

Vegetable Gums in Paper Industry

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The use of vegetable gums as paper additives is nearly as old as paper-making itself. Internal sizing of paper with starch was already known in the 5th century. Thereby, starch is the oldest vegetable additive used in paper-making.

From the chemist's point of view starch is a polysaccharide constituted by α -linked glucose units. It was only logical that modern structural chemistry looked for similar built products deriving from natural resources, for evaluating their specific efficiency in this same field of application.

As a consequence, a series of other polysaccharides such as alginates, carboxymethylcellulose, vegetable gums and others, with all their possible derivatives found their way into paper-making.

In this paper, of the above mentioned additives, only vegetable gums will be discussed. These vegetable gums, being known to Japanese art-paper makers centuries ago, were discovered only in the late thirties of this century by the European paper industry. The secret of producing the strong low-weight Japanese paper by using extremely long fibres not mechanically treated, consisted in the addition of a particular root extract to the fibre suspension at a rate of 1:1. This specific type of vegetable gum was the cross linking agent binding the single fibre together.

Stimulated by these discoveries, chemists examined similar natural vegetable extracts evaluating their suitability for the paper industry. These products were found in the seeds of the Locust Bean tree as well as those of the Guar-, Tamarind- and Tara-plant.

It is worth while to discuss a few details concerning the structure of these seeds.

Botanical Origin

The Locust Bean tree growing in the Mediterranean area reaches a height of nearly 10 metres. It belongs to the botanical group of Leguminosae. The fruit of this tree is a pod of 10-12 cm. length containing the seed. Guar—an annual plant—is a leguminous specie and is extensively grown in India and Pakistan. Pods as in the case of Locust Bean contain the seeds. Both Locust Bean and Guar seeds consist of an external hull covering the germ and the endosperm from which the gum is extracted.

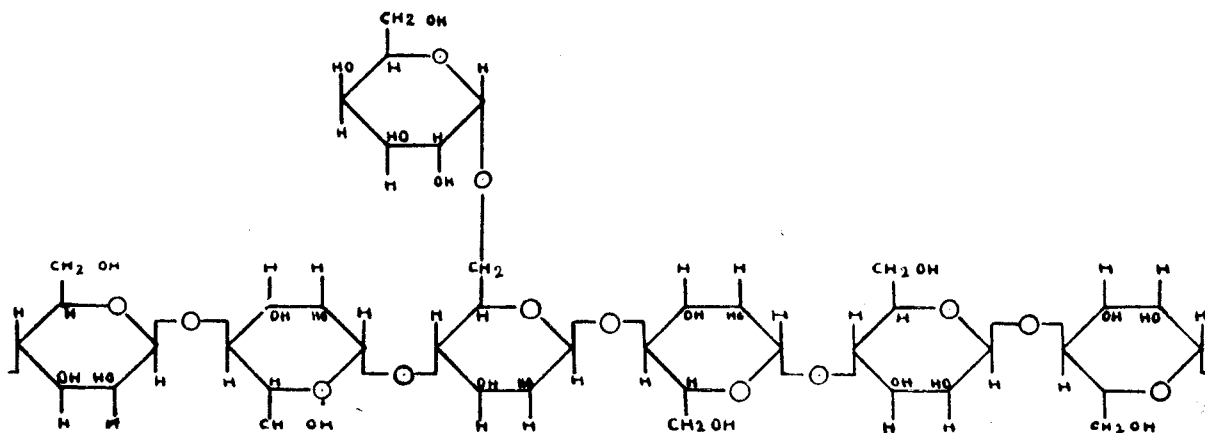
The endosperm represents about 40% of the total seed weight and is the substance, DAICOL and other paper additives are derived from. Tamarind and Tara seeds have a similar conformation.

The industrial process separates the endosperm from the hull and the germ, and transforms it into a wide range of products used in the paper, textile, mining, food and pharmaceutical industry.

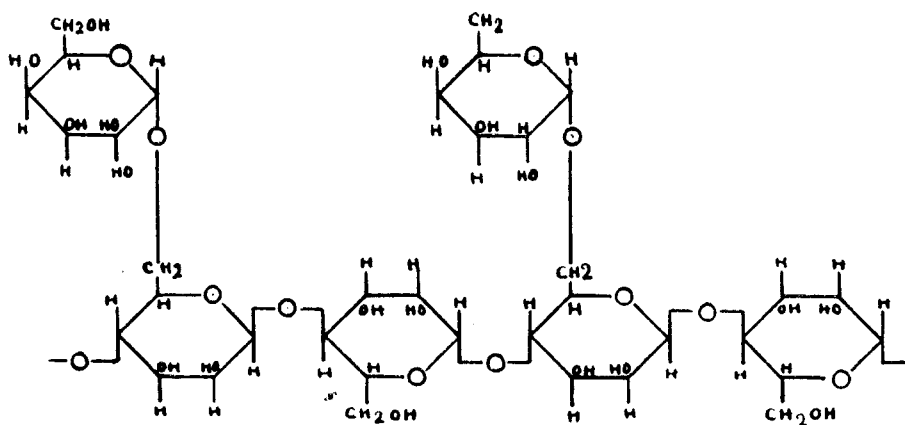
Chemical Structure

The chemical formulae (Page 26) describes the structure of the basic constituents of Locust Bean and Guar gum: Guaran and Carrubine. In both cases we have an α -glycosidically linked polymer chain of mannose units joined in statistical distribution and in 1-6 position to the C₆-atom galactose units. The galactose mannose ration is 1:2 for Guar and 1:4 for Carrubine.

The average molecular weight figures are



CARRUBINE



GUARAN

the following ones: Carrubine 310.000, Guar 220.000.

The configuration of gums being macromolecules defines also their physical properties, as known e.g. in starch chemistry. Carrubine chains show the tendency to attach to each other by secondary valences. Consequently more energy is required to separate these aggregations and to bring the gum into solution. This high energy required corresponds to a temperature of 90°C. In the case of Guaran, sterical configuration hinders the formation of such aggregations. The product is cold soluble.

These considerations explain why, in practice nearly all cold soluble manno-galactan paper additives are based on guar gum. On the other hand, Locust Bean gum is the basic constituent of many paper additives, the suspensions of which have to be cooked before being added to the stock.

The intermolecular forces which cause chain aggregation do not only act inside the structure of these gums. In what follows we shall see, that these forces act on cellulose molecules as well and that additives based on Locust Bean gum result in a higher

yield as to their technological effects, compared to Guar gum based products.

