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ABSTRACT

A SERIES OF PROPOSED
LABORATORY EXERCISES

By

John Charles Dargis

Seven laboratory proposals are presented which deal with subject material pertinent to the field of packaging. Proposal one concerns itself with the presentation of some of the basic parameters of statistics including concepts of central location, standard deviation, t-test and statistical analysis. The theories behind and characteristics of stress-strain analysis of packaging materials is the subject of proposal two. Proposal three deals with packaging materials as a barrier against water vapor transmission and the construction of isotherm moisture content curves. The bursting test, edge crush, flat crush and top to bottom compression strength encompass the physical testing of corrugated paperboard in providing the basis for proposal four. Proposal five presents the qualities and physical test values of recycled paper. Qualitative values are compared in the making of recycled paper while varying ratios of recycled to virgin fiber constitutions of paper are brought out through several physical tests including

bursting strength, stiffness, tearing resistance and tensile strength. The materials and construction of three common plastic packages--the skin, blister and shrink packages--are examined in proposal six. The basic gas laws and their application to the aerosol package system comprise the contents of proposal seven.

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DEDICATED TO

MY PARENTS FOR THEIR UNFAULTERING AND UNQUESTIONING SUPPORT

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INTRODUCTION

Packaging laboratories have come under the scrutiny of both faculty and students. Although opinions have varied from person to person and from time to time, it is generally held by all that packaging laboratories should reflect the conditions and needs of the industrial world (with which the school of packaging so closely associates) as well as the interests of students and faculty. It may even be implied that the medley of labs existing in packaging now could eventually be superseded by industrially oriented, initiated and sponsored work-study arrangements. Since the realization of such arrangements is some distance away, this thesis is but a step in that direction by proposing revisions and additions to what exists now.

The packaging laboratory proposals were compiled from a variety of interest and informational inputs. As a teaching assistant, the author became aware of the shortcomings of packaging labs through both his own observations and feedback from students who he instructed in lab over the terms. Coupling many conversations with faculty members in packaging and the author's own research into literature reflecting the current movements of industry pertaining to packaging, this thesis was able to take substantive form.

The roots of many of the following proposals stem from Packaging 422 Lab, Packaging 321, and it's precursor--the old Packaging 320 Lab. In essence, the proposals are limited primarily to materials and material testing, but contain many branching implications for further didactic laboratory situations. To enhance the evaluative input of students concerning these labs, an attempt was made to obtain objective data from them by means of an attitude survey. The details of this survey may be found in Appendix A.

Students have experienced confusion over ASTM Standards, how they came about, and just how they are intended to be used in packaging. Many of the following proposed exercises will incorporate reference to or in some way employ the use of ASTM Standards.

The American Society for Testing and Materials is an international nonprofit, technical, scientific, and educational society which has developed more than 4,700 standard specifications for the methods of testing materials (1973 ASTM[1] figures). The mainstream of activity flows through more than 115 main technical committees which insure a balanced representation among producers, consumers, and general interest groups, i.e., universities and independent laboratories. There are some 33 volumes, reviewed or revised each year, covering specifications and test standards for materials such as paper, leather, steel, and cellular plastics, to name a few.

The use of ASTM Standards is purely voluntary. In fact, cases do arise where the use of ASTM Standards are more restrictive than needed. Usually a new test procedure, or the modification of an old one, begins in a laboratory. Many test procedures are used to predict the performance in use of the material undergoing test. Thus, agreement among different laboratories concerning the proposed test method becomes a necessary although not always sufficient, criterion of a good test procedure. The initiating laboratory has the responsibility of varying the test conditions from the nominial specified values to find out what happens. If the laboratory finds it necessary to set and hold the relevant conditions within very narrow limits in order to achieve good repeatability, the usefulness of the test may be seriously limited. It should be demonstrated that results will not be altered by departures from specified values of the test conditions that are likely to be encountered when using routine equipment (say from one laboratory to another). In other words, a good test procedure must not be too sensitive--it must tolerate departures from the specified conditions as stressed by Youden[2]. Interlaboratory testing (repeatability) then becomes a confirmation of the claims made by the procedure, obtaining results acceptable within the limits of some set standard deviation. From here the procedure is then reviewed by the appropriate ASTM technical committee for acceptance.

Many of the ASTM Standards are highly technical and laborious for the average reader. For the purposes of lab exercises it is not necessary to know all the information contained in each standard cited. The purpose of reading the ASTM Standards is to obtain basic knowledge concerning the structures and operation of the material testing equipment, an understanding of calculations using the test data and a feeling for the significance of the test. The easiest way to understand each standard is to read the standard, run several tests and then analyze the data. A point should not be made to concentrate on sections concerned with test equipment specifications or test equipment set up.

PROPOSAL 1: STATISTICS

I. Any laboratory or exercise worth its salt involving data gathering utilizes statistical analysis to some degree. This is because statistics functions as a mathematical way of formalizing the amount of information while decreasing the number of computations for some experimental data. Statistics is also a way of summarizing comprehensive data. Finally, statistics allows conclusions about some pool of data (population), with a stated error of probability, to be made without measuring all the elements of that population.

Thus, the examination of some of the basic parameters of statistics is most appropriate for a proposed first lab exercise, as well as a tool to be used for ensuing exercises. To consider some of the quantitative aspects of statistics within the framework of a laboratory exercise, several guidelines must be contemplated.

A. Only the basic parameters (not necessarily the simplest) of statistics should be explored. Most packaging students, especially beginning and visiting students from industry, have either forgotten or had limited exposure to statistical methods. What is more, most laboratories obtain maximum information using just these basic parameters.

B. The "idea" of statistics frightens most students because of their vague notions of what it is and what it can do. They many times cloak it with an aura of mystery. The basic parameters of statistics should be presented in such a way as to avoid the students apprehension and puzzlement over the subject.

C. The interests of both items A and B may best be served by presenting statistics within the framework of examining and measuring some quantitative aspect of packaging. In this way, the student could functionally learn statistics without ever realizing it is indeed statistics he is dealing with.

D. It is suggested that as an example of the quantitative aspects of packaging, the specification and measurement of bottle cap diameters be considered. Of course this may be expanded to include any number of other packaging dimensions or package component dimensions, such as glass bottle or metal can specifications, film or board thicknesses (ASTM D585-68[4], ASTM D645-67[5]), or paper specifications (ASTM D685-44[3]). The choice of "what" to measure will depend on what is readily available at the time in terms of quantity and ease of working with the dimension.

II. The following are the proposed parameters of statistics to be considered with a laboratory framework. Each is functionally defined, explained or used in the context of the lab.

A. Definitions of population and sample.

B. Methods of finding central location--mean or average of sample ($\bar{x}$), mean of population (u), median (m) and mode.

C. Frequency distributions.

D. Measurement of dispersion or variation--standard deviation.

E. Test of a statistical hypothesis, null hypothesis, t-test, level of significance and knowledge of how to use the table of critical values of t.

F. (optional) The normal curve, x and z scales, confidence intervals and knowledge of the table for normal curve areas.

(For an elaborate examination of the above parameters, the student should refer to Crow ct. al.[6], Freund and Williams[7], or Koosis[8].)

III. Functionalization of Statistical Parameters

A. The stage is set by asking each lab group to view itself as a representative of a company in the production of glass bottles, seeking to contract for a supply of bottle caps. Four sets of bottle caps are distributed which represent sample sets from four different bidding suppliers. They, the lab group, are to determine whether or not these sample sets satisfy required diameter specifications. (The cap specifications may be given to each group at the beginning of the lab, say 30 mm.)

1. Each cap of each set is measured in mm. The sample sets may vary from 10 to 50. (This of course depends on how much time and how many caps are available.)
2. Each sample set of measurements could be plotted to yield a frequency distribution.

(The student has now been exposed to concepts of population, sample sets, data gathering and frequency distribution.)

B. With data now gathered, it is a natural step to next determine the central location of the data followed by measuring dispersion or variation of that same data. This may be accomplished by simply presenting the mathematical notations for both mean ($\overline{x}$) and standard (s) deviations of sample sets and ask the student to calculate these values. The equations could be presented in this way:

1. $\overline{x} = \frac{1}{N} (x_1 + x_2 + ... x_N) = \sum_{i=1}^{N} x_i$

   This reads the summation of x_i (x_i being a bottle cap within a set) i going from 1 to N, where N denotes the sample size.

2. $$s = \sqrt{\sum_{i=1}^{N} \frac{(x_i - \bar{x})^2}{N-1}}$$

Being interested in the size of the deviation of our data from the mean, and not their signs, the student can first square the deviations and then average their squares.

C. The mean ($\bar{x}$) and standard deviations (s) may be calculated for all four sample sets. This gives the student some novel information but it is of little value unless put to use. To do this, each lab group may be asked to perform a statistical test for each sample set of bottle caps. This will determine if the sample average ($\bar{x}$) of each sample set is significantly different from the original specification of the desired cap size.

1. Students are asked to compare ($\bar{x}$) to their original specification (A) i.e., H_0 (null hypothesis) becomes $\mu = A$. (It should be mentioned that the null hypothesis is called such because we make the initial assumption that there is no difference between μ and A. Then we go about testing if there is a difference.)

2. The t-test provides the student with information concerning the validity of the comparison:

$$t = \frac{\bar{x} - A}{s/\sqrt{N}}$$

3. The student has already worked with $\bar{x}$, s and N and is given A (the specification). He may then calculate a t-test value for all four sample sets.
4. To use these calculated t-test values the student must familiarize himself with the table of t-test values. If the absolute value of the t-test calculated value is not greater than the t-test value found in the table, then H_o is not significantly different from A, the original specification. All four sample sets may be tested in a like fashion to determine the validity of H_o or $\bar{x} = A$.
5. Since the normal curve is the cornerstone of modern statistical theory, it may be apropos to introduce the table of normal curve areas. This is a bit of powerful information to know, since the probability of getting a value between two numbers is given by the corresponding area under the curve. In order to use the table of normal curves, the student must be given didactic information concerning the difference between the x scale and the z scale employed by the table.

6. Five practice problems have been included which give the student exercise in using basic statistical parameters. They have been arranged in order or presentation of the parameters within the lab and may be found in Appendix B.

IV. It may be argued that a lab in statistics is not necessary since it is already presented in other packaging courses. It could also be said that if statistics is to be used in lab, why not introduce it in a step fashion over a series of labs.

There are no laboratories that are absolutely necessary, only ones which are beneficial. True, statistics is represented in other packaging courses. However, their presentations vary according to content, approach and style. Moreover, it cannot be denied that statistics is illusive with a high priority, among students, to be forgotten. A laboratory on statistics provides a functional approach geared for laboratory use.

