Fermilab

TM-1125
2562.000
August 1982

A SENSITIVE AND SIMPLE METHOD FOR MEASURING WIRE TENSIONS

M. Atac
Fermi National Accelerator Laboratory, Batavia, Illinois 60510, USA

and

M. Mishina
National Laboratory for High Energy Physics, KEK, Ibaraki-ken, Japan

INTRODUCTION

Measuring tension of wires in drift chambers and multiwire proportional chambers after construction is an important process because sometimes wires get loose after soldering, crimping or glueing. One needs to sort out wires which have tensions below a required minimum value to prevent electrostatic instabilities.[1)]

There have been several methods reported on this subject[2)] in which the wires were excited either with sinusoidal current under magnetic field or with sinusoidal voltage electrostatically coupled to the wire, searching for a resonating frequency with which the wires vibrate mechanically. Then the vibration is detected either visually, optically or with magnetic pick-up directly touching the wires. Any of these is only applicable to the usual multiwire chamber which has open access to the wire plane. They also need fairly large excitation currents to induce a detectable vibration to the wires. Recently there was a report[3)] in which change in wire resistance on the resonance due to cooling of the wire by the vibration was detected. Again the excitation current had to be large enough to heat up the wire. Still, the change in the resistance was so small that it needed carefull measurement with a bridge circuit.

Here we report a very simple method that can be used for any type of wire chamber or proportional tube system for measuring wire tension. Only a very small current is required for the wire excitation to obtain a large enough signal because it detects the induced emf voltage accross a wire. A sine-wave oscillator and a digital voltmeter are sufficient devices aside from a permanent magnet to provide the magnetic field around the wire. A useful application of this method to a large system is suggested.

EXPERIMENTAL ARRANGEMENT

Fig.1 shows the test set-up. An audio frequency oscillator was used to feed the excitation current to the anode wire of a sample proportional tube. The tube was 100 cm long and 7 mm x 10 mm in cross section made of conductive plastic. The anode wire was 50 μm thick gold plated tungsten strung with a tension of about 200 grams.

The AC voltage accross the wire was measured by a digital voltmeter in AC voltage mode.

The tube was inserted into the gap of a permanent magnet whose field was about 1.8 kGauss with pole pieces about 15 cm long along the tube. The frequency of the oscillator was continuously monitored by a frequency counter which might not be necessary if the tension needs not to be measured down to a few tenth of a percent level.

The large capacitor in series was to block DC current and the two fairly large resistors were to form a constant current source. They were also necessary for minimizing the current due to the induced emf. Otherwise the sensitivity would have been reduced. Possible noise pick-up was also blocked by these resistors.

TEST RESULTS

Typical resonance curves are plotted in Fig.2 for the excitation currents of 200 μA and 20 μA, with the latter being scaled up by a factor of 10. In both cases the peak values at 123.6 to 123.7 Hz show an enhancement of 54 % above the off-resonance level. In this measurement the magnetic field was increased to 2 kGauss by adding iron pole pieces. The graph shows the third and the fifth harmonic resonances for 200 μA excitation current with the frequency axis scaled down respectively. The second and the fourth harmonics were not measurable because the magnet was placed at the middle of the wire so that the even number harmonics were not excited. Also, even if they could have been mechanically excited, the induced voltage should have been exactly cancelled due to phase cancellation. In fact when the magnet was displaced from the middle of the wire, the second harmonic was sizable and the third was much weaker.

The peaks in this graph are quite sharp indicating that the tension can be easily measured to a few parts in 10 accuracy. The four resonance peaks with proper scaling down for the higher harmonics,were actually in good agreement with each other within 0.1 Hz. This was almost accounted for by the frequency counter last digit fluctuation because the gate was 10 seconds long. With the measured value of the resonance frequency, 123.65, the tension can be calculated using the following familiar formula,

$$f = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$$

where f : resonance frequency (Hz),
L : wire length (cm),
μ : mass per unit length (gram/cm),
T : wire tension (gram cm / sec^2),
or reducing T to weight m in gram and μ to density d in gram/cm,

$$f = \frac{17.67}{2rL}\sqrt{\frac{m}{d}}$$

where r : wire radius (cm),
resulting in 236 gram.

