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Recent Applications and Problems of the Pressure Time Method

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SUMMARY

Due to the easiness and rapidity of its installation, the use of the pressure time method with computerized data acquisition systems has become more and more interesting.
After a brief description of the theory and of the procedure for the application of this method, the paper performs an analysis of the experimental data concerning three different powerplants in order to report some general evaluations and to focus the attention on some of the most common problems that could arise.

SOMMAIRE

Grâce à la facilité et à la rapidité d'installation, l'usage de la méthode pression temps avec systèmes computerisés pour l'acquisition des données est devenu de plus en plus extrêmemet interessant.
Après une brève description de la théorie et des modalités d'application de la méthode, on analyse les données expérimentales concernant trois aménagements dans le but d'exprimer des considérations generales et d'adresser l'attention vers quelques-uns des problèmes les plus communs.

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1. INTRODUCTION

The pressure time method, originally known as the Gibson method, has recently become again very actual thanks to the development of the calculation and of the digital acquisition systems. As a matter of fact, the method presents many good qualities such as the easiness of installation, the quickness of tests execution and the wide range of its application. Said qualities are even more remarkable if we consider the more and more increasing interest in an optimal utilization of the hydroelectric powerplants and the primary role played in this field by the determination of the efficiency and of the best operating range either during commissioning tests or during periodical checks.
The good qualities of the pressure time method make it certainly competitive with respect to the traditional methods that require a very long outage of the units (like the methods that provide for the use of current meters or ultrasonic flowmeters).
On the other hand, the execution modalities of the pressure time method can be critical in case of weak and not interconnected networks.
However, the interpretation of the results is not always easy owing to some errors that can be deceitful and difficult to identify.
The analysis of the experimental data concerning three extremely different powerplants has shown that some problems of great importance can arise. On one side the attention has been focused on the pressure taps, on the connections of these to the transducers as well as on the choice of the most suitable sensors and, on the other side, some possible sequences have been compared in order to highlight the problems related to the different test execution procedures.
Even if each specific case requires a particular analysis for obtaining reliable results, some simple guide lines, useful to choose case by case the most suitable solutions, have been pointed out.

2. DESCRIPTION OF THE METHOD

Theoretical principles

The pressure time method for measuring the discharge is based upon the Newton law and on the laws regarding the fluid dynamics that express the relationship existing between the force due to the two sections pressure difference variation and the acceleration or deceleration of the water mass between these sections caused by the operation of tha main valve or the wicket gate. Even if the method is theoretically valid both for the turbine and for the pump operation, in the second case it is not used because of some not very good results obtained owing to some particular operation ranges that the machine must cross by during the transients.
The following simplifying hypotheses give rise to the analytical relations on which this method is based:

1. The effects of the water compressibility and of the penstock elasticity, as well as those of the compressibility and elasticity of the connections to the transducers, are negligible.
2. The penstock load losses are almost quadratic with respect to the water velocity.
3. The fluid motion inside the measurement section should be considered as monodimensional (the velocity vectors in one section perpendicular to the penstock axis are simplified with a direct vector according to the penstock axis and with a modulus equal to the mean velocity) [1] [2].
Therefore, the following resulting forces act on the infinitesimal volume element of a constant section penstock piece (**fig. 1**):

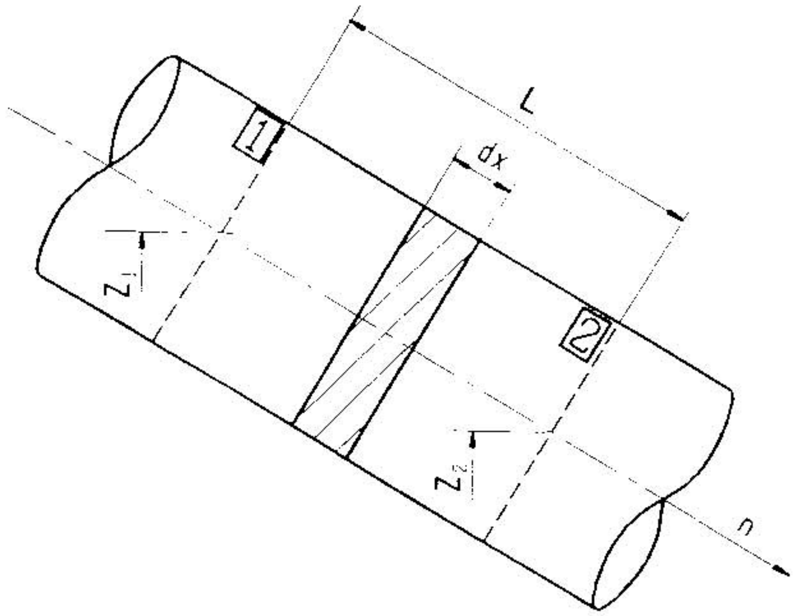


Fig. 1 Principle diagram of the method.

- Force of pressure: $F_p = -S\,dx\frac{\delta p}{\delta x}\bar{n}$

- Force of inertia: $F_i = -S\,dx\rho\frac{dv}{dt}\bar{n}$

- Force of weight: $F_g = -S\,dx\rho\, g\frac{dz}{dx}\bar{n}$

- Force of friction: $F_a = -S\,dxk|v|v\bar{n}$

By expressing the balancing conditions and by integrating for the whole L long measurement piece defined by the sections **1** and **2**, we obtain:

$$(p_2-p_1) + \rho\, g\,(z_2-z_1) + \rho\, L\, {}^{dv}/_{dt} + k|v|v\, L \;=\; \Delta p + \rho\, L\, {}^{dv}/_{dt} + k|v|v\, L \;=\; 0$$

where Δp represents the indication of a differential manometer placed between the two measurement sections. Then, by integrating in the time interval defined by the instants t_a e t_b where the check valve operates, we have:

$$\rho\ L(v_{ta} - v_{tb}) = \int_{ta}^{tb} (\Delta\ p + k|v|v\ L)\, dt$$

$$Q_{ta} = S\ v_{ta} = (S/\rho\ L) \int_{ta}^{tb} (\Delta\ p + k|v|v\ L)\, dt + S\ v_{tb}$$

The discharge $Q_{tb} = S\ v_{tb}$ that remains at the end of the operation, must be determined separately. This determination does not require a very high precision since the residual discharge must be a reduced fraction of the total measurement discharge (not exceeding 5%, according to the IEC Code No. 41/91).

