

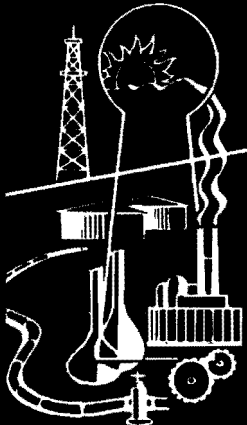
PRESERVATION AND STORAGE
OF SOUND RECORDINGS

M. M. Lemcoe

PROJECT NO. 721-2
Progress Report No. 4

March 21, 1958

Department of Engineering Mechanics



SOUTHWEST RESEARCH INSTITUTE

8500 CULEBRA ROAD
SAN ANTONIO 6, TEXAS

Department of Engineering Mechanics
March 21, 1958
In reply, please refer to: 721-2

Dr. Harold Spivacke
Chief, Music Division
The Library of Congress
Washington 25, D. C.

Dear Harold:

This letter constitutes Progress Report Number 4 on Project Long-Fi (721-2), covering the period from February 1 to March 1, 1958.

Enclosed is a copy of the Minutes of our meeting here at SwRI on March 3 and 4. Should there be any inaccuracies in these Minutes, please let us know and we will make the appropriate changes.

Since the abovementioned meeting, our main emphasis has been on setting up the electronic system for making noise measurements. This system automatically integrates the white noise over several revolutions of the record, so as to give us a numerical index of total noise below a prescribed sound level. The system also gives a count of the number of spikes which occur during the same period of play, thus giving a numerical index of the "pops" or crackles above a certain reference sound level. Tests of this type are now under way. The procedure is to measure the noise level on a fresh record over a given portion of the record. The same record is then subjected to accelerated aging environments, and the change in noise level observed. Among other things, these tests will help in the establishment of the most appropriate temperatures and humidities at which records should be stored. We sincerely hope that vinyl unmodulated groove records (Type 2) will be forthcoming in the very near future so that the noise measurement test may be continued without interruption. Present noise tests have been made with acetate records. We have only a few left and urgently need 20 more 12" unmodulated groove 33-1/3 rpm acetate records for completion of these tests. As mentioned in my letter to you of March 19, Mr. Wegner has virtually completed all of the 12" 78 rpm Type 2 unmodulated groove vinyl records. We would appreciate receiving these as quickly as possible, and hope that the other changes suggested in the letter meet with your approval and that Allied can proceed as rapidly as possible in filling the remainder of the order.

The stress superposition tests mentioned during our meeting are under way. The purpose of these tests is to validate certain assumptions used in the development of analytical expressions for the creep occurring in records

when stored on the shelf in an off-vertical position. (In lieu of a precise tilting level, deflections will be measured with Schaevitz differential transformers.) This test will be of 100 hours duration, and carried out in the creep chamber under closely controlled temperature and humidity conditions.

Phase I gross effects thermal cycling tests are continuing in the "hot-cold" box for both acetate and vinyl records, with and without prior exposure to intense ultra-violet radiation under ambient environmental conditions.

Preliminary measurement of the residual stresses in vinyl records is also under way, in an endeavor to obtain information as to the over-all importance of residual stress with respect to the warping and groove distortion in records. This study will also provide information for a possible analytic work on residual stresses we may wish to carry out in the near future.

Fungus studies on acetate, vinyl, and shellac compositions are still in progress in our chemical exposure chamber, under conditions of ambient temperature and 90 to 100% relative humidity conditions. The records are separated by cardboard infected with fungi. The amount of damage to the records as a result of etching and other effects are being observed and will be discussed in greater detail in the next progress report.

