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## Assessment Of The Risk To Aircraft From Ringaskiddy Resource Recovery Centre Exhaust Plumes

Concern has been expressed in regards to the risk to helicopters approaching at Haulbowline Naval Base and Spike Island due to the exhaust plume from the Ringaskiddy Resource Recovery Centre (RRRC). The exhaust stack will emit a plume with both some initial thermal buoyancy and momentum as it will have an initial temperature of 418K (145°C) and an exit velocity of 13.5 m/s.

The Federal Aviation Authority (FAA) in the US reviewed this issue in 2006 in the publication "*Safety Risk Analysis of Aircraft Overflight of Industrial Exhaust Plumes" (January 2006)* and summarized the risks associated with industrial exhaust plumes as follows:

"*Given the considerably large pool of safety data available, it is safe to conclude that the accident/incident rate for overflights of exhaust plumes is of the order of $1 \times 10^{-9}$ or less. Since the target level of safety was determined to be $1 \times 10^{-7}$, the probability of an accident or incident from overflight of an exhaust plume is less than the target level of safety. Since the target level of safety is met, the current likelihood of an accident or incident caused by an overflight of an exhaust plume is acceptably small."*

The FAA in 2015[1] updated the guidance, stating that:

> *"the FAA has determined the overall risk associated with thermal exhaust plumes in causing a disruption of flight is low. However, the FAA has determined that thermal exhaust plumes in the vicinity of airports may pose a unique hazard to aircraft in critical phases of flight (particularly take-off, landing and within the pattern) and therefore are incompatible with airport operations"*

The updated guidance identifies the factors which may have an effect on the plume size and the severity of impacts including:

- Stack size, number and height, type of exhaust;
- Proximity of stacks to airport flight paths;
- Temperature and vertical speed of the effluent;
- Size and speed of aircraft encountering exhaust plumes; and
- Local winds, ambient temperatures, stratification of the atmosphere at the plume site.

The FAA contracted MITRE Corporation to develop a model to predict plume size and severity of flight impact from thermal exhaust plumes. The MITRE Corporation has recently published the model formulation / user guide[2] for the "Exhaust-Plume-Analyzer" model.

[1] FAA (2015) Technical Guidance And Assessment Tool For Evaluation Of Thermal Exhaust Plume Impact On Airport Operations
[2] MITRE (2012) Expanded Model For Determining The Effects Of Vertical Plumes On Aviation Safety

The user guide[2] details the likely impact of the exhaust plume on aircraft based on a range of parameters / criteria. One important criterion is the buoyancy of the plume. The USEPA SCREEN3 model has algorithms which allow the buoyancy flux and momentum flux to be determined. The SCREEN3 model was run for the RRRC stack to determine the worst-case buoyancy flux and momentum flux under maximum operation:

- Thermal buoyancy = 67 $m^4/s^3$ (based on an ambient temperature of -10°C (263.15K))
- Momentum Flux = 162 $m^4/s^2$

**Helicopter Risk**

The guidance[2] deals specifically with the issue of helicopter risk. The guidance notes that in relation to helicopters, the issue of turbulence is not a big concern but that elevated temperatures and/or low oxygen concentrations of the plume may lead to engine failure.

<u>Plume Elevated Temperature Risk</u>

Shown below in Figure 1 is the relationship (in blue) between the initial exit velocity of the plume and height above the stack at which the plume is equivalent to the temperature risk value[3].