Measurement method

From an operational point of view, two measurement sections, connected through manifold to a differential transducer, are prepared. Each measuring section is generally equipped with four taps, dia. 4 mm, positioned 45° to the horizontal axis so to obtain a reliable pressure average. The distance between the sections must be longer than 10 m and such as to satisfy, under the full load conditions, the relation: $v_{ta}\ L > 50\ m^2/s$.
The differential transducer connecting pipings must be as short as possible, stiff, and their internal diameter must be of at least 8 mm. Particular care should be put in removing the air present inside the circuit. Some experimental investigations have been performed on the influence of these pipings and on possible alternative installations.
The selection of the transducer is very important too considering that the natural frequency of the measuring system must be at least 10 times higher than the highest significant frequency available in the pressure signal.
Previous studies [3] have pointed out that the transmitters Smart (HW ST 3000) are usually able to supply good results.
The data acquisition system must have a sampling frequency of at least 50 smp/s; during the tests this paper is dealing with, an acquisition card NI-AT-MIO 16 x 2 with 16 channels multiplexed on a 16 bit converter with 100 ksmp/s has been used. The differential pressure has been then acquired with 250 smp/s in order to have an analysis frequency of 100 Hz. The converter resolution and the sampling frequency have been chosen in order to reduce at the minimum the errors either of conversion (about 0.003%) or of time (about 4 ms). The program for calculating the integral interpolates linearly point by point with a maximum conversion and time error that is always lower than ± 0.01%.
Furthermore, the program, that manages both acquisition and analysis including integration, allows to have a wide flexibility both for what concerns the choice of initial and final integration instants and for what concerns the introduction of digital filters.
Also when choosing the exponent suitable for determining the recovery line, the program allows to select the most appropriate one. Actually, while the quadratic relation approaches properly the steady conditions during turbulence, the same cannot be said for the transient state and for the laminar flow that take place during transition towards discharge zero. A more general law (see Colebrook and White) allows to perform a stricter evaluation of the temporal trend of the load losses.
The results we have obtained by adopting, in the real cases examined, the exponent deduced from the losses measured along all the penstock, were slightly different from the ones obtainable through a more rigorous approach.
The choice of the operating sequence of the check valve has to be done in order to satisfy two conflicting requirements. From one side, the transient should be quick enough to determine

quite high counterpressures able to improve the signal/noise ratio (in first approximation we can assume that $\Delta p_{max} = 2 L Q/g t S$); from the other side the frequencies determined by the phenomenon should be far enough from the possible resonance with the measuring system. Moreover, it is worthwhile to remember that particular transients can determine the passage through unsteadiness and backflow conditions that can affect the reliability of the measurements.

3. MEASURED CASES

This paper deals with the efficiency measurements performed on three very different powerplants both by means of the pressure time method and of other methods in order to be able to compare the various methodologies from the point of view of the reliability of the results.

Case 1: Vertical shaft Francis turbine with the following characteristic data:

H = 68 m $Q = 160\ m^3/s$ P = 98 MW   D = 5.180 m.

The inner diameter of the penstock piping is 6.125 m and the measurement taps have been placed 16 m one from another; the comparison methodology consisted in index tests with pressure differential on Winter Kennedy taps which coefficient had been deduced from the maximum efficiency value obtained by step up from tests performed on a similitude model.
The regulation of the flow has been carried out by closing the wicket gate; the leakage has been assessed with the aid of dimensional measurements and also by measuring the pressure differential across the closed wicket gate with the unit under operation.
The diagrams of efficiency versus power and discharge (**fig. 2**) illustrate the results of above said measurements. It is worthwhile to underline the good agreement between the results obtained by this method and the comparison one and the extreme repeatability of the measurements.

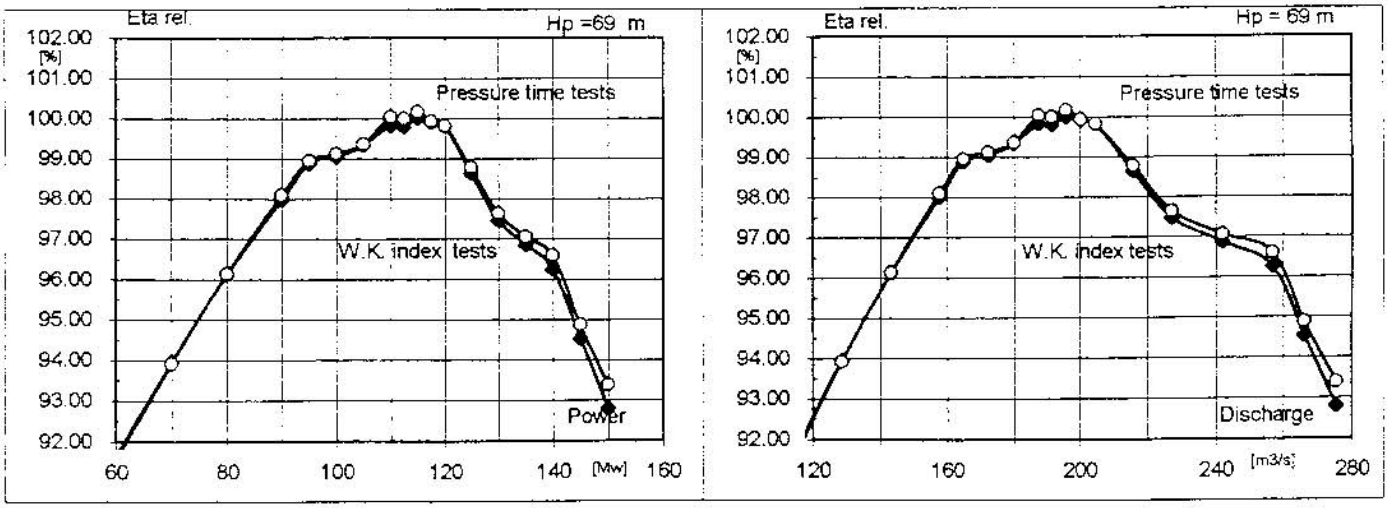
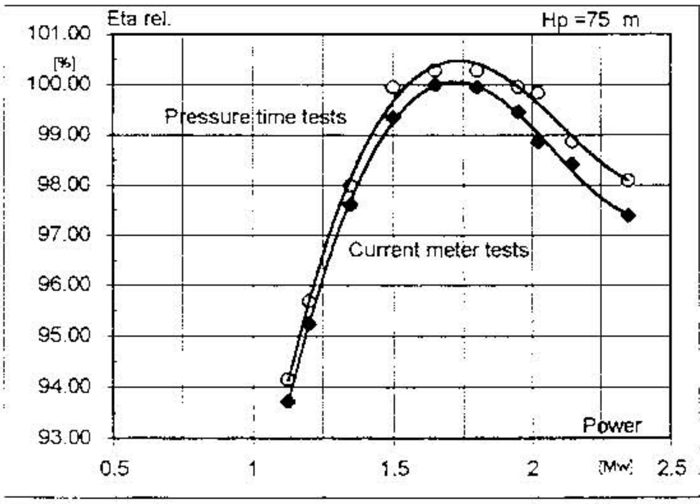