In order to find the useful sensitivity range, the excitation current was varied from 2 μA to 1.6 mA. Fig.3a shows the larger current part up to 1.6 mA and Fig.3b shows the smaller current part of the measurement up to 500 μA. The peak resonance voltage points along the upper lines are the maximum voltage observed each time, sweeping the oscillator frequency in fine steps around the resonance peak. The frequency was checked after the maximum was found and was 123.6 to 123.7 Hz for all of the points. The off-resonance voltage level was measured at 120 Hz. As was seen in Fig.2, the off-resonance voltage while keeping the current constant was quite flat since the wire is essentially a pure resistance for such a low frequency.

The magnetic field in this measurement was about 1.8 kGauss and the magnet was about 12 cm off the middle of the wire. The graphs show good proportionality of the induced resonance voltage to the excitation current up to about 500 μA.

In Fig.4 the peak resonance voltages are plotted as a percentage of the off-resonance voltage level. The black dots in this figure are for the magnetic field value of 2 kGauss, with the magnet at the middle of the wire.

In both cases it is seen that from 10 μA to 500 μA the induced voltages are quite sizable and are in good proportion to the excitation current.

The corresponding mechanical vibration amplitude was measured for the excitation current of 800 μA. The amplitude was 118 μm indicating the amplitude at the 10 μA point is only 1.5 μm, which is far smaller than what is normally used in other methods.

Since the signal is induced by the mechanical vibration of the wire within the magnetic field the signal can be enhanced at will by either increasing the field strength or the length of the field along the wire.

CONCLUSION

It was demonstrated that the emf voltage induced on a wire excited by resonance frequency sinusoidal current could be easily detected by commonly used devices to measure wire tensions with good accuracy.

The necessary excitation current can be much smaller than usually considered, and the method does not depend on the structure of the wire chamber.

It is imaginable that this method can be used for an in-situ checking of the wire tensions of a chamber system which is within a magnetic field. This is the case for the end cap electromagnetic calorimeter of the Fermilab Colliding Detector Facility currently planned for the 2 TeV $\bar{p}p$ collision experiment. The calorimeter utilizes proportional tubes as the sensing layers and is inserted in a uniform solenoidal field of 15 kGauss with the orientation of the tubes perpendicular to the field.

The signal will be much larger because of the stronger magnetic field and also the entire length of the wires will be active both for the mechanical vibration and the signal induction. There will be no even harmonics because of complete phase cancellation and the odd number harmonics will be suppressed almost by a factor of the harmonic number.

This kind of diagnosis would be useful to correct the observed shower information if any wire is found to be loose even though all the wires will be inspected prior to the installation.

REFERENCES

[1] T.Trippe, CERN NP Internal Report 69-18(1969); J.H.Dieperink et al., CERN NP Internal Report 69-28(1969).
[2] K.B.Burnes et al., Nucl. Instr. and Meth. 106(1973)171; M.Cavalli-Sforza et al., Nucl. Instr. and Meth. 124(1975)73; A.Borghesi, Nucl.

Instr. and Meth. 153(1978)379; R.Stephenson and J.E.Bateman, Nucl. Instr. and Meth. 171(1980)337; M.Calvetti et al., Nucl. Instr. and Meth. 174(1980)285; B.Koene and L.Linssen, Nucl. Instr. and Meth. 190(1981)511; Y.Wang, Private communication (1981).
[3] H.Hultschig and A.Ladage, DESY Report 81-065(1981).

FIGURE CAPTIONS

Fig. 1. Experimental arrangement for measuring wire tension. The Magnetic field was 1.8 kGauss without shim and 2 kGauss with shim.

Fig. 2. Typical resonance curves for wire excitation currents of 200 μA and 20 μA. The ordinate for 20 μA points was scaled up by a factor 10. Therefore 10 mV on the ordinate reads 1 mV for 20 μA points. The third and the fifth harmonics were plotted with the frequencies scaled down by the harmonic numbers. The curves are to guide the eyes.

Fig. 3. AC voltage accross the wire for various excitation currents. The peak voltage points along the upper lines are the maximum values of the voltage observed by finely sweeping the oscillator frequency around the resonance peak with the excitation current fixed. Every time after the maximum was found, the frequency was checked. For all of the points the frequency was 123.6 to 123.7 Hz. The off-resonance voltage level along the lower line was taken at 120 Hz. The magnetic field was 1.8 kGauss and placed slightly off the middle of the wire.

a) For currents up to 1.6 mA.

b) For currents up to 500 μA.