To present statistical parameters in a series of labs allows for better familiarity and ease of understanding if an initial introduction has been made to begin with. It has been the experience of the author that if this is not the case, the main themes of succeeding labs are often superseded by confusion over employing statistics. The following lab proposals incorporate statistical techniques to some degree, but only after the student has had the opportunity to more fully explore these techniques in the fashion of an introductory lab in statistics will he better understand them.

PROPOSAL 2: STRESS-STRAIN ANALYSIS

I. Stress and strain characteristics (particularly the tensile properties of flexible packaging materials) are of value for the relative comparison of one material to another. From time to time, feedback received from people in industry has indicated the wide range and importance of material tensile values. It should be stressed that tensile tests will indicate, not predict, material performance. Evaluations by producers of new materials depend, in part, on the measurement of tensile properties. However, tensile values will vary with changes in the test method. The standardization of tensile test methods, then, becomes a crucial issue.

In Packaging 321, some of the basic elements of stress strain theory were presented. This was to serve as the theoretical network explaining load deformation curves produced by the Instron Testing Machine. However, students hesitated to experiment with the machine without a few procedural guidelines. The Instron literally "looks" too complicated to use, even when the student is armed with the theory to explain load deformation curves. In view of what had been discussed, the following are proposals for a restructured lab on stress strain analysis.

A. A brief presentation, in the context of the lab exercise, is a necessary beginning. It should concern itself with the following:

1. Hooke's Law, F = kL; this alone alludes to tensile stress, strain, elongation and Young's Modulus (elastic modulus).
2. Differences between shear stress and normal stress.
3. Concepts of elasticity and plasticity. This encompasses the proportional limit, elastic limit, yield point and modulus of elasticity.
4. Fracture characteristics--differences between ductile and brittle materials, fatigue fractures.

(For a more elaborate examination of the above concepts, the student could familiarize himself with Jastrzebski[13], Modern Packaging Encyclopedia[14], and Stevenson, *et*. *al*.[15])

B. To actualize the contents of part A, each lab group may run load deformation curves for five representative flexible packaging materials in accordance with ASTM Standards D828-60[9], D638-71[10] and D882-67[11]. It is suggested that these materials be considered for demonstrating different load deformation curves: kraft paper, aluminum foil, polyethylene, cellophane and polystyrene. Once these materials have been tested and load deformation curves secured, the students may identify, explain or calculate the following:

Breaking Factor

Tensile Strength

Tensile Strength at Break

% Elongation at Break

Yield Strength

% Elongation at Yield

Elastic Modulus

C. To alleviate confusion and the feeling of being "swamped" with quantitative analysis, it would be to the best interests of the student to present or include a stress-strain curve with sample calculations as a model. Polyethylene nicely demonstrates all necessary points of reference.

D. There has been much confusion on the part of the students, over the operation of the Instron Testing Machine. Complete instructions have never been proposed for the procedural operation of the Instron. This has been attempted and reflects on the student as someone who is more than just a button pusher and dial twister. Explanations of the intrinsic functioning of the machine (Instron Corp., Operating Manual[12]) serve to back operational instructions. In this way, the student will hopefully become more appreciative of the consequences or effects of manipulating controls. It is also a frequent complaint by students that "cookbook" operational instructions can become offensive to the student, serving only to diminish his sense of competence. A presentation of operating instructions for the Instron (found in Appendix C) stands as a suggested model, attempting to take into consideration what has been discussed above.

E. Another source of confusion stems from the lack of comprehending effects of the differences between crosshead motion and chart motion. This necessarily leads to some adjustments in calculations derived from the chart. The following examples are suggested to clarify this important point.

1. In most standard load elongation tests, the crosshead speed does not equal the chart speed. Since the curve is a representation of what happens to a sample between the jaws of the crosshead mechanism, and since all informative data is taken from the curve, certain calibration factors must be considered to adjust different speeds between crosshead and chart.

   Elongation: For example, if the crosshead moves at .5 inches per minute and the chart moves at 20 inches per minute, for every one inch the jaws move apart, the pen moves along the x axis of the chart 4 inches. To find elongation of a sample, it is necessary to multiply the distance the curve extends along the x axis by the factor:

$$\frac{\text{CROSSHEAD SPEED}}{\text{CHART SPEED}}$$

Thus, if the distance along the chart is 3.75 inches, the elongation of the specimen is:

$$\frac{5}{20} \times 3.75 = 0.94 \text{ inches.}$$

This means that although the pen traveled a distance of 3.75 inches along the x axis, the actual elongation of the sample in the jaws was 0.94 inches.

2. For each test, the full scale load setting determines the number of pounds required to deflect the pen full scale. Less than full scale deflections are a proportionate part of the full scale load.

   LOAD DETERMINATION: For example, if the full scale load is 50 pounds, and the pen is deflected to a chart reading of 6.8 at failure of the sample, the load at failure is:

$$\frac{6.8}{10} \times 50 = 34 \text{ pounds}$$

II. In essence, this exercise accomplishes three things:

A. It acquaints the student with elementary stress-strain theory.

B. The theory is applied in testing various flexible packaging materials and identifying various characteristics of their consequent load deformation curves.

C. The student becomes familiar with standard procedures of testing tensile strength and the operation of the Instron Testing Machine.

PROPOSAL 3: WATER VAPOR TRANSMISSION

The permeation properties of materials is of obvious value to packaging people, particularly those involved with food packaging. Not only may the product within the package change or be transformed from exposure to water vapor, but the fundamental characteristics of the packaging material may change as well.

The lab taught in Packaging 422 concerning water vapor transmission was, to be charitable, weak in methodology. This has been perhaps the most confusing of all packaging labs which led the student to constant erroneous and inconsistent results. The primary reason for this is that it attempted to do too much with too little. Both individual and component water vapor transmission tests were correlated with total package water transmission rates and then to predictions of shelf life. Knowing the water vapor transmission of package components when comparing one material to another is helpful in depicting which material is the better barrier against water vapor. But other factors, such as sealing effectiveness, fabrication, fluctuations in environmental conditions, and handling make water vapor transmission values for components of little value for predicting ultimate shelf life.

Accelerated testing (exposure of package to superimposed extreme environmental conditions) of component package materials is of some value in predicting shelf life *if* they can be correlated with actual previously run field tests. However, field tests yield results highly specific for each particular package, are time consuming, expensive and for practical purposes, beyond the scope of a packaging lab at this time.

Moreover, the accelerated conditions utilized by the cup test (ASTM E96-66[16]) have come more and more under the scrutiny of industry. According to Peter[18] and Wood[20], a test taking three or more days is inconveniently slow for quality control purposes and absolutely useless for production control. As a consequence, more companies, especially major cereal producers, are reverting to new advancements in the measuring of water vapor transmission. Devices exist now, employing a sensitive infrared hygrometer, which measure water vapor permeance (and other vapors and gases as well) in a matter of seconds and with a precision that the cup test could only hope to approach.

Perhaps part of the reason the cup test has survived as a standard method is due to the conservatism and inertia within the paper and packaging world. However, the cup test does have one significant advantage stemming from the fact that permeance determinations are based upon fundamental parameters of temperature, humidity, time, weight and specimen area as Wood[19] asserts. On the assumption that all these factors can be accurately measured and controlled, the cup test stands as a method that, in principle, should not require calibration against some reference standard. It seems likely that the School of Packaging will in the future acquire such an apparatus for quickly and accurately measuring permeation of vapor and gases not only for instructional use, but for more efficient research as well. Until then, however, the cup test may still remain a functional method for introducing the student to the material properties of permeation, some of the problems involved in obtaining meaningful measurements of permeation, and the concept of the effect of environment (primarily temperature and relative humidity) upon the permeation characteristics. In light of the above discussion, the following revisions are suggested:

A. Have students obtain two (2) samples each of the following materials:

1. Glassine
2. Wax Coated Glassine
3. Paperboard (non-coated)
4. Laminated Paper-Foil
5. 1 mil Polyethylene
6. 1 mil Cellophane

Here we have a wide range of commonly used packaging sheet materials which surpasses the limited selection of materials used in the permeability lab of 422. There should be twelve samples in all. Test these samples according to ASTM

Standard E96-66[16] procedures C and D. (One set of samples will be under conditions of low humidity and high temperature, while the other set of samples are subject to conditions of high humidity and high temperature.)

B. Weighings should be made twice a day until the requirements of the method are satisfied. Instructions should be included right in the lab for proper use of the Fisher Gramatic Balance. (These instructions already exist, being part of the old Pkg. 320 lab manual.)

C. As directed in section 15 of ASTM E96-66[16], plot the results of successive weighings against elapsed time. Also calculate water vapor transmission, permeance and average permeability (Also found in section 15). This should familiarize students with the differences in permeability between various package materials and under different environmental conditions.

D. To equate total package permeability with concepts of accelerated testing, the student could follow this course of procedure:

1. Either provide, or have students bring to lab, four unit packages of the same size, construction and containing the same product (small cereal packages are good sample units). Two of these packages are to be used under room

conditions, two are to be used as experimental samples.

2. At the beginning of the lab, place one container in each of the two humidity cabinets with the specified environmental conditions set by procedures C and E of ASTM E96-66[16]. Also at the beginning of the lab, open a third box and remove enough contents to take a moisture reading (% H_2O by weight) on the Cenco Moisture Balance under room conditions. Record these results.
3. Toward the end of the lab procedure, the student may remove both sample boxes from the humidity cabinets. Take another moisture reading on the Cenco Moisture Balance for each of the two products which were in the humidity cabinets. Also make another moisture reading on the contents of the fourth box which has been kept in the lab under room conditions.
4. Note and compare the difference between moisture readings of all four samples. The two samples in the humidity cabinets have been exposed to accelerated conditions (an attempt to simulate accelerated environmental conditions).

E. Isotherm moisture content curves may be included to correlate moisture content with relative humidity and temperature. These curves clearly demonstrate that, depending on the temperature of the surroundings, moisture content of the package contents, relative humidity of both the headspace within the package and the air surrounding the package, water vapor may be absorbed by the package contents to establish equilibrium. In cases of moist products or extremely dry (low relative humidity) surrounding, the package contents may yield moisture to its surrounding atmosphere to reach equilibrium. The curves also demonstrate that water vapor transmission is not necessarily constant over time. An isotherm moisture content curve may be constructed by students using the following method.

