DESIGNING, PROTOTYPING AND TESTING OF A NOVEL SAXOPHONE PRACTICE MUTE

by

MUHAMMAD KHAIRI BIN ROSLIM

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Mechanical Engineering)

JANUARY 2012

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CERTIFICATION OF APPROVAL

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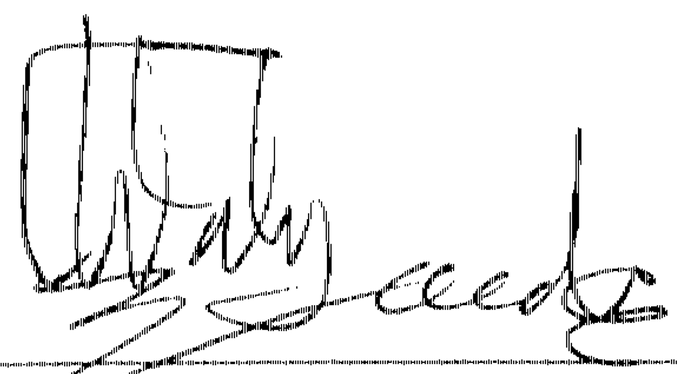

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UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
January 2012

CERTIFICATION OF ORIGINALLY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the reference and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified source or persons

MUHAMMAD KHAIRI BIN ROSLIM

ABSTRACT

A saxophone mute is a device fitted to saxophone to alter the sound produced by affecting the timbre, reducing the volume (noise), or most commonly both. There exist saxophone mutes also known as muffler comprising a muffling bag with a durable external vinyl layer and internal layer of sound absorbing material. This softens the tones of the saxophone and can be useful in classical settings as it also dampens the sound a bit. However, with regards to comfort ability, and mobility of the muffler, it is not convenience to play the saxophone in the bag. Thus, it is a need for us to determine a new design of the mute and its key component that may lead to compactible design of saxophone mute instrument. The objective of this proposal is to give introduction about the objective and to state the problem along with the objective. Furthermore, the report continues with literature review of the project in second chapter and followed by methodology of the project in the next chapter. The study will focuses on the design, prototype and testing a new mute instrument which has new specification in order to reduce 50% percentage of saxophone noise. The key of the project is the working system and the material selection. At the end, the mute instrument will undergoes certain tests to measure the reduction of noise.

ACKNOWLEDGEMENT

In the Name of Allah, The Most Merciful and Compassionate, praise to Allah, He is the Almighty. Eternal blessings and peace upon the Glory of the Universe, our Beloved Prophet Muhammad (S.A.W), his family and companions.

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CHAPTER 1

INTRODUCTION

Introduction

The alto saxophone is a member of the saxophone family of woodwind instruments invented by Belgian instrument designer Adolphe Sax in 1841. It is smaller than the tenor but larger than the soprano, and is the type most used in classical compositions. The alto and tenor are the most common types of saxophone.The alto saxophone (alto sax) is made of brass with a tapered bore. It has a single reed similar to a clarinet and a fingering system is based on that of the oboe. The alto saxophone is a common instrument in saxophone ensembles, concert and symphonic bands, big bands, and often as a solo instrument in rock, Rock n' Roll, rhythm and blues, and jazz genres.

In some cases, the sound of the saxophone has to be softening such as playing it during funeral and traditional orchestra. For this purpose, a device called as mute is used to reduce the sound without changing the intonation of the saxophone.

1.1 Background of Study

A mute is a cone or cylinder of metal, plastic, cardboard, or felt which is slipped into the mouth or bell of a horn to reduce the sound output and alter the quality. A saxophone mute is a device fitted to saxophone to alter the sound produced by affecting the timbre, reducing the volume (noise), or most commonly both.

There exist saxophone mutes also known as muffler comprising a muffling bag with a durable external vinyl layer and internal layer of sound absorbing material. This softens the tones of the saxophone and can be useful in classical settings as it also dampens the sound a bit.

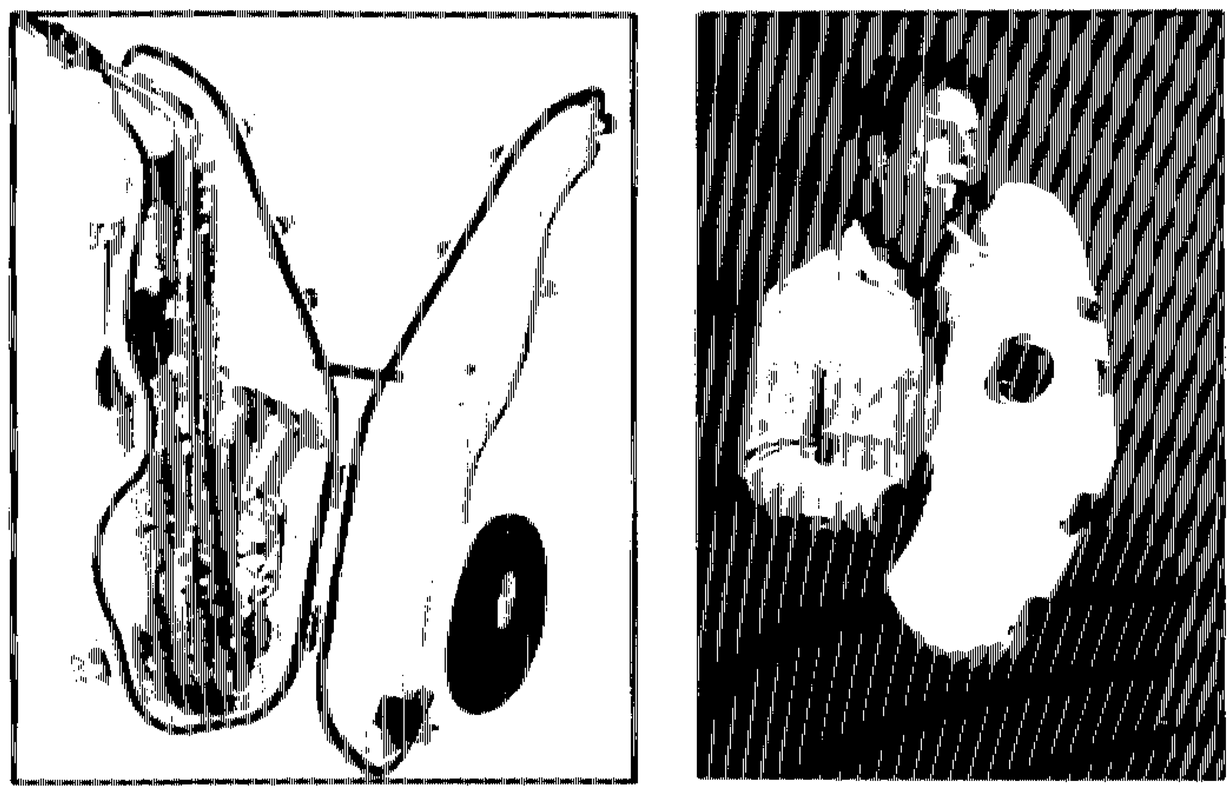


Figure 1.1.1: Muffler

In the research, the main objective is to change the design of the mute since the muffler is not very compactible to carry. Further concern, the design has to be made only to reduce the sound without changing the instrument tune. In studies by W.W.Rudd (1948) and J.A.Altosine (1948) the invention has to provide a mute which:

i. Is simple and inexpensive construction
ii. Is very light in weight
iii. Is not affected by water, dirt or moisture
iv. Is easy to attach and remove from the bell

Due to that, new design of improved mute has to be made and the main objective is to reduce the percentage of noise. The analysis on characteristic of the sound and material to be used as sound's absorber will serve as basis to propose new design of saxophone mute instrument.

1.2 Problem Statement

In this research, a saxophone currently is mute with muffler comprising muffling bag. The saxophone is entirely ensconced inside the saxophone muffler except for the mouth piece and is securely held there in by an external carriage assembly. It is basically a hard shelled case that muffles out all of the saxophone sound. Then, a small microphone in the case will relay the sound. The sound relayed is full and rich and the volume of the sound is adjustable. Therefore, asaxophone can be play loudly without disturbing anyone.

With regards to comfort ability, and mobility of the muffler, it is a need for us to determine a new design of the mute and its key component that may lead to compactible design ofsaxophone mute instrument. This new design intends to provide a new mute instrument which is simple, light and easy to carry and it will works with new mechanism.

1.3 Objectives

The main objectives of this research are:

i. To design, prototype and testing a saxophone mute instrument.
ii. To reduce 50% of the noise level of saxophone.

1.4 Scope of the study

The research project target is to get an understanding of the working principle of the muffler and trumpet mute instrument. In addition, it is necessary to know the acoustic properties of saxophone. This will lead us to new design of the saxophone mute instrument which works in improvised working principal. The scopes of study of this project are:

a) Design

- To draw a new design of mute instrument.
- To propose the material of mute instrument.

b) Prototype

- To build a new mute instrument with selected material and specification.

c) Testing

- To reduce 50% of noise level of saxophone by using new mute instrument.

1.5 Relevancy of the study

The project undertaken is relevant to me as a student that takes Mechanical Engineering. Since I am taking manufacturing and material course, this topic will provides a good learning medium for me to apply the knowledge.

1.6 Feasibility of study

For this project, the technical feasibility of study consists of:

- Familiar with mute device mechanism
- Familiar with application (AutoCAD)
- Familiar with other tools that support the system such as vibration/ sound sensor

The size of this project is:

- People: Muhammad Khairi bin Roslim
- Timeframe: 28 weeks (May 2011 - December 2011)

CHAPTER 2

LITERATURE REVIEW

2.1 Saxophone

A saxophone also referred to as the sax is a conical-bore transposing musical instrument that is a member of the woodwind family. Saxophones are usually made of brass and played with a single-reed mouthpiece and basically saxophone consists of an approximately conical tube of thin metal, most commonly brass and sometimes plated with silver, gold, and nickel, flared at the tip to form a bell.

The saxophone consists of an approximately conical tube of thin metal, most commonly brass and sometimes plated with silver, gold, and nickel, flared at the tip to form a bell. At intervals along the tube are between 20 and 23 tone holes of varying size, including two very small 'speaker' holes to assist the playing of the upper register. These holes are covered by keys (also known as pad cups), containing soft leather pads, which are closed to produce an airtight seal; at rest some of the holes stand open and others are closed.

The keys are controlled by buttons pressed by the fingers, while the right thumb sits under a thumb rest to help keep the saxophone balanced. The fingering for the saxophone is a combination of that of the oboe with the Boehm system, and is very similar to the flute or the upper register of the clarinet. Instruments that play to low A have a left thumb key for that note.

The simplest design of saxophone is a straight conical tube, and the sopranino and soprano saxophones are usually of this straight design. However, as the lower-pitched instruments would be unacceptably long if straight, for ergonomic reasons, the larger instruments usually incorporate a U-bend at, or slightly above, the third-lowest tone hole. As this would cause the bell of the instrument to point almost directly upward, the end of the instrument is either bevelled or tilted slightly forward.

2.1.1 Alto Saxophone

The alto saxophone is a member of the saxophone family of woodwind instruments invented by Belgian instrument designer Adolphe Sax in 1841. It is smaller than the tenor but larger than the soprano, and is the type most used in classical compositions. The alto and tenor are the most common types of saxophone. The Alto saxophone was selected to be used for this project purpose.

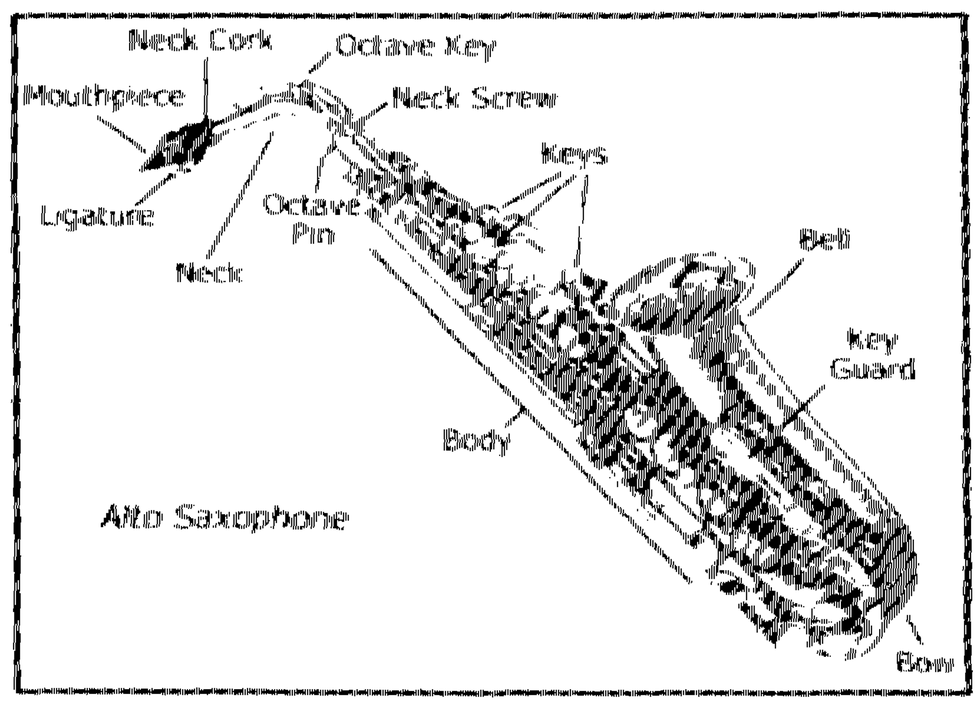


Figure 2.1.1: Components of Alto Saxophone

Each type of saxophone covers a fundamental range of about two and one half octaves, and for alto saxophone the range is $D_{\bullet 3}$ to $A_{\bullet 5}$. The overall length of the alto saxophone is 15 ¾ inches.

2.2 Saxophone Mute Instrument

A mute is an object attached to the music instrument which slightly muffles the vibration of the instrument. Although mutes will make the instrument quieter, their primary purpose is to alter the tone colour to achieve a particular effect. According to J.A.Altosina (1948), he stated that the main objective of the mute is to change the vibration of the sound of each note emanating from the instrument and still keeping the instrument in tune. It is further object to provide an attachment for a wind instrument which will muffle or soften the tone at the same pitch as the open instrument without pitch.

