A STUDY OF THE MARKET
for
HIGH-FIDELITY PHONOGRAM PICK-UPS

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Massachusetts Institute of Technology      May 18, 1939
M. I. T. Dormitory, 
Cambridge, Massachusetts, 
May 18, 1939.

Professor George W. Swett, 
Secretary of the Faculty, 
Massachusetts Institute of Technology, 
Cambridge, Massachusetts.

Dear Sir:

In accordance with requirements for 
graduation, I herewith submit a thesis entitled 
A Study of the Market for High-Fidelity Phonograph Pick-ups.

I want to express here my appreciation 
to Professor Ross M. Cunningham for his assistance as advisor, to Mr. Lewis P. Reitz, Jr. for his technical aid in preparing the test record and to those individuals who cooperated in giving interviews.

Yours truly,

G. Arthur Morrell, Jr.
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SUMMARY

Problem

The problem is to determine what features the LT-1 pickup possesses that distinguish it from others in the field, whether these features make it more suitable than others for certain applications and, if they do, how they can best be presented to the radio broadcasting stations and recording studios.

Findings

The LT-1 has certain features that make it suitable as it is for certain applications. If a low frequency equalizer and a selective low pass filter be added as accessories, this pickup will be more suitable for the radio broadcasting stations and recording studios.

Recommendations

It is recommended that (1) a low frequency equalizer and a selective low pass filter be designed for sale as accessories for the pickup, (2) the design be modified to protect the armature from damage, (3) certain appeals should be emphasized in selling to the two markets analyzed and (4) direct mail advertising should be used to supplement direct sales efforts.
INTRODUCTION

Statement of the Problem

In its essence, the problem is how to market a new, high fidelity, lateral phonograph pickup, hereafter called the LT-1*. It is felt that this pickup has certain features that make it particularly suited to certain applications, which it is the purpose of this report to discover. More specifically, then, the problem is to determine what features the pickup possesses that distinguish it from others in the market, whether these features make it more suitable than others for certain applications and, if they do, how they can best be presented to the two markets that have been investigated; i.e., radio broadcasting stations and recording services.

The problem comes down to finding out what the potential users desire in a pickup; knowing what the users want makes it possible to formulate a method of approach which will present to them in the most effective manner those features of the pickup which satisfy their special requirements.

*The LT-1 is the fictitious name of a new pickup recently put on the market by a manufacturer of sound recording apparatus.
Scope

The survey made as part of this solution was limited geographically to radio stations and recording services serving metropolitan Boston. Naturally, the survey covers only lateral type pickups having high fidelity characteristics now on the market and the analysis is limited to the two markets, radio stations and recording services. It should be recognized, however, that there is another market in the consumer class and perhaps in the custom builders field. It is quite possible that persons having a leaning toward the technical aspects of phonograph recording and reproduction would be a fertile market. It is possible also that the marketing procedure indicated here might be appropriate in other cities where similar conditions with regard to the markets prevail.

Method

Unfortunately, the most obvious way of finding out what the user wants, that of asking him outright, does not always yield dependable answers. Often, he is not sure what he wants; other times he consciously or unconsciously makes his answer what he thinks should be the answer correct from the viewpoint of the person asking the question. Furthermore, a user hesitates to admit the failings of a piece of equipment in which he may have
invested upwards of $100.

In view of these difficulties, we decided that a surer way of learning what the user wants is to determine what equipment he has and to try to discover what features he likes or dislikes. The best way of doing this is also the simplest, that of visiting the user and talking with him informally in an effort to sound out his opinions.

(a) Bibliography

In preparation for this phase of the research, we considered it advisable to conduct a preliminary bibliographical investigation in order to become familiar with the present state of the art of reproduction of sound from phonograph records. A detailed summary of this information may be found in Appendix A, but the outstanding impressions gained by the writer were that average phonograph reproduction is at present far from perfect and that there is much yet to be learned about the behavior of the pickup stylus in the record groove.

(b) Questionnaire

The next step was the preparation of a list of questions to be asked. At first, some questions of opinion were included but it was found that satisfactory direct answers could not be obtained.
QUESTIONNAIRE

1. To what extent do you use transcriptions and recordings?
2. Do you do any recording?
3. If so, for what purposes?
   On what materials?
   With what equipment?
4. What types of pickups do you use now?
5. How long have you had them?
6. What characteristics have they?
   Frequency response
   Output level
   Needle pressure
   Interchangeable or permanent stylus
   (if interchangeable, what types used?)
7. How much did they cost?
8. Did you install this equipment "as is", or do you experiment to get the results you desire?
9. If you experiment, what results do you aim for?
10. What is your policy regarding obsolescence of this equipment?

This is a sample of the questionnaire used in the interviews.
Questions that might arouse prejudice or bias or might require too much generalization in answering were avoided wherever possible. It must be admitted, however, that the question pertaining to experimentation violates to some extent these principles. Furthermore, a direct answer to the question pertaining to obsolescence was not obtained in any of the interviews, perhaps because it requires too much generalization or because there is no policy.

(c) Test Record

In addition to the questionnaire, we felt that it was desirable to know the needle pressure and needle point impedance of various types of pickups inasmuch as they are important factors in record wear. From the standpoint of simplicity and the psychological effect on the person being interviewed, it appeared that the most satisfactory test could be made with a special record.

Considerable experimentation showed that a pickup exerting high needle pressure would cause an appreciable increase in the surface noise of an unmodulated groove in an acetate coated record after about 100 playings. Similarly, a pickup having high needle point impedance would cause an appreciable decrease in the level of a high frequency signal recorded in acetate. This phenomenon,
mentioned by Hunt and Pierce, appears to be caused by the fact that the force required to accelerate the needle point at the high rate required for high frequency reproduction exceeds the elastic limit of the acetate and the modulations of the groove tend to be smoothed down by the needle point. It is quite probable that this leveling is not equal on all parts of a sine wave and therefore distortion is introduced also in the process. It is interesting to note that much of the attenuation occurs in the first few playings, being in some cases as great as 4 decibels in 10 playings.