Fif. 4. Peak induced voltage above the off-resonance voltage level as a percentage of the off-resonance voltage. Open circles are for the magnetic field of 1.8 kGauss and with the magnet slightly off the middle of the wire. Dark dots are for the magnetic field of 2.0 kGauss and with the magnet at the middle of the wire. The mechanical vibration amplitude was measured as 118 μm for an excitation current of 800 μA for the former condition.

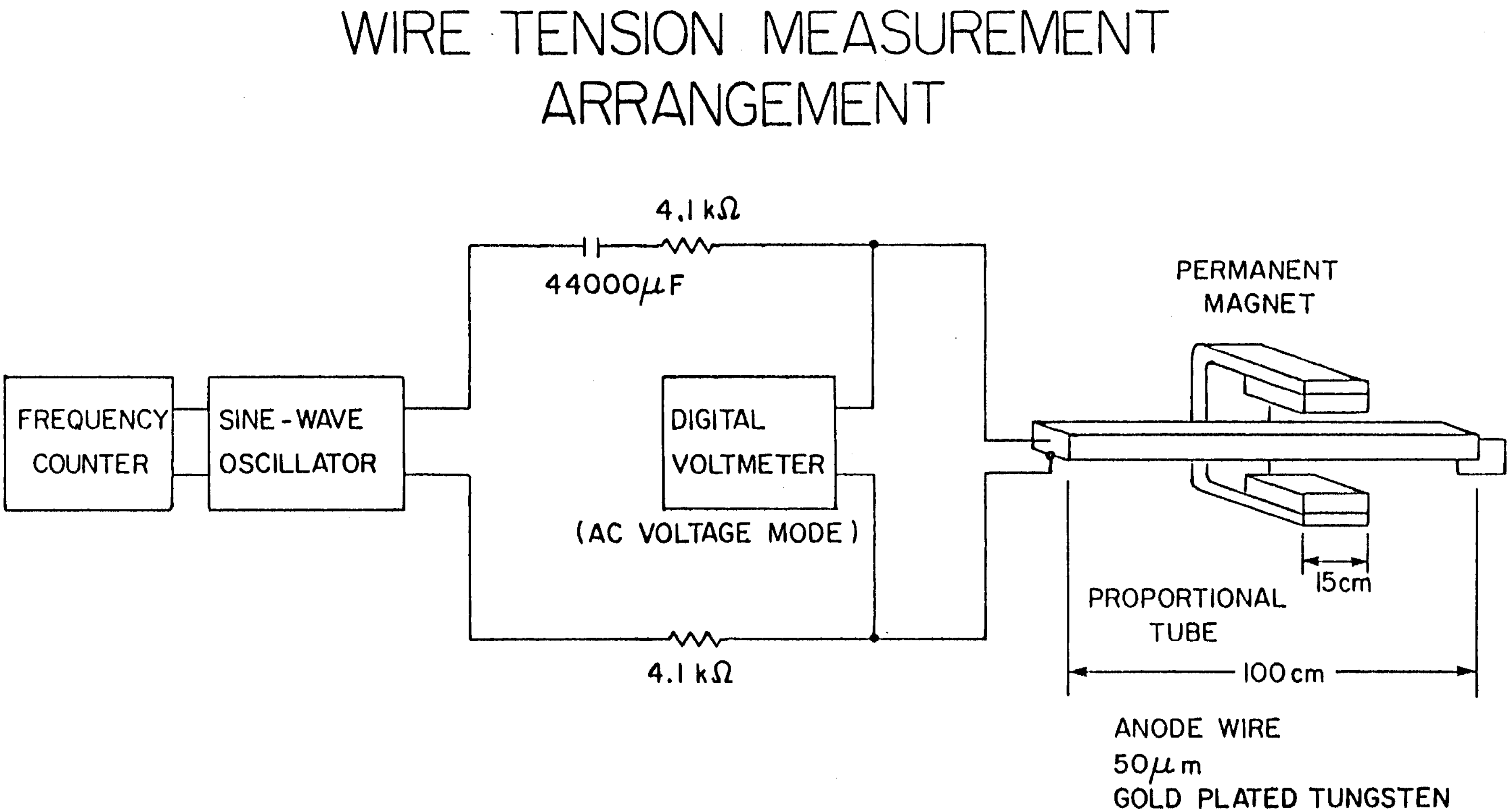
WIRE TENSION MEASUREMENT ARRANGEMENT
4.1 kΩ
44000μF
PERMANENT MAGNET
FREQUENCY COUNTER
SINE-WAVE OSCILLATOR
DIGITAL VOLTMETER
(AC VOLTAGE MODE)
15cm
PROPORTIONAL TUBE
4.1 kΩ
100 cm
ANODE WIRE
50μm
GOLD PLATED TUNGSTEN