Thank you very much for forwarding the questionnaire from Columbia Records. They did a beautiful job in filling out the questionnaire and it contains exactly the type of information we had in mind. We are also very pleased to learn from the covering letter dated March 10, 1958, that Columbia is going to provide us with fresh vinyl records and unused records of 1948 vintage, both from the same known formula. These records will be particularly useful in providing a check on our hypotheses for predicting long-term effects on the basis of short-time test results. The information from Columbia's questionnaire and that contained in the data provided by Mr. A. W. Johnston of the Brunswick Radio Corporation is considered quite complete and we hope that this will be true of the information received from the other companies now under consideration. We have contacted Mr. A. L. McClay of RCA and Mr. James W. Bayless of Capitol Records, as suggested in your letter of March 10. We will do likewise on any additional companies you suggest at a later date.

Mr. Tanner of TNT here in San Antonio has suggested that Collins, Caldwell, and Dague, 16616 Garfield Avenue, Paramount, California, be contacted regarding information of the type we are seeking with our questionnaire. Mr. Tanner states that they are one of the largest biscuit suppliers to the record industry. Perhaps the initial contact should be at the top level, and for this reason we wonder whether you would consider making the contact for us. They would probably be more receptive to you than to an organization of our type.

A literature search relating to the magnetic tape storage and preservation problem is now under way. Approximately one half of the literature to be studied has been accumulated. However, it will not be possible, at this time, to ascertain how much of each different type of tape will be required. It is estimated that it will be approximately two weeks before we can give you a plausible estimate of what will be required. It is, of course, already certain that we will want to consider at least two different base materials and two different coatings, from at least two manufacturers. It is felt that through the careful study of selected literature, now in progress, needless duplication of effort and project expenditure will be avoided.

A paper from Dr. Prager on "Deformation and Creep of Recordings", prepared by Dr. E. H. Lee, has been received and is now being evaluated. It is hoped that the analytic expressions contained in the paper and experimental data will provide a means of estimating the long-term warp in vinyl records stored in the off-vertical position. A copy of this paper will appear in the next historical report.

Project expenditures to March 1, 1958, total approximately \$17,900.

With kindest personal regards.

Very sincerely yours,



M. M. Lemcoe, Manager
Strength Analysis Section

MML/bb

Enclosure

cc: Dr. Wm. Prager

Minutes of Committee Meeting - Project Long-Fi (721-2)
Southwest Research Institute - March 3 and 4, 1958

The meeting was attended by Dr. Harold Spivacke, of the Library of Congress, Professor William Prager, of Brown University, and the following personnel of Southwest Research Institute:

Frederick Bieberdorf, Chemistry
Martin Goland, Vice President
M. M. Lemcoe, Engineering Mechanics
Roy McCutchan, Chemistry
William Mussen, Electrical Engineering
Andrew G. Pickett, Engineering Mechanics
M. J. Prucha, Electrical Engineering
Edward Wenk, Jr., Engineering Mechanics
Eugene Whitlow, Chemistry

The meeting was opened with a statement of the conference objectives, which were outlined as:

1. To review the work that has been done to date on the project.
2. To define the test parameters (both causes of degradation and indices of degradation) which will be used and to determine their relative importance in order to derive the most benefit in terms of allotted time and funds.
3. To further formalize the program for future work.

Laboratory activities to date were described as mainly confined to Phase I gross effects studies of acetate records and development of test techniques and apparatus for Phase I and Phase II studies. It was mentioned that tests involving vinyl records would commence as soon as vinyl records were received.

It was pointed out that considerable benefit has been derived from the literature search because the plastic materials involved--nitrocellulose and the rigid co-polymer of polyvinyl chloride and polyvinyl acetate--have been studied extensively and their properties are well documented. The status of the questionnaire to record manufacturers which sought additional information (prepared by the Institute and distributed by the Library of Congress) was also discussed. It was decided to send a follow-up letter to those companies from which an answer to the questionnaire has not been received, outlining the information desired and suggesting that they submit this information in any form. Dr. Spivacke mentioned that he was still endeavoring to obtain the composition of the acetate records. To assist in the development of analytical expressions for creep in vinyl records stored in the "off-vertical" position, Dr. Prager mentioned that the validity of using stress-superposition principles be investigated experimentally, in addition to a determination of Poisson's ratio for vinyl material. A summarization of the knowledge

acquired to date indicated that the parameters responsible for storage degradation are the same as those originally chosen for study, i.e.:

1. Stress (both gravity loads and residual).
2. Temperature.
3. Humidity.
4. Fungus.
5. Sulphur Dioxide.
6. Oxidation.

Accordingly, it was agreed that detailed laboratory investigation will be confined to these parameters.