1. At certain temperatures and when confined to a closed space, certain chemicals when in contact with a saturated aqueous solution will demonstrate a specific % humidity.
2. Air tight testing jars may be employed to individually house saturated solutions of the following:

	% Humidity (At approximately 20°C)
Phosphoric acid ($H_3PO_4 \cdot 1/2\ H_2O$)	9
Lithium chloride ($LiCl \cdot H_2O$)	15
Potassium acetate ($KC_2H_3O_2$)	20
Calcium chloride ($CaCl_2 \cdot 6H_2O$)	32
Potassium carbonate ($K_2CO_3 \cdot 2H_2O$)	43,44
Ammonium Phosphate ($NH_4H_2PO_4$)	93

(For additional information, See General Chemical Tables in Handbook of Chemistry and Physics[17])

3. After several days are allowed for the solutions to come to equilibrium with their confined atmosphere, dry cereal (perhaps corn flakes) may be introduced into each chamber. After exposure to the testing jar conditions for several days, the product may be removed and the moisture content determined using the Cenco Moisture Balance. A curve of moisture content vs. humidity may now be constructed.

F. The manufacturing of component test samples using the test dishes and dessicant, involves the use of molten wax in establishing a water proof seal. The wax, if too hot, allows at best a clumsy application, as the wax will run all over the sample in most cases. It should be stressed that if the temperature is kept low enough, a point will be reached where the wax still melts but high viscosity is retained. In such a state, the wax will not run over the sample surface destroying it for permeability measurements. Instead, a very neat seal can be made. Related to this, it is a common misfortune of lab instructors to be left at the end of a term with a pile of wax coated dessicant dishes. This condition may be promptly alleviated if it is required that each lab group hand in 12 cleaned dessicant dishes along with their results.

Essentially, the student has been familiarized with the water vapor transmission of several packaging materials under two different accelerated environmental conditions. The Cenco Moisture Balance was employed to demonstrate the effects of the same two accelerated environmental conditions on the total package contents. Finally, the effects of humidity on moisture content were introduced in the construction of an isotherm moisture content curve for one particular product.

PROPOSAL 4: CORRUGATED PAPERBOARD TESTING

I. Nearly every product used in our lifetime is packaged in a box, the vast majority of these being corrugated containers. Corrugated paperboard containers are mass produced to match the mass produced goods they protect. According to the Handbook of Corrugated and Solid Fiberboard Boxes and Products[27], the production of corrugated is even an indicator of the overall "health" of our economy.

One major problem in the corrugated paperboard industry and experienced by many (Buchanan[26], Oates[27], Wachuta[28]) who, in packaging, have found their way into the corrugated paperboard industry, is one of specification and lack of standardization. Not only does board size, caliper, basis weight, quality, etc., vary from one manufacturer to another, but quantitative test results such as the puncture test, edge crush, flat crush, etc., also vary. (As a contrasting example, the steel industry has rigid standards when specifying sheet metal. For instance, one may predict with good certainty that the supply will arrive having a certain weight, caliper, tensile strength, finish, etc.) For corrugated paperboard there are no standard machine settings nor any established ranges of similarity between one manufacturer's board to another. The corrugated box supplier can change the facing weight, medium and adhesives as he sees fit.

Up to now, corrugated paperboard has been represented in packaging labs as another packaging material on which several ASTM tests could be applied. These tests produced results which, to the student, were somewhat less than meaningful. The student did nothing with his results save produce them. The following proposals are intended to correlate certain test results on corrugated board to that unique situation which the student is likely to encounter in the packaging world, that of specifications.

A. Four test methods may be employed in evaluating a sample shipment of corrugated board. These tests include bursting strength, flat crush, edge crush and whole box top to bottom compression strength. A hypothetical problem will lie in determining whether the results of these tests performed on the given samples correlate with given data for each test supplied by the instructor. It may be assumed, as a hypothetical situation, that for each test a given range of values is desirable and that this range favorably reflects upon the specified use of the board. In other words, the corrugated paperboard from one manufacturer has proved competent in packaging uses. The four standard tests mentioned above were applied to the competent board to yield certain sets of results. These specifications for each test are given to the student. A new shipment of corrugated paperboard is in question. Samples from this new supply are tested to determine whether or not they meet the specifications of the previously used competent board.

1. One of the most important properties of the corrugated paperboard is compressive strength. The mechanical strength of corrugated paperboard containers may be classified into one or the other categories of rough handling (including vibration and shock) and stacking strength. It also serves as a useful index to the overall quality of the fiberboard materials and the workmanship in corrugated and box shop operations.
2. Experiments have shown (Wachuta[30]) that the box reaches its maximum load when the combined board fails at or near a corner of the panel. In as much as the corrugated paperboard in this region of the box is essentially flat (by comparison with the central region of the panels) both liners and corrugated medium are approximately uniformly stressed in edgewise

compression. For this reason, the edgewise compression strength of the corrugated paperboard (in the direction of the flutes) is of primary importance to box strength.

3. The burst test (Mullen Test) has been included primarily due to its wide spread use and the paper industries' persistence in perpetuating this test. The results of this test depend on the materials used and not on the structure of the corrugated paperboard. For this reason the burst strength is of little use as an indicator of case performance if one is interested in compressive strength. However, the burst test is easy and quick to carry out and it is an indication of the ability of cases to contain contents such as cans, as Buchanan[26] suggests.

4. The flat crush is a different test altogether. It is not directly correlated with compression tests but evaluates the resistance of flutes in corrugated paperboard to a crushing force applied perpendicular to the surface of the board. Low flat crush values may indicate poor formation of corrugations, substandard materials or damage to corrugations after they are formed.

B. Test specifications may be given to the student in a number of ways. This will necessarily imply the use of a few statistical techniques such as those found in exercise #1.

1. The student could simply be given the average value and standard deviation for some population of values for one particular test. All ensuing tests on the sample board for that same test would have to yield values 95% of which must lie within say two standard deviations of the given mean to be acceptable. For example, a student could be given that for a specified corrugated paperboard and container construction, the average compression strength is 589 pounds with a standard deviation of 42 pounds. 95% of the students test values would then have to be within 84 pounds of the given mean in order for the board to be accepted.

2. Taking a reverse approach to the one above, students could perform the tests and derive their own sample averages ($\bar{x}$) and standard deviations (s). Now, given some specification value (A) and a level of significance (α), the student could reject or accept his sample values on the basis of the t-test. For example, a specification (A) for the Mullen Test could be given as 200 psi. The student may then test to within a level of significance

of 0.05 whether or not there is a correspondence between the given specification (A) and the average sample test values.

3. The average value for some test may be given with imposed plus and minus limits. In this instance, 90% of the students' test values may fall within the established limits of the specification to be termed acceptable. For example, a specification for edge crush for single wall B flute corrugated paperboard might be 175 lbs./in. ± 25 lbs.

C. For compression strength the Baldwin-Emery SR-4 Compression Testing Machine may be used in accordance with ASTM D642-47[22]. A lab in Packaging 422 dealt with the making of corrugated paperboard containers followed by simulating shipping conditions using the inclined impact (or Conbur) test. In simulating shipping conditions one is talking about primarily shock and vibration. The Conbur Test is grossly inferior to the shock and vibration tests developed over the years. However, corrugated container construction has merit in introducing the student to handling corrugated (Handbood of Corrugated and Solid Fiberboard Boxes and Products[27]), figuring box dimensions and score allowances (BRDA Technical Bulletin, No. 4[25]). For this reason, it is proposed that corrugated paperboard container construction be retained as an exercise in itself and as a means of producing samples for compression testing.

1. The dimensions of the sample boxes may be uniformly set by supplying the student with, for example, a glass bottle. The corrugated paperboard container could then be constructed to contain 12 of these bottles--3 wide and 4 deep. The bottles are then used as both a means of determining the box dimensions and as a means of testing the "fit" of the container once it has been constructed.
2. To be of any significance, it is advisable to have ten or more compression values. It would be expensive in both time and materials used, for each student or group to manufacture 10 or more corrugated containers. It is suggested that each student or group construct one or two such containers to be used collectively in one compression test schedule.

D. For the edgewise compressive strength of corrugated paperboard the National Forge Compression Testing Machine may be used in accordance with ASTM 2808-69[23].

E. For flat crush of corrugated paperboard, the National Forge Compression Testing Machine may be used in conjunction with ASTM D1225-66[24]. It is also feasible that the Instron Testing Machine, if set up for compression testing, could also be employed as an alternative in performing flat crush tests.

F. For measures of bursting strength, the Model D (Jumbo) Mullen Tester may be used with ASTM D2529-68[21]. Although the ASTM Standard does not specifically apply to the measurement of corrugated paperboard, the general measuring procudure may be used.

II. A science has burgeoned over the past years from attempts to empirically relate edge crush values with compression test values and establish a compression strength formula for corrugated containers (Buchanan[26], Wachuta[29] and Wachuta[30]). Such a correlation and formula would greatly enhance the predictability of corrugated container performance. This could constitute an appropriate part to any lab exercise dealing with corrugated. However, as of this time there are conflicting reports and somewhat less than precise evidence about the topic. Until some consensus is established and recognized, such information would be better suited in a lecture context.

III. In summary, the student has been introduced to corrugated paperboard and major standard tests of corrugated board--mainly the flat crush, edge crush, bursting and compression test. The tests are operated within an experimental specifications paradigm in which the student's test values are compared or correlated to given specification values. Several statistical techniques can be employed to make this comparison. During the course of the tests, the student also becomes familiar with corrugated handling, scoring and techniques of container construction.

PROPOSAL 5: PAPER AND RECYCLING

I. Paper, in all forms from newsprint to the finest writing paper, is largely wood which has been reduced to cellulose fibers by chemical or mechanical means and rearranged into a sheet form. Carr[38] pointed out, as the waste problem increases and availability of virgin materials decrease, productive nations all over the world are finding it increasingly economical to recover and reuse wood fiber products. This has been the main drive behind the use of recycled materials, one among them being recycled paper. In addition, current movements in the concern for ecology and conservation have sponsored some pressure to use recycled (secondary) fiber products. Recycling has captured the public imagination and recycling research programs are quite naturally prime material for news headlines. The packaging industry uses a substantial portion of paper and paper products. It also contributes to the solid waste problem. In response to packaging's involvement with solid waste, pollution and the environment, an entire course, Packaging 340, was developed to study just this issue. Also, the characteristics and processes of paper and paper manufacturing comprises a portion of packaging 320. Since paper products will continue to be a major packaging material, the purpose of this proposal is to focus on some of the properties of general importance concerning virgin as well as recycled paper.

