Effect of Stack Exit Velocity and Gas Temperature on Plume rise using different equations

Dr. Akshey Bhargava

M.Tech, Ph.D. (Engineering.), LL.B
Professor, Civil Engineering, Global Institute of Engineering and Technology, Hyderabad

Abstract: **Stack Plume Rise is a conceptual phenomenon which is mainly dependent on two forces, namely, Buoyant and Momentum force. Buoyant forces are governed by temperature, heat emission rate of the stack exit gases whereas Momentum forces are governed by Stack exit gas velocity. Plume Rise is also dependent on various factors like Atmospheric wind speed, Atmospheric stability condition, and Atmospheric turbulence besides some other internal parameters like Stack gas temperature, Heat emission rate, Stack Height and Stack gas exit velocity. The Plume Rise is an important parameter in the overall air pollution control mechanism which directly interferes the dispersion of pollutant over a period of time and space, the more is the plume rise, the better would be the dispersion of air pollutants resulting into less ground level concentration of air pollutants. An effort has been made in the present research paper to optimize the Plume Rise using various equations that are employed to estimate the Plume Rise under different stability conditions, and also Effect of changes of Stack Exit Velocity and Gas Temperature**

Introduction:

There are different equations used for estimating Plume Rise, the details of which are given here under:

1. Carson and Moses equation:

- **Carson equation for unstable condition:**

  □h = 3.47 vs. d/u + 5.15 Qh^0.5/u.

- **Carson equation for neutral condition:**

  □h = 0.35 Vs. /u + 2.64 Qh^0.5/u.

- **Carson equation for stable condition:**

  □h = 1.04 Vs. d/u + 2.64 Qh^0.5/u.

Where,

- **□h = plume rise in meter**
- **Vs. = exit gas velocity in m/s**
- **d = Stack diameter in meter**
- **u = wind speed at stack height in m/s**
- **Qh= Heat emission rate in KJ/s**

2. Holland equation

□h = Vs.d /u [1.5+ 2.68 * 10^-3 pd (Ts – Ta)/ Ts]
Where,
p= Atmosphere pressure in milli bars

3. Briggs formula for Momentum sources (less than 50 ambient above temperature)

□h = 1.5(Vs. /u).d
=1.5 Rd

4. Smith equation Momentum sources (less than 50 ambient above temperature)

□h = d (Vs/u) ^ 0.4

- **Briggs equation and Smith equation :**
- **Takes into account only momentum dominated plumes and ignores buoyancy dominated character of plumes**
- **Can be applied where exit velocity of flue gases are high , preferable above 20 m / s , and stack gas temperature below 100 C**
- **Gives results with reproducibility of 60 to 70 %**

5. CONCAWE FORMULA

Δh = 2.71 * (Qh) ^ 0.5 / (u) ^ 0.75
Q = m Δh =[] (d ^ 2 / 4) vs. ρs Cp (Ts - Ta)

6. THOMAS FORMULA

Δh = 4.71 (Qh) ^ 0.444 / (u) ^ 0.694

7. BUOYANT SOURCES

7.1 BRIGGS EQUATION
FOR UNSTABLE AND NEUTRAL CONDITION
Δh = 150 F / u ^ 3

7.2 FOR STABLE WITH CALM CONDITION
ΔH = 5.0 (F) ^ 0.25 / S ^ 0.375

Where:

F = g Vs (d / 2) ^ 2 (Ts - Ta) / Ta

As a function of downwind distance, x

- **Δh = 1.6 (F) ^ 0.333 * (x) ^ 0.666 / u**
- **(ρs - ρa) / ρa = (Ta - Ts) / Ta**

Where :
- **ρs = Density of stack gas**
  ρa = Density atmospheric air

8. WHALEYS EQUATION

Δh = 262*(Qh) ^0.24 / u
Where:
Qh = Heat emission in MW

9. LUCAS EQUATION

Unstable and Neutral conditions
Δh = ((60 + 5 H)/U)*(Qh) ^0.25
For average meteorological conditions
Δh = ((275 + 2 H) / U) * (Qh) ^ 0.25