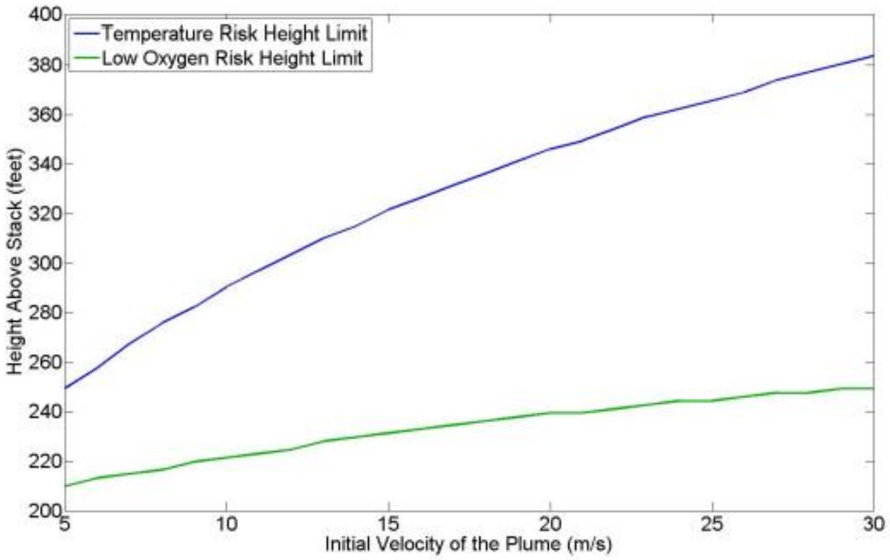


**Figure 5-2. Comparison of recommended height limits to mitigate elevated temperature risk and reduced oxygen concentration risk**

*Taken from "MITRE (2012) Expanded Model For Determining The Effects Of Vertical Plumes On Aviation Safety"*

***Figure 1*** Recommended Height Limits To Mitigate Elevated Temperature Risk And Reduced Oxygen Concentration Risk.

[3] The actual scenario is of a single exhaust stack plume of 10m diameter, an exhaust temperature of 200°C (473K), 273K ambient temperature, calm winds and an exit velocity varying from 5 m/s to 30 m/s. The particular example has a buoyancy approximately 20 times greater than the RRRC stack.

The result shows that for an exit velocity of 13.5 m/s (as per the RRRC stack), the maximum height above the stack where the temperature exceeds the threshold level is 310 feet (95 metres). After 95 metres, the plume temperature will be lower than the risk temperature and will pose no risk to helicopters.
Therefore the temperature of the plume will not be a risk for helicopters that are flying more than 95 metres (310 feet) from the top of the stack.

Plume Depleted Oxygen Risk

Also shown in Figure 1 is the relationship (in green) between the initial exit velocity of the plume and height above the stack at which the plume is equivalent to the low oxygen risk value[4].

The result shows that for an exit velocity of 13.5 m/s (as per the RRRC stack), the maximum height above the stack where the oxygen level is depleted is 230 feet (70 metres). After 70 metres, the oxygen levels will increase to above the oxygen risk level and will pose no risk to helicopters.

Therefore, the oxygen levels of the plume will not be a risk for helicopters that are flying more than 70 metres (230 feet) from the top of the stack.

Plume Severe Turbulence Risk

The guidance[2] has also issued a severe turbulence risk table based on the temperature excess of the plume and the initial exit velocity of the plume[5]. As shown in Table 1, based on an exit velocity of 13.5 m/s and a maximum excess temperature of 155°C (based on an ambient temperature of -10°C), the maximum height of severe turbulence is approximately 165 feet (**50m**)).

| | | **Temperature Excess (°C)** | | | | |
|---|---|---|---|---|---|---|
| | | **0** | **100** | **200** | **300** | **400** |
| **Initial Vertical (m/s)** | **5** | 0 | 0 | 0 | 0 | 0 |
| | **10** | 62 | 62 | 0 | 144 | 176 |
| | **15** | 111 | 144 | 193 | 242 | 275 |
| | **20** | 144 | 193 | 275 | 340 | 373 |
| | **25** | 176 | 258 | 340 | 422 | 488 |

**Table 1** Maximum Height In Above The Stack (ft) Where Severe Turbulence Could Be Experienced For A Stack Diameter Of 3m (Source: Mitre (2012))

Therefore, the turbulence levels of the plume will not be a risk for helicopters that are flying more than 50 metres (165 feet) from the top of the stack.

