The Environmental Protection Group Ltd
Warrington Business Park
Long Lane
Warrington
WA2 8TX

T: 01925 652980
F: 01925 652983
W: www.epg-ltd.co.uk
E: consultantrequest@epg-ltd.co.uk

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Tony Tough
VertaseFLI Limited
Number One
Middlebridge Business Park
Bristol Road
Portishead
BS20 6PN

Ref: EPG/2011/Upper Heyford, VFLI/R005/1

Dear Tony

Upper Heyford, Venting Capacity of POLs

Please find below our risk assessment relating to ventilation of the Type 1 tanks that form part of the petrol, oil and lubricant (POL) system at the above site. The assessment is based on the following approach:

1. Assessment of vapour emissions into the tank atmosphere – this has assumed that contaminated water could enter the tanks, which from the statements made in Waterman's Report seems very unlikely. Their assessment of groundwater levels compared with the tank base levels has determined that there is a risk to only two tanks (23A and 25A). The remediation solution for these two tanks is to fill them with PFA to a minimum depth of 1m above the tank base to remove the risk of groundwater ingress. Nevertheless the assumption made is that contaminated water could be present 0.5m below the surface of the PFA partial infill for these two tanks, the remaining 7 being completely empty. Migration of vapours into the free air space of the two partially filled tanks has used the equations that form the basis of the Johnson and Ettinger model. These have been modified to suit this particular situation and consider advective and diffusive flow of vapours. It is unlikely that the tanks or any connected lines are a significant source of vapour after they have been cleaned out and degassed.

2. Estimation of the fresh air flow required through the tank to maintain the vapour concentration within it below explosive levels. The assessment assumes the tanks will not be entered unless stringent precautions have been taken to ensure the atmosphere is acceptable beforehand. The design concentration has been taken as 20% LEL and it is assumed the tanks are not to be entered as a routine. The method used is widely used in ground gas risk assessment and also forms part of the Johnson and Ettinger vapour risk assessment model.

3. Estimation of the capacity of the current venting layout. This uses the guidance provided in BS 5925. The current vent provision is summarised on the attached schedule of POLs. Photos of the three vent types that are provided to the POLs are also attached.

The indicator labels on the Type 1 tanks suggest that they were used to store JP-8 aviation fuel. This was used by the US Military and replaced the previous commonly used fuel JP-4. JP-8 was used to increase combat survivability because it is less volatile and less flammable than JP-4. The LEL of JP-8 is typically around 0.6% and the upper explosive limit is 5.6%. These values have been used in the assessment to derive the acceptable concentration of vapour within the tanks.

Typically the principle components of JP-8 are:

C8– C9 aliphatic hydrocarbons, vol % ˜ 9%
C10–C14 aliphatic hydrocarbons, vol % ˜ 65%;
C15–C17 aliphatic hydrocarbons, vol % ˜ 7%;

Therefore we have based our assessment on the C10 to C12 aliphatic band of hydrocarbons (ie the lighter end of the C10 to C14 range) as this is the predominant constituent of the fuel that was stored in the tanks.

The tanks have been cleaned out and degassed. All lines have also been cleaned out and/or severed to isolate them from the tanks. The risk of vapour migration back into the tanks from this source is therefore negligible. The tanks were partially filled with water after RAF Upper Heyford was closed. The standing water has been present since about 1994. TPH concentrations of standing water in the tanks measured in 2008, before the current operations started, were between 0.74mg/l (POL24) and 85mg/l (POL21A).

The tanks are still intact and would be expected to be reasonably watertight. The only conceivable risk is if groundwater contamination could migrate back into the tanks and cause vapours inside them. As stated previously Waterman have determined that this risk is credible only for POL23A and 25A.

The venting assessment assumes that contaminated groundwater has migrated into the PFA fill inside the two filled tanks (unlikely so very conservative). It assumes that the contamination volatilises and produces a vapour concentration within the PFA fill (using the partitioning equations from the CLEA software which are known to be very conservative). The flow of vapour from the PFA into the tank airspace is modelled for both diffusion and advection. The ventilation is modelled using the approach recommended in BS8485: 2007 *Code of practice for the characterisation and remediation from ground gas in affected developments*.

