USING ACCEPTANCE SAMPLING TO CHECK THE MOISTURE CONTENT OF LUMBER SHIPMENTS

By J. G. Haygreen

Introduction

As the new American Lumber Standards regarding moisture content and size are adopted, both the manufacturing and consuming segments of the lumber industry will become more aware of the importance of proper drying. I believe this is an accurate statement, and I believe that this awareness will benefit the industry. It will mean that the value of the people responsible for drying will go up in the eyes of both management and the consuming public.

As a result of this increased interest, I feel there will probably be greater efforts toward checking the moisture contents of lumber shipments than ever before. Who will be doing this checking? I would divide the groups which may be interested into three categories: 1) lumber manufacturers, 2) lumber associations, and 3) purchasers such as wholesale or retail yards, and tract and manufactured-home builders. You people, of course, fall into the first category and I am sure you are checking your drying performance in some way at the present time. In our discussion today we are going to be concerned with methods of checking which could be used by the other two groups which I just mentioned. These methods could also be used by you at the mill. However, there are other statistical sampling methods which might be better for you to use.

You might well ask at this point, "Why should I be concerned about sampling methods which might be used by the person who is buying my lumber?" The answer is simply that is you have an understanding of the basic idea behind statistical sampling you will be able to foresee problems which may arise and, therefore, avoid them. Perhaps you can also use some of these ideas in your own mill.

Throughout our discussion let us assume that we are checking the moisture content with a resistance-type meter. We are using the meter properly with the correction required for species other than Douglas-fir. We are measuring each piece in such a way as to determine an average moisture content for the piece. Just how to do this is a subject suitable for an entire discussion in itself, but it is not the purpose of our talk now.

Put yourself in the position of a wholesaler, or an association inspector, who wants to check the moisture content of a load of lumber as it is either loaded or unloaded from a car. You must decide whether or not 95 percent of the shipment is below 20 percent moisture content. What are the methods that you could use to decide this? The first possibility would be to check the moisture content of every piece in the car. This would be an accurate procedure but would be a considerable job. Another way would be to check a fixed percentage, say 10 percent, of the pieces. You might then assume that the whole car had the same proportion of different moisture contents as your 10 percent sample.

A third way would be to check an occasional piece--that is to spot-check. How can you decide on the basis of a spot-check whether or not 5 percent of the car is above the desired moisture content? The answer is you can't with certainty. A fourth possible method is to use statistical acceptance sampling. This method has some distinct advantages over the other ways of checking which I have mentioned.

As far as I know, statistical acceptance sampling is not being used in the lumber industry today. It has been used and is being used widely in metals, electronics, and various secondary manufacturing industries. I would like to suggest that it may be a valuable tool for use in checking the moisture content of loads of lumber shipments. It is too costly to do so. The purpose of my talk is to demonstrate how acceptance sampling works and describe some of its advantages.

Statistical Acceptance Sampling

First, let's define what is meant by this term. Sampling is simply the process of taking a part or segment of the whole. In order that this segment be representative of the whole shipment it must be taken in a "random" way. This is a very important point and will be discussed later. An acceptance plan is one used to decide whether or not the shipment meets the specified requirements. This type of plan tells us that the shipment is probably either "acceptable" or "non-acceptable." It will not give an estimate of the average moisture content. A statistical sampling plan is one in which the laws of probability are used to predict the results of using the plan. You are all familiar with probabilities as related to coin tossing, dice rolling, or card playing. Probabilities can be treated in a mathematical way which allows the probable outcome of a sampling plan to be predicted.

Now let us look at an actual acceptance sampling plan. Suppose we have a shipment of 3000 2x4's and we want to check to see that the moisture content is 19 percent or below. One commonly used guide to acceptance sampling plans is Military Standard 105-D. A plan recommended in this reference and suitable to the moisture content question calls for a sample size of 50 and a rejection number of six. This means that in unloading this shipment we must check 50 randomly selected pieces for moisture content. If five or less of these pieces have a moisture content of over 19 percent we will accept the shipment as being adequately dry. If six or more pieces have a moisture content of over 19 percent we will refuse to accept the shipment as is. We would then proceed to check every piece, laying aside those which have excessive moisture. Note that in order to specify a sampling plan, two numbers are given. First the size of the sample and second the number of defective pieces which would cause the shipment to be rejected. Sometimes a "c" number is used rather than the rejection number. The c is the greatest number of defectives which can be found and still allow the shipment to be accepted.

We must recognize that when using statistical sampling our plan will occasionally give us the wrong answer. This is because we are working with probabilities. Consider an example of this. The probability of rolling a three on a die is 1/6th, but this does not mean that in six rolls we will always get a three exactly one time. It means that over a period of time we would expect to get an average of one three every six rolls. It should be emphasized again that the sample must be taken randomly; that is, each piece in the shipment must have an equal chance of being selected. If the sample is not taken randomly the probabilities associated with sampling cannot be predicted.