Being high molecular products manno-galactan gums yield high viscosity solutions, a problem which has to be considered when planning technical equipment for the preparation of gum solutions.

It is necessary to stress that most gum derivatives available on the market are submitted to various physical and chemical treatments which bring about modifications of their basic properties and particularly of their viscosity. In any case a gum solution should never be prepared at concentrations higher than 1% in order to operate within security limits.

Influence of Alkalies, Acids and Salts.

Gums have neutral reactions and the action of electrolytes does not change their viscosity. The only exception is represented by a few salts which form complex gel structured precipitations at a pH higher than 7.

Like all other α -glycosides, vegetable gums are sensitive to extreme pH conditions, over long periods of time or at high temperatures. Under such extreme conditions they are split by hydrolysis into low molecular fractions. When preparing gum solutions precautions should be taken to prevent the above mentioned phenomena.

Tamarind and Tara gums show similar properties. However, only Tamarind finds a certain restricted application in the paper industry. The chemical structure of Tamarind is somewhat more complicated and its yield in practical use is inferior to the one of Guar gum but better than the one of starch.

Finally, it should be mentioned that all mannogalactan based paper additives are fully compatible with other paper additives being used by the industry.

Influence of Gums on the Paper

Extensive literature exists on the influence of gums on paper web formation. Swanson (1) demonstrated that an addition of 0.5% of Locust Bean gum to bleached kraft pulp beaten for 15 minutes gives a finished paper sheet possessing the same Mullen bursting strength as a sheet obtained from the same pulp beaten 50 minutes without any gum addition. This corresponds to a 70% saving in beating energy or to an increase of strength of more than 30% in comparison to the same pulp beaten to the same freeness without any gum addition. At the same time Swanson noted a considerable increase of other mechanical properties such as breaking length and folding endurance.

The simultaneous reduction of tear leads to the conclusion that the addition of gums to the pulp leads to an effect being similar to mechanical refining. On the other hand, a fibre having not undergone any mechanical treatment was not significantly influenced. Thus the conclusion was drawn that the gum's action on paper actually starts with the increase of the specific surface of the fibres, i.e. after the beginning of fibrillation.

Therefore, the expression "chemical refining" was coined to indicate the fact that a simple addition of a natural gum to the pulp brings about microscopical effects which normally are obtained only by cutting and fibrillating the fibres by mechanical refining.

All this confirms the existing theories on the role of polysaccharides in the refining process. It is in fact well known that polysaccharides, such as natural hemicelluloses, which develop in the course of refining, have a positive influence on the strength of paper.

Campbell (2) and Runkel (3) believe that strongly hydrated hemicelluloses are being pressed together with adjacent cellulose fibres and act as an adhesive agent when

passing through the drying section of the paper machine.

Wise (4) concluded that the mannan portion of hemicelluloses is mainly responsible for this adhesive effect. At this point we will remind that mannogalactan gums are primarily constituted by a chain of mannose units.

Jayme (5) considered the swelling capacity of cellulose fibres in function of hydration and he demonstrated that the changes of colloidal conditions of the fibres in the course of the beating process bring about the adhesion effect.

Ranby (6) presumes an absorption of hemicelluloses by the fibres which creates a hydrophilic system decidedly influencing the properties of cellulose fibres in an aqueous medium through formation of a protective colloid.

Quantitative investigations have been carried out as well. Jayme (7) spoke of "maximum strength" of a sheet of paper presuming that a certain amount of hemicelluloses must be present in a pulp to impart a maximum strength to the resulting sheet of paper. Experience gained in mill application confirms this statement to be valid for gums also, as the maximum strength improvement is obtained with a maximum addition of 0.7% of gum.

Now, we will shortly discuss the theory of fibre bonding for a better understanding of the action of gums on paper-making fibres. It is known that Van der Waals' forces are acting between the fibres. The strength of a sheet of paper mainly depends on 4 factors:

- (i) Strength of the single fibre.
- (ii) Strength of fibre to fibre bonds.
- (iii) Number of fibre to fibre bonds.
- (iv) Distribution of fibres and bonds.

As gums do increase the strength properties of a sheet of paper it can be assumed that they do influence one or more of these 4 factors.

Leech (8) investigated the influence of gums on these factors by evaluating the extent of their action on each of them. He found that the increase of the strength properties of a sheet of paper as a consequence of gum addition can be attributed for,

- 15% to increased bonded area ;
- 25% to better sheet formation ;
- 60% to increased strength of fibre to fibre bonds.

According to this analysis the action of gums concentrates essentially on fibre to fibre bonds. In other words fibre-gum-fibre bonds are much stronger than normal fibre to fibre bonds.

