Ministry of Defence

de&S

Post-fire Monitoring Rationale & Policy Review

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Legislation

- UK Health & Safety at Work Regulations impose a general duty on employers to review preventative and protective measures

- Requirement to adequately investigate the immediate and underlying causes of incidents
  - ensure that remedial action is taken
  - lessons are learned
  - and longer-term objectives are introduced

- The MoD must discharge its Duty of Care to comply with the requirements to reduce the risk to ALARP (As Low As Reasonably Practicable)

Effects of fire

- Materials burnt in air produce toxic gases
  - narcotic, irritant, smoke aerosols and heat
- Products affected by:
  - Type(s) of material(s) burning
  - Quantity
  - Ventilation available
- If individuals are exposed to one or more fire products at sufficient concentrations over time, they can develop potentially serious physiological effects

Fire characteristics

- Fire testing to be considered for general use within a submarine
  - surface spread of flame
  - oxygen index
  - smoke index
  - temperature index
  - toxicity index
- The required tests to determine the fire characteristics of materials are detailed in the Def. Stan. 07-247
- Only the results of fire toxicity testing iaw Def. Stan. 02-713 are being considered for post-fire monitoring

Issues

- During a fire & post-fire clean-up: submarine crew on secondary breathing system (EBS)
  - Period may last several hours
  - Monitoring throughout all compartments of the submarine
  - Not comfortable, restricts movement, time limited
- A review of post-fire monitoring requirements requested by operating authorities

Current post-fire monitoring

- Oxygen
- Carbon dioxide
- Carbon monoxide
- Hydrogen cyanide
- Hydrogen fluoride, Hydrogen chloride + Hydrogen bromide
- Hydrogen sulphide
- Nitrogen oxides
- Hydrogen Sulphide
- Sulphur dioxide
- Chlorine
- Total organic compounds + Tenax tube samples
- Total aerosols

MPC_{60} limits for the fire test gases

Gas	MPC_{60} / ppm
Carbon dioxide	50,000
Carbon monoxide	175
Hydrogen cyanide	10
Hydrogen fluoride	5
Hydrogen chloride	10
Hydrogen sulphide	100
Nitrogen oxides	15
Sulphur dioxide	20
Formaldehyde	9.6

Total Aerosols, CES_{90} 0.5 $mg.m^{-3}$

Total Organics, CES_{90} 40 $mg.m^{-3}$

Aims

- Review gases produced in fires involving materials used on board submarines
- Assess:
  - combustion products produced in high concentrations
  - those that pose a serious health risk
- Highlight main marker gases produced in fires
  - Concentration
  - Relative toxicity (acute or chronic)
- Propose a *new* safe, efficacious protocol for post-fire monitoring
  - Reduced number of gases needing to be monitored post fire
  - Minimise time taken to report concentrations post incident
  - Minimise time spent on EBS

Narcotic gases

Carbon dioxide

Carbon monoxide

Hydrogen cyanide

- Normal body function is possible up to a certain concentration for a period of time, and then deterioration of the body functions are quick and severe
- Potential effects:
  - Slight headaches
  - Dizziness
  - Lethargy
  - Depression of the CNS
  - Incapacitation
  - Loss of life

Irritant gases

Acid gases (HCl, HF, HBr)

Nitrogen oxides

Hydrogen sulphide

Sulphur dioxide

Formaldehyde

- Potential effects:
  - Instantaneous response: sensory irritation eyes & upper respiratory tract
  - Pain: may be considered as functionally incapacitating
  - Accumulated dose effect. High dose / short duration, or lower dose / long duration: respiratory difficulties of lower respiratory tract potentially leading to loss of life

