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GUIDE TO THE USE OF ISO RECOMMENDATION R 390, "SAMPLING AND INSPECTION OF ASBESTOS-CEMENT PRODUCTS"

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FOREWORD

The ISO Recommendation R 390, *Sampling and inspection of asbestos-cement products*, was drawn up by Technical Committee ISO/TC 77, *Products in asbestos-cement*, the Secretariat of which is held by the Association Suisse de Normalisation.

The Committee has studied the American Military Standards 105 B* and 414 and has used many of the principles underlying these in the drawing up of ISO Recommendation R 390. It was felt, however, that the relationship between manufacturer and purchaser of asbestos-cement products is very often quite different from the typical relationship in military procurements. For this and various other reasons the Committee decided to prepare its own Recommendation concerning asbestos-cement products and an associated Guide.

With respect to the Guide it is also appropriate to refer to additional works of a more extensive character, for example :

(1) Administration of sampling procedures for acceptance inspection, Handbook H 105, Department of Defense, Washington D.C., 1954**.

(2) Defence guide to sampling inspection, Ministry of Defence, London, 1962***.

(3) Mathematical and statistical principles underlying Military Standard 414, Department of Defense, Washington D.C., 1958.

Anybody interested in systems of sampling inspection will profit from reading these handbooks.

The present Guide, however, has the much more limited purpose of explaining the use of the very simple collection of sampling plans in ISO Recommendation R 390 which represents a balanced compromise between theoretical statistical points of view and practical economical considerations. It is the hope of the Commiteee that the sampling plans will prove applicable in practice, and they will certainly give a safer basis for the distinction between good and inferior material than do the rules and methods hitherto used, thus providing greater protection to the user.

The sampling plans recommended have approximately the same properties as certain plans for which the *acceptable quality level (AQL)* is equal to 4 % in the Military Standards studied.

The Committee has found it useful to include in the Guide an additional section dealing with the conditions under which a rejected lot may be resubmitted for inspection.

* The latest edition is now (1969) No. 105 D.

** The latest edition is now (1969) : H 53, Guide to sampling inspection.

*** The 1966 edition of the Defence Guide has not been taken into account by the Committee.

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GUIDE TO THE USE OF ISO RECOMMENDATION R 390, "SAMPLING AND INSPECTION OF ASBESTOS-CEMENT PRODUCTS"

1. SCOPE

This ISO Recommendation explains in more detail than in ISO Recommendation R 390 the rules laid down for batching, sampling and inspection, and clarifies the consequences of using the methods of sampling inspection recommended. Also, a number of examples are given. In addition, it describes the conditions under which rejected lots can be resubmitted for inspection.

2. UNIT OF PRODUCT

The term *unit of product* means the entity to be inspected in order to determine its quality characteristics. The unit of product is specified in the relevant ISO Recommendation.

The unit of product is used as a *counting unit* in determining lot size, sample size, number of conforming units, etc.

3 . CONFORMING AND NON-CONFORMING UNITS

A *conforming unit* is a unit of product having quality characteristics in conformity with the specified requirements in the relevant ISO Recommendation.

Examples :

ISO Recommendation R 391, *Building and sanitary pipes in asbestos-cement*, (clause 4.3.1) specifies : The unit bursting stress R_t of pipes of type A should be not less than 100 kgf/cm^2 [10 MN/m^2].

This means that a building and sanitary pipe of type A (i.e. one unit of product) having R_t equal to or larger than 100 kgf/cm^2 (10 MN/m^2) is a *conforming unit*, whereas a pipe having R_t less than 100 kgf/cm^2 (10 MN/m^2) is a *non-conforming unit*.

ISO Recommendation R 393, *Asbestos-cement corrugated sheets for roofing and cladding*, (clause 2.5.3) specifies : During the 24 hours of the impermeability test, traces of moisture may appear on the lower surface, but in no instance should there be any formation of drops of water.

