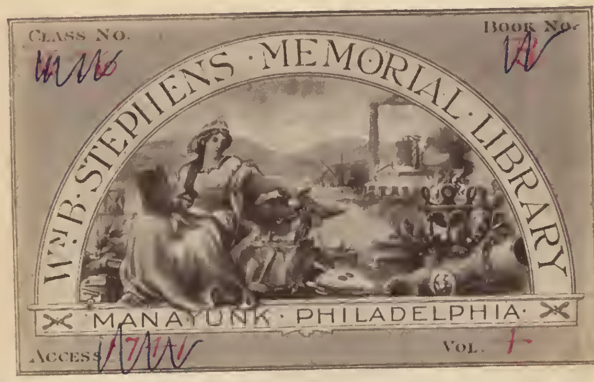
CHAPTERS

ON

PAPERMAKING.

Vol. IV.

CLAYTON BEADLE.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VOL.

Chapters on Papermaking

VOL. IV.

CONTAINING DISCUSSIONS UPON WATER SUPPLIES AND THE MANAGEMENT OF THE PAPER MACHINE AND ITS INFLUENCE UPON THE QUALITIES OF PAPERS

BY

CLAYTON BEADLE

Lecturer on Papermaking before the Society of Arts, 1898, 1902 *and* 1906*; at the Papermakers' Exhibition,* 1897*; at the Dickinson Institute, on behalf of the Hertford County Council,* 1901, *and at the Battersea Polytechnic Institute,* 1902*; awarded the John Scott Legacy Medal and Premium of the Franklin Institute by the City of Philadelphia, the Gold Medal of "La Société pour l'encouragement de l'Industrie Nationale" of Paris, the Silver Medal by the Council of the Society of Arts in* 1906, *and other Medals and Awards.*

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PREFACE.

THIS volume is supplementary to Volume III., being a continuation of the discussions on the "test questions" set by the author in 1902–3, under the circumstances referred to in the introductory chapter of Volume III. They are for the most part more advanced than those contained in Volume III., and the number of answers to each question are more numerous in consequence of the system having become better known.

The author gives this to the paper trade in the hope that it will be used in conjunction with Volume III. by the aid fo the index as a work of reference, and that it will be of service not only to papermakers and mill hands, but also to the vast number of users of paper.

The author wishes again to record his thanks to his colleague, Dr. H. P. Stevens, for many suggestions and for his valuable assistance in passing proofs for press.

Laboratories: 15, The Boro',
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CHAPTER XVI.

GENERAL INTRODUCTION TO VOL. IV.

THE work, the outcome of which has resulted in the production of this and the preceding volume, was started in 1902 as a result of a conversation which the author had with Mr. James Duguid, the then editor of PAPER AND PULP.

After taking the opinions of leading members of the paper trade who were found to be favourable to the scheme, an attempt was made to conduct correspondence classes. The scheme was not based upon correspondence tuition as generally understood; the author called his system "Test Questions," the object being to set a number of practical questions which should be a test as to the knowledge and capacity of those who answered them. The original object of these test questions was to assist paper-mill workmen to prepare themselves for the examination on paper manufacture by the City and Guilds of London Institute. As the work advanced it became evident that the various workers were far more interested in vying with one another in their answers than in seeking to prepare themselves for any after examination.

It was arranged that the names of the writers of the papers should not be made known, and that there should be no direct correspondence between the examiner and those who sent in their answers, the only medium of their correspondence being the columns of PAPER AND PULP, so that any comments and criticisms made by the examiner could be read by all readers of the journal. Marks were given to each of the answers, and the winner of the series was awarded a prize. On the award of the prizes, with the consent of the first three on the list, the first three names were published. The papers were freely quoted from, and some of special value and interest were published *in extenso*.

Many of those who entered were working men, without any experience of preparing an examination paper, some possessed very poor literary style, others showed some ability to express their views, but, whether illiterate or not, the great bulk of the answers showed considerable labour and thought, and reflected the greatest credit on the workers' industry. As the examiner was conducting Test Questions with the primary object of helping lame dogs over stiles, in order that an illiterate working man might, if he possessed the knowledge, have as good a chance as an educated manager's son, he judged the answers entirely on their value as conveying, or seeking to convey, information. But education must tell in the long run, as it gives a man the power to think as well as to express his thoughts. Many of the writers undertook special researches for the purpose of throwing light upon the questions. The answers to the first questions were comparatively poor, due, no doubt, to the inability of the writers to express their views, but the majority gained some experience and profit by the general interchange of opinions resulting from the publication, and comments upon one another's answers. As a result the answers slowly but steadily improved. All were specially cautioned against divulging any trade secrets or stating anything that might be regarded as special information belonging to their firm. The author cannot recall a single instance in which such information was tendered in the answers. Furthermore, many employers expressed themselves in favour of the system, and in no case can the author recall a single instance in which the employer raised an objection to his workpeople making use of the system.

It has been urged that correspondence tuition tends to discourage class teaching, which latter is considered far more valuable, and consequently correspondence teaching should not be resorted to. As proof against this view, the author found that the greatest number of students, in any one locality, who availed themselves of the correspondence tuition, were, at the same time, attending lectures and classes conducted privately by their employers. It does not appear that correspondence tuition will in any way interfere with the lecture attendance, but it would appear, rather, that one will assist the other. There are many things to be said in favour of correspondence tuition; for instance, there are many difficulties to be contended with in classes, which do not occur in correspondence tuition. The classes are few and far between, and not accessible to many, whereas correspondence teaching is equally accessible to students in all parts of the country. Correspondence tuition is perhaps a misnomer; in so far as it relates to the scope of these volumes, the attempt has rather been to help and guide mill-workers by setting them leading questions of a practical nature. The average paper-mill worker, however thorough his practical knowledge may be, requires practice in constructing his answers before he enters for the examination.

Apart from actual aid for examination purposes, "test questions" may have a wider and more important scope—namely, that of stimulating inquiry. The worker has the questions before him, and he goes about his everyday work in the mill and thinks them over. His own work may have some bearing on the questions set him; they are not sprung upon him all of a sudden, as at an examination. He has plenty of time to think them over before he need answer them.

The following is a list of the "test questions" set and commented upon in the manner above referred to, the details of which are published in this and the previous volume:—

Vol. III.

1. Give your views of the relative value of "brass" and "steel" beater bars for Hollanders.

2. What speed (in revolutions per minute) do you recommend for a Hollander beater roll? Does the size of roll, and number and arrangement of bars, affect the question?

3. What do you think of Prussian blue for colouring paper? What papers would you use it for? Under what conditions do Prussian blue papers fade?

4. Can you easily demonstrate, by means of a hand mould, the effect of lowering the breast roll? Explain why a slight lowering of the breast roll will have so much effect upon the removal of water.

5. Why does loading make some papers more opaque than others? Give instances.

The following question is set for those who care to exercise their ingenuity and test their ability to unravel more difficult problems, such as we might find set in the Honours Grade. Since the primary object of undertaking a correspondence class is to help and guide the mill-workers, the more difficult questions will be dealt with separately, and the following question therefore does not count in the competition for the prize offered by "Paper and Pulp:"—

6. A "furnish" for writings contains 100 lbs. of commercial terra alba per 400 lbs. of dry fibre. A small sample of the terra

alba in question, when burnt, will be found to yield 55 per cent. of ash. The stuff is diluted in chest with 23 parts of water for every part of dry fibre. The web, as it passes on to drying cylinders, consists of 28 per cent. dry material and 72 per cent. of water (for purposes of calculation we must assume no loss through leakage, etc., or dilution of back-water, other than that necessary to make up for moisture in web of paper). After a run of 5 tons of paper (total weight at cutter), the machine is shut down, and the terra alba found collected on sand tables and in saveall, etc., weighs 320 lbs. An average sample of this, on burning, is found to yield 35 per cent. of ash. What ash would you expect to find in the finished paper? Show details of calculation, and where losses occur and how.

7. What is the exact influence of alum upon gelatine, both before and after its application to paper? How does the use of alum enable us to regulate the amount of gelatine absorbed by the paper?

8. Give your reasons for and against raising the temperature of bleach in the poacher. What precautions would you consider necessary?

9. What is the action of a refining engine as compared with that of a Hollander? How far can refiners be made to do the beating with advantage? For what class of stuff would you recommend the use of refiners?

10. Does rapid agitation assist bleaching? If so, why?

11. What is the effect of heating the stuff as it passes on to the paper machine, and why should this produce a change in its behaviour on the machine?

The following more difficult question is not for competition, but to test the capabilities of those who might be disposed to enter for the London and City Guilds Examination (Honours Grade):—

12. Give your views of the comparative merits of two well-known systems of soda recovery.

13. How do you account for paper becoming electrified during manufacture; and what steps would you take to prevent it?

14. Why are some papers more transparent than others? Give instances as well as reasons.

15. What influences the "life" of machine wire? Give an instance with full particulars.

16. What is the action of edge runners, and for what special purposes would you recommend their use?

Vol. IV.

17. Why are some papers lighter, bulk for bulk, than others? Give instances.

18. What are the special qualities and uses of "art" papers?

19. What papers are improved and what papers are deteriorated by keeping in stock? To what is the change due?

20. In what instances would you use lime for boiling? Give your reasons.

21. How can you control the mark of a "Dandy"? Make some general remarks on the management of the "Dandy."

22. What are the comparative merits of "machine" and "hand" cut rags from all points of view?

23. What do you consider to be the cause of froth or scum on the machine? Of what does it consist? And how can it be prevented?

24. What harm is there to the paper if the scum is allowed to accumulate?

25. Give the amount of water (in gallons per ton of finished paper) required for any quality of paper you like to choose, and show what is required for the different stages of treatment, beginning with the boiling and finishing with the water used on the machine?

26. Make some remarks upon the management of suction boxes with different kinds and qualities of paper.

27. How can you control the shrinkage of a paper, both in the "machine" and "cross" direction during its manufacture on the machine?

28. How far is it possible to make a paper, either by Fourdrinier or cylinder machine, which, when once made, neither expands nor contracts with change of moisture in the atmosphere?

29. How far is it possible to make a paper on the Fourdrinier machine which does not stretch when tested for "breaking strain"?

30. How far is the quality as mentioned in question 28 (*i.e.* expansion or contraction with moist or dry air), connected with the quality as mentioned in question 29 (*i.e.* stretch when tension is put upon the paper)?

31. The qualities of paper for commercial purposes are sometimes judged by their "breaking strain," at others by their "bursting strain," and at times by the amount of "stretch"

which they undergo when tested for "breaking strain," and finally, both by "breaking strain" and "stretch" combined. Discuss the relative advantages of these different methods, and give your own opinion as to what particular class of paper (if any) each method is with advantage applied to.

32. What paper-testing machine do you prefer to make use of? Give your reasons for any particular preference.

CHAPTER I.

THE BULKING OF PAPERS.

Effects of beating—Pressing—Calendering—Loading—Comparisons—Thickness of reams.

QUESTION 17.—*Why are some papers lighter, bulk for bulk, than others? Give instances.*

The following are extracts from B's paper :—

"By practice, papermakers get to know approximately how much loading, time in beating and treatment on machine, etc., to give papers in order that they may 'bulk' equally for the same weight.

"The task of keeping his weights and bulk correct is one of the trials of a machineman, and if the problem were confined entirely to the regulation of the stuff-cock and the speed of the machine, he would more often be held responsible than he is. But in the 'filling-in' there is always the liability of more material and less loading, and *vice versâ*, and the difference in the specific gravities of different loadings, to say nothing of the difference in time of beating in the various engines in making for the same order, all tend to affect the bulk.

"As an example, a sheet of esparto paper, $40 \times 30 \times 0{\cdot}008$ ins. (9·6 cubic inches), weighing 0·2 lb., contained 15·5 per cent. loading. The reduction of loading to 9·5 per cent. reduced the weight to 0·15 lb., and a further reduction to 8 per cent. loading was mainly responsible for the sheet weighing 0·146 lb."

C's remarks are interesting, but he falls into one error—

"The difference in the bulk of a paper is accounted for by a difference in the beating of the stuff, and the pressing and calendering. When the paper leaves the press roll damper, and is not calendered, it will bulk more. Increased pressure at the press rolls will very often put an end to the inequality in bulk. Badly ground calender rolls will affect bulking qualities."

D.—" Paper made from cotton or sulphite pulp bulks better than any other class of paper. Heavy calendered papers would weigh heavier than light calendered papers, bulk for bulk. Paper that is running through a super-calender would be flattened out half an inch or more in width."

E remarks that "the pressing at couch rolls and press rolls has nothing whatever to do with the bulking." Notice that he goes to the other extreme, and says exactly the opposite to what **C** does: " I have seen papers which felt very much lighter and thicker for their weight than others. This, I think, is caused by the stuff being taken out of the beaters as fast as possible, and the fibres kept as loose and free as possible."

F gives a good practical answer :—

" If we take two sheets of paper, one having all cotton fibre and produced from quickly beaten stuff (say, for two hours), and another sheet containing 25 per cent. linen from stuff beaten the same time, the cotton fibre will produce the bulkier paper, because the canal in the cotton fibre is larger than the linen one, and the linen fibres will lie straight on top of one another, whereas in the all-cotton one, having the greater proportion of cotton fibres twisted up so much, they lie in a light bundle and so are bulkier.

" If we take two sheets of paper, one having 10 per cent. loading and the other none, both containing the same sort of fibres and produced from stuff beaten the same length of time, the one with the loading will be the thinnest paper, assuming, of course, that they are of equal weight per ream.

" If we take two sheets of paper made from the same class of fibres, one having no Kollergang papers in it, and the other having 20 per cent. of edge-runner broke, the one having no paper will stand the thickest.

" Again, if we take two sheets of paper, both made from the same class of fibre, and in one engine we have a dull roll and dull plate, and beat the paper for six hours, and in the other engine we have a sharp roll and plate, and beat in one hour, the engine beaten off in one hour will yield the bulkier paper. A prolonged beating tends to convert the fibres into a gelatinous mass and causes the paper to handle thin.

" In another instance :—We take two engines, beat alike so that the fibres in both engines are of the same length. One of them we shake very close on the wire, couch and press hard, the other we work with less shake on, and with less pressure on the couch and press rolls. The paper produced under the latter conditions will be the bulkier. To produce bulky papers use cotton fibres, no loading, no paper, long fibres, only fair shake, lightly pressed, and beaten fast with sharp roll and plate."

G's remarks are also practical, and to the point :—

"Different papers vary considerably in weight, bulk for bulk. Papers made from cotton are lighter than papers made from esparto, which in turn are lighter than papers made largely from wood, bulk for bulk. Jute in a paper will bulk better than flax. Two papers made from the same materials would weigh more or less according to the amount of loading used. Another factor is the pressure to which the paper is subjected on the machine, at the presses and calenders."

H goes wrong when he endeavours to show that difference in the weight of a paper on the addition of mineral is connected with the difference between the specific gravity of the mineral and the cellulose. He has got the specific gravity of clay very low—it is considerably over 1·91. He will see where he has gone wrong if he reads through my answers to the City and Guilds bearing on this subject. His mode of argument could only hold good if there were no air-spaces in paper. A pure paper without air-spaces would have the same specific gravity as the cellulose which composes it, viz. 1·5 ; but the bulk of a pure paper represents the bulk of air-space plus cellulose. Instead of being 1·5 it may only be 0·7, or less. A pure paper which does not bulk at all would be represented by the figure 1·5. The greater the bulk the lower the figure (grammes per c.c.) would become. Of course any addition of mineral would decrease the bulk for a given weight per ream, and the greater the addition of mineral the less the bulk on this basis. It follows, then, that papers of equal thicknesses containing varying proportions of mineral would increase in lbs. per ream in direct proportion to the ash. Supposing you take a series of papers, the first of which contains no mineral, the second contains five parts of mineral per 100 of fibrous material, the third contains ten parts per 100 of fibrous material. Now suppose that you have papers of equal thickness from each, so that a ream of each gives you the same measurement. Suppose now the first furnish weighs 25 lbs. Demy, the second will weigh 26¼ lbs. Demy, the third will weigh 27½ lbs. Demy, and so on. It would thus seem that pure fibrous paper gives a definite bulk, and that the addition of clay does not increase this bulk, but merely fills in the interstices.

I remarks: "Should he (the beaterman) require a light demy paper to bulk well he raises the couch and press rolls, leaving enough pressure on them to ensure the proper amount of water being got out. The paper is now reeled off the machine without having any nips at the calenders. If it were nipped, the sheet would be compressed to half its bulk again. With a heavy demy paper the machineman can make it up to at least 100 lbs. and still retain the same bulk as above. He crushes it again and again in the calenders until he gets the correct thickness. The stuff is still in the paper, but occupying a smaller space."

L writes: "This is due principally to the physical structure of the fibres themselves; a paper made from cotton, for instance, which has a large central canal and thin cell walls, being lighter than linen papers of the same thickness, due to the linen fibres being more solid in structure."

Notice that he speaks of the hot dry state in Question 13. He realizes that the paper must be dry. He suggests that the electricity might be made use of, but I do not think there is anything in this. He is well on the point in his answers to Question 14, especially when he speaks of removal of incrusting substances. The other points on this question and the points on Question 15 have already been dealt with. Certainly "quality and quantity" of paper both affect the life of machine wire.

L goes wrong in drawing a comparison between the cotton and linen fibres. A paper made from cotton is not lighter because the cell walls of the cotton fibre are thinner. It must not be forgotten that although the cell wall of cotton is thin the tube is a collapsing one, and the central canal is reduced almost to nothing for this reason. The reason for cotton bulking so well is that the cell of cotton on collapsing assumes a corkscrew shape. These corkscrew fibres, when felted together, leave greater spaces between than the comparatively straight linen fibres.

Since writing the foregoing I have noticed in the PAPER TRADE REVIEW, March 7, 1902, an account of a method employed by Mr. O. Winkler, for the determination of the opaqueness of printing papers, which is very similar, although not identical, with that which I employ. I am glad to see that Winkler thinks there should be some standard method of determining the opacity of paper, to be agreed upon by the buyers and sellers. The method such as he and I have made use of might very well be employed in ordinary commercial practice. Apart, however, from the employment of such a method by buyers and sellers, it would be of the utmost value to many manufacturers for making comparison of their different makes. The difference revealed to them by their different makes and compositions would assist them in determining in which direction to work both for opaque or transparent papers. Much of the difficulty now experienced by manufacturers is due to the roughness and looseness of their methods of comparison giving too much scope for individual bias, and introducing an uncertain and undesirable factor which chemists generally call the "personal equation." All tests for commercial purposes should be such as to eliminate, as far as possible, the "personal equation."

The answer given below is wrong on a fundamental point, viz. on the bulking qualities of minerals of different specific gravities. As explained above, mineral does not, at any rate, as a rule, add to the bulk of a paper. If, therefore, you have two papers, each containing, say, 10 per cent. of mineral, A 10 per cent. of clay, B 10 per cent. of barytes,* each of them contains 90 per cent. of fibrous material, and if this fibrous material is the same for the two papers in every respect the bulking of these two papers will be the same. Neither the clay nor the barytes add to the bulk, but simply tend to fill the interstices. The clay being of lower specific gravity than the barytes, and consequently occupying a greater space for a given weight, will fill the paper to a greater extent than the barytes, but neither of them will bulk the paper. I do not wish to assert that papers containing a very large proportion of mineral matter are not increased in bulk thereby, but within reasonable limits the mineral simply fills the interstices in paper and diminishes the air-spaces. Of course when you come to a paper heavily loaded, the air-space of which is largely closed by the mineral matter, it will not diminish in bulk to the same extent at the super-calenders as an unloaded one. This stands to reason from what has already been stated. Furthermore, it is obvious that of two papers, A containing 25 per cent. of clay and B containing 25 per cent. of barytes, B could be reduced in thickness more on super-calendering than A. All these points are of interest and of some practical moment, and a thorough mental grasp is a desideratum.

M.—There are three principal factors affecting weight of a paper in relation to its bulk, viz. (1) Surface; (2) Loading; (3) Beating.

* Barytes, otherwise known as sulphate of baryta, sometimes erroneously described as "baryta."

"(1) *Surface.*—The greater the pressure on the calender rolls and the number of times the paper has been subjected to this pressure, the less the bulk. Compare the weight of a superfine calendered paper with a machine-finished paper of same bulk, or, say, a pasting that has not passed through the calenders at all to a machine-finish, other factors being equal in both cases.

"The following were the results of four papers I tested for bulk, all of the same weight (30 lbs. Demy, 480 lbs.), and same furnish, including loading :—

Plate-glazed	3·8	thousandths	of an inch.
Best machine-finished ...	4·6	,,	,,
Super-calendered	3·5	,,	,,
Rough antique-finished ...	6·0	,,	,,

Other factors being equal.

"(2) *Loading.*—Of two papers of equal bulk, one with loading and the other without, the former will weigh more than the latter, owing to the loading being of a higher specific gravity than the other constituents of the paper. The higher the specific gravity of the loading used, the heavier the paper will weigh. For instance, 1 lb. of clay will bulk the same as 2 lbs. of barytes.

"Compare the weights of a litho. containing 20 per cent. clay to a special vellum paper with none, bulk and other factors equal.

"(3) *Beating.*—Fine stuff diminishes bulk, long stuff increases bulk. Compare the weight of an envelope paper made of long stuff with a fine writing of equal bulk."

Q speaks of the necessity for thorough circulation of the stuff in the chest. Imperfect agitation allows the loading to accumulate at the bottom, causing the first part to be more lightly loaded than the last. Note that a paper mill must be badly arranged to allow of such a thing as this happening.

R has taken a lot of trouble over his answer, and it serves to demonstrate in a practical way what I have been endeavouring to explain above. I should like to point out that **R** has kept the exact question in mind, which many of the others have not done, viz. Why are some papers lighter, bulk for bulk, than others ? I did not ask, for instance, what was the cause of bulking, or how you would define the bulking of papers, or how the treatment and composition of the material affected the bulking qualities. In this question I said "Give instances," more with the idea of the students making a few measurements from which they could draw their conclusions.

Answer.—"The difference in weight, bulk for bulk, of papers may, I think, be mainly attributed to the material from which they are made, and the treatment on the machine. I have made tests with printing papers made from the same material, of the same demy weight, with four different finishes, and the bulk is as follows :—

1. M.F.	... ...	2·54 inches per ream.
2. S.C.	... ...	2·4 ,, ,,
3. W.F.	... ...	2·28 ,, ,,
4. Rough	... ...	3·96 ,, ,,

"The loading in these would be equal in 1 and 4, about 5 per cent. more in 2 than 1, and double of 1 in 3.

"I also tested some workings with the following results :—

Laid	... ...	1·80 inches per ream.
Wove	... ...	1·80 ,, ,,
* ,, P.G.	... ...	1·80 ,, ,,
,, S.C.	... ...	1·56 ,, ,,
Vell. Wove	... ...	1·92 ,, ,,
Rough Vell. Wove	... ...	2·52 ,, ,,

Same demy weight. Same loading.

"From above it will be seen that the finish has a prominent effect on the bulk, and by tests such as these we are able to say what extra weight is required for a certain bulk ; for instance, No. 3 W.F. would require about 10 per cent. added to its demy weight to equal No. 1 in bulk. The amount and kind of loading also has an effect on the weight and bulk, as owing to its higher specific gravity and the place it occupies in filling up the minute spaces between the fibres it does not add to the bulk, while it increases the weight. The kind of fibre, also, from which paper is manufactured affects its bulk, as, other things being equal, paper from cotton bulks better than that from linen.

"In my tests I state that for a 37 demy substance we have 2·54 inches in M.F., and 2·4 in S.C. Now, calculating on this basis, we should require to increase the weight of the S.C. by 2 lbs. in order to get the same bulk as the M.F., and to prove this I tested a 39 demy in S.C. and found the bulk to be 2·52 inches. This, I think, is a very good example of 'why some papers are lighter, bulk for bulk, than others.'"

S writes : "Paper that is lighter, bulk for bulk, than another might be rougher, which would make it bulk better, or it might

* As the P.G. is left rough at the machine, it should be equal to good M.F.

have less clay in it. Tripoli esparto makes a very good bulking paper, compared to Spanish or Oran esparto."

U.—"A paper made from fine stuff is always heavier than a paper made from long stuff, other things being equal. The reason is that fine stuff felts closer, long stuff leaving interstices between the fibres, which would be larger than in the case of paper made from fine stuff if not filled up by the use of finer stuff."

V says: "But the kind of fibre used is, I take it, what the question means." I intend by the question to include anything in the ordinary manufacture which will affect the weight, bulk for bulk. "A paper made from 50 per cent. cotton and 50 per cent. linen will not bulk so well as one made from 100 per cent. cotton." In order, of course, to have kept in a line with the question so as to have avoided any possibility of confusion, the statement should have been made more in this way. "A paper made from 50 per cent. cotton and 50 per cent. linen will be heavier, bulk for bulk, than one made from 100 per cent. cotton." "Of the chemical pulps, sulphate bulks better than soda and sulphite. It is for this reason that sulphite is added to esparto in making book papers (also on account of its opaqueness)." Notice the following sentence as compared with the question: "Loaded papers do not bulk so well, relatively speaking; in fact, sometimes loading is added to make the paper handle thin." To be in line with the question I should like to have seen this statement put rather in this way: "Loaded papers bulk for bulk are heavier than unloaded papers of similar fibrous composition. It is for this reason that loading is added to make some papers handle thin." The second half of the sentence is a natural inference from the first, but it might well be pointed out that the paper in question is required to handle thin in comparison with another paper of the same weight per ream. In making a paper heavier bulk for bulk, by the addition of mineral, we, of course, make it thinner weight for weight. This is really what is meant when we say that "by the addition of mineral to a paper we can make it handle thin." "Of course, stuff beaten wet would carry more loading, and hence would bulk less for the weight." To put this in plain language: "With stuff of a given furnish, mineral matter included (other things being equal), wet stuff would give a paper heavier, bulk for bulk, than free stuff, on account of the wet stuff retaining a greater proportion of the mineral matter."

W certainly has kept to the question. "Some papers are lighter because they have not so much loading material in them.

Two papers that are treated in exactly the same manner in the beating-house would not weigh so heavy if the loading was left out."

We discussed the question as to whether minerals of a different specific gravity affected the bulk of a paper, and I hope these remarks have not caused any confusion. To follow up Question 17. We may conclude that a paper containing 5 per cent. of clay would not be heavier than a paper containing 5 per cent. of barytes, bulk for bulk. Assuming, furthermore, that we substitute in place of the 5 per cent. of mineral matter, 5 per cent. of broke, and assuming that the broke occupied the spaces between the other fibres—mind, I say "assuming"; I don't say it is so in practice, although it is quite possible it might be so—the paper containing the broke (other things being equal) would have the same weight per ream as the paper containing mineral in the event of the two papers being of the same thickness, which is only another way of saying in the event of the papers being the same bulk for bulk. Such questions as these are not matters for experiment, but rather for the exercise of the reasoning faculties. They are not put as conundrums, but given at some length because a proper appreciation of these points is, or should be, of practical value.

CHAPTER II.

SPECIAL QUALITIES OF "ART" PAPERS.

Special qualities and uses—Enamelling—"Life"—Removal of wire mark—Disadvantages of—Opinions of users.

QUESTION 18.—*What are the special qualities and uses of "art" papers?*

B gives a very fair answer indeed. He goes rather more into the manufacture and coating of "art" papers than he need have done, but he is more or less justified in doing this, as he has thought it necessary to define what an "art" paper is. He is quite right in giving us a definition, as there is a certain amount of confusion as to what an "art" paper really is. The chief physical distinction between an "art" paper and any ordinary paper used for printing, is that the former has a smooth continuous surface which no ordinary paper possesses to the extent of enabling it to receive the half-tone impressions. This can be better appreciated by examining the surface of an "art" paper with a hand magnifying-glass, and noting the sizes of the fine points or lines which form the half-tone impressions. If you then examine an ordinary sheet of paper that has not been enamelled or undergone the "water finish," you can readily see that the undulations on the surface of the paper are too large for the half-tone impressions. It is due partly to the absolute continuity and regularity of the surface, but largely, no doubt, to the materials of which the surface is composed, such as clay, etc., that these so-called "art" papers are specially suitable for half-tone printing. Clay and such-like materials have a special and peculiar power of absorption which cellulose or the material which composes the ordinary paper does not in the same measure possess. It must be borne in mind that the surface of the "art" paper, *i.e.* that which meets the eye, and that which comes in contact with the ink, does not consist of cellulose at all. This can readily be seen in some printed "art" papers by washing them, especially those which are heavily coated. After immersion for a short time and rubbing, the whole of the printed matter is removed, leaving the plain paper underneath. As **B** justly remarks, it is a question more of making a paper which will receive the enamel than making a paper suitable for printing, if regarded purely from the printer's point of view. There is a considerable amount of mechanical wood in some "art" papers, but these in course of time in contact with the sunlight deteriorate, and the discoloration is seen through the enamel. Nevertheless, such paper after coating is capable of receiving the finest impressions. **B** speaks of the use of formalin in rendering mucilaginous matter insoluble. It has, of course, a powerful action on glue, but it probably has also another useful property, namely, that of preventing the enamelled surface decomposing, as it is a well-known powerful preservative. As **B** says, the "lifting" is generally the effect of having insufficient mucilaginous matter. The inference that he draws from the coating being of a neutral character, and not affecting inks and types to the extent that ordinary papers do, may in a measure be correct, but I should judge that the wear of the type would be less marked in consequence of its coming in contact with clay than with cellulose. It is a question rather of diminished wear and tear, than of diminished chemical action. In regard to litho work, where as many as fourteen different colours have been satisfactorily lithoed; the colours being applied to a surface of clay, or some similar material in place of cellulose, renders this possible,

B.'s Answer.—"*Special Qualities.*—Briefly—Their coated or enamelled, impressionable, smooth, highly-finished surface or surfaces.

"*Uses.*—For high-class lithographic work.

"For magazine and other printing where the sharpest impression is required (the trade call it 'Printing fine process blocks'); and this where its use is not dependant on the question of price.

"Before proceeding further with the exact answer required—*i.e.* Qualities and Uses—it is necessary to define an 'art' paper.

"An 'art' paper is essentially one which has been coated or enamelled after making.

"An ordinary litho paper is used for art work, but is not an 'art' paper.

"An imitation 'art' is also different, for the reason that it is practically produced by the 'water doctors' before it leaves the machine.

"The special quality or advantage which a coated paper has over the ordinary printing paper lies in the fact that it is the 'coated surface' which receives the impression. What quality the body paper possesses is of minor importance.

"There seems to be a general idea that an 'art' paper is one that invariably requires a special furnish. This is erroneous. Some of the best coated papers are those made from the hardest and cheapest material. The difference in what might be termed the sticking quality between, say, a wood and an esparto paper is comparatively insignificant.

"Only in the case of a high-class magazine would a special furnish be stipulated.

"Coating mixture can be applied with good results to any moderately rosin-sized paper.

"For ordinary magazine work a fine china clay is mixed with caseine or gelatine liquid. For higher class work satin white is the mineral more often used. The many and various colouring matters are added in the mixing box.

"Formalin serves the purpose of rendering the mucilaginous matter insoluble, so preserving the surface; another special quality of the 'art' paper.

"Coatings add anything from 8 to 18 per cent. to the weight of the 'body' paper.

"'A Reader' in the 'Manufacture of Art Paper' in Paper and Pulp—a recent issue—states that a high-class art-paper is coated on the two sides separately. This is not necessarily so. Most 'art' papers are coated or enamelled by machinery; sheets and boards by hand.

"The principal defect in 'art' paper is the 'lifting'; generally this fault is caused by insufficient mucilaginous matter in the mixing and 'soft' drying, when the reeling of the paper disturbs the coating.

"Coating is generally of the neutral character, and does not affect inks and type to the extent, and in the same way, that ordinary papers do.

"Some of the many uses of 'art' papers may be enumerated:—

"For litho work—where as many as fourteen different colours have been satisfactorily lithoed.

"White coated 'art' (both sides) for the higher-priced magazines.

"Duplex-tinted papers for programmes, magazine covers, etc.

"Cloth-lined coated boards for covers.

"Single-coated paper for book end work.

"Single-coated paper and chromos for menu cards.

"The use of 'art' papers for magazine work is almost entirely dominated by the question of cost. The highest price is about *4d.*, and the cheapest *3d.* per lb.* Therefore, the production of imitation 'art' is now occupying the attention of the trade sellers and buyers."

D speaks of the degree of enamelling varying in accordance with the printers' requirements. This is an interesting part of the subject. The amount of enamel necessary varies very much. He gives the uses—chromo-lithography, almanacs, illustrated catalogues, magazine work, illustrations, and plates for general bookwork. He mentions that the finishing is done by bowl calendering or plate glazing.