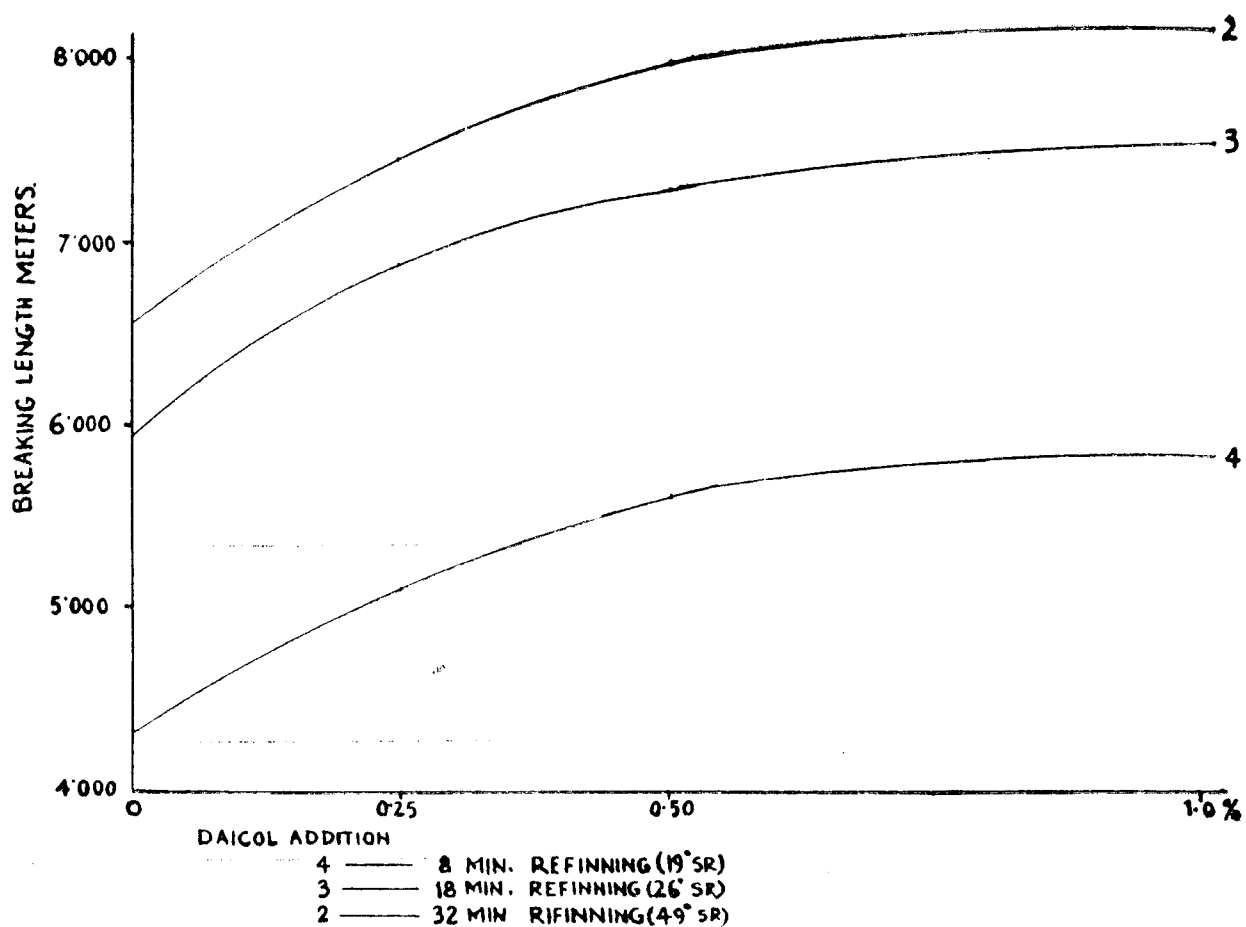
The particular structure and the high swelling power of gums explain why their use increases bonded area. It also explains their capability to deflocculate fibre suspensions. This was confirmed by Cronert (9) who could deflocculate a stock which was already highly defibrated by ultrasonic waves by means of gum addition.

Practical Conclusions

Having thus reviewed the theory it will be useful to discuss the most important and visible effects of the gum on the paper. The following graphs demonstrate the influence of gums added in different quantities to a bleached spruce sulphite pulp which has been treated in a Valley beater to various degrees of freeness.

Graph 1: Influence of gum on breaking length.

The graph illustrates that the percentual strength increase obtained by gum addition decreases with increasing refining time. The stock was beaten 8' (19°SR), 18' (26°SR) and 32' (49°SR). Apparently gum addition produced the highest percentual increase

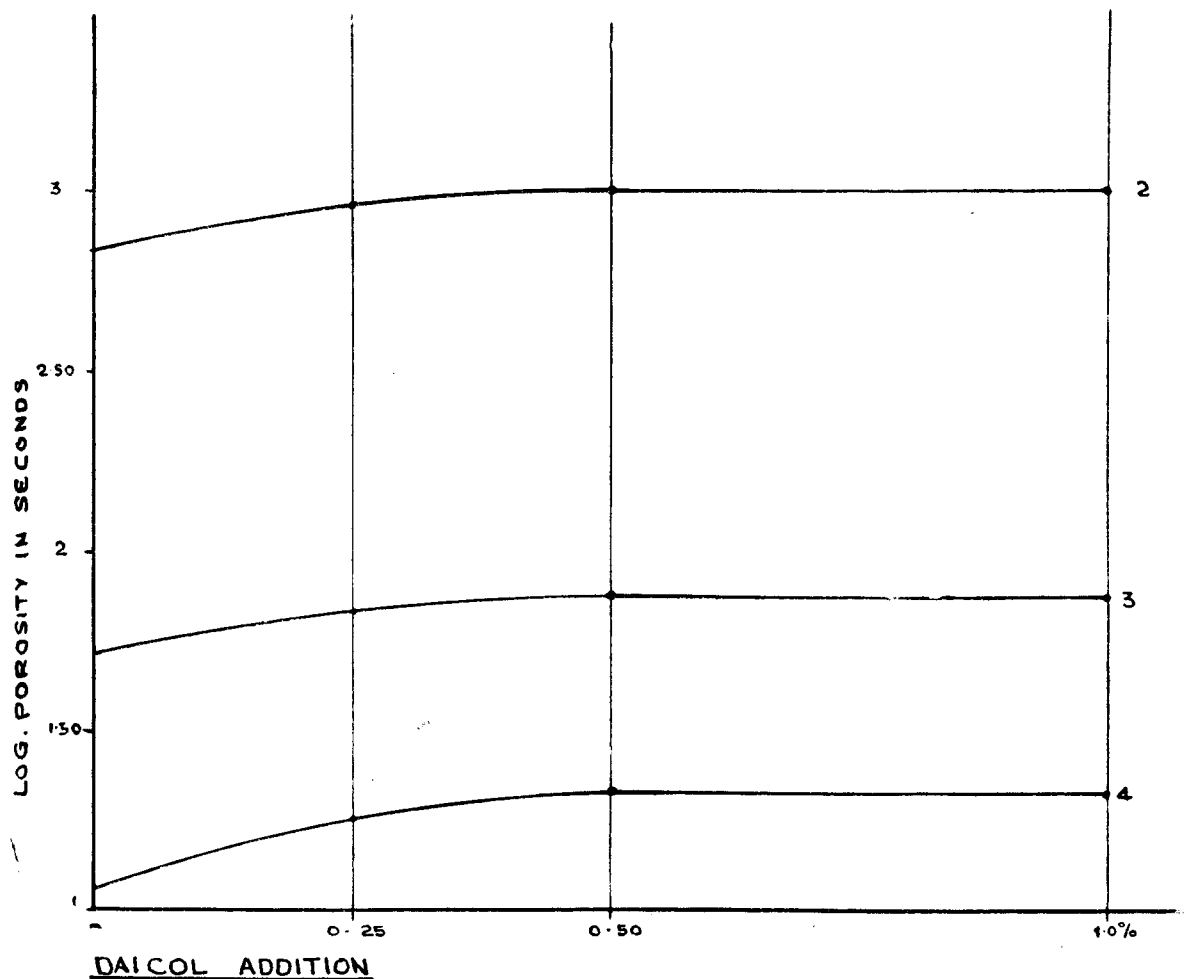


Graph 1: Influence of Gum on Breaking Length

in strength when using a relatively low beaten pulp.

