Derivation of the THERMAL OXIDISER Size & Duty requirements for 500 kg Batches

ASSUMPTIONS MADE

1) The heat transfer rate into the PC, and hence the syngas evolution rate will be essentially proportional to the heat transfer surface area.
PC drum is 1030 mm id and 1650 mm deep. Base area is 0.833 m^2
Cylinder area is 3.236 m^2 / m fill height

So for a 100 kg batch with a 412 mm fill height we had 0.833 + 1.333 m^2 equals 2.166 m^2 of heat transfer area.

Assuming we can get a 500 kg batch in a full, 1500 mm fill PC drum, the area becomes 0.833 + 4.854 = 5.687 m^2.
I.e. The 500 kg batch is likely to produce 2.63 times the evolution rate of syngas for a 100 kg batch equivalent to 0.33 x 2.63 = 0.87 kg/min, assuming effective heat transfer rates are retained.

2) The volatile content of the WEEE remains constant at 12 % w/w (88kg recovered from a 100 kg batch) so 60 kg of syngas will be produced during processing of a 500 kg batch.
At the presently seen rate this implies that the syngas will be evolved over a 69 minute pyrolysis cycle.

3) All of the syngas will make it into the TO.

4) Due to heat transfer control improvements, the syngas evolution period can be reduced to 35 minutes, producing a 60 / 35 = 1.714 kg/ min syngas mass rate into the TO, nearly twice that anticipated from 1/ above. Therein lies my contingency factor.

5) The quantity of inertisation Argon gas will remain constant at 17.8 l/min with the bigger batch size.

IMPORTANT ! THE APPLICATION OF THESE ASSUMPTIONS RESULTED IN THE DESIGN BASIS OF BOTH THE THERMAL OXIDISER AND THEREBY THE STACK GAS CALCULATIONS AS DETAILED in sections A and B on the following pages.

A) Part 1 SYNGAS RATE INTO THERMAL OXIDISER for 500 kg Batch of WEEE

Copied below is our calculated syngas rate and composition for a 100 kg batch synthesis.

Table 1 - Expected 100 kg batch Syngas rate into TO if no VOC's condense out en-route to it

Gas	Volume	% v/v	MW	Mass	% w/w
CO_2	1.892	3.317	44.01 g/ mol	3.717	1.120
CO	1.191	2.088	28.0097 g/ mol	1.489	0.449
H_2	3.326	5.831	2.01568 g / mol	0.299	0.090
CH_4	0.904	1.585	16.043 g / mol	0.647	0.195
N_2	1.098	1.925	28.0134 g / mol	1.373	0.414
$C_{12}H_{26}$	19.232	33.719	170.33 g / mol	146.240	44.083
$C_{20}H_{42}$	11.593	20.327	282.55 g / mol	146.232	44.080
Plus Ar	17.8	31.208	39.948 g / mol	31.744	9.569
Syngas	57.036 l / min	100	130.286 g /mol	331.741 g/min	100

If we now apply our 500 kg batch assumptions to the mass values by multiplying everything, except the Argon injection rate, by 1714 / 300 we end up with 5.713 times the individual gas species mass rates.

If we take this 1714 g/min syngas rate and add our 31.744 g/min constant Argon rate we end up with a 500 kg syngas rate and composition as defined in Table 4/ below where the NTP syngas volume rate have been derived applying the universal gas constant and the mean Mr of the syngas mix.

Table 2 - Design Duty 500 kg batch Syngas rate into the TO

Gas	Volume	% v/v	MW	Mass	% w/w
CO_2	10.808	4.467	44.01 g/ mol	21.235	1.216
CO	6.803	2.812	28.0097 g/ mol	8.507	0.487
H_2	18.981	7.846	2.01568 g / mol	1.708	0.098
CH_4	5.163	2.134	16.043 g / mol	3.696	0.212
N_2	6.272	2.592	28.0134 g / mol	7.844	0.449
$C_{12}H_{26}$	109.872	45.415	170.33 g / mol	835.469	47.861
$C_{20}H_{42}$	66.231	27.376	282.55 g / mol	835.423	47.858
Plus Ar	17.8	7.358	39.948 g / mol	31.744	1.818
Syngas	241.93 l / min	100	130.286 g /mol	1745.626 g/min	100

Please Note: The Ar % v/v Content has Dropped to Less Than 1/3rd of its 100 kg batch value.
As this reflects its status during syngas evolution it should only be evaluated against the risk of the counter balancing presence of oxygen donor sources such as Li batteries. The system geometry and vessel volumes have not changed so pre -heat and pre pyrolysis stage inertisation rates should not be adversely affected since, at that time, the Ar content should proximate to 100% v/v concentrations and it is just the time taken to establish this that is rate dependant.

Please see the next page for derivation of the required Thermal Oxidiser capacity.

B) Part 2 THERMAL OXIDISER SIZING

The values in table 2 were then used as fuel components to be oxidised and run through combustion calculations to derive the flue gas volume rate generated by thermal oxidation of the syngas. This being the parameter used to size the TO in order to achieve a 2 second VOC destruction residence time.

Further assumptions were made for the completion of this exercise and these are stated below:

i) Target oxidisation temperature at TO outlet is 950°C.

ii) A 300 kW burner is used to preheat the TO and that its gas rate will be automatically throttled back, to a 50 kW thermal input during the period that syngas generation occurs creating autothermal combustion within the TO. Autothermal combustion was seen to reliably occur on 100 kg batch feeds.
(It doesn't materially change things if a larger pre-heat burner is used so long as the 50 kW combustion support firing assumption applied during syngas generation is accepted and held)

iii) The TO burner combustion air fan and flow rate are constantly On at 33 m^3/h.

iv) Natural gas (CH_4) burn rate of the TO burner for 50 kW combustion support will be 5 m^3/h

v) The TO will receive a syngas combustion air rate twice that required to stoichiometrically combust the syngas, or to meet an exhaust gas 11% v/v O_2 dry content, whichever is the greater.

Applying these assumptions resulted in the flue gas rate and composition tabled below, ignoring acid gases at this time, being created within the Thermal Oxidiser during the syngas oxidation process.

Gas	**Mass rate**	**% w/w**	**Volume rate**	**% v/v wet**	**% v/v dry**
N_2	0.5011	74.75	0.4012	74.788	83.975
O_2	0.0751	11.19	0.0525	9.797	11.000
CO_2	0.0471	7.03	0.0240	4.475	5.025
H_2O	0.0471	7.03	0.0587	10.940	-
	0.6704 kg / s	**100**	**0.5364 Nm³ / s**	**100**	**100**

These values are summarised below:
Flue gas density 1.2498 kg / Nm³
Wet Flue gas volume rate 1931 Nm³ / h
Dry Flue gas volume rate 1720 Nm³ / h Ref 11 % v/v O_2 dry gas.

IF we now assume that the TO is located on a site 64 m amsl (Bridgenorth) and the exit gas temperature is 950°C at a relative pressure of -25 mm WG, then the actual flue gas volume rate requiring a 2s treatment time within the TO is 8732 Am³ / h, or 2.426 Am³ / s.

CONCLUSION: TO Sizing for single unit BRP processing 500 kg loads
A TO whose firing gas chamber internal dimensions are 2m x 1 m would have to have a post ignition stage chamber length of 2.5 m to ensure a 2 s treatment time.
Gas velocity = 2,426 / (2 x 1) = 1.213 m / s over a 2.5 m length gives 2.06 s TT.

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