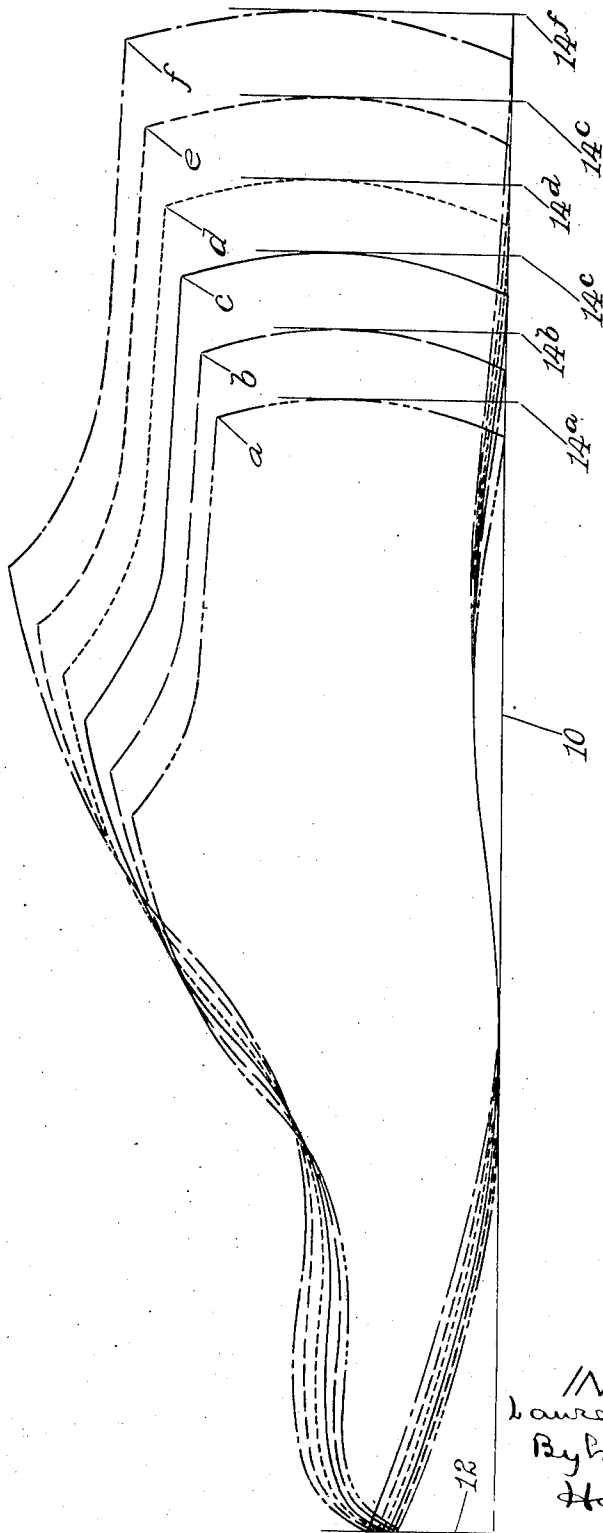


Feb. 27, 1934.

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LAST AND SHOE GRADING
Filed March 15, 1930

1,948,547



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UNITED STATES PATENT OFFICE

1,948,547

LAST AND SHOE GRADING

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Application March 15, 1930. Serial No. 436,197

5 Claims. (Cl. 12—142)

This invention relates to the manufacture of lasts and shoes.

Heretofore it has been the custom to grade lasts and shoes arithmetically, that is, by equal increments per unit of increase in nominal length and width. These increments are, in size grading, $\frac{1}{8}$ inch in length, as measured on the size-stick, and $\frac{1}{4}$ inch in perimeter at the ball, as measured by a tape around that part of the forepart known as the ball, per unit increase in length; and in width grading, $\frac{1}{4}$ inch in perimeter at the ball per unit increase in width. For example, the standard 7C last is $10\frac{1}{2}$ inches long on the size-stick, and is $8\frac{1}{2}$ inches in perimeter at the ball. The 8C of this model is $10\frac{1}{2}$ inches long and $8\frac{3}{4}$ inches in perimeter; the 10C is $11\frac{1}{2}$ inches long and $9\frac{1}{4}$ inches in perimeter, and so on: while the 7D is $10\frac{1}{2}$ inches long and $8\frac{3}{4}$ inches in perimeter, and the 7F, $10\frac{1}{2}$ inches long and $9\frac{1}{4}$ inches in perimeter. In short, the size-stick length of any last of the standard dimensions will be $10\frac{1}{2}$ inches plus $\frac{1}{8}$ inch times the algebraic difference between its length number and 7; while its perimeter at the ball will be $8\frac{1}{2}$ inches plus $\frac{1}{4}$ inch times the algebraic sum of the algebraic differences between its length and width numbers and those of the 7C respectively. It should be noted that the nominal width of a last defines no dimension of it; it indicates only some relation between the length and the girth.