We recognize now that in any sampling plan there is a possibility of coming up with the wrong answer. The advantage of using a statistical sampling plan is that we will know ahead of time what the chances of making a mistake will be. This information can be obtained from what is called an Operating Characteristic Curve (O.C. curve). This curve is computed from laws of probability. Figure 1 shows an O.C. curve for the example we just talked about. The horizontal axis represents the actual percent of pieces over 19 percent moisture content in any shipment. The vertical axis represents the percent of the time that a shipment with a certain percent defective will be accepted

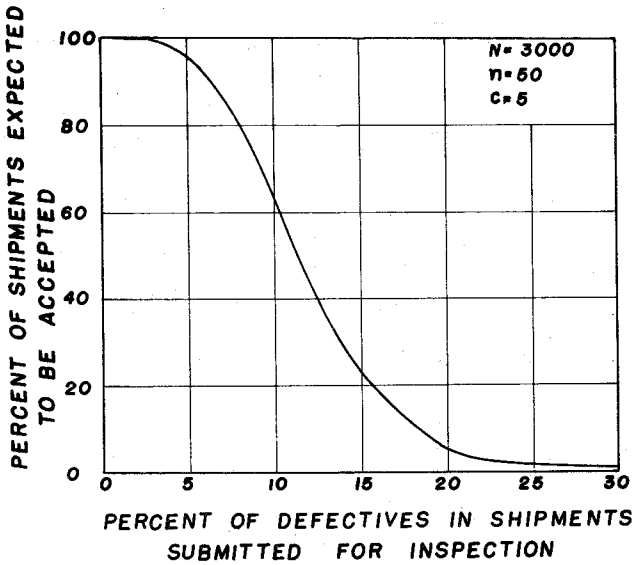

Figure 1 - Operating characteristic curve for an acceptance sampling plan with N = 3000, n = 50, and c = 5.

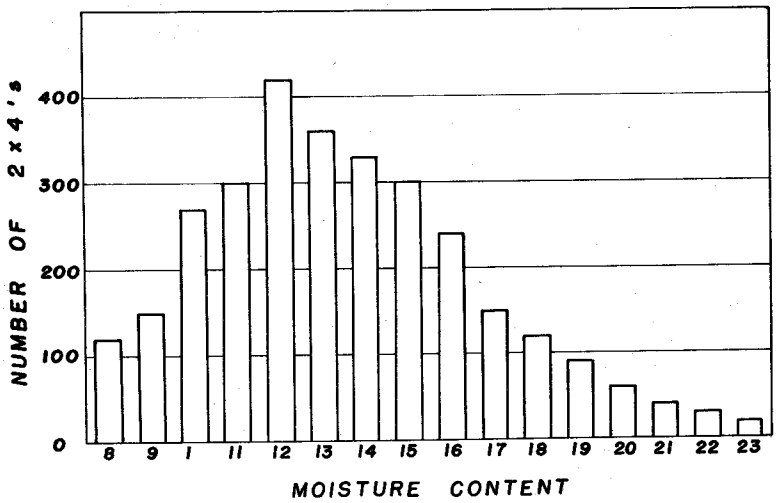

Figure 2 - Hypothetical distribution of moisture content in a shipment of 3000 2 x 4's with 5 percent of the pieces exceeding 19 percent moisture content.

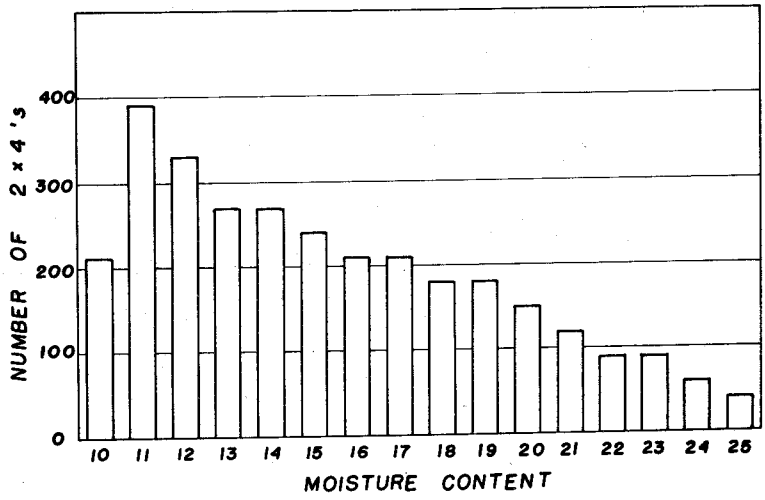

Figure 3 - Hypothetical distribution of moisture content in a shipment of 3000 2 x 4's with 18 percent of the pieces exceeding 19 percent moisture content.