A saxophone mute instrument is an object attach to the saxophone, which fits into the bell, neck or cork of the saxophone in order to change the quality and attenuate the sound output.

2.2.1 How the Mute Works

The primary purpose of the mute is to reduce or attenuate the sound of the open horn. The actual value of reduction does is dependent on the materials from which it is made. Theoretically, mutes made of harder surfaced materials like metal will have less attenuation than a mute made of a more porous material such as wood or fiberboard with the dimensions being identical. However, all straight mutes for brass instruments act similarly with regard to the reduction of sound.

A thesis written by Martin Kurka found that mutes attenuate the sound of the instrument the greatest in the low register, approximately nine decibels. The mute softened the instrument's sound by six decibels in the upper register and only four and one-half in the middle register.

The mute gives the brass instrument a brighter, less mellow sound because it dampened the fundamental of the sounding pitch and strengthened the upper partials. On most pitches the mute would add at least one upper partial.

2.3 Saxophone acoustic

2.3.1 Background of saxophone acoustic

In the saxophone, the reed acts like an oscillating valve (technically, a control oscillator). The reed, in cooperation with the resonances in the air in the instrument, produces an oscillating component of both flow and pressure. Once the air in the saxophone is vibrating, some of the energy is radiated as sound out of the bell and any open holes. A much greater amount of energy is lost as a sort of friction (viscous loss) with the wall. In a sustained note, this energy is replaced by energy put in by the player. The column of air in the saxophone vibrates much more easily at some frequencies than at others (i.e. it resonates at certain frequencies). These resonances largely determine the playing frequency and thus the pitch, and the player in effect chooses the desired resonances by suitable combinations of keys.

2.3.2 Vibration of air in Saxophone

The natural vibrations of the air in the saxophone, the key that cause it to play notes are due to standing waves. These standing wave modes arise from the combination of reflection and interference such that the reflected waves interfere constructively with the incident waves. An important part of the condition for this constructive interference is the fact that the waves change phase upon reflection from a fixed end.

2.4 Attenuation of Sound Waves

The loudness of sound is related to theamplitude of the sound wave. However, the pitch of sound is the same as the frequency of sound wave. When sound travels through a medium, its intensity diminishes with distance. In idealized materials, sound pressure (signal amplitude) is only reduced by the spreading of the wave. Natural materials, however, all produce an effect which further weakens the sound. This further weakening results from scattering and absorption. Scattering is the reflection of the sound in directions other than its original direction of propagation. Absorption is the conversion of the sound energy to other forms of energy. The combined effect of scattering and absorption is called attenuation.

2.5 Mechanics of Instrument

The alto saxophone is similar to the clarinet in that it is a reed instrument. The reed, which is usually made of a springy piece of cane and has vibrational tendencies, is secured to the mouthpieceand is forced to vibrate by the air stream of the musician. The vibration in the air within the instrumentcauses the saxophone to resonate. Resonance refers to the creation of large amplitude vibrations as asystem which vibrates with a certain frequency is acted on by a periodic disturbance with the samefrequency. This means that the instrument vibrates at the same frequency as the air flowing through it.

Depending on the key combination, different tones will be produced as the length of the instrument is shortened or lengthened. The longer the instrument, the longer it takes for the wave to travel throughit, resulting in a lower frequency. Lower frequencies correspond to a lower pitch, which is the subjectiveevaluation of the frequency of a sound, and higher frequencies correspond to higher pitch. This

explainswhy a lower note is produced when all of the valves on the saxophone are closed. The frequency of the note can also be changed by the embouchure, or the shape of the musicians lips around themouthpiece.

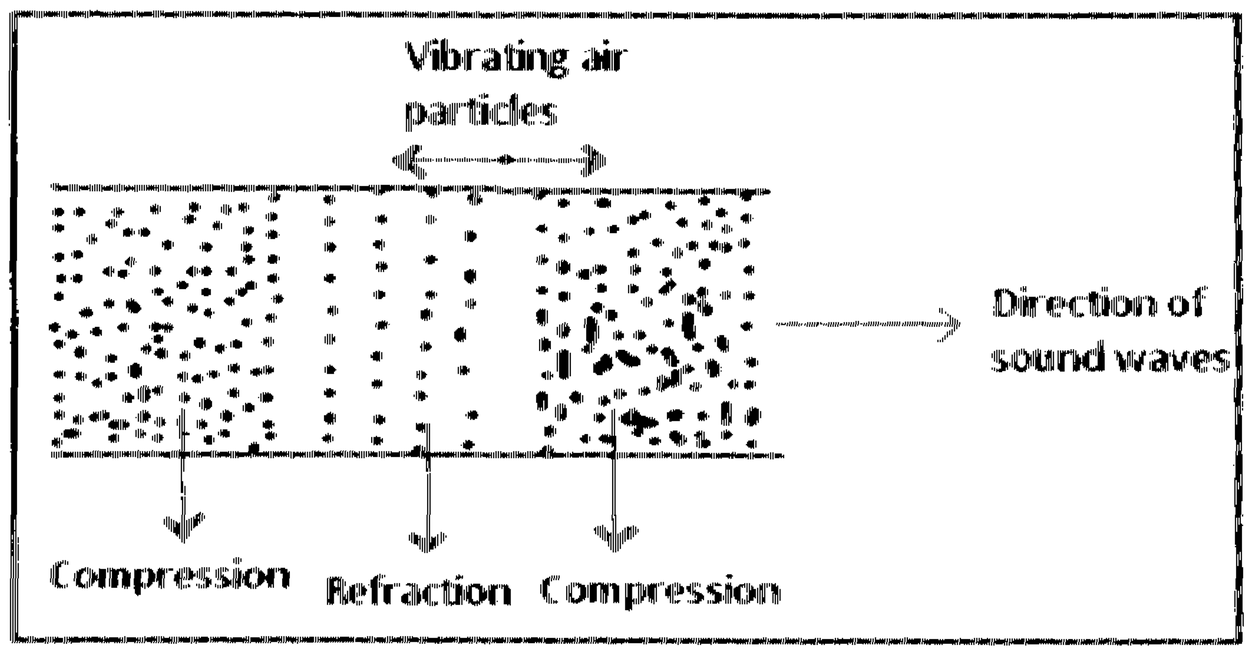


Figure 2.5.1: Direction of sound waves

As the sound travels through the instrument, the waves or particles experience compressions and rarefactions as demonstrated by the picture on the right. The saxophone is similar to the clarinet in that it is open on one end and closed on the other, however, it acts more as a conical tube and therefore plays all harmonics, or the integer multiples of the fundamental frequency, rather than just the odd harmonics. The bell of the saxophone helps the sound waves radiate more into the air and travel to the audience.

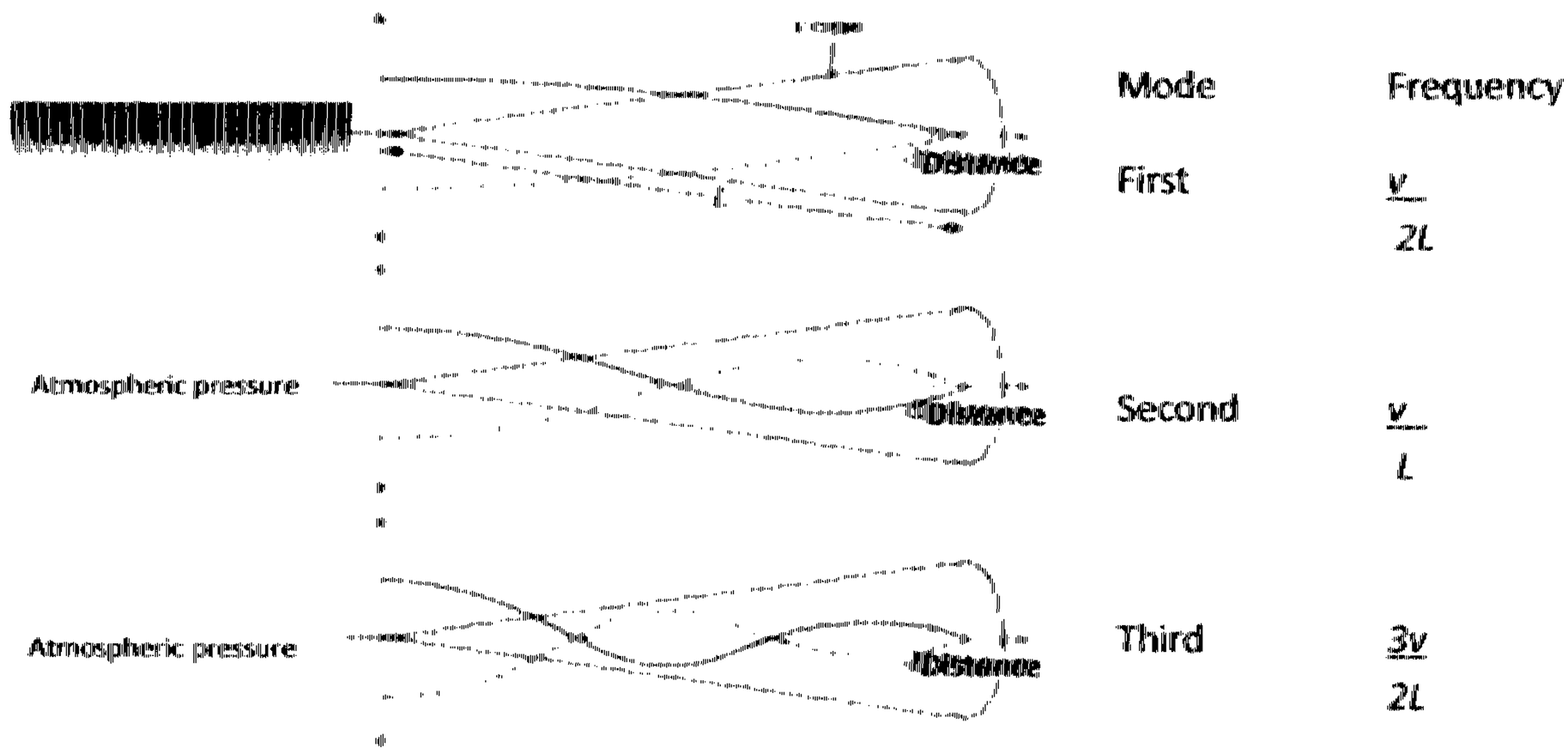


Figure 2.5.2: Sounds travel through air

2.6 Sound absorption

Materials that reduce the acoustic energy of a sound wave as the wave passes through it by thephenomenon of absorption are called sound absorptive materials. They are commonly used to soften theacoustic environment of a closed volume by reducing the amplitude of the reflected waves. Absorptivematerials are generally resistive in nature, either fibrous, porous or in rather special cases reactive resonatorsLewis H. Bell, (1994). Classic examples of resistive material are nonwovens, fibrous glass, mineral wools, feltand foams Porous materials used for noise control are generally categorized as fibrous medium or porous foam.Fibrous media usually consists of glass, rock wool or polyester fibers and have high acoustic absorption.Sometimes fire resistant fibers are also used in making acoustical products Claudio, (1998). An absorber, whenbacked by a barrier, reduces the energy in a sound wave by converting the mechanical motion of the airparticles into low-grade heat. This action prevents a buildup of sound in enclosed spaces and reduces thestrength of reflected noise Lewis H. Bell., (1994).

For this project, the sound wave is neither reflected nor transmitted and its energy isabsorbed in the material. There are many ways by which this can happen.

a) By viscous losses as the pressure wave pumps air in and out of the cavities in theabsorbers.
b) By thermal elastic damping.
c) ByHelmoltz type resonators.
d) By Vortexshading from sharp edges.
e) By direct mechanical damping in the material itself.

There are three basic categories of sound absorbers: porous materials commonlyformed of matted or spun fibres; panel (membrane) absorbers having an inflexiblesurface mounted over airspace; and resonators created by holes or slots connectedto an enclosed volume of trapped air.

Common porous absorbers include carpets, draperies, spray-applied cellulose, aeratedplaster, fibrous minerals wool and glass fibres, open-cell foam, and cast porousceiling tiles. Generally, all of these materials allow air to flow into a cellular

structurewhere sound energy is converted into heat. Damping refers to the capacity of the material to dissipate energy. It measures thefractional loss of energy of a wave per cycle, as it propagates within the materialitself. Thicker materialsgenerally show greater damping. In this project, the author has decided to use open-cell foam as main material.

Moreover, there are several factors that contributed in influencing the quality of material sound absorption.

Fiber Size:

Koizumi et al. (2002) reported an increase in sound absorption coefficient with a decrease in fiberdiameter. This is because, thin fibers can move more easily than thick fibers on sound waves. Moreover, withfine denier fibers more fibers are required to reach equal more fibers for same volume density which resultsin a more tortuous path and higher airflow resistance, Sun, Banks-Lee and Peng, (1993). A study by YounEung Lee et al. (YounEung Lee and Chang WhanJoo, 2003) concluded that the fine fiber content increasessound absorption coefficient values due to an increase in airflow resistance by means of friction of viscositythrough the vibration of the air. A study by Koizumi et al. (2002) also showed that fine denier fibers rangingfrom 1.5 to 6 denier per filament (dpf) perform better acoustically than coarse denier fibers. Moreover it hasbeen reported by Koizumi, T. that, micro denier fibers (less than 1 dpf) provide a dramatic increase inacoustical performance.

Airflow Resistance:

One of the most important qualities that influence the sound absorbing characteristics of a fibrous materialis the specific flow resistance per unit thickness of the material. The characteristic impedance and propagationconstant, which describes the acoustical properties of porous materials, are governed to a great extent by flowresistance of the material MingzhangRen and Finn Jacobsen, (1993). Fibers interlocking in nonwovens are thefrictional elements that provide resistance to acoustic wave motion. In general, when sound enters thesematerials, its amplitude is decreased by friction as the waves try to move through the tortuous passages. Thusthe acoustic energy is converted into heat (Conrad, 1983). This friction quantity which can be expressed byresistance of the material to airflow is called airflow resistance and is defined in following equation as:

Tortuosity:

Tortuosity is a measure of the elongation of the passage way through the pores, compared to the thicknessof the sample. According to Knapen et al. (2003), tortuosity describes the influence of the internal structureof a material on its acoustical properties. Con Wassilieff Con Wassilieff, (1996) describes tortuosity as ameasure of how far the pores deviate from the normal, or meander about the material. Horoshenkov(2001) stated that, tortuosity mainly affects the location of the quarter-wavelength peaks, whereas porosity andflow resistively affect the height and width of the peaks. It has also been said by the value of tortuositydetermines the high frequency behavior of sound absorbing porous materials.