This system has the advantage that in testing the product of a last lathe or in ascertaining the length and girth of a given last, a single size-stick, or caliper, graduated in $\frac{1}{8}$ inch units, and a single tape, graduated in $\frac{1}{4}$ inch units (in actual practice an ordinary tape, graduated in $\frac{1}{8}$ inch units) can be used to check or ascertain the dimensions of any last whatever and its relations to a model from which it was cut. The system is, however, subject to serious disadvantages, which will appear from the following discussion.

A little computation will show that all lasts of a series (or set of the same style) of the same nominal width are nearly geometrically similar solids, but that the magnification factors necessary to produce them from one another in turn are not equal. For example, the length magnification factor necessary to produce a standard 8 from a 7 is $131/127=1.0315$; to produce a 9

from an 8 is $135/131=1.0305$; to produce a 10 from a 9 is $139/135=1.0296$, and so on. The variation in the grading factor in shoemaking generally, however, is really much greater than this because of variations in actual length of lasts of the same nominal length due to varying styles. A 7C model will measure anywhere from 7 to 11 on the size-stick, depending on its style; that is, it may be anywhere from $10\frac{1}{2}$ inches to $11\frac{1}{2}$ inches in length. The length magnification factors necessary to produce an 8C from two such models are $131/127=1.0315$ and $147/143=1.0280$ respectively, which requires adjustments of the length grading apparatus differing by 10% of themselves, since the movement of the adjustment pointer of a last lathe grading mechanism is a measure of the difference of the grading factor from unity.

This results, furthermore, in a practical disadvantage in shoemaking and shoe fitting. All of these 7C last models of varying styles and absolute lengths are substantially alike from the heel to the ball, that is, over the foot fitting part of the last. Since a short 7C last is graded more rapidly than a long 7C last, in order to produce the $\frac{1}{8}$ inch increment per length unit, the absolute length of the heel-ball portion of a short 8C will be greater than that of a long 8C. Consequently shoes of the same nominal size but of different styles will fit differently; furthermore, in such a machine as the automatic leveling machine where the length of the travel and the tip of the leveling roll are regulated by the position of the ball line, the machine should be set differently for a long style than for a short when treating shoes other than the model size.

It will thus be clear that when operating a last lathe equipped with a simple length grader the same settings of the apparatus cannot be used, according to the system used heretofore, in grading from two models of the same nominal length but of different actual lengths. The actual length grading apparatus used in the last lathe comprises a swinging lever having a sliding pivotal connection with a fixed pivot in the frame, a fixed pivot on the model wheel carriage, and a pivotal connection with the cutter carriage which is adjustable along the lever to positions on either side of the second-named

pivot to establish the grading ratio or factor. It has been attempted to obviate the difficulty inherent in the necessity of varying grading factors by making the pivot in the machine frame adjustable along the lever, thus changing the advantage of the lever to make it correspond to the same setting scale for all models, but this scheme has not been practically successful since an accurate adjustment of the lower pivot is more trouble than the operator is willing to take, and an approximate adjustment does not materially diminish the amount of empirical trial necessary to produce a last of the proper length. The proper position of the pointer on the adjustment scale is thus practically always found by trial and consequent waste of a number of blocks and considerable time.

The above discussion has been based on the 7C model alone, but the range in length from children's to men's work necessitates the use, in producing all the lasts required in shoe making, of models which vary between far wider limits than those indicated; so that the real difficulty is much worse than the figures given above would indicate.

The difficulty in width grading is exactly similar, due to the great variation in perimeters of the models used for the different lines of work, from children's to men's lasts. In the case of the width grading mechanism of the last lathe there is no way at all of even reasonably approximately taking care of the difficulty, and the width grader setting is utterly empirical in most cases.