This means that the corrugated sheet from which the test piece is cut and which shows formation of drops of water during testing is a *non-conforming unit*.

4. INSPECTION LOT

An inspection lot is a collection of units of product which is accepted or rejected as a whole, depending on the quality characteristics established by inspection of the units of product drawn from the lot.

The manufacturer should arrange for the dividing of the consignment into inspection lots and provide for identification and segregation of each lot. It is important to maintain a separate identity until a decision regarding acceptance or rejection of the lot has been taken on the basis of the results of the sampling and testing.

The inspection lot should be presented in such a form that every unit of product is accessible as far as practically possible.

Inspection lots should be homogeneous, i.e. consist of units of product made under essentially the same conditions. This may be attained by forming the lots from units that are produced

- within a relatively short period;
- from similar raw materials;
- by means of similar moulds (or patterns);
- under similar conditions of manufacture, hardening and maturing, etc.

It should be emphasized that by selection of homogeneous lots, the system of sampling inspection employed will lead to a better discrimination between lots of good quality and lots of bad quality.

The relative sample size – i.e. the sample size as a fraction of the lot size – is decreased considerably as the lot size is increased. Therefore, taking into account the costs of sampling, inspection and testing, it will be advantageous to use as large inspection lots as possible; subject to the limitation discussed above with respect to the homogeneity of the inspection lot. Also the discriminating power of the sampling system will increase with increasing sample size.

It is therefore recommended that the parties concerned should agree upon a maximum lot size as large as possible without coming into conflict with the homogeneity requirements and other obviously practical considerations. To avoid unreasonable inspection and testing costs for small lots, a minimum inspection lot size should also be agreed upon. In the event of agreement not being reached, the figures for maximum and minimum inspection lot sizes given in the relevant ISO Recommendation should be used.

Example :

Size of inspection lot	Sample size	Relative sample size
200	4	2 %
2 000	15	0.75 %
20 000	35	0.175 %

5. DIVISION OF A CONSIGNMENT INTO INSPECTION LOTS

By a consignment is meant a delivery or the part of a delivery which comprises units of the same category.

Examples :

Sheets of same profile but of different lengths may be regarded as of the same category.

Sheets of different profiles are regarded as of different categories.

Pipes of same diameter, class, type, or series, but of different lengths, may be regarded as of the same category.

Pipes of different diameters are regarded as of different categories.

Pipes of same diameter but of different classes or types are regarded as of different categories.

Any consignment which is known to be, or is expected to be, non-homogeneous as regards any of the properties to be tested by sampling should be divided by the manufacturer into assumed homogeneous sub-consignments prior to the division into inspection lots.

Any homogeneous consignment or sub-consignment should be divided by the manufacturer into inspection lots.

If larger than the minimum inspection lot size, any fraction of a consignment remaining after the highest possible number of maximum inspection lots has been taken out forms an inspection lot. Similarly, if larger than the minimum inspection lot size, any homogeneous consignment or sub-consignment smaller than the maximum inspection lot size forms an inspection lot.

Consignments or fractions of consignments smaller than the minimum inspection lot size are not submitted to sampling and testing.

However, should the testing of one or more of the inspection lots justify rejection of any of these lots the parties may agree to disregard this provision and to submit the remaining fraction to sampling and inspection.

Example to show the importance of having the largest possible inspection lot :

Suppose that a consignment consists of 1400 building and sanitary pipes of 250 mm diameter and that the maximum and the minimum inspection lot sizes agreed upon are 400 and 100 pipes respectively (see ISO Recommendation R 391, clause 4.2.2), then the consignment should be divided into 3 inspection lots of size 400 and 1 inspection lot of size 200. According to Table 1 of ISO Recommendation R 390, the sample size for lots of size 400 is 5 pipes and for lots of size 200 is 4 pipes, making a total of 19 pipes.