Since the purpose of this report involves, among other things, comparison of the wearing effects of various pickups, we concluded that a record bearing sets of both modulated and unmodulated grooves would be satisfactory for making comparison tests of different pickups. The record was made on a standard recording outfit by setting the cutting head on the record and allowing it to cut 4 or 5 turns; it was then lifted for several turns of the record and lowered again. In this way, a series of 8 or 10 cuts were made at the

inside with no modulation and at the outside with 6000 cycles per second fed to the cutting head. The high frequency was cut near the outside, where the linear velocity of the record is greatest, to minimize the crowding of the modulations and to minimize the effect of change in radius on the recording of high frequencies. It was cut at high amplitude to minimize the effect of surface noise on measurements.

The method of using the test record follows: during the interview, the record was placed on a 33-1/3 rpm turntable and the pickup to be tested started in the proper test groove. When it reached the end of the last turn of that cut, it would cut back into the preceding turn and would continue in this manner to ride in the last groove. The pickup was allowed to ride in the last unmodulated groove 100 times, since this number seemed to give the best results from the standpoint of measurements. The procedure was identical for the modulated grooves, with the exception that the last groove was played only 33 times, since this number gave a measurable decrease in signal but no appreciable increase in surface noise. When possible, the pickup was used with the type of needle ordinarily used by the establishment for playing acetate recordings.
Otherwise, a shadowgraphed steel needle for acetate was used. At the end of each run, the record was cleaned with a liquid consisting of a light, protective oil dissolved in carbon tetrachloride.

Measurement of the results was accomplished by playing the record at 33-1/3 rpm with a magnetic pickup feeding into an amplifier through a high-pass filter to eliminate motor noise. A decibel meter was connected to the amplifier output and readings of an untouched groove compared with those of the used grooves. Since the purpose of the test was to get relative indications, this method was satisfactory. It must be admitted, however, that there is at least one possible weakness in the test, namely, that the needle may wear abnormally in cutting back at the last turn and might therefore cause abnormal wear on the groove. Lack of time prevented investigation of this matter but it may be discounted as having a negligible effect in view of the fact that steel or jewel styli were used and that the acetate is relatively soft.

(d) Interviewing

The questionnaire was not shown during the interview in order to avoid any possibility of making the person being interviewed reluctant to
divulge some of the more private aspects of his policy. In at least one instance, it seemed to the interviewer that the person being inter-viewed was uneasy and it was decided that hence-forth no notes would be taken during interviews. It was found that writing the notes immediately following the interview was successful. On the whole the persons interviewed were quite cordial and cooperative.

It was impossible because of lack of time and because of conditions at the stations always to see an engineer or an executive, therefore it was not always possible to get accurate answers to questions of policy or of a technical nature but it was usually possible to piece together bits of information picked up during the conversation that gave clues to the general policy of the management.

Definitions

In order to avoid confusion, some terms that will appear frequently in the report have been defined here.

Pickup - This refers to any reproducer used for electrical reproduction of records having laterally modulated grooves.

Needle pressure - The actual weight in grams or ounces exerted by the stylus or needle of the pickup.
Needle point impedance - The combined effect of damping resistance and inertia due to mass of the parts of the pickup that move at the frequency of the signal of modulations of the record groove. This factor varies with frequency and becomes a serious limitation on the response at higher frequencies. The combination of needle point impedance and needle pressure is an important factor in determining the life of a record.

Record - Record is the generic term but in this report it applies to commercial lateral type pressings containing abrasive material; these are the type usually sold to consumers.

Transcription - This term applies to material consisting of vertical or lateral-cut pressings made especially for broadcasting.

High Fidelity - High fidelity, as used in this report, means (a) approximately equal efficiency at all frequencies from 30 to 10,000 cycles per second (b) freedom from harmonic distortion or phase shift (or not more than about 3% harmonic distortion).
FINDINGS

The findings of the interviews have been summarized in Tables I and III for radio stations and recording services, respectively. The results of the test for record wear are shown in Tables II and IV. In this connection, it should be noted that the apparently small decreases in the level of the 6000 cycle signal are probably due to both the high amplitude and the magnitude of the frequency. In actual practice, the amplitude would be smaller and probably easier to erase. The erasing of higher frequencies would be more pronounced. The reason 6000 cycles was chosen is that it approaches the upper limit of the frequencies an ordinary pickup will reproduce. Making it higher would give more pronounced changes but would be unjust to those pickups not made to reproduce that frequency.

Another discrepancy was observed; the increase in surface noise was not more than 3 decibels after 100 playings with most pickups and, although 3 decibels is said to be the minimum change in level noticeable to the average ear, there was a pronounced difference in the nature of the sound issuing from the speaker when the pickup is played in an untouched groove and a worn groove. In other words, although the
<table>
<thead>
<tr>
<th>Station</th>
<th>Equipment</th>
<th>Program Material</th>
<th>Musical Library</th>
<th>Acetate Recording</th>
<th>Policy</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAAB</td>
<td>WE 4A</td>
<td>popular records</td>
<td>popular records</td>
<td>Yes - for</td>
<td>Do not think present records are good enough to warrant an expensive pickup - station's pickups are serviced by an outside concern.</td>
</tr>
<tr>
<td></td>
<td>WE vert.</td>
<td>and transcriptions, studio, network</td>
<td>and vertical transcriptions</td>
<td>auditions &amp; rebroadcast.</td>
<td></td>
</tr>
<tr>
<td>WBZ</td>
<td>RCA 71-A</td>
<td>records, vertical &amp; lateral transcriptions, network, studio</td>
<td>vertical and lateral records and transcriptions</td>
<td>Yes - for reference, auditions.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RCA vert.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WCOP</td>
<td>RCA 71-A</td>
<td>popular and 2</td>
<td>popular records, vertical transcriptions</td>
<td>Yes - for auditions.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RCA vert.</td>
<td>classical records and transcriptions, studio</td>
<td>vertical transcriptions</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RCA old</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WEEI</td>
<td>WE 4A</td>
<td>popular records, transcriptions, network, studio</td>
<td>popular records, vertical transcriptions</td>
<td>Yes - for reference, audition.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>WE vert.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WHDN</td>
<td>RCA #4358</td>
<td>popular and 2</td>
<td>popular and classical records, lateral records, studio</td>
<td>No.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RCA vert.</td>
<td>classical records, studio lateral transcriptions</td>
<td>classical records, lateral transcriptions</td>
<td>Really progressive - try to get the most out of the material at hand.</td>
<td></td>
</tr>
<tr>
<td>WMEX</td>
<td>RCA #4358</td>
<td>popular and 2</td>
<td>popular and classical records, lateral transcriptions</td>
<td>No.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>classical records, lateral transcriptions, studio</td>
<td>classical records, lateral transcriptions</td>
<td>Try to keep up with latest developments.</td>
<td></td>
</tr>
<tr>
<td>WNAC</td>
<td>WE 4A</td>
<td>vertical transcriptions, network, studio</td>
<td>vertical transcriptions</td>
<td>Yes - for rebroadcast &amp; audition.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>WE vert.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WORL</td>
<td>RCA #4358</td>
<td>popular records, lateral transcriptions, studio</td>
<td>popular records and lateral transcriptions</td>
<td>Yes - for auditions.</td>
<td></td>
</tr>
</tbody>
</table>

1. Records for rebroadcast used only once; wear is unimportant.
2. These stations have arrangements with outside organizations which loan them records in exchange for advertising.
3. Used only for commercial recordings.
### TABLE II

Results of test for record wear. Radio Stations.

