MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

PRESIDENT'S REPORT

FOR THE

Year ending Sept. 30, 1874.

BOSTON:
PRESS OF A. A. KINGMAN.
1875.

PRESIDENT'S REPORT.

To the Corporation of the Institute :—

Your attention is respectfully asked to the report of the Secretary, and accompanying documents.

The aggregate attendance for the year was 310, a decrease of 65 from the previous year. This decrease was probably due in great part to three obvious causes: (1), the financial crisis which came upon us so suddenly at the beginning of our year, and almost entirely cut off the usual accession of special and advanced students, who join the school after the opening; (2), the increase of the fees from $150 to $200 per annum, which now first took effect; and (3), the increase in the requisites for admission, the elements of French and solid geometry having been added to the requirements of the preceding year. And while these additional requirements, especially the French, were poorly met, and not rigorously enforced in the admission, it is still certain that they influenced the result. The second cause named is known to have changed the intention of some; but it is very probable that the first cause, and which is still operating, was the most potent of all.

It is well known that the success of the previous year was marred by the crowded state of our building. The size of the lower classes made a division into four sections necessary for the proper instruction in some subjects, which made an additional number of lecture and recitation rooms desirable; and in these respects but little relief has been experienced during the past year. Some relief has been afforded by professors using their private rooms more freely for small classes in their own departments; but I am obliged to again ask your earnest attention to our want of room for the proper development of several departments of the school. Nothing more can be done in our present building for perfecting and expanding the work already entered upon; and particularly in the higher departments of instruction upon which, finally, the real rank of our school must rest. No matter how good the instruction involved in our courses may be, nor how perfect the appliances, we shall bar the way to all high aims and results, if we do not in all possible ways encourage a spirit of investigation, and furnish the amplest opportunities for the most advanced instruction, and particularly for scientific research, the most powerful stimulant for both teacher and taught. It is evident that the proper buildings and equipments cannot be had without a large expenditure, and after they are obtained, cannot be maintained without a large current expense; still, if we would attract the highest grade of students, and especially if we would do all in our power to give the proper rank to industrial education, and thus aid, through research in connection with the higher instruction, and through the thorough training of our graduates, in properly developing the wonderful resources of our country, these expenditures must be met. I hope to be pardoned, if I seem too earnest in again pressing this subject upon your attention; but it cannot be, if the facts in the case were fully known by the public, that there would not be a hearty and generous response. The erection of our proposed Chemical Laboratory building, for which the State has already generously given us a site, would give the needed relief, and would probably be all we should require in the way of buildings for some years to come.

Professor Charles H. Wing, who has charge of the department of Analytical and Organic Chemistry, during the temporary absence of Professor Crafts, says that "the room at the disposal of the department is not sufficient for instruction in Analytical Chemistry, many processes must be omitted for want of suitable arrangements for conducting them with safety, and the Professor has viewed with considerable apprehension certain operations, too important to be omitted, involving, for want of a proper room, some danger to the student and also to the building. But Analysis is the mechanical portion of Chemistry and were instruction to cease there, the student would, on graduating, have neither a knowledge of applied chemistry, nor any idea even of the scientific methods of modern chemists, would only be qualified to do the drudgery, to be the 'hewer of wood and the drawer of water' to the chemist proper. The instruction should go farther than this; and the time now allotted in the revised course for laboratory work and the zeal displayed by the students now in this department will, in the opinion of the writer, render it possible to complete the necessary analytical work during the Third Year, leaving the remaining year to be devoted to the study of practical and scientific chemistry. Omitting any discussion of the wants of the department of applied chemistry, if the erection of the new Chemical Laboratory is to be delayed, there is an almost imperative demand for a building of one story, practically fire-proof, affording to the department of analytical and organic chemistry additional room say 30 x 50 feet, more if practicable, less if needs be, but at all events some room properly fitted for chemical research (and for such operations in analytical chemistry as should not be done in the present laboratories) ready to be occupied at the commencement of the next Collegiate year."

I also ask your attention to the able and interesting statement of Professor Ordway, as an important part of this presentation.

The Courses of Instruction. During the early part of the year much time was devoted to a revision of the courses of instruction. It had become apparent not only that too much was asked of the students in all the courses, but that the amount required in the different ones was quite unequal, as was also the work of the different years in the same course. These difficulties had grown gradually by the addition of new subjects, and also by the desire of each Professor to make his own instruction as complete as possible. A new course in Metallurgy was established for those who found the mathematics of the Course in Mining too difficult, and preferred to devote more time to the chemical side of their profession. To meet the wants of the increasing number of students who do not wish to take any of the strictly professional courses, two new ones, one in Physics, and one in Philosophy, were added, and all of them were made distinct from the beginning of the second year, instead of the third, as heretofore. This extension of the strictly professional studies over three full years will prove of great advantage in all the courses. These revised courses went into operation, with few exceptions, at the middle of the year; and although a few more changes will from time to time be found desirable, yet I think that they have substantially solved the difficulties.

Graduation. The question is sometimes asked why so small a proportion of each class graduates, and whether it is not mainly owing to the fact that the courses are too difficult for the average student?

Year.	*Total.*	*Special Students.*	REGULAR STUDENTS.				*No. of Graduates.*	*Percentage.*
			1st Year.	*2d Year.*	*3d Year.*	*4th Year.*		
1864-5	27							
1865-6	72	9	32	31				
1866-7	137	27	64	24	22			
1867-8	167	43	56	37	14	17	14	.518
1868-9	172	63	57	23	22	7	5	.156
1869-0	206	54	68	45	24	15	9	.141
1870-1	224	77	73	36	17	21	17	.304
1871-2	264	84	91	39	33	17	11	.193
1872-3	375	140	115	61	27	32	31	.309
1873-4	310	128	68	59	34	21	16	.219

To answer this question properly we should, in the first place, deduct all special students, as is done in the above table. In the second place, we should also deduct those who take all the studies of the first year without the intention of graduating, which is probably not less than twenty-five per cent. of each entering class; but this allowance has not been made in computing the percentages.

It is undoubtedly true that in the past, inadequate preparation, and an over crowding of the courses, have been efficient causes; but they are no longer controling with the majority of students. It quite frequently happens that a good student takes a strong dislike to a particular subject, and prefers to give up his degree rather than to continue it; and another supposes that by dropping some subject, which he regards as not vital, he will be able to do better in the remaining studies, a supposition which is seldom realized. There is, however, a growing desire on the part of students to graduate, and this, with better preparation for admission, and a better adjustment of our work, will from year to year increase the percentage of graduates in each class.

Theses. This is the first year in which the graduates have presented their theses before the final examination, a change which has been found feasible by the relief afforded in the revised courses during the second half of the fourth year. The general excellence of these theses, and the marked ability of several of them, certainly justify the change. Your attention is called to the abstracts on page 81 of this report.

Preparation for Admission. The High Schools and Academies of the country are, in general, becoming from year to year, more distinctly schools of science and the modern languages, and whatever tends to improve them for the education of the large numbers whose school days end with graduation from them, will the better adapt these schools to fit students for admission to the Institute.

We still need a better preparation for admission to be able to do well in four years what seems desirable: and I take this opportunity to respectfully ask the attention of teachers who may be called upon to prepare students for admission to the Institute, to this subject. We now require "arithmetic (including the metric system of weights and measures), and algebra through equations of the second degree, plane and solid geometry, French grammar through regular and irregular verbs,[1] English grammar and composition, rhetoric, (so much as is included in the first part of Bain's Rhetoric, or its equivalent), and geography. In general, the training given at the best High Schools, Academies, and Classical Schools, will be a suitable preparation for this school."

To make more clear what we still wish to accomplish in the near future, I will also quote from the Catalogue the scheme of our First Year's work.

ALL COURSES. — FIRST YEAR.

			No. of Exercises	Hrs. per week
1	Algebra finished	1st half	45	3
	Plane and Solid Geometry reviewed	2d half	15	3
	Plane and Spherical Trigonometry	2d half	30	3
2	General Chemistry	1st half	60	6
	General Chemistry	2d half	30	2
	Qualitative Analysis	2d half	30	4
3	Structure of the Sentence	1st half	30	2
	Rudiments of Logic	2d half	30	2
4	French		90	3
5	Mechanical Drawing and Elements of Descriptive Geometry and Perspective		90	6
6	Free Hand Drawing		90	3
7	Physiology and Hygiene	2d half	30	2
8	Military Science and Tactics		60	2

We will refer to the subjects in the order given in the scheme. In the mathematics, one-third of the time was spent in a review of what was required for admission. This seemed necessary on account of the inequality in the preparation of

[1] "The amount of French at present required is embraced in Part I. of Otto's Grammar, and the first twenty-five pages of Bôcher's French Reader, or their equivalent."

different students. In the near future we must ask preparation in logarithms, and a few other subjects in algebra, and plane and spherical trigonometry, which will enable us to complete analytic geometry and calculus by the end of the second year, and thus give two full years for analytic mechanics and applications.

We are not likely to ask any preparation in chemistry for some time to come; and yet every secondary school should have a small and inexpensive chemical laboratory in which the elements of the subject should be thoroughly taught. With such aid we could make our general course in chemistry, which ends with the first year, much more complete.

The preparation in English is defective, not perhaps that the student is ignorant of the facts of history and literature, but because he has neither skill, nor ease, nor even accuracy in the use of the language. The remedy is not in the study of history and literature, but in the study of the structure of the language, and a constant application of the few general principles involved, until they become fixed in the memory and in the habit so firmly as never to be forgotten or disused. An occasional exercise in composition is not sufficient. An exercise in writing, in some form or other, should be the one never to be omitted for a single day, until, first, accuracy, and second, facility of expression, have been acquired. A ready use of the language should be made of the greatest aid in the study of all other subjects. What can be clearly expressed must be clearly thought, and no test is of so much value as a written examination.

In French the preparation was better than in the previous year, but upon the whole, not satisfactory. There will be a gain from year to year, and we wish to increase the amount until we can get about twice as much as is now required. This will enable us to complete the general course in this language at the end of our first year, and give proper time in the following years for German.

Free Hand and Mechanical Drawing and the Elements of Descriptive Geometry will soon be well taught in the best schools, and we shall be relieved of most of our first year's work in these subjects.

Believing that these changes will be for the elevation of all the schools involved, we earnestly ask the aid of our fellow teachers in making them a reality.

Discipline. The discipline consists almost entirely in the examinations, all of which are written. The intermediate examinations are those which are held once in about four weeks and occupy one hour, the time of the ordinary exercises. No time is allowed for preparation for these examinations, nor are they allowed to interfere with the current work in any department. The papers are carefully read and marked on a scale of 100. The marks are recorded, and also communicated to the students for their information and guidance. Besides the above, there are the semi-annual and annual examinations. While these are in progress all the exercises of the school are suspended. The position of the student is determined by these examinations. At the semi-annual examinations the record is, passed, passed with conditions, can continue as a special, and dropped. At the annual examinations the record is, passed, passed with conditions, can continue as a special, must repeat the year, and dropped.

Department of Military Science and Tactics. This department has always labored under two serious difficulties; (1), the want of a fixed policy to guide and limit it, and (2), the want of a suitable hall, conveniently situated, in which to give the practical, and by far the most important part of the instruction.

It ought perhaps to have been expected that a subject, entering so little into the main purposes of the school, would be simply tolerated, rather than welcomed, by both teachers and pupils; and that this want of sympathy should have given rise to more care and anxiety than has been demanded by any other department. On this account, also, there has been a wide diversity of opinion as to the exact place it ought to hold in our scheme, and particularly with what detail and rigor the instruction should be given. These have been the vexed questions upon which the Faculty have year after year deliberated; only to find, that no sooner was one settled, than another equally important in the opinion of some one, would arise to take its place. Thus, year by year, had we approximated towards a practical solution of the problem, when, as you are aware, the whole subject was put into the hands of a special committee whose able report adopted June 16, I include for the information and guidance of all concerned. The conclusions were only reached after a careful consideration of all the questions involved, and with the aid of all the experience which the Faculty could offer; and I believe that the opinion entertained by some, that our school was becoming too military in its character has had no foundation in the past, and will have none in the future, other than that which can be fairly drawn from the facts and conclusions of the report. There has been no intention on the part of any one, so far as I know, or even wish, to give the military element undue prominence and importance, much less to convert our school into a military one.

My only desire has been to make it as efficient and valuable as possible, within the limits assigned to it. This has been simply my duty in the matter, and in short the only course which could prevent the department from becoming a demoralization and disgrace to the Institute.

The want of a suitable hall for drill, which could be reached without loss of time, and without discomfort in bad weather, has been a constant source of trouble and embarrassment to the department. This want was carefully considered by the committee and the plan submitted and adopted as the one, which upon the whole, seemed most feasible to meet the pressing emergency, was carried out during the summer vacation; and I now have the pleasure of reporting that we have an excellent building 155 feet long by 50 feet in width, and one story in height, covered with corrugated iron and a slated roof, containing a light and well ventilated drill-hall, with ample space for gun-racks, wardrobes for uniforms, and boxes for those who use the gymnasium.

Physiology and Hygiene. A large number of our students live on the lines of the railroads leading into Boston, and find it convenient to remain in town all day. They must therefore either dine in the city or bring a lunch, which for the sake of economy is done by the larger number. The result is that these students remain in the building all day, and seldom take the proper exercise, and in bad weather none, except what is got in travelling to and from their rooms, or homes. This want of exercise and a proper midday meal, taken at the right time and under favorable conditions, is having effect upon the health of our students, and is a much more serious matter than hard study. Where the health of one student is injured simply by over study, the health of many is injured by want of exercise, or other preventable causes, while over study is usually the only cause assigned. It is true that each class hears an excellent course of lectures on Physiology and Hygiene, but it is to be feared that too few make a personal application of what is taught them, and thus fail to gain what this instruction is mainly intended to impart. I am deeply impressed with the conviction that a radical change in this department is necessary, and that the laboratory system is quite as important in this as in other departments of the school. To make the instruction of the greatest value to each student it must be applied practically in each case; and while I am not now prepared to advocate a compulsory system of gymnastics, I am satisfied that incalculable good would come from a more personal application of the instruction, with opportunities for systematic exercise under the direction, not of a mere gymnast, but of a physician who had made this application a matter of special study. If our students lived in dormitories, as at most colleges, or so near each other that their spare time could be spent in out-door athletic sports, the case would be somewhat different; but there is probably hardly another school in the country where the students are so thoroughly scattered, and such exercise had, if at all, at so great disadvantage.

Our only remedy therefore, in addition to what is afforded by the drill to only a portion of our students, is a gymnasium. I take advantage of the delay in the issue of this report to briefly indicate what has been already done in this direction. When the drill-hall was finished we took immediate steps to fit it as a gymnasium. The apparatus which could be best placed against the wall is fixed; but that occupying the central portions of the hall is so arranged, that it can readily be raised a sufficient height from the floor as not to interfere with the drill. By this means the hall has been made equally available for both uses. This gymnasium is open to all the students from early morning till 9 o'clock in the evening. We have also availed ourselves of the opportunity which the drill-hall has afforded us to establish, by way of experiment, a *lunch room*, where professors and students and their friends can get a well-cooked and well-served dinner or lunch, as desired, at a very reasonable cost; so reasonable as to induce those who have depended upon a cold lunch to do so no longer. Dinners, or lunches, are served from 12-30 to 3 P. M., during which time all can be accommodated. Dinners consisting of soup, fish, meat or poultry, dessert, and a cup of tea or coffee, is served for 35 cents, and a lunch at a correspondingly low rate.

In this matter the Institute assumes no responsibility or expense, except that no charge is made for rent or for fuel used in cooking. We fix the prices charged; and the quality of the food, the cooking, and the manner of serving, must be satisfactory to us. In spite of the imperfect conveniences, the experiment thus far has been unexpectedly successful; and if it shall continue equally so in the future, it will be desirable to provide better accommodations, which can readily be done at a very small expense. Then good board can be obtained at from three dollars to three and one-half a week. I trust that those members of the Corporation who have not already done so, will make a personal examination of this matter, and thus be able the better to judge of its importance and bearing upon the welfare of the school.

I cannot close without acknowledging the energy and zeal of Lieut. Zalinski in the erection of the drill-hall, and his valuable service in equipping the gymnasium, and superintending the lunch room experiment.

Lowell School of Industrial Design. In my last report a pretty full account of the establishment of this important department was given, with such indications of success as so short an experiment seemed to justify. Although a good proportion of the students of the First Year returned, it was by no means sure that their zeal and perseverance would not flag before they were at all qualified to enter upon their professional work with a fair prospect of success. But the results of the Second Year have fully realized all reasonable expectations, as I think the facts set forth in Mr. Kastner's report show. In another year some of the students will probably complete the prescribed course and be entitled to the proper diploma, or certificate of proficiency.

The Zoological and Palæontological Laboratory. This laboratory has been fitted up in the building of the Boston Society of Natural History for the joint use of the Society and the Institute. Here Professor Hyatt gives his instruction in Palæontology, and also his course in Comparative Zoology, in the third year, and the laboratory work of the fourth year to students in the course of Natural History. This gives the best possible opportunity for the convenient and proper use of the valuable collections and library of the Society, under the direction and care of the Society's own Custodian. In this way is the Society aiding to place within reach of all the amplest facilities for study in all departments of Natural History.

Department of Mining Engineering. On the first of January, 1874, after nearly five years of efficient service as Professor of Mining Engineering, Professor Rockwell resigned his professorship to accept the responsible position of Fire Commissioner o the City of Boston. The duties of the Chair were divided between Professors Ordway, Hunt and Richards, and we were particularly fortunate in being able to have the instruction continued without a break by Professor Rockwell's associates in the department. The mining laboratory has been improved during the year by the addition of such machines as were found necessary to carry on the required work.

Department of Architecture. The work in this department is now arranged in two courses; one of four years for regular students, leading to the degree of Bachelor of Science; and the other of two years for special students which includes all the drawing and architectural instruction of the longer course. For admission to this special course no examination is required; the applicant must be sixteen years of age, and if he wishes to take additional studies, must be examined if the subjects require it. This shorter course is arranged for those whose time and means are limited.

Department of Mechanical Engineering. In my last report Professor Whitaker gave the plan of the kind of laboratory which it was thought desirable to build up to aid in the instruction in this department, and also adapted to the solution of any new problems which might arise in relation to steam and power, and such other questions as are involved in their use. I have now great pleasure in calling your attention to Professor Whittaker's report showing what has been done during the year towards carrying out the proposed plan. This marked and substantial progress is mainly due to the timely aid of Mr. George B. Dixwell, who has not only furnished us with a large part of the means, but what is far more important, has set us a definite problem of the highest scientific as well as practical importance to solve, thus imposing conditions of a very high order, and at the same time aiding us with the knowledge and experience gained by years of study and reflection upon the nature of steam. It is difficult to conceive of a more fortunate combination of circumstances, and at the same time used to better advantage than they have been by Professor Whittaker; and it is my pleasure as well as duty to testify to his zeal and ability in carrying out his plans, regardless of all personal sacrifices. The interest of the students of this department in this laboratory has been so marked, and their aid so valuable as to be entitled to special mention and commendation. We still need, to make this laboratory as complete as possible with the space at our disposal, a few of the most approved machine tools, and whatever else may be necessary to furnish a small shop.

The Society of Arts. This important department merits more attention from the Corporation. The meetings for the year have been fairly well attended, and the communications have been of more than common interest and value. The Secretary has given a fuller report than usual, which is an improvement over the very condensed abstracts of previous years. The value of the report would be increased by a still more liberal summary of the records; but this cannot take the place of a monthly bulletin in which a full record of the meetings can be given. This form of publication, more full and frequent than the annual report, and more permanent and convenient than any newspaper report, however good, can be, would increase the interest in the meetings and improve the value of the communications, because much more care would be taken in their preparation.

Again, the Society needs better facilities for exhibiting in operation the various kinds of machinery, subjects of interest and instruction to all. The extension of our laboratories will in time furnish to the members better opportunities for experimental researches than we can now offer, and add very much to its effectiveness as a Society of the Industrial Arts. Your attention is respectfully asked to these considerations.

Department of Civil and Topographical Engineering. The instruction in this department has been continued substantially as in past years, except that more attention has been given to the practical details of bridge construction. In this subject, as also in hydraulics, and particularly in water-supply and drainage, there is need of fuller instruction in the practice, that the graduates in the department may be as well qualified to enter upon these subjects as they are upon railroad construction. The subjects of water-supply and drainage are rapidly growing into prime importance, and it is extremely desirable that the students should have the advantage of the widest and best experience which can be obtained. If the instruction as now given could be supplemented by courses of not more than thirty lectures each, on bridge construction, and water-supply and drainage, to be given on alternate years to students of the third and fourth years, by an engineer of large experience, and illustrated by some of the excellent examples to be found in the vicinity of Boston, nothing more would be desired. This addition would not overburden the course, nor add largely to the expense of the department; nor would it be difficult to find one among the many able and experienced engineers of this city, who would undertake to give this instruction.

On May 30, 1864, the Committee on Instruction reported through its chairman, President Rogers, the "Scope and Plan of the School of Industrial Science of the Institute," in which it was proposed to establish laboratories for instruction and research in several of the leading departments. In order that we may readily compare what we have been able to accomplish during the past ten years towards realizing the proposed plans, I quote from the report the part relating to this subject.

"The laboratory arrangements of the school are designed, when complete, to embrace the following departments:—

1. A Laboratory of PHYSICS AND MECHANICS.
2. A Laboratory of GENERAL CHEMICAL ANALYSIS AND MANIPULATION.
3. A Laboratory for METALLURGY AND MINING.
4. A Laboratory for INDUSTRIAL CHEMISTRY.

While intended primarily for the instruction of the students, these laboratories will be used for the prosecution of experiments and investigations on subjects referred to them by the Committee of the Museum or the several Committees of Arts, including the examination and testing of new machines and processes, and the conducting of original researches in the different departments of applied science; and in these critical studies and experiments the advanced students may, when expedient, be permitted to assist.

Laboratory of Physics and Mechanics.

In this laboratory, it is proposed to provide implements and apparatus with which the student may be exercised in a variety of mechanical and physical processes and experiments. Thus he may learn practically the methods of estimating motors and machines by the dynamometer, of experimenting on the flow of water and air or other gases, and of testing the strength of the materials used in construction. He may become familiar with the adjustments and applications of the microscope; be practised in observing with the barometer, thermometer, and hygrometer; and, in a room fitted up for photometry, may learn the mode of measuring the light produced by gas and other sources of illumination, and the value of different kinds of burners, lamps, and their appendages.

Laboratory for General Chemical Analysis.

In this laboratory, provision will be made for a complete and comprehensive course of instruction in qualitative and quantitative analysis,—embracing organic as well as inorganic substances,—and blending lectures with the systematic practice of the laboratory.

Students proposing to take the course will be expected either to have passed through the first two years' teachings of the Institute, or to be possessed of such knowledge of general chemistry and physics as these preliminary studies are intended to impart.

Besides this general and extended course, it is proposed to have certain partial courses, in which students having a special object in view may obtain instruction of a specific kind, without going through the entire range of laboratory training. Such would be,—

1. Exercises in Organic Analysis.
2. Exercises in Blowpipe Testing.
3. Household and Commercial Analyses, including the Testing of Waters, Detection of Adulterations in Food, &c., Alkalimetry, Acidimetry.
4. Chemical Toxicology, Detection of Arsenic and other Poisons.

Laboratory for Mining and Metallurgy.

Connected with the general laboratory, but forming a distinct department, will be a laboratory of mining and metallurgy, designed for special instruction in whatever relates to practical mineralogy, the chemical valuation of ores, and the operations of smelting and other processes for the separation and refining of metals.

In this department, students already trained to some extent in analytical processes will be exercised in the examination and discrimination of rocks and minerals by mechanical and chemical tests, including a course of practice with the blow-pipe; and will be taught the several methods of assaying the ores and alloys of copper, iron, lead, silver, and other useful metals, as well by the dry as the wet method; of analyzing the fluxes used in the smelting furnace, and the slags resulting from the blast; and of determining the combustible value of the mineral or other fuel with which furnaces are supplied.

In aid of these instructions, the student will have the opportunity of studying the models of mines, and of mining and metallurgical implements and machinery and the collections of rocks, fossils, minerals, and ores, with their manufactured products, provided and arranged specially to facilitate his studies in this department.

Laboratory for Industrial Chemistry.

It is further proposed to connect with the general laboratory a department of industrial chemistry, where students may have an opportunity of becoming practically familiar with the materials, implements, and processes of the more important chemical arts and manufactures.

In this department will be provided a collection of dye-stuffs, mordants, discharges, and other substances used in the operations of dyeing, color printing, and bleaching; together with such apparatus as may be necessary, on a small scale, to exemplify these several processes as in actual use.

Here the student will have access to suites of specimens, embracing the crude materials and products of the glass and pottery, and brick and tile manufactures, the different soaps, soda ash, bleaching salts, acids, saline products, lakes, pigments, inks, cements, tanning substances, and other materials and products of the chemical arts; and will be provided with facilities for studying practically the re-actions and processes connected with their use and manufacture.

Provision will also be made in this laboratory for the practical illustration of the chemical modes of engraving and lithography, and for exhibiting the various methods and processes of electro-metallurgy as applied to silvering, gilding, and the deposition of copper and brass."

It will be observed that two objects were contemplated in the establishment of these laboratories; first, the instruction of the students as a part of their general education, and second, to afford opportunities for investigation in special subjects, in which competent students might participate, or even conduct the research under proper direction and supervision. Thus far our means and energies have been mainly expended in providing for the instruction, the provision for special investigation being incidental, and limited to such inadequate space and resources as are at our disposal. We are now, however, the better prepared by the experience of the past years, to enter upon this wider field, and can but hope that the near future will provide the means to attain this most desirable end. When this is done we shall be much better prepared than now, in some important particulars, to attract graduates of our own and other institutions to us for advanced and more comprehensive courses of study.

Railroad Fares. The average age of students entering the Institute has gradually increased with the increase in the requirements for admission. On this account the number of those living on the lines of the railroads, and coming within the rule of half fare while under eighteen years of age, has been growing relatively less. I have now the pleasure to report that during the year, at my solicitation, all the roads, with a single exception, have abolished the rule and now carry all our students without reference to age at the reduced rates. For this important reduction in the expense of a large number of our students the thanks of the Corporation of the Institute are due.

In closing this summary of our very satisfactory year's work, I must recognize two important conditions as always largely influencing the amount and quality of the instruction. The first is found in the fact that so many of our students come to the Institute from choice, with a more or less well defined purpose as to the preparation they desire for the duties of active life, and are not sent by parents or guardians against their wishes. This indicates a maturity of character and a seriousness of purpose, upon which we have found it entirely safe to rely in all our dealings with our students. We grant, that in the above respects they are men, and not boys, and our discipline is shaped in accordance with this fact. We insist upon respectful conduct, and entire honesty in all examinations and other exercises, and the least infraction of these general rules makes it undesirable to continue the student's connection with the school. Instances where such discipline is needed are exceedingly rare, and made so, mainly, by the spirit which prevails among the students in relation to the causes of it.

The other condition is found in the devotion of all the teachers to the interests of the school. That all should conscientiously perform all assumed duties is expected and requires no special remark; but in the building up of laboratories, and best adapting them to the purposes of instruction, particularly in departments where there was little or no experience to guide, there was needed knowledge, and energy, and above all patience and faith. So many of our Professors have commanded success by the devotion of all their time and energies, and in addition, by contributing liberally of their private means, that the fact is worthy of special mention and recognition.

Deeply grateful for the measure of success which has rewarded the labors of the year, I close this report,

J. D. Runkle, *President.*

SECRETARY'S REPORT: 1873-74.