It was pointed out that the parameters to be measured for analysis of storage degradation have been reduced in number and that the means for measuring them have been simplified. The physical properties of interest were defined as:

1. Dimensional changes which affect playback.
2. Embrittlement.
3. Surface cracking.

It was decided that these parameters are best measured by playback. Also noted was the fact that playback measurements have been simplified and were considered to be:

1. Noise - most important, and, by use of appropriate techniques, can serve as an index for measurement of surface damage (cracking, etc.), embrittlement, and random dimensional changes.
2. Overall harmonic distortion - a measure of systematic, but not uniform, dimensional changes.
3. Frequency response and overall attenuation - a measure of change in certain mechanical properties of the material.

In addition, it was mentioned that visual inspection and measures of gross weight and dimensional changes will be made during aging to establish indices of gross degradation.

The future test program was outlined as:

1. Acetate Discs
 - a. Thermal aging at various humidity levels with and without prior exposure to ultra-violet light. Time correlation of accelerated

aging to shelf aging will be attempted by the time-temperature superposition principle¹ and tests of old records compared with artificially aged newly made records of the same formulation².

- b. Thermal and humidity cycling to establish resistance of the material to accelerated service conditions for determination of optimum thermal and humidity environments³.
- c. Chemical exposure to environments of high oxygen and sulphur dioxide content, with prior exposure to ultra-violet light in the case of oxygen.
- d. Fungi studies to determine optimum means for inhibiting growth of fungi.
- e. A possible search for quantitative chemical analytical tests (hydrogen chloride, carbonyl group, and unsaturation for vinyl discs and the oxides of nitrogen for acetate discs) to establish analytical indices for prediction of record longevity.
- f. Creep studies of vinyl discs (both experimentally and theoretically) to determine the effect of gravity loads and residual stresses in producing dimensional changes--as opposed to chemical agents.

The philosophy for these studies was emphasized as being one concerned with cause and effect only, with little or no emphasis given to the actual internal mechanisms involved, in order to obtain the maximum of useful information in terms of time and funds.

Positive contributions which will probably be made were foreseen as:

1. Establishing design criteria for air conditioning systems to provide optimum storage environment, including the possible use of an alkaline dust scrubber.
2. Design of a record jacket and/or envelope which may contain fungus inhibiting agents and preservatives.
3. Recommendations relating to storage attitude.
4. Possible recommendations as to methods for estimating record longevity on the basis of embrittlement, etc.

Dr. Spivacke commented on the results of his observations as follows:

1. Existing record jackets are more expensive items than one would normally

¹Doyle, C. D., "Application of the Superposition Principle to Data on Heat Aging of Plastics", Modern Plastics, July 1957, p. 141ff.

²Youmans and Maasen, "Correlation of Room Temperature Shelf Aging with Accelerated Aging", Industrial and Engineering Chemistry, Vol. 47, No. 7, p. 1487ff.

³ASTM D756-501.

think they are, and the permissible manufacturing cost for a new type jacket acceptable to the industry would allow considerable latitude in design.

2. Recommended storage attitude should include specifications which would serve as a guide to manufacturers in developing designs for storage shelves for records. Such record shelves for libraries are badly needed by libraries throughout the country.
3. Record manufacturers would probably be interested in using selected materials for special "long-wear" pressings for libraries, in the future, if a demand for such premium records existed. There are so many libraries with sound disc collections that the investigators should consider the possibility of recommending the future development of better material for such specific use.