Where:
Qh = Heat emission in MW
For stable and low wind speeds
Δh = (116* / u) / (Qh) ^ 0.25

For stable and high wind speeds
Δh = (160 / u) * (Qh) 0.25

10. MORTON, TAYLOR, AND TURNER EQUATION

(Stable conditions with little or no winds)

Δh = 5.0 (F ^ 0.25) / (S ^ 0.375)
Where:
F = Buoyancy flux parameter
S = Stability parameter

11. BIS SUGGESTED BRIGGS EQUATION

For hot gas with heat release of 10^6 Cal/s or more

Δh = 0.84 * (12.4 + 0.09 * H) * (Qh ^ 0.25) / U

Where:
Qh = heat emission rate in Cal/s

For momentum dominated, not very hot release

Δh = 3 vs. d / u

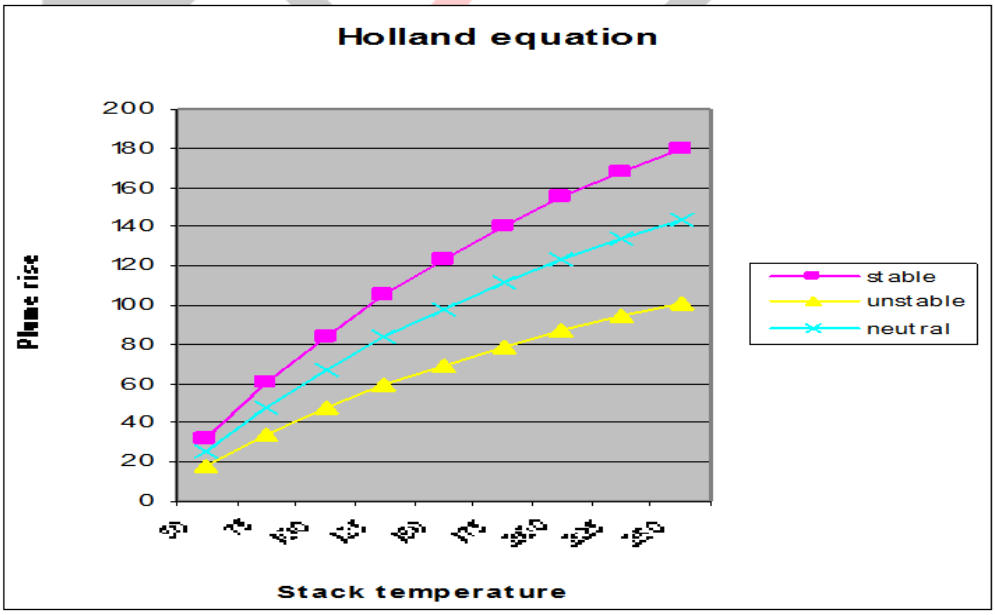
An effort has been made in the present research paper to analyze the effect of Stack Exit Velocity and Gas Temperature on Plume rise using for a Power Plant of capacity 1000 MW using different Plume Rise equations by considering following variable parameters:

Effect of Stack gas temperature on Plume rise

- Stack gas temperature:50 deg C to 250 deg C with an interval of 25 Deg C
- Constants
- Exit velocity: 20m/s
- Wind velocity: 10meters/s
- Stack height: 100m
- Plume rise=?

