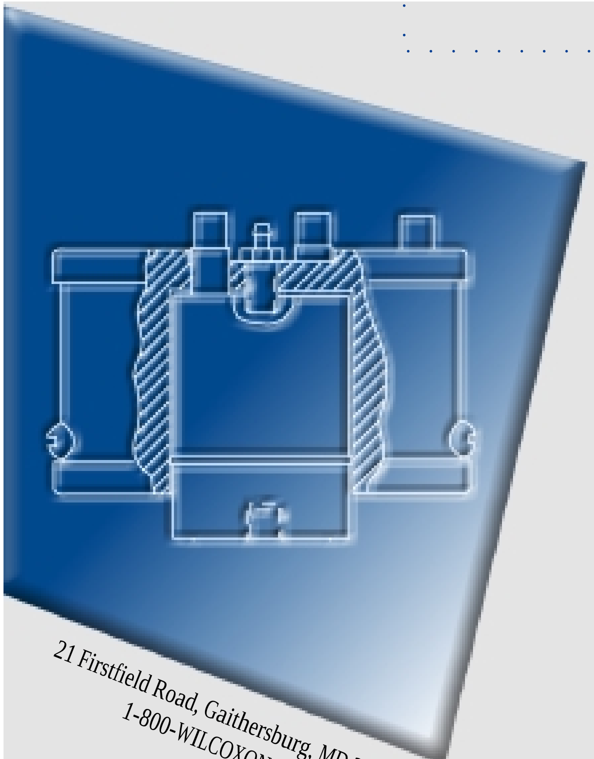
i m p e d a n c e

Technical Note 2

Choosing An Impedance Head



21 Firstfield Road, Gaithersburg, MD 20878 USA
1-800-WILCOXON • Tel 301-330-8811
Fax 301-330-8873
Email sensors@wilcoxon.com
Web www.wilcoxon.com

Among the factors that must be considered in choosing an impedance head are the range of impedance of interest, and the effect that the impedance head may have on the vibratory characteristics of the test specimen.
The ranges of impedance for which the Wilcoxon Impedance Heads Z602WA and Z820WA can be used with the rated precision, which is based on the frequency response of the accelerometer, are indicated in the following table.

Impedance Head	Minimum Impedance	Maximum Impedance
Z602WA	Impedance of a mass of 0.05 lb (0.02 kg)	Impedance of a mass of 250 lb (113 kg), or of a stiffness of 6 x 10^5 lb/in (9 x 10^8 N/m)
Z820WA	Impedance of a mass of 0.3 lb (0.14 kg)	Impedance of a mass of 10^4 lb (4536 kg), or of a stiffness of 7 x 10^6 lb/in (1.2 x 10^9 N/m)

The impedance head — and shaker, depending on the method of attachment — can influence the vibratory characteristics of the test specimen by acting as a constraint on it, and be stiffening it locally near the point of attachment. Both of these effects are undesirable since they introduce errors in the measurements by changing the system which includes the impedance head and its driver. Both effects can be reduced by use of the Z602WA since it is lighter, has a lower moment of inertia about a diameter through the contacting surface of the base, and has a smaller contacting area.

The constraining effect can be further reduced by supporting the shaker separately from the impedance head, and coupling to it by means of a relatively short flexible wire. Lateral resonant frequencies of the wire should be above the frequency range of interest or should be suppressed by the application of a thick layer of damping material. The stiffening effect introduced by the Z820WA can be reduced, at the expense of increasing its moment of inertia and its inertial constraining effect, by attaching it to the test specimen by means of the conical base-diameter reducing adapter.

Certain criteria must be met if the test specimen is to remain unchanged in its vibratory characteristics. After attachment of an impedance head, the lineal and rotational impedance of the head looking into its base, and about a line through the axis of symmetry of the head and the plan of the contacting surface between head and specimen must be much less than the lineal and rotational impedance of the specimen and the point of the head.

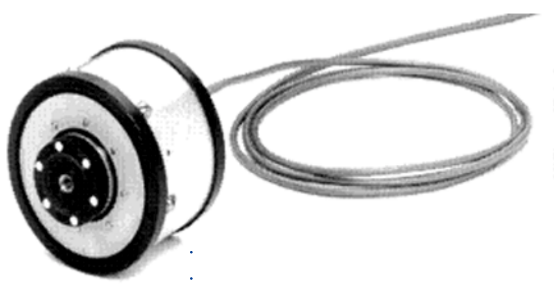
WR WILCOXON RESEARCH

Attaching Vibration Generators To The Impedance Head

Impedance heads can be driven most conveniently by integrally mounted vibration generators (shakers). Although such generators are necessarily small and have relatively low force output, all but the most stiff and massive structures can be investigated with them if satisfactory electronics can be employed.

Vibration generator models F3 and F4 with maximum force ratings of 0.75 and 1.5 lbs are available for integral mounting on the Z602WA and Z820WA impedance heads respectively. Contact Wilcoxon for further information.

If large shakers are to be used with the impedance heads in other than a vertical position, they must be supported independently, in such fashion that the only vibratory force applied to the test specimen is that transmitted through the head. The shakers may be attached to the impedance head by short thin rods or wires as mentioned above. Care must be taken when such attachment methods are used not to damage the shaker coil or its suspension.



F4/Z820WA

Attaching The Impedance Head To The Test Specimen

Trapped holes are provided in the center of the base of impedance heads for their attachment to test specimens. The Z602WA uses a 10-32 attachment stud and the Z820WA uses a 3/8 NC - 16 stud for direct attachment.