<table>
<thead>
<tr>
<th>Pickup</th>
<th>Used at</th>
<th>Increased noise for 100 times</th>
<th>Decreased 6000 cps for 33 times</th>
<th>Needle used</th>
</tr>
</thead>
<tbody>
<tr>
<td>WE 4A</td>
<td>WAAB, WEEI, WNAC, WOOP</td>
<td>21 db$^1$</td>
<td>4 db$^1$</td>
<td>Steel, for acetate</td>
</tr>
<tr>
<td>RCA 71-A</td>
<td>WOOP, WBZ</td>
<td>3 db</td>
<td>3 db</td>
<td>Steel, for acetate</td>
</tr>
<tr>
<td>RCA #4358</td>
<td>WHDH, WMEX, WORL</td>
<td>3 db</td>
<td>1 db</td>
<td>Diamond - permanent</td>
</tr>
</tbody>
</table>

### TABLE IV

Results of test for record wear. Recording Studios.

<table>
<thead>
<tr>
<th>Pickup</th>
<th>Used at</th>
<th>Increased noise for 100 times</th>
<th>Decreased 6000 cps for 33 times</th>
<th>Needle used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audax 25-A</td>
<td>General Television</td>
<td>10 db$^2$</td>
<td>2 db</td>
<td>Steel, not for acetate</td>
</tr>
<tr>
<td>Audax 1-C-5A</td>
<td>Fidelity Recordings</td>
<td>1 db</td>
<td>2 db</td>
<td>Steel, for acetate</td>
</tr>
<tr>
<td>Audax A-6-U</td>
<td>Fidelity Recordings</td>
<td>0 db</td>
<td>3 db</td>
<td>Steel, for acetate</td>
</tr>
<tr>
<td>Audax ?</td>
<td>Kaspar-Gordon</td>
<td>10 db</td>
<td>2 db</td>
<td>Steel, for acetate</td>
</tr>
<tr>
<td>Lansing 100-LR</td>
<td>-</td>
<td>1 db</td>
<td>0 db</td>
<td>Sapphire - permanent</td>
</tr>
<tr>
<td>LT-1</td>
<td>-</td>
<td>0 db</td>
<td>1 db</td>
<td>RCA steel, for acetate Rec-O-Ton steel, for acetate</td>
</tr>
</tbody>
</table>

1. Played only 10 times because the pickup began to cut into the base of the record.

2. Abnormal wear probably caused by wrong type needle.
<table>
<thead>
<tr>
<th>Establishment</th>
<th>Recording equipment</th>
<th>Playback pickup</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fidelity Recordings</td>
<td>Presto portables with Neumann cutting heads</td>
<td>Audax A-6-U Audax 1-C-5A</td>
<td>Largely personal service - operators are musically trained; have experimented considerably in trying to get satisfactory quality - unsatisfied with playback pickups.</td>
</tr>
<tr>
<td>Kaspar-Gordon Studios</td>
<td>Presto portables with Presto cutting heads</td>
<td>Audax no model no. about 7 yrs old</td>
<td>Principally commercial service - do not experiment to improve quality because too busy - said they had trouble with chattering of pickups.</td>
</tr>
<tr>
<td>General Television Corp.</td>
<td>Presto portable with Presto cutting heads</td>
<td>Audax 25-A</td>
<td>Recording seems to be only a sideline to television - said they had trouble with old pickup chattering.</td>
</tr>
</tbody>
</table>
increase in actual power of sound caused by wearing of the groove as measured by a meter may be too small to be detectable, there is a change in the composition of the surface noise which makes it distinctly more noticeable.

Radio Stations

Table I shows the correlations significant for our purposes. They may be summarized as follows:

(1) It is clear that the stations making extensive use of recorded material have up to date, high fidelity pickups. On the other hand, those depending on vertical cut transcriptions and network programs have outdated lateral pickups. WCOP is the one exception to both rules; this may be explained on the basis that it depends on both lateral and vertical cut material. In other words, the stations not wishing to pay the cost of leasing vertical cut transcriptions try to make the best use of the available material.

(2) The correlation between libraries of lateral material and equipment is relatively insignificant because only one station, WHDH, has the problem of wearing of an expensive library, since libraries of popular records usually become obsolete before
they wear out. We suspect, then, that wear is not the primary factor, if it is a consideration at all, influencing the purchase by these stations of pickups that cause little wear.

(3) There is little correlation between the equipment and whether the station does recording. Three stations play their acetate recordings with pickups that are really brutal and three other stations with light weight pickups. The mitigating factor is that wear on these recordings is a minor consideration because they are used only once or a few times. The same conditions exist if frequency response is considered instead of wear but this may be discounted somewhat in view of the fact that the average acetate recording does not warrant the use of an extremely wide range pickup. The stations using heavy pickups appear not to be concerned about the possibility of damaging a valuable record by careless handling of the pickup.

(4) The correlation between policy and equipment is quite close, which is as it should be. Incidentally, the closeness of correlation can be construed as an indication of the accuracy of the interpretation of policy as it was distilled
through the mind of the interviewer and, sometimes, that of another person. It should be noted that the stations generally purchase equipment ready to install "as is". This is to be expected, since they are in business to provide service rather than to function as experimental laboratories.

Other correlations might be found but they involve the use of data not obtained in the survey. The relationship between pickup equipment and station power or equipment and audience might be of interest. It seems that a very important relationship to be investigated might be that between pickups and associated amplifying equipment with respect to frequency response and need for additional amplification to handle low-level pickups.