Effect of different Temperature on plume rise in Holland equation

Graph: 1 Plume rise vs. Stack Gas Temperature



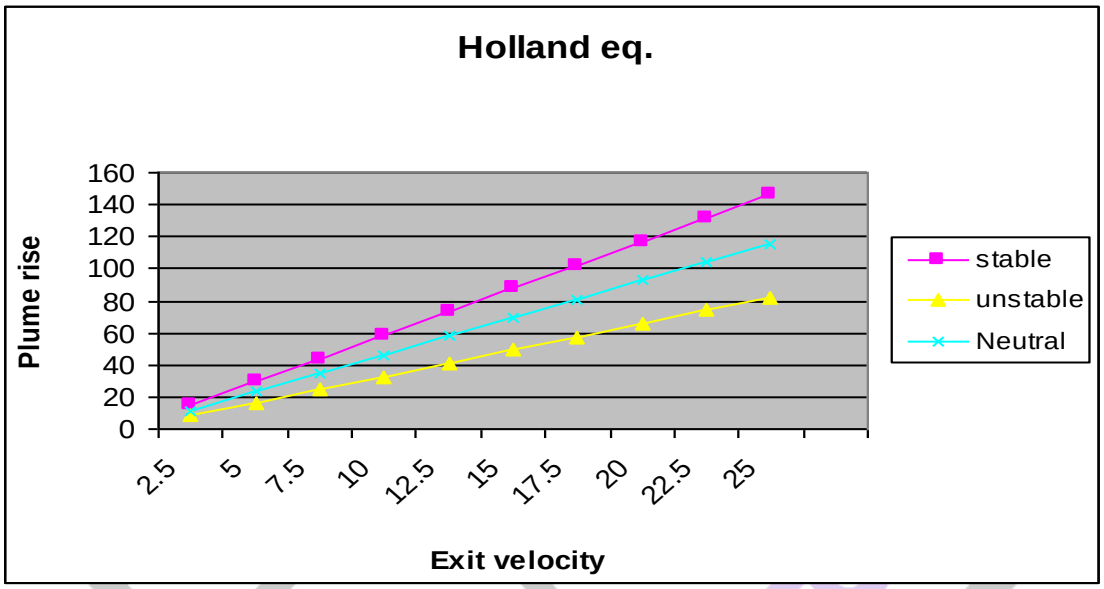
Plume rise increases 0.739, 0.415 and 0.587 meters for every 1degree Celsius Increase of temperature under stable, unstable and neutral condition respectively

Effect of Exit velocity on Plume rise

- Exit velocity:2.5m/s to 25m/s with an interval of 2.5m/s
- Constants
- Stack gas temperature: 150 deg C
- Wind velocity: 10m/s
- Stack height: 100 meters
- Plume rise=?

Effect of different Exit velocity on plume rise in Holland equation

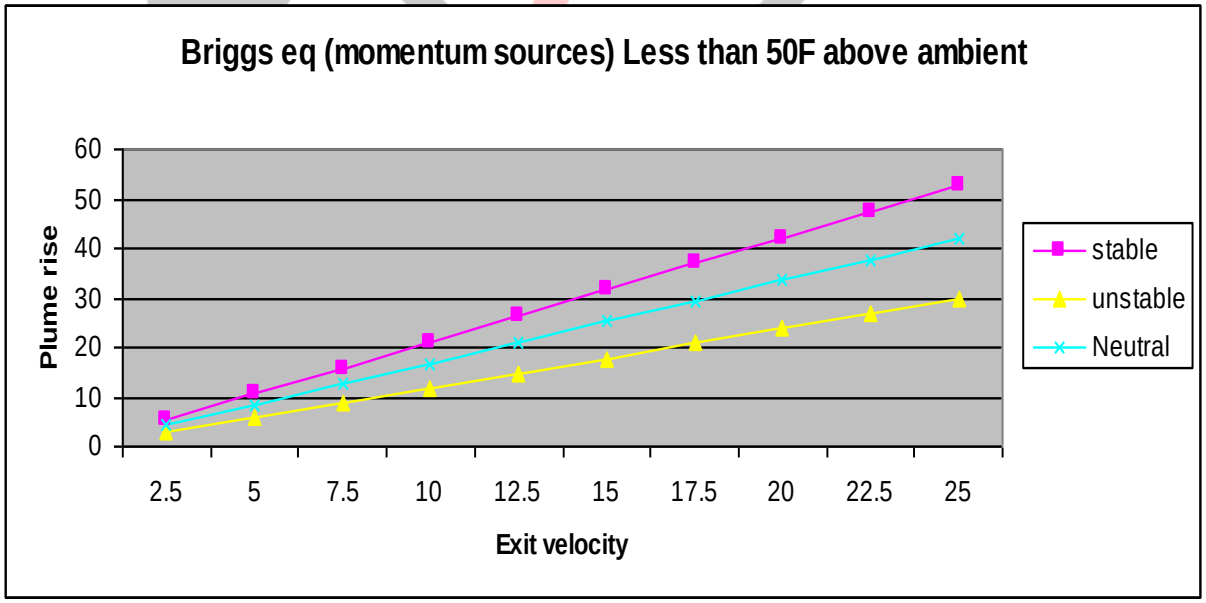
Graph: 2 Plume rise vs. Stack Exit Velocity