As a matter of fact a 0.25% gum addition to a stock beaten to a freeness of 19°SR improves breaking length of about 17%,

while the corresponding increase of the 26°SR pulp amounts to 15%, and only to 12% when the same stock is beaten to a 49°SR freeness. Addition of higher percentages of gum does not give further improvements of strength.



DAI COL ADDITION

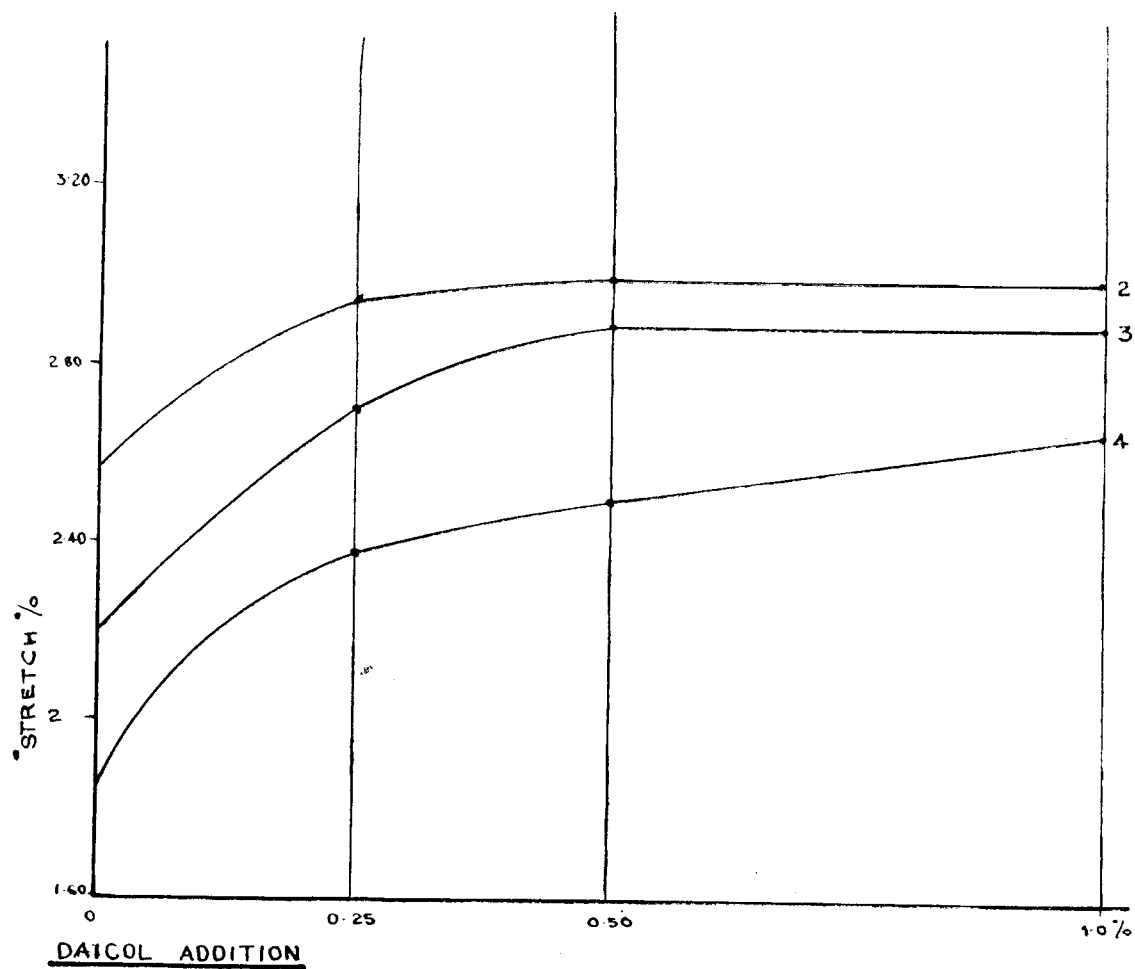
4 - 8 MIN. REFINING (19° SR)
3 - 18 MIN. REFINING (26° SR)
2 - 32 MIN. REFINING (49° SR)

GRAPH-2: INFLUENCE OF GUM
ON POROSITY.

Graph 2: Influence of Gum on Porosity

In this graph porosity is shown in logarithmical scale for better demonstration. As

little as 0.25% gum addition reduces porosity considerably while higher additions do not cause further reductions.