Accumulated effects

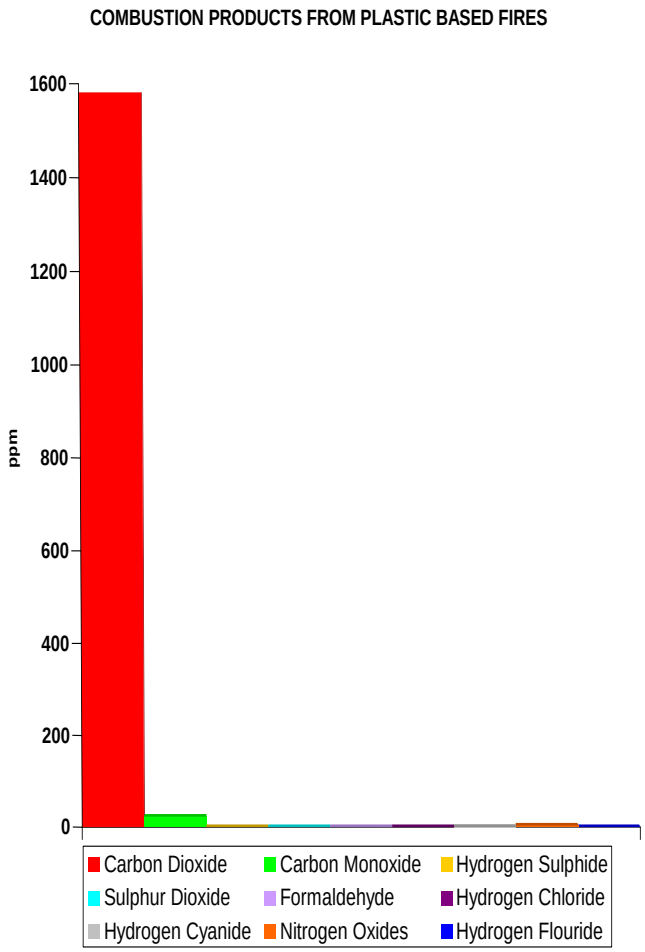
Accumulated dose = concentration of gas x duration of exposure

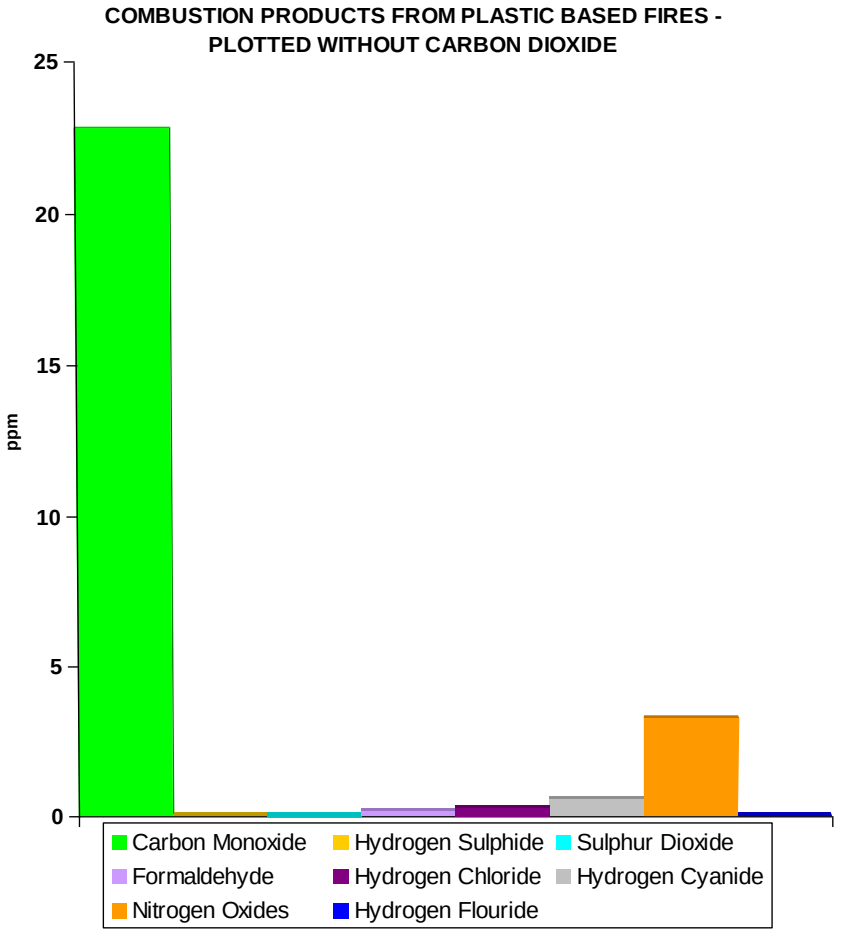
Exposure to multiple gases = Synergistic effect

