I. TECHNIQUES FOR MEASURING TRANSPORTATION AND HANDLING ENVIRONMENTS; II. AVAILABLE LITERATURE AND HOW IT MAY HELP PACKAGE DESIGNERS

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ABSTRACT

This report contains the text and figures used in two presentations made at the University of Wisconsin in March 1970 during a symposium on transportation environment.
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I. TECHNIQUES FOR MEASURING TRANSPORTATION AND HANDLING ENVIRONMENTS
(Shock, Vibration, Temperature, and Humidity for All Modes of Transport);
II. AVAILABLE LITERATURE AND HOW IT MAY HELP PACKAGE DESIGNERS

Introduction

This report is the text of two presentations made on March 18, 1970 at the University of Wisconsin, Madison, Wisconsin.

These presentations were two of seven talks which centered about the theme: "Transportation Environment - Its Measurement and Protective Systems."

The topics covered in these seven talks were as follows:


II. "The Role of the Department of Transportation in the Shipping Environment," by Byron Nupp, Assistant Director, Office Policy Review, Department of Transportation, Washington, D. C.


IV. "Product Design and How It Should Be Coordinated with the Packaging Engineer," by George W. Kahler, Jr., Plant Engineering, Western Electric, Kansas City Plant.

V. "Techniques for Measuring Transportation and Handling Environments (Shock, Vibration, Temperature, and Humidity for All Modes of Transport)," by Jerry T. Foley, Sandia Laboratories, Albuquerque, New Mexico.

VII. "The Use of Moisture Vapor Barriers, Dessicants, and Corrosion Inhibitors for Protection of Packaged Articles," by Frank J. Rubinate, U. S. Natick Laboratories, Natick, Massachusetts.

A number of requests have been received for a written record of the remarks made in talks V and VI. This report was written to fulfill these requests and to serve a permanent record of these presentations.

Theme of Presentations

The abstracts of these two presentations serve to outline the approach taken. They are given in Appendix A. The material sources from which the author's remarks were derived are given in Appendix B.

Each slide used in the presentations is reproduced here as a figure preceding the related text.
This morning, I will talk about field-test techniques, that is, the kind of test techniques from which we obtain the environmental definitions which Fred Ostrem showed you yesterday. Although some of the material I will use to illustrate field-test techniques will be associated with instrumentation (some of it rather simple and some rather complex) I want to stress at the outset that I am not endorsing a particular manufacturer of instruments to the exclusion of other instrument manufacturers. Further, I am not implying that since I selected and used a particular system of instrumentation to record environments that this is the only system that can do the job.
1. What are your test objectives?

2. What depth of analysis are you going to perform to satisfy (1)?

3. What measurement accuracy is needed to perform (2)?

4. Any further uses of data contemplated other than (1)?

Figure 1. Checklist for Determination of Test Techniques

I hope to show you this morning that test techniques should be based upon such considerations as your test objectives, how sophisticated your analytical methods will be to satisfy your test objectives, the degree of flexibility you wish to retain in the data to perform alternative analyses, and the degree of accuracy with which you must measure the time parameter to satisfy the requirements of immediate interest and your analytical procedures. I believe that when you have determined the answers to the questions in Figure 1 you will find that your have almost automatically defined the instrumentation requirements and techniques which you may employ in your particular field test effort.
1. Research
   a. For design (modeling)
   b. For test levels (laboratory)

2. Demonstration
   a. Qualify design of package
   b. Determine quality of package

3. Surveillance
   a. Damage (legal implications)
   b. Quality (cost effectiveness)

Figure 2. Test Objectives

After listening to the speakers yesterday and the subsequent panel discussions, I outlined the general objectives for measuring the field environment which we have heard proposed at this symposium.

