MEASUREMENT OF DISCHARGE BY PRESSURE-TIME METHOD FOR FIELD ACCEPTANCE TEST OF HYDRO TURBINE AND COMPARISON WITH MODEL TEST RESULT

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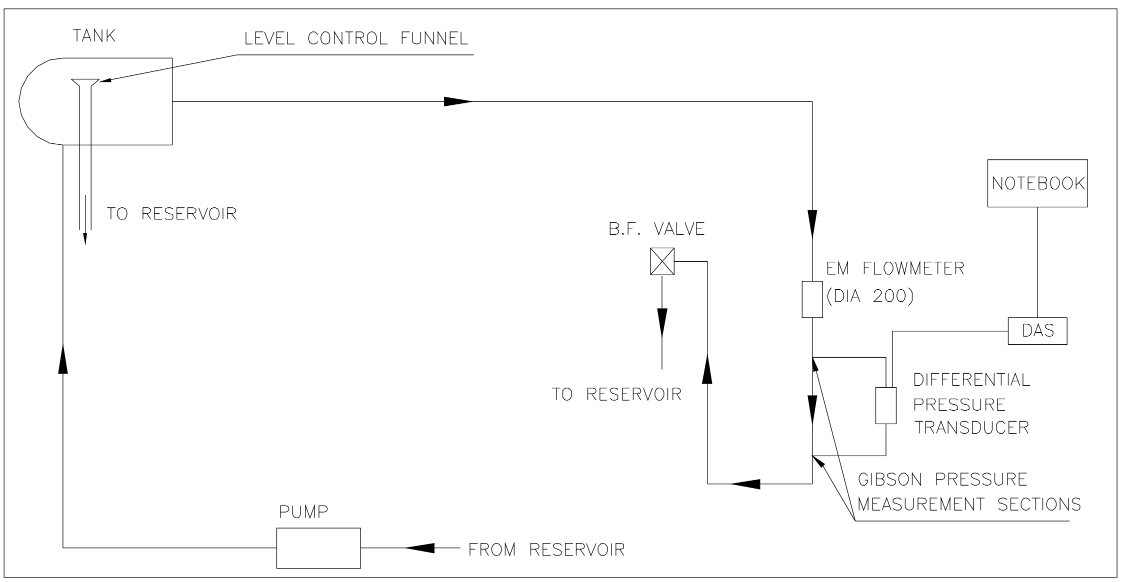
Introduction-

Gibson method of discharge measurement also known as Pressure-Time method is based upon Newton`s law and derived law of fluid mechanics which gives the relation between the force due to change of pressure difference between two sections and acceleration or deceleration of the mass of water between these sections due to guide vane movement.

Gibson developed pressure-Time method using mercury manometers and simple pendulum and taking their photographs to get pressure against time plot. However this method was not popular for measurement of discharge for turbine field acceptance test due to its cumbersome instrumentation & photography. With advancement in instrumentation especially in data acquisition and emergence of accurate dynamic pressure transducers this method got a new lease of life and different agencies/manufacturers have shown renewed interest in this method. New IEC 60041 –1991 gave some basic measuring system requirements. This needed further refinement and development for practical application keeping in mind latest sophisticated instrumentation and user-friendly computer programming technique. For development and validation of required system laboratory investigations were carried out with in-house developed software. The method has been applied at several powerhouses and the efficiencies matched quite well with the predicted prototype efficiencies from model test.

Laboratory Validation-

An arrangement was made at Hydro Laboratory BHEL Bhopal, India for the measurement of discharge using Gibson Method. Dynamic Differential Pressure Transducer, Druck make was connected across the two sections of the measuring length. The output of the Druck transducer was connected to the HP DAS, which in turn was connected to Laptop using IEEE to USB converter. A butterfly valve was connected at one end of the pipe, which was operated using pneumatic actuator. Schematic sketch (fig-1) of the arrangement is enclosed on the following page. Water was made to flow through the pipe and the valve was gradually closed using continuous movement. The voltage readings of the Dynamic Differential Pressure transducer were recorded against time. The software developed by BHEL was used to calculate pressure using voltage reading and a graph of Pressure against time was plotted then discharge was calculated using the graph. Discharge calculated by Gibson method was verified using Calibrated Electromagnetic Flowmeter readings. Data are given in Table-1.



SCHEMATIC SKECTH FOR VALIDATION OF GIBSON METHOD

Fig-1

Table-1

Data filename	Pressure-time Area	Discharge m^3/s	Flowmeter Reading m^3/s
Gib0105	4.471671	0.156	0.1575
Gib0205	4.557665	0.159	
Gib0305	4.529	0.158	
Gib0405	4.529	0.158	
Gib0505	4.471671	0.156	
Gib0605	4.511801	0.1574	
Gib0705	4.497469	0.1569	
Gib0805	4.52900	0.158	
Gib0905	3.89838	0.136	0.136
Gib1005	3.93851	0.1374	
Gib1105	3.863982	0.1348	
Gib1205	3.866849	0.1349	
Gib1305	3.875448	0.1352	
Gib1405	3.909846	0.1364	
Gib1505	3.892647	0.1358	
Gib1605	3.904113	0.1362	
Gib1705	5.372025	0.18741	0.188
Gib1805	5.447986	0.19006	
Gib1905	5.400689	0.18841	
Gib2005	5.427921	0.18936	
Gib2105	5.360559	0.18701	
Gib2205	5.366005	0.1872	
Gib2305	5.446266	0.19	
Gib2405	5.429067	0.1894	

Average flow from pressure-Time method is quite close to flow measured by calibrated electromagnetic flowmeter and the random error calculated given in table-2 below as per IEC 60041 appendix – c is within ± 0.6%.