In grading shoe upper patterns in the pattern grading machine the same difficulty is met, and is dealt with by the provision of about 50 setting scales which are interchangeably mounted in the machine to correspond to different kinds of work, and even then a considerable amount of experimentation is necessary. This scheme is prohibitively troublesome in the last lathe and has never been adopted.

It is a principal object of the present invention to obviate all these difficulties, and I have found that this can be accomplished by grading lasts and shoes geometrically, as distinguished from arithmetically, as in the system heretofore in use. By geometric grading is meant that successive members of a series of graded objects vary by a uniform percentage of a given characteristic, from one to another, instead of by a uniform absolute amount, from one to another. Thus the grading factors in producing a last of any given nominal length and width from a model of any style will always be the same, regardless of the actual length and girth of the model, and a single grading scale can be readily provided for each grading mechanism and used for all work, strictly in accordance with its own indicia; that is, the graduation marks on it will mean exactly what they say as regards nominal increases in size and girth, irrespective of the model in the machine, and the same is true of the graduation marks of the corresponding single size-stick and tape used to check the work of the machine or to ascertain the size and width characteristics of any given last relatively to its model. This avoids the waste of time and material due to the necessity of cutting and trying under the present system. The machine will produce the desired result at the first trial, and the relation of the length and girth of the last produced to those of the model used can be ascertained by using one last stick and one tape,

irrespective of what the length and girth of the model were.

It should be noticed that the grading system provided by this invention is not merely equivalent to the acceptance of a different desideratum as to the relations between the lasts of a set. It is of course possible to set the length and width graders of the ordinary last lathe two sizes up, for example, by the scales provided with the machine, and to call the last produced two sizes longer than the model and of the same nominal width. This procedure would not secure all the advantages of the present invention because the problem of ascertaining the relations of such lasts to the models from which they were graded would entail hopeless confusion. Suppose, for example, that the machine were built to grade $\frac{1}{3}$ inch increments in length per size from a standard 7C model, as described above. A tape and last stick can be constructed, with their graduations corresponding to the dimensions of the successive lasts produced from this model by the machine, but these will not work in connection with a shorter or longer model and the lasts generated from it in this machine. For example, with such a machine the 4C would be 1 inch shorter than the 7C; its length grading factor would be 115/127, and inversely the 7C would be 127/115 as long as the 4C; and if the machine were set to grade three sizes up, the 10C would be 139/127 as long as the 7C. But if this 4C last were put in the machine as a women's model and a 7C graded from it by setting the graders up three sizes from the zero mark the 7C produced would be 139/127, instead of 127/115, as long as the 4C model. If this 4C model and 7C last thus graded from it were placed on the size-stick constructed as stated above, the graduation marks measuring their lengths would not be three sizes apart on the stick. Thus a distinct stick and tape would have to be made for every length and girth of model used. With the present invention, a last three sizes longer or wider than a model will always be longer or wider than the model by the same percentage of the model length or girth, and the measurement of the model and the last on the same stick and tape will always show the same graduation differences.

The practice just described of using the present machine would sacrifice the advantage of using the same measuring apparatus for all work which is found in the system used heretofore, for the advantage of economy of material in which the old system is lacking. The present invention preserves the former advantage and secures the latter.

Another advantage of the present invention is that the foot fitting portions of lasts of all styles will be graded alike since the grading factors are constant for all styles.

In the proposed system the large objects differ more from one another in absolute dimensions than do the small ones, since the uniform percentage is taken on a larger quantity among the large objects than among the small. This constitutes another advantage of the invention, since it is not advisable to grade large objects in such small absolute intervals as in the case of small objects.

Any disadvantage which might result from this characteristic of the system under special conditions (for example, if it is desired to grade children's shoes on a larger percentage than men's, as children's feet are growing), can be avoided

by making the constant percentage upon which the system is based a submultiple of the different percentages desired throughout the whole range, and using a larger multiple of it in the smaller lasts than in the larger. This will of course require more care on the part of the operator (unless exactly the same scheme of multiples is adopted for all classes of work), but the inherent advantages of always setting the machine exactly on the same definite mark and of using a single measuring apparatus are retained, and this is something that has never been accomplished in last making or pattern making in all classes of work.

