GUIDANCE NOTE 28

THE DETERMINATION OF Z RATIO

Definition and Use of Z Ratio

GN28.1

For CHP Schemes which include fully or partially condensing (pass-out) steam turbines, Power Efficiency will decline as steam extraction increases for a given fuel consumption, so there is a balance between increasing heat recovery and reducing power output.

The trade-off between heat to site and power for these CHP Schemes is known as the Z ratio.

The Z ratio can be derived from actual measurements of the CHP Scheme in question or may be determined by calculation. The Z ratio depends on the pressure and temperature of the steam supplied to site, the steam turbine generating set's thermodynamic (isentropic) and mechanical efficiencies and the vacuum (or pressure) maintained in the condenser. Rigorous calculation requires knowledge of all of the above parameters.

GN28.2

Table GN28-1 shows Z ratios for different steam export pressures and for turbine thermodynamic efficiencies that are typical in operation for steam turbines in the size ranges shown. This Table is illustrative as the Z ratio is influenced by the steam turbine loading and the condition of the turbine blades. Each CHP Scheme must determine, and supply evidence of the Z ratio that is applicable to its operation. Manufacturers' specifications are not generally representative of normal operation (but can be corrected for fall-off in performance since new).

GN28.3

Where there is more than one pass-out or steam export pressure, the Z ratio should be the mean of the values at each pressure level weighted in proportion to mass flow. For a fully condensing steam turbine (no pass-out) the steam export pressure should be taken as the steam pressure before the steam turbine.

Table GN28-1 Typical Z ratios for given steam turbines and steam pressures

Steam turbine size range	2 to <5 MW_e	5 to <10 MW_e	10 to <25 MW_e	25 to <50 MW_e	Above 50 MW_e
Typical thermodynamic (isentropic) efficiency	65%	70%	75%	80%	84%
Steam export pressure					
21.7 bar(a)	5.0	4.7	4.4	4.1	3.9
14.8 bar(a)	5.4	5.0	4.7	4.4	4.2
11.4 bar(a)	5.7	5.3	4.9	4.6	4.4
7.9 bar(a)	6.1	5.7	5.3	5.0	4.7
3.8 bar(a)	7.2	6.7	6.3	5.9	5.6
2.4 bar(a)	8.1	7.5	7.0	6.6	6.3

DETERMINATION OF Z RATIO

GN28.4

To determine the Z ratio by measurement requires some careful manipulation of the CHP operation and requires that adequate metering of power and steam outputs is in place. Each site must decide how to carry out the test without disrupting process operations or putting plant or personnel at risk. In general, it is suggested that the start point should be with the condensers at the highest load possible. Ideally, the boilers supplying the turbine steam should be on fixed output (firing set point) to give a constant flow, pressure and temperature at the turbine inlet. The steam extraction or export can then be increased in small steps thereby reducing the flow to the condensers, and the changes in steam export and power generation observed. If some or the entire site heat load can initially be provided by standby boiler plant, which can then automatically be backed off as the extraction is increased, this will enable the test to cover the greatest operating range. It may otherwise be necessary to vent surplus steam during the test to permit a reasonable range of condenser loading to be covered.

GN28.5

Where there is more than one pass-out pressure it may be possible to determine the Z ratio for each pressure by keeping the other pass-out(s) constant. Otherwise, a single experiment will enable the mean isentropic efficiency to be determined and then the individual Z ratios may be determined by calculation.

GN28.6

Determination of the Z ratio by calculation also involves some on-site measurements but avoids the need to alter the turbine operation.

Measurements of at least two of the three mass flows (steam in, steam out and condensate out) and the power output are necessary. In addition, the pass-out steam pressure and temperature and condenser vacuum (pressure) are required.

The calculation requires the use of steam tables, a steam enthalpy-entropy diagram, or software such as the ASME97 steam tables.

- Refer to Appendix 4 of the Guidance Notes for an example calculation of Z Ratio.

GN28.7

Where it is not possible to determine the Z ratio based on steam turbine performance testing a statement giving the reasons is required. In such cases, the Z ratio may be taken from Table GN28-1, interpolating, if necessary, between the steam pressures tabulated.