There have been during the year eleven meetings of the Society of Arts, at which the average attendance was seventy-five.

Nov. 13, 1873. Mr. Frederic Ransome, of England, read a paper, illustrated by specimens, experiments, and diagrams, on "Discoveries in the Manufacture and Uses of Artificial Stone," with special reference to the process which bears his name.

Of the processes, his was one of the earliest and most successful, he having commenced his experiments more than thirty years ago, with hard silicious sands and cements of various kinds under great pressure. These proving unsatisfactory, he employed with the same sands a concentrated solution of soda or potash in the form of a silicate. With silicate of soda as a liquid, he mixed chloride of calcium in solution, and produced a stone of flinty hardness, which he could mould into any form; the silicate of lime thus formed in the stone is practically indestructible in the air, and the chloride of sodium is removed by washing. With silicate of potash a firm stone is made, disintegrating under the influence of heat, the soda stone being affected by moisture. The setting takes place quite rapidly, and the insolubility is in proportion to the amount of silica.

The experiments of Mr. Ransome fully proved, in opposition to the statements of chemists, that the silicate of lime thus formed was a permanent stone. It has been subjected to the extremes of heat and cold, with sudden transition from one to the other, to acids, and to various gases, with no effect on its structure. Being nearly all silica, it is practically indestructible; having no oxidizable constituent, it is unalterable in the air; being impermeable to moisture, it cannot be injured by frost. It may be used for any purposes of construction or architectural ornament that natural stone can be employed for. It has been used for twelve years in Europe, and for some time in Chicago and San Francisco.

His latest form, called *apœnite*, grows stronger with age, may take any color by the use of metallic oxides, and may be made almost anywhere, as the materials are very common, thus saving the expense of transportation.

Prof. T. Sterry Hunt followed in some remarks, showing how this method imitates processes of nature on a grand and beneficent scale.

Prof. Ordway made some further practical statements on the composition and uses of water-glass and hydraulic cement, both involving some of the principles of Mr. Ransome's process.

An automatic Elevator Brake was also exhibited at this meeting.

Dec. 11. Mr. J. P. Putnam exhibited his invention for lighting gas by frictional electricity, by the simple turning of the gas cock, avoiding the danger and the trouble of the use of matches. No perishable material is used, brass and ebonite, or hard rubber, being the principal ones. The apparatus was tested several times before the meeting, and it was as certain in its action as it was simple and durable in its construction.

Mr. Horace McMurtrie read a paper, with illustrations, on "Sectional Boilers," and especially on the form known as the "Wiegand Boiler"; he described also the "Miller or American," and the "Exeter" boilers,—all of cast iron, which is claimed to be the best conductor of heat, and the safest material to guard against destructive explosions. All such boilers are open to the objections of many joints exposed to the direct action of the fire; of unequal expansion and contraction; of insufficient circulation from the divided state of the water; and of inaccessibility for purposes of examination, repairs and cleaning; each joint is an element of weakness, and the system of hanging tubes is disapproved by many engineers.

Jan. 8, 1874. Mr. Samuel Batchelder, of Cambridge, presented a dynamometer of his invention, with a detailed description of the same. It is applicable both to steam and water power, for heavy or light machinery, and affords the means for accurate measure of power exerted.

Prof. Whitaker then read a paper on shafting as a means of distributing power, alluding to some of the old-fashioned methods of shafting mills, some deviations from these methods in use, and others contemplated. Without wishing to condemn the prevalent use of light, rapidly-rotating shafting, he stated, that, though this appears to consume much less power than heavier shafting, the difference is far less than is generally believed; the gain, he thought, was more in the use of better materials, more careful workmanship, and more perfect lubrication, than in the increased speed of the lighter shafting.

Jan. 22. Mr. Albert K. Mansfield, of Lowell, made a communication on the "Theory of Turbines," passing in review the four principal methods of converting the power of water in motion into useful effects, viz.: 1, by *impact*; or allowing the water to impinge on planes, or floats in motion, set at right angles, or nearly so, to the direction of the flow; 2, by *pressure*; the water pressing on the floats in motion, but so confined as to move no faster than these; 3, by *reaction*; of the water flowing from orifices against their walls; 4, by *deviation*; of the water from the direction in which it tends to flow, according to the principle that a body resists deviation from straight line motion. The action of water in wheels is often a combination of two or more of these methods. He gave the theoretical formulæ in each of these cases.

Prof. Whitaker drew attention to the indefinite way in which the word *theory* is used, as distinguished from *practice*. The popular, and a very mischievous, belief is that practice is opposed to theory; practice may be opposed to *hypothesis*, which many mistake for *theory*. Theory, in its true sense, means the *whole theory* of a scientific problem, all disturbing elements having been considered, and thus is the same as practice. When an incomplete theory is under discussion, its incompleteness should be stated, and then we should hear no more of the supposed, but really non-existent, antagonism between theory and practice.

Feb. 12. Mr. David Renshaw described from a model a new form of sectional boiler, of his invention, which had been in successful operation for several months in Hingham, Mass.

The material is cast iron, and the form that of the reverberatory furnace. This form secures the hottest part in the crown or arch, and by a gradual increase from below upward; the boiler is of a corresponding form, being in its outer portion a true half circle, giving the reverberatory form of furnace and drop flues; all the fire surfaces are directly over the grate, and are very large. The circulation is rapid, and cleaning easy; none of the joints, always a fruitful source of trouble in sectional boilers, come in contact with the direct action of the fire; they are very few, and very accessible. His plan retains the colder, heavier water in the lower portion of the boiler, where it ought to be — a great security against explosion from sudden rise of pressure.

Feb. 26. Mr. Horace McMurtrie read a paper on "Boiler Explosions no Mystery" — being a careful review of the facts presented in the Report of the "Hartford Steam Boiler Insurance Company."

He alluded to the well known causes, of defective materials, faulty construction and form, and especially the ignorance and carelessness of those having charge of boilers. Improper riveting and insufficient bracing, safety valves overweighted or corroded in their seats, inaccurate steam and water gauges, defective setting, inattention to the supply of water, neglect of inspection, were in turn taken up. He gave the record of nearly 12,000 defects discovered in a single year by the inspectors, from the examination of a very small proportion of the boilers in the United States, and of these nearly 2900 were dangerous.

He thought the mystery was that, under the circumstances, more boilers did not explode.

March 12. Mr. J. R. Robinson read a paper, in answer to Mr. McMurtrie, admitting the facts stated, but citing numerous cases which had come under his official investigation, where the explosion of boilers could not be accounted for by any of the conditions above named. He believed that there was a mystery in the causes of these explosions, and that the only safe way was to investigate this mystery, so important for the users of steam.

March 26. Mr. Stephen M. Allen read a paper on "Light and Heat, and their relation to Steam."

Mr. Guthrie made a communication on the Morton Ejector Condenser, explaining its construction by diagrams. This condenser dispenses with the air pump; the exhaust steam escaping from the cylinder is so directed as to unite in a jet with the injection condensing water, by which it is condensed — having first, however, imparted a sufficient velocity to the combined jet, to enable this to issue direct into the atmosphere in a continuous impulsive stream; the contents of the condenser, both water and air, are thus ejected without the use of the pump, and without impairing the vacuum maintained in the condenser.

An interesting discussion took place on various points suggested by this communication.

April 9. Prof. A. Graham Bell occupied the evening in remarks on "Visible Speech," or the "Science of Universal Alphabetics," a system invented in 1864 by his father, Prof. A. Melville Bell.

In this system sounds are represented by symbols indicating the positions of the vocal organs assumed during their production. These may be arranged in a linear series, like letters, forming an alphabet capable of representing the sounds of all languages — a system of universal alphabetics.

He illustrated its application in teaching the deaf to speak. In the deaf the vocal organs are perfect, and the deaf have hitherto been dumb simply because they cannot hear and imitate sounds, and because the concealed mechanism of speech cannot be seen. By his system the deaf can see how to place the tongue, lips, etc., for the production of every sound, and thus to speak. The system was first introduced in England in 1869, and in America, in Boston, in 1871; it has been attended with remarkable success, and is now extensively used in this country for the education of the deaf and dumb, a class fortunately now not neccessarily dumb because they are deaf.

Its value was demonstrated to the audience by several pupils of his. The system is now adopted by the Boston University.

May 14. Mr. A. C. Cary, of Malden, made a communication on a process, invented by himself, of weaving on a rotary loom. It both knits and weaves at the same time, making a very strong, non-elastic cloth, of any desired width, a yard a minute, and at a very cheap rate. Specimens of this fabric were exhibited.

Mr. E. H. Hewins then read a paper on some of the principal points of difference between the American and European systems of iron bridge building, in which he gave his reasons for preferring the former.

May 28. Mr. Robert B. Forbes read a communication on the best means for preventing collisions at sea, and of strenghtening vessels.

The importance of the so-called Maury lanes, now adopted by the Cunard Company, was dwelt upon. The necessity of the adoption of some such plan has been demonstrated by a series of recent terrible disasters.

He advocated the frequent use of the steam whistle in a fog, sounded so as to indicate the general course of the ship. He dwelt also on the necessity of having ships with double bottoms, without openings between engine room and fire room, or between coal holds and fire room, except in the last by some sort of elevator to carry the coal over the load line into the receiver, near the furnaces.

Mr. C. W. Hinman, a graduate of the Institute, and now "State Inspector of Gas," made a communication on "Gas Analysis."

After giving a history of the apparatus and processes employed by Lavoisier, Bunsen, Regnault, Williamson, and Russell, he explained his own in detail. His process is much simpler than any others in use.

Mr. C. A. Morey, a pupil of the Institute, described the various methods of rendering sounds visible, and gave the results of an extensive series of experiments made by him the past winter with the "Phonautograph" — modified and improved by himself. The curves made by the style set in motion by the vibrations of the membrane of the instrument, were exhibited, highly magnified, by the oxy-hydrogen lamp.

There have been elected during the year eight associate members. Seven associate members have died during the year viz: Messrs. Copeland, Derby, F. H. Jackson, Jewett, Reed, Sweetser, and Thompson; five have resigned, and fourteen have been dropped for non-payment of fees. The list now comprises 297 members.

The attendance at the School of Industrial Science for the year, has been 310; as follows: Resident Graduates, 2; Regular Students of 4th year, 21; of 3d, 34; of 2d, 59; of 1st, 68: Students not Candidates for a Degree and Special Students; 4th year, 13; 3d, 27; 2d, 25; 1st, 35; Students in Practical Design, 26, of whom 15 were females. Of these, as in former years, nearly five-sixths are from Massachusetts, principally from Boston and vicinity; from other New England States, 17; viz: from Maine, 5; New Hampshire, 5; Vermont, 3; Rhode Island, 3; Connecticut 1. From other States there are from New York, 7; Ohio, 8; Pennsylvania and Illinois, each 5; Minnesota and Western Islands, each 3; Indiana, Kentucky and California, each 2; New Jersey, Maryland, Kansas, Missouri, Nebraska, Colorado, British Provinces, Japan, and the Sandwich Islands, one each.

Thirty-eight professors and teachers have been connected with the school, and several advanced students have rendered assistance in the laboratories, drawing, and surveying. The fees from students have been over $50,000, considerably more than last year.

The School of Design continues to be a successful department of the School, and the report of the teacher in charge will show the artistic and pecuniary value of the work done.

The Lowell Courses this year have been as follows:

Logic: An Examination of the System of J. S. Mill. Eighteen lectures on Monday and Friday evenings, at 7½ o'clock, beginning November 17, by Prof. Howison.

Sound. Eighteen lectures, illustrated by a full series of experiments, on Wednesday and Saturday afternoons, at 3 o'clock, beginning January 7, by Prof. Cross.

Machine Drawing for advanced students. Twenty-four exercises, of two hours each, on Tuesday and Friday evenings, at 7½ o'clock beginning November 18, by Instructor Schubert.

Elementary Descriptive Geometry. Eighteen lectures on Monday and Thursday evenings, at 7½ o'clock, beginning November 17, by Prof. Lanza.

Chemistry: Qualitative Analysis. Twenty-four laboratory exercises on Wednesday and Saturday afternoons, at 2½ o'clock, beginning Feb. 11, by Prof. Nichols.

Architectural History and Design. Eighteen lectures on Wednesday evenings, at 7½ o'clock, beginning December 3, by Prof. Ware.

Elementary German, Eighteen lessons on Monday and Wednesday evenings, at 7½ o'clock, beginning November 17, by Instructor Krauss.

The Corporation have held eleven meetings during the year.

At the meeting of Dec. 10, 1873, the Degree of Bachelor of Science was conferred upon 19 Graduates of the Institute; in the Department of Civil Engineering, 9; of Chemistry, 6; of Geology and Mining Engineering, 2; of Mechanical Engineering, 1; of Architecture, 1.

Profs. Watson and Rockwell have resigned during the year; Prof. Channing Whitaker was appointed in the place of Prof.

Watson, and the work of Prof. Rockwell was divided among Profs. Ordway, Hunt, and Richards.

At the same meeting was received and accepted the gift of a marble bust of the late Albion K. P. Welch, from the executors of the estate.

At the meeting of Feb. 11, 1874, it was voted to establish a Mechanical Laboratory, whenever it could be done without encroaching on the present funds of the Institute.

A valuable gift of 79 volumes of the American Journal of Science and Art (Silliman's), substantially bound, from the commencement to 1860, was made by Thomas G. Appleton, Esq.; also a cannon, the invention of the late Prof. Daniel Treadwell, by Mrs. Treadwell.

At the meeting of Feb. 20, on a proposition of the Boston University, it was voted that the Professors of Physics in the Institute be authorized to receive a class in Physics from the Boston University, for one year, on conditions presented by the Committee on the School.

On April 8, was presented, from Mr. Cummings, a marble bust of Prof. Wm. B. Rogers, with pedestal.

At the meeting of June 16, it was voted to confer the Degree of Bachelor of Science on the following students, who had successfully passed their examinations, and fulfilled the required conditions:

Herbert Barrows	Reading	Dep't of Civil Engin'ing.
Wm. T. Blunt	E. Somerville .	" "
George E. Doane	Middleboro' . .	" "
Joseph S. Emerson . . .	Hawaiian Is. . .	" "
Elliot Holbrook	E. Abington . .	" "
Aechirau Hongma	Japan	" "
Chas. P. Howard	Hartford, Conn. .	" "
Herbert B. Perkins . . .	Ware	" "
Edward S. Shaw	Cambridge . . .	" "
Arthur W. Sweetser . . .	Cliftondale . . .	" "
George H. Barrus	Reading . . .	Dep't of Mech. Eng'ng.
Willis H. Myrick	Peterboro', N. H.	" "
Frank H. Pond	Woonsocket, R. I.	" "
Francis H. Silsbee	Salem	" "

Frank H. Jackson	Brighton . . .	Dep't of Mining Eng'ng,
Wm. B. Dowse	Boston	Dep't of Architecture.
Robert C. Ware	Marblehead . .	Dep't of Sci. and Liter.
Stephen H. Wilder . . .	Cincinnati, O. .	" "
Benj. E. Brewster (1872) .	Boston	Dep't of Mining Eng'ing.
Geo. W. Blodgett (1873) .	Boston	Dep't of Civil Engin'ing.
Sam'l M, Felton, Jr. (1873)	Thurlow, Pa. . .	" "
Frank W. Very (1873) . .	Salem	Dep't of Chemistry.

Subjects of Theses, with abstracts, will be found on p. 81.

The progress of the school in the various departments will be found in the reports of the Professors, and the President.

SAMUEL KNEELAND, *Sec.*

DEPARTMENT OF GENERAL CHEMISTRY.

President Runkle: —

Dear Sir: — As the changes which have been made during the past year in the Courses of Instruction have involved some changes in the instruction in General Chemistry, it may not be inappropriate briefly to allude to the plan at present pursued.

The method originally adopted for teaching Elementary Chemistry was based upon the ideas, — 1st. That all the regular students of the School should receive a certain amount of instruction in General Chemistry and in Qualitative Analysis. 2d. That some knowledge of the facts and principles of the science should precede the attempt to learn Qualitative Analysis, with which branch of the subject the instruction in some institutions begins. 3d. That the proper method of learning these fundamental facts and principles is by actual work in the laboratory where the student sees and handles for himself, this laboratory work being supplemented by systematic study of the text-book, enforced by familiar lectures or oral explanations. This system has been followed since the laboratory was opened, and there is no reason to feel that any better general plan could be pursued.

The amount of time devoted to the subject by the students of those regular courses which do not involve a knowledge of Chemistry as a prime necessity has been somewhat decreased, and the allotted time so distributed that now the entire course in Elementary Chemistry is completed during the First Year, instead of extending over two years as formerly. This change was made with the present Second Year's Class during their First Year, and they in consequence suffered from the change, but that the effect of this concentration of work will be felt to be beneficial in the case of the present First Year's Class, I have not the slightest doubt.

Methods of Instruction. — A regular student of the First Year's Class now attends each week two exercises in the Laboratory (of two hours each), one recitation, and one lecture. Frequent *written recitations* and regular monthly *written examinations* serve to inform the student of progress made and to give warning if necessary. During the first term the laboratory exercises are devoted to chemical manipulation: each student performs, under the supervision of the Professor and of his assistants, a large number of experiments intended to illustrate the laws of chemical action, and the properties of all the more important chemical elements and their principal compounds. During the second term the laboratory exercises are devoted to the practical study of Qualitative Analysis.

The text-books used both in General Chemistry and in Qualitative Analysis, were prepared expressly to meet our own wants, and for use in our own laboratory.

Lectures. — The lectures, if indeed they can be designated by this term, are familiar expositions and are intended simply to aid the student by calling attention to the more essential points of the subject under discussion, and to allow the performing of a few important experiments which are either too complicated or too dangerous to be undertaken by beginners. At present the students are almost all entirely new to the subject, and, indeed, to any subject of like character, so that the multiplication of experiments beyond those described in the text-book used tends to confusion, and the performing of striking experiments involving complicated apparatus tends to distract the mind from the real point at issue. Hence the apparatus employed is of the simplest kind, and the lack of *lecture-apparatus* is not under the circumstances felt as a misfortune.

Instruction during the Second Year.—The students who pursue such courses as involve the subsequent study of Quantitative Analysis continue, during the first term of the Second Year, their laboratory work in Qualitative Analysis, and the students in the courses of Chemistry, Metallurgy, Natural History, Physics, Science and Literature, and Philosophy study the principles of Chemical Philosophy.

Assistants. — Except during the very early years of the School's history, the assistants have always been persons who have acquired their knowledge of chemistry in our own School and are, consequently, familiar with the usages and traditions of the laboratory. At present, two assistants during the first term, and one during the second term are assigned to aid in the instruction, but all the class work, — recitations and lectures, and the inspection and correction of the examination papers is entirely performed by the Professor himself.

Appliances.—It is perhaps not necessary to allude to the disadvantages under which the department of Elementary Chemistry labors in having only one Laboratory, and that none too spacious, in which must be given the instruction, both in chemical manipulation and in Qualitative Analysis, — a matter of less discomfort, to be sure, this year than last, when the laboratory was taxed to its utmost capacity. In addition to the regular classes the laboratory has also to accommodate a "Lowell" Class, and this year we have been obliged to encroach upon the little space remaining in the lower entry by the erection of temporary cases for the storage of apparatus.

Laboratory of Research. — Another need of this department of the Institute is a laboratory for the private work of the Professor. At present our only accommodation is a small room 25 by 23 feet, one portion of which is partitioned off for a weighing-room, and another portion for a hood. This room, which is also badly ventilated, is the only place afforded for analytical and other laboratory work to the Professor of Industrial Chemistry and his assistant, the Professor of Mining and his assistant and the Professor of General Chemistry and his assistant.* It seems appropriate that the Chemical Laboratory of the Institute of Technology should be a place to which chemical questions arising in the various departments of the State and also in the case of private individuals should be brought for solution. In spite of our limited accommodations which prevent us from making efforts for this kind of work, except during the summer vacation, considerable of such work has been done. The receipts, which are divided between the persons doing the work, and the "library-fund" of the chemical department, have enabled us to acquire some of the more important works of reference, — a nucleus of what we hope may some time grow into a sufficiently complete *working-library*. At present we have no proper place for its reception, as its separation from the acid fumes of the laboratory is impracticable owing to lack of space.

Although this is not strictly connected with the instruction in General Chemistry, I may in this connection allude to the investigation of certain scientific and practical questions undertaken at the request of the State Board of Health. These investigations have been as follows: —

1870. In the Second Annual Report of the Board of Health appears a report by W. R. Nichols, "On the action of Cochituate water on lead pipes," (recording the results of 10 determinations); also, a report by W. R. Nichols, "On the condition of Mystic Pond and its Sources of Supply," (involving some 100 separate determinations); also a report by A. H. Pearson of the results of more than 75 determinations of "The amount of carbonic acid in the air of various schoolhouses in Boston and in the outer air in different localities, and under different circumstances." These experiments were made under the direction of Professor Storer.

* The Professor of Analytical Chemistry occupies a corner of the chemical storeroom.

1871. The Third Annual Report of the State Board of Health contains a paper by Dr. F. W. Draper of Boston, "On the evil effects of the use of arsenic in certain green colors." Several analytical determinations made by Mr. A. H. Pearson in our laboratory are there recorded.

1872. The Fourth Annual Report contains a paper on "Sewage, Sewerage, etc., prepared by Dr. George Derby and Professor Nichols. The analytical work, involving some 1100 single determinations, was performed mainly by Miss E. H. Swallow in our laboratory. Investigation was also made into the character of certain slaughter house products.

1873. The Fifth Annual report contains a paper by Professor Nichols, "On the present condition of certain rivers of Massachusetts, etc." The analytical work involved more than 1300 single determinations, nearly all made by Miss E. H. Swallow, one of our graduates.

1874. The present year, for sufficient reasons, not very much has been done; still it is hoped that an investigation now in progress, the results of which will appear in the Sixth Annual Report of the State Board of Health, may not be without interest and value, and another research more important in its practical bearings is a portion of the work laid out for next year.

The advantages to the Institute in thus being recognized in the service of the State seems to me not unimportant, and the pecuniary return more than covers all expenditure for gas, water and chemicals, so that the Institute incurs no expense directly or indirectly, in the matter.

All of which is respectfully submitted.

WM. RIPLEY NICHOLS,

Professor of General Chemistry.

REPORT OF WORK IN THE DEPARTMENT OF PHILOSOPHY.

To the President:—

By the changes consequent upon the new Course of Study, adopted last January, the work devolving upon my chair is now divided into two distinct parts: (1) that required of all regular students, as a condition of a degree in any department; and (2) that required, in addition, of regular students in the department of Philosophy,— a department created at the time of adopting the new course. The report of what I have done the present year, may conveniently treat of these two parts separately.

I. THE WORK DONE WITH ALL REGULAR STUDENTS.

This, during the first half year, before the new course went into operation, comprised (1) two lectures a week, on the Syllogism, and on the Rudiments of Inductive Logic, with the Fourth Year's Class; (2) two lectures a week, on the Doctrine of Terms and Propositions, with the Third Year's Class; and (3) one lecture a week, on the Structure and Analysis of Terms and Sentences, with the First Year's Class. For this last, the class was divided into two sections.

The work, on the part of the Fourth and First Year's Classes, was of a high order; both passed a very thorough examination at the Semi-annual in January. I was able to use far more complete and difficult papers than those of the preceding year, and yet the results were quite as good. This examination brought my connection with the Fourth Year's Class to a close; and their performance of duty, throughout my acquaintance with them, has seemed to me so unusually commendable, that I cannot dismiss them from this report without a special acknowledgment of the industry, sympathy, intelligence, and success which have constantly marked them while under my instruction.

The work with the Third Year's Class was broken short in the midst, by the operation of the new courses. This interruption of plans laid out and worked upon before any definite knowledge of the proposed changes was in my possession, of course made the subject appear to the class in a very incomplete and unsatisfactory light, and caused the semi-annual examination in it to seem unreasonable. Nevertheless, they succeeded in passing a paper of unusual difficulty with decided credit, only three out of the forty-seven members of the class having been subjected to conditions.

With the opening of the second half year, in February, the new course went into operation. It was, however, decided to let my plans for the First Year's Class go on as laid out at the beginning of the year. I therefore continued to lecture to them once a week till the year closed.

My regular work with the Second Year's Class now commenced, and occupied three lectures a week for the remainder of the year, covering in outline the whole subject of Formal Logic, exclusive of Fallacies. The result with this class seems to indicate that the place and time allotted in the new course of study to the subject of Logic (the second half of the Second Year), can be made to answer a more useful purpose than I had thought they could. Although the *amount* of ground covered has been less than I should like to see, as the limit to be reached in that study in the Institute, the quality of the work has been good. In future, too, I believe we shall be able to include in our work not only the positive theory of the Syllogism, but the doctrine of Fallacies as well. I hope to accomplish this by finishing so much of the theory of Propositions in the First Year's work, as will enable us to commence the instruction of the Second with the doctrine of Inferences. To make sure of this, however, I recommend that the Institute shall in future require, as a condition for entering the First Year, a thorough acquaintance with the classification and analysis of terms, and with the parts of a proposition, and a respectable skill in analyzing sentences, both simple and complex.

As to methods of instruction, I may refer to my report of last year. The only change has been, to increase somewhat the number of preliminary written examinations, held at intervals during the progress of the lectures. These have averaged, for each class, about one in three weeks throughout the present year.

II. THE WORK IN THE DEPARTMENT OF PHILOSOPHY PROPER.

In this new department, placed under my charge, there have been enrolled, the last half-year, five students: three regulars — one of the Second Year and two of the Third — and two specials. The latter took the introductory course in Psychology prescribed for the Third Year, and the course in Ethics prescribed for the Fourth Year.

The programme of work, as shown in the course of study printed in the last annual catalogue, has been quite completely carried out. The five students, without exception, have passed successful examinations, — a fact the less remarkable, when it is recollected that they are all students from preference, having chosen the department from a conviction of its adaption to their wants, and from a sincere interest in its leading subject.

The instruction has been given directly by lectures, three a week on a general introduction to Philosophy, and on Psychology, and three a week on Ethics. Much reference of the students to standard texts as companions to these lectures, has however, been employed. For this purpose, I have used, with the Third Year men, Bowen's edition of Sir W. Hamilton's *Metaphysics*, portions of Stirling's translation of Schwegler's *History of Philosophy*, portions of Mill's *Logic* and of his *Examination of Hamilton*, parts of Ueberweg's *History of Philosophy*, and of the *Prolegomena* to Krauth's edition of Berkeley's *Principles of Human Knowledge*, and Masson's *Recent British Philosophy*. The Fourth Year Specials have read and discussed the most important parts of Calderwood's *Handbook of Moral Philosophy*, together with an outline of Kant's theories in the field of Ethics. Both classes have done a considerable amount of parallel reading on their own account.

The range and character of the work done will be clearly seen in the subjoined papers, used at the annual examination in May: —

DEPARTMENT OF PHILOSOPHY.

PSYCHOLOGY — THIRD YEAR.

May 22, 1874.

1. If we regard the subject merely from beforehand, what may we lay down as a provisional definition (or description) of Philosophy? Can you see any reason in this, why Plato should have called it a "meditation of death"?

2. If we attempt a scientific definition of it, after effectual acquaintance with its procedure and its results, what threefold distinction in regard to it must we make in order to avoid confusion, and to prevent us from supposing definitions to conflict, which are in reality quite harmonious?

3. Keeping this distinction in mind, endeavor now to define Philosophy from each of the three points of view.

4. In the light of what precedes, what would you say of Hamilton's statement that Aristotle, in calling Philosophy "the art of arts, and the science of sciences," merely intended to describe its supreme eminence? What, probably, *did* Aristotle mean?