If the consignment consists of 1250 pipes, it is divided into 3 inspection lots of 400 pipes – from each lot 5 pipes, totalling 15, are drawn – and a remainder of 50 pipes which is not normally submitted to sampling and testing.

If the parties had instead agreed upon a maximum inspection lot size of 1500 pipes, and the same minimum lot size, then the sample size would in both cases have been 10 pipes, which represents a saving of 9 and 5 pipes respectively.

6. SAMPLING

A sample comprises one or more units of product drawn from an inspection lot. Since the decision to accept or reject the lot depends on the quality of the units of product in the sample, it is of the utmost importance that the sample is representative of the lot. This can be achieved by drawing the units at random from the lot, which means that each unit of the lot should have an equal chance of being included in the sample. Ideally, the units of product should be numbered, and by drawing numbers at random as in a lottery the units of the sample should be determined. Instead of actually drawing numbers at random, a table of random numbers may be used.

In practice, truly random sampling from large lots may be difficult. It should, however, always be ensured that sample units of product are drawn from all parts of the lot and that units are selected without regard to their expected quality.

The drawing of samples is normally carried out by the purchaser, in the presence of a representative of the manufacturer, who has the right to advise the purchaser as to the correct way of drawing samples, so as to avoid common mistakes illustrated by the following examples.

Examples :

From a stack of 100 corrugated sheets from which a sample of 3 should be drawn the 3 top sheets should not be taken. Further, the 3 bottom sheets, or the top sheet, the centre sheet, and the bottom sheet should not be taken.

Moreover, if a sample of 3 should be taken from a pile of 100 sheets, the purchaser should not be allowed to go through the stack as the leaves are turned in a book in order to "select" the samples. On the contrary, he should mark on the edges the 3 sheets he desires to be tested while the pile is still intact.

When a consignment of sheets or slates is placed, for instance, on several pallets or in several piles, the units of product of the sample should not be drawn only from the piles that are easiest of access. If it appears, for instance, that there are different climatic conditions in the part of the stock shed where the consignment is stored (but not so much as to make the consignment non-homogeneous), the different climatic conditions should be represented in the sample, and the sampling should be carried out as far as possible without regard to the "expected properties" of the units of product of the sample.

A unit of product which has been marked during the sampling may later appear to be unsuitable for testing. It might occur, for instance, that one of the sheets which the purchaser has marked in a stack is found to be completely broken and unsuitable as a sample. Common sense should then be applied and a neighbouring sheet substituted for the failing sample, or the sample should be regarded as a non-conforming unit of product. In the case illustrated, the purchaser and the manufacturer may alternatively agree to take out the whole stack of the consignment and insert another.

Both parties should keep in mind the fact that random sampling is the ideal and that they should apply common sense to get as near to the ideal as possible.

7. DEFINITIONS OF INSPECTION BY ATTRIBUTES AND INSPECTION BY VARIABLES

In inspection by attributes the unit of product is classified as conforming or non-conforming with respect to each of the quality requirements specified in the relevant ISO Recommendation.

In inspection by variables the quality characteristic specified in the relevant ISO Recommendation is measured on a numerical scale and the values found by measuring the units of product sampled are taken into account.

The results of inspection by variables may therefore always be converted to attributes. For instance, a quality characteristic of the pipes of type A is the unit bursting stress, and ISO Recommendation R 391 specifies that this should be not less than 100 kgf/cm^2 [10 MN/m^2]. An inspection by variables on a sample of 5 pipes will take into account the 5 values of the unit bursting stress, for example :

110 – 107 – 98 – 103 – 105.

In inspection by attributes it will only be registered that out of 5 pipes submitted to the tests, 4 have been conforming and 1 non-conforming. In case inspection by variables is possible it is therefore necessary to decide whether to treat the observation as a variable or to convert it into an attribute. Such a decision must be taken before sampling and inspection, since the decision must be independent of the actual outcome of the inspection.

