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높은 연돌에서 배출된 環型煙과 沒入(trap)型煙이 최초로 땅에 닿는 지점까지의 거리

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The Distance from Source to the point of Looping and Trapping Plumes First Touching Ground Down-wind of a Tall Stack

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환형연과 trap형연의 최초 着地거리와 풍속간의 관계를 설정하고 요동하는 연기의 연돌에 가장 가까운 착지를 예보하기 위해서 호주의 지형이 평탄한 Mt. Isa에서 영화촬영기를 사용하여 연기확산에 관한 가시기록을 확보하였으며 관련 기상 자료와 연결지어 그 기록을 처리해서 얻은 결론은 다음과 같다.

1) 평탄한 지형에서의 환형연의 최초 착지거리와 풍속간의 직선 비례 상관식의 비례상수는 약 0.5이다.
2) Trap형연의 최초 착지거리중 최소치는 약 연돌높이 정도인것 같다.

ABSTRACT

In order to establish the relationship of the distance of looping and trapping plumes' first touching ground with wind speed and to predict the closest ground level approach of fluctuating plumes, a visual record of plume dispersion at Mt. Isa, Australia, where terrain is flat, was provided by using a movie camera.

As results of the treatment of the record in connection with meteorological data associated, following conclusions were drawn;

1) The proportional constant of a linear relationship between wind speed and the distance of looping plume's first touching ground over flat terrain is about 0.5.
2) The minimum distance of trapping plume's first touching ground appears to be around stack height.

1. Introduction

Time mean concentration measurements are usually necessary and the general practice of sampling times of the order of 0.5~1 hour was recommended. These values are derived from meteorological considerations and are relevant to a consideration of the effects of pollution.

Therefore chimney design should be based on the probability of producing certain ground level concentrations.

However, for some purposes it is considered that it is only necessary to measure or calculate maximum concentration under specified meteorologcal conditions and to use this as an index of comparison with other chimneys.[1]

As the worst conditions of plume behavior fumigation, trapping and looping are generally considered. Though looping and trapping plumes are of somewhat lower concentrations at a given distance from the source than under fumigation conditions,[2] looping and trapping can produce high surface concentrations when stacks are low.[3]

Looping occurs under superadiabatic conditions with moderate to high wind speeds and large convective mixing.[3]

Again this plume type can occur under anticyclonic and cyclonic weather types.

Trapping may occur at any time of the day in any season and is associated with subsidence inversions or with warm frontal inversions.

According to Moore, D.J. (1974)[4] the distance from source to the point of maximum ground level concentration is a complex function of the rate of emission of plume from chimney, plume height, reflection reflection parameter taking account of different dispersive powers of atmosphere above and below plume level, a dimensionless constant relating σ_y to distance from source, atmospheric diffusivity, wind speed averaged over plume depth and wind speed at reference height. However the formula made by Moore, D.J. in order to calculate the distances of maximum ground level concentration has failed in expressing the variation of the distance with wind speed.

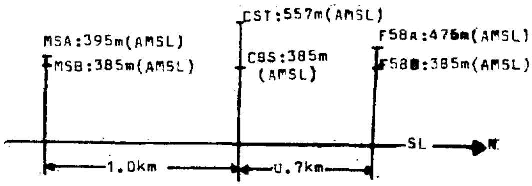
For looping and trapping plumes, the maximum ground level concentration averaged for short time may be built up at the point of plume's first touching ground because once bounded plumes continue to be diffused. Actually the duration of looping and trapping plumes' first touching ground, discussed in this paper, was around 1 to 2 minutes. Though the duration is much shorter than ordinary averaging time of ground level pollutants concentration, SO_2 of very high concentration from copper smelter cause significant impact on environment and human health since air pollution effects except eye irritation, taste and odour have been found to be proportional to exceeded dosage expressed as the prodct of pollutants concentration exceeing threshold limit and exposure duration.