[4] The scenario outlined is of a single exhaust stack plume of 10m diameter, an exhaust temperature of 200°C (473K), an oxygen content of 0% $O_2$, 273K ambient temperature, calm winds and an exit velocity varying from 5 m/s to 30 m/s. Thus, the particular example is worst-case as the RRRC stack will have an oxygen content of approximately 5%.

[5] The scenario outlined is based on a 3m diameter. The RRRC stack is 2.3m and thus the scenario in Table 1 will over-estimate the buoyancy and impact of the plume.

**Modelling Plume Dilution Using AERMOD**

The USEPA approved AERMOD model, which was used in the Air Quality Assessment for the project, was re-run using a 3-Dimensional receptor grid ranging from 100m – 500m in height in order to determine the worst-case dilution of the plume in the region above the RRRC. The maximum impact occurs very near the stack at a receptor height of 105m O.D.(30m above stack) with concentrations at 255m – 405m O.D.(180m – 330m above stack) significantly lower than the maximum levels.

Using the dilution rate derived from this modelling, an estimate of the decrease in temperature of the exhaust plume with distance downwind can be calculated. The calculation below is based on an initial emission rate of 1 g/s and assuming, as a worst-case, an ambient temperature of 30°C (303.15K):

Temperature Dilution Of RRRC Exhaust Plume

Emission rate of 1g/s (equivalent to an emission concentration of 25,300 $\mu g/m^3$)

- Downwind Exhaust Plume Centreline Concentration:
  - 100m (30m from stack top) – 1048 $\mu g/m^3$ (dilution factor – 24)
  - 200m (130m from stack top) – 66 $\mu g/m^3$ (dilution factor – 383)

- Plume Temperature at 100m (30m from stack top) (ambient temperature = 30°C (303.15K), exhaust temperature = 145°C (418.15K):
  = 303.15K + (418.15K – 303.15K) / 24
  = **307.9K (34.75**°C) (30m from stack top)

- Plume Temperature at 200m (130m from stack top) (ambient temperature = 30°C (303.15K), exhaust temperature = 145°C (418.15K), :
  = 303.15K + (418.15K – 303.15K) / 383
  = **303.5K (30.35**°C) (130m from stack top)

Again, using the same dilution rate, an estimate of the increase in oxygen content can be calculated:

Oxygen Content Dilution Of RRRC Exhaust Plume

- Exhaust plume oxygen content at 30m from stack (ambient oxygen level is 20.9% and initial plume oxygen level is 5.5%):
  = ambient $O_2$ – (ambient $O_2$ – stack $O_2$) / dilution rate
  = 20.9% - (20.9% – 5.5%) / 24
  = **20.3% at 30m from stack**

- Exhaust plume oxygen content at 200m (ambient is 20.9%)
  = 20.9% - (20.9% – 5.5%) / 383
  = **20.3%**= **20.86% at 130 m from stack**

The results above indicate that at a distance of 30m from the stack top, both temperature and oxygen content are close to ambient conditions. By 130m from stack top, levels are essentially indistinguishable from ambient conditions.

These estimations are in good agreement with a recent study[6] undertaken by Cambridge Environmental Research Consultants (CERC) in the UK using the CERC developed ADMS-5 model which has the capability of modelling plume temperature as a function of time and distance from the stack. The report assessed the impact of an Energy from Waste plant in the UK on a nearby airstrip. The report found that the maximum calculated temperatures were calculated to occur very close to the stack and that beyond 10m from the stack, the maximum increase in temperature due to the plume from the stack is always less than 10°C above ambient levels.

**Summary**

In summary, based on the worst-case analysis outlined above, the maximum risk height for each of the three parameters is:

- Risk height for elevated temperature – **100 metres**
- Risk height for depleted oxygen – **70 metres**
- Risk height for severe turbulence – **50 metres**

Thus, the exhaust plume from the RRRC stack will be in compliance with the recommended levels for turbulence, temperature and oxygen content within 100m of the stack top and thus is within the 500 feet (150m) radius which is required in order to comply with the physical structure exclusion zone.

[6] CERC (2015) Dispersion Modelling Assessment Of Temperature Impact of EfW Stack Plume On Flight Paths At Duxford Airfield