Thickness:

Numerous studies that dealt with sound absorption in porous materials have concluded that low frequencysound absorption has direct relationship with thickness. The rule of thumb rule that has been followed is theeffective sound absorption of a porous absorber is achieved when the material thickness is about one tenth ofthe wavelength of the incident sound Michael Coates and MarekKierzkowski, (2002). Peak absorption occursat a resonant frequency of one-quarter wavelength of the incident sound (ignoring compliance effect) TimothyHirabayashi, David J. McCaa, (1999). A study by Ibrahim (1978) showed the increase of sound absorption only at low frequencies, asthe material gets thicker. However, at higher frequencies thickness has insignificant effect on sound absorption.

Influencing of air gap :

The creation air gap increases sound absorption coefficient values in mid and higher frequencies, in spite of showing minima at certain frequencies. Sound absorption measurement calculations were performed with and without an air gap of 5 cm and 10 cm between the rear of sample and the backing of the movable plunger of the sample tube.

2.7 Working principal for new mute instrument

Alternative 1: Multiple Internal Reflection and Sound Wave Absorption Concept

The new mute instrument is proposed to be placed at three locations; at the cork, neck or in area between bow and bell. From the author perspective, the best location is at the area between bow and bell since the amplitude at that point is higher. Since the intensity level of sound is perpendicularly depends on the size or amplitude of the sound wave, the focus of the mute instrument is to reduce the amplitude by using multiple internal reflections and sound wave absorption concept.

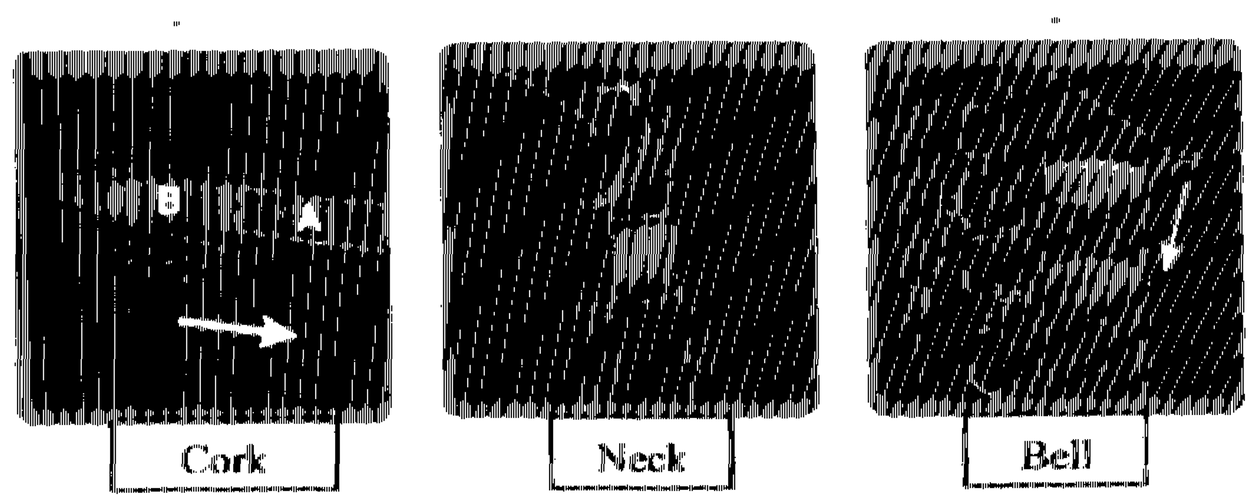


Figure 2.7.1: Position of mute instrument

The concept of multiple internal reflections is to reduce the vibration of air in the saxophone. At the beginning, sound wave will enter the mute instrument. Then the sound wave will be reflected and it will lead to produce motionless point called as nodes and antinodes of vibration and at the same time create superposition of the waves. As a result, the amplitude of the sound wave will be changedand it also will cause a reduction on

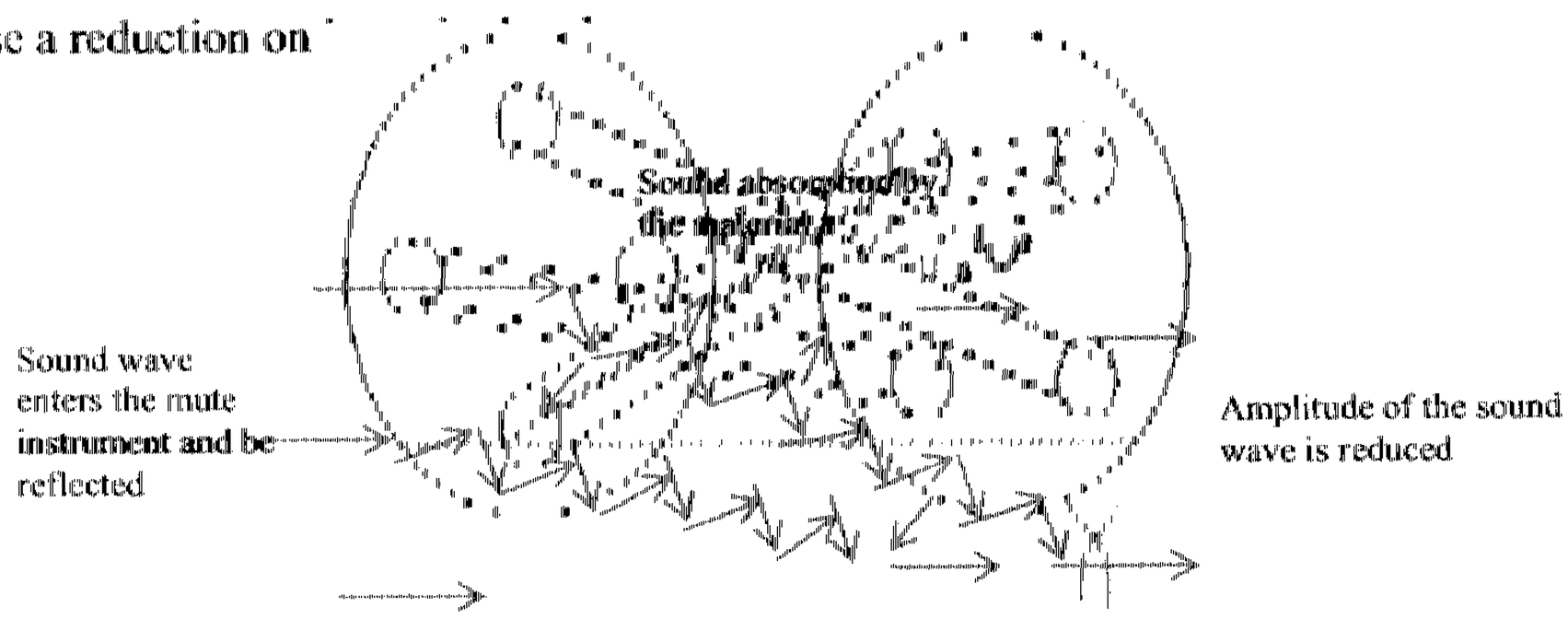


Figure 2.7.2: Multiple Internal Reflections

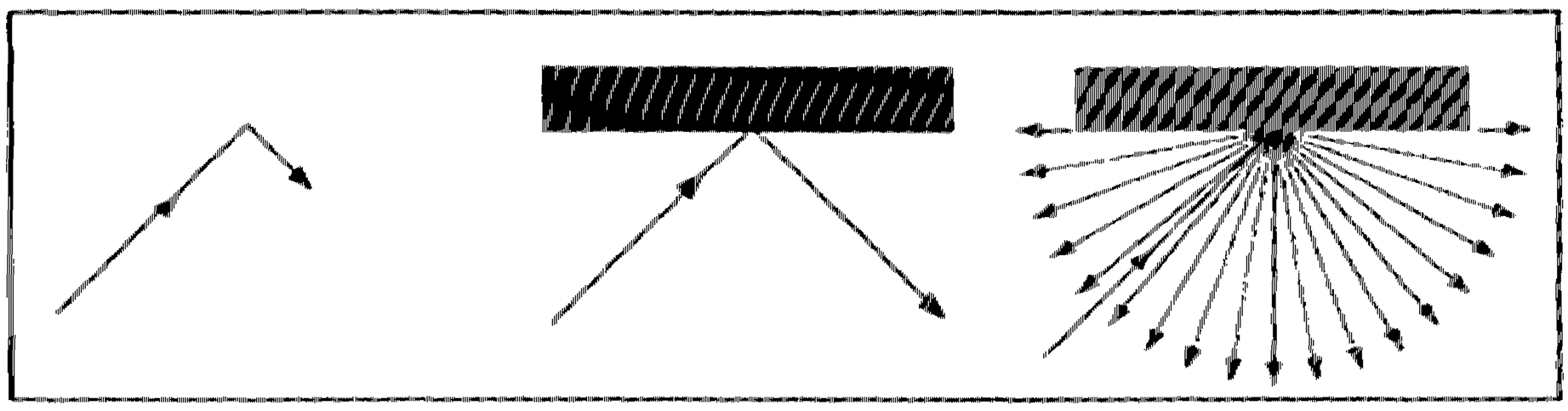


Figure 2.7.3: Surface-sound interaction- absorption (left), reflection (middle) and diffusing (right)

At the same time, there will be sound absorption by the material. As stated before, when sound travels through a medium, its intensity diminishes with distance and it is only reduced by the spreading of the wave. Thus, the absorption of the material will change the amplitude of sound wave, phase and wavelength by converting sounds energy to other forms.Thisevent will lead to attenuation of sound waves and drop the amplitude.

Alternative 2: Multiple Internal Reflection and Sound Wave Absorption with Tortuosity Factor Concept

Tortuosity is a property of curve being tortuous (twisted or having many turns). It is commonly used to describe diffusion in porous media and used to describe sound propagation in fluid-saturated porous media.

In detail, tortuosity is the physical characteristics correspond to the "non-straightness" of the pore network inside the porous material. It shows how well the porous material prevents direct flow through the porous medium. The more complex the path, the more time a wave is in contact with the absorbent (mute instrument) and hence the more energy dissipation and more absorbing capability. Therefore, it will lead to attenuation of sound waves and drop the amplitude.

2.8Material Selection

For the material concern, the author decided to use melamine foam as the main material.

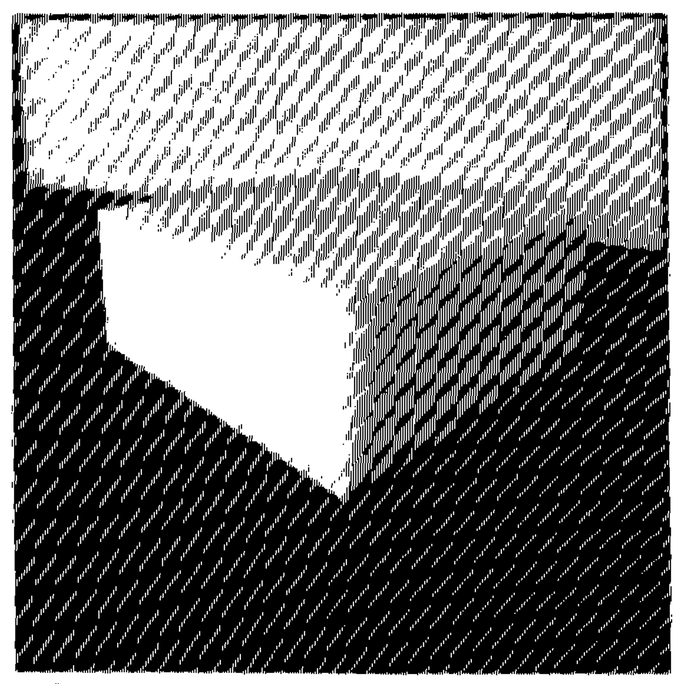


Figure 2.8.1: Melamine foam

Melamine foam is a lightweight and open-cell material. It is recommended for acoustical and thermal insulation in a large variety of applications due to its outstanding resistance to highheat, smoke, and low flame propagation. Melamine foam is also easy to cut, easy to melt and this type of materials has an advantage of not retaining moisture created by the breath of the musician.

Foam fabrication

Foam cutting is the most common method of foam fabrication. In stock form, foam is most commonly stored and transported in buns, sheets and rolls which then require secondary processing in order to meet the desired shapes and sizes of its intended use. Foam is a variable, polymer-based material which is used in a broad range of applications. Specific applications require different types of foam such as polyurethane or polyethylene, and in the same way, different types of foam cutting. All these factors should be carefully considered when determining the best type of foam and method of fabrication.

The process of foam cutting can be achieved by contour cutting, die cutting, hot wire cutting, laser or water jet cutting. Contour cutting uses a specialized saw that cuts into a foam block in the desired pattern or shape. Foam die cutting uses a process similar to stamping to produce parts from a solid piece of foam. For long duration runs, this is a consistent and efficient method of parts cutting. Another common and precise foam cutting method is hot wire cutting. This process uses a taut metal wire instead of a saw blade. The wire is heated through electrical resistance until it is hot enough to melt, or vaporize, the foam. It passes through the material at the desired location and vaporizes the foam before it comes into contact with it. The speed of the process has to be carefully considered so as not to drag the wire and damage the foam if too fast, or

create an unnecessarily wide cut if pulled through too slow. The depth of the cut is limited only by the length of the cutting wire and this is restricted by wire's tendency to sag under the force of gravity.

The standard procedure is normally used to produce mass quantity, so that the product can become cheap. In that case the equipment for standard procedure will be quite expensive. In this experiment the author has decided to use a simple way to produce the mute by improvised the method since the author needs to produce a few sample of prototype.

