Chapters on Papermaking.

VOL. II.

COMPRISING ANSWERS TO QUESTIONS ON PAPERMAKING SET BY THE EXAMINERS TO THE CITY & GUILDS OF LONDON INSTITUTE.

BY

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PREFACE.

HAVING laboured some years in the hope of being able to assist young papermakers, not only in the study of papermaking from books and other sources, but from everyday observation in the paper mill; and having written upon the subject at different times, the author thought it would be as well to collect his scattered notes, and present them to the paper trade in a handy form for reference. This small book is prepared with this object. The Author has, moreover, been encouraged to reprint his answers to the City and Guilds questions, on account of requests made to him by many who made use of these answers when they first appeared in the columns of PAPER AND PULP. No attempt has been made to include an introductory chapter. The book is merely a reprint of all the Author has published on the subject of the City and Guilds questions, together with other matter directly bearing on the subject. It is earnestly hoped that students for the City and Guilds examinations will find the book of some service by way of instruction and preparation, and further, that it will assist paper mill hands, foremen and others, to answer questions of a similar nature for themselves in their everyday work.

The Author wishes to express his thanks to those friends who have rendered him valuable assistance, among whom, he would particularly mention the Examiners, Mr. C. F. Cross and Mr. George Clapperton, and others, whose work has been referred to in the text.

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CHAPTER XIII.

I.

TECHNICAL EDUCATION AS APPLIED TO PAPERMAKING.

I AM not aware that any attempt has, so far, been made to discuss the general bearing of "technical education" in its relationship to paper manufacture. The constitutional peculiarities of papermaking render it all the more necessary that this subject should be discussed strictly on its own merits, and not merely as part of a general scheme for technical education. The national advantages possessed by such countries as the United States and Scandinavia, to whom our markets are laid open, expose us to a fierce competition and rivalry, and render it all the more necessary for us to do all that lies in our power to foster technical education, to insure the utmost economy and efficiency of working, as well as to keep up the quality of our products.

I do not claim originality in the views and statements which I am about to put forward. On the contrary, I wish it to be understood that they have been gleaned from various sources, as the result of my contact with members of the trade. I feel that the subject is now ripe for discussion, and if this paper is the humble means of initiating a discussion, I shall feel amply justified in bringing it before your notice.

There appear to be differences of opinion as to what technical education comprises. These two words, "technical education," are in the mouth of all those who discourse on the subject of education generally. For a legal definition of "technical education," I would refer you to some recent utterances of Lord Salisbury, in which he points out that even the State definition by Act of Parliament is somewhat vague. Technical education is really "special education," and, in my opinion, might well be defined as "education designed on behalf of any special calling."

The subject of technical education generally is only just beginning to assume definite shape. There appear to be no books on its general principles other than official books. I have been unable to find a single book devoted to the subject generally. This appears to be strange, because there are general principles which underlie technical education, as applied to all subjects. This is evident to anybody who has studied the subject, even superficially. A book which could demonstrate the general principles common to all departments of technical education, would be of great assistance to technical instructors and students, and would tend to bring about a uniformity in the methods of teaching various subjects. At present I venture to think there is little uniformity in the method employed by teachers of different subjects, to say nothing of those employed by teachers on the same subject in different parts of the country.

The question, therefore, that confronts us is: How are we to so design and apply education so as to render it of efficient service in the manufacture of paper? I will not pretend to give a solution to this question, but I sincerely hope that my remarks may lead those chiefly interested in the matter to give it their most serious consideration, and that by so doing some useful progress will be made.

I have already made an attempt, through the medium of the PAPER MAKER in my articles on "Technical Education as applied to Papermaking" and "Chemistry and Papermaking," to discuss the subject in its general bearings, and some of the following remarks have already appeared in the articles above referred to.

CHEMISTRY AND ENGINEERING.

In order to assess the relative importance of Chemistry and Engineering, for the purpose of papermaking, it is necessary to consider briefly the conditions of the paper trade in this country.

Prior to the introduction of "chemical" and "mechanical" wood-pulp, the whole of the chemical as well as the mechanical operations were conducted in the paper mill. Of recent years, however, a great change has taken place. Wood, which now forms a large bulk of the material used for paper manufacture (and is likely to form even a greater proportion of the materials used in the near future), is now chemically and mechanically treated close to the sources of the supply. The consequence of this is that the whole of the mechanical and chemical operations involved in the conversion of timber into wood pulp, are no longer conducted in this country, but have to be performed in the United States, Canada, and Scandinavia.

All those who are engaged in the paper manufacture in this country, and likely to remain here, do not necessarily require a knowledge of these processes, although it is advisable that they should know as much as possible of the treatment of the raw material prior to their receiving it for conversion into paper. This country is cut off from performing a large proportion of the chemical treatment, and now gives its attention more strictly to the actual paper manufacture, leaving the treatment of much of the raw material to other countries.

I venture to think that too little stress is laid upon the engineering aspect of papermaking. It is generally conceded that chemical knowledge is indispensable, but, in my opinion, mechanical knowledge is equally a necessity in modern papermaking. Papermaking may be regarded as a species of chemical engineering. Dr. Witt,* in his paper before the International Congress held at the Society of Arts in 1897, remarked, "Dyeing, calico-printing, and papermaking are perhaps the only chemical industries which may rightly claim the necessity of some special instruction in the methods of their manipulation." Notice that Dr. Witt describes papermaking as a chemical industry.

As regards the necessity for engineering in so-called chemical industries, I would draw your attention to the remarks made by Mr. G. E. Davies, in his excellent treatise on "Chemical Engineering." He endeavours to trace the influence of a qualified engineer being at the head of affairs in a chemical industry such as in "Alkali Making." One would almost judge from his remarks that in such a case he considers engineering of paramount importance, if not of equal importance with chemistry.†

There are many intricate chemical operations involved in the manufacture of paper, but, in spite of this, papermaking is very largely a mechanical operation. A proper understanding of either the chemical or mechanical operations necessitates a

* "Relations existing between the Teaching of Pure Chemistry and Applied Chemistry," by Otto N. Witt, Ph.D., at the International Congress on Technical Education.

† ". . . the fact was not to be ignored that the engineer with a little knowledge of chemistry generally was more successful than the chemist with a smattering of engineering, which goes a long way to prove that the engineering knowledge was the more valuable of the two."—"A Handbook of Chemical Engineering," by G. E. Davis, part i., p. 2.

knowledge of both chemistry and engineering, in consequence of it being impossible to separate the two branches of papermaking one from the other. The machinery of a paper mill is also intricate and of a very diversified order. From a structural point of view alone, and for the purpose of repairs and general up-keep of the mill, managers, foremen, and others in responsible positions should certainly have a considerable knowledge of engineering.

Chemistry and Constitutional Difficulties.

Science is making strides year by year, but it must be remembered that the acquisition and accumulation of scientific knowledge is a far easier thing than its industrial application. It is hard enough to apply chemical knowledge to working out and developing some new industry—even in the case of some chemical industry,—but it is far harder to apply chemical knowledge to an old-established industry like papermaking. The art of papermaking (at any rate up to the middle of the last century) had been acquired almost without the aid of chemical knowledge. Many of the most successful papermakers the world has ever seen had no chemical knowledge whatever. Moreover, a prejudice has been engendered against science by those men who had made themselves successful without it assuming that it was unnecessary, and teaching others to believe so. I would furthermore mention another difficulty, largely as a consequence of the foregoing, namely, that papermaking, being the outcome of rule-of-thumb practice, is constitutionally unscientific, and in a large measure unfit to receive help from chemistry. These are some of the constitutional difficulties which confront us. I call them constitutional advisedly, as I wish to urge that educational advance will be largely influenced by constitutional changes, or retarded by constitutional inactivity.

Papermaking as a Profession.

If we look at other industries that are as old as papermaking, but at the same time amenable to scientific treatment, we find that they have been transformed into truly scientific operations. Take, for instance, the operations of mining and the manufacture of iron and steel. These operations have been studied in the minutest details by eminent engineers, and also by the leading metallurgists and chemists in all parts of the world. The result is that their general principles are taught daily, and national institutions have sprung up where first-class training can be got, and young men thus educated are able to start their career with a thorough knowledge of the art or craft of their profession. By such means, mining and engineering have been raised to the rank of professions.

These professions gave rise to such powerful bodies as the School of Mines (now the Royal College of Science), especially for the education of young fellows who devote their lives to mining operations; the Institute of Civil Engineers; the Institute of Mechanical Engineers; the Iron and Steel Institute, &c., to say nothing of the bodies devoted to electrical engineering.

When we can bring about this much-to-be-desired change, not necessarily in the actual manufacture of paper itself, but in our mode of regarding the principles of its manufacture, and in our mode of enunciating, demonstrating, and treating them, then, and not till then, can we rank papermaking side by side with other so-called professions.

The Relation of the Chemist to Papermaking.

I venture to think that the national prosperity of papermaking in this country will largely depend upon the attitude of the papermaker to the chemist, and the attitude of the chemist to the papermaker. As this relationship must also affect the educational question, I think it deserves special consideration. The resident chemist, or, more correctly speaking, the person responsible for the routine chemical work of the paper mill, should exercise more influence than he is able to exert at present. I am strongly of opinion that, in spite of the indifference of the papermaker to science, the resident chemist has been largely to blame for his non-success. In many cases, the chemist is not a properly qualified man, he is not at all practical, he is by no means a disciplinarian in his work, and he seldom carries his work to a satisfactory issue. The chemist is too often a dabbler, who, when he is set to work out some problem, does it in a half-hearted way. He, perhaps, succeeds on a laboratory scale, and is not sufficiently in touch with the practical man to be able successfully to accomplish his work on a large scale.

I venture to think that it is a mistake for the chemist to content himself with a knowledge of chemistry only; it is advisable that he should be a good draughtsman and have some knowledge of engineering. Further, it is important, if not essential, that he should have had a thorough drilling in the paper mill. How often has a manufacturer taken a young fellow possessing a good elementary training as a chemist, and met with nothing but disappointment. It sometimes happens that a young man of this stamp will rise to the occasion, and instinctively acquire a technical grasp of the particular manufacture to which he is giving his services; but such men are few and far between, and it is consequently a dangerous experiment to employ a man under such conditions.

On the other hand, the chemist is often left too much to his own devices by the practical papermaker. He is not called upon to give sufficient account of himself and his work, and is left to study what problems he likes. It is only when something for which the chemist is supposed to be responsible goes radically wrong that he is brought to book. The appliances at the disposal of the resident chemist are, as a rule, altogether inadequate for useful work, and as the equipment that a chemist requires for paper-mill work is not expensive, there can be no excuse for his not having what he requires. I am inclined to think that the chemist is partly to blame for not adequately equipping his laboratory for the work he has to do.

Duties of Works Chemist.

The foundation of the work of a resident chemist should be routine work, undertaken at the instance of the principals of his firm. The work should be carefully chosen, care being taken, of course, that no unnecessary work is done. There are many tests that should be undertaken as routine work, either daily, weekly, or fortnightly, as circumstances warrant. The laboratory should be so equipped as to render this work as easy and rapid as possible. Records of the tests should be kept in books, to which members of the firm can refer, and there is no reason why they should not be entered with as much regularity and precision as entries are made in the day-book or ledger in the counting-house. The rapidity and precision of routine chemical work is largely dependent upon the choice of suitable methods.

When certain observations become matters of everyday routine, it is possible so to arrange the work as to reduce labour and minimize the possibility of error. An investigation should be conducted in such a way as to bring into due prominence the particular point requiring elucidation. A chemist will sometimes take too much pains over details that have no bearing whatever on the point at issue; this, of course, is a great waste of labour.

There are many questions relating to papermaking that are extremely complex, and a chemist should form no judgment, except after repeated verification of his results. In bringing his results before a practical papermaker, if need be, the chemist should present his figures in such a way as to be thoroughly intelligible to an unscientific mind. The choice of work should have very careful consideration. In this matter the chemist should be largely influenced by the practical papermaker. The work might be conveniently divided under three headings—

(1) Routine chemical work.
(2) Special investigations.
(3) Research work.

No. 1 should be undertaken first, No. 2 as occasion requires, and No. 3 as time and circumstances permit. Under the heading of No. 1 there are, I should judge, twenty lines of work applicable to any paper mill. Under No. 2 must be included all special work that the chemist is called upon to undertake from time to time, such as the testing of any new process. No. 2 will be a greater test of the chemist's capabilities than No. 1.

The research work should be entirely spontaneous on the part of the chemist. If he has the time and opportunity, he might undertake investigations on his own initiative, and he should not be discouraged from so doing by his employers, so long as the work in question has some important bearing on papermaking.

My reasons for stating that a chemist should be something more than a chemist, are as follows: He should certainly be able to do such things as indicate a steam engine, conduct boiler trials upon the evaporative efficiency of fuels, or determine the relative efficiencies of different types of furnaces, &c.; unless he is somewhat of a mechanic, he will not be able to make special appliances required for his investigations, or to instruct others to do so; unless he is a draughtsman, he will not be able to make his own designs or submit drawings to his principals. Unless he has actually been drilling in papermaking, he will most likely content himself by testing a process on a laboratory scale only. With practical experience of industrial processes a man, however scientific, if properly balanced, will not be contented with laboratory investigations alone; he will regard such work as stepping-stones only, and proceed to repeat his experiments on a more extended scale, and under conditions which obtain in practice. Then, and not till then, can he feel the least assurance of success on an industrial scale.

I have said enough in reference to the duties and responsibilities of a paper-mill chemist, but the primary responsibility appears to rest with the practical man. How is it that most papermakers have no resident chemist at all, whilst others have men who are mere dabblers, who, absolutely devoid of system, do just what they like and leave the rest? Whose fault is it that such is the case? I venture to think that the papermakers are partly to blame for not employing thoroughly good men, and placing the necessary appliances at their disposal. Such men will be forthcoming if the papermakers show more desire to enlist their services.

The Want of Educational Opportunities.

The student who desires to instruct himself, either for his general advancement or for the purpose of passing the City and Guilds of London Institute Examination, is confronted with many difficulties, and it is as well that these difficulties should be appreciated. He is more likely than not to be living in some out-of-the-way place where he is dependent entirely upon his own resources. We take it for granted that he holds some post in a paper mill. It is hardly to be expected that his employers would permit him to "poke his nose" into every department in the mill for the purpose of gaining information. If this would be permitted (which is extremely improbable, not to say unreasonable) no one mill will afford a sufficient object-lesson for the purpose of his studies. He is therefore thrown back on what literature he can obtain. He would require to save up his money for a considerable time in order to purchase the books recommended for study in the syllabus of the City and Guilds of London Institute, the total cost of these books being about £11.*

The publication of Hofmann's Treatise was discontinued

* City and Guilds of London Institute. Programme of Technical Examinations, p. 57.

after a sixth number, and therefore only about a third has appeared. Also the student cannot now obtain copies of the "Practical Papermaker," by Dunbar, and the "Art of Papermaking" (Kent & Co.), as both these books are now entirely out of print; it must not be forgotten also that the "Chemistry of Papermaking," by Griffith and Little, and also Dr. Arnot's Lectures, are out of print. The student is therefore severely handicapped, as out of eleven books recommended for reading, four are now out of print, and one is only partially issued. Special articles, also, referred to in the trade journals, are for the most part out of print, and therefore impossible to obtain. Even assuming that the pupil has all the literature on the subject available, either in his own possession or at some institute, he must have guidance in his studies.

Papermaking Literature.

The text-book literature is, for the most part, empirical, it does not deal with the general principles involved in the manufacture of paper, it gives a general description of the various processes, receipts, and illustrations of plant, &c. General principles hold good for all time, but empirical knowledge becomes obsolete in proportion as the industry advances. Many of the text-books on papermaking are old, and consequently out of date. The student who studies these may be unconsciously acquiring knowledge of what was done twenty or thirty years ago, instead of what is being done at the present day. Of course we cannot do more than make use of the literature that we have at our disposal, but those who are attempting to educate students should warn them of the difficulties with which they have to contend, and should direct and advise them in their studies, so as to save them unnecessary labour.

Although text-book knowledge is very useful in its way, and very much to be encouraged, it will never make a man a good papermaker; the ordinary text-book is more to be desired as a book of reference or a book at the elbow than a book to be committed to memory. That which comes to the memory should savour more of practical experience than of text-book knowledge.

From an educational standpoint, a knowledge of the *general principles* involved is much to be desired; this can be acquired, in a measure, by careful study of the history of paper manufacture. History reveals a gradual evolution since the introduction of the Fourdrinier machine. This is itself a valuable object-lesson demonstrating the unfolding of general principles. History also lends additional interest, and will often stimulate reading as well as inquiry. The reasons for the abandonment of one appliance in favour of another, and the effect of such a change on the improvement or otherwise of the product under treatment, and also upon economies of production, if followed in all its stages, reveals to us in the truest light the scientific aspect of papermaking. Such studies are to be recommended for advanced students, and will be found most fascinating, besides being of real practical value and encouraging scientific methods. One cannot over-estimate the importance of following step by step the *improvements* that have been effected from time to time in paper manufacture, their cause and effect, and why we have held to certain things, and why we have abandoned others.

TECHNICAL EDUCATION FROM THE WORKMAN'S POINT OF VIEW.

Let us now regard the question of education from the working man's point of view. Mr. Davis says (see above), "It is quite evident that the ordinary working man is not dependent in any way for the excellence of his work upon any scientific knowledge he may possess. It would not be fair to say that the possession of any scientific knowledge on his part would be a disqualification for his work, but in all ordinary cases he would be just as well without it." However true this may be in some chemical industries, I do not think it is true of papermaking. It is important that the working man should have an intellectual grasp of the general principles involved in the particular work he has to perform (which is only another way of saying that he should have scientific knowledge of his work), however limited in scope that work may be. In the case of papermaking, which perhaps is a peculiar one, he should have more than this, for the simple reason that each process is dependent upon its predecessor, and influences that which is to follow. The working man, therefore, in order that he may do his work well and intelligently, should have some scientific knowledge of the other branches of the work which influence his own or are influenced by his own. I am sure many practical papermakers are fully alive to this.

It is said that paper is made in the rag-house: this implies that the preliminary treatment of the raw material before it receives its real chemical and mechanical treatment, affects the whole of the subsequent operations.* And yet, how little the foreman of a rag-house, to say nothing of those under him, knows of the after processes. Many of these workpeople, and undoubtedly with good reason, have not been permitted to walk through the other departments of the paper mill. The same may be said of the "boiling," and perhaps with greater force of the "beating" departments. The beaterman, in my opinion, should possess a considerable knowledge of the processes to which the stuff is submitted, prior to the beating, and also (which is perhaps more important) a knowledge of the influence which some slight change in the beating will produce in the behaviour of the stuff on the machine, and its effect upon the qualities of the finished paper.

I claim, also, from another standpoint, that all workmen should be able to avail themselves of technical instruction. In order to appreciate their claims to technical education, let us endeavour to place ourselves in their positions. Undoubtedly workmen are ambitious of improving their positions. The boy comes to a paper mill, and is put into some irresponsible position where he has to do little else than manual labour. As time goes on, and as opportunities present themselves, he is given a "rise" and put in a better position. He is drafted, perhaps, from one department to another, and he gradually takes a more responsible position. He may, in the course of his multifarious duties, have occupied every position in a paper mill. It is important that he should have the opportunity from the very commencement, not only in his own interest but also in the interest of his employers, of obtaining a more intellectual grasp of the work he has to perform than he can gather from mere observation in the mill itself. Such knowledge must tend towards efficiency, it must give additional interest to work, and also it must assist a man to qualify himself for a better position.

Education by Tradition and Geographical Isolation.

In former days knowledge was acquired by the old system of apprenticeship. The accumulative experience in many mills must have been great. This knowledge was handed down by tradition from one generation to another. Men, in order to

* The same remark is often applied to the "beating."

maintain their positions, perhaps, after they were disqualified through age or want of energy from carrying out their duties efficiently, would refuse to impart the knowledge they possessed to those under them. The result has been, over and over again in many industries and in many mills, that this unwritten knowledge has died with the individual, and has to be reacquired by some means or other.

There is also another barrier. Paper mills are distributed in various parts of the country, often in inaccessible and isolated places; from a geographical point of view, therefore, there are barriers to united action. A papermaker often had little or no knowledge of what his next-door neighbour was doing. His instructions were often verbal, and there was no written literature of the mill. The valuable knowledge gained, after many years of experience, might easily become extinct on the death of one of the members of the firm, or perhaps on a change of management. It must not be forgotten that experience is not inherited, but has to be acquired.

What militated, not many years ago, against any possible chance of educational advancement, or perhaps industrial progress, was the conservatism and isolation, and, sometimes perhaps, the jealousies of the papermakers in different parts of the country. This state of affairs, from the industrial point of view, has for the most part been remedied. Rapid advancement, keen competition, and change of methods have wiped out all this, and the keen competition which now assails all members of the trade compels them to look for some united action to enable them to maintain their individual, as well as their national supremacy.

THE NECESSITY FOR TEACHING THE "PRACTICE."

Sir Philip Magnus, in his paper on the "Theory and Practice of Trade Teaching," refers to the interpretation put upon the following words in the Technical Instruction Act: "Shall not include teaching the practice of any trade or industry or employment." * He points out how these words have received very liberal interpretation. It is difficult to conceive how any trade or industry can be taught to any great advantage, unless the *practice* of the trade is taught at the same time. There is a good deal to be said on this point in relation to papermaking. The

* "International Congress on Technical Education," p. 27.

Act appears to throw the onus of teaching the *practice* of the industry upon the manufacturers themselves. It must be conceded that indiscriminate teaching is likely to be productive of as little good as indiscriminate charity. Like everything else, it requires to be properly organised. It is impossible, for reasons above stated, for the average student who desires to make a study of the general principles of papermaking, to obtain a sufficient diversity of practice, or of knowledge, in the capacity in which he works in a paper mill. His technical knowledge will, of necessity, become limited unless the practice of the art can, in some way, be demonstrated outside his individual work. On the other hand, the papermakers, as individuals, cannot resolve themselves into educational bodies.

Technical Equipment.

To overcome these difficulties the Municipal School of Technology, Manchester, are setting a most excellent example by the erection, at a great outlay, of an installation of papermaking appliances on a small scale, by means of which the various processes of paper manufacture can be demonstrated to paper-mill workers. I am much indebted to Mr. J. H. Reynolds, Principal of the Municipal School of Technology, Manchester, for his courtesy in supplying me with details of the equipment, The plant has since been installed and is working successfully. It comprises the following :—

Equipment of Paper-testing Laboratory.—Microscopes, microphotographic outfit, tearing machines, micrometers for measuring the thickness of papers, stoves for ascertaining the moisture in wood pulp, apparatus for ascertaining the resistance to folding and crushing, paper balances, ash balances, and numerous other appliances.

Papermaking Plant.—Rotary spherical boiler, breaker, beater, stuff chest, sand tables, strainers, Fourdrinier machine (to make paper 24 inches wide, wet end), two wet presses, two batteries of drying cylinders, smoothing calender, slitter knives, reeling apparatus, rereeling apparatus, sheet cutter, ordinary and friction calender, embossing calender.

"*Hand-made*" *Plant.*—Vat, couching arrangement, special drying arrangement, spindle press, plate-glazing calender.

As far as I can gather from all sources, I shall be right in saying that the above equipment is quite unique, and it is to be hoped that the committee's heavy expenditure will receive the support that it deserves from the paper trade in all parts of this country. I am informed that Mr. Julius Hübner, F.C.S., is the head of the paper department; he instituted the technical classes in connection with papermaking about nine years ago. I feel it only right to say that the trade is much indebted to Mr. Hübner for the enterprise and public spirit he has displayed. It was, I believe, due in a large measure to his support that the Municipal School of Technology decided to take the bold step, originally suggested by Mr. Robert Marx, of erecting model papermaking plant for educational purposes.

"Education Intégrale."

In order that any real and substantial progress can be made in the technical education of papermaking, it is necessary that *practice* and *science* should go hand in hand. To read about a process, or even to be lectured to about a process by a practical papermaker, could not give the same acquaintance as a combination of such teaching with the actual working of the process itself. On the other hand, seeing a process carried out, or even conducting a process for one's self, on a commercial scale, does not necessarily convey anything like a full knowledge, unless the scientific principles are, at the same time, fully enunciated. This is powerfully urged by Krokoptin, who condemns the arbitrary division of society into brain workers and manual workers, and advocates the system known as *Education intégrale*, in which both brain work and hand work are cultivated side by side. The importance of this mode of procedure, as far as an industry will permit it, cannot be over-estimated.*

It should be borne in mind that since the introduction of the Fourdrinier machine, the papermaker is no longer the man who makes paper, in the literal sense of the word, but rather one who understands how to make it. The "hand" cannot be used in conjunction with the "head," to the extent to which it can be in many other industries; but notwithstanding, the "hand" should be used to the extent of being able to operate any machine used in the process of paper manufacture, in addition to assist the understanding of diagrams and plans setting forth

* "Fields, Factories, and Workshops," by P. Krokoptin. Swan, Sonnenschein & Co., Ltd.

the full details of the machine, and education should extend to a full knowledge of the general principles of its working.

It is to be hoped that the enterprise displayed by the Municipal School of Technology at Manchester will be productive of much good in this direction. It is quite feasible that a great deal of useful educational work could be done with a small papermaking machine. It is, perhaps, too much to expect that workmen would become practical machine-men by merely familiarizing themselves with the working of a small machine; but they could certainly rapidly acquaint themselves with the general principles of the machine and the influence of the different factors which control the properties of the web of paper far more quickly by such means than they could ever hope to do by acting as an assistant to a machine-man on a big machine. With such a small machine the thickness, the shake, the suction, the drying, and the pressure of the rolls, the temperature of the stuff, and all such details could be controlled and rapidly changed at will, and the influence of all the changes could be studied in their effect upon the finished paper. A small machine might also be used for any class of material. An immense amount of useful information should be imparted by such means, which might prove of the greatest industrial as well as educational value.

A small machine, such as that being erected at the Municipal School of Technology, can hardly be expected to do the work exactly in the same manner as a large machine would. I contend that this is not necessary for educational purposes. We all know that there is a difference between a chemical reaction on a few grains in the laboratory, and the same reaction, when carried on on a commercial scale; but there is, nevertheless, a direct relationship between large and small operations, which can be absolutely accounted for. It is conceivable, therefore, that a relationship can easily be established between operations of a small paper machine and those of a large paper machine, so that valuable and practical deductions can be arrived at even in the event of the small machine affecting the stuff somewhat differently. The Municipal School of Technology, Manchester, and also the engineers, Messrs. Hemmer Brothers, are to be congratulated on this very bold experiment, the results of which will undoubtedly be looked forward to with great interest by members of the paper trade. Should it succeed, I think we should be compelled to modify our views as to the possible scope of technical instruction from a papermaker's standpoint.

It is encouraging to know that the technological examinations are becoming more and more practical every year; this must help to make the teaching more practical also. The responsibility of the examiners is very great, because the character of the questions which are set will, in a large measure, influence the character of the teaching, as a large bulk of those who go in for technical education do so with the object of passing the City and Guilds' examination. It is very gratifying to see so many more students entering for the examination, but it is to be hoped a far larger number will enter in the near future.

The student has, perhaps, at present, four courses open to him, whereby he may acquire a knowledge of papermaking.

1st. By his actual work in the paper mill.

2nd. By reading text-books.

3rd. By his attending classes.

4th. By correspondence teaching.

The limitations to the first of these have already been discussed.

Technical Articles, Lectures, and Examinations.

Text-book knowledge is valuable in its way, it is extremely useful in conjunction with practical work; but something more is wanting than text-book knowledge to supplement the ordinary practice in the mill. To supplement text-book literature, I would suggest that much good might be done by the publication from time to time of technical articles, dealing rather with general principles than with bare statements or descriptions of the processes; but whatever direction these articles take, it is important that we should keep them up to date. It is important that the mill-worker should have the opportunity of close contact with those who are endeavouring to teach him, hence the necessity for lectures in all the most important centres.

Technical education will be of little or no service unless it keeps abreast of the times. It is no good teaching what has been, but what is and is to be. It will be no good employing academic teachers. Practical men of good standing, alive to all recent improvements, and in close touch with the industry which they profess to teach, will be required—men who can acquire and assimilate all the most recent improvements, and not men who teach the same thing year after year with little regard to changes that are taking place. What benefits shall we derive from men who go about the country lecturing on technical subjects, the whole of their knowledge of which is derived from text-books? In order to impart technical skill and knowledge, a man must be what he wishes his pupils to become. An intelligent pupil, if he desires to, can assimilate knowledge from a text-book without the aid of a public exponent. Instructors are wanted for the purpose of imparting that intimate knowledge that cannot be derived from text-books.

Fifteen years ago, on good authority, we are informed that the attitude of the workman towards education was positively hostile. Five years ago we were told that this feeling had almost disappeared. To-day we find the National Union of Paper-mill Workers, or the Amalgamated Society of Papermakers, meeting and discussing the subject of technical education, and even urging the necessity for it as a means of fighting foreign competition. The men themselves have not only lived down their prejudices, but are now crying out for technical instruction.

At a meeting of the Trades Union held in 1894, a fear was expressed that the technical education would tend to overstock the trade with working men, and consequently bring down the wages and increasing the unemployed. It has been considered necessary by many to stipulate that only those engaged in the trade should receive instruction. I am very much in sympathy with those who consider it unfair on *bonâ fide* paper-mill workers to give instruction to outsiders, and that the instruction should be limited only to *bonâ fide* paper-mill workers. This view has been expressed by members of different trades, and not without good reasons. If the examinations could be made an absolute test of practical experience and knowledge it might not be necessary, or, perhaps, desirable to make this stipulation. It has, however, under existing circumstances not proved possible to make the examinations a real practical test. As the result of the examinations, Mr. Slingo * informs us that "one city clerk was, in his year, the prize carpenter of the United Kingdom; another took the prize in the electric lighting; another the prize in the electrical instrument making; another in tools; and another, who had never been out of London for more than a week or two at a time, obtained a certificate qualifying him as a teacher for agriculture." Under such circumstances, and until

* "The True Basis of Technical Education," by William Slingo, before the International Congress.

examinations can be made an absolute measure of practical knowledge and experience, it would be only fair to prohibit all outsiders from competing. It is very encouraging, therefore, to know that the technological examinations are becoming more practical year by year, but it is impossible to urge upon the examiners too strongly the necessity of making them more so, and to be satisfied with nothing less than an examination which shall be an absolute measure of practical experience.

Correspondence Tuition.

It has been urged that correspondence tuition tends to discourage class teaching, which is considered far more valuable, and therefore correspondence teaching should not be resorted to. I have conducted a correspondence class in the paper trade, and have found that the greatest number of students, in any one locality, who have availed themselves of the correspondence tuition, have at the same time been 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 a 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; my ambition has rather been to help and guide mill-workers by means of test questions. I have endeavoured to set them leading questions of a practical nature, and on receipt of their answers have published, through the medium of Paper and Pulp, my remarks on each answer. Each worker has the advantage of reading my remarks on all the answers. In many cases I have quoted from the answer, and in some cases, where the answers are very good, have published them in full to encourage the workers as much as I can. Whatever objections may be raised against this by the City and Guilds of London Institute, the result is certainly very encouraging. All the workers, I think, without exception, have improved in their answers; they are getting to know how to tackle questions and how to express themselves better. The average paper-mill worker, however thorough his practical knowledge may be, requires practice in constructing his answer before he enters for the examination. Apart from actual aid for examination purposes, "test questions" may have a wider and more important scope—they stimulate 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 question 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.

I do not wish it to be thought that correspondence tuition should take the place of classes and lectures. I think that probably the first aim should be to establish classes and lectures in important centres; but inasmuch as classes and lectures, however well they may be organised and attended, can only benefit a limited number, whereas correspondence tuition, or "test questions," somewhat on the limits above indicated, can be made to reach everybody, I think they are much to be encouraged.

The Hertfordshire County Council did me the honour of asking me to lecture before the Dickinson Institute, and I delivered a course of six lectures last autumn. I was much struck with the enthusiasm displayed by the workpeople, about eighty of whom attended. The Hertfordshire County Council have perhaps shown as much enterprise as any centre; they have again enlisted the services of Mr. J. T. Ainslie Walker in preparing students attending the Dickinson Institute for the forthcoming examinations. The trade in general in and around London are indebted to Mr. John Wilson, F.C.S., for having started a class at the Battersea Institute. Last session Mr. Wilson delivered a course of lectures on the "Chemistry of Papermaking," and this year he has secured the services of Mr. E. J. H. Stallybrass (Assistant Examiner of Paper in H.M. Stationery Office). The course this session is chiefly devoted to paper testing. The course has started well with thirty-five entries, the practical work being the great inducement, especially as the course is quite novel in the London district. Other classes and courses are being held, but space will not permit me to go further into these details.

Education Abroad.

I am indebted to Mr. Robert Marx for the following information in regard to work that is being done on the Continent:—

As far as the technical education of workmen in Germany is concerned, it may be stated that there is no institute for paper-mill workers. There are, of course, places where mill foremen can obtain the requisite knowledge, and others for fitters; but, generally speaking, the mill hands have to learn everything connected with their work in the paper mill itself. Furthermore, there are no technical schools provided for papermakers.

Some time ago Professor Kirchner, of Chemnitz, gave several lectures to students, but was compelled to abandon them on account of insufficient support. There is, however, a school for papermakers in Vienna, attached to the Royal Technical Museum, under the control of Mr. H. Schultze. Some of the universities and technical institutions in Germany give regular courses and lectures on papermaking, but all these are chiefly intended for papermaking engineers. As far as I can ascertain, very little is being done in the United States to further technical education for papermakers.

The Value of Research.

As a part of the educational scheme, it is impossible to overrate the importance of chemical research. Research work may be divided under two headings: (1) Industrial Research and (2) Pure Research. The very basis of our national advancement and prosperity must, of necessity, be largely dependent upon the careful and systematic prosecution of chemical research. There are a lot of questions pertaining to the paper trade, many of them apparently small but important details, only awaiting exhaustive and systematic study. In any adequate scheme for technical education, those who pose as instructors and demonstrators should have an intimate knowledge of what they desire to teach, but without research this cannot be done. I venture to think, therefore, that any institution or technical school that takes in hand instruction in papermaking, should recognise the necessity of students applying themselves systematically to technical research.

There is a kind of research which is outside the ken of the majority of workers, but which is nevertheless of great importance if we are to safeguard our interests in the future. I speak of pure research. In the prosecution of pure research the chemist, more often than not, has no immediate industrial object in view; but if we read the history of modern progress correctly, we cannot fail to recognise that many of the most important economic changes have been the direct outcome of pure research. And so it must be, but in a greater degree, in the near future. Although there are several workers on the Continent, Messrs. Cross and Bevan stand practically alone in this country in the prosecution of pure research in connection with the paper industry.

Our war of the future must of necessity be an industrial war. There will be little good in waging this singly and individually; it calls for the most perfect and efficient equipment, and for united action. The trade as a whole should, I venture to think, recognise the necessity of furthering to the utmost technical education, and seriously consider the best means of effecting the desired end.

To sum up, I venture to say that what is needed is a central Papermakers' Institute to undertake the prosecution of industrial and pure research, as well as the technical education of all students. It will be necessary, of course, to have the use of a thorough equipment, such as the Municipal School of Technology are now installing. This institute should organise classes, lectures wherever possible, and a course of correspondence tuition. The intelligence department should jealously watch publications of all sorts bearing on papermaking in all parts of the world, and should issue publications to all papermakers who support the Institute. They should make it their chief aim to render men more efficient in their daily duties, and to qualify them for better posts. They should make it their aim, also, to qualify those who desire it, for the City and Guilds of London Institute, and to urge upon the institute the necessity of modelling the examinations so as to make them in every way a thorough test of practical knowledge and experience. When this can be accomplished, a certificate from the City and Guilds of London Institute will serve to qualify a man for a better position; and what is of more importance, perhaps, papermakers might insist upon their workpeople, at any rate those in responsible positions, taking certificates.

Our paper industry, containing as it does many practical, progressive men, alive to their own interests, is still *lacking* in the department of technical education, and lacking possibly because private enterprise alone cannot promote it sufficiently. State aid may do some good, but the initiative must come from the members of the trade, and, whatever shape the movement takes, it must be the outcome of united action on the part of those who are to reap the benefit that is bound to accrue.

II.

THE USE OF SPECIALLY PREPARED SIZE IN DRY SHEETS FOR PAPER SIZING.

WHEN animal size first came into vogue papermakers almost universally manufactured their own size, and have continued to do so up to the last few years.

Since the manufacture of gelatine has become an industry in itself many improvements have been effected.

It is necessary to make distinctions between what is known as gelatine and glue. The former is made from pure raw materials, and has much greater gelatinising power than the latter.

Gelatine is used almost universally for coating and sizing, whereas glue is prepared of adhesive material and its colour is immaterial. Glue has very little gelatinising quality. The name of glue is often applied to high-class gelatines, but this is somewhat misleading. The higher class are generally distinguished by their high gelatinising power, and their good colour and freedom from ash. These high qualities, however, are not all that the papermaker requires. It is extremely important that the colour should be good, for the simple reason that if the material is at all coloured it will lower the tone of all high-class papers.

With browns, and all papers where colour is immaterial, the gelatine need not be of very high colour, but it is essential that it should possess certain other qualifications to make it of universal advantage for the purpose of paper sizing.

It is important, for instance, that there should be a right degree of penetration and surface. Size that only remains on the surface is of little or no value for rendering the paper impervious to ink. It is necessary that it should penetrate sufficiently to make the paper bear ink. When manufacturing size in paper mills it is by no means an easy thing to produce a uniform product, as the size is not manufactured on a sufficient scale to render it easy to do so.

The raw materials used for size manufacture, such as wet hide pieces or fleshings, vary considerably in the yield which they give, as well as the degree to which they have been treated for the removal of the lime, &c.

When the manufacture is conducted on a very large scale, as it is in some of our large-sized factories, much larger stock can be kept, and the composition kept uniform by means of taking material of average quality. But apart from this question, and one which is of greater importance, is the fact that size suitable for the purpose of paper sizing cannot be produced from any one raw material alone. In order to obtain the necessary degree of penetration, and that the material should give the requisite surface consistent with the proper ink-bearing power, it is necessary to blend several raw materials, so as to give these different qualities of a sufficient degree to make the size useful for paper sizing.

With any one raw material the different draughts vary in their composition. Thus the first draughts from wet hide pieces are of a very much better colour and of a greater gelatinising power than the last draughts.

The only way at present of gauging the strength of solution in the paper mill is by means of the aerometer, a species of hydrometer especially designed to show the percentage strength of size without any calculation.

It is graduated on the stem in percentage of dry gelatine in solution. If the solution stands at 75° C., or 167° Fahr., no correction is necessary, but in case the temperature should be slightly above or below this, a thermometer is used in the lower part whose bulb forms the base of the instrument. The thermometer is graduated in such a way that the graduations are made to compensate for the variations of temperature. If the temperature is too high the reading on the thermometer must be added to the reading on the stem, and if too low it must be deducted.