This paper was made to find out the relationship of the distance of looping and trapping plumes' first touching ground with wind speed and to predict the closest ground level approach of fluctuating plume.

2. Data description

2.1. Raw data acquisition

The division of process technology, C.S.I.R.O., Australia, from which the available material for making this paper was obtained, operated a time-lapse movie camera 8km apart from stack in order to provide a visual record of plume dispersion at Mt. Isa where terrain is homogeneously flat. One frame was exposed about every 9 seconds.[5] Meteorological data including wind data measured at 10m and 91m height above ground were given by the Mt. Isa Mines' weather station. By correlating observed changes in wind direction as they affect the plume with the five minutes averages of wind direction it was possible to infer the time the photographs were taken with reasonable precision.



SL ; Sea Level
AMSL ; Above Mean Sea Level
MSA ; Meteor. Station Anemometer Altitude
MSB ; Meteor. Station Base Altitude
CST ; Copper Stack Top Altitude
CSB ; Copper Stack Base Altitude
F58A ; F58 Anemometer Altitude
F58B ; F58 Base Altitude.

Fig. 1. Altiude associated with wind profile

The measurements are restricted to periods when the plume direction is approximately across the line of sight of the camera.

Wind observation stations are located within about 1km from copper smelter stack and there is not any significant physical obstruction between observation stations interfering the vertical distribution of wind. Altitude associated with wind profile and the relative positions of stack and wind observation stations are shown in *Fig. 1*.

2.2 Data treatment

The distance between two known stacks serves as a reference scale for distance. Trigonometric corrections are applied to this scale and to the observations of closest ground level approach of plumes to allow for non-orthogonality to the line of sight. Wind profiles were determined by using equation (1).

$$U_z = U_{10} \cdot \left(\frac{z}{10}\right)^P \quad (1)$$

where z ; height in m

U_z ; wind speed at z in m/sec

U_{10} ; wind speed at height 10m in m/sec

P ; exponential parameter

However, even at low level atmosphere over open country or rural areas the power law of wind profile does not apply if wind speed at high altitude is slower than that at low altitude as shown in *Fig. 3*.

Since plumes were observed to approach the ground in a nearly straight line, mean speed of wind affecting the plume from surface to the top of stack was determined as shown in *Fig. 2.* when the exponential parameter of power law of wind profile is greater than 0.05 under consideration of Touma's work.[6]

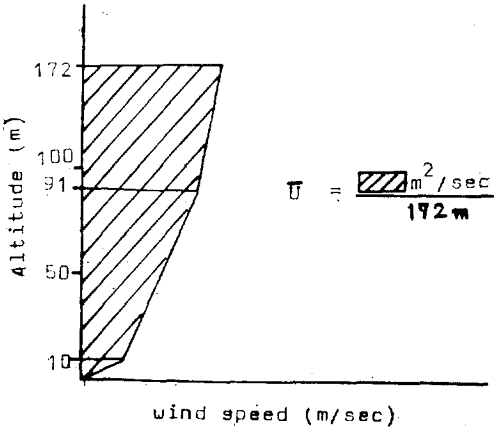


Fig. 2. Determination of mean of mean wind speed.

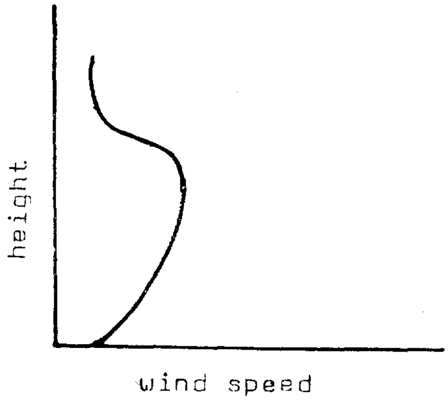


Fig. 3. Typical wind profile for trapping plume.