Fig. 2 Francis turbine 98 MW. Comparison between the pressure time method and the index measurements (similitude model).

Case 2: Vertical shaft Francis turbine with the following characteristic data:

H = 75 m Q = 3.50 m^3/s P = 2.40 MW D = 0.625 m.

The inner diameter of the penstock piping is 0.900 m and the measurement taps have been placed 38 m one from another; the comparison methodology consisted in discharge measurements performed by means of current meters: 30 current meters had been positioned on five verticals (six current meters for each vertical) along the machine outlet channel.
The regulation of the flow has been carried out both by closure of the butterfly valve and by closure of the wicket gate; in the latter case the rising time of the discharge reservoir has been utilized for measuring the leakage of the gate.
The diagrams of efficiency versus power and discharge **(fig. 3)** illustrate the results of these measurements. In this case the agreement with the comparison method is not so strict: the efficiency measured by the pressure time method results higher of about 0.50%; anyway, also in this case the extreme repeatability of the measurements has to be noticed.



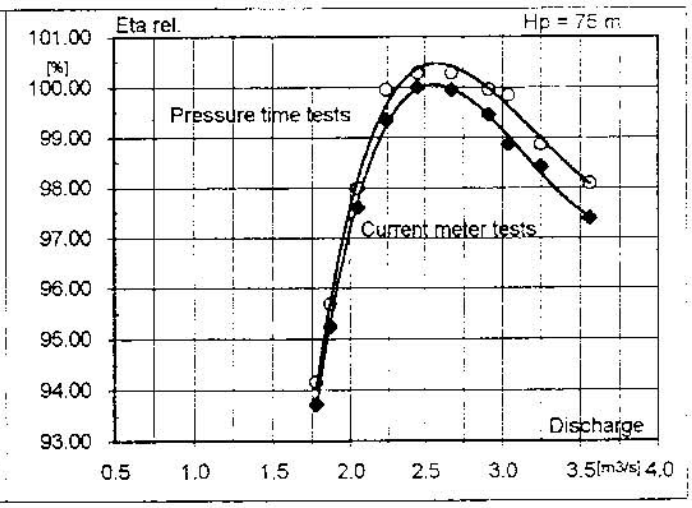


Fig. 3 Francis turbine 2.4 MW. Comparison between the pressure time method and the current meters.

Case 3: Vertical shaft Pelton turbine with the following characteristic data:

H = 695 m Q = 11.50 m^3/s P = 72 MW D = 1.880 m.

The inner diameter of the penstock piping is 1.800 m and the measurement taps have been placed 20 m one from another; the comparison methodology consisted in measuring the efficiency through the thermodynamic method with two measurement points upstream and six measurement points downstream.
The regulation of the flow has been performed both by closing the spherical valve and by closing the needles; in the first case it was also possible to measure the by-pass discharge by means of the pressure time method.

The diagrams of efficiency versus power and discharge **(fig. 4)** illustrate the results of these measurements. In this case the agreement with the comparison method is good enough: the efficiency measured with the pressure time method is 0.22% higher, the repeatability of the measurements is good.

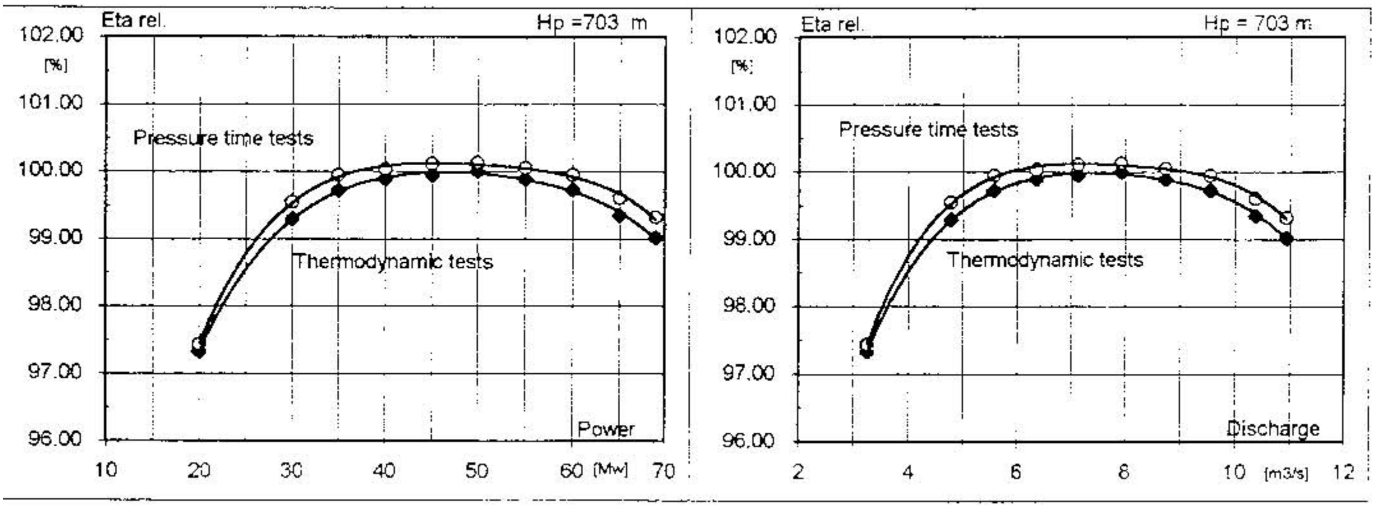


Fig. 4 Pelton turbine 74 MW. Comparison between the pressure time method and the thermodynamic method.