Through bolts may be used for attachment to thin specimen; thick specimens may be drilled and tapped for coupling by a stud. If holes in the test specimen are not permitted, the impedance head may be attached to mounting pads which have been cemented in place. Because of the relatively low elastic modulus of cements, the layer should be as thin as possible, preferably not more than 0.005 inches thick. For the Z602WA, a satisfactory pad would be 0.5 inch in diameter by 3/16 inch thick aluminum. For the Z820WA, 1 5/8 inches in diameter by 3/8" thick steel. A mounting pad for the Z602WA can be used with the conical reducing adapter for the Z820WA.

System Calibration and Driving Point Impedance Measurements

The system which includes the head and electronic amplifying equipment may be calibrated without determining individually the sensitivities of the force gage and accelerometer or the gains of the amplifiers. The weight W_x below the force gage — provided by Wilcoxon on the calibration sheet for each impedance head — serves as the calibrating weight. If for some reason a larger weight is desired for calibration, an internal weight may be added to W_x by attaching it to the base of the impedance head. The calibration should be performed immediately before and after an investigation. For calibration, the impedance head is driven at any frequency between about 50 and 2000 Hz with the base free by seismically suspending or supporting the assembly. The natural frequency of the suspension system should be well below 50 Hz. The frequency-independent ratio of the voltage at the output of the acceleration channel E_A cal to the voltage at the output of the force channel E_F cal should be determined.

If the impedance head is subsequently attached to a specimen without changing the gain setting of the amplifiers, it can be readily be seen that the "apparent weight" of the specimen, which includes the weight below the force gage, is

$$\frac{E_F}{E_A} \; X \; \frac{E_{A\,cal}}{E_{F\,cal}} = W_x$$

Equation 1

where E_F and E_A are the voltages at the output of the force and acceleration channels when driving a specimen.

The magnitude of the impedance is 2Õ f/g times (Figure 1), where f is the frequency and g is the acceleration of gravity. The magnitude of the true driving point impedance (without the weight below the force gage) can be computed by subtracting the reactance of the weight below the force gage and is $(R^2 + X^2)^{1/2}$

where: $$R = \frac{2P\,f}{g} \; W_x \; \frac{E_{A\,cal}\,E_F}{E_{F\,cal}\,E_A} \sin Æ$$

Equation 2

and

$$X = \frac{2 P f}{g} W_x \left[\frac{E_{A\,cal} E_F}{E_{F\,cal} E_A} \cos \text{Æ} \;\; -1 \right]$$

Equation 3

and where Æ is the angle by which the signal in the acceleration channel leads the signal in the force channel. The phase angle of the impedance is $\tan^{-1} X/R$.

Electronic Cancellation Of Weight Below Force Gage

The effect of the weight below the force gage plus any other additional weights, such as mounting pads, may be cancelled electronically. The signal which must be subtracted from the force amplifier is proportional to W_x x a, where a is the acceleration. It is therefore necessary to subtract from the force channel a signal proportional to the acceleration and derived from the acceleration channel. Note that this electronic subtraction would be difficult to accomplish with a transducer whose output is not proportional to acceleration. The adjustment for electronic subtraction is performed immediately after calibration as described above by adjusting a linear potentiometer in the subtracting circuit so that the output from the force channel is zero or nearly so, the mechanical system being the same as that used for calibration with the base free and the assembly seismically suspended. Better than 25 dB cancellation should be obtainable over the entire frequency range with well designed circuitry. If a mounting pad is used and is also to be subtracted, a different setting of the potentiometer will be necessary and is obtained by attaching the pad to the base when the potentiometer is adjusted for zero output from the force channel.

The magnitude of impedance of the specimen with the electronic subtraction is

$$\frac{2 P f}{g} W_x \frac{E_{A\,cal} E_F}{E_{F\,cal} E_A} = \text{constant} \quad \frac{E_F}{E_A} f$$

Equation 4

The phase angle between the two channels will be the phase angle between the applied force and resulting acceleration, provided there is no relative phase shift in the electronic circuitry. For ease of operation, the electronic subtraction should be accomplished in the preamplifier circuits at points prior to the gain controls.

Transfer Impedance Measurements

For transfer impedance measurements, the Model 732 accelerometer is recommended for use with the Z620WA, and the Model 720 accelerometer for use with the Z820WA. To electronically cancel the weight below the force gage in transfer impedance measurements, it is necessary to have three transducers and preamplifiers, two accelerometers, and one force gage. However, the transfer impedance is usually of such magnitude that the error introduced by not cancelling is usually small.

The calibration is performed exactly the same as that for driving point impedance measurements except that the transfer accelerometer is attached to the base of the head and the acceleration signal is derived from the transfer accelerometer. The calibrating weight, therefore, is W_x plus the weight of the transfer accelerometer (W_{acc}) and any other hardware which may be needed, such as studs, etc.

The transfer impedance is approximately equal to

$$\frac{2 P f}{g} (W_x + W_{acc}) \quad \frac{E_{A\,cal} E_F}{E_{F\,cal} E_A} \qquad \text{where}$$

$$\frac{E_{A\,cal}}{E_{F\,cal}} = \text{ratio of the signal from}$$

the transfer accelerometer to the force signal with the transfer accelerometer attached to the base of the head during calibration.

Although it may not be necessary in transfer measurements to correct for the weight below the force gage, it is necessary especially at the higher frequencies to correct for the weight of the external accelerometer. If the impedance of the accelerometer Z_{acc} is of the same order of magnitude or higher than the driving point impedance of the specimen at the transfer accelerometer location Zp, then the corrected transfer impedance

is $$\frac{Z_P}{Z_{acc} + Z_p} Z_{t,}$$ where Z_t is the measured transfer impedance. All of the above impedances are, of course, complex quantities.

For technical assistance, please contact Wilcoxon at 301-330-8811 or email: techasst@wilcoxon.com.