**Recording Studios**

The number of establishments contacted here is so small that there are no correlations of importance to be drawn. However, there are several generalizations that are significant.

(1) Most of the playback pickups found in use are, in general, not quite worthy of the average acetate recording from the standpoint of frequency response, inasmuch as it runs at present from about 50 to 6000 cycles per second.
(2) From the standpoint of record wear, they are not all that could be desired. However, the mitigating factor is that the records are usually played only once at the studio.

(3) All the playback pickups found in use in recording studios have the common serious drawback that they would wreak havoc with a record if handled carelessly and allowed to drop on or to slide across the grooves. Certainly, the users must realize this but they continue to use their old pickups and risk serious losses of time and money.

There are several possible reasons for this; (a) financial; the users are unable to afford the better pickups; (b) they simply feel that the cost of the new pickup is too great in terms of the risk that it removes; (c) there is some defect that makes the new pickups less satisfactory than the old ones.

Of the local recording enterprises, the two most representative, Fidelity and Kaspar-Gordon, do not appear to be restricted financially. The last two reasons, however, seem to have some bearing on the matter. We suspect (b) is the less important of the two because of its contingent nature; business firms often fail to realize the full import of risk.
Furthermore, the fact that some control can be exercised over the handling of the pick-ups makes the possibility of damage seem still more remote. On the other hand, the loss of a recording probably is less important in the type of work done by these concerns than in the case of recording an event that will never be repeated. A one-minute drama may be reproduced, but an historical event may never be repeated. Obviously, there is no accurate measure of the risk factor.

In (c) we are dealing with a system that only approaches perfection in that part of the original performance is not reproduced (the extremely high frequencies, for example) and some added sounds (harmonics) are present in the reproduction. Under these conditions, it is possible that reproduction that is perfectly flat from thirty to five thousand cycles per second and free of harmonic distortion and phase shift may not sound as good to some people as the same reproduction with some harmonic distortion and perhaps augmented volume of low frequencies. In other words, it is possible that the human ear requires some form of distortion of reproduction where range is limited in order to produce a pleasing sensation. This modification may be complicated
Further by the differences in taste of individuals. Thus, the use of a pickup having a flat response may not give pleasant reproduction. Furthermore, in the actual case there is usually some distortion on the record itself, caused by the recording system. This distortion may be of such order of frequency as not to be reproduced by the poorer pickups; therefore, a wide range reproducing system may disclose objectionable distortion that is not heard when the poorer pickup is used.

The first of these factors is only a matter of conjecture but the second is known to exist; both then, may be the basis for some dislike of high fidelity pickups on the part of the recording studios. We are faced with the situation where the listening test, although more subjective, is often a deciding factor when purchase is being considered. A partial solution of the problem would be the use of a low pass filter providing selective high frequency cutoffs at say 7000, 5000 and 4000 cycles per second. This would also improve performance with recordings of materials having different surface noise characteristics and different frequency ranges.

Comparison of the LT-1 with Competing Units

Table V shows the pertinent information concerning the high fidelity pickups now on the market
TABLE V
Comparison of pickups competing with the LT-1.

<table>
<thead>
<tr>
<th>Make &amp; model</th>
<th>Frequency range cps (1)</th>
<th>Price (3)</th>
<th>Equalizer</th>
<th>Scratch Filter</th>
<th>Needle Press. (oz.)</th>
<th>Stylus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audax RF-6</td>
<td>30-10000</td>
<td>$125</td>
<td>no⁶</td>
<td>no</td>
<td>Interchangeable</td>
<td></td>
</tr>
<tr>
<td>Brush S-16</td>
<td>30-10000</td>
<td>$75</td>
<td>no⁴</td>
<td>no</td>
<td>1 to 1, 1¾</td>
<td>permanent</td>
</tr>
<tr>
<td>Lansing 100-LR</td>
<td>30-10000</td>
<td>$100</td>
<td>no⁷</td>
<td>no</td>
<td>0.2 to 1.0</td>
<td>permanent</td>
</tr>
<tr>
<td>LT-1</td>
<td>30-9000²</td>
<td>$65</td>
<td>no</td>
<td>no</td>
<td>0.8</td>
<td>Interchangeable</td>
</tr>
<tr>
<td>RCA</td>
<td>30-9000</td>
<td>$125 to $150 (5)</td>
<td>yes</td>
<td>yes</td>
<td>¾</td>
<td>permanent</td>
</tr>
</tbody>
</table>

1. As stated by the manufacturer, within about 3 decibels.

2. This was with a dural shank, sapphire needle. A steel needle was found to cause a pronounced peak in the response around 5000 cps.

3. These are only approximate because of varying discounts.

4. Does not require a low frequency equalizer. However, it is furnished with an equalizer for decreasing response above 2000 cps, for optional use.

5. This is only approximate: the manufacturer will not disclose his prices to broadcasting stations. The price shown was given by owners of the pickup.

6. Equalization is accomplished mechanically in the pickup.

7. An equalizer consisting of a resistance-capacity network can be obtained from the manufacturer to be installed in the amplifier circuit.
that would compete with the LT-1. A perusal of this material shows that the LT-1 has the lowest price and about the same frequency range as its competitors but it is not furnished with an equalizer to correct for the needle velocity vs frequency characteristic of lateral recordings. It lacks also the adjustable needle pressure feature and the adjustable low pass scratch filter.

Lack of an equalizer can be justified to some extent by the fact that there is no standardized velocity characteristic for lateral records; different records often have different characteristics and a playback equalizer designed to work with one type of recording will be unsatisfactory for others. In this respect, the LT-1 is an experimenters', manufacturers' and custom builders' device; the buyer may adapt it to the characteristic he desires by proper equalization.

The fixed needle pressure feature of the LT-1 limits its flexibility to some extent but simplifies its use, which tends to make it well adapted for the non-technical user. This indicates an opening in the custom builders' and the manufacturers' fields.

The interchangeability of needles again makes the LT-1 an experimenters' device but makes it less satisfactory than a permanent stylus unit for continuous use, as would be the case in a broadcast studio.
Lack of a selective scratch filter again puts the LT-1 in the experimenters' and manufacturers' fields but makes it less satisfactory for broadcast use.

