THE EFFECT OF COLD-WORKING UPON THE INTERNAL FRICTION OF ANNEALED POLYCRYSTALLINE COPPER

by

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A THESIS

submitted to

OREGON STATE COLLEGE

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

June 1956

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Date thesis is presented May 8, 1956

Typed by Elaine M. Anderson

ACKNOWLEDGMENTS

I would like to express my appreciation to Dr. J. J. Brady for suggesting the problem and for his assistance and helpful suggestions during the project.

Mr. C. O. Heath and Mr. M. B. Larson assisted in cold-working the reeds.

I am grateful to Mrs. Elaine M. Anderson for her kind cooperation in the typing of the thesis.

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INTRODUCTION

If a solid is stressed by a periodic force a certain fraction of its vibrating energy will be continuously transformed into heat. This effect is observed in all experimental arrangements and the underlying mechanism involved in the energy loss is called internal friction.

The exact nature of energy dissipation in a vibrating system is not known at this time, but a partial explanation of many experimental phenomena in this field is given in terms of the dislocation theory. This theory was proposed by Taylor (10, pp.405-415) in 1934 to explain the low critical shear stress of sodium chloride. Theoretically the critical shear stress should be of the order of 10^6 gm/cm^2, while actually it is only of the order of 10^4 gm/cm^2. For copper the theoretical value is something like 10^7 gm/cm^2 with the actual being about 10^5 gm/cm^2. Now a dislocation is a definite concept which involves the atoms being arranged in a certain specified way, which amounts to a structural imperfection. The facts that are known about dislocations are the result of many years of effort. It is known, for example, that many properties of materials like the resistivity, density, and heat capacity, are rather insensitive to structural imperfections while others like the critical shear strength and the internal friction are structure sensitive (8, p.1). The use of the idea of a dislocation does not imply that it is completely understood, but there are several reasons for believing that they actually exist.

The critical shear argument is one of the reasons and others are discussed by Shockley (9, pp.131-138).

The internal friction may be measured in terms of the logarithmic decrement which is defined as the logarithm of the ratio of two amplitudes one period apart, being determined after the source of power which creates the vibration has been turned off. This means we measure the relative loss of amplitude during one cycle of vibration. Since the energy of vibration is proportional to the square of the amplitude, the energy loss per cycle is proportional to twice the logarithmic decrement. Another quantity, the elastic phase constant Q, may also be used and is defined from a resonance curve of amplitude versus frequency. Let f_o be the resonant frequency, with f_1 and f_2 as the frequencies at half-power. Then Q is defined as the ratio of $f_o/(f_2-f_1)$. Q^{-1} is sometimes referred to as the bluntness of resonance and is equal to the logarithmic decrement divided by pi; thus it is proportional to the energy loss per cycle. The experimental arrangement in this study made it most convenient to measure the internal friction in terms of Q^{-1}. The apparatus was designed by Jewell (4, p.5) and consisted of a symmetrical transducer for driving the reed, a precision frequency meter for the transducer and a microscopic arrangement to observe the amplitudes of vibration of the reed. It has been used several times in the past few years to study different variables associated with the internal friction.

O'Halloran, Larson, and Falk have each made some measurements of the internal friction following cold-working. The first two workers reported results characterized mainly by high values of the internal friction and marked amplitude dependence. O'Halloran reports a decrease in the internal friction with cold-working following an anneal. This decrease reaches a minimum for about 3000 lbs/in^2 and then rises sharply at 5000 lbs/in^2. Larson and Falk each reported some decrease of the internal friction with cold-working when the anneal itself did not result in a minimum internal friction. Falk reported that an anneal at about 215° C. yields a minimum value of the internal friction with the anneal time being another possible variable.

It was decided to test the effect of cold-working again to see if a maximum value of the internal friction versus cold-working curve, as reported by Weertman and Koehler (12, p.624), could be obtained. This entailed some modification from the tests made previously. In the first place, a hydraulic press capable of operating at both low and high pressures was available. With this machine cold-working could be accomplished in nearly even steps through intervals from 50 to 35,000 lbs/in^2. Also, by using the anneal temperature which results in a minimum value of the internal friction, it was anticipated that the effect of cold-working could be more easily detected. Another problem, the ability to duplicate previous experiments, would also be reduced by using a standard anneal temperature as well as a standard procedure. Examination of the previous studies illustrate the changes that the annealing temperature introduced.

With these justifications another examination of the cold-working effect seems worthwhile. This paper is a description of the examination and the results obtained from it.

APPARATUS

The apparatus was designed by Jewell (4, pp.1-108) and used with some modifications by O'Halloran (7, pp.8-16), Larson (5, pp.10-15) and Falk (1, pp.6-10). These modifications were made in the transducer and strobotac drives with the result that the operation of the system was made more dependable. The equipment used in this investigation was the same as used by Falk and is shown in Figure 1. While becoming acquainted with the apparatus it became evident that small components of the system were either being used in other studies or stored to prevent breakage. The latter was especially true in the case of the microscope. In order that others might restore the system to working order in the least amount of time, a list of these components is included in the appendix. The apparatus is described in more detail by the aforementioned authors.

The system as a whole functions through the combined operation of three parts: the symmetrical transducer; the electronic driving equipment; and the optical arrangement. The driving signal for the transducer originates in a precision oscillator, hereafter referred to as the frequency meter. The frequency is known to six significant figures. The frequency of this signal is much too high and is reduced to the desirable transducer driving frequency by two banks of binary scalars. During the course of this investigation the system failed to operate and after checking the signals down to these scalars, Number 10 scalar was found to be blocking the signal. This tracing was done with a Tectronix oscilloscope. The neon bulbs in the scaling units also gave some indication of the condition of the bank as a whole. In checking the components of the scalar unit a faulty condenser was located and replaced with the result that the system would again function. Jewell (4, p.54) mentions that such scalars as have failed, have done so because of defective condensers. The faulty condensers were detected in that they blocked the signal in the scaling bank.

The calculation of the internal friction requires actual measurement of the amplitude of the reed. This was accomplished by observing the motions of the end of the reed through a microscope, with the light being obtained from the strobotac through a vertical illuminator and focused on the end of the reed. By adjusting the time delay, the reed could be observed at any position of the vibration cycle.

Falk (1, pp.16,17) reports that at certain settings of the frequency meter, the transducer frequency, as calculated from the frequency meter and the appropriate power of 2 from the scalar circuits, does not agree with the frequency as calculated from the Lissajou pattern on the oscilloscope. A check was made of the transducer signal as the frequency meter was changed from 0 to the maximum of 5000 (195-2000 kc.). It is possible to use a head-set and listen to this signal providing the transducer voltage is high enough.

Figure 1. The assembled apparatus for measuring the internal friction.

Two tests were made; the first soon after the equipment was turned on and the second almost 1 hour later. In the first test the frequency increased steadily until the 2900-3200 frequency meter interval was reached. In this interval several abrupt changes occurred, each one lowering the transducer frequency. From the 3200 reading the transducer frequency again increased steadily to 3700. At this reading the transducer frequency dropped again and then increased until the frequency meter reached its maximum of 5000. The second test was made in the same manner with similar behavior but at different intervals. Instead of the changes occurring at 2900-3000 and 3700, they were now heard at 3500-3700 and 4300.

The transducer frequency in the 3500-3700 frequency meter range is so unstable that any work done here would be uncertain. However, the range from 3700-4300 is stable and it is supposed that it was in this range that Falk made some measurements and converted them by the ratio 1.5 to the true values. This is possible since some transducer frequencies may be obtained in the 3700-4300 region which will drive the reed in its fundamental mode of vibration.

In order that no confusion would result from the measurements made in this study, the frequency meter readings corresponding to the resonant and half-power frequencies were recorded in the data sheets and are seen to be located in the interval 722-947. The actual meter frequency is readily obtained from the frequency meter handbook. The transducer frequency is obtained from the meter frequency by dividing by the appropriate power of 2. This power was held constant at 12 during the measurements of the internal friction. Thus the original oscillator frequency was divided by 2^{12}, or 4096, to give the transducer frequency. The meter frequency interval corresponding to the 722-947 meter interval was 221.1-231.5 kc. By dividing by 4096 we obtain 53.9-56.5 for the transducer signal interval.

It is recommended that these intervals be rechecked when the equipment is used again to avoid any measurements which will have to be adjusted in order to give the true transducer frequency.

METHOD FOR ANNEALING THE REED

An examination of previous annealing procedures showed that O'Halloran (7, p.17) had attempted to use a small oven to anneal the reed, but in the process the reed became oxidized. In the final arrangement the reed was mounted between two electrodes and brought to a dull red by passing a current of 60 amperes for 30 seconds. The oxidation problem was solved by placing the whole system in a vacuum. The time allowed for the reed to cool was about 3 hours. Larson (5, p.16) followed a similar procedure with some modifications. The reed was pressed to the electrodes with small weights and made to glow a dull red by passing a current of 140 amperes for 65 seconds followed by 200 amperes for 15 seconds. The cooling time was the same as in O'Halloran's work. Falk (1, pp.11,12) constructed a thermocouple to indicate the annealing temperature and he also made an attempt to reduce the temperature gradient in the reed by including it in a much longer length of copper material with similar dimensions to those of the reed. The temperature was controlled by varying the current, and anneal times of 1 hour were used.

Since the temperature needed for the anneal of this investigation was moderately low, a decision was made to employ a different anneal procedure using an electric furnace surrounding an evacuated glass tube holding the reed and a thermometer. This arrangement gives an annealing apparatus which can be both evenly heated and easily used. The anneal apparatus is shown in Figure 2.

A 0-400° C. thermometer was used to indicate the annealing temperature. The electric furnace was obtained from a previous project in the department and was cylindrical in shape with a power rating of 1000 watts. A ground glass joint was obtained and used in the construction of a glass tube of sufficient size to accomodate both the thermometer and the reed. The tube could be easily taken apart. The vacuum system was an experimental arrangement in the Modern Physics Laboratory and had a valve for connecting additional systems to the pump. The operating pressure of this system was found to be about 2 microns during the annealing procedure. The tube was fastened to the supports of the vacuum system with clamps and is also shown in Figure 2. In order to minimize the heat loss at the ends of the furnace, asbestos packing and pads were used at both ends. This was especially helpful at the upper opening since heat around the ground glass joint could result in failure of the seal and destroy the vacuum. However, with the insulation and packing, the joint remained cool throughout the annealing process.

Actual use of the apparatus required a preliminary experiment to determine the current setting needed to maintain the desired temperature. This was accomplished by noting the equilibrium temperature for different current settings. Some adjustments were found necessary as the line voltage often varied over a period of time.