Inspection by attributes is simpler to understand, requires less detailed records, and the testing is often cheaper than the corresponding measurement. In inspection by variables more information is obtained per unit of product, with the consequence that variables inspection on the average requires a smaller sample than attributes inspection to obtain the same power of discrimination between lots of good quality and lots of bad quality. To be carried out correctly, inspection by variables requires some skill in arithmetic.

Further, the sampling plans for inspection by variables are based on the assumption that the measurements are normally distributed. (The distribution of Laplace-Gauss). This will generally be the case for the products in question.

ISO Recommendation R 390 states that inspection by attributes is normally employed, but the manufacturer may, prior to the drawing of the sample, opt to employ inspection by variables if applicable.

As far as inspection by variables is concerned the sampling plans given in ISO Recommendation R 390 are limited to cases where the relevant ISO Recommendation specifies either a lower or an upper limit for the quality characteristic in question.

Therefore, when double limits are specified (for example, for certain geometrical characteristics) inspection by attributes should be employed, and it should be kept in mind that all measurements outside the two specified limits must be counted as non-conforming (see ISO Recommendation R 390, footnote to Table 1, column 8).

Quality characteristics which are measurable on a numerical scale and which, consequently, make inspection both by attributes and by variables applicable are, for instance :

- unit bursting, crushing and bending stresses of pipes;
- unit bending stresses of slates and flat and corrugated sheets;
- density of flat sheets and slates.

Quality characteristics which are not measurable on a numerical scale and which, consequently, make only inspection by attributes applicable are, for instance :

- impermeability;
- frost cracking;
- visual aspects.

8. OPERATING CHARACTERISTIC OF A SAMPLING PLAN

The operating characteristic (or OC) curve of a sampling plan indicates the average percentage of the submitted lots which are accepted (the percentage probability of acceptance) in relation to the quality of submitted lots, expressed as the percentage of non-conforming units in the lot.

Any sampling plan has its own OC-curve, which makes it possible to predict what will happen in the long run by using the sampling plan under alternative assumptions regarding the quality of submitted inspection lots. In the example opposite the OC-curve shows that the probability of acceptance equals 97 % for lots containing 4 % non-conforming units. This means that by using the sampling plan for a long series of lots, all of quality 4 %, 97 lots out of a 100 will be accepted, while the remaining 3 lots out of a 100 will be rejected.

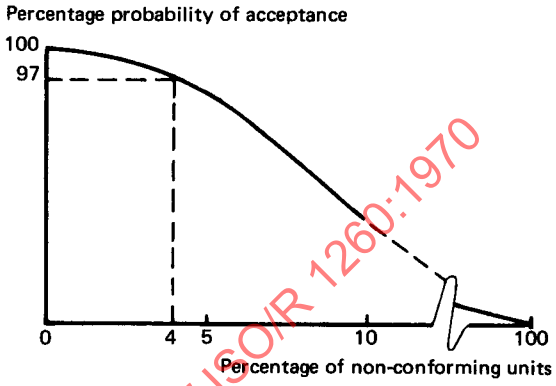


FIG. 1 – Operating characteristic (OC) curve

The OC-curves are computed on the assumption that the sample units of product are selected from the inspection lot by a truly random procedure, and that no errors are committed in the classification or evaluation of the sample units.

The OC-curves for the sampling plans in ISO Recommendation R 390 are shown in the two diagrams at the end of the Guide. They have been derived by means of the theory of probability and are almost independent of the lot size N when the sample size n is less than, say, 10 % of the lot size, which is always the case for the sampling plans provided in ISO Recommendation R 390.

Looking at the diagrams it will be seen that the probability of acceptance is nearly 100 %, if submitted lots contain less than 2 % non-conforming units. For plans with a sample size of 7 or more the curves intersect approximately at the point corresponding to a lot quality of about 9 % non-conforming units and a probability of acceptance for such lots of about 70 %. For a lot quality of 20 % non-conforming units the probability of acceptance is rather low for all these plans.