One serious disadvantage of the Brush unit is the short radius on which the head is pivoted, which makes it essential that the record be absolutely flat if wavering of reproduction is to be avoided.
Radio Stations

1. The type of pickup equipment used by the stations is closely allied to the extent to which recorded material is used.

2. Wear on record libraries is a minor consideration in determining the type of lateral pickups used.

3. In stations which make acetate recordings, the wear on these recordings caused by the pickups is not important. The frequency response of the pickups need not be better than 50 to 5000 cycles per second because of the quality of the recordings.

4. In the case of some of the recording done by stations, there is the possibility of irreparable loss through the damaging of an acetate recording with a heavy pickup carelessly handled. However, this appears not to be recognized by the stations as important.

5. Stations seem to prefer to purchase equipment which may be installed quickly and easily and with a minimum of experimentation.

6. The cost of pickup equipment is a relatively unimportant factor.
Recording Studios

1. The playback pickups used by recording studios have, in general, a range not quite wide enough to make the most of the present day recordings on acetate at their best.

2. These pickups, in general, cause more record wear than the new, light weight pickups.

3. Most of the playback pickups in use are capable of seriously damaging a record if carelessly handled but this is mitigated somewhat by the fact that a new record can usually be made.

4. We feel that one reason for lack of popularity of light weight pickups among recording studios is that their increased efficiency at high frequencies results in reproduction of objectionable distortion and noise consisting of frequencies higher than those recorded, and of distortion that was not troublesome when a poorer pickup was used.

5. Cost of the equipment is not a deterrent if better performance is provided by the expenditure.

6. Recording studios are more likely than radio stations to experiment with equipment to get satisfactory quality.
The LT-1

1. The LT-1 is about on an equal basis with its competitors from the standpoint of frequency range, but is lower in price.

2. Lack of equalizer, selective scratch filter and interchangeability of the needle make the LT-1 well suited to use by those who experiment during installation in order to get the results they desire but they make it less desirable for broadcasters.

3. The LT-1 would be suitable for manufactured or custom-built phonograph equipment for the consumer on the basis that it has no needle pressure adjustment to be confusing and to be misused and that it can be adapted to any type of recordings by proper design by the manufacturer of the phonograph of the low frequency equalizer and the scratch filter.
RECOMMENDATIONS

In making the following recommendations, it has been assumed that the company wishes to build up the sales of the LT-1 pickup so that it may become an independent, self supporting member of the company's line of products.

1. An equalizer and an adjustable scratch filter should be designed for the pickup to increase its appeal to the broadcasting stations.

2. The design of the pickup should be modified (if this has not already been done) in such a manner that the armature is protected from damage by too vigorous twisting of the needle screw or by a sideways blow on the needle. This might be accomplished by placing stops near the needle so as to prevent movement of the armature great enough to cause damage.

3. In selling to broadcasters, the following appeals should be emphasized (granted that recommendations 1 and 2 have been followed):
   
   a. The pickup has a frequency range of from 30 to 9000 cycles per second, yet is low priced. The possibility of obsolescence of this pickup due to improvements in lateral recordings and
transcriptions is minimized by its wide range.

b. It has low needle pressure and low needle point impedance, therefore will cause practically no wear on records and will not damage valuable records when handled carelessly.

c. The pickup with its accessories (equalizer and selective scratch filter) can be installed simply by connecting it to a 125 ohm, low level input.

d. The scratch filter permits maximum fidelity with each type of recording without permitting reproduction of objectionable surface noise and distortion.

e. The pickup is simple enough to permit operation by inexperienced persons, such as announcers.

4. In selling to recording studios, the following appeals should be emphasized (granted that recommendations 1 and 2 have been followed):

a. The pickup has a frequency range of from 30 to 9000 cycles per second, yet is low priced. The possibility of obsolescence of this pickup due to improvements in lateral recordings and transcriptions is minimized by its wide range.
b. It has low needle pressure and low needle point impedance, therefore will cause practically no wear on records and will not damage valuable records when handled carelessly.

c. The scratch filter allows the use of maximum frequency range permitted by the characteristics of the cutting head and its associated amplifier consistent with minimum surface noise and high frequency distortion.

d. The pickup is rugged enough for playback operation and requires no delicate adjustments.

e. The customer may install an equalizer of his own design to provide best results with his particular cutting head or he may purchase one already made to meet average conditions.

f. The interchangeability of needles permits use with whatever type of needle is desired.

5. The LT-1 has not the backing given by a name such as Western Electric or RCA, therefore the salesmen should be aided by direct mail advertising carefully phrased to present the appeals listed above to the two markets. It would be desirable to arrange to have the prospect receive the mail folder several days before the salesman
planned to call on him. Demonstrations, of course, are recommended.

It should be recognized that the recommendations given above are based on findings made only in the Boston area. However, they might be applied equally well to other territories where the conditions are found to be similar to those in Boston, after a preliminary investigation.
APPENDICES

APPENDIX A -

Bibliographical Material
The following is a group of abstracts of bibliographic references pertinent to the subject of my thesis, "A Study of the Market for High-Fidelity Phonograph Pickups."

R. P. Glover, "A Record-Saving Pickup", Electronics, February, 1937

This is a description of the Shure "Zephyr" crystal pickup. The author describes the positioning of the crystal reproducing element and the tilting of the needle receptacle so that the angle of the axis of the needle motion and of the projection of the needle on the record is reduced over that of a conventional mounting. Theoretically, the angle of these two elements with the groove should be zero. The new mounting makes this angle much smaller than is the case in conventional mountings. The author claims that this reduces distortion of reproduction at high frequencies and that record wear is reduced because the needle is not being continually reshaped to fit the sides of the groove as its angle with the groove changes with the position of the arm in its motion across the record.
Benjamin Olney, "Phonograph Pickup Tracking Error vs Distortion and Record Wear", Electronics, November, 1937

In this paper, the author casts considerable doubt upon the statements made by Mr. Glover in the article previously mentioned. He first states that records are made by a cutting needle constantly perpendicular to the line of cutting therefore, the point of the reproducer stylus should move in the same fashion, ideally. However, this is impossible with existing mountings, although it can be approached. He shows by a drawing that the "needle-tilt" principle results in the projection of the needle on the record being tangent to the groove but the path of the needle point does not coincide with a radius of the record, as would occur in the ideal case.

The author describes a test made with two identical magnetic pickup heads, one on a conventional straight arm mounted to give a maximum tracking error of 15° and the other mounted on a tangent type arm. The pickups were played simultaneously and repeatedly on two identical records specially chosen as suitable for the test and the records compared from time to time for loss of quality and increase of surface noise. The only feasible test was a direct comparison by ear but this showed no detectable difference in either loss
of quality or wear caused by the two pickups.