II. The Council on Economic Priorities recognizes the Groundwood Process as oldest and simplest pulping method. In this strictly mechanical process, raw materials are pressed against large rotating corrugated stones, discs or blades under a flow of water. The abrasion pulverizes the raw material by physical force until it is reduced to fiber bunches. These are flushed away, pressed, matted and dried into a sheet. Groundwood is the cleanest, cheapest and least harmful pulping process. From the standpoint of pollution control, groundwood is the optimal process (The Council on Economic Priorities[39]). (However, because mechanical grinding tends to bruise and rupture the fibers, the paper produced by this method is of lower quality--less tear resistance and tensile strength, for instance--when compared to paper produced using other chemical processes.) To introduce students to the effects of beating and different constituents of recycled paper, it is suggested that students utilize the Valley Iron Works Groundwood pulp beater.

A. Various beating times may be crossed with several "raw" materials.

Table 1: Various Raw Materials At Different Beating Times

(raw materials)		(beating time in minutes) 15	30	45
	100% newsprint			
	100% brown paper			
	50% newsprint 50% brown paper			
	100% virgin pulp			

Brown paper in the previous table refers to old kraft grocery bags, wrapping paper, old corrugated, etc.

B. After each beating, the water may be drained and screened through a fine wire mesh leaving the fibers behind. The draining is accomplished via a brass drain plug and connecting hose located to one end of the water trough. The screening may take place directly over the drain tile in the lab floor. It is important that the fibers be distributed evenly across the screen and not allowed to collect in any one place. Shaking the screen while the water drains through it and pressing the final contents with any ridged flat surface should provide a relatively even spread of fibers. The screen may then be set aside to dry and the resulting sheets examined for qualitative differences due to different beating times and composition.

C. The orange colored lever, positioned by two lock bolts, adjusts the tolerance between the revolving blades and pulverizing plate through which the fibers flow. Increasing this tolerance tends to reduce fiber rupturing and bruising resulting in a larger proportion of longer fibers. The opposite is true of decreasing the tolerance. It is suggested that this adjustment be kept in the middle position. As an option, however, the student may wish to use blade tolerance as another variable effecting the beating process.

III. As the social and economic pressure to use recycled material increases, meaningful specifications for these recycled materials will become important. With paper and paper products, specifications of the percentage of recycled fibers can be deceiving. Recycled paper differs as a function of not only the level of recycling but also the quality and type of recycled fibers used. At this time, no standards exist which attempt to define or in some way correlate one recycled paper to another. Because of the many variables involved, it is extremely difficult to microscopically differentiate a recycled fiber from a non-recycled fiber (Van Huysen[42]). In fact this reflects more of an art than a science for in most cases the differentiations reduce to judgemental calls based on experience.

It is suggested that we turn from identifying fibers to physical testing in an analytical procedure to provide a basis for comparisons of paper materials. The form of the physical testing (Britt[37]) is familiar and will also serve the purpose of acquainting the student with various testing methods. If two samples of paper differing in constitution are tested for this difference, the testing methods should take on an added utility or value dimension. This value dimension was lacking in previous labs dealing with paper testing in that the student would run methodical tests and derive results which were not particularly meaningful or relevant with a pivot point of comparison. The following proposals are a result of the discussion above.

A. It would be naive to suggest obtaining paper samples made of 100% virgin pulp vs 100% recycled pulp. Rather, it would be more realistic to obtain a sample of paper whose constitution has a significantly higher proportion of recycled fibers to virgin fibers. Because of the problems of specifications already discussed, one would have to rely on the supplier for information pertaining to the amount and type of recycled pulp that was used in manufacturing the paper. However, this does not constitute a major problem when it is considered that the relative differences between materials are the basis for testing them.

B. It is suggested that the student acquaint himself with information on paper discussed in the Modern Packaging Encyclopedia[40] and by Britt[37]. The physical testing should be preceded by determinations of basis weight (ASTM D646-67)[31], caliper (ASTM D645-67)[36] and machine direction versus cross direction (ASTM D528-63)[34]. These values primarily coordinate samples and sample cutting.

C. The physical tests reflecting any differences between the samples may entail tensile strength (ASTM D828-60)[35], tear test (ASTM D689-62)[33], bursting strength (ASTM D774-67)[32] and bending stiffness (Taber Model 150-B, V-5 Stiffness Tester Instruction Manual)[41].

D. The physical tests may be applied to both types of paper--the one type containing a proportionally larger number of recycled fibers, the other types containing a proportionally larger number of virgin fibers. The compiled results, including sample means and standard deviations, may be quantitatively compared to distinguish differences.

IV. Through this exercise, the student has been given a functional introduction to recycled paper and paper testing. The effects of variable beating times and different constituent materials were examined in the production of paper sheets from recycled fibers. Also various test methods and apparatuses commonly used to determine properties of paper were employed in discerning differences between two sample papers of unequal recycled constitution.

PROPOSAL 6: PLASTIC PACKAGES

I. From a review of current packaging literature one can easily see the rapid increase in utilization of various plastics and their properties in the construction of shrink, skin and blister packages, (particularly in the packaging of foods as cited by Young[51]).

A. In the context of today's limited availability of corrugated paperboard and the relative availability and stable prices of plastic films, (recognized by Package Engineering[48]--particularly polyethylene), utilization of shrink packages has taken the most astonishing leap. The shrink wrapping of corrugated trays and entire pallet loads leads one to these advantages; reduced damage from over-the-road hauls, reduced moisture penetration, contour fit, (better stacking, especially with mixed cases), less pilferage, more supermarket selling space, cleaner cases and an excellent customer acceptance of shrink wrapped loads (Modern Packaging Encyclopedia[46] and Package Engineering[50]). The shrink film has become a standard method of packaging.

B. A close kin to shrink packaging, skin packs are also on the increase and they share many of the same advantages. Their unique importance is in immobilizing the product with skin tight fits (Lindell and Cook[45], Modern Packaging Encyclopedia[47]). This becomes a critical consideration in the packaging of small component parts or a mixed lot of products (Package Engineering[49]).

C. The contour fit of blister packs allows them to be primarily highly visible unit packs. Perhaps the largest increase of blister packaging in recent years has been sponsored by the pharmaceutical industry. According to Dean[43] this type of packaging is particularly preferred for convenience in dispensing and product security, i.e., the product is identified up to the point of use.

II. The School of Packaging has the machinery and many of the materials to construct all three types of plastic packages (skin, shrink and blister packs). Because of the increase in use of these forms of packaging and the continuing corrugated shortage, it is suggested that students become familiar with both the materials and machinery employed in forming these packages.

A. The Cryovac Shrink Tunnel may be used for the production of shrink packages. The heat shrink characteristic is usually built into the film during manufacturing by stretching under controlled conditions to create molecular orientation, or by locking the film in stretched condition by cooling

(Griffin and Sacharrow[44]). This stored shrink energy is released by heating to soften the plastic or melt the plastic structure, allowing the film to pull back toward its original position. Within the plastics industry, shrink films are often attributed with a "memory". In other words, when softened by heating, they try to assume their previous shape. In producing shrink wraps the student may be introduced to three different variables affecting the wraps; type of film, temperature and conveyor speed.

1. It is suggested that students work with the shrink properties of Polyvinyl Chloride, Polyethylene (crosslinked) and Polypropylene. Vinyl films are one of the more widely used shrink films. It has high shrinkability, high transparency, but only a medium barrier to gases and vapors (Griffin and Sacharrow[44]). Polyethylene films are used extensively for shrink wrapping pallet loads and are the most readily available film (<u>Modern Packaging Encyclopedia</u>[46]). Polypropylene possesses good barrier properties and high tensile strength (Griffin and Sacharrow[44]).
2. The student may vary the effects of temperature and conveyor speed control on the shrink tunnel. Each student can vary the controls until he

determines the most suitable shrink package for each film. To assist in this operation the student may refer to the film charts and graph located in the Modern Packaging Encyclopedia[46] under the section dealing with flexible packages.

3. To further explore the shrink characteristics of each film the student may measure for himself the percent of shrinkage. This may be accomplished by cutting one specimen (10 in. x 10 in.) of each of the heat shrinkable films and identify type, machine direction and cross direction of each with a grease pencil. Place each specimen between two pieces of chipboard (12 in, x 12 in.) and place the specimen and chipboard into a preheated oven 250° F for 10 minutes. Dividing the changed area by the original area and subtracting this result from 100% gives the percent change in total area of the shrink film. The procedure may be repeated at various temperatures (300°F and 470°F) for 10 minute exposures.

B. The skin package is normally made by using the product as a mold. A piece of plastic film is heated and drawn over the product by heat and vacuum. Acquired recently, the Trans-Seal (model SST-77) Skin Packaging Machine utilizes 5 1/2 mil polyethylene to produce skin packages. The operation of the machine is quite simple and safe.

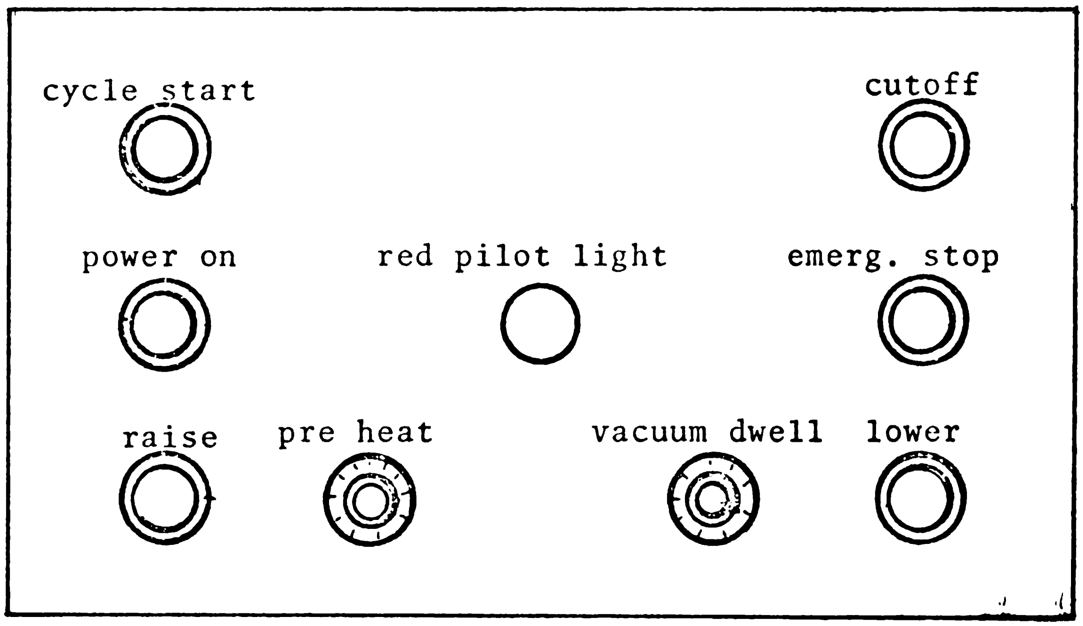

Figure 1: Control Panel (SST-77)

1. Push the green "power on" button and select preheat and vacuum dwell knob settings. Depress the green "cycle start" button. The bridge will rise carrying with it a section of shrink film. The product and appropriate backing material are now placed in position under the bridge. Once the polyethylene in the raised bridge ends its selected preheat cycle, the bridge will lower and form the skin package under vacuum automatically. Upon completion of the selected vacuum cycle, the bridge will rise once more to

allow the packaged product to be removed. When the skin pack is out from beneath the hood, press the yellow "cutoff" button. This serves to both free the package from the roll of polyethylene and reloads the carriage with new polyethylene sheeting for the next skin pack. The bridge holding the polyethylene may be manually raised and lowered by operating the blue "raise" or "lower" bottons.