F.—We give **F**'s answer, but would remind him that a part of it at least is rather wide of the question. An account of the manufacture of "art" papers is not asked for, but merely their special qualities and uses. Under such circumstances, therefore, you should only refer to any point in the manufacture from which you can infer some quality, but outside this you should not go. Of course, the use of a paper is determined by its quality. If it has some special quality it may have some special use, and what we wanted really was to see the special qualities of "art" papers fully explained, and the reasons why they are adapted to special uses. However, there are many practical points in **F**'s paper. The question of the underneath side of a paper remaining rough is a difficult one, even with an "art" paper. I have noticed in some publications, where process blocks are used for the purpose of illustration, that the printers are not always careful to print on the top side of the paper, and you can distinctly see the effect of the wire mark if you examine the illustration carefully. This may be a matter of bad management, but even some of the leading printers are not sufficiently careful about it, and **F** does well to refer to this difficulty. Streaky marks caused by the paper being too smooth before enamelling is the result of bad management also.

F's Answer.—"The qualities of an 'art' paper are several. The paper must not be harsh; as it is wanted to have a mellow, kindly feeling, it must work free on the wire. There must be freedom from grit and dirt. The shrinkage must be very little, or it will buckle a good deal when damped.

"The paper must be fairly strong; and it must be rosin-sized

* 1902–3 prices.

sufficiently to keep from lifting when the enamel is applied ; for if it is soft it will lift, and when under the printer's blocks it will stick to them, and so break the surface of the paper and make bad work.

"The paper has to be coated with enamel made of china clay, satin white, blanc fixe, and gelatine, the latter added to keep the enamel from lifting up.

"Absence of wire marks on the underneath side of the paper, hence the necessity of applying the enamel a second time on underside to overcome all roughness.

"Paper must not be very smooth at first ; for if it is too smooth, it will run when it is being enamelled, and produce streaky marks ; this is very objectionable.

"The paper when made is enamelled by a special coating machine, where the coating is applied to a felt by a series of six or seven brushes, the paper being coated on one side at a time. It is caught up on sticks and dried, hanging down in loops, in a room at about 80° Fahr. When dry it is re-reeled and coated on the opposite side. Most of the enamel is spread on the underside of paper.

"It should be noticed that the paper is slit in proper widths before being enamelled.

"When dry on both sides it is taken to a stack of super-calender rolls and glazed very highly, great care being taken to get rid of all the wire marks on the underside of the paper. It is very important that no hard pieces of enamel be allowed to adhere to the edges of the paper, as this would damage the paper rolls.

"'Art' papers are used for special publications where good illustrations are the chief desiderata. On looking at such papers as the ILLUSTRATED LONDON NEWS, the GRAPHIC, the SPHERE, the SKETCH, the KING, the LADIES' PICTORIAL, BLACK AND WHITE, etc., also the smaller magazines with excellent illustrations, it can be seen how important it is that these papers should have the special qualities mentioned in the above remarks.

"I think it only fair to add that I am much indebted to the able article on 'art' papers that came out in PAPER AND PULP, December, 1901, and January, 1902, and signed 'A Reader.'"

I remarks that "the quality is judged almost solely by its surface. This 'art' paper is used for high-class magazine work which is only required to stand printers' ink. An 'art' paper which requires less ink than another to produce equal results, is considered by the printer the better of the two, and he will very likely buy it in preference to the other, even should it be slightly more expensive. This is on aeeount of the cost of ink whieh he uses." This remark undoubtedly holds good with two papers that in other respects are equal. A printer could not go far in paying extra priee for a paper for the purpose of saving ink.

M's answer is very short, but he is able to put a good deal of information into a very few words. "'Art' papers must have a very smooth even surface, and should be capable of taking very fine impressions from photo blocks. The surfaee should also be soft, so as to lick up the slightest trace of ink. What is generally called an 'art' paper is a coated paper; imitation art is made with water finish and super-calender. Coated papers should be free from eoating lumps, as they damage the proeess blocks. Uses:—Proeess blocks, lithographic and chrome work."

Freeness from stretch is an important quality. It is unfortunate that there is a confusion in referenee to terms. We have "real art," and "art" and "imitation art papers" referred to. No doubt members of the trade know exaetly what is implied by eaeh of these terms, but in order to avoid any eonfusion it would be as well if the Papermakers' Assoeiation would fix on certain definitions whieh should always be adhered to.

R.—"As to its uses, these are prineipally high-elass magazine work, block printing and illustrations, calendars, and music; and for these purposes the special qualities mentioned above tend to produce clear, distinct, and equal prints.

"Of late years *imitation* 'art' papers have to a large extent superseded real 'arts,' and a large pereentage of our monthly and periodical magazines are printed on the former, with perhaps the addition of real 'art' for the more important portions. While there is a great differenee in the appearanee of these two types of paper, the imitation has reaehed a high degree of perfection, the wire marks on the underside of many samples being almost invisible. Imitation 'arts' from esparto are more or less full of white spots, owing to the heavy rolling to which they are subjected."

S mentions the speeial qualities of an art paper as a fine, smooth, and even surfaee. This is perhaps a better description than a high surfaee. It should not be necessary for the printing that the surfaee should be highly glazed, provided that it ean be fine, smooth, and even, but unfortunately the result cannot be got at present without the paper being highly glazed. We shall make further referenee to this aspeet of the question later.

U states that "art" papers are always opaque. This is the result of their containing a large amount of clay, but this feature can hardly be described as a special quality of "art" paper. He speaks of the paper absorbing ink readily. I certainly think this is a special quality, due of course to the enamel and not to the paper itself. To this particular quality the value of "art" paper is very largely due, as a smooth, even surface alone would not give the desired effect in contact with the blocks. But this property, taken in conjunction with the great power of absorption which the enamel possesses for inks with which it comes in contact, gives results which cannot be obtained by other means. "The particularly high finish of the coated papers gives a very pleasing effect, these papers being often used in coloured illustrations." The "pleasing effect" is rather doubtful—at any rate, it is a matter of opinion. I think it would be fairer to say that the special property which the paper possesses in enabling it to reproduce the half-tones is undoubtedly pleasing, but the paper *per se* is certainly not pleasing to a great many people, and if the same result could be obtained without such a highly reflecting surface to fatigue the eye it would be much preferred by the public.

V writes as follows: "The special qualities of 'art' paper are :—

"An exquisitely fine surface, a high degree of porosity, and fastness of colour to light and air.

"'Art' papers should show the least possible expansion when moist, as, for example, when in contact with the damp roller in litho printing. Also they must not be so porous as to "lift" under the printer's block or to cause inaccurate register.

"Surface is a most essential quality, strength a secondary consideration.

"'Art' papers are particularly adapted for fine printing, as from process blocks prepared from photos, where the relief and depression is so slight that ordinary paper would give nothing but a blotch ; they are also adapted for litho printing, where the wire mark must be obliterated ; and for chromo printing, where the ink must be readily absorbed and a fine impression got. This class of paper is best suited for three-colour work, although supercalendered paper is often used in inferior work.

"Enamel-coated book paper is also especially adapted for halftone printings.

"'Art' paper is used largely for gold printing, where a fine surface is indispensable, and which enables the finest bronze powder to be used ; also for collotype printing, where a light impression is given."

Mr. W. L. Newcombe has been kind enough to forward me his letter appearing in the British and Colonial Printer and Stationer, in which he states that "Mr. Tuer's hatred of the coated 'art' and the non-coated but highly-glazed imitation 'art' papers was inveterate. Notwithstanding this, however, much of the work done at the Leadenhall Press of recent years is on these papers, for it has been found impossible to print successfully from half-tone blocks on any other papers. Mr. Tuer's objections to coated papers were that the highly glazed surface is painful, and consequently injurious to the eye; that the book produced is inordinately heavy, and that there is no guarantee that in course of time the coated surface will not come off and the printing be lost entirely or its beauty marred." There is no doubt that reading of books printed on "art" papers is painful to the eyes, and, of course, books printed on "art" paper are inordinately heavy. From the fact of the printed matter being on the enamel only (at least with heavy coated papers), and the enamel being so readily removed by moisture, it seems highly probable that the surface *will* come off, or, at any rate, the beauty of the illustrations be considerably marred in course of time through the destruction and oxidation of the mucilaginous matter which is the only thing that holds the clay together and keeps the enamel on to the paper. For all publications that are likely to be used to any extent for reference over a period of many years the utility of "art" papers is very doubtful. Mr. Newcombe further goes on to state that a dull-surfaced and highly handling paper which will supersede "art" or "imitation art" papers for half-tone printing has yet to be invented, and there is a fortune and the heart-felt thanks of all serious-minded printers and their patrons awaiting the inventor.

It is also evident that the general public have formed their own opinion on the subject of "art" papers. There has been some interesting correspondence in the *Standard* on this subject. The following is an extract from a letter to the *Standard* on January 8, 1902:—

"About a week or ten days ago there was a letter in the *Standard* complaining of books printed on glazed or shiny paper as being very trying and injurious to the eyes. I have for a long time been thinking of making the same complaint, and have been expecting to see some further correspondence on the subject.

"Whenever I find a book or periodical printed on this kind of objectionable paper, I always lay it aside as being not worth the strained effort required to read it, and if writers of articles and publishers knew how much the public appreciated good paper and good print they would not risk the rejection of their contributions by sending them to such periodicals as use this kind of paper and illegible print. I have before me several such periodicals, but I will not mention them. Suffice it to say I do not attempt to read them."

A number of people have written in this strain, and although such people are unduly prejudiced, there is a good deal to be said against "art" paper for ordinary publications. What has been said in "Chapters on Papermaking," vol. iii. pp. 97,108, in reference to the physical qualities of opaque and transparent papers throws considerable light on the subject. An "art" paper may be regarded as being extremely opaque; but with the high reflective power, and with the fact that the reflection largely takes place, not at innumerable angles as is the case with ordinary papers, but almost wholly on one plane, viz. that of the surface of the paper, "art" papers behave more like an ordinary mirror in their power of reflecting light. They are consequently very uncomfortable and fatiguing to read in a bright light, and especially in direct sunlight, as in certain positions the rays of the sun are largely reflected to the eye, and the paper becomes dazzling. The contrast is particularly noticeable on looking through a publication which is partly printed on "art" and partly on ordinary uncoated papers. When such a book is held in a position in the sunlight so that the rays are reflected from the "art" paper to the eye, on turning over the leaves the difference between the two kinds of paper will readily be noticed. These remarks are merely made in order to show that "art" or a coated paper, although particularly suited to one class of work, has its limitations, and it is as well that these limitations should be fully appreciated.

CHAPTER III.

THE "AGEING" AND STORAGE OF PAPERS.

Improvement of drawing-papers—Wrapping papers—Effects on fibres—Gelatine—Surface—Strength—Litho papers—Discoloration—Deterioration—Lowering of colour—Oxidation—Effects of rosin—Mellowness—Dulness—Time of keeping.

QUESTION 19.—*What papers are improved and what papers are deteriorated by keeping in stock? To what is the change due?*

In **B**'s answer there are several interesting points. He has, however, omitted one matter, viz. the importance of dry seasoning. With some papers it is a decided advantage to keep them in stock for a number of years. It is a well-known fact that certain drawing-papers by a well-known maker, of certain dates, are much prized by artists. The artists state that it is due to the improvement in what they call the "tooth," and is the result of ageing. In this case we have an improvement in the surface of the paper which is brought about by ageing. But it is evident that papers, even of similar composition, age differently, because the makes of some years improve on ageing, whereas the makes of other years do not; at any rate, to the same extent. This appears to be very much like the ageing of wine.*

There is much in **B**'s contention that the distribution of moisture by the best artificial damper is not equal in its effect to the moisture taken up by the atmosphere in the ordinary course of natural air-drying.

It is impossible to closely imitate by artificial damping the air-drying of paper. This is a very interesting subject, and one which the author dealt with at some length in articles in the

* See also Orme Masson, F.R.S., *Roy. Soc. Proc.*, vol. 74, pp. 230–254; Orme Masson, F.R.S., and E. S. Richards, B.Sc., *Roy. Soc. Proc.*, A., vol. 78, 1906. Clayton Beadle, NATURE, vol. 49, p. 457; Clayton Beadle, CHEMICAL NEWS, vol. 71, p. 1; Clayton Beadle, CHEMICAL NEWS, vol. 73, p. 180.

Chemical News and in the Papermaker, showing the rate at which cotton fibres such as exist in paper take up moisture under various atmospheric conditions, and the effect which this has on the physical qualities of the fibre. The hydration or air-drying is partly a chemical and partly a physical operation. It is not generally known that paper which has been thoroughly dried and allowed to cool will, when coming in contact with the moist atmosphere, rise in temperature whilst the moisture is being absorbed. The behaviour of amorphous cellulose under these conditions will show how much cellulose alters in its physical qualities according to the amount of moisture it contains. If it is very dry it becomes brittle. With a certain amount of moisture it becomes much stronger and more pliant. With more moisture still it loses by degrees its power of "felting." There is a point, therefore, with all papers, and all fibres, when the maximum strength is obtained. It may not be at absolute air-dryness, but it is certainly a fact that papers dried under ordinary atmospheric conditions are much stronger than if they are hard dried. The fibres in the papers are under tension when drying rapidly on a machine. They settle down as it were on resuming their atmospheric moisture, but undoubtedly, in some cases at least, it takes time to overcome this strain and stress and for the fibres to resume their more natural conditions. Hence it is that some papers improve very much by keeping, and the improvement can only be effected by keeping them a certain length of time. It is not an uncommon thing for a parcel of paper, especially in the case of certain qualities of browns, to be rejected by the buyer when first made, and after a few months to be accepted as different paper altogether. It is merely a matter of keeping the paper in stock to get the desired qualities.

B is quite wrong in attributing the increase in absolute strength with different degrees of gain in weight, with what I have said in my lectures in paper sizing; in this case I should judge that the gelatine has not much to do with it. The foregoing remarks will, I think, give him a correct explanation of this.

Paper which has not been dried very slowly indeed—in fact, perhaps all machine-made papers—are under a stress or strain which is, to some extent at any rate, relieved by keeping the paper until it has entirely settled down.

Gelatine papers, especially those which are dried hastily, are also considerably improved in many instances by keeping in stock, during which time the gelatine, which in its normal state contains about 17 per cent. of air-dry moisture, resumes its atmospheric condition. You will notice with sheets of gelatine that when they are laid in the sun in a warm dry room they become brittle, but in dampish weather it is possible to bend a good sample very considerably without breaking it. The same holds good in regard to the microscopic films of gelatine formed in the interstices of the paper. I do not think it is generally understood in what way mechanical wood deteriorates. This point I endeavoured to explain in a popular way in my lectures before the Dickinson Institute. It may seem strange that "mechanical" made from pine wood will deteriorate rapidly on exposure to the air and light, whereas chemical pulp made from the same wood is, if properly prepared, a very durable material. The fact is that the non-cellulose portion of the wood which remains in the "mechanical" acts in a deleterious manner upon the cellulose fibre of the wood. It acts as a conveyer of oxygen both to itself and the fibre, and its action is not unlike the action of oil in an oily rag, which will absorb oxygen from the atmosphere and quickly rot the cellulose in the rag, and the action in the latter case is so rapid at times as to bring about spontaneous ignition. It follows, therefore, that both "mechanical" and "chemical," other things being equal, become more durable in proportion as they contain less lignin. This is well exemplified in the case of carefully prepared and bleached sulphide wood. Such wood, although not perhaps quite so lasting as cotton or linen, is at the same time fairly durable and resistant to atmospheric influences.

Of course, when paper is kept in stock it is for the most part out of the influence of the light and atmosphere, except on the edges, and is therefore not liable to the same deterioration as it would be when in everyday use. It is important to draw a distinction here.

In regard to the question of ultramarine papers, there is almost always an interaction between the alum and the ultramarine, even in those colours which are fairly fast to alum. It is an extraordinary fact that most ultramarine papers are exactly neutral to litmus even with considerable quantities of alum added. At one time I tested a large number of ultramarine rag papers with different indicators, and compared the same with uncoloured papers of similar composition; the acidity or alkalinity depended, in the case of the ordinary papers, upon the amount of alum and other substances present, but I was surprised to find that the ultramarine papers were all neutral. It is often noticed that as the ultramarine paper leaves the drying cylinders it has a distinct smell of burning sulphur. I am inclined to think that the decomposition takes place whilst the paper is being dried on the cylinders, and that there is no further chemical action between the alum and ultramarine after the paper is put into store.

I do not think there should be any liability to putrefaction of gelatine in papers except in such climates as India, which favour the growth of bacteria in gelatine. For such climates paper should be specially prepared so as to prevent this. In an ordinary English climate, at any rate, under the conditions in which paper should be stored in a paper-mill, there should be no fear of putrefaction when a proper proportion of alum is used.

B's Answer.—"It will be scarcely fair to dogmatically state that any paper is either improved or deteriorated by keeping in stock until a general survey of the terms has been made.

"Improvement *by* '*Seasoning*.'—When paper is kept in stock it is done so for the purpose of seasoning; this means that it (1) gains in weight, (2) its expansion is corrected, (3) its liability to afterwards wrinkle and cockle is less, (4) in some instances its strength is increased, and (5) its colour may be said to have improved.

"(1), (2), and (3).—These are brought about by allowing the paper to absorb its natural quantity of atmospheric moisture.

"Suppose a litho paper was cut immediately after it came off the machine, and was then tightly packed and kept in a cool place. The air would gradually permeate and moisten it; the paper would expand in any direction where the packing was weakest. When opened it would be found to be in a wavy and wrinkled condition. Or if a dry reel of paper taken from the machine was immediately calendered, the sudden damping would cause cockling, for the distribution of moisture by the best artificial damper could not possibly take the place of the slower and natural alternative, the atmosphere.

"From the foregoing it can be seen in what manner papers are improved by keeping, and that this improvement is due to atmospheric influences.

"(4).—It is a fact that some papers increase in strength by seasoning, but the reason of this is not easily explained.

"I once tested a tub-sized paper for strength, and then carefully rolled the sheets and laid them on a high shelf where air, but diffused light only, could reach them. *Ten months* later I again tested them. The following are the figures :—

Original Trial.		2nd Trial.
Breaking strength.		
Average Dn. and Ac. Mc.	3·781 km.	4·145 km.
Breaking expansion ...	5 per cent.	3·6 per cent.

Increase of weight = 3 per cent.

"This increase in absolute strength *without* a decrease in weight I can only attribute to what Beadle infers in his 'Paper Sizing' lecture, pages 43 and 44—that the film was broken in the drying, and that in course of time the gelatine was affected by the atmosphere and became coherent.

"(5).—*Improvement of Colour.*—This may be reduced to preservation of colour. For instance, up to a certain point, an iron-toned paper will become slightly deeper in shade by further oxidation of the precipitated hydroxide.

"Deterioration.—Paper deteriorates by keeping in three ways—Loss of Strength, Discoloration, Loss of Finish.

"These may be brought about by the direct action of light and air, and by the interaction of constituents of the papers themselves.

"*Light and Air.*—Rag papers containing more than 3 per cent. of rosin will deteriorate in strength—and if heavily starched—due to partially unboiled starch.

"Papers containing wood, and especially newspapers, will rapidly become weaker—due chiefly to the combination of lignin and oxygen.

"*Coloured Papers.*—Those colours of mineral origin are the most stabie to the action of light. The aniline dyes are much more easily affected, and some of the reds are particularly fugitive.

"In papers where the material has been overbleached with the formation of oxycellulose, and where the bleached material has not been properly washed, the after-formation of chlorides are known to be detrimental to the strength of papers.

"In cases where a great excess of alumina sulphate is used a modified form of hydro-cellulose is sometimes produced.

"I remember on one occasion a paper that had been in India was returned in a very brittle condition. It was due to its extreme acidity, and it had a faint smell of acetic acid.

"*Discoloration.*—The discoloration of 'self-colour' papers is generally brought about by oxidation of the non-cellulosic portion of the material, but with some rag papers where this was formerly thought to be the case it has been shown to be due to the excessive quantity of rosin used. This is acted on by sunlight, and a brown, sandy colour is produced. The formation of sulphides is a most objectionable feature with ultramarine-coloured papers, and this combined with the action of alum causes the colour to fade.

"The finish of a paper is affected by keeping, and this is generally accompanied by discoloration; as in the case of the putrefaction of a gelatine-sized paper when small whitish-green spots are formed.

"Sometimes the surface of a highly super-calendered paper will diminish with a blackening effect when kept in a cool place. A high finish imparted above a certain temperature is not lasting. By comparison, a plate-glazed surface is practically everlasting.

"The bulking qualities of certain papers are improved by keeping—a rough antique will not bulk more, a heavily pressed paper will.

"Papers, then, which may be said to improve by keeping in stock are—

"Printing, litho, and tub-sized papers for the seasoning purposes mentioned, but these and other papers also deteriorate under the action of the influences already enumerated.

"I realize that as all papers deteriorate in time, it is only by the use of such a term as 'keeping in stock' that improvements and deterioration can be compared, and I have attempted to deal as logically with this question as with the others."

E states that printing and cream-laids are apt to turn flabby and soft if they are kept too long in a damp stock-room. Of course, if the atmosphere is allowed to get damp papers would deteriorate, but this should never be.

He furthermore adds that the colour is often affected by the ultramarine not being added to the stuff at the right time, and thereby getting acted upon by the alum and fading. **E** in this question is rather liable to go off from the main issue. It is not desirable to discuss the manufacture of the paper so much. A certain amount of information in regard to the manufacture which bears directly on the point is, however, not out of place.

"Again, lithographic and animal-sized papers are improved by keeping; the former after seasoning do not stretch so much on the lithographic machine. Animal-sized papers harden up." The point in regard to lithographic papers is certainly an important one, and has been dealt with in a previous question. This, again, only emphasizes what we have said before, namely, that when papers are not properly made, as when they are too hastily dried, it takes time for them to return to their normal state.

F, in talking of cotton and linen papers, says: "If they have been sized well with animal-size and not too much alum, they will last for some hundreds of years." Undoubtedly this is a fact, but it is difficult to judge how machine-made papers will last as compared with hand-made. Of course, we can only judge of hand-made paper in this respect, as we cannot go back further than about one hundred years with machine-made papers.

In speaking of the improvement in papers consisting of half cotton and half linen, he states that they get more mellow, or as it is put in the trade, "the paper ripens and works better." Perhaps "ripening" is a very good expression to describe the change which takes place in the paper.

F realizes the fact that esparto straw and mechanical wood deteriorate. We have not pointed out, in referring to the above subject, that in addition to substances like mechanical wood, other celluloses which have been deprived of the foreign bodies which they contain are liable to deterioration for another reason. Esparto and straw are residues which partake of the nature of oxycellulose. They may be regarded as cellulose which is already partially oxydized, and in consequence are more susceptible to further oxidation. **F** states that wood is not much affected by the atmosphere "unless there is something which will act as a conveyer of oxygen to the cellulose; then comes a change."

I states that "super-calendered printings and imitation art, when kept in stock, deteriorate. This may be seen by the surface having 'gone back.' As the value of a paper is partly dependent on the nature of the surface, such paper would not fetch such a good price." This is a very good instance of paper deteriorating, *i.e.* becoming of less value from being kept in stock. In speaking of esparto, chemical wood, and mechanical, he states that they do not store for any length of time without showing signs of decay. "This is noticed," he remarks, "by comparing reference sheets made a year or two back with others just made." Such comparisons, if carefully made with papers of known composition, would be of very great value in settling this important point. It would be necessary to take note of the conditions under which the paper was stored, whether in a damp or dry place, and whether in the light or dark, etc. It is important, also, to note that hard-sized paper stands keeping better than soft-sized. This is largely due to the fact that with soft-sized papers the air can more readily get at the fibres and rosin, the hard-sized being protected by gelatine from the direct action of the atmosphere. So long as rosin is not in sufficient quantities to bring about deterioration on its own account, it may, with some papers, tend rather to preserve than to destroy them, but this is a question on which we have very little knowledge.

M.—We reprint a portion of this answer. The question of the stocking of papers reducing the tendency to curl is worth noting, as such curling retards the feeding into the folding and gumming machines. The idea that the curling of the paper is normaly due to one side being softer than the other when wetted, is altogether wrong, and I would refer **M** to an article of mine in the Papermaker on this subject which deals with the question at some length.

The curling of the paper is due to the expansion of one side. Cellulose always tends to expand when moist and to contract when dry. One side becoming moist whilst the other remains dry causes the expansion on the wet side, and there being no corresponding expansion on the other side, the paper naturally curls over.

The peculiar curling of a machine-made paper on wetting a disc can be explained from the fact that the fibres lie more in one direction than another, and consequently tend to expand more in one direction than another. The greater expansion of the disc in one direction causes it to curl over. "Waviness of the edges which often causes creasing at printing machines, and is due to uneven absorption of moisture, is cured by keeping the paper in stock." This is a good practical statement.

There may be something in the statement which **M** makes in regard to free stuff being particularly liable to go back in surface when kept in stock after calendering. He gives it as his opinion that the fibres part with the water too quickly on the wire, leaving a lot of fibres standing on end and not properly intcrwoven, and if this is the case the calendering might certainly only temporarily flatten thcm, so that when the paper is stocked for some time, the fibres would tend to recover their original position, and cause the surface of the paper to go back.

"Among papers improved by keeping are Envelopes, Lithos, and Printings.

"1. Envelope papers are improved by lying in stock, as this cures the tendency to 'curl,' which causes great annoyance to the envelope manufacturers when feeding the blanks into the folding and gumming machines. The curling is due to the moisture from the air getting in at the edges of the sheets; if exposed a sufficient time the sheets will absorb the moisture uniformly all over the sheet, and curling is remedied.

"'Curl' due to moisture can be demonstrated by cutting a disc of paper about 2 in. diameter and floating it on water, then taking it out, care being taken not to wet the upper side; the paper will then curl away from the wet side." The idea that the curling is probably due to the fibres becoming softened on the one side giving way to the shrinking action of fibres on the other side, is, as above shown, erroneous.

"Note direction of curl, which invariably takes place parallel to direction of web.

"2. *Lithographic Papers.*—All papers on absorbing moisture stretch a little in both directions, *i.e.* both along and across the direction of the web, but principally across. Therefore if a paper is lithographed without being properly matured, it runs a great chance of stretching during the interval between the impressions, throwing the final impressions out of register.

"3. *Printings.*—Waviness at edges often causing creasing at printing machines, due to uneven absorption of moisture. Lying in stock cures this.

"Among those papers which deteriorate on keeping are high-surfaced papers, coloured papers, mechanical wood-pulp papers, badly manufactured papers, and rosin-sized papers.

"1. High-surfaced papers all tend to go back slightly in surface, but papers made from 'free' stuff especially so, probably due to the fact that with free stuff the water parts from fibres on the wire too quickly, leaving a lot of fibres standing on end and not flatly interwoven, which the calenders only temporarily flatten on resumption of normal moisture. These fibres tend slowly to straighten themselves, and in so doing lower the surface.

"2. Coloured papers all fade (with the exception of cobalt blue) if kept long enough in stock. Heat and light hasten the decomposition of the colours, therefore coloured paper should be kept in a cool, dark place.

"(Above remarks are on deterioration that occurs during the ordinary period of lying in stock, which I presume means not more than about two years at the outside. Remarks below may be irrelevant, as they refer more to paper deteriorating after a much longer period).

"3. Mechanical wood-pulp papers lose strength and become brittle and discoloured, owing to formation of oxidation products, produced by the decomposition of resinous bodies in the wood.

"4. Papers which on digestion with water show traces of free acid or free chlorine will become brittle and deteriorate in strength.

"5. *Rosin-sized Papers.*—The action of light on rosin-sized paper gradually produces discoloration in proportion to amount of rosin it contains."

N considers that the better qualities of paper are improved by keeping in stock, and gives extra strong "bank" newly made as an instance. This tends to handle harsh and brittle, and does not tear so well as after it has been kept a month in stock. He mentions that coloured papers tend to deteriorate in stock. This, of course, is rather too general a statement. If what are known as fast colours are chosen for colouring the paper the tendency to fade is much less than if fugitive colours are used. With pigments the same is true. For instance, we should not expect any deterioration in colour of a paper containing smalts unless due to deterioration in the colour of the fibres themselves.

R has given a very fair answer. The remarks he makes in regard to the removal of dryness and brittleness on storing imparting better finish, and the fibres not breaking so much under pressure, is partly true, but the author is under the impression that for anything like a permanent surface it is necessary that the fibres should not be broken, but physically altered to a large extent, so as to flatten the cell walls.

If the calendering only causes the fibres to lie down without flattening them, the finish is very liable to go back.

The fact that colour fades more quickly at seaside places may be due to the fact that there is a greater amount of ozone (not oxygen) in the air, combined with a greater amount of moisture. The amount of oxygen in the air, whether at the seaside or any other place, is practically constant, but the amount of ozone varies, and is greatest at seaside places, and as ozone is an active bleaching agent and requires a certain amount of moisture to give it its greatest activity, it is highly probably that the fading of papers at seaside places is due to this cause. Of course the term ozone is used in the meteorological sense representing the active agent in the atmosphere which blues starch iodide papers. Whether this is actually the chemical substance ozone (O_3), or some other substance such as hydrogen peroxide or oxides of nitrogen, all of which blue starch iodide papers, it is impossible to say.

R's Answer.—"All papers, with few exceptions, are improved by being kept in stock, as they gather a 'mellowness' and 'maturity' which is lacking in new papers. Especially is this the case with printing and M.F. litho papers. New hard-dried paper has a brittleness and want of *folding* qualities, owing to all the hygroscopic moisture having been driven off. When allowed to stand in a cool atmosphere for some time it regains its moisture, with accompanying strength and 'kindliness.' The foregoing characteristics, especially if there is any irregularity in drying, are generally accompanied by '*cockling*.' This can almost entirely be overcome by allowing the paper to lie out flat in small parcels for some days. Or, instead of lying flat, it may be hung up. This has the effect of making it lie flat by relieving it of its insulating qualities and allowing the electricity which it contains to become dissipated. Papers which are to be plate-glazed will be greatly improved by being stacked in a cool room for a few weeks and then hung up before being glazed. The dryness and brittleness having been thus removed, a better finish can be imparted, and the fibres will not break so much under the pressure.

"On the other hand, M.F. papers, if kept long in stock, especially in a cool room, will go back in finish owing to expansion of the fibres. In this connection I might say that soft-sized papers will lose their finish quicker than hard-sized, and printings quicker than writings, the presence of the size, especially if it be rosin, preventing the absorption of an undue amount of moisture. The colour will also fade, and the sheet will have a '*dulness*' which is absent from new sheets. The colour will fade more rapidly in seaside places, due, I suppose, to the larger quantity of ozone in the air acting in conjunction with moisture.

"T.S. papers, if kept in a damp atmosphere, will deteriorate, as the animal size is liable to putrefy and cause an obnoxious smell, especially if an inferior gelatine has been used. Storing in too damp an atmosphere should be avoided with all papers, as they are liable to 'wrinkle.' Especially is this the case with wood and straw papers, owing to the hard nature of the fibre."

S remarks that all papers kept in stock should be covered up, as the light affects the colour, more especially if aniline dyes have been used for the colouring. This is certainly a wise precaution, as, although the bulk of the paper may not be affected, the edges are liable to be, especially if the paper is stored in a light place where the sun is likely to fall on the stacks.

U's remarks with reference to the keeping of "news" a few days are thoroughly practical. "Newspaper and common printings are well known to improve by keeping for a short time, the paper working much better and taking the ink from the type easier, so as to produce a well-printed sheet. The reason for this is that the paper often leaves the machine too dry, and when in contact with the atmosphere for some time the paper becomes air-dried, or damper than when it left the machine, and damp paper always prints better than dry, absorbing the ink better." The following is an abstract of **U**'s answer.

"Newspaper and common printings are well known to improve by keeping for a short time, the paper working much better, and taking the ink from the type easier, thus producing a better-printed sheet. The reason for this is that the paper often leaves the machine too dry, and when in contact with the atmosphere for some time becomes air-dry, or damper than when it left the machine, and damp paper always prints better than dry, absorbing the ink better. The paper also expands when in contact with moisture, and the paper being packed tight, particularly when in reels, the fibres are crushed and more interwoven, giving a stronger paper. Paper which is intended for calendering beyond machine finish, is improved by keeping a few days, so as to allow of all the electricity in the reel or sheets being conducted away by the moisture in the atmosphere, thereby preventing the sticking together of the sheets in calendering and finishing. Tub-sized papers should not be kept in stock too long in a damp place, as the gelatine is liable to decompose, giving an offensive smell, particularly if only a small quantity of alum has been used."

The question of paper, which has been made from material bleached at too high a temperature, going back in colour is worth noting. We have here no cellulose, but oxycellulose and hydrocellulose to deal with, which whether produced from cotton or linen by chemical treatment (generally the result of bad management), or whether as a cellulosic residue, such as that of esparto or straw, will bring about deterioration in time. **V** mentions the results of Herzberg's investigations, viz. that paper is at its strongest when it contains from 3 to 5 per cent. of moisture. This figure, the author thinks, depends largely on the composition of the paper, but there is no doubt that many papers are not at their strongest when they are air-dried in an English climate. In a dryer climate than that of England some paper would tend to test rather stronger because the amount of moisture would be nearer to that at which it possesses the greatest strength.

V's Answer.—"Most papers seem to deteriorate somewhat when stored under ordinary conditions."

"Papers containing mechanical pulp are more liable to deteriorate. The pulp is oxidized and soon becomes discoloured, disintegration taking place to a greater or less extent. It has been shown that when disintegration does take place it is accompanied by an alkaline reaction, and if the paper be dyed with a colour sensitive to alkalies the colour is destroyed.