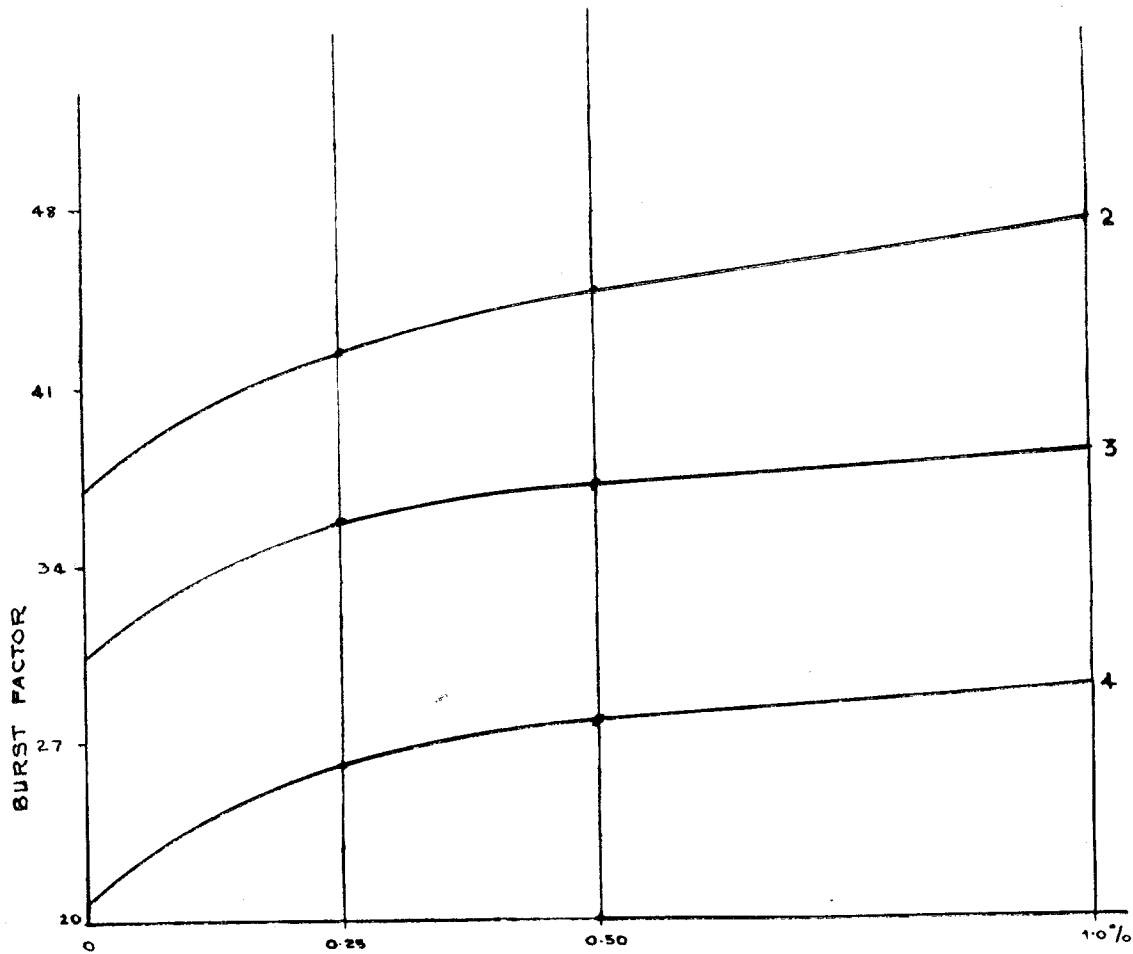
DAICOL ADDITION

4 - 8 MIN. REFINING (19° SR)
3 - 18 MIN. REFINING (26° SR)
2 - 32 MIN. REFINING (49° SR)

GRAPH 3. INFLUENCE OF GUM
ON STRETCH

Graphs 3 and 4: Influence of Gum on Stretch and Bursting Strength

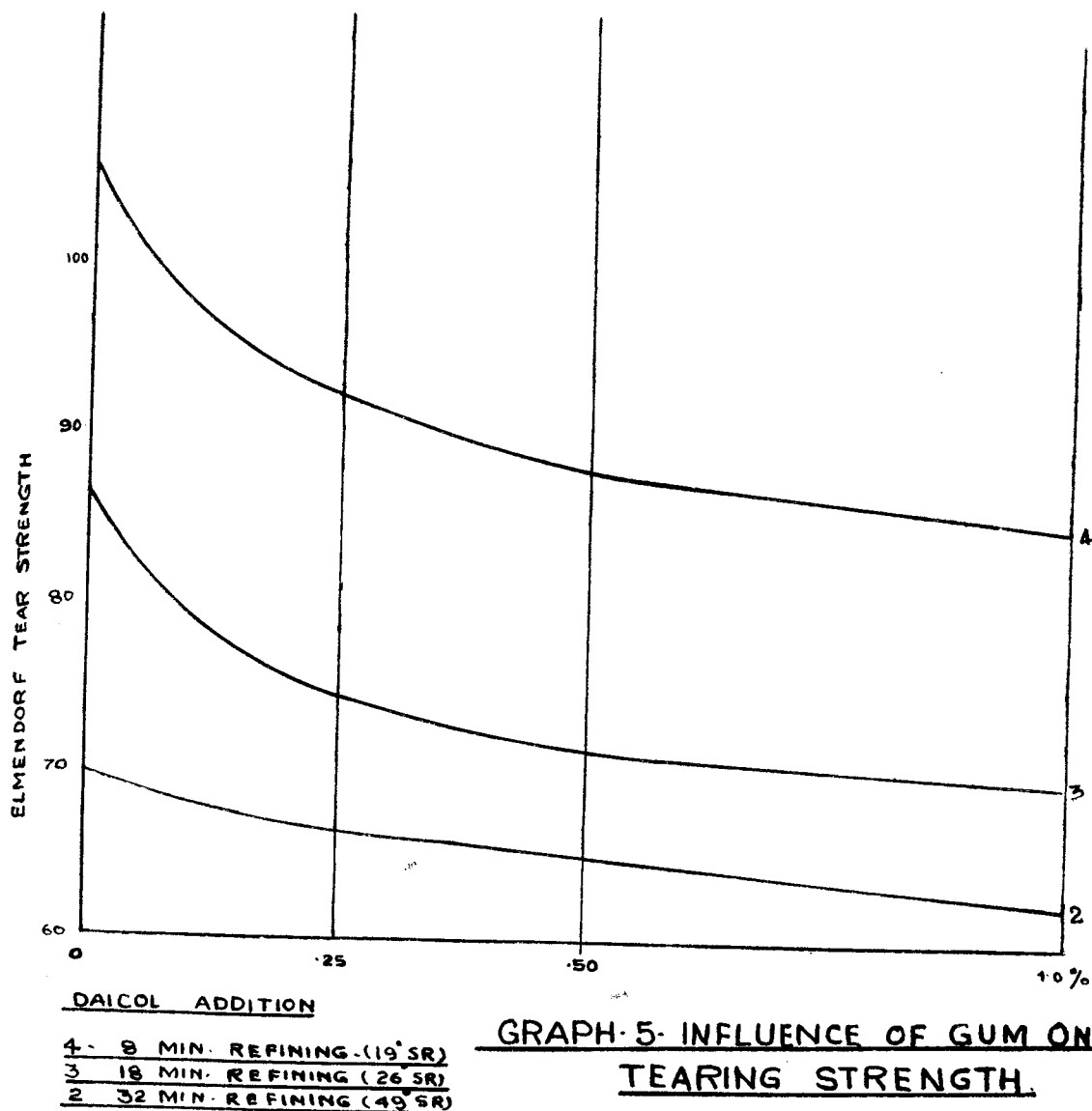
Here we have the same tendencies as shown in graph 1.



DAICOL ADDITION

4- 8 MIN. REFINING (19 SR)
3 18 MIN. REFINING (26 SR)
2 32 MIN. REFINING (49 SR)

GRAPH-4 INFLUENCE OF GUM
ON BURST STRENGTH



Graph 5: Influence of Gum on Tearing Strength

Figure 5 shows that tearing strength is reduced by gum addition. This is quite understandable: all other strength improvements depend on: (i) improved sheet formation, (ii) increase of bonded area, (iii) re-inforcement of fibre to fibre bonds.

However, the increase of bonded area influences negatively on the tearing strength,

as a greater number of bonds tend to tear the fibres instead of separating them one from the other.