Dr. McCutchan reported on the chemical literature search. Emphasis was given to the basic differences in degradation mechanisms between the plasticized nitrocellulose composition of acetate discs and the rigid plastic of vinyl discs which present independent problems. It was pointed out that (1) these changes can result from a chemical reaction with an environmental constituent or a self-reaction incited by the environment; (2) the environment can provide activation energy (in the form of heat or light), oxygen, traces of harmful acids, and water vapor; (3) there are three ways in which the polymeric material can undergo chemical change which would be reflected in change of physical properties:

1. Chain scission.
2. Cross linking.
3. Sidegroup modification.

Other changes might result from the gain or loss of other than polymeric constituents (such as volatile solvents or plasticizers).

The vinyl discs were discussed first. While thermal decomposition mechanisms are not completely understood, it was pointed out that it is assumed to follow this pattern:

1. Evolution of hydrogen chloride (linear reaction).
2. Formation of carbonyl group (chain reaction).
3. Evolution of hydrogen chloride (chain reaction).

This autocatalytic reaction is accelerated by ultra-violet light and is probably due initially to small amounts of terminal unsaturation and is inhibited by stabilizers used in record manufacture. The chemical tests proposed to measure susceptibility to degradation and amount of degradation are for the presence of hydrogen chloride, carbonyl group, and unsaturation. The expected results of this chemical action are chain scission and cross linking, which would result in embrittlement, shrinkage, "mud cracking", and changes in

mechanical properties. Atmospheric oxygen seems to increase the rate of evolution of hydrogen chloride which initiates the reaction.

It was also noted that nitrocellulose lacquer discs can lose plasticizer, which induces warping and embrittlement, without a change having occurred in the chemical nature of any of the component molecules. The nitrocellulose, itself, is so unstable that one cannot form a judgment of the significant mechanism of degradation from the literature alone. Hydrolysis of cellulose derivatives (accelerated by high temperatures and residual acids) causes chain scission. Denitration was mentioned as a significant parameter and it is proposed to study this parameter by the standard techniques of correlating instability (or degradation) to vaporized decomposition products.⁴ The peculiar odor of acetate records was mentioned and it is proposed to attempt to determine what volatile constituent produces this odor. The change in color of transmitted light of the lacquer film will also be investigated as a possible indicator of chemical change.

Dr. Bieberdorf reported on his investigation of the effects of fungi. Fungi had been found on degraded records supplied by the Library of Congress and records have been exposed to fungal attack at the Institute. Three modes of action by fungi were noticed:

1. Fungi living and reproducing on the record.
2. Fungi living on the record but requiring an auxiliary site for reproduction.
3. Fungi living and reproducing on an auxiliary site but etching the record with their waste products.

It was felt essential to prevent fungal growth on records or on organic materials in contact with the records. This can be done by controlling humidity below 70% R.H. and by using fungicides in record jackets. In order to permit control of this parameter in stacks, where humidity is not controlled, it was decided to seek a fungicide which would be inert towards the record material and could be incorporated in the record jacket. The cardboard jacket and separator in common use seem to provide excellent culture media for numerous varieties of fungi.

Dr. Lemcoe outlined the conceptual considerations which resulted in the test design for vinyl discs. Predicated on the linear visco-elastic properties of the material (which will be investigated) the time-temperature superposition theory⁵ (or method of reduced variables) will be used to convert the time scale of tests at elevated temperatures to form a master curve of deformation vs. time at ambient temperatures under stress fields similar to various shelf storage conditions. The stress superposition theory will also be investigated using the same data. From these tests it is hoped that valid predictions of warp from gravity loads can be predicted for long periods and

⁴Scribner, B. W., "Summary Report of Research at the National Bureau of Standards on the Stability and Preservation of Records on Photographic Film"

⁵Tobolsky, Arthur V., "Stress Relaxation Studies of the Visco-elastic Properties of Polymers", Jour. of Appl. Physics, Vol. 27, No. 7, p. 673ff.

that a determination of the effect of creep on sound fidelity can be obtained, in addition to information on optimum storage attitude. All equipment for these tests has been fabricated and calibrated and these tests will begin on delivery of vinyl records.