"Papers in which a high white colour has been produced by using large quantities of bleach are liable to become 'tendered,' owing to the formation of oxycellulose, and especially so if not thoroughly washed after bleaching or carefully neutralized. I have noticed that when too high a temperature has been used in bleaching the stock, the paper made from that stock has gone back in colour a great deal after being stored a couple of months.

"I have noticed that blue papers dyed with paste blue and topped with an aniline fade considerably round the edges of the ream and considerably into the interior when in stock about two years in a damp place, and also papers pink-dyed with eosine very soon fade at the edges.

"Papers with a high finish lose this somewhat when in stock, especially in damp weather. The finish put on by means of condensing steam on a roller just as the paper passes through the calender seems to be the most liable to this loss, as the moisture is only on the surface, and the finish is not so thorough as when the paper is properly damped.

"I think that most papers improve by being kept in stock until they have absorbed the amount of moisture they would do under ordinary conditions, that is, their hydroscopic moisture, but after that time I do not think any improvement takes place, although drawing-papers are said to be improved by storage. Architects prefer drawing-paper after it has been stocked three or four years.

"Herzberg has kept paper made from (1) pure rags; (2) 75 per cent. rags, 25 per cent. bleached sulphite pulp; (3) 40 per cent. rags, 60 per cent. bleached sulphite pulp; and has found that after seven years' storage in a dark, dry cupboard no loss of strength has taken place, and he has also shown that paper containing 3 to 5 per cent. moisture is at its strongest.

"Animal-sized papers soon deteriorate if stored in a damp place, and soon develop a disagreeable smell, owing to the decomposition of the gelatine."

The question of the effect of storage on the qualities of the paper is a wide and important one, and there is a great deal to be said on the subject, which I think is as well understood by stationers as it is by papermakers. Stationers have large quantities of stored paper under their notice, and have a good opportunity of making observations of any changes.

A better knowledge of the subject would be useful both to the stationer and the papermaker, and might possibly result in a better understanding in the case of disputes arising between them as regards surface, colour, strength, feel, etc., which sometimes arise between the papermaker and the stationer, from the fact that the paper has undergone some change as a result of time in storage from the time of its manufacture to the time when the stationer and printer make use of it.

CHAPTER IV.

THE USE OF LIME IN BOILING.

Action of—Comparison with soda—Comparative cost—Boiling of hempen rope—Preparation of milk of lime—Comparison of different limes.

QUESTION 20.—*In what instances would you use lime for boiling? Give your reasons.*

B is wrong in supposing that the action of caustic soda is the same as that of lime. They only resemble each other to the extent of saponifying the fatty matter with which they come in contact. They differ essentially in one respect, viz. that soda forms soluble soaps when in contact with fatty or greasy matter, whereas lime forms an insoluble soap. Soda soap is therefore removed on account of its solubility. The removal of the lime soap is a mechanical operation. A great deal of the lime soap detaches itself and remains in suspension during the boiling. That which is not detached remains in contact with the rag or other material under treatment, and is removed subsequently by mechanical operations, as when the rags are washed in the breaker.

The lime compound is easily removed by mechanical treatment, on account of its extreme friability. If it were not for this the lime treatment would, to a large extent, be useless. The difference between the behaviour of these two substances is mainly due to the above cause. The question of the difference in the solubility of the lime and soda, of course, in a measure influences their action, but only to a minor degree, the lime being sparingly soluble in water possibly slows down the rate of chemical action.

I do not think **B** should exclude the treatment of straw in this answer, because straw is treated both with caustic alkali and caustic lime. If it is desired to only partially resolve the straw, such as for the purposes of strawboard manufacture, the use of lime is resorted to ; if, on the other hand, it is required to remove the whole of the silicious and non-cellulose matter, it is usual to treat with caustic soda.

The silica would not be removed by treatment with lime, as lime would fail to act upon it.

Under heading (*a*), **B** mentions, "for lime a lesser degree of cleanliness and a greater length of time in washing." As he divides his answer under headings, it would be much more consistent if he made here two distinct headings, as "a lesser degree of cleanliness" is quite distinct from the question of "greater length of time in washing."

The difficulty of cleansing from lime is due, of course, to the insolubility of the lime itself. If the lime could be dissolved like caustic soda, there would be no difficulty in separating out the dirt, by allowing it to settle, and running in a clear solution. But as a clear solution of lime is so weak, this, of course, would not be practicable. If the lime is carefully slaked, the particles are very fine, the milk of lime can be passed through a sieve of fine mesh, which retains the greater part of the dirt. "The greater length of time taken in washing," is the result of the lime compound being insoluble, the washing bringing about the removal of the insoluble compound by mechanical means, whereas the water, in the case of the soda compound, removes the same by dissolving it out.

The washing of the lime compound is not so much a question of a large amount of water as it is a question of thorough and rapid agitation, but this must not be carried to the extent of detaching the fibre more than is absolutely necessary. I quite agree that it may be necessary to use a larger quantity of water for washing lime-boiled rags than soda-boiled, but this can be largely minimized if the washing is properly conducted.

Under the third heading he mentions the brighter colour. Although lime-boiled rags are brighter as compared with soda-boiled rags immediately after they are boiled, it does not follow that by the time they are washed and bleached they will be a better colour than the soda-boiled rags. It may be taken as a general rule that an alkaline treatment tends to lower the colour or intensify that of all lignified fibres. We would expect, therefore, that the "shieve" contained in linen would show up more if the boiling is conducted with soda than with lime, but, nevertheless, although these particles are seen more readily after the soda treatment, they should more readily soften and consequently bleach more readily than if boiled with lime only.

B is quite in error when he remarks that "on this basis, supposing lime was equally soluble, the quantity of pure calcium hydrate by weight would be . . ." He is right in his quantities and calculations but wrong in his conclusion. It does not depend upon the question of equal solubility, from the mere fact that as lime is exhausted from solution its strength is renovated by fresh lime being dissolved. The relative potential energies (if one may use such an expression) of milk of lime and caustic soda solutions is only partly dependent upon the relative amounts of chemicals in solution at any onc time. He is right in concluding from his figures, however, that a much larger molccular ratio is required in the case of lime than in the case of soda, chiefly, in my opinion, due to the fact, not that lime is so sparingly soluble, but that it forms a lime soap that is insoluble, coating the fibres and rendering further chemical action difficult, and in order that the lime may get at the remaining unsaponified fatty matter considerable excess is needed. Some such explanation as this is required to account for the fact that a much higher molecular ratio is needed in a lime than in a soda boil.

As regards the rapidity of action of caustic soda, and the quantities required for the treatment of different rags, the author would refer students to his lecture on "The Treatment of Rags," before the Dickinson Institute.

In speaking of dissolving caustic soda. There should be no trouble in this respect, because the method of breaking up caustic soda in the drums and adding the lumps is altogether out of date. The proper plan is to take the lid off the drum, and by means of a chain and block to lift the drum (with the exposed portion of the caustic soda downwards) into a copper, partially filled with water. By means of a jet of live steam projected upwards, a stream of hot water is made to impinge on the exposed portion of the soda until the whole is dissolved ; the empty drum is then removed, and another one placed in the copper, and so on, until liquor of the requisite strength is obtained. This process really entails far less labour than the preparation of milk of lime. Even on a small scale this method is much easier to work than breaking up the caustic soda, which is at all times a troublesome, not to say dangerous, operation.

We quite agree that where a mill has plant for the recovery of caustic soda, the question is considerably affected. It might influence paper-makers in favour of caustic soda, because the spent liquors could be recoverable along with the strong liquors of the esparto or wood boiling.

There is nothing in **B**'s suggestion in the use of lime from the point of view of its softening action on the water. It is only when a very small amount of lime is added to water (viz. that necessary to combine with one half the carbonic acid contained as bi-carbonate of lime) that the water becomes soft; lime does not affect what is called the permanent hardness. With excess of lime, however, the water becomes hard again, perhaps 10 or 20 times as hard as the original water, in consequence of the presence of calcium hydrate. **B** will see, therefore, that his conclusion is the opposite of the truth. Soda, on the other hand, softens water on account of its seizing hold of the carbonic acid and so converting the bi-carbonate of lime into insoluble carbonate, which becomes deposited or remains suspended in the liquor, but quite inert; the water remains soft even with excess of soda, and moreover the soda removes even the permanent hardness by acting on the sulphate of lime and forming sulphate of soda. The case is therefore the reverse of what **B** states in regard to this matter. Caustic soda does not act on $CaSO_4$ to remove permanent hardness except in presence of CO_2 as the $Ca(OH)_2$ is soluble.

B states that the soda treatment is more drastic, and the fibres are consequently weaker. This the author does not regard as true of most qualities of rags, but it is undoubtedly true in the treatment of jute. The strength of jute is dependent, not upon the ultimate fibre, but upon the filaments, which consist of a number of ultimate fibres; if the non-cellulose which binds these fibres together is too much softened, the strength of the jute, from a papermaker's point of view, is largely destroyed. The art of jute treatment consists of only partially resolving the raw material, so that the jute filaments remain unimpaired in strength as far as possible. This is best done by resorting to a lime boil. A certain amount of soda can be used for jute treatment in conjunction with lime, but only within certain limits. Although lime treatment is to be recommended from several points of view, it has distinct disadvantages.

If the insoluble lime remaining from the boiling is left in the rags for some time before washing, this lime may have a weakening effect upon the fibre. For many purposes this is, of course, a great disadvantage, but it is made use of in certain classes of manufacture where tender material is required.

B's Answer.—" For boiling old hempen and manilla ropes and tarred canvas. For rags, where cleanliness is not of first importance. The low cost of lime. The brighter colour produced. Greater strength of the boiled material. The foregoing are subject to modification, as will be explained in detail.

"*Chemical Bearing of Lime on Rags.*—Caustic soda and caustic lime are the two practical chemicals for the isolation of rag cellulose (wood esparto and straw need not be considered in the answer). Both are alkalies, and therefore the principle of reduction from this point is the same with either. There is, however, a difference between them, which brings about modifications in boiling, etc. Soda is extremely soluble in water, lime very sparingly so, and the low solvency of lime is indirectly the cause of (*a*) a lesser degree of cleanliness and greater length of time in washing ; (*b*) the need of a larger quantity ; (*c*) a brighter colour.

"*Cleanliness.*—The cleanliness of the rags is affected in three ways. Lime is associated with more or less grit, and the straining of the 'milk' is never perfect enough to avoid this from mixing with the rags. It also forms insoluble soaps with the grease, which are exceedingly difficult to remove, and there is invariably a quantity of lime which does not go into solution. It is the removal of 'dirt' of this nature which necessitates nearly twice the time in washing as with soda-boiled rags. I have washed hemp for four hours with a continuous stream of water, and then extracted lime salts. After the first wash the use of cold water is to be recommended for the completion, as lime is more soluble in cold than hot water.

"*Larger Quantity.*—To take a specific case : Old hemp rope will be satisfactorily reduced with 10 per cent. of 77 per cent. caustic soda (reckoned on the weight of the raw material) to an air-dry yield of 73 per cent. (unbleached). On this basis, supposing lime was equally soluble, the quantity of pure calcium hydrate by weight would be

$$10{\cdot}8 \text{ per cent.} \begin{cases} Ca.H_2O_2 & 74 \\ 2NaOH & 80 \end{cases} \quad \frac{80 \times 10}{74} = 10{\cdot}8$$

but owing to its insolubility (or chiefly that in this case) the quantity of an 85 per cent. lime required is about two-and-a-half times more than soda to give the same result. This fact alone does not settle the question of superior or inferior caustic properties of lime and soda.

"*Brighter Colour.*—The reducing action of soda is much more rapid than that of lime (although this does not appear to be taken sufficient notice of). A rag is generally allowed to stew in soda liquor longer than is necessary to reduce it, consequently the compounds stain the fibres, and in some cases it is difficult to bleach the rag to a pure white. Especially is this the case with caustic soda lyes which have been made with grass or straw wash-water. With lime, on the other hand, the reducing process is slower, and the staining compounds less readily formed. Calcium compounds also have a false bleaching action on the shieve and woody tissue, and these facts, combined with the whiteness of deposits, tend to impart a brighter colour. Gunny bagging is more readily bleached to a fair colour when boiled with lime, and this is the case with many other rags.

"*Cost.*—A direct comparison is of course in favour of lime, as for instance—

		£.	s.	d.
30 cwt. of clean gunny—				
Lime used	7 cwt. at 1*s*.	0	7	0
70 per cent. caustic soda used, $2\frac{1}{2}$	,, 9*s*. 6*d*.	1	3	9

There is the extra washing to be considered, and if properly conducted at least two hours less boiling if soda is used. Where caustic soda has to be bought in the drum, there is the labour incurred in opening, and the difficulty in handling and breaking. But where the caustic lye is made in the mill, there is invariably a recovery plant, and here the difference in the cost of the two chemicals is more open to question. In boiling with lime the whole of the spent lye is waste, as I know of no mill which can afford to use a reclaimer. If soda is used, about 80 per cent. of it is recovered, and as the use of a recovery plant is at least a necessary evil with inland mills where esparto is boiled, the actual cost of treating the few hundred gallons of rag lye in the evaporating house is very small. Lime softens the hard boiling water, but it is doubtful whether this is a material advantage.

"*Strength.*—The strength of lime-boiled material is greater. Soda treatment is more drastic and the fibres are consequently weaker. Summing up the case for lime, its use is to be recommended where strength is the all-important feature."

D states that he would use lime for boiling rags for "blottings," and then allow the rags to stand, with the lime-water in them, on the floor. This process has a certain effect upon the cellulose itself, the exact nature of which is not at present thoroughly understood. It helps to render the stuff free, and to increase its absorbent power. **D** recommends the use of lime for dirty rags, jute, and lower grades of flax, if cleanliness is not of very great importance.

E remarks that "lime boils most rags very well. The action of caustic soda in solution is too strong and violent, except for lowest grades. Linen rags take almost double the quantity of lime to boil them than cotton rags do." The same holds good when using caustic soda, and an extra amount of chemical is necessary to soften the shieve.

There is no need for the remark that soda solution is "too strong and violent except for lowest grades." If the proper amount of soda is added, as is required for each quality, and the boiling conducted under proper conditions, not exceeding the time necessary, there is nothing strong and violent in the use of soda.

The statement in regard to linen requiring about double the quantity of lime that cotton does may be taken as a fair one, and in a different manner applies to the use of soda also. The extra amount required with linen, especially on the lower grades, is in consequence of the shieve which the linen contains. The body of the linen does not require such drastic treatment as is necessarily given to it by the stronger soda, but the treatment must be severe enough to soften the shieve so that it will be afterwards bleached to a good colour. It is important to notice here a difference between lime and soda treatment, which might in a measure justify **B** in his statements. The rate of action of lime is limited, on account of its limited solubility, whereas the rapidity of action of soda can be increased by increasing the strength of solution. The only way, therefore, to make up for the low solubility of lime is to increase the time of the lime boil. The shieve is the woody portion of the flax plant which has not been properly removed during the process of "retting." If the shieve is insufficiently treated when boiled, the bleach chlorinates rather than bleaches it. I should not think that it is at all desirable to keep the jute stacked in a heap after it is treated with lime, unless a soft and comparatively weak and absorbent paper is required, as the tendency would be the same as with cotton and linen rags, but I should judge that the action would be even more drastic. I think, therefore, that **F** is wrong in his opinion, unless he qualifies it by stating that such treatment should be resorted to only for certain purposes, and that the treatment should not be prolonged to the extent of rotting the fibre. The process of allowing the excess of lime to react after discharging from the boilers is, I know, made use of in the case of straw treatment, but straw is of a different class altogether, and only produces a weak paper. It is important to well wash the straw after it has undergone this treatment to remove the non-cellulose acted on by the lime during the fermentation which sets in on standing after boiling. I do not think that Dunbar's statement that lime alone is preferred for boiling the finest qualities of rags holds good at the present day. Doubtless lime was used before the introduction of caustic soda, and when caustic soda was introduced it was a long time before its action was properly understood, and no doubt a good deal of damage was done to the fibre, which prejudiced manufacturers in favour of lime for boiling. I believe that in the States more lime is used for rag boiling than in this country; at least, I have heard so. The same applies to Germany.

F does not, in my opinion, give a reason for the preference given to lime for boiling jute.

F's Answer.—"Jute may be boiled with lime only, and I think this will do it good if it is stacked in the heap after coming out of the boilers. I have seen it done in this way, and made a fine small hand paper.

"Jute is nearly always boiled with lime alone: with about 20 per cent. lime at 30 lbs. pressure for ten hours. I would boil nothing but jute with lime alone.

"James Dunbar, in his Practical Papermaker, says that lime alone is preferred for boiling the finest qualities of rags, as it is believed to be less injurious to delicate fibres than caustic soda.

"In America, some papermakers prefer to boil their stock with lime instead of caustic soda.

"The reasons I would boil jute with lime only are that, it is much cheaper, and jute being a highly lignified fibre, the lime is a good thing to eat away all the incrusting particles of a non-cellulose character, and jute being cheap and only fit for making a low-priced paper, it would not be wise to increase the cost by using a more expensive article with no better results.

"Lime contains a lot of gritty matter, as coal-dust, sand, and this makes it very likely that these small particles may be fixed in the fibres, and may be very difficult to get rid of; but in a paper made from jute these dirty specks would scarcely be noticed, although in a good-quality paper they would be most objectionable."

I's reason for the abandonment of the use of lime in some mills is a good one, but does not apply to mills where rags are the chief raw material treated. He states "that nowadays only a small quantity of rag is used in mills; it does not pay to boil with lime, on account of the trouble and expense in preparation;" and further he says, "Before lime can be used for high-class stock it must be free from all insoluble matter." I presume that he refers to dirt, and does not intend to convey that only the clear solution of lime water should be used.

"The quicklime should be slaked in the vats, and the resulting liquor allowed to flow slowly from one vat to another. This allows any solid matter to settle down, and when it is ready for use the liquor should be quite clear." It would be impossible to adopt this method in most cases, because the amount of lime dissolved by the water after the insoluble lime has settled is far too small to combine with all the fatty matter in the raw material.

He does not appear to grasp the conditions of a lime boil. We have, on the one hand, at the first onset nearly the whole of the lime suspended in solution, and taking no part in the chemical reaction. The small proportion dissolved combines with the fatty matter as an insoluble soap, and by so doing is removed from solution, making way for some of the undissolved and suspended lime to enter solution, and go through the same cycle of operations. This goes on (or should go on) until the bulk of the suspended lime is combined as an insoluble lime soap.

It is not a bad plan, after making up the milk of lime in a copper, to allow the milk to flow over a bay, so that the heavier particles of dirt may settle, and then through a fine wire sieve to catch as much of the dirt which remains in suspension as possible; but in doing this care must be taken to keep the lime in suspension and only let the dirt settle.

M is right in stating that lime combines with the fatty bodies in the rags, forming an insoluble calcium stearate, as almost all fats contain stearates yielding calcium stearate with lime, but is wrong in stating that these calcium stearates cannot be removed by washing, causing dirt and bad bleaching.

There would be little, if any, stearic acid in rags, but whatever the greasy matter is, the calcium compound is of a friable nature, and if sufficient lime is used, there should be no difficulty in removing it during the wash. The saponifiable matter contained in rags must be of a very mixed character, and derived from innumerable sources.

"Lime is also used for rags intended for the manufacture of blotting. After boiling, the rags are spread on trays, and allowed to rot for a week or two—this renders them tender and free when beaten." This process has already been referred to in reference to a previous answer.

N states that "if the rags are of a greasy nature, a first boiling with lime is better—it kills the grease better than soda." I cannot follow this argument. Lime certainly cannot saponify the grease more quickly and more thoroughly than soda can; in fact, it must of necessity be more sluggish in its action, as previously explained.

There is one great difference in ordinary practice between the use of soda and the use of lime, which may account for some of the remarks made. If you go on anyhow with lime you are much less likely to do harm than if you go on anyhow with soda; and the chief reason for this, as aforesaid, is that with lime there is very little in solution at any one time.

R remarks that "lime can generally be got of sufficient good quality at no great distance from a mill." This leads up to a question which we have not yet considered, and that is the composition of the lime most suited for lime boils. The author has analyzed various limes which have been found best adapted to this purpose. It is important to get a pure lime. The Dorking greystone lime is a very good one for the purpose. The Otford lime is not so good. There is nothing to equal the Buxton lime, which contains a high percentage of CaO. Otford lime contains 80 to 85 per cent. CaO, it has a yellowish cast, and contains, in my opinion, too much iron for the best papers. Buxton lime is practically white and pure, and contains 95 to 97 per cent. CaO, and is mostly from pure limestone. This is the class of lime to use for high qualities of paper. For building purposes a different type of lime is generally required. Thus, a lime which would be a very strong hydraulic lime would be altogether unsuitable for the treatment of rags, in consequence of it containing certain other substances, viz. clay, magnesia, silica, etc., which give to it its hydraulic qualities, but which would retard its action in the process of boiling rags, etc., as well as add to the impurities in the rags. This aspect of the question, viz. the composition of the lime most suitable for the purpose of boiling, might well form the subject of an article in itself. It is hardly worth while here to make any further remarks on this aspect of the subject, but it might in a great many cases be a mistake to buy lime close to a mill, even if it could be got cheaper than at a distance, unless its composition is a suitable one for the purpose.

In order that the paper-mill chemist might fully realize the difference in composition and properties of limes for different purposes, he would do well to read that portion of "Thorpe's Dictionary of Applied Chemistry" devoted to this subject. This deals more with lime from the builder and engineer's point of view, but it will readily be seen that a lime suited to one purpose may be useless for another, and a cheap lime bought locally may prove much more expensive in the end than a dearer but suitable lime from a distance.

R says that the general equipment and requirements of a mill would settle the question whether lime or soda should be used. "For instance, a mill working esparto papers with a percentage of fine rags, would, I think, find it more convenient to use caustic." I think we must all agree with this view.

R points out the necessity for draining rags as soon after the "blowing off" as possible, the better to get rid of the dirt. This is an important matter. It is advisable in most cases, in my opinion, to take the material forward and conduct the washing as soon after boiling as possible, and even before the material has been allowed to get cool, if it is practicable to do so.

R refers to the suitability of a revolving boiler for lime treatment. This point is worth noting. I do not think it would be possible to use with advantage any form of keir or stationary boiler such as used to be used in Scottish mills. In order that lime may exert its action there must be not only free circulation of liquor (this alone would not be sufficient), but also agitation and motion of the rags themselves. In fact, a certain amount of friction is necessary in lime boiling, so as to ensure, as far as possible, the detachment of the insoluble lime compounds, so that the free lime in solution can act upon the unsaponified matter still remaining in the rags. A keir or stationary boiler of any kind would be further objectionable in that the mass of rags through which the liquor passes would tend to act as a filtering medium and to filter out the suspended lime.

R's Answer.—"I would only use 'lime' to boil 'jute' or other coarse and low grades of stock which cannot be used for fine *white* paper, and where cleanliness is not of first importance. Cheapness might be said to be its chief recommendation, and it can generally be got of sufficient good quality at no great distance from any mill. Its drawbacks, however, are greater than its recommendations, and, except when causticized with the recovered soda, would not appear suitable for the majority of mills. The equipment of the latter must, of course, necessarily decide to a great extent whether it is practicable to use it or not, as, for instance, a mill working esparto papers, with a percentage of fine rags, would, I think, find it more convenient to use all caustic. It is not suitable at all for boiling esparto. When used, the rotary or spherical boiler (former preferred) should be the style adopted. Lime is very sparingly soluble in water, and in hot less than cold (when cold one part requiring 700, and at boiling-point

1500 parts to dissolve it), and to quicken this process the revolving boiler is of advantage, keeping the rags in motion and bringing the lime in contact with fresh water. As the lime is absorbed by the fatty and soapy matters in the rags fresh portions are dissolved, this process continuing until all such matter is removed. But it is just here that one of the principal drawbacks to the use of lime comes in. To ensure a thorough action on the material being boiled, rather more lime than is actually required must be used, and instead of forming soluble soaps, as in the case of soda, insoluble compounds are formed. This entails extra washing, and therefore extra time, water, and labour, notwithstanding—and portions of the dirt are liable to remain fixed to the stuff. In mills where the supply of water is limited, it will be seen this renders its use prohibitive. In boiling coloured rags soda is preferable, some colours, especially red, resisting the action of lime. The quality of the lime itself must also regulate its use, all lime to a more or less degree being mixed with coal, sand, etc. It should be as free from iron and magnesia as possible. By diluting and straining it into the boiler in the form of milk, most of this dirt can be kept back.

"All things considered, fine stock soda would seem to be preferable, ensuring a cleaner material, admitting the use of the ordinary stationary boilers, and rendering unnecessary the adoption of extra apparatus for straining, etc. I have no data as to the losses in boiling of the respective agents, but the time, pressure, etc., are very similar. If the rags are left for a longer period under the action of lime, the dirt is more firmly fixed and a hardening influence exerted on the cellulose. The draining should take place as soon after 'blowing off' as possible, the better to get rid of the dirt. On coarse, dirty stock, where vigorous treatment is required, and rotary boilers used, which shake up the rags and loosen the dirt, it can be used to advantage, and if the rags happen to have a large percentage of wool it is thoroughly softened. Strong fibres also are better able to withstand the friction caused by the revolving motion, which in the case of finer qualities results in the partial disintegration of the fibres, and a consequent loss, when washing."

S is wrong when he infers that "If you have excess of lime it is harmless, because so little of it is in solution, and even that is soon transformed into insoluble carbonate of lime when exposed to the air, and as such devoid of all action on fibres." If this remark referred to the lime boil it would be all right, but he has evidently in his mind the action after the discharge from the boilers. As it happens, it is not only lime still in solution which remains in contact with the boiled material; there is also the quicklime which was originally in suspension in the liquid remaining in contact with the fibre. Although a portion of the lime, mostly on the exterior, is quickly carbonated when the boiled material is left in a heap, the interior remains caustic for a great length of time—in fact, for weeks—and it may also remain heated. The lime, therefore, has ample opportunity of acting upon the fibres and breaking down and weakening the cellulose under such conditions.

U remarks that "Lime is almost invariably used for treating jute, manilla, hemp, gunny bags, etc., and all classes of stock for the production of dull-coloured papers, brown packing, etc., the fibres being used in some cases without washing, the maximum yield being thus obtained, as none of the insoluble lime compounds are lost."

The question of maximum yield is an important one in connection with lime treatment. In order not to harm the raw material, a small amount of lime would have to be used, so as to leave little or no free lime at end of boil, especially if the material goes without washing, in order to avoid excess of lime and any harm to the fibre. I would not suggest that there would be no harm in allowing the insoluble lime compound to remain and form a part of the paper under these conditions. Of course such treatment would give an inferior product, but good enough for many purposes, and would certainly give a maximum yield. As regards pressure, **U** remarks: "Too high a pressure must not be used with lime liquors, or the insoluble compound formed will often be fixed on the fibres."

I cannot speak from experience in this matter, but with a lime boil high pressure is certainly not necessary. It is quite possible that a high pressure might have the effect which **U** states. I should not think that a high pressure in the case of lime would accelerate the action as it may in the case of soda. On the other hand, there are good grounds for believing that high pressure would absolutely retard the lime boil. He remarks that insoluble lime compound has the effect of giving the material a harsh tone, and states that lime is seldom used for the manufacture of best paper. Such remarks as this are undoubtedly true in some instances, but the question of after-treatment would materially affect his conclusions. We think this remark holds good only so long as insoluble compounds find their way into finished paper, but if removed in the wash the harshness would, I think, disappear.

V appears to be the only one who realizes that, in order to get the greatest benefit from jute, an imperfect treatment, as he calls it, is required, and points out that the filaments are wanted, rather than the ultimate fibres. He also touches on the question of using soda instead of lime in a mill when soda is used for other purposes and recovered. He remarks, finally, that "lime is particularly applicable for boiling such stuff as jute and low grades of flax waste, because the action cannot get too drastic owing to the slight solubility of lime in water; on the other hand, the lime takes more washing out afterwards."

CHAPTER V.

CONTROLLING THE MARK OF THE "DANDY."

The management of the "dandy"—Heating of stuff—"Drag"—Lowering of brackets—Effects of beating—Cleaning "dandy"—Appearance of sheet—Hints for management—Controlling of watermark.

QUESTION 21.—*How can you control the mark of a "dandy"? Make some general remarks on the management of the "dandy."*

B.—Among other means of control, **B** mentions the heating of wet stuff. This, of course, is one way of controlling the mark, but one which should not be resorted to more than is absolutely necessary for the control of watermark alone, because it has a too general effect on the behaviour of the stuff on the wet end of the machine. If it is desirable for other reasons to heat the stuff, and if by so doing the mark of the dandy can be rectified, it should, of course, be resorted to, but not in cases where it is calculated to do harm in other directions. The author does not suggest that **B** is not justified in mentioning "heating" as a means of control, but in order to put such a means in its right place, he would have done well, however, to have qualified his statements by such an observation as "heating should not be resorted to unless no other ready means can be found, and, if possible, only in cases of emergency."

Then, as regards his statement, the revolution of the dandy roll as being practically dependent upon the travelling of the wire, is perhaps rather misleading, because, although the dandy roll is driven either by the wire, or by the stuff on the wire with which it comes in contact, it does not necessarily travel exactly at the same speed. It is due to this fact that the dandy can be made to "drag," so that the water-mark can be, in a large measure, controlled. But possibly **B** fully realizes this fact from the remarks he makes later on in his paper.

"When extra moisture is needed before the proper mark can be obtained, this can be instantly effected by opening the air-valve connected with the box, thus checking the action of the pump and allowing more water to go forward." This is very well expressed.

The author does not think that the use of a skeleton roll in the place of a tube roll directly beneath the dandy roll will materially accelerate the removal of water. The fact that the escaping water has to run over the surface of the tube roll does not necessarily lead us to infer that the water is impeded. The tube roll only touches along a line. It is not as though the wire lapped to any extent round its surface; if it did, it might be found advantageous to have a skeleton roll to get the water away more quickly.

B's Answer.—"By the lowering or raising the roll by means of the dandy brackets.

"By the lowering or raising the dandy cloth on to the roll.

"By the regulation of the vacuum in the first suction-box.

"By the use of one or two tube rolls, or a brush, beneath the wire underneath the dandy.

"By heating wet stuff.

"By lowering the breast roll.

"These are the principal means of controlling the 'mark' of the dandy. I will consider them more fully.

"The revolution of the dandy roll is practically dependent on the travel of the wire. As a first consideration, then, it must be hung in the brackets low enough to press on the paper and to feel the momentum of the wire. Obviously, this does not leave room for an extensive adjustment by raising or lowering the roll, but there is still sufficient scope for the manipulation of the bracket screws when using a heavy and a light roll.

"Generally raising the roll is only resorted to when making name papers, where the size of the dandy and the expansion of the paper does not allow of sufficient cutting margin. This raising or hanging reduces the speed of revolution.

"The cloth also plays an important part in checking the speed of the dandy when making name papers. This is done by lowering it. In its ordinary capacity it plays the part of what might be termed a 'dandy doctor.'

"The regulation of the vacuum in the first suction-box is a most potent factor, and affords a ready means of altering the mark. With most classes of paper the spread can be obtained dry enough, by the action of the pump, to receive an impression which will not be spoiled or blurred by the couch and press-rolls, but often extra water is needed before the proper mark can be obtained, and this can be instantly effected by opening the air-valve connected with the box, thus checking the action of the pump, and allowing more water to go forward.

"The use of the tube-roll or rolls is to keep the wire cloth from giving against the pressure of the dandy, especially with hard and hydrated stuff, when a clear mark is needed.

"There does not appear to be any reason why a wire-covered skeleton roll should not be used instead of a tube, so as to allow the water to percolate through the mesh instead of being carried over the surface, as in the case of the tube-roll. The underneath wash of water is of no use after the mark has been made.

"With very 'wet' stuff the dehydration by heating in order to make an impression is an obvious method, and in cases where the vacuum at the first suction-box is not sufficient, the breast roll can be lowered (a rather unlikely occurrence), or the speed of the machine can be lessened.

"Much that can be said about the management of a dandy is contained in CLAPPERTON'S PRACTICAL PAPERMAKING, which it is unnecessary to repeat.

"Although both a fine wove and a large laid mesh will 'lift,' the former is the more likely to cause trouble in this direction, as resinous fibre particles more quickly fill up the mesh.

"One of the chief troubles experienced with dandy rolls is the gumming of the mesh. The only remedy is to take the roll out and rub it with kerosene, to dissolve the adhesive matter, and then turn on the hose pipe to wash out the fibrous material, or to apply a strong steam jet, which answers both those purposes, by first inserting and then blowing the particles out."

D remarks "that if too much water is under the dandy, the dandy puddles in the stuff, and the result is bad."

This is often noticed when too much water is going forward.

"If there is not enough water under the dandy to alter it, the first pump may be closed a little, more shape put on, or a little more water put in with the stuff at the sand traps, or some of the tube rolls may be lowered."