Fig. 1

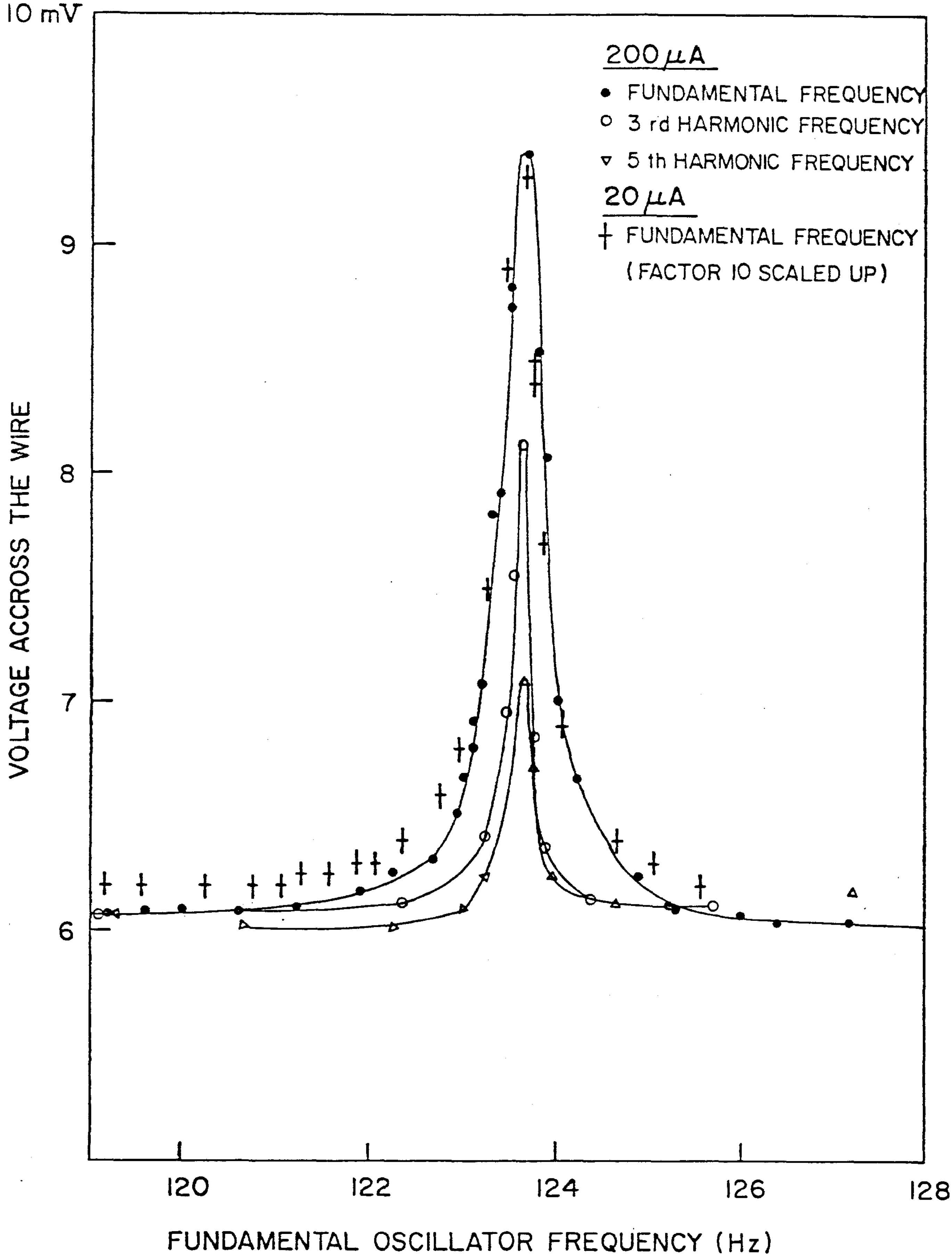
10 mV
9
8
7
6
VOLTAGE ACCROSS THE WIRE
200 μA
● FUNDAMENTAL FREQUENCY
○ 3 rd HARMONIC FREQUENCY
▽ 5 th HARMONIC FREQUENCY
20 μA
┼ FUNDAMENTAL FREQUENCY
(FACTOR 10 SCALED UP)
120
122
124
126
128
FUNDAMENTAL OSCILLATOR FREQUENCY (Hz)