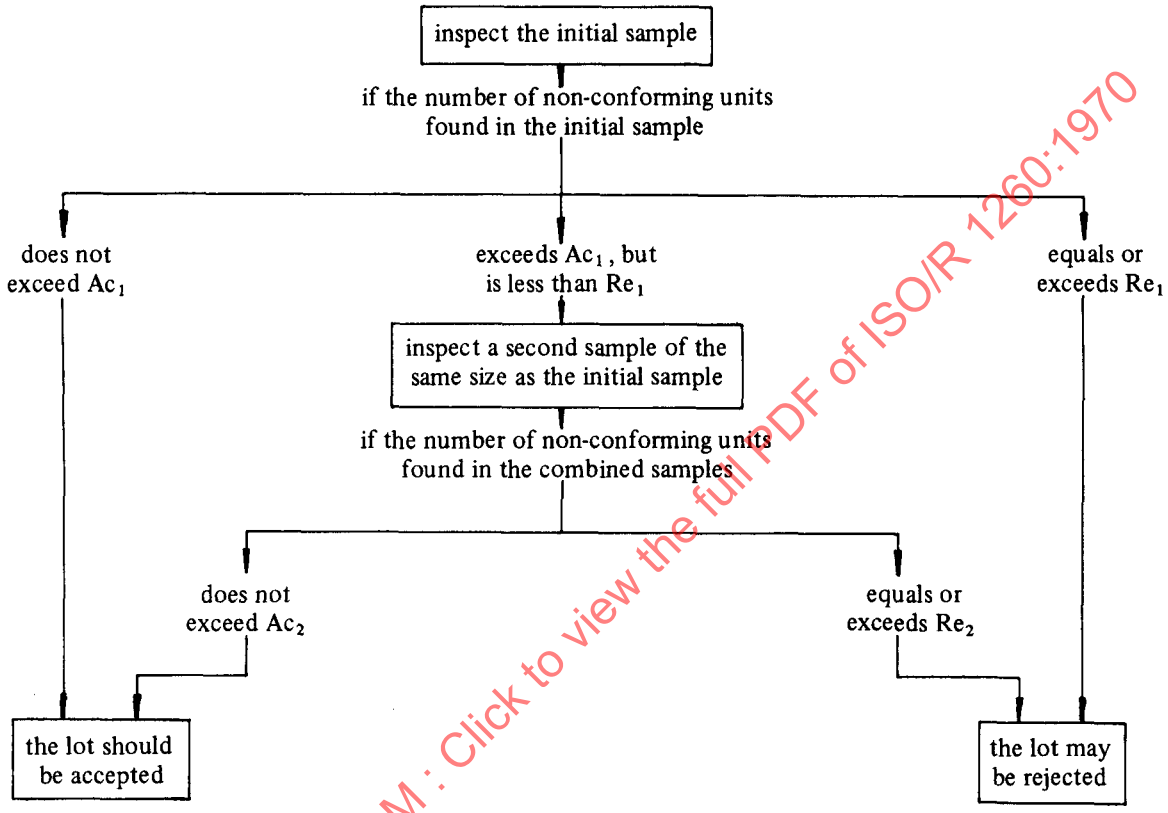
Comparing the two diagrams, it will be seen that the corresponding curves are almost identical which means that the sample sizes and the acceptability criteria have been chosen in such a manner that the sampling inspection plans by attributes and by variables have almost the same discriminating power.

To demonstrate what can be read from the diagrams, consider for example double sampling inspection by attributes with an initial sample of 25 units and a second sample (if necessary) of another 25 units. If submitted inspection lots contain 3 % non-conforming units, then, on the average, 99 of such lots out of 100 will be accepted and 1 lot will be rejected (the probability of acceptance is about 99 %). If on the other hand submitted lots contain 20 % non-conforming units, then, on average, 6 of such lots out of 100 will be accepted, whereas 94 will be rejected (the probability of acceptance is about 6 %).