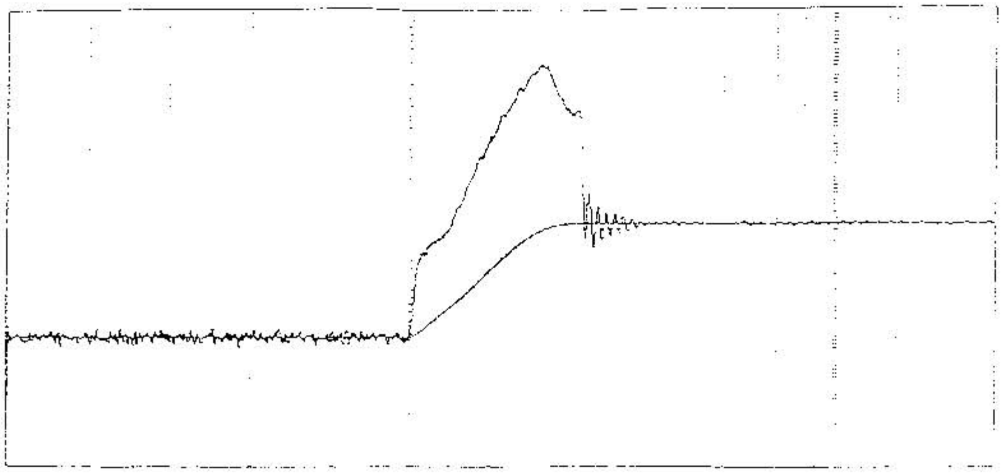
4. ANALYSIS OF THE RESULTS

The results have to be considered extremely satisfactory; nevertheless, it is necessary to point out that they would not have been attainable if the method had been applied in an uncritical and mechanistic way.
Among the problems relating to the application of the method, the tests have allowed to point out some important aspects .

4.1 Connecting pipings

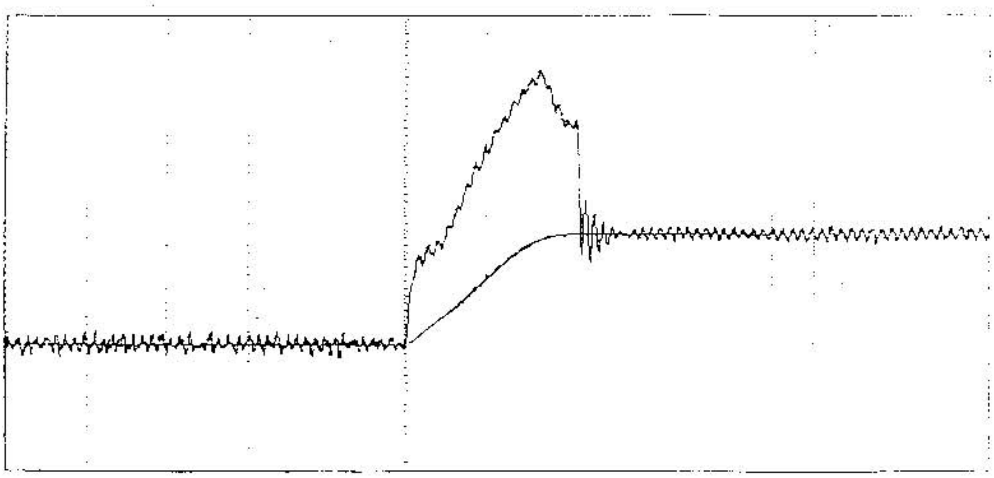
The codes precribe that the connecting pipings be stiff, it is obvious that in the sphere of a dynamical phenomenon, the concept of stiffness cannot be inpendent of the frequency range relating to the event. In principle, it is clear that the most suitable solution is the adoption of metal pipings (preferably of steel) even if it presents some practical disadvantages among which the necessity to manufacture new pipings for each powerplant. Furthermore, with these pipings it is almost impossible to perform a continuous check of the presence of any trapped air. Experimental data have pointed out that the presence of air bubbles, even if very small, entails anyway macroscopic effects **[4]**
In order to overcome said problems, high pressure armoured rubber pipings and Rilsan 12/8 pipings have been tested. Before performing the tests, these pipings have been measured in laboratory for determining their elasticity coefficient in order to be sure that the dynamic of the phenomenon would not be affected.

The transients obtained from the three different types of pipings have been compared for the same powerplant (1). The length of the pipings is very important too.



without air bubbles

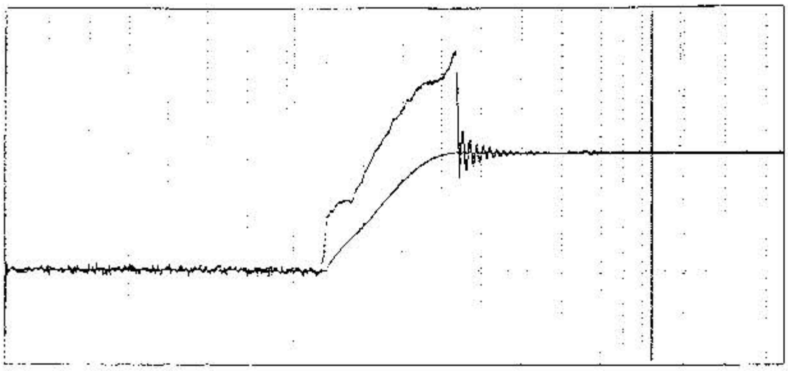
scala X : 10s/div		scala Y: Min= -8.999kPa	Max= +8.004kPa
PRESSIONE INIZIALE	= -4.1966 kPa	PERDITE DI CARICO	= 4.1910 kPa
PRESSIONE FINALE	= -0.0056 kPa	DENSITA' DELL'ACQUA	= 999.90 kg/m^3
PORTATA Prima Iter.	= 8.0446 m^3/s	PORTATA Ultima Iter.	= 8.5619 m^3/s
PORTATA INTEGRAZIONE	= 8.5619 m^3/s	FREQ. DI ACQUISIZIONE	= 100.00 Hz
PORTATA TRAFILAMENTI	= 0.0070 m^3/s	FREQ. DI FILTRAGGIO	= 10.00 Hz
PORTATA TOTALE	= 8.5689 m^3/s	Iteration No. 6 (4710÷ 9175)	