The drawing shows the profiles of a series of six lasts marked *a* to *f* illustrating the invention. To avoid confusion of the lines of the drawing the lasts illustrated are two sizes apart, and their shank portions are not separately drawn. The grade used is 3% per size: that is, each last illustrated is $(1.03)^2$ as large in length and girth as its next smaller predecessor on the drawing. (1.03 is a rough average of the grades heretofore used in men's work.) The outlines of the six lasts are formed with lines of different types of discontinuity to make them recognizable.

These lasts are shown as resting on a line 10 which corresponds to the size-stick, in the positions in which their lengths are measured on that instrument. Their toes are shown abutting on a line 12 which corresponds to the fixed abutment of the size-stick, and their heel ends are shown as abutting on lines 14_a to 14_f which correspond to the movable abutment of the size-stick in its different positions. The spacing of these lines 14 illustrates the geometric characteristic of the grade. An ordinary set of lasts thus shown would cause the lines 14 to be equally spaced.

Any one of the lasts shown can be regarded as a model, and any one of the others graded from it in a last lathe provided with geometric setting scales, by merely setting the graders the proper number of graduation marks up or down from the neutral mark which corresponds to 1:1 reproduction, and a single geometrically graduated size-stick and tape will enable any two of them to be directly compared. It must be understood that each last in this set is $(1.03)^2$ as long as its next shorter neighbor. The last marked *c* being taken as the model, the last marked *b* is

$$\frac{1}{(1.03)^2}$$

as long as the last marked *c*.

For example, suppose the full line outline C on the drawing be regarded as that of a standard 7C. The series will then run from 3C to 13C by two-size intervals. The lengths in inches of these lasts in the two systems are shown below and in the column G—A are shown the differences between the geometric and arithmetic lengths.

Size	Arithmetic	3% geometric	G—A
3C	9.250	9.403	+0.153
5C	9.917	9.976	+0.059
7C	10.583	10.583	0.000
9C	11.250	11.228	-0.022
11C	11.917	11.912	-0.005
13C	12.583	12.637	+0.054

The differences in the last column are not very significant as regards fit, except for the 3C which

is about $\frac{1}{2}$ size too long, but any such discrepancies, except that of the 11C, would heretofore entail rejection of the last in the last factory. The two systems are therefore essentially different.

Many grading systems having the herein-described geometrical characteristics may be developed, according to the practical manufacturing conditions that may exist. Suppose, for example, that we are given the problem of developing a set of lasts corresponding as closely as possible to the run of men's lasts from 5 to 11, and in widths A to E of the ordinary system.

The lengths and girths of these lasts in the arithmetic system are given below, assuming the lengths to be the same in all widths.

Table A—Lengths

No.	Size	Length
1	5	9.9167
2	5½	10.0833
3	6	10.25
4	6½	10.4167
5	7	10.5833
6	7½	10.75
7	8	10.9166
8	8½	11.0833
9	9	11.25
10	9½	11.4167
11	10	11.5833
12	10½	11.75
13	11	11.9167

Table B—Girths

No.	Size	Girth	Weight
1	5A	7.5	1
2	5½A	7.625	1
3	6A, 5B	7.75	2
4	6½A, 5½B	7.875	2
5	7A, 6B, 5C	8.000	3
6	7½A, 6½B, 5½C	8.125	3
7	8A, 7B, 6C, 5D	8.25	4
8	8½A, 7½B, 6½C, 5½D	8.375	4
9	9A, 8B, 7C, 6D, 5E	8.5	5
10	9½A, 8½B, 7½C, 6½D, 5½E	8.625	5
11	10A, 9B, 8C, 7D, 6E	8.75	5
12	10½A, 9½B, 8½C, 7½D, 6½E	8.875	5
13	11A, 10B, 9C, 8D, 7E	9.000	5
14	10½B, 9½C, 8½D, 7½E	9.125	4
15	11B, 10C, 9D, 8E	9.25	4
16	10½C, 9½D, 8½E	9.375	3
17	11C, 10D, 9E	9.5	3
18	10½D, 9½E	9.625	2
19	11D, 10E	9.75	2
20	10½E	9.875	1
21	11E	10.000	1