Review

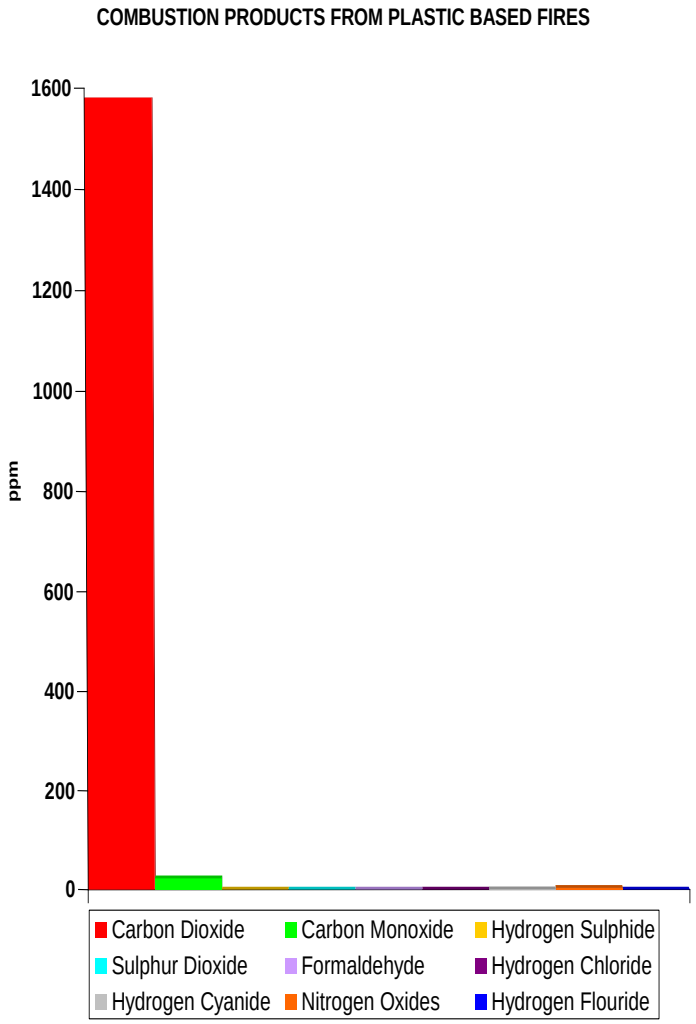
- Materials involved with fires on submarines are:
  - Plastics
  - Deck coverings
  - Fabrics
  - Rubbers
  - Electricals
  - Paints
- Materials database test results of sample sets (19-31)
  - absolute concentrations of the nine relevant toxic compounds recorded
- Only materials approved for use in submarines were selected
- Results used to produce graphs
  - Absolute concentrations (arithmetic mean) / ppm
  - Percentage of MPC_{60}
  - Effect of extreme values