With the exception of damage assessment objectives, I believe you will see in the examples I will show you some of the techniques which can be applied to satisfy these objectives.
1. Climatic Environments
   a. Temperature
   b. Humidity
   c. Pressure
   d. Precipitation
   e. Wind

2. Dynamic Environments
   a. Shock
   b. Vibration
   c. Acceleration/time histories
   d. Acoustic noise
   e. Trajectory

Figure 3. Climatic and Dynamic Environments

Here are some of the specific environments I will discuss, separated into the two very general categories of climatic and dynamic environments. Of these, the ones least touched upon will be those of trajectory and wind.
Two basic characteristics of a transport medium are those of inputs to, and responses of, a system. Input is defined as the environment acting at the interface of the transporting vehicle and the package. Response is defined as the environment within the package. These are the two system characteristics which can be measured in a transportation test of packaging.
Two basic environmental parameters which can be measured are intensity and time. One can say, then, that a field test of packaging environment can only measure inputs to the package and responses of the package in terms of environment intensity and time. With the ability to measure only these two parameters, what can we do with these measurements? The environmental analyst has two basic analytical tools he can use: auto-correlation and cross-correlation. These terms are merely expertise for a simple form of logic.
We see that the term auto-correlation can be equated to the term self-comparisons, and the term cross-correlation equated to the term separate comparisons. Since the environmental parameters which can be measured in a transportation test are intensity and time, it would seem to follow that one can only make comparisons of environmental intensity and time. To me, this is the foundation upon which all environment testing techniques are based: that of measuring various inputs and responses and then making comparisons of environmental intensities and times.
Certain conventions have been adopted in making comparisons of environmental intensities and times primarily because these conventions make it possible to apply mathematical techniques. One of the most usual conventions to use is to consider intensity versus time characteristics. When one adopts this convention, called an intensity-time history, the terms auto-correlation and cross-correlation may take on the following interpretation: auto-correlations are comparisons of a single intensity-time history, and cross-correlations are comparisons of intensity experienced by two or more intensity-time histories.
Figure 8 is an example of a simple auto-correlation technique wherein, for a single package response measurement, the environment intensity measured at one time of occurrence is compared to the intensity measured at another time of occurrence. Now, suppose I divide one of these intensities by the other to give the value of these ratios over the entire time length of my data record, trying various time intervals. I think it would be evident to you that, in this example at the specific time spacing shown, the numerical value of this ratio will approach 1. When this happens, we obtain a definition of the period of time in which the data repeats itself, and therefore we have the length of time which represents all the variations in intensity we observed throughout the measurements.

This is only one auto-correlation technique. There are many others which are far more efficient and require the use of computers, but they all have one basic limitation: they tell us many things about a single input or response, but nothing about how this single input or response is related to any other input or response that may be occurring in the test system.
The purpose of cross-correlation is this relating between two time histories. In the simple cross-correlation example given in Figure 9, I am attempting to illustrate that one can compare the intensity variation of two system parameters at the same time. The mathematical logic might be the same as for the auto-correlation example given in Figure 8, that of computing the ratio of intensities. However, in this cross-correlation, the ratio values I obtain are a reflection of the degree of protection afforded by the package and also of whether this degree of protection is constant or is changing during the test period. Again, this is just one cross-correlation technique; there are many others.
I think these examples are representative, as a general illustration, of the history of development of test techniques over the years. In most of the older transportation tests, only hand or desk calculator forms of auto-correlation and cross-correlation could be performed because the time constants of test instruments were long and the calculating speeds of computers were low.

As time-measuring efficiency of instrument systems increased and calculation speeds of computers increased, the analyst was able to improve the efficiency of his analytical techniques and in many cases apply interpretative techniques on computers which could only be expressed in mathematical theories a few years ago. I look on the great majority of present-day test techniques as being based not upon measuring just the intensity of environment but intensity and time, with time requirements being the most important requisite in determining the testing techniques for a given test.

