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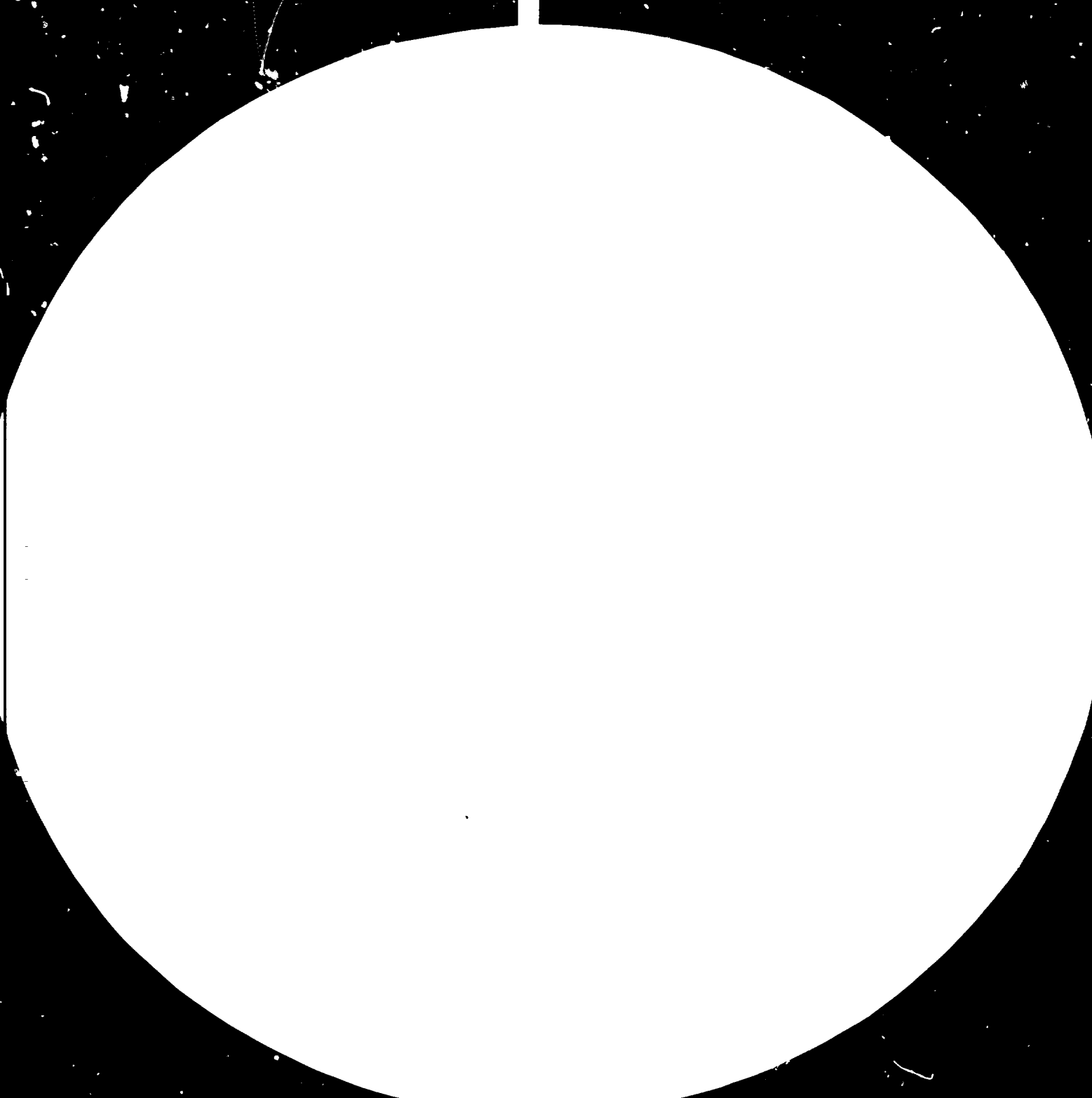
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Quality-Control of Man-Made Fibres
Principle and Methods

In many branches of industry quality-control of raw material
- coming in, and the products - going out is done by a single
laboratory. For instance in a yarn spinning plant methods for
testing the fibres to be processed are about the same as methods
for testing the yarns produced. Even part of the instruments
can be used for both purposes.

In man -made-fibre-industry matters are quite different.
Raw materials are chemicals and tested by methods of chemistry.
The fibres produced are tested by physical and textile methods.
So to our best knowledge there is no company of man made fibre
industry who has only one laboratory for quality control, testing
of raw materials and fibres always being separated. If here we
are going to speak about quality control, we will confine to the
fibres being produced.

The most characteristic aspect of quality control of man made
fibres is the disproportion of amounts of fibres produced and
fibres tested. Even under optimal conditions, for every fibre
being tested more than 10 billion of fibres go by unnoticed.
Therefore it is impossible to use test results obtained with
a sample to give exact figures for the property of production
where this sample was taken from. Information can be gathered
only in a statistical manner, saying the property is between
given limits with a certain probability. This is the reason,
why sometimes the term "statistical quality control" is being
used.

Of course, if there is any grave trouble in production, giving distinctly different results of testing, this should be found even with a small, none-representative sample, provided the sample has been taken when and where the trouble did occur. There should be a close cooperation between management of production and quality control to ensure extra samples to be taken and tested if there are any production problems.

On the other side, quality control can give valuable information to production management. Fibre properties evaluated by physical means of quality control do not necessary in every case give an immediate measure of the quality of fibres. For instance variations in tenacity of man made fibres do not necessary by themselves involve different quality. But stepwise increase or decrease of tenacity does indicate stepwise changes of the production process of fibres. This may lead to problems not at all related to tenacity, like with dyeing properties of fabrics, later on made of those fibres.

So quality control should and can do a lot more than keep measured fibres properties within certain levels which the customers want. It should also help to have the fibre producing process running as smooth and undisturbed as possible.

If anybody speaks of quality control, he thinks of testing and measuring. In fact, there are three steps of quality control, each of them equal important :

A. Sampling
B. Testing and measuring
C. Evaluation

We have to consider all of them.