The specific gravity of a solution of gelatine increases with the percentage present. The increase is found to be about ½° Twad. for each per cent. of gelatine. The co-efficient of expansion of gelatine solution, unless the same be very strong, is nearly that of water.

When first draughts are taken from wet hide pieces and well filtered, the percentage of gelatine present agrees very closely with the readings of the instrument—

Analysis.	Hydrometer Reading.
5·06 per cent.	5·15 per cent.
4·05 ,,	4·04 ,,
3·24 ,,	3·15 ,,
2·59 ,,	2·75 ,,
2·07 ,,	2·02 ,,

When all draughts are mixed from wet hide pieces and after filtration :—

Analysis.	Hydrometer Reading.	Per cent. too high.
6·29 per cent.	7·05 per cent.	19·6 per cent.
6·26 ,,	7·05 ,,	19·6 ,,
6·00 ,,	6·95 ,,	15·2 ,,
6·06 ,,	6·95 ,,	15·2 ,,

Hydrometer Reading.	Gelatine Actually present.	Difference.
1.—6·0 per cent.	5·59 per cent.	7·0 per cent.
2.—8·5 ,,	6·56 ,,	22·0 ,,
3.—7·2 ,,	5·86 ,,	18·0 ,,

The difference shows the error of hydrometer in percentage when gelatine equals 100 in each case.

1 = A second and third draught mixed from wet hide pieces.

2 = The same after the addition of the necessary soap and alum.

3 = The same as No. 2, but containining somewhat less alum.

It will be seen from the foregoing that the hydrometer reads considerably higher than it should do in the later draughts, and that even when all draughts are mixed from hide pieces about one-fourth must be deducted from the reading to arrive at the true percentage. The deduction of alum and soap also increases the gravity considerably. In the ordinary method of adding alum and soap about 2 per cent. must be deducted. Thus, if the instrument recorded 8 per cent., the amount of gelatine present would be about 6 per cent.

It is necessary to determine exactly what influence the addition of sulphate of alumina, or alum, has upon the specific gravity of size solutions. With that view the following experiments were performed :—

Trials made to see how much alum is required to thicken gelatine solutions.

The jelly taken was found on analysis to contain 4·97 per cent. gelatine; 16 ozs. of the above, in 20 ozs. of water, required 200 grains of a solution of 20° Twad. sulphate of alumina.

Therefore, one ton of size at the above strength would require $6\frac{1}{2}$ gallons of sulphate of alumina solution at 20° Twad., or 13 lbs. of commercial sulphate of alumina.

Ten gallons of the size would require 0·57 lb. of sulphate of alumina. It is important to note that 50 per cent. more sulphate of alumina can be added without reducing the thickness of the size, and four times the original quantity can be added before the size is reduced to its original consistency.

The size used for the experiment was a first draught from wet hide pieces. It showed a reading of 5 per cent. before the addition of the sulphate of alumina, which is identical with the analysis. After the addition of the sulphate of alumina the hydrometer read 6·4 per cent. The addition of the sulphate of alumina, therefore, raised the specific gravity enough to cause the instrument to read 1·4 per cent. higher, equal to an error of 28 per cent. on the gelatine present.

We are right, however, in concluding that increase of specific gravity per unit of strength denotes, I think, without exception, the presence of some impurity, in which case we should expect to find a high ash; also that a low specific gravity per unit of gelatine points in the direction of a high-class gelatine and freedom from impurities. A gelatine of highly gelatinising power appears always to exhibit a low specific gravity in solution, and with glues of low gelatinising power the opposite is the case. Also, the first draughts from any raw material, so far as my experiences have gone, are of a lower specific gravity, of higher gelatinising power, and almost invariably contain a lower percentage of ash than the later ones. For size from any particular raw material the difference between the percentage of gelatine by specific gravity and the actual percentage by analysis may be taken as a measure of impurity and quality in making a comparison of the value of the different draughts, but it can hardly be considered comparative when the size solutions under observation are obtained from any different raw materials.

All this trouble in regard to taking the strength of the solution can be avoided when air-dried size is used, because a given quantity of air-dried size can be weighed out, and after immersion in cold water for twelve hours to soften, the sheets can be dissolved to any required strength by the addition of hot water. The necessary amount of alum and soap can then be added, and there is no difficulty in arriving at the percentage strength of size under these circumstances.

After long experience, some manufacturers of gelatine who have made a speciality of this product for the purpose of paper manufacture have been able to arrive at a product giving the necessary amount of penetration and surface, by making it on a large scale and blending the necessary ingredients. It is by no means an easy matter, on a small scale, to ensure the complete removal of lime, grease, and blood in the raw materials used. If either of these substances remain in the raw material they become a part of the size, and very much impair its qualities.

It has been claimed that size is never so good when first prepared. Its qualities improve when the water is removed. Air-dried size when dissolved again has much better sizing qualities than the jelly from which the air-dried size has been originally prepared. This gives a decided advantage for air-dried size over any class of size prepared and manufactured by the papermakers.

It is generally admitted that the jelly kept for any length of time loses some of its strength, but I have no definite data to go upon in support of this contention.

It is often found necessary to stock a quantity of the jelly, and at times it is necessary to keep it in stock for some months. In warm weather this jelly is very liable to putrefaction, unless some preservative is added. Dried sheets of size can, however, be kept for any length of time if stored away in a dry room, and these sheets are not liable to undergo putrefaction.

On account of the imperfection in the methods of drying tub-sized papers it is important that the size solution should set to a jelly at a fairly high temperature. The temperature of the drying-room should be kept down to the point at which the size solidifies. The secret of the successful drying of tub-sized papers is to arrange the drying so as to keep the whole of the jelly in a solid mass. If it remains in the interstices of the paper in the form of liquid, as the moisture dries out of it this liquid will quickly form a coating round the individual fibres instead of filling up the air spaces. If it were possible, the whole of the drying should be conducted at a temperature only a few degrees above the freezing point of water. The drying should be done by means of cold dry air instead of hot dry air. The longer the drier the more likelihood there is of this being accomplished, with a short drier this is absolutely impossible. This is the ideal to be aimed at, but unfortunately it is a long way short of practical attainment.

Size for papermakers must, therefore, to be of any service, be of fairly high gelatinising power. It is quite impossible to fulfil all these conditions in even the best appointed mill, even if papermakers had the latest and most perfect plant at their disposal, they still would have a difficulty in making the size which would fulfil all the necessary conditions, and it stands to reason that they cannot make one of uniform composition on account of the irregularity in the quality of the raw materials which they buy from time to time. There is a variation from time to time in the quality of size made in even the best appointed mill, which renders it almost impossible to papermakers to make their own size, and to ensure absolute regularity in the sizing qualities of their paper.

It must not be assumed that because the paper contains, say, for example, 6 per cent. of size, that it is necessarily hard-sized and impervious to ink. I have myself tested a paper and found as much as 9 per cent. of size, when the paper had been rejected as soft-sized and not bearing the ink test. This was due to the quality of the size used and the way it had been applied to the paper.

If the quality of the size can be kept uniform, as it can by the use of air-dried size *of a known standard*, these difficulties should not occur.

The tendency of the present age is to specialise and to give up the subsidiary industries, as it is found in the state of present competition that it no longer pays for a manufacturer to attempt to make everything for himself.

Take the case of wood pulp. The papermakers of this country no longer make their own wood pulp, but are supplied from those countries where the wood is available and where it can be converted at a comparatively low cost. They take the pulp already prepared for their use.

The manufacture of soap, which at one time was an ordinary household operation, is now manufactured on an enormous scale, and specialised in different grades; and even the manufacture of rosin size, which is a comparatively simple operation as compared with that of size, is now being discontinued by many papermakers, who find it better and cheaper to let those who have made it a special study make it for them.

The same argument might apply in regard to the manufacture of ultramarine, pearl hardening, and other products used in the manufacture of paper. As far as I can gather, on the Continent practically the whole of the manufacturers have discontinued the manufacture of size, finding it better and safer to purchase air-dried size specially prepared for their purpose, and I do not think the time is far distant when all the papermakers in this country will realise that it will no longer pay them to produce size for their own use, and that the manufacturers who have made a special study of the preparation of size for the use of papermakers can give them better results than anything they can do for themselves.

There is a great deal of difference between the amount of size required to give the proper ink-bearing qualities. One size will do as much with 2 per cent. as another will do with 5 per cent. All these points have to be carefully weighed and taken into consideration when arriving at the value of any size for the purpose of paper sizing.

In order to study the effect of different classes of animal size upon waterleaf paper, a number of different materials were selected, and among them some of the best known brands of gelatine in the market. Solutions were made from each ; of such strength that a gallon of each contained an equal value of the gelatine. Three sheets of waterleaf paper were separately weighed and dipped into each of the solutions, kept at the proper temperature of the sizing trough. They were then weighed after drying down. The difference between the first and second weighings gives the amount of gelatine solution taken up by the paper. The difference between the weight of the waterleaf and the weight when dried down, gives the dry weight of gelatine taken up by the paper. The papers, after removal from the hot size, are passed through a pair of squeezing rolls, to imitate, as near as possible, the large scale of working. From the weight after drying down, the percentage of size in the sized paper can be calculated in each case. It will be seen from the tables that there is a wonderful regularity (with a few exceptions) in the amount of gelatine retained in each series. The amount of gelatine retained by each paper after sizing is dependent upon the concentration of the sizing solution. One thing was established by these and other similar trials, and that is, that the finer grade gelatines are cheaper in the end. The sizing effect of any gelatine is chiefly dependent upon the "gelatinising power" of the gelatine. Supposing that we have a number of gelatines and prepare a 5 per cent. solution of each, and allow them all to set to a jelly, and leave them at least 24 hours after setting ; the gelatine which yields the firmest jelly is the best sizing agent. A comparison of these jellies is really a comparison of the gelatinising powers of the gelatines. Supposing, now, that we adjust the strength of the solutions in such a way that the jellies from each have the same degree of firmness. Each of these jellies will have the same sizing value, or approximately so, and if the price of each gelatine be known, it is easy to get some idea of their relative value for papermaking—which of them is the cheapest for sizing. I have taken a number of gelatines in this way, and, generally speaking, the highest grade is the cheapest in the end.

PAPERS SIZED WITH DIFFERENT GELATINES.

	No.	Waterleaf.	Sized.	100 parts become	Mean percentage of size.
A	1	1·442	1·574	109·15	
	2	1·438	1·568	109·04	
	3	1·426	1·546	108·40	8·34
B	4	1·433	1·566	109·30	
	5	1·469	1·602	109·06	
	6	1·450	1·582	109·10	8·39
C	7	1·456	1·586	108·93	
	8	1·439	1·569	109·05	
	9	1·410	1 537	109·00	8·26
D	10	1·428	1·596	111·71	
	11	1·424	1·591	111·73	
	12	1·428	1·596	111·76	10·57
E	13	1·440	1·603	111·32	
	14	1 460	1·643	112·53	
	15	1·466	1·636	111·60	10·28
F	16	1·463	1·608	109·91	
	17	1·462	1·607	109·92	
	18	1·460	1·599	109·59	8·93
G	19	1·473	1·643	112·22	
	20	1·460	1·626	111·37	
	21	1·457	1·623	111·39	10·22
H	22	1·447	1·575	108·84	
	23	1·450	1·577	108·75	
	24	1·444	1·563	108·55	8·01
I	25	1·451	1·537	105·93	
	26	1·452	1·540	106·03	
	27	1·454	1·543	106·12	5·68

It is a well-known fact that it is easier to size hand-made papers hard, than machine-made papers. Perhaps it would be truer to say that it is easier to size hard in the single sheet than in the web. After discovering by the foregoing trials which gelatine was best adapted for sizing, I endeavoured to determine, by a series of experiments, in which I used diminishing strengths of gelatine solutions, what limit could be attained with single-sheet sizing without destroying the sizing effect. These results are given in the following table. Down to Nos. 38 and 39 the hard sizing was certainly maintained. In Nos. 40 and 41 it appeared to be very slightly deficient, and in No. 42, although in some respects it might be considered hard-sized, it was decidedly lower than No. 41 :—

TUB-SIZING IN THE SHEET WITH DIMINISHING QUANTITIES OF GELATINE.

	No.	Weight of waterleaf.	Weight when sized.	100 of waterleaf become	Per cent. of gelatine in paper.	Per cent. of gelatine in sizing solution.
K	28	1·488	1·584	106·46		4·030
	29	1·495	1·598	106·88	6·25	4·030
L	30	1·500	1·596	106·40		3·788
	31	1·484	1·584	106·74	6·17	3·788
M	32	1·462	1·548	105·81		3·561
	33	1·471	1·585	107·75	5·49	3·561
N	34	1·462	1·550	106·10		3·327
	35	1·469	1·552	105·65	5·54	3·327
O	36	1·458	1·528	104·80		3·127
	37	1·472	1·555	105·63	5·32	3·127
P	38	1·479	1·553	105·00		2·940
	39	1·462	1·538	105·20	4·85	2·940
Q	40	1·487	1·560	104·90		2·764
	41	1·485	1·553	104·60	4·52	2·764
R	42	1·503	1·566	103·55	3·43	2·598

After severe testing I came to the conclusion that No. 39 was quite equal in ink-bearing power to No. 1. From this I conclude that there is no advantage to be got by the use of a solution containing more than 5 per cent. of gelatine of this class.

If very great care is exercised in the treatment, I believe that a lower strength still would suffice. The first draughts from these gave the highest results. I succeeded in producing a thoroughly hard-sized paper with a minimum of gelatine. These first draughts gave also the highest gelatinising power.

To justify the opinions and conclusions expressed in this article, certain information no longer available in consequence of the publications in which this information was first made public being out of print, has been drawn upon. For instance, the information contained in an article on "The Influence of

Impurities upon the Specific Gravities of Gelatine Solutions," from the PAPER MAKER, and an article on "Animal Sizing," which appeared in the PAPER MAKER of March, 1896. The conclusions I feel are fully justified, namely, that papermakers can no longer conduct the manufacture of size in competition with those who make it their special business, and who are able to conduct it on a large scale and so ensure regularity and uniformity. It is evident that we experience the great difficulty of not being able to gauge correctly the strength of our solution by means of a glass, whereas this does not occur with solutions prepared for air-dried sheets. And, further, I would repeat the papermaker does not buy in sufficient quantity and a sufficient diversity of raw material to enable him to endow the size with all the necessary qualities to meet all the requirements for tub-sizing.

III.

THE PAPERMAKING EXAMINATION.

1901.

THE City and Guilds of London Institute's Examination on "Paper Manufacture" took place on May 1st, and the following are the instructions to candidates and the questions set :—

INSTRUCTIONS.

The candidate must confine himself to one grade only, the ordinary or honours, and must state at the top of his paper of answers which grade he has selected. He must *not* answer questions in more than one grade.

If he has already passed in this subject, in the first class of the ordinary grade, he must select his questions from those of the honours grade.

The number of the question must be placed before the answer in the worked paper.

Three hours allowed for this paper.

The maximum number of marks obtainable is affixed to each question.

N.B.—Candidates are cautioned to avoid giving in their answers to the following questions any particulars of processes used in the works in which they are employed which are not matters of public knowledge.

ORDINARY GRADE.

Not more than *nine* questions to be attempted.

1. How do you measure the thickness of a paper? Estimate the thickness of a book of 240 pages made of a paper of thickness 0·054 millimetre. Express the result in terms of the inch. (*20 marks.*)

2. What instructions would you give to the beaterman for the preparation of a superfine blue writing paper? How would you manipulate the various parts of the machine to impart the desired

characteristics to such a paper? State also what steps you would take to prevent the colour from fading when in contact with the animal size. (*30.*)

3. How are the following fibres detected in a paper: Jute, esparto (cellulose), mechanical wood? How would you estimate the quantity of each when in admixture with rag fibre only? (*30.*)

4. What are the advantages, if any, possessed by plate-glazed papers as compared with those finished on the supercalender? What precautions would you take to prevent variations in colour when friction-glazing soft-sized pink printing paper? (*20.*)

5. A delivery of pulp of 1,769 bales, unbleached sulphite, with 12 per cent. moisture (allowed) is to be sampled and the moisture determined. Give exact particulars of the test and the form in which the result is expressed. (*20.*)

6. Suppose a machine so fitted that the wire frame can be raised or lowered from the breast roll as desired, what variations from the level would you make when running the following grades: (1) Strong rag cartridges, (2) news, (3) fine printings, (4) blottings, (5) thin sulphite caps? State your reasons in each case. (*25.*)

7. State exactly how you would treat for conversion into half-stuff, new cotton pieces, new linens (grey), Manilla ropes, and broke from tub-sized writings. (*30.*)

8. What materials would you use for the production of (1) news, (2) fine writings, (3) E. S. printings, (4) blottings? State the proportions of each material you would consider necessary to give good results. (*25.*)

9. Define specific gravity. What is the weight of 7 gallons of a solution of 11° Tw.? Taking specific gravity of cellulose equal 1·50 and of china clay equal 2·75, what is the exact effect of 20 per cent. loading on the specific weight of a paper? (*20.*)

10. State the type of beating engine you would adopt for the preparation of stock for (1) strong book papers, (2) esparto printings, (3) blottings, (4) sulphite casings. Give also the horse-power required for a four-hundredweight beater in each case, and the amount of coal necessary to make and dry one ton of each grade on the machine. (*30.*)

11. What are the waste products from a rag mill (fine writings); an esparto mill (fine printings); a soda wood (half-stuff), and sulphate wood (half-stuff)? Which of these are treated for recovery of useful products, and what are final wastes? (*30.*)

12. Describe the method of imparting a "water finish," and discuss the merits of water-finished as compared with super-calendered paper. (*20.*)

13. What systems are used in practice for dealing with the fibres which find their way into the various waste waters of the mill. (*25.*)

Honours Grade.

Not more than *nine* questions to be attempted.

1. Examine very carefully and in all respects the position of esparto as against wood celluloses. Forecast their future relative positions in this country, and give your opinion as to how far this depends upon price, and how far on intrinsic papermaking quality. (*30 marks.*)

2. How would you equip a mill to turn out 100 tons of news and 50 tons of E. S. writings per week? Give your reasons for the adoption of any special appliances. (*30.*)

3. State what you know of the systems for wood pulp manufacture known as the "Drewsen Drœnfeldt" processes, and discuss the advantages claimed. (*20.*)

4. How many tons of coal would you expect to use per week in the mill referred to in question 2? State the proportion you would use in each department, assuming that the motive power is steam throughout. (*25.*)

5. You are given an unknown fibrous material, and are required to determine its suitability as a raw material for papermaking: state exactly how you would do this, and on what main points you would base your estimate of value. (*25.*)

6. In what departments, if any, of the mill do you consider that the electric motor can be successfully substituted for the steam engine? State your reasons fully. (*25.*)

7. What do you consider the special requirements of papers for (1) parchmentising, (2) converting into nitrocellulose, (3) quantitative chemical work (filter papers), (4) for making paper bowls, (5) for litho and general fine printing, (6) for cartridges, (7) for water-colour drawings, (8) for cable insulation? In each case state the composition of half stuff you would take in making the paper. (*25.*)

8. Given 10 tons of Spanish esparto of an average quality, how would you proceed to make an "art" paper such as is used for high-class magazine work? State fully the practical details to be observed in each of the various processes from the duster to the finishing house, giving a tabulated statement of the duration

of each process, and the percentage of the various chemicals, including loading and sizing, also the amount of finished paper you would expect to produce. (*30.*)

9. Examine thoroughly the question of engine-sizing with rosin and alum. Give your view of the mode of action of the size, both in the engine and in the paper. Give practical recommendations for preparing and using the rosin size. (*25.*)

10. State your opinion of the merits of Annandale's improvement in the machine for the imparting of "hand-made" characteristics to the web in process of formation on the wire. Discuss the difficulties in the way of its successful adoption, and state in which class of paper you consider it will give the best results. (*15.*)

11. Let A = the area of a sheet of pure cellulose paper in square centimetres.
T = thickness of a sheet in terms of centimetres.
S = specific gravity of cellulose.
W = the weight of the sheet in grammes.

What do you take to be the meaning of the expressions $\frac{W}{A.T.}$ and $\frac{A.T.}{W} - \frac{1}{S}$ and how would you bring the quantities so represented into practical use in the mill. (*25.*)

12. What instructions would you give to the breaker-man in regard to the washing, breaking in, and bleaching of (1) Manilla ropes for strong cartridge paper, (2) soft cottons for superfine printings, (3) linen thread for bond papers? Give the percentage of bleaching powder you would expect to use in such case. (*25.*)

13. Give a method for rapidly analysing the machine backwater with regard to suspended fibrous matter and sulphate of alumina (in solution). Describe any modern appliances you know for separating suspended fibres from waste waters. (*25.*)

IV.

CITY AND GUILDS OF LONDON INSTITUTE.

EXAMINATION ON PAPER MANUFACTURE.

1902.

THIS examination took place on Saturday, April 26th, from 2.30 to 6.30 p.m., when the following questions were set. We have arranged with Mr. Clayton Beadle to answer these in the same way as he answered last year's questions, and non-subscribers are requested to apply early for copies of the issues containing these answers, as only a limited number of spare copies will be available.

INSTRUCTIONS.

The candidate must confine himself to one grade only, the Ordinary or Honours, and must state at the top of his paper of answers which grade he has selected. He must *not* answer questions in more than one grade.

If he has already passed in this subject in the first class of the Ordinary Grade, he must select his questions from those of the Honours Grade.

The number of the question must be placed before the answer in the worked paper.

Three hours allowed for this paper.

The maximum number of marks obtainable is affixed to each question.

N.B.—Candidates are cautioned to avoid giving in their answers to the following questions any particulars of processes used in the works in which they are employed which are not matters of public knowledge.

ORDINARY GRADE.

Not more than nine questions to be attempted.

1. In boiling rags with caustic soda, what are the principles which regulate the conditions of treatment, viz. chiefly : Proportion

of soda and of total liquor to rags, temperature, and time of boiling. What information as to progress of the treatment is furnished by analysis of liquor? (*30 marks.*)

2. What are the characteristics most desirable in papers for (1) photograph mounts, (2) typewriting, (3) ledgers, (4) school books (illustrated in colours)? Give the furnish you consider most suitable, and state the precautions you would adopt to secure the best results. (*25.*)

3. What instruments are used in the mill to measure (1) temperature, (2) proportion of moisture in the air, (3) specific gravity, (4) weight and thickness of papers? State briefly what you know of the uses of such measurements. (*30.*)

4. Give a concise description of (1) Lowden's Steam Regulator, (2) the Marshall Train, and discuss the advantages claimed in each case. (*25.*)

5. In boiling Spanish esparto, how much caustic soda would you use per ton of grass, and at what dilution? State the latter as percentage (NaOH) on the liquor, and from this the (approximate) number of gallons per ton. At the conclusion of the boiling, how would you estimate the addition to volume of liquor due to condensation of steam? (*20.*)

6. What style of damper do you consider most suitable for damping (1) super-calendered printings, (2) imitation parchments, (3) glazed casings, (4) soft-sized friction-glazed printings? Give practical details to be observed in damping each of the papers named. (*20.*)

7. State what you know of the composition of bleaching powder and the bleaching action of the hypochlorites. How would you carry out the bleaching of half-stuff so as to provide for an intermediate washing of the pulp? What are the advantages of so doing? (*25.*)

8. State fully the treatment you would adopt to impart to a strong book paper the characteristics of a handmade sheet. Give furnish you would use, with proportions of boiling and bleaching liquors; the duration of treatment in each department, and reasons for the adoption of any special appliances. (*30.*)

9. What compounds of cellulose are soluble in water, and how are they prepared? Which of these are used in papermaking, and what are the special effects they produce? (*25.*)

10. Describe Cornett's system of handling and treating esparto, and discuss its merits compared with any other system you are acquainted with. (*25.*)

11. What materials are used—

(*a*) For weighting or loading papers in the engine ?
(*b*) For surfacing or coating ?
(*c*) For colouring (in the beater) red, blue, yellow, and black ? (Mention one pigment and one soluble dye in each case). (*25.*)

12. What precautions would you take to prevent froth and air bubbles when making thin printings at a fast speed, with a furnish of 30 per cent. broke and 70 per cent. esparto. (*20.*)

Honours Grade.

Not more than nine questions to be attempted.

1. Permanganate of potassium is used as a bleaching agent in neutral solution. How does it break up, and what further treatment of a pulp would be required to eliminate the products of decomposition ? Compare approximately the cost of this bleach at £50 per ton for $KMnO_4$, with that by bleaching powder of 35·5 per cent. " available Cl " at £6 10*s*. per ton. (*25 marks.*)

2. Which variety of wood fibre do you consider most suited to blend with (1) linen rags for typewriting papers, (2) esparto for fine printings, (3) soft cottons for blottings, (4) Manilla ropes for cartridge papers ? State the treatment you would adopt for the preparation of the various wood pulps from the raw materials, and give data for boiling, washing, and bleaching, also composition of boiling and bleaching liquors, with the yield of pulp you would expect from 10 tons of raw wood. (*30.*)

3. Discuss fully the question of economy in boiling rags with caustic soda. By what chemical tests would you control the operation and fix the best conditions in particular cases ? (*25.*)

4. State your opinion regarding the use of exhaust steam from the machine engine, for heating the drying cylinders, and compare the method with that of employing a condensing engine and drying with high-pressure steam. Show how you arrive at the steam consumption for each method. (*30.*)

5. What are the average limits of thickness of writing papers ? For a given mean thickness, calculate the weight per square metre of paper of 50 per cent. " cellulose density " (*i.e.* equal volumes fibre substance and air space). Taking a breaking length of 7,500 m., what maximum weight will the paper support per 1 c.m. of breadth ? (Take the sp. gr. of cellulose at 1·5). (*25.*)

6. Describe the plant you would put down to recover and causticise the soda in the liquors from the boiling and washing of 100 tons of esparto per week. State the approximate number

of gallons per boiler, the percentage of soda you would expect to recover, and the cost for labour, lime, and coal, per ton of soda recovered. (*25.*)

7. Discuss fully the conditions of penetration of papers by size solutions in tub-sizing. How would you vary these conditions, including the composition of the size, to produce the best effects? How would you investigate the paper to ascertain the distribution of the size and the sizing effect? (*20.*)

8. State fully how you would handle the beating tackle when beating the pulp for the papers mentioned in Question 2. What special methods would you adopt to secure that the wood fibres would be so blended as to prevent the finished sheet from having a "woody" appearance? (*20.*)

9. State what you know of the hydrated modifications of cellulose, and their functions in the papermaking process. What special effects are obtained by these hydrates chemically prepared. (*25.*)

10. Wherein lie the advantages of the multiple effect evaporator and the rotary furnace? State what you know of the practical working of each, and compare them with the Porion system as to the efficiency and cost of maintenance. (*20.*)

11. Give briefly a full scheme for the analysis and testing of writing and book papers. Give also a selection of these tests for *rapidly* determining the main features of composition. (*25.*)

12. Schedule the proportions of chemicals you would use in boiling and bleaching (1) Manilla ropes, for strong cartridges; (2) flax waste, for caps; (3) unbleached cottons, for loan papers; (4) jute, for casings; (5) muslins, for blottings. State temperature, pressure, and duration of boiling, together with any special modifications you consider advantageous. (*30.*)

V.

CITY AND GUILDS OF LONDON INSTITUTE.

EXAMINATION ON PAPER MANUFACTURE.

1903.

THE City and Guilds of London Institute's Examination on the Manufacture of Paper was held on May 1st, and the following were the questions set. The instructions were the same as in former years.

ORDINARY GRADE.

1. Describe the structural features of straw and esparto and of the fibres of their respective half-stuffs. What are the average dimensions and structural features of cotton and linen (flax) when fully beaten? (*25 marks.*)

2. What advantages are gained by using bronze in place of steel for beater bars and plates? State the materials in the preparation of which you would expect to secure the best results from the use of bronze. (*20.*)

3. Mention the various forms of wood pulps, with their more particular uses. Give a short account of their preparation from the original woods. What do you understand by a "strong sulphite pulp," and how would you determine whether a given sample conforms with this description? (*25.*)

4. Describe the conditions which give rise to "blowing" in front of the first press rolls, and state the precautions you would take to prevent it when making thin paper on a close-textured wet felt. (*20.*)

5. With bleaching powder of 35·5 per cent. "available chlorine" at £4 15*s.* a ton, calculate the value of the "chorine" per pound and per kilo. A waste bleach liquor is tested, and found to contain 0·01 gramme "chlorine" per 100 cc.; what quantity does this represent on 963 gallons of the liquor? Calculate the quantity of sulphite antichlor—$Na_2So_3 7H_2O$—required to neutralize. (*25.*)

6. What advantages, if any, are obtained by running esparto over the presse-pâte previously to bleaching? (*25.*)

7. What do you understand by (*a*) a neutral, and (*b*) an acid rosin size? Give working particulars for preparing and using them. What is an average dilution of the rosin size in the beater, and how is the rosin compound affected by the dilution? (*30.*)

8. Which type of refining engine would you put down to supplement the beating power for the preparation of stock for (1) esparto printings, (2) news, (3) typewriting papers, (4) glazed casings? Give your reasons for the adoption of any particular type, and state what increase in the production you would expect to obtain. (*30.*)

9. A water is found to contain—

	Grains per Gallon.
Lime	11·2
Magnesia	8·0
Sulphuric anhydride	8·0
Carbonic anhydride (expelled on boiling) ...	13·2

Express these results as "parts per 100,000," and give the chemical formulæ for the constituents. What chemicals would be required to soften this water? (*20.*)

10. Give a brief description of Bertram's vacuum ejector, and discuss its merits compared with the ordinary vacuum pumps for extracting the water from the paper in its passage over the wire. What saving in power would you expect to obtain when using the ejector? (*25.*)

11. Give a brief account of the substances represented by the following formulæ, and describe their ordinary commercial forms—$NaOH$, Na_2CO_3, $NaHCO_3$, CaO, $CaSO_4$, $Ca(OCl)_2$, Al_23SO_4. State what you know of the composition of ultramarine, smalts and china clay, casein and gelatine. (*30.*)

12. State the practical details you would observe when making a thick chromo paper, so as to ensure freedom from stretch and dusting in printing. (*25.*)

Honours Grade.

1. With Spanish esparto at £4 15*s*. a ton f.o.r. trace the increments of cost of the cellulose through the several stages of preparation up to the stuff chest. (*25 marks.*)

2. Draw up a scheme for the production of the following

papers, showing the proportions of the various materials you would use, and their approximate cost per ton of finished paper—(1) Fine writings at 5*d*. per pound, (2) E. S. printings at $2\frac{1}{2}$*d*. per pound, (3) news at $1\frac{1}{4}$*d*. per pound, (4) M. G. caps at $1\frac{1}{4}$*d*. per pound. State the average cost of production in each case. (*30.*)

3. Write a short general account of rosin sizing, dealing particularly with the following points: (*a*) Proportion of soda to rosin, (*b*) effect of dilution before adding to the beater and in the beater, (*c*) hard and soft waters and use of back-water in the beater, (*d*) auxiliary action of colloidal alumina, starch, and cellulose, (*e*) thin and thick papers, (*f*) "wet" and "free" running on the machine. (*25.*)

4. State your ideas as to the future of electricity as a motive power in the paper mill, and describe what you know of its application at the present time. (*25.*)

5. What tests can be applied to stuff in the beater to follow the progress of beating? Sketch a plan of systematic records in regard to the preparation of the stuff. How can the beating be influenced by chemical means? (*25.*)

6. How would you proceed to produce a "feather weight" printing at $2\frac{1}{2}$*d*. per pound? Schedule the materials you would use, and the practical details you would observe in the manufacture, in order to impart the desired characteristics to the finished sheet. (*25.*)

7. Give a general account of hard and soft waters in relation to (*a*) steam raising, (*b*) the papermaking processes. A water contains, per 100,000 pts.,—

$CaCO_3$ (as bicarbonate)	18·5
$MgSO_4$	9·4

Calculate the chemicals required to soften per 1,000 gallons, and show the advantages of using the softened water in the case of an esparto mill. (*30.*)

8. What do you know of the requirements of an "imitation art"? Give an approximate furnish for this grade of paper at $2\frac{3}{4}$*d*. per pound, and state how you would treat it in the various processes from the wet end to the cutter in order to get the best results. (*20.*)

9. Criticise the expression "breaking length" of papers, and show where it fails as a comparison of actual breaking strains. What do you propose in its place? Propose such tests of

"opacity" and "surface" or finish as admit of numerical records. (*25*.)

10. Describe how you would proceed to convert 10 tons of jute bagging into a strong cartridge paper, and schedule the duration of each stage, with the percentage of chemicals, steam pressure and temperature of bleaching solution. State how you would prevent chlorination of the fibres, when obtaining as white a colour as possible, consistent with retaining the strength and the yield of finished paper you would expect to obtain. (*25*.)

11. Give a classification of raw fibrous materials and commercial half-stuffs, (1) according to chemical characteristics, (2) according to the main types of paper which they are used to produce. (*25*.)

12. Whether do you consider it to be more economical, to supplement the steam raising plant by installing a forced draught apparatus with mechanical stoking, or by adding an additional boiler and firing by hand? State which type of forced draught and mechanical stoker you consider most efficient. (*25*.)

VI.

CITY AND GUILDS OF LONDON INSTITUTE.

PAPERMAKING EXAMINATION.

1904.

THE following are the questions set in the examination on paper manufacture, held on April 30th :—

ORDINARY GRADE.

1. What is the volume of a ton of water? Give an approximate estimate of the dimensions of a reel of newspaper weighing 250 kilos. What is the thickness of a cigarette paper, and the approximate weight per square metre? (*25 marks.*)

2. What dyes would you use for the production of the following papers: geranium red, canary yellow, fast blue? State the precautions you would adopt to produce the best results, most economically, in each case. (*25.*)

3. Specify furnish for (*a*) best white blottings, (*b*) biscuit caps, (*c*) cutlery wrapping. Contrast the details of preparation of the stuff in relation to the particular qualities. (*25.*)

4. State the materials you consider most suitable for the production of a buff copying, and give a brief outline as to how you would treat them so as to give the desired characteristics to the finished sheet. (*25.*)

5. Write a short account of the water-soluble compounds of cellulose. (*25.*)

6. How would you manipulate the various parts of the paper-making machine in order to produce a fine printing, the under side of which would be, as nearly as possible, as smooth as the top side? (*20.*)

7. Specify composition of normal papers (*a*) for documents of permanent value, (*b*) for book papers. Explain the defects in chemical composition to be avoided. (*25.*)

8. State the characteristics most desirable in a "body" paper

for surface enamelling. Give the proportions of the materials you would use, and state how you would handle the beating tackle. (*30.*)

9. Give practical details for making, storing, distributing, and using bleach liquor in the mill. State what you know of the chemistry of bleaching powder, and the bleaching action of its solution. (*25.*)

10. Describe briefly Marshall's patent drive for the paper-making machine, and state the advantages you consider to be gained by its adoption. (*20.*)

11. What are the special chemical and physical features of (*a*) chemical filter papers, (*b*) blottings, (*c*) grease-proof, (*d*) paper for protecting photographic films and plates, (*e*) paper for wrapping cutlery and plate, (*f*) cable papers? How would you test each in regard to special use? (*25.*)

12. What advantages are to be gained by covering steam pipes with non-conducting material? Give an estimate of the saving which may be effected in a modern two-machine mill in which a complete system of covering is adopted. (*30.*)

Honours Grade.

1. Examine critically the efficiency of a beating engine, both as to economy of power and control of the range of effects required in the preparation of an esparto furnish. (*30 marks.*)

2. Discuss the question of rope *versus* belt driving for the paper mill machinery. (*20.*)

3. How would you investigate the effects of calendering upon the physical properties of papers? Show in what respects the ordinary methods of paper testing fail to exhaust the problems involved. (*25.*)

4. How would you proceed to ensure accurate register if, on starting to make an E.S. writing, the distance between the water-marks was an eighth of an inch too small? (*20.*)

5. What are the limitations of wood pulp (cellulose) in regard to papermaking effects? How far is this due to structural and chemical features of the cellulose, and how far to deficiencies in treatment in the mill? (*25.*)

6. What plan would you adopt to guard against excess of soda when supplementing causticised soda liquor with 77 per cent. alkali in boiling esparto? (*25.*)

7. In colouring or dyeing papers in the engine, what causes affect the permanence of the effect? How would you examine

dyed papers in regard to the quality of fastness? Specify for a fast medium blue, red, yellow, and brown, on pure cellulose papers. (*25.*)

8. State your opinion regarding the adoption of gas for motive power in the paper mill, and describe any gas-producing system with which you are acquainted. (*25.*)

9. What are the main causes of the deterioration of book papers? Give a chemical account of the effects referred to and their specific causes. (*25.*)

10. What are the special requirements most desirable in a paper for photographic prints? Draw up a scheme for the production of such a paper to sell at 6*d.* per lb., stating the materials you would use and the precautions you would adopt to ensure the best results. (*30.*)

11. State what happens when a drop of iron gallo-tannic ink diffuses into a blotting paper. What use would you make of your observations in comparing the qualities of blottings and controlling the processes of manufacture? (*25.*)

12. How would you manipulate the various parts of the machine when making "news" at a high speed, so as to produce large equal-bulking reels, free from breaks? (*25.*)

VII.

PAPERMAKERS AND TECHNOLOGY.

EXAMINATION PAPERS.

1905.

THE examination in paper manufacture of students attending technical classes, under the auspices of the City and Guilds of London Institute, was held on April 29th. The following were the questions:—

ORDINARY GRADE.

Not more than eight questions should be attempted.

1. Mention three systems of making straw into half-stuff. Give a brief outline of the processes. (*20 marks.*)

2. Describe briefly the action of a Kollergang, and discuss the limits of its usefulness as a substitute for the beating engine when worked in conjunction with a refining engine. (*30.*)

3. The following data are obtained in testing a paper: Weight per square metre, 34·2 grm.; thickness, 0·07 millimetre; breaking length, machine direction, 5,473 metres; cross direction, 3,724 metres. Calculate specific gravity and mean breaking strain per square mm. section. (*30.*)

4. Discuss the relative merits of paper, cotton, and woollen-paper for covering calender bowls. (*20.*)

5. What is the influence of iron oxide on the durability of paper? How would you show its presence, and how would you trace the source or sources from which it is derived? (*20.*)

6. What advantages are to be gained by the use of rubber-covered bottom press rolls? (*20.*)

7. Trace the relations in the quantity of water to (per 100 kilos.) bleached esparto pulp (calculated as "*dry*") from the time it enters the beaters until it reaches (as paper) the last of the drying cylinders of the machine. (*30.*)

8. State the precautions you would adopt to prevent frothing when working a large proportion of an aniline dye, such as cotton scarlet. How would you ensure complete exhaustion, and a clean back-water? (*25.*)

9. What cellulose would you select for making papers with regard to the following particular characters respectively: Strength, bulk, opacity, transparency, purity? Can any of these qualities be varied by chemical treatment? If so, how? (*25.*)

10. Describe the type of strainer you consider the most suitable for the production of (1) rag papers, (2) esparto papers, (3) wood pulp papers. (*25.*)

11. What is a thermometer, hydrometer, hygrometer? What are the practical uses of these instruments in a mill? (*25.*)

12. What saving in coal would you expect to result from feed water at 180° Fahr., as compared with 60° Fahr., the increased temperature being obtained from the use of the waste steam from the machine cylinders? (*30.*)

Honours Grade.