In order to secure the best correspondence between the two systems we will treat the length and girth problems independently. Taking the length problem first, we desire to find a length, *L*, for the #5 last, and a $\frac{1}{2}$ size grading factor, *G*, such that, as closely as possible, the following equations will be satisfied:

No.	Equation
1	$L = 9.9167$
2	$LG = 10.0833$
3	$LG^2 = 10.25$
etc.	
13	$LG^{12} = 11.9167$

This problem can be solved by the method of least squares. To do this the Equations (C) must be reduced to linear form. One way of doing this is to put the Equations (C) into logarithmic

form. Let $x = \log L$ and $y = \log G$. Then the Equations (C) become

No.	
1	$x - 0.99637 = 0$
2	$x + y - 1.00360 = 0$
3	$x + 2y - 1.01072 = 0$
etc.	
13	$x + 12y - 1.07616 = 0$

which are linear in x, y . If the j th equation of (D) be written in the form

$$a_j x + b_j y + n_j = 0 \quad (E)$$

where a, b , and n are the numerical coefficients the two normal equations giving the best values of x and y are

$$[aa]x + [ab]y + [an] = 0$$

$$[ba]x + [bb]y + [bn] = 0 \quad (F)$$

where $[aa]$ = sum of the 13 products aa , $[ab]$ = sum of the 13 products ab , and so on.

These normal equations, when thus formed, are

$$13x + 78y - 13.48594 = 0$$

$$78x + 650y - 82.12479 = 0$$

which give

$$x = .99752 \quad L = 9.9430$$

$$y = .0066437 \quad G = 1.01542$$

The lengths of the lasts are given in the following table in the column marked L_g . The column marked $L_g - L_a$ gives the differences between the geometrically graded lengths and the arithmetically, or standard, graded lengths.

No.	Size	L_g	$L_g - L_a$
1	5	9.9430	+ .0263
2	5½	10.0963	+ .0130
3	6	10.2520	+ .0020
4	6½	10.4100	- .0067
5	7	10.5705	- .0128
6	7½	10.7334	- .0166
7	8	10.8989	- .0177
8	8½	11.0669	- .0164
9	9	11.2375	- .0125
10	9½	11.4107	- .0060
11	10	11.5866	+ .0033
12	10½	11.7652	+ .0152
13	11	11.9466	+ .0299

In solving the corresponding problem relative to the girths it is necessary to remember that the same numerical conditions arise from different numbers of lasts of the set (given in the "Weight" column in (B)): the 5A girth comes in only once, while the 9A girth (since it is the same as that of the 8B, 7C, 6D and 5E) comes in five times. There are 65 equations in all, and they must all be used as if they were all really different, in order to get the best solution for the system as a whole. There were 65 equations in the length problem, too, but they all entered five times each, so that it was necessary to use only the 13 different ones.

The normal equations formed as above from the 65 girth conditions are, if w is the logarithm of P , the girth of the 5A, and z is the logarithm of the half-size girth grading factor, G' ;

$$65w + 650z - 61.16674 = 0$$

$$650w + 7930z - 620.57068 = 0$$

whence

$$w = 0.87877 \quad P = 7.5642$$

$$z = 0.0062261 \quad G' = 1.01444$$

The girths of the lasts are given in the following table in the column marked P_g . The column marked $P_g - P_a$ gives the differences between the geometrically graded girths and the arithmetically, or standard, graded girths.

No.	Size	P_g	$P_g - P_a$
1	5A	7.5642	+ .0042
2	5½A	7.6735	+ .0485
3	6A, 5B	7.7843	+ .0343
4	6½A, 5½B	7.8967	+ .0217
5	7A, 6B, 5C	8.0108	+ .0108
6	7½A, 6½B, 5½C	8.1264	+ .0014
7	8A, 7B, 6C, 5D	8.2438	- .0062
8	8½A, 7½B, 6½C, 5½D	8.3628	- .0122
9	9A, 8B, 7C, 6D, 5E	8.4836	- .0164
10	9½A, 8½B, 7½C, 6½D, 5½E	8.6061	- .0189
11	10A, 9B, 8C, 7D, 6E	8.7303	- .0197
12	10½A, 9½B, 8½C, 7½D, 6½E	8.8564	- .0186
13	11A, 10B, 9C, 8D, 7E	8.9843	- .0157
14	10½B, 9½C, 8½D, 7½E	9.1140	- .0110
15	11B, 10C, 9D, 8E	9.2456	- .0044
16	10½C, 9½D, 8½E	9.3791	+ .0041
17	11C, 10D, 9E	9.5145	+ .0145
18	10½D, 9½E	9.6519	+ .0269
19	11D, 10E	9.7913	+ .0413
20	10½E	9.9327	+ .0577
21	11E	10.0761	+ .0761