Below shown the properties of melamine foam:

Table 2.8.1: Technical data for Melamine Foam

Physical Properties	**Value**	**Test Standard**
Colour	White	n/a
Thickness	1"	n/a
Density	0.59 lbs/in^2 min	ASTM D-3574-86
Elongation	10% min	ASTM D-3574-86
Tensile Strength	17.4 lbs/in^2 min	ASTM D-3574-86
Tear Strength	3.8 lbs/in^2 min	ASTM D-3574-86
Temperature	Range -45°F – 300°F n/a	n/a

Table 2.8.2: Random sound absorption / noise reduction (without / with 0.001" film facing)

Freq. Hz	**125**	**250**	**500**	**1000**	**2000**	**4000**	**NRC**
1" Foam (%)	18/23	23/38	50/64	82/98	96/82	99/80	65/70

CHAPTER 3
METHODOLOGY

3.1 Project Methodology

The author has planned several phases in order to complete the research. The phases are distributed accordingly which are:

i) Research and review on saxophone working principal.
ii) Understand the mechanism of the muffler and trumpet mute instrument, its components and usage.
iii) Design and prototype a new mute instrument that has more mobility and compactible specification.
iv) Testing and do measurement to collect data of end result.

3.2 Project Activities

3.2.1 Design Phase

In designing phase of this project, the author has decided to use new design, material and working principal. The design concept of mute instrument has been illustrated in 3 dimensions by using AutoCAD software. In order to do design, the dimension of the bell saxophone is required. The proposed design consist oftwo cylindrical melamine foam at top and bottom which are connected to each other and will be used to reflect the sound wave. Tool required: AutoCAD software

In order to make a new design, the trumpet mute approach has been used. The design was studied and enhanced by considering factors that influencing the sound absorption in material.

Firstly, the measurements including the diameter of the saxophone bell need to be taken. This will give the accurate diameter of the mute. Since the diameter is depends on height, the mute will two different diameters at front and bottom. The height of the bell is about 7.0 cm, with diameter 6.2–8.1 cm. Therefore, the diameter and height of the new mute have to be at that range.

The cylindrical shape is proposed since it has a capability and easy to attach and remove from the bell.

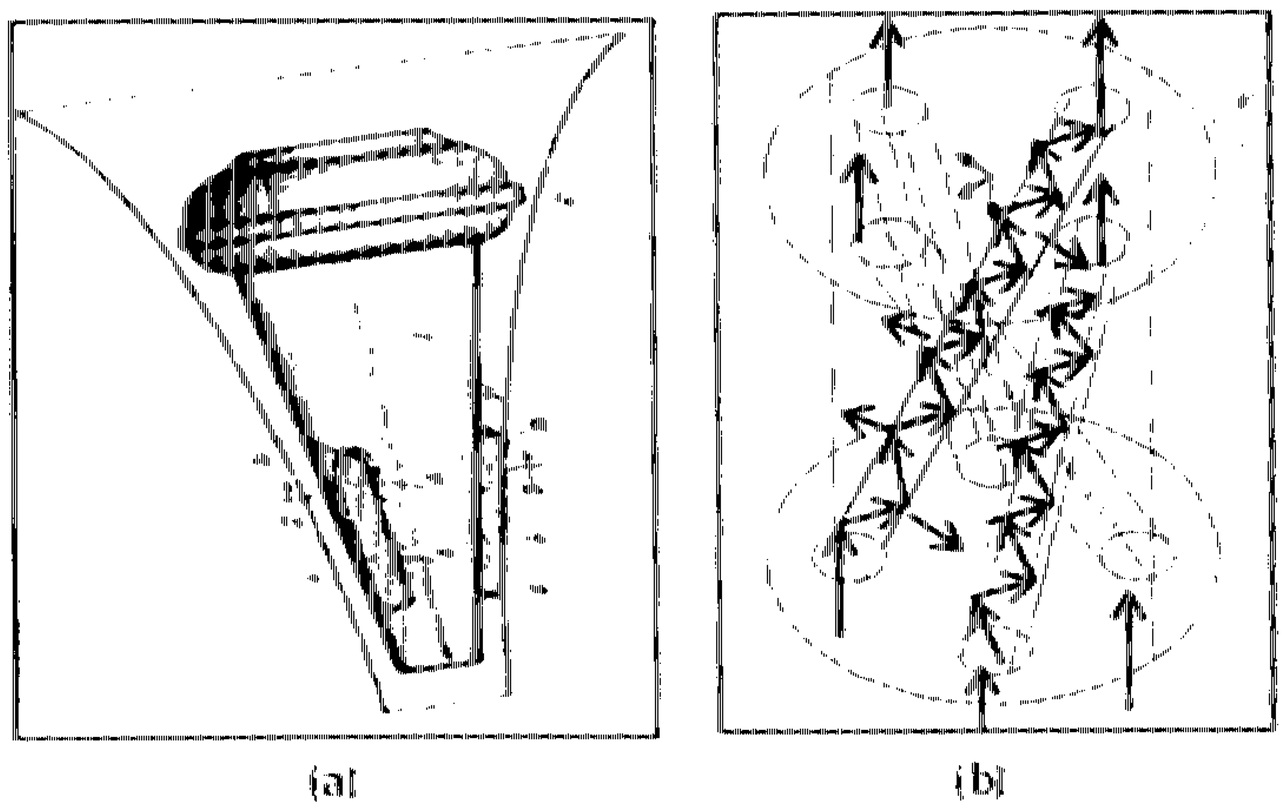
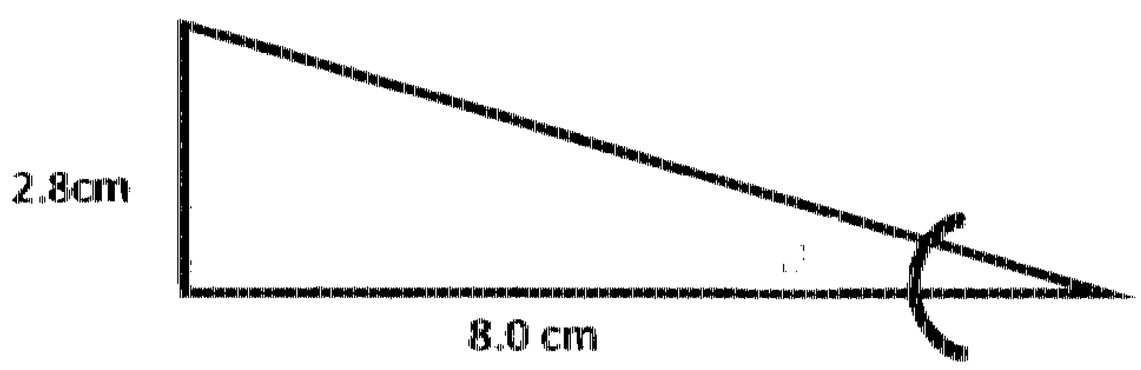


Figure 3.2.1: (a) trumpet mute design, (b) alternative 1

Considering air gap influence, in between top and bottom mute part, air gap creation is created in 6 cm length. This part will be cut off and add up by sharp edges to increase vortex shading which contribute in material sound absorption.

After considering the tortuosity factor, curve or twisted shape need to be added up in current design. The main concept is to elongate the time for the wave that enters the material. More long the path, more time it takes and thus, more sound waves will be absorbed by the material.



The height of the top mute is 2.8 cm with 8.0 cm diameter. So, based on Pythagoras theorem, the longest path is by taking the hypotenuse of the triangle. Therefore, the angle of the tortuosity factor should be:

$$\tan \theta = \frac{2.8}{8.0}$$

$$\theta = 19.29^{\circ}$$

For the bottom mute, the height is 2.8 cm with 6.2 cm diameter. So, based on Pythagoras theorem, the longest path is by taking the hypotenuse of the triangle. Therefore, the angle of the tortuosity factor should be:

$$\tan \theta = \frac{2.8}{6.2}$$

$$\theta = 24.3^{o}$$

After considering all factors, the author has proposed and come out with final design. The proposed design:

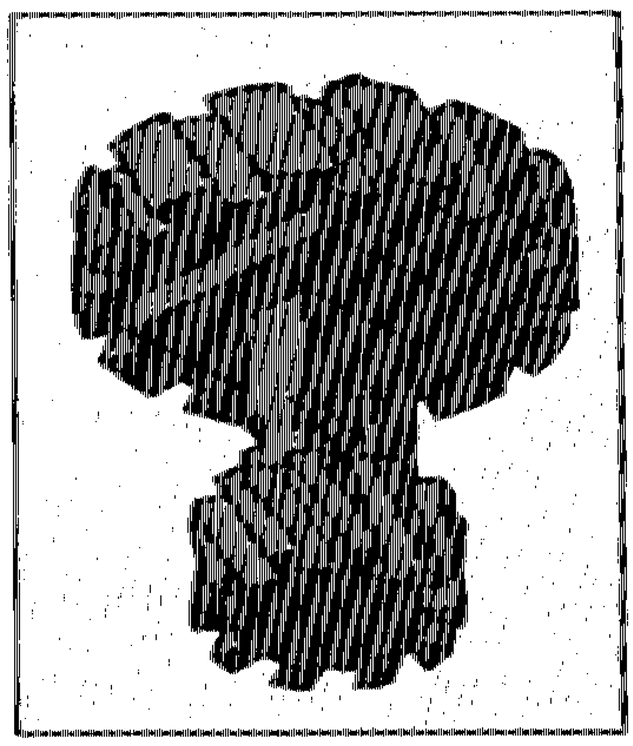


Figure 3.2.1: (c) Proposed design

Table 3.2.1: comparison of Alternative 1 and Proposed design

	Alternative 1	Proposed Design
Material	**Melamine foam**	**Melamine foam**
Tortuosity	**No**	**Yes**
Air gap influence	**No**	**Yes**
Edge shape	**Yes**	**Yes**
Porosity	**Yes**	**Yes**

3.2.2 Prototype Phase

In prototyping phase of this project, the author will build the mute instrument based on the drawing, material selection and the working system. From preliminary research, the author proposed to have mute instrument with following selection:

Material: Melamine Foam

System: Multiple Internal Reflection and Sound Wave Absorption with Tortuosity Factor

In order to fabricate the mute instrument, the author needs to know all the detail measurement of the instrument. The details that are required are:

a) Specification of the instrument

The mute instrument will be placed at the bell of saxophone. Therefore, the specification of the bell such as its diameter and height of the bell is very important to measure precisely in order to ensure the mute is fitted.

b) Process flow to fabricate the instrument

For the concern to fabricate the mute instrument, the procedure of fabrication plays an important role. Melamine foam is very easy to cut and light in weight. It needs a proper flow to ensure the end result is accordingly followed as required drawing.

c) Tools required

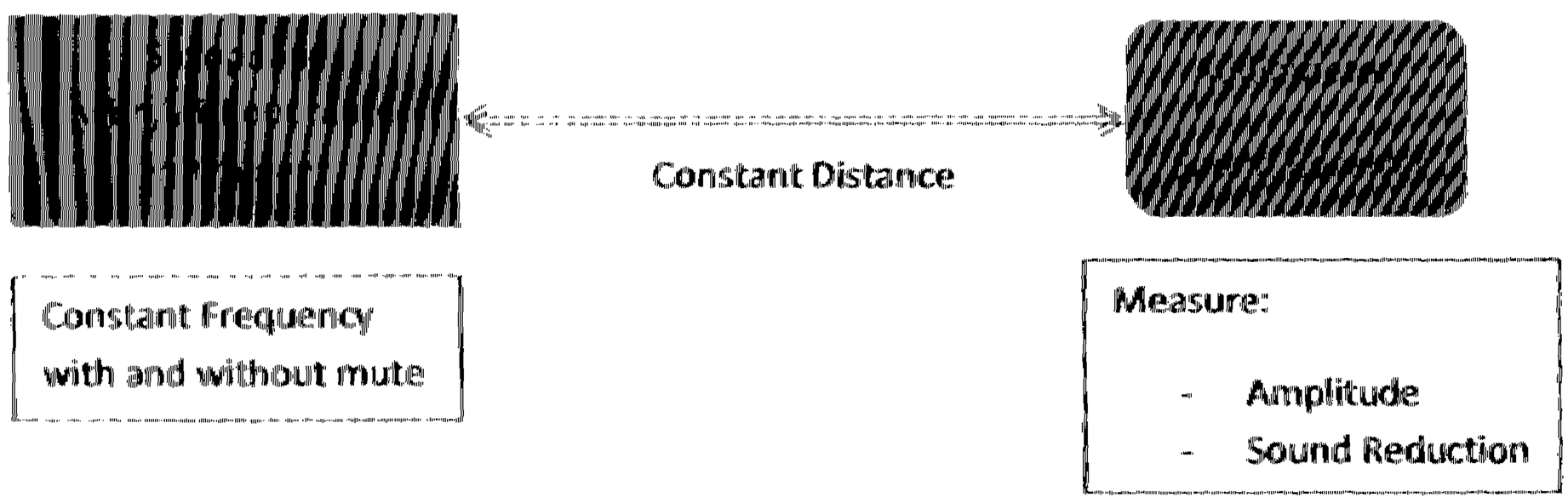
The main process at this phase is foam cutting. For this purpose, the author uses a sharp blade and electric wire cutter as cutting tools. However, the speed of cutter has to be emphasized to ensure the melamine foam is not damaged.

Tool required: Foam cutter, melamine foam

3.2.3 Testing Phase

In testing phase of this project, the author will conduct several tests to measure the intensity level (in decibel) of the saxophone before muted and after muted. The percentage of reduction will be calculate and record.

Tool required: saxophone, microphone /sound receiver, oscilloscope, audio input module



3.3 Project Scheduling (Gantt Chart)

The following Table 1 and Table 2 will list out all the work done and proposed dateline throughout Final Year Project 2 (FYP2).