Not more than eight questions, or five questions and one essay, to be attempted.

1. How would you proceed to investigate the ratio of sizing effect to quantity of sizing agent used in the case of (*a*) engine sizing (rosin), (*b*) tub sizing (gelatine)? (*25 marks.*)

2. Describe Masson's patent bleaching tower, and discuss its merits as fully as you can. (*20.*)

3. Give working particulars, with quantitative details, of three methods of preparing half-stuff from straw. Show how you would estimate the costs of the half-stuffs in each case. (*25.*)

3. Discuss the relative merits of Spanish and African esparto, and state fully the percentage of chemicals and the duration of treatment necessary to produce a well-boiled pulp of good colour in each case. (*30.*)

5. How would you make a paper to contain (*a*) one gram of calcium carbonate per square metre (surface measure), (*b*) per 100 cubic centimetres (volume measure)? How much paper in each case would be required to neutralise 17 c.c. normal HCl? (*25*).

6. Describe any one of the various forms of kneaders you are acquainted with, and discuss the limits of its usefulness in the treatment of paper stock. (*20.*)

7. Describe three methods of estimating mechanical wood pulp in papers. (*25.*)

8. Describe Parson's steam turbine, and give an outline of its possibilities as a motive power in the paper mill. (*30.*)

9. From what you know of the ultimate structure of esparto cellulose, calculate the average number of fibres per 1 c.c. of a printing paper containing, in addition, 22 per cent. of china clay (specific gravity 2·83). (*25.*)

10. State what, in your opinion, are the most important developments in papermaking machinery during the past year. (*25*).

11. How would you investigate coloured papers (*a*) for resistance to light, (*b*) for the specific or direct causes of fading? In matching papers, how would you make observations by transmitted light, and what value do you attach to these in matching shades? (*25.*)

12. What are the characteristics most desirable in a paper for cable insulation? Draw up a scheme for the production of such a paper, and schedule the duration of the various processes you would employ, with the proportions of chemicals necessary. (*25.*)

As an alternative to questions 3, 7, 11, the student may write an essay on subject A below; or as an alternative to questions 8, 10, 12, the candidate may write an essay on Subject B below.

Subject A.—"The general chemical characteristics of cellulose are those of a 'Colloidal Salt.'" Examine this statement critically, both from the standpoint of theory, and of the functions and industrial uses of cellulose. (*75 marks.*)

Subject B.—Discuss exhaustively the question of Beating, dealing with the several types of beaters, their mechanical work, in relation to economy of power, and the incidental chemical effects produced in the beater. (*80.*)

VIII.

ANSWERS TO THE QUESTIONS AND EXPLANATORY NOTES.

INTRODUCTORY REMARKS.

I CONFESS I feel some diffidence in consenting to answer the questions set by the examiners of the City and Guilds of London Institute on papermaking. The questions are, in my mind, the best that have ever been set. They may be described as "leading questions," many of them. However, it is one thing to set these questions, and another thing to answer them in a way that does not lay one out to considerable criticism. The answers to many of the questions are straightforward enough, but others are more a matter of opinion than a matter of fact. On some questions it would be safe to say that no two papermakers hold the same opinion, and I am quite prepared to find that those who are *au fait* with the particular subject raised by the individual question will, if they express their opinion at all, have a good deal to say in criticism of my remarks. My desire is rather to lead out the individual faculties of the students, and to·teach them to think for themselves, than to attempt to supply a key to the questions already set. I trust that my humble attempts in this respect will be of some service to those who desire to enter for future examinations.

ORDINARY GRADE.

1901.

QUESTION 1.—*How do you measure the thickness of a paper? Estimate the thickness of a book of* 240 *pages made of paper of thickness* 0·054 *millimetre. Express the result in terms of the inch.* (20 *marks.*)

ANSWER 1.—By the use of a micrometer gauge.

By carefully measuring the thickness of a ream of paper under pressure, and dividing thickness of ream by number of sheets per ream.

The thickness of a book of 240 pages made of paper 0·054 mm. thick, is as follows :—

$$\frac{240 \times 0{\cdot}054}{2} = 6{\cdot}48 \text{ mm.}$$

$$\text{or } \frac{6{\cdot}48}{25{\cdot}4} = 0{\cdot}255 \text{ inches. Approx. } \tfrac{1}{4} \text{ inch thick.}$$

REMARKS—The accuracy of the measurement with a micrometer is increased by folding the sheet a number of times. Of course the reading must be divided by the number of thicknesses. Care must be taken that only a moderate force is exerted in screwing up the micrometer, otherwise the paper will be compressed, and the micrometer will give a false reading. The most accurate measurements are obtained with a specially designed micrometer that will only exercise a certain amount of pressure when screwed up. For ordinary readings the ordinary micrometer divided into $\frac{1}{1000}$ of an inch is quite sufficient, if used with care.

QUESTION 2.—*What instructions would you give to the beater-man for the preparation of a superfine blue writing-paper? How would you manipulate the various parts of the machine to impart the desired characteristics to such a paper? State also what steps you would take to prevent the colour from fading when in contact with the animal size.* (30.)

ANSWER 2.—Beat for four hours. Gradually increase the pressure on bedplate by lowering roll a little every 20 minutes. Full pressure of roll should be on bedplate during the last half of third hour and first half of fourth hour, and until fibres are sufficiently beaten to suit the special characteristics of the paper to be produced. Then raise the roll so as to brush bedplate for twenty minutes, to free stuff from knots.

The flow of stuff from the chest must of course be regulated to suit the required thickness of paper. Live steam must be introduced into the steam-box where the saveall mixes with stuff from chest. The temperature of stuff flowing to machine should be so maintained for a paper of medium thickness that most of the water leaves before the first suction-box, and that the stuff is not too wet under the dandy-roll, but sufficiently wet to take the necessary impression. The temperature of stuff and proportion of saveall water must be so regulated as to insure that the shake is effective as far along the wet end as possible. The speed should be between 40 and 60 feet per minute, according to circumstances. Undue heating on drying cylinders should be avoided as far as possible, to prevent decomposition of blue by alum. Ultramarine should be used as the colouring agent, except where it is a *sine qua non* that the paper should not fade, as in the case of ledger paper, when "smalts" must be used. In either case the greatest care should be exercised to prevent the suction boxes from drawing away the pigment from the under surface, and so making the two sides of a different tint. If uniformity of colour is a necessity, avoid too great dilution of stuff, and slow shake of machine, so as to prevent the gravitation of the pigment to the under surface.

The fading of colour can be prevented when in contact with animal-size by the use of smalts, which is unacted on by the alum, or by the use of an alum-proof ultramarine and avoiding an unnecessary excess of alum in the gelatine. It is essential that the alum used should not contain free acid; it is better also, for the sake of the paper, that a basic sulphate of alumina be used in place of the ordinary sulphate.

REMARKS.—Mr. Clapperton, in his book on paper-making, speaks of smalts fading. I have never found this so, and think it must be due to smalts adulteration with ultramarine. No two makers would proceed in the same way, and the *modus operandi* is dependent largely upon innumerable circumstances. The question is a good one to test a student's knowledge, but to write fully on the subject would fill a good-sized book as well as divulge many trade secrets. Notice that blue papers give off sulphurous acid gas passing over cylinders, and often are neutral to the most delicate tests with the most delicate indicators. These two facts are a proof of the decomposition of ultramarine.

QUESTION 3.—*How are the following fibres detected in a paper: Jute, esparto (cellulose), mechanical wood? How would you estimate the quantity of each when in admixture with rag fibre only?* (30.)

ANSWER 3.—

	ANILINE SULPHATE.	MICROSCOPE.
Mechanical Wood	Brilliant yellow, quickly developed even in cold.	Flat clusters of fibres, sometimes broken, often with medullary rays. Fibres often showing pitted vessels.
Jute	Brilliant yellow, quickly developed even in cold.	Fibres very long, often separate. Diameter very irregular. Hair on surface. Central canal fine and sometimes invisible.
Esparto ...	Pink on prolonged boiling.	Seed hairs proof of esparto.
Red Fibre ...	No change	

The mechanical wood and jute can be quantitively determined together by means of Dr. Wurster's "di-paper" (dimethyl-para-phenilene-diamine) and comparison with his standard scale. The relative proportion of mechanical wood to jute can be roughly ascertained by counting the number of fibres of each under the microscope. The esparto is recognised by its red colour after treatment with aniline sulphate and by the presence of leaf hairs. In order to judge of the proportion of esparto, the pulp under examination should be examined by the side of an authenticated specimen of esparto cellulose. The fibres of esparto by no means resemble the other fibres of the paper. They can furthermore be differentiated from the rest by the staining with iodine. By this treatment mechanical wood and jute are coloured yellow and the rag fibres are coloured brown, whilst the esparto is left colourless.

By following the above plan a rough estimate can be arrived at of the relative proportion of each fibre. As a check, mix together mechanical wood, jute, esparto, and rag fibre, in the proportions you judge to exist in paper, and, after staining, compare with original.

QUESTION 4.—*What are the advantages, if any, possessed by plate-glazed papers as compared with those finished on the super-calender? What precautions would you take to prevent variations in colour when friction-glazing soft-sized pink printing paper?* (20.)

ANSWER 4.—Plate-glazed papers possess a certain refinement of finish which cannot be imitated by other means. The surface is particularly agreeable for high-class writing paper, as it takes the ink in a way that is not possible by friction-glazing. The pen glides over the surface without appearance of greasiness. Plate-glazing renders the paper more transparent, a quality liked for certain classes of writing paper, but obviously disadvantageous for envelopes. It does not lower the colour and character of surface in the way that friction-glazing does. It, however, tends towards brittleness, and causes the paper to break when sharply folded. If carried too far, it "crushes" the paper, and often obliterates the water-mark.

Keep moisture in paper and pressure on rolls absolutely uniform.

REMARKS.—If dry pink is used, specks are often produced on the underside of the paper. The friction-glazing would very much intensify these specks if glazed on side specks appear. The difficulty can be overcome by following instructions given in Mr. Clapperton's book: "A very simple way to use carnation is to dissolve it in a dilute solution of ammonia, to which a little cream of tartar has been added."

Notice that the high finish obtained by plate-glazing closely resembles a superior finish obtained by the housewife when "getting up" linen. In both starch plays an important part.

QUESTION 5.—*A delivery of pulp of* 1,769 *bales, unbleached sulphite, with* 12 *per cent. moisture (allowed) is to be sampled and the moisture determined. Give exact particulars of the test and the form in which the result is expressed.* (20.)

ANSWER 5.—At time of delivery set aside 4 per cent. of the bales (taken from all parts of consignments) for the purpose of sampling. The number of bales in this instance would be

$$\frac{1769 \times 2}{100} = 35$$

Take sample from five sheets in each bale. The first sheet to be taken $\frac{1}{2}$ in. from top. The second sheet to be taken halfway between this sheet and the middle of bale. The third sheet to be taken at middle of bale. The fourth and fifth sheets to be taken in corresponding position to Nos. 2 and 1 respectively.

Each sheet should be sampled by cutting out small pieces, by means of a sharp knife or a sharp hollow circular punch, from four different points, equidistant between the centre and each of the four corners of sheet. The pieces so removed must at once be placed in a dry, well-stoppered glass bottle, previously carefully weighed.

When all the bales are thus sampled, the bottle is carefully weighed. The pulp is then carefully removed to drying chamber and dried at 212° Fahr. until the sample ceases to lose weight.

Assuming that the weight of the moist pulp was 542 grammes, and bone-dry pulp 412 grammes, the amount of air-dry pulp containing 12 per cent. moisture is calculated as follows:—

$$\frac{412 \times 100}{(100-12)} = 468 \text{ grammes air-dry pulp}$$

The percentage of air-dry on original pulp would be

$$\frac{468 \times 100}{542} = 86{\cdot}3 \text{ per cent.}$$

86·3 per cent. deducted from 100 per cent. equals 13·7 per cent. surplus moisture.

REMARKS.—This question tests a student's faculties more than if the air-dryness had been taken as 10 per cent. (*i.e.* the figure now adopted by the British Wood Pulp Association), as it would be useless for him to learn the formula $\frac{100A}{90}$ by heart. A student should test the correctness of his figures. He can do this in the above case by finding out the amount of air-dry moisture to be added to the bone-dry weight. The two figures together should equal the calculated air-dry weight.

$$\frac{412 \times 12}{100 - 12} = 56 \text{ air dryness.}$$

Bone-dry. Air-dryness.
To be added—412 + 56 = 468 air-dry fibre.

The mode of sampling above cited is practically on the lines of Sindall's recommendations, and constitutes the best method known.

QUESTION 6.—*Suppose a machine so fitted that the wire frame can be raised or lowered from the breast roll as desired, what variations from the level would you make when running the following grades :* (1) *Strong rag cartridges,* (2) *news,* (3) *fine printings,* (4) *blottings,* (5) *thin sulphite caps? State your reasons in each case.* (25.)

ANSWER 6.—(1) Lower breast roll ¾ of an inch. (2) Not to be lowered or raised. (3) Lower breast roll ½ to ⅜ of an inch. (4) Not to be lowered or raised. (5) Lower about ½ an inch.

REMARKS.—The general principle of lowering and raising the breast roll depends on the softness of the stuff. Thus, to get a strong rag cartridge well closed and put together, it would be advisable to lower the breast end of the frame about ¾ of an inch, in order that a good well of water and stuff may be formed, just where the action of the shake will have the most effect in lacing the fibres together. For free stuffs, such as news, which is apt to part with water only too easily, there is hardly any necessity to lower the breast roll at all, and the same applies to "blottings," which are usually very "free," although so thick.

Fine printings are usually prepared by fine beating, and thus hold the water well, and in order to get additional water in so as to obtain a close even sheet the breast is generally lowered.

With thin sulphite caps running at a high speed the fibres are inclined end on, thus causing the paper to be stronger when torn across the webb. The breast is generally lowered to obviate this.

It is somewhat difficult to follow the argument, but I trust I have made it clear. It appears that the breast is lowered for two reasons, either to get the water out or to enable one to put more water in. Since putting more water in implies necessarily taking more out, the result is very much the same in both cases.

QUESTION 7.—*State exactly how you would treat for conversion into half-stuff new cotton pieces, new linens (grey), Manilla ropes, and broke from tub-sized writings.* (30.)

ANSWER 7.—New cotton pieces, unless quite free from dress, should be treated in a spherical boiler with "malt extract" equal to 1½ to 3 lbs. of malt per cwt. of rags, at a temperature of 160° Fahr. until all starch is converted into sugar. The liquor is drawn off and the mass washed with hot water, so as to thoroughly remove the sugar before bleaching. The new pieces are thoroughly bleached with bleaching powder, to which a little vitriol is added, then broken-in in ordinary 3-cwt. breaker for four hours. They should be washed for the first two hours of the beating.

New linens (grey) should be boiled for eight hours with 3 to 4 per cent. NaHO, so as to thoroughly soften the shieve. Washed in boiler whilst emptying. Washed subsequently through revolving rag-washer, &c. Broken-in in 3-cwt. breaker four hours. Washed first two hours of treatment. Bleached in steeping tank with 3 per cent. bleaching powder solution.

Manilla ropes must be chopped up and boiled in lime—10 to 20 per cent. lime—for 15 hours. Washed in washer fitted with stone bedplate.

Broken tub-sized papers must be boiled with water alone for the removal of gelatine, and, when thoroughly softened, they can be put direct into breaker. Some makers prefer to grind them in kollergang or pass them through cone breaker, and use them afterwards for thickening up beaters.

REMARKS.—The above mode of treating new pieces is far preferable to treatment in water or weak soda. (For full description see "Treatment of New Pieces," Beadle, PAPERMAKER.) The sugar must be removed before bleach, or it decomposes, leaving stuff bad colour.

New linen. (For further description see "Treatment of Rags," Beadle, PAPERMAKER.)

Manilla.—A stone bedplate will give the maximum strength of fibre as the material is gradually drawn and bruised, and not "cut." Soda should never be used for boiling papers (except in minute quantities to prevent boiler-plate from "pitting"), as it lowers the colour of paper by decomposing the gelatine.

Grey linens must have a vigorous treatment with soda to soften "shieve."

QUESTION 8.—*What materials would you use for the production of—(1) news, (2) fine writings, (3) E. S. printings, (4) blottings? State the proportions of each material you would consider necessary to give good results.* (25.)

ANSWER 8.—(1) 75 per cent. of mechanical wood, 15 per cent. of chemical wood, 10 per cent. of china clay. (2) 60 per cent. of cotton rags, 40 per cent. of linen rags, and sized with 5 per cent. gelatine. (3) 20 per cent. bleached sulphite, 40 per cent.

nubleached sulphate, 40 per cent. of white shavings (12 to 15 per cent. clay). (4) Entirely of cotton, with a little starch, but no sizing material.

REMARKS.—Of course, the composition of news varies according to quality, the better class containing more chemical wood. Fine writings vary almost indefinitely in composition, but the best are made from rags sized with gelatine. Engine-sized printings used formerly to be made of esparto, with about 20 per cent. of broke, and no doubt some mills make them so still where the price will admit, but the tendency is to replace esparto with wood pulp. In some cases bleached soda pulp is used, in other cases unbleached sulphite, also bleached sulphate and white shavings. News will not carry more than 10 per cent. of clay economically, as it is too thin to hold it.

QUESTION 9.—*Define specific gravity. What is the weight of 7 gallons of a solution of 11° Tw.? Taking specific gravity of cellulose equal 1·50 and of china clay equal 2·75, what is the exact effect of 20 per cent. loading on the specific weight of a paper.* (20.)

ANSWER 9.—Specific gravity is an expression of the number of units of weight in units of volume; water being taken as 1·0.

The weight of 7 gallons of a solution of 11° Tw. is—

$$\frac{7 \times 10 \times 1000 + (11 \times 5)}{1000} = 73·85 \text{ lbs.}$$

The specific weight of the paper in question must be increased by the addition of 20 per cent. of china clay. The clay not only adds to specific weight of the paper from the fact that it possesses a greater specific gravity than the cellulose, but also because it occupies the interstitial spaces, and does not "bulk" the paper. The exact specific weight cannot be determined unless we know the specific weight of the said paper without the addition of 20 per cent. clay.

REMARKS.—We must first arrive at the specific weight of a cellulose paper containing no clay before we can state what the specific weight would be on the addition of 20 per cent. clay. Neither the specific gravity of the fibres or of the clay will afford us the necessary data.

Let us take an instance.

Cut a square from the paper in question just 50 mm. by 50 mm., and determine its thickness by means of a micrometer, and its weight in grammes on a sensitive balance. In the present instance the thickness is $\frac{6}{1000}$ of an inch, and is equal to $\frac{6 \times 25}{1000}$ or 0·150 mm.

In order to arrive at the bulk occupied by the piece of paper in question, we must, of course, multiply 50 × 50 × 0·150 = 375 mm. or 375 cm.

We know that one cubic centimetre of water weighs one gramme.

We also know that 0·375 cubic centimetre of the paper in question weighs 0·415 gramme.

The specific weight of the paper is got by dividing the weight of the volume.

$$\frac{0{\cdot}415}{0{\cdot}375} = 1{\cdot}11$$ the specific weight of paper without clay.

What would be the specific weight of the above paper if 20 per cent. clay is added.

This is very simple to calculate.

The paper without clay weighs 1·11 gramme for every cubic centimetre of bulk.

The paper containing clay is to have the composition cellulose 80 per cent., clay 20 per cent.

Clay does not add to the bulk.

These are the simple facts to guide us.

The proportion of cellulose to clay is as four pounds to one. To add the clay we must add one quarter on to the weight of the cellulose. To arrive, therefore, at the specific weight of the clay paper, we have merely to add one quarter on to the specific weight of the paper containing no clay. Thus:—

$$1{\cdot}11 + \frac{1{\cdot}11}{4} = 1{\cdot}39$$

The exact effect in this instance is, therefore, the raising of the specific weight of the paper in question from 1·11 to 1·39 by the addition of 20 per cent. of clay.

Specific weight as above expressed must not be confused with specific gravity. There is no difficulty in ascertaining what would be the exact effect upon the specific gravity of paper with figures given in the question. We have, as above explained, four parts of cellulose of specific gravity 1·5 for every one part of clay of specific gravity 2·75.

$$\begin{aligned} 1{\cdot}5 \times 4 &= 6{\cdot}0 \\ 2{\cdot}75 \times 1 &= 2{\cdot}75 \\ 5)&\overline{8{\cdot}75} \\ &\ \ 1{\cdot}75 \end{aligned}$$

The specific gravity of the paper in question must be 1·75.

It is evident that specific gravity is intended in the question. It is to be hoped that in future, if the examiners set a similar question, they will define what is meant by specific weight. I take it to mean weight per unit of actual bulk by measurement, which is quite another thing to specific gravity. In this case the answer I have given in answering the question is about all that can be said on the subject in the way of an actual answer to the examiners.

QUESTION 10.—*State the type of beating engine you would adopt for the preparation of stock for* (1) *strong book papers*, (2) *esparto printings*, (3) *blottings*, (4) *sulphite casings. Give also the horse-power required for a 4-cwt. beater in each case, and the amount of coal necessary to make and dry one ton of each grade on the machine.* (30.)

ANSWER 10.—(1) The Hollander type. (2) The Coburn Taylor. (3) The Hollander type. (4) Hibbert's patent beater.

Power for 4-cwt. beater: The Hollander type when beating strong rags will take from 30 to 40 horse-power. Esparto printings will require about 25 to 30 horse-power. Blottings will require about 30 to 35 horse-power. Sulphite casings will require about 25 horse-power.

Under up-to-date conditions, one ton of stock should be made into paper with 10 to 12 cwt. of coal (steam for machine-engine and drying only of course). Wet stuff is much more difficult to dry, and uses more steam owing to being dried more slowly, in order to get an even sheet.

The following do not include steam used for tub-sizing and drying: Book papers, 12 to 14 cwt. of coal per ton of paper. Esparto printings, 10 to 12 cwt. coal per ton of paper. Blottings, 10 cwt. coal per ton of paper. Sulphite casings, 10 to 12 cwt. coal per ton of paper.

REMARKS.—A great difference of opinion exists on the subject of beaters for various purposes. There is nothing like the old-fashioned Hollander for beating rags such as are used for book papers.

The Coburn Taylor patent beater gives very good results for esparto printings, but in some instances is not to be recommended for rag stuff, owing to liability of circulating fan to become choked.

The old Hollander, with sharp tackle and rapid treatment, is the best for blottings.

Hibbert's beater has the advantage over the Hollander, in that it admits being filled with stiffer stuff, and the circulation still remains good, but it has the drawback that it does not take the dry sheets of sulphite wood very well, whereas the Hollander does so without any trouble.

QUESTION 11.—*What are the waste products from a rag mill (fine writings), an esparto mill (fine printings), a soda wood (half-stuff), and sulphate wood (half-stuff)? Which of these are treated for recovery of useful products, and what are final wastes?* (30.)

ANSWER 11.—

RAG MILL.

Rag dust from dusters.
Wash-water from rag boiling.
"Lint" from rotary rag washers.
Short fibres from "saveall" from wash-water of breakers.
Sediment from backwater.
Residues from causticising and bleach mixing.
"Shoddy" from rags, bagging, &c.
Wash-water from bleaching.
Knotter stuff.
Fat, bones, and oil, from sizemaking.

Esparto Mill.

Esparto liquor from boiling.
Dirty wash-water from final washing.
Roots and untreated particles picked out.
Mineral matter, &c., in backwater.
Charred mass from lixiviating recovered soda.
Bleach and causticising residues.
Dust from dusting dry grass.
Wash-water from bleaching.
Knotter stuff.

Soda Wood Mill.

Soda liquor from boiling.
Bleach liquor residue and causticising residue.
Wash-water from breaking in and bleaching.
Black ash waste.

Sulphate Wood Mill.

Barks and knots.
Bleach liquor residue.
Waste sulphite liquors.
Wash-water from breaking and bleaching.

Rag Mill.

Rag dust used for manufacture of felt hats, and the dirtier kind used by florists as a fertiliser for certain plants.

Lint contains long fibres, but, on account of dirt, can only be used for low quality papers.

Bones and oil from size sometimes sold; latterly used for manure.

Short fibres from "saveall" contain dirt, and can only be used for low-quality paper, but the short fibre from the cleanest and best rags can be used in better quality paper if kept separate.

Shoddy from rags sells sometimes for as much per cwt. as was paid for the rags from which they were picked.

Bagging available for papermaking.

The other waste products in a rag mill are of no use.

Esparto Mill (fine printing).

Esparto liquor must be treated for recovery of soda to make process pay. 90 per cent. of soda is recoverable, and is used over again. Final waste is black ash residue and sludge from causticising ash.

Mineral matter sometimes settled out and put into lower quality paper.

Other waste products are thrown away.

SODA WOOD MILL (half-stuff).

The same products are recovered as with esparto.

The residue from black ash treatment has been found available for electric light carbons.

SULPHATE WOOD MILL.

Waste sulphite liquors are, as a rule, thrown away.

The organic matter can, however, be precipitated by adding lime. This has been used as a sizing material in paper, and as a precipitant for animal size. It can also be used for sticking purposes. The liquid has recently been recovered as a fine dry powder, and has been used as a "weight giver" in coarse textiles.

REMARKS.—This appears to be the form in which the answer should be given. The answer does not call for any comments.

QUESTION 12.—*Describe the method of imparting a "water finish," and discuss the merits of "water-finished" as compared with super-calendered paper.* (20.)

ANSWER 12.—The "water finish" is produced by causing water to flow on to the calender roll in such a way that the roll will bring it in contact with the paper under the "nip." The idea was first developed in America, and is much used there for the thick box-making and label papers. The surface obtained is more even and closer than can be got from the super-calender, and the feel of the paper is much more silky. The process can be carried out much cheaper by fitting water-doctors to existing stacks of rolls, but it requires a lot of study and attention to details, in obtaining the web at the proper degree of dryness, to ensure uniform results.

QUESTION 13.—*What systems are used in practice for dealing with the fibres which find their way into the various waste waters of the mill?* (25.)

ANSWER 13.—

(1) Otto Schmidt stuff catcher.

(2) Ordinary revolving conical saveall.

(3) Roeckner's patent clarifier.
(4) Wilson's patent automatic self-cleansing filter.
(5) Greig's patent filtering apparatus.
(6) Reeve's patent filter.
(7) The Warren filter.
(8) The Dervaux water purifier.
(9) Johnson's and other filter-presses.
(10) Large precipitation tanks.

Remarks.—1, 2, 3, 8, and 9 can be used where it is desired to re-utilise the fibres for papermaking.

4, 5, 6, 7, and 10 are used for the purpose of clarifying effluents, where the small amount of fibre caught is of no value.

IX.

ANSWERS TO THE QUESTIONS AND EXPLANATORY NOTES.

HONOURS GRADE.

1901.

QUESTION 1.—*Examine very carefully and in all respects the position of esparto as against wood celluloses. Forecast their future relative positions in this country, and give your opinion as to how far this depends upon price, and how far on intrinsic papermaking quality.* (30 *marks.*)

ANSWER 1.—The position of esparto as compared with the wood celluloses is a somewhat complex one. Esparto comes into this country in its raw state, and is manufactured into pulp, whereas wood pulp comes into this country in its manufactured state, and is no longer manufactured here. Esparto is converted in the mill where it is to be made into paper, whereas wood is chiefly treated close to the sources of supply. Esparto is particularly prized for a certain class of printing and illustration, publishers and printers of this country much preferring it to any form of wood fibre for the purpose.

The general opinion now is that esparto should not be used for manufacturing paper of a lasting nature. Bleached esparto is a form of oxy-cellulose, and is in time oxidised and destroyed by atmospheric influences. It is more susceptible of change than well-prepared chemical wood pulp, but less so than mechanical. England is the great consumer of esparto, probably on account of its early and successful introduction into this country. Publishers having once acquired a taste for esparto papers are slow in adopting paper made from other materials, especially as they find that it suits the public taste of this country.

That esparto is not an essential ingredient of such papers is proved by the practice of other countries. In the States the papermakers use poplar fibre in place of esparto. With the improved manipulation of wood, and a judicious choice of fibre to suit specific requirements, English papermakers will in time place themselves in an independent position in regard to esparto, and the use of it or not will depend entirely upon economic considerations.

The two great factors of cost are—the price delivered of the grass and the cost of chemical treatment. It may happen that esparto grass is down in price, and yet the pulp is expensive to produce on account of the high price of caustic soda and bleaching powder.

Taking for the sake of simplicity, the average yield of fibre at 50 per cent., the average consumption of caustic at 10 per cent., and of bleaching powder at 15 per cent. on the weight of grass treated. With grass at £4, caustic at £11, and bleach at £7, we can easily arrive at the cost per ton of finished fibre.

Cost per ton of treated grass for—

		£	s.	d.
Raw material,	2 tons at £4	8	0	0
Caustic	4 cwts. at 11*s*.	2	4	0
Bleach	6 cwts. at 7*s*.	2	2	0
		12	6	0

In cases where recovery of soda is effected, allowance, of course, must be made. A sum must be added to the above for general charges, including all such items as fuel, labour, rent, interest, depreciation, &c., in connection with the plant used in the conversion of grass into bleached pulp. Such charges, of course, depend upon local conditions, and vary largely in different localities. The cost so arrived at must be corrected from time to time, with a change in the market prices, &c., before we can compare the price of esparto with the market price of such a material as American poplar. If, of course, the general equipment of the mill was for esparto treatment, the disposition would be to make esparto pulp as far as possible. On the other hand, many modern mills are not laid down for esparto treatment, and so cannot add esparto to their papers.

My opinion is that esparto will always be used in this country, but only in as much as it can compete against a certain class of wood pulp. The demand will largely depend upon the market price of caustic and bleach. The use of it will be chiefly in those mills especially equipped for the purpose, and where its treatment is well understood. A restriction of supply can only within certain limits raise the price, as its use beyond a certain limit of price would be discontinued in favour of wood. Wood has a slight preference for printing paper required of a lasting nature, but if this country follows the excellent example of Germany, wood and esparto will be eliminated altogether from the best writing and book papers, and, consequently, esparto as well as wood will be relegated to papers of a different class.

REMARKS.—This question is largely a matter of opinion. What the future will bring forth no one, not even the wisest, can foreshadow with any degree of certainty. Some such answer as the above is evidently what is expected by the examiners. The figures I have given for chemical treatment are a pure supposition. This should not affect the value of the answer, as it represents correctly the *mode* of arriving at the cost for comparison with chemical wood. The examiners would probably think more of the answer if the conclusions are logical. Students should stick to the point when answering a question, and not wander from it. All irrelevant matter, however correct it may be in itself, does not add to the value of an answer.

QUESTION 2.—*How would you equip a mill to turn out* 100 *tons of news and* 50 *tons of E.S. writings per week? Give your reasons for the adoption of any special appliances.* (30.)

ANSWER 2.—We start on the assumption that the news is manufactured from mechanical wood, sulphite wood pulp, clay, and, of course, sized with rosin, and would contain a certain portion of "shavings" and "broke."

We should require to have the following plant:—

Two revolving boilers for softening sulphite, mechanical wood, and papers, as required.

Two kollergangs, or if moist mechanical is to be used, then two disintegrators; one of each would doubtless be sufficient, but to assure a regular supply of uniform stuff it would be advisable to have two of each.

Two of Hibbert's patent beaters, 10 cwt. capacity each.

One Marshall refining engine.

The usual sizing and alum plant.

The paper machine should, of course, be an up-to-date "news" machine, 120 inches wide, fitted with the latest improvements, such as Marshall train, Fullner backwater plant, &c.

Two good "slitting" and "winding" machines, and the usual finishing house appliances.

For the E.S. writings the following would be required:—

One revolving boiler for soaking white shavings.

One poacher. Capacity, 10 cwt. of dry stuff.

One kollergang or disintegrator.

Five Coburn Taylor beaters, 7 cwt. capacity.

One Marshall refining engine.

One 92-inch paper machine, fitted with the latest improvements, such as water doctors and calender rolls, Marshall train, Fullner's backwater plant, spray damping arrangement, &c.

One super-calender.

One single-sheet cutter.

One revolving angle cutter.

Guillotine, &c.

I have ignored the laying out of mill for the treatment of esparto, although esparto is largely used in engine-sized writings. The tendency is, however, to replace esparto by wood, and by so doing an enormous saving of cost is effected, vomiting boilers, evaporating plant and recovery plant being dispensed with. I should mention that the plant given above for E.S. papers is based on the assumption that the furnish is sulphite wood pulp and white shavings.

The steam boilers should be 28 feet long by 8 feet diameter, of the Lancashire type, and fitted with Galloway tubes and economisers; they should be placed near driving engine so as to avoid loss by radiation or sharp bends.

REMARKS.—The engine should be an up-to-date type of the tandem type, condensing, of course. It should work with from 2½ to 3 lbs. per horse-power per hour. (Many makers of engines claim to do with less than this, but it is seldom realised.) The coal consumed, of course, is dependent upon the quality used, as well as the general evaporative efficiency of the boilers. It would be best to state that the engine should work with a consumption of 20 lbs. of steam per horse-power per hour; by so doing one leaves out of the question the quality of the fuel, &c. With an evaporative efficiency of 8 lbs. of water per lb. of coal, and allowing for radiation, an engine requiring 20 lbs. of steam per horse-power per hour would consume somewhere between 2½ and 3 lbs. of coal per horse-power per hour.

In the working up of white shavings a machine such as Cornet's cone breaker is preferred by many to a kollergang.

For the E.S. machine one revolving boiler would be sufficient, as the two on the news side could be worked with it, and it would be used mostly for soaking the white shavings.

One poacher is considered sufficient for bleaching the wood pulp, as bleached wood pulp can be obtained comparatively cheap, and it is often therefore better to buy bleached pulp.

It is advisable at the beginning of the answer to state on what the estimate is based, then to follow on with a detailed estimate, and finally to give reasons for the adoption of certain appliances.

QUESTION 3.—*State what you know of the systems for wood pulp manufacture known as the "Drewsen Drønfeldt" processes, and discuss the advantages claimed.* (20.)

ANSWER 3.—In this system soda bisulphite is used in place of calcium, or magnesium bisulphites for treating wood. The liquor is calcined after use, and the recovered soda is a mixture, suitable direct for the production of soda wood.

The process of V. B. Drewsen consists of heating with lime under pressure, yielding calcium monosulphide (with sulphate and the lignone complex in insoluble form). The sulphite is redissolved as bisulphite by treatment with sulphurous acid.

REMARKS.—An account of these processes has recently been published in Continental journals.

For further information, see also "Researches on Cellulose," by Cross & Bevan (Longmans, Green & Co.)

QUESTION 4.—*How many tons of coal would you expect to use per week in the mill referred to in Question 2? State the proportion you would use in each department, assuming that the motive power is steam throughout.* (25.)

ANSWER 4.—The Hibbert beaters would take 50 horse-power per hour for 10 cwt.

The Coburn Taylor 30 to 40 horse-power per hour.

The Marshall engine would not take much power, as the cone should be touching very slightly, while the disc should be pretty well up.

The machine engines should be compound condensing, and should run from 2½ to 3 lbs. of coal per horse-power per hour.

The coal consumed over all would amount from 30 to 35 cwts. per ton of paper produced, but the amount of finishing by super-calender would cause a variation from time to time, about 100 to 120 tons being used to the production up to the machines.

The consumption of coal for the manufacture of machine and drying on cylinders would amount to about half a ton per ton of paper produced. The balance to make up the 30 cwts. to 35 cwts. would be used in final operations.

Coal has an evaporative performance of 8 lbs. of steam per pound of water.

REMARKS.—This is a question on which there might be great difference of opinion. The idea of gauging the power required in the consumption of so much coal per ton of paper is a very loose one, since coals differ so much in evaporative efficiency. The student should acquaint himself with the relative heat values of different fuels, and should state the class of coal he has in his mind when giving such figures. He could hardly be blamed for not doing so, however, since authorities publishing figures frequently do not state the heat value of their coal. Hence endless confusion and difference of opinion on such-like subjects.

The best work to enlighten the student on the subject of fuel, &c., is "A Manual of Rules and Tables," by D. K. Clark, published by Blackie & Son, Ltd.

QUESTION 5.—*You are given an unknown fibrous material, and are required to determine its suitability as a raw material for papermaking; state exactly how you would do this, and on what main points you would base your estimate of value?* (25.)

ANSWER 5.—Determine percentage of ash by burning 1 gram until weight of ash is constant. (Note colour of ash.)

Determine moisture by drying at 212° Fahr. until weight is constant; weighing must be done in tube. Determine the cellulose by the following method :—

Boil in dilute alkali until fibre is softened.

Wash and expose to chlorine gas for several hours, in beaker, which should be kept cool by surrounding with cold water. (Note whether fibre is changing in colour in chlorine.)

Wash chlorinated fibre to free from HCl, and place in weak solution of neutral sulphite of soda. (Note whether magenta colour is developed.) After one hour boil solution until colouring matter is dissolved.

Wash with hot water.

Bleach with weak solution of sodium-hypochlorite. If cellulose is not white, give further treatment in chlorine gas or in bromine water; but be careful that treatment does not injure fibre. Then repeat treatment with sulphite; wash, bleach, wash, acidify with acetic acid, dry at 212° Fahr., and weigh in weighing tube. The weight calculated on the air-dry original gives the percentage of cellulose.

Note the general appearance and character of the cellulose. Examine cellulose under microscope, and note how near it approximates to one or other of the various fibres in common use for papermaking.

From the microscopic characteristics can be judged, in a large measure, the relative value of this cellulose in comparison with other materials.

If sufficient material is available, treat 1000 grammes in 5000 grammes caustic soda liquor in a small spherical revolving boiler. The strength of soda must be carefully ascertained by titration at commencement, and care must be taken throughout the treatment that no steam is allowed to escape, thus altering the liquor in strength. Boil at 100 lbs. pressure, and draw off at intervals of an hour small samples, which test for free alkali. When the free alkali remains constant discontinue boiling; carefully wash boiled pulp, taking care that no fibre is lost.

Dry and weigh pulp at 212° Fahr.; this weight gives the percentage of unbleached pulp on original weight of fibre. Let the pulp become air-dry by long exposure to air, and until it no longer gains weight; weigh pulp, and calculate percentage of air-dry pulp on raw material; this is the figure that should be taken for commercial purposes.

From the analysis of the liquor you know exactly the percentage of soda neutralised during the boiling. For the purpose of final analysis of liquor, the liquor, together with all the washing, is made up to a known volume, and the "free" and "total" soda are carefully determined. The difference is the soda combined and used up by the fibre.

The original amount of soda added is known. We can easily calculate the weight of soda consumed, and then see what percentage this bears to the original weight of the fibre treated.

