15. Index tests

15.1 *General*

15.1.1 *Object*

The methods of discharge measurement described in Clause 10 are fundamental methods as they give among others the absolute values of discharge and efficiency, which determine whether or not the machine meets the guarantees (see 3.2). On the contrary the index tests give only relative values of the above-mentioned quantities and are considered as secondary methods. They are normally used during the commissioning and operation of the machine (see IEC 545 and 805) and can be considered as a part of the field acceptance test only when the relative discharge measuring method is calibrated by a method accepted in this standard or when it is used to determine the correct relationship between runner/impeller blade angle and guide vane opening in the case of a double-regulated machine (see 5.1.4). In some cases an index test can be used, if both parties agree, to check the power guarantee.

Except for the cases described above, the results of index tests are for information and should never be used for assessment of penalty or bonus payments or any other contractual consequences concerning guarantees.

15.1.2 *Definitions*

An index value is an arbitrarily scaled value. Relative values are derived from index values by expressing them as a proportion of the value at an agreed condition.

The index efficiency is calculated using the measured values of specific hydraulic energy (see 15.3.1) and power, and the discharge, measured as an index value by an uncalibrated device. Relative efficiency is expressed as a proportion of any index efficiency at a reference index efficiency, for example the maximum value.

15.1.3 *Applications*

An index test may be used as a part of the field acceptance test for any of the following purposes:

- to determine the correct relationship between runner/impeller blade angle and guide vane opening for most efficient operation of double-regulated machines. This procedure may essentially reduce the number of points for which the actual efficiency must be determined and thus the time needed for the acceptance test (see 5.1.4 and 5.1.5).
- to provide additional test data during a field efficiency test. This is particularly important if the primary method shows excessive uncertainties or falls out in a certain operating range. The index discharge device in this case shall be calibrated by discharge field measurements performed in the favourable operating range (see 14.5.4).

In addition to the field acceptance test, an index test may be useful also for other purposes, such as:

- to determine the performance characteristics as expressed by the relative values of power, discharge and efficiency;
- to check the power guarantee if both parties agree;
- to extend information on performance outside the guaranteed range if the index discharge device has been calibrated;
- to assess the change in efficiency and/or power due to the onset of cavitation resulting from a change of suction specific potential energy and/or specific hydraulic energy of machine;

- to assess the change in efficiency and/or power of the machine resulting from wear, repair or modification. When using an index test for this purpose it must be noted that modifications may affect flow patterns in the measuring sections;
- to obtain data for permanent discharge measuring instruments by assuming an absolute value of turbine efficiency at some operating point or by calibration with field efficiency test results;
- to optimize the operation of a power station with several units;
- to compare the index curves on the prototype with the curves expected on the basis of model tests.

Index tests are of reduced value if the available operating range of the machine is not such that a reasonable portion of the performance curve can be covered.

15.2 *Relative discharge measurement*

An index test does not require any absolute measurement of discharge. For the measurement of relative discharge one of the following methods may be used.

15.2.1 *Relative discharge measurement by differential pressure methods*

15.2.1.1 Measurement of the pressure difference between suitably located taps on the turbine spiral case

This is the Winter-Kennedy method and discharge is usually well represented by $Q = kh^n$ where h is the reading of a differential manometer connected between the taps and n theoretically equal to 0,5 (see 15.5).