5. In general, what two great fields does Philosophy include? Distinguish between them as accurately as possible.

6. Tabulate the schools of Philosophy, as they have thus far appeared in history, arranged upon the principle of their *Theory of Knowing.*

7. Do the same, upon the principle of their *Doctrine of Being.*

8. Endeavor to make out a division of them according to their *Method of Research.*

9. State the doctrine of the Relativity of Knowledge in its most general, least determinate form, i. e., as held in common by *all* Relativists.

And the form it assumes in the hands of Transcendentalists.

And the intense form of it peculiar to Empiricists.

Are these two schools necessarily Relativist?

10. Why may Kant's "Critical" philosophy justly be termed Transcendental Skepticism? Why is Hume's called Empirical Skepticism? Is there any essential difference in their theoretical results? In their practical?

11. How does Hume's Skepticism differ from Nihilism? How can you account for its being so repeatedly charged by able men with being essentially the same doctrine?

12. How would you distinguish a *Person* from an *Individual*; or, more exactly, *personality* from *individuality*?

13. State the doctrine of the Trinity, as involved in Pure Consciousness — i. e., in the *Idea of Personality.*

14. In what sense does this Trinity "appear" in Consciousness the Sensation, and in what sense not?

15. Where do the English, the Scottish, and the Positivist schools of Philosophy all essentially agree in placing the "Beginning" of science? Why must this render it certain beforehand that they can never establish Substantive Being? What does this show in general, in regard to the effect upon Philosophy of the Psychologic starting-point?

16. In what peculiar manner does Hamilton regard the term *Psychology*? In what way does he then divide the field which he thus denotes? In doing this, what further departure does he make from the general usage of philosophers? Is the *distinction itself* which he makes here valid? Give your reasons.

17. When Calderwood says that the Ego is given *immediately* in consciousness, what does he mean, and what criticism may be made upon his view?

18. Distinguish between "consciousness" and "self-consciousness." State Hamilton's peculiar views in this connection, and criticise them, both from his own contradictions and from the facts.

19. Why is Hamilton's philosophy of Perception called *Natural* Realism? Why *Dualistic* Realism? Where does he find the theoretic warrant for his two Substances?

20. Give Hamilton's classification and nomenclature of the "Faculties"—and the common names along with his technical ones. What *is* a "faculty"?

DEPARTMENT OF PHILOSOPHY—YEARS III, IV.

EXAMINATION IN ETHICS.

May 25, 1874.

I.

Write as complete and as accurate an account as you can, of the so-called *Intuitional Theory of Morals.*

Show what it is intended as a theory to account for; making all the necessary distinctions between processes of knowing, of feeling, and of acting.

Show how it finds the warrant for obligation, having defined Obligation.

Show, also, how it states the universal *Law of Virtue*, i. e., in what it makes Virtue essentially to consist, irrespective of the particular form.

Show the peculiar difficulties to which the theory is liable, and how its advocates attempt to overcome them.

Show the distinction between Judgments of Right and Judgments of Duty. Decide whether Calderwood, under this distinction, really includes all the vital facts of moral consciousness. If you think he omits any, show what, and why you think so.

Discuss Conscience. Point out the distinction between Rights and Right.

Make as good a list as you can of what Intuitionalists generally consider the *à priori* First Principles of Right.

II.

Present a similar treatment of the so-called *Development Theory of Morals*, going into details as far as you have time. Take especial notice of its doctrine concerning the origin of knowledge in general, the origin of conscience in particular, and of its most general Principle of Rectitude.

III.

Make a list of the leading philosophers who have advocated either view.

It deserves mention, that, although answers to but half of the foregoing questions were *required* of the students, and the students were allowed to select this portion for themselves, they voluntarily offered answers to all, and that a great majority of these answers were satisfactory.

I think these results entirely justify the course of the Government in creating this new department. To ensure its complete success, I believe it will only be necessary to carry out, as far as possible, with respect to it, the principle of equipment with the requisite implements and laboratories (if I may be allowed the expression), which characterizes the administration of instruction in the other departments of the Institute. The proper "laboratory" of a department of Philosophy, is, of course, a sufficient collection of the works of those thinkers who have really contributed to the historical development of Philosophy, together with such illustrative commentaries and charts presenting systematic views as wholes, as will serve at once to instruct the student and to stimulate him to independent investigation. In short, the need is a good special *library*, properly arranged for rapid consultation, and yet in some place suited also for the most patient study, with appliances enabling the student to make his own abstracts and charts of systems, where such are needed.

The beginning of such a library has been put in our possession. The department has now a room sufficient for its immediate wants, and the nucleus of a special collection in philosophy, from a small appropriation assigned us during the year, is already obtained. This, together with the works in my own collection, will answer all purposes, provided it can gradually be increased as the department goes on. A very small annual appropriation for this object — so little, even, as fifty dollars a year — will serve to meet the probable wants of the department as it develops, and, in the course of time, to secure a positively *complete* collection of such works as are of any real significance in this field of knowledge.

The progress of my instruction in this department has already convinced me that important alterations must be made in its course of study as printed in the last catalogue. More time must be assigned to its special subjects in the Third and Fourth Years, and those subjects must be brought in a prominent and special form into the Second Year. To make room for these changes, certain of the miscellaneous studies, now pursued by students of this department in common with those of other departments, must be dropped. The details of these alterations will be presented to the consideration of the Faculty at an early day in the ensuing year.

Respectfully submitted,

GEO. H. HOWISON.

Boston, June, 1874.

REPORT UPON THE LOWELL SCHOOL OF PRACTICAL DESIGN.

Mr. President: —

At the close of the second year I have the honor to submit the following Report of the progress attained in this Department: —

The second annual session of this school commenced with twenty-six pupils, — fifteen old and eleven new ones. The old pupils started at the beginning of the year, upon original compositions; and gradually so improved, that the results proved highly satisfactory to me, and commendable to themselves.

The new pupils after working from copies until January, and having gained skill in execution, were put upon such variations of work as naturally lead them to produce original compositions. This change proved also, in the highest degree, beneficial, and all of them exhibited great originality in their subsequent efforts at composing.

During the month of May last, I sent from time to time all the original designs, from both classes, to different manufacturers, for inspection; and every manufacturer who saw our samples, purchased some of them. Thus 23 patterns were disposed of to the amount of $200 — each pupil receiving the money for his or her specimens.

Two young designers have been furnished, from the advanced class, to the Pacific Mills, where they are now permanently engaged, giving great satisfaction. We have had two public Exhibitions, one at Horticultural Hall, Boston, and one at Huntington Hall, Lowell — which have proved highly attractive and interesting to the public.

The school also contributed to the art department at the late exhibition of the Mechanics Charitable Association, held in Boston, and was awarded a prize of a gold medal.

I am happy to add that the pupils in this school evince great application and perseverance in their studies, as well as good will; and I can very confidently affirm that their patterns exhibit generally a goodly share of taste and originality in design.

It is with great pleasure that I am able now to state that, in my judgment, we shall be able hereafter to furnish from this school well qualified American designers, in all branches of this important art.

The generous contribution made last year by Mr. James L. Little, has not yet been exhausted. The "Claude Fréres patterns," furnished to the School, by Mr. Lowell, have proved an invaluable aid in the work of the past year.

I am, very respectfully,

Your Ob't Serv't.

CHA'S. KASTNER.

THE DEPARTMENT OF ARCHITECTURE.

President Runkle :—

Dear Sir : — The instruction given during the last year in the Department of Architecture did not materially differ in character from that of the previous year. Three regular students and about twenty special students have been in attendance, about the same number as in previous years. But the quality of the classes visibly improves from year to year, partly because it has been found that young men without either character or intelligence are no better suited for these studies than for others, so that we are no longer troubled by their presence, partly because the department has come to be favorably known in the more distant parts of the country, and, other things being equal, students who come a long distance are in general the best workers. It has accordingly happened that the results of the year's work have been more satisfactory than in any previous year, as good work has been done and more of the work has been good.

At the beginning of the year one of the two students who passed the final examinations the previous year presented his thesis and received his degree. The subject chosen was a building for water-works in a public park. The drawings showed the arrangement and aspect of the building itself, with the machinery for pumping and controlling the water. The text accompanying them contained calculations of the dimensions of the principal parts of the structure and of the flow and supply of the water.

During the year the rule was adopted that the graduating thesis should be presented before the close of the school year. A second thesis and the accompanying drawings was accordingly presented in May, by the student who passed his final examinations at that time. The subject chosen was a Railway Station, situated on a bridge over the track. The drawings showed the structure in plan, elevation and section, with details of the wood, iron and stone work. The thesis itself discussed the thrust and equilibrium of the arches, the strength of the retaining walls, the resistance of the tower to wind, etc., etc.

The Third Year's class, to which most of the special students were attached, were occupied during the year with the following problems: — 1, an arch; 2, a *Porte-cochère*; 3, a Portico; 4, a Peristyle; 5, a Staircase; 6, a Billiard Room; 7, a Pompeian House; 8, the use of Four columns; 9, a Monumental Bridge; 10, a School of Architecture; 11, a Dwelling House. At the same time the Fourth Year's class made designs for 1, a Temple Tomb; 2, an Iron Pavilion; 3, a *Café Chantant*; 4, a School House; 5, a Railway Station. This class also made sketches of most of the problems given out to the other class. They also made careful drawings of King's Chapel, to which the Wardens kindly allowed them access at convenient hours. Two of the designs for the Railway Station were given in the September number of the Architectural Sketch Book, a professional journal published by Messrs. Osgood & Co.

The course of History this year covered the Greek and Roman Period, as usual, in the first half of the year, and in the last half the period of the Renaissance. The usual lectures in construction were continued through the year. The collections have not been materially increased.

I am, very truly,

Your Ob't Serv't,

WILLIAM R. WARE.

REPORT OF THE DEPARTMENT OF MILITARY INSTRUCTION.

President J. D. Runkle: —

SIR: — Since rendering my last report, the discipline and efficiency of the corps of students receiving military instruction has been much improved, and comparatively little discontent is now apparent. I have endeavored to make the instruction as little burdensome as was consistent with making it efficient. The instruction was given under many disadvantages, not the least of which was the want of a proper drill-room. Whilst the disciplinary rules which were adopted were neither harsh nor severe in themselves, they were felt as irksome by some of the students who had been accustomed to the comparatively loose discipline, or rather, absence of discipline, which prevailed previous to my reporting for duty. I have observed that the few cases which were at all troublesome were invariably those of students who were troublesome in other departments of the Institute. The inference then is fair, that the difficulties of making the military instruction at the Institute both respectable and efficient, are not inherent in its incompatibility with the strictly civil character and proper work of the school, but rest more particularly with the individual character of its students. In order to make military instruction effective, military discipline must be enforced during the hours assigned for that purpose. This discipline is necessarily more minute and less yield-ing than the ordinary discipline of a civil school, such as the Institute of Technology. But the inflexible exercise of it, at stated times, must have a tendency to make the students more amenable to the general discipline of the school, and of rendering impossible the stay of those unruly characters whose presence is injurious than otherwise.

In addition to the instruction in infantry drill, some instruction was given in artillery drill and signalling. Voluntary practice in day and night signalling was given at distances between stations ranging from one to six miles, and many of the students became skillful therein. The success of this instruction is due chiefly to the able efforts of Mr. Henry N. Mudge, who was Signal and Ordnance Officer during the greater portion of the year. Aside from its utility as a military exercise, the instruction in signalling may be useful to the students whenever they may be called upon to perform surveying, or other similar out-of-door work. It enables them to communicate at distances far beyond the reach of the human voice, but within the range of vision. It requires no special apparatus or preparation for either day or night communication.

Lectures were given on the following subjects, viz:

1st. "Discipline"—manner of establishing and enforcing it.

2d. "Feeding troops"—ingredients, proportions and manner of preparing food in camp and on the march.

3d. "Military Hygiene"—sanitary measures necessary in camp and on the march.

4th. "Military Courts"—composition of, principles governing their actions, and the forms of procedure.

It is my intention to continue with the second year class, during the school year of 1874–75, the lectures upon the 3d of the above mentioned subjects. My aim in giving these lectures is to give the instruction which is essential to the proper care and preservation of the health and efficiency of troops when exposed to the abnormal conditions of the camp and the march. This instruction may be useful to the students when, as engineers, they are called upon to assume charge of large bodies of workmen in the construction of railroads, or other similar work. A knowledge of the proper manner of feeding and taking care of these laborers can not but increase the efficiency of their services, and the amount of work accomplished in a given time.

The lectures upon Military Courts were given with a view of enabling the students to enforce their own discipline by courts composed of the officers of the corps.

The officers of the corps labored under great disadvantages in the instruction of their respective commands. There was such an absolute certainty of a change in the then existing system of tactics, that they felt and received but little encouragement in studying up the details which are so essential in acquiring proficiency of drill. They are deserving of much credit for the thoroughness with which they performed all duties assigned them. I beg leave to mention their names in this report, viz.:

STAFF OFFICERS RANKING AS FIRST LIEUTENANTS.

Adjutant,	B. Leighton Beal.
Quartermaster,	F. M. Learned.
Signal and Ordnance Officer,	H. N. Mudge, resigned, succeeded by C. H. Goodrich.

	Captains.	*1st Lieuts.*	*2d Lieuts.*
Co. A.	T. Aspinwall, Jr.	G. C. Avery.	C. L. Dennett.
Co. B.	T. E. Schwarz.	W. D. Townsend.	J. B. Henck, Jr.
Co. C.	W. R. Munroe.	W. R. Cabot.	J. M. Wilson.
Co. D.	C. F. Main.	E. L. Caldwell.	S. W. Holman.

At the close of the school year, about fifty students desired to go into a voluntary encampment for a week. It was not at that time considered expedient to permit them to do so. Such encampment coming immediately after the severe tasks imposed by the annual examinations would serve as a most healthful relaxation, enabling me, at the same time, to impart some useful instruction. The experience would be such as to be useful to them as engineers, when required by their work to live in tents. Opportunities would be afforded for base ball, foot ball, and other healthful out-of-door sports. Whilst such an encampment would serve as a recreation to the students, I feel confident that it will go far, from the pleasant associations which it will undoubtedly engender, in making more acceptable the military instruction, absolutely required as it is. I trust therefore that permission will be granted for this purpose.

So much of the school year of 1874–75 has elapsed at the time of writing this report, that I take the opportunity to briefly mention some of the changes which have been made during that time.

As a mistaken impression regarding the relative status of the military element seemed to have been gaining ground in the minds of some of the friends of the Institute, every effort, consistent with its efficiency, has been made to render it as little conspicuous in appearance as it is in fact. With this in view, black gutta-percha buttons have been substituted for the bright metallic buttons heretofore worn. The uniform, thus changed, is inconspicuous.

In compliance with the recommendation embodied in the report of the Committee of the Corporation "On the Military Instruction given at the Institute of Technology," the amount of writing necessary in the transaction of official business has been reduced as far as practicable. The amount of "red-tape," so called, which was demanded of the majority of students, has been much exaggerated. It was, in fact, a demand of less than *five* minutes labor in writing explanation for one or more absences from *required* exercises, and but little more than *one* minute's labor in writing an explanation of tardiness.

The manner of appointing the officers is somewhat different than that of last year. Only *acting* appointments have been made, subject to approval and confirmation by the Faculty. The *full* appointments will be made after the semi-annual examination, at which time they will doubtless have shown their degree of fitness for different offices. The details of instruction and discipline have been left, in a greater measure than last year, in the hands and control of the officers. They have performed their duties with a sound judgment and discretion. The burden of the responsibility in disciplining and instructing the corps has rested upon the acting Captains commanding companies. I would ask no better fortune, should I be called upon to organize a regiment for actual service, than to have these young gentlemen as my assistants. The acting Adjutant, Quartermaster and Signal and Ordnance Officer have efficiently performed essentially the same duties which they would be called upon to perform in actual service. The roster of acting commissioned officers is as follows, viz.:

STAFF OFFICERS RANKING AS FIRST LIEUTENANTS.

Adjutant,	J. F. Swain.
Quartermaster,	E. H. Gowing.
Signal and Ordnance Officer,	C. Cushing, Jr.

	Captains.	*1st Lieuts.*	*2d Lieuts.*
Co. A.	A. K. Plimpton.	W. E. Chamberlin.	W. B. Bradford.
Co. B.	C. H. Norton.	C. H. Fisher.	W. S. Frost.
Co. C.	F. E. Peabody.	H. E. Monroe.	W. M. Peters.
Co. D.	W. Jenney.	I. M. Story.	F. P. Spalding.

The report of the Committee (previously mentioned) leaves nothing for me to say regarding the beneficial effects of military instruction, from physical and mental points of view, nor of its necessity from patriotic motives and an honest intention to comply with the spirit, as well as the letter, of the terms of an obligation assumed. I feel confident that the graduates of the Institute will serve with credit in the ranks of the citizen soldiery, should they be called upon to defend their homes and liberties.

Respectfully submitted,

E. L. ZALINSKI,

1st Lieut. 5th U. S. Art'y.

REPORT ON MILITARY INSTRUCTION.

The Committee appointed by the Corporation of the Institute "to take into consideration the whole subject of the military instruction to be given in the Institute," beg leave to present the following

REPORT.

Chapter 186 of the Acts and Resolves of the Legislature of Massachusetts for 1863, contains the following provision, namely: "Said Institute of Technology, in addition to the objects set forth in its Act of Incorporation, shall provide for instruction in military tactics." This condition forms part of the Act which appropriates to the Institute one-third part of the annual interest or income received from the fund created by Act of Congress approved July 2d, 1862, granting public lands of the United States for certain purposes of education.

So long, therefore, as the Institute shall continue to receive this endowment, "instruction in military tactics" seems to form a necessary part of its curriculum.

Accepting this condition as imperative, the only questions open for consideration respecting military instruction must relate to the amount, the kind, and the modes of imparting it. It is hardly possible in a report of this kind to discuss fully the value, either absolute or relative, of instruction in military tactics; a few considerations may be presented. And first of all, it is well to remember that at the time when the Legislature selected the Institute of Technology as one of the institutions which might receive the national bounty for educational purposes, the country had but recently entered upon the great civil war, when its untrained army, composed largely of volunteers, almost wholly destitute of military knowledge and practice, were encountering the fatigues of the march and the camp, and the perils of the battle-field. Surely any provision which is the offspring of such a crisis as liberty or slavery, of life or death, must be regarded with the deepest interest. In any country, however peaceful, yet subject to the exigencies of war, and relying less upon the strength of a standing army than upon the patriotic response of its citizens to any necessary call to arms, the value of some practical knowledge of military tactics by its people, and especially by its educated classes, is too obvious to need argument. A striking illustration is given in a communication written at the time of which we are speaking, concerning the students at the United States Naval Academy, at Annapolis.

"When Washington was defenceless, Baltimore in riot, and all Maryland in a state of revolt, communication being cut off at Annapolis, there was great fear of an attack upon that important strategic point. The pupils were prepared for any exigency, and slept with their loaded rifles over their cots. At an alarm of a night attack, there was no hesitation among those gallant little fellows. They were up directly; fell in their ranks and off at *double quick* for the point of danger in an almost incredible short space of time. The elder boys dragged their howitzer with them. Had an attack taken place, those pupils would have given a good account of themselves, and have stood their ground with courage and steadiness. The secret of this is *discipline*, for which they are indebted to the assiduity of their brave and experienced Superintendent, Captain Blake, of the Navy."

Had even a tithe of this military discipline been received by the men who composed the loyal army at the beginning of the war, how vast might have been the saving of life, of suffering and of property! It was doubtless the inevitable recognition of this fact which induced the Legislature to impose the condition, that those who participated in the benefits of the national bounty for educational purposes in this Institute, should become qualified to return a special service in the field, should such be required for the national honor and welfare. The national academies of military and naval science and practice will continue to afford the means of educating a limited number of officers for the regular Army and Navy on a peace basis; but it is neither practicable nor desirable so to enlarge these institutions as to embrace corps of students sufficient in number to lead the volunteer forces in case of war. It is not desirable to cultivate a warlike spirit among our people, nor to withdraw from civil pursuits, to be maintained at the public cost, a needless force of military men. The safest and most feasible alternative seems to be found in making instruction in military tactics a part of the curriculum of our higher schools. As the country shall increase in extent and population, and these institutions in wealth and diversity, it may be useful and desirable, should the domestic and foreign relations of the country require an increase of military men of high culture, to establish in some of them departments of military science as parts of a university system. No such department has been established in the Institute of Technology, and none is now recommended. Since, however, instruction in military tactics is promised by accepting the legislative bounty, it is doubtless the purpose of the Corporation that this obligation shall be fulfilled in the true spirit and intent of the statute, and in such manner and with such results as shall correspond with the general vigor and thoroughness of study and discipline in all other departments of the Institution. In the opinion of your committee, the value of military instruction and discipline is by no means to be estimated alone by their possible relations to a state of war, when the citizen is transformed into the soldier. Such instruction has great and peculiar value as an educational and disciplinary agency, and as a sanitary exercise of the highest type. It cultivates habits of neatness, order, precision, quickness of thought and action, and that absolute obedience which those must first learn who are afterwards fit to command. It inspires a manly and chivalric spirit, gives ease of carriage and movement, develops muscular energy and endurance, and stimulates the intellectual powers by kindling all the vital forces into healthy activity. If, therefore, education be interpreted as a process of developing the intellectual faculties, as well as a mode of receiving and classifying knowledge, it is believed that military tactics compare most favorably as a branch of study, with certain branches of mathematics, and with many other studies which especially engender habits of concentration and persistent application. Military practice is certainly superior to either in the particular that it blends recreation with acquisition. If we mistake not, the courses of study in the National Military Academies are as difficult of accomplishment as are those in the average of American colleges; and yet they are completed in as many months as the college courses, notwithstanding students in the former are subjected to frequent and protracted military exercises daily. And testimony is abundant to prove that the time employed in the military drill is more than accounted for in the increased mental activity and energy which it produces. In a letter to the chairman of this committee, Rear Admiral Worden, Superintendent of the United States Naval Academy, says:

"The average time assigned to the drill of each student during the academic year (eight months) is seven hours per week. This includes the time occupied by all seamanship, Great Guns, Field Artillery, Boat Howitzers, Infantry, Fencing and Boxing Exercises and Dress Parades. Besides these exercises, those members of the Fourth Class who enter in June, are practised in gymnastics during the summer months, three hours every week, and in swimming every morning. The Third Class has instruction in gymnastics about three hours per month; and all the classes are invited and encouraged to use the Gymnasium for exercise during recreation hours. The average time assigned to drill in Infantry tactics does not exceed two hours per week throughout the academic year. . . . . As to the amount of drill which can be profitably employed in such a school as the Massachusetts Institute of Technology, for purposes of exercise, discipline, etc., I am of opinion that one hour per day could be so appropriated with great advantage to the physical culture and mental development of the students. . . . . I have always been strongly impressed with the necessity of bodily culture as the true complement of mental development; and I know of no readier and more congenial method of obtaining a good result than the practice of military exercises in the full meaning of that term. For in that sense what is called military training — a kind of training which is but a small part of a military education, and which ought to be *common* and not peculiar to soldiers and sailors — is to be valued not only in a muscular point of view, but as generating habits of just subordination, of manly self-control and of neatness and good order in person and personal property."

Admiral Worden also refers in his valuable letter to an elaborate article on "Physical and Military Exercise in Public Schools — a National necessity," contributed by General Edward L. Molineux, of New York, to Barnard's "Military Systems of Education," first published in 1862, and revised in 1872. In this article we find the following suggestions:

"The influence of health upon the faculties of the mind is acknowledged by all, and yet how few in this country devote attention to those important exercises which are necessary to the preservation of health, and without which intellectual power cannot be applied to its highest use. The talents, the experience of our best educators of youth are taxed to devise exercises to develop the *mental* faculties, forgetting that too close application to study is detrimental to the growth of the body. . . . . What then is the most simple, feasible and useful plan to adopt for physical exercise in our colleges, normal and public schools? We unhesitatingly reply that the only successful, orderly and systematic method is to engraft them upon the course of studies during school hours, and to carry it out under strict military discipline; the exercises being such as are best suited to the ages, strength and capabilities of the pupils, namely: calisthenics and walking for the girls and younger children, and military exercises for the elder boys."

High English authority is cited in support not only of the practice of infantry tactics in schools, but even of cavalry drill for the middle and higher grades. The Vice Chancellor of Oxford testifies that the institution of the systematized exercise of the volunteer drill in that College has been attended by an improvement of the mental labors, and of the whole of the order and discipline, as well as of the health of the University. The Honorable Joseph White, the present experienced Secretary of the Massachusetts Board of Education, and also a member, on the part of the Commonwealth, of the Corporation of this Institute, says:

"Let the drill be regular and compulsory, taking the place of the very irregular and insufficient physical exercises now taken, and our colleges would be vastly improved in their educational power, and the Commonwealth would, in a short time, have a numerous body of educated men well skilled in military science and art, who will become teachers in our lower grades of schools, and in our military companies and associations, and be competent, when the alarm is sounded, to lead our citizen soldiers to the field."

The adoption of the military drill in many private academies and high schools, which depend upon public approbation for their support, indicates the increased interest in the importance of this branch of education, and may be regarded somewhat as the verdict of experience respecting its value. The amount of instruction in military tactics to be given in the Institute, may be safely assumed to be at least so much as to answer all purposes of physical exercise, with the addition of so much as shall constitute a suitable return to the State and the country for the military bounty which the Institution receives. In their investigation of this point the committee personally examined the course of study and practice already adopted by the Institute, and also witnessed the drill exercise, and held consultation and discussion with the Faculty upon the general subject now under consideration. Much diversity of opinion prevailed among the members of the Faculty, qualified somewhat, as it appeared to the committee, by the more or less strictly scientific nature of the departments which they represented respectively. At the request of the committee, the Faculty at a later day transmitted a letter embodying their opinion of the amount of instruction in military tactics which should be given in the Institute, together with their views upon the relation which this instruction should bear to other departments of study, and some remarks upon an alleged exaggerated and mistaken public opinion respecting it. The views expressed therein as to the time which may be allotted to military instruction correspond with those of the committee, and accord also with the present regulations. It seems to be generally conceded that two hours per week is as little time as can be given with any profit to this course, and the committee do not recommend more; although, as has been already shown, this time falls far short of what many experienced educators would assign to it, and possibly short of what experience may prove to be practicable and beneficial.

If, as we believe, the time allotted to the drill be more than compensated for in the increased physical and mental power of the students, it cannot with propriety be counted as so much consumed, which, without the drill, could be appropriated to other branches of study; neither do we concur in the suggestion that this should be regarded as an extraneous, and possibly injurious, element in our system. The committee venture with much diffidence and with entire respect to express any opinion at variance with those which have received the concurrence of any considerable number of the members of the Faculty of the Institute; and yet their investigation and their report would be of little value if they suppressed their own convictions in simple obedience to even high authority. The committee are of opinion that, whatever be the time allowed to this branch of instruction, and whatever the limitations affixed, its importance within that appropriated sphere should be as completely recognized, and its discipline as rigidly enforced, and its authority as fully asserted and admitted, as are those of any other department.