Plume rise increases 5.832, 3.28 and 4.632 meters for every 1m/s Increase of exit velocity under stable, unstable and neutral condition respectively

Effect of different Exit velocity on plume rise in Briggs equation (momentum sources) Less than 50F above ambient

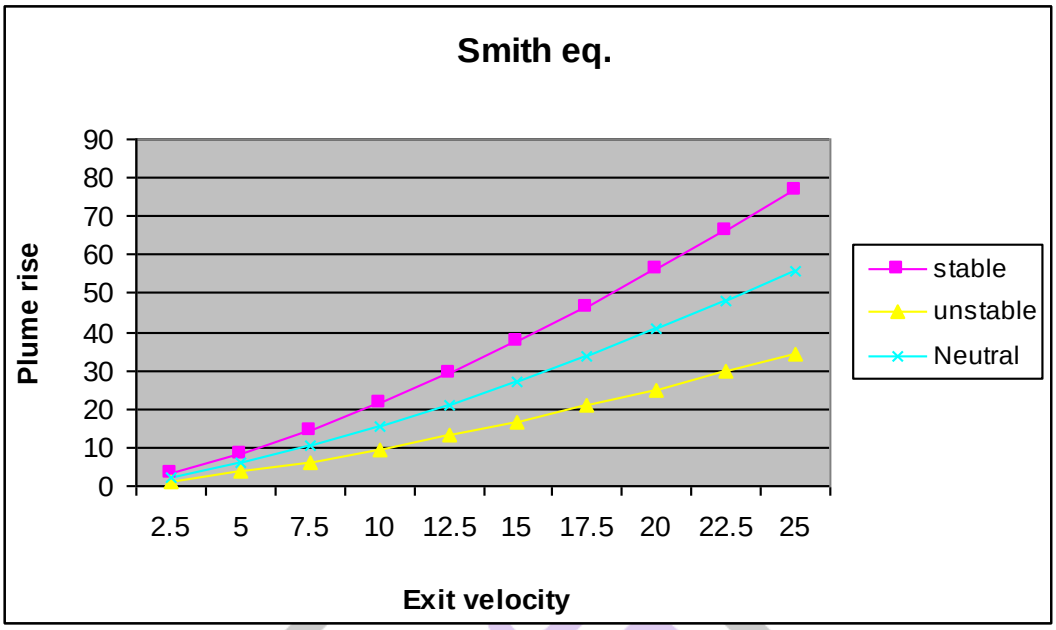
Graph: 3 Plume rise vs. Stack Exit Velocity



Plume rise increases 2.102, 1.185 and 1.674 meters for every 1m/s Increase of exit velocity under stable, unstable and neutral condition respectively

Effect of different Exit velocity on plume rise in Smith equation.

Graph: 4 Plume rise vs. Stack Exit Velocity



Plume rise increases 3.272, 1.467 and 2.370 meters for every 1m/s Increase of exit velocity under stable, unstable and neutral condition respectively

Conclusion: The present study concludes the fact that with the increase of Stack Exit Velocity and Stack Gas Temperature, Plume Rise increases under all stability conditions and as such needs to be planned and considered at the initial stages of plant set up in order to have minimum ground level concentrations of Air Pollutants from such plants.

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