2. The preheat time and vacuum dwell time are variables affecting the quality of skin packs. The student may apply different combinations of vacuum and preheat time settings in determining the most suitable skin pack for his particular product.

C. A blister package utilizes a preformed "blister" or "dome" made from a transparent sheet of plastic which is then usually sealed or otherwise placed on a paperboard or plastic card with the product inside. The Atlas Vac-Machine may be used to make blister molds. The variables here are type and thickness of film, vacuum time and heating time.

1. It is suggested that the student experiment with two films--polyvinyl chloride and cellulose acetate of two thicknesses ranging from 4 mils to 10 mils.

2. The student may again vary heating time and

vacuum time in determining the effects of this manipulation on the different films and thicknesses.

3. Vacuum formed blisters are usually thinner at the top but thicker near the base web. The distribution of thickness is in part determined by the depth and angle of the draw. Distributions of wall thickness can be checked by either measurements or the use of a graph like lattice marked on the surface of the film before heating. The degree of thinning is then indicated by the dimensions and distortions of the squares after the blister has been made. Strain within the plastic blister can be observed under polarized light.

III. Virtually anything that will fit through the shrink tunnel may be wrapped as long as it is not combustible or otherwise subject to degradation at the set temperature. The same thing holds for the skin pack machine also. The blister pack requires a mold. In some cases the product itself may serve as a mold, but in most cases a prefabricated mold which accommodates the product is used instead. For the shrink and skin pack it is suggested that the student bring to lab his own product and package it. For the purposes of the blister pack, several molds should be provided which demonstrate different draws, heights and angles.

IV. The student, in this exercise, has been given selected exposure to both the materials and methods used in the growing fields of shrink, skin and blister packaging.

PROPOSAL 7: AEROSOLS

I. There existed as part of PKG 422, a lab concerning the aerosol package system. There is no doubt the aerosols are a unique facet of packaging with a stable course of future development (Package Engineering[52]). However, having taught this lab several times, the need for several major revisions became prevalent to the author.

A. The first revision proposed is one of approach because the PKG 422 aerosol lab, as taught previously, emphasized fill methods while diminishing the construction and operation of the aerosol package. The lab was set up to assimilate essentially four different fill methods; the pressure fill, the piston fill, the cold fill and the compressed gas fill. The cold fill is seldom used by industry anymore. The compressed gas fill is limited to those aerosols intended for use in extremes of high and low temperatures where liquid propellants decrease in efficiency or become too dangerous to use (Sanders[54]). Moreover, the sophistication and quantity of different filling methods is changing by the day. For these reasons, it is proposed that the emphasis be shifted from filling methods to the aerosol package system. This may be accomplished by using three fill methods (pressure, cold and compressed gas fill) as an instructional tool in demonstrating the properties of gases and propellants in the aerosol system, rather than an end in itself. The subject of fill methods may be more appropriate within the context of lecture material or field trip seminars.

B. Because of this switch in emphasis, it is possible to cut down on material use by more than half and still maintain as much, if not more, information. The following is suggested:

1. In lab, the characteristics of five aerosol packages could be compared, which would be manufactured using two different fill methods. These two methods employ combinations of three different propellants (Freon 11, Freon 12, and compressed gas) with one common product (ethyl alcohol).

Fill Method: COLD FILL
Formulations: -20% propellant (50% Freon 12, 50% Freon 11)
80% ethyl alcohol

Fill Method: PRESSURE FILL
Formulations: -50% Propellant (30% Freon 12, 70% Freon 11)
50% ethyl alcohol
-50% propellant (70% Freon 12, 30% Freon 11)
50% ethyl alcohol
-compressed gas 50psig-50% ethyl alcohol

All percentages are by weight except for compressed gas. Here 50% of product (ethyl alcohol) refers to volume.

2. Notice that the ratio of Freon 11 to Freon 12 is held constant in the cold fill operation, while the ratio of propellant to product is varied. In the pressure fill method the ratio of propellant to product is held constant while the ratio of Freon 11 to Freon 12 is changed. The proposal is more concerned with the effects of these ratio changes (propellant to product and Freon 11 to Freon 12) than to the differences in fill method.

C. In order to understand the operation of aerosol packages, it is desirable to incorporate a few basic gas laws and functionally work with them in lab. Without this background theory, it is impossible to understand the intrinsic working of an aerosol package. The basic gas laws necessary should include: (The student should refer to Sanders[54] for an expanded presentation.)

1. Boyle's Law: The volume of gas is inversely proportional to the pressure if the temperature is constant.

$$V = k \frac{1}{P} \quad k = \text{constant} \quad (T \text{ constant})$$

2. Charles Law: The volume of a gas is directly proportional to temperature if the pressure remains constant.

$$V = kT \quad (P \text{ constant})$$

3. Ideal Gas Law: An expression that relates the pressure, volume and temperature.

$$PV = nRT$$

where P = pressure exerted on the gas
V = volume occupied by the gas
n = number of moles of gas (concentration)
T = absolute temperature
R = gas constant

4. Raoult's Law concerns the lowering of vapor pressure of a liquid by the addition of another substance. More specifically, the depression of the vapor pressure of a solvent upon the addition of a solute is proportional to the mole fraction of solute molecules in the solution. (It is also proportional to the solvent; solvent refers to the original liquid, solute to the material being added.) Mathematically, we may express this relation as:

$$P_s = P_1x_1+P_2x_2+P_3x_3+\ldots, \quad P_s = \sum_{i=1}^{N} P_ix_i$$

where P_s = vapor pressure of solution
P^s = vapor pressure of pure components
x = mole fraction of component

D. The main identifying characteristic and "power" behind any aerosol is its vapor pressure (Modern Packaging Encyclopedia[53]). The vapor pressure of an aerosol product is also an important property to know for insurance of safe transportation and use (Sanders[54]). For this reason it is suggested that each lab group calculate the vapor pressure of each formulation before actually manufacturing the aerosol. By so doing, the student demonstrates his ability to work with the basic gas laws. He will also become aware of the differences between compressed gas propellants and liquid propellants. In addition, the effects of varying the ratio of one liquid propellant to another becomes readily understandable.

After calculating what the theoretical vapor pressure should be for each aerosol, the student may then manufacture the aerosol and compare its actual vapor pressure to what was just calculated.

EXAMPLE: With these basic laws in mind, the student has a means of calculating the vapor pressure of any solution if he knows the composition of the solution, the molecular weights of the pure components and vapor pressures of the pure components in the following five steps. (Students may refer to Sanders[54] for more detail)

Step 1. The vapor pressures and molecular weights of the two propellants are as follows:

Freon 12	VP (at 70°F) = 84.9 psia	
	Molecular weight = 120.9	
Freon 11	VP (at 70°F) = 13.4 psia	
	Molecular weight = 137.4	

(psig-pound per square inch gauge; measures are set at 0 for one atmosphere (14.7psi). psia-pounds per square inch absolute; are measures of pressure where 0 is a vacuum. Thus, psia = psig + 14.7 psi, psig = psia - 14.7 psi).

Step 2. Assume 100 g of total solution. The moles of the two component propellants are obtained by dividing the component weights each respectively by their molecular weight.

$$\text{\# moles Freon 12 } \frac{90}{120.9} = .744$$

$$\text{\# moles Freon 11 } \frac{10}{137.4} = .078$$

Total moles in mixture = .822

Step 3. The mole fraction of each component is found by dividing the moles of each component by the total moles in the solution.

$$\text{mole fraction Freon 12 } \frac{.744}{.822} = .905$$

$$\text{mole fraction Freon 11 } \frac{.078}{.822} = .095$$

Step 4. The partial pressure of each component is obtained by multiplying the absolute vapor pressure of the pure component (Freon 12 = 84.9 psia, Freon 11 = 13.4 psia) by its mole fraction in the liquid phase.

partial pressure Freon 12

84.9 x .905 = 76.8 psia

partial pressure Freon 11

13.4 x .095 = 1.27 psia

Step 5. The total pressure is merely the sum of the component partial pressures

76.8+1.27 = 78.07 psia or 63.27 psig

One can see from this that by the addition of 10 g of Freon 11 to 90 g of Freon 12, we decrease the absolute pressure of Freon 12 by 6.83 psi (at 70°F).

E. Knowing density allows the student to determine the weight and volume of propellants and products that can be packaged in an aerosol container. Because Freon propellants boil at room temperature (21°C) and one atmosphere, propellants should be metered out directly into the aerosol can by either ml or cc for purposes of the cold fill. By using weight as a method of proportioning the propellant (as the aerosol packaging lab 422 suggested) the student disseminates too much of the propellant to the atmosphere in the weighing process. Thus, each lab group should use density in determining respective volumes of each component to be used in a formulation.

For example, to find the density of a Freon 12-114-11(50/30/20) mixture at 70°F, and the relative amount of each (by weight and/or volume) used in any fill method may be calculated as prescribed by Sanders[54].

Step 1. The densities of the components are:

Freon 12 - 1.32 g/cc
Freon 114 - 1.47 g/cc
Freon 11 - 1.48 g/cc

Step 2. Assume a total blend of 100 g. The volume in cubic centimeters (cc) contributed by each of the components is calculated by dividing the weight of the component by its density. For a 50/30/20 mixture by weight the following volumes may be determined.