"Instruction in military tactics" should not be regarded as an excrescent and superfluous innovation, but as an established and important element in the course of study and discipline; fulfilling thus the reasonable expectation created by the list of "Officers of Instruction," presented in our Catalogue, where there is embraced a "Professor of Military Science and Tactics." Any attempt to unduly compromise it, or subordinate it, would be to paralyze its usefulness and success, and bring it into disrepute with the students and the public. There should be no attempt to hide it from view, nor to apologize for its existence. It is due to the public and to the Commonwealth, that it shall be widely known and fully understood that instruction in military tactics forms part of the curriculum of the Institute; and that compliance with regulations concerning it, and proficiency attained in it, will be required and accounted in the meritorious standing of students in those classes in whose course of study it is found. If, then, there be students who do not wish to receive this instruction to the extent now established in the Institute, they will not be deceived by coming where by law and good judgment it is required; and no prejudicial errors will vex the public mind in consequence of any doubtful or hesitating policy upon a subject which is held in favor by many of the best educators in the world, and which seems to be gaining strength by every day's experience.

Complaints will doubtless be made by the indolent and unaspiring against all strict and positive discipline, without which excellence is seldom attained. And if the standard be lowered to meet the demand of those who would perhaps be most injured by concession, there will still be a class below who will renew the complaint; while the ambitious and hopeful student will delight in the discipline which imparts health to his body and vigor to his mind, at the same time that it measurably prepares him to discharge the highest obligations of patriotism in the hour of his country's peril. The last fear that need be entertained is that the Institute shall excel in this attractive and important branch of instruction to a degree commensurate with its success in all other branches embraced in its Catalogue.

The committee do not recommend any other kind of military instruction than the Infantry drill already established, and what is necessarily connected with it. The Artillery and Cavalry practice, however desirable in an institution thoroughly military, and necessary to the professional soldier, are not compatible with the appointments of this Institution, nor consistent with its purposes and objects. Even within the course of instruction and practice in the Infantry drill, as now conducted, it is quite possible that the requirements in respect to certain clerical details, such as daily reports, orders, requisitions, etc., may be needlessly onerous, and that they consume time which might be more profitably employed by the officers to whom such duties are assigned. The committee recommend such modification in this particular as shall remove all ground of reasonable objection. We are of opinion that such modification may be profitable.

Two collateral topics have engaged our attention, namely: a uniform for the students and a hall for drill, which may also serve the purpose of a Gymnasium. A uniform of some kind appeared to have been agreed upon before the committee was appointed; and thus the necessity, or at least its expediency, was conceded. A sample coat of gray cloth with elaborate trimming of black braid and gilt buttons was exhibited as a style of uniform which could be obtained at moderate and satisfactory cost. This seemed to the committee too conspicuous for the purpose, and not in good taste otherwise. After some investigation and inquiry, a uniform was designed of plain blue cloth, of the Middlesex Mills, with very little trimming, and of so simple decoration generally as to be distinctive without being offensively conspicuous. It consists of a frock coat, vest and pantaloons and cap, all of the same color and material. The buttons are the badge of the Institute, provided by it, as is customary with other institutions. This uniform is furnished to the students at very small advance upon its cost to the manufacturer, and at less price than the original sample here described; and it has been generally approved for its neatness and suitableness to its purpose. The matter of a drill hall is one of much greater importance and difficulty to decide. It is manifestly very desirable that all the studies and exercises of the students shall be conducted at the Institute; and especially is this necessary for this study, if by unanimous assent of the Corporation and Faculty two hours per week, the present allotment, be all that can be allowed, and yet the least that can be used to any profit for military instruction. Any abridgment of this time in travelling to and from some remote hall must be proportionably detrimental. Indeed the great want of a drill hall at the Institute is conceded; and the only, or the chief, obstacle to its erection is the lack of the necessary funds.

No better plan than that suggested by Prof. Zalinski, of a temporary building, has occurred to this committee, and while it is not what we desire, not what can be accepted as permanent and sufficient, yet the need of some place for the purposes mentioned is so urgent and immediate, that we recommend the adoption of this one as the best that is available, and the least likely to interfere with other interests and purposes for which funds must be immediately provided.

All of which is respectfully submitted,

ALEX. H. RICE,
JOHN CUMMINGS,
EDW. ATKINSON.

Boston, June 16th, 1874.

EXPEDITION OF MINING STUDENTS TO LAKE SUPERIOR.

The professional courses of the Institute of Technology, as a rule, give a student a fair insight into his profession without going far from the city of Boston.

For the mechanical engineers there are shops, works, and factories, in the vicinity of Boston, that can be visited to give life and reality to the instruction by the Professor. For the civil engineering course there are bridges, railroads, depots, and water works, etc. The architects have buildings always at hand. The analytical chemist can learn the use of his tools in the laboratory. There seems, however, a peculiar need that the mining engineers and metallurgists should make expeditions to a great distance from the school as there are no neighbouring mining regions; if there were, there would also be other dissimilar regions at a distance. The effort to make a mining engineer without showing him a mine would be as fruitless in its result as the effort to make a sailor without allowing him to go to sea.

For these reasons it is all important that visits should be made by the students of this course to the various mining regions of the country.

Although the ores of iron, copper, lead, and silver, and the seams of different kinds of coal are all of them mined by different methods, undergo a different subsequent treatment, and occur in dissimilar deposits, still a person while visiting one mining region gains much that will be valuable to him in studying other districts. It would be impossible in the limited time that can be devoted to expeditions, to visit a great variety of regions. It is stated in the catalogue that each mining student shall have at least one opportunity to visit one mining district during his course at the school.

The following instruments have recently been added to the equipment of the mining department especially for use on these expeditions: — a light mining transit and the German markscheide instrument with its grad-bogen.

It is deemed advisable that the second, third and fourth year's classes shall all be liable to receive the invitation to go upon expeditions. The second year will start to be sure entirely ignorant of the subject, but the expedition will add reality and interest to the subject when studied in the following year. The third year will make the excursion almost contemporaneously with their course of lectures. The fourth year, although they make the expedition a year later, yet it serves to brush up the subject in a practical way, and gives them opportunity to look about for places. There can be no fixed rule as to which classes should go on the expedition in any given calendar year, as circumstances come in to modify the case in regard to expense, time taken, and the number wishing to go.

An expedition during the summer of 1874 was made to the mining regions of Lake Superior. The party numbered fifteen, and contained members of the three professional years besides the two Professors in charge of the party.

While passing over the New York Central Railroad the party spent a day in studying the very extensive and carefully systematized salt works of Syracuse. The courteous attention of Dr. Englehardt added much to the mental enjoyment of the day, as did the thoughtful provision of Mr. J. W. Barker and of Mr. M. D. Burnett, to the physical comfort of the party. A day of recreation was spent at Niagara. The party were very kindly received by Mr. Grout of the Lake Superior Copper Smelting Company's works at Detroit. After two and a half days of pleasant sailing upon the lakes the steamer came to its destination at Houghton, a town situated in the heart of the copper region. While at Houghton visits were made to the Pewabic mill under the superintendence of Mr. Uren. The low pressure engine is run on the exhaust steam from the Ball stamp; the pressure used is but one pound per square inch, the atmosphere doing the work.

At the Lake Superior Copper Smelting Company's works the students were in clover. Mr. James R. Cooper spared no pains to make the morning pleasant and instructive. The works are an example of neatness and order. Not a pound of copper is allowed to go to loss without being challenged by the most available methods to prevent it. Mr. M. B. Patch (graduate of Mass. Inst. Tech.) added much to the profit of the visit by explaining matters.

At the Quincy mill the large battery of heavy cam shaft stamps was a great object of interest, as they are probably the heaviest stamps of this pattern in the country. It was to Mr. L. E. Emerson and to Captain John Cliff that the party owed a very pleasant morning within the Quincy mine. The party went down the man engine calling "change" at every step. The prospecting within this mine is far ahead of the stoping. The mine excellently illustrates the value of a cross cut from a barren part of the vein to prospect its adjacent productive spot.

The Atlantic mill was visited by a few of the party. It is a very complete mill; the ore worked in it is difficult of treatment. Mr. Wm. Harris, in company with Mr. S. W. Hill, spent a morning with the party at the Houghton mill, and at the purported new vein staked out by the mysterious "Dowsing rod." The Isle Royale mill contains a very remarkable machine, consisting of four enormous edgestone wheels made of cast iron, seventy tons weight in all, or eighteen tons on each wheel. The Osceola mine was visited, but on account of the breaking of a telegraph wire Mr. F. G. White was not informed of the party's visit. Mr. Jenney, however, explained the plans. The shaft houses are arranged for a large business. On account of the fineness of the copper grains, rolls are to be used for crushing. At the Calumet mine Mr. Wright kindly gave the party the freedom of the mine and mill. Under the charge of Mr. G. G. Richards they made a trip to the mill, which is the largest at the lake, and has a very systematic tailing mill to check the work of the other. The clerk, Mr. John Camm, gave the party over into the hands of Captain Wm. Daniell, who took every pains to make the visit below ground interesting and instructive.

At the Phœnix mine Mr. M. A. Delano courteously gave the freedom of the mill and mine. He personally showed the mill, pointing out alike its strong and its weak points. Captain Wm. E. Parnell took the party down the mine, showed the difficult survey to locate the present incline shaft, and pointed out the false system formerly pursued of working the *ash bed* for itself; also the present advantageous system of working *mass copper* mainly, and *ash bed* incidentally. He showed quantities of mass copper in sight and explained how his prospecting work was gaining on his stoping. The Copper Falls was visited. Mr. Emerson entertained the party with a nice lunch and gave them free leave to examine and criticize everything. Mr. E. R. Parks, engineer, and the mining captain accompanied the party down the mine. The extensive *ash bed* workings were noted, and the slip in the ash bed visited. The masses are not quite so large as in the Phœnix, but there seemed many of them. The circular slime buddles in the mill attracted special attention.

The party next took a week of recreation on Isle Royale, which might have been well named the Island of Mirage, on account of its numerous atmospheric phenomena of looming and deception. The party were the guests of the Hon. S. W. Hill's camp on Fish Island which lies on the north shore of Isle Royale. In Mr. Hill's boats they made vigorous raids on the fish, and their zeal did not abate at his table. The workings of the prehistoric race of men around McCargoe's cove, which were shown by Mr. Davis, are very numerous and very interesting. The rock hammers brought seventeen miles, from the north shore of Lake Superior, in canoes are found by tons. The country is rich in copper, and parties of prospectors under Messrs. Hill & Davis are now examining veins, intending to start works should they prove rich enough. Recently very encouraging indications have been met with.

At the Island mine Capt. George Hardie hospitably entertained the party. This mine is still in its infancy. The rock resembles the Calumet and Hecla, but the rule of the mine, that is where and when the copper will probably thicken, has not yet been ascertained.

At Silver Islet the party was given the freedom of the island by Capt. Wm. B. True, who took great pains in explaining matters. Captain Trethewey accompanied them, and Mr. James C. Hill, the clerk of the company, attended to their bodily wants.

The Lake Superior Copper region has afforded an excellent opportunity for the students of the Institute of Technology to study the very systematic process of ore dressing, which has grown up in the country by the efforts of Lake Superior men, and though its machines are like in principle to those used elsewhere, the plan is entirely peculiar to Lake Superior.

On returning, the party visited some of the iron mines in the Marquette region ; — the Superior mine, the Cleaveland mine, and the Angeline mine ; also the Negaunee and Deer Lake furnaces. On the way home they also passed a very interesting three hours at the Chester Emery mine. The expedition left Boston June 17, and returned July 25, time taken thirty-eight days ; the average necessary expense per student being $110.00, or $2.89 per day. The B. & A. R. R. and the G. W. R. R. of Canada gave half fare. The steamers reduced their fare from $32.00 to $26.00 for the round trip ticket. The hotels also made deductions. One hotel charged 64 per cent. of its regular rate, another charged 80 per cent. The week at Isle Royale cost the students nothing ; the party while there being the guests of Mr. Hill's camp.

Respectfully submitted,

J. M. ORDWAY.
R. H. RICHARDS.

STUDIES IN THE MINING AND METALLURGICAL LABORATORIES.

The experiments in the mining and metallurgical laboratory during the winter of 1873–4 were mainly tentative. Each machine and each furnace needs to be proved with every variety of ore that it is likely to be called upon to work, before the laboratory can be said to be an automatic department of the school.

During the past year several studies have been made. Mr. B. E. Brewster made some experiments upon silver lead ore from the Winamuck Mine, Bingham Cañon, Utah. His report has been condensed as follows:

These experiments were tried with a view to test the capabilities of the furnaces and to furnish certain data for future experiment. The Winamuck ore at the Institute is of two sorts. One a third class carbonate from the upper workings of the mine, and the other a sample of galena from lower down in the mine. The carbonate is in the form of powder, in which no minerals are distinguishable except a few small lumps of undecomposed galena, and a large amount of quartz in small grains. A quantitative analysis of a sample of the whole gives the following composition: —

Silicious Gangue,	34.01	per cent.
Lead,	33.78	"
Silver,	.21	"
Copper,	.33	"
Ferric Oxide,	12.07	"
Alumina,	1.50	"
Zinc,	1.21	"
Sulphur,	2.72	"
Carbonic acid,	6.60	"
Water,	7.10	"
Undetermined, arsenic, antimony, etc.,	.47	"
	100.00	per cent.

The galena is in lumps with very little fine stuff. There are several other minerals occurring with it of which the following were detected: Iron Pyrites, Sulphur, Zinc Blende, Quartz, Chalcopyrite, Blue clay, Tetrahedrite, Feldspar. Only a small quantity of Tetrahedrite was found, not more than two or three grams in looking over 225 lbs. of ore.

A quantitative analysis of a sample taken from 225 lbs. of the galena is as follows:—

SiO_2	8.56	per ct.	SiO_2,	8.56	per ct.
Lead,	49.42	"	Galena,	57.06	"
Silver,	.34	"	Silver,	.34	"
Copper,	.78	"	Copper pyrites,	2.27	"
Iron,	8.17	"	Iron pyrites,	14.87	"
Alumina,	1.70	"	Ferric oxide,	.63	"
Zinc,	8.33	"	Alumina,	1.70	"
Sulphur,	20.47	"	Zinc blende,	12.43	"
	97.77	per ct.		97.86	per ct.
Undetermined arsenic, anti'ny, water,	2.33	"	Undetermined,	2.14	"
	100.00	per ct.		100.00	per ct.

Experiment 1st. To Smelt Winamuck galena in the Reverberatory furnace by the Flintshire method.

This process consists of two parts; the ore is first roasted to convert a considerable proportion of the galena into sulphate and oxide of lead; and secondly, the heat is raised, causing the sulphate and oxide of lead to react upon the still remaining sulphide of lead, whereby metallic lead is liberated and sulphurous acid gas is disengaged. The method yields a slag very rich in lead, which is subsequently treated in a cupola furnace.

The following is an analysis of Flintshire ore.

Galena,	89.95	per ct.
Zinc blende,	.99	"
Oxide of lead,	5.15	"
Lime,	.65	"
Ferric oxide,	.29	"
Alumina,	.13	"
Carbonic acid,	1.62	"
Insol. residue,	.85	"
	99.63	per ct.

Metallic lead, 82.71 per ct.

The resulting slag contained 50 per cent. lead.

To apply this method to such an ore as Winamuck galena seemed rather hopeless, still it was thought that by taking more time a reduction to metallic lead might be effected; at all events it would show what the furnace would do. The furnace hearth is 4′ × 5′ with a slope from all points to the tap hole. The following is the narrative of the experiment: —

Furnace fired at 9.15 A. M. with Cumberland coal. At 10.15 the furnace being at a dull red heat, a charge of 100 lbs. of finely powdered galena was introduced, the galena covered the bed with a layer 1″ to 1¼″ deep; the roasting was continued until 4.30 P. M. A sample was taken every hour to show the rate of desulphurization. These samples were afterwards tested with the following results.

	Per ct. sulph.		Per ct. sulph.
Galena before treatment,	20.47	No. 4, after 5 hrs. roasting,	8.75
No. 1, after 2 hrs. roasting,	13.26	No, 5, " 6 hrs. "	7.65
No. 2, " 3 hrs. "	11.87	No. 6, slag after fusion,	2.30
No. 3, " 4 hrs. "	10.10		

The next morning fire was lit at 9.30 and was urged as much as possible. At 12.30 the charge had assumed a semi-liquid and an air blast was now put on under the grate, 20 lbs. sulphate of soda were added to aid in the fusion, 10 lbs. of scrap iron were added to separate metallic lead; but all was in vain. At 5.30 the firing was stopped and the charge withdrawn. The failure to produce any metallic lead was due to the fact that the ore contained just enough lead to make a flintshire slag and none to spare. The resulting slag was much the same as the Flintshire gray slag, containing, however, a little less lead.

Pb = 45 per cent.
S = 2.3 "

Experiment 2d. To smelt Winamuck carbonates and the rich slag from Expt. 1st, with tap cinder and a little galena in the cupola furnace.

The furnace measures eight feet from tap hole to feed door; the interior cross section measures twelve by eighteen inches. The tuyere in the rear is seven inches above the tap hole.

The blast is fed through a $\frac{7}{8}$ inch tuyere and is of a pressure equal to $\frac{1}{2}''$ of mercury. The fuel used was gas coke. In all furnace work of this character it is all important that the slag should be of such a composition that it may be melted easily and after melting to run liquid. Hence it is all important for the smelter to ascertain from the materials at hand, the proportions most efficient to produce a liquid slag, which shall not be so basic on the one hand as to choke the furnace with salamanders, nor so acid on the other hand as to become viscid and stiff as soon as it appears outside the furnace. The slag in this instance was planned to have

Silica,	30	per cent.
Ferrous oxide,	50	"
Alumina,	20	"

Which corresponds to the formula,

$$2(Al_2O_3)\ 7(FeO)\ 5(SiO_2).$$

And the mixture used for each charge was:—

Carbonates,	25	lbs.	
Slag from Expt. 1st,	$6\frac{1}{2}$	"	
Tap cinder,	25	"	
Galena,	$3\frac{1}{2}$	"	
Coke,	8	"	= 2 shovels.

Narrative of the experiment:—A fire was lit the night before to dry and heat the furnace. In the morning put blast on at 9 A. M., first ore charge at 10.35; charged every fifteen minutes. At 11 A. M. the first lead appeared; from this time on the lead and slag were tapped every ten to fifteen minutes. The furnace passed through various vicissitudes during the day none of which were very encouraging. About 6 P. M. the furnace became hopelessly constricted, and on tearing down the front a salamander about ten inches in diameter of aggregated metallic iron was found. This result proves that the slag was too basic. However, the composition of the tap cinder was not perfectly known and this error is probably enough to cause the failure. This slag carried 6.33 per cent. of lead.

Experiment 3d. To smelt Winamuck carbonates and a small proportion of galena with lead slag from Expt. 2d and so much tap cinder and lime as to produce a double silicate slag FeO, CaO, 2 (SiO_2).

This slag would contain,

Silica,	48.4 per cent.
Ferrous oxide,	29 "
Lime,	22.6 "

The proportions for the charge were:—

Carbonates,	25 lbs.
Lead slag,	25 "
Tap cinder,	1 "
Lime,	7 "
Coke,	½ hod.

The trial was a failure. It will be unnecessary to describe its details. The slag was so acid and viscid that it could hardly be made to run from the furnace. It seems evident from these experiments that basic slags will have to be used in this furnace. The radiation of heat is very large, while the heating power is comparatively small. Basic slags are much more fusible than acid ones.

Experiment 4th. To smelt a mixture of Winamuck carbonates and galena in the proportion of 2 : 1 by weight. Fluxes to be magnetic iron ore and lime, mixed to produce a monosilicate slag.

$$3(FeO)\ CaO\ 2(SiO_2).$$

This formula would require,

Ferrous oxide,	55 per cent.
Lime,	15 "
SiO_2,	30 "

And an allowance also of iron to desulphurize the galena.

The charge used in the furnace was:—

Carbonates,	12 lbs.
Galena,	6 "
Magnetite,	12 "
Lime,	3 "
Coke,	8 " = 2 shovels.

Narrative of the experiment:—The furnace was warmed and dried by a fire the evening previous. The first charge of ore was put in at 10.35, charged every fifteen minutes. At 11.57 lead appeared. At 1 P. M. finding that the slag was too basic, the amount of twelve lbs. of magnetite per charge was reduced to eight lbs. By 2.40 P. M. having used this charge six times the slag became so stiff as to render it almost impossible to tap the furnace. Two lbs. of sulphate of soda were now added, and helped matters considerably. At 4.30 the charge was changed so as to contain ten lbs. of magnetite, and with an addition of ten lbs. of foul slag which was made during the early part of this run. The furnace was soon running finely giving a good ingot of lead and clean slag at every tap. This continued during the rest of the run. The material in the furnace stood at about 3′ 7″ deep. At 8.30 P. M. stopped charging. At 10.30 P. M. took off blast. Material in the furnace was 1′ 6″ deep, tore down the front and raked out the residue. The furnace was in better condition than after the previous run, there was a small scaffold on the back side. The slag contained 1.34 per cent. of lead. Unfortunately but a partial analysis of this slag has been made.

Silica,	34.27	per cent.
Ferrous oxide,	35.28	"
Lime,	7.10	"

This slag contained but 1.5 per cent. lead, and its composition differs largely from the above plan.

The old proverb "we learn by our failures," is doubly true of this laboratory. I think that any practical metallurgist will at once recognize the advantage to a student of a study like the one just described. Another sample of laboratory work is here given.

A silver lead ore worked by Mr. F. H. Jackson. This ore is from the 2d vein that is intersected by the Burleigh tunnel, which is situated near Georgetown, Colorado. The ore was examined for its mineral species. The following minerals were discerned:—Galena, coarse and fine grained; zinc blende (black); pyrites, mostly granular; chalcopyrite; feldspar; mica; quartz.

The galena, zinc blende, and pyrites formed the greater part of the ore, the galena being by far the predominating mineral. From inspection of the ore it was evident that it would be advisable to separate the galena into one portion fit for smelting; the zinc blende into another to be treated by chlorinating roasting followed by amalgamation in a tub; and lastly the dust resulting from crushing, etc., which would contain too much galena for amalgamation and too much zinc for smelting. This dust it was thought might be treated successfully by gas chlorination, followed by a leaching with salt or hyposulphite of soda. The method of ore dressing had to be planned therefore to prepare the ore for three distinct metallurgical operations. The weight of ore taken was 476 lbs. 14 oz. It was at first sorted, making on the one hand a heap of pure galena, and such pieces as contained galena and pyrite, but in every case free from zinc blende. The other heap was made up of pieces containing zinc blende and other minerals.

(A.) The galena portion weighed 144 lbs. 14 oz.

(B.) The zinc blende portion weighed 331 lbs. 2 oz.

The portion (B) was crushed in a Blakes crusher set at $\frac{3}{8}$ of an inch, and sized with sieves and made ready for jigging. That which passed through a sieve of twenty meshes to the inch was saved in a separate portion, it being too fine for successful jigging. The sizes which were obtained by the sieves were

Grains which passed $\frac{3}{8}''$ sieve but remained on $\frac{1}{4}''$ sieve.
" " " $\frac{1}{4}''$ " " " " $\frac{1}{8}''$ "
" " " $\frac{1}{8}''$ " " " " $\frac{1}{20}''$ "

The jigging was performed in a sieve one foot in diameter suspended from a long wooden spring, the sieve being in a tub of water. The operation of jigging consists in placing the mixed ore upon the sieve; the sieve is shaken up and down, being kept under water at all times. By this means at every jerk downwards of the sieve, the ore particles are all of them allowed to fall through water; the heavier invariably sink faster than the lighter. When the jerks have been repeated a sufficient number of times, the whole of the heavy ore will be found underneath while the light parts will be found on top. By this means an almost perfect separation of ore from gangue may be effected. Each of the above mentioned sizes was jigged by itself, for it is not desirable to treat all sizes together, as a large lump of a lighter mineral will settle as fast as a small lump of a heavier mineral. When the portion (B) was jigged four distinct layers were obtained. Gangue, blende, pyrites, and galena. In scraping out the sieve however, the division was made into two portions

(C.) Gangue, Zinc blende, and pyrites, 79 lbs. 2 oz.

(D.) Pyrites and Galena, 187 lbs, 2 oz.

Of that portion which passed through $\frac{1}{20}$ inch mesh sieve, the coarser part which remained upon $\frac{1}{40}$ inch mesh sieve was treated upon a Rittinger shaking table and yielded quite a clean separation of galena from zinc blende.

The results of this work may be tabulated thus

Galena smelting portion,			
From hand picking,	144 lbs.	24 oz.	
" the jigger,	187 "	2 "	
" the shaking table,	10 "		
Total,	342 lbs.		
Zinc blende amalgamating portion,			
From the jigger,	79 lbs.	2 oz.	
" the shaking table,	12 "	15 "	
Total,	92 lbs.	1 oz.	

Dust for gas chlorination below $\frac{1}{40}$ inch in size, 42 lbs. 13 oz.

This investigation was not finished satisfactorily on account of lack of time.

The above will suffice to indicate the character of the work, and its value to a student whose profession will hereafter demand the solution of such problems.

Respectfully submitted,

ROBERT H. RICHARDS,

Professor of Mining Engineering.

THE INSTRUCTION IN MECHANICS AND MECHANICAL ENGINEERING.

President J. D. Runkle: —

DEAR SIR: — In the Department of Mechanics the methods of Professor Rankine's work on "Applied Mechanics" have been mainly followed, this having been used as a text book, together with my printed "Notes on Mechanics." The ordinary subjects of Statics, viz., the Composition and Resolution of Forces, and the Conditions of Equilibrium, were first taken up; subsequently the subject of Distributed Forces was considered, both as applied to determinations of centres of gravity and the internal stress of bodies.

A set of models illustrative of the latter subject in its applications to tensile, compressive, and transverse strength, and also the internal conditions as to stress of homogeneous granular masses, have been employed with decided advantage.

But little time was left for the subject of Dynamics, and this was devoted to a consideration of the most important of the laws governing motion, momentum, force, energy and allied subjects, such as Moments of Inertia, Radii of Gyration, etc. The instruction is given partly by lectures, partly by recitations and blackboard exercises, and partly by the computation of numerical and practical examples, which last forms an important feature of the work in this subject.

The progress of the class was quite satisfactory, only three students having been conditioned at the close of the last school year, all of them having subsequently made up their conditions at a re-examination.

A proper knowledge of Applied Mechanics being vital to all successful progress of the student in any of the Engineering Courses, it has been, and is, the aim of this department to so arrange the work and so give the instruction that they may have a direct bearing on those subjects considered in the professional departments which depend upon mechanical laws; and, moreover, to point out as far as possible, and enable the student to keep in view and understand the methods of making the applications of the theoretical topics presented for his consideration. The plan of the instruction, therefore, involves the discussion of the applications of statical and dynamical principles immediately after, and in connection with, the principles on which they depend. A few of these subjects are the following:

1. The methods of determining the stresses in the different parts of a structure; in beams and in columns under given loads; and the mode of distribution of these stresses in the single pieces; also the forces acting on the moving pieces of machines, such as connecting rods, wheels, shafts, etc., both in regard to the motion produced and the stresses acting in the pieces themselves.

2. Methods of determining the thrusts in arches, retaining and reservoir walls, etc.

3. Determination of the momentum and energy of moving bodies, either pieces of machinery or not, and other kindred subjects.

It is hoped by this means to so familiarize the student not only with the theory, but also with the mode of readily applying mechanical laws, that he may find in his Mechanics a ready tool with whose use he is familiar, and which he can apply with facility and judgment to any of the investigations he is required to make in his professional work, either at the Institute, or hereafter.

The adoption of the new scheme of studies last session could not at the time much affect, in this particular subject, the condition of a class as far along as their Third Year; but in the present year the three following consequences of the scheme promise to aid materially in carrying out more fully the plan already laid down.

1. The Calculus, instead of being studied contemporaneously with the Mechanics, is completed before the Mechanics begins; hence the student does not have his attention divided between these two serious studies.