with one air bubble 15 mm long

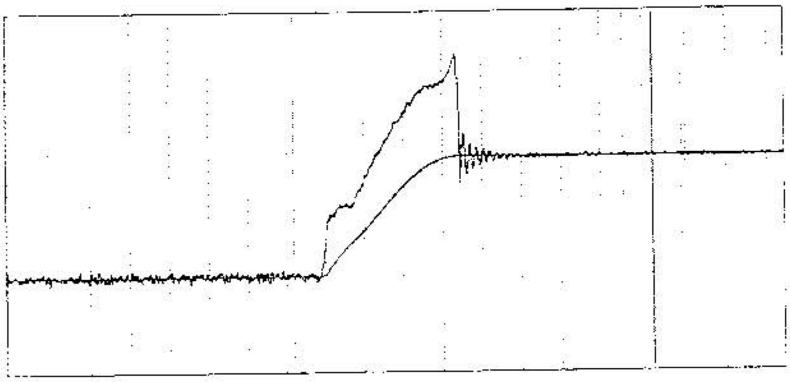
scala X : 10s/div		scala Y: Min= -8.994kPa	Max= +8.255kPa
PRESSIONE INIZIALE	= -4.1703 kPa	PERDITE DI CARICO	= 4.2035 kPa
PRESSIONE FINALE	= 0.0333 kPa	DENSITA' DELL'ACQUA	= 999.90 kg/m^3
PORTATA Prima Iter.	= 8.0566 m^3/s	PORTATA Ultima Iter.	= 8.6522 m^3/s
PORTATA INTEGRAZIONE	= 8.6522 m^3/s	FREQ. DI ACQUISIZIONE	= 100.00 Hz
PORTATA TRAFILAMENTI	= 0.0070 m^3/s	FREQ. DI FILTRAGGIO	= 10.00 Hz
PORTATA TOTALE	= 8.6592 m^3/s	Iteration No. 6 (4710÷ 9175)	

Fig. 5 Influence of the presence of air bubbles inside the connecting pipings.



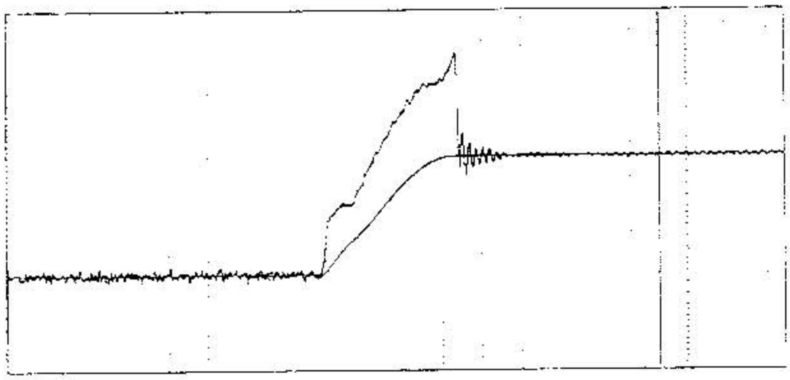
stainless steel pipe

scala X : 10s/div		scala Y: Min=-11.024kPa	Max= +7.434kPa
PRESSIONE INIZIALE	= -6.1003 kPa	PERDITE DI CARICO	= 6.0938 kPa
PRESSIONE FINALE	= -0.0065 kPa	DENSITA' DELL'ACQUA	= 999.90 kg/m^3
PORTATA Prima Iter.	= 9.7004 m^3/s	PORTATA Ultima Iter.	= 10.2898 m^3/s
PORTATA INTEGRAZIONE	= 10.2898 m^3/s	FREQ. DI ACQUISIZIONE	= 100.00 Hz
PORTATA TRAFILAMENTI	= 0.0070 m^3/s	FREQ. DI FILTRAGGIO	= 10.00 Hz
PORTATA TOTALE	= 10.2968 m^3/s	Iteration No. 8 (4310÷ 9320)	



rubber high pressure pipe

scala X : 10s/div		scala Y: Min=-11.028kPa	Max= +7.458kPa
PRESSIONE INIZIALE	= -6.1015 kPa	PERDITE DI CARICO	= 6.0965 kPa
PRESSIONE FINALE	= -0.0050 kPa	DENSITA' DELL'ACQUA	= 999.90 kg/m^3
PORTATA Prima Iter.	= 9.7025 m^3/s	PORTATA Ultima Iter.	= 10.2785 m^3/s
PORTATA INTEGRAZIONE	= 10.2785 m^3/s	FREQ. DI ACQUISIZIONE	= 100.00 Hz
PORTATA TRAFILAMENTI	= 0.0070 m^3/s	FREQ. DI FILTRAGGIO	= 10.00 Hz
PORTATA TOTALE	= 10.2855 m^3/s	Iteration No. 8 (4310÷ 9320)	