E remarks: "Stuff must be properly beaten to suit the weight of paper to be made." This remark is too general, and is of no practical value, because it does not disclose in what way the stuff should be beaten to produce any given result. "The impression will show up much better when the stuff is fine than when it is soft." It is possible, I think, for the stuff to be short, and to be fine at the same time. Possibly he intended to have used the word "long" instead of "soft"; then his remarks would have had some meaning.

F deals with his answer in quite a different manner to the others, a part of which is given below. He gives an instance of how he would prepare the stuff, and what he would do in the management of the machine for producing a good watermark paper. He appears to have a good practical grasp of the subject.

"The dandy roll derives its name because it looks very nice when it is new; it is a very smart-looking thing. It is said that when the maker of a water-marked roll first brought it into Mr. Joynson's mill, the foreman, looking at it, said, 'Well, that is a *dandy* roll,' or a smart-looking roll, and the maker caught up the idea and said, 'I will call this a dandy roll.'

"I can control the mark of the dandy first by beating. I must have a nice sharp plate and a beater not filled too thick to make it work wet. I must beat it fast and fine, and have a nice shake to keep it close. I must have the first suction-box only just open, so as not to make the pulp hard. Then, when it comes under the dandy, the pulp will receive a nice impression. I then pull all the water out by the next suction-box, couching it fairly hard, and not pressing it too hard at press rolls. I should then have what I require: a nice-looking watermarked paper.

"If I want a duller-looking paper, when the sheet is not required to be so clear, but stronger-looking, I proceed with a thicker-filled beater and a plate not so sharp in the beater, and give a longer time for beating, keeping the stuff longer. I should have less shake upon the machine and pull harder at the first suction-box, so that the pulp is harder when the dandy runs upon it, in that way so controlling the dandy that the watermark will not be so plain.

"Again, I can work more water on the machine if the pulp is dry working. This will give me some control over the dandy and make a plainer watermark; or if it was working with too much water, I could reduce it a little with beneficial results in the marking."

I gives some practical hints. He mentions the use of a twilled cotton thread wound round the end of the dandy, so as to decrease its speed in comparison with that of the wire, for the purpose of enlarging the watermark on the surface of the paper.

Then he speaks of the method of raising the roll, so as to cause it to drag a bit, and furthermore makes mention of the use of a large-diameter dandy, especially for wet stuff, on account of the small dandy filling up, owing to the action of the bubbles and stuff. He mentions that machinemen generally prefer a large dandy for this reason. Some of his remarks are given below, as they are thoroughly practical, and deserve to be read through.

"Another method for enlarging the watermark is to have the dandy touching the stuff as little as possible, but enough to make it leave a decent impression without streaking the web of paper. If it is a laid dandy, the usual felt used will help to retard its motion.

"If a very distinct mark is wanted the dandy can be pressed down hard by the adjusting screws, or, if only slightly marked, heightened till the proper impression is attained.

"A laid gives some trouble, on account of the bubbles it forms on the stuff. To get rid of these a fine jet of steam is applied in front of the dandy. Sometimes water is used for the same purpose.

"A figured dandy is very liable to pick up some of the stuff as it revolves. A piece of felt is allowed to rub on to it, as this loosens any stuff, so as to prevent the formation of holes in the soft web.

"When a dandy gets filled up with bubbles, etc., it does not make a good sheet of paper. It should be taken off and washed.

"For any given substance (a Demy) a laid dandy requires more water in the stuff than a wove. .

The condition of the beaten stuff has a great deal to do with the clearness of the watermark."

M gives practical remarks, showing how the marks can be produced so as to "cut to register." Very few have referred to this.

"When sheets are cut to register, dandy mark must fall at exactly the right distance according to size of sheet. Dandies are always made too small in circumference to allow for stretch of the paper when under tension between sections throughout the machine. If the distance between the marks is still too short for register, the speed of the wire is slackened back and second press driven up; if this is not sufficient, tape is wound round the dandy beyond the edge of the web. This increases the circumference of that part in contact with the wire, and therefore increases the distance between marks on the sheet. Rubber bands are sometimes used, as they are said not to ridge the wire so much as tape. Another method is to drag the roll slightly, either by letting the cloth down a little for removal of froth, giving more rubbing surface, or by hanging a strap over the spindle of the dandy with a weight attached to one end ; the strap, rubbing on the spindle, drags the dandy.

"The latter method is seldom used except when a great stretch is necessary.

"Dandies should always be thoroughly washed with water before and after use, and should occasionally be "blown" with injector to keep the meshes open.

"Wove dandies, after running on the machine for a while, become gradually filled with froth, and require a wash through."

N.—A portion of **N**'s answer I give below, because it deals with practical points which have been omitted by others. The question of the composition of the stuff affecting the shrinkage of the watermark, and so on, has of course a great deal to do with this subject.

"When a dandy is taken off it should be thoroughly cleaned at once. Long stuff stretches easily. A fine engine will draw the sheet. Place a lined dandy perfectly parallel. Dandies for loft-dried papers should have more space allowed between the names to make up for shrinkage. Grass papers do not require so much allowance as rag papers, as grass shrinks less."

To **R** I have awarded full marks for his answer, and this is the only paper throughout the series to which full marks have been awarded. His paper is printed in full. I consider it is a very good answer indeed, not only on account of the way it is composed, but also as showing a thoroughly intellectual and practical grasp of the subject. It deserves to be carefully read.

"The mark of a 'dandy' can be controlled by the proper adjustment of the brackets to suit the *peculiarity* of the stuff being worked, the *substance* of the paper being made, and the speed at which the machine is being driven. If the stuff is let down 'soft' and does not part with the water freely, a quick drive cannot be got, and the 'dandy' will not require to be 'full down.' In running a thicker substance than usual, the 'dandy' will have to be as far down as possible, in order to give a good impression ; this refers to named 'dandies.' In making thin papers, again, if driven too quickly the roll is liable to '*pick*,' and the speed must be slackened to overcome this. When working a wove 'dandy,' if the stuff happens to be soft and fine, the sheet will in all likelihood have a crushed appearance. In this case it should be kept as dry as possible 'before' the 'dandy,' and care taken not to drive too fast, to prevent the roll throwing the stuff forward. The weight of the 'dandy,' also, has considerable effect on the question, and when it is heavier than usual should be 'hung' as much as possible, and more water brought forward. This can be accomplished after shutting the first suction-box. A 'tray' passed through the 'dandy' will intercept the water, from whence it will gravitate to the edge.

"Great care should be exercised, and the distance between the names frequently measured to see that the sheets when cut will register properly. There is an allowance made, varying with different qualities of papers and the machines on which they are produced, to compensate for shrinkage or extension during drying. Should the distance turn out short, the 'draws' will have to be tightened by adjusting the packing on the pulleys or altering the cones if 'upright' drive is used, and *vice versâ* if it is liable to cut larger. But sometimes a sheet may be wanted to cut larger than the 'dandy' was intended for, and care in this case will have to be exercised in seeing that the stuff is properly prepared in the beaters and not made too fine, but left sufficiently long to enable the web being drawn out to the requisite size. The 'dandy,' also, can be hung as much as possible, in order to make it travel slower than the wire. It will not, however, do to stretch too much, as there is a danger of sacrificing the strength.

"When making watermarked papers, we have an instance of the inadvisability of working steam in the stuff, as 'frothing' and belling are almost sure to result, and more so if all the bleaching solution has not come under the decomposing action of the antichlor. To overcome this, a perforated pipe should be passed through the 'dandy' and steam let into it, passing out in a tangential direction to pass clear of the stuff. Instead of a pipe, some 'dandies' have the journals bored for this purpose. When running *laid* 'dandies,' 'bells' and 'worms' are apt to be formed, and when broken many bad sheets are thereby produced. In this case, if the machine is not too broad, the roll should be *hung* a little. On broad machines, however, when this is done the 'dandy' is liable to 'sag' in the middle, and the better plan is, I think, to wrap a strip of flannel round the edges clear of the web. This will ensure its running level. When making *laid* papers caution should be observed in running the *proper deckel*, as a sheet which is wanted cut *quarto* must be run in the opposite direction to one wanted octavo. Care should also be exercised in seeing that the roll runs exactly parallel, so that the laid lines shall fall exactly in position over each other. Equality of pressure at the press rolls should be given to ensure the web being evenly dried to prevent undue contraction.

"With named 'dandies' I think the letters should always, when possible, be sewn on instead of soldered, as the latter practice is often the cause of *rust* spots."

S remarks "that in working a name-dandy, the drier you can work the stuff the better the name will appear on the paper." This statement conflicts with a statement made in one of the other answers. There is a happy medium. It is possible to get the stuff *too* dry. On the other hand, as we all know, when the stuff is too wet the mark becomes obliterated. **S** realizes that when the stuff is too dry it will pick up on the dandy. "When the dandy is working, a jet of steam flowing on helps to keep it clean."

U gives an instance above referred to, and says that "if, however, the web is dry, the impression is not good. Fine stuff receives a better impression than long stuff, but this is on account of the dandy having a tendency to displace the fine fibres, making the web thinner at these points, while the long fibres instead of being displaced are pushed up, making the mark less distinct.

"Fine machine dandies, wove in particular, cannot be run on fast-running machines (above 300 ft.), on account of the dandy licking up the stuff; in these cases a wire with more than 40 meshes to the inch cannot be used.

"A heavy dandy forms a better impression than a light one. If a dandy is too heavy it tends to pick up the stuff."

V remarks: "The mark can also be altered by stretching the paper. This can be done by driving the first and second presses slightly faster than the wire."

It is interesting in this connection to read the communications sent to the Paper Trade Review. They reveal the fact that in many cases, instead of there being a shrinkage on the paper in its length, there is an elongation, which, of course, will largely depend upon the difference between the speed of the wire and that of the first and second press rolls. "When the dandy shows a tendency to lift the pulp, steam blown in jets from a pipe running parallel with it and through it, just before the surface of the roll touches the surface of the pulp, will often prevent the lifting."

CHAPTER VI.

"MACHINE" AND "HAND" CUT RAGS

Comparative merits and costs.

Question 22.—*What are the comparative merits of "machine" and "hand" cut rags from all points of view?*

B's answer is very fair indeed. He goes into it with his characteristic thoroughness, giving figures in regard to the cost of the two methods. It is important to note the difference in the character of the dust from rags which have been machine cut, as compared with those which have been hand cut. There is a greater waste of fibre in the dust of machine-cut rags. There are many small chips in the machinc-cut rags which pass through the meshes of the revolving drum of the duster.

B speaks of the buttons which are not removed during the process of machinc cutting. This is not such a scrious matter as might at first be supposed, as the perforated plate in the front of the breaker roll catches most of them, and those which are not caught in the breaker or beater are mostly removed by subsidence in the sand traps.

The difficulty of emptying machine-cut rags from revolving boilers is very much against machine cutting. The boiler is often revolved for hours before the rags are finally discharged. This is due to the stringy nature of the rags, which causes them to mat together. Undoubtedly there is less distinction when using spherical boilers, especially when the manholes are of a fair size.

There are many difficulties with machines for cutting rags, and one of the greatest arises from the blunting of the knives. Some of the machines made about twenty years ago were provided with zigzag knives. When the knives got blunted or worn on the face the rags got jammed in between the two knives, giving the lumps of cut rags the appearance of being glued together. In consequence of the enormous pressure to which the rags were subjected between the two knives, the cell walls of the fibres were literally crushed. This action, in addition to destroying the fibrous character of the rags, occasions unnecessary expenditure of power. The same is sometimes true of other rag cutters. Muslins are very difficult to cut by machine, as they have a tendency to crumble up, and when unfolded are found to be cut into very irregular pieces ; it is, therefore, advisable to cut them by hand if possible, although even hand-cut muslins are not entirely free from the above-mentioned defect, hence the difficulty above referred to.

It is right to state that it is necessary to cut rope by an ordinary fly knife cutter. It is interesting to note what he says in regard to the expenditure of power in cutting one ton of rope, as compared with that required for cutting ordinary rags.

B states that when cutting by hand the cutters can feel if there is anything in the seams, thus buttons, rubber, and all foreign matter can be cut out. The rags get a better supervision and sorting by hand cutting, and there is consequently less waste of fibre.

Machine cutting is resorted to for lower qualities of rags. In order to get the whole of the dirt out of the rags it is absolutely necessary to rip up or tear open the seams.

" The latter, *i.e.* hand-cut rags, are much more costly to produce, but are comparatively free from rubber, buttons, dust, etc. They are also more regularly cut.

" I will deal in detail with the chief differences on which their respective merits depend.

" *Cost.*—In a specific case dealing with all grades of rag (rope excepted), if cut by machinery, ten sorters will be sufficient for a total output to the boilers of four tons per day of twelve hours. The cost of sorting and cutting in suitable lengths for the cutter will be 80 cwts. at 5*d.* = £1 13*s.*

" An 8 to 10 h.p. engine will drive a cutter, four dusters, and travelling belts. If hand cutting, the same number of sorters will get through 25 cwts. The cost will be at the rate of 1*s.* per cwt. 80 cwts. at 1*s.* = £4.

" The saving in steam power is small, as the machine has to be kept running to work the dusters and 'devillers,' etc.

" The cost of hand-cut rags is therefore nearly three times as much as that of machine-cut rags.

" In the old days when hand cutting was universal, a larger staff was necessary to keep up the output.

"*Cleanliness.*—The question of cleanliness is one of the two important advantages of hand-cut rags. The sorters can give more attention than when they are simply picking and cutting for the machine, consequently seams are opened and more dirt and rubber (the great enemy of rag papers), buttons, hooks, etc., are removed. Buttons are often overlooked in sorting for the cutter, and go forward, getting smashed by the knives and rolls, and thus into the finished sheet. I have sometimes found rag paper containing small pieces of metal of the button composition. With all the seams opened the dirt naturally falls out in the passage through the duster. It is interesting to note in passing, that the total dust mechanically removed from all rags (rope excluded) is approximately 3 per cent.'

"*Regularity in Cutting.*—This has a bearing on the future treatment and *strength* of the rag.

"The best and most practicable size is acknowledged to be about four inches square. The sorters could not rapidly and without danger to themselves cut smaller pieces. Large pieces sometimes get matted and stringy, retain more dirt, are more difficult to wash and remove from the boiler, and involve more power at the breaker; and unless the boiled rags are fairly uniform as regards the size and flatness of the pieces they are not 'broken' and bleached to a uniform strength or length. This is where hand cutting is decidedly the better method.

"The cutter can be set to cut four strips, but in a combined slitter and cutter, the knives will often tear the rag in strings, this especially is the case with soft rags and hard canvas when the knives are slightly worn.

"Muslins and threads are cut by hand, and even then they will roll in small bundles in a rotary boiler.

"Rope can be cut with an ordinary fly knife cutter, but not with a slitter. It is then often cut by hatchet into 12 to 18 in. pieces and then 'devilled.' The power required, by the way, to 'devil' one ton of rope is sufficient to cut four or five tons of ordinary rags.

"The sorters, where the rags are of larger size, cut them into 12 to 18 in. pieces for the cutting machine.

"Many rags—those bought as trimmings, as shoe cuttings, and new cuttings, often need no cutting at all.

"Finally, a papermaker's ends are best served by hand cutting where a very high-class paper is required, when he can afford to take the maximum amount of trouble and expense to produce the cleanest and strongest half stuff, and therefore, in my opinion, the only merit machine-cut rags possess, by comparison, is their less costly production."

E states "that cutting by machinery has not been a great success. The knives usually get blunted very quickly and then cut the rags very unevenly. If they are unevenly cut there is a great waste." His conclusion is that it is more economical to have the whole process done by hand, except the dusting.

Most of **F**'s answer contains useful information. In one place he states: "I have known mills where the machine has been tried for some time and afterwards abandoned, for they found that where the paper was a high-class one it was the most difficult job to get the paper clean enough when cutting by machine." In comparing the cost of machine and hand cutting, he says: "The cost of cutting can be safely said to be more than double." Then, in favour of machine cutting, he makes the following remarks: "Where the price of paper is low, and the employer would perhaps have to pay another £100 in labour for cutting, he finds it a greater saving to have his machine and the paper dirtier. In reckoning the cost of machine cutting he has to set off the first cost of the machine, royalty, and the cost of power for driving and a small extra loss for fibre."

One fails to find among the answers any mention of a compromise between the two systems. It is possible to resort to far more thorough hand-sorting, and then finally to machine-cut the rags. The waste in cutting new materials such as shirt pieces by machine is very great indeed. In such cases it is very considerable even in hand-cutting, in consequence of the small chips which fall through the meshes of the duster.

In speaking of machine-cut rags, **I** mentions a point which the majority have lost sight of. "When the latter kind (machine-cut rags) are added to the breaker in which they are to be washed, they have a great tendency to get in between the sides of the roll; in time they get twisted round the shaft, and become so tight that the roll is unable to revolve, and the driving belt slips off."

M mentions that with machine cuttings there is a greater tearing action and consequent loss of fibre. The author thinks that as much harm is done with those machines which have a chipping action as above referred to.

N remarks: "For low-quality rags, such as canvases and gunney, the machine is all right." Certainly for such material there is no necessity to resort to hand-cutting at all.

There is a good deal in **R**'s remark that "machine-cut rags give more difficulty in the boiling process." In consequence of their containing a large proportion of small pieces, they lie together, and thus obstruct the free passage of the liquor. This difficulty, already referred to, has as much to do with the stringy nature of the rags, and to their getting entangled from the constant revolution of the boiler.

"In comparing the merits of 'machine' and 'hand' cut rags, much depends on their quality, the kind of paper to be manufactured, and the 'grading.' Some mills separate them into quite a number of grades, while others, in which other materials than rags are used, content themselves with separating cottons, linens, and coloured rags only. Cutting by hand would seem to be preferable, the quality of the work being of a more thorough description, and it is a question for each mill to decide if the price of the rags and labour favours hand cutting or not. There is no questioning the fact that cutting by hand has the most advantages. Even rags sorted by the dealer contain extraneous material such as buttons, buckles, seams, etc., and these will be more readily detected by hand. There is less loss of fibre also, as the women can always tear them in the direction of the 'woof,' and then cut them into regular-sized pieces on the knives. Machine-cut rags are cut in both directions and into various sizes, sometimes in strings. When cutting by hand, the weak pieces can be left as long as possible and the stronger ones cut smaller. I have seen quite a lot of rubber, elastic, etc., taken from rags bought as sorted, and it can readily be understood that if such material was allowed to pass it would cause a vast amount of trouble. The knives of the machine cut it up into small pieces and mix it up with the fibres, and it is no uncommon thing for 'stamps' at the glazing calenders to be traced back to this cause. Sewn into other pieces, etc., it is only by careful hand cutting and sorting that such matter can be detected. Machine-cut rags also give more difficulty in the boiling process, as, containing a large percentage of small pieces, they lie closer together and thus obstruct the free passage of the liquor. The 'stringiness,' also before-mentioned causes some trouble when emptying the boiler. The *kind* of cutter adopted also affects the question, some cutters '*tearing*' the rags more than others, owing to the knife arrangement. Those with the knives fixed in an angular direction, cutting after the style of a pair of 'shears,' will give a cleaner-cut rag than the ordinary revolving cutter. The more *torn* the rags are in cutting the greater will be the loss, as when subsequently dusted the fibres are liable to be detached and lost. Care should be exercised in regularly feeding into and controlling the machine. The slower they are fed in the more often they will come in contact with the knife and the shorter they will be cut, thus entailing more loss and trouble. For such strong material as bagging, canvas, and ropes, the cutter can be used to advantage."

S states, that by hand-cutting, the seams, which contain a lot of dirt and grit, can be cut up ; and the lower classes of rags, such as hemp, flax waste, manilla ropes, etc., may be cut by machine.

U states : "In rags or linen cutting intended for high-class papers, coloured threads, silk, etc., used in the button-holes and seams have to be cut out, or the fibre would be weakened unduly by the strong bleach solution subsequently used to discharge the well-fixed colour."

The presence of silk is always an objection ; even if not coloured it shows up after treatment with alkali, and is likely to show in the finished paper. **U** ends up by stating that machine-cut rags are used in common papers, and machine cutting is resorted to when rags are dear.

V states that machine-cut rags cannot be so well sorted, even if the rags are overhauled while passing over the travelling felt to the duster.

CHAPTER VII.

FROTH ON PAPER MACHINE.

Effects of size—Colour—Loading—Agitation—Pumping—Modes of prevention —Defective plant—General explanation.

QUESTION 23.—*What do you consider to be the cause of froth or scum on the machine? Of what does it consist? And how can it be prevented?*

On this question there exists less difference of opinion than on any of the questions set by the author in 1902 : there is consequently a greater similarity of the answers received and less conflicting statements. From each of the answers we shall therefore select here and there statements by way of illustration.

A attributes the presence of scum to the carbonic acid escaping from the liquid, and states that it can be prevented to a large extent by the use of some alum. We hope afterwards to make it plain that this cannot be taken as correct in all instances, as often even a large excess of alum will not prevent frothing. A good froth-killer can be made by mixing together linseed oil, bleach, and a little turpentine.

B states that with white rosin size the froth is of more trouble than with brown rosin size, and attributes this to the exceedingly fine distribution of the rosin. He states that the precipitate from brown size is much coarser, and for this reason froths less.

Although his statements may be true in some cases, the same cannot be said of his conclusions. The amount of froth would chiefly depend upon the relative amounts of free alkali still remaining. If the white size contained a large amount of free alkali, as it may do, in the form of carbonate of soda, the tendency would be to produce froth by the decomposition of the carbonate of soda by the alum setting free carbonic acid gas. The brown size may be prepared in such a way as to contain only a trace of free carbonate of soda, and in consequence very little carbonic acid would be set free on the addition of alum. It might happen, on the other hand—and this is more likely—that the white size contained little alkali and the brown size a considerable excess, in which case the reverse would be the case as regards the froth, and this is perhaps the general experience.

It is pointed out by **B** that in the beating, the froth will be more troublesome when the beaters are lightly loaded than if heavily loaded. Several students refer to this. It is a question of agitation, or a difference between the agitation of heavily loaded and light loaded beaters, to which reference is made later. **B** gives a recipe for preventing froth—$1\frac{1}{2}$ gallons of linseed oil mixed with 1 gallon of bleaching solution, and points out that it should never be used when the froth and scum are allowed to accumulate, as it will cause it to come away in large quantities. If this is to be used at all it should be used from the beginning, and before any deposit or accumulation has taken place.

C points out that a special froth oil is now sold for the purpose of preventing the formation of the scum. Some dyes cause a good deal of froth, and he notices this particularly with orange, but does not state what orange this is : presumably it is coal-tar colour.

D states that the froth caught at the machine, in the first place is made in the beaters. This is not, by any means, always the case ; the froth is largely the result of the decomposition and the result of the gradual evolution of the carbonic acid gas from the water, which begins to take place, perhaps, in the beater, but continues in the chest, and subsequently at places where agitation is going on.

D made an examination of some of the froth caught on the breast strainer, and found that it contained some very fine fibres of esparto. These were probably the fine leaf hairs, which easily find their way through the machine wire. He also found that when the scum was dried down it gave a 40 per cent. residue of clay. Undoubtedly the composition of scum varies enormously in different mills, and would depend chiefly upon the composition of the ingredients used in the manufacture of paper, but also upon the conditions under which the paper was manufactured. When stuff is dyed to a deep colour there will be found some colouring matter in the froth ; when ultramarine is used the froth will contain a considerable amount of this substance. Many aniline dyes colour the froth, but many of them not to the same extent as ultramarine.

E attributes the cause of froth on the machine, to overloading or sizing, and states that the froth consists principally of size. Undoubtedly the causes he mentions are often true ones, but there are several reasons for the formation of froth, and these are not always those met with in practice ; nor does the froth by any means always consist principally of size, especially when the cause is overloading, in which case there would be a tendency for the froth to consist largely of mineral matter. He also points out that too much froth oil is detrimental to the stuff, and for this reason many manufacturers object to its use. Altogether, its use requires a good deal of discretion.

F considers that froth is due to the heating of the stuff and the working of the strainers. Heating does promote or accentuate the froth, as when stuff charged with carbonic acid gas is heated, the tendency is for the gas to be driven off and to bring about the formation of froth. Heat has a further tendency, for it tends to make wet stuff work free, and free stuff is known to be more productive of froth than wet stuff.

H explains the chemical action which takes places when alum is allowed to act on water containing lime salts. This has already been explained in communications to PAPER AND PULP, and also in one of the author's lectures delivered at the Battersea Institute, which is briefly this, that when bicarbonate of lime is dissolved in water, as it is in most hard waters, the alum acts upon it to form sulphate of lime (which remains in solution), and hydrate of alumina (which produces flocculent precipitate), and the carbonic acid gas is liberated, but this being soluble in water is to some extent not set free until heat or agitation brings about its liberation. **H** refers to the undecomposed bleach solution as having the same effect. It is well known that if any bleaching solution is left in the beater it has a tendency to froth. With many materials that require a lot of bleaching, when the solution is washed or agitated, and the bleaching has for the most part taken place, it will be noticed that there is an immense amount of frothing. This is in a large measure due to the organic by-products formed by the action of the bleaching on the non-cellulose or incrusting matter which enters into the solution. The mere neutralizing of this with an antichlor would only in part remove frothing tendency, as an antichlor only reduces the chlorine, leaving the various chemical substances still in solution as well as the soluble organic products. It is important, therefore, that the material in question should be for the most part washed free from all bleaching liquor. If then a trace of chlorine remains, it can easily be "neutralized," and the frothing from this cause reduced to a minimum. **H** points out that when animal size is used the frothing is more troublesome than when only rosin is used. This is of little consequence in general practice, because there are not many mills where animal size is used in the beater, except, perhaps, when precipitated with tannic acid, and then no frothing should result. **H** considers that scum consists of fine particles of fibre, loading, and flocculent particles of rosin; but when tinted papers are being made, the scum is coloured by the dye-stuff used. He points out that the stuff should be led forward to the wire with as little agitation and rush as possible.

I considers that scum consists of minute air-bubbles surrounded by a thin covering of the materials themselves. He also points out that there is a great difference in the appearance of scum from different sources—for instance, with heavily loaded stuff, the scum will have the appearance of soapsuds, and this gradually sinks and becomes heavy like mud on the top of the flow on the wire. On hard-sized paper free from much loading the froth will rise up and be of a lighter nature, and not become so sagged and heavy as in the heavily loaded papers. The fact is, that scum containing a large amount of mineral matter floats for a time, but as it accumulates some of the bubbles are dispersed, and there comes a time when the scum is too heavily loaded with mineral matter for the amount of air it contains to keep it afloat, and it sinks *en masse*. When it comes away in this form it is liable to do considerable damage. Mention is made of the use of spray diffusers placed just in front of the slices for the dispersal of the froth. Further reference will be made to this later.

J points out that froth is more frequently met with in soft-size papers, but generally comes away at the slices, and to prevent this they can be lowered a little. He recommends that alum should be used when furnishing. When froth bells get broken by the "dandy," particles of dirt form on the surface of the sheet.

K considers that heating will often cause froth, especially when a quantity of soap is present, and back-water causes a lot of froth, as also does hard water. We gather from his remarks that he considers the froth is much worse when the back-water is used over and over again as far as possible. Hard water causes froth from reasons already mentioned. "The use of a size prepared with an excessive proportion of alkali also causes froth." This has already been referred to. Froth or scum at the paper machine consists largely of clay, rosin, and starch. The use of a fine spray of water across the breast of the machine is very effective in preventing froth travelling forward and damaging the paper.

L states that froth can almost entirely be overcome by abandoning the use of rosin size. This, however, is out of the question ; as a froth preventer the use of linseed or sweet oil with a little bleach and some turpentine is recommended.

O divides his paper into various headings. He endeavours to give a list of those conditions which will bring about the formation of froth. He attributes it to the presence of carbonic acid and air in the water, to the stuff and minerals used in loading, and the alkali left in materials from imperfectly washed stuff. These would produce froth if the alkali left in the stuff had become carbonated, but there should be no alkali left in the stuff by the time it reaches the beater. In badly boiled and badly washed stuff there may be a tendency to froth due to resinous and soapy bodies not removed. Then there is no mention of any alum in the beaters. Of course if the alum is insufficient to precipitate the rosin, leaving some in the form of rosin soap, there would be a decided tendency to froth. We all know that a small amount of soap dissolved in soft water will produce a permanent lather on agitation ; the same thing may happen with the stuff as it passes on to the machine, and especially where curd soap is used in conjunction with the size if insufficient alum is added. When too much size is used in the beaters there is a tendency to froth. The size should be kept down as low as possible, consistent with the requirements of the paper.

Then we have the question of imperfect beating, such as when free stuff is produced, as the result of hurrying through the process of beating, causing the stuff to work spongy.

Then we have the suction pipes of the back-water pumps producing froth if insufficiently covered with water, as under these conditions they are drawing air. In order to avoid froth the suction should not draw in air, but should be just sufficient to remove the water.

O recommends that rosin size should be allowed to stand a few days before using, as when fresh size is used there is a greater tendency to froth.

Froth is sometimes due to insufficient water worked on the machine. This is especially noticeable when making thick papers, when as little water is being worked as possible ; also when stuff is wet, as less water can be worked than when free, in which case heating the stuff is often beneficial, as it makes it work free and allows more water to be used. These statements of **P**'s rather conflict with previous ones as regards the question of heating, but nevertheless the answer is correct as far as it goes. Whatever will enable more water to be used to prevent the suction-boxes drawing air would tend to reduce the froth, and to this extent heating the stuff may be beneficial, but, nevertheless, it has the inverse effect, namely, of making the stuff work free and producing froth. In any case, where there is no difficulty either one way or the other in keeping the suction-boxes sufficiently covered, the greater the heating of the stuff the more the tendency to froth; but where heating is resorted to for the purpose of keeping the suction-boxes covered, then it may be of some benefit; but this is one of those questions which it is difficult to explain, and in which common sense and practice are of greater value than any amount of explanation.

Q.—Froth depends upon the construction and arrangement of the pumps and pipes for the machine back-water, and is largely dependent upon whether the open back-water has any open run in its fall or not. It is suggested that one of the greatest causes of froth is the utilization of the machine back-water for emptying the beaters after it has been separated from the clay and fibre by passing through Fullner, or such apparatus. It certainly is economical, but it is likely to add to the production of froth. **Q** finds that even after every precaution is taken to minimize the froth as far as possible, it is still often necessary to add some oil prepared as an antifroth to disperse the bubbles.

S suggests the disadvantage of using a size freshly prepared, and considers that it is dangerous to use a too strong solution of bleach. In order to prevent froth, it is suggested that the mixing boxes should be 2 ft. below the level of the sand tables, and to have the pulp come in at the bottom so that the whole will rise quietly.

V finds that froth or scum is often caused by too great a rush of solution from the mixing boxes along the sand traps to strainers. Froth or scum consists of finely divided fibre, resinate of alumina, clay, mineral colouring matter, carbonic acid gas, and air. He recommends, among other things, a thorough washing of all the stuffs used in the breakers, a careful neutralizing of the stuff of the bleach after bleaching, and the use of a good antifroth oil.

Y states that the amount of froth depends greatly on the nature of the stuff on the machine, but has noticed that when working "free" stuff the accumulation of froth is always greater. When more water is required on the machine, the agitation is largely increased, and consequently the amount of froth; he considers that paraffin oil is about the best preventive, but is inclined to make the sheet greasy and sticky at the press rolls.

A2 refers, among other things, to the froth being produced by imperfectly boiled or bleached stuff. He furthermore refers to froth as consisting of small particles and fibres, such as mechanical wood. In order to prevent froth, he recommends the treatment of rags with weak acid solution before washing commences.

D2 remarks that when making soft size papers the froth is usually much more troublesome than when alum has been added to the stuff, and, furthermore, that papers heavily loaded usually froth badly at the machine. A little turpentine is a very good thing.

F2 remarks that if it were possible to bring the stuff on to the machine without any agitation whatever, we should have no froth. Of course this is out of the question. He refers to furnishing the engines thin, resulting in the stuff being lashed about the beater; this is specially the case with more modern fast circulating beaters. We do not follow his meaning here, by the "more modern beaters"; presumably he means beaters like the Taylor, Reed, Acme, Hemmer, etc. The great feature about these beaters, which have an independent means of circulation, is that there is practically no energy wasted in lashing the stuff about, and consequently they should cause very much less scum than hollanders. We cannot speak from experience on this point, but we should judge that the hollanders are the greatest offenders in this respect.

F2 speaks of defective hog boxes and the steam being blown into the stuff to clear knots, resulting in the formation of scum; he suggests that revolving strainers should be placed end-on to the machine, and that the hog boxes should be constructed so as to effect an even distribution of the stuff with the minimum of agitation. The ochres, umbers, clay, etc., form a good deal of froth by reason of their soapy nature.

General Remarks.

There are one or two things omitted in the foregoing remarks which would be worth while referring to. There are certain substances existing in resinous bodies which are not affected by alum; these substances remain soluble in water. It is highly probable that ordinary rosin contains such substances as are found in saponaria or soap-wort. The author had occasion to investigate the aqueous extract from the soap-wort some years ago; it gives an extract having the appearance of rosin when dried down, but soluble in water. It is due to the presence of this substance that the soap-wort has those peculiar soap-like and lathering qualities. This rosin-like body has the peculiar power of producing a permanent lather in water, even when present in as small a quantity as one part per million, and, unlike most lather-giving substances, it is not affected by the presence of lime salts dissolved in the water. It would readily be seen that the presence of such substances in rosin might account at times, at any rate, for the peculiar appearance of excessive froth when no other reason is forthcoming.