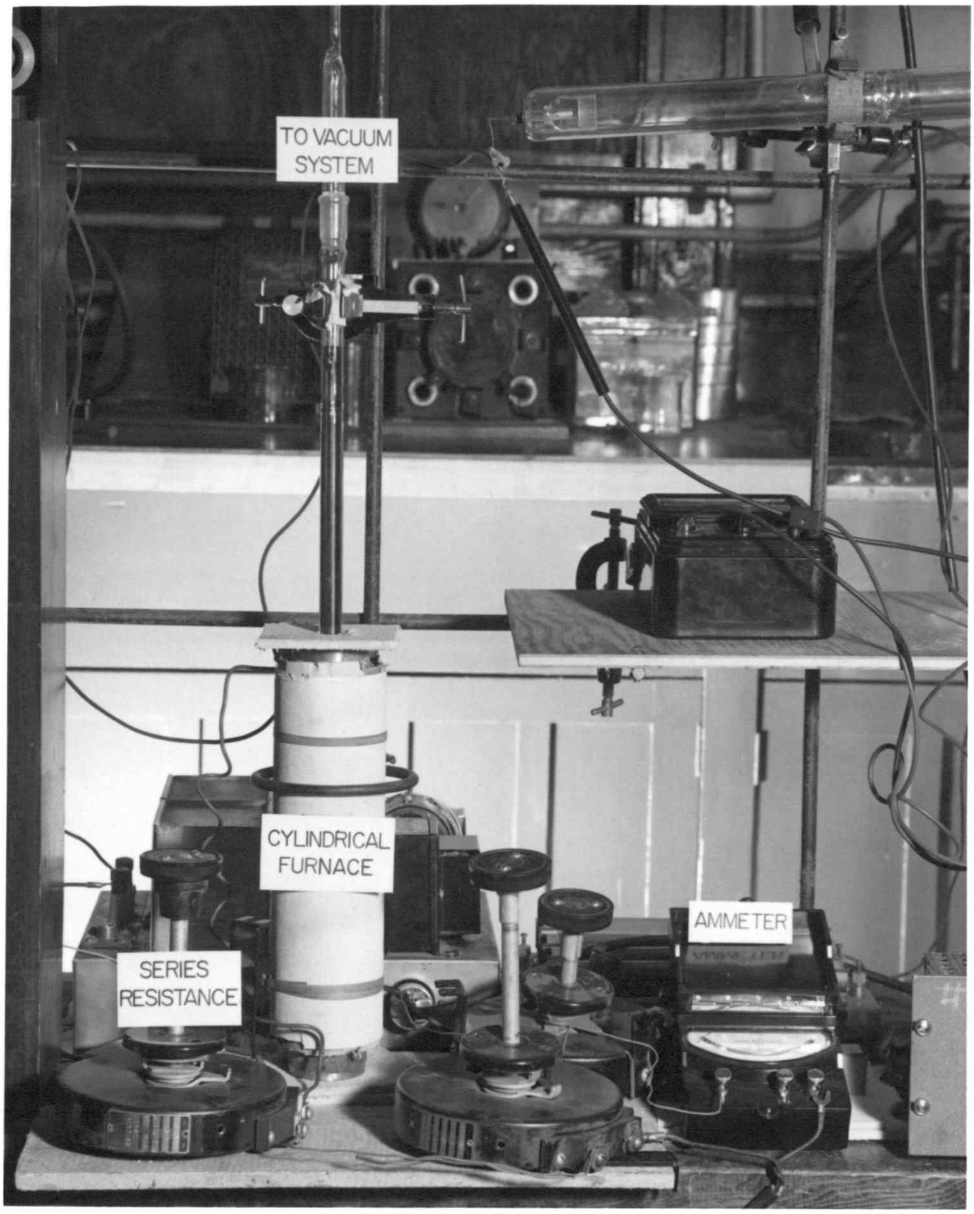


Figure 2. The annealing apparatus.

The first anneals were made at about 218° C. in order to be in the region of minimum internal friction. These anneals were accomplished by carefully placing the thermometer and reed in the glass tube and closing the ground glass joint to form the vacuum seal. At this point the vacuum system and furnace were turned on with the initial furnace current being 5 amperes. In about 10 minutes the temperature in the tube had risen from room temperature to 110° C. at which time the resistance was increased to lower the current to 2.8 amperes. This current setting resulted in an equilibrium temperature of 218° C. which was reached in an additional 20 minutes. The pressure at this time was about 2 microns. The reed was allowed to stay at this temperature for the designated annealing time.

The other temperature used in this experiment was 350° C. By maintaining the 5 ampere setting until the temperature reached 315° C. and then reducing it to 4.1 amperes the equilibrium temperature was reached in about 30 minutes. Two anneals at this temperature were made. The cooling time for all the anneals varied from 1 to 3 hours.

METHOD FOR COLD-WORKING THE REED

Prior to any actual cold-working it was necessary to machine two steel blocks to hold the reed. These blocks were cut from stock steel to 3.15 x 7.60 x 20.3 cm. and were rough ground in the Industrial Arts Laboratory. One face of each block was finished with a precision grinder to 0.001 of an inch. The entire reed could then be pressed between these blocks.

The Baldwin Testing Machine, located in the Mechanical Engineering Laboratory was the same as used by Larson (5, p.16). It is possible to attach a swivel head to the machine, and this was done to decrease the possibility of beveling the reed during the cold-working.

The reed was carefully placed between the two steel blocks and installed in the testing machine, the force being applied slowly as contact was made, and then it was increased nearly uniformly to the predetermined total force. With some practice in manipulating the controls it was possible to hold the total force nearly constant for the cold-working period of 1 minute. The force was then released slowly and the reed carefully removed.

The cold-working pressure was calculated from the total force, as read from the machine, and the area of the reed. Reed number 1 with dimensions of 0.085 x 0.70 x 11.1 cm., had an area of 1.20 in^2. Reed number 2 with dimensions of 0.085 x 0.71 x 11.0 cm., had an area of 1.21 in^2. With the cold-working pressure recorded, the reed was ready for installation in the transducer apparatus.

METHOD FOR MEASURING THE INTERNAL FRICTION

Before any conditioning of the reed was attempted, a sharp line was made upon it to aid in aligning the reed in the vise. After the reed had been annealed or cold-worked, whichever the case may have been, it was carefully placed in the vise and clamped in position. This resulted in a near-uniform effective length of the reed each time it was removed and replaced in the transducer. The vise was then placed in the apparatus and the vacuum pump turned on.

The motion of the reed was observed through a microscope which was clamped tightly to a wooden frame to prevent it from moving during the measurements. After the reed had been placed in the transducer, its end was observed through the microscope and some reference point on the end chosen. This is a critical procedure because it is difficult to find a mark which is both sharply contrasted with the background and comparable in size to the width of the movable vertical line. Smaller marks are difficult to see while larger ones do not give consistent reference readings. Adjustment of the vertical illuminator was often necessary for optimum light conditions. A micrometer stage was used to determine the magnification of the microscope. It was found that a motion of 100 units in the filar eyepiece equaled a displacement of 0.073 mm. of the reed.

One hour was allowed for the electronic equipment to stabilize before any measurements of the internal friction were made. During this period a check of the frequency meter drift was made to determine how effective the warm-up was. These checks were reassuring since there was no detectable drift of frequency at the end of the hour. At different intervals throughout the course of acquiring the data, checks were made on the frequency at the transducer. Several checking methods were possible, the most useful one being to set the frequency meter at the reading which would produce resonance in the reed. This meter reading was then converted to the actual meter frequency and divided by 2^{12} to give the frequency of the signal supplied to the transducer. This transducer signal was then compared with the frequency obtained from the Lissajou pattern on the oscilloscope. A second method was to set the frequency meter at some reading and obtain the meter frequency from the meter handbook. The frequency output of the sixteenth scalar was obtained by counting the number of flashes from the neon bulb for a given length of time. By multiplying the frequency by 2^{16}, the meter frequency could be closely approximated. It was also possible to obtain a rough check of the meter frequency directly with the Tectronix oscilloscope.

Standard data sheets similar to those used by Falk made it much easier to record and assemble the data. A typical data sheet is included in the appendix. Before a run was begun, the run number, date and time were recorded, along with the reed dimensions and anneal or cold-work condition. The resonant frequency was found by simultaneously varying the frequency meter and the time delay unit until the maximum amplitude of the end of the reed was observed. The filar eyepiece reading of this amplitude was recorded along with the frequency meter reading. It was noted that the small amplitude vibrations yielded blunt resonant peaks, while the larger amplitudes produced sharp resonant peaks and a slight shift of the resonant frequency (4, p.75). This made it necessary to average several readings of the resonant frequency meter to obtain the resonant frequency for small amplitudes. The half-power amplitude was obtained by taking 0.707 of the difference between the rest position and the maximum amplitude. This value added to the rest position reading gave the half-power setting. The filar eyepiece was then set at the half-power position and the time delay unit and frequency meter simultaneously adjusted until the maximum amplitude of the reed coincided with the vertical line. The two meter readings corresponding to these conditions were then recorded. Several readings were then averaged for the final value.

The internal friction was then the ratio of the change in frequency to the resonant frequency. The strain amplitude was computed for each of the readings and is defined as the ratio of the resonant amplitude to the length of the vibrating reed.

RESULTS

The original data with the computed values of the internal friction and strain amplitude for the measurements of this investigation are condensed and recorded in Table II of the appendix. Figures 3 through 10, for reed number 1, show the internal friction as a function of the strain amplitude for different amounts of cold-working, following a 1 hour anneal at 215° C. Figures 11 through 30, for reed number 2, show the internal friction as a function of the strain amplitude for different amounts of cold-working following 1 hour anneals at 216° C. and 219° C. The 1 hour anneal time was arbitrary and a brief study was made of the effect of annealing time at about 218° C., as shown in Figure 31. Figure 32 shows the results of two other anneals made at 350° C. A plot of the internal friction versus cold-work is shown in Figure 33. The data of this study shows the internal friction ranging from (1.6 to 3.4) x 10^{-3}. Falk (1, p.28, Figure 9; p.29, Figure 13) reports values between (1.7 and 3.3) x 10^{-3}. The corresponding ranges for Larson (5, p.25, Figure 9; p.24, Figure 8) and O'Halloran (7, p.27, Figure 10; p.28, Figure 11) are (2.1 to 5.3) x 10^{-3} and (2.8 to 4.7) x 10^{-3}.

A comparison of Figures 3 and 11 shows a difference in the effect of the same annealing process on the two reeds. Reed number 2 exhibits a lower internal friction than reed number 1. Since the annealing process was held constant, the small differences are probably due to the past histories of the reeds involved. It is noticed that the anneals in Figures 3 and 24 give curves of the same slope with the latter yielding the lower value of the internal friction.

The highest value of the internal friction was obtained when the reed was accidentally dropped. This value is shown in Figure 4 as 3.4×10^{-3}. Dropping the reed altered the amplitude dependence by making it more dependent at small amplitudes and nearly independent for amplitudes of $(2.5\text{-}3.0) \times 10^{-3}$. The next cold-work resulted in a marked decrease in the internal friction and partially restored the linear slope of the anneal. The internal friction increases somewhat, as shown in Figure 7 and then decreases in Figure 8 and 9, with a slight rise in Figure 10. It is regrettable that the 3000-9000 lbs/in^2 interval was not made with reed number 1 and compared with the results of reed number 2.