Stack height is 172m and plume rises were negligible compared with stack height. Again the distances from stack to the point of effective stack height established were negligihle compared with those of plumes' first touching ground. Actually plume rises ranged from about 10 to 20m and Davidson-Bryant equation, expressed in equation(2), appeared to be best suitable for calculation of plume rises at atmospheric conditions discussed here.

$$\Delta H = d\left(\frac{V_s}{U}\right)^{1.4} \cdot \left(1 + \frac{\Delta T}{T_g}\right) \qquad (2)$$

where ΔH ; plume rise in m

d ; inside diameter of stack in m

U ; wind velocity at the top of stack in m/sec

V_s ; stack gases velocity in m/sec

ΔT ; temperature of effluent gases over ambient air in ^{0}k

T_g ; stack gas temperature in ^{0}k

In cases the wind speed at 91m is slower than that at 10m and the value of power of wind profile is smaller than 0.05, wind speed at 91m height above ground was used as representative one under consideration that elevated stable layer was established and no other method to determine really representative wind speed with available data does exist. Wind profiles in such cases are abnormal even at low level as shown in *Fig. 3.* and such wind profiles are typical when plumes are trapping.[3]

Insolation data were indirectly obtained from 5minutes average temperature data by using approximately linear relationship between incoming solar radiation and temperature measured at Mt. Isa during other period under considation that insolation data needed for determining stability classes are not necessarily to be very accurate.

Turner's stability was determined by insolation and wind speed at 10m height during day time when the sky is not overcast.[7] They can be used for studying low level dispersion problems over open country or rural areas[8] and some meteorolgists regard atmospheric layer below around 100m height as low level. However, they would not contribute to interpretation of vertical fluctuation of trapping plumes even though plumes move at low level.

Treated typical data are listed in *Table*

Table 1-1. Wind speed, stability and the distance of plume's first touching ground for looping plumes

Date	Wind speed (m/s)			Insolation	Stability		Dist.
	91m	10m	$\bar{U}$	(cal/cm². hr)	P	Turner	(m)
78. 2. 4							
1⁴ : 40	3. 86	2. 86	3. 60	36. 0	0. 16	B	331
14 : 45	2. 44	2. 00	2. 77	36. 0	0. 09	B	275
15 : 14	2. 54	1. 57	2. 23	32. 1	0. 22	A-B	291
15 : 31	2. 85	2. 15	2. 89	35. 0	0. 13	B	265
15 : 41	3. 00	1. 00	3. 77	35. 0	0. 50	A-B	213
78. 2. 25							
13 : 31	5. 17	3. 85	5. 06	43. 4	0. 13	A-B	358
13 : 52	7. 44	5. 51	7. 41	43. 4	0. 14	C-D	759
15 : 25	7. 83	3. 81	7. 32	28. 6	0. 32	B-C	703
15 : 57	6. 30	3. 69	6. 83	31. 2	0. 24	B-C	586
16 : 00	5. 72	3. 72	6. 15	33. 9	0. 20	B-C	502
16 : 25	5. 56	3. 50	5. 46	33. 9	0. 21	B-C	248

Table 1-2. Wind speed, stability and the distance of plume's first touching ground for trapping plumes

Date	Wind speed (m/s)			Insolation	Stability		Dist.
	91m	10m	$\bar{U}$	(cal/cm₂·hr)	P	Turner	(m)
78. 2. 4							
15 : 24	2. 25	2. 51	2. 25	35. 0		B	346
15 : 45	2. 22	2. 25	2. 22	35. 0		B	178
15 : 48	3. 61	3. 55	3. 61	35. 0	0. 01	B-C	147
78. 2. 25							
14 : 00	4. 22	4. 78	4. 22	43. 4		B-C	447
14 : 09	6. 99	6. 70	6. 99	37. 3	0. 02	D	792
14 : 25	3. 61	6. 17	3. 61	37. 3		D	292
14 : 27	5. 13	6. 06	5. 13	37. 3		D	314
14 : 29	6. 66	5. 95	6. 66	37. 3	0. 05	C-D	463
15 : 20	3. 83	4. 44	3. 83	30. 0		B-C	202
15 : 35	4. 28	4. 56	4. 28	31. 2		B-C	377
15 : 49	4. 68	4. 90	4. 68	33. 9		B-C	249
16 : 02	3. 32	4. 91	3. 32	33. 9		B-C	182