A mathematical analysis is carried out on a sine wave to show that under the worst conditions of frequency and groove amplitude and a tracking error of 15° the maximum harmonic content introduced would not exceed 4% (about 8% is considered barely noticeable by the average human ear.)

Olney describes the "pinch effect"* and states that distortion from this source would probably mask other distortion caused by non-tangent tracking. He also states that record wear caused by the reshaping of the needle referred to by Mr. Glover would be mitigated by the constant change of the angle of the groove tending to polish off the sharp corners on the needle point.

*Since the cutting stylus is flat rather than round on the leading face, as it moves from side to side it cuts a groove of varying width, the narrowest points being those cut when the needle was moving sideways. However, the reproducing stylus is round and, if it rides on the sides of the groove, when it reaches one of these constricted places it is squeezed or "pinched" upward, out of the groove. If the mechanism of the reproducer is such that this vertical motion cannot be accomodated at the signal frequency, the narrowest portions of the groove will be worn out to the same width as the rest of the groove, thus causing distortion.

This is a description of the Audak "re-
layed frequency "principle, which makes use of
a small armature of very little mass in a spec-
ial magnetic circuit. No damping is required,
and since the needle is removed from the mag-
netic circuit, some distortion is eliminated.
The armature is so light that its weight is ex-
ceeded by that of the needle, which means that
the kind of needle used has considerable influ-
ence on the frequency response. With a special
needle of one third the conventional mass and
certain modifications of the pickup, the frequency
response can be made flat within 3 decibels from
40 to 8000 c. p. s.

F. V. Hunt, J. A. Pierce, "HP6A: A Radical
Departure in Phonograph Pickup Design", 
Electronics, March, 1938

This pickup was inspired by the discovery
that some recordings of the Harvard Tercentenary
proceedings had frequencies up to 10,000 cps and
that playback with conventional reproducers caused
the higher frequencies to be erased after a few
playings. It was desired to make a reproducer
which could be used to play these recordings with-
out thus damaging them. The design finally agreed
upon makes use of a single-turn loop of phosphor bronze ribbon of very small dimensions in a magnetic field. The loose ends are clamped to terminals and the closed end of the loop is fastened to a conical shell of aluminum pointed with a saphire stylus. A pyralin membrane provides damping and holds the loop in position. A transformer at the other end of the tone arm acts also as a counterweight.

The response of the pickup is found to be within 3 db. from 30 to 18,000 cps. A test showed that no detectable increase in surface noise of a lacquer coated record took place after 100 playings at 5 grams needle pressure. The pickup can be dropped from a distance of one inch above the record or slid across the grooves without damaging either record or pickup.


The authors discuss a form of distortion called tracing distortion. This is caused by the fact that the center of a circle of finite radius whose circumference rolls or slides on a sine curve does not describe a sine curve. Therefore, a stylus of finite radius moving in a sinusoidally modulated groove will not move in a sinusoidal
path if it is driven by the sides of the groove.

Furthermore, the pinch effect causes a lifting of the stylus partly out of the groove at narrow places and the reproducer must accommodate this motion if it is not to cause distortion and wear. If the stylus is not free to move vertically at the signal frequency, it will ride upwards at the narrow parts of the groove and, because of its inertia, will stay in that position until the next narrow point, and so on, until the narrow parts of the groove have been worn out to the same width as the rest of the groove; when the needle is in this elevated position it is actually out of contact with the groove at wider portions and the distortion so caused is inharmonic but otherwise unpredictable.

It is demonstrated mathematically that the distortion due to tracing error is less in laterally modulated than in vertically modulated grooves because the even harmonics so caused are 180° out of phase on each side of the groove and cancel, leaving only the odd harmonics. In general, the distortion caused by laterally modulated grooves is less than in vertically modulated grooves but in increases more rapidly with increasing frequency, de-
creasing ratio of needle tip radius to minimum groove radius and decreasing speed of the record past the needle point.

Among other things, the authors recommend reduction of the stylus point diameter to 0.75 mils (made possible with the new, light pickups) and closer spacing of grooves on the record to reduce distortion and give longer playing time.


In this paper the author points out the high inertia and troublesome resonance of commercial magnetic pickup armatures, necessitating damping, thus causing high needle point impedance which is the primary cause of record wear. He suggests a novel armature design of light sheet metal with no needle socket, the needle resting in place, held by the weight of the pickup on the record and by the magnetism of the field. The butt of the needle rests in a cavity in the pole piece and the shank passes through a notch in the armature, so as to drive it. The equivalent mass at the needle point due to armature and needle is 0.07 grams as compared with 0.17 grams in the commercial unit.
One interesting point made by the author is that elastic deformation of the point of the needle at high frequencies is probably a factor in the response of the pickup to high frequencies. Frequency response curves show his pickup to be within 5 db from 150 to 5000 cps., which was better at the time than a commercial oil damped and a commercial rubber damped unit.

On the basis of this bibliographical information, the conclusion is that more attention is being given to high quality reproduction of phonograph records than has been the case heretofore. Attention is also being given to the matter of record wear, which is one of the most discouraging factors in present equipment used in the home, as it affects fidelity of reproduction and life of the record. It is to be hoped that the future will see a high fidelity, reasonably priced phonograph pickup on the market in conjunction with high fidelity records of low noise level and long wearing qualities. Extension of playing time would also be welcomed. In the light of the above information, these wishes seem to be coming closer to realization.
APPENDIX B

Reports of Interviews
These are the full reports of the interviews conducted at the radio stations and recording establishments in Boston. It should be recognized that the individual contacted was not always in a position to give accurate information concerning technical questions and matters of policy, therefore, the interpretations of the interviewer may be inaccurate.

Interview with Mr. DeMars and Mr. Robinson: Stations WAAB and WNAC (Yankee and Colonial Networks, National Broadcasting Company and Mutual Broadcasting System networks)

Both stations use the same building for their studios and both use transcriptions and records extensively for advertising, sustaining and repeat programs, the last being network programs which cannot be broadcast locally at the time of performance. These are recorded on acetate coated discs at 33-1/3 rpm with Presto equipment, lateral cut, and played with Western Electrical type 4A pickups using steel needles. Since these records are seldom played more than once, wear is unimportant.