Volume of 50.0 g of Freon 12 $= \frac{50}{1.32} = 37.9$cc

Volume of 30.0 g of Freon 114 $= \frac{30}{1.47} = 20.4$cc

Volume of 20.0 g of Freon 11 $= \frac{20}{1.48} = 13.5$cc

Thus, to formulate this mixture, one must add 50 g (or 37.9 cc) of Freon 12 to 30 g (or 20.4 cc) of Freon 114 and 20.0 g (or 13.5 cc) Freon 11.

Step 3. The total volume of this 100 g blend is simply the addition of the volumes of each individual component:

37.0 cc + 20.4 cc + 13.5 cc = 71.8 cc

Step 4. Since density is mass/volume, the total density of the blend is the weight of the blend divided by the total volume of the blend.

$$\text{Density of Blend} = \frac{100.0\ \text{g}}{71.8\ \text{cc}} = 1.39\ \text{g/cc}$$

II. The gas laws are presented in theory in Packaging 320 lecture, however, they are not used in practice or application. This exercise has suggested that they be presented once again for the explicit purpose of explaining two operative functions. The first has been mentioned already (the intrinsic workings of an aerosol package). The second function is that of the lab procedure itself. The student will now realize the premises behind techniques, such as changing a gas to a liquid by lowering the temperature which is the basic machinery of the cold fill. He will also note that the same results may be obtained by application of pressure on a gas, leading to the technique of pressure filling. Moreover, the different characteristics of the propellants and their effects on one another will come to bear more meaning. A greater awareness of the possibilities and implications of the aerosol package to the manufacturing and consumer world would, hopefully, result.

APPENDICES

APPENDIX A

ATTITUDE SURVEY

The following questionnaire was designed to elicit evaluative, judgmental feedback from students pertaining to two lab courses: Pkg 422 lab and Pkg 321 lab (or the revised 320 lab before it became independent and Pkg 321). The questions, administered in the spring of 1974 to students familiar with the courses in question, were as follows:

> Concerning lab 422 only, please rate on a scale of 1-5 how much you enjoyed or liked participating in the 422 labs (8 in all). A response of 1 indicates this was the LEAST enjoyable lab. A response of 5 indicates that this was the MOST enjoyable for you. A response of 3 indicates an AVERAGE lab--one which you neither enjoyed or disliked. A response of 4 indicates a SLIGHTLY ENJOYABLE lab and a response of 2 indicates a SLIGHTLY DISAGREEABLE lab.

1. Lab #1: Container Construction and Measurement (Paperboard cartons--set up box, folding carton)
2. Lab #2: Container Construction and Measurement (Bags, wraps, overwraps)
3. Lab #3: Blister, Skin and Shrink Packages (use of plastic films)
4. Lab #4: Aerosol Package System
5. Lab #5: Measuring the Efficiency of Packaging Systems (glass bottles and caps)
6. Lab #6: Cereal Packages and Water Vapor Permeability Tests

7. Lab #7: Corrugated Shipping Container (glass bottles with or without partitions in RSC's)

8. Lab #8: Examination of Gases in Packages, Gas Chromatography

Using the same rating scale of 1-5, please consider each lab in 422 again, from the point of view of most information gained or conveyed by the experiment. A response of 1 means that you derived the LEAST information from this lab. A response of 5 indicates that you learned a lot from the lab, or it conveyed to you the MOST USEFUL information. A response of 3 indicates an AVERAGE informational content, a response of 4 indicates informational content value SLIGHTLY ABOVE AVERAGE and a response of 2 shows informational content value SLIGHTLY BELOW AVERAGE.

9. Lab #1

10. Lab #2

11. Lab #3

12. Lab #4

13. Lab #5

14. Lab #6

15. Lab #7

16. Lab #8

For each of the following items, each lab in 422 is associated with three things. Please choose the one thing which you recall correctly, or most closely associates with the lab.

17. Lab #1: 1) Slit Lock Flaps 2) Gussets 3) End-Fold Underfold

18. Lab #2: 1) Slit Lock Flaps 2) Gussets 3) Bristol Lund Formula

19. Lab #3: 1) Vacuum Time 2) Pressure Time 3) Plastic Flow

20. Lab #4: 1) Vacuum Time 2) Compressed Gas 3) Vacuum Fill

21. Lab #5: 1) Spring Torque Tester 2) Moisture Balance 3) Heat Sealers

22. Lab #6: 1) Heat Sealers 2) Moisture Tunnel
3) Moisture Balance

23. Lab #7: 1) Incline Impact Tester 2) Drop Test
3) Muller Test

24. Lab #8: 1) Carbon Dioxide, Nitrogen, Hydrogen
2) Carbon Dioxide, Nitrogen, Oxygen
3) Carbon Dioxide, Nitrogen, Water Vapor

25. Please indicate during which term you took Pkg 321 (or 320)
1) Fall Term 1973
2) Summer Term 1973
3) Spring Term 1973
4) Fall Term 1972
5) Summer Term 1972 or earlier

26. Please rate how much information you think you derived from Pkg 321 lab on the same 1-5 scale.

27. Please rate how enjoyable or how much you liked participating in Pkg 321 lab on the same 1-5 scale.

28. Overall, would you rate 321 above or below 422 lab?
1) Above 2) Slightly Above 3) About the same
4) Slightly Below 5) Below

<u>FORMAT</u>: As one can see, the questions were designed to reflect both the affective value (enjoyableness) and information content value of the labs. This was done to distinguish one lab being rated informationally valuable, yet not enjoyable to perform but perceived as having low informational value. Thus, questions 1-8 dealt with the "enjoyableness" (Hedonic rating) of the 422 labs and questions 9-16 with the informational value of each lab in 422. Similarly, questions 26 and 27 pertained to the informational value and "enjoyableness" of lab 321 respectively.

Questions 17-24 were designed to establish recall and possibly correlate high informational content with recall as an indication of a good lab procedure. Finally, question 28 pitted lab 321 against lab 422 for an evaluative comparison of both "types". (Currently 422 is still taught using a laboratory manual containing eight exercises. Packaging 321 is currently a two credit lab and largely independent study with assigned readings and optional research project.)

RESULTS: A total of 32 current packaging students filled out the questionnaire. The additive results of each question were as follows:

Table 2: QUESTION NUMBER FOLLOWED BY ACCUMMULATIVE RESPONSE ORDER

# 1)	1.1	# 2)	1.2	# 3)	1.1	# 4)	1.2	# 5)	1.1	# 6)	1.1	# 7)	1.2
	2.3		2.5		2.1		2.1		2.9		2.8		2.55
	3.10		3.12		3.2		3.5		3.10		3.10		3.7
	4.15		4.10		4.66		4.9		4.10		4.11		4.1
	5.3		5.3		5.23		5.15		5.2		5.2		5.2
# 8)	1.4	# 9)	1.0	#10)	1.0	#11)	1.0	#12)	1.2	#13)	1.1	#14)	1.2
	2.3		2.5		2.6		2.3		2.1		2.5		2.4
	3.9		3.11		3.15		3.8		3.3		3.11		3.11
	4.10		4.12		4.9		4.10		4.11		4.14		4.9
	5.6		5.4		5.2		5.11		5.16		5.1		5.6
#15)	1.1	#16)	1.2	#17)	1.23	#18)	1.2	#19)	1.26	#20)	1.0	#21)	1.27
	2.2		2.5		2.4		2.23		2.0		2.27		2.3
	3.7		3.10		3.5		3.4		3.6		3.4		3.1
	4.2		4.8		4.1		4.0		4.0		4.1		4.0
	5.2		5.7		5.0		5.0		5.0		5.0		5.1
#22)	1.5	#23)	1.7	#24)	1.6	#25)	1.12	#26)	1.6	#27)	1.7	#28)	1.3
	2.4		2.4		2.26		2.0		2.5		2.4		2.3
	3.22		3.3		3.0		3.10		3.5		3.7		3.3
	4.0		4.0		4.0		4.2		4.9		4.5		4.5
	5.0		5.0		5.0		5.3		5.3		5.5		5.11

The correct response for question's 17-24 is circled.

DISCUSSION: The two most popular labs in Packaging 422 were by far those dealing with shrink, skin and blister pacs (lab #3) and aerosols (lab #4). There was also a high correlation between their "enjoyableness" and their rated informational content value. The two least enjoyable labs in Packaging 422 turned out to be those labs which dealt with W.V.T. and shelf life (lab #6) and glass bottles and caps (lab #5). The two labs rated the least informative were those on bags, wraps and overwraps (lab #2) and gas chromatography (lab #8). There was also good to fair recall on Packaging 422 labs save for lab #6 and some confusion over labs #1 and #7.

On the whole, lab 321 ranked about average in both enjoyableness and informational value. The results also indicated lab 321 rating below lab 422 in overall value opinion. From this it may be inferred that laboratory exercises are preferred over independent study arrangements supplemented with assigned readings.

APPENDIX B

SAMPLE STATISTICS PROBLEMS

1. Use the proper mathematical notation in finding the mean (μ) of the following population distribution: 82, 64 87, 91, 59, 60, 77, 52, 99, 101, 63, 75, 88, 81, 47, 102, 39.

$$\mu = \frac{1}{N} \sum_{i=1}^{N} x_i = \frac{1267}{17} = 74.53$$

2. Using a random sample of elements from above consisting of 64, 77, 99, 88, compute $\bar{x}$, the sample mean, and s, the standard deviation of the sample.

$$\bar{x} = \frac{1}{N} \sum_{i=1}^{N} x_i = \frac{328}{4} = 82$$

$$s = \sqrt{\sum_{i=1}^{N} \frac{(x_i - \bar{x})^2}{N - 1}} = \sqrt{\frac{224.67}{3}} = 14.99$$

3. Establishing the null hypothesis of $H_o = A$, $H_o = \bar{x}$, i.e., $A = \bar{x}$, use the t-test to confirm or reject the hypothesis. (knowing $\bar{x}$, μ, s and N from above and given $\alpha = .05$)

$$t = \frac{\bar{x} - \mu}{s/\sqrt{4}} = \frac{82 - 74.53}{14.79/\sqrt{4}} = .997$$

T-table value = 3.182, the absolute value of t calculated, $|.997|$, is not greater than t-table value, thus, H_o holds.