We should now conduct another boiling trial, adding soda slightly in excess of that found to be "consumed" in the first trial. The extent to which this soda should be diluted must depend upon the condition of the raw fibres, and must be left to the discretion of the observer. The same pressure is applied (unless there is good reason to suppose that a higher or lower pressure would be advantageous from the general appearance of the first treated lot). Samples are again drawn off every hour, and the boiling continued until no further neutralisation of soda takes place. The rest of the treatment should be conducted as in previous trial. The calculated percentage of pulp should be near that of first trial.

The cellulose should now be determined in a small portion of the bone-dry boiled pulp, and should not be less than 90 per cent.; the ash should also be determined in unbleached pulp.

A portion, say half of one of the boilings, should be carefully weighed and then treated with successive quantities of bleach solution, equal to 5 per cent. of dry bleaching powder at a time. One quantity should exhaust itself before another is added. Any excess of bleach remaining after the colour no longer shows improvement should be determined and deduction from the total added before calculating the bleach consumed by fibre.

A second bleaching experiment should be done as a check, adding just the equivalent of bleach found to have been consumed in first trial. The bleached pulp is washed, acidified, washed, dried, and weighed, and then exposed to air-dry. Bleached pulp should be calculated upon the original raw fibre boiled. The ash of bleached pulp should be determined.

Put some of bleached pulp in beater, beat carefully, and make into paper on hand-mould, with or without clay, alum, starch, &c.

Take stuff from known mill furnish, and make also into hand sheets, under the same conditions as far as possible.

Compare the relative strengths and other physical qualities. The stuff of known furnish will produce paper on machine of known qualities ; from this we can form some rough judgment of what might be expected from the fibre under examination.

Note the comparative shrinkage of the sheets, the comparative felting qualities, and such-like qualities.

From the foregoing work one can form a very fair estimate of value. *Ceteris parabus* the raw material would be in the long run more valuable in proportion as the consumption of chemicals, &c., and treatment was small, the ease with which it can be manipulated, the cleanliness of the pulp, &c. The length of the fibres, the whiteness and purity of the fibre, and also general utility and adaptability are judged from the quality of paper it produces.

It should be ascertained, if possible, how much bulk a given weight of raw fibre will occupy. If bulky the freight will be high, and possibly preclude its use.

In fibres of low yield and consuming a large amount of chemicals, the cost of chemical treatment per ton of finished stuff is often so high as to condemn the material for industrial use, no matter even if the resulting cellulose is of excellent quality, and the raw material had for the asking.

Such considerations as these must be weighed with the greatest care in estimating the value of any material for the purposes of paper manufacture.

Remarks.—There is a lot condensed into the above answer, perhaps more than would be expected from the student. I would commend the details to the reader's careful consideration, as there is no published work setting forth this information, and it is an important subject to the paper-mill chemist.

Question 6.—*In what departments, if any, of the mill do you consider that the electric motor can be successfully substituted for the steam engine? State your reasons fully.*

Answer 6.—Glazing calenders, guillotines, plate-glazing rolls, enamelling plant, and all machines that are run intermittently.

Electric motors are particularly applicable in the instances above cited. They are also useful in those parts of a mill where comparatively little power is required, and where it is difficult to convey steam power. The motors must, however, be kept in a clean and dry place, and should be boxed in to keep them free from dust and dirt. They are furthermore useful for driving fans for the ventilation of buildings, especially in inaccessible places.

REMARKS.—In connection with this question the student would do well to consider the cost by means of transmission through electric conductors, and reconversion into power, as compared with the cost of transmitting power by means of a given line of shafting, belting, &c. With the electric current we have first the loss sustained by conversion of power into electricity, then the loss through the resistance of the conductor, and finally the loss by converting the electricity back into the power again. One has also to consider the question of prime cost as well as practical adaptability. In many instances it is not possible to lead a line of shafting to a given spot, whereas there need be no difficulty in fixing a wire and erecting a small motor. The power may further be transmitted by laying a steam pipe to a given spot. In this case we have the question of radiation along the steam pipe to take into consideration. This question on the whole is worthy of every consideration and study.

Electrically driven pumps can be worked automatically for maintaining a given head of water, such as for supplying tanks on high buildings where a constant head of water is required. The pumps automatically start and stop, and so keep the tanks supplied without requiring attention. The transmission of power by electric current is particularly adaptable to mills depending upon water power.

QUESTION 7.—*What do you consider the special requirements of papers for* (1) *parchmentising*, (2) *converting into nitro-cellulose*, (3) *quantitative chemical work (filter papers)*, (4) *for making paper bowls*, (5) *for litho and general fine printing*, (6) *for cartridges*, (7) *for water-colour drawings*, (8) *for cable insulation? In each case state the composition of half-stuff you would take in making the paper.* (25.)

ANSWER 7.—(1) Originally made of cotton and linen, but well-treated straw in conjunction with rag or even chemical wood will do. If the parchmentising effect is to pass right through the sheet no sizing material must be used, but if superficial treatment only is required, as is sometimes the case, the paper must be sized more or less with rosin.

(2) Made after the manner of copying papers, but must contain only well-treated cotton and no size, fibre long; a little starch is permissible; there must be freedom from grit. Weight low, 10 to 20 grammes per square metre.

Nitro-cellulose used for special purposes other than for explosives has been prepared from well-treated esparto stock.

(3) Cotton and linen stock, chiefly cotton. Tender stuff rapidly beaten with sharp knives after the manner of making blottings. Greatest care must be taken to keep free from contamination. Ash removed by treatment with hydrochloric and hydrofluoric acids. Made on the machine so as to "bulk" well,

must be absolutely free from sizing material, alum, &c. Should be kept from contact with iron during manufacture. A little starch is permissible.

(4) Strong unbleached sulphite pulp, drawn out with blunt tackle so as to work wet and give great strength, and mixed with ingredients shown as under.

(5) Surface and bulk, and so shrunk as to show close register in successive printings. Fine, even surface, often enamelled. White opaque, super-calendered.

(6) Carefully drawn out sulphite pulp with mineral and rag fibre. All unbleached or partially bleached. Rosin sized.

(7) Mixture of cotton and linen, wavy surface, bleached stuff, but not whitened with blue. The best is hand-made, sized with gelatine, pressed and kept in stock for many years to improve "tooth" of paper. The paper must be neutral, and consequently must be finished with no more alum than is necessary for the gelatine. All chemical residue should be removed by carefully washing the stock. Paper must not be greasy to the brush, but firm and hard, and must expand as little as possible when wetted with colours. Machine-made drawings are now more in use than formerly; these are made somewhat like cartridge paper, but from rags, and gelatine sized. The character of surfaces is got by means of special felts; except for very best work, machine-made drawings will suffice. To save expense in the drawing-office, ordinary cartridge paper is sometimes made to do service for drawing paper. Whatman's drawing paper of certain dates are specially prized by some leading artists for the character of tooth which these papers possess, which they say they have never seen imitated.

(8) Made from strong manilla, beaten out long with dull tackle and worked wet to give great strength, sometimes mixed with unbleached sulphite. Colour no object. Well-sized with rosin. Must resist moisture as far as possible. Strong unbleached sulphite will do for inferior stuff.

(1) 60 per cent. cotton } or, 60 per cent. straw.
40 „ linen } 40 „ chemical wood.

(2) 100 per cent. cotton.

(3) 100 „ „

(4) 20 „ unbleached sulphite.
10 „ rosin size.
70 „ glutenous matter containing peat.
10 parts of alum added and three parts of starch to harden mass.

(5)	60 per cent.	short-fibre bleached soda wood.
	20 ,,	bleached sulphite.
	20 ,,	mineral.
(6)	40 ,,	unbleached linen or sulphite.
	40 ,,	,, cotton.
	20 ,,	mineral.
(7)	40 ,,	cotton.
	60 ,,	linen.
(8)	40 ,,	unbleached manilla.
	40 ,,	,, sulphite.
	20 ,,	jute, partially bleached.

3 parts of rosin.

REMARKS.—For composition of blottings, see Abstracts of papers contained in Society of Arts Report upon the Deterioration of Paper.

There are many receipts for paper bowls, but the above is one which has, I believe, been extensively used.

I have given above a recipe for paper bowls (hand-bowls), but it occurs to me that calender-bowls may be intended. For the latter purpose new cotton black rags without chemical treatment are occasionally used, but perhaps the best paper is one made from unbleached hemp and possessing a peculiar permanent stretch when passed through the fingers.

Closeness and water resistance are the great things with cable paper. The paper must, of course, be a good insulator of electricity, and rosin, of course, tends to this.

QUESTION 8.—*Given* 10 *tons of Spanish esparto of an average quality, how would you proceed to make an "art" paper such as is used for high-class magazine work? State fully the practical details to be observed in each of the various processes from the duster to the finishing house, giving a tabulated statement of the duration of each process and the percentage of the various chemicals, including loading and sizing, also the amount of finished paper you would expect to produce.* (30.)

ANSWER 8.—The esparto is first of all opened up and passed through a "willow." It then passes over an endless belt, and is hand-picked. The "willowing" and "hand-picking" will result in a loss of 6 per cent.

The willow dust contains the following:—

Water	6·2 per cent.
Organic matter	64·6 ,,
Mineral ,, ...	29·2 ,,

The organic matter contains 90 per cent. of cuticular rosins and waxes. The mineral matter consists for the most part of silica, chiefly derived from sand and dirt, and forms no part of the grass itself. The following are particulars of boiling:—

Weight of charge	... ...	50 cwt.
Gallons of caustic lye per charge	... ...	1570
Pounds of 60 per cent. caustic per gallon	...	509
Total pounds of 60 per cent. dry caustic	...	900
Maximum steam pressure	... ...	20 lbs.
Time under pressure	... ...	$2\frac{1}{2}$ hours.
Yield of unbleached pulp (air-dry)	... ...	44 per cent.
Yield of bleached pulp (air-dry)	... ...	40 „

The boiling is conducted in a vomiting boiler.

The cooked grass is washed by a special process, such as that of Cornett's, so as to obtain the liquor in a concentrated form ready for evaporation. Time of washing, 24 hours. By this slow process the fine fibres are retained.

The grass is next bleached with 10 to 12 per cent. bleaching powder.

Time of bleaching, four hours. The mass is heated to accelerate the action, but care must be taken not to heat too much.

Sometimes the pulp is passed through strainers and over a "presse-pâte" before bleaching, but as the "presse-pâte" wires are now made to withstand the action of the bleach, this operation can be done after the bleaching. The "presse-pâte" removes the greater bulk of the bleach liquor, and the strainer retains the knots and untreated portions. Any dirt escaping the strainers can be picked out by hand. The stuff is now furnished to the beater, and a little antichlor added if necessary. The stuff is beaten rapidly so as to work "free." To the furnish, at the close of the beating, is added 5 per cent. long rag fibre, treated in another beater. 25 per cent. of mineral can be added on the weight of dry stock, and the whole is sized with 2 to 3 per cent. of rosin and alum. The size is added not only to size the paper, but to assist in retaining the mineral. To keep the mineral in the paper it is sometimes added to the rosin size. It is very necessary that the paper should be free from grit and dirt.

Paper of the above furnish would equal about 50 per cent. the weight of raw grass taken. For the purposes of a modern "art" paper the web, after passing the drying cylinders, is enamelled by means of a brush machine. The paste supplied to the paper contains barium sulphate, calcium sulphate, and a proportion of liquid glue. This treatment adds to the finished weight of the paper to the extent of 15 to 20 per cent., the finished weight being from $5\frac{3}{4}$ tons to 6 tons of dry paper for every 10 tons of Spanish esparto grass.

The broke, made at the machine, and during the enamelling process, is, after disintegration, returned to the beaters.

With the very best plant 90 per cent. of the soda can be recovered from the waste esparto liquors.

REMARKS.—If the paper is heavily enamelled it should carry less clay in the furnish. If lightly enamelled, it should carry more clay. The amount of rosin required is partially dependent upon the amount of clay added. With heavily enamelled papers the colour of the paper before enamelling is not material, as the coating of enamel alone is visible after treatment. If, therefore, a blue paper is wanted for the cover of a journal, the blue is added to the enamel and not to the paper furnish. The conditions of boiling are practically those given by Beveridge.

QUESTION 9.—*Examine thoroughly the question of engine-sizing with rosin and alum. Give your view of the mode of action of the size, both in the engine and in the paper. Give practical recommendations for preparing and using the rosin size.* (25.)

ANSWER 9.—Rosin sizing is resorted to either as a substitute for, or in conjunction with, gelatine, where it is not necessary that the paper should be very hard sized.

It is used alone on printing papers and in conjunction with gelatine in low and medium-class writings. It is commonly known as engine-sizing, as the operation is generally performed in the engine, and to distinguish it from "tub" or gelatine sizing. In the latter the size was formerly contained in a tub, into which the hand sheets were dipped.

Rosin, or colophonium, is obtained from the sap of firs and pines by a process of purification. It contains a mixture of substances of the nature of acids. Their properties will be more fully described later.

Rosin combines with metallic oxides to form salts, in which it plays the part of an acid. These salts are called resinates. In the case of the alkalies the resinates are soluble in water, forming soapy solutions. These are known as the "soaps of rosin." The resinates of the other metals are mostly insoluble in water. Rosin is considered by Dr. Wurster to be represented by the formula $C_{20}H_{30}O_2$, which is equivalent to a molecular weight of 302. It begins to soften at 120° Fahr. and melts at 170°–200° Fahr., and contains about 10 per cent. of water.

Rosin size is made by boiling rosin broken up (preferably powdered) with caustic soda, soda crystals, or soda ash, dissolved in water. The operation is performed in an iron copper heated by a steam coil. The reaction that takes place may be represented by the following equation:—

$$2C_{20}H_{30}O_2 + Na_2CO_3 = 2C_{20}H_{29}O_2Na + CO + H_2O.$$

During the heating, carbonic acid is given off, and resinate of soda and water are formed. According to the above equation, 100 parts of rosin would require—

17·54 parts of soda ash.
10·26 parts of sodium oxide.

One part of sodium oxide would equal 9·746 parts of rosin, or 1 part of soda ash would equal 5·7 parts of rosin.

There are two reasons why these proportions are not adhered to in practice. (1) The rosin always contains moisture, and (2) the best size is considered generally to be that which contains "free" rosin.

If we take the moisture at 10 per cent., in order to produce a neutral size it would be necessary to use—

$$1 \text{ of soda ash to } \frac{5{\cdot}7 \times 1000}{90} = 6{\cdot}33 \text{ parts of rosin.}$$

After a large number of trials I used 1 of "soda ash" to 7·65 of rosin, which gives a soap containing a considerable amount of "free" rosin, and one which will keep well, and on dilution will form a clear milky solution.

The following is a good recipe for making :—

1,300 lbs. of rosin.
170 lbs. of soda ash.
200 gallons of water.

The boiling will have to be continued for about seven hours. Just before the finish the volume should be made up to 225 gallons, which is best done by having a mark on a stick, which, when held vertically in the solution and resting on the bottom, corresponds to 225 gallons.

Ten gallons of such solution contain—

58 lbs. of rosin.
7·6 lbs. of soda ash.

The solution is a dark treacly liquid when hot, and can be filtered through fine wire gauze to free it from particles of dirt. It becomes opaque on cooling, owing to the separation of "free" rosin. After long standing some liquor separates out, which contains most of the colouring matter originally contained in the rosin, and some "free" soda.

The following is an analysis of some size made after the above recipe :—

Combined rosin	40·59 per cent. by weight.	
Free rosin	14·37 ,,	,,
Combined soda	6·72 ,,	,,
Free soda	1·34 ,,	,,

The specific gravity was found to be from 1·11 to 1·13. One gallon can therefore be taken as 11·2 lbs. As the size contains 54·96 per cent. of total rosin by weight, one gallon contains—

$$\frac{11{\cdot}2 \times 54{\cdot}96}{100} = 6{\cdot}14 \text{ lbs. of rosin}$$

For every 100 parts of rosin 26·1 parts are free. It will be seen from the above that the size contains both "free" soda and "free" rosin. It is possible that dissociation takes place on cooling, but it has not yet been proved to be the case.

The red liquor which separated out of the size was found to be alkaline, and to contain rosin.

Its specific gravity, 1·0425.

It contained 1·03 per cent. rosin and 2·7 per cent. soda.

The liquor should be thrown away, as it is of a dark colour, and contains very little rosin.

It will be noticed that the amount of soda used in the foregoing recipe is insufficient to saponify the whole of the rosin, and yet the analysis shows that the size contains free soda. I am of opinion that no amount of boiling would induce the whole of the soda to enter into combination, even if the rosin be largely in excess. Further, that it would be necessary to have a large excess of soda to ensure that the whole of the rosin is in combination. It follows, then, that size made according to recipes which vary somewhat from that which I have given, contains both "free" soda and "free" rosin.

Size which contains free rosin when diluted with water forms a white milky solution, from whence it receives the name of "white size." The solution is called "milk of rosin."

When the whole of the rosin is in combination as resinate of soda, so that on dilution it forms a clear brown transparent solution, it is called "brown size."

Wyatt, in his excellent paper on "Sizing Paper with Rosin," gives a recipe for the manufacture of brown size, the amount of soda being that theoretically necessary to just saponify the whole of the rosin. I have good reasons to believe that this proportion would not produce a brown size, as it would probably show on analysis both "free" rosin and "free" soda. Wyatt states that it is not advisable to have more than 20 per cent. of the rosin in the free state, as it is difficult to dilute the milk without some of the rosin appearing as flocculent particles, which affect the appearance of the finished paper.

That which I have found to give the best results contained as much as 26 per cent. of the rosin in the free state. It seems that he assumes that the whole of the soda is in combination with rosin, and that the difference represents the free rosin.

Brown size may, for some reasons, be preferred to white size. It is certainly more easy to manipulate, and it is improbable that any spots of rosin should find their way into the paper. White size has, however, the advantage of requiring less alum to precipitate it.

The milk of rosin should contain from one to two pounds of size per gallon; it is advisable to dilute this further before adding it to the beater.

Some papermakers prefer to add the alum before the size, as it prevents frothing in the beater. It is best, in order that the size may be thoroughly incorporated with the pulp, that the size be added first, so that it may thoroughly penetrate the fibres. If the alum be added first, the size is likely to be precipitated away from the pulp. As, however, the sizing effect is generally acknowledged to be due, not to resinate of alumina, but to "free" rosin which melts during the passing of the paper over the drying cylinders, the order in which these ingredients are added may not be of so much importance. I would prefer, however, to add the size before the alum, as I think it likely that a greater proportion of the rosin is retained by the pulp. By the use of a large amount of rosin in the pulp the paper is rendered brittle, and lowered in colour. One great object is, then, to produce the greatest possible sizing effect with the least amount of rosin.

When alum or sulphate of alumina is added to the rosin-size contained in the pulp, so that it is just neutral to litmus, resinate of alumina and sulphate of soda are formed thus—

$$6C_{20}H_{29}O_2Na + Al_2 3(SO_4) = 3Na_2SO_4 + (C_{20}H_{29}O_2)_6Al_2.$$

Nearly all the rosin-sized papers I have examined have been found to be acid to litmus; and on comparing the amount of alum actually used in practice with that indicated by the above equation, it is often as much as eight times that necessary to form resinate of alumina, and is seldom below four times. In almost all cases

I conclude the reaction which really does take place is as follows—

$$6C_{20}H_{29}O_2Na + 3Al_23(SO_4) + 3H_2O = 6C_{20}H_{30}O_2 + AlSO_4 + 3Na_2SO_4.$$

This equation, after making allowance for 10 per cent. of moisture in the rosin, and 50 per cent. of moisture in commercial sulphate of alumina—

Rosin : sulphate of alumina : : 670 : 686.

A correction must, however, be made (1) for the free rosin in the size, which of course requires no alum; (2) for the soda in combination with rosin.

The above equation supposes that the soda is in combination as resinate of soda, and makes no allowances for any free rosin or free soda present in the size, 1 part of sodium carbonate being equal to 5·7 parts of rosin.

Supposing the size used is made according to the recipe given, and that the composition is the same as that given above, we can easily calculate the ratio of rosin to sulphate of alumina—

(1) By equation: 1 lb. of rosin equals $\frac{686}{670} = 1{\cdot}024$ lbs. of commercial sulphate of alumina.

(2) By equation also: after assuming that the rosin contains 10 per cent. of moisture, 1 lb. of soda ash is equal to 6·33 lbs. of rosin.

(3) By analysis: 1 lb. of soda ash is found to be equal to 7·61 lbs. of rosin. Therefore 1 lb. of rosin would be equal to $\frac{1{\cdot}024 \text{ lbs.} \times 6{\cdot}33}{7{\cdot}61} = 0{\cdot}852$ lb. of commercial sulphate of alumina.

It will be found, however, in practice this quantity of sulphate of alumina is very much exceeded, and for obvious reasons.

As the treatment that the raw material undergoes is throughout an alkaline one, except in a few instances, we would naturally expect that the pulp has a tendency to be alkaline. The alkalinity of the pulp varies considerably, and depends upon the amount of chemical treatment the material has received, but more especially upon the extent to which the chemicals used have been removed by washing. The pulp should give but a slight basic reaction if it has received a thorough washing in the breaker. Sometimes the bleaching is conducted in the beater, and the excess of bleach has to be "antichlored." Both the bleach and antichlor used are strongly alkaline, and render the pulp distinctly basic. The hardness of the water is another cause of alkalinity.

Before the size can be properly precipitated by the alum, it is necessary that the bases present in the pulp should be neutralised.

Sulphate of alumina acts on the carbonate of lime contained in the water converting it from "temporary" into "permanent" hardness; that is, from carbonate to sulphate, thus—

$$3CaCO_3 + Al_2 3SO_4 = CaSO_4 + Al_2(OH)_6 + 6CO_2$$

Carbonic acid is given off and hydrate of alumina is precipitated. The weight of water in the chest is about twenty times that of the dry stuff. If we know the number of degrees of temporary hardness and the weight of stuff in the chest, we can calculate the amount of alum required per ton of paper to neutralise the alkalinity due to the water. In one case, in which 30 lbs. of soap had been added per ton of paper, the amount of sulphate of alumina consumed per ton was as follows:—

	Sulphate of alumina. 20° Tw. solution.
30 lbs. of soap required	13·6 gallons.
Water in chest, &c., equal 7,000 gallons, required	20·4 gallons.

In another case the consumption was accounted for as follows:—

Per ton of paper.	20° Tw. sulphate of alumina.	Sulphate of alumina. Percentage consumed of total put in.
7 gals. of rosin size	6·88 gals.	... 15·3 per cent.
30 lbs. of soap	4·55 ,,	... 10·1 ,,
7,000 gals. of water	20·45 ,,	... 45·5 ,,
Sulphate of alumina in excess ...	13·12 ,,	... 29·1 ,,
Total sulphate of alumina	45·00 ,,	100·0 ,,

This shows that of the sulphate of alumina used, only 15 per cent. was required by the rosin size. After making allowance for the curd-soap and alkalinity of the water, more than a quarter still remained in excess. Some of this, but only a small quantity, was used up in neutralising the bases present in the pulp. The finished paper was found to give an acid reaction to litmus: this I have always found to be the case with rosin-sized papers. The dilution of the alum is so great that it is only reasonable to expect that more than the calculated quantity must be added to bring about the precipitation of the size.

The action of the alum upon curd-soap is the same as on the rosin size, forming an insoluble "soap" of alumina and the fatty acid of which the "soap" is composed. These insoluble alumina soaps are often soft, and give to the paper a soft feel. The excess of alum tends to make the paper hard, and the rosin to render it brittle, if present in sufficient quantity; the action of the soap has the reverse, and therefore a neutralising effect.

REMARKS.—The above has been discussed at length, as the question demands it, although of course a student would not have time to go into the matter so fully. The foregoing sets forth my views as the result chiefly of my own work and experience. The student might reasonably be expected to treat the question in the same spirit. (For further information, see Beadle, PAPERMAKER, 1892, pages 347, 406, 407, and 464, from which the above answer has been condensed.)

QUESTION 10.—*State your opinion of the merit of Annandale's improvement in the machine for the imparting of "hand-made" characteristics to the web in process of formation on the wire. Discuss the difficulties in the way of its successful adoption, and state in which class of paper you consider it will give the best results.* (15.)

ANSWER 10.—Annandale's idea is to get the fibres well mixed together. One great drawback of machine-made papers would be overcome to a large extent if this method could be applied successfully. Machine-made paper tears more readily in the direction of the web than across the web, due to the fibres arranging themselves in the direction in which the machine is running. In order to arrange the fibres in all directions the material must be shaken equally both laterally and longitudinally. This is possible on hand-made paper, but not on the ordinary Fourdrinier machine. Annandale's method requires a good deal of alteration to the machine to make it workable. Such a process is desirable in the manufacture of high-class papers which should expand and contract uniformly with changes of atmospheric influences. It is desirable also for paper used for water-colour drawings.

QUESTION 11.—

Let A = *the area of a sheet of pure cellulose paper in square centimetres.*

T = *thickness of a sheet in terms of centimetres.*

S = *specific gravity of cellulose.*

W = *the weight of the sheet in grammes.*

What do you take to be the meaning of the expressions $\frac{W}{A.T.}$ *and* $\frac{A.T.}{W} - \frac{1}{S}$ *and how would you bring the quantities so represented into practical use in the mill?* (25.)

ANSWER 11.— $\frac{W}{A.T.}$ is the weight in grammes per centimetre, the reciprocal is the volume in c.c. per gramme of the paper in centimetre.

The first expression has some useful applications; we take, for instance, a sheet of blotting paper, measuring 50 centimetres square, weighing 0·450 grammes, and having a thickness of $\frac{15}{1000}$ inch, when measured by means of a micrometer. As 25 millimetres are equal to one inch, the thickness of paper in millimetres is as follows: $\frac{15 \times 25}{1000} = 0·375$ millimetres. The bulk of this amount of paper, therefore, is as follows: $50 \times 50 \times 0·37 = 925$ cubic millimetres, or 0·925 cubic centimetres.

We now know the exact weight and bulk of the piece of paper, from which we can calculate the number of grammes weight per centimetre cube, by making use of our first formula $\frac{0·450}{0·925} = 0·486$ grammes per cubic centimetre.

The most simple application of this figure is to find the weight of a cubic foot of paper. We now know the grammes per cubic centimetre of the paper in question; we also know that one gramme of water is equal to one cubic centimetre; we furthermore know that one cubic foot of water is equal to 62·5 lbs. weight. All that we have to do now is to multiply $62·5 \times 0·486$, which gives us 30·4 lbs. of paper per cubic foot.

By the same method a sheet of cartridge paper is found to weigh 1·17 grammes per cubic centimetre. A cubic foot of this would therefore weigh $62·5 \times 1·17 = 73$ lbs.

This method of procedure is useful in a paper mill for taking stock in the salle of stacks of paper at stocktaking time, and for similar purposes.

REMARKS.—By a similar method we find that a cubic foot of chemical wood pulp weighs 39 lbs., or that a cubic centimetre weighs 0·62 grammes. We know that the specific gravity of the fibre is 1·5, which is only another way of saying that 1 cubic centimetre weighs 1·5 gramme. The actual volume occupied by the fibre itself, together with the volume of air space surrounding the fibre, can now be readily determined. The volume occupied by the fibre is as follows:—

$$\frac{0·62 \times 100}{1·5} = 41·4 \text{ per cent.}$$

The air space, of course, is the difference between 41·4 and 100, which is 58·6 per cent. The bales of pulp consist, therefore, as follows:—

Chemical fibre by volume	41·4 per cent.
Air space by volume	58·6 ,,

The volume percentage of different papers affords us useful information. With blotting and filter papers it gives us an expression of absorbent qualities. On the other hand, when the percentage by volume of fibre and other ingredients is high, and consequently the percentage by volume of air space is low, the percentage by volume of solid ingredients affords us a direct expression of hardness, compactness, resistance, &c. The influence of mineral matter upon the specific weight of a paper has already been dealt with in answering Question 9, Ordinary Grade.

I leave the students to find out for themselves the meaning of $\frac{AT}{W} - \frac{1}{S}$

QUESTION 12.—*What instructions would you give to the beater-man in regard to washing, breaking in, and beating of* (1) *Manilla ropes for strong cartridge paper*; (2) *soft cottons for superfine printings*; (3) *linen thread for bond papers? Give the percentage of bleaching powder you would expect to use in each case.* (25.)

ANSWER 12.—(1) Manilla ropes should be washed well and drawn out before putting to bleach; mill well, but do not lower the roll too rapidly or the fibres will be shortened.

(2) Soft cottons. Wash well for two hours and until wash-water is clear of dirt. The bleach must not be added until the wash-water is clear.

(3) Linen thread. Lower the roll very slowly unless the thread tends to roll up in a bundle in front of the roll; if so, grip it well until it begins to open out; ease off as soon as it begins to behave nicely, and keep fibres long and as well milled as possible.

Manilla ropes require 5 to 6 per cent. of bleach; cottons, 2 per cent.; linen thread, 3 to 4 per cent.

QUESTION 13.—*Give a method for rapidly analysing the machine back-water in regard to suspended fibrous matter and sulphate of alumina* (*in solution*). *Describe any modern appliances you know for separating suspended fibres from waste waters.* (25.)

ANSWER 13.—Take a given volume of the back-water in question; for instance, 100 c.c., care being taken that sample is measured whilst all the suspended matter is held up in the solution. Place a filter-paper in an air bath at a temperature of 105° Centigrade. When paper is thoroughly dry, weigh it in a weighing tube; then filter the back-water through the paper, dry it at 105°, and weigh. Ignite on a platinum dish, and deduct the amount of ash found from the weight found in suspension. The difference between these two figures approximately represents the fibrous matter in the back-water. When 100 c.c. of the solution is taken, the weight found in grammes gives the percentage of dry fibre in solution without any calculation. This figure divided by ten would give the weight in pounds per gallon.

To the filtered solution add a drop of hydrochloric acid, boil, add ammonia, boil until the smell of ammonia has disappeared, filter, wash, ignite, and weigh the precipitate so formed. This precipitate is alumina. If you are using a sulphate of alumina containing 16 per cent. of alumina, you have merely to multiply the weight of the precipitate in grammes by seven to arrive at the amount of commercial sulphate of alumina present in the back-water.

The appliances used for separating suspended fibres from waste waters are as follows :—

(1) Otto Schmidt stuff-catcher.
(2) Ordinary revolving conical "saveall."
(3) Rockner's patent clarifier.
(4) Wilson's patent automatic self-cleansing filter.
(5) Greig's patent filtering apparatus.
(6) Reeves' patent filter.
(7) The Warren filter.
(8) The Dervoux water-purifier.
(9) Johnson's and other patent filter presses.
(10) Large precipitating tanks.

1, 2, 3, 8, and 9 are used where it is desired to re-utilise the fibres for papermaking.

4, 5, 6, 7, and 10 are used for the purpose of clarifying effluents where the small amount of fibre caught is of no value.

REMARKS.—As a rapid method is asked for in this question, there is no good in attempting to describe a really accurate method for the examination in the back-water, as any accurate method would require a considerable time. The suspended fibrous matter caught on the filter contains, in addition to fibre, rosin, starch, &c. To remove the rosin it would be necessary to treat the dried residue in a fat-extraction apparatus with boiling absolute alcohol. On redrying the residue, the diminution in weight represents rosin. Treat with weak acid and again weigh; the starch is now removed. If the mineral contained in the suspended residue is "pearl hardening," the acid will dissolve the mineral matter; if it is clay, it will be left behind with the cellulose. Now filter the solution back into the original filter-paper, wash thoroughly free from acid with boiling water, dry, and weigh as before. The residue now contains the fibre, less rosin, starch, and pearl hardening, but contains the clay if any is present. Ignite the residue, deduct the weight of the ash; the difference represents the weight of the fibrous material. The alumina is precipitated by adding hydrochloric acid and then ammonia to the original back-water as above described. It is readily seen that it would not do to determinate the sulphate of alumina by estimating the amount of sulphate present, as sulphates are present in the back-water from other causes than alum or sulphate of alumina. They may either be due to the permanent hardness of the water itself, or to the presence of pearl hardening in the solution. It is safest, therefore, unless we know that sulphates are not present in other forms, to find out the amount of sulphate of alumina by precipitating the alumina. A detailed analysis of the back-water can only be carried out by a skilled chemist.

THE MANUFACTURE OF "ART" PAPER.

Question 8 (Honours).

"To the Editor of Paper and Pulp.

"I am sure all the readers of your popular paper have been more than gratified at the excellent answers given by Mr. Beadle to the questions on papermaking, and, while realising all the difficulties in endeavouring to answer these questions in a concentrated form without going into details, there are numerous portions of his answers quite open to candid criticism. I intend taking into consideration in this contribution Question No. 8, Honours Grade, which is very interesting to one and all of us, and I think Mr. Beadle might have given us a little more of an up-to-date answer; in fact, regarding the latter part of the question, he is painfully at sea. This I will refer to later on. Question 8 comprises two distinct branches of the papermaking industry—papermaking, and the after-process of enamelling. In many cases both industries are combined in one factory, while in others the latter is a distinct concern altogether. In such cases it will be difficult to find a student who would have the opportunity of studying both processes, and very little chance of obtaining information from text-books. In setting a question like this, the examiners ought to have studied it out more carefully, as, to a certain extent, it shows ignorance of the practical details of a process. This also I will refer to later on. I intend making a lengthy contribution on this question, which may assist those who have not opportunities of studying both processes, confining myself solely to No. 8 Question.

"There are various processes for the treatment of esparto after boiling, but what I intend referring to is one quite adequate for the making of paper suitable for enamelling purposes. The quantity of Spanish esparto to be treated is 10 tons, and this we will treat in four boilings of 50 cwts. each.

"Willowing, commonly called Dusting.—The grass duster of to-day consists of a revolving conical drum fitted with spikes, covered with a casing of stout sheet-iron, made easily removable, and on the top, inside this casing, is a parallel bar fitted similarly with spikes. The bottom consists of a dust separator formed of wrought-iron rods or grids, finely pitched, to which is connected a dustpan capable of removing the dust and grit from the grasses. At the discharge end of the duster is a revolving rake, which delivers the grass to a link chain elevator and conveyor, discharging it right into the filling door of the boiler. The bales of esparto, sixteen to eighteen in number, are arranged alongside the duster, the bands are removed, and the sheaves are fed into the hopper, where they are disintegrated by the spikes of the revolving drum being brought in contact with the spikes in the stationary bar. To dust and fill a 50-cwt. boiling of grass in this manner does not occupy a period of more than 40 minutes.

" BOILING.—There are many forms of grass boilers, but it is a recognised fact that the most suitable boiler for the treatment of esparto is one of the Sinclair system. These boilers use less soda, and boil the esparto more regularly and quickly than any other stationary boiler now in use. The circulation is all that can be desired. On the top there is a douche chamber, the full diameter of the boiler, and the circulation is effected by conductors riveted to the inside shell of the boiler; underneath there is the necessary false bottom for draining liquors and washing waters. Taking such a boiler as Sinclair's, the steam pressure generally used is from 40 to 50 lbs., and the time in boiling varies from two to two and a half hours. In most esparto mills, lye made from recovered ash is used, making up the loss in recovery with 70 per cent. caustic, and, if profitable to make into lye, alkali (58 per cent.) is used. Mr. Beadle states in his answer 900 lbs. (60 per cent.). I infer from this that the lye may be made from 70 per cent. caustic, but that the quantities are expressed in terms of 60 per cent. With Sinclair's boiler very good results can be obtained by 13 per cent. of 70 per cent. caustic, or, say, on a boiling of 50 cwts.—735 lbs., or, taking a lye of 10° Twad. at the normal temperature containing 4·61 per cent., 70 per cent. caustic—3·18 per cent. Na_2O, we would have a volume equal to 1,595 gallons. If I were to use the esparto for a fine writing, I should add 7½ per cent. more; but as in our case little surface is required, the quantities I have stated are ample. Sufficient care must be taken that the volume of liquid in the boiler be such as to properly cover the grass; hot water is often added. After the requisite amount of caustic lye has been measured—this is generally done when filling operations are concluded, otherwise the grass will always have a tendency to have a hard top—the lid is closed down, and, the desired pressure having been attained, the boiling is continued for a period of from two to two and a half hours. The steam valve is now closed, and the steam remaining in the boiler is exhausted into a tank containing water, which, after the strong spent lye is drained from the grass, is used for scalding purposes. The filling lid is now removed, and the strong spent lye is drained to the storage tanks in connection with the recovery department. In many cases the lye is blown off with from 3 to 5 lbs. steam pressure on the boiler, but this is not advocated where the Chapman or Yar Yan evaporator is in use, owing to the finely divided fibre leaving the boiler along with the lye, which, if not carefully strained, finds a resting-place on the inside of the evaporating tubes, and materially affects the results. Hot water is now introduced into the boiler—sufficient to cover the grass—and the pulp scalded for fifteen minutes, forming the first weak liquor. This is drained to the evaporating plant, as is also a second weak liquor. Mr. Beadle mentions the washing of the grass by the subsequent return of weak liquors. This is all very well, so far as concentration of the volume of lye to be treated by the recovery plant goes, but it lowers the colour of your grass, and, where colour after bleaching is a dire necessity, then nothing beats clean water. It is just the same as trying to make clean white clothes with dirty washing water. I have tried both. Continual washing with cold water is the next operation, the boiler being filled with water, after which the drain-valve is partly opened, sufficient clean water being added to equal the volume discharged by the drain-cock, always maintaining as nearly as possible the same head of water in the boiler. One and a half hours are sufficient for washing purposes, and the grass is now allowed to drain and made ready for emptying. A period of from eight to nine hours has elapsed since we started the dusting; it may be done more quickly, but, to give everything its time, there is not much time lost in having a boiling of esparto ready in eight or nine hours; that is, provided outlets and draining pipes are capacious. Spanish grass treated in this manner is of bright yellow canary colour.

"BREAKING AND BLEACHING.—The boiled esparto emptied into boxes is transferred to the breaking and bleaching department, and may be treated by the Cornet system, but the process which most readily presents itself in our case is the ordinary Hollander, which acts the part of a breaker and poacher as well.

These may be of any capacity from 300 to 1,200 lbs. dry stock; the latter size I think is the most desirable. The breaker ought to be well dished in the casting, a well-filleted backfall, and low breast. The roll may only be fitted with paddles, but in many cases ordinary bars suffice. This style of breaker ought to be fitted with two drum washers made of mahogany, covered with hexagon brass backing, and covered with ordinary brass wirecloth of 66 to 72 mesh. The idea of the two washers is, one to remove the washing water, and the other the spent bleach. The grass is now introduced into the breaker and further washed with clean water for a period of twenty minutes; generally the spent bleach liquor is used along with the water, which assists in getting up the colour more quickly, after which the desired quantity of bleaching liquor is added. The density commonly used varies from 6° to 6½° Twad. at normal temperature, containing 1·94 per cent. of available chlorine, or 0·54 of bleaching powder, testing 36 per cent. of available chlorine. Taking one ton of esparto (unboiled weight) representing half a ton as near as possible boiled, which would be sufficient for one of these breakers, a very good colour will be obtained by the addition of 260 gallons in one and a half hours' time, the bleaching being assisted by the aid of heat; but this should never exceed 100° to 110° Fahr. The drum washer for removing the spent bleach is now let down on the stuff, and clean water is introduced and kept continuously running for forty minutes or so; the spent bleach is run into a tank, from which it is pumped back to the mill for further operations. Then the stuff is further washed until remaining traces of bleach have been removed, the other washer at the time being used. A little antichlor is now added, and the stuff let down into the presse-pâte chest, the bleaching and washing operations having occupied fully a period of four hours. You will find the colour of the stuff goes back, but it is a fine, natural-looking colour, slightly creamy in shade.