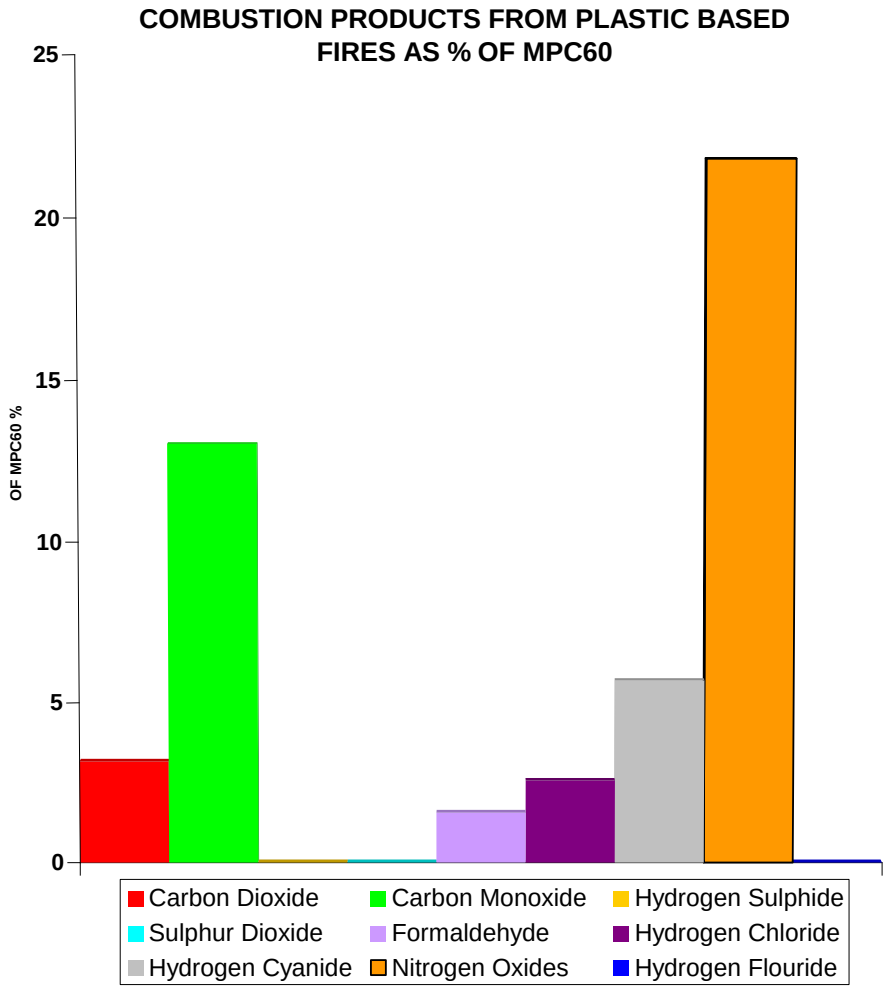
Plastic based fires - concentration



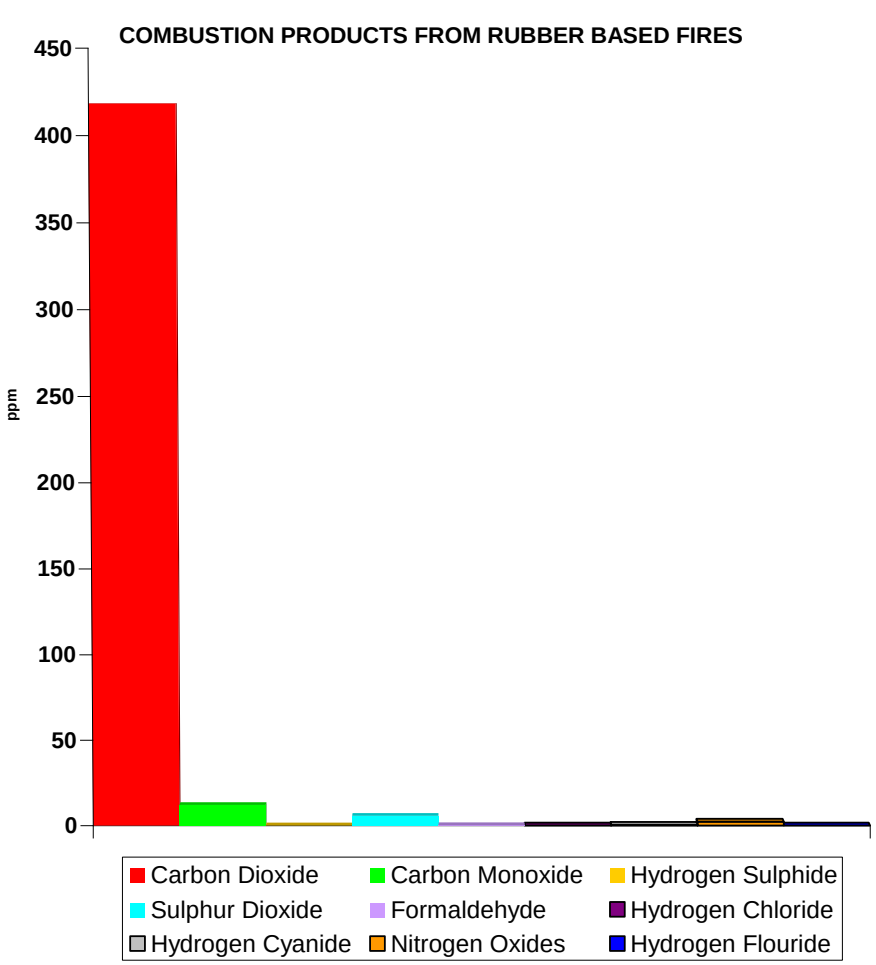


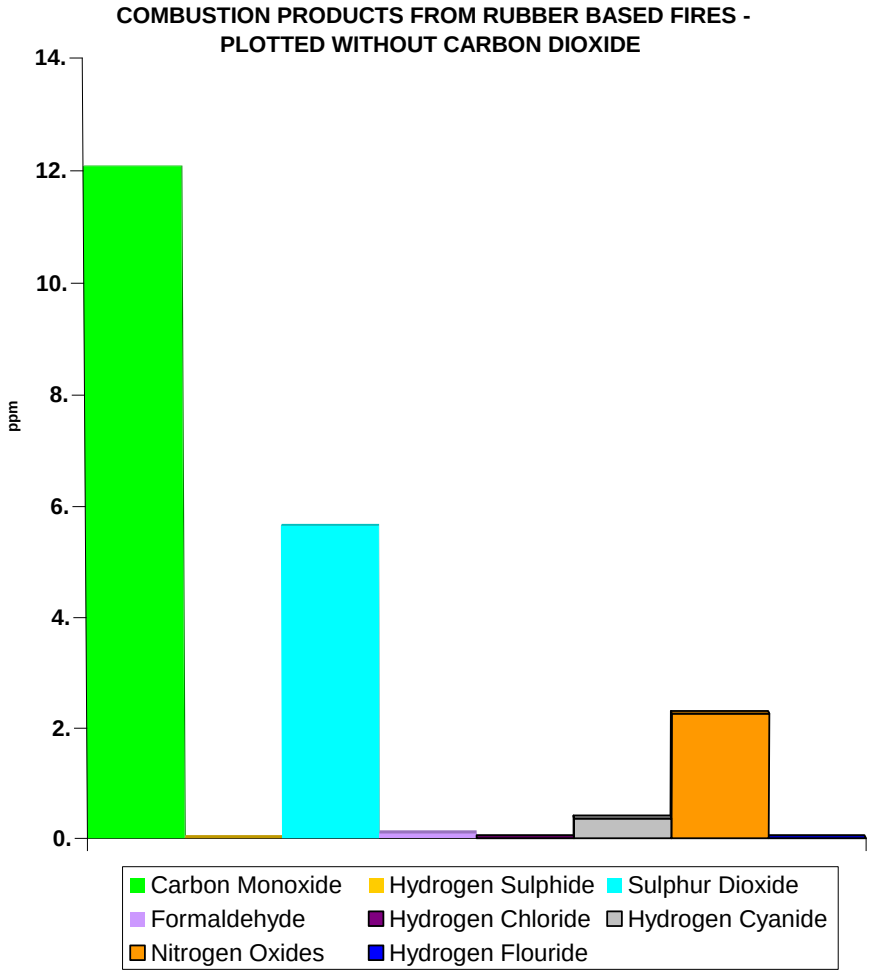
Plastic based fires - % MPC_{60}



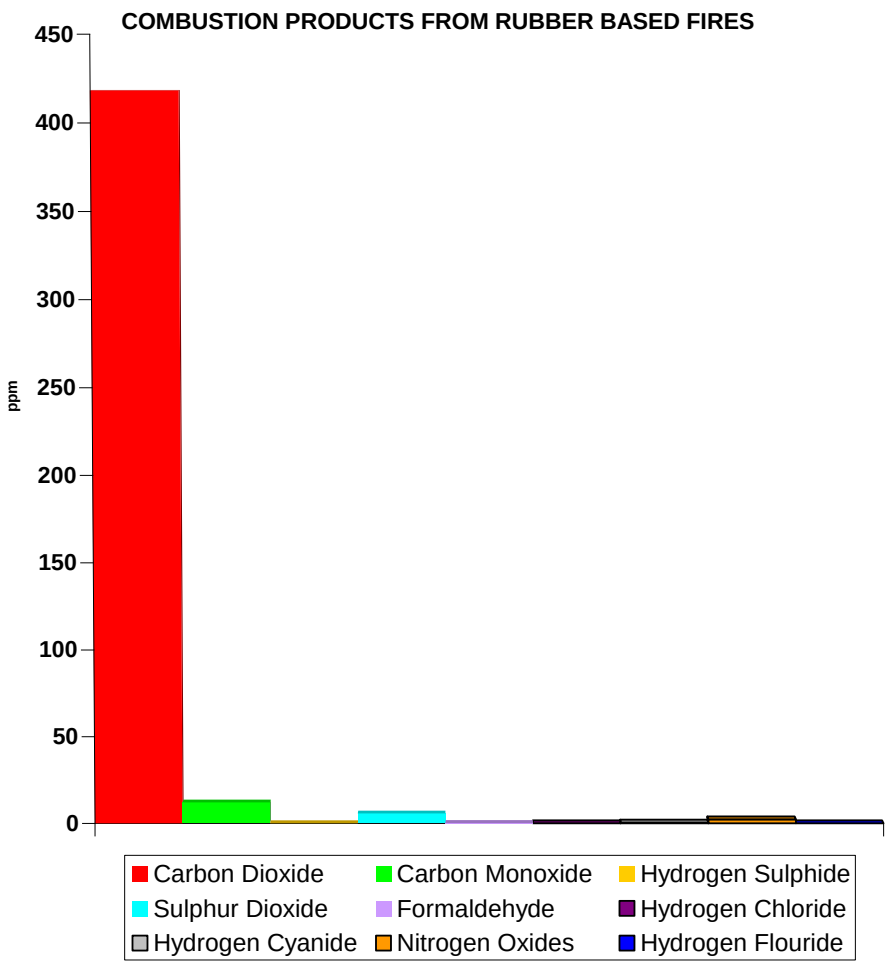


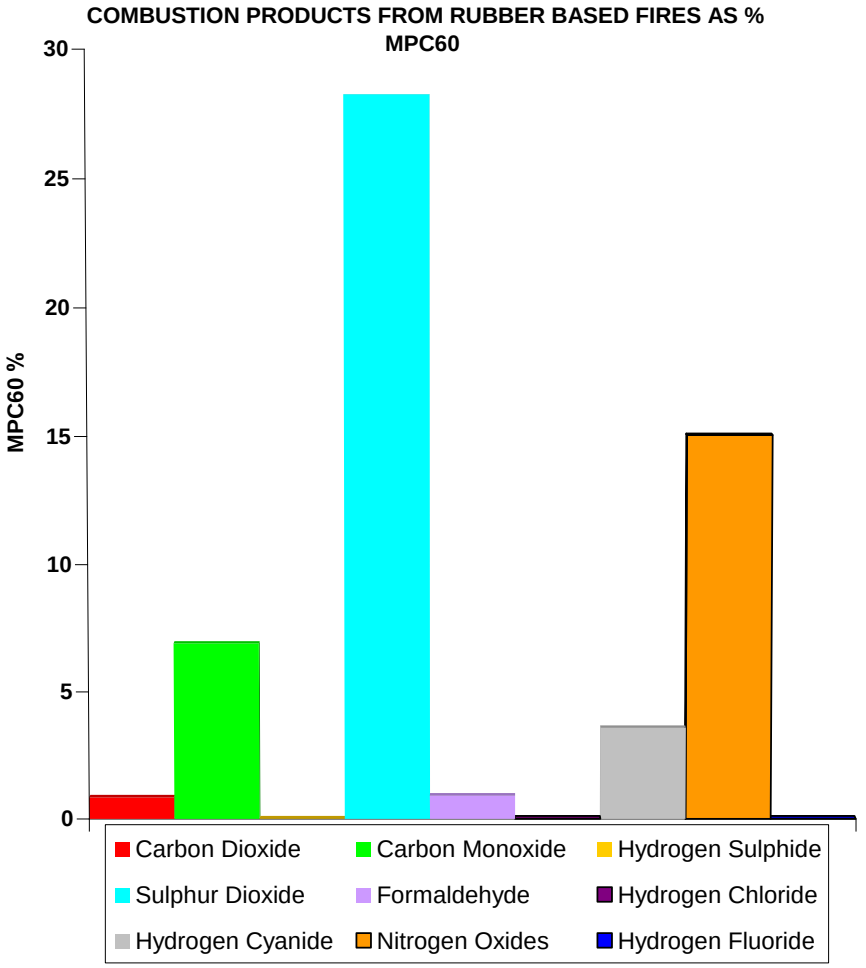
Rubber based fires - concentration





Rubber based fires - % MPC_{60}





Summary of data analysis results

Gases in order of highest % of MPC_{60}	Plastic based fire	Deck covering based fire	Fabric based fire	Electrical based fire	Rubber based fire	Paint based fire
1	Nitrogen oxides	Nitrogen oxides	Nitrogen oxides	Nitrogen oxides	Sulphur dioxide	Nitrogen oxides
2	Carbon monoxide	Hydrogen cyanide	Hydrogen cyanide	Hydrogen chloride	Nitrogen oxides	Carbon dioxide
3	Hydrogen cyanide	Carbon monoxide	Carbon monoxide	Carbon monoxide	Carbon monoxide	Carbon monoxide