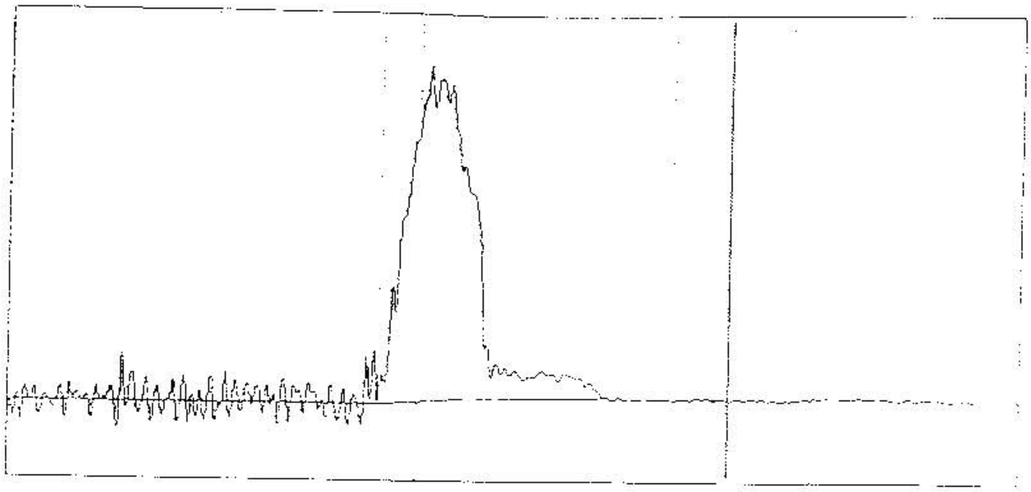


rilsan 8/12 mm pipe

scala X : 10s/div		scala Y: Min=-11.030kPa	Max= +7.470kPa
PRESSIONE INIZIALE	= -6.1028 kPa	PERDITE DI CARICO	= 6.1066 kPa
PRESSIONE FINALE	= 0.0038 kPa	DENSITA' DELL'ACQUA	= 999.90 kg/m^3
PORTATA Prima Iter.	= 9.7106 m^3/s	PORTATA Ultima Iter.	= 10.2634 m^3/s
PORTATA INTEGRAZIONE	= 10.2634 m^3/s	FREQ. DI ACQUISIZIONE	= 100.00 Hz
PORTATA TRAFILAMENTI	= 0.0070 m^3/s	FREQ. DI FILTRAGGIO	= 10.00 Hz
PORTATA TOTALE	= 10.2704 m^3/s	Iteration No. 8 (4710÷ 9420)	

Fig. 6 Influence of the connecting pipings on the pressure transient trend.

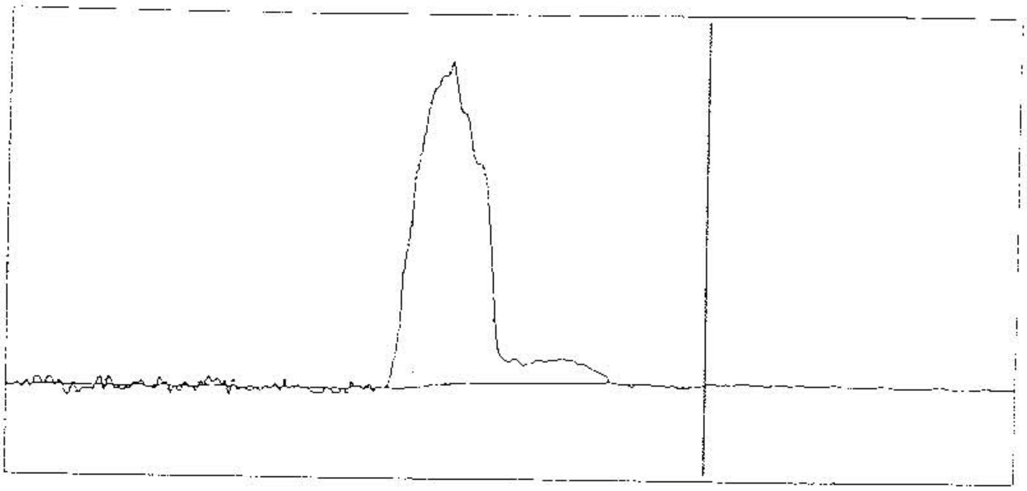
Experimental data show that the transient trend can be different depending on the length of the two connection pieces. Two transients obtained from two pipings of different length have been compared (**fig. 7**).



pipe lenght 2 x 10 m

X scale : 10s/div
STARTING PRESSURE = -0.3223 kPa
FINAL PRESSURE = 0.0213 kPa
DISCHARGE first Iter = 265.6809 m^3/s
INTEGRATED DISCHARGE = 220.9538 m^3/s
LEAKAGE DISCHARGE = 0.7000 m^3/s
TOTAL DISCHARGE = 221.6538 m^3/s

Y scale: Min= -5.534kPa Max=+25.867kPa
FRICTION LOSSES = 0.3010 kPa
WATER MASS DENSITY = 996.91 kg/m^3
DISCHARGE last Iter = 220.9538 m^3/s
SAMPLING FREQUENCY = 100.00 Hz
FILTERING FREQUENCY = 4.00 Hz
Iteration No. 3 (1808÷ 3298)



pipe lenght 2 x 9 m

X scale : 10s/div
STARTING PRESSURE = -0.4356 kPa
FINAL PRESSURE = -0.0917 kPa
DISCHARGE first Iter.= 283.2867 m^3/s
INTEGRATED DISCHARGE = 223.7561 m^3/s
LEAKAGE DISCHARGE = 0.7000 m^3/s
TOTAL DISCHARGE = 224.4561 m^3/s

Y scale: Min= -6.630kPa Max=+25.331kPa
FRICTION LOSSES = 0.3438 kPa
WATER MASS DENSITY = 996.31 kg/m^3
DISCHARGE last Iter = 223.7561 m^3/s
SAMPLING FREQUENCY = 100.00 Hz
FILTERING FREQUENCY = 4.00 Hz
Iteration No. 3 (1860÷ 3200)

Fig. 7 Influence of the connecting pipings length.

In this specific case, the discharge integral is affected in a very limited way.
In order to definitely solve this kind of problems, the best solution would be to adopt transducers with surfacing foil or transducers that are somehow directly connected to the measurement manifold obtaining then the difference electronically **(fig. 8)** [5].