1-1 and *Table 1-2*

3. Analysisof data

The linear realionships between wind speed and the disthance of looping and trapping plumes' first touching ground are derived as shown in *Fig. 3-1* and *Fig. 3-2*. In order to generalize the relationship between two factors so that the relationship can apply to other cases of different stack height, perpendicular axis was expressed as a dimensionless term, a ratio of the distance to stack height.

Such linear relationship may partly be attributable to the fact that vertical atmosp-

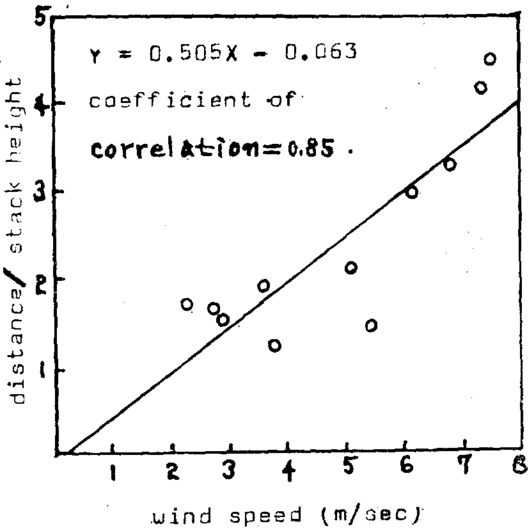


Fig. 4-1. The relationship between wind speed and the distance of looping plume's first touching ground

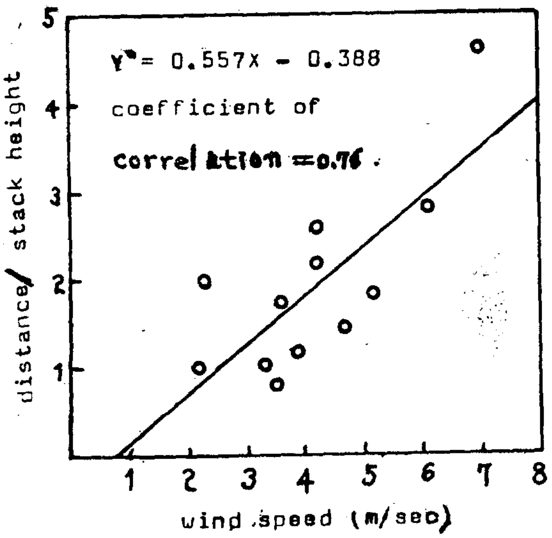


Fig. 4-2. The relationship between wind speed and the distance of trapping plume's first touching ground

heric diffusion become restricted as wind speed increase.[4]

Since mechanical turbulence and wind profile which partly influence on the vertical fluctuation of plume are affected by terrain and surface roughness, proportional constants for roll terrain and different roughness would be different from those arrearing in *Fig. 4-1* and *Fig. 4-2*. The proportional constant for looping plume over flat terrain from *Fig. 4-1* appears to be general one, but that for trapping plume from *Fig. 4-2* may need confirmation. In the cases that those data expressed in *Fig. 4-1* and *Fig. 4-2* were plotted on log-log paper correlation coefficients lowered to 0.45 and 0.63 respectively.

Though it has been known that for elevated sources maximum concentrations for time periods of few minutes occur with unstable conditions and the closest distance to the point of maximum concentrations is about 1 stack height,[7] the minimum distance of trapping plume's first touching ground also appears to be around stack height.

4. Conclusion

(1) The proportional constant of a linear relationship between wind speed and the distance of looping plume's first touching ground over flat terrain is about 0.5 and such relationship for trapping plume is also linear.

(2) The minimum distance of trapping plume's first touching ground appears to be around stack height.

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