By way of a more direct example of time implication, consider Figure 10. I have shown the two generalized environment categories, climatic and dynamic. Note the difference in the time parameter table for these categories. Time constants of climatic environments are quite long; they range from days to minutes. Dynamic environment time constants, on the other hand, are very short; they range from seconds to microseconds. From this comparison, one can conclude that climatic environments should require slower measuring devices than dynamic environments; and for the most part, they do. The difference is in how accurately one must measure time. By the way, did you notice that a word-form of cross-correlation analysis was just performed on this time information? I shall now discuss test data using worded forms of auto- and cross-correlation techniques.
I have tried to select data examples which cover climatic environment measurements, and for transportation modes, I have selected some examples from truck, rail, and aircraft field research tests to illustrate how various input and response measurements can be used to determine the environmental aspects of these transportation modes.
This is a photograph of the instrumentation system utilized in these tests. It consists of a platform containing a battery supply and a camera which was originally a motion picture camera but was reworked so that it would expose only one frame of film at a time. The camera is taking a picture of the vertical board on which are a series of indicator lights, a wrist watch, and an ammeter. This system is capable of accepting the responses from six thermister (a form of thermocouple) measuring transducers.

The sequence is as follows. Transducers are placed at selected input and response points throughout the transportation system being measured, and the readings from each location are recorded on film. When one of the transducers is queried by the system, a light corresponding to the position of that transducer is lighted in the row of indicator lights. The camera shutter is opened by the timer, and the camera takes a picture of a clock time and the meter reading. Through calibration, one is able to interpret the meaning of the meter reading in terms of temperature in degrees Fahrenheit.
The data reduction technique consists of visual reading of the reduced film. One just reads the meter value off the pictures and records the values and the clock time at which the numbers occurred.

This temperature recorder was developed approximately ten years ago, and it still sees occasional use. It has been utilized in measuring the temperatures experienced in the bays of cargo aircraft, the temperatures experienced in train shipments in the summer and in the winter, and the temperatures experienced in truck shipments in the summer.
Figure 13 shows the temperature data obtained during the field test of a 40-foot trailer van during summer shipment in a desert climate. Two system parameters are plotted: van ceiling temperature variation versus time and cargo package surface variation versus time. This is a time comparison of the effects which occur between a point a considerable distance from the package and the input interface to the package. The purpose is to determine whether something between the van ceiling and the cargo case provides an insulating effect. A cross-correlation of these data indicates that one can depend upon little or no protective insulation from something between the van ceiling and the surface of the package. An auto-correlation indicates a very definite cycling tendency at the package interface. A second cross-correlation indicates that this cycling effect is also reflected in the air surrounding the cargo package.

The conclusions to be drawn are that (1) input to the package in a trailer van of this type equates to the air temperature surrounding the package and (2) there is some cycling aspect to this environment which should be investigated to determine its source.
Figure 14 shows temperature data taken during a winter train shipment. Again, two parameters are plotted: the air outside the rail car and the inside air 3 feet above the floor. Cross-correlations of the data would indicate that (1) one can expect little or no protection of the cargo from this type of rail car and (2) the cyclic tendency of the data is produced by climate variations.
Figure 15. Summer Train Shipment, Car Finish - New White Paint

As shown in Figure 15, these temperature measurements were taken in a rail car which had been painted with a particular type of white paint. Note that there is a lesser response of the air 6 feet above the floor and a lesser intensity of environment experienced at the input interface of the cargo packaging. Cross- and auto-correlation evaluations of these data lead one to conclude that transport vehicles coated with special paints may offer a considerable degree of protection to the package that is being transported by the vehicle.
Figure 16. Flight Temperatures

Figure 16 illustrates how much protection may be afforded by the aircraft mode of transport. The air temperature outside the aircraft is on the order of -50°F to -60°F. The temperature of the skin ranges from +20°F to -20°F. The variation in cargo space air temperature is from +50°F to 5°F or 10°F. Cross- and auto-correlation examinations of these data show that the aircraft is a very large heat source in itself; it has a long thermal time constant. Even though the aircraft is exposed externally to extremely low outside air temperatures, sufficient heat functions are provided, such as heated air spaces within the cargo compartment or the fuel carried by the aircraft.
These comparisons and analyses, which I have made visually, apply primarily to the particular test situation and type of cargo. Our concern was the thermal properties of the particular package and transporting vehicle. Now, there is no guarantee in any given field test that these properties are representative of the worst condition or worst forcing function that may be present under all transportation conditions. By way of example, the temperature variation in the rail car with the white paint (see Figure 15) indicates that the fluctuating climatic temperature range experienced was between +105°F and +60°F. We know, from weather records, that higher temperatures can occur.