"PRESSE-PÂTE.—This is essentially the wet end of a paper machine, consisting of two stuff chests, three or four strainers of the diaphragm pattern, an auxiliary of the jog pattern, stuff and back-water pumps, two suction boxes, wire frame and its accessories, couch, and in many cases a pair of press rolls. Sand-traps are essential, as they prevent grit passing forward in the stuff. The strainer plates are wider in the cut than the plates used at the machine, usually from 4½ to 5 cut, Bertram or Watson's gauge. If proper care be taken in the washing of the stuff, little or no difficulty will be experienced with the presse-pâte wire, and in many cases these have lasted from nine to ten months. The stuff, or half-stuff as it is now called, is ready for the beater, and nothing can be better than the ordinary Hollander, with roll and plate made from good Swedish Bessemer—charcoal ingots. The formation of the beater ought to be the same as the breaker, well-dished sides and well-filleted backfall. Capacity not less than 600 lbs. dry stuff. Good speed is essential, and the roll should not travel less than 2,000 feet per minute, the distance being taken on the periphery on the cutting edge of the bar. Different substances require different beating; that is, the thinner the substance the longer treatment it ought to get, brushing the fibres well out, keeping them fair in length, at the same time making them wet enough so that they may carry the water well on the wire. Thicker substances require sharp treatment, and on no account ought the stuff to be allowed to sludge about the mill, making it wet and greasy at the machine, as the stuff is more likely to stick at the press roll. Always maintain a fair strength in the fibre, and there will be no fear of trouble afterwards. The sizing is most important, and on no account must the paper be soft. Very good results are obtained with the addition of 4½ to 5 per cent. sulphate of alumina and 2 per cent. rosin. The idea being not only to size fibre and loading together, but to put the paper in such a condition, that when the enamel is applied it will not lift when under the influence of the printer's blocks. In many cases, when the paper is not of the quality it should be, the enamel adheres to the blocks, and lifts it completely away, breaking the surface of the paper. The mineral added should be china clay, owing to its finishing property, and in a really good art paper should not exceed 18 to 20 per cent. on the weight of dry stock. Very little colour is added to the stuff in the beater, as generally the colour is matched in the enamelling; a little blue and red is added, with a view to brightening, but never to any excess. The stuff, after four hours' beating, which may be taken as an average, is let down to the machine chests, and is ready for making. It is passed over the sand-traps, through the strainers, both sets of press rolls, smoothers, but little calendering; a smooth surface is wanted, but no finish to speak of, as on the application of the enamel, and the brushing, the coating will run, causing streakiness. The paper on reels is now taken to the slitting and winding machine, where it is slit into widths suitable for the sizes ordered—if double crown, 30½ reels; double demy, 35½ reels, &c.; half an inch is always allowed, as the art paper is always trimmed before being baled up, owing to what is termed a thick edge. I do not know of any instances of paper leaving the cylinders of a paper machine and being transferred to a coating machine right off. First of all, the web would not always be of a suitable size for the coating machine. Secondly, the speed of the paper machine would not correspond with the speed of the coating machine. Thirdly, a high-class art paper is coated on two sides separately, not in one operation, which necessitates the reel being brought back and recoated on the underside. There are double-coating machines, but the speed and width of a paper machine makes it impossible to have such an operation carried out; and, lastly, it would be impossible to have a level coating, which is most necessary. The paper in reels is taken to the coating department and the enamelling applied.

"The coating machine consists of a cylinder or drum, varying from three to four feet in diameter, which acts as a support to the paper as well as a carrier when under the influence of the brushes. The colour-box is made of copper, and is arranged so that heat may be applied—in order to keep the colour always at the same temperature. The coating is applied to the paper by means of a vertically-running felt, which does not pass through the colour-box, but to which the colour is transferred by means of a copper roll running in the box, the amount of coating so transferred being regulated by the degree of pressure of the felt against a parallel roll between which the paper passes. The distribution of the coating is effected by means of five or seven brushes, the bristles being so selected in quality as to become softer and softer in succession. The brushes work with different motions, some being stationary, others moving to and fro sideways, the latter motion being supplied by cranks all fixed on one shaft and driven by belt. At the end of the coating-machine is generally fixed a pneumatic suction-table, on to which the now coated paper passes. This table acts as a drawer, and prevents the paper slipping on the drum, after which it passes on to the drying apparatus. This apparatus consists of a system of endless chains, on which are carried sticks, the paper hanging from these sticks in loop form, and is subjected to a temperature varying from 80° to 90° Fahr. If the drying-room is not long enough this apparatus is fitted with a turntable, which takes the sticks, describes with them a semi-circle, puts them in turn on to returning chains, and finally delivers them into a self-taking and removing apparatus, the coated paper passing on the reeling-machine. After the reel is of sufficient size it is taken off, and, in the case of a high-class 'art,' is recoated on the opposite side. As a rule, part of the day is devoted to coating one side, and the rest the opposite side. The coating or enamel consists of a mixture of satin white, blanc fine, enamel or china clay, used in various proportions according to the desired finish. Gelatine is added to the mixture to size, in order to prevent the coat from lifting when printed. The speed of coating varies according to the width of reel coated, but an average may be taken at 80 to 120 feet, and in some cases at the speed of 140 feet. As to the amount of coating applied, it is just here that Mr. Beadle and the examiners have gone wrong. It is impossible to state the gain per cent., as it may be anything. Surface colour is applied so many pounds for so many square inches, but it is impossible to take 5 tons of paper, coat it, and then state what the added weight to the finished paper would be per cent. We will take two examples for demonstration. We have 5 tons of body paper, and have two orders to execute. The size of the sheet to be demy, 18 × 23 (art size). In the first case the substance of the ream is 20 lbs. before coating, and 5,600 lbs. of paper is allotted for this order. In the other case the size of the sheet is the same, but the substance of the ream is 60 lbs. before coating, 5,600 lbs. of paper being also allotted for this order. What is the percentage of added weight to the finished paper? We will increase the weight of these substances by the addition of 10 lbs. of enamel per ream of demy, that is, the 20 lbs. will become 30 lbs. and the 60 lbs. 70 lbs. after coating. 5,600 lbs. will represent in reams of 20 lbs. demy, 280. To each ream is added 10 lbs., that is, on 280 we have added 2,800 lbs. of coating, the total weight of body paper plus enamel being 5,600 + 2,800 = 8,400 lbs. finished weight, or that the weight of the paper has been increased by 50 per cent.

"Take the other substance: 5,600 lbs. will represent in reams of 60 lbs. demy, $93\frac{1}{3}$. To each ream is added 10 lbs., that is, on $93\frac{1}{3}$ reams we have added 933 lbs. of coating, the total weight of body paper and enamel being 5,600 + 933 = 6,533, or that the weight of the paper has been increased by 16·6 per cent. In these instances I have disregarded broke for the sake of calculation. From what I have said you will notice it would be impossible for a student to give a direct answer to the latter part of the question, as his gain might be anything. 'Five tons of paper' is not enough for that question; you must have other data to go on. If the examiners had put it: Five tons of paper, representing so many reams in double-crown or royal, etc., substance before coating being given, what would the added weight be to the finished paper per cent.? then there would be some sense in it, but there is none in its present form. The paper after coating is transferred to the calender-room, where it is glazed. The most modern calender consists of eight rolls of papier-maché and chilled iron arranged alternately. As a rule, where an extra high finish is wanted, the coated paper is rolled twice, first the under side and then the top side. Prominence of the wire-mark on the under side must be avoided, as it leads to bad printing. To obviate this, additional coating is always applied to the under side, and extra calendering is often required. After cutting into the desired size, the paper is transferred to the overhauling room, where in the hands of expert sorters all defects are removed. The most common faults to be found in coated papers are faulty and miscoloured sheets and creases from calenders, which are considered everyday occurrences. Pieces of hard enamel which adhere to the surface of the paper are the most serious objection. When any undue pressure is used in printing with process-blocks so that the prints may be clear, these hard lumps have often a tendency to destroy or make faulty the block. After sorting and finishing, the reams are taken to the guillotine, where the ripped edge is trimmed. This is done to remove the hard edge, which consists of enamel, and which is obtained from the drum while the paper is in process of coating. The paper after trimming is tied up and ready for despatching. Taking 10 tons of good Spanish esparto, and following the different processes as I have described them, I should expect at least the following result: 10 tons esparto—equal to 22,400 lbs.—with the addition of 5,000–5,600 lbs. of china clay, ought to produce 14,800 lbs. of paper. The percentage loss at the ripper would be about $3\frac{1}{2}$ per cent., and, as near as possible, the amount of paper sent to the coating-room would be 6 tons. To ascertain the percentage gain by coating, we must assume a size and weight before coating, then calculate the added weight to the body-paper. To show really what the finished weight would be, we will take it in two substances and weights—say, quad crown, 30×40, and royal, 20×25. Taking the quad crown first, and assuming the uncoated weight to be 60 lbs. per ream, 6 tons of body-paper would represent 224 reams, to which we apply 30 lbs. of enamel per ream. This would make the weight added 6,720 lbs., and 13,440 lbs. + 6,720 = 20,169 lbs. finished weight after coating, or equal to a gain of 50 per cent. Taking a royal art board 20×25, substance of 80 lbs. a ream before coating: in the 6 tons of paper we would have 138 reams, and the weight added per ream is $12\frac{1}{2}$ lbs. On 138 reams we would add 1,725 lbs., making the total weight finished 15,156 lbs., equal to a gain of 28 per cent. Now, if you look into both results you will find that the finished weight from the 10 tons of esparto in the quad crown example would be 9 tons, while in the royal it would only be 6 tons 16 cwt.

"With regard to tinted enamels, the body-paper is white, the tinting is added to the colouring.

"As to soda recovery, I reckon it would take a most up-to-date plant to recover 90 per cent. As far as I know, 75 per cent. seems to be about the highest point attainable, and if 90 per cent. is recovered, the extra cost in evaporation and manipulation of the lyes will not be covered by the extra percentage gained.

"I trust I have made the contribution interesting, but I only write this with the view of showing how mistakes can be made in putting such a question.

"A Reader."

SOME CRITICISMS.

C. F. Cross.

"I have read with a good deal of interest your issue of October 1, 1901, and consider that Mr. Beadle has done a very difficult piece of work with his usual thoroughness. The only misstatement of fact which I have noticed is on page 694, in dealing with the precipitation of the organic or sulphonated derivatives from wood liquor. Mr. Beadle does not seem to be familiar with C. D. Ekman's work on 'Dextrone.' I think the treatment of the questions is excellent, and there is no doubt your paper has done good service in getting Mr. Beadle to take on this novel office."

George Clapperton.

"I think the Ordinary Grade has been very well handled indeed."

Richard Barton.

"I am pleased to see Mr. Clayton Beadle has taken this up, and I feel confident good will come of it. I have also to thank you for the help to, and interest you have taken in, the Technical Classes."

Workmen.

"Pleased to see your announcement *re* special articles on examination questions by Mr. Beadle. It speaks well for the progressive and enterprising character of your journal.

"Paper Mill Worker,
"Bolton."

"Allow me, on behalf of self and friends, to congratulate you on your idea for having the recent examination questions answered by such a well-known technical and practical expert as Mr. Clayton Beadle. The questions have been carefully drawn up, and the answers will be of great value to manufacturers, managers, students, and also teachers.

"Walter T.,
"Lancashire."

"Your valuable journal seems intent to fill up the position of a real technical and practical journal for the trade by the proposed new features of articles by Mr. C. Beadle on the questions set at the recent examinations in papermaking. These will be of great assistance to students and teachers, as well as to the members of the trade in general. Wishing your paper every success in your new departure.

"Student,
"Derbyshire."

"I notice that in the last issue of your journal you are publishing the questions set at the last papermakers' examination, and answered by Mr. Clayton Beadle. I am very pleased indeed to see that you have taken a step in that direction, and one which I believe will be welcomed by many such young fellows as myself in the trade.

"Bury."

Question 7.

"I should like to offer a few remarks on Mr. Beadle's furnishes for some of the papers mentioned in Question 7.

"(3) With regard to filter-papers for quantitative chemical work, he gives the furnish as all cotton. I had always understood that the best of these papers were made from all or nearly all linen rag, and I know of a mill in Sweden who make one of the finest filter-papers, and they use nothing but linen.

"(5) Litho and fine printings. Would not esparto give a better litho paper than soda wood? Soda wood will certainly make up into a good printing paper, but it does not equal esparto.

"(6) Cartridges. This class of paper is a very large one, and may mean a paper from 2½*d.* to 5*d.* per lb. Some are made all wood, and I have made some all bagging, and again have made them all good, clean, mixed, old, and new rag, but the furnish given can hardly be called a representative one, and it seems very peculiar to load a paper up to 20 per cent. after using such a remarkably good furnish. By unbleached cotton and unbleached linen, does Mr. Beadle mean a new unbleached rag, or an old rag which is to be used without being bleached?

Questions 8, 9, and 11.

"Question 8, Ordinary.—I notice that Mr. Beadle gives the furnish for news as containing 10 per cent. of clay. I have burnt several samples and cannot find this amount of clay, and I have never heard of more than 3 to 5 per cent. being put in, and always thought the general practice was not to put in any loading at all. Would a paper containing 75 per cent. mechanical stand 10 per cent. loading?

"QUESTION 9.—Has Mr. Beadle stated this sum correctly? Worked out as it is printed the answer does not agree. Should it not be as under?

$$7 \times 10 \times \frac{1000 + (11 \times 5)}{1000} =$$

"QUESTION 11.—Is Mr. Beadle serious in saying that the oil from animal-size making is used for manure? It fetches a good price, and if kept clean is often sold for over £20 per ton.

"SUPERFINE."

CHINA CLAY IN NEWSPAPERS.

"In common with several others I have evidently misunderstood Mr. Beadle. I understood that the 10 per cent. loading referred to the amount in the finished paper, but he meant it as 10 per cent. added to the engine, which makes a considerable difference. His figures giving the ash in different papers are very interesting, but only ten out of the fifteen samples carried over 5½ per cent., and the average of the ten lowest is only 4 per cent.

"On Mr. Beadle's figures the average of 5·7 per cent. ash required 9·7 per cent. of clay added to the engine, which is a retention of only 59 per cent. It is a well-known fact that the larger the amount of loading added, the smaller is the percentage of the quantity retained in the paper, and yet Mr. Beadle says that 14 per cent. clay added to the engine would carry 10 per cent. of ash. I should think that it would be necessary to add something like 30 per cent. to the engine to carry 10 per cent. ash. I did not dispute that a newspaper might carry 10 per cent. ash, but that a paper containing 75 per cent. mechanical and only 15 per cent. chemical wood would carry 10 per cent., and this I still can hardly understand. Perhaps some of your readers who make common news can say.

"SUPERFINE."

X.

CITY AND GUILDS OF LONDON INSTITUTE EXAMINATION ON PAPER MANUFACTURE.

ANSWERS TO THE 1902 QUESTIONS.

WHEN first reading through the questions set by the examiners I was appalled at the large amount of ground which these questions covered. To many of the questions I found it extremely difficult to give anything like adequate answers—in fact, it would not be possible to give an answer to some of them which would not be open to considerable criticism. On first looking through the questions, and making an attempt to answer them, I was on the point of giving the work up in despair. I fear I should have been compelled to do so if it had not been for the generous assistance which was accorded me. It is one thing to set a question, and another to answer it in a satisfactory manner, especially to those who are familiar with the subject. In many instances I feel the weaknesses of my answers, but I should be gratified if those who take the trouble to read them, and have special knowledge of the subject, would communicate their remarks to the columns of PAPER AND PULP. Any criticisms of this sort would undoubtedly be instructive to the readers of this Journal.

The plan adopted is as far as possible the same as last year, of first of all giving an answer to a question, and then making remarks on the same. It would be difficult to give a full answer to many of the questions. An endeavour has been made to give a fair amount of information in answer to each question without going too fully into details, except in one or two instances where the nature of the question appears to call for more detailed description. I have to express my indebtedness to certain gentlemen who have so generously given me the benefit of their knowledge and experience in answer to certain questions. Some of these I will take the opportunity of acknowledging in due course as the answers are published.

I take this opportunity of thanking Mr. George Clapperton for the assistance he has rendered me on many practical points.

ORDINARY GRADE.

1902.

QUESTION 1.—*In boiling rags with caustic soda, what are the principles which regulate the conditions of treatment, viz. chiefly, Proportion of soda and of total liquor to rags, temperature and time of boiling? What information as to progress of the treatment is furnished by analysis of liquors.* (30 *marks.*)

ANSWER 1.—The treatment of rags is almost universally looked upon, not only by the manufacturer, but also by the chemist responsible for their chemical treatment, as being entirely of an empirical order. Manufacturers do not regard such a material as rags as being amenable to any scientific treatment, although the manufacture of sulphite and soda wood pulp is carried out in the most systematic and scientific manner.

The conditions under which rags are now treated in the best mills have been arrived at after many years of observation. As good, if not better, results might have been arrived at after as many months almost by pursuing a scientific method of investigation. In the ordinary method of procedure, rags of a given quality are dumped into a boiler with what is considered sufficient soda liquor, and after a certain number of hours' treatment under steam pressure, the rags are washed and removed. If the result is considered good enough the conditions are repeated, but if the result is in any way unsatisfactory, one or other of the conditions is varied. It takes years by this plan of procedure to arrive at a point where no further improvement can be noticed.

The following is a practical and rapid procedure for arriving at the best conditions for boiling rags with soda which can be carried out by any ordinary working chemist: One quality of rag is taken for investigation. The rags are filled into the boiler with a known quantity of soda. The capacity of boiler, the weight of rags, and the volume of liquor are noted. The charge should be as much as the boiler will take when "trodden in" after the liquor is added. The liquor should be just sufficient to ensure complete saturation of rags, but no more. The time of bringing boiler to full pressure is noted. Samples of liquor are withdrawn every hour, and tested for "free" soda, and the boiling is continued until the free soda remains practically constant. The total soda is determined in the first and last sample, and in the case of a boiler heated with a steam-coil, the total soda should remain constant throughout the boiling. When the rags are washed and removed from the boiler a sample is kept for comparison.

A second boiling is conducted on the same lines, but using soda only slightly in excess of that found to be consumed in the first trial. The boiling is continued until the free soda remains constant. The boiled rags should then be compared with the first trial, and the result should be practically the same. In order to ascertain the loss during treatment, 10 lbs. of rags, which must be so selected as to represent absolutely the bulk, are tied up in a loose bag made of coarse cheese-cloth. This bag is reclaimed after the boiling, and the contents of the bag are bone-dried, exposed to the air to air-dry, and weighed. From this the loss during boiling is calculated.

The examination of liquors taken during the boiling, to avoid unnecessary calculation and work, are treated as follows: The liquor from each hour is placed in a marked bottle. The bottles are fitted into rough wooden boxes resembling cruet-stands, with leather straps for handles, which can easily be transported. Each box contains a series of bottles sufficient for a boiling. By this means samples from half a dozen boilings can be transported from boiler-house to laboratory by the chemist in one journey. From each sample 32 c.c. is withdrawn by means of a pipette made to measure this quantity. This is titrated with normal sulphuric acid until it no longer shows alkalinity, when a drop is placed on a perfectly neutral non-absorbent litmus paper. On account of the colour of liquor no indicator can be used in solution. For determination of total soda, 32 c.c. is evaporated down in a platinum dish, ignited, and the charred mass wetted with water and again ignited. The soda can then be dissolved out with water, and titrated without filtration in presence of methyl-orange. The readings on pipette give the percentage of Na_2O by dividing by 10. This method of determining the free and total soda has been checked by evaporating a quantity of the liquor to a solid mass, and examining for "free" soda by the method of "salting out." The two methods give almost identical results—

Dilute liquor tested as above, 28·5 per cent. of total soda "free."

Concentrated and "salted out," 26·9 per cent. of total soda "free."

When once the conditions of boiling are fully established, check tests can be done from time to time in a more simple manner, as follows: A portion of the first and last sample is mixed in equal volumes, from which 32 c.c. is withdrawn, and total soda determined. Such quantity of each sample is then drawn off as to give reading on burette which, when divided by ten, represents percentage of "free" on "total" soda, without further calculation. The results are finally expressed in percentage of "free" soda on "total" soda. By examination of these figures the exact behaviour during boiling can be ascertained. I have found, moreover, that still further can be learned by plotting curves showing the diminution of "free" soda per hour during boiling, expressed as percentage on total "soda" present. The table shows the conditions arrived at after pursuing the mode of procedure above indicated. It must be remembered that no two mills have the same requirements, and there is no regular plan of procedure common to them all or to the majority of them. Furthermore, the different grades of rags in one mill are not comparable with those in another. The table cannot, therefore, be used as a guide for general practice, but merely as showing the mode of expressing the different factors of boiling, and by comparing them with curves constructed as above indicated an idea can be arrived at as to how the conditions influence the rate of absorption of soda. Curve No. 1 should show the absorption of soda per hour of different qualities of rags when treated under the conditions as shown in table. A dotted curve should be constructed from the mean of these. Curve No. 2 should show the absorption of soda per hour of No. 3 Linens when the conditions are varied as shown in table. A dotted curve constructed as the mean of No. 2 series is extremely regular, and gives a good idea as to how the rate of absorption of "free" soda should progress under favourable circumstances. Broad conclusions can be arrived at from a mean of all the curves which should hold good in a measure for all classes of rag-boiling. About one-half the total soda is neutralised at the end of the first hour, and after the third or fourth hour the chemical treatment has practically come to an end. Any further treatment is not only wasteful and unnecessary but harmful, as the rags go bad in colour. Many papermakers are, however, treating for twelve to twenty hours, as they have no means of telling when the action is at an end. The amount of soda used also is merely a matter of guesswork.

Some such system as I have outlined above should, I venture to think, be introduced into every paper mill where rag treatment is carried on on an extensive scale.

REMARKS.—The foregoing is abstracted from a contribution to the CHEMICAL NEWS of November 29, 1901. It appeared best to give this in most of its detail as it is a fairly complete answer to the question. Of course, the conditions vary in different mills, and would depend upon the class of boiler used as well as the pressure available, and the quality of paper to be produced; but I venture to think that the general principle holds good in all paper mills. The table referred to in the above answer is not here reproduced, but it can be read in the original paper. The various curves plotted from these tables were not published in the original paper, but were afterwards published in the PAPERMAKER.

QUESTION 2.—*What are the characteristics most desirable in papers for* (1) *photograph mounts*, (2) *typewriting*, (3) *ledgers*, (4) *school books* (*illustrated in colours*)? *Give the furnish you consider most suitable, and state the precautions you would adopt to secure the best results.* (25.)

ANSWER 2.—(1) The photo mounts must be free from any trace of antichlor, or any chemical which would tend to spot the photos, and its ideal furnish would be all soft clean cottons beaten very fine, and prepared by boiling with only a small percentage of soda, and taking all known precautions to ensure that all traces of antichlor are washed out; indeed, when colour admits, there should be little or no bleach or antichlor used.

(2) Typewriting papers. 30 per cent. bleached sulphite and 70 per cent. strong linens make a good paper if well beaten and passed through a refiner, which has the effect of making the wood and linen blend, and removing all trace of a woody appearance. Some of the Yankee papers are mostly sulphite, but they must cost a lot to produce, as they are so well milled.

(3) Ledgers. For the best qualities 25 per cent. linen, 75 per cent. cottons, coloured with Smalt's blue. In addition to the usual engine size and tub-sizing, they should be sized again through the hand sizer and air dried. The principal requirements are fast colour, cleanliness, strong well-milled look—but not so greasy as to cause the ink to flood, and good erasure properties.

(4) School books. Say 25 per cent. bleached sulphite, 75 per cent. esparto. Well beaten but long stuff, and not too hard sized, as they are wanted to print nicely, and when the pictures are printed in colours about 20 per cent. china clay, so as to absorb the oils and prevent them appearing on the other side of the sheet.

NOTE.—This answer is answered as briefly as possible, and appears to call for a brief statement of a student's experience or knowledge.

QUESTION 3.—*What instruments are used in the mill to measure* (1) *temperature,* (2) *proportion of moisture in the air,* (3) *specific gravity,* (4) *weight and thickness of papers? State briefly what you know of the uses of such measurements.* (30.)

ANSWER 3.—(1) The mercurial thermometer, either Fahrenheit or Centigrade, is almost universally used for measuring temperature. There is also a spirit thermometer in which absolute alcohol takes the place of mercury; this can be used for lower temperatures. For the purposes of registering the maximum and minimum temperatures there is what is known as a Maximum and Minimum thermometer, the maximum temperature being registered by means of a small pin or index resting loosely in the tube, in what is known as the torricellian vacuum. This index is pushed along by the surface of the mercury as it expands, and when the mercury recedes after recording the maximum, the index remains at the maximum point, and the maximum temperature can be read off at any time. After taking the reading the index is either drawn back to the surface of the mercury by means of a magnet or shaken down. The minimum thermometer contains spirit, coloured red, in which the index is immersed. As the spirit contracts, the index is drawn along the tube and remains at the lowest point reached by the spirit, from which the minimum temperature can be read off. The index is drawn to the surface of the spirit by means of a magnet.

There is an instrument made by Waltham Watch Company resembling a barometer, the hand moving along the dial and indicating the temperature, which is marked on the dial. The movement, I believe, is due to the uneven expansion of the two dissimilar metals. But this instrument is little used in this country, and liable to get out of order; furthermore it cannot be used for immersion in a liquid.

There are instruments now constructed which give an electric register of the temperature. By laying wires from where instruments are situated to any common centre, a record can be kept of the temperature of the drying-rooms and various departments where a record of the temperature is considered necessary. I am acquainted with a very ingenious American machine for this purpose, originally designed, I believe, for recording the temperature of the ocean at different depths.

(2) The proportion of moisture in the air is generally recorded

by what is known as a wet and dry bulb thermometer. The dry bulb registers the actual temperature of the air and the wet bulb a lower temperature, which is lower in proportion to the dryness of the atmosphere, due to the evaporation on the surface of the bulb.

By taking readings of the dry and wet bulbs, and referring to Glaisher's tables, it is possible to arrive at the percentage saturation of the atmosphere at any time, as well as the amount of moisture contained in a cubic foot of the air, &c. Wurster's hygrometer gives the percentage saturation of the air for any ordinary temperature. This is indicated on the dial by means of a fine pointer. The pointer is connected by means of a human hair, which expands and contracts in accordance with the condition of the atmosphere. I have taken readings of this instrument against a standard wet and dry thermometer (for which I hold a Kew certificate), using Glaisher's tables for reference, and have found Wurster's hygrometer to agree within 1 or 2 per cent. of the actual readings obtained by means of this most delicate instrument. From such readings the dew point can be calculated, and also the actual amount of moisture in a cubic foot of air, &c.

(3) The specific gravity is roughly determined by means of the Twaddle hydrometer, the degrees of which are marked on the stem. In some mills the Baumé hydrometer is used. This is on the same principle as the foregoing, but the degrees have a different value, and it is constructed to be used for liquids either heavier or lighter than water. There are other instruments on the same principle, but marked in actual specific gravity. The specific gravity is sometimes determined by means of a small bottle of a known capacity, in which the liquid to be tested is weighed. This is known as the specific gravity bottle. An instrument of the same class, but in the form of a U tube, is known as the Sprengel tube, and is extremely accurate. For most purposes the Twaddle hydrometer is accurate enough in the mill.

(4) The only instrument that I know of for determining the thickness of papers is a micrometer gauge. This is usually constructed in the form of a clamp, and is either divided into 1000th of an inch or the 100th of a mm. With this, any sheet of paper, however thin, can be measured with a great degree of accuracy, especially if ten sheets are taken at a time and the recorded measurement divided by ten. This may be found advisable with very thin papers. There is another form of this

instrument which gives the reading of thickness on a dial. This may be found more convenient when the thickness of paper is repeatedly taken.

USES.—(1) The thermometer is a most useful instrument throughout the mill, and is not used to the extent it might be. I would mention a few instances where it should be used incessantly: For taking the temperature when making up milk of rosin size; temperature of warm bleach, when the warm bleach process is resorted to; temperature of stuff when it flows into the machine; temperature in the sizing-trough and drying-room; and in steam boiler-house for temperature of feed-water in and out of economisers.

(2) The moisture in the air might with advantage be recorded in the machine-house close to the drying cylinders; in the drying-room of machine loft-dried papers; in *salle* or stores where paper is stored. The advantages of such records are obvious, but space will not permit me to go into them further.

(3) Specific gravity must, in all cases, be recorded where aqueous solutions of chemicals are measured, as the quantity of a chemical substance depends not only upon the weight or volume taken, but also upon the strength as recorded by the hydrometer. In such cases also, the record of the temperature should be taken, or rather the liquid should only be measured at the temperature at which the hydrometer is constructed to be read.

The strength or percentage of most chemical liquids as used in the paper mill can be arrived at by taking the degree Twaddle, and referring to published tables, such as those given in Bayley's "Chemist's Pocket Book."

The measurement of the thickness of paper of a given weight per ream gives a direct indication of its bulking properties. If the bulk is great, the measurements in comparison with weight will necessarily be great, and *vice versâ*. An instrument for this purpose will also be useful for indicating the extent to which the paper is reduced during calendering.

REMARKS.—Notice the difference between hydrometer and hygrometer. The former is an instrument to measure the density of a liquid, and the latter is an instrument for measuring the moisture saturation of the atmosphere. For full description, see "Ganot's Physics." The question of measuring by means of a micrometer, and inferences to be drawn from such measurements, have been so fully discussed in the columns of PAPER AND PULP that I do not think it necessary to give any further particulars.

QUESTION 5.—*In boiling Spanish esparto how much caustic soda would you use per ton of grass, and at what dilution? State* *the latter as percentage ($NaOH$) on the liquor, and from this the (approximate) number of gallons per ton. At the conclusion of the boiling, how would you estimate the addition to volume of liquor due to condensation of steam?* (20.)

ANSWER 5.—I would suggest the use of 18 lbs. of 60 per cent. caustic soda per cwt. = 18 × 20 = 360 lbs. per ton. I should take the liquor at 0·509 lb. of 60 per cent. caustic per gallon of lye, as given by Beveridge. Since $NaOH$ is approximately equal to 78 per cent. caustic, the above strength would be equivalent in $NaOH$ to $\frac{0·509 \times 60}{78} = 0·39\ 1$ lb. $NaOH$ per gallon. The *approximate* number of gallons per ton can be calculated from the amount of 60 per cent. caustic per ton (= 360 lbs.), and the dilution in lbs. of 60 per cent. caustic per gallon (= 0·509)—

$$\frac{360 \times 1}{0·509} = 707 \text{ gallons per ton of esparto.}$$

An approximate figure of gain in volume of liquor, due to condensation of steam, can be arrived at by carefully determining the *total* soda, both before and at the conclusion of boil. Supposing, merely for the sake of argument, the liquor showed 4·00 per cent. $NaOH$ before, and 3·15 per cent. at finish, it would indicate that each 100 lbs. of original liquor had become $\frac{100 \times 4·00}{3·15} = 127$, or had gained in volume to the extent of, approximately, 27 per cent. If the total volume of liquor at start was $\frac{707 \times 50}{20} = 1767$ gallons, the increase in volume per boiler due to condensation would be, approximately—

$$\frac{1767 \times 27}{100} = 477 \text{ gallons.}$$

The above figures may be nowhere near what is found in practice, they are merely given by way of illustrating the mode of calculating.

REMARKS.—Ask yourself the question, How many gallons will be required for 360 lbs. of "60 per cent. caustic" when 1 gallon contains 0·509 lb.? I presume the foregoing is the kind of thing desired in answer to this question, although it appears to be a process of working backwards. It seems that one would naturally know the volume in gallons per ton of the liquor. I can understand the reason for asking the caustic soda per ton of grass, but the dilution would, I should think, be arrived at after the number of gallons is known. The dilution would, in the ordinary course of events, be derived from the total volume, and not the total volume from the dilution.

Of course there is one thing that might be done which, perhaps, the examiners have in mind. Suppose you know the caustic per ton, the weight of esparto, and you add, say, an unknown quantity of water in dissolving up your soda, you might calculate the weight of water after analysing the wash liquors per ton of soda. But it is quite possible that in giving the above answer I have not caught on with what the examiners have in view in asking this question.

I have assumed that figures as given in Beveridge's "Pocket Book," page 56, are correct, and I think I am justified in assuming that this is a reasonable figure, and is borne out in practice.

Notice that it is stated that the figures are approximate only. It would be next to impossible to arrive at the absolute figure without an elaborate process of chemical analysis. The figures are near enough for all practical purposes, and perhaps more instructive than if a more elaborate and accurate description had been given.

In estimating addition to volume due to steam condensation, it is necessary to take the liquor and boiled stuff *en masse* to get absolutely accurate results. It must be borne in mind that fibres condense soda from solution (pure cellulose has this effect with many salts in solution, as also with acids). Take a quantity of boiled stuff with liquor *en masse* as it is blown out of the esparto boiler under pressure, carefully take the weight, wash all liquor out with boiling water until fibre is no longer alkaline, mix all washings with liquor, take weight, and carefully determine total soda in same. The percentage on total volume of washings gives you the weight of soda in sample taken from boiler. But to get at the percentage of soda contained in the liquor at the time of boiling, you must dry off the washed fibre, weigh, and deduct weight of same from weight of original sample before you can calculate the percentage from the weight found in washings. This mode of procedure sounds complicated, but some such method is needed to ensure anything like accuracy.

An approximate figure is got by the method explained in the above answer; this, I presume, is what the examiners intended.

For the conversion of 60 per cent. soda to NaOH, I have taken the ratio of 60 to 78 as being near enough to the real figure. As a matter of fact, it is not possible to arrive at the exact equivalent by calculation. I should advise all young chemists to read carefully Cross & Bevan's paper on "The Economy of Pure Caustic Soda," SOCIETY OF CHEMICAL INDUSTRY JOURNAL, April 30, 1899. The author shows that 60 per cent. caustic, by reason of the retarding influence of its impurities, has not the same value for boiling *pro rata* with 77–78 per cent. caustic, which is practically pure NaOH, as furthermore they show that the ordinary method of titrating "60 per cent." soda solution gives erroneous results.

QUESTION 6.—*What style of damper do you consider most suitable for damping* (1) *super-calendered printings*, (2) *imitation parchments*, (3) *glazed casings*, (4) *soft-sized friction-glazed printings? Give practical details to be observed in damping each of the papers named.* (20.)

ANSWER 6.—Milne's Patent Damper appears to be the best for fine papers, and the spray blown from the meshes of the wire which trails through the water-box is beautifully fine and regular for imitation parchments. For glazed casings, any of the ordinary types of brush damper are good. The best results are obtained by damping the paper after it has been cooled. Milne's Patent Damper possesses the following features, which are necessary in any first-class damper :—

1. Perfect regularity and uniformity in the quantity of water applied.
2. Very fine subdivision of the particles of water.
3. Great range of the quantity that can be applied.
4. Easy and perfect adjustment of the quantity to suit the various papers, so that a repeat order can be damped correctly without doubt or trouble.

In arrangement this machine consists of a wire cloth mounted on copper rolls. One of these rolls is jacketed and runs in a trough of water, and imparts the water to the wire cloth. The wire carries the water forward to the blast pipe, the air from which discharges it on to the paper below.

The quantity of water is regulated by the speed of the wire cloth, and cone gearing is arranged for this purpose. It is usual to run the wire cloth from 25 to 75 feet per minute, as it meets all ordinary requirements. Messrs. Bertrams, Limited, made a test with one machine to ascertain the quantity of water discharged, which gave the following results with a wire 50 mesh, 84 inches wide : When running at $17\frac{1}{2}$ feet per minute, 1·3 lb.

of water per minute were discharged; and when at 59 feet per minute, 10 lbs. of water were discharged per minute.

The first machines were fitted with 60-mesh wire cloth, but the spray was found to be so fine that it has been found advisable to increase the mesh gradually to 40 and 35. The wider the mesh the larger the quantity of water.

It will be seen that absolute uniformity is ensured by the wire cloth being filled by the jacketed roll and emptied by the blast pipe. The subdivision is very fine, as in each inch of width of wire there are 40 or more drops, each of which is broken up by the air blast into many more. The higher the blast pressure the greater the pulverisation.

It is not an easy matter to give any opinion as to the requirements of the various kinds of paper, or the various methods of damping, but uniformity is necessary if the best results are to be obtained, and in this particular Milne's Patent Damper gives excellent results. They have been successfully applied to damping fine papers at 250 feet per minute, which, however, is an unnecessary speed, as the damper does not require to run quicker than the calender. Dampers of this style are running on the finest papers.

It appears evident that this machine would give good results in mottling paper if colour were used instead of water, but Messrs. Bertrams, Limited, inform me that they have not yet had an opportunity of trying this.

For most of the foregoing information I am indebted to Messrs. Bertrams, Limited, of Edinburgh.

The "spray box" of Paul Lechler appears to give excellent results at high pressures of water for the purpose of damping, and is remarkably simple in construction. It will be referred to in connection with another answer, where a description of its working will be given.

QUESTION 7.—*State what you know of the composition of bleaching powder and the bleaching action of the hypochlorites. How would you carry out the bleaching of half-stuff so as to provide for an intermediate washing of the pulp? What are the advantages of so doing?* (25.)

ANSWER 7.—Chloride of lime or bleaching powder. This well-known body was originally considered to be a compound of chlorine and lime. Balard, in 1834, was the first to give an explanation of the constitution of this compound, and his explanation has from that time been generally adopted. According to this view, bleaching powder is a mixture of calcium hypochlorite and calcium chloride, $Ca(OCl_2) + CaCl_2$. Another view of the constitution of bleaching powder has been taken by Odling. He looks upon this substance as a kind of double salt, $Ca\begin{cases} Cl \\ OCl \end{cases}$, being at the same time a chloride and a hypochlorite.