Table 3.3.1: Gantt chart of work and dateline proposed in FYP1 semester

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Research on saxophone working principal														
Research on muffler and trumpet mute instrument														
Extended Proposal submission														
Proposal Defence														
Sketch and Design														
Material selection														
Interim Report submission														

Table 3.3.2: Tabulation of work and dateline proposed in FYP2

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Prototyping														
Testing and Measuring														
Progress Report submission														
Pre-EDX														
Dissertation writing														
Draft Report Submission														
Dissertation Submission (Soft bound)														
Technical Paper Submission														
Oral Presentation														
Dissertation Submission (Hard bound)														

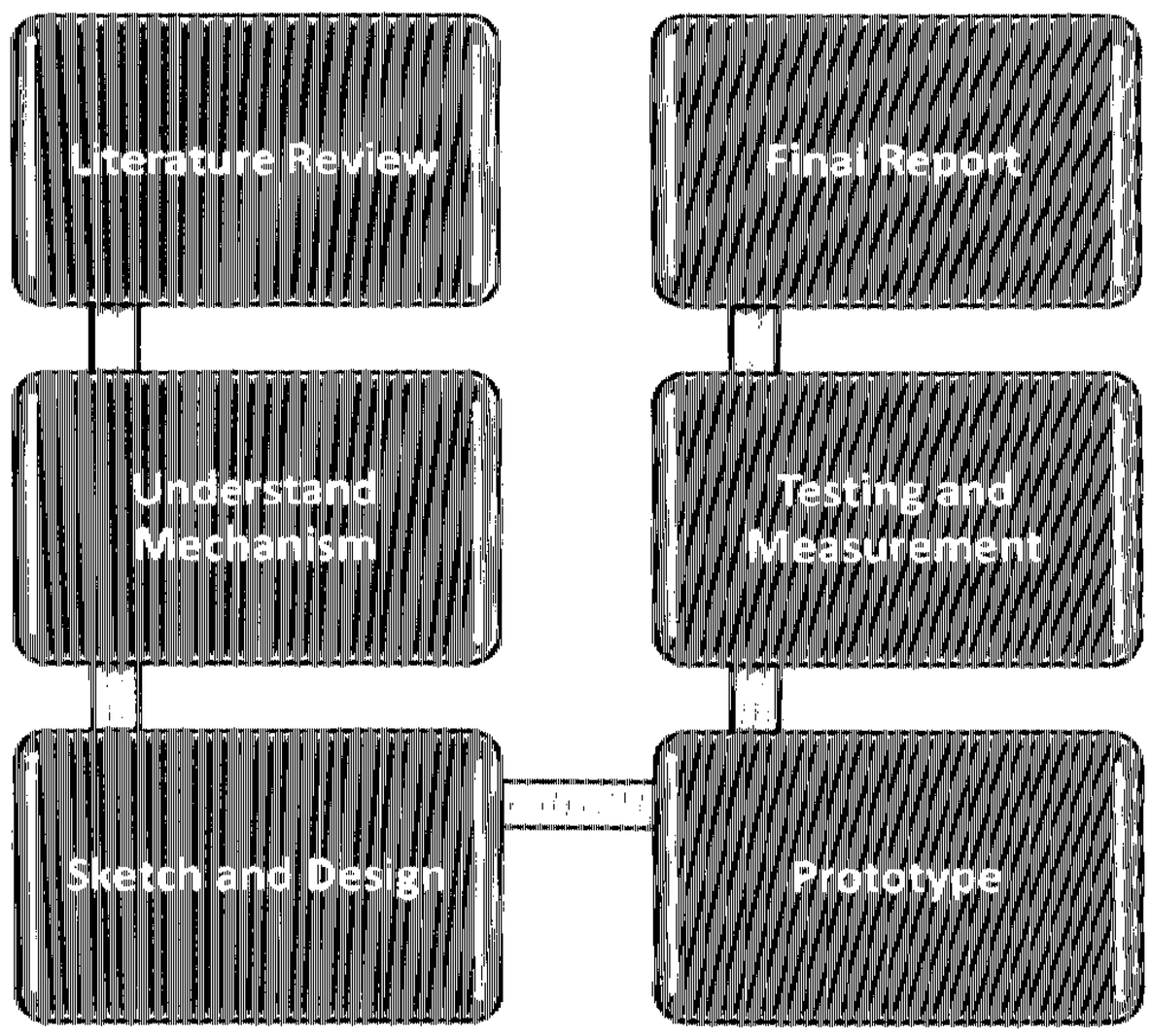
3.4 Key Milestone

Table 3.3.3: Project Milestone

Task	FYP I		FYP II			Remarks
	May	Sept	Sept	Oct	Dec	
Feasibility Study						Done
Designing						Done
Material Selection						Done
Fabrication and Prototyping						Done
Testing and Measurement						Done
Analysis						Done

For the concern in FYP2, the author will provide the prototype of the mute instrument. Testing and measurement on the new improved mute will be done and the data will be collected through several experiments. From the data collected, the actual reduction of the sound will be determined.

The flows of the research can be summarized as:



CHAPTER 4

RESULT AND DISCUSSION

4.1 Result

4.1.1 Designing process

The proposed design of the mute instrument plays important roles in this project. In order to achieve the objective to reduce and attenuate the sound, the design has to consider and integrate with mechanism selected; Multiple Internal Reflection and Sound Wave Absorption with Tortuosity Factor.

In undertake designing phase, two phases are required which are:

a) Sketching
b) Drawing in AutoCAD

Sketching

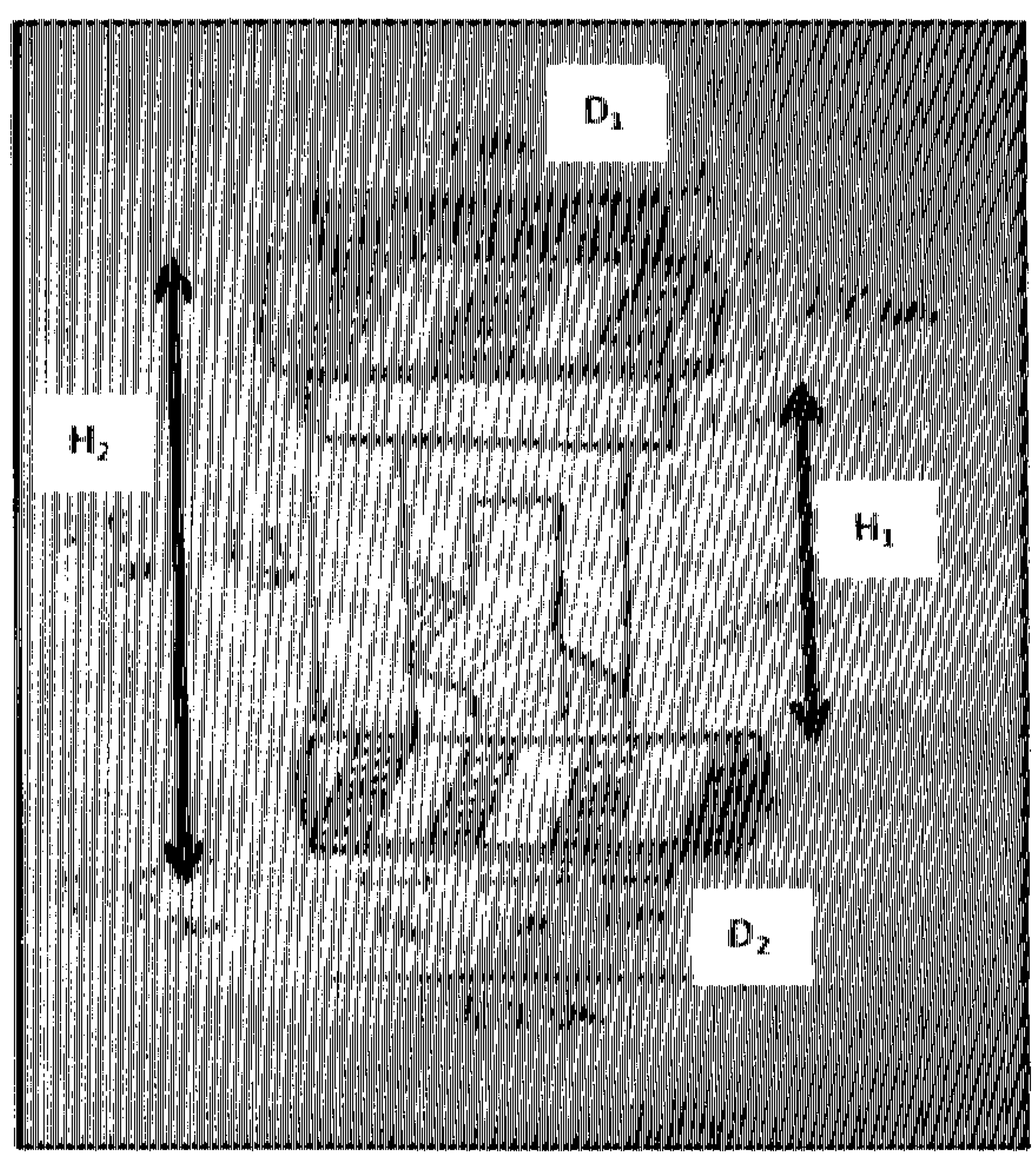


Figure 4.1.1.1: Sketch of Mute Instrument

AutoCAD Drawing

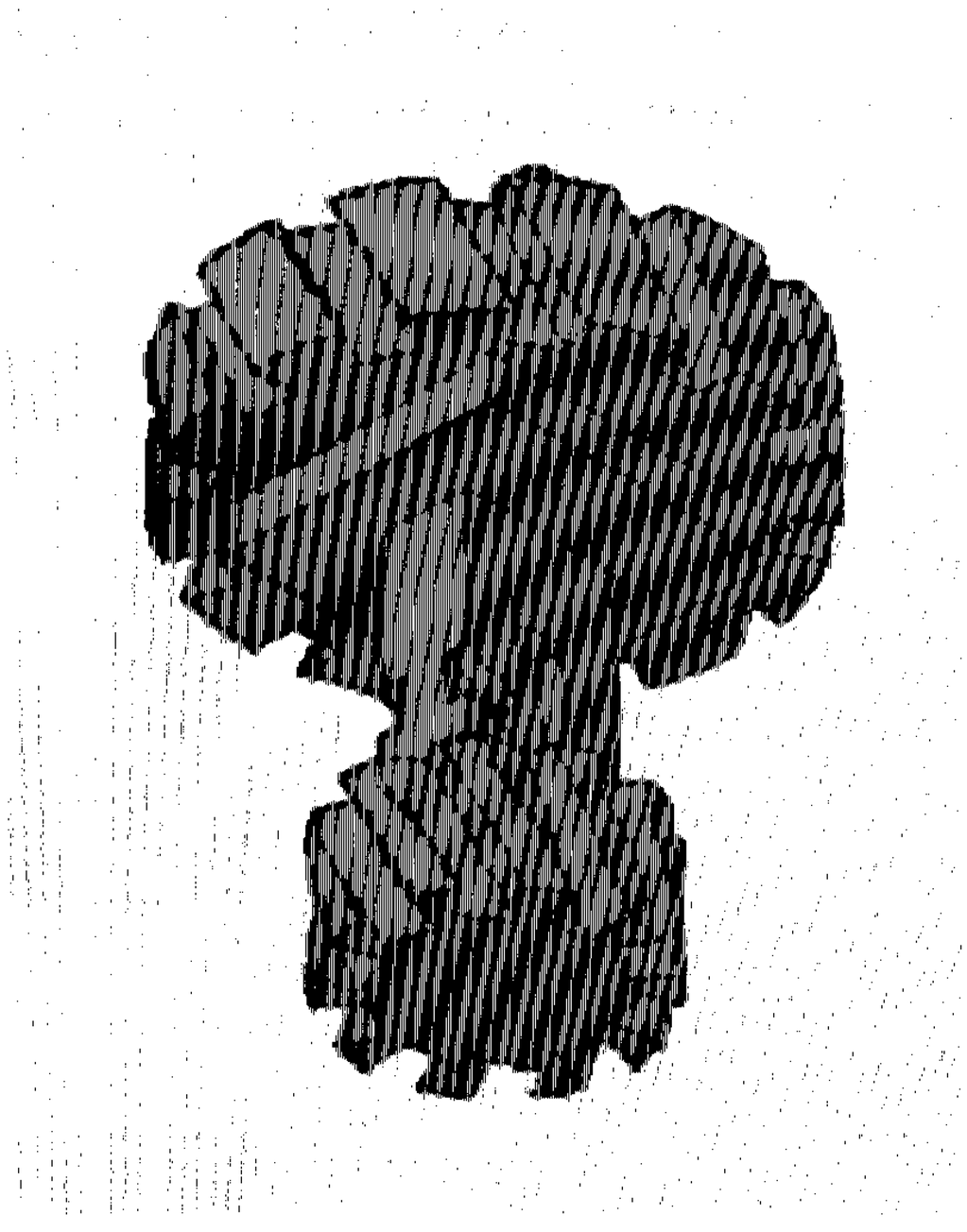


Figure 4.1.1.2: AutoCAD drawing for mute instrument

The new saxophone mute instrument is different with current muffler in term of size, dimension, material used and system applied. This new mute has dimensioned which shown in table below:

Table 4.1.1.1: Dimension of new mute instrument

Specification	Data
Diameter, d_1	8.0 cm
Diameter, d_2	6.2 cm
Height, h_1	6.0 cm
Height, h_2	12.5 cm
Material	Melamine Foam

Function of Parts

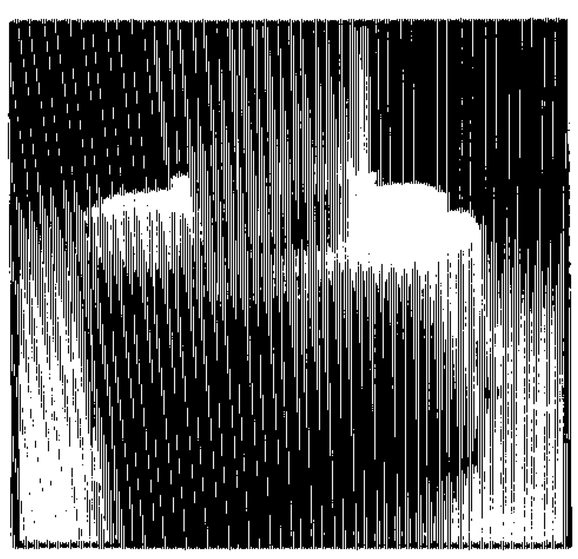
For the concern in reflecting and attenuating the sound, every single part has its own function. The main objective is to absorb the sound wave through melamine foam, reflect the sound wave through edges and attenuate the sound with tortuosity factor.