Fig. 2

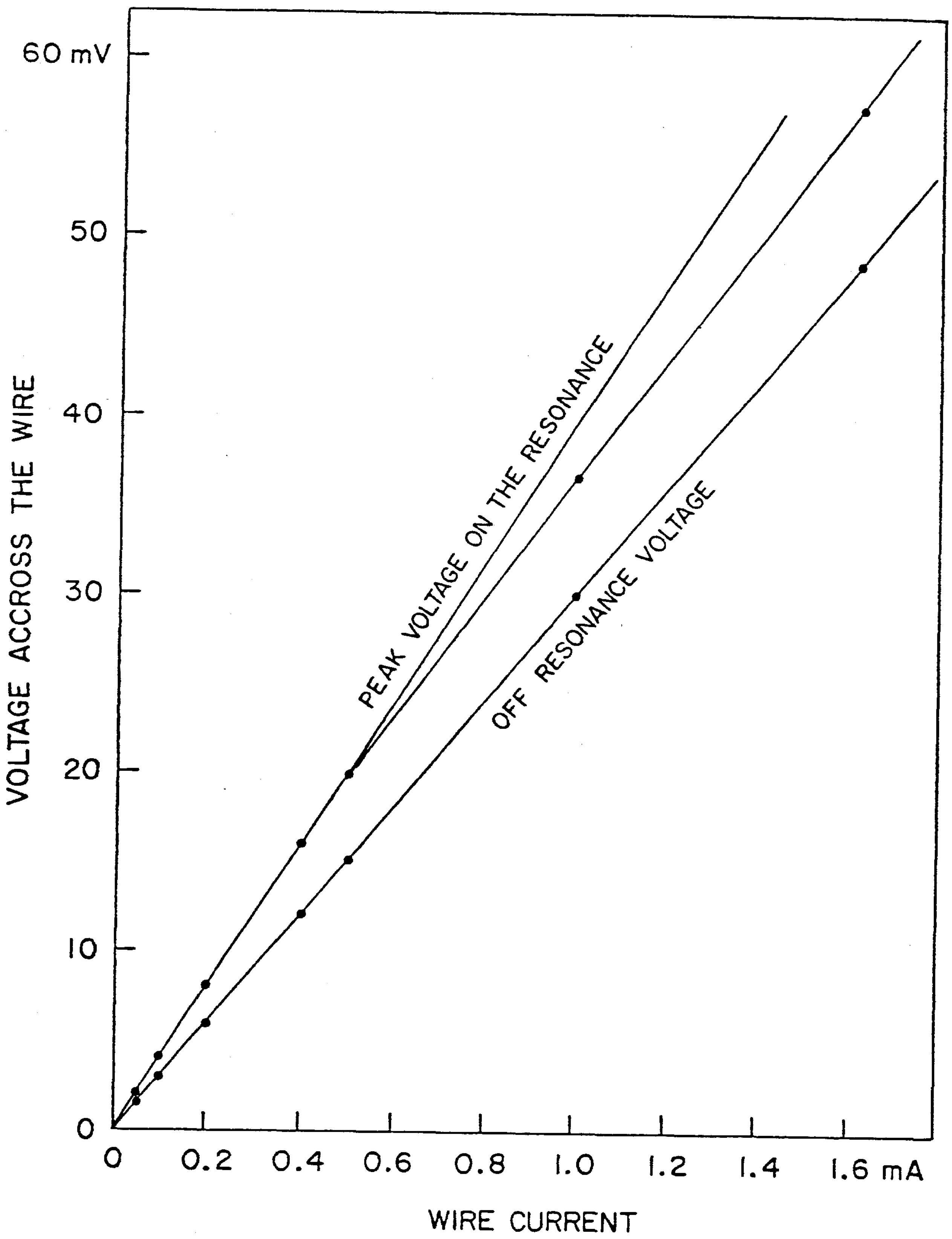
60 mV
50
40
30
20
10
0
VOLTAGE ACCROSS THE WIRE
PEAK VOLTAGE ON THE RESONANCE
OFF RESONANCE VOLTAGE
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6 mA
WIRE CURRENT