A. Sampling

In most cases it will be impossible to take samples of every unit produced, say every bale or spool or box of spools. This would be by far to expensive and is not necessary with a

smooth running production. It also is not favourable to open
ready made packages or bales in order to take samples.
So it would be best, to take samples from the end of the produc-
tionline at certain time intervals. It is reasonable to choose
this intervals according to the time fibres take to advance
from the spinning jet to the packaging machine. Depending on
the type of fibres and process this will in many cases be of
the order of half an hour or an hour. Even if only part of the
tests are done on every sample or if not every sample is tested
at all, it is reasonable to keep the time pattern. In case of
any trouble reported from production line it allows for additional
tests done with intermediate samples that have been kept.
The logical consequence of using a time pattern for sampling is
the amount of work for testing does not depend on the capacity
of production. It depends only on the speed of production.
Testing to evaluate a small pilot plant takes the same expense
as testing for a large scale production running with the same
speed.

In some of existing standards it is reqired to make "mixed
samples" for testing purpose by combining fibre from time-
pattern samples say for a shift or a whole day.
We cannot share this point of view. Imagine for instance the
cutting machine of a staple fibre production line was out of
order for about one hour. There will be two samples infected with
many long fibres. Samples before and after are in good order.
By testing fibre length it is possible to pin down the part of
production to be rejected. If there had been any mixed sample
of the whole day it would be infected with long fibres and no
possibility to find their original concentration and time of
origin. If one wants to save working time in laboratory it is
by far better to reduce work on each sample or to leave out
some part of samples, keeping them for additional tests done
only if necessary.

General rules should be : Better take samples more frequent
than you want testing !
Better do less testing on more samples !
Do not manually mix fibres of different
samples ! (mixing should be done by
computation using results)

B. Testing and measuring

Testing for quality control is not always confined to labora-
tory measuring. Sometimes it is advantageous to process staple
fibre to staple yarn or even to process filament yarn to knit-
ware, both being done by production type of machinery but on
very small scale. Those tests give an indication of the manu-
facturing properties of fibres being processed. They cannot
be carried out on each sample taken, as this would be to
expensive. Some man-made fibre companies make tests of manu-
facturing properties on one sample of each consignment, others
are doing this test at regular time intervals of great distance.
This is sufficient as long as any change in fibre manufacturing
process is avoided.

For certain laboratory tests on staple fibre tops or slivers
are being used. This preparation of samples must also be done
on small scale manufacturing machines like carding machines
for testing purpose.

Part of the laboratory tests in principle can be done on single
fibres as well as on small collectives of fibres. Some tests
must necessary be done on collectives of fibres. Generally
speaking if it is feasible to do the measuring on single
fibres this has to be preferred.
Some authors claim testing on collectives to be better on
behalf of saving time. This is an error, as any time saving
is combined with less information on fibres properties. In
most cases there is no time saving at all, as we are going
to see when speaking about titre.

It is impossible to give here methods of measuring all existing and important properties of man-made fibres. Therefore it was necessary to confine to a selection of important properties.

a) Examples for tests better to do on single fibres if possible

1. Titre

Titre is defined by the mass (or weight) of a specific length of fibres or yarn. So sometimes it is called linear mass or linear weight. As most fibres are more or less crimped, the term "specific length" must be considered carefully. To remove the crimp, a suitable tension must be applied to the fibre or yarn. This tension depends on the amount of crimp and the titre of the fibre. it must at first be found out experimentically. The decrimping tension under which the specific length is taken, therefore is necessery to define titre. This is forgotten in most standards. If titre is measured using different methods with different decrimping tensions one cannot expect to get the same results.

Worldwide there are two systems in use for titre :

The tex system

$$\text{Titre (Tex)} = \frac{\text{grams}}{1.000 \text{ meters}}$$

(for single fibres it is better to use the subdivision decitex or dtex)

The denier system

$$\text{Titre (den)} = \frac{\text{grams}}{9.000 \text{ meters}}$$

The rather new tex system is used in Europa, the older den system is still in use in many countrys, including the United States.

A simple computation using the above definition gives
the real meaning of fibre titre.

$$Titre = q \cdot c$$

q = square of mean fibre
cross section

c = specific mass of fibre
material

As the specific mass is constant for a given polymer and
does not differ much in any case for important fibre
forming polymers titre is a measure of the cross section
or thickness of fibres. The great advantage of this definition
lies in the fact it is independent of the shape of fibres
cross section which is irregular for most fibres.

According to the definition a simple method to measure
titre would be to take a known length of fibre being under
the defining tension and put it on a balance. This is the
adopted procedure for all kinds of filament yarns. The
number of single filaments in the yarn is known and so it
is possible to calculate the titre of yarn, which in most
cases is asked, and the mean value of titre of the single
filaments forming the yarn as well.

When testing staple fibres matters are different. It is
nearly impossible to weigh single fibres of low titre
with adequate accuracy. So single fibres titre cannot
be measured by balance method. To find the mean titre of
a sample therefore, it is useful to weigh a whole bundle
of fibres together. The length of each fibre of the bundle,
being under defining tension, can be measured individually.
Some people measure the bundles length together. This can
give bad accuracy, as it is impossible to apply the defining
tension to all fibres of the bundle at the same time.

Instead of length measurement there can be made use of
a cutting device to gain fibres of a definite length. In
this case also it cannot be recommended to cut the bundle

of fibres as a whole. Defining tension must be applied
during cutting and this is scarcely possible for the
whole bundle.

The amount of fibres in an bundle or the length of
filament yarn to be put on the balance depends only on
the accuracy and sensitivity of the balance in use.

Measurement of the titre of individual fibres is important
for two reasons :

To be able to calculate the frequency distribution curve
of single fibres titre in a sample.

To allow for the titre of each individual fibre when using
it for subsquent tests, if there has been done no harm to the
fibres by titre measuring.

The only instrument existing to measure the titre of single
fibres without spoiling fibres, is the vibroscope.

In this instrument a certain length of vibre at the titre
defining tension is vibrated at its natural frequency. The
titre can be calculated using the formula :

$$T = \frac{F}{2\,L\,v}$$

wherein means :

T = Titre

F = Tension (applied and
    defining titre)

L = length of fibre
    vibrated

v = frequency of vibration

Modern instruments feature a direct read-out of titre, making
calculations unnecessary.

The advantage of measuring titre of single fibres can be
seen on Fig. 1. It shows single fibres titre frequency
distribution curves of two samples. The great diffe ence
in distribution could be gained in reasonable time by no
other means.

The second advantage will be demonstrated when speaking of the tensile test.