Let us then consider additional usages of these data. One can mathematically model the rail car in terms of heat transfer characteristics, using the various thicknesses of material, coefficients of heat transfer of the various materials, and the geometry of the overall package and its contents. After this has been done, one can use the air temperature measured at, say, 6 feet from the cargo or closer to drive the mathematical model of the cargo and find out whether the model predicts the internal temperatures that were measured in the test. In other words, one uses the data to validate a modeling technique for the overall system. Once this has been done, one may model other cargos with this technique, changing the climatic inputs to worst-case conditions and predicting the responses that the worst case would produce on other cargos. This technique is commonly used not only in thermal evaluations but also in shock and vibration evaluations. This technique saves one from having to take new test data. The only time one would take new data would be when the data taken in a test did not prove to be of the same order of magnitude as the environment intensity and duration of the condition of interest. Thus, by utilizing analytical techniques, which may range from simple calculations to complex computer models, one may solve not only a problem of a particular test or define a response of a given package, but also apply these data to other situations and cargos.

Now some words about the humidity environment: I consider the humidity environment a second-order environment because in general it is measured indirectly in terms of dry bulb/wet bulb or dew point temperature. In addition, it seems that little useful information is obtained by measuring system input and cargo response humidity parameters and performing cross-correlation analyses on the data. The humidity environment experienced in transportation is one in which only response-measuring techniques appear to yield useful information. Some of the techniques with which I have had some success are measuring relative humidity variations within a package by use of transducers to directly measure moisture content versus time or indirectly by measuring temperature variations versus
time within the package, or measuring the highest humidity value experienced during transport using passive change-color type elements.

The choice of testing technique is more directly related to the particular package design and purpose of the package design and has little application to predictive modeling methods. If the package design is of the vapor barrier type, then passive measuring elements inside the barrier can be employed to determine how effectively the package design has provided protection. Collection of a large amount of this kind of data will permit use of statistical predictions of the quality of a package design in a transportation medium. If the package utilizes breathing valves in conjunction with desiccant, that is, metal-type containers with pop-off valves for air transportation, then temperature-response data from temperature tests, similar to those I have illustrated, can be used in conjunction with thermodynamic equations to predict desiccant quantities needed to maintain a requisite moisture level. Humidity test methods, then, are based on the purpose of a particular test; they relate to a specific packaging design and exclude most of the potential modeling prediction uses of the data but still offer help through statistical prediction techniques.

These single-purpose tests are the most common types of tests performed as opposed to the research examples which I have shown you on the temperature environments. There are, however, combination purpose tests that can be performed. As my concluding example of test techniques, I would like to show you an example of such a dual-purpose dynamic environment test which integrated both particular packaging and research purposes in one test effort.
Figure 17 shows the cargo used in the dual-purpose dynamic environment test. It consists of a one-quarter size cask and a tiedown system for transporting radioactive fuel elements to nuclear reactor power plants. It weighs 15 tons. During development of this cask system by the Nuclear Division of Union Carbide Corporation, Paducah, Kentucky, under contract to the AEC, it was necessary to demonstrate that the cargo system would not fail in normal modes of rail and truck transport and that it would provide the required containment of radioactivity. Union Carbide decided to combine these test requirements by shipping the empty cask system on a rail car to Oakridge, Tennessee, for radiation tests and after the tests return the system to Paducah on a truck.
The AEC, through previous contact with the Sandia Environmental Criteria Group, was aware of the research activities this group sometimes conducts in the field and suggested to Union Carbide that mutual benefit might be derived from this transportation test. Union Carbide thereupon extended an invitation to Sandia's criteria group to participate in the test on a noninterference and separate-funding basis. We have data on rail environment taken under worst-case conditions, but it is always of interest to have at least one additional environment definition to help determine how large the variation in environment is from an average to a worst-case type situation. We already had a developed and proven instrumentation system for testing of this nature and, since we decided not to use all the data channels, Union Carbide was able to instrument and measure response parameters of their system which otherwise would not have been possible.