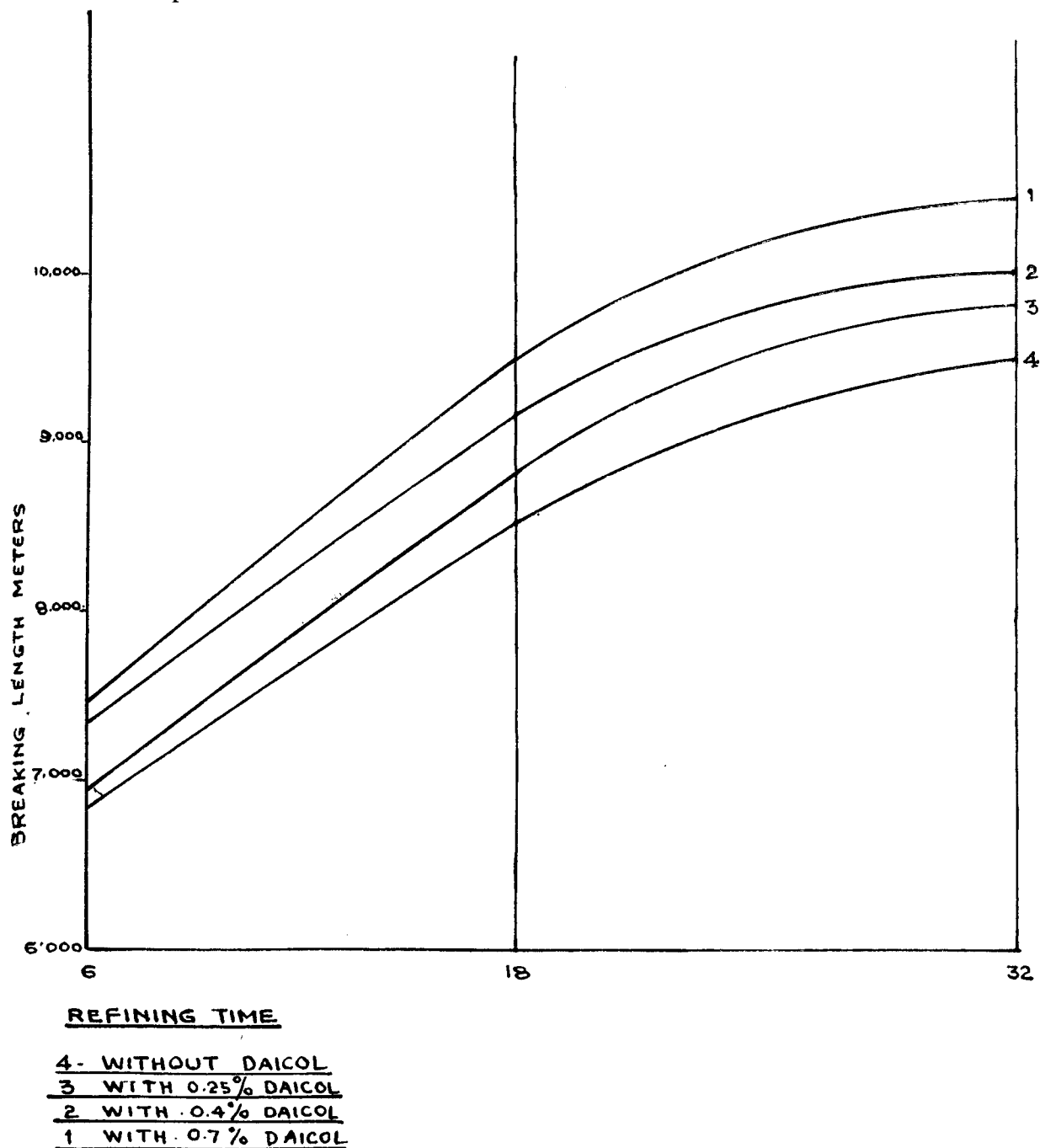
All these data demonstrate that 0.5% represent the ideal quantitative gum addition to obtain maximum results at a fairly economic level.

This conclusion is based on extensive laboratory investigations which often give results differing from the results obtained in

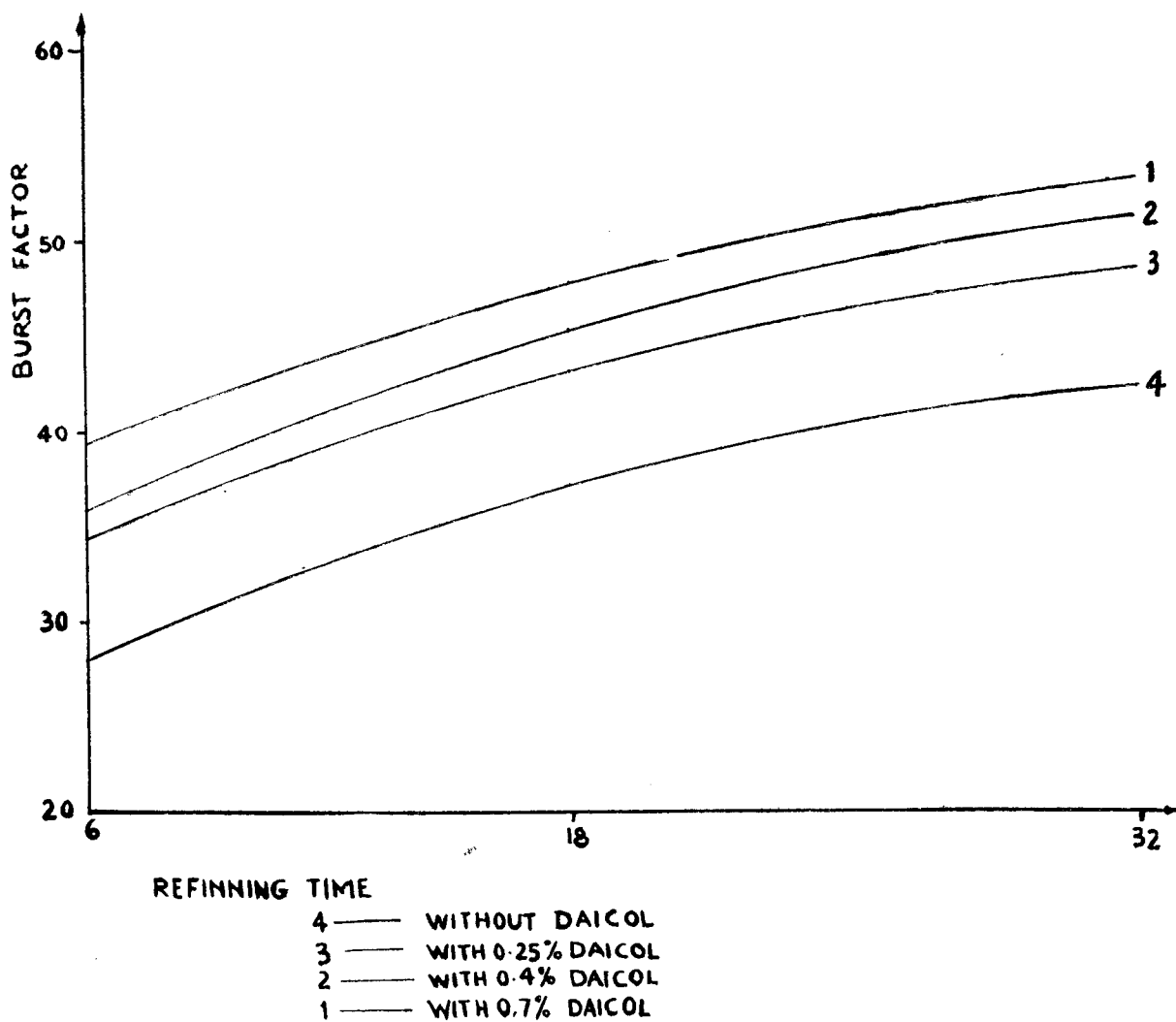
paper mills where higher percentual additions are sometimes required depending on prevailing manufacturing conditions. This is particularly true when the gum is added to the pulp in dry form during refining. In this case a partial mechanical damage of