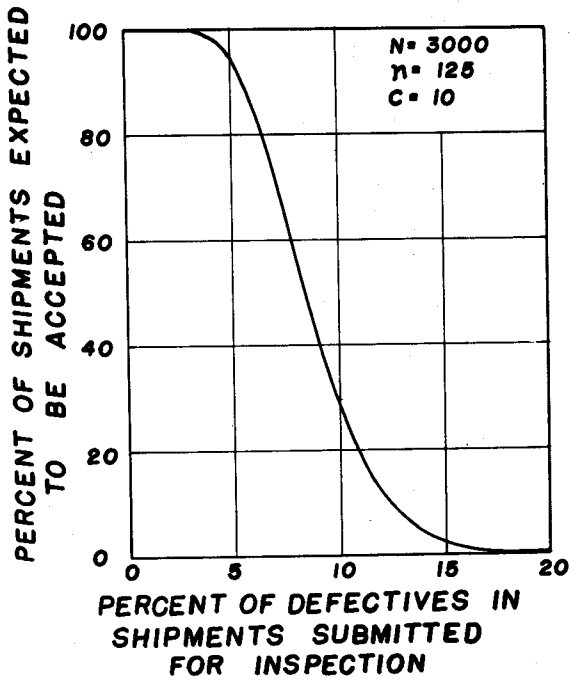

Figure 4 - Operating characteristic curve for an acceptance sampling plan with N = 3000, n = 125, and c = 10.

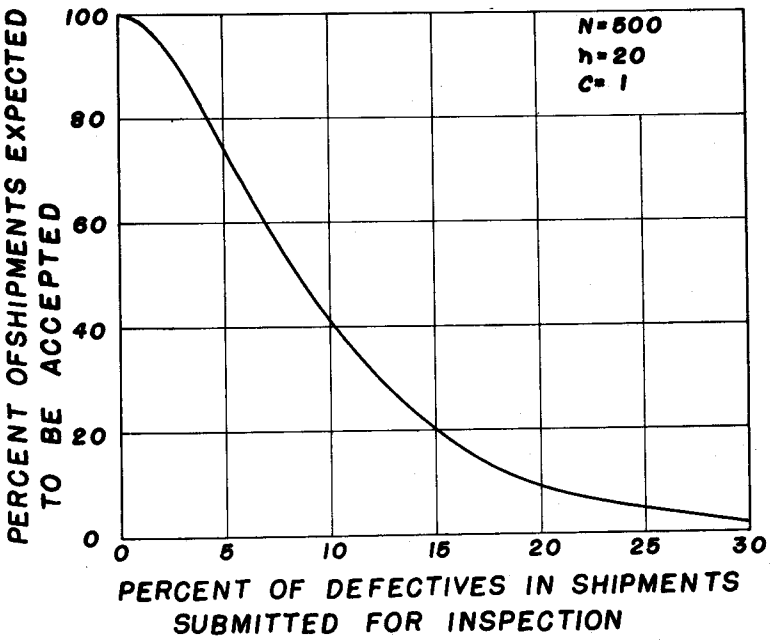

Figure 5 - Operating characteristic curve for an acceptance sampling plan with N = 500, n = 20, and c = 1. For use with the simulated cars of 2 x 10's.

when using this plan. A defective is, of course, any piece over 19 percent moisture content. Let us assume that we use this sampling plan to check 100 cars of 2x4's. Each of these 100 cars has exactly five percent of the pieces with a moisture content of over 19 percent. The distribution of moisture contents in each of these cars is shown in Figure 2. From the O.C. curve you can see that about 95 of these cars will be accepted. About five of the cars will be rejected because the sampling indicates the moisture content is higher than we want it to be. These five cars will then be inspected 100 percent. Rejecting these five cars is a mistake which our plan makes if we consider five percent defective as acceptable.

Suppose that another 100 cars of 2x4's with 18 percent of the pieces in each car above 19 percent moisture content are checked using this same sampling plan. The distribution of moisture contents in each car is shown in Figure 3. From the O.C. curve you can see that about 90 of these cars will be rejected as not being adequately dry. It can be seen from these examples that this sampling plan will usually, but not always, give us the correct answer.

