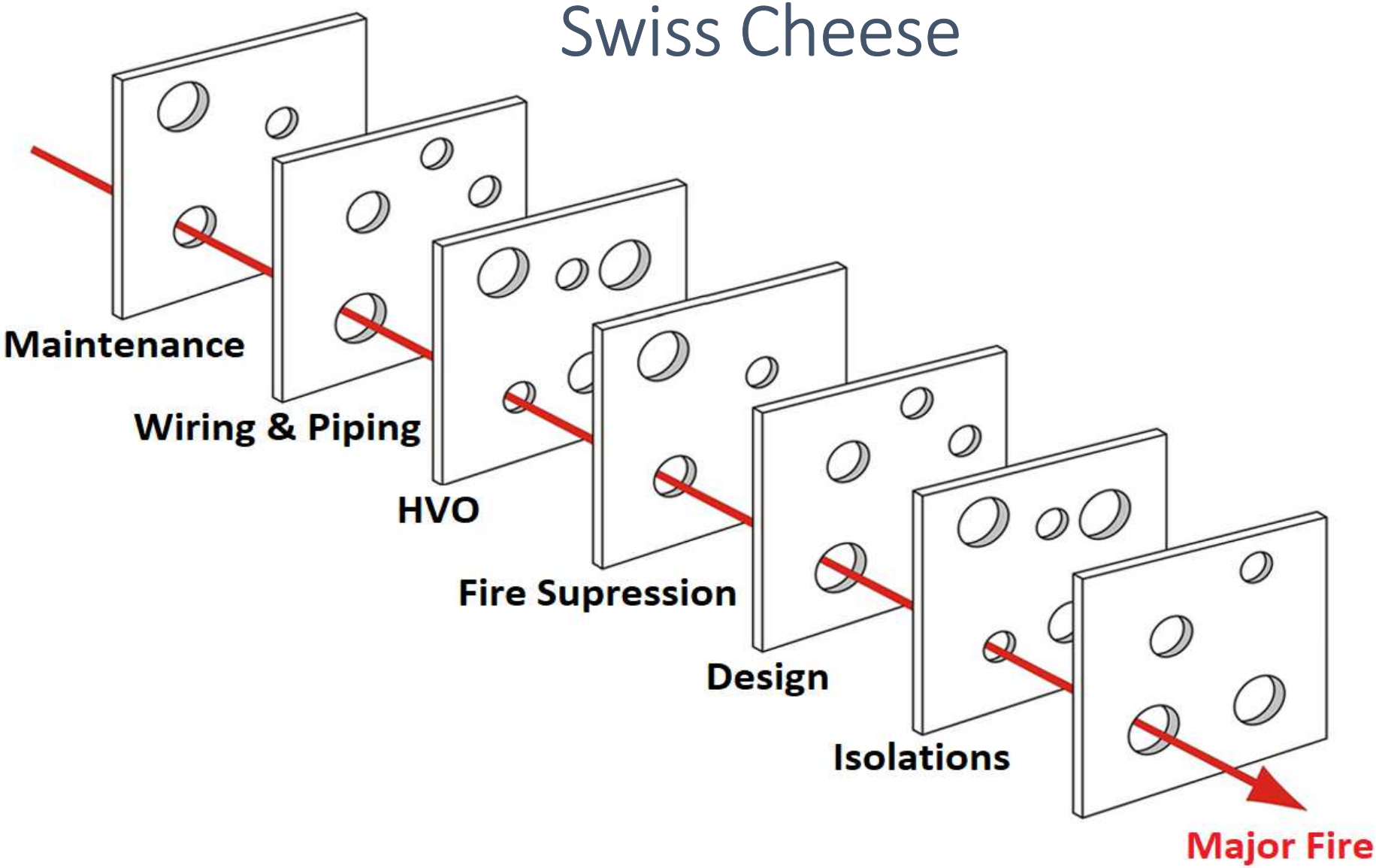
1 dry Powder vessel inside power pack (Not easy to access)



After fire:

Dual system vessels fully accessible (outside the power pack)

Swiss Cheese



Conclusions

- **Investigations & Key Outcomes**
  - Fire Risk Assessment was adequate & Emergency procedures worked well as drill runs regularly
  - Collaborative Investigations during all process,
  - No clear route to identify fire cause (Electrical fault, HVO or hydraulic leak)
  - No Material Breach of Legislation found by HSE

→ Dual System implemented & Re-engineering all power packs conditions and increase PPM regime.

- **Further Thoughts for the industry**
  - Understanding & implementation BS6164 "to decrease the likelihood of re-ignition"

Particularly around the meaning and implementation of dual systems that provide: Suppression & Quenching.

  - Use of HVO as fuel alternative – Suitability & design of engine units (working temperature) for use needs further investigation
  - Guide line for power pack design to be implemented? (Elec, fuel, hydraulic segregation, support cables, hoses,…)
  - Fire Fighting Systems & their integration around power pack as part of Design / Manufacture – Should this be an industry standard?

Fire Remains **OUR** greatest Risk – We all want to go home safely.

Prepared by Didier Jacques & Shannon O'Keeffe