Measurements made on the 34,000 lbs/in^2 cold-worked reed, after a two day interval showed that the internal friction had risen about 15%. Run numbers 155 through 158 show the hysteresis effect for cold-working at 3060 lbs/in^2. After 12 days the internal friction had dropped about 6%. The decrease agrees with Hasiguti and Hirai (3, p.1084), who report a decrease in the internal friction of cold-worked single crystal copper when left at room temperature. Weertman and Koehler report a low value of internal friction with heavy cold-working but no mention of the hysteresis effect was made.

The measurements made on reed number 2 show that there is little effect due to cold-work up to 3500 lbs/in^2. This is shown in Figure 33, where the internal friction is plotted as a function of the cold-work with the strain amplitude held constant at (0.5 and 3) x 10^{-3}. A maximum occurs at about 4500 lbs/in^2, with the internal friction decreasing for higher cold-working. The maximum of the curve was not particularly dependent upon the strain amplitude. Weertman and Koehler (12, p.624) report a maximum in the internal friction versus cold-work curve for single crystal copper, with the position of the maximum dependent upon the strain amplitude. An attempt is made to explain this action, using a dislocation model. Lawson (6, p.330) also reports a maximum internal friction for cold-working using polycrystalline copper.

Several connections begin to appear from the various studies. Figure 6 and 13 show that a decrease in internal friction may occur at low cold-working if the anneal has not already reached a minimum value. Larson (5, p.24) also shows this to be true, although in his case the anneal was at a much higher temperature. The individual behavior in the two cases is attributed to the different annealing temperatures. Both O'Halloran and Larson report high values of the internal friction which are presumably due to their annealing procedure. When the anneal is accomplished at about 215° C., the internal friction is quite low. After examining the various graphs it seems that cold-working reeds which were annealed at high temperatures resulted in a lowering of the internal friction, while cold-working reeds annealed at about 215° C. produced little effect, providing the anneal resulted in an internal friction of about 1.6×10^{-3}. If this was not the case the cold-working still tends to lower the internal friction slightly.

Larson (5, p.33) did not find the maximum of internal friction with cold-work, suggesting that lower amounts of cold-working be tried. Falk (1, p.30, Figures 14, 15, 16; p.33, Figures 21, 22, 23, 24) reports results of cold-working after 450° C. and 235° C. anneals. No change was observed for the first case, where the cold-working ranged from 530 lbs/in^2 to 3820 lbs/in^2. A slight variation is recorded in the second case, with cold-working ranging from 510 lbs/in^2 to 3600 lbs/in^2. This slight variation following the anneal was reported as a minimum and was compared with the minimum which O'Halloran obtained at about 4000 lbs/in^2. It is proposed that the decrease reported by Falk (1, p.22) is another example of the internal friction being lowered by cold-working following an anneal which does not give a minimum value of the internal friction. It is also proposed that the initial maximum seen from O'Halloran's work (7, p.29) is due primarily to the annealing procedure and is minimized in the case of anneals made around 215° C., so that only a slight dip is observed with increased cold-working in the 0-1000 lbs/in^2 range.

The annealing time was found to be a factor in obtaining the lowest value of the internal friction with a minimum being reached in the 5 hour anneal. The results of the 10 hour anneal are shown in the data and were omitted in Figure 31, since they were almost the same as the results from the 5 hour anneal. Figure 32 shows the internal friction for an anneal at 350° C. A 1 hour anneal time resulted in values of the internal friction from 1.6×10^{-3} to 2.35×10^{-3} for strain amplitudes of 0.5×10^{-3} and 2.5×10^{-3}, while the two hour anneal raised the internal friction slightly with values of 1.75×10^{-3} and 2.5×10^{-3} respectively.

CONCLUSIONS

The results of this study yield a minimum value of the internal friction which seems to be unaffected by anneals or cold-working. This value, found to be 1.6×10^{-3}, was obtained by both annealing and extreme cold-working. It is recognized that the 1 hour anneal time does not always yield a minimum value of the internal friction; therefore it is suggested that this time be lengthened to at least 5 hours.

Following a good anneal, it was found that cold-working had little effect on the amplitude dependence but did affect the internal friction. For low cold-working the internal friction was nearly constant. A maximum value was observed for cold-working at 4500 lbs/in^2, while the internal friction decreased with cold-working at 8000 lbs/in^2.

The actual procedure in cold-working a reed is, in itself, a variable and it is proposed that the effect of cold-working time be examined. The reed may also be annealed following each cold-working to examine the effect of this action.

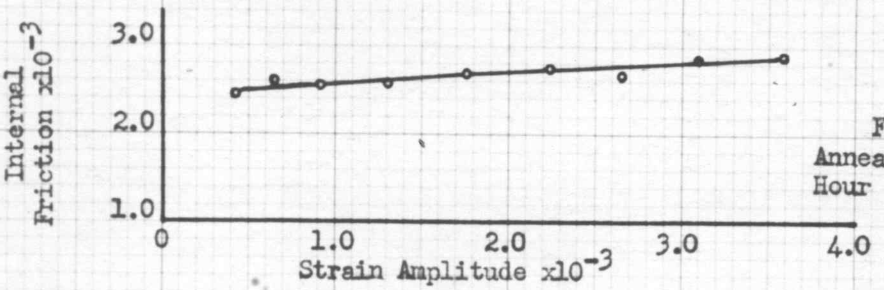


Figure 3
Annealed 1
Hour at 215° C.

