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in modern dispersion models**

by

**D.J. Thomson and P.J. Tonkinson**

**Headquarters, Bracknell**

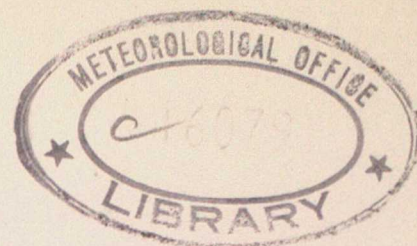
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## Using Met Office Pasquill-Stability analyses in modern dispersion models.

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18<sup>th</sup> December 1992

The Met Office has for some time been producing data on the Pasquill Stability  $\mathcal{P}$  for use in dispersion applications. Here we provide a method of obtaining estimates of the surface sensible heat flux  $F_{\theta 0}$  from  $\mathcal{P}$  for use in modern dispersion models such as the UK Atmospheric Dispersion Modelling System (UK-ADMS) currently under development by Cambridge Environmental Research Consultants Ltd. (CERC), National Power and the Met Office (Carruthers et al 1991). With the aid of this method, UK-ADMS could be run using data on wind speed, direction,  $\mathcal{P}$  and boundary layer depth  $h$  (and rainfall if wet deposition estimates are required and both sea surface temperature and near surface temperature over land or the difference between them if the coastline module is to be used), or even on just wind speed, direction and  $\mathcal{P}$  as UK-ADMS will make an estimate of  $h$  if this isn't provided. It should be emphasised however that, as a consequence of the approximations involved in such an approach, results are likely to be inferior to those obtained using data which is obtained without using  $\mathcal{P}$  as an intermediate step. It should also be pointed out that the schemes the Met Office will use to estimate  $F_{\theta 0}$  and  $h$  in analyses carried out for UK-ADMS are different (hopefully improved) from those used in the standard Pasquill-Stability and boundary layer depth analyses, and this will be a further cause of differences in results.

Two distinct methods are used by the Met Office to estimate  $\mathcal{P}$ . The first method deduces  $\mathcal{P}$  from  $F_{\theta 0}$  and wind speed  $U$  during the day (solar elevation  $> 0$ ) and from  $U$  and 'modified' cloud amount  $N_m$  at night (the 'modification' to the cloud amount is to account for the different effect of clouds at different heights and is based on Nielsen et al (1981)). The equations used are

$$\mathcal{P} = 7 - [2.26 + 0.019(\hat{U} - 5.6)^2][0.1\hat{F}_{\theta 0} + 2 + 0.4\hat{U}^{3/2}]^{[0.28 - 0.004(\hat{U} - 2)^2]} \quad (1)$$



during the day and

$$\mathcal{P} = 3.6 + \frac{120 - 13.3N_m}{27 - 2N_m} \exp\left(-\frac{3}{8}\hat{U}\right) \quad (2)$$

at night. Here  $\hat{U} = \min(U, 8)$ ,  $\hat{F}_{\theta 0} = \max(F_{\theta 0}, 0)$  with  $U$ ,  $F_{\theta 0}$  and  $N_m$  measured in m/s,  $W/m^2$  and oktas respectively. The daytime formula is an expression fitted by Farmer (1984) to the curves given by Smith (1973) (see also Pasquill and Smith (1983, p337)), while the nighttime formula is a proposal of Smith (1983 - unpublished) which is reported in Farmer (1984). Both formulae are plotted in figure 1.  $F_{\theta 0}$  is determined using a scheme based on Berkowicz and Prahm (1982) and Nielsen et al (1981).  $\mathcal{P}$  is then converted to a letter as follows

numeric $\mathcal{P}$	alphabetic $\mathcal{P}$
$\mathcal{P} < 1$	A
$1 \leq \mathcal{P} < 2$	B
$2 \leq \mathcal{P} < 3$	C
$3 \leq \mathcal{P} < 4$	D
$4 \leq \mathcal{P} < 5$	E
$5 \leq \mathcal{P} < 6$	F
$6 \leq \mathcal{P}$	G

The second scheme, described in Farmer (1984), uses  $U$  (in knots) and total cloud amount  $N$  (in oktas). During the day the incoming solar radiation  $K$  (in  $W/m^2$ ) is estimated as  $880sf(N)$  where  $s$  is the sine of the solar elevation and  $f$  takes the following values