As pointed out above all these lasts have the advantage inherent in the old system, that they can be checked and their relations to one another ascertained, by means of a single size-stick and tape, the former built on a grade of

$$(1.01542)^2 = 1.03108 \text{ per size}$$

and the latter on a grade of

$$(1.01444)^2 = 1.02909 \text{ per size.}$$

They also have the advantage, not attainable heretofore, of being cut by direct setting of a grading mechanism having a geometric scale without previous trial.

If it be desired, the length and width aspects of the above-described problem may be combined, and the same grading factor obtained for both length and girth. There are then three unknowns to find, the length and the girth of the smallest last, and the common grading factor, and three normal equations will be found from the 130 fundamental equations. The system of geometrically graded dimensions which will best correspond to any given system can be found in this way.

Another advantage of the geometric system relates to the adjustment of shoe machinery for different sizes. In this system, if the length grading factor per size is, say, 1.03 (or in ordinary words, if we are using a 3% grade), the distance from the heel to the ball of all lasts of the same nominal length graded from size 7 models will be always the same, irrespective of style, since this distance in the 7's of all styles is always substantially the same, and is increased 3% of itself in making the size 8's. Thus the question of adjusting shoe machinery for different sizes is simplified, for example, in the leveling machine adjustment discussed above.

The set of lasts provided by the present invention can thus be cut on a last lathe provided with length and width grader setting scales the graduation marks on which will always mean exactly the same thing, and a machine in proper adjustment can be always set exactly on these marks to produce the required lasts, with no experimentation or loss of time and material.

For the purposes of this application a series of lasts is defined as a number of lasts having a progressively varying dimensional or size char-

acteristic. Other such characteristics may or may not so vary, in the series.

Having described my invention, what I claim as new and desire to secure by Letters Patent of the United States is:

1. That improvement in manufacturing lasts which consists in generating from a given model irrespective of its style or dimensions a series of lasts having a progressively varying dimensional characteristic, by making the ratios of the numerical values of said characteristic in each two successive lasts of the series all equal to the same number irrespective of the dimensions of the model.
2. That improvement in manufacturing lasts which consists in generating from a given model irrespective of its style or dimensions a series of lasts having a progressively varying dimensional characteristic, by making each of the ratios of the numerical values of said characteristic in each two successive lasts of the series an integral power of the same fundamental number throughout the series irrespective of the dimensions of the model.
3. That improvement in methods of manufacturing lasts which consists in generating from a given model irrespective of its style or dimensions a last having a given dimensional characteristic of the same numerical value as that of the corresponding dimensional characteristic of the model, generating from the said model a last differing from the model in the numerical value of the said characteristic by a given percentage of the numerical value of the said characteristic of the model, and generating from the said

model a last differing from the last secondly referred to in the numerical value of the said characteristic by the same said percentage of its numerical value in the last secondly referred to, irrespective of the dimensions of the model.

4. That improvement in methods of manufacturing lasts which consists in generating from a given model irrespective of its style or dimensions a last having a given dimensional characteristic of the same numerical value as that of the corresponding dimensional characteristic of the model, generating from the said model a last differing from the model in the numerical value of the said characteristic by a given percentage of the numerical value of the said characteristic of the model, and generating from the said model the remaining members of a series of lasts each differing from its predecessor in the numerical value of the said characteristic, by the same said percentage of the numerical value of that characteristic in the predecessor, irrespective of the dimensions of the model.

5. That improvement in methods of manufacturing a set of lasts of the same style having a progressively varying dimensional characteristic, which consists in pantographically generating each of such lasts in a copy turning machine from a model and utilizing in each different case a magnification factor which is a different integral power of one fundamental number to effect the said progressive variation of the said characteristic throughout the set, irrespective of the dimensions of the model.

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