4. Find the normal curve area between Z = 0.50 and Z = .75.

using a table of normal curve areas we find:

at Z = .75, area = .2734
at Z = .50, area = .1915

the area is found by taking the difference between these two values:

(.2734 - .1915) = .0817 X 100 = 8.17%

5. The grades obtained by a large number of students in a final examination in finger painting had a mean of 68 and a standard deviation of 8.2. Assuming that these grades are approximately distributed in a normal curve fashion, below which grade will we find the lowest 10 percent of the class?

using the table of normal curve areas and the equation:

$$Z = \frac{x - \mu}{\sigma}$$

we may solve for the value of x which designates that grade below which we will find the lowest 10% of the class. the lowest 10% of the area under the normal curve is preceded by 40% of the area under the normal curve to the left of μ . The closest approximate Z value at .40 is -1.28.

$$Z = \frac{x - \mu}{\sigma} \quad ; \quad -1.28 = \frac{x-68}{8.2} \quad ; \quad x = (-1.28 \text{ X } 8.2)+68$$

$$x = 57.5$$

APPENDIX C

OPERATING INSTRUCTIONS FOR THE INSTRON TESTING MACHINE

The Instron Testing Instrument incorporates a highly sensitive electronic weighting system with load cells that use strain gauges for detecting and recording tensile (or compressive) loads. An applied load on the cell causes a proportional change in the resistance of the strain gauges. The resulting signal is fed into the pen driving circuit of a high-speed recorder.

There are basically two units composing the Instron Machine. The crosshead mechanism, driven by two vertical drive screws, houses the load cell at the very top. This load cell connects to the upper jaw (clamp) of a pair which function in holding test samples in place. The second mechanism is the chart and recorder which is driven synchronously with the crosshead. The following instructions, if used carefully, will make the operation of the machine safe and simple.

1) Turn on first the MAIN POWER switch, then the AMPLIDYNE switch, both located in the lower panel of the recorder, (see Figure 2). A warmup period of about 10 to 15 minutes is necessary before the load cell reaches maximum stability. A red indicator light is illuminated when the main power switch is in the ON position.

2) ZEROING. Turn on the PEN MOTOR SWITCH located on a small panel above the right side of the recorder case. (When the pen power is off, a red pilot light beside the switch acts as a warning to return the power to the pen motor before starting a test). Press the ZERO BUTTON and adjust the ZERO CONTROL KNOB until the pen is at the desired zero (left) position on the chart. (This effectively controls the zero position of the recorder independently of any signal from the load cell.) When the ZERO BUTTON is now released, the pen will probably go off zero due to the imbalance in the load cell circuit.

3) BALANCING. Remove the upper jaw from the load cell coupling (Diagram #3), (pen should be OFF while removing jaw). Turn COARSE BALANCE and then FINE BALANCE controls in direction pen should move until the pen is brought back on zero and it coincides with the previously adjusted zero point. (This adjusts the balance of the resistance bridge in the load cell). The adjustment of balance should always be made with the LOAD SELECTOR SWITCH in the "1" position--for the greatest accuracy of adjustment.

4) CALIBRATION PROCEDURE. With the position of the load selector switch on "1", attach the one pound weight to the load cell coupling. Now turn pen ON and rotate the CALIBRATION CONTROL KNOB until the pen comes to rest on the zero line of the right side of the graph. Lock the calibration knob in place by rotating the knurled ring behind the knob in the clockwise direction. Turn PEN OFF, remove the one pound weight and replace the upper jaw. (The sensitivity of the load cell has now been adjusted so that the cell is effectively calibrated for all the available ranges within its rated capacity.)

5) With the jaw back in place, turn PEN ON and re-balance (using the coarse and fine balance knobs) the pen needle back to the zero position on the left side of the graph. Lock the fine balance knob in place and turn PEN OFF.

6) FULL SCALE LOAD SELECTOR essentially changes the amplification of the load cell signal for various values of load range. The switch selects the full scale load range at values of 1, 2, 5, 10, 20, or 100. However, our particular load cell has a maximum capacity of 50 pounds--do NOT use the 100 position of the full scale load selector. If the full scale load of 1 is selected, a one pound tension on the upper jaw will cause the needle to deflect across the entire span of the graph. If a full scale load of 2 is chosen, it will now take a tension of two pounds on the upper jaw to deflect the needle to full range of the graph. A similar reasoning may be applied to tension of up to 50 pounds for this particular load cell. What full scale load setting to select during a test depends upon the material being tested. In most cases, a full scale load setting producing a graph over

the mid to maximum ranges of the chart paper for clear and readily discernable results is optimum. If the full scale load is set too high, the resulting graph will not have enough range for easy legibility. If the full scale load is set too low, the pen will run right off the far right edge of the graph. WARNING: this causes an overload situation on the load cell which may permanently deform the strain gauge elements! If the needle runs over the range of the chart, STOP THE TEST IMMEDIATELY and select a higher full scale load setting in order to bring it back within range.

7) CROSSHEAD SPEED CONTROL. The selection of crosshead speed is governed by the characteristics of the sample and the desired test conditions. The crosshead is driven by a set of gears located behind the CONTROL DRIVE DOOR SWITCH in the lower right corner of the recorder (Figure 2). Opening the door stops the crosshead should it be moving at the time, i.e., the door must be closed to operate the crosshead.

Behind the door switch you will find a center shaft driven by either of two other shafts. The lower shaft is the HIGH SPEED gear, rotating 10 times as fast as the upper one, marked LOW.

The CROSSHEAD SPEED TABLES (attached to the back of the door switch) give the selection and arrangement of change gears to obtain the various crosshead speeds, in combination with the two positions of the MAIN DRIVE SHIFT LEVER.

The MAIN DRIVE SHIFT LEVER provides a change of 10 to 1 in crosshead speed. This lever is operated by the large shift handle on the right side of the instrument (Figure 3). When pushed to the rear, the higher range of speed is obtained; when the lever is pulled forward, a 10 to 1 reduction is accomplished. The neutral position is in the center of the lever throw.

The MAIN DRIVE SHIFT LEVER functions together with the CHANGE GEARS to produce the full 1000 to 1 range in available crosshead speeds (see Figures 4 and 5).

To the right of the change gear shafts, you will also find a MANUAL POSITIONING KNOB which is used to fine adjust the crosshead position when placing test samples between the jaws. With this knob, the crossheads can be positioned manually to within .001 inches quickly and accurately.

8) CHART DRIVE. A similar set of drive shafts operate the chart speed (Figure 7). These are located on the rear of the recorder mechanism which swing out. Use only that panel of gear shafts designated "A SPEED". Again, change gears in connection with three shafts projecting from the gearbox, determine the chart speeds. The central gear is driven by

the change gears on either of the two other shafts. The upper driving shaft marked HIGH rotates 10 times as fast as the LOW shaft.

A chart speed table showing the selection and arrangements of the change gears to obtain various chart speed, (in inches/minute), is located on the inside back of the recorder housing. There too, you will find a set of change gears stored on studs. The chart speed is usually selected to give a convenient length of record, which is usually 5 to 10 inches.

All change gears are installed by fitting the slot in its hub over the key that is part of the collar on the shaft. A knurled nut is then firmly screwed to the end of the shaft to retain the gear in place.