Both stations have duplicate pickup equipment, but WNAC uses vertical cut transcriptions
almost exclusively, and WAAB uses both vertical and lateral cut material. Under a contract with a Boston concern the pickups are tested and repaired regularly. Other modernization steps consist of replacement of equalizers from time to time as new models are brought out by the manufacturer. No experimentation is resorted to, new equipment is installed as it comes from the manufacturer.

In general, the policy stipulates that radio should offer something a little better than the listener can have in his home, hence the use of vertical transcriptions. The men stated that the station tries to keep up to date with this equipment (in spite of the WE 4A pickups!) However, they did state that they felt the present quality of phonograph records (used by WAAB) does not warrant the use of an expensive pickup.

Reproducing Equipment
WNAC, WAAB have duplicate equipment

- 2 16" turntables
- 2 WE 4A lateral pickups
- 2 WE vertical pickups

Recording Equipment
- 2 16" Presto turntables with Presto cutting heads and Audak pickups (not used)

Library
WNAC - vertical transcriptions
popular phonograph records

WAAB - vertical transcriptions
Interview with Mr. Wright;  
Station WBZ (National Broadcasting Company)

WBZ uses vertical cut transcriptions and lateral cut records for a portion of its broadcasting time. Some recording is done on acetate discs with an RCA cutting head and lead screw assembly on an RCA transcription turntable. The pickup equipment, which has been in use some 2 or 3 years, consists of 3 RCA transcription tables with RCA 71-A lateral reproducers; one table also has a vertical reproducer. These lateral pickups are used with steel needles for all lateral records and transcriptions.

Recording is done largely for reference (political speeches) and for auditions. Wear on the reference material is, of course, not an important consideration and audition material is usually played elsewhere so record wear is unimportant at the station.

In general, equipment of this type is installed as received from the manufacturer (RCA, since the station is RCA-owned) but if it is unsatisfactory it is returned or complaints are made until it is rendered satisfactory.
Mr. Wright said that the station does not go to extremes to keep this equipment up to date because the average receiver now in use does not warrant the quality obtainable.

Reproducing Equipment
3 RCA 16" transcription turntables, model 70-A
3 RCA 71-A lateral reproducers
1 RCA vertical reproducer

Recording Equipment
1 RCA cutting head and lead screw assembly

Library
vertical transcriptions
lateral transcriptions

Note - WBZ also uses some Victor Red Seal records loaned by the manufacturer. Wear on these records is not a concern of the station, since they are played only once and returned.
Interview with Mr. Darce:  
Station WCOP

This station uses records and transcriptions to a large extent and does some recording for audition purposes. The recording equipment consists of an RCA unit mounted on an RCA transcription turntable which carries in addition an RCA 71-A lateral and an RCA vertical reproducer. Additional equipment is in the form of two Western Electric 33-1/3 rpm 16" turntables equipped with Western Electric vertical and Western Electric 4A lateral reproducers used for vertical transcriptions and 16", slow speed lateral recordings, mostly of a commercial nature. There are also two 2-speed 12" RCA turntables of the type used in record-changing phonographs of several years ago. The pickups used with these are of the same vintage. Steel needles are used in all lateral pickups. These four turntables are in use almost constantly while the station is on the air.

This equipment is installed "as is" and is serviced by a local service concern specializing in this type of work. Apparently, responsibility for keeping this equipment in good condition electrically and mechanically
rests with this organization. According to Mr. Darce, the station attempts to keep up to date but the Western Electric turntables and the smaller turntables have been on the market for at least five or six years. It appears also, that they are satisfied if the signal sounds good to the ear; they feel it unnecessary to test and experiment continually, particularly in view of the poor quality of most receiving equipment.

Reproducing Equipment

2 RCA two-speed 12" turntables
2 RCA pickups to match
2 WE 33-1/3 rpm 16" turntables
2 WE 4A lateral pickups
2 WE vertical pickups
1 RCA two-speed 16" turntable, model 70-A
1 RCA vertical pickup
1 RCA 71-A lateral pickup

Recording Equipment
1 RCA unit (on RCA turntable)

Library
popular phonograph records
vertical transcriptions

Note - This station has an arrangement with a local music dealer whereby the dealer loans classical recorded music in return for advertising by the station.
Interview with Mr. Morse:
Station WEEI (Columbia Broadcasting System)

Vertical transcriptions are used to some extent for musical sustaining and commercial programs. Phono records are used to a limited extent in the early morning when "not many are listening and are not critical of the poorer quality than is available from transcriptions." Some acetate recording is done, with two Presto outfits. This is mostly for reference, auditions and when it is wished to preserve programs broadcast over the station by celebrities. There is also some recording done for rebroadcast.

Pickups used are a Western Electric vertical and some Western Electric 4-A lateral units for transcriptions and phonograph records and acetate recordings, respectively. The lateral heads are used with steel needles for all lateral recordings. An engineer stated that the recording equipment is being worked on constantly to improve it mechanically and electrically. The lateral reproducers are not expected to be better than within 2 decibels from 100 to 4000 cycles per second.

There was some feeling that things were soon to be changed; no definite statements were
made, but Mr. Morse said that he thought the
transcription equipment would be modernized in
the near future.

Reproducing Equipment
1 WE 16" turntable
1 WE vertical reproducer
4 12" two-speed turntables
4 WE 4-A lateral reproducers

Recording Equipment
2 Presto 16" turntables with Presto
cutting heads (portable recorders
mounted in a bench)
2 Audak playback pickups (original equip-
ment, used only for checking)

Library
vertical transcriptions
a few popular phonograph records
Interview with Mr. Watson and Mr. Matheson
Station WHDH

This station depends heavily upon recorded material for its programs. The material consists of phonograph records and lateral-cut transcriptions for entertainment and advertising. The equipment consists of two RCA transcription turntables equipped with the new RCA modernization kit, which includes a #4358 pickup head having a response of from 30 to 9000 cycles per second, a diamond pointed stylus and a needle pressure of $\frac{3}{4}$ ounces, an equalizer and a low-pass filter allowing high frequency cutoff at any of three frequencies, to accommodate the scratch frequencies of different recordings. These units have been in use about five months. One table has an RCA vertical head used only for commercial recordings of the vertical-cut type. Mr. Watson stated that he also had the Western Electric new 9-A pickup on order.