2. The parts of the Calculus used in the Mechanics are already known by the students, so that they are not obliged to stop and devote part of the time that belongs to the Mechanics in studying the mode of performing the necessary Calculus operations.

3. The number of exercises, though not materially increased as a whole, has been made three per week instead of two, as heretofore.

These changes must inevitably aid in a decided manner the fuller carrying out of the above scheme. I would further suggest that it would be extremely desirable, whenever it is possible, and there are no special reasons to the contrary, that such subjects in the professional departments as depend directly on, and involve the applications of, mechanical laws, should be treated by the department at such times as the students are considering in their Mechanics the theories involved; also that experiments bearing on such subjects should, as far as possible, be made at the same time in the laboratories, as it is believed that approaching a subject at the same time from different points of view is conducive to a more thorough understanding of it on the part of the student.

Such an arrangement has been made in the department of Mechanical Engineering, and in whatever other department it should be found practicable to adopt such a system, it could not but infuse a new life into the interest taken by its students in their Mechanics, besides saving more or less a repetition and review on the part of the professional department of the modes of applying the mechanical laws to the practical cases, before being able to proceed with the purely professional work depending upon them.

I would also submit that whenever the previous preparation of the students shall warrant the completion of the Calculus in the second year, and allow the Mechanics to be studied three times per week for the whole of the Third Year, the degree of completeness with which the scheme already laid down can be carried out will be even further increased.

The work done in the Mathematical part of the Mechanical Engineering Course during the last school year was as follows: in the Fourth Year's Class the subjects studied were Dynamics of Machinery, Strength of Materials, and Thermodynamics; in the Third Year's Class, Mechanism and Thermodynamics; in the Second Year's Class, Mechanism.

Professor Rankine's treatises on Machinery and Millwork, and on the Steam Engine, were used as textbooks, and the above subjects were taken up in the order followed in these works: thus in the Dynamics of Machinery the laws governing Momentum — Energy and Work of Machines and parts of Machines were first considered. Subsequently the subject of Friction, and the work used in overcoming it, the efficiency and counterefficiency of Primary pieces and of modes of connection in Mechanism were discussed, and also the subjects of Brakes, Dynamometers, Indicators, Flywheels, Governors, etc.

In the Thermodynamics the greater part of Chapters I, II, III, and IV, Part III of Rankine's Steam Engine were studied; the following being a part of the subjects discussed, viz: Thermometry and Calorimetry, Absolute temperature, Specific heat, real and apparent, Sensible, Latent, and Total Heat of expansion, evaporation and fusion, Efficiency of furnaces and boilers; Evaporative power of fuel, Total Heat of combustion of fuel and Draught of Furnace, Isothermal and Adiabatic lines, Potential and Thermodynamic functions, Indicator diagrams of jacketed and of unjacketed cylinders, Efficiency of steam in the cylinders, Properties of Saturated and Superheated steam, etc., etc.

In the Strength of Materials Part III of Rankine's Machinery and Millwork was studied, and such explanations and illustrations given as seemed necessary for a full understanding of the subject. The Third Year's Class in Mechanism completed the greater part of Part I of the Machinery and Millwork; and the Second Year's Class took up the subjects of Cams, Connection by Bands, Linkwork, Reduplication, and Hydraulic connection. The same subjects are presented at the same time to the student in this and in the other three parts of the Mechanical Engineering course, viz., the Practical, the Graphical and the Excursional; and he is made to approach them from a different standpoint in each. This system keeps up the interest of the student in his work, and gives him a far greater degree of familiarity with it than he would otherwise acquire.

The instruction is given partly by lectures, recitations and blackboard exercises. But few written exercises and computations are required to be handed in in this part of the course; this belonging more particularly to the practical part of the course. Care is also taken not only to collect from Professor Rankine's other works whatever is said on any particular subject, but also to utilize all other available sources, in order to present to the class the simplest and clearest demonstrations.

Such models as the Institute is already provided with have been used with the greatest advantage, and indeed are indispensable. It is only to be hoped that their number may be increased as rapidly as possible. The progress of all the classes was very satisfactory; all the students who stood the final examinations having passed without conditions.

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REPORT OF THE DEPARTMENT OF MODERN LANGUAGES FOR THE YEAR 1873-4.

President Runkle:—

DEAR SIR: In the absence of any previous report of this department it is difficult to obtain a satisfactory idea of its past course and policy. For the following brief statements and impressions in regard to the year immediately preceding that under consideration, I am principally indebted to the tabular views in the catalogue and the examination papers.

1. *Brief review of the department for the preceding year.*

During the year 1872–3 French was taught in all the classes throughout the year, excepting in the second half of the Fourth Year. The same is true of the German, excepting the first half of the First Year. The number of exercises per week varied from one to four, rising to the latter number only in the First Year during the first half in French, and falling to the former number only in the First Year during the second half in German. The number of exercises per week, with these exceptions, varied from two to three. Taking this year as a basis, the number of exercises of an hour each a student would have during his entire course would be 270 in French, and 225 in German. These exercises were almost entirely in the form of recitations. As to the amount of time allowed or used outside of the recitation room for work, whether beforehand or afterwards, on these exercises, I am unable to obtain any exact data. What indications there are would lead to the conclusion that this was not very much nor very regular. The amount read, however, in both French and German, was considerable, amounting to 300 pp. or more in either language. The entire number of recitations a week varied from twenty-four in the first term to sixteen in the second. As a result the graduates have for the most part, I believe, been able to read easy French at sight, but as much cannot be said of the more difficult German. As to the accuracy and strength of the students' knowledge it would be difficult to make any statement.

With respect to the above, it should be remarked that the number of recitations, 495 in the regular course in French and German, is very large. Moreover those in German were disproportionately smaller than those in French, whereas they should be more numerous, in view of the much greater difficulty of the same and the greater time necessary for attaining the same degree of proficiency. If the impression be a correct one, that very little independent work was done by the student outside of the recitation hours, the results would indicate that such work is necessary for accuracy and strength in the practical use of these languages.

2. *Scheme for the modern languages at the beginning of the year* 1873–4.

At the beginning of the year 1873–4, it appeared that the time previously assigned to both French and German had been very much curtailed, owing to an action of the Faculty aiming at lessening the pressure of work upon the students, which had been found to be too great. On the basis of this half year as indicated by the tabular view, the entire number of exercises in the regular course would be in French 150, and in German 210, instead of 270 and 225 respectively as in the preceding year, or 360 for the entire course instead of 495 as before. Besides, it was expressly provided that no preparation should be allowed for one of the exercises, and only an hour for another. The diminished number of exercises would have sufficed, in itself considered, but the difficulty was that the students, excepting the First Year, were unable on account of the pressure of their profes-

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The entire number of recitations per week in the regular course this term were 12 in French and 10 in German, counting the repetitions on account of division of classes. In the special Italian course there were 2, making in all 24.

3. *New scheme for the French and German, being a part of the general revision of the studies of the Institute.*

Before the close of this term it was found necessary to undertake a complete revision of the entire scheme of study of the Institute. This was very carefully and deliberately worked out and put into operation, so far as possible, the second half of the year. The provisions of the same, so far as it referred to this department, were as follows. (1) But one modern language is to be taken up at a time, and this finished before another is commenced. (2) Three exercises a week for two years are allowed to each language. (3) Two hours for preparatory or subsequent work are provided for each exercise.

(1.) In regard first to the time when one language can be dropped and give place to another. Inasmuch as French is required for admission, this would naturally be continued until finished, when German would be commenced and receive the length of time assigned to it. As the requirements in French at the first examination on this subject for admission were equal to about half a term's work in the school, this language would be finished by this class at the middle of the second half of the Second Year. The requirement for admission as fixed in the catalogue for the next class being about twice as much as above, this class would be through with its French by the middle of the Second Year, and so on in proportion as the French requirement for admission may be increased. In the second case the German would be finished by the middle of the Fourth Year.

(2.) In regard to the length of the course and frequency of the exercises. A smaller number of exercises per week than three, especially at the beginning, would, it is thought, fail of securing such a concentration of the student's attention upon his work as is to be desired. This number, however, would secure that object and produce probably the best proportionate results, being at the same time consistent with the student's exercises in other departments. Three exercises a week for two years give a course of one hundred and eighty exercises. This number is smaller than that allowed the German the first half of the year in question, and much smaller than that allowed either language last year. It happens to be exactly the same length as the course in each of these languages at another prominent and well-established scientific Institution, except that there the time at the student's command for previous and subsequent work is somewhat greater. A course of this length prosecuted in the manner indicated should, it would seem, enable a student to translate ordinary French at sight, with a fair amount of accuracy and strength in dealing with passages of special difficulty. This would probably be too strong a statement for the German, whose construction is more involved, and which requires much more practice than the French. But although the time given it is no more than that given the French, it should be said that it is taken up after the student has had the training in language afforded by the latter course. It is to be understood that this scheme has reference principally to the regular courses for all students. The Science and Literature and optional classes would naturally be treated more or less differently. The former for instance, where the course in French and German is more of a literary and philological character, might have more time allowed them; while the latter, where the object is principally practice and the acquisition of a vocabulary, could pursue advantageously a course of two exercises a week without being called upon to do any outside work.

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(3.) The final and perhaps most important point of this scheme to be considered is the time assigned for work outside of the recitation room. This has reference partly to the rapidity of the student's progress, but more especially to the character of the work done. A very considerable part of the recitation room exercises, such as practice in pronunciation, learning new words, becoming familiar with forms, and practice in translation can be done as well by the student alone, after he has received specific directions with illustrations in regard to the above. An allowance of time therefore for work outside of the recitation or lecture room necessarily accelerates his progress to a corresponding degree. But of more importance than this is the consideration that the character of his knowledge is largely dependent upon the student's unaided work by himself. There is a strength in the knowledge and use of a language gained by working out a translation alone which can be gained in no other way. Thus the student is forced to decide why this must be so, and why it cannot be otherwise, either by searching for and comparing other similar cases or examining the law in the grammar. Besides, when for the sake of acquiring words and fluency in the use of the language, easy French or German is read to the class in the recitation room, the full and proper results of such an exercise are only secured when the student has subsequently gone over by himself what he has followed in the class room. But to require such outside work in the study of the languages is apt to be looked upon with suspicion, as it is so often misused for the memorizing of disconnected grammar rules, or even a too minute or extensive attention to the analysis or construction to the sacrifice of the thought. But when the time is legitimately used, as hinted at above, the bearings of the work are recognized, and there is no reason why it should not be agreeable, and not an irksome task. The ability to comprehend a foreign language with readiness and accuracy is an acquisition of no slight value, and in this as in other departments of science the value of the results is apt to correspond pretty closely with the work required in order to attain them. However much a proper method may facilitate the accomplishment of the object in view, much time and work is indispensable.

4. *General views in regard to the instruction in the modern languages.*

In connection with the above scheme it is desirable to consider also by what general method the student can best pursue his study of a modern language. Shall it be (1) the rote or practice method, such as a child pursues in learning its mother tongue, or the similar so-called Ollendorff method; or (2) what we may call the *à priori* or dogmatic method, such as is generally pursued in the study of the dead languages; or (3) a mean between the two combining the excellences of both, while avoiding their defects. We think decidedly the latter.

For what is the object in view? It is to learn to *read*, with *accuracy* and *readiness* a scientific work in French or German. Accuracy and readiness, theory and practice, both are essential, but they must be in due proportion. To proceed as a child does in learning its mother tongue, although such a course if continued long enough would undoubtedly produce a satisfactory result, is neither necessary nor practicable. Developed powers of judgment and thought give him an advantage over the child, not only with regard to the point at which he can take up the subject, but also the manner of pursuing it. Why not take up at once the actual text and apply his powers of observation and the principles of induction, being assisted in learning the laws of the language both by the teacher and the embodiment of the same in the grammar. Talking is not his object, although conversational exercises will prove of assistance in making him familiar with the laws and idioms, and in learning words. Should he visit the country where the language is used, in which case alone he will have occasion to speak it, that facility will follow readily, as experience can testify. Facts also prove that he can enable himself to comprehend accurately and readily the page of a foreign writer, although he might not be able to hold a conversation in the same language. This is all he needs, and it is not consequently necessary to consider the more psychological than philogical or practical question, as to whether a person can read intelligently a foreign language, who cannot speak it or think in the same. But practically his other engagements are such that he cannot devote a large amount of time at frequent intervals, room exercises, such as practice in pronunciation, learning new words, becoming familiar with forms, and practice in translation can be done as well by the student alone, after he has received specific directions with illustrations in regard to the above. An allowance of time therefore for work outside of the recitation or lecture room necessarily accelerates his progress to a corresponding degree. But of more importance than this is the consideration that the character of his knowledge is largely dependent upon the student's unaided work by himself. There is a strength in the knowledge and use of a language gained by working out a translation alone which can be gained in no other way. Thus the student is forced to decide why this must be so, and why it cannot be otherwise, either by searching for and comparing other similar cases or examining the law in the grammar. Besides, when for the sake of acquiring words and fluency in the use of the language, easy French or German is read to the class in the recitation room, the full and proper results of such an exercise are only secured when the student has subsequently gone over by himself what he has followed in the class room. But to require such outside work in the study of the languages is apt to be looked upon with suspicion, as it is so often misused for the memorizing of disconnected grammar rules, or even a too minute or extensive attention to the analysis or construction to the sacrifice of the thought. But when the time is legitimately used, as hinted at above, the bearings of the work are recognized, and there is no reason why it should not be agreeable, and not an irksome task. The ability to comprehend a foreign language with readiness and accuracy is an acquisition of no slight value, and in this as in other departments of science the value of the results is apt to correspond pretty closely with the work required in order to attain them. However much a proper method may facilitate the accomplishment of the object in view, much time and work is indispensable.

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Nor, on the other hand, is the method currently used in the study of the dead languages adapted to the end in view. That involves too much anatomical work, and fails to give the necessary practice and readiness in appreciating the thought of the author. It is open to the charge of studying the grammar, etymology and logic, too much, but the language, too little, which, though it might be defended with a purely educational end in view, cannot be where the object is a practical one. This system sacrifices the practice and favors the theory, the former favors the practice and sacrifices the theory.

But a mean between these two extremes seems best adapted to conduct the student most surely and expeditiously to his object, which is to read understandingly and readily. He should have the practice and attention to the thought of the author on the one hand, and on the other such a systematic knowledge of the main laws of the language as will ensure him strength and accuracy in interpreting its authors, and which being thus fixed in the mind will never be forgotten, though the practice should be intermitted. In a word, the student should from much practice acquire a practical readiness in appreciating the thought of the writer on the one hand, and on the other such a survey and comprehension of the structure of the language, as will make his acquisition a permanent one, and one enabling him to meet with strength serious difficulties of interpretation.

In practically carrying out these views, the actual text of the foreign language in some form has been presented to the student from the outset for his practice and study. In connection with this the forms have been studied and practiced, so also the principal laws and usages of the language, in the progress of the student's course. Consequently grammar, or a systematic embodiment of these forms and laws, has been a constant subject of study. Much reading gives the requisite practice, while a careful attention to the grammar or laws of the language not only facilitates the acquisition of the same, but ensures the student accuracy, and the permanency of this acquisition. But it is very important practically to know what is understood by the study of grammar. If it means learning a number of technical, obscure expressions, or the memorizing of a body of rules or observations not in immediate connection with the living text, but which it is intended to apply to that at some future time, then it is not strange that it should be to the student a very unwelcome work, and its study seem a very irksome and unprofitable task. But if grammar means a regular induction of the laws of the language, resulting from the observation and comparison of individual cases and their systematic arrangement, then its study affords a satisfaction and sense of mystery to the student, and he is as much interested in it as he is in the laws of any science. He realizes that there can be no accuracy without these laws, and that, from the fact that he can comprehend them more quickly than the child and apply them with less practice, he progresses far more rapidly in acquiring the language. The aim has been, accordingly, constantly and regularly to call the student's attention to these laws as the text has presented them, and to use the grammar as a reference book for a fuller statement, and also a permanent one for him to refer to at his pleasure. Much importance has been attached to dictation exercises as a means of presenting these laws and affording practice on them, also of learning words, idioms, and the general spirit of the language. They have accordingly been a frequent and regular part of the work.

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Nor, on the other hand, is the method currently used in the study of the dead languages adapted to the end in view. That involves too much anatomical work, and fails to give the necessary practice and readiness in appreciating the thought of the author. It is open to the charge of studying the grammar, etymology and logic, too much, but the language, too little, which, though it might be defended with a purely educational end in view, cannot be where the object is a practical one. This system sacrifices the practice and favors the theory, the former favors the practice and sacrifices the theory.

But a mean between these two extremes seems best adapted to conduct the student most surely and expeditiously to his object, which is to read understandingly and readily. He should have the practice and attention to the thought of the author on the one hand, and on the other such a systematic knowledge of the main laws of the language as will ensure him strength and accuracy in interpreting its authors, and which being thus fixed in the mind will never be forgotten, though the practice should be intermitted. In a word, the student should from much practice acquire a practical readiness in appreciating the thought of the writer on the one hand, and on the other such a survey and comprehension of the structure of the language, as will make his acquisition a permanent one, and one enabling him to meet with strength serious difficulties of interpretation.

In practically carrying out these views, the actual text of the foreign language in some form has been presented to the student from the outset for his practice and study. In connection with this the forms have been studied and practiced, so also the principal laws and usages of the language, in the progress of the student's course. Consequently grammar, or a systematic embodiment of these forms and laws, has been a constant subject of study. Much reading gives the requisite practice, while a careful attention to the grammar or laws of the language not only facilitates the acquisition of the same, but ensures the student accuracy, and the permanency of this acquisition. But it is very important practically to know what is understood by the study of grammar. If it means learning a number of technical, obscure expressions, or the memorizing of a body of rules or observations not in immediate connection with the living text, but which it is intended to apply to that at some future time, then it is not strange that it should be to the student a very unwelcome work, and its study seem a very irksome and unprofitable task. But if grammar means a regular induction of the laws of the language, resulting from the observation and comparison of individual cases and their systematic arrangement, then its study affords a satisfaction and sense of mystery to the student, and he is as much interested in it as he is in the laws of any science. He realizes that there can be no accuracy without these laws, and that, from the fact that he can comprehend them more quickly than the child and apply them with less practice, he progresses far more rapidly in acquiring the language. The aim has been, accordingly, constantly and regularly to call the student's attention to these laws as the text has presented them, and to use the grammar as a reference book for a fuller statement, and also a permanent one for him to refer to at his pleasure. Much importance has been attached to dictation exercises as a means of presenting these laws and affording practice on them, also of learning words, idioms, and the general spirit of the language. They have accordingly been a frequent and regular part of the work.

In addition to the semi-annual and annual examinations, there have been intermediate examinations of an hour each on the amount gone over the preceding month. It is believed that these have been of much value, in giving the student a definite indication of his progress, while they also afford practice in writing translations, and precision in the expression of his knowledge.

After considering the shortest way, so far as is consistent with strength, permanency and accuracy, of attaining to the ability to read readily a foreign work, the thought naturally arises, what is the value of this course of training as a means of general culture. Were the latter the direct object, some modifications would perhaps be desirable, but as it is, there can be no doubt that such a course, being of a methodical nature, and having to do with the written works of other people, must exert much influence in the direction of a liberal and general culture. This consideration presents an additional reason for allowing this work an adequate provision of time, and bestowing upon it especial attention.

5. *Work done in the several classes during the year.*

French. *First Year.* In addition to exercises in especial connection with Otto's Grammar, the class read during the year fifty-nine pages in Otto's Reader and thirty-five pages in Corinne. There were three exercises a week, with two hours for preparation during the second half. *Second Year.* The French was confined to the first term, at the rate of two exercises a week, no preparation being allowed. Seventeen pages in Corinne were read. *Third Year.* The French was also here confined to the first term, at the rate of two exercises a week, with one hour for preparation on each. The "Atala" of Chateaubriand was read, or one hundred pages. In the *Fourth Year* there was no French.

German. *Second Year.* There was no German in the First Year, but the Second Year commenced this study at the rate of three exercises a week. In the second half of the year the class had two hours' preparation for each exercise, in the first half there was often no time for this, and the amount was in general small and irregular. In addition to dictation and other exercises, fifty pages in Whitney's Reader were read. *Third Year.* Selections from German ballads, also Heyse's "Die Einsamen," eighty-eight pages. There were also dictation exercises. *Fourth Year.* Besides a few German ballads, Goethe's "Egmont" was read, making one hundred and forty pages. The class continued the study optionally through the second term with the Science and Literature class.

In addition to the above, in which all of the regular and some of the special students participated, five members of the Science and Literature and Philosophical departments pursued in the Third Year, second half, an advanced course in French, reading three plays of Molière (149 pages) with regular exercises in dictation, and the translation of longer extracts from English into French. Members of the same department in the Fourth Year, continued during the second half their German, reading the last three acts of "Egmont".

There was an optional class in Italian during the year composed of six Fourth Year students. Two hours a week were assigned to it, and the subject pursued in such a manner that no outside work was required. It would seem advisable to urge students to go farther in French and German rather than take up Italian or Spanish, in which they can at best get only an introduction. But for those, who for special reasons, as students in architecture desiring Italian, or those in engineering expecting to go to Spanish-speaking countries, the best arrangement would seem to be, to have classes in these languages on alternate years open to students of both the Third and Fourth Years. That would enable each graduate to pursue a course in one or the other.

The time assigned in the second half of the Fourth Year to a course in the Science of Language, for students in the departments of Science, and Literature and Philosophy, it was impossible to utilize for want of time on the part of instructors. It is hoped that so valuable a course may be carried out the next year.

The whole number of exercises per week during the first half

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The whole number of exercises per week during the first half year was twenty-four, during the second half twenty-three. Eight of these exercises in the first half, and six in the second half were repetitions, owing to the division of the First and Second Years.

6. *The regulation requiring French for admission.*

The regulation making French one of the requirements for admission was first put into operation at the commencement of the year of which this is a report. The amount required was "The first nineteen lessons of Otto's Grammar," that is, the elements of the language as far as regular verbs, with some practice on sentences illustrative of the same. This would be equal to at least half a term's or two month's work in the Institute. This requirement was poorly answered. The class at the beginning numbered seventy-nine, of whom thirteen had never studied French at all. The average mark in French of the whole class at admission, not including ten who had advanced much farther than the amount required, was somewhat below fifty on a scale of one hundred. There were thus three distinct divisions in the class, each demanding different treatment by themselves. The ten students advanced in French were excused entirely for the First Half Year. The thirteen who had never studied the language at all should have been enabled by more frequent exercises, and by reciting by themselves to catch up with the class, which could have been easily done by the semi-annual. But means of instruction failing for this, it was necessary that the whole, thus unequally constituted, should go on together, to the disadvantage of both, neither receiving the treatment best adapted to it. It is especially to be recommended that there should be in future such a separate class, at least until the requirements are better responded to.

The amount required in French the following year was: "Pt. I of Otto's Grammar, and the first twenty-five pages of Bôcher's Reader, or their equivalent." This is probably rather more than twice as much as the amount required at the first examination, and rather more than half a year's work at the Institute. It is to be hoped that it will soon seem feasible to increase this amount, so as to include a knowledge of the main principles of the language and more practice in reading, so that a year's work can be done before entering, and the French as a regular study discontinued at the end of the first year.

Undoubtedly a small amount of Latin would have been easier to obtain than the French. A majority of the students study Latin before coming to the Institute, and without reference to entering it. At the High Schools, where most of them receive their previous education, Latin is a regular study, whereas French is taught, I believe, in comparatively few. It therefore becomes a serious matter of expense as well as of difficulty to obtain the necessary preparation in French, especially as it is a subject which the student cannot work up alone, as would be quite possible in the case of the Latin. It should, however, be stated on the other hand, that the colleges are now beginning to require French for admission, which will have its influence on the High Schools and others, where students prepare for the Institute. Hence it is likely to become easier each year to meet a French requisition for admission, especially should the indulgence shown candidates not prepared in French be continued, whereby they are allowed to join their class on condition of making up, by extra work, their deficiency.

7. *A modification of the present scheme in French and German proposed.*

A slight change in the scheme already arranged would make it more satisfactory, so far as this department is concerned, without affecting unfavorably any other one, so far as can be seen. As it at present stands, the German cannot be taken up before the middle of the Second Year, when the time (two years) assigned to the French will be concluded. The proposition is to commence the German at the beginning of the Second Year, and complete the remaining half year to which the French is entitled at another point in the course. The latter might be done in the first half of the Fourth Year, in which case a course of optional French reading in the interval would obviate the difficulty of so long a suspension of the language. Or the same object might be accomplished by allowing the French an additional number of lessons a week the First Year, which seems to me the better plan. The regular course in French would thus be secured, and on the other hand that in German would be greatly improved. For, in the first place, the strictly technical German, which is much more difficult than the strictly technical French, can be advantageously learned only in the departments needing it, and with the assistance of the Instructors there; in order to which, however, the study should be commenced, at least, as early as the beginning of the Second Year. In the second place, the German, being a much more difficult language than the French, and demanding much more practice, should have a place in the course where it can be pursued seriously and without interruption. But students in the Fourth Year, being closely confined to their professional work, would be in danger of failing to give it the time and attention which it could have the year before. Moreover, if the regular German course were finished at the end of the Third Year, there would be left an entire year for an optional course in practice-reading in the same, occupying but two hours a week of his time, and which would be of great value in increasing his vocabulary and facility in recognizing the thought of the writer. Besides, it would then be possible to extend over the whole Fourth Year the literary and philological course of the Science and Literature students, which now has but half the year. It seems also especially desirable to make such a change in behalf of the German, since this language, as it now stands, does not receive so much attention as the French, and students have not consequently attained the same proficiency in it as in the latter. Even with this change made, it is hardly possible that students will be able to reach the same point in German as in French.

In addition to the above, I would propose a course of optional practice-reading of a year each, in both French and German, which, in regard to the latter, has just been alluded to. The object would be to enable the student to increase his vocabulary, and require additional readiness in following the thought of a writer. Popular presentations of various branches of science in French and German would in part, at least, afford profitable texts for such reading, although strict scientific treatments of subjects, especially in German, should be taken up by the students in the several departments with the help which they would receive from their Instructors and laboratories. Such a course should come at the conclusion of the regular one, when students are able to read at sight, even though hesitatingly, easy French and German. The best place for that in French would be in the Third Year, or better, in the Second, should that not be too much crowded; and for that in German in the Fourth Year. This course might consist of two exercises a week, no preparation on outside work being required or expected, and it being optional with a student, according to the time he may have at his disposal, to take it up or not, it being understood, however, that if he do begin he is to attend punctually, and pass the usual intermediate and annual examinations.

With arrangements as suggested above, the Science and Literature, and Philosophy students, would have the entire Third Year for an advanced course in French, and the Fourth Year for an advanced course in German. They would also have, as at present, the Second Half of the Fourth Year for the course in the Science of Language, intended to consist of familiar presentations and discussions with regard to the nature of language, its life and growth, the place its study occupies among the sciences, the separation of languages into dialects, the characteristics of the great families into which human speech is divided, and, finally, the question of the origin of language; these subjects being considered as much as possible with reference to the English, and illustrated by examples from the same.

The Italian and Spanish optional courses would continue as above indicated.

With expressions of sincere appreciation, Mr. President, of your constant and very valuable support of the management of this department the past year, the above is

Respectfully submitted.

C. P. OTIS.

THE INSTRUCTION IN INDUSTRIAL AND PHYSIOLOGICAL CHEMISTRY.