Those who are chemists and desire to go more profoundly into the subject, and to really understand it from a scientific point of view, should read Lord Kelvin's lectures,* in which he goes into the subject of the surface tension of different liquids, and the effects of mixing one liquid with another on its surface tension. The author would advise readers to consult some modern work on Physics dealing with the subject of surface tension. In an interesting paper by Lord Rayleigh on the subject of the influence of oil on the surface of water,† he shows how exceedingly thin is the film of oil produced when a small drop of oil is brought in contact with a large volume of water; the oil immediately spreads over the surface of the water, producing, as we have all seen, iridescent colours. The action of such thin films upon a rough sea is well known. Lord Rayleigh shows how very minute the thickness of the film need be in order to prevent the travelling of minute particles of camphor. If a froth killer is used to disperse froth it should be used exceedingly sparingly, and provided that it becomes properly distributed it is just as likely to become beneficial as when used in larger quantities, and there is much less likelihood of doing damage to the paper afterwards. I would furthermore mention a little book on the subject of the soap bubble by Professor Boys; ‡ it is written in a

* Popular Lectures and Addresses by Sir William Thomson (Lord Kelvin). (Macmillan and Co.) Part I., Chapter iv.: Capillary Attraction and Cohesion. Appendix C: On the Equilibrium of Vapour at a curved surface of Liquid.

† Appendix C: On Measurements of the amount of Oil necessary in order to check the Motions of Camphor upon Water.

‡ "Soap Bubbles and the Forces which mould them," by Prof. C. V. Boys, F.R.S. Published by the Society for Promoting Christian Knowledge.

very simple manner, and helps to explain what constitutes a bubble, what tends to produce it, and what will cause it to burst.

There are many organic substances that will disperse bubbles ; for instance, if you open a bottle of ether, and, without pouring the contents out, merely allow the vapour to pass on to the surface of the water containing the lather, you will notice that the bubbles are quickly dispersed ; this illustrates the mere action of vapour of ether upon the surface of bubbles.

A few words in reference to the question of formation of froth in the beating engine. It has been pointed out that this is greater when the stuff is rather dilute. This is really a question of agitation, and for further information on the subject I would refer you to a series of articles on the Theory and Practice of Beating, published in the PAPER-MAKER ; one of them deals more particularly with the question of agitation in the beater, and the travelling of stuff, etc. Under certain conditions the beater roll beats a lot of air into the stuff, and produces very rapid agitation. Apart altogether from the question of circulation and beating, rapid agitation would accentuate the formation of froth. If the beater is furnished in such a way as to cause a comparatively small amount of agitation, it is only reasonable to expect that the formation of scum in the beater would be far less.

As to the use of the spray box ; this is briefly referred to in one of the author's answers to the London City and Guilds Questions.* The Lechler spray will be found very effectual. If a fine nebulous spray can be made to fall upon the surface of the bubbles as they are formed, it should be the best way out of the difficulty. Paraffin oil is a difficult substance to deal with if impure. This oil may contain dissolved in it other paraffins of the same series, but of higher molecular weight, such as paraffin waxes. This oil is also liable und er certain conditions to produce insoluble marks and spots, but I do not think that if the oil is used sparingly there is any likelihood of this happening. The spray boxes should be placed at a distance of about a foot apart, on a one-inch pipe, and about one foot from the end of the sand trap of the paper machine. Thus, for instance, four diffusers will be sufficient to cover a width of five feet. The size of the particles of the spray can be regulated by altering the size of the nozzle, which the makers supply. For destroying scum or froth the $\frac{1}{24}$ or $\frac{1}{16}$ in. nozzles are generally used. It is important to have a good pressure of water, and where such is not available a pressure pump should be used.

* "Chapters on Papermaking," vol. ii. p. 107.

This fine drizzle, falling as it does in the form of small particles on the froth, breaks the film and bursts the bubbles. There are other means of doing this, such as by using some substance which will overcome the surface tension of the bubbles, causing them to break. Frothing is often the result of some mechanical defect in the way the stuff is manipulated. The stuff should be made to flow, and manipulated in such a way as to agitate the surface as little as possible.

Any amount of agitation below the surface is not so calculated to produce froth. The cause or causes of frothing are in a large measure a mystery. There are undoubtedly several causes. One, the liberation of CO_2 as the result of agitation; another, the presence of soluble bodics as impurities in the rosin, such as exist in the saponaria, giving rise to a permanent lather or froth, even when present in minute quantities, such as one per million. But, whatever the cause, at times a scum is unavoidable, hence the necessity of some ready means of dispersing it.

CHAPTER VIII.

SCUM SPOTS IN PAPER.

"Belling"—"Nip"—Extra water—"Froth bells"—"Outweights"—"Broke"—"Retree."

Question 24.—*What harm is there to the paper if the scum is allowed to accumulate?*

A writes—When the froth is allowed to accumulate, it will find its way along the wire, and will sometimes cause "worming" at the dandy.

B states that he has never seen a machine working stuff with rosin and alum in it where more or less froth and scum did not accumulate; he finds the trouble greater when working alum very close, and with blue papers. It is advisable in some cases to lower the slices a little, and so prevent froth from escaping, but not to lower them sufficiently to cause the stuff to rush underneath. The "belling" is always worse when steam is used to heat the stuff. It was formerly the custom to guard against froth by adding a few drops of petroleum oil to the beating engine before emptying.

C remarks that the stuff, if allowed to accumulate, will come away on the wire, and in passing the couch roll will be crushed into the paper, often giving it a very mottled and wild appearance in the "look through."

D refers to the worming at the dandy, and attributes it to the bubbles of air clinging to the dandy just at the "nip" pressing on the liquid stuff, and producing long streaks; but he finds that when making these boards up to the weight of 120 lbs. Demy, these fine bubbles do not give any trouble.

E finds that specks due to the breaking away of the froth are seen most in tinted papers.

F states that the accumulation in the breaking away of the froth from the slices gives the paper the appearance of being run at a high speed, and shows small round specks like "air bells" at the dandy.

H states that dye spots are sometimes wrongly attributed to undissolved dye; they appear on the sheet as the result of scum in which the dye material has accumulated. Working, a little extra water will help to break up the "bells" (previously mentioned) before they reach the dandy, and prevent them from spreading. Where convenient, a good supply of size should be kept in stock, old size being better than new.

I gives another reason for the objectionable character of the scum. If the scum is allowed to accumulate it will cause the weight of the paper to vary, so that the "B" side and "F" side of the sheet will very often show a great difference. It will also alter the appearance of the paper, and by breaking away cause the dandy to fill up.

J states that if the froth or scum is allowed to accumulate it comes away and forms a cloudiness in the sheet, and carries dirt along with it. When the "froth bells" get broken by the dandy, the particles of dirt form on the surface of the sheet, and it comes away very specky.

K, in speaking of the accumulation of froth, shows that it comes forward producing so-called "bells" on the sheet; at the slice it causes streaks and often hardens and comes away as lumps or blotches, making "broke." In the sand traps, if allowed to accumulate, it retards the flow of the stuff and causes irregular weights.

L finds that when there is a lot of scum it usually first forms against the sides and the corners of the sand tables, and keeps edging back until it falls over the sides, carrying with it a lot of fibres, etc. Scum breaking away is liable to adhere to the top couch roll, causing the paper to run round the roll; at times it is sufficient to damage the machine wire.

O informs us that if the froth is allowed to accumulate for any length of time in the sand traps it becomes dead and heavy, and being heavier than the stuff, it will cause it to ebb and flow. This gives rise to "out-weights."

P refers to the froth gradually filling up wove rolls. These rolls so filled up will crush the stuff unless washed out with water at intervals. The question of machine-wire or dandy-wire deposit is closely connected with this, as also the question of keeping the dandy rolls clean.

Q refers to the accumulation of scum especially about the breast and slices. When the bells begin to fall and form solid matter, the scum comes away in lumps in the sheet, sometimes breaking it at the press roll. Sometimes the scum is fine and dispersed over the surface of the sheet; this also makes "broke" and "retree."

S refers to the accumulation of stuff at the sand tables and its liability to get heavier, etc.

V states that the scum has a tendency to become sodden, falling to the bottom of the sand traps and strainers, and coming away as small lumps, etc.

Y has noticed that when the froth is heavy an alteration in the "spread" at the suction boxes is often noticeable.

A2 points out, among other things, that if the scum is allowed to accumulate, it will blotch and streak the paper.

B2 shows that when the scum comes away in blotches, after passing through the calenders it is liable to be picked up by the rolls, and it becomes a source of annoyance to the machine-man by forming "stamps" which spoil the paper if not detected at once.

E2 points out that blotches as the result of scum breaking away are bad on account of the sticking at the first press or the calenders and the consequent breaking of the paper.

F2 states that as the mass of froth becomes larger, large portions will break away and form a soft and bad place in the sheet, which, if it passes the presses without breaking, will most likely fall away in the last two or three cylinders, and in a short time will become burned and fall to powder, causing dirt on the cylinders. He adds as a postscript that he does not intend his remarks to apply to slime formed in pipes, sand tables, etc., by loading and so forth.

The "ebb and flow" already referred to, which in effect is what sometimes takes place, is due, in the author's opinion, not to the greater weight of the scum, but to a peculiar set of conditions produced by the accumulation of the scum, which phenomena is noticeable on a slow running or eddying stream, where scum and froth prevail.

CHAPTER IX.

CONSUMPTION OF WATER IN THE MANUFACTURE OF PAPER.

Influence of locality—Quality of paper—Arrangement of plant—Consumption of water at different stages for rag, esparto, and wood papers.

QUESTION 25.—*Give the amount of water (in gallons per ton of finished paper) required for any quality of paper you like to choose, and show what is required for the different stages of treatment, beginning with the boiling, and finishing with the water used on the machine.*

This question is unlike the two preceding ones, it gives rise to a considerable diversity of opinion; the fact is, practice differs in different parts of the country. In one locality water may be very plentiful and pure, in another water may be impure and comparatively scarce. In one district possibly water is derived from sinking deep wells in the chalk, in another it may be derived from pumping from ponds or from springs which rise to the surface. In other localities again the water is derived direct from streams, and as result of rainfall varies considerably in quality and quantity at different periods of the year.

The cost of pumping is a factor affecting the whole question of water consumption. Provided that there is an ample supply of water no attempt is made to minimize the water consumption; it becomes, therefore, a matter merely of the cost of pumping. This would depend upon one or two things—upon the cost of horse-power at the mill in question, which in turn depends upon the cost of fuel and the efficiency of pumps and engines used. It would depend furthermore upon the height to which the water has to be pumped; if from deep wells, the water has to be raised to a considerable height, representing so many foot-pounds of energy. With the large water companies the efficiency of the pumps is well known. The exact height through which the water is raised, of course, is known, and within a little the volume or weight of water so raised. Most careful records are kept of the amount of coal burned. The efficiency of the pump or system of pumps is expressed as so many foot-pounds per cwt. of coal burned. It is interesting to note, furthermore, that the efficiency is expressed in so many foot-pounds per cwt. of anthracite, or per cwt. of the particular coal used. As the coal in question has a fairly definite calorific value, the percentage efficiency can be arrived at, so that systems using different classes of fuel can be strictly compared with one another as to economy and efficiency. This, of course, is out of the question in most paper mills, but might be arrived at, to a certain extent, in mills where electric drive is resorted to.

The restrictions imposed upon various manufacturers through recent legislation in connection with the question of river pollution, tends rather to the economy of water. Even if there is ample water to spare, the requirements of the river commissioners may render it necessary to settle all the impurities out of the water before returning same to the river. It may be necessary to minimize also, as far as possible, the volume of water leaving mill as effluent. Some mills find it necessary to pass all their water through filtering appliances, and the best of the water so treated is used again, possibly, for the purpose of cooling the condensers, or for the purpose of preliminary washing. Of course, the utilization of back-water is primarily resorted to not for the sake of economizing water, but for the sake of economizing fibres and chemicals ; but, nevertheless, it results in considerable economy in consumption of water also. This is of considerable importance, more particularly in those districts where water is becoming every year more scarce. A mill working up waste papers which are not washed or bleached or boiled would naturally require a comparatively small amount of water. A mill, on the other hand, treating rags which are, after boiling, washed in the boiler with copious supplies of water, washed again in a rag washer and again in the breaker for perhaps a couple of hours, and possibly again after they have been bleached in the half-stuff, would result in the consumption of a large amount of water per ton of paper made. The consumption of water for steam raising is a comparatively simple thing to calculate and may be regarded as a minor item. It can be calculated from the coal consumption per ton of paper made. In a general way, if this figure is multiplied by eight, the consumption of water for steam raising per ton of paper made is arrived at. The author wanted the students to give the amount of water for some particular kind of paper, because if the composition and thickness of a paper is altered, so is the amount of water required per ton. It is an easy matter to transpose the figures in gallons per ton to tons of water per ton of paper; it may be taken as a rough statement that 1000 gallons equals $4\frac{1}{2}$ tons of water.

A instances a good rag bank. His total comes out at 77,525 gallons, of which 40,000 gallons are for washing; in the engine he puts the same quantity of water for boiling and subsequent rinsing in the boiler, viz. 1500 gallons per ton.

The author would refer to his lectures before the Dickinson Institute on the treatment of rags. In general practice 1500 gallons per ton of rags is perhaps a fair figure, but by careful manipulation this quantity can be very materially decreased. It is difficult to see, in a number of the answers, how some of the figures are arrived at, such as the figure for the water required for the spray pipe of strainer as well as the water for emptying beaters. For washing purposes the water may be measured by taking the height of the waterflow over a given bay. Of course, this is more an engineer's job than a chemist's.

B, in some instances, arrives at his estimates in a similar manner to **A**. He gives 57,000 gallons per ton for washing rags, and 16,000 gallons per ton for couch roll and suction boxes, and, furthermore, he includes an item of 6000 gallons per ton of paper for washing the skins. Of course, in those mills where sheet gelatine is bought, and where the process of size manufacture is no longer resorted to, this item would be cut out. In addition to the tabulated statement **B** gives a description of how various quantities of water were accounted for, which is sufficiently interesting to warrant my giving details. To make it somewhat more intelligible to readers I give an abstract. In making estimates care should be taken to see that the quantities of raw materials treated should be enough to yield one ton of finished paper. Thus one ton of rags would in no case be sufficient to yield one ton of finished paper unless there is sufficient loading, etc., added to the furnish to make up for loss sustained by the rags on treatment. The only other operation likely to augment the weight is the tub-sizing, which in hard-sized papers might amount to 5 per cent., or even 8 per cent.

"For each ton of rags 1000 gallons of water are used in the boiler, and to which is added 100 gallons of liquor in which the soda is dissolved, making in all 1100 gallons. No water is used for rinsing the boiler, the washed rags (presumably a ton, final weight) make five washing-enginesful. Then wash with water flowing at the rate of 84 gallons per minute for a period of 90 minutes, making 7560 gallons per engine, which is equal to 37,800 for five engines.

"For removing the bleach the following quantities of water are used: 50 gallons per minute for 20 minutes, equal to 4000 gallons for each engine, making 5000 gallons for the five engines required to make the ton. The stuff is then emptied into the beater and thickened with a few papers which have necessitated the use of 500 gallons of water for scalding, 8 gallons per engine is used for mixing starch and loading, equal to 40 gallons for five engines, 20 gallons used for dissolving the alum, 25 gallons for the rosin size; 5000 gallons for emptying the stuff into the chest for each five engines. The stuff used on this machine making two sheets of 12 lbs. Large Post at the rate of 224 lbs. per hour. Water was run in at the auxiliary strainer at the rate of 550 gallons per hour for a period of 10 hours, making 5500 gallons. Water was put in with the spray pipe on the strainers, pump plunger $1\frac{3}{4} \times 9$ making 50 strokes per minute, equal to 0·23 gallon per stroke or 2300 gallons per 10 hours. The water used at the couch roll, suction boxes, and for rinsing the wire was 16,000 gallons; 6000 gallons were used for washing 9 cwt. of skins, being the quantity used for sizing 1 ton of paper, and a further quantity of 70 gallons of water was used for preparing the tub size; about 100 gallons for rinsing the strainers, etc."

A's summary, given over page, is by no means an unfair estimate for paper of good quality made from rags, and strangely enough is in close agreement with **B**'s answer. A summary of the two is given together, so that they can be compared together, but as it will be seen hereafter, the amount of water required per ton of paper varies, perhaps, with every quality of paper produced, and, therefore, unless details are given, it is somewhat difficult to judge of the value of the answer. As in many of the later answers, the author has in **B**'s case worked out the percentages of water used in the different operations, and put it against his figures :—

A.

A Good Rag Bank.

	Galls. of water required per ton of paper.		Per cent. on total enumerated.
Boiling rags	1500	=	1·8
Rinsing do.	1500	=	1·8
Washing in engines	40,000	=	51·5
Mixing bleach	75	=	0·1
Washing out bleach	5000	=	6·4
Half-stuff emptied from washers direct to beaters—			
The mixing of clay, starch, rosin, alum and colour will require ...	150	=	0·1
Emptying beaters	5000	=	6·4
Spray pipe on strainer	2300	=	3·1
Couch roll, wash roll and suction boxes	16,000	=	21·5
Washing skins and preparing animal size	6000	=	7·3
	77,525		100·0

B.

Rag Paper, 12 lbs. L.P.

	Galls. of water required per ton of paper.		Per cent. on total enumerated.
Boiling rags	1100	=	1·30
Washing rags	37,830	=	47·10
Mixing bleach	200	=	0·20
Washing bleach out	5000	=	6·10
Starchers loading	40	=	0·06
Dissolving alum	20	=	0·02
Making rosin	25	=	0·03
Scalding papers	500	=	0·61
Emptied with beaters	5000	=	6·10
Auxiliary strainers	5500	=	6·80
Spray on strainer	2300	=	2·80
Couch roll suction wire boxes ...	16,000	=	20·00
Washing skins	6000	=	7·60
Preparing size	70	=	0·08
Rinsing strainers	100	=	1·20
	79,685	=	100·00

C.—With a wood paper, especially when there is no bleaching to be done, and where there are few changes in the makes, speeds, etc., it should be a comparatively easy matter to arrive at the water required for the different processes.

There is one error in **C**'s mode of calculation which a few others have fallen into. He states that the stuff as it goes on to the machine is diluted to 1 per cent., from which he calculates the gallons per lb. of paper equal to so much per ton of paper. A little consideration will convince anybody that this calculation is wrong. It would be approximately correct, provided that the whole of the back-water, etc., is thrown away. If the whole of the water is run to waste, and stuff diluted to 1 per cent. before passing on to the machine, we should have 100 tons of water used for every ton of paper made, but as a very large proportion of the back-water, etc., is used again, we never find this figure in practice. This will be gone into more in detail later on.

The 7 per cent. argument is correct, provided that the stuff in the chest contains 7 per cent. dry material and 93 per cent. water; the ratio of one to the other gives us the data for calculating the actual amount of water in the chest. The author believes, however, that the stuff in the chest is seldom, if ever, 7 per cent., and considers 5 per cent. a very fair figure for the dry weight of stuff in the chest; the proportion of dry material to water is, roughly speaking, as one is to twenty. 224 gallons of water weigh 1 ton, therefore, for every ton of paper there would be $224 \times 20 = 4480$ gallons of water in the chest.

C's answer is given in order that others may see the fallacy of this mode of calculation, as given below.

He states that he has not had much experience with boiling, but as regards wood papers he calculates the following to be the usual quantities of water per ton of finished dry paper :—

"Beaters, engine containing 700 lbs. of dry paper, average 7 per cent. = 93 per cent. water = engine containing 700 lbs. dry stuff and 9300 lbs. water, or 32,617 lbs. of water per dry ton of paper, or 3261·7 gallons.

"Stuff in chests about 5 per cent., 4256 gallons water per dry ton, and as it goes on to the machine it is further diluted to about 1 per cent. = 22,176 gallons, 9·9 gallons = 1 lb. of paper."

Water per dry ton (*i.e.*) 2240 lbs. of paper = $2240 \times 9{\cdot}9$ gallons.

D gives a long answer, but falls into an unfortunate blunder in his mode of calculation. In order that others may see where he has gone wrong, and avoid making mistakes which he has been guilty of, his answer is given in full, with the exception of his sketches.

The furnish of paper in question is Esparto, all Spanish. Figures given below are taken rather at random, especially the dilution of stuff when leaving the breakers :—

Boilers, Sinclair, 9 ft. × 9 ft.—Space filled with liquor,

$$= \frac{22}{7} \times \frac{81}{4} \times 8 \text{ ft.}$$

(Leaving 1 ft. for condensation) = 509 cub. ft. for 50 cwts. of raw grass (the equivalent of 25 cwts. of green stuff) = 400 cub. ft. for 20 cwts. of boiled grass.

Boiler filled three times for grass boiling process = 1200 cub. ft. (1 cub. ft. = 6·2 gallons of water) = 7440 gallons of water.

Breakers of 20-cwt.—Cubical contents, without ends, 8 × 10 × 4 ft. = 320 cub. ft.

$$\text{Circular ends} = \frac{22}{7} \times 16 = 50. \quad 50 \times 4 \text{ ft.} = 200 \text{ cub. ft.}$$

Total, 520 cub. ft. 520 × 6·2 = 3224 gallons of stuff and water. Half the water removed by washing.

Bleach.—20 cwts. of grass @ 24 gallons of bleach per cwt. = 480 gallons.

Emptying breakers to chest.—Chest, 14 ft. × 8 ft. = 1232 cubic ft. Supposed half-stuff and diluted half,

$$\text{chest filled} = \frac{1232}{2} = 616 \text{ cub. ft.} = 3800 \text{ gallons.}$$

Presse-Pàte Machine.—For working stuff dilute the stuff from chests as much again. Before (in chests) 3800 gallons. At machine, 7600 gallons.

Beaters, 1000 lbs. Engine.—4480 lbs. wet stuff = 1 ton of paper. Capacity without ends = 6 × 8 × 4 = 192 cub. ft.

$$\text{With ends} = \frac{22}{7} \times 16 = 50. \quad 50 \times 4 = 200 \text{ cub. ft.}$$

Total 392 cub. ft. = 2430 gallons × 4 engines = 9720 gallons.

Machines.—Back-water, 2500 gallons per hour, estimated by Fullner tank, machine running 100 ft. per minute. 84 in. deckel = 1080 lbs. per hour = 2160 lbs. per two hours, say 1 ton. Back-water as above, 2500 gallons per hour, water to save-all from couch-roll and under boxes, 1250 gallons per hour. Total, 3750 gallons per 1 hour = 7500 gallons for the two hours.

	Galls. of water required per ton of paper.		Per cent. on total enumerated.
Grass Boilers	7440	=	17·6
Breakers	3224	=	8·0
Bleach	480	=	1·2
Breaker Chests	3800	=	9·8
Presse-Pâte	7600	=	19·1
Beaters	9720	=	25·5
Machines	7500	=	18·8
Total used per ton of paper ...	39,764	=	100·0

Except perhaps in the case of the boiler, the cubical contents of the vessel in which the water is used is no guide as to the amount of water consumed. In filling a boiler it is, of course, a different matter, but I would suggest that the easier way to arrive at the water generally used in a boiler is by measuring it before it passes into the boiler, as by following the author's suggestions in connection with esparto boiling.*

Even on the assumption that in the case of the breakers and beaters where the cubical contents would give the amount of water used, the calculation is not correct. **D** evidently assumes that the breaker is filled to the brim, for he takes the total depth of the breaker in feet, and, furthermore, assumes that the bottom does not "shelve," and makes no allowance for the volume occupied by the backfall and that portion of the roll immersed. But even apart from this, the cubical contents of the breaker is no guide as to the amount of water used. The only way to arrive at this is by measuring the amount of water passing into the breaker whilst the washing is being proceeded with.

What is the meaning of the expression of "half the water removed by washing"? It may be taken to mean that the water used for washing is equal to half the volume of water in the breaker. There is no connection whatever between the two. The simplest plan is to proceed in the manner indicated in Part VII. of "Theory and Practice of Beating," as published in the Paper-Maker.

E.—The author is inclined to think the figure for the total amount of water in the case of esparto paper given by **E** is about three times what is found in general practice in up-to-date mills. It would appear that the figures are fictitious, but without further details it is not possible to judge; the substance of the paper

* "Chapters on Papermaking," vol. ii. p. 104.

will affect the question, as also the amount of loading added, and furthermore, the washing and mode of recovery The total amount of water given for esparto paper is 94,000 gallons per ton, of which 50,000 (or 53 per cent. of the whole) is reckoned as being consumed in the breaking and beating engines.

"The quantity of water used in making 1 ton of esparto paper is reckoned at about 94,000 gallons, and made up as follows, viz. :—

	Galls. of water required per ton of paper.		Per cent. on total enumerated.
Boilers, including washing in boilers...	4700	=	5
Breaking and Beating Engines ...	50,000	=	53
Presse-Pâte	15,000	=	16
Making Machine	15,000	=	16
Liquor Tanks, Clay Pots, etc. ...	9300	=	10
	94,000	=	100

This is on the assumption that water is used only once, and it does not, of course, account for water required for motive power, and therefore is complete.

If the above figures are correct, it means that about 400 tons of water are required in the making of 1 ton of esparto paper.

F's answer is by no means explicit, and the amount of water required appears to be enormously over-estimated. It is to be hoped that in no mills in the United Kingdom 136,300 gallons per ton of esparto paper are being used, at any rate, as an average quantity. It would appear that **F** has gone wrong chiefly on the item of breaker washing, which he gives as 112,000 gallons per ton. This item alone is three times the total consumption for many grass papers.

H gives the impression of having carefully thought out his answer, and appears to have a good idea of the apportionment of the water between the various processes. I should, however, like to have seen a few further remarks on the mode of treatment which the material in question is subjected to, as this would considerably affect the question.

In a mill making writing and printing papers from esparto I would allow 40,000 gallons of water per ton of finished paper, and apportionate it to the different processes as under :—

	Galls. of water required per ton of paper.		Per cent. on total enumerated.
Soda recovery and Esparto Boilers ...	3000	=	7·5
Potchers and Presse-Pâte	10,000	=	25·0
Beaters	6000	=	15·0
Machine	13,000	=	32·5
Water as steam	6000	=	15·0
Sundry purposes	2000	=	5·0
	40,000	=	100·0

I have for the convenience of others calculated the percentage distribution of the water between the processes and placed them against the figures in **H**'s summary.

H supplies some further information which is important and of interest to others. In place of the amounts given under sundry purposes **H** sends the following :—

	Galls. of water required per ton of paper.
Liquor	1640
Washing	3400
Water as steam	960
	6000

when the total per ton of paper = 41,000 gallons.

The "water as steam" item above is calculated on the quantity of coal used for recovery, and I have allowed for condensation in the boilers and for the "blow-off."

I unfortunately does not give his figures in the form of a summary, as many of the others have done, but his remarks on the circumstances which affect the amount of water used, are worthy of notice. The author leaves those who are practically instructed in the subject to summarize for themselves the figures given below and form their own opinion.

I's Answer.—"After boiling grass you would drain off the liquor, and provided you had not any hot, weak liquor you would use water, but after the first boil you would always have a supply; then you would require about 1000 gallons for two more washes (one boil equals 3 tons). You would require, further, a supply going into the breaker. The quantity of water required for the strainers would depend a good deal on how the grass was boiled, as if insufficiently boiled a large quantity of water would be required. I should estimate about 3000 gallons are required for drum washing in the potchers, when potcher contains 15 cwt.

"On the presse-pâte you would use say 400 gallons per hour.

"Beaters carrying about 3 cwts. would take, say, 800 gallons. When in the chest this would be raised to, say, 900 gallons. If taken thick in the chest it gets shotty.

"On 60-inch machine, making 4½ cwts. per hour, say, 500 to 600 gallons per hour would be required.

"The above quantities are for an ordinary grass paper."

J states that the approximate amount of water per ton of finished paper of the better qualities would be about 40,000 gallons for between 100 to 150 tons per week, made up as follows :—

PER TON OF PAPER MADE.

Boilers (being three times washed), 1800 × 3 galls.,
Breakers (three times washed), 750 × 3 galls.,
Presse-Pâte, 5000 galls.,
Beaters, 3000 galls.,
Machines, 23,600 galls.,

and also an allowance for water for steam, ash recovery plant, engine condensers, and waste at machines.

The first portion of **K**'s answer shows, and of this I have not the least doubt, that there is an enormous difference in the amount of water used in different mills, even in the case of esparto papers; he gives some reasons for this. As the latter portion of his answer is not tabulated, I have re-arranged it in tabular form, calculating and adding the percentages of water used in the different operations. He writes as follows :—

"In making an esparto paper, say fine printing and E.S. writing, about 50,000 gallons of water per ton of paper is usually required. This, however, depends, to a great extent, on the arrangements in force for using the water over again in the various processes or departments. For instance, in some mills no water is used at the esparto boilers except that sent to the plant for recovering caustic. The other water being re-used until it becomes the actual strong liquor which in turn has to be evaporated. In other mills the esparto is washed several times with pure water, which is run to waste. Some mills wash a great deal at breakers, others very little; some use machine back-water for beaters, others do not, and run to waste all machine water not actually required for the machine itself. Taking an average of 50,000 gallons per ton, I should say the approximate proportions would be as follows :—

	Galls. of water required per ton of paper.		Per cent. on total enumerated.
Esparto Boilers	5000	=	10
Cornet process	10,000	=	20
Breakers	3000	=	6
Press-Pâte	10,000	=	20
Beaters	2000	=	4
Actually used as above this, going to machine	20,000	=	40
	50,000	=	100

L takes, as an instance, a cream paper of medium weight, about 23 lbs. Large Post, made from 75 per cent. rags and 25 per cent. best quality sulphite and paper. He suggests the use of a mixture of slightly dirty white rags with some coloured shirting, and that they should be boiled in a spherical revolving boiler for six hours after pressure is up at 20 lbs. One ton of rags should be put into the boiler with as little water as possible so as to economize the caustic soda, starting, therefore, with 800 gallons of water and caustic dissolved. The boiler should not be jacketed so that the steam going into the boiler condenses, and on the completion of the boiling the boiler contains 268 gallons of water in addition to the 800 gallons before mentioned, making in all 1068 gallons for boiling. The steam is then let off and the water drained away, and the rags are ready for breaking-in by means of an ordinary hollander, and emptied direct into the beater; they are then washed for 1½ hours with 7560 gallons of water; chloride-of-lime liquor is then added (30 gallons to each engine equals 180 gallons per ton of paper). The rags are then washed again for half an hour with 1050 gallons of water to each washer, then emptied down into the beater, the washer supplying the water for the beater—hence, washing and breaking-in the rags and washing out the bleach liquor requires 8610 gallons—30 gallons chloride-of-lime liquor for each breaker, or 27,840 gallons for six washers per ton of paper. The rags are then thickened in the beater with sulphite wood and paper, using 100 lbs. sulphite and paper to engine.

Satinite loading is used in the beater dry, and rice starch is mixed with 20 gallons of cold water; and 5 gallons rosin size and 6 gallons sulphate of alumina added to complete the furnish of engine.

The beating is completed in four hours, and the contents emptied into chests of 35,000 gallons capacity, making 7000 gallons per ton in both chests of pulp and water—31¼ tons, or 70,000 lbs., or rather more than thirty times the quantity of water to dry weight of paper. Twenty thousand gallons of water are used for the wire and suction-boxes, and 6000 gallons of water for washing the skins, 70 gallons for a sufficient quantity of skins to size a ton of paper.

L's Answer.

	Galls. of water required per ton of paper.		Per cent. on total enumerated.
For rag boiling	1068	=	1·90
For washing and breaking in six engines, after deducting 500 gallons left in each washer to fill up beater	42,360	=	50·60
For washing out bleach in six washes	6300	=	7·20
For water to mix chloride of lime ...	180	=	0·20
For water to mix starch	120	=	0·12
For water to mix rosin	30	=	0·03
For water to mix sulphate alumina	36	=	0·03
For water to scald papers	200	=	0·14
For water to empty into chests with pulp	6814	=	7·80
For water to use in auxiliary strainer	600	=	0·70
For water to rinse couch rolls and suction boxes	20,000	=	24·30
For water to wash 8½ cwts. skins ...	6000	=	6·90
For water to use with skins ...	70	=	0·08
	83,778		100·00

The above total may be much exceeded, such as in the case of materials requiring longer washing, as when making a bank paper.

O's answer bears a very close resemblance to A2's answer. It appears that he has had a very similar experience in paper-making in the same district. He gives as his total for esparto paper, 37,000 gallons per ton. Estimating that the amount of water used in the boiling is represented by the figure 1, merely for the purposes of comparison, the water for washing would be represented by the figure 8, that for bleaching by the figure 1, and for washing out the bleach by 1½, that added to the beaters by the figure 1, and water used on the machine by the figure 9.