Absorption

All surface of the melamine foam is used to absorb the sound wave and the same time attenuating the sound that enters and pass through mute instrument

Reflection

Edges are made to reflect the sound wave when it enters the mute. The more edges, more sound will be reflected.



Tortuosity Factor

This non-linear shape is used toprevent direct flow through the mute instrument. It will increase time a wave is in contact with the mute thus increase energy dissipation and more absorbing capability.

Figure 4.1.1.3: Part Function

4.1.2 Prototyping Process

Aside from designing process, prototyping process takes part in producing and constructs the prototype of a saxophone mute instrument. In order to make sure the prototype of mute instrument is shaped accordingly to selected design, the author used a simple foam fabrication method and cutting tools to cut and fabricate a new saxophone mute instrument prototype. At this stage, foam cutting takes its role.

Foam Cutting

With the intention of fabricate the new mute instrument, the author was used several tools. The most important tool is the cutting tool. The best way to cut the foam is by using the electrical wire cutter since it has a capability to cut in precise and accurate. In other way is by using cutting blade. However, it has to be entirely sharp to ensure the melamine foam is not damagedduring cutting process. For this purpose, the author was used the blade and electrical wire cutter as the cutting tool.

The tools required for fabrication as shown below:

Table 4.1.2.1: Tools to fabricate

Tool	Specification	Quantity
Blade/ wire cutter	Sharp and clean cutting tool	1
Paper or cardboard	-	1
Glue	-	1
Melamine foam	1in x 5in	5

During the cutting process, the speed of cutter has to be precise. The speed of the process has to be carefully considered. It has to be ensure not to drag the wire and damage the foam if too fast, or create an unnecessarily wide cut if pulled through too slow.

After cut the melamine foam into a shape, it has to been assemble as an end product. All the parts including the cylindrical shape foam (with tortuosity factor) and rectangular shape foam have to be attached to each other. For this purpose, the author has used a hard glue to join them. The procedure in fabricating the mute instrument is stated as below:

Procedure and Steps

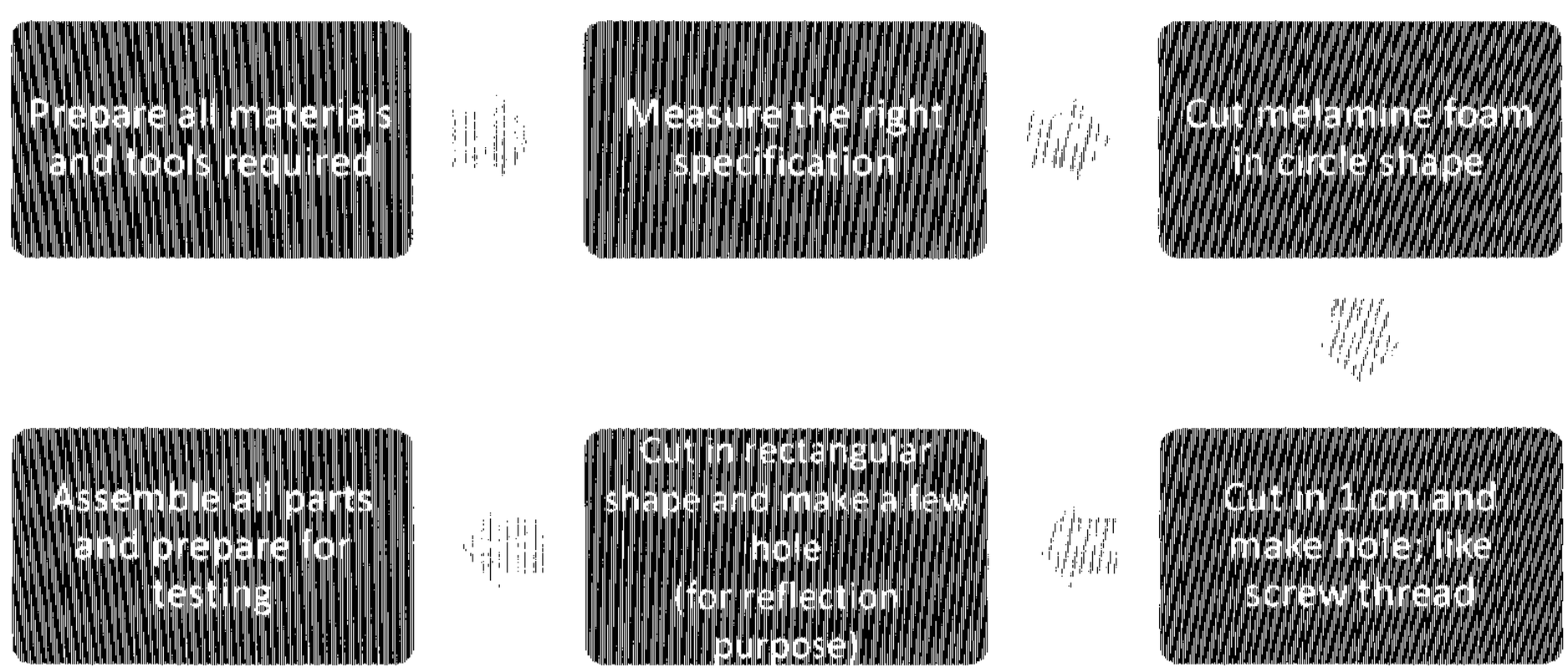
1. Determine the dimension and size of bell of an alto saxophone. The size of mute has to fit the bell's size.
2. Prepare all materials and tools required :

   Tools: Wire Cutter, blade, glue, board, ruler, pencil, and geometry set

   Materials: 1 in. x 5 in. melamine foam
3. Then, measure the exact specification and do sketch on the melamine foam.
4. Make a circle shape with diameter 8.0 cm and 6.2 cm by using geometry set.
5. After that, cut the melamine foam in circle shape by using foam cutter.
6. By using ruler, measure 3 cm and for each 3 cm cut in 1 cm and make a hole slightly like screw thread.
7. Take new melamine foam. Cut in and get rectangular shape with 2.3 cm. x 6 cm.
8. Assemble all parts. Attach and glue foam with cylindrical shape at each end of the rectangular.
9. Cut small foam in rectangular shape with 1.5 cm x 5.5 cm and glue at the top of the mute as its holder.

Flow of Prototyping Process

The flow of the process can be simplified as shown below:



The end product:

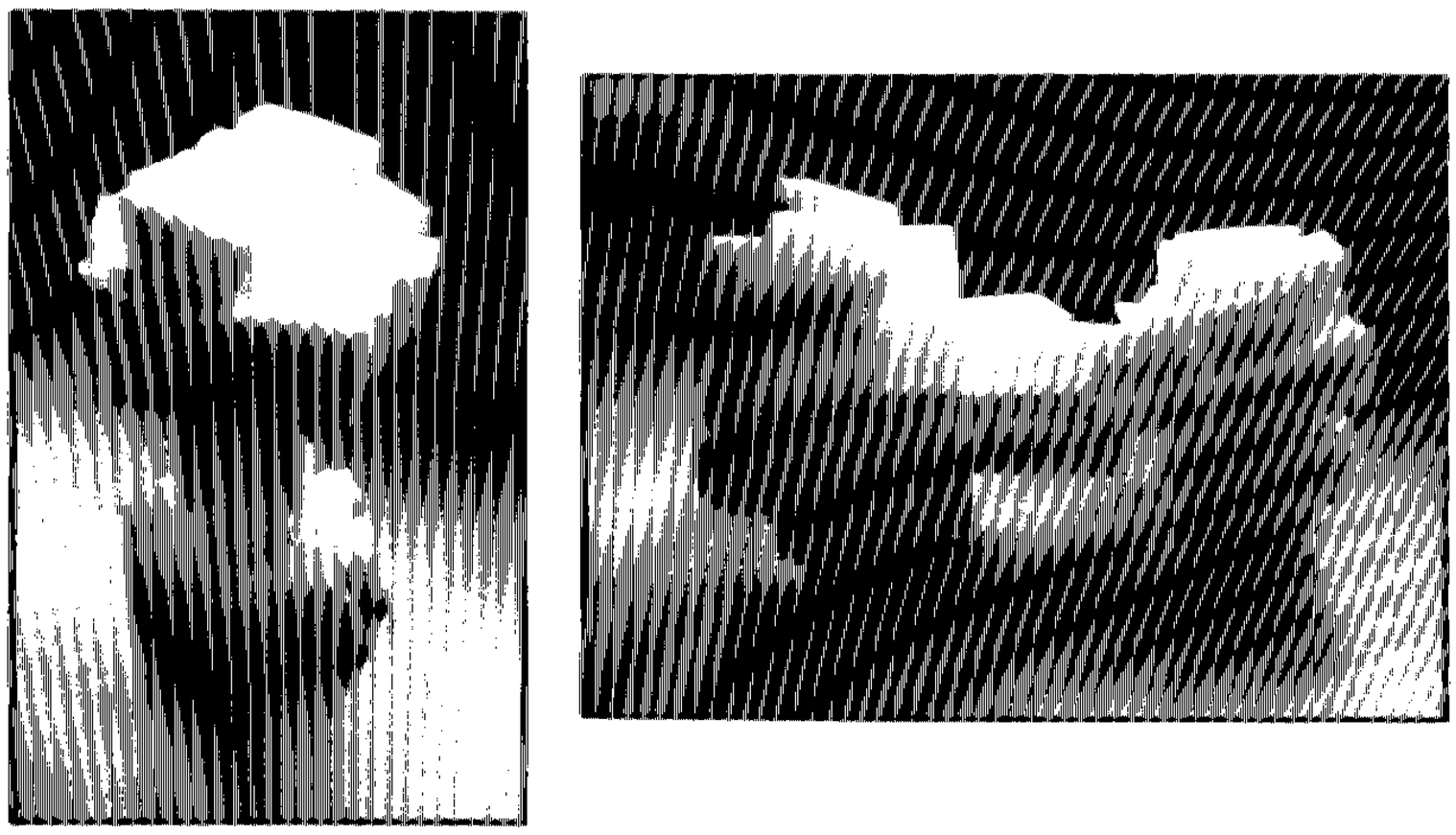


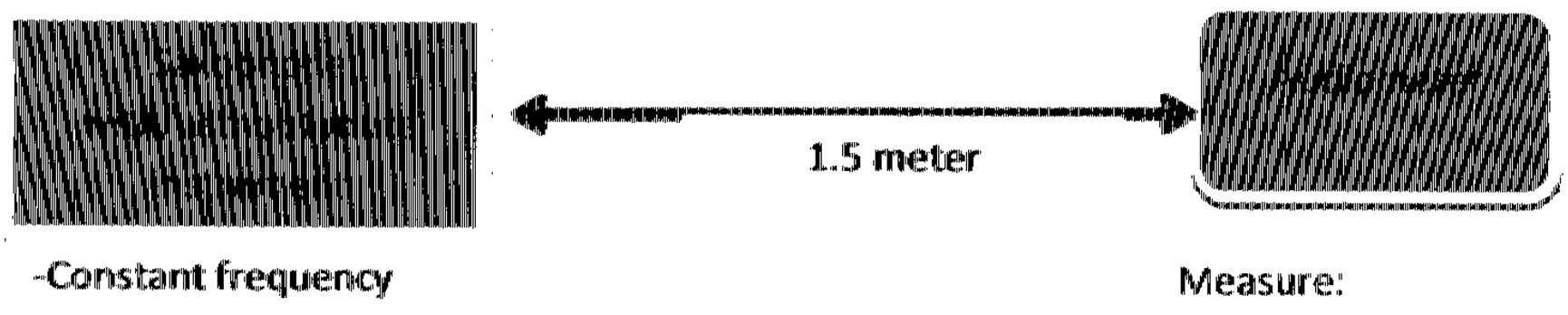
Figure 4.1.2.1: New saxophone mute instrument

4.1.3 Testing Process

The last process in this project after completed with fabrication of the mute instrument is to conduct testing and measurement. Basically, the objectives of the test conducted are to get data and value of:

- The noise reduction before and after attach with new mute instrument
- The amplitude and frequency of the sound

Planning



Tools and Equipment

There are several tools and equipment that being used in order to conduct testing and measurement.