Fig. 3a

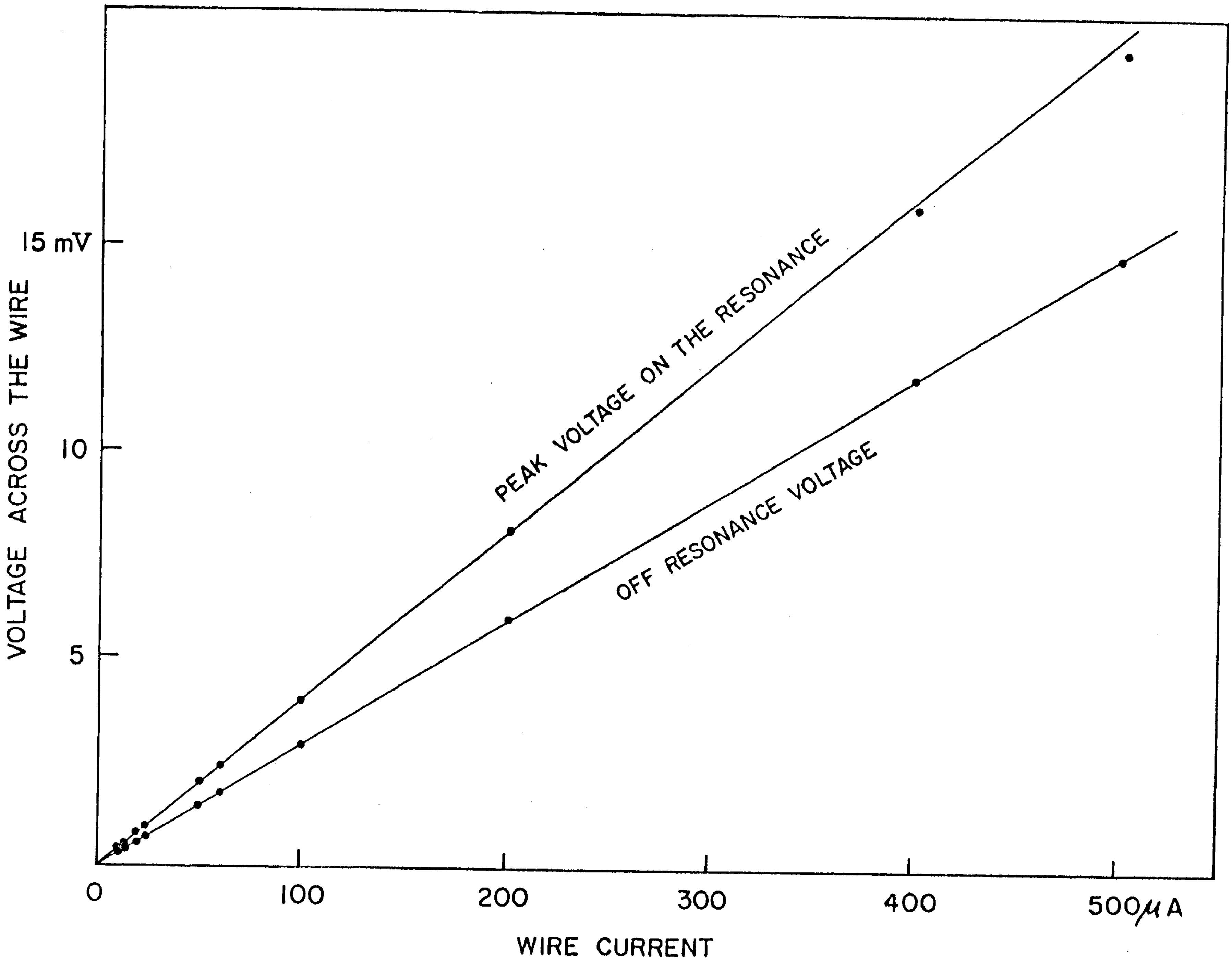
15 mV
10
5
0
100
200
300
400
500μA
VOLTAGE ACROSS THE WIRE
WIRE CURRENT
PEAK VOLTAGE ON THE RESONANCE
OFF RESONANCE VOLTAGE