*Results of this rail test will be presented at a technical symposium by M. B. Gens, a member of the Sandia Environmental Criteria Group.
Before conducting a field test, one must know what the order of magnitude of the intensity of environment is going to be. If one does not have this information to within an order of magnitude, one cannot set the recording instruments to measure the intensity. If one guesses high, the data will be in the noise level of the instruments, and if one guesses low, the instruments will saturate and the highest intensities will not be measured. A solution to the problem, if data are not available from similar type tests, is to pretest and take gross intensity measurements.
The instrumentation system used in pretesting the Union Carbide experiment is shown in Figure 18. Accelerometers were attached to the frame of the caboose of a freight train, hooked into the meter through appropriate signal conditioning equipment. In this way, the experimenters who were riding in the caboose were able to identify the order of magnitude of environment intensity to be expected and also cross-correlate various gross intensities observed with activities of the train, such as starting and stopping, run-in and run-out, crossing switches, bridges, and also identifying at what mile post marker or near what mile post marker these activities occurred.

From the pretest, we knew the range within which we should set our instruments in the fully instrumented test and we knew at what points during the trip we should take detailed samples of the environment. This is very important in transportation shock and vibration research because the time constants one operates on in performing cross- and auto-correlation analyses require measuring intensity variations within durations on the order of microseconds. Although computers and instrument systems can handle time constants such as these, to handle many of them is costly. Since computer time costs are in the order of hundreds of dollars an hour and several hours of computer time may be required to cross-correlate a few data samples of 10 seconds duration, one must be selective at the outset as to the number of analyses to make.
Figure 19 shows the fully instrumented flat car used in the Union Carbide test. The test group rode in a caboose which was attached to this car. The three-man group consisted of a Sandia environment analyst who decided when the instrumentation should be activated, a Sandia instrumentation engineer who controlled the operation of the instruments on the car by radio and repaired the gear at division stops if needed, and an official of the railroad company who assisted in finding mile-post locations in the middle of the night and informed us when to expect run-ins and run-outs. He also contacted the engineer of the train and the conductor by radio and delivered our requests to operate the train in a manner such that certain event measurements could be made.
Figure 20 is a closeup of the various points at which measurements were taken. Union Carbide measured such things as tiedown strain, and internal cask pressure, and Sandia measured such things as the inputs to the tiedown system and the points at which input accelerations and forces were produced at the interface of the flatcar and the cargo. A cross-correlation of these data provides a piece of information called apparent weight. Not shown in Figure 20 are the Sandia measurement points of input to the car frame at the interface of this car and the next car and the Union Carbide measurement points of pressure variation within the cask and the acceleration responses of the cask at the skid-to-cask interface.
Figure 21. ELI 31 Recording System

All of these measurements were fed into the recording system shown in Figure 21. This system records all inputs and responses simultaneously on 14 channels of magnetic tape which permits cross- and auto-correlation analyses to be performed at a later time. Also shown in Figure 21 is an instrumentation system which was used in this field test for the first time. This system is one-third the size and about one-quarter the weight of the older system. The reason for its use was that the pretest revealed an order of magnitude intensity difference in environment in switching yards. This required an instrumentation system with a different intensity measuring sensitivity setting. Note also in Figure 21 the emergency battery and the light panel which verifies to the radio operator that his commands are being followed and that each recorder is in operation. The box in the foreground contains the radio receiver and the push-button test lights which permit the instrumentation engineer to test all system functions quickly in a trouble-shooting mode.
Now I would like to discuss the handling phase of packaging and in particular the shock environment produced in dropping and/or bumping and jouncing packages in activities associated with hand-carrying, fork-lifts, stradle carriers, carts, and dolly-type transfers.