Chloride of lime is obtained by the action of chlorine gas upon dry slaked lime. When chlorine is passed into milk of lime, a reaction which is analogous to the formation of Eau de Javelle takes place.

$$2Ca(OH_2) + 2Cl_2 = CaCl_2 + Ca(OCl_2) + 2H_2O$$

If, however, dry slaked lime be employed, a large proportion of the lime remains unaltered. This fact was formerly explained by the supposition that the calcium chloride produced forms a coating round the particles of lime which prevents the further action of the chlorine. But even if the mixture be from time to time well rubbed down in a mortar, and then again treated with chlorine, it is not possible to obtain a material containing more than 40 per cent. of available chlorine. Hence this substance would appear to be a mixture of basic salt with chloride of calcium, according to the formula.

$$3Ca(OH)_2 + 2Cl_2 = 2Ca\begin{cases} OH \\ OCl \end{cases} + CaCl_2 + 2H_2O$$

If water be added to this product the soluble chloride dissolves and the basic hypochlorite decomposes as follows :—

$$2Ca\begin{cases} OCl \\ OH \end{cases} = Ca\begin{cases} OH \\ OH \end{cases} + Ca\begin{cases} OCl \\ OCl \end{cases}$$

In practice it is found that 11 cwt. of caustic lime are required to form one ton of bleaching powder. In the preliminary slaking and dressing of the lime, probably 1½ cwt. is lost. The lime ready for use contains about 25 per cent. of water and 1·2 per cent. of carbon dioxide, so that 20 cwt. of bleaching powder would be made up as follows :—

	Cwt.
Lime...	9·5
Water, 25 per cent. on the 100 of hydrated lime...	3·2
Chlorine, 35 per cent. on the finished bleaching powder—say	7·3
Bleaching powder ...	20·0

The intermediate washing can be done as follows: The simplest way is to exhaust from 8 to 10 per cent. bleach on the pulp, then add about 1 per cent. carbonate of soda and that run down on the presse-pâte. This gives a beautiful cleanse, and a mere touch of bleach afterwards is usually sufficient to bring it up clear. The drum washer scheme is, of course, available.

I am informed that Messrs. Sommerville have a continuous plan, and that both De Naeger and Cowans have systems of their own.

Remarks.—The importance of an intermediate washing where a large amount of bleaching has to be done is worth nothing. It is often impossible to do the whole of the bleach in one operation. The bleaching should be conducted up to a certain stage, and the by-products should be removed before any further bleaching is attempted. The accumulation of by-products from bleaching has a retarding effect, and it also destroys any fresh chlorine that may be added, hence to bleach economically the process should be conducted in two operations. By the use of alkali after the first bleach, the by-products are easily removed, and the semi-bleached material so cleansed that only a small amount of bleach is required afterwards to complete the bleaching.

The first portion of the answer dealing with the constitution and manufacture of bleaching powder is taken from "Roscoe and Schorlemmar," part i., vol. ii.

Question 8.—*State fully the treatment you would adopt to impart to a strong book paper the characteristics of a hand-made sheet. Give furnish you would use, with proportions of boiling and bleaching liquors; the duration of treatment in each department, and reasons for the adoption of any special appliances.* (30.)

Answer 8.—

Furnish.	Per cwt.	Pressure.	Boil.
25 per cent. strong linen	4 lbs. of 70 per cent. soda.	30 lbs.	6 hours.
25 per cent. strong unbleached cottons	3 lbs. of 70 per cent. soda.	30 lbs.	6 hours.
50 per cent. clean cottons	$1\frac{1}{2}$ lbs. of 70 per cent. soda.	30 lbs.	4 hours.

Strong linen, 10 per cent. to 12 per cent. of bleach if there are many black threads, but if not, possibly 6 per cent. to 8 per cent. would suffice. Unbleached cottons, 4 per cent. to 6 per cent. bleach. Clean cottons, 1 per cent. to 3 per cent. bleach. Washing, bleaching, and breaking can be done in about 4 hours. Beat 8 hours with heavy engines and put roll down gradually, though it may be necessary to *grip* a little just to get the stuff to travel at first, but it should be eased off as soon as the stuff begins to open out. Phospher-bronze bars and plates make the best job of the stuff when wanted to work wet and look cloudy like hand-made.

Annandale's patent makes the best imitation through having the pump pull the fibres down when the stuff is rushing about, just under the sluices, but it may be advantageous to use a short apron so as to allow of the tube-rolls drawing out the water, and thus forming a layer of fibres before the natural flowing end-on action begins. There must not be any rush of stuff on to the wire or you will get most of the fibres end on, just as logs float down stream.

It is necessary to realise the differences between hand-made and machine-made papers. First of all, of course, the fibres of the machine-made sheet are mostly in the direction of the web, and consequently the paper is stronger when pulled in the direction of the web than when pulled across the web. There are other important differences which are not properly realised, viz., the shrinkage takes place almost entirely across the sheet. A web of paper would, if allowed to shrink freely, become considerably reduced in length, but in consequence of the pull on the sheet of paper on the machine it is prevented from doing so. The paper, therefore, is dried under strain. Measurements taken of the length of paper between the join marks of the machine-wire show that there is an absolute elongation in some cases if these measurements are compared with the length of the machine-wire itself. The pull exerted on the sheet whilst it is in a wet or half-wet condition preventing it drying naturally, must materially affect its strength.

The next point is the couching. With a machine-made paper this is done by means of a felt-covered roll running in contact with the wire. The pressure is along a line, and is never a flat pressure, but is a pinching or shearing pressure, and also the pressure is only exerted for a moment.

With hand-made paper the sheets are placed between felts and submitted to flat pressure. This constitutes an important difference, as besides being a flat pressure it is exerted for some considerable period of time, assisting in the felting and compacting of the sheet whilst the water is draining out. By taking a sheet of paper after it has passed the wire and pressing it between felts and drying as with hand-made, the paper is found in some cases to be 40 to 50 per cent. stronger than the same paper finished on the machine and dried on steam-cylinder.

There is no disposition to shrink in area during couching, as there is no drying taking place. This undoubtedly accounts for an important difference in the strength as well as in the appearance of machine and hand-made papers. It also assists to obliterate the wire-mark, and undoubtedly gives a superior strength to the hand-made sheet.

Annandale's idea is to get the fibres well mixed together. One great drawback of machine-made papers would be overcome to a large extent if this method could be applied successfully. Machine-made paper tears more readily in the direction of the web than across the web, due to the fibres arranging themselves in the direction in which the machine is running.

In order to arrange the fibres in all directions the material must be shaken equally both laterally and longitudinally. This is possible with hand-made paper, but not on the ordinary Fourdrinier machine. Annandale's method requires a good deal of alteration to the machine to make it workable. Such a process is desirable in the manufacture of high-class papers, which, if at all, should expand and contract uniformly with change of atmospheric influences. It is desirable also for paper used for water-colour drawings.

Paper supposed to have the characteristics of hand-made paper is made on a cylinder machine, and in the desired sizes. These sheets are obtained on the cylinder by arranging bands on the same. In the place where these bands are on the cylinder less stuff is collected, and in that way the irregular borders are formed as they appear in hand-made paper. Paper made as above gave the following results :—

Imitation hand-made white. Size of sheet, 12 in. $\times$ $4\frac{1}{2}$ in. ; thickness, 0·10 mm.

Paper length-wise of sheet. Breaking strain on strip 1 in. wide expressed in pounds—

(1) 35, 31, 31, 32 = mean 32·5 lbs.

Across-wise of sheet—

(2) 20·5, 20·0, 19·5, 19·5 = mean 19·9 lbs.

Ratio of 2 to 1—

19·9 : 32·5 :: 100 : 162

Imitation hand-made blue paper, 10 in. $\times$ $7\frac{3}{4}$ in.
Cross-wise—

(1) 22·9, 23·1, 23·6, 22·0 = mean 22·9

Length-wise—

(2) 16·7, 16·7, 17·2, 16·8 = 16·8

Ratio of 2 to 1—

16·8 : 22·9 :: 100 : 136
mean 100 : 149

There is a much greater stretch in the weaker direction than in the stronger. The stretch is mostly near the breaking-point. As the pointer nears the breaking-point it stands stationary, or nearly so, whilst the machine is further wound. Showing that the stretch takes place almost entirely near the breaking-point.

Hand-made paper on mould.

Length-wise—

9·0, 10·5, 17·0 = 12·25

Across—

11·0, 14·8 = 12·90

Showing practically no difference in mean of each direction. The inference is that whereas real hand-made shows little or no difference in the two directions of sheet, the imitation hand-made of about same size shows a difference of 36 to 49 per cent.; and the further inference is that whereas imitation hand-made on cylinders can be produced to have a close resemblance to real hand-made, it differs nevertheless in physical qualities in that it shows great differences in other ways of the sheet, both in strength and stretch.

QUESTION 9.—*What compounds of cellulose are soluble in water, and how are they prepared? Which of these are used in paper-making, and what are the special effects they produce?* (25.)

ANSWER 9.—

(1) A compound of cellulose known as viscose.
(2) Cellulose cuprammonium.
(3) Cellulose dissolved under the action of zinc chloride.
(4) Cellulose treated with sulphuric acid.

(1) Cellulose is combined with caustic soda, which gives the following product—

$$(C_{12}H_{20}O_{10} + 2NaOH)$$

This first operation was effected many years ago by Mercer, whence the name "mercerised cellulose." Although soluble in water, the substance can only be preserved by keeping it from the air. Vapour of water, as well as carbonic acid, decomposes it into carbonate and hydrate of soda, and a derivation of cellulose coloured blue by iodine.

Mercerised cellulose is treated with carbon bisulphide at ordinary temperature, the resultant being cellulose xanthate. The reaction can be interpreted according to the two following formulæ—

$$(1)\ C_{12}H_{19}O_9OH + 2NaOH + CS_2 = C\begin{cases} OC_{12}H_{18}O_9Na \\ = S + 2H_2OSNa \end{cases}$$

$$(2)\ C_{12}H_{19}O_9OH + NaOH + CS_2 = C\begin{cases} OC_{12}H_{19}O_9 \\ = S + H_2OSNa \end{cases}$$

In the arts mercerised cellulose is prepared by well titrating 100 parts of cellulose (preferably of cotton) to a very divided state with 300 parts of a solution of caustic soda (15 per cent.). It is very important that the cellulose be well divided and well impregnated with soda. Cellulose so prepared possesses a thick consistency.

Xanthate of cellulose is also produced when 100 parts of mercerised cellulose are introduced in a vessel kept in a rotary motion, together with five to ten parts of carbon bisulphide, which is admitted little by little, the whole being preserved from contact with the air. The mixture must be as intimate as possible. At the commencement of the operation heat is involved, and the reaction is terminated after an hour or two.

The mercerised fibre is then transformed into a gelatinous substance, its yellow tint being due to the sulpho-carbonate of soda, CS_3Na_2, and other products of the reaction. The mass is then treated with an equal volume of water, and at the termination of several hours, after the addition of a further quantity of water, the solution is complete.

Viscose, prepared as above, is used in the beater as a sizing agent to give strength. It is precipitated by means of zinc sulphate and other precipitating agents together with alum. The quantity used may vary from 1 to 5 per cent. (cellulose), on the weight of the furnish according to requirements.

There are special precautions necessary for the preparation of viscose for this purpose, which cannot be discussed here.

(2) Cellulose cuprammonium. This solution can be prepared on a small scale by taking cotton wool mixed with a few copper filings, and passing strong ammonia through and drawing air through at the same time. The solution will assume a deep blue colour and dissolve the cellulose. This, on evaporation, gives a film.

The process is used in a somewhat different manner for the preparation of the well-known Willesden canvas and paper. A solution is prepared which acts superficially on the cloth, partially converting same into a solution of cellulose. When the ammonia is dried off this, the paper is rendered rot-proof, as well as strengthened and hardened.

(3) Zinc chloride will dissolve cellulose when used in strong solution to a syrupy liquid or a plastic mass. This is made use of for the production of incandescent electric lamp filaments, which, when carbonised, are used in the ordinary incandescent lamp. Zinc chloride is also used to act on sheets of paper, which are stuck together to make up boards of different thicknesses. The zinc chloride is removed by washing, and when dried is found to be very hard and tough. This product, under the name of vulcanized fibre, is used largely for electrical work.

(4) Strong sulphuric acid dissolves pure cellulose. But before entering into solution the cellulose becomes gelatinous. If this treatment is applied to a web of paper for a few minutes, and the paper afterwards washed to remove all trace of acid, it is very much toughened and rendered resistant to water. This process is used for the manufacture of parchment papers, and was originally patented by De la Rue many years ago.

QUESTION 10.—*Describe Cornett's system of handling and treating esparto, and discuss its merits compared with any other system you are acquainted with.* (25.)

ANSWER 10.—Cornett's system. The chief advantage of his plan is that he keeps the esparto in such a state that it will flow through pipes to various departments, and thus saves a great deal of labour and handling. There is really nothing, I believe, new in his ideas, but he had the foresight to lay down the mill on scientific principles, and is now reaping the benefit in these days of competition.

Cornett's system of treating esparto consists of passing the boiled grass through a "cone breaker" to reduce it to a pulp without breaking up the roots, &c. The pulp flows from the "cone breaker" to a stuff chest, from which it is pumped to sand-tables and strainers to remove impurities, allowing the clean pulp to flow to another stuff chest, as much water being removed as is necessary to leave the pulp ready for bleaching before it passes to chests.

From this latter chest the pulp is pumped to potchers and bleached, being afterwards run into chests and passed over the presse-pâte in the usual manner.

There is a strong family likeness between this system and the "green" presse-pâte system, which, for some reason, never "caught on," although it is, no doubt, the most rational method.

The actual difference between the two systems consists in the application of the "cone breaker," instead of a potcher to prepare the stuff for the sand-tables and strainers, which are the real cleansers and the essence of both systems.

A potcher will prepare the stuff equally as well as a "cone breaker," and will at the same time complete the washing, allowing the stuff to go to the strainers clear of soda.

An objection to both systems is the space required; the number of stuff chests and pumps and piping, which, although they save labour, increase complications otherwise.

Opinions differ as to the advantages of Cornett's system: many seem to be against it. One says it reduces the cost of bleaching but requires better boiling, while others say the introduction of centrifugal pumps on the bleaching engines has increased the work required from the beaters, probably owing to the "greasing" action of these pumps as compared with the action of a roll on the pulp previous to the beating.

Altogether the results obtained do not seem to warrant the expenditure on plant and space, as compared with the usual system of washing and bleaching in potchers and passing over presse-pâte. The potchers should either be fitted with slow-running paddles, or with rolls kept well clear of bedplates, which do quite well made of cast iron.

To get clean pulp by either system it is imperative that the cut of strainers be fine, to allow only ultimate fibres to pass through the action of diaphragm gently, and that there be ample surface of strainer plates. The most usual mistake made in this direction is to have too few strainers, which require strong suction to pull the quantity of stuff through, causing much of the impurities to pass with the clean pulp.

REMARKS.—A well-known papermaker has given me his opinion, which is partly expressed in the above. I am also indebted to Messrs. Bertrams, Limited, for their help.

QUESTION 11.—*What materials are used—*

(a) For weighting or loading papers in the engine;
(b) For surfacing or coating;
(c) For colouring (in the beater), red, blue, yellow, and black?
(Mention one pigment and one soluble dye in each case). (25.)

ANSWER 11.—(*a*) Clay, terra alba, pearl hardening, asbestos, blanc fixe, yellow ochre, agalite, chalk.

(*b*) Clay, blanc fixe, satin white.

(*c*) Venetian red, cochineal, ultramarine, Paris blue, yellow ochre, brilliant yellow, lamp-black, nigrosine.

QUESTION 12.—*What precautions would you take to prevent froth and air bubbles when making thin printings at a fast speed, with a furnish of* 30 *per cent. broke and* 70 *per cent. esparto?* (20.)

ANSWER 12.—The best method, in my opinion, of overcoming the froth and air bubbles when running at a fast speed, is to distribute a fine spray of water in the form of a fine rain in a regular stream across the end of the sand-table. I do not know of any better method of doing this than by the use of Lechler's Water Spray Diffuser, made by Paul Lechler, of Stuttgart. These 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.

This fine drizzle falling, as it does, in the form of small particles on the froth, breaks the film and bursts the bubbles. This appears to be a most effective way of dispersing the froth. 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 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 bodies as impurities in the rosin, 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.

XI.

HONOURS GRADE.

1902.

QUESTION 1.—*Permanganate of potassium is used as a bleaching agent in neutral solution. How does it break up, and what further treatment of a pulp would be required to eliminate the products of decomposition? Compare approximately the cost of this bleach at* £50 *per ton for* $KMnO_4$, *with that by bleaching powder of* 35·5 *per cent. "available Cl" at* £6 10*s. per ton.* (25 *marks.*)

ANSWER 1.—It has been known for a long time that potassium permanganate is a powerful bleaching agent, and attempts have often been made to utilize it commercially; but, as far as I am aware, these attempts have not been attended with very great success. Potassium permanganate is well known in commerce for its disinfecting properties. It exists as small needle-shaped crystals. It dissolves in about 15 times its weight of cold water, producing a deep violet-red solution. When it comes in contact with any substance capable of being bleached, the permanganate colour is discharged from the solution, and the bleached, or partly bleached substance becomes coated with a thin brown film of oxide of manganese. When 1,500 lbs. of soda ash is heated to redness with finely divided manganese dioxide, a mixture consisting of manganate and permanganate of soda is formed. This is valuable as a disinfectant when dissolved in water, and it is to this substance that Condy's Fluid owes its antiseptic properties. In order to convert the whole of the manganate contained in the above mixture into permanganate, it is neutralised with sulphuric acid, and evaporated until Glauber's salt begins to separate out. Sodium manganate, a commercial substance that can be used in place of the above, is both cheaper and contains a greater percentage of available oxygen for bleaching purposes.

When we come to consider the relative merits of these two substances, it will be seen that there are serious difficulties when using sodium manganate, which appear to be sufficient to prevent it coming into commercial use. Potassium permanganate, $K_2Mn_2O_8$, gives up some of its oxygen in contact with unbleached material, forms a coating of black oxide of manganese. The action, when complete, is as follows:—

$$\underset{\text{Potassium permanganate}}{K_2Mn_2O_8} = \underset{\text{Potassium oxide}}{K_2O} + \underset{\text{Black oxide or manganese}}{2MnO_2} + \underset{\text{Bleaching oxygen}}{O_3}$$

On the addition of a mineral acid, such as sulphuric, the dark coating is dissolved, and the material is found to be bleached or partly bleached. The film of oxide at the time of decomposition is generally of a brown colour, and being precipitated in a hydrated condition is readily removed by the acid. The coating of manganese dioxide is quickest removed by the addition of sulphurous acid. As, during the reaction, an amount of caustic potash equal to the potassium contained in the potassium permanganate is liberated, any acid added for the removal of the black oxide has first to neutralise the alkali.

It is sometimes found preferable to remove the alkali by washing, and to add the necessary amount of acid afterwards for the removal of the manganese dioxide. Three hundred and sixteen pounds of pure potassium permanganate would give us 48 lbs. of bleaching oxygen, which is equal to 15·2 per cent. As, however, the commercial salt contains about 94 per cent. of $K_2Mn_2O_8$, the amount of bleaching oxygen may be reckoned at one-seventh of its weight.

It must be remembered that the strength of bleaching powder is reckoned by the amount of available chlorine it contains, which is generally 35 per cent. This is equal to 8 per cent. of bleaching oxygen. From these figures we see that 4 tons of potassium permanganate would supply as much bleaching oxygen as 7 tons of bleaching powder. This must be taken into consideration when comparing the cost of the two substances. But this, however, is by no means all we have to consider, as the bleaching oxygen in a permanganate solution is entirely different in its action from the oxygen liberated by means of the chlorine in bleaching powder. To begin with, permanganate bleaches almost simultaneously, whilst bleaching powder takes hours and sometimes days to complete its action.

When a fibre is bleached by permanganate the action is suddenly stopped by the incrustation of the black oxide, which prevents any further action of the oxygen. Often the action is so rapid as to oxidise the cellulose ; to prevent this, the permanganate must be used in very dilute solution. If one operation is not enough to effect sufficient bleaching, the coating of black oxide can be removed by the addition of sulphurous acid, and, after washing, the operation can be repeated.

I made some comparative experiments on a large scale in a breaker. I took 2 cwts. of unbleached rag half-stuff and bleached it up to a certain colour by the addition of a known weight of bleaching powder, which was entirely discharged at the end of the bleaching. I did the same thing with permanganate, and I found that 1 lb. of potassium permanganate was equal in bleaching effect to 10 lbs. of bleaching powder. As, however, the bleaching oxygen of permanganate is to that of bleaching powder as 7 is to 4, I expected to find that 4 lbs. of permanganate would equal 7 lbs. of bleaching powder in bleaching effect. The difference can only be accounted for on the supposition that the oxygen of the two substances act very differently. This is well known to be the case when we make a comparison of an electrolised solution of magnesium chloride (Hermite's solution) with a solution of bleaching powder of equal chlorine (*i.e.* oxygen) strength. In this case, 3 lbs. of oxygen of the Hermite solution does as much bleaching as 5 lbs. of the bleaching powder solution. In a like manner, sodium hypochlorite differs from calcium hypochlorate, and calcium hypochlorite itself, in turn, varies in the efficiency of its oxygen according to the method by which it is prepared.

It follows that from what is above stated that 1 lb. of bleaching oxygen of permanganate does as much bleaching as $\frac{(4 \times 10)}{7}$, or say, $5\frac{1}{2}$ lbs. of oxygen of ordinary bleaching powder.

At the time the experiments were done to determine whether permanganate could be commercially used in place of bleaching powder, although only one-tenth of the weight of permanganate was required, it cost as much to do the bleaching, as, at that time, the price of permanganate was about ten times that of bleaching powder. To the cost of the permanganate must be added that of the sulphurous acid.

The amount of sulphurous acid depends, of course, as to whether the fibre is washed before the acid is added. I made a number of experiments to determine what action took place between the sulphurous acid and the manganese dioxide. It is generally supposed that dithionic acid is produced. My experiments, however, did not confirm this opinion, and appeared first to point conclusively to the formation of manganese sulphate according to the simple equation—

$$MnO_2 + SO_2 = MnSO_4$$

After, however, carefully noting the action of sulphurous acid upon ordinary black oxide of manganese under varying conditions, I have come to the conclusion that the action generally takes place in two stages, as follows :—

$$MnO_2 + SO_2 + 2H_2O = \underset{\text{White manganous hydrate}}{Mn(HO)_2} + H_2SO_4$$

$$MnH_2O_2 + H_2SO_4 = MnSO_4 + 2H_2O$$

On shaking some black oxide of manganese with a weak solution of sulphurous acid, the sulphurous is rapidly oxidized to sulphuric, and in a short time manganese sulphate is found in solution. The black precipitate, before entering into solution, to a large extent loses its colour. The last portions of it change from black to a greyish white, and I believe this is due to the sulphurous acid deoxidising the black oxide of manganese with a formation of a white precipitate of manganous hydrate, $Mn(OH)_2$, and a corresponding amount of free sulphuric acid as shown by the first equation. The sulphuric acid then dissolves the manganous hydrate with the formation of manganous sulphate as shown by the second equation.

The reaction taking place in two stages, as shown above, accounts for certain difficulties that are experienced with permanganate bleaching. It often happens that after permanganate bleaching the pulp goes back in colour. This, I think, is to be attributed to the fact of the reaction having taken place only as far as the first stage, that is, manganese dioxide is rendered invisible, for the time being, by its conversion into the white manganous hydrate, which is retained by the fibre. This substance is well known to oxidise rapidly in the air, assuming a brown colour. Care must, therefore, be taken to ensure that all the manganese is converted into the sulphate, the whole of which must be carefully removed by washing. On the assumption that washing is resorted to before the addition of sulphurous acid, for every molecule of $K_2Mn_2O_8$ we should require two molecules of SO_2, or 10 lbs. of permanganate would require about 3 lbs. of actual sulphurous acid. These figures are, however, arrived at by theory, and in practice it is found necessary to use somewhat larger quantities. Bisulphite solutions can, of course, be used instead of sulphurous acid, if found more convenient.

It is not at present known why the bleaching oxygen of different agents, such as permanganate and ordinary bleaching powder solutions, should be required in different quantities, according to the agent employed, to produce a certain amount of bleaching effect; but it appears to me to be accounted for by the formation of a mixture of ozone, or active oxygen, and ordinary oxygen.

The latter has no bleaching effect whatever, whilst the former is a powerful bleaching agent.

If the action of ordinary bleaching powder solution gives rise to oxygen containing a small proportion of ozone, whilst permanganate contains a large proportion, it would certainly be sufficient to account for the great difference between the two. This is a theoretical point which deserves more attention, and, perhaps, if properly understood, would result in much more economical bleaching. It is worthy of note that as the bleaching efficiency of the oxygen increases, so also its rate of action increases; thus the Hermite solution is much more rapid in its action than a solution of ordinary bleaching powder, and at the same time the bleaching oxygen is about $1\frac{3}{4}$ times as efficient. With permanganate, the action, instead of taking hours, is almost instantaneous, and the bleaching oxygen is $5\frac{1}{2}$ times as efficient as the oxygen of ordinary bleaching powder. I can see no reason why permanganate bleaching should not come into use for some purposes, especially where rapidity of action is an important consideration.

The reaction is so easy to control. I believe few attempts have been made to utilise it, on account of its high price as compared with bleaching powder, and that, if manufacturers had known that 1 lb. of permanganate would do as much bleaching as 10 lbs. of bleaching powder, attempts would have been made to bring it into use commercially.

The cheaper product, sodium manganate, which is prepared by roasting together caustic soda and black oxide of manganese, is objectionable, as it is not stable, unless prepared very alkaline.

On account of its strongly alkaline reaction, it is far more likely to injure the fibre. If, however, it could be made use of, providing that the bleaching efficiency of its oxygen is equal to that of potassium permanganate, it would be far cheaper than bleaching powder.

This substance has been manufactured on a large scale as a disinfectant, and I have it on good authority that a certain governing board who had been making use of permanganate, erected works for the manufacture of sodium manganate, and were able to turn this material out at a cost of about £11 per ton. When we take into consideration the amount of available oxygen in this substance as compared with that of bleaching powder, the latter would stand very little chance of competing if the difficulties which at present stand in the way of using sodium manganate could be overcome. I have no reason to believe that these difficulties are insurmountable.

In practice, as above shown, potassium permanganate, $KMnO_4$ or $K_2Mn_2O_8$, has ten times the bleaching effect, weight for weight, of bleaching powder, at 35·5 per cent. "available chlorine." If the former is taken at £50 per ton, and the latter at £6 10*s.*, a comparison can be arrived at by multiplying the £6 10*s.* by 10. This gives us £65 worth of bleaching powder to give us the same bleaching effect as 1 ton of permanganate. In practice, therefore, on these prices the proportionate costs would be—

£50 : £65 : : 100 : 130

showing that the bleaching powder would cost 30 per cent. more to use than the permanganate.

Remarks.—The student must not be misled by forming any conclusion as to the relative costs of bleaching powder and permanganate from the figures set by the examiners, which are purely hypothetical, and merely given to test a student's ability to make the necessary calculation. The actual market values on September 29, 1902, were for bleaching powder £6 10*s.*, and permanganate £37. It must not be forgotten, however, that the after use of sulphurous acid adds considerably to the cost of the permanganate bleaching. A student would get some idea of what this should amount to if he reads the above answer, and looks up the price of sulphurous acid in one or other of its forms. This item of cost the examiners evidently did not intend the student to take into account in his answer.

According to molecular ratios, it will be seen above that 4 lbs. of permanganate should equal 7 lbs. of bleach. If calculated on this basis—

$$\frac{£6\ 10s. \times 7}{4} = £11\ 8s.\ 0d.$$

According to this, £11 8*s.* of bleaching powder would do as much work as £50 of permanganate on examiners' figures; this, however, is not at all true in practice, as explained in above answer.

My results, as given in the first portion of the above answer, were originally given at greater length in an article contributed to the Papermaker, now out of print.

Question 2.—*Which variety of wood fibre do you consider most suited to blend with* (1) *linen rags for typewriting papers*, (2) *esparto for fine printings*, (3) *soft cottons for blottings*, (4) *manilla ropes for cartridge papers? State the treatment you would adopt for the preparation of the various wood pulps from the raw materials, and give* *data for boiling, washing, and bleaching, also composition of boiling and bleaching liquors, with the yield of pulp you would expect from* 10 *tons of raw wood.* (30.)

ANSWER 2.—(1) Bleached sulphite, 25 to 30 per cent., prepared by the real not the bastard Mitscherlich process.

(2) American bleached poplar blends very well, and gives a fine glossy feel when passed with the esparto through a refiner. Bleached soda is also good, and feels rather firmer than the poplar.

(3) Bleached poplar is best for this purpose. I am informed that a good blotting is made in Scotland solely from poplar ; this was examined by an expert and found to consist of poplar wood. I had a very excellent filter-paper submitted to me of foreign make, suitable, I found, for chemical filtrations, made entirely from linen.

(4) Pine wood prepared by the sulphate process, bleached if necessary for colour. This blend gives a long silky fibre, with a good sheen on when well beaten and passed through a refiner.

Refiners are admirably suited for blending wood with rags, and, indeed, for milling most papers. The boiling and bleaching of the wood would occupy too much space to discuss here ; there is considerable information in Griffin and Little's book. The great drawback which all papermakers experience in this country is that they have no control over the conditions of boiling, everything being done for them by the pulpmaker. So much more might be accomplished if the papermaker could modify the conditions of boiling to suit his own special requirements. The papermakers have to use wood pulp boiled in a way that usually admits of no variations, as the pulpmaker does not know what papers it is wanted for. This is a great drawback to papermakers. I am informed that the Germans are taking to special boilings from their own pulp mills for special grades, which, of course, makes all the difference when wanted to blend with, say, soft cottons in one instance, and manilla or hemp ropes in another.

QUESTION 3.—*Discuss fully the question of economy in boiling rags with caustic soda. By what chemical tests would you control the operation and fix the best conditions in particular cases?* (25.)

ANSWER 3.—This question has been fully discussed in answer to Question 1 in Ordinary Grade.

QUESTION 4.—*State your opinion regarding the use of exhaust steam from the machine engine, for heating the drying cylinders, and* *compare the method with that of employing a condensing engine and drying with high-pressure steam. Show how you arrive at the steam consumption for each method?* (30.)

ANSWER 4.—You will find the answer to this in Economist's papers in WOOD PULP. The whole question largely depends upon circumstances. It depends upon whether the engine is fully up to its work, and the amount of drying power in the cylinders. One authority informs me that in many instances, viewed from all points, it is better in the end to use a condensing engine and high-pressure steam for drying. To be economical the drying with exhaust steam must be conducted with everything up to the mark, while with the high pressure reduced, say to 10 to 15 lbs. pressure, you can keep your cylinders fairly uniform, and are free to drive up the engine without being troubled with the back-pressure making the engine run badly.

Messrs. Bertrams, Limited, have been good enough to give me their opinion on this subject, which I give in their own words as follows:—

"Our opinion is quite decided in favour of using exhaust steam in the drying cylinders, as theory and practice prove it to be the most economical method. When the exhaust is condensed in the cylinders at say 5 lbs. pressure, the latent heat is used in drying the paper, and the sensible heat is recoverable as feed-water, available work being done by each unit of heat in the steam.

"A very important point to be noted in connection with this is the small increase of total heat required by steam as it is increased in pressure. To increase steam from 5 lbs. to 80 lbs. pressure only requires the addition of about 29 units of heat, and in reducing the pressure it only loses that amount while giving off the power in passing through the engine. The exhaust steam is therefore not far short of the value of live steam for drying purposes.

"It is somewhat difficult to arrive at correct figures for steam required to dry paper, as it depends on so many varying conditions. Theoretically about 2 lbs. of steam, ordinary pressure, should suffice, but practically it requires much more.

"Some engineers (Continental) claim that 0·16 to 0·2 lb. of coal will dry 1 lb. of paper, but we are very doubtful indeed of these figures.

"Our experience shows that about 3 lbs. of water are discharged from the cylinders per 1 lb. of paper made when exhaust steam is used, this, of course, including all the condensation right from boilers, and includes that from the engines. In one case we tested where live steam was used, the results were practically identical, but unless proper arrangements are made to collect the water for a considerable period, errors must be expected. The above, however, would show that about $\frac{1}{3}$ to $\frac{3}{8}$ lb. of coal is required for driving the machine and drying the paper, depending on the quality of coals, which we had no means of estimating. The machine we refer to was driven by two steam engines, which were never indicated, but which would probably indicate 50 h.p. steam pressure—about 80 lbs. There was thus about 2,700 lbs. of steam condensed in the cylinders, a little of which was live steam added to supplement the exhaust. Had these engines been condensing they could not possibly have required less than 25 lbs. of steam per h.p. per hour, or say 1,250 lbs. per hour, while the paper would have required about 2,600 lbs. live steam, making a total of 3,850 lbs. steam against 2,700 lbs. steam per hour, or a saving of 1,150 lbs. per hour on 900 lbs. of paper. We may say that when the machine we refer to was started, an old one with condensing engine was stopped, and the coal bill reduced by from 4 to 10 cwts. per ton of paper."

QUESTION 5.—*What are the average limits of thickness of writing papers? For a given mean thickness, calculate the weight per square metre of paper of* 50 *per cent. "cellulose density"* (i.e. *equal volumes fibre substance and air space*). *Taking a breaking length of* 7,500 *m., what maximum weight will the paper support per* 1 *cm. of breadth?* (*Take the sp. gr. of cellulose at* 1·5.) (25.)

ANSWER 5.—The thickness of writing papers varies very considerably. It would be almost impossible to say what the minimum or what the maximum thickness is, but I give below a fair statement expressed in mm. of the thickness of writing papers :—

	mm.
Thin paper	0·05
Foreign note	0·04
Thin bank	0·05
General run of typewriting	0·07
Very thin	0·04
Ordinary notepaper for private use	0·10–0·12
Thick notepaper	0·188–0·20
General limits	0·04–0·20
Expressed in inches	0·0016–0·0080
Ratio of thickest to thinnest	1 : 5
Typewriting papers used for carbon copies as thin as	0·025

Taking 0·1 mm. as mean thickness, with a mean cellulose density of 50 per cent., the weight per unit of area in grammes per c.c. would be $\frac{1{\cdot}5 \times 50}{100} = 0{\cdot}75$ grammes per c.c. As 1 c.c. $= 10 \times 10 \times 10$, or 1,000 c.mm., a paper 0·10 mm. thick, and 1,000 c.mm. volume, would have a surface of 10,000 sq. mm. Now 1 sq. metre is equal to $1{,}000 \times 1{,}000 = 1{,}000{,}000$ sq. mm.; therefore, 1 sq. metre of paper, with a thickness of 0·1 mm. and cellulose density of 50 per cent. would weigh $\frac{0{\cdot}75 \times 1{,}000{,}000}{10{,}000}$ = 75 grammes, which in ozs. would be about $\frac{75}{28}$ = say $2\frac{3}{4}$ ozs.

One cm. = 10 mm.

One metre, 10 mm. wide $= 10 \times 1{,}000 = 10{,}000$ sq. mm., but it has been shown above that 10,000 sq. mm. of the paper in question weighs 0·75 gramme. Therefore a strip of the paper 1 cm. wide and 1 metre in length would weigh 0·75 gramme. Therefore the maximum weight which this paper would support on a width of 1 cm., and with a breaking length of 7,500 m., would be $0{\cdot}75 \times 7{,}500 = 5{,}625$ grammes $= \frac{5625}{453} = 12{\cdot}4$ lbs.

Remarks.—I do not think the term "cellulose density" would be understood. It evidently here refers to a paper consisting of 50 per cent. cellulose by volume and 50 per cent. air space. It is quite evident that if the specific gravity of cellulose is taken at 1·50, the specific weight of this paper would be half this, or 0 75 gramme per c.c.

Note that 1 cm. width is very narrow for a test, and is far too narrow for most practical purposes. Although this paper only supports 12·4 lbs. on a width of 10mm. (or $\frac{2}{5}$ of an inch), on an inch width it would support at least $\frac{12{\cdot}4 \times 5}{2}$ = 31 lbs.

For further information on this subject see Paper and Pulp, Nov. 1, 1901, page 763.

Question 6.—*Describe the plant you would put down to recover and causticise the soda in the liquors from the boiling and washing of* 100 *tons of esparto per week. State the approximate number of gallons per boiler, the percentage of soda you would expect to recover, and the cost for labour, lime, and coal, per ton of soda recovered.* (25.)

Answer 6.—This question is largely a matter of the amount of liquor which may be run into the stream without alarming the all-powerful riparian authorities. Briefly, I should put down two up-to-date Porion roasters with large evaporating chambers; four lixiviators, say 6 feet square; two causticising cisterns fitted with agitators, 9 feet diameter by 9 feet deep; two large tanks for the causticised liquor, say 30 feet long by 10 feet wide by 7 feet deep, with the necessary pumps; one large shed or house for the recovered soda to burn out in, and the chimney would be, say, 200 feet high, so as to get rid of the fumes. The question of tanks for the liquor from the grass would depend on the number of the waters to be evaporated. The lime mud should be treated in a vacuum filter so as to get out as much of the caustic liquor as possible. With from 2,500 to 3,000 gallons of lye to evaporate per boiler the above plant would work very well, and the soda recovered should average from 60 to 70 per cent., and the cost for labour, lime, and coal should run out at from 25*s.* to 20*s.* per ton of ash recovered. The conditions vary very much in different mills, and it is claimed that the Yaryan can do better than this. It is difficult to say what it costs for the upkeep of a multiple effect, but whatever may be said against the Porion it must be admitted that it can be kept in order for very little.

QUESTION 7.—*Discuss fully the conditions of penetration of papers by size solutions in tub-sizing. How would you vary these conditions, including the composition of the size, to produce the best effects? How would you investigate the paper to ascertain the distribution of the size and the sizing effect?* (20.)

ANSWER 7.—I have given a good deal of information on this subject in my lectures on sizing before the Dickinson Institute. The conditions of penetration depend upon several factors. First of all we have the gelatine itself. Some gelatines have much greater powers of penetration than others. The first draught would act differently to the third draught from any given raw material. Gelatines prepared from different raw materials differ in respect to penetration one from the other. This is partly due to their power of gelatinising and partly to other causes. Another factor is the paper itself. Some papers allow the penetration of size much more easily than others. This would depend not only upon the material of which the paper was composed, but also on the way in which it has been beaten and the extent to which it has been beaten. It would depend also very largely upon whether the paper had been rosin-sized. Rosin size, of course, reduces the penetration very materially, and renders the gelatine sizing more or less superficial, according to the amount of rosin present. Apart from the question of rosin, the penetration depends on whether or not the paper has had alum in the furnish. If alum has been put into the engine, so as to give the paper an acid reaction, the penetration is reduced enormously. The addition of alum to the furnish is, perhaps, the most easy way of controlling the penetration, although for obvious reasons it is very seldom resorted to.

Next we come to the strength of the gelatine. If the gelatine is strong a high percentage of gelatine penetrates much less readily than a low percentage, on account of the difference in the viscosity of the solutions. The temperature of the size also influences the degree of penetration. The higher the temperature the less viscous the liquid, and consequently the greater power of penetration. The next point is the question of the amount of alum in the size. The thickness of the solution is largely dependent upon the amount of alum present. This I have discussed at length in another publication. Up to a certain point the gelatine thickens on the addition of alum. By the dextrous use of alum in the sizing-trough the penetration can be regulated to a very large extent. Next, the question of the way in which the paper is passed through the sizing-trough makes all the difference to the penetration. If both sides are totally immersed, it reaches the size the air more or less occluded, preventing the size penetrating and retaining the gelatine on the surface. If, on the other hand, the paper is wetted with the solution on one side first, so as to allow the gelatine to soak up to the upper surface before the upper surface is immersed, the air is driven through, and the penetration is very largely increased. The rate at which the web passes through the solution has something to do with the penetration. The question is also affected by the dampness of the paper after it leaves the drying cylinders. It is usual to have the paper bone-dry before it passes into the sizing-trough. If it is at all damp, or even air-dry, the air is more readily driven out of it than it is when it is bone-dry, consequently the penetration is rendered easier. The penetration may be affected by the addition of soap to the size. Some papermakers use a certain amount of soap in their size; others use a clear solution. This alters the behaviour of the size towards the web of paper. Lastly, the penetration may be affected by the amount of pressure put upon the squeezing rolls used for squeezing the surplus size out of the paper back into the sizing-trough. The tendency of the rolls would be to squeeze any remaining air out of the pores of the paper.