President Runkle: —

DEAR SIR: — As the number of our students has increased from year to year, the repeated demands for more room for chemical manipulation and analysis, and for metallurgical work, have been but insufficiently met by extending the laboratories so as to take up all the available space in the basement of the building. Other departments have also felt the need of an extended area, and in this continual struggle for space the less elementary branches have been compelled to yield. Hence the subjects which come under my special charge, industrial and physiological chemistry, still lack a local habitation, and many long felt wants remain unsupplied. But we invite students in advanced and special chemistry, and in order to keep up the rank which we have hitherto held among schools of science, it is important that laboratories should be established for the instruction of such students. For instruction and for research in chemistry, as applied to the arts, we should have facilities for operating on pounds of materials instead of grains, and there is needed apparatus similar to what is actually in use on the large scale. One who has worked only with test tubes, watch glasses, beakers, platinum crucibles, and small gas burners, is ill fitted to make such practical experiments as are required for the improvement of manufactures, and he necessarily feels much at a loss when brought in contact with the operations of real life.

There should be a *Laboratory of Industrial Chemistry*, affording room to work with tubs, stoneware jars, bag filters, large retorts, furnaces, and steam kettles. Connected with it there should be a *crystallizing room*, cool, and free from dust.

Such a laboratory is not for the industrial chemist only. Students who have to engage in special researches, whether practical or purely scientific, often find it necessary to prepare in the first place the chemicals required, for they are not to be found in commerce, or the shops afford them of unsuitable quality. The laboratory of analysis is no place for such manufactures, and lacks apparatus suitable for making the quantities required.

He who studies the proximate analysis of organic substances, or the synthesis and the metamorphoses of carbon compounds, must operate on comparatively large amounts of material, and on account of such needs, at least one room should be set apart as a *Laboratory of Organic Chemistry*.

Methods of analysis, synthesis, and transformation, have been latterly coming much into use, which involve the heating of substances in closed tubes and under high pressure. Of course there will sometimes be explosions, which not only scatter glass at random, but also diffuse suddenly through the whole room unpleasant or noxious vapors. Such things must needs disturb the equanimity of students quietly engaged in ordinary analysis, and the rapid and thorough ventilation which is suddenly called for, proves inconvenient where a large number are busy with nicer operations. The good of the greater number must therefore be sacrificed occasionally unless there is a special *room for high pressure experiments*.

The chemist who is restrained by wooden floors and tables from using combustible fluids finds the paths of investigations very much hemmed in, and longs for a vaulted room in which he can distil a few ounces of ether or benzole without watching his retort every moment with a hydrant hose in hand. *A fire proof room* prevents such anxiety, and much waste of time.

A special *room for gas analysis* should be added to the ordinary analytic laboratory.

That part of chemistry which relates to the growth of plants and animals is by no means of subordinate importance. And it has been felt that a professedly liberal course of education must be incomplete when physiology and biology are left out of account. Therefore in rearranging our courses of study, it was deemed proper to include botany and zoology as in themselves useful and as laying the foundation for that higher branch of chemistry which relates to the vital operation of living organisms. Hitherto the instruction in all these branches has been given by lectures or recitations, with the help of such specimens as can be conveniently handled in the class-room. But all science teaching is defective, which does not take in laboratory or field work on the part of the student himself. Experiments in germination, fermentation, respiration, diffusion, assimilation, and the like, need facilities for the exact and continued regulation of light, heat, moisture, and surrounding media. *The Physiological laboratory* then must have its peculiar arrangements differing greatly from those of the work-rooms already mentioned.

In the study of animal and vegetable chemistry much use is made of the microscope and the spectroscope. *An optical room* and an *apartment for dissections* are, therefore, essential adjuncts of the physiological laboratory.

If any one fails for the moment to understand why the chemist should extend his studies into the domain of Natural History, let him consider how many phenomena, which fifty years ago were set down as simply owing to some abstruse chemical action, are now found to be intimately connected with the development of cryptogamic growths. Let him remember, that in the examination of natural waters with reference to domestic use, the microscope often makes important revelations when chemical analysis fails to give satisfactory indications. Let him reflect that in studying the adulterations of food, drugs, textile fibres, and so on, the microscope is indispensable. So there are many matters that a chemist may be called to report upon, which are extra chemical and which the mere chemist is incompetent to investigate. It is indeed true, that in looking the world over, we very rarely find physiological laboratories connected with schools of science. But how few years is it since even physical laboratories came into existence; and yet, who would now think an institution for scientific teaching to be complete without a physical laboratory? I believe the time is not very remote, when there shall be a like feeling with regard to the physiological laboratory.

A much felt want is that of a *working library room*, light, dry, airy, and clean, in which may be gathered books of reference, monographs and details of researches in chemistry, biology, microscopy; and this room should be provided with tables for writing and drawing, and with racks for charts and diagrams. The chemical department has, at present, no fit place for the few books and periodicals which we possess, and it can offer no shelves on which the Professors may place often consulted works from their own private collections, without fear of injury.

Shall I weary you by going on to say, that the use of classrooms in common with other departments admits of no special adaptation to our particular requirements and gives little opportunity to prepare for lectures which should be enlivened by the exhibition of specimens, drawings, or projected images of actual tissues?

Excuse me for reminding you how straitened we are for room, when you call for a report on condition and progress. As to what has been accomplished during the past year, I can only say, "we have left undone many things that we ought to have done" and have done simply what we could. In respect to industrial and physiological chemistry, and botany, without even asking or receiving an appropriation we have gone on providing out of limited private means what was needed for the daily instruction, and have been gradually securing apparatus, specimens, charts, and books with reference to future work, hoping that the time will come when there shall be places for these things and room to work in.

Respectfully yours,

JOHN M. ORDWAY.

THE DEPARTMENT OF PHYSICS.

President Runkle:—

DEAR SIR:—Since the presentation of the last Report of the Physical Laboratory several important changes have been made both in its organization and in the facilities offered to the student. With the establishment of Physics as an independent Department, a Four Years' course is offered to a student who wishes to make a specialty of this subject, either to teach it, or for its applications. Like the Departments of Philosophy and Science and Literature, the course is also designed for those wishing an education of a less professional nature, but unlike them, the scientific studies are rendered more prominent than the literary. The exact course of study offered is detailed in the Catalogue and need not be repeated here, but it will be noticed that it combines most of the studies, not of a strictly professional character, of both the Engineering and Chemical departments. It differs from them mainly by the introduction of several special courses, including Photography, Lantern Projections, Electrical Measurements, Microscopy, Spectroscopy, and other advanced physical work.

The exercises in Physics given to all the students during the Second and Third Years are substantially the same as before, and it is not probable that any changes will be made in them except in details. All the lectures on general physics will now be given during the Second Year, instead of partly in the First Year as heretofore, and both the lecture and laboratory courses have been improved by the purchase of additional instruments.

Prominent among the latter are a Holtz machine and Induction coil, the want of which has heretofore been seriously felt.

The exercises in Photography consist in part of lectures, giving the theory and description of the most important processes and their applications, and practical exercises in which each student shall perform the whole work of taking photographs himself. A student can become a really skilful photographer only by long practice, but in a short time, if properly taught, he may obtain very good results and will be saved much time and money if he begins his work in the presence of some one who can point out his errors, and show him how to correct them. Otherwise, he may simply obtain poor pictures and be unable to decide what is the difficulty. Students will be taught to take both negatives and positives, special attention being paid to the former as the basis of almost every photographic process. They will then learn to take positives on glass suitable for projection in the lantern, and paper prints. As subjects they will employ mainly such as have a scientific value, as drawings and apparatus, and later, microscopic objects, spectra and other more difficult objects.

A course of Lantern Projections was given last year with results that justify its introduction as a permanent part of the course. The theoretical principles involved are given in the form of lectures, and each student then learns to perform the various experiments with the lantern, such as projecting photographs, chemical and electrical decompositions, opaque objects, spectra, using the vertical lantern and other applications of this most useful instrument. The method of making the calcium and other brilliant lights is also taught, and the method of measuring their intensity photometrically. The aim throughout is to enable the student, if required to deliver a course of lectures, to illustrate them fully by the lantern.

Another course tried for the first time during the past year is that entitled Advanced Physics. The object of this course is to supplement the other exercises and supply a place where any matter which a student should know may be properly introduced. Its special object is to furnish the information ordinarily required by a scientific man from societies and periodicals. This want is met in some institutions by scientific societies among the students, but the objection to them is that a portion only of the students are in general interested, and of them most of the work is generally done by two or three. Moreover, although they may be started with much enthusiasm the interest often flags, and they are neglected for the regular studies of the school or for other duties. In the present case on the other hand attendance is required, as at any other exercise of the school, and special subjects being assigned to each student, all take part. During last spring a series of exercises of this kind was held, and eight students took part in them. One of the class was each time asked to act as Secretary, and took notes which he afterward copied and read at the beginning of the next meeting. Another student was then appointed in his place, and their notes form a permanent record of the work done. The meetings were attended with great regularity and the interest was well sustained. Some of the papers were original, but in many cases a subject was assigned to a student on which he prepared a paper, and presented it to the class. All the papers were illustrated, as far as possible, by experiments prepared by the student, who in some cases, also made the apparatus.

Among the papers were the following:—

Forms of Water in Clouds. Mr. F. H. Very.
Sternberg's Heat-registering Apparatus. Mr. S. J. Mixter.
A Fire-escape. Mr. C. F. Howard.
Pendulum Curves. Mr. C. A. Morey.
Zöllner's Horizontal Pendulum. Mr. T. H. Sampson.
Self-registering Barometers. Mr. S. J. Mixter.
Artificial Flight. Mr. C. A. Morey.
An Optical Dynamometer. Mr. W. O. Crosby.
Divisibility of Matter. Mr. S. J. Mixter.
Lippman's Capillary Electrometer. Mr. T. H. Sampson.
An improved Phonautograph. Mr. C. A. Morey.

During the past autumn a partition has been erected along the further wall of the Laboratory and small rooms thus formed for some optical and electrical experiments which are best prepared in the dark. This change is found to be a great improvement and to add materially to the available space. It is a step in the direction long advocated by the writer of employing a number of small rooms, instead of one large one for a physical laboratory. The manuscript of directions for performing a number of electrical experiments has been prepared, and through it much work has been done by the special students in physics in the measurement of absolute electrical resistances, currents and electromotive forces. An admirable practical application of this work has occurred in the tests now in progress of a large magneto-electric machine loaned to the Institute by its maker, Mr. M. G. Farmer. It is greatly to be desired that this machine may be secured permanently for the Institute, as its value would be very great in many ways. First, it would furnish a current of electricity of sufficient magnitude to produce an intense light which could replace the calcium light and might be used for lighting the large hall. Secondly, it opens a broad field of experiment for the students in almost every branch of physics. In mechanics it affords an extremely easy method of altering the amount of work done, and thus affording a very convenient subject for test by the dynamometer; several interesting questions in heat are also opened, especially with reference to the heating of wires traversed by the current. In light not only does it bring the electric light within convenient reach for daily experiment, if desirable, and of photometric and spectroscopic examination, but by an incandescent wire it furnishes a constant source of light, which opens quite a new field in photometry. Again in electricity and magnetism the value to the student of such a current constantly in readiness can only be estimated by those who have had occasion to employ powerful batteries for similar purposes.

The want strongly urged in previous reports, of some form of motor in the laboratory, and so generally supplied in other similar institutions, is still felt with ever increasing urgency, and seems to demand immediate action. The simplest solution seems to be to keep one of the engines, now in the building, constantly running and letting the escape steam pass again into the circulation. The loss of heat would then be very small, being only that converted into work, and that lost by conduction. A countershaft should be run the whole length of the building, and the various departments could thus have power constantly available. Running a second countershaft across the physical laboratory, power could be carried by cords to any part of the room. If this was done, many instruments like the Holtz machine and stroboscope could be run continually and regularly, while several important experiments, such as the measurement of work and power would be easily available to the student.

Some problems in Astronomy have so important a bearing on affairs of every-day life, that every well educated man should be able to solve them. For instance, the determination of the latitude and longitude, of the time, and the direction of the meridian. It is therefore proposed to introduce some experiments of this kind into the course of Physics and to let the students determine these quantities by the sextant and transit.

During the past autumn the students in physics were taken to the works of the Howard Watch and Clock Co. at the invitation of Mr. J. Hamblet, and to the rooms of Welch and Andres Magneto-Electric Telegraph Co. at the invitation of Mr. Andres. Both excursions proved both interesting and instructive, and it is hoped that many similar excursions may be carried out when the weather becomes warmer. Several problems have been assigned to the students in designing apparatus, and this is made an important feature of the examinations. The demand for teachers of Physics would seem to justify the increasing number of students who are preparing themselves to fill such positions.

All of which is respectfully submitted.

EDWARD C. PICKERING,

Thayer Professor of Physics.

DEPARTMENT OF ENGLISH AND HISTORY.

President Runkle:

During the past and present years I have continued my efforts to bring my work within a manageable compass, and to give my instruction the form that would best meet the actual wants of my students. As the experience of each new year defines more clearly the distinctive character of our School, it becomes easier to determine the limits of each department. We are not a University, and cannot undertake the teaching of general subjects on a university scale. Our limited resources forbid the attempt to occupy a wider field than that which strictly belongs to us, namely, the sound training of young men destined for technical professions or for active business life. For the present, moreover, as I have before had occasion to point out, the imperfect preparation of our pupils compels us to keep the element of general study within even narrower limits than fairly belong to it, in order to secure, without detriment to the student's health, the amount of attention to technical study which is absolutely necessary to justify us in conferring our scientific degrees. While the standard of preparation for our school is undoubtedly rising, no sudden change can be effected through the influence of rigorous entrance examinations. We are in the midst of a slow-moving revolution in Education which will, sooner or later, make elementary English and scientific teaching what it should be; but for us to set our standard of admission much above the present teaching-capacity of the schools is either to put a premium upon cramming or to deprive ourselves of students. Any industrious young man of sixteen or seventeen, of good capacity, and with such an amount of mathematical knowledge as will enable him to master our scientific course, and such a training in English studies as the schools are competent to afford, has a good right to claim access to the opportunity our school furnishes to qualify himself for a calling which requires technical preparation, without being held to the necessity of conforming to all the requisitions of an ideal scheme of Education, which it is impossible at present to realize.

Our scheme of *general* instruction must therefore be limited for the present, both by the limited attainments of the pupils, and by the very limited amount of time at their disposal after deducting that required by their professional studies. An attempt was made last year to remedy the difficulty of overwork by reducing the amount of time to be devoted to each separate study, while the original multiplicity of obligatory studies was retained. Experience soon showed that, though the evil of overwork was perhaps diminished, yet the reduction in the time assigned to many of the non-professional studies was so great as to leave it an open question whether the result produced in them was worth having. Compulsory attendance in non-professional work on the part of students already overtasked with professional study answers but little purpose, even when the will of the student is ever so good to profit by the instruction. It is far better, both for health and mental discipline, that the number of subjects should be diminished, and thus a reasonable amount of attention secured to those that remain. To make the English and historical instruction more efficient, I have therefore proposed—and the proposal has been adopted—that for regular students an option shall be given between the English and History and certain other general studies, and that the student shall be held to an examination only in such general study, or studies, as he chooses, liberty of voluntary attendance on the other general courses being at the same time granted to all students who have the inclination and can find the time. Thus the abler and better prepared students may avail themselves of the opportunity to pursue a wider range of general studies, while the slower and worse prepared, by being relieved from compulsory attendance on so many non-professional lessons, will gain sorely-needed time for their strictly professional work. The instruction in general subjects will also gain the advantage of being relieved of a dead-weight of overburdened or unwilling attendants. The arrangement need not be considered as more than temporary. As the quality of the preparation brought up to us by candidates for admission improves, a larger element of general study may again be required of professional students.

This change of arrangements will not preclude the attendance of any student on the literary and historical lectures who has time enough for that, but not time enough for more. And I think that in literary and historical instruction mere lectures may be made of great value in organizing the student's miscellaneous knowledge, and giving system and direction to his miscellaneous reading. But attendance on them should be purely voluntary, and no farther requisition should be made in the way of examination than, perhaps, the handing in of a brief set of notes at the close of the course. It is absurd to expect from them the same results as from regular and systematic study. On the other hand, as the change is likely to give me a smaller body of students who will have time for work, I desire to state briefly my view as to the proper nature of that work. The question becomes more important, in consequence of the increasing number of students in the department of Science and Literature, who, not being candidates for either of the technical degrees, are expected to devote a larger share of their time to general studies.

It is obviously impossible for a single instructor to embrace in his instruction the whole of fields so wide as those of Literature and History. The mere reading of manuals and compends is *not* the study of Literature and History, but a bad and barren way of studying Biography and Chronology. Literature is really studied where authors are really read, and if History can be taught at all, it can only be by some method which will teach the student not so much History as how to read History. For a teacher whose time is limited that object can best be accomplished by selecting some definite period, and arranging a system of reading and study on the part of his pupils, which shall bear some resemblance to the system of physical research and experiment pursued in the laboratories below. A library is the working-laboratory of the student of Literature and History, and the chief aim of the instructor should be to teach the art of handling and using books. So far as the object of making the student into a writer is aimed at, that cannot be done by setting him merely to the study of rules in the rhetorics but by turning him into the literary laboratory, there, in the closest connection with all his study of the writing of others, to practise writing himself. And where, as in the present case, the instruction in Rhetoric, Literature and History falls to the charge of a single teacher, it is obviously better to combine these subjects together as closely as possible rather than to separate them widely from one another by too careful attention to formal divisions.

The question as to what portion of History and Literature is best suited to be the subject of research and investigation by students in such a school as ours, can hardly be open to doubt. However desirable, as a matter of general culture, it may be for the man of business to be familiar with the whole record of the past, it is *essential* that he should understand the world he is to live in, and security had better be taken in school that he study that. I would therefore begin my course of instruction with the study of the present condition of things, and thereby supplement, as far as possible, our students' insufficient knowledge of civil and political geography. And it seems to me eminently suitable in such a school as ours, that special attention should be given to the statistics of Commerce and Industry, and to the history of those Arts and Sciences whose principles are the subject of study in other departments of the school.

The study of the present political, social and economical condition of the nations would naturally lead back to that of the events of the immediate past out of which that condition has arisen. The period of history beginning with the middle of the last century, includes several series of events which are specially adapted to be the subjects of extended investigation by students like ours. On the economical and industrial side it includes the whole story of those remarkable labour-saving inventions and of the application to them, as well as to locomotion, of the motive power of steam on which has arisen the vast fabric of modern commerce and industry, as well as the history of the wonderful growth and expansion of modern physical science in all its departments, while on the political side it embraces the story of our revolt from the mother country and the building-up of the republican institutions under which we live, as well as the outbreak of that great European revolution which followed, and a knowledge of the early stages of which is so essential to a right understanding of the present political condition of Europe. And further, this period includes the advent of a new era in literature in the appearance of that generation of writers who immediately preceded our own.

If I am right in the principle that the best method of studying literature is to read books, and the best method of teaching History is not to waste time on wide surveys and barren generalizations, but, by confining the student's attention to the detailed study of a definite period, to teach him how to investigate for himself, no period could be better suited to such a purpose than the one I have described. There is also this great advantage in teaching modern History and Literature, that while, to excite interest in the remote past, time, leisure and the cultivation of a special taste are required, no difficulty is found in interesting young men who are about entering upon the duties of active life either in the serious interests of the present or in the events of the immediate past.

But the study of History, if it is to be productive of any practical results, must be accompanied by, or must lead up to the study of Political Science on the one hand, and of Economic Science on the other. The lectures on History are followed by a course on Law and Government in the form of commentaries on the U. S. Constitution, and a course on Political Economy accompanying the reading of a manual. These, for students in Science and Literature and for all regular students who enter this course for work, are accompanied by the collateral reading and writing described above.

As it is obviously useless as well as impossible to frame distinct courses for different sets of pupils, it will be seen that in my instruction I have to keep in view three sets of students; 1st, the regular students who can only attend lectures without work; 2d, regular students who elect to do work in connexion with my lectures; and 3d, "Science and Literature" students who have time for a larger amount of work. To meet the wants of the last, I organize small special classes, meeting in my library for supplementary reading and study. This has proved so interesting both to teacher and pupils that I propose to increase their number as far as time allows, and I see no reason why, under proper restrictions, volunteers from the regular classes and special students from other departments should not be admitted to them, without regard to the years in which they are classed.

Specimens of written work are herewith presented; among them elaborate papers on France and Russia by Messrs. R. C. Ware and S. H. Wilder, graduates in the department of Science and Literature, and one on British India by Mr. F. C. Bowditch, a special student in the department.

I have to report a uniformly excellent spirit in my department. I have never lacked interested and attentive hearers, and the conduct of the students in lecture-room and reading-room has been unexceptionable.

All which is respectfully submitted,

W. P. ATKINSON.

DEPARTMENT OF MATHEMATICS.

To the President: —

The instruction in this department now conforms to the new arrangement of studies contained in the catalogue. In consequence of this change, what was formerly a three years' course in mathematics is now concentrated within two years and two months. The number of exercises in the entire course remains unchanged, but instead of the former unequal distribution, there is now a uniform number of three exercises per week throughout the course. By thus completing his mathematical studies earlier in the course, the student is less embarrassed in those departments where this knowledge is applied.

Even more might be accomplished in this direction, if our students entered better prepared. Fully half of the First Year is now occupied in a review of branches which are among the requirements for admission. A higher standard of mathematical instruction in our preparatory schools will alone enable us to dispense with this review. A marked improvement in this respect is already apparent in some of the schools located near us, and if all our students before admission had the advantage of equally thorough instruction in mathematics, the course in this department would be materially strengthened. But when we take into account the character of the average instruction in mathematics in the high schools, where the majority of our students receive their preparation, it is evident that we cannot, at present, assume that thorough knowledge of algebra and geometry which will allow us to entirely omit these branches from our course. It is hoped, however, that at no distant day we shall attain this very desirable object, and that our students will complete their course in pure mathematics at the end of the second year.

GEO. A. OSBORN,

Prof. of Mathematics.

ABSTRACTS OF THESES PRESENTED BY GRADUATES OF 1873-4.

The following abstracts of the theses presented have been furnished either by the departments, or by the authors.

DEPARTMENT OF CIVIL ENGINEERING.

The students in Civil Engineering, of the class of 1874, were required to present as theses, designs for a single track railroad bridge, 192 feet in length. They were divided alphabetically into five parties of three each, and a different form of truss assigned to each party.

Of the fifteen students in the class, two were not candidates for a degree, two did not succeed in passing the examinations, and one has failed to hand in a thesis. The ten remaining, being those recommended for graduation, presented theses as follows:—

Herbert Barrows, a Post Truss; Wm. T. Blunt, a Post Truss; George E. Doane, a Double Warren Truss; Joseph S. Emerson, a Linville Truss; Elliot Holbrook, a Linnville Truss; Aechirau Hongma, a Warren Truss; Charles P. Howard, a Warren Truss; Herbert B. Perkins, a Murphy Whipple Truss; Edward S. Shaw, a Murphy Whipple Truss; Arthur W. Sweetser, A Murphy Whipple Truss.

The general treatment of the subject of these theses was necessarily nearly the same in all. A description of the particular truss is given, and its peculiarities pointed out. Next comes a discussion of the method of finding the shearing forces and bending moments acting at different sections of the bridge, followed by a determination of the stresses upon the upper and lower chords, the struts, the main ties, the counter ties, and the connecting pins. The size that these members must have in order to sustain safely the stress upon them is then computed. The floor beams are next considered and the size fixed. The horizontal strain at top and bottom is also determined. Lastly, the weight of each member of the bridge is calculated, and the total weight of the bridge ascertained.

The drawings accompanying each thesis are two in number, and give a view of the finished structure in plan, elevation and section, and on a larger scale a diagram of stresses and the necessary details.

DEPARTMENT OF MECHANICAL ENGINEERING.

COTTON MANUFACTURE AND THE RING FRAME. ABSTRACT BY THE AUTHOR, F. H. SILSBEE.

In this thesis I have endeavored to present, more or less fully, the following points.

1. A general description of the growth of cotton cultivation, since the improved facilities for manufacturing it, and the structure of the cotton fibre.

2. The history of the introduction and progress of the cotton manufacture, and the most important inventions of cotton machinery, from the first introduction of this industry into England in 1760, to its introduction into this country in 1787, when the first cotton factory was built at Beverly, Mass.

3. A general account of the process of the manufacture of cotton cloth from the raw material, together with a slight description of the various machines employed and the object of their use.

4. The special spinning machine known as the Ring Frame, which is now so universally adopted in this country, especially for spinning the warp. This subject I have entered into the most fully, giving

(a) A brief history of the invention of the Ring Frame, which is due to John Thorp, of Providence.

(b) A general description of the frame, illustrated by a drawing; and also a detail description of the mechanism by which the traverse motion is obtained.

(c) An account of some of the most important styles of spindles and rings.

(d) Tables showing the power required to drive the various spindles, and also the power required to drive the frames under different conditions of banding.

(e) A table showing the strength of the Throstle, Ring, and Mule yarns.

(f) A summation of the merits and defects in the Ring Frame, as compared with the other spinning machines.

(g) An examination of the relative motion of the traveller and spindle, which shows that the traveller loses one revolution each time the yarn is wrapped once around the bobbin.

(h) A consideration of the matter of real and apparent twist, and the rules ordinarily adopted for calculating the same.

(i) A calculation of the irregularity in the twist, which arises necessarily from the manner in which the yarn is unwound from the bobbin, which shows that this irregularity is very slight.

(j) An examination of the effect on the evenness of the yarn which the traverse motion causes; from which it appears that this motion produces no error in the twist.

(k) A calculation of the comparative work of friction of the ordinary or heavy spindle, weighing 11 ounces, and the Sawyer Spindle weighing 3¼ ounces; from which it is shown that about 36 per cent. of the difference of power required to drive the two frames is due to the friction arising from the weight of the spindle and empty bobbin, and diameter of step, the rest of the difference being probably used up in overcoming the friction caused by the tightness of the bands.

(l) A calculation of the speed of the traveller through space, which is found to be at the rate of 30 miles per hour, when the spindles make 6,000 revolutions per minute.

THE CORLISS STEAM ENGINE. ABSTRACT BY THE AUTHOR, FRANK H. POND.

The earlier steam engines may be considered as steam-pumps, and that of Newcomen the connecting link between the steam-pump and the modern engine. Newcomen's engines, improved in various ways by Brindley, Smeaton, and other engineers, continued in use during the greater part of the last century; but it was in effect the same until the days of Watt, the result of whose labors has been a harvest of wealth, prosperity, and ingenuity, without a parallel in the history of the world.

I considered my subject in three parts.

Part First. The Efficiency of Heat Engines in general.

Part Second. The Efficiency of the fluid in Steam Engines. I deduced the formulæ for finding the area of the Indicator diagram, assuming a theoretical diagram as being the most simple from which to deduce them. This theoretical diagram is constructed upon four suppositions.

1. That the steam, when it enters the cylinder, presses upon the piston with the elasticity existing in the boiler.

2. That this pressure continues uniform, as long as the steam valve remains open.

3. That after the steam valve is closed, the pressure diminishes inversely as the volume of steam increases by expanding, according to Mariotte's law.

4. That the exhaust port is opened at the instant the piston reaches the end of its stroke, and remains open during the entire return stroke. Now this very seldom happens, as is shown by experience. The causes which affect the power of the engine, as well as the figure of the diagram, are wire-drawing at cut-off, clearance, compression, or cushioning, release, conduction of heat, and liquid water in the cylinder.

I then considered the effect of back pressure; the thermodynamic functions, and adiabatic curve, for mixed water and steam; the approximate formula for adiabatic curve; the liquefaction of steam working expansively; and the efficiency of steam in a non-conducting cylinder, of which the Corliss engine is a good example.