This gives one a rough idea of the relative quantities of water used up in the different processes above mentioned.

P has given the best answer for esparto paper, and furthermore he gives good reasons for his statements. I consider it a good specimen of the way an answer should be given; he states that the quantities for presse-pâte are guesses, but I venture to think very fair guesses, of the amount of water actually used.

The end of his answer is specially worth noting. He gives as a check on his figures the amount of water flowing over the weir measured by taking the depth and width of the flow, and also the amount of water from the centrifugal pump for a 6-in.-diameter discharge pipe. In regard to the weir water, on referring to Hennell's hydraulic tables, I find that the amount of water passing over the weir of the width and depth given would work out at 56·3 gallons per minute, instead of 53 gallons per minute; but it is possible, of course, that **P**'s answer gives a more correct figure, as the exact shape of the weir and the flow of the stream at the back of it affect the question of flow somewhat, and he may have taken this into consideration. Against his quantities I have calculated the percentages to make his table more complete.

P's Answer.

Summary :—

	Gals. of water required per ton of paper.		Per cent. on total enumerated.
Boiling	1,200	=	3·4
Steeps	2,200	=	7·0
Potchers (including dilution in presse-pâte stuff chests)	8,000	=	25·6
Presse-Pâte	4,000	=	12·8
Beaters (including dilution in machine stuff chests)	8,000	=	25·6
Machines	8,000	=	25·6
	31,400	=	100·0

Quantities all calculated, with the exception of presse-pâte and machine, which are guesses. The water in these cases equals water before guard or couch roll and pump box water and spray for keeping wire clean (these I have no means of estimating). The total of 31,400 gallons per ton finished paper must approximate fairly closely, because I checked it by estimating the total amount of water flowing into the pond, which for one week was as follows :—

Spring water, $1\frac{1}{2}$ ft. depth flow on weir, $11\frac{1}{2}$ ft. wide = 8·51 cub. ft. of water discharged per minute = 53 gallons per minute = 534,200 gallons.

River water centrifugal pump, 6-in. discharge pipe = 550 gallons per minute, working forty hours per week, 1,320,000 gallons.

Paper made per week = 60 tons, requiring 1,854,200 gallons of water = 30,900 gallons of water per ton of paper.

Q's answer is given below. It will be instructive to compare these figures with the preceding ones. The figures are somewhat different, but not materially so, and not more than might be expected with the different modes of working. Space will not allow the author to go into details of comparison, but readers should derive considerable benefit by making comparisons for themselves.

Q states that with reference to the water at the beaters, there may be a great difference at this stage, even in the same class of papers, as some can work the stuff much thicker in the chests than others. When the stuff is kept long, it should, for instance, be thinner in the chests to avoid "knotting." However, I reckon that for an ordinary thickness of stuff there would be required for emptying 10,000 gallons per ton of finished paper, making in all for—

	Gallons.		Per cent.
Boilers	3055	=	20·2
Breakers	4876	=	24·2
Beaters	10,000	=	55·6
	17,931	=	100·0

Then on the machine proper there is no fresh water used, as a rule, except for washing the wire, coucher, etc., yet if we count the water which is always retained in the making of the sheet, there will be flowing over the breast for every ton of paper made from 12,000 to 15,000 gallons, according to the weight of the paper being made, or from 53 to 60 tons of water per ton of paper. In all processes say = 32,900 gallons.

It is obvious that Q is wrong somewhere in his calculations.

S states his opinions, and shows how different conditions bring about variation in the figures. This is instructive to others, and those who care to might with advantage tabulate his figures, and calculate the percentages in the form already given for some of the others. I leave those who have a special knowledge of the subject to consider whether 40 lbs. double crown cream laid would require, under ordinary circumstances, 56,350 gallons of water, or whether this is exceptional.

S appears to have fallen into the same error as some of the others by including the water which is used over again in the total consumption of water for a ton of paper.

He would be quite right in giving this figure if he were making out a balance sheet, as it were, of the water utilized in the different processes, but the amount actually consumed is the difference between the gross total and that used over again. Except for this item of 30,000 gallons, the author would regard his answer as a good one.

"The question is a difficult one to answer, as the conditions vary so much. However, let us take E.S. esparto cream laid paper, the substance of 40 lbs. double crown. To boil well, start with 2000 gallons of water for 4 tons of esparto grass, then before it leaves this stage of the process you require 4300 gallons for washing, which works out as near as possible to 3650 gallons per ton for this department. Then for the breaker, for the equivalent of every ton treated, *i.e.*, washed and bleached, you require 5500 gallons. Leaving this, your ton now goes to the presse-pâte, where it parts with 3700 gallons more, 1500 gallons passing on to the beaters. Add to this water that contained in the alum, size, clay, etc., also water to empty, and you have 13,500 gallons ; so that up to this point you will have used 26,350 gallons per ton. We will now bring our ton on to the machine, where, to begin with, you have 13,500 gallons; add to this the return water, wash roll-water, etc., and you have 30,000 gallons used on machine for every ton of paper produced. So that, in this class, you require, in my opinion, 56,350 gallons of water per ton of paper."

V's tabulated figures given below show that the amount of water required for a paper containing grass, sulphite wood, and broke is considerably less than that for paper consisting of grass alone, but considerably more than is required for a paper made entirely of sulphite wood, especially if the same is used ready bleached. Of course, the more broke you put back into a paper, the less water per ton of finished paper would be required, and furthermore, if the bleaching is omitted, the saving of water is considerable.

"Water used in making ordinary cream-laid E.S. writing, from "grass," sulphite, wood, and "broke" :—

			Galls. of water required per ton of paper.		Per cent. on total enumerated.
Grass House.	To boil	3000 lbs. grass	100	=	0·6
	,, wash	,, ,, ,,	1850	=	6·1
Breakers.	To wash and bleach	,, ,, ,,	5300	=	19·8
	,, empty	,, ,, ,,	5000	=	19·3
	,, ,,	400 ,, wood	1000	=	4·8
	,, ,,	400 ,, broke	700	=	1·1
Beaters.	To fill for 1 ton paper	... ...	1500	=	2·1
	,, empty ,, ,,	... ...	10,000	=	46·2
			26,050	=	100·0

It would not be possible, under any conditions, to make a white linen paper with consumption of only 800 gallons per ton on the machine, or total for beater and machine combined of 2000 gallons.

B2 has only given his figures under four headings ; very little consideration will, I think, convince him that a much larger quantity of water must, in any case, be used than he states. Working the water in the chest alone takes about 20 to 1, that is, not less than 4480 gallons per ton.

A linen bank would, in the nature of things, require a great deal of water ; the water used for washing would be considerable, and there would be a further quantity required for washing after bleaching, and a fair expenditure of water on the machine. The author has no reason to doubt the value of the figures in **D2**'s answer, and it serves to demonstrate that the water consumption is largely affected by the kind of paper produced as well as by the class of fibre treated.

	Water required to make a ton of Linen Bank Paper.		Per cent. on total enumerated.
For boiling 28 cwts. of rags ...	1100	=	1·1
Washing in engine for $2\frac{1}{2}$ hours at 70 gallons per minute, 70 gallons × 150 minutes × 5 engines ...	52,500	=	53·7
Washing out bleach for 15 minutes at 50 galls. per min. for 5 engines	3750	=	3·9
Water emptied with 5 beaters, 1200 gallons	6000	=	6·3
Water run in at auxiliary strainer (500 gallons per hour for 8 hours)	4000	=	4·1
Water put in as spray on knotters	1840	=	1·9
Water used at suction-boxes, couch roll, and spray pipes for wash rolls	20,000	=	21·8
For washing 9 cwts. of skins for size	7000	=	7·2
	96,190	=	100·0

F2 with his characteristic thoroughness has given a good answer, which is reproduced *in extenso* for the benefit of readers.

The author does not gather how he arrives at the figures he cites, but he gives one the impression of knowing what he is talking about. From his tabulated figures given hereunder the percentages of water consumption for each stage are given in a separate column.

ANSWER.—I will take for example a mill making printings from straw and esparto only, paper containing 47 per cent. of straw to 47 per cent. esparto, and 6 per cent. of loading. The water taken for 1 ton of this class of paper I estimate to be about 40,000 gallons. The quantities used vary considerably in different mills, depending on the supply and the various methods of treating the material, and also on the quantity of the material itself. The quantity of clean, sorted fibre I take as 24 cwts. of esparto and 25 cwts. of straw, and in boiling 790 gallons of liquor (esparto boiling); 600 gallons from condensed steam (esparto boiling); 2500 gallons from washing in tank, the grass being washed in a series of tanks; 1000 gallons of liquor, 10° Twaddle (straw, wheat or oats); 700 gallons from steam; 2600 gallons from washing as above.

The pulp in potcher takes for washing, before the bleach is run in, 5000 gallons for esparto and 6000 gallons for the straw, there now being 11 cwts. grass to 11½ of straw. The water taken for bleach and the presse-pâte amounts to about 4000 gallons for each class of material, and in the beaters about 1800 gallons each. The amount of half-stuff to be treated here will be about a ton. The fresh water consumed on the machine will be about 4400 gallons in addition to the water supplied by the back-water. A quantity of back-water may also be used at the beaters. The finished paper will amount to about 21 cwts., including loading. Allowing 5 per cent. for waste and broke, most of which will be re-pulped and used again, we construct the following summary :—

	Galls. of water required per ton of paper.		Per cent. on total enumerated.
Boiling	3090	=	7·7
Washing	5100	=	12·8
Do. in Potcher	11,000	=	27·5
Presse-Pâte	8000	=	20·0
Beaters	3600	=	9·0
Machines	4000	=	10·0
Steam Boilers, clay dye and jets for machines, etc.	5210	=	13·0
	40,000		100·0

There is great difficulty in judging the relative merits of the above answers. Some of the figures are arrived at apparently without any data, or, at any rate, no explanation is given as to how the figures are obtained; it is difficult, therefore, to judge between an answer which is the result of practical experience and knowledge, and one which is, more or less, guess work; but some of the papers, on the face of them, bear evidence of a practical experience, and even original work, whilst others appear to be arrived at second-hand, or by consulting somebody who has some knowledge of the subject. I am bound to admit that some of the papers are undoubtedly guesswork, but on the whole I think I can sort them out in accordance with their intrinsic merits.

There are some important points in regard to this subject which are worthy of every consideration. I will attempt briefly to refer to them, in the hope that they may be of some assistance to those who wish to pursue the subject further.

It is hardly necessary for me to say that each class of paper requires a different quantity of water, even when made at the same mill, and possibly from the same class of material. Even although the preliminary treatment of rags, for instance, requires a fairly fixed and known quantity, the subsequent treatment, more particularly that on the machine, may run away with more or less water, according to the thickness and peculiar nature of the paper to be produced. The general arrangement of the machine, and means of working the save-all, must considerably affect the amount of water used. The greatest possible consumption of water must be in the production of those papers made from rags, where cleanliness is of primary importance. Where such papers fetch a high price, a lot of water is used in washing the rags after boiling, and washing in the breaker to ensure that the whole of the dirt is got rid of. Where rags are used on the machine with a large quantity of water, the consumption per ton may be excessively high, and one would hardly like to say what it is for some special papers. The other extreme is the manufacture of "news," where the stuff first comes in contact with water in the breaker or beater.

I would like to suggest that the consumption of water with "news" is somewhere between 7000 and 10,000 gallons per ton. With a wood paper, where there is bleaching, it would be more than this, depending upon the amount of bleach required. The figure for an esparto paper can, on an average, be taken at about 30,000 gallons per ton, but, of course, it is influenced by the amount of mineral and broke as well as by other questions already referred to.

It is necessary to note that if no back-water is re-utilized the water consumption for dilution of the stuff would amount to 22,400 gallons per ton on the assumption that the stuff as it passes on to the wire contains about 1 per cent. of fibre. This must have been the state of affairs in the early days of the paper machine, before the water of the save-all was re-utilized. The consumption of water, taking it as an all-round figure, must have been at least 18,000 gallons per ton in excess of what it is at present for all qualities. The extent by which this item is reduced is dependent not only upon the dilution of stuff but upon the extent to which the water is used over again, and with our more modern appliances for gauging and pumping the water from the suction-boxes, save-all, etc., the loss has been very materially reduced. As regards the water used in steam raising it is best got at from the coal book, which gives the whole consumption per week. The calculated quantity of coal per ton of paper must be multiplied by the evaporating efficiency of the coal; a very fair average all-round figure is 8 pounds of water per pound of fuel.

There are various published formulæ for arriving at the flow of water over weirs, through pipes, etc. This matter is fully explained in D. K. Clark's "Tables for Mechanical Engineers," * but for a simple book of reference, which avoids, as far as possible, all complex formulæ, I would refer you to the little manual by Thomas Hennell.† This gives the flow of water over sluices, weirs, etc., and the tables, in many instances, avoid the necessity for calculation; by means of such tables the water flowing into the breakers, the save-all water, and the water used in various parts of the machine can be very readily calculated with a fair approximation to the truth. Where the total effluent can be measured, the figure can be used as a check upon all the other measurements, such as has been done in one of the answers above cited. In making use of any of the tables given, care must be taken to see that the pipes are in good condition.

* London: Crosby, Lockwood & Son.

† "Hydraulic and other Tables." By Thomas Hennell, M. Inst. C.E. (E. & F. Spon, Ltd., 125, Strand, London.)

CHAPTER X.

THE MANAGEMENT OF SUCTION-BOXES.

Effects of removal of water—Wear of wire—Marks on surface—Control of "Dandy"—Number of boxes—Amount and distribution of suction—Appliances for vacuum.

QUESTION 26.—*Make some remarks upon the management of suction-boxes with different kinds and qualities of paper.*

A remarks that if stuff is both fine and wet it will have a crushed appearance. To prevent this, the shake should be put back as much as possible, the air-cock of the first pump should be opened, and the air-cock on the second pump-box shut. In the case of coloured papers, if the suction is drawing too hard, colour will be drawn away from the under surface.

B gives an instance of what sometimes happens when working strong wet stuff. The breast roll has been lowered to enable the water to get out as far as possible, a lot of "broke" is made by water flooding over the boxes and "worming" in front of the coucher. This happens more often when the boxes are faced with mahogany than when vulcanite or brass is used. It is pointed out that mahogany has the advantage of being a softer material, and less likely to damage the wire, although it is very liable to cause the wire to vibrate when drawing hard, which necessitates leaving the air-cock open. He remarks that it is better to use a little steam to enable the water to get out than to draw hard on the suction. This is a choice between two evils: it will depend largely upon the character of the paper to be produced. It might so happen that by raising the temperature of the stuff, the paper would be altered in character, and it might be better for the quality of the paper to keep the stuff cool, although there might be some trouble with the suction-boxes.

C points out that when making papers of good quality where the stuff works wet, and for thin papers, where the stuff is also wet, more suction is required than where the papers are of common quality, and the stuff free and long. The reason is that when the stuff is free and long, a large proportion of the water has gone before reaching the suction-boxes.

D explains how that the suction-boxes are designed to draw in and out to suit the different " deckels," and explains the necessity for packing rag in front of the " draws " of the boxes. He states that the disadvantage of this device is that the rag is liable to dry up and allow air to pass; but this can be obviated by having some water to trickle into the stuff. He remarks that when on a machine with two boxes, the first one does the making of the sheet. The air-cock of this first box is regulated according to the amount of water on the wire. The second box has the air-cock always full on. The amount of water required on the " web " at the second box is regulated by the first one. There must be sufficient water brought up the wire of the first box to close the sheet. When sufficient water is not present the sheet cannot be closed properly, and it consequently has a wild appearance, looking like " news." When on the " less side," presumably the side where there is insufficient water, the box begins to " howl " in consequence of drawing air, a small tap is opened on the box to atmosphere, to lessen the vacuum. The tap is kept open until more water comes up the wire. When too much water passes the first box, the second will be flooded; this causes the finished sheet to have a crushed look and also wet stuff to go forward. The amount of water in the stuff after leaving the first box must be sufficient for the " dandy " to make a good impression.

E's remarks are all of them short, but as a rule well to the point, and savour of practical experience. He remarks that when running an esparto paper the boxes must be kept perfectly level with the last wire tube. The boxes should be kept fairly slack, if too slack the paper is broken in appearance. If they are drawing too hard they spoil the water-mark. The steader the boxes draw the more uniform the paper.

F remarks that when the boxes are properly set and level a steady draw must be maintained: the stuff working wet causes more trouble at the boxes. If the water is let too far up the boxes a limpy, broken-looking sheet will result. When working a cover on the under coucher the paper is very liable to " crush " at the coucher, and breaking is the result. When making a " laid " paper, the first box should be shut as far as the "look" of the sheet will allow. He points out that when thick papers are made, the boxes must be made to draw harder, and he calls attention to the fact, as many others have, that too much suction with tinted papers causes a difference between the two sides, and notices this particularly with "azures."

H points out that so much depends upon the various conditions that no rule can be laid down "as to the number of square inches." He leaves it in doubt as to whether he refers to the area of suction-boxes. So much depends upon the good work at the boxes that the regulating of same is a fine art. What is wanted is to draw off as much water at the suction-boxes as possible, but to avoid violent suction, which would not only be injurious to soft, pliable stuff, but would result in an undue amount of mineral matter and fibre being drawn through the wire meshes.

A sheet that is required to be opaque will have to be drawn fairly hard to give it a wild appearance ; this also applies to news which is run at a high speed. In raising the speed of the machine the extra water must be removed by additional suction. In making antique papers, which get little or no couching, a good vacuum must be worked to dry up the "web" as much as possible, otherwise it is apt to stick at the press rolls.

It sometimes happens that the stuff is both soft and fine, and in this case the paper should be sucked as dry as possible to avoid the finished sheet having too crushed an appearance. He lays a great stress upon getting the boxes dead level.

On shutting down for a wash-up, etc., the air-cocks should be shut to allow the boxes being filled with water.

As the pulp comes on to the boxes, taps are opened to form an outlet for the water, and the vacuum thus formed creates a suction, which is regulated by the air-cock. This mode of treatment would be all right for a certain kind of suction only.

I points out that by working the boxes harder, the life of the wire is decreased. Of course, the life of the machine wire has to be taken into consideration, and, furthermore, with very fine stuff containing mineral matter, the suction is liable to draw fine particles into the spaces between the wires, and as these become partially filled up more suction is necessary to draw the water through, and as a consequence the wire is more liable to get injured and worn.

This subject has been discussed in a previous question on the life of machine wires.

J gives as instances thick cartridge paper, which requires a heavy "draw," and thin papers, which require as little "draw" as possible. He points out that it is possible to get stuff so soft that it will hardly stand any "draw" at all. There is a little mystification in the expression.

There is likely to be confusion between Questions 26 and 27, from the fact that the word "draw" is used in one sense in Question 26 and in another sense in Question 27; it would have been preferable to have used the word "suction" or "vacuum" in Question 26.

K.—They (meaning the suction-boxes) must be in proper line with the wire rolls; the ends must be kept in close touch with the edge of the sheet and sufficiently clear to make a dry edge and yet not allow any air to get between.

Boxes of various construction and consisting of different materials are required for different classes of paper; some have wood tops, others mahogany, vulcanite, gutta-percha, etc. They should be designed to produce as little wear on the wire and suction-box as possible, and to keep as even a surface as possible, with a minimum of friction. The last box should be adjusted so as to allow the couch-roll to do its work properly.

L states that the suction-box is one of the most important things in a paper mill—if anything goes wrong with this the paper is spoiled, and the wire likely to be damaged, the couch-roll jacket is sometimes cut in grooves, and perhaps the wet-felt spoiled as well. The early paper machines were provided with one suction-box only, gradually increasing in number up to the present time. The mammoth machines of to-day have as many as four or five, but most fine writing mills have only two. The number of suction-boxes of course depends upon the rate of speed and output, which of late years has greatly increased. When making a blue paper, the colour is often lessened on the underside of the paper by drawing hard at the boxes.

When making a cartridge paper where a rough-looking sheet is wanted, pulling harder on the first box often tends to give it a "wild" rough look.

If the paper is sticky at the press-rolls, a hard pull on the boxes will tend to stop it. In mills where fast running is a necessity, each suction-box has to do its share of helping to get rid of the great quantity of water that is flowing down the wire.

It is claimed that a small suction-box placed underneath the slices and exerting a gentle pull will help to make the paper more opaque and close-looking, thus imitating the suction that is caused by the vatman when taking the mould out of the vat. There are a variety of ways in working the suction-boxes, and a constant watch has to be kept on them, in order that any variation in the condition of the pulp may be rectified. A fast free stuff does not require such a hard pull as a wet soft stuff does, nor a blotting such a hard pull as a bank, or a "loan" or "cartridge." A blue paper does not want pulling so hard (to be a good "even-sided" blue) as a "cream" does.

O remarks that when making heavy coloured paper with mineral dyes, the greater the "water shake" the greater the suction required. The suction may result in drawing more colour to the under surface.

It is suggested that machines which have to run "wet" stuff should have three boxes, so as to divide the suction more; the first two to be held in check by the regulating valve, to regulate the suction as is consistent with closing the sheet. In those cases where the suction is evenly divided between say three suction-boxes, the mark of the machine wire will not be so prominent as when only two boxes are used, for in the case of two boxes the suction may become too violent.

P states that in a paper in which a good "look through" is essential, the water under the dandy requires to be very carefully adjusted. This may be done by regulating the amount of suction at each box. Paper machines have generally two boxes, sometimes three, the last box being usually worked full open, the other two only partly open. A good machineman can often make a good job of indifferently beaten stuff, by humouring it at the suction-boxes. He needs to be constantly on the alert for any change in the condition of the stuff, as when a "free" working engine is emptied into the chest, and *vice versâ* with wet stuff.

The boxes are fitted with air-cocks on "fore side," the first box cock being generally shut, leaving the large box to be controlled by the vacuum. It is generally necessary to have air-cocks slightly open to give the pumps play. Insufficiency of air makes the pumps "roar;" this makes the stuff "dance" on the wire, and spoils the look of the sheet, besides wearing the wire and roughening the underside of sheet by drawing fibre into wire, It is often necessary to have the air-cock full open when working wet stuff with a minimum quantity of water.

Q remarks that as a rule in making a cream laid sheet, if the first box is open very much, the stuff is what is termed "set" on the wire. The dandy roll has in such cases very little effect, the laid mark being broken and the laid lines indistinct. If the first box is kept as nearly shut as possible, but still drawing sufficient to keep the sheet from "watering," the laid lines will come out clear and distinct.

"It is a mistake to have a box 'derling' (if I may use a common expression) under the impression that the box is doing better work: it breaks the make of the sheet and is very bad for the wire, and does not give a steady suction. The first box should never be allowed to draw irregularly, for although its effect may scarcely be seen on the wire, still it becomes evident when the paper reaches the calenders, by the irregular 'piping' on the sheet, which sometimes causes 'creasing,' more especially if the sheet is not very heavy."

S.—"It is practically impossible to lay down rules for the management of suction-boxes. I may say, however, that provided the stuff is in good order for making, say a printing sheet, the first box should be just open enough to allow sufficient water to pass under the dandy roll. If you draw too hard with the first box, you incline to fix the pulp on to the wire, and then no matter how much water you have, you may not have a satisfactory sheet. On the other hand, if you do not draw enough, you will have a watery-looking paper. Keep the last box (two boxes in use) open full. The same remarks apply to laid and wove papers, also antiques, except perhaps for antique-laid, and wove book papers, which are usually very free on the wire; in this case you draw as easy as possible with the first box."

For extra heavy "cards" the first box should be kept well open, or a crushed "look through" may result. For strong papers, which are usually wet on the wire, a good hold should be kept with the first box. Always keep the last box full open, except, of course, when the suction is too great, then either open the air-cock or close the last box a little. The latter course is often better, as it tends to keep the pumps drawing steadily.

V remarks that in making laid papers the first suction-box should be well shut to allow a sufficiency of water to come under the dandy. This enables the stuff to take on a nice mark, and the last box can be used to full advantage. If the last box is drawing too hard, it is better to ease it by drawing up the first box a little more than by opening the air-cock. In making equal-sided antique papers, the stuff should be kept fairly dry on wire, and the suction-boxes should be made to draw light but steadily.

Wove papers require more suction with first box than laids, bringing the water well forward on wire.

Y remarks that a laid paper generally requires a good deal more water than a printing paper. In making "laids" extra water is necessary, because the first box requires to be pretty well opened to prevent the dandy roll from curling or lifting the stuff at the edges, but at the same time it must be wet enough at the dandy roll to give the sheet a good "look through." In the case of a wove paper less water is required than in the making of a laid paper, and the first box can be shut much more without affecting the sheet.

A2 remarks that vacuum boxes are worked by pumps or steam ejectors; some machines have three or four. If worked by pumps, the pumps are driven at a good speed, and there is a regulating tap on the front side of the machine. He considers the system with vacuum pumps to be a good one if the stuff is kept at a uniform temperature. The boxes worked by steam (ejectors) could be used to more advantage on lower grades of paper. He states that they are more certain and easy to control. On the question of the relative merits of the two, there may be a good deal of difference of opinion, the steam ejector might be fairly economical where coal is cheap, but it is certainly more economical on a fairly big scale at any rate to use pumps for producing the vacuum. The fact of raising the temperature of the water and consequently of the back-water, must absolutely prevent the use of the ejector in many mills. There is also a strong objection in many mills to raising the temperature of the stuff at all. The boxes should be rounded off on the edges. In working three boxes the strain or buckle is not so severe on the wire as in working one or two boxes, because excessive pressure on any one box may be avoided.

B2 suggests that it is usual to take the bulk of the water away at the first box, leaving the water visible and just disappearing as the first suction of the second box comes into operation.

E2 remarks that in making a fine printing paper the first suction-box should be closed, and the second suction-box should be opened as much as is necessary to take the water out of the stuff. This remark is applicable to free stuff. For a strong paper, such as cartridge, the first box should be opened, so as to take the water out of the stuff as far as possible; the second box should also be fully opened; in the latter case where dealing with soft or wet stuff, it is important to see that the stuff does not get crushed. This crushing is caused to a large extent by the suction.

F2 gives a very good answer. He deals with the subject more in the way that the author had hoped others would do. He gives specific instances of the amount of vacuum required in lbs., and shows the effect of too much suction upon the working parts of the machine; he also mentions the uses of "self-vacuum," and gives distances where the "false end" of the first box should be inside the web.

"Suction-boxes, on all papers where a dandy is used, should be worked so as to appear just moist under the dandy, which is generally placed before the last box. In news, printings, esparto, and straw papers, the stuff is usually fairly free, though the speed of the web is much greater than with rag papers, *i.e.* 150 to 450 feet. The vacuum for boxes making these papers should be about 6 lbs., the web being left nice and moist after leaving the last box but one, so as to receive a good impression from the dandy. Sulphite "caps" and blotting papers work very free, both being quickly prepared, while sulphite stuff always works free. No dandies are used on these papers, and the water is often removed by self-vacuum; in some mills a little vacuum is exerted by pumps. Writing, loans, and rag papers in general retain their water very obstinately, due to long beating, and a strong vacuum of from 9 to 12 lbs. is needed. Papers which are heavily loaded with clay, ochres, etc., always work very wet, and the boxes must draw keenly.

"Boxes which are worked by self-vacuum must be filled up with water before the stuff is run on the wire. To start the vacuum, the delivery pipe must be curved upwards at the bottom, or air will enter the box. Air will also enter if the false box end is beyond the edge of the web, and will cause the suction to fail. In the wetter working papers, steam ejectors or pumps are used. The false end should be packed round with rag stuff, and water should be kept running over into this portion, or the box will draw air. The false end of the first box should be a quarter of an inch inside the web. If outside, the box will draw the deckel straps and cause them to slip. If the pumps draw too keenly when the taps are shut, a "backlash" is often produced; this may crease the edges of the web and produce breaks at the calenders. This may be overcome by putting in another box, so reducing the vacuum, or the stuff may be beaten so as to work "free." Paper dyed with pigments will often be light in dye on the bottom side if drawn too hard at the first box.

General Remarks.

The papers are so much more valuable where figures are given. There is very little value in a paper that deals only with generalities, as some do. It would be far better to give specific instances, even if the result of a limited experience, than to attempt to generalize and often guess, and to assume a greater knowledge and experience than is justifiable. I place much more value on answers which savour of practical experience.

Reference might well be made by some of the students to the number of boxes, the available suction area of each box, the amount of water removed at the first, second, and third boxes per hour or per minute for a given output of paper, and how the water is apportioned as between the first, second, and third boxes; also when it is advantageous to use only one box; when two, three, and four. Furthermore, the relative merits of "syphon" as compared with plunger pump and steam exhaust. A few more figures dealing with these points would have added very materially to the value of the answers.

Of course, when the stuff comes on to the wire with a large proportion of water there is a lot of water to be removed at the suction-boxes. The proportion of water to fibre and the rate of output affect the work to be done by the suction-boxes, and it is not a very difficult matter to arrive at the actual amount of water taken away by the suction-boxes for any class of paper, when once the output of the machine is known, and a sample of the stuff as it passes on to the wire is taken and estimated for the amount of fibre, and the amount of water draining away from the wire, etc., has been measured. The force that has to be exerted to draw the water from the paper and wire is largely influenced by the closeness of the stuff, and in a measure by the mesh of the wire. If the wire is new and not blocked up, the water is more readily pulled through than when the wire has become rough and blocked up to a large extent.

CHAPTER XI.

THE SHRINKAGE OF PAPER ON THE MACHINE.

Means of control—Adjustment on machine—"Cross" shrinkage—Wet stuff—Amount of water—Length of stuff.

QUESTION 27.—*How can you control the shrinkage of a paper, both in the "machine" and "cross" direction during its manufacture on the machine?*

This question is a fairly specific one, but it is one upon which so much depends, and no doubt in giving answers it is rather difficult to avoid discussing other questions of a similar nature. The author's intention was that the subject of beating and the condition of the stuff, or rather alterations of the conditions of the stuff, should be left alone, and that with any given stuff which the student might like to name, passing over the machine for the production of a given paper under conditions which he might specify, the question of shrinkage in both directions should be discussed.

A shows that the shrinkage can be controlled by putting all the weight possible on the couch-rolls and working the press-rolls as hard as possible, also by driving slowly and shutting off most of the steam at the first one or first two of the drying cylinders, and he explains that this is advisable, because when wet paper comes in contact with very hot drying cylinders it is almost sure to shrink. By eliminating the water as far as possible by pressure before it reaches the drying cylinders, and leaving less work for the drying cylinders to do, the drying becomes less sudden and the shrinkage reduced to a minimum.

B points out that there is always an allowance made with the dandy roll, but, of course, whatever allowance is made in the name or relative positions of the names, so as to allow for any alteration in the web of the paper whilst drying, it can only be considered as an average allowance, because the shrinkage will vary with the thickness of the stuff of which the paper is made.

He states that should the distance turn out short, by which, presumably, he means should the shrinkage be too great in the finished sheet bringing the names too close together, the "draws" will have to be tightened by adjusting the packing of the rolls, or altering the cones if upright draws are used, or *vice versâ*.

If the name is liable to cut too much, as sometimes happens when making name papers, he points out that the dandy roll should be hung lightly, etc., so as to revolve more slowly. This question has been discussed in the columns of WOOD PULP under "The Management of the Dandy," and is really outside the question we are here considering. Altering the dandy in this way does not affect the expansion or shrinkage of the paper, but merely affects the distance of the names by causing the dandy to drag. The same remark also applies to the question of placing something round the exposed ends of the dandy so as to make it revolve more slowly.

C goes into the subject of altering the shrinkage by altering the "shake" of the machine. If the stuff is short and beaten finely the paper is more likely to shrink than if the stuff be long and free. It is difficult to understand what is meant here; presumably if the stuff works wet even if beaten finely it is more liable to shrink than if long and free. The length of the fibres would not have so much to do with the shrinkage as with the condition of the stuff, that is, whether "free" or "wet." Of course, if the stuff works "wet" the shrinkage can be diminished by turning on steam, which tends to make the stuff work free and to reduce shrinkage.

D says that when there is too much water in the boxes the sheet stretches; with less water it contracts. This is noticed at the cutters on name paper. The foremost of the cylinders of the machine should only be slightly heated to prevent sudden contraction. Sudden heating is to be avoided as far as possible; it not only brings about increased and rapid shrinkage, but also very much reduces the strength of machine paper. Unfortunately, with many of our fast running machines it is a difficult thing to avoid. The shrinkage on the cross direction of the machine is regulated by the "draws," couch-roll and press-roll. When the machine-man wants to enlarge his deckel a little without drawing out his deckels, he slacks the "draws" between the rolls. The slacker the "draws" the less contraction across the web and *vice* *versâ;* the same should hold good for the machine direction for the web.

Should the felt travel faster than the wire, the web would be stretched in the length and contract across.

In order that there should be uniformity in strength as well as in contraction, there should be a uniform stretch exerted in both directions, but the stretch should be as slight as possible; unfortunately, these conditions are seldom obtained in practice.

H gives a very fair answer, which is here given:—"The shrinkage of the web on the machine is controlled by the adjustment of the 'draws' and drying power. In the first place, however, the condition of the stuff as it comes from the chests has some bearing on the question. Stuff which has been rendered 'wet' by long beating or standing, has a tendency to greater shrinkage, but nevertheless results in a stronger sheet. Steam applied to the stuff in the strainers or sand-traps will make it work more freely.