$N$ :	0	1	2	3	4	5	6	7	8
$f(N)$ :	1.07	0.89	0.81	0.76	0.72	0.67	0.59	0.45	0.23

(see Smith (1973)). If  $s < 5/44$  the Pasquill Stability is taken to be category  $D$  (this is intended to account for times within about 1 hour of dawn and dusk). Otherwise the Pasquill Stability is estimated using the following table:

TABLE 1	$N = 8$	$N < 8$		
		$K < 300$	$300 \leq K < 600$	$600 \leq K$
$U \leq 3$	C	B	A-B	A
$3 < U \leq 5$	C	C	B	A-B
$5 < U \leq 9$	C	C	B-C	B
$9 < U \leq 12$	D	D	C-D	C
$12 < U$	D	D	D	C

During the night  $\mathcal{P}$  is estimated directly from  $U$  and  $N$  using the following table:



TABLE 2	$N = 0, 1$	$N = 2, 3$	$N = 4, 5, 6, 7$	$N = 8$
$U \leq 1$	G	F	F	D
$1 < U \leq 3$	F	F	F	D
$3 < U \leq 5$	F	F	E	D
$5 < U \leq 9$	E	E	D	D
$9 < U$	D	D	D	D

For  $\mathcal{P}$  calculated with the first scheme, it is relatively easy to estimate  $F_{\theta 0}$ . First  $\mathcal{P}$  is converted back to a numeric value as follows

alphabetic $\mathcal{P}$	numeric $\mathcal{P}$
A	0.5
B	1.5
C	2.5
D	3.5
E	4.5
F	5.5
G	6.5

For unstable conditions (i.e. for  $\mathcal{P} = A, B$  or  $C$  or, in the numeric equivalent,  $\mathcal{P} = 0.5, 1.5$  or  $2.5$ ) we can assume equation (1) has been used. This is easily inverted to give

$$F_{\theta 0} = \min[300, 10(r - 2 - 0.4\hat{U}^{3/2})] \quad (3)$$

where

$$r = \left( \frac{7 - \mathcal{P}}{2.26 + 0.019(\hat{U} - 5.6)^2} \right)^{1/[0.28 - 0.004(\hat{U} - 2)^2]}$$

Because accuracy has been lost in converting  $\mathcal{P}$  to a letter and then back to a number it has been necessary to limit  $F_{\theta 0}$  to  $300 \text{ W/m}^2$  in (3). Without the limitation on  $F_{\theta 0}$  it is possible to obtain some unrealistically large heat fluxes. In near-neutral conditions (i.e.  $\mathcal{P} = D$ ) we recommend taking  $F_{\theta 0} = 0$ . Finally for stable conditions (i.e.  $\mathcal{P} = E, F$  or  $G$  or, in the numeric equivalent,  $\mathcal{P} = 4.5, 5.5$  or  $6.5$ ) we can assume equation (2) has been used. In this case (2) can be easily inverted to give  $N_m$  using

$$N_m = \begin{cases} 0 & r \geq 4.44 \\ \frac{120 - 27r}{13.3 - 2r} & 1.24 < r < 4.44 \\ 8 & r < 1.24 \end{cases}$$

where

$$r = (\mathcal{P} - 3.6) \exp\left(\frac{3}{8}\hat{U}\right).$$



As in (3) we have applied corrections for the loss of accuracy in  $\mathcal{P}$ .  $F_{\theta 0}$  can then be estimated using any of the nighttime schemes which express  $F_{\theta 0}$  in terms of cloud amount and wind speed. UK-ADMS has such a scheme (due to Holtslag and van Ulden (1982)) built in and the user could simply supply  $U$  and  $N_m$  to the model together with a time of day and year (these times need not be correct but must be such as to allow the model to deduce that it is nighttime).

For the second scheme a different approach must be adopted. In unstable conditions, table 1 can be approximately inverted (ignoring the  $N = 8$  column) to give  $K$  in terms of  $U$  and  $\mathcal{P}$ .  $F_{\theta 0}$  can then be estimated using Smith's (1973) formula,  $F_{\theta 0} = 0.4(K - 100)$ . The result is the following table of  $F_{\theta 0}$  values:

TABLE 3	A	A-B	B	B-C	C	C-D
$U \leq 3$	260	140	20	(15)	10	(5)
$3 < U \leq 5$	(300)	260	140	(80)	20	(10)
$5 < U \leq 9$	(300)	(300)	260	140	20	(10)
$9 < U \leq 12$	(300)	(300)	(300)	(300)	260	140
$12 < U$	(300)	(300)	(300)	(300)	260	(140)