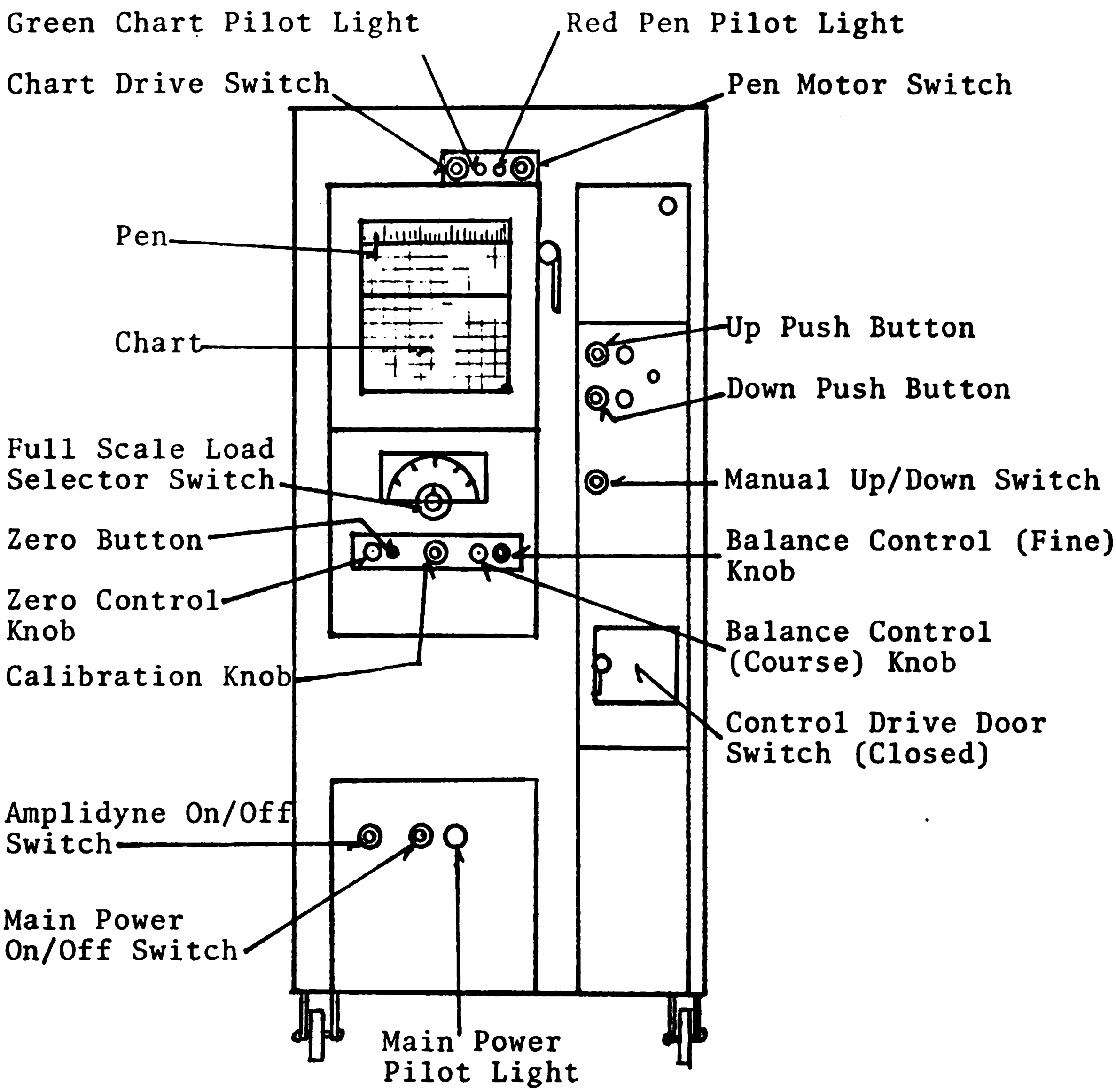

Figure 2: Recorder Mechanism

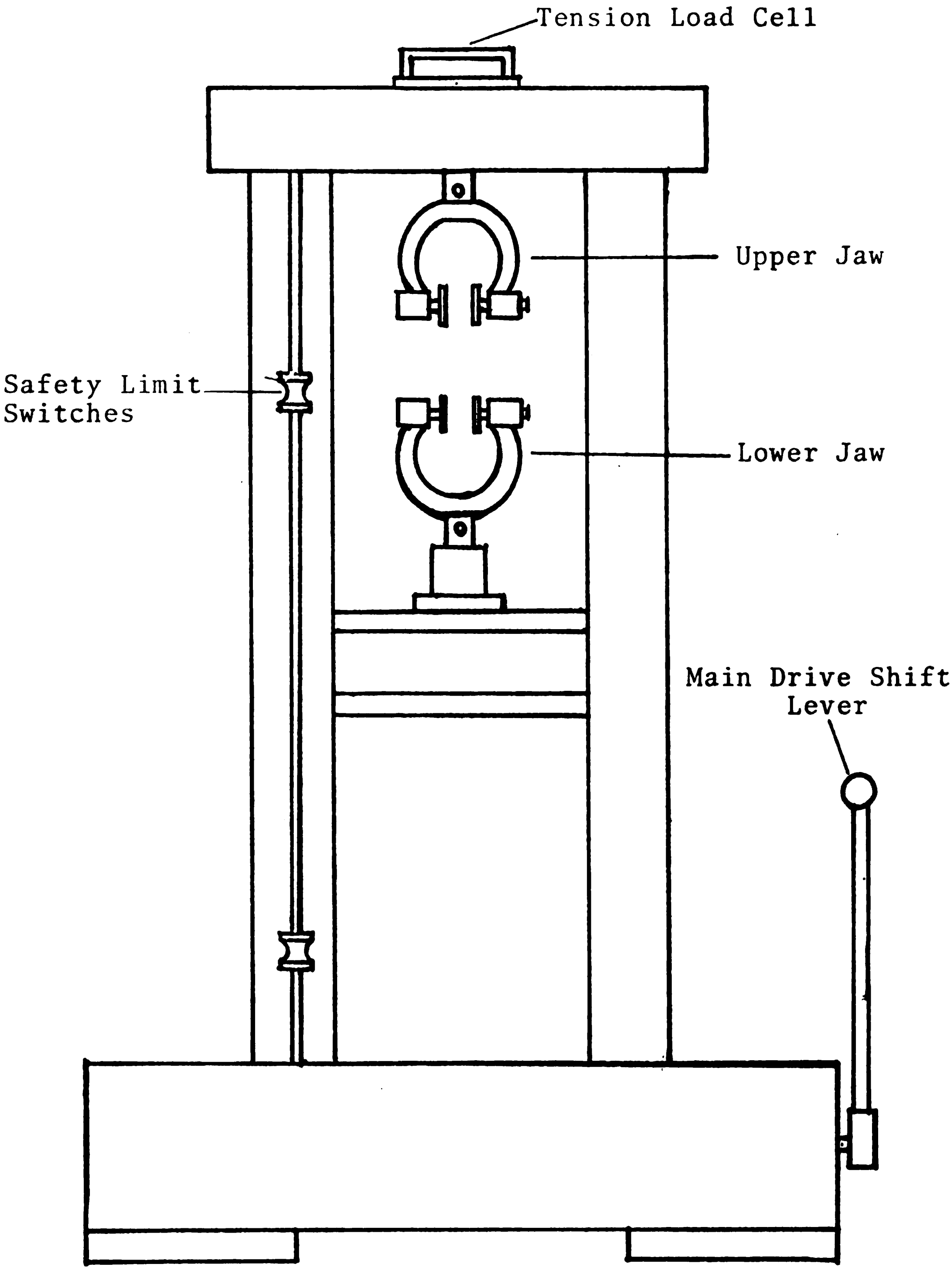

Figure 3: Crosshead Mechanism

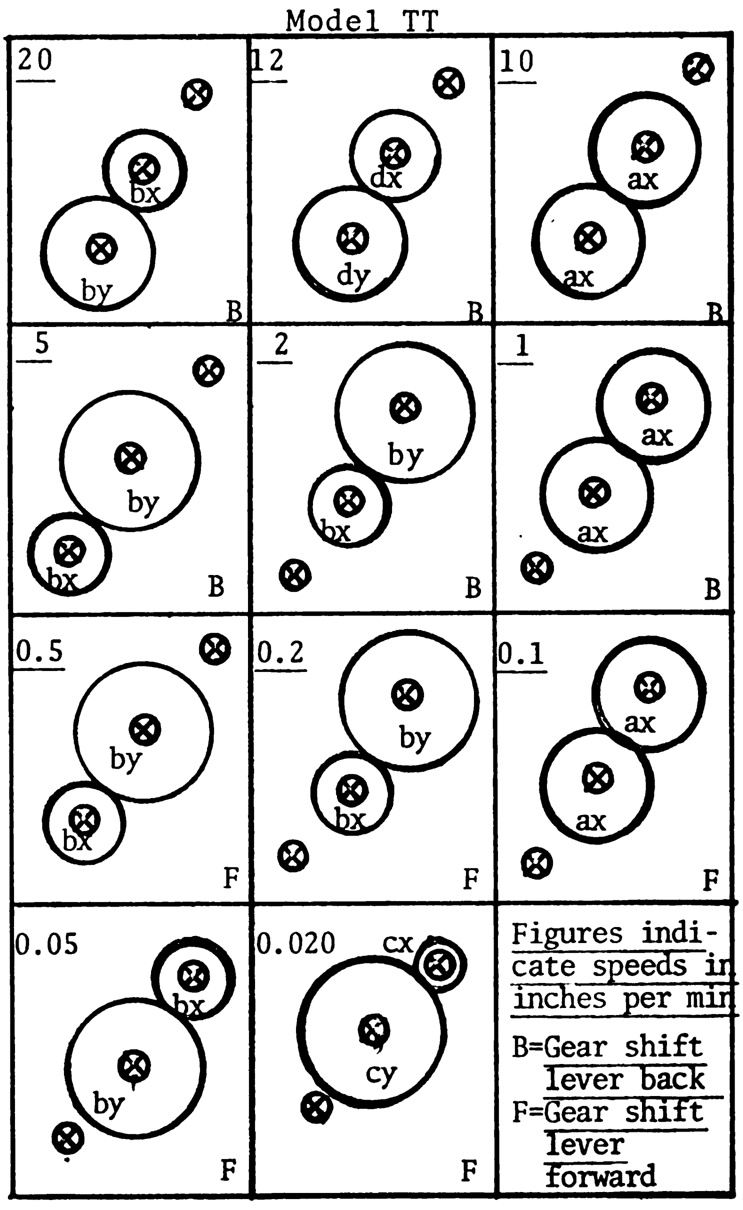

Figure 4: Crosshead Gear Ratios

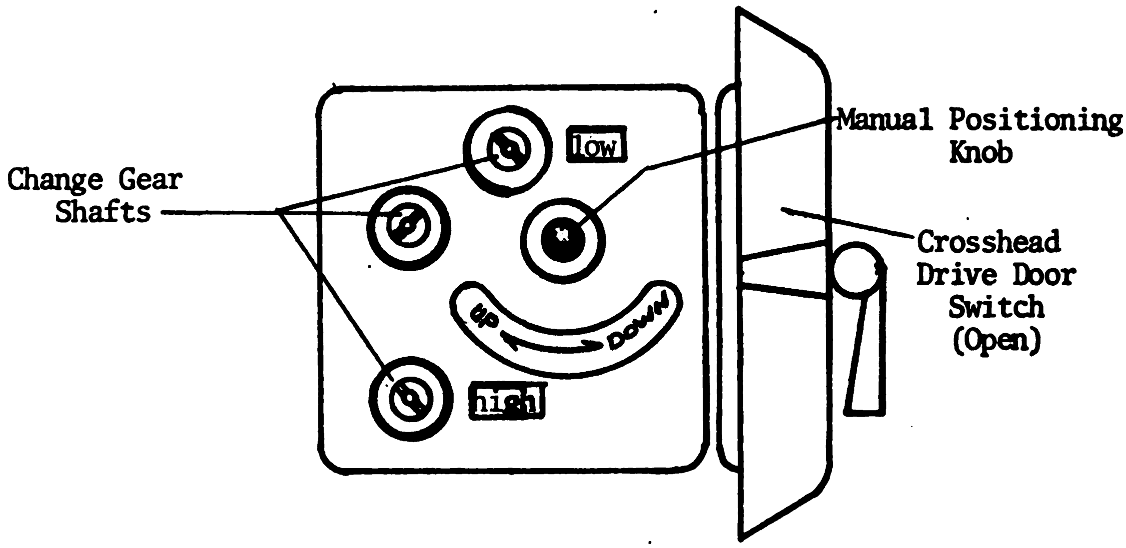

Figure 5: Crosshead Door Switch

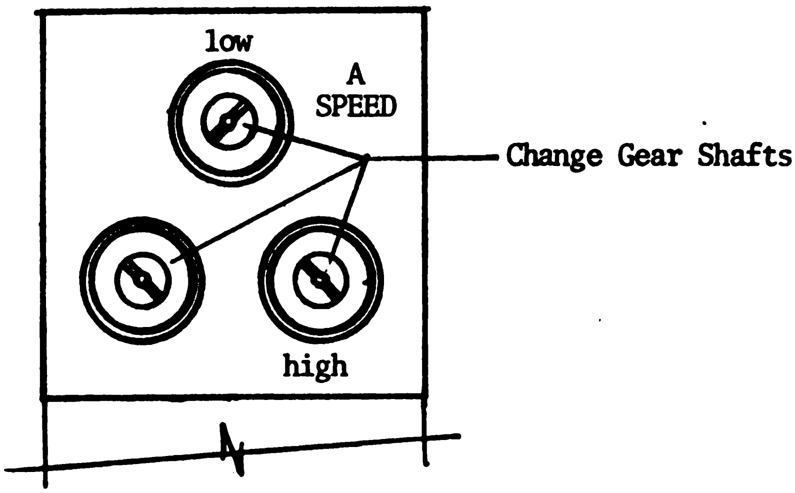

Figure 6: Recorder Gear Shafts

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