The station has a library of musical recordings, mostly of the shellac variety, and uses them quite extensively. They formerly were played with imported German pickup heads (Neumann), using steel needles, and the library had to be replaced yearly because of wear. Mr. Watson stated that he thought the library would last indefinitely with the present pickups.
Mr. Watson seemed to be quite interested in high quality reproduction; he mentioned some of his experience in building speech apparatus in an effort to obtain high fidelity. Unfortunately, lack of time prevented further continuation of this discussion. In general, the policy seems to be progressive and stipulates the best possible quality with the material at hand. There is little possibility of experimentation here because the equipment is in almost constant use.

Reproducing Equipment
2 RCA 16" two-speed turntables, model 70-A
2 RCA #4358 lateral reproducers
1 RCA vertical reproducer

Library
lateral transcriptions
classical and popular phonograph records
Interview with Mr. Pote
Station WMEX

WMEX makes extensive use of phonograph records and lateral transcriptions. No recording is done. The transcription equipment consists of two RCA transcription turntables with the RCA modernization kit including lateral head #4358. The pickups have been in use about eight months and are used essentially as intended by the manufacturer, although some experimentation is attempted to get the desired results. The manager stated that the policy was to try to keep up to date as much as possible. This was evidenced by his pride at their being the first station in Boston to have these pickups; he mentioned a few other "firsts".

Reproducing Equipment

- 2 RCA 16" two-speed turntables, model 70-A
- 2 RCA #4358 lateral heads

Library

- popular and classical phonograph records
- lateral transcriptions
Interview with Mr. French
Station WORL

This station uses phonograph records and lateral transcriptions for most of its programs. The pickup equipment consists of two recently acquired RCA #4358 lateral heads with 16" two-speed turntables designed by the station engineer and two RCA pickups of the type used in receivers several years ago with 12" turntables.

The station does some recording on acetate with Presto equipment for audition purposes. These are now played with the new pickups. Some experimentation is carried on during the installation of this equipment in order to get the best results but the equipment is in almost constant use and it is therefore impractical to conduct extensive experiments or tests. The interviewer was unable to learn how the station stood on the matter of obsolescence.

Reproducing Equipment

2 16" two-speed turntables
2 RCA #4358 lateral heads
2 RCA pickups
2 12" turntables) to be discarded

Library
popular phonograph records
lateral transcriptions
Interview with Mr. Brown and Mr. Pearson
Fidelity Recordings

Messrs. Brown and Pearson are a partnership firm organized to make records principally for personal use, although some commercial work is handled occasionally. The equipment consists of two Presto portable recorders (16" turntables) equipped with Neumann cutting heads. For playback one recorder is equipped with an Audax A-6-U pickup and an Audax 1-C-5A pickup, both of which have been in use less than one year. Steel needles made for use with acetate are used for playback and, since the record is played with these pickups only once or twice at the studio, and since the customer's pickup is almost certain to be hard on the record, the wear caused by these pickups is not serious on the average.

Considerable effort is made to improve the quality of the recordings. Both men are musically trained and tend to favor reproduction that sounds good to them even though it may be poor from an engineering standpoint. This is suggested by the fact that they were unsatisfied with the standard Presto cutting head and even with a head specially built by Presto. They are also unsatisfied with both pickups and look forward to getting
a new pickup designed by Neumann. They are now quite satisfied with a Neumann cutting head.

Both men are deeply interested in the subject of recording and have an eye to the future; they mentioned the eventuality of film recording and said they hoped to install equipment for film recording in the near future to take care of the demands of amateur sound photographers.

Recording Equipment
----
2 Presto portable 16" recorders with
1 Audax A-6-U pickup and
1 Audax 1-C-5A pickup
Interview with Mr. Buzzell
Kaspar-Gordon Studios

Kaspar-Gordon Studios makes records principally for commercial applications such as short dramatic episodes. The material used is acetate but many of the jobs require that pressings be made and these are made by an outside concern; the acetate record is used as a master for this process. The recorders are Presto 16" portables mounted in a bench and used with Presto cutting heads. The playback pickups are those originally furnished with the recorders and have been in use some seven years. The model number could not be determined, but it is certain that they are magnetic units.

Mr. Buzzell stated that they had had trouble with the pickups chattering on certain types of records. This was eliminated by replacing the rubber grommets on which they were mounted. Some of the equipment was built and installed by the company itself and occasional changes are made but no extensive experimentation can be carried on because the equipment must be always ready for use.

They try to get results that sound good to the ear but little is done in the way of
actual measurements to check the quality of recording and reproduction from time to time.

Mr. Buzzell is a great believer in having plenty of power in reserve; the present amplifier is rated at 19 watts and he is planning to replace it with a 25 watt amplifier. He is also planning to replace the present portable recording equipment with some heavier, studio type equipment.

**Recording Equipment**

- 2 Presto portable 16" recorders with
- 2 Audak playback pickups
Interview with Mr. General Television Corporation

This concern does recording as a sideline to its principle activity of television experimentation. The equipment consists of a Presto 16" portable recorder equipped with a Presto cutting head and an Audax 25A playback pickup. Acetate blanks are used. Playback is with steel needles of a special shape; the diameter of the shank near the point is reduced to about half that of the rest of the shank. As far as could be learned, these needles are not recommended for acetate.

The pickup originally furnished with the recorder was an Audak. It was found to be unsatisfactory because it would occasionally break into a state of oscillation or vibration while playing a record. This oscillation would persist for a short period and would seriously distort the reproduction meanwhile. Little could be learned of the policy of the company regarding this equipment.

Recording Equipment

1. Presto 16" portable recorder with
1. Audax 25A pickup
APPENDIX C
Test Record Data
## Test Record Data

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Using M. I. T. communications amplifier,
General Radio level meter,

Sound Scriber recorder,
Allied 12" acetate coated record balnk
APPENDIX D

Recommendations for Further Study
Recommendations for Further Study

This report has dealt with only two possible markets for the LT-1 pickup but it has indicated that there are possibilities definitely worthy of investigation in several other fields, the manufacturers and custom builders of phonograph equipment and the experimenters. The writer recommends further investigation in these fields.

Although it is beyond the immediate scope of this report, the writer wishes to recommend further study of the behavior of the pickup stylus in the record groove. One method of actually observing this that has occurred to the writer is that of examining with the aid of a microscope the needle riding in a groove modulated with a constant frequency while illuminated with a stroboscopic light flashing at the frequency on the groove. Varying the phase relationship would enable the observer to examine the actual movements of the needle.