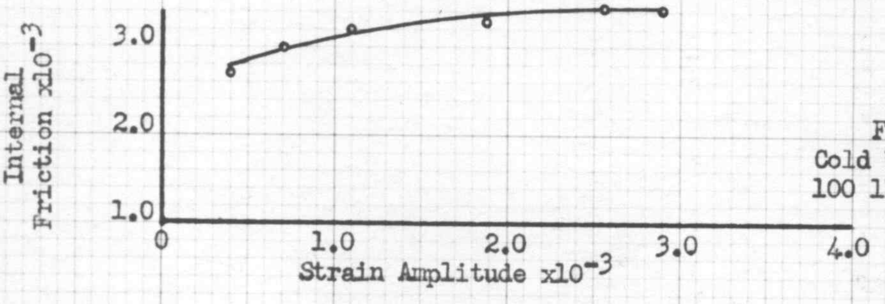


Figure 4
Cold Worked
100 lbs/in^2

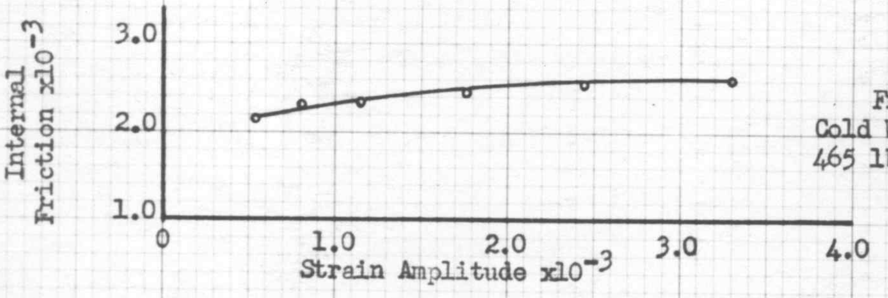


Figure 5
Cold Worked
465 lbs/in^2

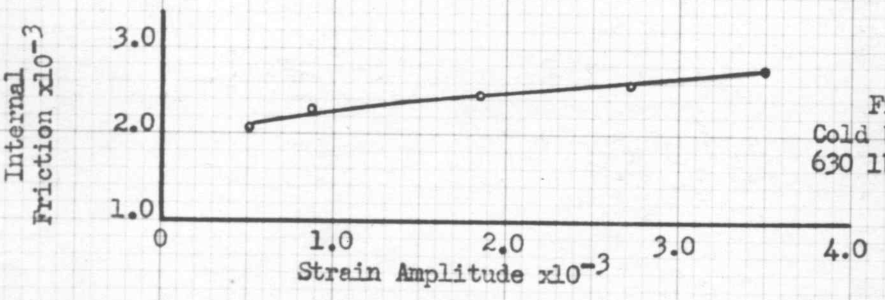


Figure 6
Cold Worked
630 lbs/in^2

FIGURES 3, 4, 5, and 6
INTERNAL FRICTION VERSUS STRAIN AMPLITUDE
FOR REED NO. 1

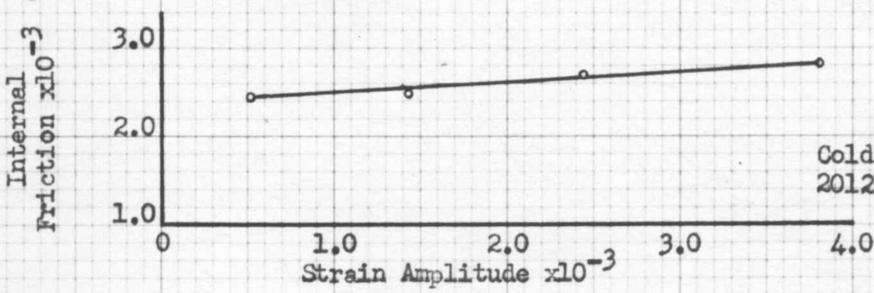


Figure 7
Cold Worked
2012 lbs/in^2

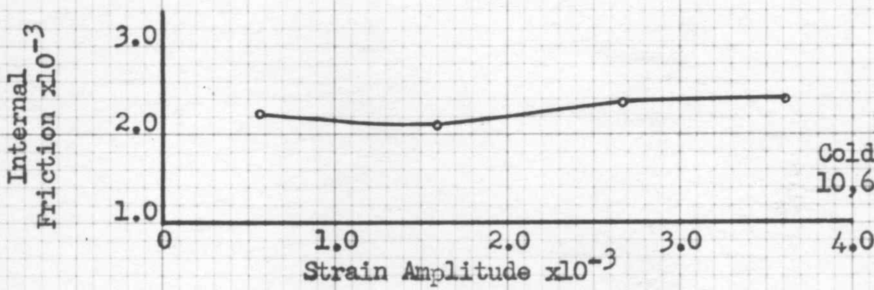


Figure 8
Cold Worked
10,650 lbs/in^2

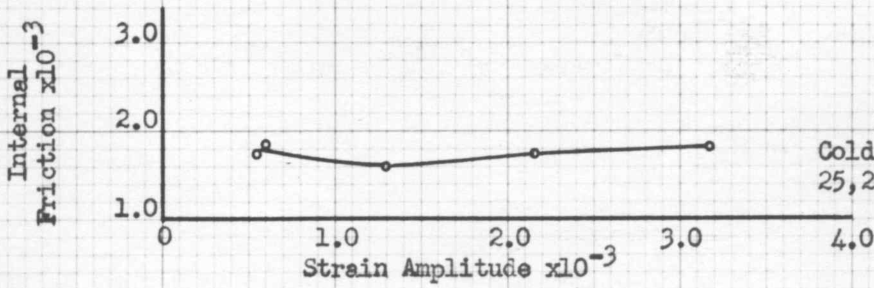


Figure 9
Cold Worked
25,200 lbs/in^2

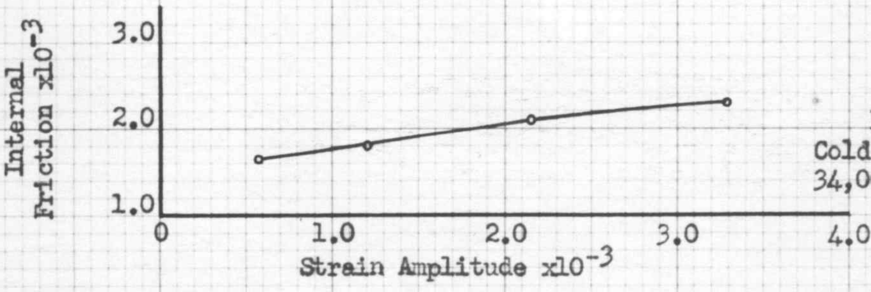


Figure 10
Cold Worked
34,000 lbs/in^2

FIGURES 7, 8, 9, and 10
INTERNAL FRICTION VERSUS STRAIN AMPLITUDE
FOR REED NO. 1

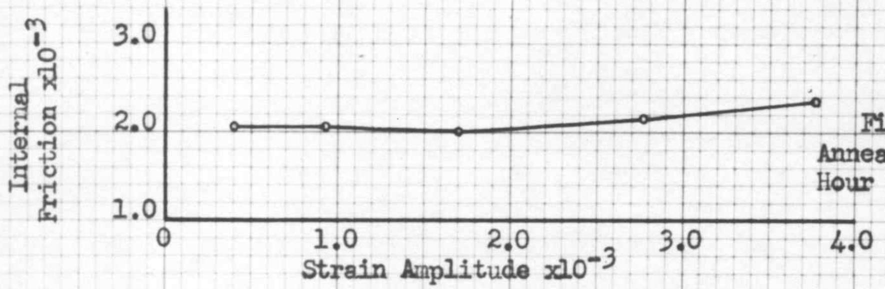


Figure 11
Annealed 1 Hour at 216° C.