In contrary to the balance method the amount of fibres to be tested depends only on the variance of the sample and of the precision required.

The table below shows the number of fibres, viscose staple,1,7 dtex to be tested in order to have the same precision or confidence limits comparing balance method and vibroscope. Both balance and vibroscope were of the make most in use, balance accuracy demands use of bundles of fibres of at least 50 each.

number of fibres to test

with balance		with vibroscope
150 (3 bundles)		20
200 (4 -"-)		45
300 (6 -"-)		100
450 (9 -"-)		200
600 (12 -"-)		300

It takes by far less time to measure the amount of single fibres with vibroscope, than count fibres of bundles, cut or length-measure the greater amount of fibres and weigh bundles, if one wants the same precision of test.

2. Tensile Testing

Yarns or fibres are fastened between clamps and stretched with a constant speed or rate of extension. In most cases stretching is carried on until the yarn or fibre sample ruptures.Before clamping a small force is applied in order to remove crimp. The tension caused by this small force is called pretension. One of the clamps is connected to

a force measuring device, the other is movable, motor-driven,
to allow for the stretching take place with the desired speed.
the moving clamp is connected with a length measuring device.
Modern instruments feature electronic devices for measuring
both force and increase of length. They sometimes also employ
an autographic recorder to give a curve representing the
connection of force and length during the whole test.

It is essential the clamping force should be constant and
adjustable, clamps being spring loaded or operated by magnetic force
or compressed air. This is most important for filament yarns
in order to keep all filaments together and prevent slippage.
Clamps with too high pressure give damage to fibres especially
when testing single fibres.

Tensile tests give a lot of information, most important being
the following :

2.1. Breaking force and breaking elongation.

After having stressed a sample until it ruptures, both
properties can be gained from the instrument immideately.

The dimension of breaking force is Centinewton (cN), the
suitable subdivision of the now world-wide used unit. For
practical reasons Centinewton can be compared with sufficient
accuracy with the obsolete "pond" oder "gram force". This
means, a weight of one gram acts upon its base approximately
with the force of one Centinewton.

Breaking elongation is always given as a percentage of the
initial length of the sample. Initial length depends on
standard in use and type of fibre. For yarns there is customary
500 millimeters, for staple fibre 20 millimeters.

2.2. Force-elongation curve.

An instrument with an autographic recorder gives during
the test for each elongation the respective force. This
curve has a welldefined end when testing single fibres.

In a filament yarn each single file breaks at a somewhat
different elongation. The resulting curve, as shown in
Fig. 2, has an ending going back in force again. It is
customary, to make the point of highest force end of
curve. Testing part of the single filaments of the yarn
and giving their respective force-elongation curves might
be better, but as the yarn as a whole is to be used, sometimes
the yarns curve must be taken.

2.3. Tenacity

The tenacity is defined as breaking force of sample
divided by its titre. The dimension therefore would be
cN/dtex. In former times, there hat been used a measure
for tenacity given by the length of yarn or fibre that might
break under its own wight. Those figures, calles "Kilometers
to breake" are approximately the same as tenacity measured
in cN/tex. This is the reason, why most standards use cN/tex.
This is most confusing, as titre is measured in dtex, but
it seems impossible to do anything about it.

When the sample is a filament yarn, the titre of the yarn
has to be taken. When the sample is a single filament or
staple fibre, the titre must necessary be taken of the
single fibre to be tested. In this case the use of vibros-
cope is essential. Some standards make use of titre measured
on different fibres, dividing the mean breaking force by
the mean titre. This procedure cannot be recommended. The
consequences are bad accuracy and impossibility to do any
statistical calculating with test results. Fig. 3 shows
stress-strain curves of cellulose modal fibres with and
without allowing for the single fibres titre. The spread
of curves using mean titre of the sample gained on
differend fibres is larger.

The time consumption to measure titre of each single fibres
is to be neglected. It can be done during the tensile test
of one fibre for the fibre next to be tested by the same
person. In this case the vibroscope is to be situated side

by side with the tensile testing instrument. Modern tensile
testers allow for the titre to be adjusted at a lever of
the instrument.

2.4. Modulus

Modulus is defined by the force per titre at a certain
elongation. In common use there are 2 or 5 percent elon-
gation. Therefore the dimension of Modulus is cN/tex/%.
As stated above, the use of vibroscope is necessary.

2.5. Wet tests

All properties stated above may be investigated in the wet
state as well. This is useful only with fibres of hygros-
copic type. For all fibres of cellulosic material tenacity
in the wet state and wet modulus are most important.

b) Examples of tests that must be carried out using collectives
of fibres in any case.

1. Content of defective fibres

There are not existing any generic names of such fibres. Every-
body is using his own definitions and names. So at first we
also must state what with "defective" fibres to denote.

It means all fibres of a small group which are distinctly
different from the great quantity of fibres produced with
uniform shape. There are many types of defective fibres
depending on the fibrespinning process. The most important
can be arranged in one of the following groups, shown by
drawings on Fig. 4.

1.1. Bundles of long fibres (Fig. 4a)

They are only possible in staple fibre samples. Their
origin is sometimes a malfunctioning cutting machine. Some-
times they origin by breaking of fibres during the stretching
process. Here also when subsequent cutting is done, part
of fibres gain length very different from the normal staple.

Of course it is always possible to find separated single
long fibres within a sample. To find the origin, it is
most useful to compare the stress-strain curves of normal
and long fibres. They differ largely if the stretching process
is involved.

1.2. Splinters or fibres adhering (Fig. 4b)

In dry spinning process, when fibres are still sticky, they
may be pushed together by turbulence of spinning gas.
This may result in adhering of one fibre to another or
even several fibres together. If they do not stick very
much, they may be seperated again at stretching process.
They also may be seperated partly at the ends of staple
after cutting. They are found in filament yarns as well
as in staple fibre. In wet spinning process they are less
of a problem, as the spinning bath does not favour them.

1.3. Thick fibres or unstretched fibres (Fig. 4c)

The typical frequency distribution curve of a samples single
fibre titre can be calculated from vibroscope measurement.
There are always some fibres with titre far above the end
of this distribution, say with a factor of three or fife.
The high titre of those fibres may have its origin in
variations of viscosity within the spinning solution or
melt, caused for instance by temperature variations. In this
case the fibres have about normal properties. The second
possibility of origin is, when single filaments break at
the spinning jet, due to small pieces of foreign matter
or gas bubbles within the spinning solution or melt. The
broken filaments of course are completely unstretched.
They differ very much from normal fibres in physical
properties. In many cases they are so brittle to break
from touch with pincers.