Table-2

Average flow m^3/s	Actual Flow m^3/s	Random error %
0.1574	0.1575	0.56
0.1358	0.1360	0.53

0.1886	0.1880	0.56

Instrumentation and Software-

Software on Visual Basic was developed which calculates Discharge as per the Gibson method described in IEC60041. Data Acquisition & Calculation Of Discharge: - Voltage readings of Druck transducer against time are acquired using DAS from a few seconds before the start of closure of valve to the end of closure. Data acquisition frequency was 100readings /second. Linearity of Dynamic differential pressure transducer was better than $1x10^{-3}$ over the whole measuring range. The measuring system natural frequency was very high as compared main frequency present in pressure time signal. These voltage readings are converted into pressure taking into account the calibration coefficients of Druck transducer. A graph of pressure versus time is plotted. The required data are taken from the input file, which contains following information and is created with the software developed: -

i. Value of "g" in m/s^2 ,
ii. Distance between sections in m.
iii. Section area in square meter.
iv. Calibration constant of transducer

The data file contains the voltage readings of the differential pressure transducer against time.

The software has the provision for selecting any required time scale as well as voltage scale. Once the Pressure-time graph is displayed, the software calculates the half-period of after wave (B) and ratio of peak height of two adjacent after waves (E). Once the data is accepted, the values of Discharge, Running loss and pressure time area are calculated and displayed. An option for taking hard copy is also provided.

Discharge Measurement at Power house-

BHEL has carried out Discharge measurement at different powerhouse having Kaplan turbines with rated output ranging from 10MW to 50 MW and diameter of runner from 3m to 5m and Francis turbine of 60MW. The turbine efficiencies at all the power stations were found to be matching quite well with the predicted efficiencies from model tests.

Typical instrumentation and data acquisition is shown in photograph fig-2.

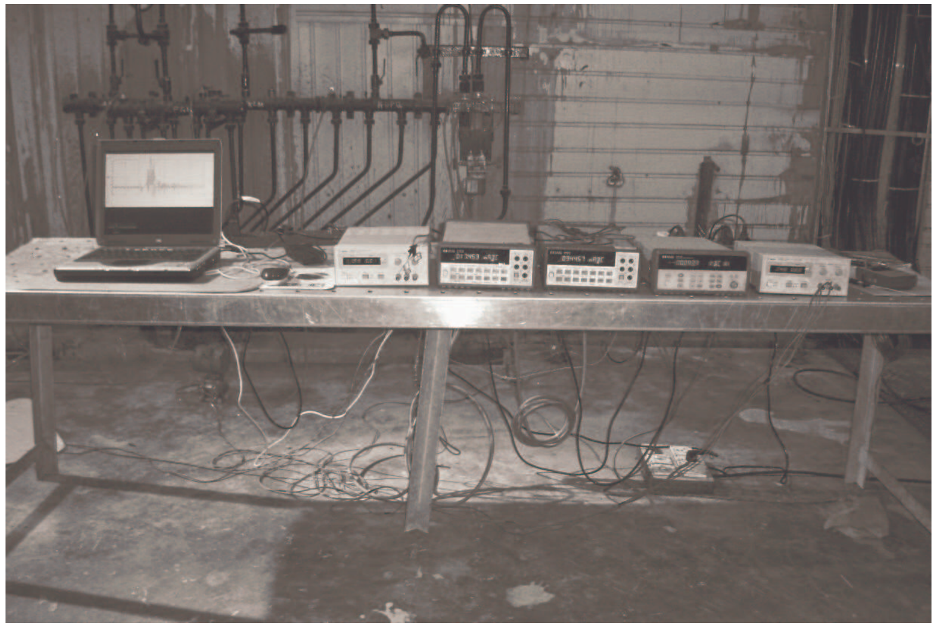


Fig-2

Typical Pressure plot is shown in fig-3.