The investigation of the paper so as to determine the distribution of the size is by no means an easy matter. It would be extremely difficult to determine the percentage of gelatine on the different portions of the paper, and it would be a most tedious operation, as there is no method for the determination of the percentage of gelatine which could be used by an ordinary mill operative. It is a process which requires a good deal of chemical knowledge and skill. The distribution of the size on different portions of the paper can only be judged in the finished sheet by testing the paper for its power of resisting ink. Some idea can be arrived at, however, by standing underneath the web of paper as it leaves the squeezing rolls and looking through it. It will be noticed that some portions of the sheet are more wetted than others, unless the pressure on the rolls is absolutely uniform throughout the width. This is extremely difficult to ensure. It may result, therefore, in an irregular distribution of the size. Any irregularities in the make of the paper and in the thickness may also result in a bad distribution of the size.

These, and other causes, may account for a difference of sizing qualities in different portions of the sheet. The most common method of testing paper for its ink-bearing properties is to take standard ink (Stephens' blue-black ink is almost always used for this purpose). Into the ink dip a new quill pen, and with this pen full of ink trace lines along the sheet of about one-eighth of an inch in width, also trace lines at right-angles to these, and allow the paper to remain until the ink is completely dry. Then turn the sheet over, and observe whether the ink shows any signs of penetrating through. It does not follow that because the ink can be seen on the other side it has necessarily penetrated, as the ink being seen may be due to the transparency of the sheet. In order to test to what extent the ink has penetrated, tear the sheet along the line where the lines have been drawn, and observe whether the torn edge is completely black, due to the complete penetration of the ink, or partly white on the one side and partly black on the other, showing the partial penetration of the ink. If by this test one portion of the sheet or web should show any difference from the other, it would not necessarily indicate that there was a greater percentage of gelatine on the one side than on the other, but it would indicate that the size had not been regularly distributed.

The above test should be repeated, using a steel pen. The latter, of course, tends to cut the surface of the paper. The advantage of the former is that it merely shows where the ink itself will penetrate without cutting the surface; as, however, a steel pen is generally used, and often with a sharp point, the papers used for writing upon should stand this latter test. It is important also to test the paper after it has been glazed, as the glazing of the paper often reduces its power of resisting ink, especially when crushed through excessive pressure in plate glazing.

There is another and very useful test, and that is a test used by Leonhardi, described in Herzberg's book on "Paper Testing." A series of lines are drawn on one surface by means of a pen containing neutral solution of chloride of iron. When this has been allowed to dry, the opposite side is damped with a solution of tannic acid in ether. If the chloride of iron has penetrated the paper, on coming in contact with the tannic acid it will form a black mark. This test can with advantage be varied, such as by brushing one surface with the tannic acid solution, and when this has dried, letting drops of the chloride of iron solution fall on to different parts of the sheet, observing how long it takes for a black mark to be formed when the sheet is held so that the light can be seen through it. I have used this test on many occasions and found it exceedingly useful; but the test with the quill pen and Stephens' ink is the one which is generally regarded as the practical one.

QUESTION 8.—*State fully how you would handle the beating tackle when beating the pulp for the papers mentioned in Question 2. What special methods would you adopt to secure that the wood fibres would be so blended as to prevent the finished sheet from having a "woody" appearance?* (20.)

Answer included in No. 2.

QUESTION 9.—*State what you know of the hydrated modifications of cellulose, and their functions in the papermaking process. What special effects are obtained by these hydrates chemically prepared?* (25.)

ANSWER 9.—This is too wide a question for me to discuss. The best thing I can do is to refer you to the following publications, and to others by Cross, Bevan, and myself bearing on the subject.

REFERENCES.—See "Cellulose," by Cross, Bevan, & Beadle, papers mentioned on p. 28, and other publications by these authors appearing in the JOURNAL OF THE CHEMICAL SOCIETY, the SOCIETY OF CHEMICAL INDUSTRY, the SOCIETY OF ARTS, and in foreign journals. Also in the following publications by the author: "New Cellulose Derivatives and their Industrial Applications," August, 1894, JOURNAL OF THE FRANKLIN INSTITUTE (vol. cxxxviii., No. 824), "Viscose and Viscoid," JOURNAL OF THE FRANKLIN INSTITUTE, January, 1897.

QUESTION 10.—*Wherein lie the advantages of the multiple effect evaporator and the rotary furnace? State what you know of the practical working of each, and compare them with the Porion system as to the efficiency and cost of maintenance.* (20.)

ANSWER 10.—In order that you may arrive at some definite conclusion in regard to this matter, I would refer you to an article on "Comparative Results of Quadruple and Open Effect Evaporation," PAPER AND PULP, August 15, 1902, and the pamphlet on the Porion Evaporator by Messrs. Davis Bros., Blackfriars Street, Manchester.

In Lecture 4, before the Dickinson Institute, I attempted to show certain points of difference between the two systems which might help a student to form some conclusion when he has some particular instance under consideration, but, not being an expert on this subject, I would not venture to give a more general opinion.

QUESTION 11.—*Give briefly a full scheme for the analysis and testing of writing and book papers. Give also a selection of these tests for rapidly determining the main features of composition.* (25.)

ANSWER 11.—I should propose the following scheme for rapidly determining the main features of composition for writing and book papers. Boil in 1 per cent. solution of aniline sulphate, and note if solution turns yellow or red. If yellow, it indicates the presence of wood; if red, straw and esparto. Immerse small pieces in a very dilute solution of iodine. Blue coloration indicates the presence of starch. Boil a small portion with distilled water for a quarter of an hour, filter, add, thoroughly dissolved, 1 per cent. solution of tannic acid. Flocculent brown precipitate indicates the presence of gelatine. Boil a small portion with strong alcohol, cool, decant off into distilled water. If an opaque ring is produced where the two liquids meet after standing for half an hour, rosin is probably present. Shake the alcohol and water together; cloudiness indicates the presence of rosin. In the event of there being no wood, esparto, or straw, &c., a fragment of paper placed partially immersed in a watch-glass in strong pure sulphuric acid, if it gives brilliant red coloration, would indicate the presence of rosin. Apply Wurster's reagents, and compare with scale to see if there is any mechanical wood.

The fibres are best recognised by taking a portion of the paper after it has been boiled for half an hour in the 1 per cent. solution of carbonate of soda, shaking in bottle with water containing agates, and placing a drop of the water on the microscope glass. The fibres are treated with strong sulphuric acid and with iodine, and examined under the microscope, and can be recognised by their various characteristics.

Burn a gramme of paper, weigh ash, to determine percentage. If ash is entirely insoluble in the weak solution of hydrochloric acid, it is probably due to clay; if soluble, and precipitate formed by the addition of a drop of barium chloride, the ash is probably terra-alba. Agalite is insoluble but can be distinguished from clay under the microscope by its needle-shaped crystals. If the paper is blue and the colour is discharged by strong acid, it is probably due to ultramarine, especially if the blue colour remains in the ash. If not discharged and the blue remains in the ash, the colour may be due to smalts.

REMARKS.—The above tests are by no means conclusive, but I could not suggest a better brief scheme for the examination of papers to get some rough idea of composition.

QUESTION 12.—*Schedule the proportions of chemicals you would use in boiling and bleaching* (1) *Manilla ropes for strong cartridges;* (2) *Flax waste for caps;* (3) *Unbleached cottons for loan papers;* (4) *Jute for casings;* (5) *Muslins for blottings. State temperature, pressure, and duration for boiling, together with any special modifications you consider advantageous.* (30.)

ANSWER 12.—

(1) Manilla rope. 15 per cent. lime, 3 per cent. soda ash. 12 hours at 15 lbs. press.

(2) Flax waste. 15 per cent. lime, 3 per cent. soda ash. 12 hours at 15 lbs. press.

(3) Unbleached cottons. 3 per cent. lime, 70 per cent. soda, 6 hours at 20 lbs. press.

(4) Jute. 15 per cent. lime. 12 hours at 15 lbs. press.

(5) Muslins. ½ per cent. 70 per cent. caustic. 4 hours at 20 lbs. press.

(1) Bleach. 10 to 12 per cent. according to colour required.
(2) Bleach 8 per cent. according to colour.
(3) „ 6 „ „ „
(4) „ 12 „ „ „
(5) „ 2 to 3 „ „ „

OMISSION.

MR. H. J. BROWN, JUNR., of Messrs. Olive Bros., Ltd., has been good enough to bring to my notice the fact that I had made a serious omission in answer to Question 11, Ordinary Grade, page 115. I had mis-read the question, and as a consequence, made the answer shorter than it otherwise should have been.

Mr. Brown took the view that under (*a*) and (*b*), in addition to giving the mineral and colouring constituents, it should have included the fixing agents.

I communicated with the examiners, who informed me that this was what was intended in the question. Under (*a*) might be included gelatine and lignone, which, on precipitation, assist in the fixation of mineral matter—also casein used in the beater, and the more ordinary constituents, rosin, precipitated by alum, and, lastly, starch. Under (*b*), of course, we have gelatine and casein, with the addition of alum and formaline, the latter tending to render both these substances insoluble.

For further information I would refer you to existing publications, among them the Battersea Institute Lecture on "Art Papers," and Croxley Lecture on "Paper Sizing."

XII.

ANSWERS TO THE 1903 QUESTIONS.

REMARKS.—I shall not attempt this time to give specimen answers, because by so doing I should in many cases be repeating points that have been thrashed out already at considerable length in PAPER AND PULP. My endeavour will be this time to give information in respect of most of the questions, which, as far as my judgment goes, would enable students to see how they might have shaped their answers. Some of the questions are very much on the lines of some PAPER AND PULP articles, and the ability to answer such questions would largely depend upon the extent to which PAPER AND PULP has been read. I would once again remind all those who wish to advance their knowledge by their own personal effort, to make use of the index of last year's PAPER AND PULP, and by its means follow up the literature under the different headings. This mode of procedure is far more satisfactory (at least I have always found it so) than attempting to read through a text-book. I would, of course, advise the use of as many text-books as possible as books of reference when reading up any branch of the subject of papermaking, in which case the indices of the text-books should be made free use of.

In all reading, students will, if they read carefully and not too quickly, find contradictions and errors, and will, therefore, find it necessary to use a great deal of discretion in accepting or rejecting statements. They must think and judge for themselves, and try to ascertain how far their own personal experience and observation agree with the current literature. Students can best advance their knowledge by taking up a somewhat independent position.

Before setting to work to prepare remarks and information in reference to the 1903 questions, I consulted my friends Mr. Cross and Mr. Clapperton. I am much indebted to both of these gentlemen for their valuable suggestions and information. I am further indebted to Messrs. Bertrams, Ltd., for information in regard to certain questions; and to a practical papermaker, whose name I am not privileged to mention, for information in regard to Question 8, Honours Grade. I am also indebted to the British Westinghouse Electric and Manufacturing Company, Ltd., for their courtesy in supplying me with up-to-date information. The publication of this work has been somewhat delayed on account of my absence in the United States and Canada.

ORDINARY GRADE.

1903.

QUESTION 1.—*Describe the structural features of straw and esparto and of the fibres of their respective half-stuffs. What are* *the average dimensions and structural features of cotton and linen (flax) when fully beaten?* (25 marks).

Answer.—Straw and esparto may be classed as short fibres when regarding them in comparison with cotton and linen, as they are somewhat less in diameter than the two latter, but are very much shorter. They differ from cotton, furthermore, in that they have very small central canals, and as a consequence are non-collapsible. The ends of esparto are solid and rounded, and, in consequence of the lateral pressure exerted by one fibre upon another, the sides are often hexagonal instead of round, resembling honeycomb in section but nearly solid, with small hole in centre—the shape naturally assumed when rodlike materials capable of compression and of being moulded are influenced by a lateral pressure. The lateral pressure is the result of growth and expansion in a confined space.

Straw is smoother on its surface than esparto, and is more polished; it is also more inclined to take up water and work "wet" on the machine. It is the shortest of papermaking fibres, with the exception, perhaps, of mechanical wood, which, when finely ground, is sometimes shorter.

The great feature in regard to esparto is its excellent surface for taking printers' ink in fine lines and half tones, a property which is not possessed in a like degree by any other fibre.

Straw, on account of its extreme shortness of fibres, being only about a fourth the length of those of esparto, or $\frac{1}{75}$th that of cotton fibre, is seldom used alone for papermaking. Its chief use may be said to be in conjunction with rag stock, where it fills in the interstices between the large fibres, and has a very beneficial effect in certain cases, giving hardness and rattle in a rag paper even when used to the extent of 5 per cent. On account of its tendency to work wet, it imparts qualities to other stock very much needed in certain cases.

I give here, as information in regard to the latter half of the question, particulars of the dimensions of cotton and linen fibres both before and after beating, and have arrived at an average by taking different kinds of cotton both for length and diameter.

BEFORE BEATING.

Calculated from tables given in Cross & Bevan's Book on Paper-making.

Cotton.	Average length.
Glossypium barbadense	4·05 cm.
„ acuminatum	2·84 „
„ arboreum	2·50 „
Bombax heptaphyllum	2·50 „
	11·89

Mean of four varieties—

2·97 cm.
= 29·7 mm.
1·188 inch.
Say $1\frac{1}{5}$ inch.

Cotton.	Diameter. Max.	Min.	Mean. $\frac{1}{100}$ mm.
Glossypium barbadense	1·92	2·79	2·35
„ acuminatum	2·01	2·99	2·50
„ arboreum	2·00	3·78	2·89
Bombax heptaphyllum	1·90	2·90	2·40
Mean of four varieties			2·53

The mean diameter = 0·0253, or, say $\frac{1}{1000}$ of an inch.
The normal diameter for the three first is 0·0281 mm.

There are three classes of fibres in all cotton—viz. (1) ripe, (2) half-ripe, and (3) unripe fibres—and, as a consequence, the fibres vary considerably in length, diameter, and in general appearance.

"Normal" fibre (*vide supra*) may be described as the one generally found, which does not necessarily, however, represent the "average" fibre. The effect of beating is to broaden and flatten cells and so increase their diameter. The appearance and dimensions of the cells after beating depend largely upon whether the fibre is got from new rags or from well-worn tendered rags; it depends somewhat upon the chemical treatment, but very largely upon the way the beating is conducted. With well-worn rags there is a tendency of the fibres to become very much bruised and mutilated, and to split off into fibrillæ. The "mean" length of beaten cotton varies enormously. With short stuff for thick papers it may be only one millimetre, or $\frac{1}{25}$th of an inch, but in strong papers it frequently reaches from $\frac{1}{3}$ to $\frac{3}{4}$ of an inch, or 8 to 18 millimetres. It seldom happens that the beating is conducted in such a way as to leave the fibres intact. This would hardly be possible even when beating very gently for a period of say 8 hours. The proportion of fibrillæ may be from 10 to 20 per cent. of the whole weight of fibrous material, and it is impossible to say what length and dimensions these fibrillæ have. In the case of cotton, furthermore, it is often no easy matter to distinguish between the fibrillæ and the ultimate fibres, and the two are often connected. A fibre may be intact for a portion of its length, and at one end split off into brush-like fibrillæ.

With blottings, filter-papers, and such like, where the fibres are worked with sharp tackle and quickly beaten, it is easier to determine the length of the individual fibres under a microscope.

The most easily defined is a paper in which the fibres are cut with sharp tackle, and from new material.

	Lengths.		
	Min.	Max.	Mean.
	cm.	cm.	cm.
Linen (flax) fibres before beating ...	2·0	4·0	3·0

Mean length ... 30·0 mm.

	Diameter of Fibres.		
	Min.	Max.	Mean.
	$\frac{1}{100}$ mm.	$\frac{1}{100}$ mm.	$\frac{1}{100}$ mm.
Linen	1·2	2·5	1·85

Mean diameter ... 0·0185 mm.
Normal diameter ... 0·0160 „

Or, in inches the flax fibre would have a mean dimension of—

Length, 1·2 inch, or $1\frac{1}{5}$ inch.

Diameter, 0·00074 inch, or three-fourths of the mean diameter of the cotton fibre.

If raw flax is used for papermaking, and provided that it is incompletely retted or boiled, it may exist in the finished paper as filaments, in which case the filaments may be four times the length of the ultimate fibres; but under ordinary circumstances this is not so.

Flax is very liable to split up into very fine and long fibrillæ, which cover the field of the microscope between the other fibres. The presence of fibrillæ in flax pulp is due chiefly to severe mechanical treatment, often in the dry state before boiling.

The physical characteristics of flax fibres are very much destroyed in a fabric, as a result partly of weaving, heckling, &c., but chiefly to subsequent wear and washing; and, as a consequence, it often has an entirely different appearance under the microscope to an ordinary flax fibre—*i.e.* raw flax which has not been used for weaving. Fibres from tendered and well-worn linen rags differ very materially from the fibres from fine canvas, not only in strength, but in physical qualities generally, as well as in behaviour to chemical reagents. If the beating is carefully conducted and long continued, the fibres of strong stuff, particularly raw flax, may be drawn out almost to full length of fibres, in which case they may exceed an inch; but the average length of the fibres in any case must be much less than this, even in the strongest papers, and in short stuff some of the fibres do not exceed the length of one millimetre, or $\frac{1}{25}$th part of an inch.

REMARKS.—I have answered this at fuller length than would be expected from a student at the examination, but the *kind* of remarks and information as would be expected from a student are here given for his guidance. Any student qualifying for the examination should carry in his mind some approximate figures to the actual dimensions of the leading papermaking fibres. If he is unable to think or realise dimensions in millimetres, he should express himself in inches. If he cannot express himself in decimals of an inch for diameters, he should put down the number of fibres per inch when placed side by side; thus cotton would go about 1,000 per inch, linen about 1,450 before beating, but fewer to the inch afterwards.

QUESTION 2.—*What advantages are gained by using bronze in place of steel for beater bars and plates? State the materials in the preparation of which you would expect to secure the best results from the use of bronze.* (20 marks).

ANSWER.—By using bronze tackle the pulp is mellowed and works much softer, with the result that the fibres carry the water better, and, when making cartridges, &c., and kindred papers, the mellow greasy appearance is more easily obtained than when working steel tackle. The freedom from iron impurities is considerably greater, but if steel tackle is used in the breakers the advantage of using bronze in the beaters is neutralised to a large extent. The whole question is, of course, governed by the skill of the beater-man, and a good man will easily produce better results with steel tackle than an indifferent man with bronze tackle; but taken all round, the use of bronze for the stronger qualities of rag stuff and for the better qualities of paper gives distinctly better results.

Bronze bars do not rust when lying idle, and do not give rise to dissolved iron as steel bars do. At times verdigris is formed on bronze when lying idle, but not so readily as rust on steel bars, and it is not so objectionable as rust. If a bolt or nut gets between the bars the fracture is not so serious as with steel. The rust on a steel bar causes a bad and rounded edge or a jagged and uneven edge. The wearing away of a bronze bar keeps a square edge.

Bronze is better than steel where the work to be done is of a brushing nature. Bronze does not break like steel. Bronze does not vary in temper like steel. Bronze is not liable to burn or blacken fibres like steel. A good price can be got for old bronze bars, and the sharpening is more easily effected.

REMARKS.—Please note that you are not requested to give a comparison between bronze and steel bars. You are asked to hold a brief for bronze, and point out all its advantages and none of its disadvantages. As good a case, perhaps, could be made out in favour of steel bars. Steel cuts better, requires less power per ton of output, and does not wear down so quickly on its edge. At one time steel bars had all to be rehammered or discarded, but now they are often chipped *in situ*. For many purposes the presence of a little rust or metallic iron is of no consequence, therefore steel is preferred. Where the work requires the roll well down bronze would soon wear away, but steel would stand. Steel bars are only about one-quarter the price, &c., &c.

QUESTION 3.—*Mention the various forms of wood pulps, with their more particu'ar uses. Give a short account of their preparation from the original woods. What do you understand by a "strong sulphite pulp," and how would you determine whether a given sample conforms with this description?* (25 marks.)

ANSWER.—The botanical classification gives us the best clue. Thus the coniferæ give us the long fibres—the pine and spruce. They come in for wrappings and to strengthen "mechanical" for news and such cheap papers. When bleached they can be used for higher class, such as strong writings; and if the ultimate fibres are beaten and reduced they can be used in place of cotton and linen. Long beating and not reduced but bleached for banks.

The sulphate process is now in a large measure taking the place of the soda process. The "process" does not now determine the nature of the pulp so much as formerly. It is now possible to produce a sulphite pulp soft and so as to impart bulk, or hard nonbulking. The sulphate pulp can be made use of in place of soda wood.

The coniferæ belong to the gymnosperms. The fibres show pores or pitted vessels under the microscope if not too much reduced by boiling and chemical bleaching.

The cottonwood, aspen, poplar, &c., belong to the dicotyledons, and are exogenous—that is, they grow from the outside. The fibres are much shorter, and are used largely in the States in cases where we in England would use esparto. The effect, however, is not exactly the same. I believe the aspen is more often used in its bleached condition. They are prepared either by the soda, sulphate, or sulphite processes, or ground mechanically and sold as mechanical wood pulp. The chemical pulps are sold either as bleached or unbleached, moist or dry, according to circumstances. The mechanical is always, I believe, sold in the moist condition.

There is something in the nature of "mechanical" which would make it inadvisable to dry down. It should never be dried down below 50 per cent. water before being put into the beater. There are terpenes and other bodies essential to the proper working of mechanical that are removed on drying. Mechanical should always be made from unseasoned wood. Waste paper consisting chiefly of mechanical works "free" if remade. Few people seem to realise the fact that the volatile constituents of mechanical play an important part, and in estimating the moisture in mechanical, these volatile bodies are driven off with the moisture.

I understand by a "strong sulphite pulp," wood pulp chemically prepared by the sulphite process from a long-fibred wood such as *pinus sylvestris.* The pulp must be underboiled or incompletely boiled in such a manner as to leave a hydrated non-cellulose residue, from which the pulp largely derives its strength. The condition in this respect can in some measure be judged by the behaviour of pulps to certain reagents, a table of which I give on p. 141 from my own observations.

QUESTION 4.—*Describe the conditions which give rise to "blowing" in front of the first press rolls, and state the precautions you would take to prevent it when making thin paper on a close-textured wet felt.* (20 marks.)

ANSWER.—"Blowing" is usually caused by the presence of air between the wet felt and the web of paper, and may be cured in various ways; and to ensure that the conditions which give rise to it shall be avoided, the wet felt should be kept tight and the seam quite square, as otherwise the felt will become twisted and the texture much closer, so that the air will have much greater difficulty in getting away. The felt roll immediately in front of the press rolls should be slightly raised. Should "blowing" still continue, then a small roll run on the top of the paper may cure

Effects of Different Reagents upon Pulps.

Reagent.	A.	B.	C.	D.	E.	F.	G.	H.
1	Nil	Nil	Nil	Practically nil	Very pale brownish yellow	Very pale yellow	Bright yellow with reddish coat	Brilliant violet magenta
2	Faint reddish	Faint reddish brown	Faint reddish brown	Very faint brownish red	Do.	Do., with reddish brown tinge	Deep brickdust red with magenta fringe	Deep reddish brown
3	Nil	Faint yellow	Nil	Very faint yellow	Do.	Pale yellow	Primulene yellow	Brilliant primulene
4	Nil	Magenta, faint	Nil	Very faint magenta	Faint magenta	Pale magenta	Magenta red with bluish tinge	Bright magenta
5	Slight brownish coloration	Charcoal black	Slight brownish	Very faint brown	Very faint brown	Very faint brown	Charcoal black, mottled	Charcoal black
6	Pale blue band with slight reddish fringe	Oxford blue with reddish fringe	Pale blue band, reddish fringe	Cambridge blue, no red fringe	Pale Oxford blue	Pale Oxford blue	Greenish blue, developing deep Prussian blue	Greenish blue, developing deep Prussian blue
7	Nil	Reddish fringe, slight	Nil	Yellow centre with reddish fringe	Like D	Like D	Pale yellow	Nil
8	Nil	Nil	Nil	Very faint reddish tinge	Like D, but stronger tinge	Practically nil	Nil	Nil

Reagents.

1. Wurster's Gelbe Reagenslosung.
2. Wurster's Di-Losung.
3. Aniline sulphate, 5 per cent.
4. Phlorogluscine.
5. Cross and Bevan's ferric-ferri reagent, ½ per cent.
6. Strong sulphuric acid.
7. 1 per cent. bleach solution.
8. Water.

Pulps.

A. Bleached poplar pulp (American).
B. Unbleached sulphate pulp.
C. Bleached sulphate pulp.
D. Unbleached sulphite (Norwegian).
E. ,, ,, ,,
F. Unbleached sulphite.
G. News, 80 per cent. mechanical; 20 per cent. chemical.
H. 100 per cent. mechanical (paper).

it, or it may be cured by putting a suction box under the felt just before the press rolls, and thus drawing the air through the felt. This plan is most effective.

Another plan is to pass the web of paper over a small roll just before it goes under the press roll, but if the paper is very thin this often causes much broken.

REMARKS.—A little consideration will show that the "blowing" is due to air-locking, and some provision must be made either to prevent the air from reaching this spot or of removing it. The roll to lift the paper off the felt will allow air to escape, and a roll bearing on the top surface will cause the air to pass out sideways. The raising of the felt roll immediately in front of the press rolls persuades the air to escape at the highest point, and, of course, the suction box draws the air down through the felt. So long as the felt is maintained with open texture, the air can pass through. The pocketing of the air is due to press rolls, which prevent the air from coming further forward.

QUESTION 5.—*With bleaching powder of* 35·5 *per cent. "available chlorine" at* £4 15*s. per ton, calculate the value of the "chlorine" per pound and per kilo. A waste bleach liquor is tested, and found to contain* 0·01 *gramme "chlorine" per* 100 *c.c.: what quantity does this represent on* 963 *gallons of the liquid? Calculate the quantity of sulphite antichlor—$Na_2So_37H_2O$—required to "neutralise."* (25 marks.)

ANSWER.—To make the first calculation, the price per pound of "chlorine" is arrived at as follows:—

$$\frac{4\cdot75 \times 100 \times 20}{2{,}240 \times 35\cdot5} = \frac{9{,}500}{79{,}520} = 0\cdot119 \text{ shilling};$$

$$\text{or, } 0\cdot119 \times 12 = 1\cdot428 \text{ pence per lb.}$$

This would equal in kilogrammes—

$$\frac{1\cdot428 \times 1000}{453} = 3\cdot15 \text{ pence per kilo.}$$

The "neutralisation" by sodium sulphite takes place in the following proportion:—

$$Cl_2 = Na_2So_37H_2O$$
$$35\cdot5 \times 2 = 46 + 64 + 48 + 18 \times 7$$
$$71\cdot0 = 284$$

A waste liquor containing 0·01 Cl per 100 c.c. would equal 1 lb. per 1000 gallons; 963 gallons would, therefore, contain 0·963 lb. This would equal in crystalline sodium sulphite—

$$\frac{0\cdot963 \times 284}{71} = 3\cdot85 \text{ lbs.}$$

Remarks.—The above question is an extremely good test of a man's ability to work out this sort of problem. In nine cases out of ten, or perhaps ninety-nine out of a hundred, no formulæ are required; all that is necessary is a little thought and common sense. I always find the easiest way is to think for a moment, and then set down the vulgar fraction straight away, without the use of any formulæ. I have tried to make it plain how this may be done in the above answer.

Question 6.—*What advantages, if any, are obtained by running esparto over the presse-pâte previously to bleaching?* (25 marks.)

Remarks.—This question was evidently put to test the students as to their ideas regarding the economical production of the paper. As the bleaching previous to running the esparto over the presse-pâte is generally adopted, it is quite an open question as to whether the method of running the grass over in the green state is not the most economical in the long run, owing to the freedom from dirt which is thus obtained. The whole question turns on whether the price of the finished paper will bear the additional cost of having two presses-pâtes, taking into consideration the question of the requirements of the finished sheet as to cleanliness. I doubt very much whether it would pay to run the esparto over before bleaching in nine cases out of ten.

Question 7.—*What do you understand by* (a) *a neutral, and* (b) *an acid rosin size? Give working particulars for preparing and using them. What is an average dilution of the rosin size in the beater, and how is the rosin compound affected by the dilution?* (30 marks.)

Answer.—I understand by an "acid" size one made somewhat after the following:—

1,300 lbs. of rosin,
170 ,, soda ash,
200 gallons of water.

Ten gallons of which would contain—

58 lbs. of rosin,
7·6 ,, soda ash.

This would be considered an acid size, in that it has a considerable amount of free rosin (rosin being of the nature of a weak organic acid).

Its composition by analysis is—

	Per cent.
Combined rosin	40·59
Free rosin	14·37
Combined soda	6·72
Free soda	1·34

Dissociation may be said to exist even in a concentrated size, since it shows both free rosin and free soda, which, during the process of manufacture, may have been in combination. An acid size gives a milky solution, due to the presence of free rosin in suspension.

I understand by a "neutral" size, one in which there is a sufficient excess of soda present to keep the rosin from appearing in the milky form on reasonable dilution. Such a size is, however, in point of fact, generally strongly alkaline; and all, or nearly all, so-called "acid" rosin sizes are somewhat alkaline, due to the presence of some free carbonate or caustic soda. The rosin size should always be diluted and dissolved in water as little above blood heat as possible, to prevent coagulation of fine particles of rosin. The milky solution should be about 5° Tw. or under. It should be allowed to settle out any coarse particles or dirt, and strained through fine wire or cloth.

The dilution of rosin size in beater depends mostly upon the percentage of rosin on weight of paper stock used.

Taking 2 per cent. as an average on weight of paper, and the average dilution in beater at 5 per cent., or 1 in 20, the dilution of rosin in beater would be as follows :—

$$\frac{2 \times 1}{100 \times 20} = \frac{1}{1000} \text{ or } 0{\cdot}1 \text{ per cent. rosin.}$$

The effect of dilution upon rosin is to free it from its combination, or to bring about what chemists call dissociation. As the dilution increases so the dissociation increases, giving more free rosin in suspension, with a corresponding amount of free soda in solution. It is highly probable that the presence of the fibres may aid dissociation by what is known as dialysis and osmosis, aiding in the ionic dissociation. There is, furthermore, the chemical effect of the fibre substance, as the hydroxyls of the cellulose molecule have both acid and basic functions, and would tend to combine both with acid and basic substances.

When milk of rosin size is raised above a certain temperature (about the melting point of rosin) coagulation takes place. The rosin curdles into lumps and the solution becomes clear. If the heating is prolonged, more and more rosin curdles out from the clear solution. Heat, therefore, promotes dissociation in dilute solution, and it must not be forgotten that the temperature in the engine has a lot to do with the sizing effect got with rosin.

REMARKS.—The above question evidently calls for a more or less theoretical answer, especially the end portion. As not more than eight questions are to be attempted, the student who has not some theoretical knowledge could avoid this.

"February 28, 1904.

"To the Editor, PAPER AND PULP.

"SIR,

"With reference to Mr. Beadle's reply to Question 5 in your last issue, he appears to have calculated out his weights on hyposulphite instead of sulphite of soda, although the formula is written for the latter (excepting printers' errors). This makes the answer nearly ½ lb. too high.

"I should feel much obliged if he would give the equation by which 2 volumes of chlorine are neutralised by 1 volume of sulphite of soda. Other authorities appear to give 2 volumes of sulphite of soda to 2 volumes of chlorine, the equation being—

$$Ca(ClO)_2 + 2Na_2SO_3 = CaSO_4 + Na_2SO_4 + 2NaCl$$

If this is correct the answer is 6·85 lbs.

"Yours truly,

"SUPERFINE."

"March 2, 1904.

"To the Editor, PAPER AND PULP.

"SIR,

"In Question 5, Ordinary Grade, the chemical equation has been worked out wrongly.

"Mr. Beadle has evidently worked the equation out under the impression that sodium thiosulphate $Na_2S_2O_3$ was to be used instead of Na_2SO_3 sodium sulphite as per question. The calculation should be—

$$Cl_2 = Na_2SO_37H_2O$$
$$35{\cdot}5 \times 2 = 46 + 32 + 48 + (7 \times 18)$$
$$= 71{\cdot}0 = 126 + 126$$
$$71{\cdot}0 = 252$$

"Therefore a waste liquor containing 0·01 Cl per 100 c.c. would require—

$$\frac{0{\cdot}963 \times 252}{71} = 3{\cdot}42 \text{ lbs.}$$

"Perhaps this has not been noticed, so I send correction on.

"Yours truly,

"DARWEN."

"Laboratories, 15, Boro', London Bridge, S.E., March 7, 1904.

"To the Editor, PAPER AND PULP.

"DEAR SIR,

"I see in your issue of March 1, 1904, that 'Superfine' and 'Darwen' both write pointing out an error that I made in calculating the amount of sulphite necessary to neutralise the bleach as mentioned in Question 5, Ordinary Grade. I am much obliged to these gentlemen for having drawn my attention to this error, which was merely one of calculation, as will be seen on referring to my answer.

"'Superfine,' although he has spotted the error, has failed to give the correct figure for the answer, although he has stated the equation correctly.

"'Darwen,' however, has given the correct figure, namely, 3·42 lbs.

"'Superfine,' in asking whether any readers of your journal can tell him how to test for casein in paper in the presence of animal size, asks a very difficult question indeed. Millon's Reagent is reported to show a distinction between casein and animal size. This distinction cannot be made except, perhaps, between a perfectly pure gelatine containing no albuminoids and ordinary casein. When the gelatine, as is always the case in ordinary practice, contains albuminous matter, there is no further distinction by means of this reagent. The nitrogen estimation will, of course, not help you, neither will the precipitation with tannic acid. There is no simple means of distinguishing between gelatine and casein, and when it comes to estimating the one in the presence of the other, it is almost impossible. The distinction can only be made, in my opinion, by those who are expert in organic analysis.

"Yours faithfully,
"CLAYTON BEADLE."

QUESTION 8.—*Which type of refining engine would you put down to supplement the beating power for the preparation of stock for* (1) *Esparto printings*, (2) *News*, (3) *Typewriting papers*, (4) *Glazed casings? Give your reasons for the adoption of any particular type, and state what increase in the production you would expect to obtain.* (30 marks.)

ANSWER.—*Esparto Printings.*—Pearson & Bertram's gives a good result, as the action required is merely to rub out the knots and the unbroken papers which are present when "broken" is mixed with the esparto.

News.—Pearson & Bertram's will do good work on news stock, but if a Hibbert beater is used there is little need for a refiner. The Taylor beater is, as far as I can learn, thoroughly efficient and economical, and requires no refiner.

Typewriting Papers and Glazed Casings.—The Marshall type is the better form of refiner, as it mills the stuff in addition to clearing it.

Remarks.—A refiner may often add 25 to 30 per cent. to the beating power. One usually finds that in actual practice the horse-power shows no reduction, bu the papers show a distinct improvement, as the average beater-man likes to keep his beaters all furnished up, and, when the power is available, the stock gets the advantage of being much better milled.

I feel a great deal of diffidence in answering this question at all. To make a bald statement without any qualification is not justifiable. I was surprised to find the ordinary type of hollander so much in vogue in what are considered up-to-date news mills in the States. I can only judge that the horse-power is so much cheaper, and the horse-power per ton of stuff so much less, in consequence of the stuff flowing right away from grinders, &c. For an English news mill fed with sheets of pulp, I know of nothing to beat the Taylor.

The figures supplied to me by Messrs. R. & W. Watson, details of which were published in The Paper Maker, July 3, 1902, show the relative proportion as between the beaters and refiners by leaving out of consideration the breakers.

	Beater H.P.H. per cwt.	Refiner H.P.H. per cwt.	When power for Beater and Refiner is taken as 100. Beater.	Refiner.
New jute threads	9·69	2·30	80·8	19·2
New linen threads	15·59	4·21	78·8	21·2
Manilla rope	8·43	3·13	72·9	27·1
Sulphite wood	10·72	1·80	85·6	14·4
Mean of four materials			79·5	20·5

It will be seen from the above table that, taking the average for the four materials, about 80 per cent. of the power is expended by the beater, and about 20 per cent. by the Marshall refiner.

I regard the Marshall engine as the best for all high-class stock, but where mere rubbing out is required on news stuff, I am informed by a practical paper-maker that Pearson & Bertram's refiner is as good as any. The following are some practical details:—

The sole plate is of the usual box section construction, and on it is an annular casing which contains the refining discs, and is set high enough up so as to allow of these discs being withdrawn. The casing is bored out and lined with copper, and in the back there is fixed a disc, containing a fourth of the number of the bronze bars which are in the whole apparatus. The means of fixing in these bars is exceedingly simple, there being a dovetail groove turned out, to which the bars are made to suit; they are put in in four sections with hard timber dividers, and are all tangential to the centre.

The revolving disc is then put in, having bars let into it in the same manner as the back disc just described, the bars being in both sides of this revolving disc, radiating. The front disc is constructed in the same manner as the back disc, but is made to move out and in so as to give the necessary contact between the bars at the back and front sides of the refiner. The revolving disc is shrunk on a steel spindle, the ends of which project through the back and front discs, and is carried externally in long bearings. Attached to the front disc there is a cross-head connected to a screw with fine thread, which sits in the front disc and gives the necessary grade of pulp required to be produced. To prevent the revolving disc coming forward against the front disc by the pressure of incoming pulp, a simple arrangement is adopted whereby this is entirely overcome.

When the refiner is to treat pulp hard at one side and lighter at the other, a double contact arrangement is introduced, and where exceedingly thick pulp is desired to be treated, it is introduced at both sides of the revolving disc, the usual inlet arrangement being on the back disc only. A feed regulating box is applied to the top of the casing, and a regulating discharge valve fixed to the side, thereby giving the pulp the desired time in the refiner before being sent to the machine.

It is claimed, and I believe with good reason, that this refiner assimilates the various classes of pulp and produces a perfectly equal sheet of paper improving the clearness of laid papers and closeness of wove papers, and that it lessens the quantity of "broken" by brushing out all the unboiled particles which are apt to come on the edge of the paper and cause a break.

The function of a refiner possessing the above action is to improve the surface of the paper, and so allow the press and calender rolls to lie flatter on the paper, and allow high speeds to be obtained with greater ease. Refining is often an additional process to beating, and does not in every case necessarily relieve the beating operations either in point of time or power required. But it is frequently resorted to to impart qualities to the stuff that the beater alone is unable to give.

QUESTION 9.—*A water is found to contain—*

	Grains per gallon.
Lime	11·2
Magnesia	8·0
Sulphuric anhydride	8·0
Carbonic anhydride (expelled on boiling) ...	13·2

Express these results as parts per 100,000, *and give the chemical formulæ for the constituents. What chemicals would be required to soften this water?* (20 marks.)