1.4. Splashes of spinning liquid (Fig. 4a)

Sometimes the liquid coming out of one single orifice

of the spinning jet does not form a filament. It adheres
to the surface of the spinning jet, forming a drop and
at last becomes entangled with fibres from neighbouring
orifices, being carried away with them. Such drops or
splashes of spinning liquid with adhering unstretched
fibres are more frequently found in fibres from wet
spinning process, than in dry spun fibres.

All those types of defects are a severe drawback in quality
of fibres production, especially in staple fibre, as behind
the cutting machine they are spread over a large volume of
fibre. In filament yarn they can more easy be detected and
removed when spooling. It must be emphasized, that the usual
process of carding does not succeed in removing them. In
contrary only a very small part of the largest defects is
found remaining in the carding machines, most of them is at
last found in the staple yarn, resulting in bad yarn egality.

In staple fibre production it is therefore of the greatest
importance to measure the content of defective matter within
the fibre produced for quality control purpose.

There are two possible aproaches to this problem :

1.5. Weigh a small amount of the staple fibre and search it for
defective fibres manually and visually. This gives exact
figures of number of defective fibres per gram of fibres.
The procedure takes a long time, so the quantity of fibre
to be tested must be small, say a few grams. The disadvantages
of this method therefore are the large time consumption, the
small amount tested and therefore bad reproducibility of
test. Considering the origin of defective fibre it is to
be expected they are not at all equally distributed within
a given sample. Advantage is, besides gaining absolute correct
values in principle, defective fibres may be recovere to
examine them with a microscope and establish their type
and origin.

1.6. Make a sliver of staple fibre only for testing purpose, weigh it, taking about some hundred grams. This sliver is stretched and spread with an instrument originally used to test slivers. The moving fleece is visually inspected, a counter being operated manually every time a defectiv fibre can be seen. Advantage of this method is the sufficient amount of samples fibres to be tested. As the sliver is always moving, the time consumption is low. Unfortunate with this method only a very small part of defects is detected. This amount would increase, if the instrument were stopped at intervals for inspection of fleece. In this case timeconsumption would increase as well. For the purpose of quality control the exact absolute figure of defects per weight is not really needed. What one needs is a figure to compare with similar figures gained at different samples. That can be done using this method, the result of test being called something like "figure of defective fibres". It must be stressed, this figure is only a proportional value, but its reproducibility is rather good. When giving an estimation of the precision of this test one must consider it is the result of some counting. In this case a repeated test would give a result within limits as shown in Fig. 5 with high probability. The mathematical law used here for calculating the borders was made by Poisson.

2. Tests using a tristimulus colorimeter

Four most important measurements on fibres can be done using the same instrument in principle. Fig. 6 gives diagrams of how it works.

The sample to be tested is illuminated. Light being thrown back by the samples carries information on the samples properties. It is analysed simultaneous or step by step using optical filters and photocells. If the filters have suitable properties three analysing channels are sufficient. The

output of photocells is amplified and evaluated using a computer. It is essential to give a smooth and flat surface to the sample. This can easily be done with filament yarn. it is wound on a small flat board using a special machine. Staple fibre are either pressed to give a firm feltlike cake, or they are measured pressed behind a plane of glass. In this case, the influence of glass must be taken care of by calibration or computation.

An instrument of this type can be used for the following tests :

2.1. Colour of spun dyed fibres

In many cases, a colouring agent is added to the spinning-solution or even-melt. Those pigments are imbedded in the fibre processed, giving bright colours very stable and light resistent. Any deviations in colour of fibres can be seen as strips in carpets made of filament yarns or in fabric made using yarns made of staple fibre of this type. So the requirements of accuracy of colouring are very high. This can only be achieved by measurement.

Using an instrument as discribed above each production sample can be compared with a standard sample, which should be made of the same type of fibre and colouring agent as in production. The evaluating computer in this case can be programmed to calculate the difference in colour of standard sample and production sample. This would be one figure only. The computer can do even more. If standard and production sample differ, it is possible to state the kind of difference, say different brightness of colour or too much yellow for instance.

2.2. Test dyeing of fibres

Most fibres produced raw-white are destined to be dyed later on, at the customer, as fibres, yarns, fabrics, knit-ware, or carpets. So the dyability of fibres must be extremely constant in order to attain products without stripes.

Test is done by using laboratory type small test-dyeing machines. For testing purpose special dyes can be obtained, giving bad equality of dyes to enlarge existing differences in fibres properties.

In any case it is necessary to use a fibre sample with known and correct dyability. This standard sample is to be compared with the production sample in question.

Differences in dyability may in principle have two reasons : Either part of fibres take up the dyestuff faster from the bath than the rest, or the amount of dyestuff taken from the bath is different for part of fibres produced. So sometimes it may be necessary to carry out two kinds of tests, if it is unknown how differences in dyability of samples originate.

Fastness of dyestuff take up is tested by having standard sample and production sample in the same vessel of dye-bath, separated only by a grid of metal or plastic.

Amount of dyestuff taken by the fibre is tested by having standard sample and production sample in different vessels, each containing the same type and concentration of dye-bath.

In both kinds of test it is essential, to have the same dyeing conditions like temperature, pH and salt concentration for both standard sample and production sample.

When making the test in different vessels, in principle it would be possible to measure the decrease of dye concentration in the bath comparing both samples. This cannot be recommanded, as some fibres take up dye on their surface, other in the whole volume. Therefore it is by far better, not to measure the liquid, but the fibre sample after dyeing. If there has been made a test of fastness this is the only means of measuring in any case.

Measuring is done as described above for spun dyed fibres. The computer in this case must be programmed to give difference in colour only, as there is always the same colour of test-dye.