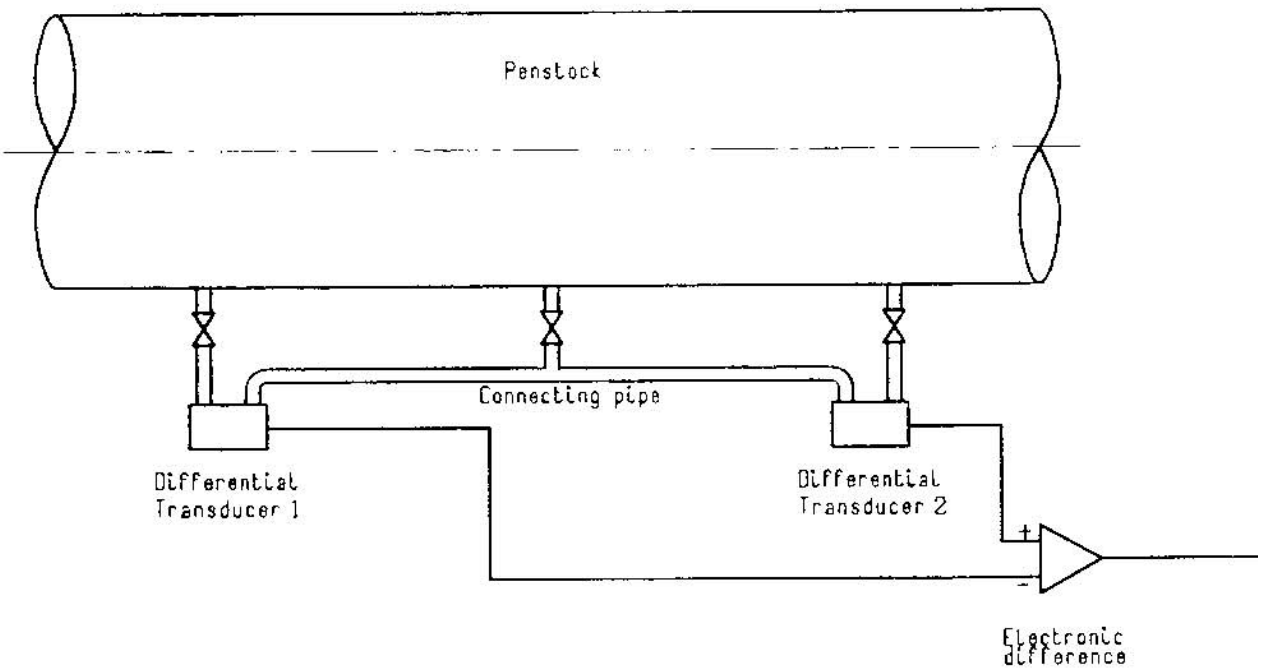


Fig. 8 Test device for reducing the influence of the connecting pipings.

Just by experimental way, a test arrangement providing for two differential transducers that assure a proper sensitivity has been proposed. The connecting piping does not suffer from the above described problems since it is not subject to remarkable dynamic phenomena. Hence the first experimental results seem to be encouraging.

4.2 Selection of the transducers

The selection of the transducers is very important [3] [4]. Actually, the stability in the time of the calibration parameters, the insensitivity to the temperature variations and the insensitivity of the differential sensor to the line pressure and to the barometric pressure variations assume particular importance. These characteristics must be specific not only to the sensor but to the whole measurement chain.
The dynamic behaviour of the sensor is very important too, but the frequency response must be evaluated as a function of the real dynamics of the phenomenon to analyse.
During usual applications of the method, the Smart type sensors have given good results: actually, they assure a deep accuracy and stability, they are internally compensated for the

temperature variations and are practically insensitive to the line pressure variations. The modest characteristics of the dynamic response (generally lower than 10 Hz) do not represent an important limit for most cases.

On the contrary, the strain gauge sensors give a good dynamic response (higher than 250 Hz). They have a great sensitivity with respect to the variations both in temperature and in pressure. Said properties have to be taken into account either during installation or during calibration.

Finally, the piezolectric sensors have very good dynamic characteristics but present a driftage from zero that is very difficult to compensate also through the normal check procedures followed before and after each test.

At the time being, it is not possible to identify a sensor suitable for all applications: the choice of the most appropriate transducer must be done case by case (**fig. 9**). The use of differential sensors with pressure-frequency quartz transducers that, through the manufacturers data, present such characteristics that are able to satisfy the widest requirements seems to be promising.

Instrument	Signal type and amplification	Normal range and resolution	ACCURACY [%]	Temperature sensitivity [ppM/°K]	Static pressure sensitivity [ppM/50%fs]	Time stability [ppM/DAY]	Frequency response [Hz]	Signal noise ratio
"SMART" transmitter	mA CONTINOUS	1-1000 KPa Infinite	0.05	20 (on zero) 10 (on gain)	100 (on zero) 10 (on gain)	10 (on zero) 0 (on gain)	10	60 dB
STRAIN GAUGE amplified transmitter	mA - V CONTINOUS	1-1000 KPa Infinite	0.15	100 (on zero) 40 (on gain)	150 (on zero) 40 (on gain)	20 (on zero) 0 (on gain)	500	20 dB
STRAIN GAUGE transducer	mV External amplifier	1-1000 KPa	0.10	80 (on zero) 40 (on gain)	150 (on zero) 40 (on gain)	20 (on zero) 0 (on gain)	5K	20 dB
Piezoelectric tranceducer	pC External amplifier	1-200 KPa Infinite	0.25	300 (on zero) 60 (on gain)	180 (on zero) 80 (on gain)	200 (on zero) 0 (on gain)	25K	20 dB
"DIGIQUARTZ" transducer	Hz FIXED	Any two probes 0.01 ppM	0.02	30 (on zero) 10 (on gain)	50 (on zero) 0 (on gain)	0 (on zero) 0 (on gain)	200	60 dB

Fig. 9 Average parameters for comparison between different sensors.

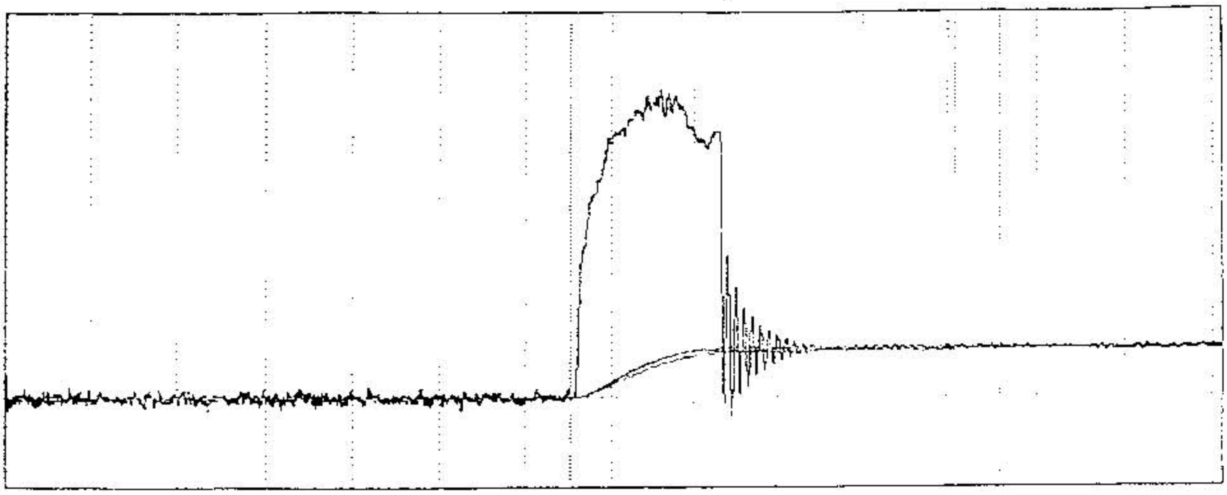
4.3 Operation sequences

From a theoretical point of view, the method followed for regulating the discharge should be irrelevant so as irrelevant is the type of intercepting device used. What's more, the codes