Most handling environment field tests take the form of shipping a package which contains a recorder which records the environmental response of the recorder in the package and, in some cases, the response at various locations within the package. These are measures of package responses. We can, therefore, describe the response characteristics of a package by use of the two correlation techniques, but we have no knowledge of the nature of the input environment which produced that response. We do not have a way of obtaining data which can be applied to other packages. We can, however, by adopting a slightly different convention of measuring and evaluating the environment, obtain what might be called a pseudo cross-correlation measurement. We measure, not intensity versus time, but the product, that is, intensity times time. An accelerometer output versus time may show a time history as given in Figure 22.

Figure 22.
We measure the acceleration times time characteristic of the data which has the dimensions of velocity. Or, in a pseudo cross-correlation sense, if we postulate conservation of momentum of the system, we have the input velocity change which the package experiences when dropped. Since the system works in the gravitational field of the earth, we can compute, using a simple calculation, from what height the package must be dropped in order to have been exposed to that velocity change. The problem now is this. By taking sample observations of the heights of loading docks and truck beds and how high packages bounce in transportation modes, we know how far they can be expected to fall, and we can compute the same input velocity change without having to take detailed field measurements. This pseudo cross-correlation tells us nothing new about the system. If we could instrument both the surface which the package struck and the package response from within the package simultaneously, we might obtain data which could be applied to other packages using modeling techniques. However, until we find a way to do this, there is no point in measuring drop-type environments in the field on a research basis. The present state of the art of in-package recording instrumentation, however, does appear to have a good potential for evaluation of quality of a given package through the use of statistical prediction techniques similar to those I have outlined in the discussions on humidity.

Concerning fork-lift, hoisting, and dolly-type handling environments, we have worked out an approximate technique for obtaining usable research data. This consists in instrumenting the pallet upon which the package rests, as well as instrumenting the response area of the package. A pallet has been designed, fabricated, and evaluated in a pretest. However, shortly after the taking of measurements was started, the research program was terminated.

In conclusion, the following check list may be useful in deriving testing techniques. I have discussed test purposes, the system inputs and responses to be measured, and the analytical techniques to be used. I have stated that if auto-correlation techniques are used the data will be restricted to specific test uses and package information. I have pointed out that cross-correlation techniques offer an opportunity to use data for other applications. Lastly, I have shown how accurately time must be measured.

Check List for Determining Testing Techniques

1. What are the test objectives?
2. What depth of analysis will be performed to satisfy (1)?
3. Are any further uses of the data contemplated other than (1)?
4. What measurement accuracy is needed to perform (2)?
Text of Remarks on

AVAILABLE LITERATURE AND HOW IT MAY HELP PACKAGE DESIGNERS

Information search and retrieval involves three steps: (1) consulting the available literature; (2) talking to others working in the same field; and (3) taking data oneself.

The subject discussed so far this morning has been the third step, taking data oneself. However, I have presented some illustrations showing how to interpret data because this is not only a part of determining the test methods, but also a part of interpreting available literature. My suggestion is that, in looking for transportation environment definition information, instead of searching the literature for a direct answer to a specific design problem, you search the literature for sources which specialize in defining the input environment and then adjust this information to your specific package design. In my endeavors in information search and retrieval and in operating a retrieval system, I have found that, in general, it is most helpful to isolate a few information retrieval systems, indicate where transport environment information may be found within those systems, and then choose representative documents to illustrate the information which may be useful.

Two information search and retrieval systems contain information about transport environments. One is the Shock and Vibration Information Center which is operated by the Naval Research Laboratory for the Department of Defense. It specializes in dynamic environments, but it is also a source of transportation information from other U.S. government agencies such as NASA, the AEC, and the Department of Transportation. In addition to its search and retrieval facilities and a service to persons asking specific questions concerning specific problems, this Center sponsors a symposium every year at which a session is devoted to transportation environmental problems. In these sessions and in the published papers which result, you will find most of the transport environment information which can be associated with inputs to packaging.

The second information retrieval system which can be utilized to find information on climatic environmental inputs is the system operated by the Institute of Environmental Sciences. This group also has annual meetings and publishes the proceedings thereof. Another facet of the Institute is that it conducts tutorial sessions at its annual meetings.
which run parallel to the presentations of the technical papers. These sessions give persons who are not specialists on environment sufficient background so that they can be more aware of what the experts are talking about in their presentations.