ANSWER.

	Grains per gallon.		Parts per 100,000.
Lime	11·2	=	16·0
Magnesia	8·0	=	11·4
Sulphuric anhydride ...	8·0	=	11·4
Carbonic anhydride ...	13·2	=	18·9

On the supposition that the free carbonic acid expelled on boiling was in combination as bicarbonate of magnesia, and that the SO_3 is in combination with the lime, we should have bicarbonate of magnesia and sulphate of lime. Every 44 parts of CO_2 expelled would be equal to 84 parts of monocarbonate of magnesia, or 40 of magnesia.

Chemical formulæ of constituents—

$$MgCO_3,\ CO_2,\ CaSO_4,\ \text{and}\ CaCO_3CO_2$$

For softening this water I should use lime and soda ash, and, if containing matter in suspension, a little alum in addition. In such a water, to avoid deposition of a hard incrustation after softening, it would be advisable to use carboniser as is used in the Archbutt and Deeley process.

REMARKS.—To calculate the amount of each, it is merely necessary to work out the necessary amount of MgO to combine with the CO_2 expelled, and the necessary amount of CaO to combine with the SO_3. If there is CaO in excess, this would exist as $CaCO_3$.

QUESTION 10.—*Give a brief description of Bertram's vacuum ejector, and discuss its merits compared with the ordinary vacuum pumps for extracting the water from the paper in its passage over the wire. What saving in power would you expect to obtain when using the ejector?* (25 marks.)

ANSWER.—A box similar to the usual low water-box is employed, into which the water from the save-all below the wire is conveyed in the usual manner; connected with this box is a centrifugal pump, preferably of brass with a special impeller; the suction of this pump is connected to the low water-box by copper bend.

The functions of this pump are—

(1) To elevate the water to any ordinary height, such as that of the "Fullner" filter;

(2) To the mixing well on the sand traps; and

(3) To circulate the water through the ejectors.

There are two discharge branches cast on the casing, the inlet of the suction water being through the back cover.

On the vertical ascending discharge there is a patent automatic regulating and non-return valve, which, when the machine stops work, retains the column of water in the pipe above; and attached to this valve there is a lever connected to a float, which regulates the amount of water ascending in the vertical discharge, and maintains a regular head of water for circulating through the ejectors.

When two vacuum boxes are employed on the papermaking machine only one ejector is necessary; when three boxes, two are used; or for two boxes and a felt box, two are also necessary.

The water from the pump which is circulated through these ejectors is discharged from the branch on the under side of the pump.

The ejectors are simple—a conical regulating orifice with a valve is formed on the end of the regulating spindle to suit same, and diffuser with serrated blades, which cause the discharge orifice of the ejectors to be entirely filled. The discharge from these ejectors passes into the low water-box through a trumpet-shaped pipe.

The connections between the vacuum boxes and the ejectors are made by means of the usual copper pipe.

When the excess backwater is elevated up to the beater house a separate centrifugal pump is applied to the low water-box for this purpose, there being a division in the box over which the said surplus water flows into the suction of the separate pump; the automatic float and valve are dispensed with when this pump is used.

The benefits to be derived, as far as my knowledge serves me, are as follows :—

A constant vacuum is obtained, as from tests it has been found that, by applying a vacuum gauge to the usual plunger pumps, the pointer palpitated from zero to 10 lbs. constantly, whereas with the ejector the pointer remains stationary. More vacuum is readily obtained than is required for the average class of papers.

The clearances being small, and velocity of water high, practically no glutinous matter is allowed to gather in the pipes or pump, thereby broken paper is greatly lessened.

In some paper machines this single pump has taken the place of seven ordinary pumps, which were used for vacuum and backwater, consequently all the complications of piping and parts, also wear and tear, disappear.

With the modern papermaking machine one of these pumps alone, with a small one for pulp, constitute the entire pumping arrangements when the water is not to be lifted up to such an altitude as the tank in the beater house. In the latter case an additional water pump is employed as already explained. The power is the same as with the ordinary pumping arrangement.

I should judge—only on this point I have no definite information—that the regular and steady vacuum should be a great relief to the wear and tear on the machine wire.

QUESTION 11.—*Give a brief account of the substances represented by the following formulæ, and describe their ordinary commercial forms : $NaOH$, Na_2CO_3, $NaHCO_3$, CaO, $CaSO_4$, $Ca(OCl)_2$, $Al_2 3SO_4$. State what you know of the composition of ultramarine, smalts, china clay, casein, and gelatine.* (30 marks.)

ANSWER.—NaOH is caustic soda or sodium hydrate, and is used for boiling rags and wood; for making rosin size; at times put into the chest to give paper alkaline reaction; and sometimes used for softening water.

Na_2CO_3 is carbonate of soda or soda ash; used in the manufacture of rosin size; causticised with lime and used as above; used for water softening, chiefly to remove permanent hardness; used at times alone for boiling rags, and sometimes jute, &c.; used in conjunction with lime for boiling rags.

$NaHCO_3$ is bicarbonate of soda; seldom used, but can be used in place of soda ash.

CaO is caustic lime; chiefly used in lime-boil of rags, jute, &c., either alone or in conjunction with soda ash; used also for water softening, and for causticizing sodium carbonate and recovered soda. When combined with chlorine gas it forms bleaching powder.

$CaSO_4$ is calcium sulphate; used as terra alba and pearl hardening, as a loading material. The crystalline form is combined with the molecules of water. Can be produced as a by-product in the manufacture of soda bleach by adding salt-cake to bleach solution. It is the basis of permanent hardness of waters. Used at times for coating papers.

$Ca(ClO)_2$ is the formula for bleaching powder solution, and is called, chemically, calcium hypochlorite. It cannot be said to pre-exist in the powder itself, but is formed on stirring with water and allowing to settle. This solution is generally used direct for bleaching, but sometimes converted into sodium hypochlorite by addition of proper proportion of soda ash, and allowing the chalk formed by the reaction to settle out; or the $Ca(ClO)_2$ can be mixed with the requisite amount of salt-cake (Na_2SO_4), and the crystalline calcium sulphate ($CaSO_4 2H_2O$) allowed to separate out. The crystals of pearl hardening so formed can be used for loading, and the sodium hypochlorite used in the ordinary way as a bleaching solution.

$Al_2 3SO_4$ is sulphate of alumina, the commercial salt; is often associated with about 40 per cent. of water in the form of granular lumps; but more conveniently supplied as a nearly dry powder. The proportion of alumina (Al_2O_3) to sulphuric anhydride is generally not strictly in accordance with the above formula, the Al_2O_3 being generally in excess, in which case it is known as basic sulphate of alumina. The two chief uses of this chemical are for (1) the precipitation of rosin, and (2) as a controller and preservative of animal size or gelatine. In the case of (1) I am of opinion that the percentage of SO_3 is the real criterion of value, provided that there is no free acid. As a consequence, the nearer the formula approaches to $Al_2 3SO_4$ the better. In the case of (2) it appears expedient and safer to use a more basic sulphate of alumina, and that the criterion of value should be judged more from the percentage of alumina, provided that the product is not so basic as to render it at all insoluble in water.

There is a further use to which sulphate of alumina is sometimes put—namely, as a precipitant and softener for water. In conjunction with lime it forms flocculent alumina, which gets entangled with the other precipitated salts, aiding their subsidence. It furthermore carries down considerable quantities of organic matter, as well as all foreign matter in suspension, and so generally clarifies and purifies the water.

Ultramarine varies somewhat in composition. The compositions given in Thorpe's "Dictionary of Applied Chemistry" give for ultramarines rich in silica a calculated mean—

	SiO_2	Al_2O_3	Na_2O	S
German manufacture ...	39·25	26·72	20·08	11·97
English manufacture ...	42·00	24·40	18·67	13·92

Hoffmann says that the kind poor in silica and of a pale blue tint has the formula $4(Al_2Na_2Si_2O_8) + Na_2S_4$. According to Thorpe, ultramarine is probably a double silicate of sodium and aluminium, together with bisulphide of sodium.

"*Smalts*" is an unfading blue used where absolute permanence is required; but, on account of its high price and comparatively low tintorial power, it can only be used on high-class papers, such as hand-made ledgers. Thorpe gives its variation in composition as—

Silica	56–70 per cent.
Potash	12–22 ,,
Cobalt	6–16 ,,

It is really a potash cobalt glass or a mixture of potassium and cobalt silicates.

Ludwig's analysis of the German deep-coloured smalts is—

Silica	66·20 per cent.
Potash and soda	16·31 ,,
Cobaltous oxide	6·75 ,,

China clay is formed through the disintegration of felspars fairly free from iron. The felspar contains also mica and quartz, which have to be separated by agitation with water and allowing to settle. The finest deposits in the world are in Devonshire and

Cornwall. China clay is a silicate of alumina. Richardson gives the analysis of Cornish china clay at—

Silica	46·32	per cent.
Aluminium	39·74	"
Oxide of iron	0·27	"
Lime	0·36	"
Magnesia	0·44	"
Potash and soda water ...	12·67	"

Casein is a form of albumen. The composition would fall within the limits—

Carbon	50–55	per cent.
Hydrogen	6·9–7·5	"
Oxygen	20–24	"
Nitrogen	15–18	"
Sulphur	0·3–2·0	"

It can be got by curdling skimmed milk with dilute acid.

Gelatine consists of carbon, hydrogen, nitrogen, oxygen, and often sulphur. It approximates to the formula $C_{41}FC_{65}N_{13}O_{13}$, and, according to F. Davidowsky, the elements can be expressed in the following percentages :—

Carbon	49·1
Hydrogen	6·5
Nitrogen	18·3
Oxygen and sulphur	26·1
	100·0

QUESTION 12.—*State the practical details you would observe when making a thick chromo paper so as to ensure freedom from stretch and dusting in printing.* (25 marks.)

ANSWER.—It appears that most papermakers now depend on damping and supercalendering to give freedom from stretch, but unless the draws are nicely regulated when bringing the web over the machine, the liability to stretch always remains.

Dusting is often due to excess of mineral matter imperfectly held together by the bad sizing.

REMARKS.—Read PAPER AND PULP, June 2, 1902, and June 16, 1902. The question of moisture in atmosphere and finishing the paper in the right condition for the printing-room atmosphere, as well as the question of time and storage, have to be considered. I am of opinion that it is a somewhat difficult matter to arrive at the desired result without reducing the bulking qualities of the paper very considerably.

XIII.

Honours Grade.

1903.

Question 1.—*With Spanish esparto at £4 15s. per ton f.o.r., trace the increments of cost of the cellulose through the several stages of preparation up to the stuff chest.* (25 marks.)

Remarks.—It is useless to attempt a specimen answer. The idea is evidently to test the students' ability to deal with such questions. It would be a mistake to take a ton of raw material as a unit, as the calculation would be rendered so complex during the different stages as the material is found to lose weight. The simplest and most expeditious way, as far as cost is concerned, would be to take a ton of bleached beaten stuff as your unit and take such a quantity of raw material as would yield this amount. Thus, if you settled in your own mind that Spanish would yield 45 per cent. of unbleached or 40 per cent. of bleached stuff, in estimating the latter you would start with $2\frac{1}{2}$ tons esparto grass at £4 15*s.*, or £11 17*s.* 6*d.* worth of raw material. To this prime cost of raw material must be added, at the different stages, the cost (per ton of bleached stuff) for dusting, picking, boiling, bleaching, beating, &c., &c. The calculation for interest, depreciation, rent, and such-like charges can be averaged up and taken together at so much per ton of output. The coal can be dealt with in the same manner, or taken at the different stages of treatment.

Question 2.—*Draw up a scheme for the production of the following papers, showing the proportions of the various materials you would use, and their approximate cost per ton of finished paper—* (1) *Fine writings at 5d. per lb.*, (2) *E.S. printings at $2\frac{1}{2}$d. per lb.*, (3) *News at $1\frac{1}{4}$d. per lb.*, (4) *M.G. caps at $1\frac{1}{4}$d. per lb. State the average cost of production in each case.* (30 marks.)

Remarks.—The idea in setting this question is evidently to test how much the students know of the commercial part of the question which regulates the cost of the materials which must be used in order to produce any given grades, while allowing for a sufficient margin of profit. The whole point lies in taking into consideration the loss which, even when the best qualities of each material are employed, invariably takes place between the raw material and the finished paper. This would be likely to prove a stumbling-block to most of the students. For instance, in setting out the furnish for the fine writings at 5*d.* per lb., it is necessary to bear in mind that even new cottons at, say, £18 per ton will cost some

15 per cent. more than the price before they are made into paper, in addition to the usual loss through imperfect sheets.

The M.G. at 1¼*d*. is, of course, an impossibility, as it is not possible to produce an M.G. cap worthy of the name at less than 1¾*d*. per lb. The average cost of production, of course, varies with the processes which the various grades have to undergo; but in the case of the writings it should run about 35 to 38 per cent., while for the news and M.G. caps it should be from 25 to 30 per cent. Should the writings be plate-glazed the cost would be about 40 per cent. The figures vary very considerably with the methods adopted in the different mills.

In this question, as in the preceding one, such a quantity of material must be set down at the onset as would yield, say, one ton of paper. With a rag losing 25 per cent. for every ton taken, only 15 cwts. of bleached stuff would be obtained. In order, therefore, to obtain a ton of bleached stuff one must take—

$$\frac{20 \text{ cwts.} \times 100}{(100 - 25)} = 26{\cdot}6 \text{ cwts.}$$

A paper made from such a rag and found to contain on burning 25 per cent. of mineral would require just one ton of rag per ton of paper, because the loss sustained by the rag on treatment would just be counterbalanced by the gain due to added mineral.

QUESTION 3.—*Write a short general account of rosin-sizing, dealing particularly with the following points: (a) Proportion of soda to rosin; (b) effect of dilution before adding to the beater and in the beater; (c) hard and soft waters and use of back-water in the beater; (d) auxiliary action of colloidal alumina, starch, and cellulose; (e) thin and thick papers; (f) "wet" and "free" running on the machine.* (25 marks.)

ANSWER.—(*a*) For convenience and general economy the proportion of soda to rosin should be such as to produce a size in which at least about 25 per cent. of the rosin is in the free state. In ordinary practice this can be done when using between 7 and 8 parts of rosin to 1 part of commercial soda ash.

(*b*) The effect of dilution is to bring about a certain amount of dissociation into free rosin which in the water is held in suspension in a hydrated or flocculent condition, so that it cannot settle out on standing. If hard water is used, the lime salts act in decomposing the rosin size as follows:—

$$2C_{20}H_{29}O_2Na + CaCO_3CO_2 = C_{20}H_{30}O_2 + CaCO_3 + Na_2CO_3$$

Rosin size and bicarbonate of lime becomes rosin, carbonate of lime, and soda ash. The effect is here to undo the saponification of the size, just as though the carbonic acid had been passed through a solution of rosin size, a process that is made use of commercially for production of size containing a greater amount of free rosin. The permanent hardness of the water in a measure would react as follows:—

$$2C_{20}H_{29}O_2Na + CaSO_4 = C_{20}H_{30}O_2 + Na_2SO_4 + CaO$$

As the proportion of lime salts to rosin size is slight, this reaction does not cut much of a figure. The effect of the dilution in the beater is to further increase the above reaction both in regard to dissociation—$2C_{20}H_{20}O_2Na$ becoming $C_{20}H_{30}O_2$ and Na_2O —and decomposition, due to size being further mixed with lime salts. The milk of rosin may, for the sake of argument, contain 2 per cent. rosin ; on being added to the beater it may become 0·1 per cent. rosin. From 2 parts per 100 it has been attenuated to 2 parts per 2,000, or a dilution of 1 to 20.

(*c*) This is dealt with above and in answer to Question 7, ordinary grade.

(*d*) I do not regard colloidal or any other form of alumina as a sizing agent, not as I understand the term "sizing agent." Colloidal alumina has as its chief property the power of occluding organic matter (*i.e.* free rosin) and causing its more perfect retention by the fibres. It has, in addition, *per se*, a marked effect upon the qualities of the finished paper. It assists, in conjunction with the rosin, in the retention of mineral, and forms, with many soluble colours, the so-called lakes, which, being formed as it were *in situ* by the addition first of the colour and then of the sulphate of alumina, are faster and firmly fixed in the fibres.

Starch may be regarded as a sizing agent under certain circumstances, as it becomes one when the paper is calendered, more particularly so when the paper is plate glazed or friction glazed. The starch is changed into other substances by the joint action of heat and moisture. It serves to harden the paper, as well as to give it a better surface, and has a marked effect upon the working of stuff on machine. If boiled previous to adding to engine, and added either separately or with the size, it becomes a mineral retainer. There is a compound known as starch cellulose, discovered by Cross and Bevan, sometimes formed when starch is added to paper. Colloid starch is often added to keep up colloid rosin.

Colloidal cellulose, in the form of viscose, is a powerful mineral retainer. At the time of its precipitating it holds the minerals and pigments, preventing subsequent loss on the sand-tables and backwater. Its other and perhaps more important function is its strength-giving qualities. This is a quality which cannot be claimed either for starch or rosin, except, perhaps, in very weak papers.

(*e*) It stands to reason that thin papers require more rosin, &c. than thick papers. Within certain limits of thickness there is no difficulty.

(*f*) A "wet" stuff requires less sizing than a "free" stuff, the wet stuff being in itself somewhat of a sizing agent. I have met with an extreme case of a fibre working so wet that it could not be operated upon the machine, and with difficulty only in the hand mould. The waterleaf when dry would bear ink as well as any tub-sized paper. The same is the case, only in a less degree, with all wet-working stuffs. Stuff working wet saves gelatine in the tub-sizing. Stuff working free requires often a large percentage to give it ink-bearing qualities.

QUESTION 4.—*State your ideas as to the future of electricity as a motive power in the paper mill, and describe what you know of its application at the present time.* (25 marks.)

ANSWER.—Paper mill manufacturers are fast awakening to the saving to be effected through the application of electricity to the driving of papermaking machinery. Cases are very rare in which a very considerable saving cannot be effected by adopting electricity as a driving power. The necessary machinery for the manufacture of paper covers very considerable floor space, resulting in either long lines of heavy shafting and considerable counter-shafting in order to drive from a single engine near the boilers, or in several engines distributed over the works at considerable distances from the boilers. With either arrangement, no provision for spares is practicable, hence the breaking down of a main engine results in the shutting down of the whole plant.

By the application of motors, the shafting and counter-shafting losses are practically eliminated, and the motors can be so distributed as to really provide spares, rendering a complete shut-down only the remotest possibility. All machinery not in continuous use can be shut down quickly, and therefore no power whatever is used in driving such machinery or its shafting except when actually in use.

Owing to counter-shafting and long transmission lines, more power is lost than is actually required to operate the small machines, such as reelers, cutters, &c. This loss is almost entirely eliminated by the use of electricity.

In general, however, machinery in paper mills can be profitably operated by electricity. Some electricians think that paper-machines which use steam-engine and exhaust steam for drying the paper are more economical. The efficiency of steam-driven plants is sometimes low, and as the power lost in driving the shafting is practically constant, regardless of load, the efficiency of operation rapidly falls with light loads.

It has been the experience of the Westinghouse Company that electrical installations in paper mills will pay for themselves in from two to five years. Electric driving is undoubtedly the future motive power for paper mills, as it allows of the greatest saving in cost of operation and requires little attendance. The repairs are small, the motors occupy little space, large speed variations can be obtained economically and quickly, extensions can be made easily, and, as a natural consequence, the output of the mill is almost invariably increased by from 5 to 10 per cent.

REMARKS.—Electrical engineers are now so far assured that they are able to guarantee large savings in many instances. There is, however, something in the criticism that the electric plant is replacing old and wasteful plant, and that the same percentage saving could not be shown against an up-to-date steam-plant. Personally, I have never been converted to the theory of economising exhaust steam for drying cylinders, although I have seen a lot of it in practice, and read and heard arguments on both sides. As to the advantages of electric drive for paper-machines, I should have thought there could have been no difference of opinion. The exhaust steam used for cylinders should not be subject to the vagaries of the engine-driving, which may or may not be equal to the drying requirements. I am inclined to think that although theory points to the steam-engine exhausting into cylinders as being more economical than steam-engine and independent supply to steam-drying cylinders, a little common sense and less theory would reveal the fact that exhaust steam into the drying cylinders is the wrong thing from an economic and practical point of view in nine cases out of ten. There might be one case in ten where the exhaust steam system would pay, but I doubt it. When electricians tell us (or some of them) that a steam-engine is more economical than a motor merely because the exhaust steam is usable for heating the drying cylinders, I fancy they must be misled by papermakers who still advocate this view.

One of the great advantages of electric drive, apart from the question of economy, is being able to know at any moment just what power your machine is absorbing, because if you know you can generally so control your machine as to save some of the power.

QUESTION 5.—*What tests can be applied to stuff in the beater to follow the progress of beating? Sketch a plan of systematic records in regard to the preparation of the stuff. How can the beating be influenced by chemical means?* (25 marks.)

As regards the length of the stuff, at the early stages of the beating the appearance and feel and travel are a sufficient guide. As the beating advances the progress can be judged by drawing a wire through the stuff from centre to midfeather and lifting it horizontally. The way the stuff lodges on the handle of the wooden stirrer as it is raised nearly horizontally from the stuff will tell an experienced beaterman at a glance the condition of the fibres at the early stages. Where great care is necessary in clearing the fibres and bringing them to the right length, a little stuff is taken in a rubber hand-bowl from different parts, so as to secure an average mixture. A second hand-bowl is taken with some water in it, and the water and stuff poured backwards and forwards from one hand-bowl to the other. The stuff is diluted down by periodically adding additional water and allowing it to overflow into the beater until separate fibres can be seen floating in the liquid. The stuff is then poured carefully and slowly from one hand-bowl to another. If the stuff is not cleared, or if the stuff contains knots, there is no difficulty in noticing them as the stuff overflows the lip of the hand-bowl. It will be noticed, furthermore, that the fibres set themselves in one direction, according to the direction of the current, and an experienced beaterman can readily judge whether the fibres are reduced to the necessary extent, and obtains a general impression of the felting qualities of his stuff. The whole process does not take longer to perform than to describe.

The rate of flow in a beater can be observed by following the suggestions as indicated in Parts VI. and VII., "Theory and Practice of Beating," *see* The PAPERMAKER, November 1 and January 1, 1903. "A rough-and-ready way is to put a streak of colour right across the stuff just as it leaves the roll, and to observe how long it takes to get back to the same spot and so make a complete revolution, the distance of which can be got at by calculation if it is desirable to find the rate of travel." For information as to systematic records see above-mentioned articles.

The beating can in certain cases be hastened by chemical means. The stuff can be tendered by acids in cases where short and free stuff is required and where strength is of little moment. Rags and jute can be piled up after lime boil, and allowed to ferment and get hot prior to beating. The chemical treatment can be made to dispose of three-fourths of the power for beating, but except for special purposes the stuff is useless. Alkaline substances cause a slipping and easier motion of the fibres, under such conditions the circulation is promoted and the beating more readily accomplished. For obvious reasons, however, these expedients cannot be resorted to in ordinary practice.

Waxy substances sometimes form on the sides of beater which alter the skin-friction, and so in a measure alter the travel. I am of opinion that when these substances are formed the stuff travels better and that there is less friction.

QUESTION 6.—*How would you proceed to produce a "featherweight" printing at 2½d. per lb.? Schedule the materials you would* *use and the practical details you would observe in the manufacture in order to impart the desired characteristics to the finished sheet.* (25 marks.)

ANSWER.—*Featherweight.*—Some mills are now producing a fairly good featherweight from bleached sulphite, but at 2½*d.* per lb. a good esparto paper can be had. The preparatory processes are as usual, but the bleaching must be done quickly, and all the machine-tackle must be worked so as to give as large a bulk as possible. The wet felt must be of a close texture so as to avoid a felt mark, which only heavy rolling will cover up, and the press rolls and couchers must be hung a little so as to give as much bulk as possible.

REMARKS.—Much has been written in PAPER AND PULP from time to time on the subject of the bulking of paper which, in a measure, would assist in framing an answer to the foregoing question.

QUESTION 7.—*Give a general account of hard and soft waters in relation to* (a) *steam raising,* (b) *the papermaking processes. A water contains, per* 100,000 *parts,*—

$CaCO_3$ (*as bicarbonate*)	... ...	18·5
$MgSO_4$	... ...	9·4

Calculate the chemicals required to soften per 100,000, *and show the advantages of using the softened water in the case of an esparto mill.* (30 marks.)

ANSWER.—As to steam raising, the hardness of water is a decided objection, as it produces scale in boilers, which makes the plates less heat-conducting and increases the coal bill, and is particularly objectionable and sometimes dangerous when there is oil in the water. Carbonate of lime alone would not be so serious, as this salt forms either a powder or a soft incrustation which is easily removed. When carbonate of lime is associated with sulphate or with magnesia salts, the incrustation is often very hard and difficult to remove. All very soft waters have a tendency to corrode the steam-boiler plates. This does not take place in presence of alkalies or lime salts, hence it is advisable to leave about 3 degrees of hardness in a softened water, unless there is a very small amount of carbonate of soda in excess. If a boiler has been run for a few days on hard water, so as to give a thin coating of lime salts, it can then be put on to soft water without any fear of corrosion to the plates.

For the purposes of papermaking hard water has its advantages. It assists the papermaker to produce neutral or slightly basic paper. It gives to certain high-class papers a finish and appearance perhaps impossible to get in districts supplied only with soft water. It can with greater safety be conveyed and stored in a paper mill in wrought or cast-iron pipes and tanks without dissolving out iron. It has the disadvantage of consuming considerable quantities of alum in the chest or engine, because the hardness of the water has to be neutralised or overcome before the alum can have its proper effect upon the rosin. On the whole, I consider a water containing up to 21 degrees of hardness is a decided advantage for papermaking (apart from the steam raising).

The advantages of a soft water are that it does not consume alum, and possibly it may produce a softer paper if desired. There are, however, some disadvantages in the use of a water that is naturally soft. Such a water is often a surface or moorland water, and more or less coloured with peaty and organic matter, and is more likely, in my opinion, to contain iron and other things likely to discolour a high-class paper. A hard water is often derived from underground sources, perhaps at a considerable depth from the surface, and has undergone a natural filtration, and is often clear and colourless. These rules, however, do not always hold good. A soft water corrodes tanks and pipes, and becomes discoloured by the dissolved iron, which is liable to affect the colour of the paper. Soft waters, especially those derived from moorland, are liable to act upon lead pipes, but this is stopped if a slight trace of carbonate of soda be added, or when the water does not contain less than three grains of lime salts per gallon.

$CaCO_3$ requires CaO for its precipitation.
100 requires 56 by theory.
100 requires 60–70 Buxton lime by practice.
$CaCO_3$ would require, say—

$$\frac{18{\cdot}5 \times 60}{100} = 11{\cdot}1 \text{ parts of lime per } 100{,}000$$
$$= 15{\cdot}9 \text{ grains per gallon}$$
$$= 15{,}900 \text{ grains per } 1000 \text{ gallons :}$$
$$\text{or, } \frac{15{,}900}{7{,}000}\text{, say } 2\tfrac{1}{4} \text{ lbs.}$$

The following extract from Mr. Harold Collet's book on water softening and purification gives the necessary information demanded in this question :—

"Sulphate of magnesia is very soluble in water, 10 lbs. of cold water dissolving 3 lbs. of it. Its solubility is also much increased by rise of temperature, and it is not liable by itself to cause any scale or deposit in boilers, although further on it will be shown that it has some action in this direction when in company with certain other substances. Nor is it corrosive or destructive to boiler plates, so that by itself it has practically no effect in a boiler. It does not even cause priming to any appreciable extent, but it very much hinders the removal of lime salts, and may thereby make itself exceedingly objectionable. This has already been mentioned when speaking of quicklime, where it was stated that its presence impedes the application of the lime (or Clark's) softening process pure and simple, by reason of the formation of sulphate of lime. An example will make this point clearer. Let us take a water containing of

Carbonate of lime	... ...	10 grains per gallon
Sulphate of magnesia	... ...	10 „ „

The hardness, as indicated by the soap test, will be about 18 degrees, but its scale-forming power in a boiler will only be 10 grains per gallon, due to carbonate of lime. If the water be treated with lime to remove the carbonate of lime, we may get rid of 7 grains of carbonate of lime, while the sulphate of magnesia will be decomposed, magnesia hydrate will be precipitated, and sulphate of lime to an equivalent extent will remain in solution. The water will then contain

Carbonate of lime	... ...	3 grains per gallon
Sulphate of lime ...	... ...	11 „ „

The hardness will be about 11 degrees by the soap test, but the scale-forming power will be 14 grains per gallon, as against 10 grains before treatment, while the resultant scale will be much harder than that made by the untreated water.

"In such a case as the preceding, soda must be used to decompose the sulphate of magnesia. The decomposition of sulphate of magnesia by carbonate of soda is different from that of sulphate of lime. When treated cold, the precipitate is a mixture of carbonate of magnesia, hydrated oxide of magnesia, and water, having the composition—

$$4MgCO_3MgH_2O_2 + 9Aq.$$

When the solution is boiled, the greater part of the water is driven out, and some of the carbonic acid, and the precipitate becomes—

$$3MgCO_3MgH_2O_2 + 3Aq.$$

The second kind of precipitate is less soluble than that first described, which explains the superior results obtained by treating magnesian waters hot. Caustic soda is a better precipitant than the carbonate of soda, as it produces the highly insoluble hydrate of magnesia; this is generally mixed, when treated cold, with some of the more soluble carbonate and hydrate mixed precipitate first described, owing to the presence of carbonic acid in the water; but if the water is treated boiling, the precipitate is nearly pure hydrate. Instead of using caustic soda, carbonate of soda may be used, with the addition of sufficient lime-water to combine not only with the carbonic acid in the water, but also with that in the carbonate of soda, which is thus partially causticised, but this method is inferior to the caustic soda process, and rarely gives such good results."

QUESTION 8.—*What do you know of the requirements of an "imitation art"? Give an approximate furnish for this grade of paper at 2¾d. per lb., and state how you would treat it in the various processes from the wet end to the cutter in order to get the best results.* (20 marks.)

ANSWER.—*Imitation Art.* — Furnish Spanish esparto, well boiled, fairly beaten, and well closed on the wire, a good pressure on couchers and press rolls, dry felts well tightened, and water doctors used on the machine calenders, so as to impart a smooth finish and cover up the wire and wet felt marks. The coucher must be regulated so as to avoid too pronounced a wire mark, and the finer the mesh of the wire the better the results will be obtained.

Another case in point. Our furnish would be 75 per cent. esparto and 25 per cent. soda wood, our engine broke in six, 30 to 33 per cent. china clay (or rather these figures in ash). The sizing exactly as for an E.S. writing. Stuff must be fine and fairly free. Fine for two reasons—(1) to carry the loading; (2) to take away the lumpiness or flaky appearance usually on the surface of printing and supercalendered papers. Our water doctors fixed on the first stack calenders. (Some mills have a small stack of three before this, the idea being to lay down the hairs usually seen on the surface of an esparto paper before treatment at the water doctor.) You are aware, of course, that the calender roll on which the doctor is runs *away* from the water, carrying a layer of water right on the roll. The roll being treated causes water to boil or effervesce as it passes in the "nip" in that condition. The underside of the sheet is treated in a like manner on the other side of the rolls, one nip lower, of course. Two stacks of calenders are used for drying and glazing (heated by 10 lbs. steam), each roll having a doctor to catch the fluff and prevent sticking. About the best way to see any difference between water-glaze and supercalendering is to compare the STRAND and WINDSOR magazines. The water used for water finish is either distilled water or condensed steam water. A small addition of rosin size is quite as good as any one of the many preparations.

QUESTION 9.—*Criticise the expression "breaking length" of papers, and show where it fails as a comparison of actual breaking strains. What do you propose in its place? Propose such tests of "opacity" and "surface" or finish as admit of numerical records.* (25 marks.)

ANSWER.—In answer to the first part of this question, I cannot do better than refer readers to the recently published pamphlets on the "C.B.S. Units."

On the second part of the question very little work has been done. I devised a simple instrument whereby the opacity of different papers could be measured and referred to a standard. The expression "opacity thickness" designates the thickness of the number of sheets in millimetres necessary to extinguish the light when seen throughout a distance of one foot from a one-candle-power lamp. The opacity number of the paper, which is dependent upon thickness as well as upon fibre substance, is the number of thicknesses of papers required at one foot from standard lamp to obliterate light. Being now engaged in a series of researches in reference to this matter, I am hardly in a position to express a definite opinion as a standard for opacity. For more detailed information, see PAPER AND PULP, March 15, 1902.

O. Winkler has been also working on the same subject (see PAPER TRADE REVIEW, March 7, 1902), and quite recently Dr. Klemm, of Leipzig, has devised a very ingenious machine for the purpose (see PAPER AND PULP, October 1, 1903). No definite suggestion appears to have been made for a standard of surface. The surface might be measured optically by measuring the reflection. If a ray of light were made to strike a paper at an angle to its surface, an unglazed paper would be illuminated, and would reflect back the light *en masse;* but if the paper was glazed or surfaced, the reflection would make the same angle with the surface of the paper as the angle of incidence. A fairly simple instrument could, I think, be devised that would take advantage of this in such a way as to admit of the reflection being measured, and give a numerical expression of the "surface" of any paper. This method is at present undeveloped.

The only other process for determination and comparison of surface, as far as I can ascertain, is what may be termed the frictional method. It is based upon the frictional resistance of the surface of the paper, by observing the rate at which a weight will travel down the surface of a paper when placed on an incline, or the angle of incline at which the weight will begin to move. I am informed that the first and perhaps the only papermaker to institute a method of this sort was the late Mr. Thomas Tait. As far as I can ascertain, his method was to place a piece of paper upon a hard, rigid surface, such as a piece of plate glass, and a weight upon its surface, which should be the same in all cases. The glass bearing the paper to be tested was slowly inclined or tilted, and the tilting continued until the weight *commenced to slide.* The angle of tilt would give you the "surface" or smoothness of the paper. The smaller the angle of tilt, the greater the surface or smoothness, and *vice versâ.* Possibly Mr. Thomas Tait's native game of curling suggested this method to his mind. This mode of testing and comparing the "surface" appears the most feasible one, and one that might be easily applied in ordinary practice.

As regards "surface" as it appeals to the touch or feel, the frictional method appears the most feasible; but from the point of view of "surface" judged from general appearance, an optical method would be the best criterion. As an instance, I would mention that the suitability of an "art" paper to receive half-tones should be judged in a measure by the frictional method, whereas the liability of an art paper to produce "fatigues of vision" should be judged and measured by the optical method.

QUESTION 10. — *Describe how you would proceed to convert 10 tons of jute bagging into a strong cartridge paper, and schedule the duration of each stage, with the percentage of chemicals, steam pressure, and temperature of bleaching solution. State how you would prevent chlorination of the fibres, when obtaining as white a colour as possible, consistent with retaining the strength and the yield of finished paper you would expect to obtain.* (25 marks.)

ANSWER.—The yield of finished paper, considering that the colour required is not high enough to cause waste by chlorination of the fibres, should be about 47 per cent. of the weight of the jute treated.

Chlorination takes place most readily when boiled jute is exposed to an atmosphere of chlorine gas. The chlorination is less and bleaching action more when boiled jute is treated with bleaching powder solution. To further avoid chlorination as far as possible, I should recommend removing as much non-cellulose as possible by boiling and washing prior to bleaching. Further and more detailed information on the treatment of jute appears in back numbers of PAPER AND PULP, where the subject of lime-boiling is fully discussed in "Answers to Test Questions."

QUESTION 11.—*Give a classification of raw fibrous materials and commercial half-stuffs (1) according to chemical characteristics; (2) according to the main types of paper which they are used to produce.* (25 marks.)

ANSWER.

Lignified Series, with Greater Lignification at Top—

Mechanical wood.
Jute, unbleached.
Straw, unbleached.
Hemp, unbleached.
Sulphite wood, unbleached.
Sulphate wood, unbleached.
Soda wood, unbleached.
Soda wood, bleached.
Sulphite wood, bleached.

Cellulose Residue Series—

Bleached esparto and straw.
Bleached flax or linen rag stuff.

Pecto Series—

Unbleached flax.

Seed Hairs—

Cotton.

Oxycelluloses, with Highest at Top—

Bleached straw.
Bleached chemical aspen.
Bleached esparto.
And all paper stock that has been over-bleached.

Hydrocellulose—

Tender rag stock.

Cellulose Hydrate—

Linen beaten "wet," whether from flax or linen rags.

Undercooked, unbleached sulphite, more particularly when used straight from digester.

Possibly bleached straw, more particularly after wet storage.

TRADE CLASSIFICATION.

Writings, Drawings, Cartridges—

Linen.

Cotton.

Bleached chemical wood.

Loans and Banks—

Linen and flax.

Sometimes carefully prepared bleached sulphite (*coniferæ*).

All beaten wet.

Filter Paper and Blottings—

Formerly nearly all cottons, but now linen properly manipulated, and a growing tendency to use certain kinds of wood. Sometimes about 10 per cent. mineral, but preferably none.

A further and useful classification can be made in accordance with cellulose percentage, which would run somewhat on the lines of lignification series, except that bleached wood would come at top, instead of mechanical.

OTHER PARTICULARS.

Typewriting Papers—

Cotton.

Linen.

With growing tendency to use chemical aspen or short-fibred bleached wood.

Best Book Paper and Best Periodicals—

Edition de luxe, rag, hand-made and machine-made.

Esparto, best printing qualities, stronger when mixed with bleached chemical.

Straw, 5 per cent. added to harden.

Printing Papers—

Chemical wood or mixtures of chemical and mechanical down to 80 per cent. mechanical for news.

For Process Printing—

Imitation "art," containing esparto, chemical wood, and clay.
The best art, containing esparto and coated.
The worst art, containing mechanical 60 per cent., chemical and clay, and coated.

Strong Wrappings—

Hemp flax and underboiled, unbleached chemical wood.
Cable Paper should only contain hemp.

REMARKS.—The above is by no means a complete classification, but merely by way of example.

QUESTION 12.—*Whether do you consider it to be more economical to supplement the steam-raising plant by installing a forced draught apparatus with mechanical stoking, or by adding an additional boiler and firing by hand? State which type of forced draught and mechanical stoker you consider most efficient.* (25 marks.)

ANSWER.—In most cases it appears that the most economical method of firing is to have one boiler more than is actually required for work and to fire by hand. If a forced draught must be used, some people prefer the Meldrum without the improved. Some consider the "Koker" stoker is the best from their experience. The Dennis has found much favour of late, and their so-called "improved 'Koker.'" Years ago the Vickers mechanical stoker was largely used.

The writer made many trials some years ago with mechanical stokers and forced draughts on different qualities of coals. The question of hand firing *versus* forced draught is largely dependent upon quality of coal used. If a good stoker uses his head as well as his hands he can save a lot of coal in hand firing, and a man in charge of mechanical stokers can waste a lot of heat if he is a fool.

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