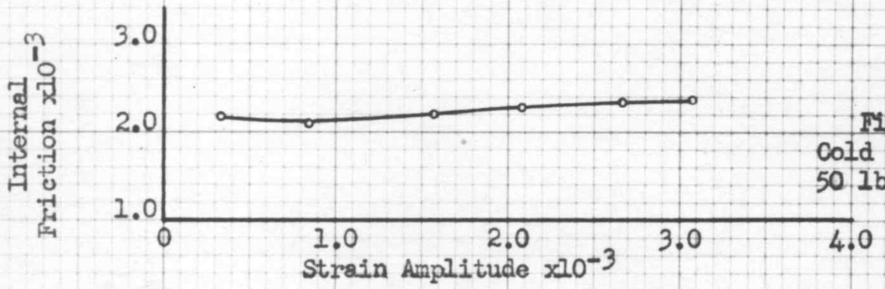


Figure 12
Cold Worked 50 lbs/in^2

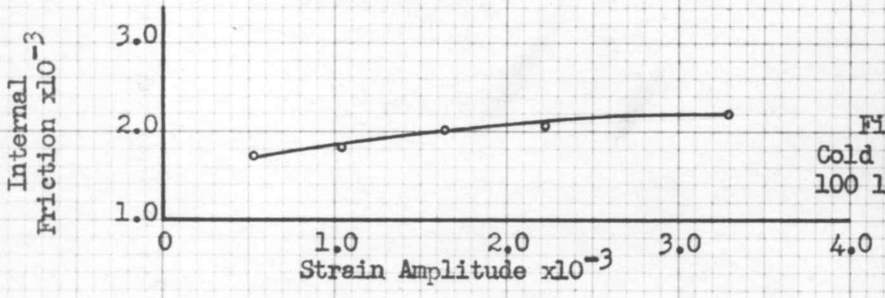


Figure 13
Cold Worked 100 lbs/in^2

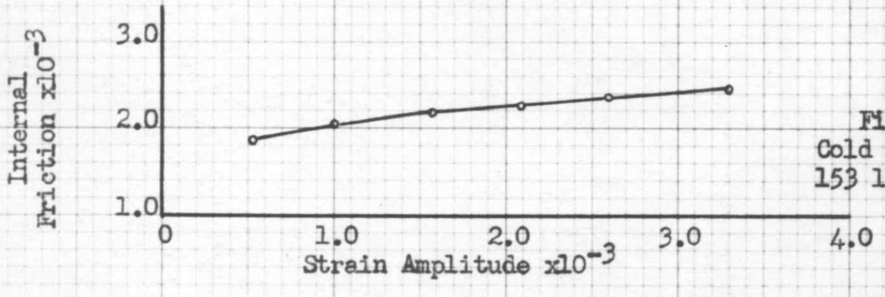


Figure 14
Cold Worked 153 lbs/in^2

FIGURES 11, 12, 13, and 14
INTERNAL FRICTION VERSUS STRAIN AMPLITUDE
FOR REED NO. 2

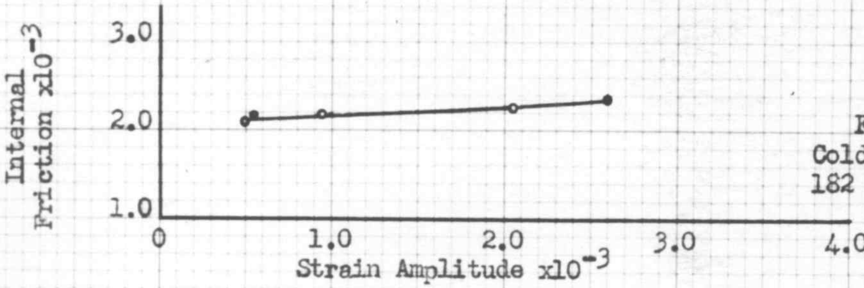


Figure 15
Cold Worked
182 lbs/in^2

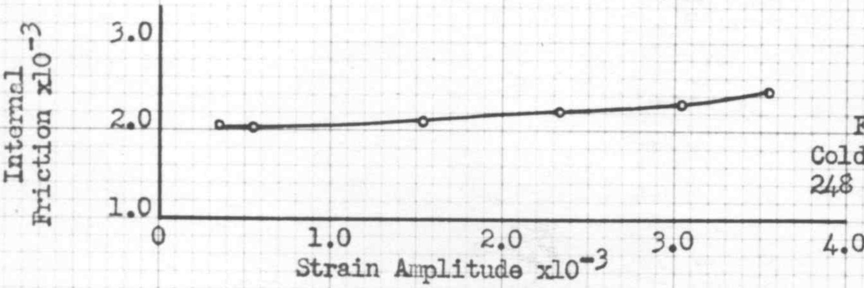


Figure 16
Cold Worked
248 lbs/in^2

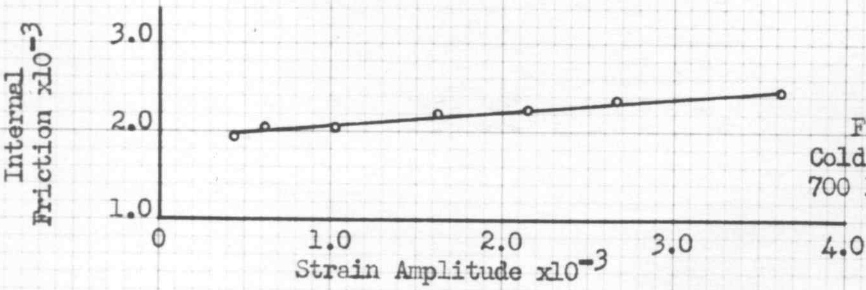


Figure 17
Cold Worked
700 lbs/in^2

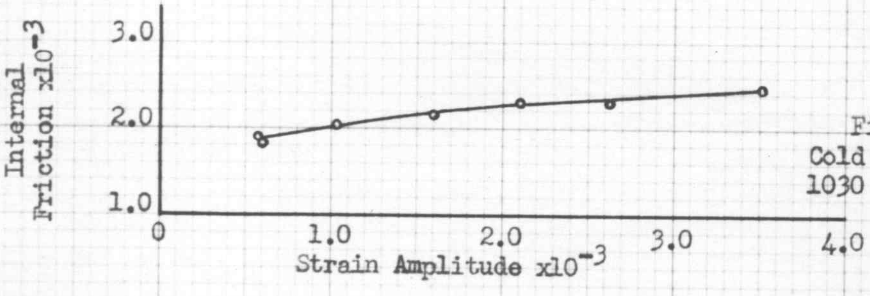


Figure 18
Cold Worked
1030 lbs/in^2

FIGURES 15, 16, 17, and 18
INTERNAL FRICTION VERSUS STRAIN AMPLITUDE
FOR REED NO. 2

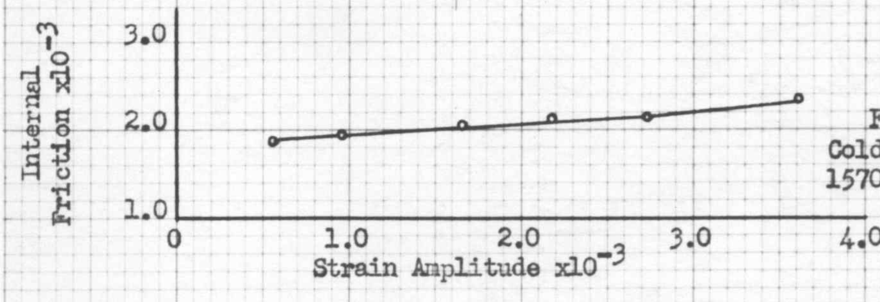


Figure 19
Cold Worked
1570 lbs/in^2

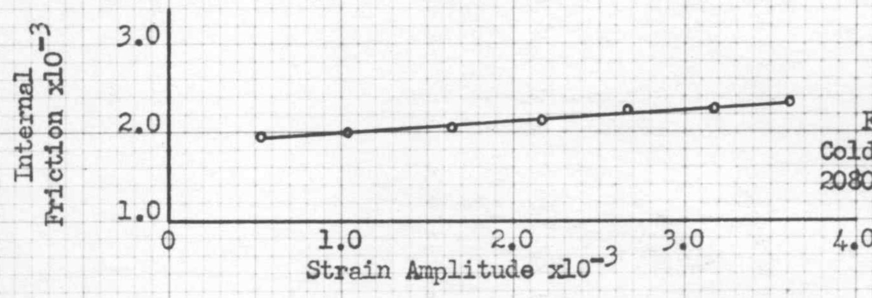


Figure 20
Cold Worked
2080 lbs/in^2

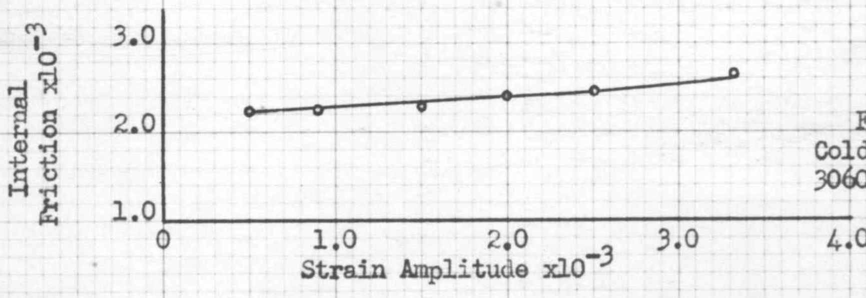


Figure 21
Cold Worked
3060 lbs/in^2

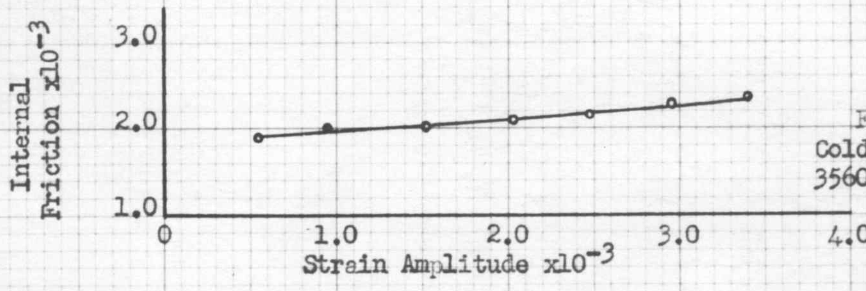


Figure 22
Cold Worked
3560 lbs/in^2

FIGURES 19, 20, 21, and 22
INTERNAL FRICTION VERSUS STRAIN AMPLITUDE
FOR REED NO. 2

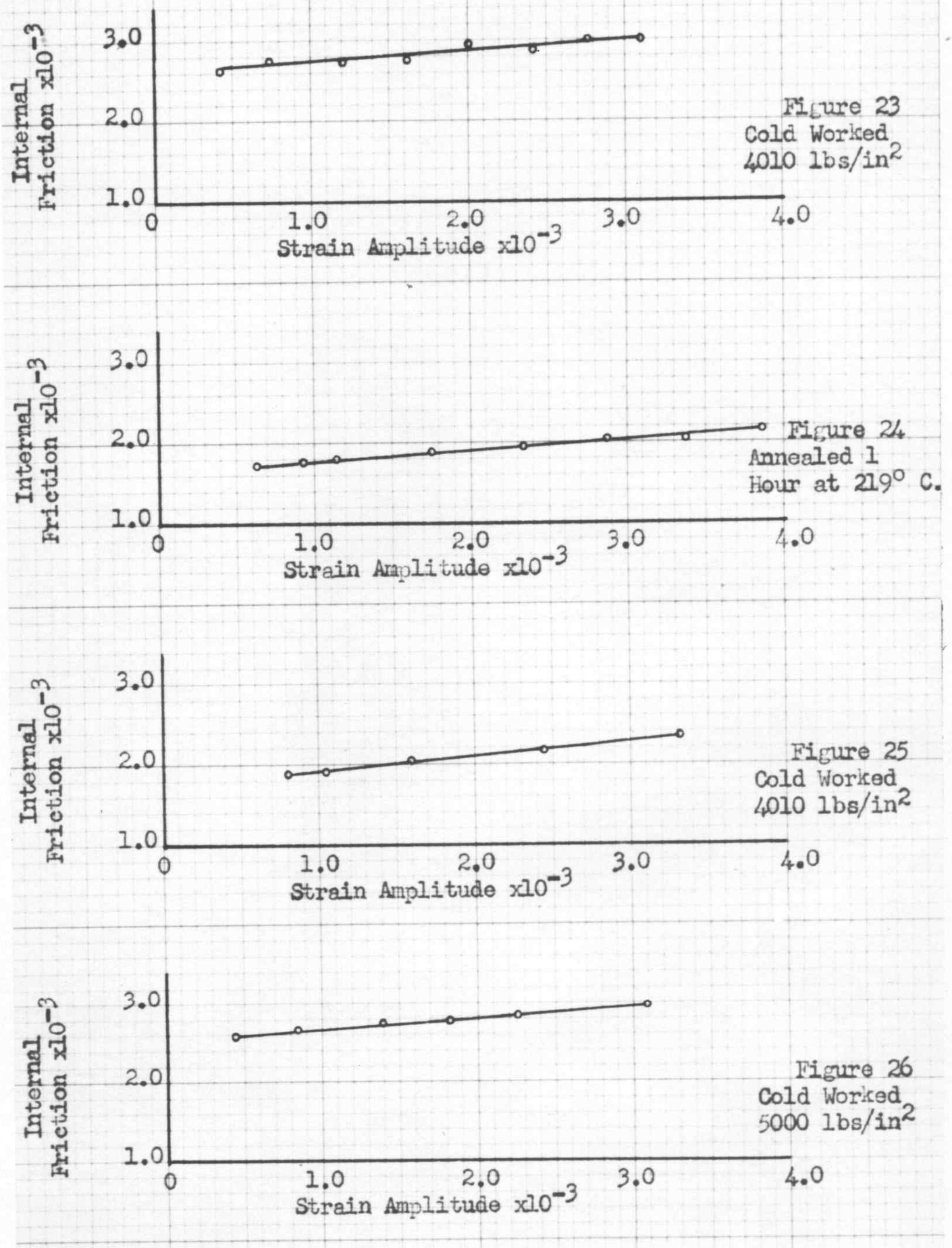


Figure 23
Cold Worked
4010 lbs/in^2

Figure 24
Annealed 1
Hour at 219° C.

Figure 25
Cold Worked
4010 lbs/in^2

Figure 26
Cold Worked
5000 lbs/in^2

FIGURES 23, 24, 25, and 26
INTERNAL FRICTION VERSUS STRAIN AMPLITUDE
FOR REED NO. 2

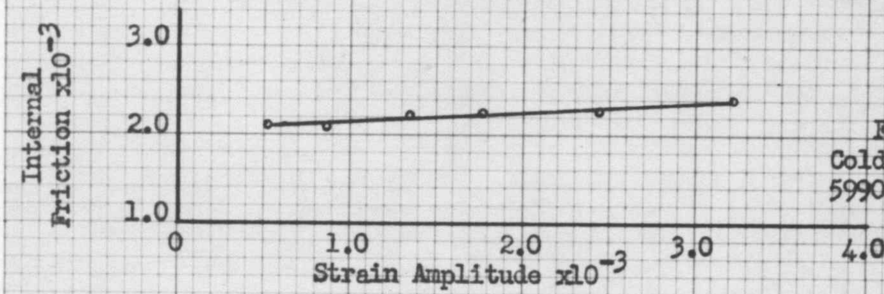


Figure 27
Cold Worked
5990 lbs/in^2

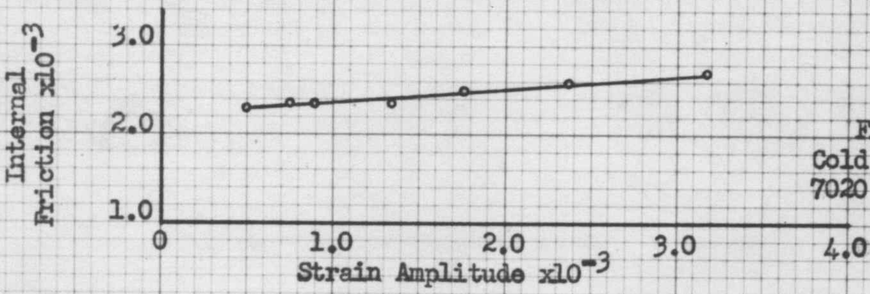


Figure 28
Cold Worked
7020 lbs/in^2

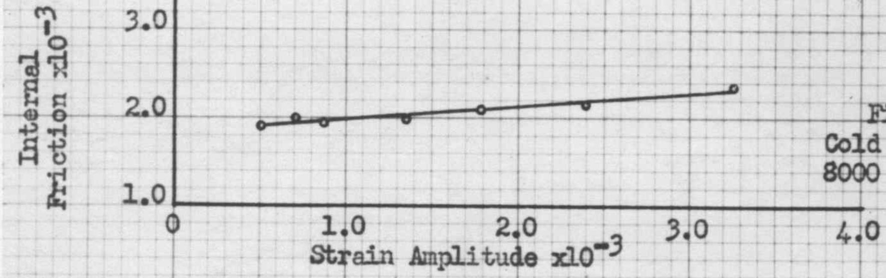


Figure 29
Cold Worked
8000 lbs/in^2

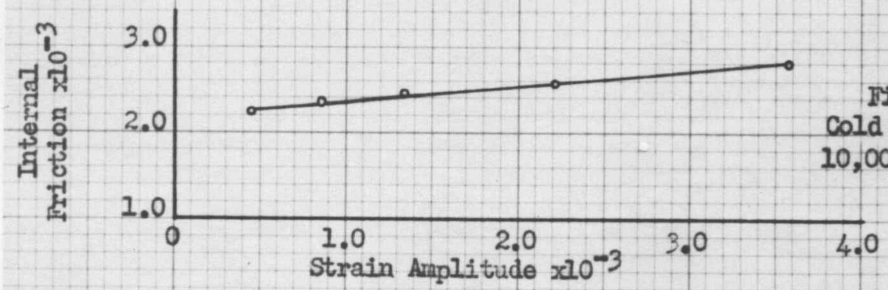
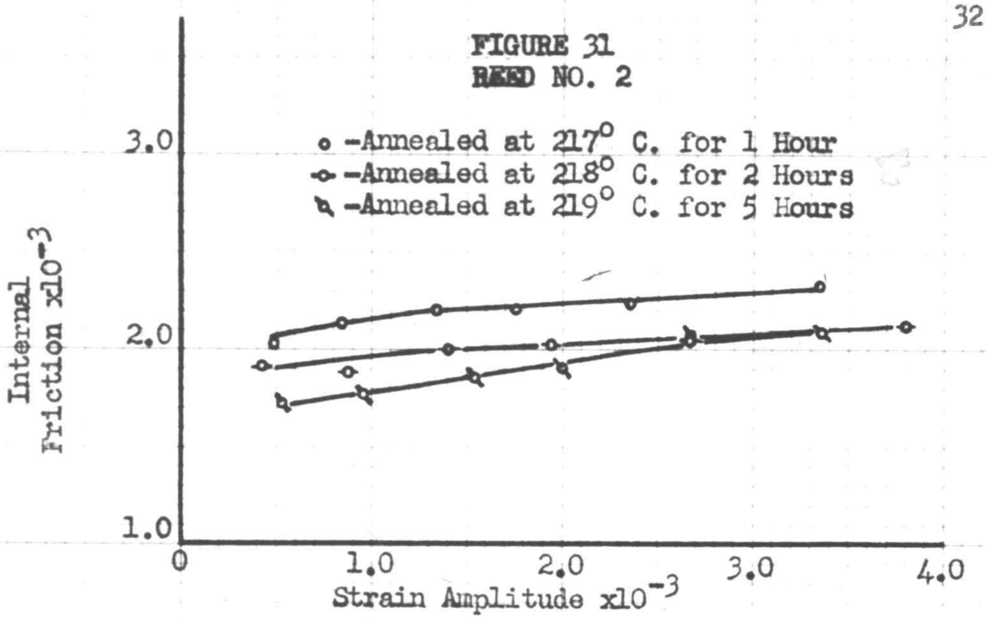
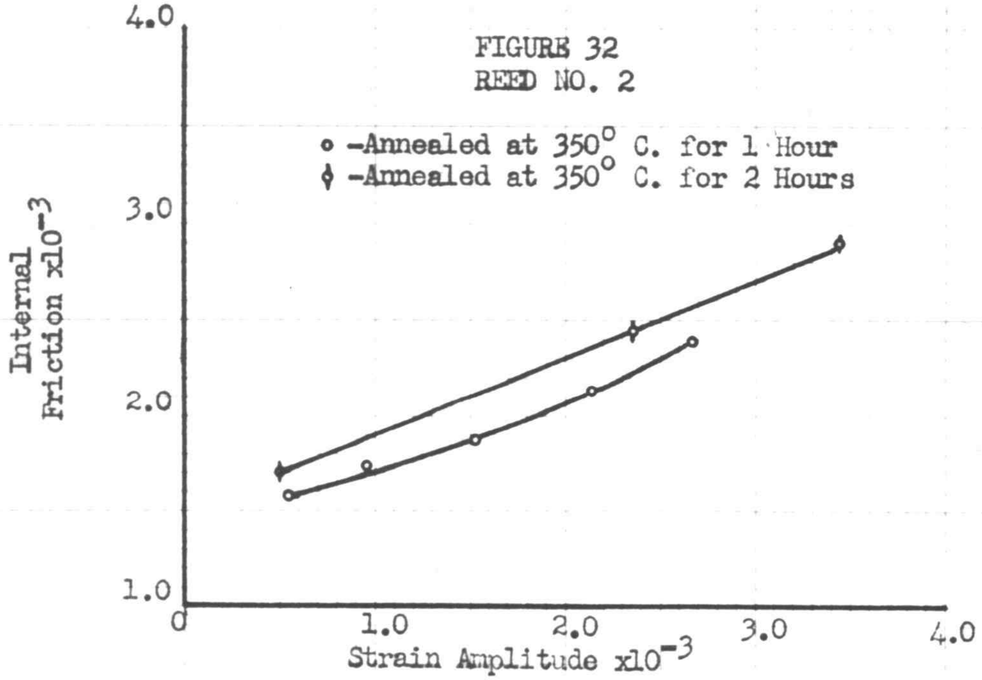