"Expansion in working a paper is less in the machine than cross direction, owing to the fibres in the former direction having been drawn out to a greater extent. The wet soft sheet as it leaves the wire stretches, and this is noticed more with a thin sheet than a thick one. Therefore, in changing from a thick to a thin sheet it is necessary to reduce the relative speed of the wire to allow of the web being taken up. The stretch can also be slightly affected by the pressure given by the top couch-roll, the drier it is couched the less liability to stretch. In regard to the 'cross' direction, the lighter the 'draws' are kept the greater the shrinkage. To obviate this, as far as practicable the 'draws' should not be kept too tight. Drying also should be regular and uniform."

The shrinkage depends largely upon the beating of the stuff. Taking a specific case, cited by **I**, where, under ordinary circumstances, there is a total width of web of 70 in., and where an engine got off hurriedly and emptied down increased the width of web to 71 in. On the other hand, if you emptied the engine of stuff which had been beaten so as to make it work wet, instead of having a width of 70 in. you would now only have a width of $69\frac{1}{4}$ in. This shows that a great difference in the width of the sheet may be due to a difference in the beating, amounting in all from one extreme to the other to $1\frac{3}{4}$ in., on an average width of 70 in.

I remarks that when making a paper 60 in. in width it is possible to reduce it fully half an inch by tightening up the "draws."

K remarks that the only means he knows of by which shrinking on the machine can be controlled is by so manipulating the stuff that it is in a condition to dry as easily as possible. Papers should be dried at the lowest possible temperature. All "draws" on machines must be made to tighten or slacken as required by the amount of stretch or shrinkage, etc.

The idea of altering the beating to suit the shrinkage was not intended to be discussed as part of the answer to the question, because it would be quite impracticable in most instances. L states, by having a sharp plate in the beater, a soft rag furnish, and by beating quickly, a paper can be produced that will not shrink when it reaches the cylinders. One or two have gone wrong in this matter. The above reply is an answer to a different question ; it would be an appropriate reply to the questions, "How can you prepare a paper which will not shrink, or what papers do not shrink on the machine ?" Then again, the question asked was how to *control* the shrinkage, not how to prevent it. In a certain measure shrinkage may be necessary. Thus, in order to bring the name in the right place. If the stuff were absolutely devoid of "shrink" it might be impossible to get the name in the right place in the sheet. You must assume that the stuff does shrink, as it does very materially nine cases out of ten.

It is possible to control it by slackening back the second press-roll and throwing the slack back on to the first press-roll. This slackening back the first press-roll and throwing the slack on to the wire, controls the stretch in the machine direction, and also the width of the paper.

O remarks that the harder the paper is pressed, the less it will shrink. And the author assumes from his answer that he considers that the shrinkage is minimized by having good and well-fitting dry felts. In proof, he says, that the harder you use the weight on the presses, the less the paper will shrink. Take an example of a one-cylinder machine, the paper made on this machine will not shrink more than a quarter of an inch, owing to its having been evenly pressed. This is a very general statement, and, although the author has no reason to doubt its accuracy, there is not sufficient evidence in the answer to show that in the particular instance cited the small amount of shrinkage is due to regular pressure ; it might, from all any one can gather from the answer, be due to some independent cause.

"It was after reading an article on shrinkage in your journal a few weeks ago that I decided to test for myself what the shrinkage of paper amounted to. We were running a named dandy at the time on an all-wood paper. Length of sheet from the circumference of the dandy was exactly 22 ins.; after going through the couch-rolls the name had stretched to 23 ins. I also took out strips after going through both presses, and also from the finished paper, but they all measured exactly 23 ins., thus proving that there is no shrinkage in length on the cylinders.

"I have taken the shrinkage in width several times, and they all seem to work out nearly the same. Of course, the wetter the stuff the more it will shrink; but this is about the average:—

Between the deckels on the wire ...	$74\frac{1}{2}$ ins.
After couching	$74\frac{1}{2}$,,
After going through first press	$74\frac{1}{4}$,,
The finished paper on the reel	72 ,,

"These measurements were made when working on a good imitation parchment paper. Paper made from very fine stuff shrank 3 ins. in width."

P shows that as wet stuff will shrink more both in the cross and in the machine direction than free stuff, it is important to get the stuff in the same condition throughout. It is certainly important that the beating should be kept uniform for any given paper. If there is a long run on any particular kind of paper, take, for instance, some name paper, any irregularity in the beating is easily noticed, as it often happens that beating cannot be conducted from day to day or from hour to hour under similar conditions, so the stuff is bound to come along somewhat irregularly. As the onus of keeping the paper right is thrown upon the machine-man, he is compelled to exercise his ingenuity in correcting any changes in contraction due to any changes in the condition of the stuff itself. In going off from a thin paper to a thick one there will be a greater contraction in the machine direction, and it will be necessary to allow for this by slowing back the speeds of sections (comparatively to one another), otherwise there will be too great a tension between sections, and "breaks" will result.

To keep shrinkage at a minimum the various "draws" must be very nicely adjusted, more especially the draw between the couch and press rolls. **Q** argues that as the cross shrinkage is diminished, so also is the stretch in the running direction.

S.—"The shrinkage is always as the stuff makes it. The least shrinkage I have observed amounted to one-eighth in. in

12 in. on the finished sheet after being wet. To reduce the shrinkage to this extent, it is necessary to keep the stuff fairly long and not too wet on the wire. Also to keep the "draws" at the wet end as slack as possible, and have the press-rolls well down so that the paper goes to the dryers as dry as possible. Keep the first two cylinders moderately cool. For "named" papers you can manipulate the size with the draws at the wet end."

V.—"Shrinkage may be controlled by using suction-boxes, couch-rolls, and press-rolls to full advantage. Bring the paper on to heated cylinders as dry as possible. Slacken in "draws" as much as possible. If the paper comes in a very wet state into contact with the heated cylinders, there is a good deal of shrinkage across the machine; it is for this reason that soft or wet stuff shows more shrinkage than free or dry stuff."

The above answer is perhaps somewhat misleading. It is not due to the fact that there is less water in the case of the free stuff as it runs on to the cylinder that it shrinks less. It is due to the fact that the one is in a more hydrated condition than the other. You might leave the "free" stuff practically wet and press the "wet" stuff so as to make it much drier, and it would be found that the "wet" stuff, other things being equal, would have a greater tendency to shrink than the "free" stuff.

Y states that he has seen a sheet stretch from half to one inch with soft stuff and has seen it contract as much. I gather from this that there is a difference between the width of the deckles and the dry web of anywhere from half an inch to two inches.

This confirms the remarks made by a previous student, but does not state on what width of web this contraction takes place. One-inch contraction on 50 in. would be two inches contraction on 100 in., and so on.

A2's remarks in answer to this question are worth noting, but like the rest he does not express himself quite clearly. He evidently intends to describe the conditions which will prevent shrinkage, but not the conditions which would enable one to control it, which is quite another thing:—

"To control shrinkage in machine direction, have the sheet well put together on the wire by the right amount of shake and water, and apply reasonable weight on couchers and press-rolls. Dry the paper gradually, beginning with a low temperature in the cylinders at the beginning. If the cylinders are all of the same diameter they will help to stop the web from shrinking in the machine direction.

"Remarks in reference to the machine direction, with the exception of diameter of cylinders, also apply to cross direction. Having the stuff well drawn out and wet will prevent it shrinking in the cross direction."

B2 remarks that all papers, when run on the machine, are liable to shrink more or less, and, to control this, the machine must be speeded up differently, as the shrinkage occurs. He shows that in some instances the travel of the wire has to be greater than that of the dry end to prevent breakage.

D2 states that the drying is controllable both before and after the web enters the size. Presumably he refers to control of shrinkage. Paper, as it passes into the animal size is, generally speaking, bone dry. If it is not bone dry, it is liable to soak up too much size and to break in the sizing trough. The drying, therefore, has to be completed for this reason. But as regards shrinkage, it is quite possible that the sheet has altered its dimensions from the fact of its being wetted again in the sizing trough and re-dried on the skeleton-drum driers or the festoon driers at a much lower temperature, and with little or no tension. This would tend to make the paper stronger. It might also affect the shrinkage. The researches conducted after the above remarks were made and published in the "Fibrous Constituents of Paper," might with advantage be consulted, as this question is gone into in detail.

E2 remarks that if it is required that a paper should shrink very much, there should be very little pressure on the press, and the cylinders should be as hot as possible, so as to dry the paper quickly. On the other hand, if it is required to make the paper without any shrinkage, the cylinders should be fairly cool, and get hotter towards the end, so as to make the drying more gradual.

F2 gives a very fair answer, and he deals with the subject much in the way the author would have liked the others to have done, and for their benefit his paper is given in full below :—

"The shrinkage of a paper depends on the 'draws' of the various sections of the machine, on the length of the stuff, and the material used. If the 'draw' from wet felts to wire, second to first press, cylinders to second press, calenders to cylinders (in a lesser degree), are tight, the paper will *expand* the machine way at the expense of the cross way, due to the continual drawing of the sheet. The contraction may be reduced in the cross way to a minimum by allowing all the draws to be slack, the machine cylinders also decreasing in diameter to the calenders, so as to keep the draws slack. If a 'worming' is put on the felt-roll leading to the nip of the press, from the centre to the sides, the wet felt is opened out, and consequently the paper too, which counteracts some of the shrinking in the cross direction. Long stuff expands much more than short stuff ; the shrinkage is therefore less in the 'cross' direction with short stuff. A well-felted sheet shrinks less in the cross way and expands less in the machine way than a badly-closed sheet, due to the fibres lying close together. Linen, cotton, and hemp expand more than mechanical wood, straw, esparto, etc. All heavy-loaded papers expand and contract very little, on account of the loading being of a non-fibrous nature."

CHAPTER XII.

PAPER THAT DOES NOT SHRINK OR EXPAND.

Suggested methods of manufacture—Effects of heat, moisture, and fibrous constituents

QUESTION 28.—*How far is it possible to make a paper, either by Fourdrinier or cylinder machine, which, when once made, neither expands nor contracts with change of moisture in the atmosphere?*

A.—"I made several tests on this question in the following manner. I first thoroughly dried the papers on the heated cylinders and then measured them. I next damped them, allowing them time to expand, and then measured again, and thus arrived at the extreme contraction and expansion with heat and moisture. One paper, a very hard one—namely, a photo paper —was measured, and after passing round the hot cylinder, placed in cold water for four hours, and then measured again, when I could detect no alteration in dimension whatever. The substance of this paper was 36 lbs. per ream of Double Crown, and was made from clean cotton rags which were washed, bleached, and 'broke' was added in the washer, then emptied stuff into strainers; bleaching solution was drained away, and the half stuff laid in the drainer several days. It was then lifted and again filled into the washer, as there was still a trace of bleach which had to be washed out. When this was done, the half stuff was emptied into the beater, and 5 per cent. of a special rosin added, reckoned on dry weight of paper, and when this was thoroughly mixed with the pulp, it was precipitated with the best alum. The stuff was beaten for about four hours as fine as it was possible to get it. On the machine a good shake was given to make a very close sheet. The stuff worked very wet and sticky. The couch roll was run light, for fear of crushing the sheet. The press rolls were worked fairly hard. After passing the cylinders, on which it had shrunk considerably, the paper was passed along a section of the skeleton-drum drier and reeled, and then passed through super-calenders four times, twice running light, for fear of crushing, and twice with all weights on, bringing pressure up to 34 tons. I consider the resistance of this paper to heat and moisture, in regard to expansion and contraction, to be due to the large amount of rosin cementing the fibres together at the cylinders, and the severe treatment the paper received at the super-calenders. Another instance in which the expansion and contraction was only slight was in the case of drying 47 lbs. Royal; the difference in this case between bone dry and damp was 5 per cent. in cross direction, and nothing in machine direction."

There is not much to be said on the above answer. He gives an account of the manufacture of a paper which he finds expands and contracts very little with moisture and heat. It would be better to show in what manner these various details of manufacture affect the question. I would suggest that the rosin prevents the absorption of moisture, and by so doing prevents change in dimensions; but there are other considerations which account for papers not changing in dimensions, even if they do take up water on exposure.

B.—"The stronger the materials used in the manufacture of the paper and the longer the beating, other things being equal, the more expansion and contraction in the finished sheet. You can control it in a measure by beating the stuff and undoing the wetness, or by having a sharp plate in the beater and furnishing with a soft rag, which is beaten quickly and fine. The stuff should be well put together on the machine wire, by adjusting the amount of water and shake, as a well-felted sheet expands less in the machine way, and contracts less in the cross way, than a badly closed sheet, due to the fibres lying close together. The "draws" at the wet end should be kept as slack as possible, by putting all weight on the couch-rolls and working the press-rolls as hard as possible, to deprive the web of water as much as possible before it reaches the hot cylinders, and keeping the first two cylinders moderately cool to ensure gradually drying. Great care should be taken in the drying, as the paper often leaves the cylinders too dry, and when in contact with the atmosphere for some time becomes air dried or damper than when it left the cylinders, resulting in a considerable expansion in the finished sheet."

B is apparently wrong in making a general statement to the effect that putting the stuff together while on the machines, and adjusting the amount of water and shake, would result in the production of a sheet not liable to expand or contract. If a well-felted sheet expands less in the machine direction, and contracts less in the cross direction, than a badly-felted sheet, it would hardly be due to the fibres laying closer together. We would expect that this would tend to the opposite effect.

In a paper which bulks well, there are as we know considerable air spaces, and the fibres are able to expand and contract individually, to a great extent, without causing the sheet, as a whole, to expand or contract in a like proportion. When, however, the paper is well felted together and compact, the air space is very much diminished, and the paper, on the whole, partakes more of the nature of the cellulose fibres of which it is composed, as regards its expansion and contraction under different atmospheric conditions. No better exemplification of this can be given than by comparing a sheet of amorphous cellulose, prepared from cellulose thiocarbonate from blotting, with a sheet of blotting-paper—the same blotting. The former, if suitably prepared, expands and contracts enormously with change of moisture in comparison with the expansion and contraction of the latter. But if the fibres of which the latter are composed could be examined and compared as individuals, there would be found a very considerable amount of expansion ; the expansion tending to fill up the air spaces, and the contraction tending to diminish them. In this latter case the interstices of the paper become smaller as the ultimate fibres expand.

H.—" As far as my experience goes, all machine-made papers expand and contract after being made, but the degree of expansion and contraction depends on various subordinate conditions, and for their consideration I would class under three heads what I consider these conditions to be.

" 1st. Nature of materials used, and their affinity for water.

" 2nd. Treatment of raw materials in the mill.

" 3rd. Treatment on machine, and amount of moisture left in paper.

" 1. The flexibility of the cellulose fibres is increased by water, and the degree of affinity for water of the materials used will thus affect their flexibility in working. The nearer a fibre approaches to pure cellulose the lower will be the amount of hygroscopic moisture it contains, which will be in proportion to the quantity of non-cellulose present in the paper. As non-stretching and contracting characteristics are most to be desired in printing and lithographic papers, the materials best suited for their manufacture would seem to be cotton and esparto, with 15 to 20 per cent. loading. The sizing, as affecting the arrangement of the fibres when under the action of the 'shake,' has considerable effect on the question. I have experimented with some papers by wetting them, and give two results for comparison. The sheets measured 10 in. by 6 in., and under the action of the water stretched as follows :—

	Machine direction.	Across.
Ordinary printing paper	... $\frac{1}{32}$	$\frac{4}{32}$
Unsized ,, ,,	... none	$\frac{2}{32}$

H remarks that the nearer the fibre approaches to pure cellulose, the lower will be the hygroscopic moisture, etc. This is true of any one fibre, such as wood ; thus the hygroscopic moisture of mechanical wood is less than raw wood from which it is produced, and the chemical wood is less than that of the mechanical wood, if measured with the same class of wood and under the same atmospheric conditions. But it does not follow that pure cellulose fibre from wood contains less moisture than impure cellulose fibre from jute or cotton, as the natures of these fibres are entirely different, as is also the moisture which they retain under the same atmospheric conditions.

The above measurements of expansion in the two directions would be of more value if expressed in percentages on the total length under observation.

I.—" It is a difficult matter to make a paper which is not affected by atmosphere, but it will help if the fibre is beaten up quickly and not got off too 'wet.'

" A strong linen paper worked wet is more liable to expand and contract."

J.—" Expansion and contraction of paper in a moist atmosphere depends :—1st, On length of fibres ; 2nd, conditions of hydration ; 3rd, amount of loading ; 4th, condition of making ; 5th, kind of fibre ; 6th, sizing.

" 1. A paper with the fibres well knit together does not contract or expand with the moisture or dryness of the atmosphere like one which is badly made on the machine. The best condition is, therefore, 'a mixture of long and short fibres.'

" 2. The hydration of cellulose influences the question. The more a fibre is hydrated, the more it is acted on by moisture. Therefore, the 'faster' the stuff the better.

"3. The amount of loading also affects it, as the more a paper is loaded the less it will stretch.

"4. To make the paper with as little 'stretch' as possible, the 'draws' should be kept slack, and the drying regulated and made as gradual and even as possible to prevent any sudden contraction. The stuff may be heated by steam to dehydrate it as much as possible.

"5. Cottons would be less apt to expand or contract than linens, and esparto less than wood.

"6. Rosin sizing would be better than caseine or glue, and caseine preferable to glue. Glue takes up moisture quicker than the two others as it is more on the surface, and on account of its physical qualities."

The last sentence of J's first paragraph as to length of fibres I am inclined to agree with, so far as my experience goes. As to paragraph 5, on the kind of fibre, I should judge that J is quite correct. He has, furthermore, given a fair statement in regard to paragraph 6, but he might have qualified it slightly by showing that the amount of moisture retained by caseine is very much influenced by the presence of formaline, especially as applied to surface-coated papers. This would, in a measure, apply to gelatine also.

L.—"There are a variety of factors that cause contraction, and the paper that contracts the more will, with a change of atmosphere, expand the most. Some causes of elongation and expansion are :—

"1. The use of linen or other strong rags.

"2. Prolonged beating.

"3. 'Speeds' pulling tight.

"4. Too hot drying cylinders.

"5. Cylinders that are of too great diameter at the dryest end.

"6. Getting the paper too dry before sizing.

"I will now proceed to suggest some means whereby the contraction of the web may be lessened by following the undermentioned advice :—

"1. Use a mixture of 80 per cent. soft cotton rags, and 20 per cent. sulphite wood.

"2. Have beater plates and rolls fairly sharp.

"3. Do not have engines loaded too heavy, but keep them travelling fast.

"4. Beat in two hours, not too fine.

"5. Use steam in back water of machine, as steam helps to dehydrate the fibres and makes them more inflexible as they contract. (It has been shown in PAPER AND PULP that the fibres contract in hot water.)

"6. Press paper as hard as it will stand it, and without damaging it.

"7. Leave the speeds as slack as you can from the wire to cylinders.

"8. Keep first cylinder only warm, and gradually increase the temperature as you go along, having the last ones hot.

"9. Do not over-dry the paper, but try and leave quite 7 per cent. moisture in it.

"Having named the causes and suggested a cure, my opinion is that when a paper that shrinks up a lot is made, it has a fibre that is swollen out, and when this comes on to the machine wire it has its width given to it by the deckle straps. This is where our width starts from. The swollen fibres are very flexible, and when they have been 'couched,' pressed, and dried the contraction is very great.

"But if they had not been hydrated or swollen out they would have laid on the wire more rigid and inflexible, and there would not have been the water to dry out. The paper would have been hard and brittle, with scarcely any contraction.

"As to imitation hand-made paper made on cylinder machines, which seems to have the appearance of hand-made by having a rough or a deckle edge, when these are tested for stretch or breaking strain they show a great difference in quality to a real hand-made, namely a difference of about 36 per cent. between lengthways and across the sheet, against scarcely any difference in a real hand-made paper. My remarks in respect to the Fourdrinier machine therefore apply equally to a cylinder machine."

Speaking of hand-made papers, it is a very unfortunate circumstance, and one which tells very materially against hand-made paper, that there are many on the market which show as great a difference in strength in the two directions of the sheet as ordinary machine-made papers.

The hand-made papers, the tests of which were given in the report issued by the Society of Arts, show that there is very little difference in strength in the two directions.

P.—"Papers made from 'free' stuff, stretch more than from 'wet' stuff on absorbing moisture; this is probably due to the fact that with 'wet' stuff the fibres are hydrated, and therefore expanded and distended with water. When dried on cylinders they lose this water, and contract to a far greater extent than when 'free,' in which state they are not so hydrated. 'Wet' fibres before contraction are more flexible, and as the ends of fibres are generally frayed and drawn out instead of cut (as with 'free'), they are more thoroughly interlaced on the wire, and when contraction takes place there is bound to be a tightening and stretching of the fibres in all directions. This will take the stretch out of them (much in the same way as the 'draws' of a machine take stretch out of a paper in machine direction), and consequently diminish tendency to stretch after manufacture.

"Tests of samples drawn from same paper—

CROSS DIRECTION.

	Sample 1. Stuff normal.	Sample 2. Stuff extra soft.
Width taken	60 ins.	60 ins.
Stretch on exposing outside in the open air	$\frac{7}{16}$ in.	$\frac{3}{8}$ in.
Percentage stretch	0·7291 per cent.	0·625 per cent.

"This was the only test I was able to make on the same paper where there was an appreciable difference in the softness of the stuff. But as the samples were taken on consecutive days, the hygroscopic moisture of the air may not have been the same, and therefore the conditions were not exactly the same. (The approximate furnish was 70 per cent. esparto, 20 per cent. sulphite wood, 10 per cent. clay.)

"Calendering—either plate glazing or supercalender; where the paper receives a heavy squeeze, the paper is stretched in both directions. This stretch is permanent, and the paper is then unaffected by moisture. The explanation (Battersea Polytechnic) by Mr. Beadle is thus given in his Lecture No. 8. 'Compression brings particles permanently into close contact and, being free from tension, they have no desire to take up water.'

"I have known P.G. esparto paper, Demy size, stretched about $\frac{1}{8}$ in. narrow way from the pressure of glazing; with rag papers the stretch is not so apparent.

"The more loading present in a paper, the less cellulose, and therefore less tendency to contract and expand, the atmospheric moisture having no contracting and expanding influence on minerals.

"Fibres not lying in the same plane as the surface of the paper will diminish the longitudinal expanding and contracting properties of paper.

"This, of course, will occur at the expense of the breaking strain, because, supposing the theory was carried to extreme—that is, all the fibres being vertical to plane of surface—then the paper would have no strength at all, the expansion would affect the thickness of the sheet and not the length of the sheet, except where due to increase of diameter of fibres, which is practically negligible (?) compared to increase of length of fibres.

"If there be any foundation for this theory, and in order to carry out the idea practically—that is, to produce a paper with a reduced tendency to contract and expand with change of atmospheric moisture, Annandale's patent wet end might have the desired effect, where we have a pump box at breast-roll end of the wire, the effect of which would be to fix or set the fibres right away up at breast. Where they are lying in all directions in tangled masses, a great many must be in vertical position which otherwise, under the usual treatment, would have been shaken horizontal while travelling along the wire."

P takes the very necessary precaution of calculating the expansion in percentage for the purpose of comparison. The "stretch," or possibly it would be better to call it the "spread," of the paper is due to plate glazing or calendering, and is somewhat affected by the amount of moisture contained in the paper at the time the operation is conducted. Furthermore, the surface produced by means of plate glazing is affected by the amount of moisture, as unless the paper is sufficiently dry the surface will not be obtained to the best advantage. Crushing results from over glazing, the cell wall of the fibre being literally flattened, and in proportion as the interstices become filled up by this flattening operation the transparency of the paper increases; its rigidity also increases, but beyond a certain point its strength diminishes, and it may become so brittle that it will not bear folding. I think it will be found, generally speaking, that the elasticity on taking the breaking strain is diminished in proportion as the paper is permanently spread by the compression of the rolls.

D2.—"1. The raw material must be taken into consideration in the manufacture of a paper which neither expands nor contracts. A soft cotton rag paper which is finely beaten and working very free on the machine should not shrink on the machine; also if free from loading, such as china clay, which readily absorbs moisture. In making papers of long, strong fibres, such as banks and loans, which shrink considerably on the wire while making up, the drying should be steady and not too hard. After passing over the hot cylinders at the dry end, it should be run round a cylinder through which cold water is passing, so that when taken into the salle (the air in which is at a lower temperature than the machine house) the paper is, practically speaking, cold, and no longer liable to take up moisture. A hard, tub-sized paper should be almost damp proof. The absence of the sizing agent admits of the fibres retaining their natural elasticity, and being shaken into position more at right angles than usual. This not only results in a strong paper, but reduces and equalizes its stretching property.

"2. It is well known that wet stuff gives increased shrinkage in the web, although resulting in a strong paper. The sudden change from its natural condition when in contact with the hot cylinders will, when wetted again, increase its tendency to resume its normal condition, with accompanying trouble in working. Stuff, therefore, for litho paper should be kept free and fine, so as to part with the water readily, and give a close-felted sheet under the shake of the wire. Mr. Clapperton, in his book, states that a 'fine' engine will draw in the sheet as much as $\frac{1}{8}$, while longer stuff will cause it to expand proportionately.

"3. While the beaterman can very materially help the machineman in producing the desired quality of paper, the final treatment on the machine decides, I think, to the greatest extent, how the paper will turn out, and the remarks in No. 1 have here a distinct relation.

"Paper shrinks in proportion to the amount of moisture abstracted, and as it only regains its original properties after acquiring the amount of hygroscopic moisture proportionate to the quality of materials used in its manufacture, the amount of moisture left in the finished paper will thus decide to a certain extent the degree of expansion. If the fibres are 'free' and 'fine,' they will be more likely to be shaken both in lateral and longitudinal directions, and this will tend to equalize the stretch.

"Annandale's patent for accomplishing this double action is the nearest approach to hand-made paper I know of. Of the treatment of the web on the machine much has been said in answer to other questions, and I would just add that to reduce the stretch to a minimum, the machine should run with all the 'draws' as slack as possible, consistent with avoiding cockling, and the web well couched before passing to the drying cylinders.

"I believe I shall be going beyond the question in saying something in regard to the finishing of the paper, and crave indulgence for the digression. With the idea of ascertaining the effect of super-calendering and plate-glazing printing papers, I tested a few sheets in the same manner as those mentioned in No. 1.

"The results were:—

	Machine direction.	Across.
Super-calendered paper ...	$\frac{2}{32}$	$\frac{8}{32}$
Plate-glazed paper ...	None	$\frac{6}{32}$

"For high-surfaced papers for lithographic work, plate rolled would seem to be the most suitable. All papers for such work should be cooled before being used, either before leaving the mill or in the printers' premises. I may mention that the papers mentioned in above experiments on being dried shrunk back to their original size."

The point dealt with in the latter half of D2's answer is a very important one. Paper when cold and when still exposed to the atmosphere, rapidly assumes its natural moisture, but so long as it remains hot, especially if reeled or in the form of reams, it takes longer. Some time ago I tested this point, and took the rate for every minute of the increase of weight due to the resumption of natural moisture. The rate of gain is very great at first exposure, and increases. It reaches the maximum rate of gain, after which the gain is slower, taking in all about 30 minutes before it comes to a state of equilibrium. If paper is taken hot from the drying cylinders, it is important that it should be allowed to cool before being glazed, but where it has come off the skeleton drums of the air-drying machine, it has had a chance of reaching its natural condition by the time it comes to the cutter, should it be still a little too damp, owing to insufficient drying. From steam-drying cylinders, however, the general tendency is to leave the cylinders too dry. The chances are, therefore, the paper will require considerable exposure before it is normally air-dry.

Inasmuch as the expansion and contraction of paper after manufacture is connected with the contraction which takes place in the course of drying during manufacture, the following results may be of some interest.

The measurements were made on small hand-made sheets, consisting of mixtures of mechanical and chemical wood pulps prepared by Mr. R. W. Sindall and myself.

SHRINKAGE OF PAPER MADE ON HAND MOULDS.

No.	Mechanical.	Sulphite, bleached.	A. x by y.	B. x by y.	Mean. x.	Shrinkage x.
1	100 per cent.	...	168·0 by 93·0	165 by 91·5	166·5	0·3
2	90 ,,	10 per cent.	165·0 ,, 91·0	164 ,, 93·0	164·5	0·9
3	80 ,,	20 ,,	164·0 ,, 91·0	164 ,, 91·0	164·0	1·2
4	70 ,,	30 ,,	165·0 ,, 91·5	163 ,, 90·5	164·0	1·2
5	60 ,,	40 ,,	160·5 ,, 90·0	163 ,, 90·0	161·7	2·6
6	50 ,,	50 ,,	162·0 ,, 90·5	162 ,, 90·0	162·0	2·4
7	40 ,,	60 ,,	161·0 ,, 90·5	160 ,, 90·0	160·5	3·3
8	30 ,,	70 ,,	160·0 ,, 90·0	160 ,, 90·0	160·0	3·6
9	20 ,,	80 ,,	159·0 ,, 89·0	160 ,, 89·5	159·5	3·9
10	10 ,,	90 ,,	161·0 ,, 90·5	160 ,, 89·5	160·5	3·3
11	5 ,,	95 ,,	160·0 ,, 90·0	160 ,, 90·0	160·0	3·6
12	...	100 ,,	160·0 ,, 90·0	160 ,, 90·0	160·0	3·6

Size inside of deckle, 167 by 91 mm.

We notice that mechanical has undergone little or no contraction. As the proportion of sulphite pulp increases, so also the contraction increases, up to 80 per cent. of sulphite. With papers containing 80 per cent. and over of sulphite pulp the contraction remains almost stationary; if anything, it is somewhat less. The maximum natural contraction, therefore, appears to be found in a paper containing 80 per cent. of sulphite pulp. It should be mentioned that the above papers were sized with 1 per cent. of rosin and the necessary amount of alum.

Another and a similar series of measurements were made on a mixture of mechanical wood and cotton; the results, however, were not so conclusive. The contraction in length of the sheet was very slight, being greatest in the sheets containing either a large proportion of mechanical wood or a large proportion of cotton, some of the intermediate mixtures showing no contraction.

There is much to be learned by measuring the natural contraction of such mixtures. Inasmuch as such sheets are dried without any tension, and dried slowly without heat, they do not give one a correct idea of what changes in dimensions would take place on the paper machine, especially on a fast running machine. But what they indicate is the inherent or latent qualities that such mixtures have, to contract and change in dimensions in the course of manufacture, and if these changes do not take place on the machine it is because the papers are prevented from so changing or from assuming their natural dimensions.

The fact that two materials, both of which *per se* are liable to considerable contraction, but when mixed in certain proportions undergo little or no contraction, is extremely interesting, but requires confirmation.

CHAPTER XIII.

THE PRODUCTION OF NON-STRETCHABLE PAPER.

Machine tests—Suggested methods of manufacture—Composition of fibres.

QUESTION 29.—*How far is it possible to make a paper on the Fourdrinier machine which does not stretch when tested for "breaking strain"?*

A.—"I made several tests of different kinds of paper made on a Fourdrinier machine, all these strips being 6 inches between the clips and $\frac{5}{8}$ inch wide. Of these papers the one with the least stretch was a strip of drying Royal, substance 47 lbs. per ream. The stretch of this paper was 2 per cent., both in machine and cross direction. It is made of soft white cotton rags, boiled for about five hours under a pressure of 30 lbs. with about 2 per cent. of 70 per cent. caustic soda, reckoned on weight of dry rags. After blowing off steam and draining off the liquor, the boiler should be emptied; the rags should then be filled into the washer. As a rule, about an hour is allowed for washing, when the water should be shut off and the drum washers stopped. About 2 per cent. of bleach should now be added and the roll let down sharp, and as soon as the bleaching is concluded the remaining bleach should be washed out or destroyed with antichlor, according to circumstances. The half-stuff should now be emptied into the beater; the stuff should be thin in the engine, and the bed-plate and roll bars should be sharp and the stuff cut up in about one and a half hours. Nothing should be added, the paper being a pure waterleaf. This stuff works very free on the machine, and a felt should be used on the top press roll to make the paper as rough as possible.

"The shrinkage on the cylinders will be very small, the paper generally being slightly damp when it leaves them, the drying being finished on the skeleton drum drier. This paper is very similar to a blotting, and can be used for the same purpose. This test on this paper was the only one in which the stretch was equal in both directions."

A in the above answer recognizes the necessity for working under uniform conditions—thus he specifies the length between the clips and the width. H. M. Stationery Office in some classes of their papers specify these conditions, and it has been already pointed out that the conditions are made different for different kinds of paper. Although the question does not ask for information in regard to boiling, beating, etc., inasmuch as these do affect the manipulation of the material upon the machine it is quite right to give details. It would have been more gratifying to see described the preparation of some kind of material or paper of a different class to blotting, which does not show stretch, when tested for breaking strain, equal in both directions. No student appears to have studied the expansion of a paper in thickness. A material such as paper is capable of expansion in three directions, viz., (1) length; (2) width; (3) thickness. It appears that by reason of the fibres running for the most part in the same plane as the surface of the sheet, or in a plane parallel to this surface, the expansion is chiefly either in length or width. Any expansion of an unglazed and unpressed waterleaf on re-wetting resulting in a corresponding contraction and re-drying must not be confused with the permanent expansion of a glazed paper on re-wetting.