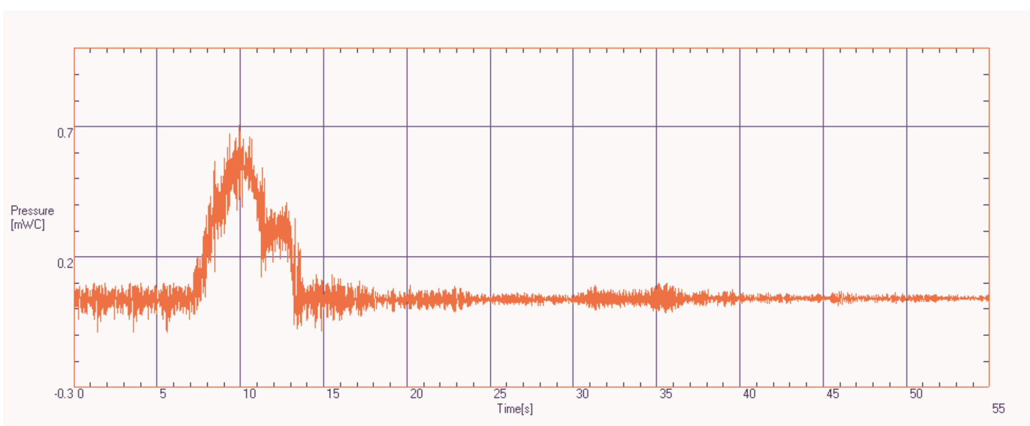


Fig-3

Comparison of predicted efficiency from model test and measured efficiency by pressure-time method for a power station Kabini HEP with Kaplan turbine 2 x 10 MW is shown in fig-4. A good agreement in results was found.

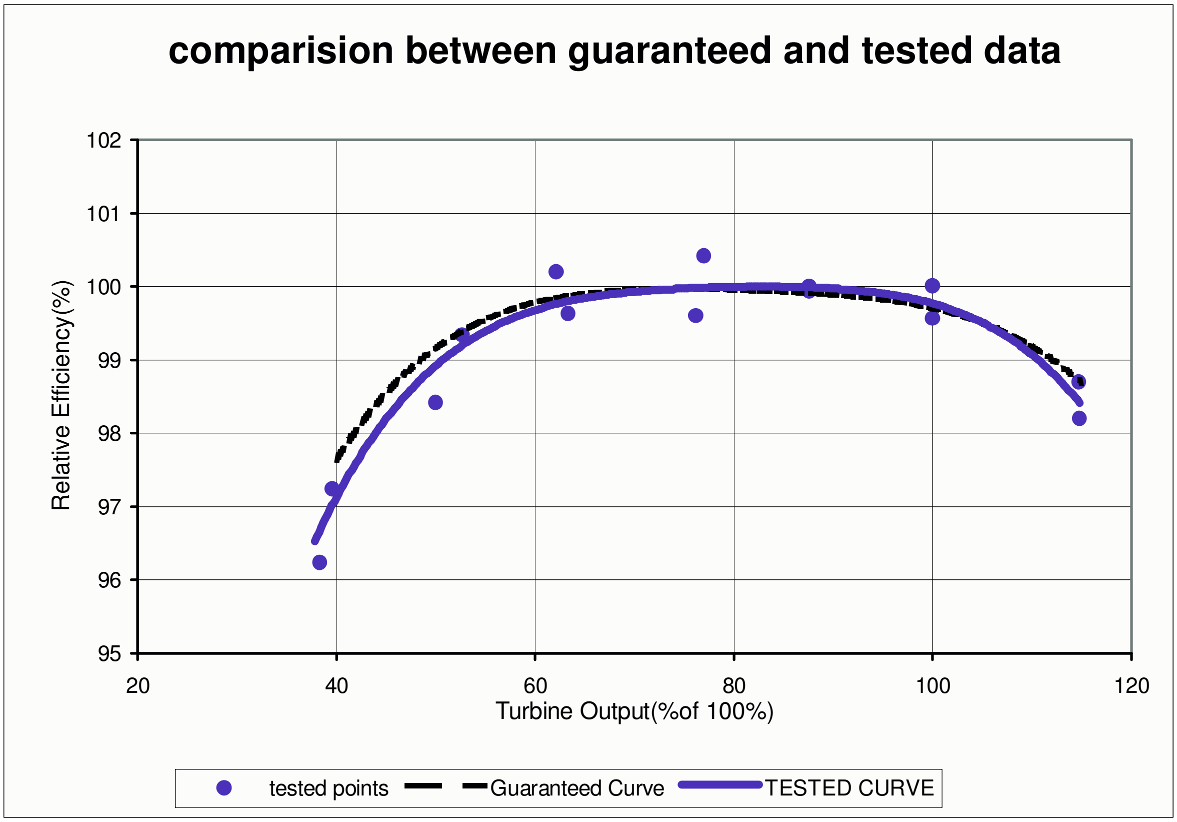


Fig-4

Conclusion-

The pressure time method gives satisfactory results for turbine field efficiency test provided measuring sections are selected to meet IEC 60041 conditions and proper instrumentation & system is deployed.

The description of the field acceptance tests using the pressure-Time method may give the false idea of an easy use of this measuring technique. On the other hand, many problems can affect the measurement accuracy and actually a deep knowledge of the phenomena and a wide experience in the real test activity is a must as to allow a proper detection and solution of all inconveniences that may occur. Finally, it is the experience that gives the reasonable certainty to obtain good results along with proper instrumentation and proven system.

Reference:

[1] International Standard CEI/IEC 60041, Field Acceptance Tests to Determine the Hydraulic Performance of Hydraulic Turbines, storage Pumps and Pump-Turbines, 1991

[2]. ASME. (1992). Performance Test Code for Hydraulic Turbines. Standard PTC-18, American Society for Mechanical Engineers, NY.