Although the assessment has made some fairly significant assumptions about the composition of the contamination, the results show that even with the most conservative of parameters the current layout of 150mm vent pipes provide sufficient ventilation to maintain vapour concentrations below 20% of the LEL for JP-8 fuel. The results are summarised below:

1. Estimated flow of vapour into tank air space by advection = $1.34 \times 10^{-6} m^3/s$

2. Estimated flow of vapour into tank air space by diffusion = $8.76 \times 10^{-6} m^3/s$

3. Maximum flow of vapour that current vents can maintain internal concentration below 20% LEL = $1.69 \times 10^{-5} m^3/s$

The calculations are attached to this letter and show that the current level of ventilation is acceptable. For the tanks that are left empty there is negligible risk of groundwater migration into them. There is no other source of significant contamination within them after cleaning and therefore the venting for those tanks is also acceptable.

There is one POL where the vent cover may impeded the ventilation (POL22) the covers should be removed and replaced with a free venting cover that is sufficient to prevent entry of large objects into the vent pipe and also to stop rainfall entering the tanks. A simple mesh cover with a raised cover will be suitable.

Please do not hesitate to contact me if you have any questions.

Yours sincerely

Steve Wilson

Technical Director

On behalf of The Environmental Protection Group Limited

Tel 07971 277869

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POL Schedule

Photos

Calculations

TYPE 1 Tanks - Summary for ventilation solutions

POL Ref	Tank Ref (Facility No.)	Tank Volume (m3)	Vent Type	Number Functional	Number requiring repair	Volume / Comments
POL 21	21A	736	Cowl	1		736
POL 21	21B	736	Cowl	1		736
POL 21	21C	1,453	Cowl	1		1,453
POL 22	22	1,457	Cowl	2	1	1,457
POL 23	**23A**	**3,640**	Mushroom Tall	2		4,440 - 800 PFA Fill = 3,640
POL 23	23B	1,947	Mushroom Short	2		1,947
POL 24	24	4,754	Mushroom Short	2		4,754
POL 25	**25A**	**3,700**	Mushroom Short	2		4,508 - 800 PFA Fill = 3,700
POL 25	25B	4,503	Mushroom Short	2		4,503

Cowl Vent has no side mounted exhaust

Upper Heyford

Photos of vents to POLs

Cowl vent (POL 21A, 21B, 21C and 22)

Tall mushroom vent (POL23A

Short mushroom vent (POL 23B, 24, 25A and 25B)

Upper Heyford - POLs

Modified Johnson and Ettinger approach — C10 to C12 Aliphatic

			Site specific parameters	Comments
Advective flow into tank				
	$$Q_v = \frac{\Delta P \, x \, k_v \, x \, A_{conc}}{\mu \, x \, Z_{conc}} x C_{source}$$			Similar approach to J&E (ie advection into building) but based on site specific tank details Limiting factor is flow through tank wall
ΔP	Pressure difference between inside of tank and the surrounding soil	$g/cm\ s^2$	10	Conversion from value in Pa in cell D41
		Pa	1	Tanks are not air tight therefore stack effect will not be signficant
k_v	PFA permeability to vapour flow (intrinsic permeability)	cm^2	1.02E-09	K_v (m^2) = K_{darcy} x 1.02 x 10^{-7} (m/s)
	Darcy permeability	m/s	1.00E-06	Permeability of PFA infill to tank (worst case)
μ	Viscosity of air	g/cm s	1.80E-04	
Z_{conc}	Thickness of PFA infill above water table in surrouding ground	cm	50	0.5m minimum
ΔP	Pressure difference between inside of tank and ground	$g/cm\ s^2$	10	
k_v	Floor slab permeability to vapour flow (intrinsic permeability)	cm^2	1.02E-09	
A_{conc}	Area of cracks	cm^2	8.00E+06	Assume contaminated water is within PFA fill over tank area
μ	Viscosity of air	g/cm s	1.80E-04	
Z_{crack}	Thickness of PFA fill	cm	50	
Q_{soil}	**Volumetric inflow of soil air into tank**	**cm^3/s**	**9.07E+00**	
		m^3/s	**9.07E-06**	
Q_v flow of vapour into tank	**= Q_{soil} x C_{source}**	**g/s**	**9.71E-03**	**Advective flow of vapour into tank**
		m^3/s	**1.33508E-06**	