highlight the requirement that the regulation operation be constant and slow enough so that the resonance phenomena can be avoided.
In practice, many experiences confirm that the passage through instability and recirculation areas affects the reliability of the measurements. The specific case of a low n_s Francis turbine (case 2) has been verified comparing the wicket gate closure of a synchronous machine (constant rotational speed in the t_a t_b interval), with respect to the same operation performed with a non synchronous machine under the same load conditions (with overspeeds typical to a normal load rejection). The obtained result is macroscopically different (**fig. 10**), the most reliable results are those obtained with synchronous machine.
We may assume that, during the overspeed, a pump effect and flow recirculations able to prevent a test from being correctly performed can take place. In the case of a quick Francis turbine (case 1), the differences have been less remarkable (about 0.35%); nevertheless, also in this case the operation with synchronous machine has supplied more reliable and less dispersive results. In the case of a Pelton turbine (case 3), no significant differences have been noticed.
Hence, from the few experiences that have been collected, the measurement performed with machine remaining synchronized during the transient seems to be more reliable: obviously this conclusion cannot be generalized without performing further checks. Anyway, it is necessary to point out that also the operation sequence is a not negligible aspect that must be tested and deepened case by case whenever performing the tests.

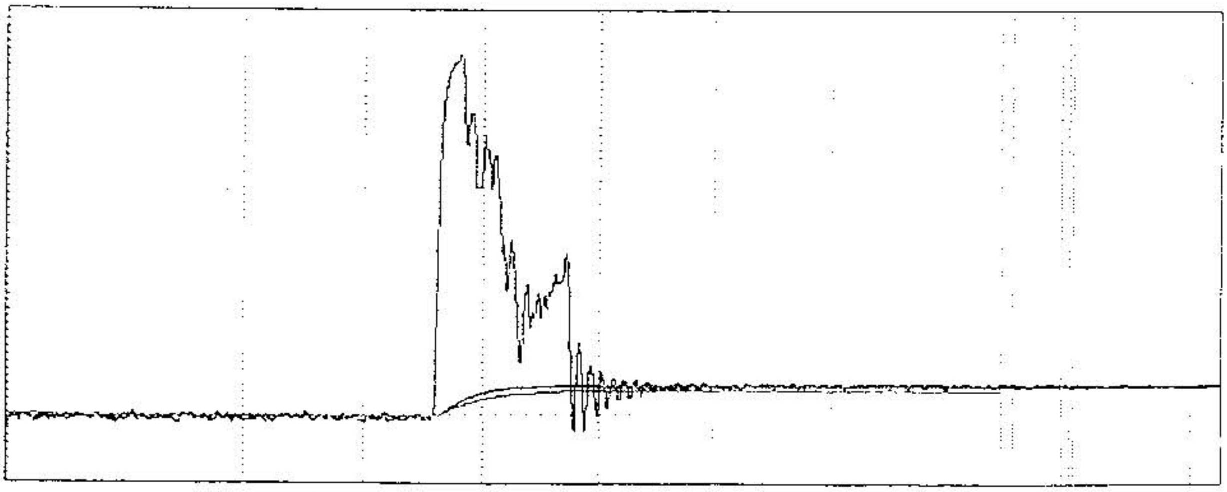
5. CONCLUSIONS

The experimental data have highlighted from one side the great potentiality of the pressure time method in terms of quickness of execution, easiness of installation and possibility of use. Furthermore, the comparisons that have been carried out show that there is a good agreement between this method and the other measurement tipologies: the differences that have been found remain always below the uncertainty band connected to the adopted methods.
On the other side, the good results come out of a deep analysis, as detailed as possible, of all possible error causes and of all problems related to the method.
Anyway, it is necessary to point out that even a careful and precise application of procedures and precautions provided by the current international codes is not enough to prevent said errors from occurring.
As a matter of fact, the application of this method always requires to perform a deep evaluation that allows to remove the uncertainty sources, sometimes devious and difficult to identify, that are connected to the type of methodology.
The pressure time method, as well as all other methods aiming at deteriming the efficiency of the hydraulic machines, can supply extremely positive results only if the analysis is carried out in the light of a remarkable experience and of a strong critical sense.



unit connected to network

scala X : 10s/div		scala Y: Min= -2.250kPa	Max= +5.451kPa
PRESSIONE INIZIALE	= -0.8068 kPa	PERDITE DI CARICO	= 0.8054 kPa
PRESSIONE FINALE	= -0.0014 kPa	DENSITA' DELL'ACQUA	= 1000.00 kg/m^3
PORTATA Prima Iter.	= 1.3339 m^3/s	PORTATA Ultima Iter.	= 1.9173 m^3/s
PORTATA INTEGRAZIONE	= 1.9173 m^3/s	FREQ. DI ACQUISIZIONE	= 100.00 Hz
PORTATA TRAFILAMENTI	= 0.0570 m^3/s	FREQ. DI FILTRAGGIO	= 10.00 Hz
PORTATA TOTALE	= 1.9743 m^3/s	Iteration No. 4	(6523÷11083)



unit disconnected from network

scala X : 10s/div		scala Y: Min= -2.368kPa	Max= +9.017kPa
PRESSIONE INIZIALE	= -0.7388 kPa	PERDITE DI CARICO	= 0.7388 kPa
PRESSIONE FINALE	= 0.0000 kPa	DENSITA' DELL'ACQUA	= 999.90 kg/m^3
PORTATA Prima Iter.	= 1.2775 m^3/s	PORTATA Ultima Iter.	= 1.7355 m^3/s
PORTATA INTEGRAZIONE	= 1.7355 m^3/s	FREQ. DI ACQUISIZIONE	= 100.00 Hz
PORTATA TRAFILAMENTI	= 0.0570 m^3/s	FREQ. DI FILTRAGGIO	= 10.00 Hz
PORTATA TOTALE	= 1.7925 m^3/s	Iteration No. 3	(10÷ 8430)

Fig. 10 Influence of the closure operation of the regulating device (wicket gate).

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