2.3. Whiteness

No man-made fibre is really "white". There always is also a small amount of colour, mostly yellow, giving the impression of reduced whiteness. So, in principle it might be best to treat white fibres in the same manner as has been described for spun dyed fibres. At least this is technically feasible. In practice most people prefer to use a "whiteness" scale being in coincidence with whiteness as seen when visually evaluating the sample. So after measuring with the tristimulus colorimeter the computer gives the whiteness as one figure calculated by a formula from the photometer output. It must be emphasized, there are several whiteness formulas in use, which give somewhat different results. Also the whiteness scale is an absolute one. Therefore use of a standard sample of fibres is impossible. A whiteness standard is used instead, to be compared with production samples. As the whiteness of this standard is as high as possible, the difference of this absolut figure and the result obtained with the production sample is rather high. The whiteness of the sample is given as percent of the standards whiteness. Cakes made of magnesiumoxyde are in use as whiteness standards.

2.4. Fluorescence

Most fibres contain optical brighteners, used by intention to fake a better whiteness the fibre does not possess, or being in the fibre unintentionally as a defilement. In every case it is necessary not only to measure the influence of fluorescence but also to separate its figures from the original whiteness of fibre matter. As any fluorescence is caused by illumination with short wavelength radiation, say ultraviolett, the colorimeter in this case must contain a source of such radiation. Best would be, to use a lamp giving normal light and UV light as well. A xenone lamp serfs this purpose best. With an additional optical filter it is possible to admit and shut out the UV-part of the light. Using the instrument and whiteness-formula as

described for whiteness test, there can be done two measurements on the same sample. The first, using only light of normal visual spectrum, gives the whiteness of sample without any fluorescence. The second, using UV-light in addition to normal light, gives the whiteness enlarged by fluorescence, using the same units of whiteness for both properties. The difference of measurement gives the effect of fluorescence alone. This is most important, as one wants to keep both, the basic whiteness as well as the fluorescence within limits.

There is always the danger, the production management might compensate for decreasing whiteness with increasing amount of optical brightener. This must not be allowed, as it leads to unequal dyeing and stripes in a white fabric or knitwear when illuminated with light containing some ultraviolett radiation.

So a tristimulus colorimeter equipped in suitable manner and used in combination with a small computer is by far the most valuable instrument for quality control of all man made fibres.

C. Evaluation

It was stated in chapter about sampling to be best taking samples from the end of production line using a time pattern. This does not mean, every property of fibres to investigate at each sample. The time interval between repeating the same kind of test depends on the type of fibre and the requirements of fibres application. When there are not problems of production the test of every property of fibres should be repeated in regular time intervals, for instance titre every hour, tenacity every three hours.

The primary information gained from samples tested for every property is the mean value and standard deviation if on every sample several measurements have been made. This is independent of the kind of test and if the testing has been

done on single fibres or filaments of the sample or on collectives of fibres. The standard deviation of repeated testing within one sample shall be called s_w.

When the production line is running some time, without changing type of fibre produced by intent, there are a row of mean values and standard deviations within samples. This is demonstrated in fig. 7. The mean values of each sample can be used to form an overall mean for the whole time the type of fibre in question is being produced. There also can be calculated the standard deviation of the mean values of samples with respect to the overall mean. This standard deviation between mean values of samples shall be called s_b.

All this calculations are easily done even using a small pocket calculator (which does not mean we recommend using pocket calculators for quality control, each calculator in use should feature a print-out of every figure to allow for finding errors).

For each sample tested and every one of properties there should be :

$$s_w \gg s_b \gg 0 \text{ approximately.}$$

As the standard deviations themselves have limits of confidence, exact comparison of both standard deviations only can be done using a computer and formulas of variance analysis.

Generally speaking one can say, if standard deviations s_b should be cero, then the production is running stright on respect of the property investigated. Also one can state, standard deviation s_w must be as small as possible, to ensure there is little variance of the property investigated.

Fig. 8 shows what is really happening. There may be a constant level of mean values of samples (bottom), but there is much variation of s_w the standard deviations indicated by the length of dark lines.

There may be constant s_w, being even rather small, but the level of samples mean values does not go stright (middle)

giving s_b larger cero. Most time there will be some small
fluctuation of s_w combined with fluctuations of the mean
level (top).

An ideal production would give short dark lines of the same
length all exactly on the same level (not indicated). This
would mean, as stated above, a small s_w combined with a s_b
near cero.

For quality control one wants to have limits of tolerance for
every property being important. It must be stated that those
limits are only to be given by the quality of the equipment
of production plant and of the efficiency of persons running
the production. This has to be established by measurement of
properties of the product. No production manager or director
is in a position to establish tolerances by wishful thinking
or considering what customers demand; doing so must lead to
descaster some time. If tolerance limits established by
measurement of production do not meet specifications of
customers or wishes of management, there only one thing is
to be done : Improve the production machinery and perhaps
training of production personnel.

Calculation of limits of tolerance in a correct mathematical
manner is rather complicated. A very simple method to give
preliminary limits which may later be corrected by experience
and are sufficient in most cases works as follows :

- Have the production run as smooth and undisturbed as
  possible for a span of time typical for production periods.

- Make tests in time pattern which shall be adopted later on.

- Calculate for each sample mean value.

- calculate the overall mean for span of time considered and
  standard deviation of means s_b.

- Take double of this standard deviation plus and minus
  from overall mean ($\pm 2 s_b$) as preliminary limits of
  tolerance.

- Repeat for each property to be tested and for every type
  of fibre to be produced. Different setting of machinery
  means another type.

- Delete and repeat if there has been any problem of
  production during span of time in consideration.

Evaluation of tests results is shown on Fig. 9. It is advisable
to draw charts of this kind for every property tested and
insert the limits of tolerance for each type of fibre in
production.

If the mean value of the sample is within the limits of
tolerance, nothing is to be done.

If the mean value of one isolated sample is outside of
limits, the test must be repeated. Never use the same sample for
repetition. A new sample must be used ! If the result again
is outside of limits, part of production is to be rejected.
To establish the amount of production to be rejected, more
samples have to be tested, covering the time before and after
the sample outside of limits.

If production is under control, the management of production
should know there was some kind of trouble and can help to
pin down the part of production out of order. If the mean
values of a row of succeeding samples are out of limits,
the whole part of production has to be rejected. In this
case repetition of test as a rule is unnecessary.

The following has to be considered carefully :

- Never reject single production units like bales or spools
  as a result of quality control unless this unit has been
  especially tested.

- Never select single production units on behalf of their
  properties derived from results of quality control tests
  which took place at the production time of unit. This
  follows logically from the fact, results of tests on samples
  need not be and in the rule are not representative of the
  whole production of the time in question.

- Never dispatch together parts of productions of very different times even if their respective samples have given similar test results.