Figure 30
Cold Worked
10,000 lbs/in^2

FIGURES 27, 28, 29, and 30
INTERNAL FRICTION VERSUS STRAIN AMPLITUDE
FOR REED NO. 2





FIGURES 31 and 32
INTERNAL FRICTION VERSUS STRAIN AMPLITUDE
FOR VARIOUS ANNEALS

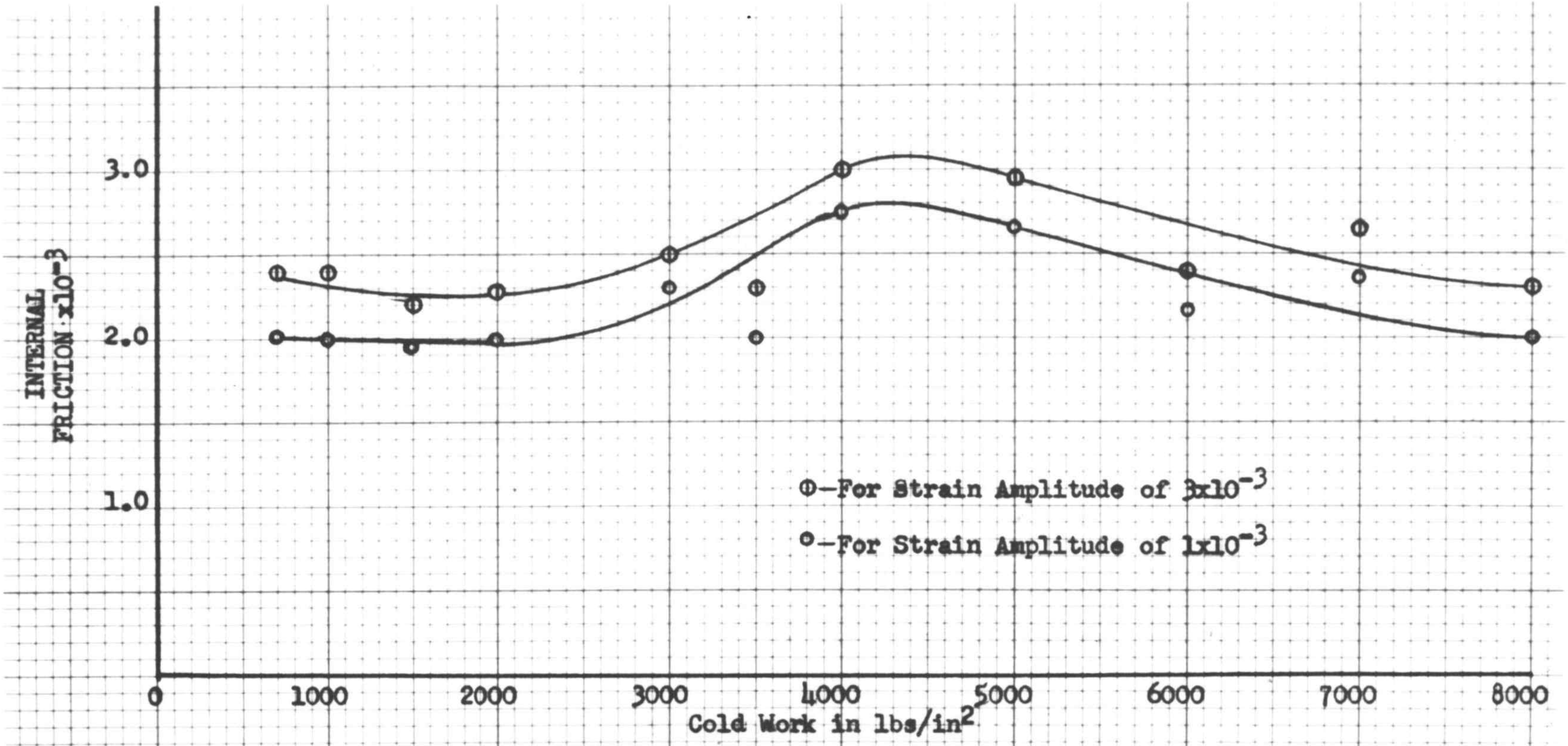


FIGURE 33
INTERNAL FRICTION VERSUS COLD WORK FOR REED NO. 2

BIBLIOGRAPHY

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4. Jewell, William R. A method for measuring internal friction. Ph.D. thesis. Corvallis, Oregon state college, 1948. 109 numb. leaves.

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APPENDIX

TABLE I

DETACHABLE COMPONENTS OF THE APPARATUS

Micrometer Filar Eyepiece - Bausch & Lomb - O S C 52601

Vertical Illuminator - Bausch & Lomb

Objective - Bausch & Lomb - 16 mm - 0.25 N. A.

Tube & Stand - #26

Audio Signal Generator - Espey Mfg. Co. - O S C 36556

Cathode Ray Oscilloscope - RCA - O S C 37479

Volt Ohmyst - RCA - O S C 56846 - 2

Vacuum Pump - A 233 Cenco

Strobotac - General Radio Co. - Serial No. 10914

Constant Voltage Transformer - Sola - Serial No. L2108

Ammeter - 0-5 Amp. A.C. - General Electric - 1293291

Resistances - 10 Amp. 600 V. - 3 Ward Leonard Electric Co.
Cat. No. ED28890

Thermometers - 0-400° C. - Brothcom New York - 79525
0-300° C. - Nurnberg U.S.A. - 2361 - ASTM

TABLE II

DATA OF THIS INVESTIGATION

Explanation of symbols used in this table:

V - applied transducer voltage

M_o - meter setting for resonance frequency

M_1 - meter setting for lower half-power frequency

M_2 - meter setting for upper half-power frequency

TABLE II (CONT.) - DATA OF THIS INVESTIGATION

Run No.	V (volts rms)	M_o	M_1	M_2	Strain Amplitude x 10^{-3}	Internal Friction x 10^{-3}
Reed No. 1 - As Found In The Instrument						
1	0.01	862.70	858.20	869.80	0.20	2.36
2	0.02	864.10	859.00	867.80	0.30	1.79
3	0.04	863.40	854.46	868.36	0.45	2.83
4	0.06	860.10	853.80	866.70	0.59	2.63
5	0.08	859.40	854.10	865.40	0.66	2.30
6	0.10	858.60	853.00	865.70	0.81	2.59
7	0.20	857.50	848.50	866.60	1.09	3.70
Reed No. 1 - Annealed at 215° C. for 1 Hour						
8	0.04	887.60	879.70	891.50	0.42	2.43
9	0.08	884.40	878.60	891.20	0.65	2.60
10	0.12	883.10	877.80	890.20	0.91	2.56
11	0.20	882.90	877.70	890.20	1.30	2.58
12	0.30	882.80	876.30	889.40	1.76	2.69
13	0.40	881.35	875.10	888.45	2.23	2.74
14	0.50	879.80	874.30	887.30	2.66	2.67
15	0.60	879.35	873.10	886.80	3.09	2.82
16	0.70	878.40	872.95	886.75	3.58	2.89
17	0.04	885.00	879.40	891.75	1.00	2.55
18	0.10	883.60	878.55	890.70	0.88	2.51
19	0.10	883.80	878.35	890.65	0.88	2.54
20	0.20	883.60	876.83	890.00	1.40	2.71
21	0.30	881.90	875.85	888.80	1.85	2.70
22	0.40	880.65	874.85	887.85	2.29	2.67
23	0.50	878.20	873.75	886.90	2.73	2.71
24	0.60	877.40	872.85	886.10	3.12	2.74
25	0.70	876.10	872.00	885.55	3.46	2.80
Reed No. 1 - Cold-Worked With 100 lbs/in^2 for 1 Minute						
26	0.04	870.50	862.10	877.00	0.42	3.05
27	0.10	870.40	861.50	876.10	0.71	3.00
28	0.20	865.40	858.60	874.20	1.10	3.20
29	0.40	862.50	856.10	871.90	1.88	3.24
30	0.60	861.70	854.20	871.00	2.57	3.43
31	0.70	859.60	853.40	870.10	2.90	3.41
32	0.04	866.50	860.60	873.50	0.40	2.65
33	0.40	862.00	856.20	871.40	1.92	3.11
34	0.04	870.00	862.80	874.90	0.43	2.49

TABLE II (CONT.) - DATA OF THIS INVESTIGATION

Run No.	V (volts rms)	M_o	M_1	M_2	Strain Amplitude x 10^{-3}	Internal Friction x 10^{-3}
35	0.40	865.10	856.80	873.70	1.80	3.47
36	0.80	860.80	853.80	872.20	3.60	3.76

Reed No. 1 - Cold-Worked With 465 lbs/in^2 for 1 Minute

37	0.04	847.35	842.70	853.18	0.54	2.15
38	0.08	846.53	841.70	853.00	0.81	2.31
39	0.14	845.55	840.85	852.27	1.16	2.33
40	0.26	844.10	839.25	851.30	1.77	2.47
41	0.40	843.00	837.65	850.05	2.44	2.55
42	0.60	839.95	835.45	848.45	3.30	2.60