Here we have assumed  $K = 150$ ,  $K = 450$  and  $K = 750$  for the classes  $K < 300$ ,  $300 \leq K < 600$  and  $600 \leq K$  and have interpolated and extrapolated the  $F_{\theta 0}$  values, subject to  $F_{\theta 0}$  not exceeding  $300 \text{ W/m}^2$ . Of course some combinations of  $U$  and  $\mathcal{P}$  should not occur – these are indicated by parentheses. In near-neutral conditions we adopt  $F_{\theta 0} = 0$ , as for the first scheme. Finally in stable conditions table 2 can be approximately inverted to give  $N$ :

TABLE 4	E	F	G
$U \leq 1$	(8)	4.5	0.5
$1 < U \leq 3$	(8)	3.5	(0)
$3 < U \leq 5$	5.5	1.5	(0)
$5 < U \leq 9$	1.5	(0)	(0)
$9 < U$	(0)	(0)	(0)

As for  $F_{\theta 0}$ , we have extrapolated the  $N$  values, subject to  $N$  lying in  $[0, 8]$  and have indicated combinations of  $N$  and  $\mathcal{P}$  which should not occur by parentheses. As for the first scheme,  $F_{\theta 0}$  can then be estimated using any of the nighttime schemes which express  $F_{\theta 0}$  in terms of cloud amount and wind speed.



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## Figure captions

Figure 1: Pasquill Stability  $\mathcal{P}$  as a function of wind speed and surface sensible heat flux during the day (figure 1(a)) and of wind speed and cloud amount at night (figure 1(b)).



Figure 1(a)

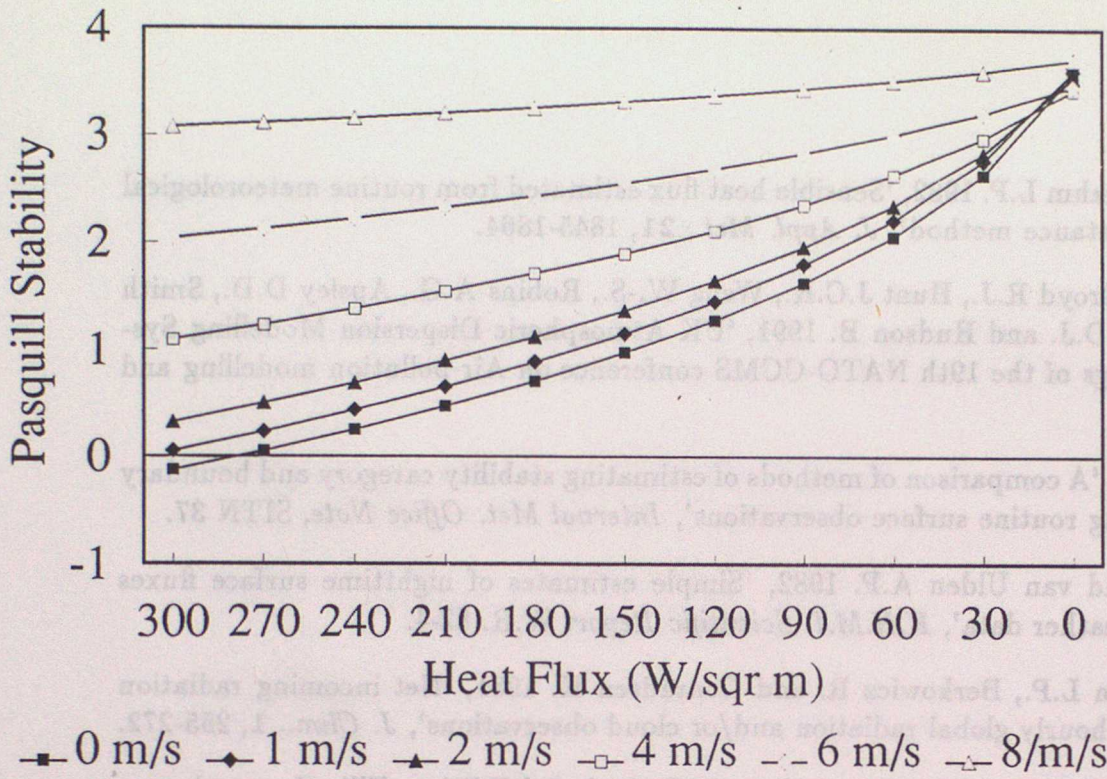




Figure 1(b)