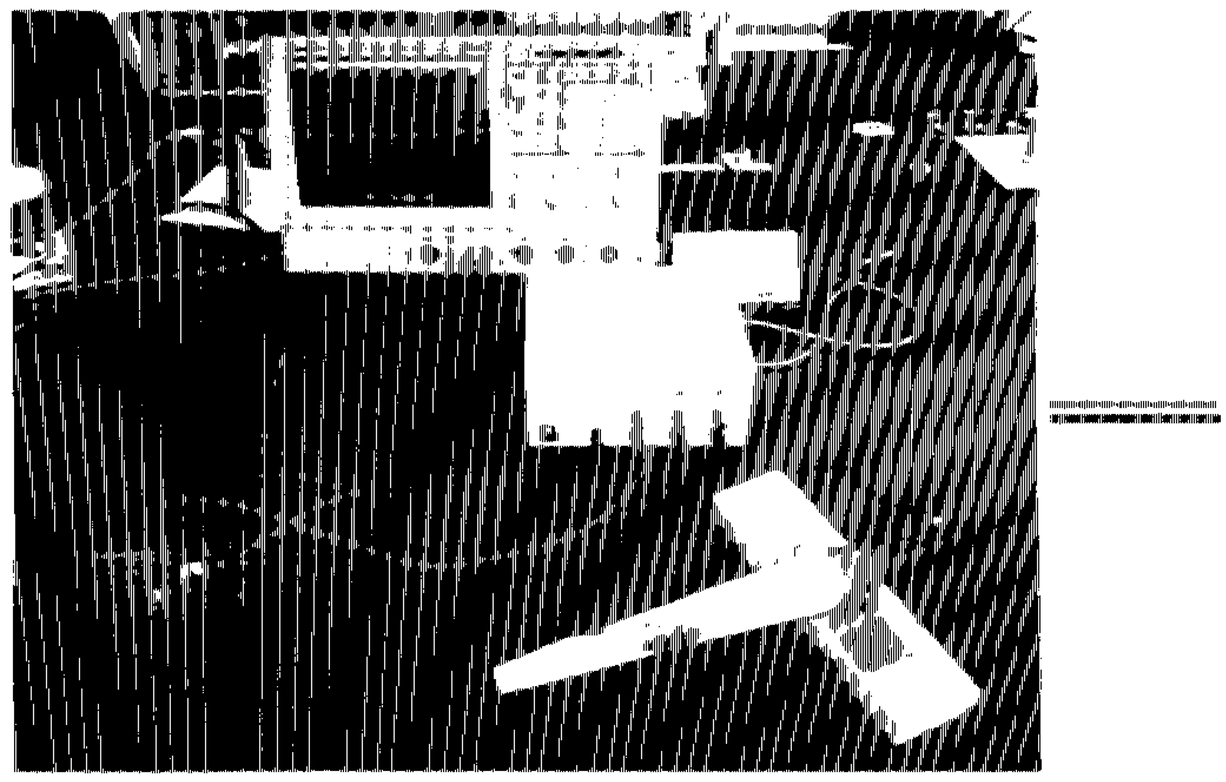
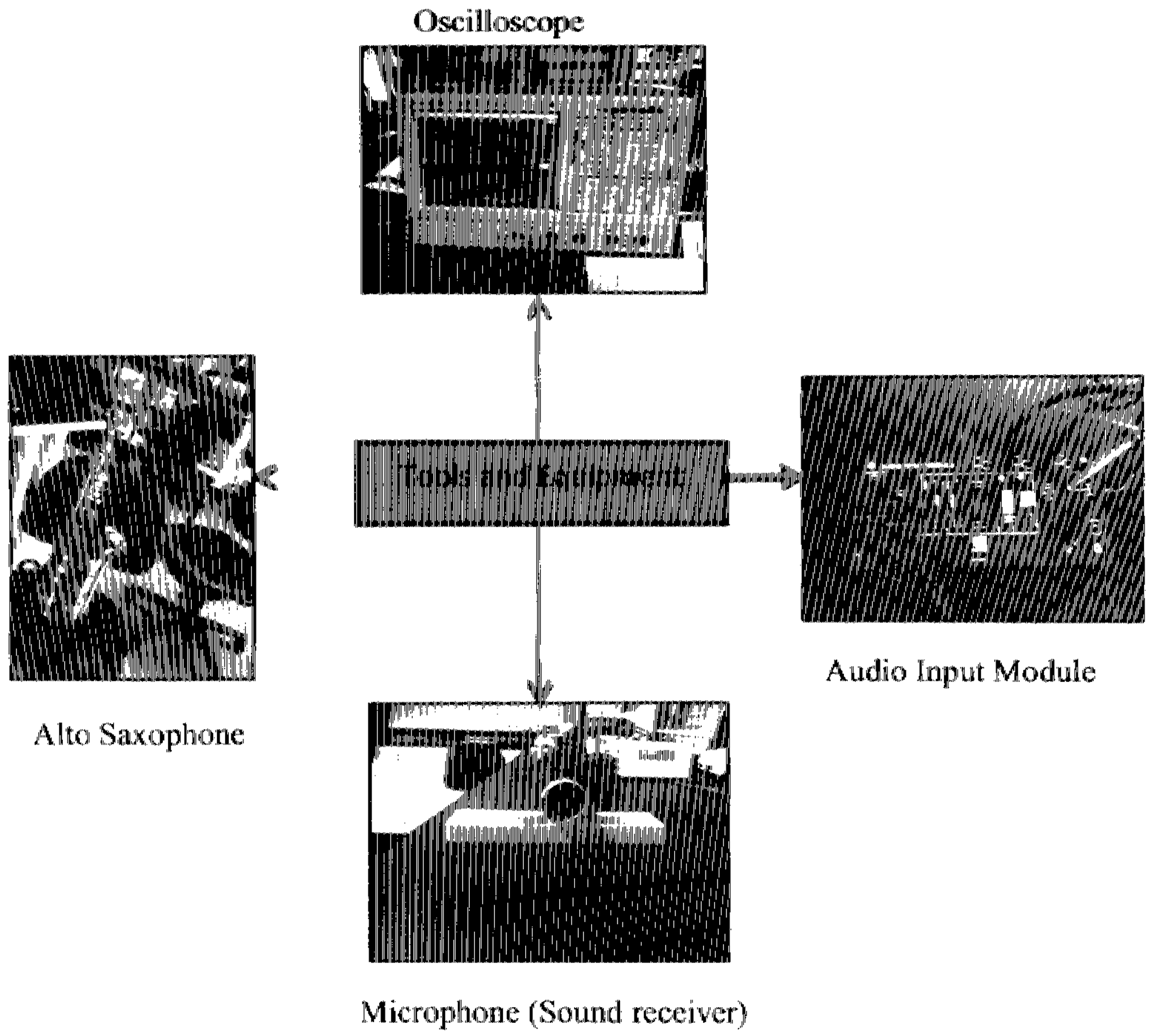


Figure 4.1.3.1: Testing Equipment System



Testing Result

Before the mute instrument attach to the alto saxophone

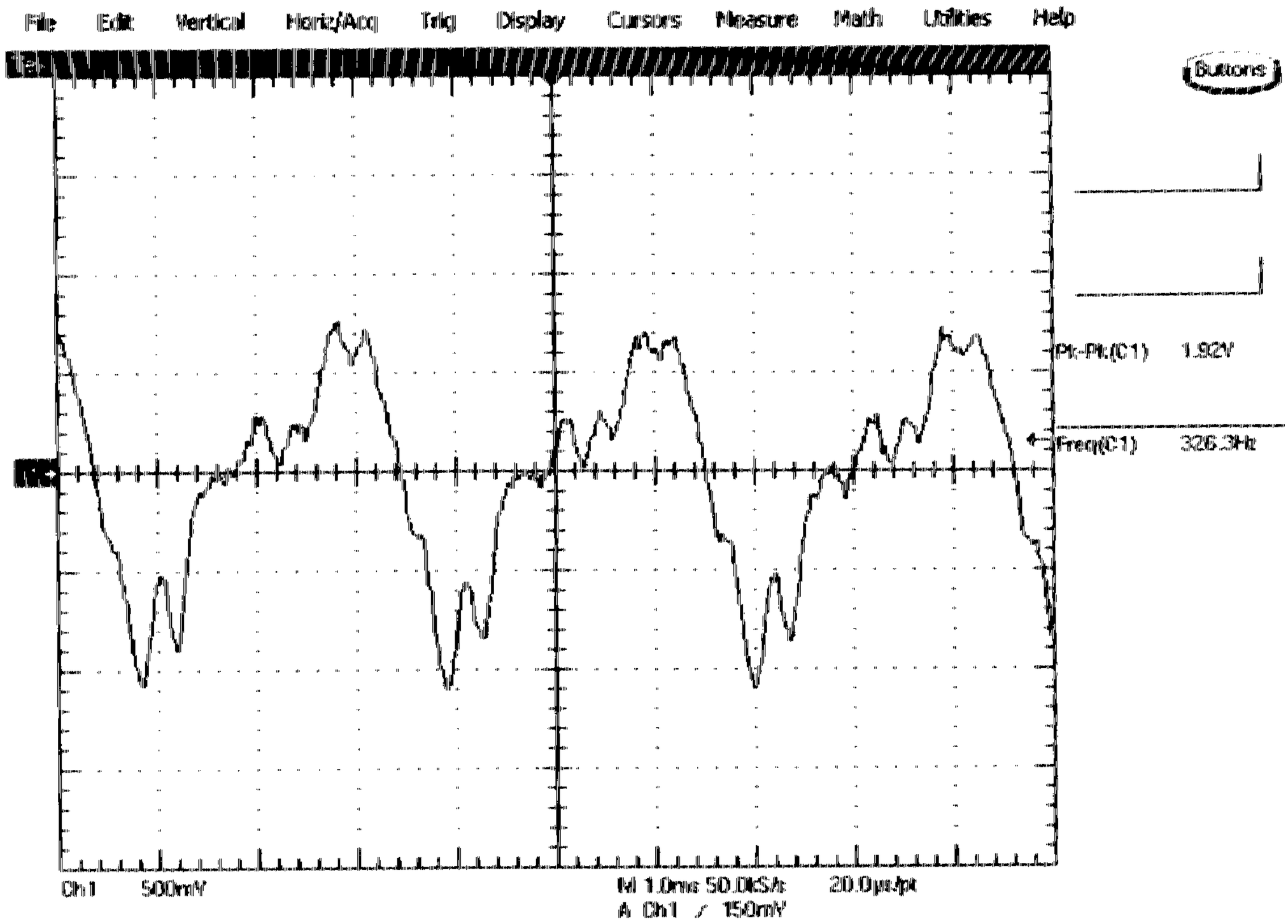


Figure 4.1.3.2: Result before attachment of mute

After the mute instrument attach to the alto saxophone

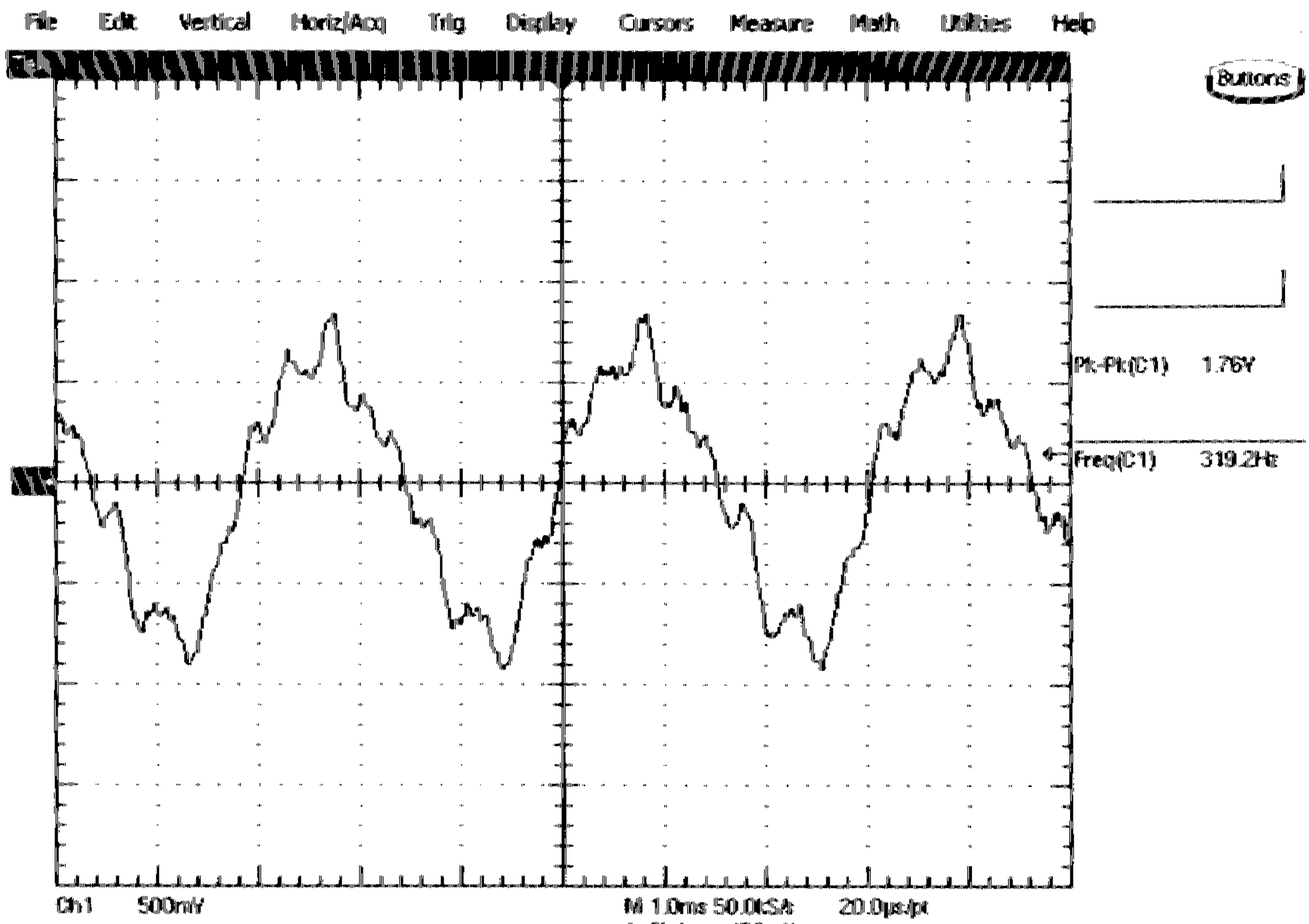


Figure 4.1.3.3: Result after attachment of mute

The testing is conducted to test the amplitude or maximum peak value of the saxophone before and after the mute instrument attach. This experiment is test for five (5) times and the result is stated as below:

Table 4.1.3.1: Data Collection and Measurement

	Free Flow Air	Player Result 01	Player Result 02	Player Result 03	Player Result 04	Player Result 05
Frequency (Hz) Before	326.3	342.5	350.8	347.9	328.9	353.5
Frequency (Hz) After	319.2	326.8	342.6	340.5	322.1	347.5
Amplitude/ Max. Peak (Volt) Before	1.92	2.26	2.37	2.33	2.01	2.42
Amplitude/ Max. Peak (Volt) After	1.76	1.98	2.13	2.08	1.81	2.19
Reduction	0.16	0.28	0.24	0.28	0.20	0.23
Reduction (%)	8.33	12.39	10.13	12.02	9.95	9.50

Percentage of reduction:

Flow Air: = (1.92-1.76) /1.92*100

= **8.33 %**

Result 01: = (2.26-1.98) /2.26*100

= **12.39 %**

Result 02: = (2.37-2.13) /2.37*100

= **10.13 %**

Result 03: = (2.33-2.08) /2.33*100

= **12.02 %**

Result 04: = (2.01-1.81) /2.01*100

= **9.95 %**

Result 05: = (2.42-2.19) /2.42*100

= **9.50 %**

Average percentage of reduction (%):

$$=\frac{8.33 + 12.39 + 10.13 + 12.02 + 9.95 + 9.50}{6}$$

=**10.39%**

4.2 Discussion

From the experiment, when the saxophone is not attached with mute instrument, the amplitude of the sound is in range between 1.92 V-2.42 V. However, after the saxophone is being attached with mute instrument, the amplitude of the sound is in range between 1.76 V – 2.19 V. Experimentally, the reduction of the sound after attach with the mute instrument is 10.39 %. When the author placed the mute close to the mouthpiece, the frequency of sound increase to double.