Reed No. 1 - Cold-Worked With 630 lbs/in^2 for 1 Minute

43	0.04	858.85	853.85	864.00	0.51	2.07
44	0.10	857.45	852.50	863.70	0.88	2.30
45	0.30	855.30	849.70	861.75	1.86	2.46
46	0.50	851.55	847.45	860.10	2.73	2.59
47	0.70	850.80	845.40	858.80	3.50	2.74

Reed No. 1 - Cold-Worked With 2012 lbs/in^2 for 1 Minute

48	0.04	802.45	797.10	808.85	0.52	2.43
49	0.20	800.85	795.65	807.65	1.44	2.49
50	0.40	798.70	793.90	806.90	2.45	2.71
51	0.70	796.55	791.80	805.40	3.81	2.82

Reed No. 1 - Cold-Worked With 10,650 lbs/in^2 for 1 Minute

52	0.04	850.65	846.50	857.35	0.57	2.22
53	0.20	848.40	844.25	854.80	1.60	2.10
54	0.40	845.25	841.15	852.75	2.68	2.37
55	0.60	842.85	839.00	850.80	3.62	2.40

Reed No. 1 - Cold-Worked With 25,200 lbs/in^2 for 1 Minute

56	0.04	788.05	783.95	793.55	0.56	2.00
57	0.14	788.85	785.75	793.45	1.30	1.60
58	0.30	787.40	784.20	792.55	2.16	1.75
59	0.50	785.15	782.35	791.00	3.18	1.81
60	0.04	790.85	787.80	795.60	0.56	1.75
61	0.04	790.90	786.20	795.10	0.59	1.85

TABLE II (CONT.) - DATA OF THIS INVESTIGATION

<table>
<tr><th>Run No.</th><th>V (volts rms)</th><th>M_o</th><th>M_1</th><th>M_2</th><th>Strain Amplitude x 10^{-3}</th><th>Internal Friction x 10^{-3}</th></tr>
<tr><td colspan="7">Reed No. 1 - Cold-Worked With 34,000 lbs/in^2 for 1 Minute</td></tr>
<tr><td>62</td><td>0.04</td><td>763.35</td><td>760.05</td><td>767.90</td><td>0.58</td><td>1.64</td></tr>
<tr><td>63</td><td>0.04</td><td>3219.20</td><td>3213.65</td><td>3225.00</td><td>0.58</td><td>--</td></tr>
<tr><td>64</td><td>0.12</td><td>761.50</td><td>758.10</td><td>766.75</td><td>1.21</td><td>1.80</td></tr>
<tr><td>65</td><td>0.30</td><td>759.90</td><td>755.30</td><td>765.30</td><td>2.15</td><td>2.09</td></tr>
<tr><td>66</td><td>0.50</td><td>757.25</td><td>752.50</td><td>763.50</td><td>3.29</td><td>2.29</td></tr>
<tr><td colspan="7">Reed No. 2 - Annealed at 216° C. for 1 Hour</td></tr>
<tr><td>67</td><td>0.02</td><td>932.30</td><td>917.65</td><td>946.60</td><td>0.48</td><td>--</td></tr>
<tr><td>68</td><td>0.08</td><td>931.65</td><td>926.40</td><td>937.15</td><td>0.93</td><td>2.16</td></tr>
<tr><td>69</td><td>0.20</td><td>930.40</td><td>926.25</td><td>936.25</td><td>1.69</td><td>2.01</td></tr>
<tr><td>70</td><td>0.40</td><td>929.00</td><td>924.85</td><td>935.55</td><td>2.77</td><td>2.16</td></tr>
<tr><td>71</td><td>0.60</td><td>928.80</td><td>923.25</td><td>934.85</td><td>3.77</td><td>2.35</td></tr>
<tr><td>72</td><td>0.02</td><td>896.00</td><td>890.70</td><td>900.90</td><td>0.40</td><td>2.08</td></tr>
<tr><td>73</td><td>0.08</td><td>894.30</td><td>889.65</td><td>899.80</td><td>0.94</td><td>2.07</td></tr>
<tr><td>74</td><td>0.30</td><td>891.70</td><td>887.35</td><td>898.75</td><td>2.23</td><td>2.32</td></tr>
<tr><td colspan="7">Reed No. 2 - Cold-Worked With 50 lbs/in^2 for 1 Minute</td></tr>
<tr><td>75</td><td>0.02</td><td>893.70</td><td>887.95</td><td>900.80</td><td>0.35</td><td>2.63</td></tr>
<tr><td>76</td><td>0.08</td><td>892.05</td><td>888.55</td><td>897.75</td><td>0.79</td><td>1.88</td></tr>
<tr><td>77</td><td>0.30</td><td>890.10</td><td>885.80</td><td>897.00</td><td>2.08</td><td>2.28</td></tr>
<tr><td>78</td><td>0.50</td><td>890.00</td><td>884.60</td><td>896.25</td><td>3.08</td><td>2.38</td></tr>
<tr><td>79</td><td>0.02</td><td>893.65</td><td>889.00</td><td>899.75</td><td>0.33</td><td>2.19</td></tr>
<tr><td>80</td><td>0.02</td><td>896.10</td><td>890.80</td><td>901.60</td><td>0.41</td><td>2.19</td></tr>
<tr><td>81</td><td>0.08</td><td>894.05</td><td>889.70</td><td>899.70</td><td>0.83</td><td>2.04</td></tr>
<tr><td>82</td><td>0.40</td><td>891.90</td><td>886.20</td><td>897.60</td><td>2.67</td><td>2.32</td></tr>
<tr><td>83</td><td>0.20</td><td>892.50</td><td>887.90</td><td>898.70</td><td>1.57</td><td>2.20</td></tr>
<tr><td>84</td><td>0.08</td><td>894.00</td><td>889.20</td><td>899.50</td><td>0.84</td><td>2.09</td></tr>
<tr><td colspan="7">Reed No. 1 - Cold-Worked With 34,000 lbs/in^2 for 1 Minute</td></tr>
<tr><td>85</td><td>0.05</td><td>732.60</td><td>726.50</td><td>738.00</td><td>0.66</td><td>2.42</td></tr>
<tr><td>86</td><td>0.20</td><td>730.80</td><td>725.30</td><td>737.00</td><td>1.69</td><td>2.45</td></tr>
<tr><td>87</td><td>0.40</td><td>729.30</td><td>723.70</td><td>736.00</td><td>2.85</td><td>2.58</td></tr>
<tr><td>88</td><td>0.60</td><td>728.50</td><td>722.40</td><td>735.00</td><td>3.98</td><td>2.64</td></tr>
<tr><td colspan="7">Reed No. 2 - Cold-Worked With 100 lbs/in^2 for 1 Minute</td></tr>
<tr><td>89</td><td>0.04</td><td>941.70</td><td>937.50</td><td>946.20</td><td>0.63</td><td>1.73</td></tr>
<tr><td>90</td><td>0.10</td><td>940.80</td><td>936.90</td><td>946.00</td><td>1.40</td><td>1.81</td></tr>
</table>

TABLE II (CONT.) - DATA OF THIS INVESTIGATION

Run No.	V (volts rms)	M_o	M_1	M_2	Strain Amplitude x 10^{-3}	Internal Friction x 10^{-3}
91	0.20	939.60	935.60	945.70	1.65	2.01
92	0.30	938.80	934.70	945.10	2.23	2.07
93	0.50	938.10	933.10	944.10	3.30	2.20

Reed No. 2 - Cold-Worked With 153 lbs/in^2 for 1 Minute

Run No.	V (volts rms)	M_o	M_1	M_2	Strain Amplitude x 10^{-3}	Internal Friction x 10^{-3}
94	0.04	898.30	893.60	902.80	0.53	1.86
95	0.10	896.90	892.40	902.60	1.00	2.06
96	0.20	895.50	891.20	902.00	1.58	2.19
97	0.30	894.50	890.30	901.30	2.09	2.24
98	0.40	894.80	889.30	900.80	2.60	2.35
99	0.55	892.90	888.00	899.90	3.30	2.43

Reed No. 2 - Cold-Worked With 182 lbs/in^2 for 1 Minute

Run No.	V (volts rms)	M_o	M_1	M_2	Strain Amplitude x 10^{-3}	Internal Friction x 10^{-3}
100	0.03	931.20	925.40	935.70	0.49	2.08
101	0.04	931.20	924.60	935.40	0.55	2.18
102	0.10	930.00	923.90	934.70	0.94	2.19
103	0.20	928.50	921.50	935.70	1.56	2.88
104	0.30	927.00	922.00	933.00	2.05	2.23
105	0.40	925.90	920.90	932.50	2.59	2.35
106	0.60	924.30	919.20	931.50	2.48	2.50

Reed No. 2 - Cold-Worked With 248 lbs/in^2 for 1 Minute

Run No.	V (volts rms)	M_o	M_1	M_2	Strain Amplitude x 10^{-3}	Internal Friction x 10^{-3}
107	0.02	924.70	918.70	928.90	0.36	2.06
108	0.04	924.20	918.35	928.30	0.55	2.02
109	0.08	923.20	917.90	927.80	0.88	2.36
110	0.20	921.40	916.50	926.90	1.54	2.11
111	0.36	919.50	915.00	925.90	2.34	2.21
112	0.50	918.50	914.00	925.10	3.04	2.30
113	0.63	918.00	912.60	924.75	3.55	2.46
114	0.08	925.10		(Equipment Failure)		
115	0.08	922.30	917.90	927.60	0.89	1.97
116	0.04	922.70	918.60	928.30	0.58	1.97
117	0.02	923.40	919.20	928.40	0.42	1.86

Reed No. 2 - Cold-Worked With 700 lbs/in^2 for 1 Minute

Run No.	V (volts rms)	M_o	M_1	M_2	Strain Amplitude x 10^{-3}	Internal Friction x 10^{-3}
118	0.02	907.30	902.70	912.30	0.44	1.94
119	0.04	907.10	902.20	912.40	0.62	2.60
120	0.10	906.00	901.60	911.70	1.03	2.04