Rate of mass transfer by diffusion

E, Rate of mass transfer by diffusion (g/s)

$$E = \frac{A_B\left(C_{source} - C_{g0}\right)D^{eff}}{L}$$

A_B	Cross sectional area of diffusive flow path	cm^2	8.00E+06	Assumed to be plan area of tank 32m diameter
C_{source}	Vapour concentration in soil	g/cm^3	0.00107088	Vapour concentration at source is determined in same way as in J&E model
C_{g0}	Vapour concentration at top of PFA	g/cm^3	8.80E-06	Equilibrium concentration from venting = 0.12%
D^{eff}	Effective diffusion coefficient of soil	cm^2/s	0.000278489	D^{eff} is calculated in same way as in J&E method
L	Length of migration pathway (depth to source in soil)	cm	50	Depth from PFA surface to standing water in tank (assuming it will rise again)
	Vapour density	kg/m^3	5.4	For kerosene (similar to JP-8)
E	**Rate of mass transfer by diffusion**	**g/s**	**0.04732442**	Diffusion of vapour through PFA fill
		m^3/s	**8.76E-06**	Assuming standing water in tank is all at 85mg/l TPH concentration

Effective diffusion coefficient through soil

D^{eff}	$$= \frac{\theta_v^{3.33}}{\theta^2{}_T} D^{air} + \frac{1}{H} \frac{\theta_w^{3.33}}{\theta^2{}_T} D^w$$				
θ_v	Volumetric content of soil vapour	cm^3 - vapour/cm^3 -	0.034		PFA with small quantity of cement. Pozzolanic reactions will fill pore spaces with gel. Use CLEA values for concrete
θ_w	Volumetric content of soil pore water	cm^3 - water/cm^3 - s	0.034		PFA with small quantity of cement. Pozzolanic reactions will fill pore spaces with gel. Use CLEA values for concrete
θ_T	Total volumetric content of pore space in soil	cm^3 /cm^3 - soil	0.068		
D^{air}	Diffusion coefficient in air - chemical specific	cm^2/s	0.1	C10 to C12	Mole Valley TPH published data
D^w	Diffusion coefficient in water - chemical specific	cm^2/s	1.00E-05	C10 to C12	Mole Valley TPH published data
H	Henry's Law constant - chemical specific	(cm3-H2O)/(cm3-a	38.8	C10 to C12	Mole Valley TPH published data
D^{eff}	**Calculated value**	**cm^2/s**	**0.000278489**		

Concentration of vapour in soil at source due to vapour phase partitioning

		Chemical	C10 to C12		
C_{source}	Vapour concentration in soil	g/cm^3			
	$$C_{source} = h C_w$$				
C_w	Initial groundwater concentration	g/cm^3	0.0000276		
		mg/l	27.6		32.5% of 85mg/l maximum TPH recorded in standing water in tanks (C10 to C14 is 65% of typical JP-8 makeup)
ρ_b	Soil dry bulk density	g/cm^3	1.4		PFA
h	Henry's Law constant - Chemical specific	Dimensionless	38.8	C10 to C12	Mole Valley published data
θ_a	Soil filled air porosity = θ_v - see below	cm^3/cm^3	0.034		
θ_w	Soil water air porosity	cm^3/cm^3	0.034		
K_d	Soil -water partion coefficient = K_{oc} x f_{oc}	cm^3/g	7535.64		
K_{oc}	Soil organic carbon partition coefficient	cm^3/g	251188	C10 to C12	
f_{oc}	Soil organic carbon weight fraction		0.03		For PFA
C_{source}	**Vapour concentration in soil**	**g/cm^3**	**1.07E-03**		
		mg/m^3	1.07E+06		