- Whenever possible, production units having been produced one after another should be shipped together unless there has been a trouble in production and production been rejected on behalf of a row of mean values being out of limits.

It should be emphasized that neglecting of above rules indicate a severe misunderstanding of the task and possibilities of quality control and are an abuse of this fine instrument.
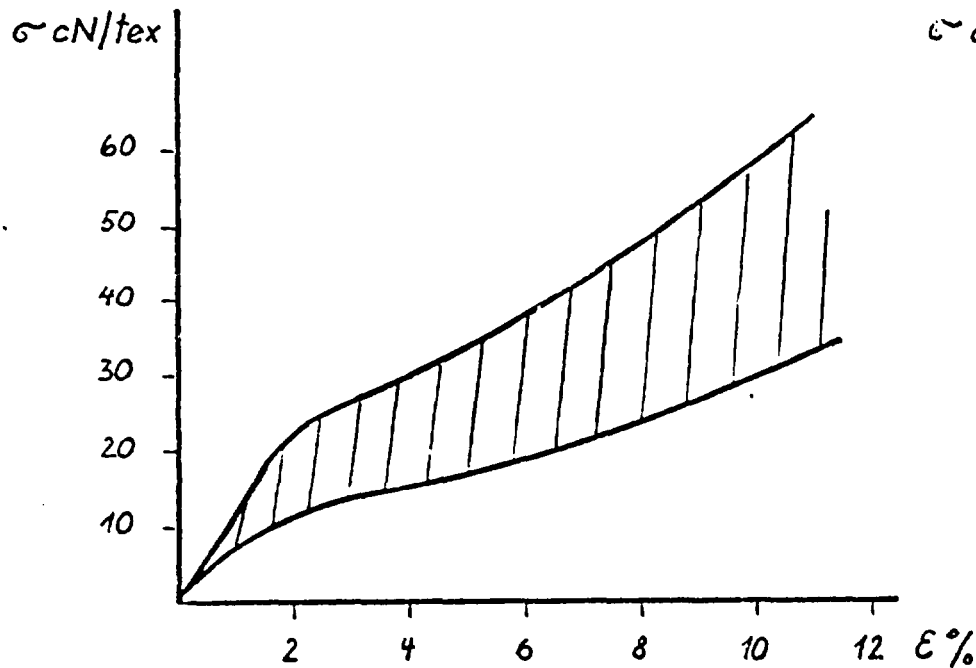
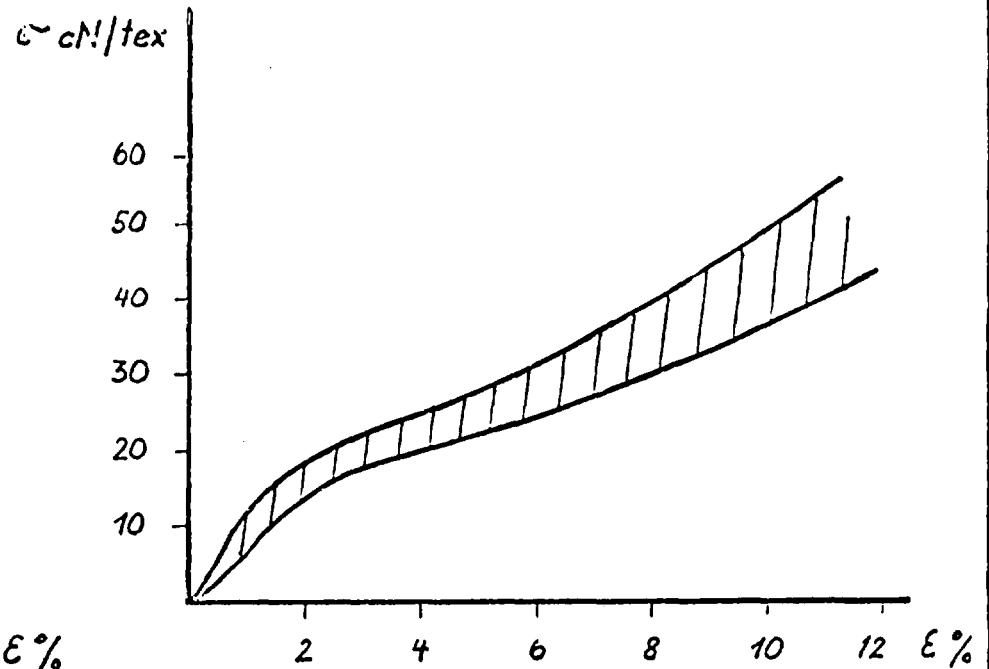titre frequency distribution curves