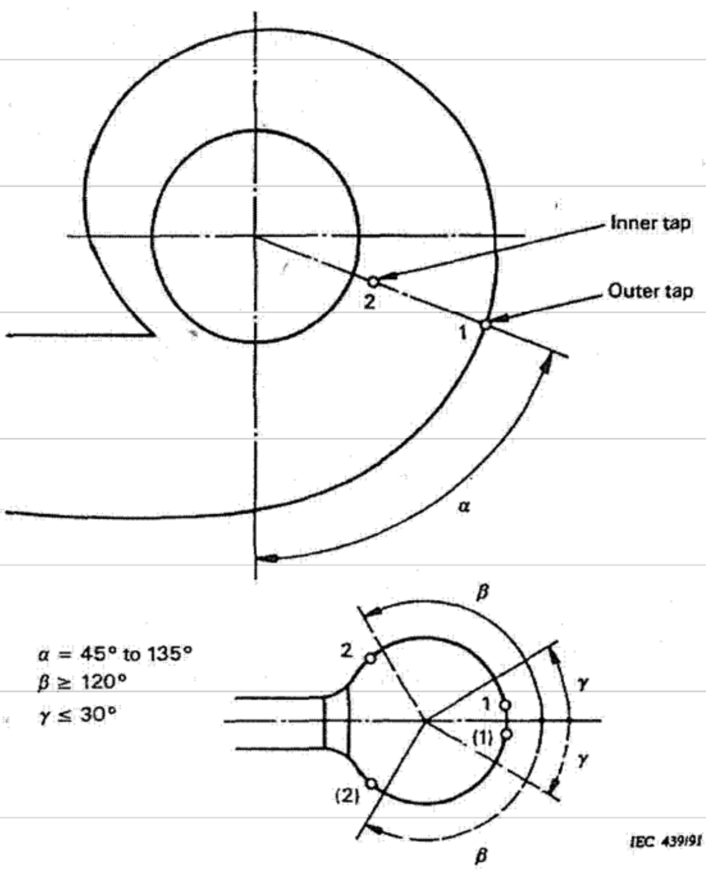

Figure 66 – Location of taps for Winter-Kennedy method of discharge measurement through a turbine equipped with a steel spiral case

The Winter-Kennedy method is applicable to turbines only. In installations with a steel spiral case it requires taps located as a general rule in the same radial section of the spiral case (see Figure 66). The outer tap "1" is located at the outer side of the spiral. The inner tap "2" shall be located outside of the stay vanes on a flow line passing midway between the two adjacent stay vanes. It is recommended that a second pair of taps be located in another radial section.

With a horizontal spiral case the taps shall be arranged in the upper half because of the better possibility of purging. The gauge taps should not be in proximity to weld joints or abrupt changes in the spiral section.

In the application of the Winter-Kennedy method to turbines with a concrete semi-spiral case the taps have to be located in a similar way in a radial section of the concrete case as shown in Figure 67. Also here it is good practice to locate two pairs of taps.

The outer tap 1 (or 1′) shall be located sufficiently far from the corners. The inner tap 2 (or 2′) shall be located outside of the stay vanes on a flow line passing midway between two adjacent stay vanes. A third tap 3 may be arranged on a stay vane, preferably at the elevation of the centerline of the guide vanes, or on the roof between two stay vanes.

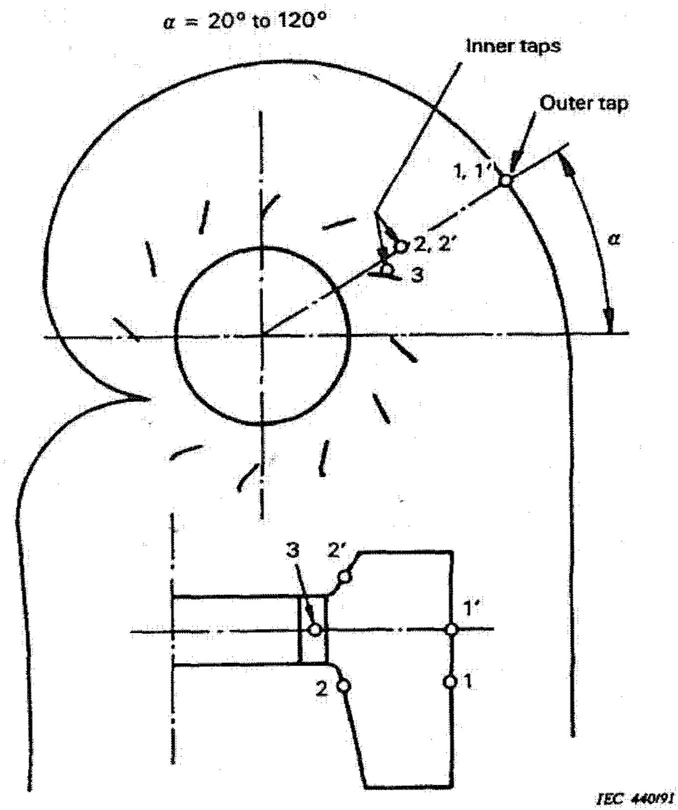

Figure 67 – Location of taps for Winter-Kennedy method of discharge measurement through a turbine equipped with concrete semi-spiral case

15.2.1.2 Measurement of the pressure difference existing between suitably located taps in a converging part of the penstock

A suitable convergence must exist to give a pressure difference large enough to be measured accurately. Discharge may be assumed proportional to the square root of the differential pressure (see 15.5).

Two pressure taps are required located at two cross-sections of different areas. The most stable pressure difference will be obtained if both taps are located on the converging part of the pipe. However, the differential pressure thus obtained is not the maximum possible and for this reason it may be preferable to locate one tap a short distance upstream of the convergent part and the second not less than half a diameter downstream of the convergent part.

