**WSGG Model for a Mixture of , and Soot**

**Line-by-line integration of the RTE**

Before we present the WSGG formulation, let us first review the Line-by-line integration of the radiative spectrum for model verification purposes. The variation of the spectral intensity is determined from

|  |  |
| --- | --- |
|  | (1) |

The mixture spectral absorption coefficient is obtained by superposition of the spectral absorption coefficients of , and soot

|  |  |
| --- | --- |
|  | (2) |

For and, the local values of and for each wave number, temperature and partial pressure should be obtained by means of interpolation from a spectral database called HITEMP2010.

For soot, the value of is obtained from

|  |  |
| --- | --- |
|  | (3) |

Where is the soot volume fraction and is a fuel dependent quantity (=4.9 for propane, unknown for ethylene).

1. **WSGG model for a mixture of , and soot with any partial pressures path length in the range 0.001-10 atm.m**

The integration of the spectral intensity in the WSGG framework is given by

|  |  |
| --- | --- |
|  | (4) |

where , is the total number of gray gases representing the entire spectrum, and subscript m refers to the mixture.

In this superposition method, each of the species is represented by its own specific number of gray gases such that

|  |  |
| --- | --- |
|  | (5) |

where subscripts *w, c* and *s* refer to and soot, respectively.

The water vapor and carbon dioxide are described using 4 gray gases and one transparent gas such that the total number of bands is 5 for each species. Soot can be represented by either 2, 3 or 4 gray gases depending on the desired accuracy of the model. Note that 4 gray gases are preferred for soot since 2 and 3 gray gases show very large errors ( in the total emittance at low soot volume fraction and low temperature . However, this error shrinks as the soot volume fraction and temperature increase (see Fig. 1 in appendix A).

The total number of bands that represent the entire spectrum of the mixture of and soot is

|  |  |
| --- | --- |
|  | (6) |

The gray gases indices are

|  |  |
| --- | --- |
|  | (7) |

The absorption coefficient of the mixture and the weighting coefficient are obtained from

|  |  |
| --- | --- |
|  | (8) |

The absorption coefficients of each species is obtained from the partial pressure and the pressure absorption coefficient which is listed in appendix A

|  |  |
| --- | --- |
|  | (9) |

The weighting coefficients are obtained from a 4th order polynomial of temperature

|  |  |
| --- | --- |
|  | (10) |

The polynomial coefficients are listed in appendix A.

Not that the transparent gas coefficients for are

|  |  |
| --- | --- |
|  | (12) |

and

|  |  |
| --- | --- |
|  | (13) |

1. **WSGG model for a mixture of , and soot with a fixed pressure ratio**

In the special case of , four gray gases and one transparent gas ( can represent both and .

Let us consider 2 gray gases for soot (, then

|  |  |
| --- | --- |
|  | (14) |

The absorption coefficient of the mixture and the weighting coefficient are obtained from