Part Third. The efficiency of steam in the Corliss engine. As Watt, in the last century, found the steam engine an imperfect and wasteful arrangement for utilizing only a small portion of the energy of the steam supplied to it, and by the invention of a separate condenser, and by his method of making the engine double acting, made it really a steam engine, so in this country the credit belongs to George H. Corliss, of Providence, R. I., for improvements by which, in the engine known under his name, simplicity of construction, together with perfection in economy of working have been secured. The improvements which Mr. Corliss has made in the mechanism of the steam engine, have been recognized by the American Academy of Arts and Sciences, and publicly acknowledged by this body in presenting him with the Rumford Medals, in January, 1870. I will give only one short extract from the address made upon the occasion by Dr. Asa Gray, President of the Academy, although in my thesis I have quoted at some length from it, as he gave a very fine description of the engine. After noticing the economy of fuel which the Corliss engine makes possible, compared with the older forms, Dr. Gray continues, "It is a great thing to say, but I may not withhold the statement, that, in the opinion of those who have officially investigated the matter, no one invention since Watts' time, has so enhanced the efficiency of the steam engine, as this for which the Rumford Medals are now presented."

The Corliss engine, from which I have taken my data in the following calculations, is a one hundred horse-power engine, built by the Corliss Steam Engine Co., Providence, R. I. The engine has been running about six months, in the largest printing house in the country, Messrs. Rand, Avery &

Co., 117 Franklin Street, Boston, Mass. The diameter of the cylinder is 18 inches, length of stroke 4 feet; when running with 60 lbs. of steam by the gauge, the engine makes 55 revolutions per minute. I took indicator diagrams from the engine April 18, 19, and 20 (1874). Diagrams will be found with the thesis, which were taken on each day, showing the manner in which we found the valves set, and as we left them. On April 19, we ran only the shafting, and found it took 20,082 horse-power. They were also running very light on April 20, the diagrams show 51.535 horse-power, or about half the capacity of the engine.

The following table shows the different ratios of expansion:

Rankine's correct (?) method	$r = 3.901$
" approximate "	$r = 4.369$
From indicator card, calculating the clearance .	$r = 5.61$
" " " measuring clearance with water	$r = 5.17$

Energy per cubic foot of steam admitted, 9014.986 foot-pounds.

Mean effective pressure, or energy per cubic foot swept through by piston, 12 lbs. per square inch, when $r = 5.17$.

Heat expended per cubic foot of steam admitted, 130305.5 foot-pounds.

Heat expended per cubic foot swept through by piston, or pressure equivalent to heat expended, 175 lbs. per square inch.

Net feed water per cubic foot swept through by piston, .028 cubic feet.

Efficiency of the steam nearly 7 per cent. (.069)

THE SWAIN TURBINE. ABSTRACT BY THE AUTHOR, GEORGE H. BARRUS.

The Swain Turbine is what is known as a combined parallel and inward flow turbine. As the name of the class to which it belongs implies, it combines the forms given to parts of two different turbines, into a single one of the same size. The openings into the wheel embrace the upper part of its periphery, the remaining part of the depth being closed by a band. The orifices of discharge lie at the bottom and the inside, extending from the under side of the crown to the lower edge of the band. The direction of motion of the particles of water in passing through the buckets varies from a horizontal to a vertical direction, depending upon their positions on entering. The vertical components of these motions act in the same manner as the water in a parallel flow turbine, while the horizontal components act like the water in a real inward flow turbine. The condition of maximum flow through the wheel is satisfied by making the area of the gate openings equal to that of the orifices of discharge.

This subject is considered under five heads. The "Description of the Swain Wheel" consists mainly of the explanation of a sectional elevation of the wheel as it sets in quarter-turn.

Under "Construction" reference is made to some of the rules used in proportioning the principal parts, the method of laying out the bucket curves, and the process of casting the wheel. A few improvements are explained which were devised by Mr. A. K. Mansfield.

The third division is headed "Theory," and contains an explanation of the action of the water as it passes through the wheel, showing the deviation which it undergoes in encountering the curved bucket. The wheel is first considered as an actual inward flow turbine, and the formulæ derived are afterward changed by introducing the mean horizontal component, before referred to, making them applicable to the real case. In the next place, the equivalent parallel flow turbine is investigated with results of a similar character. In both, the principal object in view is to obtain the velocity of the water leaving the wheel, from which the efficiency, neglecting prejudicial resistance, is easily deduced. The formulæ serve also to show the proper values of the angles, guides, and bucket curves within certain limits.

Under "Method of Testing" a general description is given of the process of testing a turbine by the use of the dynamometer; and the method of computing the efficiency from the results of such a test. The last topic embraces a comparison of the Swain wheel with other turbines in use at the present time. With economy as the basis of comparison, two points are made which should be borne in mind in an examination for relative merit—efficiency and power. It is desirable that a turbine should possess both these qualities in as large a degree as possible.

The different methods of regulating the supply of water to the wheel are noticed and their effects upon the efficiency at part gate compared. A short table containing the efficiencies and powers of a few prominent turbines shows how these remarks apply.

DYNAMOMETERS. ABSTRACT BY THE AUTHOR, WILLIS H. MYRICK.

Whatever causes, or tends to cause, increased or decreased motion in a body is a force. The continuous action of a force through space is work, the amount of which may be expressed by the product of the force, and the space passed over by that force. Power is the rate of work, or the work performed in a unit of time.

The various uses of the dynamometer are to determine the force exerted, the work performed, or the power expended, wherever motion takes place or tends to take place. Of those kinds which have for their object the determination of force alone, the most prominent were invented by Graham, Desaguliers, Leroy and Renier. Graham's instrument as well as Desagulier's were modifications of the common steelyard, while Leroy's was similar to the spring balance. Renier's consisted of an elliptical spring very much like a carriage spring having a scale and pointer so attached that it showed the force applied.

As most of the dynamometers for measuring work can be used for measuring power, and *vice versa*, the different varieties will be mentioned together under the heads of Traction, Transmission, or Absorption Dynamometers. Of the Traction form, Morin's is the only one which needs describing. It consists of two parallel rectangular springs, connected at their extremities, whose deflection taken with the distance passed over by the carriage determines the work.

A Transmission Dynamometer consists essentially of two pulleys, or shafts, one driving and the other driven, these being connected by springs, levers, or gears, in such a manner that they use up an amount of force equal to that which is necessary, at any instant, to produce the required motion, in the machine to be tested. The compression of the springs, or the amount of weight raised with the space and time, give the means of determining the power, or work. The connection between the driving and driven pulleys or shafts, varies in the different machines. In Morin's rotary dynamometer, it consists of a flexible rectangular bar, one end of which is fixed to the shaft the other to the driving pulley. A pencil is made to record the force on a moving strip of paper.

Eive's is a dynamometer with two radial springs projecting from the hub of one of the pulleys, whose extremities press upon two pins on the circumference of the other. The motion of one pulley relatively to the other, pushes the end of a rod over a cam. The motion of the rod indicates the force. Mr. Taurines has a dynamometer where the ends of two arms on the shafts are connected by springs, whose flexure determines the force. S. P. Ruggles of this city has one consisting of a pulley connected to the shaft by means of a spiral spring which encircles it. A screw and thread within the hub moves a rod which connects with the recording apparatus. Mr. Hirn obtains the work done by means of the torsion of the shaft itself. Brown's connexion consists of three spur gears in line. The middle one is small, and is attached to the short arm of a steelyard. Bachelder's is of the same principle, except that the combination, commonly called compound gears, are used instead of the spurs. Mr. Neers connects the driving with the driven shaft by means of two discs, one fixed on the inner end of each shaft. To that disc which is connected to the driven shaft, are attached two springs which oppose the motion of two chains that pass over two small wheels, on the circumference of that disc, and connect with the other disc. The motion of this second disc pulls the chains over the small wheels, while the springs opposing their motion cause the first disc to turn with it.

Emerson's transmission dynamometer consists of a combination of compound levers, connecting the driving pulley to the shaft of the driven. The force is measured by a weighted pendulum.

While examining the defects which are so detrimental to transmission dynamometers as a class, the springs which most of them use form one of the most serious, as well as one of the most common. These springs are not only affected by temperature and by age, but from the effects of centrifugal force are pulled and twisted as they revolve around the rotating shaft, thereby causing false indications. Unbalanced parts rotating around a shaft are also acted upon by centrifugal force.

Upon examining Brown's and Batchelder's machines, we find that these defects are overcome, but in their stead, we find a force in motion which is carried through revolving gears, at high speeds, causing imperfect indications.

In the dynamometers about to be described, every precaution has been taken to overcome these objections, and to obtain what seems to be a dynamometer with but few, if any defects, except those of friction, which it is impossible to get rid of entirely. The following is the description of a machine which has been designed. Two short hollow shafts are situated in line with their inner ends somewhat separated. Each carries a pulley which may serve as a driving or driven pulley, together with a bevel gear placed at its inner end. Between these bevel gears and opposite each other are situated two smaller bevel gears, forming a set of compound gears. Each small gear connects by means of a short hollow shaft with a spur gear, the spurs being near the centre of the machine, their planes parallel to each other, and to those of the small bevels. Each spur gear works in a rack, one rack being on the top of one spur gear, while the other rack is at the bottom of its spur. Both racks are connected to a rod which runs lengthwise of the machine, and through the hollow shafts first spoken of, appearing at the outer end of one. The rod here terminates in a step, the step pressing against a small steel block, which by means of a rack on its under side connects with a spur gear, to which is fastened a weighted pendulum.

If for an instant the driving pulley remains still while the driven pulley revolves, the small bevel gears will turn, consequently the spur gears, which will force the rod against the block, causing the pendulum to be raised. The pendulum reacts through the different parts, as the springs react in the other machines. Calculations have been made of the sizes of the various parts, but space will not permit their being inserted here.

Of the Absorption Dynamometers, the Prony Brake consists of several pieces of wood, connected by chains, which surround a shaft or pulley, they being held against the shaft or pulley by these chains which are connected to the short arm of a steelyard, the long arm being weighted until the shaft runs uniformly.

Mr. Emerson has made an improvement on this, by encircling the pulley with a hollow iron or brass band instead of the wooden blocks, water being forced through the band to keep it cool.

DEPARTMENT OF ARCHITECTURE.

DESIGN FOR A COUNTRY RAILROAD STATION. ABSTRACT BY THE AUTHOR, W. B. DOWSE.

This design was a solution of the problem given out in the Architectural department for a railroad depot, situated in a country town and which was to be built over the track. In its construction, stone or brick, iron and wood were to be used and it was to be so arranged that persons could pass from their carriage to the train, under cover. To meet these requirements a bridge was designed, formed of circular stone ribs, at regular distances from each other and having a solid backing up to forty-five degrees, the stone ribs being bound together by brick-work. Stone and brick were also used in the outside walls of the building itself, to a height of about four feet, and in the signal tower, to the height of the roof of the main building. Iron was employed in the corridors and stairways, forming the covered passage to the trains below. The rest of the building was to be of wood. Through the backing of the ribs of the arch runs an arched corridor, giving additional breadth of platform.

Simultaneous with the designing, approximate calculations of the strength and stability of the parts were made, but as the building was not to be large, and consequently the strains upon its parts small, as also those upon the bridge, it was found that to have any architectural beauty many of the dimensions would have to be larger than they were required to be for strength. After the design was finished the calculations were made again, showing the *necessary* size of the component parts.

The frame of the roof consists of four intersecting trapezoidal trusses. The strains on them are due to the weight of roof. They must also be able to support the roof when loaded with snow. It was found that to resist the compression in the upper beam of the trusses it must have a cross section of 23 square inches. The necessary dimensions of the other parts were also calculated. The strength of the cast iron columns supporting the iron corridor, to sustain the weight of roof when loaded with snow, being the greatest strain it would be subjected to, was calculated and the cross section necessary was only .133 square inch, too small to be cast, as the columns were hollow and served as gutters, the real cross section being 18.06 square inches. The stability of the signal tower to resist the wind was found to be ample, as the necessary cross-section of each of the four main timbers of the frame, in order to resist compression or extension, according to which side the wind acted on—was only 3.08 square inches, but being used for ornamental purposes also, they were much larger. The necessary cross-section of the braces was also found. The track ran through a cut making it necessary to construct walls, in this case surcharged, battering-faced retaining walls, on each side. The necessary thickness of the base of the wall was found to be 3.86 feet. Its stability of friction was also found and the necessary depth of foundation, disregarding frost, was 2.47 feet. Calculations were also made on the strength of the brickwork of the arch and also of the stone ribs.

DEPARTMENT OF CHEMISTRY.

A FEW INSTANCES, SHOWING THE POSSIBILITY OF APPLYING THE MICROSCOPE TO INORGANIC QUALITATIVE ANALYSIS.

ABSTRACT BY THE AUTHOR, FRANK W. VERY.

I. Introduction. *a.* Disadvantages of the method; 1. High magnifying powers are required; 2. It is not so delicate as the ordinary one. *b.* Advantages of the method; 1. A small amount of substance suffices for an analysis; 2. It is more rapid than the ordinary one; 3. One test often detects two or more elements.

II. General directions for performing the microchemical analysis, together with some remarks as to the kind of tests which should be chosen in forming a system. (*a*) Apparatus. (*b*) Tests, embracing 1. Precipitation by chemical reaction. The largest crystals are formed from moderately dilute solutions; 2. Precipitation by a less solvent liquid. The production of crystals by the agitation of supersaturated solutions is often useful; 3. Crystallization by evaporation. The crystals produced in this way vary more than the precipitated ones; 4. Electrical deposition of metals.

III. Special cases. Scheme for detecting lead, bismuth, copper and cadmium in presence of each other. Embracing, *a.* Precipitation as carbonates by sodic carbonates. *b.* Solution in nitric acid; 1. Precipitation of basic nitrate of bismuth by water; 2. Precipitation of plumbic nitrate by alcohol. *c.* Solution in chlorhydric acid; 1. Precipitation of plumbic chloride from the hot solution; 2. Evaporation of the chlorides of copper, cadmium and bismuth; 3. Evaporation with potassic chloride for cadmium. *d.* Solution in acetic acid; 1. Precipitation or evaporation of cupric acetate.

Scheme for distinguishing barium, strontium and calcium in presence of each other. Embracing, *a.* Precipitation as carbonates. The ordinary method. *b.* Solution in chlorhydric acid; 1. Evaporation of the chlorides of barium, strontium and calcium; 2. Precipitation of basic chloride by alcohol, also occasional precipitation of chloride of strontium; 3. Precipitation of the oxalates of barium, strontium and calcium, by ammonic oxalate and also by oxalic acid.

DEPARTMENT OF MINING ENGINEERING.

EXPERIMENTS ON WINNAMUCK SILVER LEAD ORES, FROM BINGHAM CANON, UTAH. BY B. E. BREWSTER.

REPORT ON THE DRESSING AND METALLURGICAL TREATMENT OF AN ARGENTIFEROUS LEAD ORE, FROM GEORGETOWN, COLORADO. BY F. H. JACKSON.

For full summaries of these theses, see "Studies in the Mining and Metallurgical Laboratories," on page 38.

DEPARTMENT OF SCIENCE AND LITERATURE.

FRANCE. BY ROBT. C. WARE. ABSTRACT.

Exceptional position of France in European history; an examination attempted of her present resources and condition, and of her past history, in order to forecast her probable future; difficulty of the subject; list of authorities; situation of France; frontier and coast surface; water-shed and river system; geology; volcanic formations; extent of tertiary and alluvial deposits; poverty in mineral wealth; climate; rainfall; agriculture;

forests; statistical tables from M. Block; population and its movements; slowness of increase.

Periods of history; barbaric, feudal, monarchic, revolutionary; extended sketch of each period; France since the fall of Napoleon III.; administration of Thiers; payment of indemnity; nature of the present provisional republic; debt; revenue; cost of the war; paper currency; exports and imports; division of land; loss of power by the R. C. church; education; immense recuperative power and favorable prospects as compared with Spain.

RUSSIA. BY S. H. WILDER. ABSTRACT.

Early condition of Russia; growing importance since the Crimean war; extent and general physical characteristics of the empire; northern Russia; central and southern Russia; surface and climate; water communication; detailed account of the geology of Russia; agricultural productions; forests; cattle, horses, sheep, etc.; mineral products; statistics of manufactures; railways and internal communication; foreign commerce; ethnology of the Russian empire; character and divisions of the Sclavonic race; the Finns and Lapps; early history; career of Peter the Great; reign of Catherine II.; Nicholas and the Crimean war; reforms under Alexander; emancipation of the serfs; Russian communism; the Russian church; the army; literature; list of thirty-six authorities consulted or read.

REPORT OF THE DEPARTMENT OF MECHANICAL ENGINEERING.

President Runkle: —

Dear Sir: — Since my report to you, made one year ago, quite important changes have been made in the course of instruction in this department. Two principal causes have led to these changes. They are,

1. The entire reorganization of the courses of instruction carried on in the Institute.

2. The existence of the long desired Mechanical Engineering Laboratory.

The nature of the reorganization of the courses of instruction was made very clear in the catalogue published one year ago. The scheme has worked admirably in my department, and while the duties of instruction in the strictly professional work of the course have been much increased, it has been possible to give the students a much more practical, thorough, and extended course of professional study.

The nature and uses of our Laboratory will be explained somewhat in detail in the latter part of my report.

We have now five sub-courses of professional instruction: — Mathematical, practical, graphical, excursional, and experimental. The number of text books and professional papers made use of in the course of instruction has been much increased. The same subject is, when practicable, under consideration in each of the five sub-courses at the same time. Such subjects are selected for the consideration of the students as seem most important to the head of the department.

The text books to be used, the excursions to be made, the proper drawing and laboratory exercises are then arranged for; the object in view always being to give the students the most correct and practically valuable view of the subject that the time will allow.

My last year's report gives an idea of the work done in each sub-course, except the experimental. But it also suggests an experimental laboratory.

During the early part of 1874, all schemes for fitting up the laboratory fell through; but a little later, Mr. Geo. B. Dixwell called to consult me concerning certain questions relating to the nature and behavior of steam in some of its applications. I found that he had carefully examined a very large number of the best recorded experiments which bore upon the questions concerning which he wished to be enlightened. As some of his questions could be most satisfactorily answered by appealing to direct experiment, I advised him to go to some engine builder and undertake in connection with him such a series of experiments as would give him the desired information.

I further expressed my regret that our laboratory was not in active operation, as in that case we should be able to answer his questions at the Institute. He corresponded with engine builders upon the subject, but after deliberation decided to have the experiments conducted at the Institute. He saw that this decision would increase the expenditure that he would necessarily be at for the purpose of gaining his information. He also saw that in case the experiments failed to result as he anticipated, his expenditure would not be wasted, for he would have aided in establishing a Mechanical Engineering Laboratory, whose value, if properly used in a course of instruction, could hardly be over-estimated. It would make students familiar with the properties of steam on such a scale that the results obtained would be of *direct* value in their future practice, and of *direct* interest to all users of steam power. It would give them facilities for becoming skilful in the manipulation of instruments used by engineers in testing steam boilers, engines, and kindred apparatus. They could be made familiar with, and thus taught to avoid the *legerdemain* of these instruments, by means of which some men frauduently, and many men ignorantly or carelessly, deceive the public or themselves.

To meet the generous contributions of Mr. Dixwell, I have, with your approval, made suitable expenditures. Two horizontal, wrought iron, multi-tubular boilers, which were formerly used for heating purposes merely, have also been connected with our apparatus.

I would now respectfully invite your attention to detailed descriptions of some of the more important parts of our apparatus, saying, once for all, that most of these descriptions were written by Mechanical Engineering students as regular Institute exercises. They formed parts of reports of experiments conducted by the students. I have taken the liberty of revising or of making such abstracts as seemed best, from their reports, and of then making them a part of this paper.

The Hot-water Collector described in the "Spectrum," a paper published last year by the students, is a plain, horizontal cylinder, its inside length being 13 feet 10 inches, and its inside diameter being 3 feet. The cylindrical part of the shell is of wrought iron, $\frac{3}{8}$ of an inch thick. The ends of the shell are flat cast-iron plates, 1 inch thick. The capacity of the tank is 97.78 cubic feet. It receives the hot water which condenses in the steam heating apparatus, and retains it until it is needed again in the boilers. The hot water is carried from this collector to a *Blake Pump*, through a 2 inch pipe, connected with which is a small cold water pipe for cooling the water, if necessary, before it reaches the pump. From the pump a $1\frac{1}{2}$ inch pipe passes along the front of the boilers. From this pipe a 1 inch pipe leads into each boiler. A cold water pipe is also connected with the $1\frac{1}{2}$ inch pipe. Its water will run into either boiler under 40 pounds pressure without the aid of the pump.

A Giffard's Injector, made by Wm. Sellers & Co., of Philadelphia, also forms a part of our boiler-feeding apparatus.

The Steam Producing Boilers, also described in the "Spectrum," are virtually alike, and the description of one is virtually that of the other. Each is 12 feet long, 4 feet diameter, and has fifty tubes, each of which is 3 inches outside and 2¾ inches inside diameter. About one half of the cylindrical part of the shell, both tube sheets and the inside surfaces of the tubes come in contact with the heated gases. The total area of heating surface per boiler is 530.35 square feet. The total boiler room is 121.34 cubic feet.

The following table shows the proportions of steam, water, and boiler room under certain circumstances:—

Height of Water.	*Cubic Feet of*		*Percentage of boiler room occupied by*	
	Steam.	*Water.*	*Steam.*	*Water.*
Lower Gauge Cock . .	65.42	55.92	53.9	46.1
Middle " " . .	49.72	71.62	41.0	59.0
Upper " " . .	36.59	84.75	30.2	69.8

There are suitable safety valve gauges, etc., on each boiler. Both boilers are provided with Etna grates; the grate area of each is 16 square feet. Two inspectors of the Hartford Steam Boiler Inspection and Insurance Company have certified that they have carefully inspected these boilers, that they find them in good condition in every respect, and that they are well adapted to bear with safety a pressure of 80 pounds to the square inch. They were built by Allen and Endicott, of Cambridgeport, in 1866. Two wrought iron chimneys carry away the waste gases from the two boilers; their capacity to carry off smoke is about one-half what is needed, and the result is at once an insufficient supply of steam and a wasteful consumption of coal. I would respectfully recommend that a suitable chimney, or a mechanical blast, be provided in order to remedy the defect.

The Small Boiler, described by Thomas D. Plimpton, is of the upright, wrought iron, tubular class, 7 feet long, and 3 feet in diameter; the distance between the tube sheets is 5 feet and there are 50 two-inch tubes. The tubes, and also 12 stays each $\frac{3}{4}$ of an inch in diameter, connect the tube sheets with each other. The water space below the lower tube sheet is an annular ring, measuring 2 inches in a radial direction. This space is more strongly stayed than is usual in boilers of this kind. The boiler is set in brick work with a space left around its upper part, extending downward not quite so low as the lower tube sheet. The hot gases pass through this space, after leaving the tubes on the way to the chimney. The furnace and combustion chamber are detached from the boiler, and the hot gases can be directed through the boiler to the chimney, in which case, they give up their heat to the contents of the boiler, or the whole or any desired part of these gases can, at any time, be made to pass to the chimney by a flue which avoids the boiler entirely. This boiler always superheats the steam more or less, more in proportion as the water level is lower. It is provided with two sets of gauge-cocks, one set near the top and the other set near the bottom of the boiler. Glass gauges run from near the top to near the bottom.

Instead of using this boiler as a steam producer, it may be used as a superheater, or again, as a steam drum or "mechanical separator" merely. When used as a superheater or steam drum, steam is introduced from the producing boilers by a pipe 2″ diameter which enters the small boiler at the top and passes down into it about $3\frac{1}{2}$ feet. A deflecting plate prevents the escaping steam from impinging upon the surface of the water in the superheater or drum, should any water be there. The exit pipe is at the top and on the opposite side from that at which the admission pipe enters. This boiler was tested by an hydrostatic pressure of 250 lbs. per sq. inch. Two inspectors have pronounced it safe with a steam pressure of 150 lbs. per sq. inch. This boiler was built in the best manner by Thomas Cunningham, of Charlestown.

The Cast Iron Superheater, described by Thomas D. Plimpton, is a cast iron box, 4 feet long, 2 feet wide, and 4 inches thick. It has partitions extending crosswise alternately from one side nearly to the opposite, causing the steam to take a zigzag course as it passes through, and bringing the moving steam in contact with all its parts. These partitions also serve for stays and practically increase the area of heating surface.

It lies flat over its furnace; the hot gases passing over the back end, return over the top and then pass into a flue. This flue conducts the waste gases, still quite hot, through the tubes of the small boiler, or directly into the chimney at pleasure. This Superheater was presented by Prof. John M. Ordway, of the Chemical Department.

The Steam Engine is a Harris-Corliss, and was built for us by Wm. A. Harris, of Providence, R. I., who says that it was built in his best manner.

The cylinder of the engine is about 8″ by 24″, the clearance about .036 of the piston displacement. It does not differ in its general style from the usual Corliss Engine pattern. It is regulated to make about 64 revolutions per minute, and when cutting off at half stroke, produces about 20 horse power, with 70 lbs. initial pressure in the cylinder. The governor furnished with the engine is of the ordinary "common pendulum" variety, and like all Corliss Engine governors, regulates the admission of steam by varying the point of cut-off. The ordinary throttle valve has been removed from the engine, and a Huntoon Governor put in its place. This governor is, as is well known, a throttle valve governor. It was presented to the Institute by E. P. Boardman & Co., of Lawrence, manufacturers of the governor, in answer to our request for their lowest price. We can at pleasure control the engine with either governor. When one governor is in use, the other is made entirely inoperative. A Peet Valve in the steam pipe is used as a throttle valve.

The Principal Parts of the Calorimeter described by Geo. H. Barrus, a graduate of the Mechanical Engineering Department, and my assistant in the laboratory, are *a Brass Coil or Surface Condenser*, which does not leak; *a Small Tank* beneath, in which to collect the water which condenses in or passes through the calorimeter; *Scales*, for weighing; *Thermometers*, for ascertaining temperatures; *a large, closed, rectangular wooden Tank*, containing the brass coil, the water which absorbs the heat that passes through the walls of the coil, and *the pump* which circulates the water; and *an Expansion Tank.*

The exhaust pipe of the engine passes through the wall of the large tank near one end and about two and one-half feet above the floor of the tank, where it is permanently attached to a nearly horizontal tube three inches in diameter and four feet long which forms a part of the coil or condenser. Another 3-inch tube lies parallel to this, near the floor at the other end of the tank. These 3-inch tubes are joined by a row of 20 Z-shaped brass tubes, one inch in diameter and 21 feet long. The Z-shaped tubes run the length of the tank, three times, falling about ten inches in each length. All the joints of the Z-shaped tubes and of the nearly horizontal tubes which they connect, are so designed that no cavities are left to collect water which condenses. When it is desired to measure the quantity of heat which is contained in a given mass of steam or water, that steam or water after traversing the exhaust pipe enters this nearly horizontal tube. All of the tubes slant sufficiently to allow any water which may arrive at or condense in any part of the coil to fall readily into a five-eighths of an inch drip pipe, which leads from one end of the lower 3-inch pipe. The drip pipe passes through the bottom of the large tank into a small tank beneath. Between the two tanks the drip pipe contains two check valves and a Chapman valve. The former prevent the water from being pressed back into the coil by the atmospheric pressure when the steam ceases to enter it. Air gains admission to the coil through a vacuum valve in the exhaust pipe near the tank. Whenever water enough has run into the small tank, the Chapman valve can be closed at any time, preventing all water from passing out of the coil. The water in the small tank can be carefully weighed, drawn off, and the weight of the empty tank taken in a short time. The efficiency of the condenser is not diminished enough through the backing up of the water confined in the coil to affect very much the back pressure of the engine. This coil was carefully tested for leakage by letting on the full head of Cochituate water, the pressure of which was in excess of 40 pounds per square inch. At first there was leakage through minute blow-holes in the cast brass connections, and at some of the junctures of the tubes; but these defects were remedied by the application of soft solder. The tubes themselves are of seamless drawn brass, and, except in one or two points, exhibited no tendency to leak.