Using single sampling inspection by variables with a sample size of 25 units, the corresponding probabilities of acceptance are 99 and 10 %, respectively.

9. USE OF SAMPLING INSPECTION BY ATTRIBUTES

The system of sampling inspection by attributes given in ISO Recommendation R 390 is a system of double sampling with the first and second sample of the same size. The following diagram shows the steps to be followed when using a double sampling inspection procedure.



The sample size depends on the size of the inspection lot and is given in Table 1 of ISO Recommendation R 390.

Example 1

Consider an inspection lot of 7000 slates.

Table 1 of ISO Recommendation R 390 shows that the initial sample will contain 25 slates and that the corresponding acceptance and rejection numbers are 1 and 4, respectively. If the sample contains 0 or 1 non-conforming unit, the lot should be considered acceptable. If, however, the sample contains 4 or more non-conforming units, the lot may be rejected. In intermediate cases, i.e. if the sample contains 2 or 3 non-conforming units, a second sample of 25 slates should be inspected. From the table it will be seen that the acceptance number for the combined samples is 5 and the rejection number is 6. If the number of non-conforming units in the two samples together does not exceed 5 the lot should, therefore, be accepted, otherwise (i.e. if the number of non-conforming units exceeds 5) the lot may be rejected.

Example 2

Consider an inspection lot of 300 pipes.

Table 1 of ISO Recommendation R 390 shows that the initial sample will contain 5 pipes and that the corresponding acceptance and rejection numbers are 0 and 2, respectively. If the sample does not contain any non-conforming units the lot should be considered acceptable. If, however, the sample contains 2 or more non-conforming units the lot may be rejected. In the intermediate case, i.e. if the sample contains 1 non-conforming unit, a second sample of 5 pipes should be inspected. From the table it will be seen that the acceptance number for the combined samples is 1 and the rejection number 2. If the number of non-conforming units in the two samples together does not exceed 1 (i.e. if the second sample does not contain any non-conforming units), the lot should be considered acceptable, otherwise the lot may be rejected.

It will be noted that the average sample size in a double sampling system depends on the quality of the inspection lot. For inspection lots of very high or very low quality the decision to accept or reject the lot will always be made from the results of the initial sample. In intermediate cases, however, there is a certain probability, depending on the quality of the lot, that a second sample will have to be drawn to reach a final decision. The average sample size will, therefore, be a number lying between the initial sample size and the combined sample size.

The advantage of using a double sampling system as compared to a single sampling system by attributes with the same OC-curve lies in the fact that double sampling has the same discriminating power as single sampling, with an average sample size which is normally smaller than the corresponding single sample size.

The use of a double sampling plan will also tend, on average, to reduce the amount of testing work since the second sample will only be tested for those properties which, at the initial test, gave numbers of non-conforming units between the acceptance number Ac_1 and the rejection number Re_1.

When the relevant ISO Recommendation calls for more than one property to be tested the decision as to acceptance or rejection should be taken on the basis of the results for each property, independently of the results for other properties from the same sample.

10. USE OF SAMPLING INSPECTION BY VARIABLES

The system of sampling inspection by variables given in ISO Recommendation R 390 is a system of single sampling with a sample size equal to the initial sample of the double sampling system by attributes. By using inspection by variables the sample size will always be less than the average sample size by using inspection by attributes.

The sample size is specified in Table 1 of ISO Recommendation R 390 and depends on the inspection lot size in the same way as for inspection by attributes.

The system is based on the assumption that the sample units of product are drawn at random from the lot and that the test results (the measurements) are recorded in the order made.

First a measure of the variability of the results is computed by means of the range, R. By the range of a group of numbers is understood the difference between the largest and the smallest number in the group. If the sample size is 7 or less the range of measurements is used directly, whereas for sample sizes of 10 or more the measurements are divided into groups of 5, the range is found for each group and the average range, $\overline{R}$, is computed by dividing the sum of the group ranges by the number of groups.