If it is important that we detect the poorly dried shipments a greater percent of the time, we can increase the size of our sample. Remember that in the previous examples we measured only 50 pieces out of a car of 3000 2x4's. If we increase our sample size to 125 we, of course, get more reliable answers. Suppose we use this sample size to check 200 cars of 2x4's all with 18 percent of the pieces above 19 percent moisture content. The laws of probability tell us that we would expect only one of these 200 cars to be accepted as being adequately dry. This can be seen from the O.C. curve in Figure 4. This demonstrates that when using statistical sampling it is possible to adjust our accuracy or chance of error by changing the sample size.

In order to determine the efficiency of acceptance sampling plans a simulated shipment of lumber has been compiled. The jar containing 500 tags represents a car of lumber containing 500 pieces of 2x10--R.L. The moisture content of each 2x10 is marked on each tag. We want to determine if this lumber is adequately dry, i.e., is 19 percent maximum moisture content or below. We decide after studying the Military Standard 105-D to use a sample size of 20 and a rejection number of 2. That is, if two or more of the samples pieces exceed 19 percent moisture content we will state that the shipment is not adequately dry. Samples of 20 each will be taken as time allows. Each sample will represent a different shipment. How well does the sampling work? The actual percent of pieces over 19 percent moisture content is shown on the large card within the jar. Did the sampling technique give us the correct answer most of the time? An O.C. curve for this sampling plan is shown in Figure 5. Can you predict the results of our sampling from this O.C. curve?

Problems in the Use of Acceptance Sampling

In order that this type of sampling be used in our industry there must first be agreement among the parties concerned that it should be used. After this general agreement is reached, the characteristics and details of the sampling plan must be worked out.

A primary consideration regarding this procedure is the cost involved. If it can be shown that this plan is less expensive than 100 percent sampling, then it certainly should be considered seriously. The mechanics of taking a random sample from a car of lumber will have to be worked out. In the case of unitized lumber, it may be possible to randomly select for inspection one or two units out of the whole shipment. At the University of Minnesota we are giving some thought to the practical problems of sampling and hope to do some cost analysis research on the subject this summer. It should be possible to save money by measuring 50 or 100 instead of 3000 pieces?

The details of a sampling plan would have to be agreed upon between the shipper, the association, and the buyer. This agreement might state that the type of plans outlined in the Military Standard

105-D would be followed. There are a number of different sampling plans outlined in this military standard and, therefore, it would be necessary that the parties involved would agree on the criterion used for selection. Basically, the decision involves picking an O.C. curve which gives adequate protection to both the producer and the consumer. The greater the protection, however, the greater the size of the sample that will be required. A compromise must be made between economy and precision of sampling.

One other technical problem would have to be solved if such sampling is to be used as described. An exact procedure must be followed to establish the moisture content of each piece that is sampled. The pieces must all be measured in the same way, with the same corrections applied, and at the same depth. It is necessary to be able to state that the moisture content of a piece is say 18 per cent, not somewhere between 16 percent and 20 percent depending on how and where you measure it. The question of repeatability is one which needs study.

Conclusion

Let us summarize the advantages which statistical acceptance sampling offers over other methods of checking the conformance of a shipment of lumber. This method should certainly be less expensive than checking every piece in the shipment. Only a small percentage of the shipment is actually checked. This system is also a much better tool than haphazard sampling or spotchecking. With statistical sampling the probability of making a "wrong" decision is known to both the shipper and the buyer. It therefore yields information which can be used to make a definite decision, rather than the rather vague "maybe" kind of answer obtained from less scientific sampling methods.

I think there is another big advantage which may be available to the industry by adopting these plans. If it were accepted practice to check the moisture content of a load of lumber by inspecting a small statistical sample, more purchasers might actually check their shipments. At the present time it is just too costly to check every piece, and a spot-check doesn't tell you much. At first your reaction may be "I don't want people checking my lumber that closely." I feel, though, that the companies represented in this kiln club group would be far ahead if lumber were more carefully scrutinized by the purchasers. At the present time you are not getting full credit which is due for a well dried product. By more careful inspection, the lumber buyers will be able to see that there is a difference in the quality of drying.

There certainly are problems which must be overcome if such sampling practices are to be adopted. Criteria for selecting the sampling plan will have to be agreed upon by those involved. The associations would undoubtedly have to carry most of this load. Plans would have to be tried out under various situations to see how best to sample a shipment. Some statistical problems of sampling would have to be studied further to see if group or stratified sampling can be applied. Also, the exact method used to determine the moisture content of a piece must be agreed upon. Despite all of these problems, I feel that acceptance sampling for moisture content should be seriously considered by those concerned.

Selected References

1. Burr, Irving W., Engineering Statistics and Quality Control, McGraw-Hill. 1953.

2. Duncan, A. J., Quality Control and Industrial Statistics, Richard Irwin. 1959.

3. Dept. of Defense, Sampling Procedures and Tables for Inspection by Attributes, Mil. Std. 105-D. April, 1963.