molecular chains due to the action of beating aggregates is observed.

The following graphs describe the effect of gum addition to unbleached kraft pulp. Refining and gum addition have been carried out in the same way as with sulphite cellulose.



Graph—6



Graph—7

Graphs 6, 7, 8 and 9

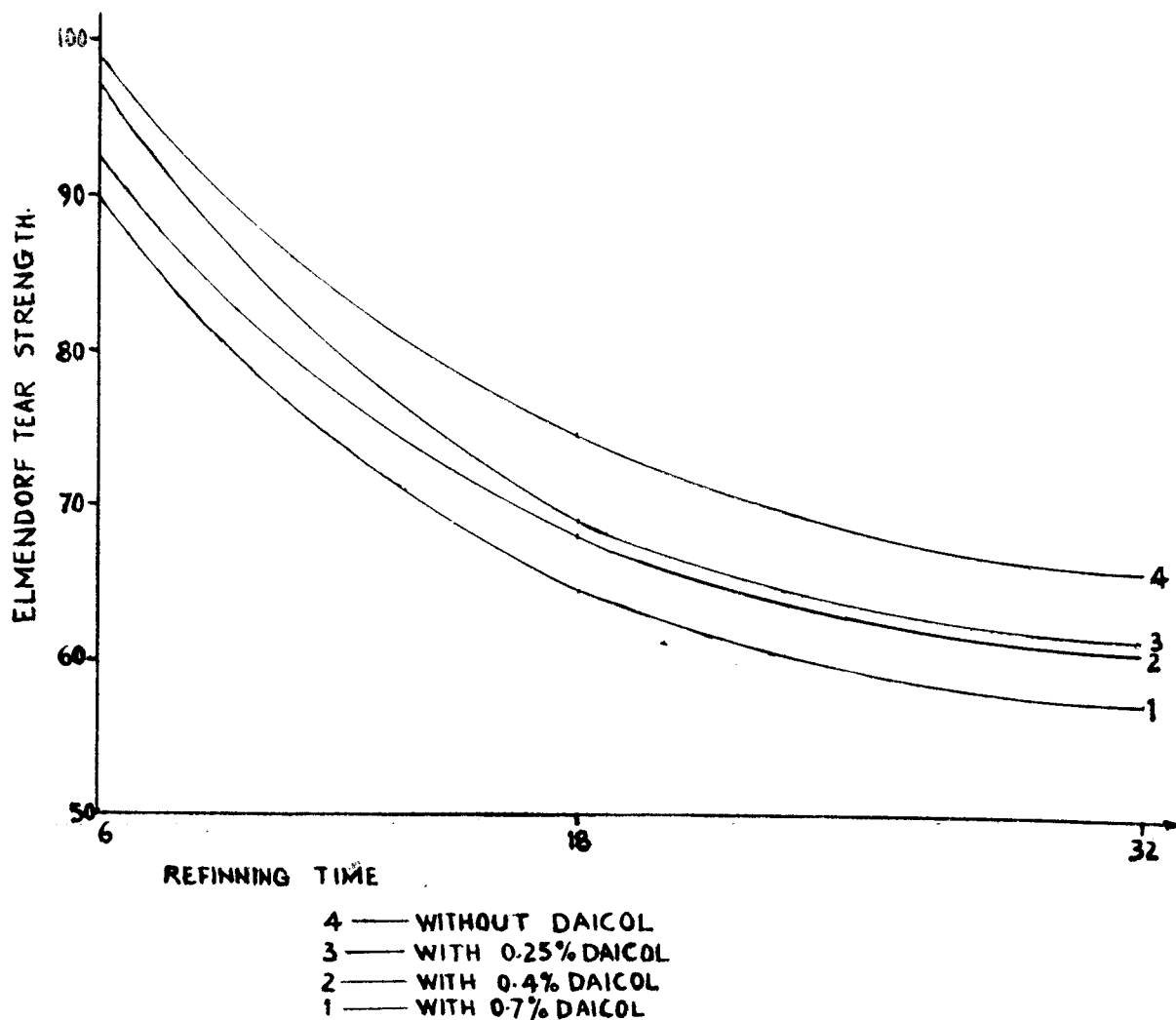
Graphs 6 to 9 show the influence of gum addition on breaking length, bursting strength, tear and folding endurance. The results show tendencies which are very similar to the ones observed with bleached sulphite pulp.

This data acquired through extensive laboratory work confirm what is actually obtained in practice from the use of gums in mill scale paper production. Let us examine these practical aspects:

Strength Properties

“Chemical Refining” obtained through gum addition results in an increase of strength properties of the finished paper, especially as far as breaking length, stretch, bursting strength, folding endurance and CMT are concerned.

Therefore, mechanical properties of the paper can be increased without reducing the quantitative output. Classical examples are: bag paper, corrugated medium and all those paper qualities which are too low in strength



Graph—8

because of the low quality of the raw materials used.