I have selected examples of the types of papers that are available from these two systems and primarily those which have been written by Sandia personnel (see Appendix B).

By way of illustration as to what these two sources of information might do for you in terms of cost savings, consider the following example. Most large companies have an organization which handles all outside requests for technical reports. At Sandia, this organization is the Office of Industrial Cooperation. This group publishes an index of those reports which have been released by Sandia to the public. The instructions accompanying the index state that to obtain these reports one should write to

The Clearing House for Federal Scientific and Technical Information
National Bureau of Standards,
Springfield, Virginia.

Each report costs $3.00.

Another group at Sandia operates a specialized search and abstracting system for use by researchers and special data bank operators. It is called the Environmental Engineering Abstracts System. Abstracts are published bimonthly. They also may be obtained from the Clearing House for Federal Scientific and Technical Information.

If you examine these environmental abstracts to find what reports are available that describe transport environment inputs, you find the great majority of abstracts dealing with the subject are abstracts of papers presented at the two symposia I have already referred to.

I have used this example to illustrate that with regard to useful literature about transportation environments, a point of diminishing return is very quickly reached.

Now, Mr. Kellicutt has some things to say about design technique literature, so I'll turn the podium over to him. Mr. Kellicutt - - - -
APPENDIX A -- ABSTRACTS

I. Techniques for Measuring Transportation and Handling Environments

Techniques for measuring transport and handling environment in the field appear to be almost limitless in number.

This seemingly infinite variety in measurement techniques is the end-result of interplay between the burgeoning field of engineering analysis, the constantly inventive instrumentation industry, and the exploding field of computer technology.

With regard to packaging, today's field testing techniques, instrumentation, and analytical methods can, for the most part, be identified as operations performed to describe either or both of two basic characteristics of a packaging system, through the measurement of two basic environment parameters.

The talk to be given will identify these two basic packaging system characteristics, the two environment parameters, and through use of examples, show how specific techniques were applied to obtain these measures of packaging in the transport environment.

The talk will be presented from the viewpoint that the purpose or purposes for which tests are conducted determine the specific analytical techniques and instrumentation to be applied.

Since research tests reflect perhaps the greatest variety of purposes attempted within a given test, tests of this nature will be used to illustrate various measurements and analysis techniques.
II. Available Literature and How It May Help Package Designers

Solution of the information search and retrieval problem can be viewed as a progressive three-step method:

1. Consult the available literature
2. Talk to others working on the subject
3. Take data yourself

The information explosion has made it difficult, if not impossible, for an individual to wade through all publications available to isolate information that may be pertinent to his particular problem. It is this situation that often precipitates the use of Step 2 to a limited degree, and the plunge into Step 3 as a desperation (and sometimes expensive) solution.

This talk proposes that, as a problem becomes more and more specific-product/package oriented, available literature will rarely, if ever, provide a complete, satisfactory solution.

It is proposed that, instead of searching the literature for an "answer" to a specific package design problem, in the case of transportation environment information, the literature be searched to locate (1) sources specializing in defining the "input" environment and (2) sources describing analysis techniques which permit "transforming" data to fit other packaging situations.

A list of information retrieval systems in which such information may be found is provided, rough guidelines as to how to locate the information within these systems are discussed, and certain representative specific documents are illustrated.
APPENDIX B -- SELECTED PUBLICATIONS

Shock & Vibration Information Center

Foley, J. T., Preliminary Analysis of Data Obtained in the Joint Army/AEC/Sandia Test of Truck Transport Environment, February 1966, pp. 57-70.


The Shock and Vibration Digest, 40th Symposium Issue, The Shock and Vibration Information Center, Naval Research Laboratory, Washington, D.C.
Proceedings of the Institute of Environmental Sciences

Bennett, Maxwell, *A Case for Low Impedance*, pp. 79-82.

Dodd, Arthur V., *Considerations in Revision of Army Climatic Criteria*, pp. 571-574.


Harley, R. A., *Impromptu Vibration Data Acquisition with the ELI-31 Recorder*.


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