|  |  |
| --- | --- |
|  | (15) |

where for

|  |  |
| --- | --- |
|  | (16) |

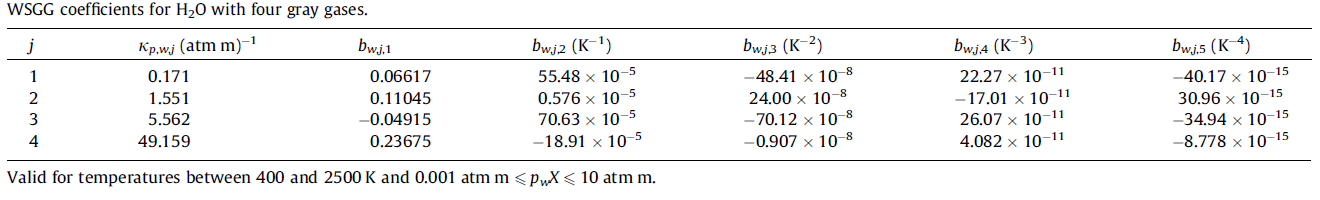
and for the transparent gases

|  |  |
| --- | --- |
|  | (17) |

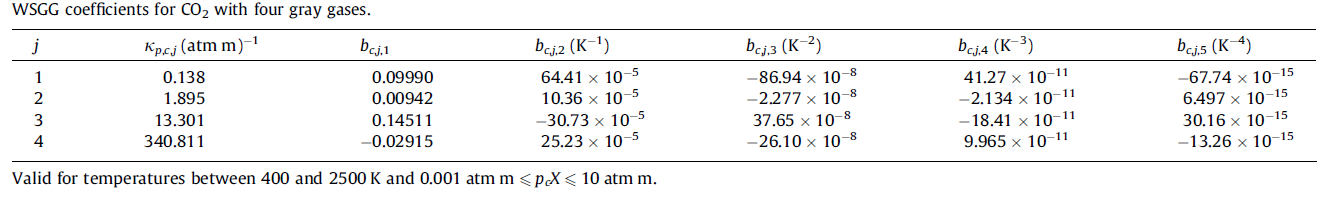
The coefficients and are listed in appendix B.

**Appendix A**

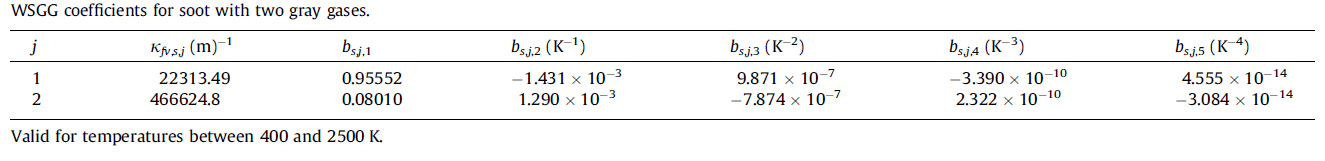
, 4 gray gases



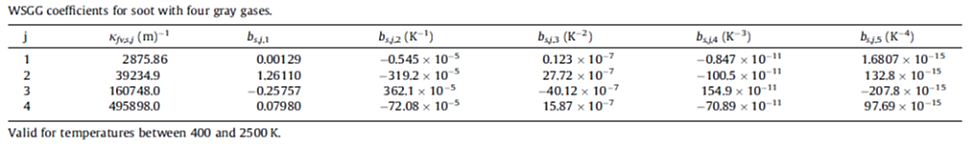
, 4 gray gases



Soot , 2 gray gases



Soot , 4 gray gases



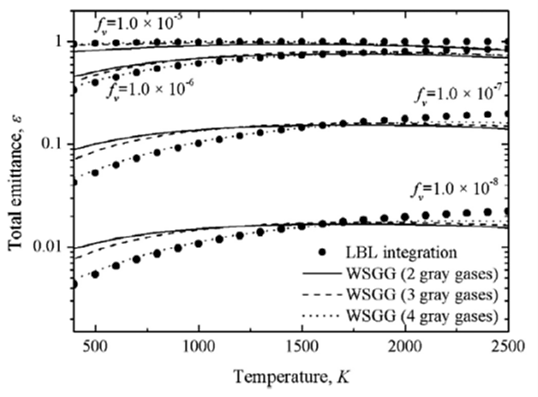
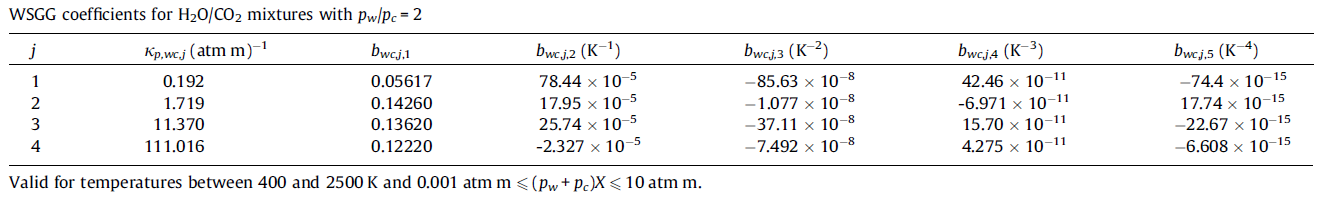


Fig. 1 Total emittance of soot computed by LBL and WSGG with different number of gray gases (Results of Cassol et al. IJHMT 2014)

**Appendix B**

, 4 gray gases

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