FIG. 1
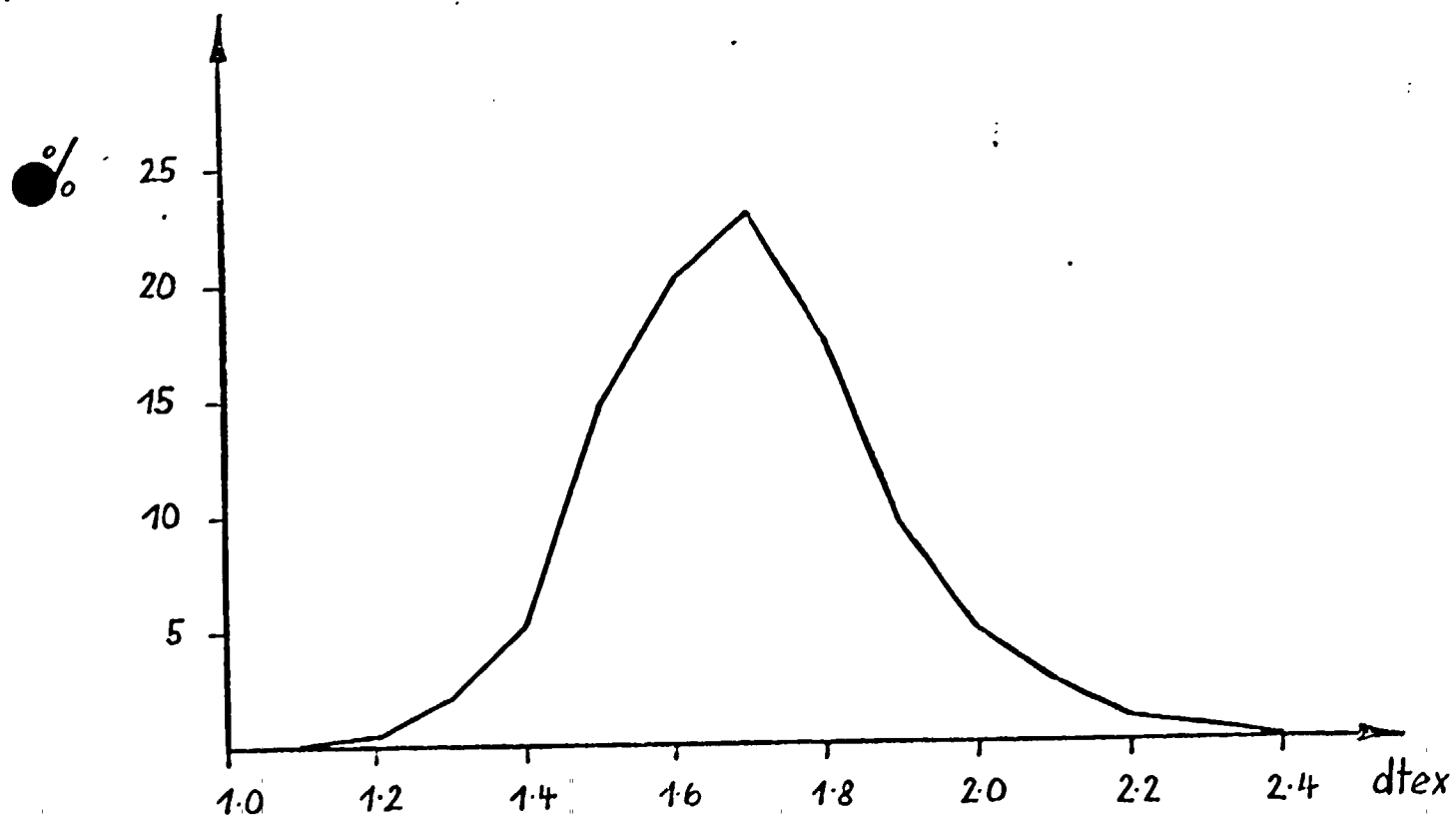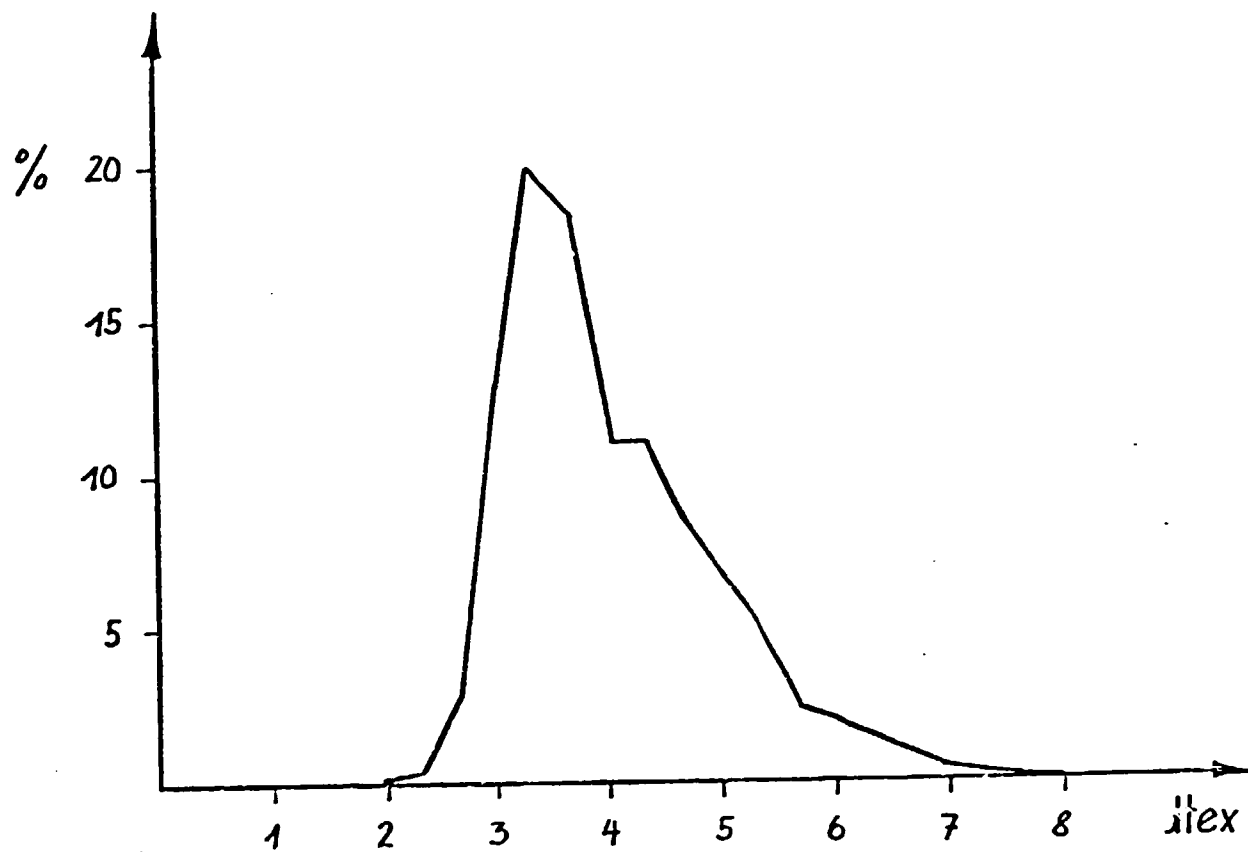
FIG. 2