15.2.1.3 Measurement of the pressure difference between suitably located taps in tubular turbines

In application of the differential pressure method of measuring relative discharge through a bulb unit the taps may be located as shown in Figure 68. The tap for higher pressure may be arranged at the stagnation point of the bulb (point 1) or of the access shaft (point 1′) and the tap for lower pressure should be located on the wall directly upstream from the guide vanes, however with sufficient distance from their profile nose at maximum guide vane opening (point 2 or 2′). Discharge may be assumed proportional to the square root of the differential pressure (see 15.5).

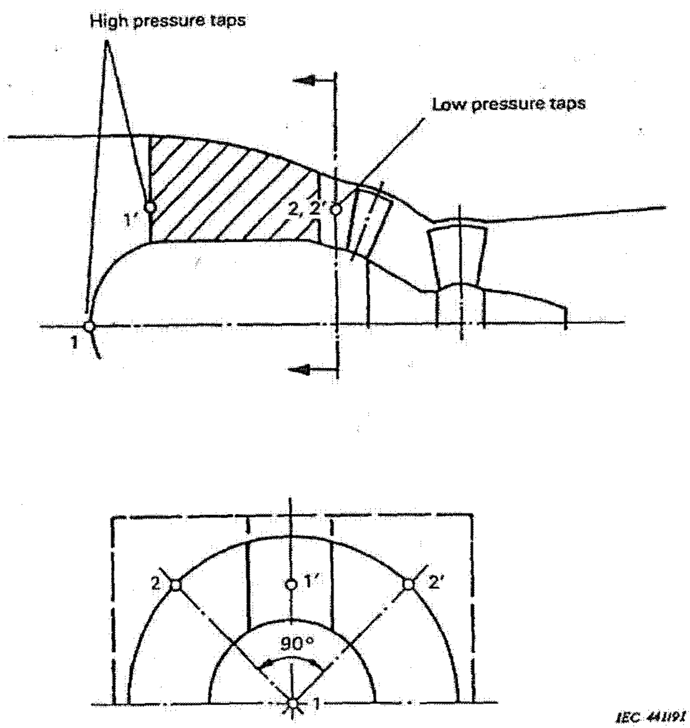

Figure 68 – Location of taps for differential pressure method of discharge measurement through a bulb turbine

For all other types of tubular turbines (e.g., pit turbine) analogous application may be made.

15.2.1.4 Measurement of the pressure difference between suitably located taps in the pump suction tube

Discharge may be assumed proportional to the square root of the differential pressure.

15.2.1.5 Specifications for pressure taps and gauge piping

The pressure taps used shall comply with the dimensional requirements of 11.4.3. Since the differential pressures to be measured may be small, special attention should be given to removing surface irregularities.

An upward sloping pipe is normally required for test purposes (see 11.4.4) since it is most easily purged. With prolonged use, an upward sloping pipe may gradually accumulate air and thus require purging, and for this reason where the pressure taps are to be used for a permanently operating discharge recorder it may be preferable to locate the pressure taps below the axis of the spiral case (see Figure 66) and use pipework with a continuous downward slope to the discharge recorder or differential pressure gauge. In this case a device is recommended to collect the possible debris.

15.2.2 Relative discharge measurement by acoustic method

This method (see Appendix J) is suitable for index testing, due to the good repeatability of measurements and good linear characteristic. For index test applications of the acoustic method, one single-path system or a double-plane single-path system, as shown in Figures 69 and 70, may be sufficient.

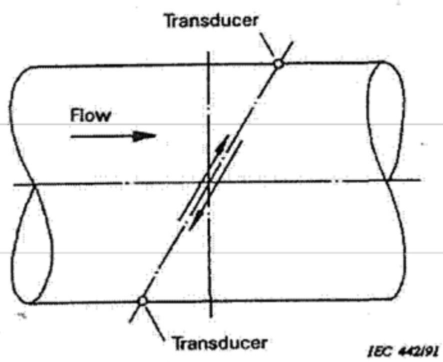

Figure 69 – Acoustic method of discharge measurement: example for single path system (successive signal transmission)

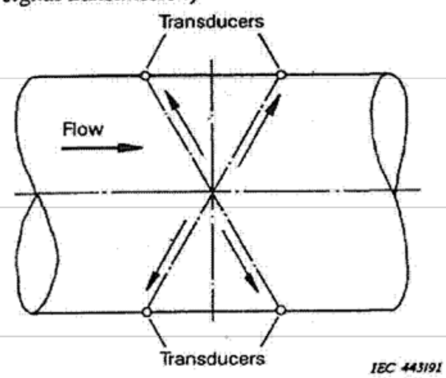

Figure 70 – Acoustic method of discharge measurement: example for double plane single path system (synchronous or successive signal transmission)