Fig. 3b

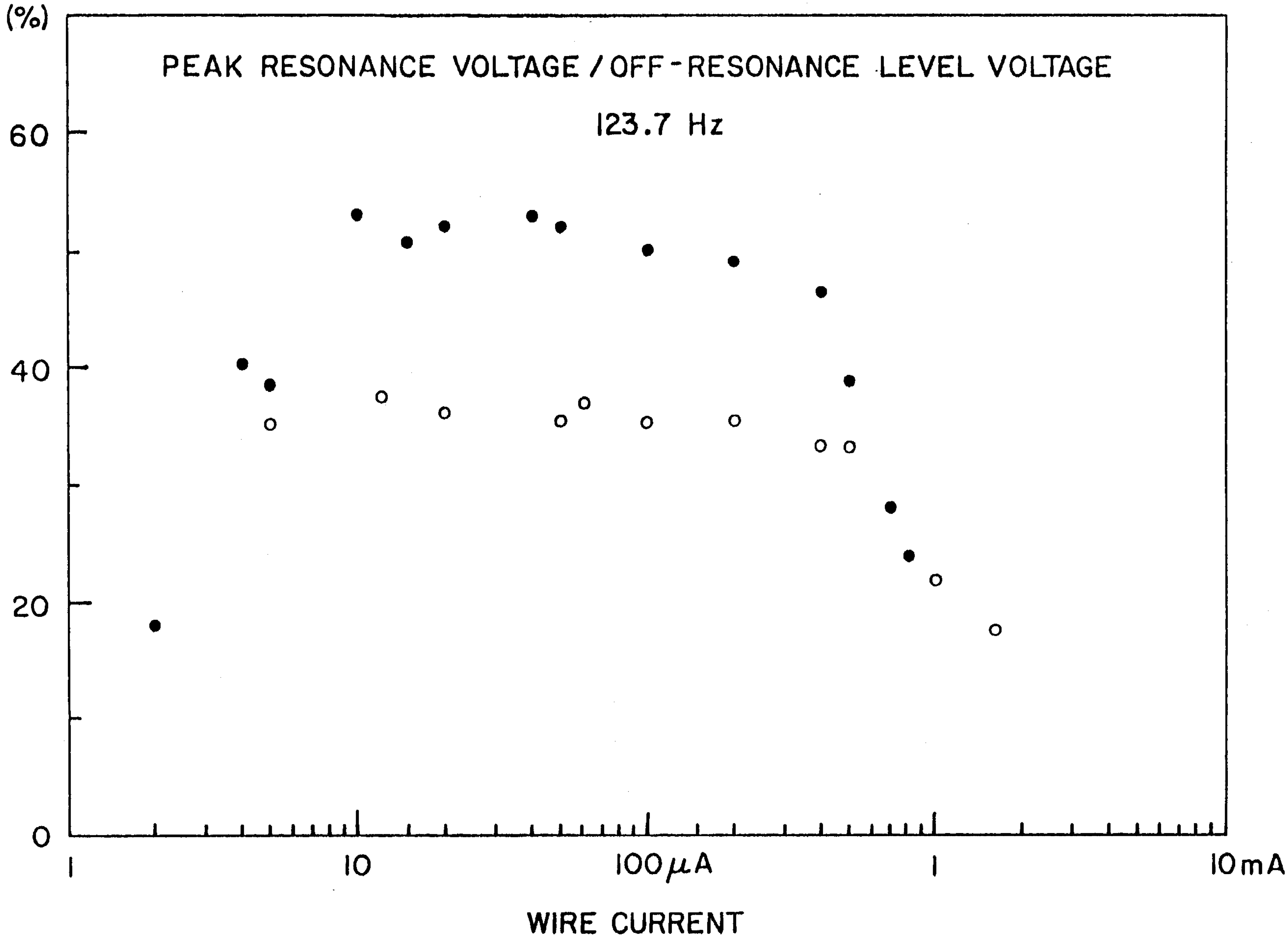
(%)
PEAK RESONANCE VOLTAGE / OFF-RESONANCE LEVEL VOLTAGE
123.7 Hz
60
40
20
0
1
10
100μA
1
10mA
WIRE CURRENT

Fig. 4