Dr. Prager reported on the creep study at Brown University. He said that little applicable creep data on vinyl co-polymers had been found and that there were two basic lines of thought. Kolsky felt that prediction of creep could be approximated by a simple measurement of elastic deformations and use of a simple multiplicative factor derived from experience. He felt, also, that residual stress was a far more important parameter relative to irrecoverable deformation than gravity loadings. Lee, on the other hand, was in favor of elastic analysis following empirical demonstration of linear visco-elasticity. For this approach, it will be necessary for the Institute to measure Poisson's Ratio and investigate the validity of stress-superposition of vinyl discs in advance of such mathematical analysis. He also hopes to obtain the results of residual stress measurements from the Institute at an early date, and mentioned the excellent mechanical support furnished by a cardboard jacket, as well as possible disc warping induced by warping of the cardboard jacket. The proposed coordination of activity between laboratory work at the Institute and theoretical analysis at Brown University is:

1. Measurement of stress superposition to justify assumption of linear visco-elasticity - Institute.
2. Measurement of Poisson's Ratio - Institute.
3. Mathematical analyses of irrecoverable deformations by elastic theory as justified by laboratory findings - Brown University.
4. Laboratory comparison of mechanically and chemically induced deformations - Institute.

Dr. Spivacke reported on record procurement. The remaining acetate records have been cut and are being processed for shipment. The vinyl discs have been pressed by Allied Record Company and have been shipped from California. Shellac discs have been placed on order. Actual costs of test records will be somewhat in excess of original estimates. The Decca answer to the questionnaire, which included formulations from 1946 through 1958, was presented as well as correspondence from other recording companies who will furnish such information. It was agreed that Institute personnel would prepare an outline of tape requirements in the near future if advance procurement of materials could be made.

Laboratory equipment and apparatus were inspected. The records exposed to fungal attack, the creep fixture and chamber, temperature and humidity cycling apparatus, and playback equipment were inspected.

A general discussion and recapitulation followed. In resume, the future program was outlined as follows:

1. Laboratory Studies at Institute.

- a. Measurement of effects of accelerated aging induced by elevated temperatures at various humidity levels.
- b. Measurement of effects of temperature and humidity cycling.
- c. Measurement of effects of chemical exposure.
 - (1) Ultra-violet radiation and oxygen.
 - (2) Sulphur dioxide.
- d. Search for chemical stability tests.
- e. Search for a satisfactory fungicide.
- f. Measurement of effect of creep and residual stress on vinyl discs.

These studies will be directed toward correlation of cause and effect instead of a study of basic mechanisms. Major test parameters will be measured by playback testing design to detect:

- (a) dimensional changes which affect playback
- (b) embrittlement
- (c) surface cracking

as reflected in noise and distortion characteristics as well as other changes in fidelity.

- 2. Dr. Prager will await the results of Institute measurements of Poisson's Ratio and stress superposition before proceeding with an exact theoretical analysis of irrecoverable deformation resulting from gravity loads and residual stresses.
- 3. The program will be generally directed towards:
 - a. Establishing criteria for optimum thermal and moisture environments, (air conditioning).
 - b. Design jackets (and/or envelopes) for record storage on a scientific basis (including fungicide, reconditioner, mechanical support, etc., as required).
 - c. Establish criteria for shelf storage attitude and support.
 - d. Establish tolerance limits of sulphur dioxide above which alkaline scrubbers should be used.
 - e. An endeavor to obtain data for prediction of useful life of records in shelf storage.
 - f. Evaluation of means of reconditioning embrittled or warped recordings.

Respectfully submitted,

M. M. Lemcoe

M. M. Lemcoe, Manager
Strength Analysis Section