Force–strain curve of filament yarn

FIG. 3
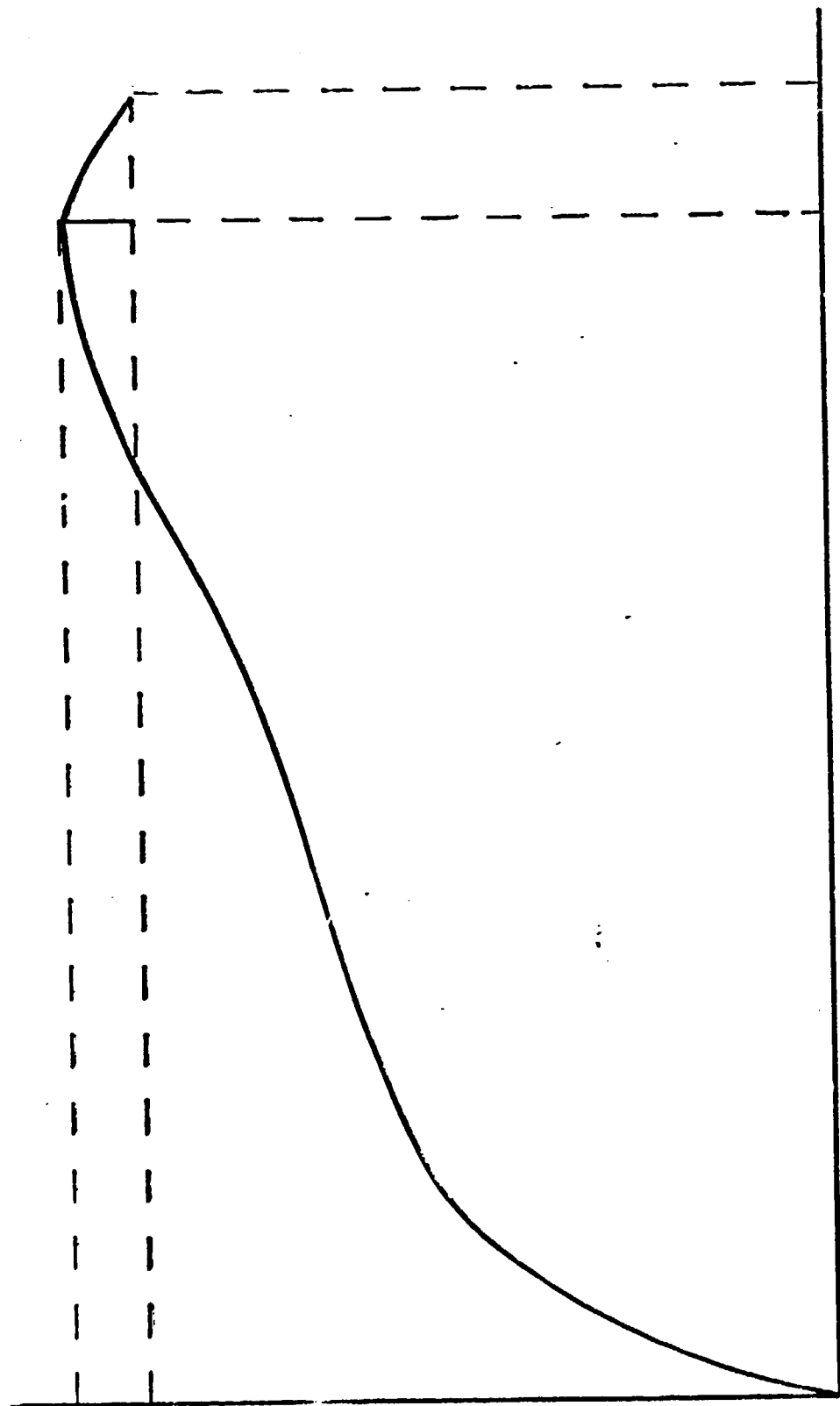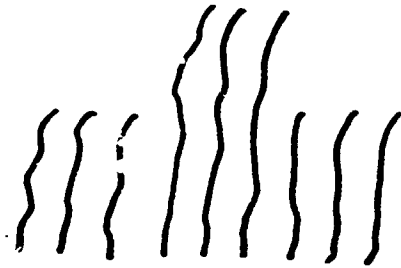

Ohne Berücksichtigung des Einzelfasertiters

Mit Berücksichtigung des Einzelfasertiters

Zugprüfung an einer Viskose – Modalfaser

Streubereiche von Zugspannungs – Dehnungslinien
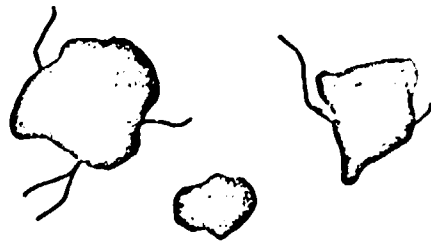
FIG. 4

Different types of defective fibres

a.)

b.)

c.)

d.)

confidence limits of counting

FIG. 5

counted figure	range of high probable result when test is repeated		
0	0	—	3
1	0	—	5
2	1	—	7
3	1	—	8
4	2	—	10
5	2	—	11
6	3	—	13
7	3	—	14
8	3	—	15
9	5	—	17
10	5	—	18
11	5	—	19
12	7	—	20
13	7	—	22
14	8	—	23
15	8	—	24
16	10	—	25
17	10	—	26
18	11	—	28
19	11	—	29
20	13	—	30
21	13	—	32
22	14	—	33
23	15	—	34
24	15	—	35
25	17	—	36
27	18	—	38
30	20	—	42
35	24	—	48
40	29	—	54
45	32	—	59
50	38	—	65
60	45	—	76
70	55	—	88
80	62	—	99
90	71	—	110
100	80	—	120
120	99	—	143
150	126	—	176
200	173	—	228
300	267	—	335

Sichtbares
Licht

blau

grün

rot

Probe Vergleichsmuster

Auswertung
über
Farbdifferenz-
Formel

⟶ Farbdifferenz

Sichtbares
Licht

blau

grün

rot

Probe Vergleichsmuster

Auswertung
über
Weißgrad-
Formel

⟶ Weißgrad

Sichtbares und
ultraviolettes
Licht

blau

grün

rot

Probe Vergleichsmuster

Auswertung
über
Weißgrad-
Formel
und Differenz
zum
Weißgrad

⟶ Fluoreszenz
als Maß für
optische
Aufhellung

FIG. 6

FIG. 7

continuous
production

production
line

samples taken by time pattern   time

moments of sampling

mean
of sample
standard
deviation
within
sample

mean
st. d.

mean
st. d.

mean
st. d.

property
tested

limits

time scale

FIG. 8

Festigkeit

Niveau und Streuverhalten schwankt

1 2 3 4 5 6 7 8 9 10 Proben

Festigkeit

Niveau schwankt

1 2 3 4 5 6 7 8 9 10 Proben

Festigkeit

Streuverhalten schwankt

1 2 3 4 5 6 7 8 9 10 Proben

FIG. 9