Conversion of vapour concentration to ppm

Volumetric concentration (mg/m^3)	= C_{ppm} (12.187 x MW)/(273.15 + T) - at an ambient pressure of 1 atmosphere.				
Volumetric concentration (mg/m^3)		mg/m^3	1.07E+06		
MW	Molecular weight of the gas or vapour.		160	C10 to C12	
T	Ambient temperature	^oC	10		Typical in ground temperature
C_{ppm}	Concentration of gas or vapour in ppm	ppm	147251.20		

Site:	Upper Heyford		
Location:	Oxfordshire	**Reference:**	0
Client:	Vertase FLI	**Calculation by:**	SAW
Structure:	Type 1 POL	**Checked by:**	SAW

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Tank data			**Source of information/justification:**
Tank volume	4754	m^3	From Waterman Report maximum volume of Type 1 POL
Height of vents	6	m	Height of vents above surrounding ground level (ground at base of earth bund)
Sensitivity	Low		
Overall FOS required	1		
Diluted equilibrium gas concentration required (c_e)	0.12	%	20% LEL of JP-8 jetfuel

Wind data:			
Category of terrain	Country		
Type of exposure	Sheltered inland		
Proportion of time wind speed is exceeded	80		
Wind direction	West		
Value of mean wind speed U_{50}	4	m/s	*BS 5925:1991 Figure 5 contours of u_{50} for the UK*
Correction ratio	0.46		

Venting data:

outlets:

Type of vent	Existing vent to tank with various covers (mushroom and domes)		
Ventilation area	17500	mm^2	Existing vents are 150mm diameter.

Ventilation:

Pipework complexity	Simple	
Discharge coefficient for sharp edges, *(C_d)*	0.61	
Pressure coefficient, *(ΔC_p)*	0.6	

Site:	Upper Heyford		
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Generic calculations: | **Source of information/justification:**

Reference wind speed:

Calculating reference wind speed, u_r, based on BS 5925:1991 using $u_r = u_m K z^a$

Where: u_r = reference wind speed at height z (m/s)

u_m = (u_{50} x correction ratio) obtained from table 9, based on location and given proportion of time wind speed to be exceeded (m/s)

K & a = constants dependant on terrain (obtained from table 8)

z = height of vent (m)

So:	Determine correction ratio from Table 9	0.46		*BS 5925:1991 Table 9*
	Therefore corrected wind speed $u_m = u_{50}$ * (6) =	1.84	m/s	
	Determine factor *K* from Table 8	0.68		*BS 5925:1991 Table 8 for open flat country*
	Determine exponent *a* from Table 8	0.17		*BS 5925:1991 Table 8 for open flat country*
	Therefore reference wind speed $u_r = u_m * K * z^a$ =	**1.70**	**m/s**	

Allowable emissions into tank using existing vents:

Calculating fresh air flow through tank via existing vents, based on BS 5925:1991, using $A_v = Q/(C_d u_r (\Delta C_p)^{0.5})$

Where:	A_v = area of ventilation	17500	mm^2
	C_d = discharge coefficient	0.61	
	u_r = reference wind as calculated	1.697	m/s
	ΔC_p = pressure coefficient	0.6	
So:	Q = air flow through tank	0.0140	m^3/s

Site:	0		
Location:	0	**Reference:**	0
Client:	0	**Calculation by:**	0
Structure:	0	**Checked by:**	0

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Calculating maximum emssions for existing air flow, based on CIRIA 149 using Q=F(100-ce)/ce

Where:	Q = total air flow through tank (m^3/s)	0.0140	m^3/s
	c_e = required equilibrium concentration	0.12	%
So:	F = Flow of vapour into tank	1.69E-05	m^3/s
Inflow of vapour that venting can cope with inc FOS		**1.69E-05**	**m^3/s**