TABLE II (CONT.) - DATA OF THIS INVESTIGATION

Run No.	V (volts rms)	M_o	M_1	M_2	Strain Amplitude x 10^{-3}	Internal Friction x 10^{-3}
121	0.20	905.10	900.40	911.30	1.63	2.20
122	0.30	903.80	899.70	910.85	2.16	2.25
123	0.40	902.80	898.70	910.40	2.68	2.37
124	0.60	902.00	897.20	909.40	3.62	2.46
Reed No. 2 - Cold-Worked With 1030 lbs/in^2 for 1 Minute						
125	0.05	887.00	881.80	892.75	0.60	1.81
126	0.10	888.90	884.50	894.60	1.03	2.06
127	0.20	887.70	883.30	893.90	1.60	2.17
128	0.30	886.50	882.50	893.50	2.10	2.30
129	0.40	885.30	881.60	892.70	2.62	2.29
130	0.60	883.90	880.00	891.90	3.51	2.46
131	0.04	889.35	884.90	894.30	0.57	1.92
Reed No. 2 - Cold-Worked With 1570 lbs/in^2 for 1 Minute						
132	0.04	891.00	886.60	895.80	0.56	1.88
133	0.10	890.00	885.95	895.50	0.96	1.95
134	0.20	889.00	884.90	894.90	1.66	2.04
135	0.30	888.00	884.10	894.50	2.18	2.12
136	0.40	887.20	883.50	893.90	2.72	2.13
137	0.60	886.20	882.00	893.50	3.61	2.36
Reed No. 2 - Cold-Worked With 2080 lbs/in^2 for 1 Minute						
138	0.04	876.00	871.70	881.20	0.54	1.96
139	0.10	875.00	871.10	880.50	1.03	1.94
140	0.20	874.10	870.10	879.90	1.66	2.02
141	0.30	973.10	869.10	879.40	2.17	2.13
142	0.40	872.30	868.20	879.00	2.67	2.23
143	0.50	871.30	867.50	878.40	3.18	2.24
144	0.60	870.50	866.70	878.00	3.61	2.32
145	0.40	871.90	867.90	878.60	2.65	2.20
146	0.20	873.60	869.40	879.50	1.57	2.09
147	0.10	874.50	870.20	879.90	1.04	2.00
148	0.04	875.50	871.10	880.30	0.57	1.90
Reed No. 2 - Cold-Worked With 3060 lbs/in^2 for 1 Minute						
149	0.04	869.00	864.00	874.75	0.50	2.22
150	0.10	868.00	863.15	874.00	0.90	2.23
151	0.20	866.90	862.00	873.10	1.50	2.28

TABLE II (CONT.) - DATA OF THIS INVESTIGATION

Run No.	V (volts rms)	M_o	M_1	M_2	Strain Amplitude x 10^{-3}	Internal Friction x 10^{-3}
152	0.30	865.40	861.00	872.70	2.00	2.40
153	0.40	864.40	860.10	872.10	2.50	2.46
154	0.60	862.80	858.50	871.40	3.32	2.64
155	0.08	871.00	866.60	876.80	0.90	2.10
156	0.15	870.50	866.00	876.50	1.25	2.16
157	0.25	869.30	865.00	875.80	1.85	2.23
158	0.45	867.60	863.50	875.10	2.80	2.40
Reed No. 2 - Cold-Worked With 3560 lbs/in^2 for 1 Minute						
159	0.04	839.60	835.40	844.60	0.54	1.89
160	0.10	838.70	834.50	844.20	0.95	2.00
161	0.20	837.60	833.70	843.50	1.52	2.01
162	0.30	836.60	832.80	843.10	2.03	2.11
163	0.40	836.40	832.00	842.60	2.47	2.17
164	0.50	835.00	831.40	842.50	2.96	2.28
165	0.60	824.80	830.80	842.80	3.39	2.35
Reed No. 2 - Cold-Worked With 4010 lbs/in^2 for 1 Minute						
166	0.04	849.00	843.70	856.50	0.42	2.62
167	0.10	848.70	842.60	856.10	0.74	2.76
168	0.20	847.80	842.10	855.40	1.21	2.72
169	0.30	847.00	841.50	854.90	1.62	2.75
170	0.40	846.30	840.30	854.70	2.01	2.95
171	0.50	845.40	840.00	853.90	2.41	2.86
172	0.60	844.50	839.20	853.80	2.77	3.00
173	0.70	844.00	838.90	853.50	3.10	3.00
Reed No. 2 - Annealed at 219° C. for 1 Hour						
174	0.04	882.90	878.90	887.20	0.64	1.72
175	0.10	881.90	878.20	886.90	1.14	1.80
176	0.20	881.00	877.40	886.50	1.77	1.89
177	0.30	880.00	876.60	886.00	2.34	1.95
178	0.40	879.00	875.80	885.60	2.87	2.30
179	0.50	877.90	875.00	885.00	3.38	2.06
180	0.60	877.20	874.10	884.60	3.87	2.17
181	0.08	881.90	878.00	886.50	0.93	1.77
Reed No. 2 - Cold-Worked With 4010 lbs/in^2 for 1 Minute						
182	0.04	878.00	872.70	882.70	0.52	2.06

TABLE II (CONT.) - DATA OF THIS INVESTIGATION

Run No.	V (volts rms)	M_o	M_1	M_2	Strain Amplitude x 10^{-3}	Internal Friction x 10^{-3}
183	0.10	876.60	872.60	881.80	1.05	1.90
184	0.20	875.40	871.40	881.20	1.60	2.02
185	0.40	873.80	869.90	880.40	2.45	2.17
186	0.60	872.30	868.50	879.80	3.33	2.33
187	0.08	876.20	872.50	881.60	0.81	1.88
Reed No. 2 - Cold-Worked With 5000 lbs/in^2 for 1 Minute						
188	0.04	823.50	818.30	830.90	0.44	2.59
189	0.10	822.80	817.40	830.30	0.85	2.66
190	0.20	821.80	816.20	829.50	1.39	2.74
191	0.30	821.00	815.50	829.00	1.83	2.78
192	0.40	820.10	814.80	828.50	2.26	2.82
193	0.60	818.70	813.30	827.70	3.10	2.98
Reed No. 2 - Cold-Worked With 5990 lbs/in^2 for 1 Minute						
194	0.04	866.50	861.80	872.10	0.53	2.11
195	0.10	865.40	861.00	871.20	0.87	2.09
196	0.20	864.40	859.70	870.50	1.34	2.21
197	0.30	863.80	858.80	869.80	1.78	2.24
198	0.45	862.20	857.50	868.70	2.44	2.28
199	0.65	860.70	855.90	867.60	3.23	2.40
Reed No. 2 - Cold-Worked With 7020 lbs/in^2 for 1 Minute						
200	0.04	851.30	845.50	856.80	0.50	2.31
201	0.10	849.70	844.60	856.20	0.89	2.37
202	0.20	848.15	843.70	855.20	1.34	2.36
203	0.30	847.20	842.60	854.80	1.78	2.50
204	0.45	845.90	841.30	853.90	2.38	2.59
205	0.65	844.90	839.80	853.00	3.18	2.71
206	0.08	849.50	844.70	856.20	0.75	2.35
Reed No. 2 - Cold-Worked With 8000 lbs/in^2 for 1 Minute						
207	0.04	838.20	834.20	843.50	0.51	1.91
208	0.10	837.50	833.50	843.00	0.87	1.95
209	0.20	836.50	832.50	842.20	1.36	1.99
210	0.30	835.40	841.60	841.70	1.79	2.08
211	0.45	833.80	830.20	840.70	2.40	2.17
212	0.70	832.00	828.20	839.70	3.26	2.36
213	0.08	837.50	832.60	842.35	0.71	2.00

TABLE II (CONT.) - DATA OF THIS INVESTIGATION

Run No.	V (volts rms)	M_o	M_1	M_2	Strain Amplitude x 10^{-3}	Internal Friction x 10^{-3}
Reed No. 2 - Cold-Worked With 10,000 lbs/in^2 for 1 Minute						
214	0.04	822.30	817.40	828.30	0.45	2.26
215	0.10	821.50	816.40	827.90	0.86	2.37
216	0.20	820.50	815.50	827.40	1.34	2.45
217	0.40	818.40	813.80	826.30	2.21	2.58
218	0.75	816.50	810.90	824.50	3.58	2.80
Reed No. 2 - Annealed at 217° C. for 1 Hour						
219	0.04	850.00	845.50	855.40	0.49	2.02
220	0.10	849.00	844.60	855.00	0.84	2.13
221	0.20	848.00	843.50	854.20	1.34	2.20
222	0.30	847.00	842.80	853.30	1.76	2.20
223	0.45	845.50	841.80	852.70	2.36	2.23
224	0.70	844.80	839.80	851.10	3.35	2.32
225	0.08	849.20	844.20	854.70	0.70	2.15
Reed No. 2 - Annealed at 218° C. for 2 Hours						
226	0.04	791.00	787.00	796.20	0.42	1.91
227	0.10	790.20	786.20	795.30	0.88	1.89
228	0.20	789.50	785.30	794.90	1.41	2.00
229	0.30	788.70	784.80	794.50	1.94	2.02
230	0.45	787.90	784.00	793.80	2.68	2.04
231	0.70	786.50	782.70	792.80	3.80	2.11
Reed No. 2 - Annealed at 219° C. for 5 Hours						
232	0.04	853.50	849.40	857.80	0.53	1.72
233	0.10	852.40	848.40	857.10	0.96	1.78
234	0.20	850.90	847.00	856.10	1.54	1.86
235	0.30	849.90	846.00	855.30	2.00	1.90
236	0.45	848.00	844.30	854.40	2.67	2.07
237	0.60	847.20	842.80	853.00	3.36	2.09
Reed No. 2 - Annealed at 219° C. for 10 Hours						
238	0.04	852.40	848.40	857.00	0.51	1.76
239	0.10	851.40	847.60	856.50	0.95	1.82
240	0.20	850.40	846.80	856.00	1.49	1.88
241	0.35	849.00	845.50	855.20	2.27	1.98
242	0.60	847.50	844.00	854.10	3.44	2.08

TABLE II (CONT.) - DATA OF THIS INVESTIGATION

Run No.	V (volts rms)	M_o	M_1	M_2	Strain Amplitude x 10^{-3}	Internal Friction x 10^{-3}
Reed No. 2 - Annealed at 350° C. for 1 Hour						
243	0.04	899.00	895.30	903.10	0.54	1.58
244	0.10	898.00	894.10	902.60	0.96	1.73
245	0.20	896.50	892.70	902.00	1.52	1.88
246	0.35	894.50	891.10	901.60	2.14	2.13
247	0.50	894.00	889.50	901.20	2.67	2.39
248	0.70	892.30	887.70	900.80	3.25	2.68
249	0.20	895.50	892.30	901.70	1.48	1.90
250	0.10	896.60	893.50	902.30	0.94	1.78
251	0.04	898.00	894.50	902.30	0.53	1.59
Reed No. 2 - Annealed at 350° C. for 1 Hour						
252	0.04	890.20	886.15	894.80	0.50	1.70
253	0.20	888.50	884.50	893.50	1.45	1.84
254	0.40	886.00	882.00	893.40	2.36	2.44
255	0.70	883.60	879.00	893.00	3.44	2.90

TABLE III

SAMPLE DATA SHEET

Run No.__________ Date__________ Time__________

Reed Condition______________________________

____

Transducer Voltage __________ V. A. C.

Resonant Frequency Determination -

Rest Position __________

	Frequency Meter		Filar Eyepiece
	__________		__________
	__________		__________
	__________		__________
Total	__________		__________
Ave.	__________		__________
KC.	__________ (f_o)	Amplitude	__________

Half-power frequency determination -

Half-power determination __________

	Frequency Meter	Frequency Meter
	__________	__________
	__________	__________
	__________	__________
Total	__________	__________
Ave.	__________	__________
KC.	__________ (f_1)	__________ (f_2)

Internal Friction __________

Strain Amplitude __________