Generic Formulation of Reagent Consumption

As stated in the comments, normative consumption of Specific Reagent for various technologies for reduction of emission of Sulphur Dioxide depends on several parameters such as (a) Normative Station Heat Rate (after duly factoring impact of ECS system) (b) GCV of Coal, (c) Sulphur content of Coal (f) Purity of Reagent (g) Design SO_2 Removal efficiency of the ECS and (h) Stoichiometric molar ratio of reagent consumption and therefore assigning normative values in some of the cases may not be correct. As such a common empirical formula may be provided to compute the specific reagent consumption for various technologies wherein it is proposed that these parameters may be considered at actual/or as recommended by CEA rather than assigning them predefined values which seems inappropriate.

In view of above following empirical formulae may be followed for working out reagent consumption in kg/kWh in case of various technologies for reduction of emission of sulphur dioxide:

RC = {(SHR/CVPF) x (S/100) x (SO_{2Mol}/S_{Mol}) x SO_{2Fac} x $SO_{2RemEff}$ x MR x (Reagent $_{Mol}$/SO_{2Mol})x (StoRat / RP) }……………………………………………………. in kg/kWh

Or

RC =1000 x {(SHR/CVPF) x (S/100) x (SO_{2Mol}/S_{Mol}) x SO_{2Fac} x $SO_{2RemEff}$ x MR x (Reagent $_{Mol}$/SO_{2Mol})x (StoRat / RP) }……………………………… in g/kWh

Where,

RC = Reagent Consumption, in kg/kWh or g/kWh

SHR = Normative Gross station heat rate (duly taking into impact on Normative Heat Rate on due to Emission Controlled System), in kCal per kWh;

CVPF = (a) Weighted Average Gross calorific value of coal as received, in kCal per kg for coal based stations less 85 Kcal/Kg on account of variation during storage at generating station;

(b) Weighted Average Gross calorific value of primary fuel as received, in kCal per kg, per litre or per standard cubic meter, as applicable for lignite, based stations;

S = Sulphur content in percentage,

SO_{2Mol} = Molecular weight of Sulphur Dioxide; 64 g/mol

S_{Mol} = Molecular weight of Sulphur; 32 g/mol

$SO_{2\ Fac}$ = Sulphur to Sulphur Dioxide Conversion factor = 1.00 (and not as per CEA assumption of 0.95)

$SO_{2\ RemEff}$ = SO2 removal efficiency, in %

Reagent $_{Mol\ =}$ Reagent Molecular Weight in g/mol = 100 for CaCO3 (limestone), 56 for CaO (lime) and 84 for NaHCO3 (Sodium Bicarbonate)

MR = Theoretical Molecular Ratio = No. of Moles of Reagent Required to convert one mole of SO2

StoRat = Stoichiometric ratio of reagent consumption (given in Table below against those mentioned by CEA for different technologies)

RP = Reagent Purity in percentage (Reactive Component purity),

Since, $SO_{2Mol,}$ $S_{Mol,}$ $SO_{2\ Fac}$ is constant, the formula can be represented in following manner:

RC = K x {(SHR/CVPF) x S x $SO_{2RemEff}$ x MR x Reagent $_{Mol}$ x (StoRat / RP) } in g/kWh

Provided that K = 10 x (SO_{2Mol}/S_{Mol}) x SO_{2Fac} /SO_{2Mol}
= 10 x (64/32)x1.00/64 = 0.3125

Whereas StoRat i.e. Stoichiometric ratio of reagent consumption will be in line with recommendations given by CEA for different technologies and enclosed in the Draft as Appendix II. However, in case of conversion efficiency is in between the efficiencies for which CEA has provided the stoichiometric Ratio, prorate may be followed to workout the stoichiometric Ratio: Below table exhibits the Stoichiometric Molar ratio of reagent consumption as mentioned by CEA for different technologies:

SL. No	Technology	Molar Ratio	Molecular Weight of Reagent (g/mol)	Stoichiometric Ratio given by CEA	Stoichiometric Ratio Suggested by us
1	Wet Limestone based FGD System (CaCO3)	1	100	1.05 at all $SO_{2RemEff}$	1.10 at all $SO_{2RemEff}$
2	For Lime Spray Drier or Semi-Dry Flue Gas Desulphurisation (CaO)	1	56	1.35 for around 70% removal efficiency range 1.8 for around 90% efficiency range.	1.56 for around 70% removal efficiency range 2.0 for around 90% efficiency range.
3	For Dry Sorbent Injection System (Using Sodium bicarbinate-NaHCO3):	2	84	0.5 for around 30% removal efficiency range 1.0 for around 50% removal efficiency range 2.0 for around 70% removal efficiency range	1 for around 30% removal efficiency range 1.5 for around 50% removal efficiency range 2.0 for around 60% removal efficiency 2.3 for around 70% removal efficiency range
4	For CFBC Technology (furnace injection) based Generating Station (CaCO3):	1	100	2.0 for around 90-95% removal efficiency range	2.0 for around 90-95% removal efficiency range
5	SNCR (Urea-(NH2)2CO)	0.5	60	1.1 for 30-40% efficiency	1.6 for 30-40% efficiency
6	SCR (Ammonia – NH3)	1	17	1.08 for 75-85% efficiency	1.4 for 75-85% efficiency

Similarly, for NOx abatement system

RC = NO_{xcon} x $NO_{xRemEff}$ x MR x Reagent $_{Mol}/NO_{xMol}$ x StoRat …………………….. in g/kWh
Where,

NO_{xcon} = NOx concentration after in-combustion control = Design NOx emission concentration x (1-Design Efficiency of In-combustion control) …. In g/kWh (subject to minimum NOx concentration of 750 mg/Nm3 converted to g/kWh with 260 g/GJ and normative SHR)
NO_{xMol} …= NOx Molecular weight = 46 g/mol
$NO_{xRemEff}$ = Design NOx removal efficiency of SNCR or SCR
StoRat = Stoichiometric ratio
MR = Theoretical Molecular Ratio = No. of Moles of Reagent Required to convert one mole of NOx

Here it is important to note that CEA has considered a fixed NOx concentration of 750 mg/Nm3, which is first brought down to 450 mg/Nm3 by In-combustion burner modification and then to 300 mg/Nm3 by SNCR or to 175 mg/Nm3 by SCR. Accordingly, CEA has computed a fixed number for reagent consumption assuming efficiency of removal in the range 30-40% (stoichiometric ratio 1.1) for SNCR and efficiency of 75-80% (stoichiometric ratio 1.08) considering molecular weight of NO2 (46). This methodology has to be modified to generic formulation given above as the numbers are for fixed NOx concentration/kWh, fixed efficiency and, hence, stoichiometric ratio, whereas percentage of nitrogen in actual coal and, hence, NOx concentration in flue gases may be higher than 750 mg/Nm3. In such cases, in combustion control may not reduce NOx to 450 mg/m3 even after 300 mg/Nm3 reduction by them. Hence, higher efficiency SNCR and SCR may be required. Thus, needing a generic formulation as suggested above for Sox removal. Further, stoichiometric ratio also increases with increase in efficiency and, hence, higher stoichiometric ratio needs to be taken for higher efficiency than 40% considered for SNCR and 75-85% considered for SCR. Higher ratio may considered as per design.