B.—"The more contraction you get on the machine, the more stretch you get in the finished sheet. We can in a measure stop the stretch of the paper by beating the stuff free and fine, as the length of the fibres has a lot to do with the stretch. The paper should be well put together on the machine wire under the action of the shake and suction. Keep the 'draws' between the wire and cylinders as slack as possible, and putting all weights on the couch-roll, work the press-roll as hard as possible, to deprive the web of water as much as possible, and keep the cylinders as cool as possible, to ensure gradually drying.

"The following are the results of some tests made for breaking strain and stretch combined. They were calculated on slips of paper $\frac{5}{8}$ in. wide, and having a free length of 7 ins. between the nips. These slips were of ledger paper substance of foolscap 16 lbs.; strength in lengthway 20 lbs., stretch $\frac{3}{16}$ in.; in the crossway, strength 11 lbs., stretch $\frac{3}{8}$ in. The furnish was 80 per cent. strong rags, 20 per cent. sulphite wood. The fibres were worked rather long on the machine. The web measured

72 ins. between the deckles on the wire, and 68 ins. when it left the cylinders. This shrunk 4 ins. on the machine.

"The following are details of tests made on a superfine writing substance of 23 lbs. Large Post; strength in lengthway 18 lbs., stretch $\frac{1}{8}$ in.; strength in crossway 9 lbs., stretch $\frac{1}{4}$ in. The furnish was 80 per cent. rags, 20 per cent. best quality sulphite wood. It measured $67\frac{1}{2}$ ins. between the deckles on the wire, and 65 inches when it left the cylinders. This is a shrinkage of $2\frac{1}{2}$ ins. on the machine.

"A strong bank, substance of 15 lbs. Medium; strength in the lengthway 9 lbs., stretch $\frac{3}{16}$ in.; strength in crossway $6\frac{1}{2}$ lbs., stretch $\frac{7}{16}$ in. The furnish was all rags and beaten rather wet and empty fibres rather long. It measured 51 ins. between the deckles on the wire, and 48 ins. when it left the cylinders. This is a shrinkage of 3 ins. on the machine."

The above answer would have been more instructive and easier to follow if the figures given therein had been tabulated and expressed also in percentages. Notice that **A** has made his tests on strips 6 ins. between the clips and **B** 7 ins. between the clips. The effect upon the breaking strain of strips of various lengths has been already admirably illustrated by diagrams in a publication by Mr. R. W. Sindall appearing in the PAPER TRADE REVIEW. As regards length of the fibres having a lot to do with the stretch, information under this head can be gained by studying the report issued by the Committee of the Society of Arts, in which abstracts of foreign publications appear dealing with the subject.

H.—"This question has a direct relation to No. 28, and nearly all the remarks on the latter refer also to this. Soft and flexible fibres give tearing strain to a paper, and from some tests which I have made I find that papers of high 'breaking strain' in most cases show a relatively high 'stretch." Stuff for papers in which strength is desired is prepared 'soft and long,' and one so made tested as follows:—

	Lengthwise.	Across.
1. Breaking strain	39 lbs.	20 lbs.
Stretch	$\frac{5}{32}$	$\frac{8}{32}$

Comparing this with a paper prepared in the ordinary way, which tested as follows:—

	Lengthwise.	Across.
2. Breaking strain	19 lbs.	10 lbs.
Stretch	$\frac{3}{32}$	$\frac{5}{32}$

it will be seen that the stretch is increased proportionately with the 'strength.' I should qualify this statement by saying this refers only to paper made from stuff prepared 'soft,' as, of course, there are other physical conditions affecting the strength, but which do not increase the stretch. For example, two strips cut from the same sheet as those mentioned in test No. 1, but hung up overnight, gave the following results :—

	Machine direction.	Across.
3. Breaking strain	45 lbs.	26 lbs.
Stretch	$\frac{5}{32}$	$\frac{6}{32}$

and it may be interesting to note that strips taken from a piece which had been wetted to ascertain its expanding qualities, and naturally dried in sunlight, tested as follows :—

	Machine direction.	Across.
4. Breaking strain	29 lbs	16 lbs.
Stretch	$\frac{6}{32}$	$\frac{10}{32}$

This loss of strength I attribute to the loss of finish.

"The better the fibres are felted and shaken into position, laterally and longitudinally, the less will be the liability to stretch. As far as practicable, care should be exercised to see that there is as little rush as possible at the 'slice,' to prevent the fibres 'heading' down the wire and preventing their equal distribution in both directions.

"The web should be slowly and equally dried, and the paper cooled before being packed, as the nearer it approaches to the natural condition the less will be its liability to stretch."

This contribution is a very good one. If the two sets of tests, as mentioned in the latter part of the answer, are for the same paper, it is difficult to understand how it is that the paper should have been diminished so much in strength, but gained elasticity after wetting and re-drying. It is evident that the degree of elasticity of the paper does not necessarily compare with the figure for breaking strain. There is a certain degree of comparison between Nos. 1 and 2, but comparing 3 and 4 the amount of stretch is in the inverse order of the strength in both ways of the sheet.

It is interesting to note the relationship between the stretch and breaking strain. In order to see how far this is constant for each way of the sheet, divide the breaking strain by the stretch thus—

$$1.\ \frac{39}{5} = 7{\cdot}8 \text{ and } \frac{20}{8} = 2{\cdot}5$$
$$2.\ \frac{19}{3} = 6{\cdot}3 \text{ and } \frac{10}{5} = 2{\cdot}0$$

This shows that the ratio each way of sheet bear a close relation to each other, and the relationship would probably have been closer if the measurements for stretch could have been taken with a greater degree of accuracy.

I.—" A lot depends on the strength of the paper. If linen is used, it will not stretch so much when tested as most other materials. If the fibre is left long it is more liable to stretch."

J.—" The longer the fibres are, the less will the paper stretch under tension, for there will be less interlacing ; and the less interlacing of fibre, the more direct is the pull on the fibre, the shorter fibres are better felted, and therefore give more before they finally break. This is for the long way of the web.

" The more the paper is drawn when being made the less it will stretch on tension. The 'freer' the stuff is, the less it will stretch. 'Free' stuff is not so elastic as 'soft' stuff.

" Paper which is dried severely on the machine will not stretch much, owing to the hardness of the fibres, too much moisture being driven out and the paper made brittle."

I do not think the above experience as regards the short fibres giving more before they finally break is borne out by the work of other observers, but it is undoubtedly true that the more the paper is drawn on being made the less it will stretch on being tested on the machine. The final remarks are quite correct.

L.—" Blotting and filter papers being both of a very 'fast' and 'free' nature, and also soft, are very tender. These papers will have the smallest possible stretch on the testing machine. Also a paper made from esparto that has been beaten fast and worked on the machine and cylinders, as in question 28, will have very little stretch in it."

The above are general remarks which have been referred to by others.

The same may be said of the following answer by D2 :—

D2.—" The paper which stretches least is a waterleaf paper of soft material, such as drying Royal, or blottings. I found in testing a drying Royal and blotting paper, the strip being $\frac{5}{8}$ in. wide and 6 ins. long, the stretch was $\frac{2}{32}$ cross, and $\frac{4}{32}$ machine direction, the blotting stretching $\frac{1}{8}$ *both* ways. Stronger papers stretch much more."

P writes—

"1. Short stuff.

"2. Free stuff.

"3. Maximum loading that paper will carry.

"4. Press the web hard at couch-rolls and press-rolls, this will reduce stretch in *cross direction* when tested for breaking strain.

"5. Keep all 'draws' as tight as possible to reduce stretch in long direction.

"6. Super-calender or plate glaze the paper.

"7. Paper should be kept in stock as long as possible, as age reduces elasticity."

The above answer of **P**'s is concise under the different headings. Of course, in carrying out the above instructions the paper would be deteriorated in quality from other points of view than those considered in this question.

CHAPTER XIV.

THE CONNECTION BETWEEN "STRETCH" AND "EXPANSION" OF PAPERS.

Discussion—Tables of results—Theories.

QUESTION 30.—*How far is the quality as mentioned in question* 28 (i.e. *expansion or contraction with moist or dry air*), *connected with the quality as mentioned in question* 29 (i.e. *stretch when tension is put upon the paper*)?

A.—"These two qualities are connected in the beating, and also in making on the machine. If an engine of stuff is beaten in say, $1\frac{1}{2}$ hours, the paper made from this stuff would expand or contract very little with moisture or heat, and the 'stretch' when tension is put on the paper would also be small. Suppose another engine of the same furnish is taken, and the beating prolonged, say, 6 hours, other things, such as the condition of beating tackle, thickness of stuff in engine, etc., being equal, the paper made from this engine would expand and contract more than the former with moisture and heat. It would also stretch more when tested for breaking strain. Then again, on the machine, when the wet paper comes in contact with the hot cylinders we have moisture and heat. If the contraction is small, the stretch when under strain is also small; if, however, there is a lot of contraction, the stretch, when tension is put upon the paper, is more, and, as a rule, the paper that stretches the most is the strongest. I here give some tests which seem to connect these two qualities. I have taken the extremes, two with a large amount of stretch, and two with very little."

The percentage of stretch under strain as indicated in **A**'s table (see p. 139) in the two directions (see p. 137) bear practically the same ratio to one another as strength tests do. These are in close agreement, so that it might be inferred that the stronger the sheet the greater the stretch, and that if there is great stretch in one direction there will also be great strength, and *vice versâ*.

Notice, furthermore, that the expansion and contraction under heat and moisture in the two directions are practically in the same order as the percentage stretch under strain, but that there is no direct ratio as in the foregoing. Nevertheless, it would appear that this relationship or ratio could be expressed by a formula. The ratios of expansion (A) to mean strength (B) is remarkable when a correction is made for the difference in substance of the papers by dividing the strength in each case by the weight per ream. They are sufficiently close to lead one to expect that if the papers were of equal weight per ream and bulk, the mean wet expansion would be in exactly the same ratio as the mean breaking strain; or that with papers of different thickness the mean weight expansion would be in direct proportion to the mean breaking length.

In investigating this subject one might well take note of the following points. The effects of heat *per se*, the effects of moisture *per se*, and the effects of the two when operating together.

Heat *per se* tends to expand. Moisture *per se* tends to expand the paper. Heat in conjunction with moisture tends to minimize the effects of moisture, owing to the fact that heat de-hydrates, and, as a consequence, causes contraction. As moisture is always present, the practical effect of heat is to diminish the volume of the paper. The ratios, as expressed in the undermentioned table, although of interest, do not express any relationship.

	Papers.			
	1	2	3	4
The expansion ratio. Proportion of machine to cross direction ...	13·6	30·0	50·0	...
The stretch ratio. Proportion of machine to cross direction when latter equals 100	56	56	67	100
The stretch and expansion ratio. Proportion of mean stretch to mean expansion when former equals 100	26	36	24	12

B.—The substance of **B**'s statement is as follows :—To make paper that will expand or contract equally as far as possible it is necessary to reduce the strength, bulk, and transparency. By heating the stuff you harden and stiffen the fibres before they become felted together. By beating it "free" you render the fibres more inflexible and more opaque ; by beating the fibres "fine" you also reduce the strength ; and by "couching" and pressing hard you reduce the "bulk" of machine-finished papers. Gradual drying would tend to improve the paper more than fast drying.

H. "With a view to finding out the connection of the two qualities mentioned in questions 28 and 29 I made a few simple tests, and while the results would seem incompatible, yet a relation is apparent. A paper on first testing, and after an interval of four months, gave the following results :—

		Machine direction.		Across.
Stretch, 1st test	...	$\frac{5}{32}$ ins.	...	$\frac{9}{32}$ ins.
" 2nd "	...	$\frac{5}{32}$ "	...	$\frac{8}{32}$ "

with an increased strength. The relation would seem to be that absorption of moisture, while resulting in expansion of the sheet itself, proportionately reduces the stretch when under tension, and evaporation reduces the size of the sheet, but adds to the stretch under tension. If I might advance a theory, in the latter case the fibres have further to go to regain their original condition, and the stretch is accordingly increased. The slight expansion due to the extraction of hygroscopic moisture from the air, reduces the degree of elongation at the same time, while giving to the fibres a better 'grip.' To make tests of value, the samples should be carefully weighed under each set of conditions. But the following may be of interest :—

	Machine direction.		Across.
Stretch under tension when dry	$\frac{5}{32}$ ins.	...	$\frac{8}{32}$ ins.
" " when damped	$\frac{1}{32}$ "	...	$\frac{4}{32}$ "
Contraction with hygroscopic moisture partially removed	none	...	$\frac{4}{32}$ "

These pieces were taken from the same sheet, and measured $9\frac{1}{2}$ ins. by $5\frac{1}{2}$ ins. No. 3, on being dried in sunlight, returned to its original size."

I am much struck with the theory that **H** advances. Sir William Crookes stated at the Berlin Conference that one is justified in enunciating a theory so long as it agrees with all

TABLE OF RELATIONSHIPS.*

Furnish.	Weight per ream large post.	Percentage of expansion and contraction with moisture and heat.			Percentage of stretch when under strain.			Breaking strain of strips, 6 ins. long between the clips, and $\frac{5}{8}$ in. wide.		
		Across.	Machine.	Mean.	Across.	Machine.	Me an.	Strip cut down machine.	Strip cut across machine.	Mean.
1. Rag, 60 per cent. ... Sulphite, 40 per cent.	11 lbs.	2·5	0·34	1·42	7	4	5·5	$7\frac{1}{2}$ lbs.	$4\frac{3}{4}$ lbs.	$6\frac{1}{8}$ lbs.
2. Rag, 100 per cent. ...	15 ,,	3·0	0·90	1·95	7	4	5·5	$13\frac{3}{4}$,,	$7\frac{3}{4}$,,	$10\frac{3}{4}$,,
3. Mechanical, 80 per cent. Sulphite, 20 per cent.	12 ,,	0·8	0·4	0·6	3	2	2·5	$5\frac{1}{2}$,,	2 ,,	$3\frac{3}{4}$,,
4. Rag, 100 per cent. ...	34 ,,	0·5	0·0	0·25	2	2	2	10 ,,	7 ,,	$8\frac{1}{2}$,,

* For deductions, see pages 129 and 130.

existing facts, but not longer. As far as I am aware, existing facts do not accord with the above theory. The view that increased hygroscopic moisture (within certain limits) gives the fibre a better grip is undoubtedly correct, and is well borne out by what is known in regard to the behaviour of cellulose to moisture, a question that has been discussed more than once in these pages.

J. "Paper which is in a moist condition (hygroscopic moisture) stretches more than when it is drier."

L.—"The more you beat the fibres and hydrate them, keeping them long, the greater will be the stretch when tension is put upon the paper."

D2. "The quality mentioned in questions 28 and 29 is almost the same, both being waterleaf made from soft cottons (muslins), and containing no loading and 10 per cent. of sulphite wood."

I presume that **D2** wishes to infer that the stretch and expansion vary in like proportion in the particular instance he mentions. The answer, although brief, has the distinct merit of being a direct answer to the question.

CHAPTER XV.

"STRETCH" AND "BREAKING STRAIN."

Their relationship to one another—Tables of results—Relative importance—Bursting strain.

QUESTION 31.—*The qualities of paper for commercial purposes are sometimes judged by their "breaking strain," and at times by the amount of "stretch" which they undergo when tested for "breaking strain," and finally, both by "breaking strain" and "stretch" combined. Discuss the relative advantages of these different methods, and give your own opinion as to what particular class of paper (if any) each method is with advantage applied to.*

A.—"The breaking strain and stretch taken together appear to me to be the best method of arriving at the value of a paper, as all papers must have a certain strength, and the stretch is an important matter in some papers. For instance, a chart paper by stretching half an inch might put a man miles out of his track; drawing papers, too, should not stretch much, and as equally as possible in all directions. The same applies to chromo and litho paper where colours are used. If the paper stretches, the colours overlap one another. Then, again, ammunition paper should stretch in one direction only, that is, in the length of the cartridge. If it stretches in the opposite direction the cartridge expands in diameter, and may possibly jam in the rifle. All banks, loan, and cartridge papers should be very strong and have a good stretch, as such papers receive a lot of handling. With regard to the bursting strain, it appears to me that it can only test one way—that is the weakest way of the sheet."

It appears that **A** is rather confusing stretch with expansion, the first being due to the pull or tension put upon the paper, and the second to the absorption of moisture. Both may and do arise in the ordinary use of papers. Inasmuch as the "stretch" is often greater with paper liable to expand on moistening, it is important to make use of it. Possibly **A** takes it for granted that the relationship is established. I think he is justified in doing so from the answer he gave to Question 30.

H.—"The breaking strain of a paper is a fair index of the amount of handling which it will stand. Strength in a paper is a quality to which attention is generally first directed. The strain in lbs. which it will withstand gives an idea of the material from which it is made, and the nature of the fracture shows up any weak points, such as knots or other hard particles.

"The bursting strain is one which I venture to think little attention is given to.

"Stretch in a paper is an index of its elasticity, and shows the amount of handling it is likely to stand. A paper may have a high breaking strain and yet not stand the same amount of handling or crumpling which a more elastic paper will. This feature is of importance in copy-book, cartridge, brown papers, and others.

"From the examples I have given in my answer to Question 29, it will be seen that for some papers the two tests taken together are valuable, the degree of stretch showing elasticity in the fibres and a proportionate increase in strength, and as the best paper is that in which the fibres occupy the greatest space, they give an idea as to the equality of making."

J.—"Most ordinary papers are tested for their breaking strain to ascertain the strength of the paper. To do this a piece is cut out of the sheet one inch broad, which is taken as a standard, and put into the machine evenly and tension applied. When testing watermarked papers a piece containing the watermark should not be taken, as the fibres are broken a little by the action of the dandy.*

"A paper which is well dried on the machine and closely made, will have a much higher breaking strain than a paper which is heavily loaded. A rag paper will stand more breaking strain than an esparto paper, owing to the fibres being stronger."

The fibres are not broken by the action of the dandy, but the watermark makes a thin place by pushing aside the fibres. This often starts a fracture. As a consequence the watermark should be avoided.

L.—"I have examined several sheets of paper on a Marshall spring testing machine, which is of German make. I took a

* See author's remarks at end of chapter.

medium quality Cream Wove Large Post, 28 lbs. 480, composed of 80 per cent. cotton rags and 20 per cent. best sulphite. I took four strips $\frac{5}{8}$ in. wide and 7 ins. long. Waterleaf and rosin sized. Four pieces showed lengthways of the machine 13 lbs., 15 lbs., 11 lbs., $14\frac{3}{4}$ lbs., with a stretch $\frac{3}{8}$ in., $\frac{1}{4}$ in., $\frac{3}{8}$ in., $\frac{3}{8}$ in., all waterleaf. Sized lengthways 20 lbs., $19\frac{1}{2}$ lbs., $22\frac{1}{2}$ lbs., $22\frac{1}{2}$ lbs.

Four strips	across,	waterleaf	8	lbs.	Average across $8\frac{7}{16}$ lbs.
"	"	"	$8\frac{1}{2}$	"	
"	"	"	$8\frac{3}{4}$	"	
"	"	"	$8\frac{1}{2}$	"	
"	"	sized	11	"	Average just over 11 lbs.
"	"	"	$11\frac{1}{2}$	"	
"	"	"	$10\frac{3}{4}$	"	
"	"	"	11	"	

"Stretch across machine was the same sized and waterleaf, *i.e.* $\frac{3}{8}$ in. Sized lengthways four pieces averaged $21\frac{1}{8}$ lbs. Waterleaf four pieces lengthways, $12\frac{7}{8}$ lbs. The stretch on four waterleaf pieces lengthways was average $\frac{5}{16}$ in. The stretch on four sized pieces lengthways was $\frac{1}{4}$ in. I also took a strip $\frac{5}{8}$ in. wide and 6 ins. long of a bank paper medium, 15 lb. waterleaf. The strip lengthways waterleaf.

	Waterleaf	$7\frac{1}{2}$ lbs.	Stretch	$\frac{3}{14}$ in.
	Sized	9 "	"	$\frac{3}{16}$ "
Across	Waterleaf	$5\frac{1}{2}$ "	"	$\frac{5}{16}$ "
"	Sized	$6\frac{1}{2}$ "	"	$\frac{7}{16}$ "

The mean of the waterleaf bank was $6\frac{1}{2}$ lbs.
" " sized " $7\frac{3}{4}$ "

"*Breaking strain only.*—The breaking strain should be specified for any class of paper that has to be printed upon from the plate, where it is required to be uniform in its texture and free from hard particles, as a strip containing a knot would be weak, and knots or weak places are shown at once with a narrow strip, and the paper would be rejected. Stationery Office people are particular in classing their tobacco brand paper as being required to stand a certain breaking strain on this account.

"*Bursting strain.*—A good hand-made paper, and also a strong ledger and a loan paper, indeed any paper where a great resistance is offered, would be a suitable one for testing in a bursting machine, as also a strong hand-made or machine-made bank paper. With such papers, in one operation you can see at a glance the mean strength of the sheet, and so save time and labour.

"*Amount of stretch.*—A high figure for stretch is a good sign, as the more elastic your paper the more resistance it will stand to handling, and the stretch is thus an index as to what amount of handling the paper is likely to stand. I would class an air-dried brown paper and an ammunition paper among those which require to show a high figure for stretch. But for a good printing or lithographic paper the less stretch it shows the better.

"*Breaking strain and stretch.*—Both breaking strain and stretch should be determined in a good air-dried writing paper, a good air-dried brown, also a good loan paper, or any class of paper where great durability is required. The Stationery Office in giving their orders for air-dried brown insist on having a proportionate increase of stretch shown if the paper shows a higher breaking strain than the minimum required, so as to ensure that the paper will be fully up to the quality."

The above answer, with the exception of the beginning, deals with the subject as it should be dealt with. The examples of tests are interesting, and would have been more so if it had been shown in what way they bear on the subject of the question.

P.—"Testing the breaking strain takes a longer time to carry out than the bursting strain, as it has to be taken in both directions and the mean calculated; also strips require to be very carefully cut free from any roughness or unevenness if the test is to be reliable, whilst with bursting strain method only one test is necessary, and the paper is simply clamped down and pressure applied—a much easier and quicker method.

"The objection to taking the bursting strain is that it gives no record of stretch. With breaking strain method, papers are tested in both directions; the difference in breaking strain of cross and lengthwise direction of web or of sheet can be noted; this is of importance, especially when testing hand-made paper. Bursting strain method is chiefly used for testing wrappers and other low-class strong papers, when a large number of samples can be tested in a short time. Breaking strain method is used for high-class strong papers, such as loan, strong book papers, cartridges, etc."

D2.—"The writing papers are mostly judged by their breaking strain. Ledgers, loans, cartridge paper, and banks, the strength being important, are judged by their breaking strain and stretch combined. Photo paper is judged by the stretch."

The author has made some investigations with the view of ascertaining whether the watermark in a sheet tends to diminish its strength. It would naturally be inferred that as the watermark is thinner than the rest of the sheet that it must of necessity be the weaker ; but this is not necessarily so, the reasons for which were discovered by the author in researches which he conducted for the " Fibrous Constituents of Paper." The watermarking effect is due partly to the difference in thickness and in part to the difference in the direction of the fibres. The direction of the fibres constituting the watermark is of such a nature as to compensate for the decreased thickness (*i.e.* they tend to cross the direction of the watermark). This quality tends to the production of a paper equal in breaking strain throughout.

CHAPTER XVI.

PAPER-TESTING MACHINES.

Different types—Comparison of results.

QUESTION 32.—*What paper-testing machine do you prefer to make use of? Give your reasons for any particular preference.*

A.—"The Leunig or Schopper is, I believe, the best machine for this purpose. The pointer of this machine has a weight at one end and a small shoulder at the other, and is pivoted near this shoulder to a small standard, the weighted end downwards. The paper to be tested is clamped to the shoulder and hangs suspended in a vertical position. The paper is now drawn tight and clamped at the lower end. By turning a small hand-wheel, bevelled wheels and a screw are set in motion and the lower clamp is drawn downwards, so that the paper by straining at the shoulder raises the weighted end up round a quadrant, on which it registers the breaking strain. When the paper breaks, the weighted pointer is prevented from dropping back by a ratchet which is attached to the quadrant. When the before-mentioned bevelled wheels and screw are set in motion, besides straining at the paper a small rack is drawn downwards, the teeth of which by working in a toothed quadrant turn another pointer much smaller than the weighted one; if the paper does not stretch, both the pointers move as one, but when the paper stretches, the small pointer forges ahead, and when the paper breaks this one registers the stretch upon a small quadrant which is fixed to the weighted one.

"My preference for this machine is because most of the others, as the Marshall, Wendler, etc., are actuated by a spring; these springs are tempered to stand a certain strain, but springs get weak in time, and the machines would then give a wrong reading.

With the Carrington there is nothing for registering the stretch, but by measuring the distance between the clips before bringing the strain on the paper and again when the paper breaks, the difference between the two measurements would give the figure for stretch."

I hardly think that **A**'s objections to spring machines are valid. A spring, if properly made and tempered, is, within the limits of its elasticity, quite reliable and accurate. I tested a Marshall machine after having used it for about ten years and found that it registered correctly. I can conceive of no better way of applying pressure than by means of a spring.

B.—" I should prefer to make use of a weight machine, either Leunig or Schopper, as I think they are more accurate than spring machines, as the springs get weakened by continual use and are not therefore reliable ; even when made by the same maker they do not always agree with one another. The samples cannot be compared without testing on the same machine. The one drawback to the weight machines is that they are very expensive."

I fancy Mr. Sindall's results show that there is fairly close agreement when testing on different machines, provided that the width and distance between the clips are the same. **B** is probably misled by the fact that paper varies so considerably in strength in different parts of the sheet. In order to determine the strength with a fair degree of accuracy, at least five pieces should be taken each way of the sheet and selected from different parts of the sheet. If different machines were tested under like conditions and under equal atmospheric conditions, I venture to think that there would be remarkable concordance. Since conditions are bound to vary considerably in ordinary practice, there is bound to be disagreement, but not necessarily due to defects in the machines.

H.—" The two testing machines with which I am familiar are Marshall's and Leunig's, and I am inclined to favour the latter as being the more complete machine of the two. The mode of producing the tension by means of a lever with a weight attached is, I think, in advance of the system of springs by which the Marshall machine is worked, and with the suspension of the strip in a vertical direction approaches most nearly to the old style, when the paper was tested in the machine-room by hanging a dead weight to the strip. With the Leunig the weight stops dead when the strip breaks. To make tests of comparative value the Demy weight should be carefully noted, and this can readily be done by using the demy scale in conjunction with Leunig's tester.

"With the latter the strips are 12 in. × $\frac{5}{8}$ ins., and the square of same is half that of the standard sheet used for the demy scale. The suitable apparatus for cutting strips which is provided with this machine is an advantage.

"The recent interest evinced in Paper Testing, with the plea for a standard machine, is worthy of note and consideration. The tests must necessarily vary with the size of the strips taken, and entail a deal of trouble in working out for purposes of comparison. With a view of ascertaining the relation between results of tests given by the two machines mentioned, I tested strips taken from the same sheet.

"With the Marshall the strips were 1 in. broad, and gave a breaking strain of—

Lengthwise.	Across.
31 lbs.	15½ lbs.

"The strips used with the Leunig were $\frac{5}{8}$ in. broad, and gave the following results :—

Lengthwise.	Across.
18 lbs.	10 lbs.

"The ratio calculated on the Marshall results should be :—

Lengthwise.	Across.
19·37 lbs.	9·68 lbs.

and while this would seem near enough for practical purposes, shows, I think, the necessity for the adoption of a standard machine and strip."

I can find no reasonable evidence as regards the relative merits of spring and weight machines. As to the Marshall machine indicator springing back a pound or two, this I have never observed, after many years of work with different machines. The machine in question must have been out of order. The principle of a spring is practically, as well as theoretically, correct, and enables the machine to be put into smaller compass, and, moreover, the spring is used on most delicate weighing instruments. Within certain limits the elongation of a spring is directly proportional to the weight put upon it. There is no advantage in testing a sheet in a vertical position. The position does not affect the reading. It is essential, however, that the whole of the strip lies in one plane, and to ensure this the four edges and sides of clips should be parallel with one another, and the faces of the jaws receiving the paper should be all in the same plane. Those physical defects to which all machines are liable through want of proper adjustment and construction may materially affect the result, more so than by variation of type.

The latter half of **H**'s answer is instructive, but the fact that he has only given the figures of one test much detracts from its value. They should be given as the average of five before attempting to translate one width into another. In spite of this they are fairly concordant. The reasons of the choice of different widths for different classes of paper have more than once been discussed here. With coarse paper a 1-in. strip would require more than double the force to break it than a $\frac{1}{2}$-in. strip, but with well-made high-quality papers the breaking strain is practically in proportion to the width (or should be if properly made). In order to ensure that such is the case, the Stationery Office specify a narrow width on certain high-quality papers. But with coarse papers, such as browns, a much greater width is chosen. When one sees the reason for the adoption of different widths, one sees the difficulty of attempting to establish one standard width for all qualities.

I.—"Marshall's for simplicity and accurate testing."

I think all are agreed that the above machine is simple. As to accuracy, my experience is that the irregularities in most, if not all, commercial samples of paper would lead to greater errors than anything in the machine itself; or, to express it otherwise, any complications in elaborate mechanism which would lead to greater accuracy in testing would be labour thrown away. What is wanted for trade purposes is a machine that can be easily handled, easily moved about, not liable to get out of order, and by means of which the time of performing each test is reduced to a minimum. The figure taken should be the mean of five in each direction when buying and selling, but where it is merely necessary to compare two or more papers for approximate strength, two tests taken each way are enough, unless any two tests taken in one direction show a considerable difference, when a second two tests should be performed.

J.—"Paper-testing machines may be divided into two classes.

"With the first class it is possible to get the strength of the paper in the two directions separately. There are generally two kinds of machines for this purpose, either Marshall's spring or Leunig's weight. Leunig's machine should be given the preference, as it is fitted up in a very complete manner, and tests to a higher degree of accuracy.

"The second class is more adapted for the bursting strain, as it is fitted with a plunger. Wooley's machine is considered the best for this class of work."

My previous remarks would apply here. I quite agree on one point, however, that a weight machine should be used as a standard of reference in case of dispute, and I furthermore agree that, inasmuch as springs do occasionally get out of order, they should occasionally be tested, which can be done at any moment and with the greatest of ease by tying standard weights on and noting whether the deflection corresponds with the weight applied. There are many delicate things used for commercial purposes, such as weighbridges, which are liable to get out of order, but this is no argument against their use, as they can be examined periodically.

L.—"There are a variety of machines in use, but they resolve themselves into two sorts. Those that are worked by means of a spring, as the Wendler machine, the Hartig Reusch, or Marshall's, and, secondly, those worked by a weight, as the Leunig, Schopper, or Carrington.

"There is a third type, mainly plunger machines, where the pressure is applied to a piece of paper by screwing a ram or piston which is buffeted by glycerine; the ram when screwed tight bursts the paper, as the American make of Mullen. I prefer to use a Mullen plunger machine for a strong writing or ledger paper, as by one operation you can obtain the mean strength of the sheet you are testing. It is quicker in action, and is as reliable as the best weight machines.

"For more information as to the strength of the sheet in machine or cross direction, I prefer a Leunig weight machine, where the stretch is registered, and the weight shown at a glance, as on his paper scales. They are reliable, having no springs that are likely to get out of order."

Do you get the *mean* strength by means of a plunger machine, or do you obtain the minimum strength? The figure for tensile strength cannot be translated into the figure for bursting strain, although a high test with the one would indicate a high test with the other. With metals the problem is somewhat different. By comparing the bursting strain of a paper of uniform texture with the tensile strain of the same paper some extremely useful inferences can be drawn, and by the use of the one the result with the other may be inferred.

In forming an opinion on these matters there is nothing after all to equal practical experience, and theory can only aid us in a limited degree.

P.—" I prefer the Leunig self-registering. With this instrument there are no springs that are liable to become weakened, the strain being produced by levers, stretch and breaking strain are taken in one test."

D2.—" There are only two types of paper-testing machines in the market, one a spring machine and the other a weight machine, although several different makers. The spring machines are made by Marshall, Wendler, and Hartig Reusch, and the weight machines by Leunig, Schopper, and Carrington.

" I should prefer the weight machine against the spring, for the continual tension which is put upon the spring while testing must tend to weaken it, while with the weight machine it is easy to test it with the weights supplied with the machine for that purpose, hence the advantage of the weight over spring machine."

The above answer is very similar to some of the others. Without committing myself to the extent of suggesting that **D2** is wrong in his choice, I would merely add that the reasons for his choice are not warranted. I would add in conclusion to this set of questions that it would not be fair for me to express an opinion here as to the relative merits of the different machines. In commenting on this and many of the preceding questions, I have attempted merely to assess the value of evidence as contained in the answers, and put my own personal opinions, such as they are, in the background.

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THE END.

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