Refining

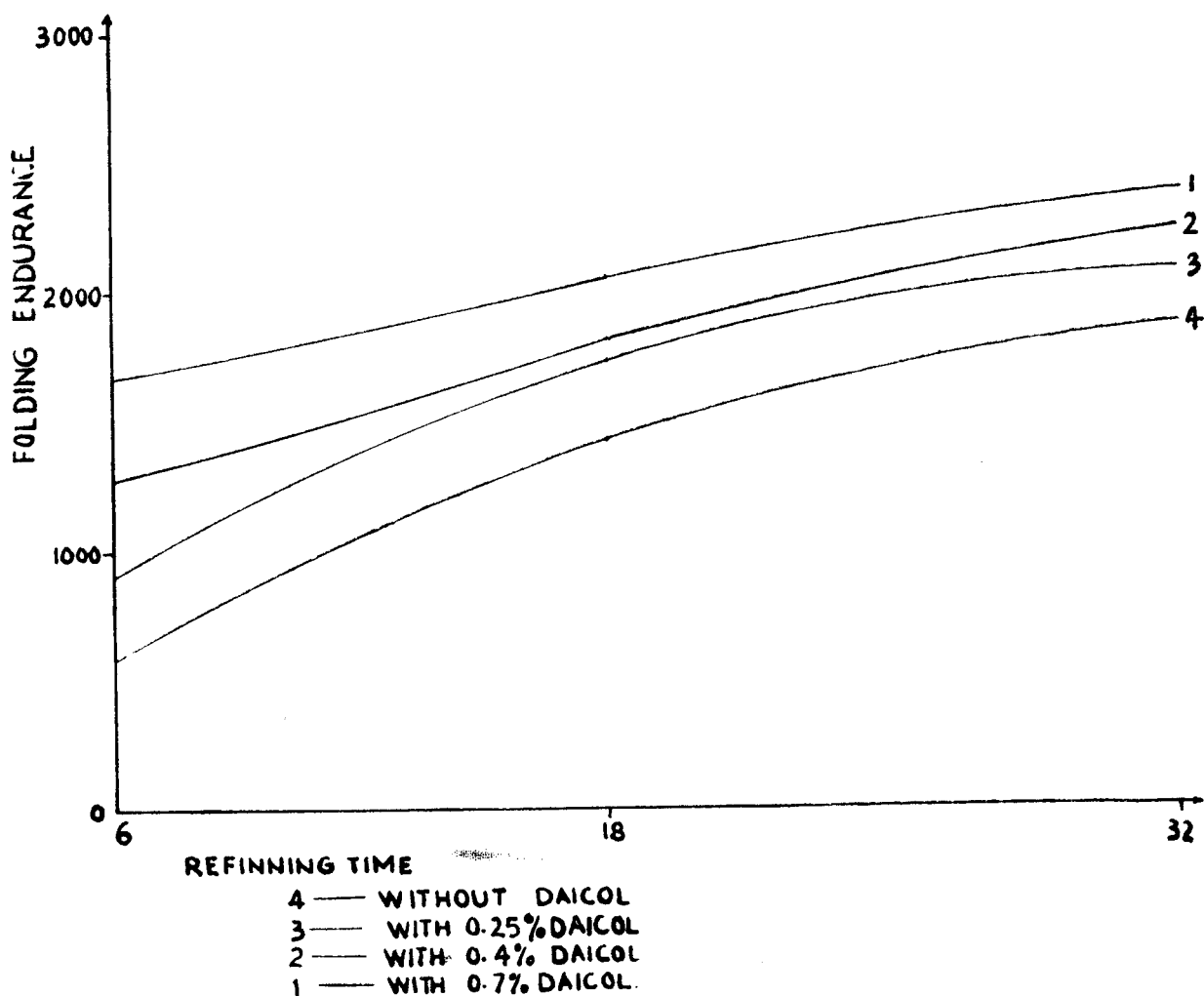
Every paper maker knows the importance of refining for the finished paper. Refining favours distribution of fibres on the wire and consequently improves sheet formation. Moreover the stock refined over a longer period of time yields stronger paper. On the other hand, paper made from a highly beaten stock although being stronger becomes more dense, shrinks more upon drying, is less opaque and has a greater tendency

to curl. Moreover a highly beaten pulp will drain slower on the wire.

Gum addition is particularly advantageous since it permits considerable savings in beating energy—eliminating the disadvantages in production deriving from prolonged refining, without reducing strength properties of the paper. Greaseproof, many other types of highly refined paper as well as kraft papers may thus benefit considerably from gum addition.

Production

Reduced refining gives another advan-



Graph 9

tage: Fibres are longer and the stock drains faster on the wire. Thanks to gum addition production can be increased without imparting the quality of the paper.

pulps is sufficient to substitute 100% softwood pulp with softwood-hardwood mixtures without imparting strength properties. Substantial economies can be thus obtained.

Raw Materials

Long fibred softwood pulps yield stronger paper than hardwood pulps which on the other hand as groundwood and waste cost less. Gums act more efficiently with long fibred pulps because hardwood and mechanical pulp already have a high content of hemicelluloses. However, the partial efficiency of gums in respect of short fibred

Fillers and Fines

Finally, we will dedicate a few words to the problem of fillers and fines, the retention of which is frequently too scarce. Because of their colloidal structure gums increase retention of fillers and fines, with consequent reductions in costs.

Gums can successfully be used to improve the surface of printing papers and boards.

Modern packaging industry tends to use increasing quantities of folding boxes made of duplex board and printed in offset. Best qualities are in- or off-machine coated to impart a more brilliant surface to the board. However, still great quantities of board do not undergo this surface treatment.

Gum may be added to the surface layer in order to improve substantially important properties of offset printing such as pick-up, dusting and oil absorption.

The use of gum is also greatly beneficial to all those types of offset paper being not surface treated for various economical reasons.

It is well known that due to its content of short fibred mechanical pulp, printing paper tends to cause dusting and fuzzing when passing through the first drying section of the paper machine, particularly at high temperatures. Later, during the offset printing process this fuzz leads to the disadvantage

that printing machines have to be stopped and cleaned frequently to eliminate the dust. High pick-up is an objectionable factor for the printer as well.

Gums added in small quantities reduce these undesirable effects, quite considerably acting as binding agents between the mechanical pulp and cellulose fibres.

The latest development in this field is the extension of the offset printing process for newsprint: the so-called Web Offset process. Practical experience has demonstrated that Guara gum addition to Web Offset paper is a must to obtain the amount of surface strength required by the offset printing process.

All practical gum applications mentioned in this study refer only to internal sizing and not to surface treatment. It should be emphasized that the high viscosity and the price level of gums do not as a rule make them suitable for surface sizing and coating operations.