4	Carbon dioxide	Carbon dioxide	Formaldehyde	Carbon dioxide	Hydrogen cyanide	Hydrogen fluoride
5	Hydrogen chloride	Hydrogen chloride	Sulphur dioxide	Hydrogen cyanide	Formaldehyde	Hydrogen cyanide
6	Formaldehyde	Formaldehyde	Carbon dioxide	Sulphur dioxide	Carbon dioxide	Formaldehyde
7		Sulphur dioxide	Hydrogen chloride	Formaldehyde	Hydrogen sulphide	Hydrogen chloride
8						Sulphur dioxide
9						Hydrogen sulphide

Monitoring priorities

1. Nitrogen oxides (irritant)
2. Hydrogen cyanide (narcotic)
3. Carbon monoxide (narcotic)
4. Carbon dioxide (narcotic)
5. Acid gases (irritant)
6. Sulphur dioxide (irritant)

Adjusted monitoring priorities

1. Carbon monoxide (narcotic)
2. Carbon dioxide (narcotic)
3. Hydrogen cyanide (narcotic)
4. Nitrogen oxides (irritant)
5. Acid gases (irritant)
6. Sulphur dioxide (irritant)

Oxygen

Oxygen required to sustain life!

- RN upper limit is 22% - safety based
- Remember - during a fire oxygen is consumed thus lowering the concentration
- Before secondary breathing system may be removed O_2 level must be above 137 Torr = (137mmHg) (based on physiological effects)

Discussion

- The amount of gas required to breach the MPC_{60} for the gases will vary according to the sizes of compartments within the submarines

- It would be inflexible to assign one marker gas for all fires
    - gases are not produced as discrete quantities
    - vary due to which compartment they are in
    - will depending on materials exposed to fire
    - *vary according to activities on board*

- Monitoring just seven key gases (including oxygen) could reduce the time spent on secondary breathing system

- Other types of fires may produce other toxic materials e.g. oils and greases – supports requirement to monitor for organics and aerosols

Conclusions

- Completed review for six sets of materials
- Considering concentration only produced one set of priority gases
- Carbon dioxide was the main product
- Other target gases were produced in relatively small absolute volumes in comparison to carbon dioxide or made no significant impact on the danger to human health as a percentage of the gas' MPC_{60}
- Assessing the concentration of gases as a % of MPC_{60} produced a different priority
- Discussion with other SMEs reprioritised the list

Conclusions

- Identified seven marker gases:
  - Carbon monoxide
  - Carbon dioxide
  - Hydrogen cyanide
  - Nitrogen oxides
  - Acid gases
  - Sulphur dioxide
  - Oxygen

- TOM & TAM monitoring at scene of fire

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Thank you

…..for your kind attention

to my *last*

international conference presentation!