This result is not reach the objective since the author target to reduce 50 % of sound level. From author point of view there are several errors that can be improvised.The main factor that contributes and may affect the reduction level is design of the mute. The design used has to be modified and been placed at different part of the saxophone. Moreover, the absorption of the material is slightly low and not much sound being reflected. This is because when mute instrument is placed at the bell, the sound still has a capability to pass through along the key of saxophone.

In addition, the error also may occur due to the player. Since the amplitude of the sound is depends on the air that enter the mouthpiece, the player have to play the saxophone in constant frequency in order to get more precise and accurate data.

4.3 Recommendation

Since the reduction of the sound after attached with mute instrument is slightly 10% of actual sound, some modification have to be made to increase the reduction level. From author point of view, the reduction of the sound can be increased by:

a) Change design and position to place mute instrument
b) Change material used

Modification in design has to align with where the mute instrument will be placed. Since to get high reduction percentage, the author strongly suggest to place the mute instrument closed to the mouthpiece. However, the design and material used has to change. The main focus is to reduce the amount of air that enters the mouthpiece.

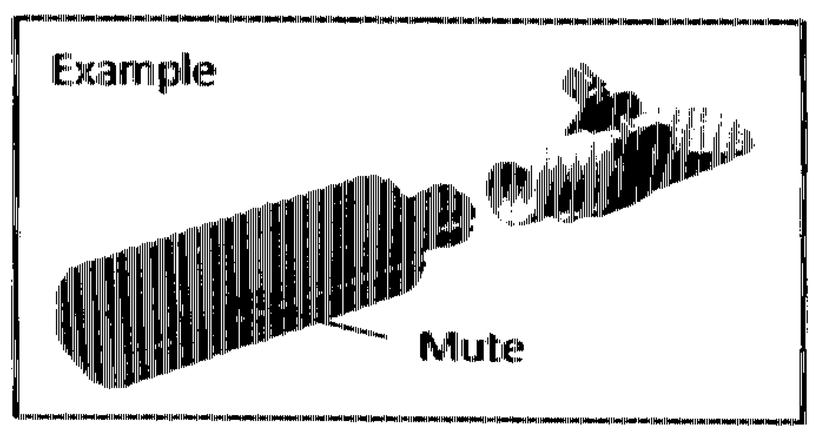


Figure 4.3.1: Recommended design

The material selection should focus more on how to increase absorption level and at the same it is easy to be shaped.

CHAPTER 5: CONCLUSION

While this report has been described, it is to *be understood that various alterations* andmodifications can be made to design, mechanism, tool/apparatus and material selection within the scope of thisresearch. Additional studies are necessary along the research duration in order to achieve 50% reduction of intensity level. Since the actual reduction is 10%, some modifications need to be done. Itshould be emphasized that the ultimate aim of this research project is to design and understand the main concept of the saxophone mute instrument. Therefore, it is hoped that thisproject could be a pioneer documented resource especially in this wide area before it will be commercialised.

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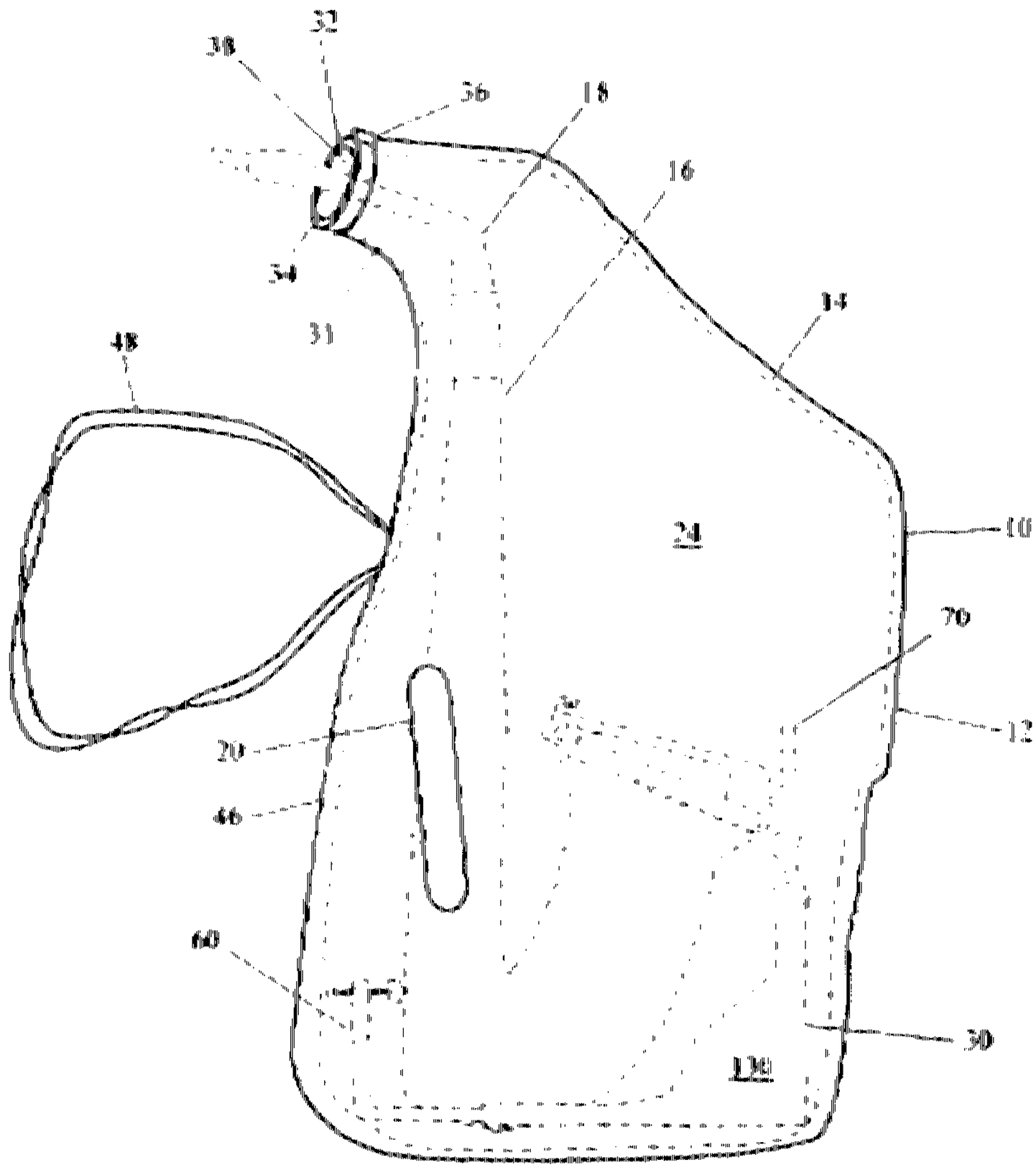
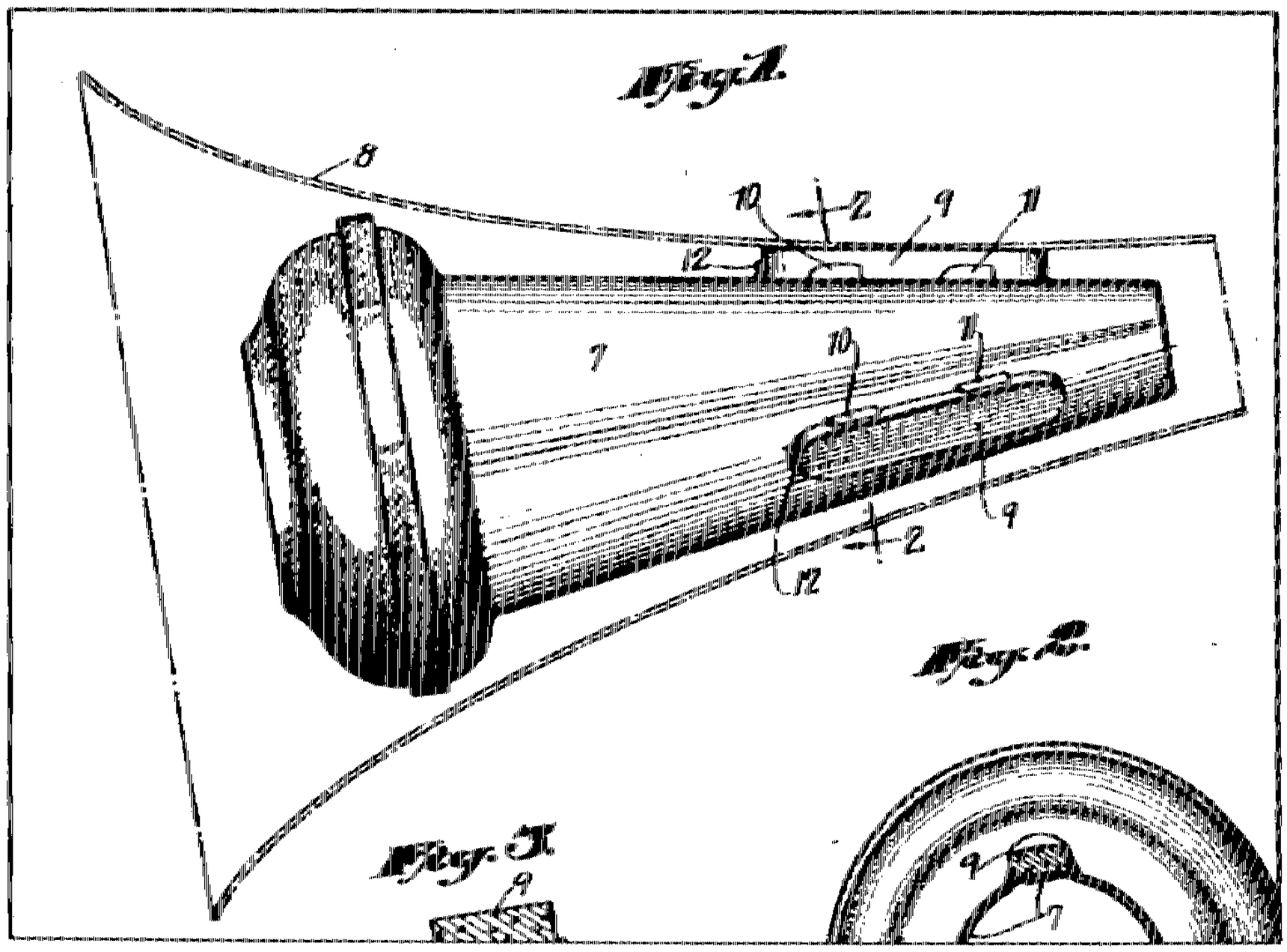
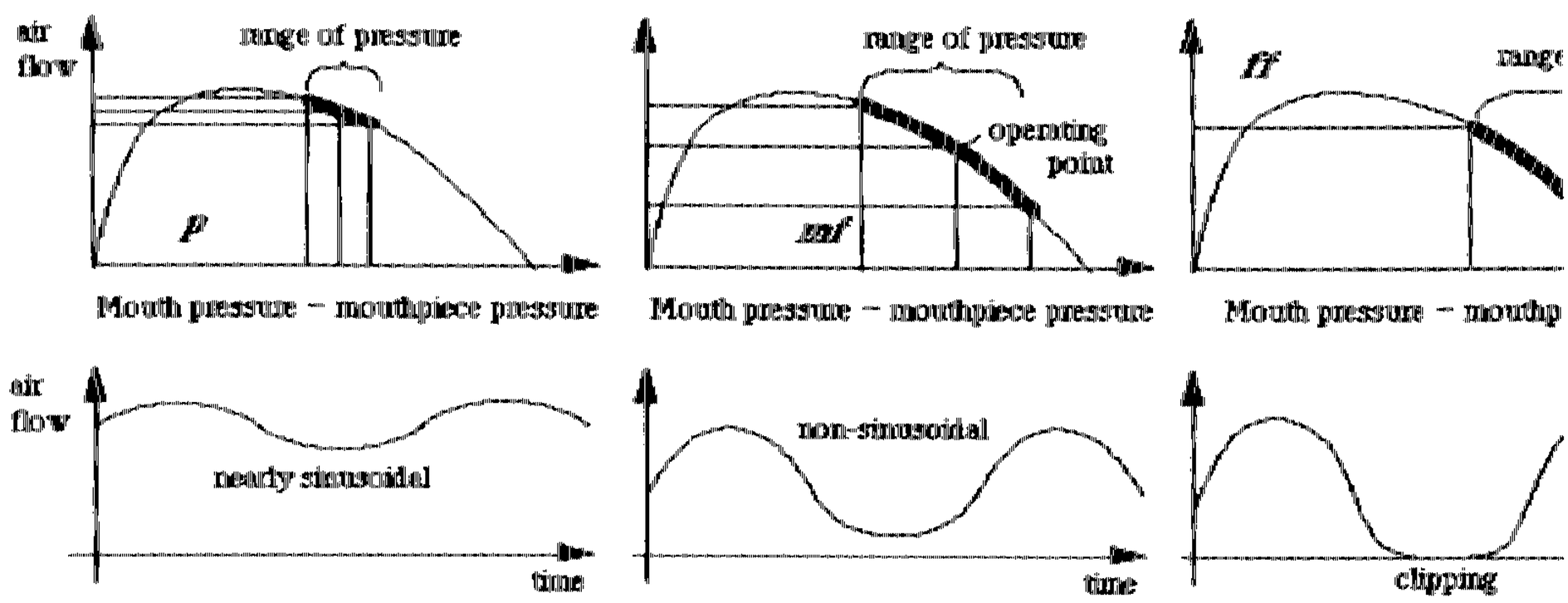
Appendix 1: Design of Muffler



Appendix 2: Design of Trumpet Mute



Appendix 3: How timbre changes

Playing softly and loudly

This diagram allows us to explain something about how the timbre changes when we go from playing softly to loudly. For small variation in pressure and small acoustic flow, the relation between the two is approximately linear, as shown in the diagram below at left. A nearly linear relation gives rise to nearly sinusoidal vibration (i.e. one shaped like a sine wave), which means that the fundamental in the sound spectrum is strong, but that the higher harmonics are weak. This gives rise to a mellow timbre.