Next the average, $\overline{X}$, of all the measurements (the sample mean) is computed by dividing the sum of the measurements by the sample size.

Each sample size in Table 1 of ISO Recommendation R 390 is given a number, k (the acceptability criterion), which should be multiplied by the average range, $\bar{R}$, or if the sample size is 7 or less, by the range, R.

For each type of product for which inspection by variables is appropriate the relevant ISO Recommendation will contain one specified limit for the quality characteristic in question. This limit may be a lower limit, L, or an upper limit, U.*

The acceptability limit AL is derived from the specified limit and the number $k\bar{R}$ as $AL = L + k\bar{R}$, or $AL = U - k\bar{R}$. The acceptability of the lot is determined by comparing the average of the measurements with the acceptability limit.

If the relevant ISO Recommendation prescribes a lower limit, then the lot should be considered acceptable if $\bar{X} \geqslant AL$, otherwise the lot may be rejected.

If the relevant ISO Recommendation prescribes an upper limit, then the lot should be considered acceptable if $\bar{X} \leqslant AL$, otherwise the lot may be rejected.

Example 1

The sample size is 3, 4, 5 or 7.

From an inspection lot of 500 corrugated sheets a sample of 7 was drawn and tested for unit bending stress R_f (ISO Recommendation R 393 – clause 2.5.2.1). The following measurements were recorded :

$$180 - 177 - 167 - 182 - 188 - 172 - 158.$$

The range R equals the difference between the largest and the smallest measurement :

$$R = 188 - 158 = 30.$$

The sample mean $\bar{X}$ equals the sum of the measurements divided by the sample size :

$$\bar{X} = \frac{180 + 177 + 167 + 182 + 188 + 172 + 158}{7} = \frac{1224}{7} \approx 175.$$

To the sample size 7 corresponds the acceptability criterion $k = 0.40$.

Lower specified limit $L = 160$.

Acceptability limit $AL = L + kR = 160 + (0.40 \times 30) = 172$.

As $\bar{X} = 175 \geqslant AL = 172$, the lot is acceptable.

* The ISO Recommendations R 160, 391, 392, 393, 394, 395 and 396, 880 and 881 and the draft proposal 77 N 305 do not apply upper limits for quality characteristics that may be verified by sampling. Some of these documents apply double limits for some of the geometrical characteristics that might be tested by sampling. For these characteristics the inspection by variables is not applicable since the sampling plans in Table 1 of ISO Recommendation R 390 (see footnote to column 8) have been worked out on the assumption that one limit only has been specified. The method prescribed in the present section should, therefore, not be applied simultaneously to the two limits. Inspection by attributes should be used instead, counting all measurements outside the two specified limits as non-conforming, (see section 7).

Example 2

The sample size is 10, 15, 25, or 35.

From an inspection lot of 2000 corrugated sheets a sample of 15 was drawn and tested for unit bending stress R_f (ISO Recommendation R 393 – clause 2.5.2.1). The recorded measurements are entered on the table below *in the order made*, which means that first group 1 is filled in, thereafter group 2 and so on :

Number of measurement within group	Group No. 1	2	3	4	5	6	7
1	180	172	181				
2	177	158	195				
3	167	185	163				
4	182	173	159				
5	188	173	175				
Sum	894	861	873				
Range	21	27	36				

Grand total $= 894 + 861 + 873 = 2628$

$$\bar{X} = \frac{2628}{15} \approx 175$$

Sum of ranges $= 21 + 27 + 36 = 84$

$$\bar{R} = \frac{84}{3} = 28$$

To the sample size 15 corresponds the acceptability criterion $k = 0.51$.

Lower specified limit $L = 160$.

Acceptability limit $AL = L + k\bar{R} = 160 + (0.51 \times 28) \approx 174$.

As $\bar{X} = 175 \geqslant AL = 174$, the lot is acceptable.