The Small Tank is made of 2-inch plank, four and one-fourth feet long, thirteen inches deep and thirteen inches wide. It is provided with a floating cover. A sheet rubber diaphragm extends from the outside edges of this cover to the inside edges of the top of the tank. The cover and diaphragm prevent the formation of vapor in the small tank. Without them, the water in the tank would lose both weight and temperature through surface evaporation. The outlet of this tank is a 3-inch pipe opened and closed by a Chapman valve. Only fifty seconds are required for emptying this tank. A Huddleston thermometer indicates at any time the temperature of the water contained in the tank. The weight of that water is indicated from second to second by the four hundred pounds Fairbanks' Scales upon which it rests. The ringing of an electric bell indicates the rising of the scale beam. Horizontal pieces of rubber hose of sufficient length connect the tank with all pipes leading to or from it. As the level of the platform of the scales changes but slightly during the operation of weighing, the rubber hose is but slightly bent and the sensitiveness of the scales is not much diminished. The rubber hose also serves to intercept the conduction of heat to or from the tank. Air communication with the inside of the tank can be made when desired, by a small valve provided for the purpose.

The Large Tank is built of 2-inch plank, strongly bolted together. Its inside dimensions are, length seven feet two inches, width four feet two inches, depth four feet two inches. It is connected with the Cochituate hydrant by a 2-inch pipe which is opened and closed by a Peet valve. A Huddleston thermometer for determining the initial temperature of the Cochituate water used in the calorimeter is screwed into this pipe. It is about twelve inches long, and is graduated from about thirty degrees Fahrenheit to about one hundred and twenty degrees Fahrenheit. The bulb of the thermometer is surrounded by the water in the pipe and is subjected to the pressure of the water. The thermometer is quite near the large tank. The effect of the pressure on the surface of the bulb is not worth considering.

The outlet of the tank is a 3-inch pipe which leads from the bottom of the tank to the waste pipe. This is opened and closed by a Chapman valve. The tank fills in thirty-three minutes and empties in fifteen minutes. The faucets at one end of the large tank, one at the top and one at the bottom, allow water to be drawn from the tank, and two Huddleston thermometers, similar to those in the Cochituate pipe, except that the graduation extends to two hundred and twelve degrees Fahrenheit, one at the top and one at the bottom of the tank, show the temperature of the tank water.

The large tank rests upon a pair of five ton Fairbanks' Scales. All pipes leading to or from the tank are connected by horizontal pieces of rubber hose so long that their direction does not change much during the operation of weighing. The scales are sufficiently delicate to indicate a change of one pound in the weight resting on the platform. The rubber connections are of service in checking very much the transfer of heat to or from the tank. That one which is in the exhaust pipe has a stout spiral spring of about the same outside diameter as the inside diameter of the connection within it and running nearly its whole length, but not touching the pipe at either end. The pitch of the spiral is about three and one-fourth of an inch, and it serves to prevent the rubber from collapsing, when the steam is shut off before the atmospheric pressure opens the vacuum valve. A safety valve attached to the exhaust pipe would blow off if the pressure in the pipe should ever reach ten pounds per square inch. No pressure, then, at all approximating to the bursting pressure of the rubber hose can ever come upon it.

The temperature of the water in the top of the tank would be much in excess of that of the water at the bottom, were it not for the *Circulating Pump.* This draws the cold water from the bottom and discharges it at the top, thoroughly mixing it. The induction pipe, about three-fourths of an inch by four feet, in cross section, is situated between one end of the coil and the same end of the tank. It begins near the bottom of the tank and extends upward as far as the top of the coil where it is terminated by a clap valve, about four feet long, opening upward. Passing through the valve the water enters a chamber reaching in height to the top of the tank, and about one foot by four feet in the plan. Leading out of this chamber near the middle of its length, is a rectangular trough, about four feet long and nine inches square, in cross section, in which the pump piston reciprocates, and through which the water passes out of the pump.

The Piston Head is a block of wood surrounded by a flanging piece of rubber which fills the trough during the forward stroke but collapses during the backward stroke, thus serving the purpose of a valve. It is worked by a rod which projects through a stuffing-box in the side of the tank. When eight hundred pounds weight of steam per hour is condensed in the coil, it is easy to keep the temperature of the water at the bottom of the tank within one degree Fahrenheit, or less, of what it is at the top, by means of the circulating pump.

The Expansion Tank is two feet square in the plan, and two and one-half feet deep. It gives the water an opportunity to expand as it receives heat through the walls of the coil. Without it, the expansive force of the heating water would readily burst the closed tank. With it, the hydrostatic pressure can never reach two and one-half pounds per square inch. A

2-inch connecting pipe passes upward through the cover of the large tank, and through the bottom of the expansion tank. A floating cover and rubber diaphragm similar to those of the small tank serve here a similar purpose. A valve in the side of the expansion tank allows communication with the air while the large tank is emptying or filling. The large tank is known to be full when the cover of the expansion tank is seen to float.

The Standard Test Gauge attached to the small boiler, described by Thomas Hibbard.

This Bourdon Gauge was manufactured by the American Steam Gauge Company expressly for the Institute, and is of the largest size. We understand that they have put their best work into it, and took the greatest care in graduating it, in order to make it as nearly as possible a Standard Test Gauge. It is graduated to one hundred and forty pounds subdivided to half pounds. The Company's Mercurial Column was used in graduating the dial. Both the gauge and the column were subjected at the same time to hydrostatic pressure, until the column indicated the desired pressure, say one pound per square inch. The proper graduation marks were obtained in a similar manner.

The gauge is attached to the exit pipe of the small boiler by a U-tube, five feet deep, which is filled with water to its highest level. By this means the tube of the gauge is entirely cut off from the *heat* of the steam, while the water readily transmits the pressure on its exposed surface to the air confined in the gauge. The advantage of this is obvious, for it is a well known fact that a gauge exposed to heat reads very differently at different temperatures. In fact, a Bourdon Gauge, under some circumstances, makes a very good pyrometer.

The Pressure Gauge on the Eastern Producing Boiler was made by the same process and by the same makers as the Standard Test Gauge. It is not quite as large as the test guage, but it was made with equal care.

The Thermometers used in determining the temperature of the steam, described by James H. Head, are two in number and were made for us by Mr. Huddleston of this city. They are substantially alike. Each is about twenty inches long, and gives readings at intervals of two degrees from two hundred degrees Fahrenheit, to a little less than six hundred degrees Fahrenheit. They were graduated at atmospheric pressure by comparison with a standard thermometer and by calibration, thus giving a great degree of accuracy in their divisions. During some experiments the bulbs are immersed directly in the steam whose temperature is to be measured. The metallic case of one of the thermometers is screwed into the steam pipe about ten inches from the pipe leading to the gauge, so causing the bulb to be in the pipe and entirely surrounded by steam. The pressure of the steam on the bulb causes an error of excess in the readings, very slight at low pressures but increasing as the temperature and pressure increase. During other experiments a cup containing mercury is screwed into the opening of the steam pipe referred to. The thermometric bulb being immersed in the mercury acquires its temperature, which under certain circumstances will not differ materially from that of the steam.

Two of Bulkley's Pyrometers have been provided for ascertaining the temperature of the superheated steam. One of these is inserted in the steam pipe, between the place where the superheated steam passes into this pipe and the engine.

Two Richards' Indicators have been made for the Institute by the American Steam Gauge Company. Their springs were coiled from wire which was at first a little too stout. They were then reduced as much as seemed necessary, being tested from time to time by the process now to be described.

An indicator with its spring, pencil and card all in position, was reversed, so that its piston rod pointed vertically downward. A scale pan was suspended from the piston rod and a base line drawn by the pencil of the indicator upon the card. A sealed weight was then placed on the scale pan, and a new line drawn upon the card. If the two lines thus drawn were too near to each other, the wire of the spring was reduced in cross section by a suitable tool. The indicators have also been tested very carefully under a steam pressure. They prove to be excellent instruments. An interesting report of this test, or rather series of tests, has been made by James B. Stanwood and Wilfred Lewis, but properly this report would be given in another place.

Indicator cocks have been attached to both ends of the cylinder of the engine, to the steam pipe near its juncture with the steam chest, and to the exit pipe of the small boiler about midway between the U-tube of the standard gauge and the thermometer. Indicators can readily be attached at those places and the pressure observed.

The Apparatus for Driving the Indicator Cylinders, described by Frank T. Sargent.

Two pulleys are fastened by set screws to the same shaft. The diameter of one is twenty-four inches, equal to the stroke of the piston of the engine, the diameter of the other is equal to the length of the diagram to be drawn on the indicator card. Both are one-fourth of an inch face and have grooves for strong, inelastic cords. About five inches from the crank end of the cylinder, there is placed a grooved carrier pulley, four inches in diameter. The top of this carrier, the top of the 24-inch pulley and the centre of a stud in the cross-head are in the same horizontal line, parallel to the piston rod.

A strong cord is fastened to this stud, carried over the 24-inch pulley to which it is so fastened that it can not slip in the groove, then around the carrier and back to the stud to which it is again made fast. Ordinarily, the 24-inch pulley is driven directly by the engine during the return stroke, and by stiff, quick acting springs during the forward stroke.

If from any accidental cause the speed of the engine should suddenly increase so much that the springs could not reverse the apparatus with sufficient rapidity, the cord running around the carrier pulley would enable the engine itself to reverse the apparatus and prevent accident to it. At either end of the cylinder and directly below the cocks to which the indicators are fastened during an experiment are two carriers, each four inches in diameter, and one-half inch face, with three grooves. These carriers are driven during the return stroke by a stout cord attached to the smaller of the pulleys on the shaft before mentioned. They are driven by a quick acting spring during the forward stroke. These carriers are readily attached to or disengaged from the paper cylinders of the indicators by short vertical cords having convenient hooks and rings. By means of this nicely constructed apparatus, which was made for the Institute by the Lowell Machine Shop, the paper cylinders of the indicators have a motion at all times proportional to that of the piston of the engine.

The Steam-Pipe, Valves, etc., were put in position by Walker, Pratt & Co., of Boston. A 3-inch pipe conveys steam from the producing boiler to the engine or to the small boiler as is preferred. A two and one-half inch wrought iron pipe, thoroughly jacketed with asbestos felting, carries steam from the small boiler to the engine, to the superheater, or to the exhaust pipe of the engine, as may be necessary.

A three and one-half inch exhaust pipe, also covered with asbestos felting, carries steam from the engine, the small boiler, or the superheater, to the calorimeter, the pipes used for heating the building or to the waste pipe.

No valves were used in these steam connections which were not carefully tested for leakage, under hydrostatic or steam pressure, by Mr. Barrus or myself.

Very great pains were taken to avoid leaky joints in the piping. If any joints proved leaky upon trial, the leaks were stopped by rust or red lead cement, or new joints were made.

The Brake for consuming the power produced by the engine, is of very simple construction. Blocks of whitewood press against the rim of the main pulley, surrounding or partially surrounding it, as circumstances require. Two long, strong chains encircle these blocks, to which they are firmly attached by wrought iron staples. A scale pan or weight box is suspended by those ends of the two chains from which the surface of the pulley runs. The other ends of the two chains are fastened to a fixed support. By varying the weights in the weight box, the power consumed by the brake can be readily changed.

Adjoining the engine room and opening from it, is a large, convenient room, which has been fitted up for the use of the students while they are working up the results of experiments, or for similar purposes.

Numerous pieces of special apparatus have been provided by Mr. Dixwell, for special experiments, but it would be premature to describe them in this communication.

The ultimate object of our laboratory instruction and experiments is to make the students so familiar with the nature of steam, heat and work, that they will feel that steam and heat are their obedient servants, that they will neither dread thermodynamic power nor deal with it recklessly, nor give undue weight to the opinion of men who know no more about such things than themselves. It will give them increased confidence in the judgment of men whose greater experience in, and whose thorough study of, these things makes them competent advisers. They can also learn something about that most important of all questions connected with the use of steam or of machinery, what is practical economy?

Among the experiments of a general character, for which we are now prepared, may be mentioned those on the conversion of work into heat or of heat into work; on the capacity of different bodies for heat; on the change of bulk of solids, liquids and gases, under constant pressure, due to changes of temperature when it is attempted to keep the volume constant; on the relation between the temperature and pressure of saturated steam; on the total heats of superheated or saturated steam or of a mixture of steam and water; on the latent heat of fusion or of evaporation; on the transfer of heat, by radiation, conduction or convection, through different substances or through different thicknesses of a substance; on the cooling of gases by expansion; on the conductivity of fluids and solids; on the boiling and melting points of different substances; on the condensation of steam; on resistance to boiling; on the comparison of quantities of heat; on the measurement of heat by evaporation; on the efficiency of heating or cooling surface. Most or all of these experiments might be conducted without much reference to the practical bearing of their results, but by judicious selection of the experiments and by carefully calling student's attention to their results, several of them might be conducted in one general experiment having for its object the solution of a practical problem. In this way we are able to solve some of the questions proposed to us by Mr. Dixwell, and other experiments of a practical nature.

Some of the practical problems which we can readily solve, relying upon the Chemical Department for assistance in the analysis of substances are; those on the efficiency and cost of operating pumps, feed water heaters, etc.; on the cost of production of steam in dollars, or in pounds of coal; on the percentage of combustible matter contained in the fuel; on the efficiency of furnace and boilers; on the waste of unburned fuel in the solid state; the waste of unburned fuel in the gaseous and smoky states; the loss of heat in the hot gas which escapes by the chimney; on the uneconomical effects of forcing fires; on the efficiency and evaporative power of boilers under various conditions of pressure or with different kinds of fuel, and the effects of bad draught upon the evaporative power; on the comparative value of different kinds of grate bars; on different methods of introducing the air necessary for combustion and dilution; on the comparative value of different styles of bafflers and bridge walls; on the most economical rate of combustion; on the comparative efficiency of firemen in charge of steam-boilers; on the comparative economy of detached furnace boilers; on the economy due to increased heating surface; on the evaporative power of boilers; on the loss of evaporative power due to bad draught; on the increase of evaporative power due to the direct action of the radiant heat of the furnace or to steam draughts; on the examination of boilers by hydrostatic pressure or by internal and external surface examination; the examination of steam and water gauges, gauge cocks, low-water detectors, safety-valves and similar apparatus; on the obstruction to the flow of steam through pipes, produced by bends and valves, and by pipe friction; on the economy due to the covering of steam pipes with non-conducting substances; on the efficiency of steam heating apparatus; on the difference between the pressure in the boiler and the initial pressure in the cylinder; on the efficiency of the steam in the engine; on the rejected heat of the engine; on the useful work of the engine; its indicated power; its efficiency with various rates of lead, cut off, release or cushioning; its efficiency at different speeds; its efficiency under a varying load; and its comparative uniformity of speed, whether controlled by a variable cut off governor or by a throttle-valve govenor; its comparative efficiency with superheated or saturated steam, or a mixture of steam and water in a steam-engine, under varying circumstances of initial or back pressure; or when cutting off at different points of the stroke; adjustment of the eccentric and valves; on the adjustment of governors; on different kinds of piston packing; on cylinder and lubricating oils; on friction in the engine; on cylinder condensation.

Experiments already conducted on the economy of diminishing the leakage past imperfect steam-engine valves and piston packing have demonstrated the fact well known to experts, that the prevention of leakage is very important to users of steam-engines.

Other experiments of equal value intrinsically are those upon cylinder condensation, the economy of using steam at different grades of cut off, the use of superheated steam, the expansion of steam in the cylinder, and many others.

The object of some experiments would be to enable the students to become skillful in the manipulation of instruments used by engineers in testing steam boilers, engines and kindred apparatus. These experiments are so planned, that the defects resulting from the ignorance or carelessness of the experimenter, will become very apparent to him when he comes to work up the results of the experiments.

The object of other experiments is to give the students experience in examining critically the instruments used in tests, making them familiar with their defects, enabling them to avoid some of the errors that inexperienced people are likely to make in their use, and to correct those other errors which of necessity exist in the best instruments.

Concerning the experiments on the critical examination of instruments used in tests, it ought to be said that most of the steam gauges, thermometers, and similar instruments that are to be found in the market are not intended by the manufacturers to be instruments of precision. Something which will tell what the steam pressure or the temperature is, in the rough, answers the purpose of a large majority of customers. These rough instruments being good enough for their purpose, they do not care to pay for more accurate, but at the same time, more expensive ones. But the makers of such apparatus manufacture a better class of instruments intended to be used by experts and others in various tests. These are much more expensive and are made with much greater precision. Engineers generally rely upon them for all ordinary purposes, and as often as they have reason to suspect that their accuracy has deteriorated, they are in the habit of sending them back to the makers to be readjusted.

But even the adjusted instruments are not sufficiently accurate to answer truthfully, nice scientific questions. Instruments suitable for such a purpose are very rarely wanted, could never be made profitably except upon order, and only then at very great expense by very careful men. Not many such instruments have ever been made, and when Regnault and other precise experimenters needed them, they were obliged to make them themselves. From the outset our laboratory was intended to be one in which practical experiments could be made in the ordinary way. Its most important use was believed to be to give young men skill in such kind of experimenting as would be of practical value. And while, as far as was possible, the best apparatus to be had upon order in the American market was obtained, we have not supplied ourselves with that exceedingly precise apparatus which can not be bought.

The celebrated experiments by Regnault determined under very favorable circumstances, with instruments of extraordinary precision, the law which connects the pressure and temperature of saturated steam. As we can easily make saturated steam of any desired pressure, one instrument of precision, either of pressure or temperature, taken in conjunction with Regnault's law, would give us the means of examining critically each of our instruments for measuring pressure or temperature, and of forming a connected scale which would practically convert them into instruments of precision; for our apparatus is delicate and sensitive, and so far as we know now, indicates the same pressure or temperature whenever subjected to the same influences.

In the former part of this report the statement was made that our indicators had been tested very carefully. It was thought to be desirable to make a critical examination of the standard test gauge, the thermometers and the indicators, under the conditions of ordinary working. Accordingly, the three instruments were attached to the exit pipe of the small boiler, at points whose positions have been described in a former part of this paper. It will be remembered that the gauge was graduated to correspond with a mercurial column; that the thermometers were graduated by comparison with a standard thermometer and by calibration, and that the indicator springs were adjusted very nicely by means of sealed weights hung upon the piston rod. We had no special reason for doubting the accuracy of either of the instruments nor that of one more than that of another; and the examinations already made have satisfied us that they were, practically speaking, excellent instruments in excellent condition; but they had not been compared with one another, and had not been compared with a common standard. We were able to compare them with one another, and that we proceeded to do. After several preliminary experiments, it was decided on account of the rapidity with which the thermometer showed changes of temperature to take the thermometer temporarily as a standard. By observing the pressures indicated by the gauge and the indicators, we should be able to judge of the accuracy of the instruments according as they corresponded with or deviated from Regnault's law. It was decided to make six experiments, three of which would compare both the gauge and the indicator numbered 562, and three others, which would compare both the gauge and the indicator numbered 567, with the thermometer assumed to be a standard. The indications of the gauge were observed by Mr. Thomas Hibbard, who made the following report:—

"Six experiments have been tried to test the gauge and compare it with Regnault's tables. In the first place, steam is blown through the small boiler which is used as a steam drum, in order to expel the air and heat up the apparatus. The valves are then closed; thus confining a certain quantity of steam in the drum, which rapidly condenses. The pressure is thus lowered below the atmospheric pressure, 14.7 pounds per square inch, and the temperature below 212° F. Everything is now ready for the experiment. Steam is admitted from the large boiler by opening the admission valve by degrees. The steam being throttled, the temperature and pressure in the drum rise slowly. The operator who reads the thermometer gives the word at every 9° F., commencing at 212° F. Just at those instants the pressure given by the gauge and indicator, is observed and recorded. The gauge was read to tenths of a pound, as nearly as could be judged by the eye. When the pressure in the drum rises so as to be nearly that in the boiler, the admission valve is opened to its widest extent. Then the steam pressure is allowed to rise gradually in the producing boiler, until it reaches about seventy-five pounds. The pressure in the drum, which is in free communication with the boiler, rises about the same. When the thermometer reads 320° F, corresponding to this greatest pressure, the admission valve is closed, thus shutting up the steam in the drum. Condensation now takes place, the temperature and pressure fall, and the readings are taken for every 9°, beginning with 320° F, down to 212° F. To accelerate the condensation, the fire-doors and dampers of the drum were opened, thus causing a draught of cold air through the tubes. When the temperature falls to 212° F. and the pressure to about 0 pounds, the experiment is complete.

"In three of these experiments the barometer was read and the corresponding deduction or additions calculated for the height of the mercury column above or below 29.92 inches, or 14.7 pounds pressure. The mean readings of the gauge for each three experiments were ascertained, and the differences between them and Regnault's corresponding pressures determined. Now with the temperatures for abscissæ, i. e., distances measured horizontally, and these differences as ordinates, or vertical distances, two curves were constructed. The straight horizontal line represents Regnault's law of pressures and temperatures, while the constructed curves in the same manner show, upon the assumption that the thermometer is correct, the errors of the gauge. It was noticed that, when the gauge was tapped, it started ahead a little, not exceeding two-tenths of a pound, however, thus showing that there was some friction in the mechanism of the gauge. Most of the pressures registered by the gauge were within one pound of Regnault's pressures, while but few of them differed by two pounds. Most of the readings were less than Regnault's, seeming to show that either the gauge did not record as high pressures as it should, or that the thermometer read too high temperatures. The curves also indicate this, since they lie almost wholly below Regnault's line. There are many sources of error in such an experiment, but we hope by repeating them a number of times, and taking the mean reading, to get a table of corrections for the gauge."

The diagrams from indicator No. 562, were taken by Mr. J. B. Stanwood, an extract from whose report is as follows: —

"The test that was made on indicator No. 562 was to determine if the pressures indicated by the instrument corresponded to the pressures calculated by Regnault in his table of temperatures and pressures for saturated steam. These tables were taken for our standard; they have an increase in the temperature column of 9°, that is, pressures are given corresponding to every 9° from 32° F., upwards. A Huddleston thermometer was used, together with the indicator, and both were placed on the steam pipe leading from the small boiler. In using the indicator, steam was kept in the cylinder until a few seconds before the line was to be drawn; it was then all shut off, and that which remained in the cylinder passed off into the air. Then steam was readmitted, and the line was taken just as the mercury passed the 9° mark. The reason for shutting off the steam and readmitting it, was in order to overcome any friction which might retain the piston in its place. At the beginning of the experiment steam was allowed to pass through the small boiler from one of the large boilers until all the air had been blown out and the boiler had been well heated up. Then the boiler was cut off from the external air, and from the large boiler, the steam that remained in it was allowed to condense until its temperature was about 210° F., then the steam was admitted slowly from the large boiler, and for each 9° passsd through by the mercury a line was taken by the indicator, showing the difference of the steam pressure from the atmospheric pressure; the first reading was taken at 212° F., and the last at 320° F. When the experiments first commenced, the pressure in the large boiler was about thirty pounds per square inch above the atmospheric pressure; as soon, however, as the pressure in the small boiler was the same, the pressure was allowed to increase in the large boiler. After the temperature was greater than 320° F., the small boiler was entirely shut off from everything, and the pressure then decreased by the condensation of the steam. Thus three experiments were made and six cards taken, three for ascending pressures and three for descending; from these cards the results of the experiments are obtained.

"After the experiments had been performed, two curves were constructed to show the variation of the indicator from the tables. One of these curves was for ascending pressure, the other for descending. A horizontal line was taken to represent Regnault's curve of pressures and temperatures; the temperatures were measured off on this line as abscissas, while the difference between the table pressures and the observations were taken as ordinates. In order to obtain the two curves only from the six different observations, the mean observation for each temperature was taken for both ascending and descending pressures, and the differences between these and the tables were taken as ordinates. The curves were below Regnault's line, until they arrived at the temperature of about 248° F., and were then above Regnault's line, the ordinates steadily increasing between 248° and 320° F. If, now, instead of trying to make our instrument more accurate we construct a table taken from experiments, we can correct for errors and obtain better results than otherwise."

The diagrams from indicator No. 567, were made by Mr. Wilford Lewis, who says in a part of his report:—"In these experiments the indicators seemed to have an almost constant error of about eight-tenths of a pound below the pressure as given by Regnault's tables. This may be due partly to the pressure of the atmosphere being about 14.7 pounds, or to a constant error in the reading of the thermometer."

Without going so much into the details of the results of these experiments as to make them very tedious, it is enongh to say that neither the indicators nor the gauge gave always the same pressure for a given temperature. Take, for instance, the pressure given by the gauge when the thermometer read 266° F., as the temperature was rising. The different readings of the gauge at that temperature were as follows:—

Experiment.	*No.* 1.	*No.* 2.	*No.* 3.		*No.* 4.	*No.* 5.	*No.* 6.
Gauge rising	24.25	24.4	24.1	Gauge rising	24.	23.5	24.8
" falling.	24.4	25.7	24.	" falling	23.9	24.	24.
Ind'r 562 rising	25.5	25.	24.6	Ind'r 567 rising	23.3	23.2	24.
" " falling	24.6	26.5	24.2	" " falling	24.1	24.2	23.9

The barometric pressure was noted in some of these experiments but not in others; but the discrepancies could not be accounted for by changes in the atmospheric pressure. Some of the gauge readings differed as much as 2.2 from others, and as there must have been a reason for these differences, I concluded to plot the different experiments, and to ascertain, if possible, the causes which produced the discrepancies. They were plotted according to the system previously indicated; Regnault's law being represented by horizontal lines, horizontal distances representing degrees of temperature on a scale of ten to the inch, and vertical distances representing, on the assumption that the thermometer is correct, the error of the instrument on a scale of one-half pound to the inch.

All indications made while pressures were rising, were indicated by circles. All those made while pressures were falling, were indicated by diamonds. All made by indicator 562 were represented by black ink; all made by indicator 567, by blue ink; all made by the gauge by red ink. The first set of diagrams showed the errors in all the pressures observed with any one instrument on a sheet by itself. This set resembles a chaos of spots. The second set showed the comparative indications of all three instruments in any one experiment.

In the diagram of the first experiment, the gauge showed almost the same indications with rising as with falling pressures, but the indicator showed from one-quarter pound to one pound more pressure when rising than when falling.

In the diagram of the second experiment, the gauge at any temperature seemed to differ from the indicator about as much with rising as with falling pressure; but both the falling curves were crooked or warped in a remarkable manner.

The diagram of the third experiment resembled that of the first except that the falling curves had changed about equally the angle which they made with the rising curves. The diagrams of the fourth, fifth, and sixth experiments also showed that some cause or causes apparently affected both instruments at the same time.

A third set of diagrams was now made, showing the errors in all the rising pressures observed with any one instrument, on separate diagrams from those exhibiting the errors in the falling pressures.

A careful comparison of these diagrams, with the recorded details of the experiments, led to the belief that one or more of six causes might have given rise to the discrepancies.

If the thermometer was slow to indicate changes of temperature; if the barometer changed considerably during the progress of an experiment; if saturated steam of a given pressure sometimes varied a little in temperature; if what we had supposed was steam had been a mixture of steam and air; if the steam which we had supposed was saturated had been superheated by any means, as by wire-drawing or by radiation of heat into it; if the indications had been incorrectly observed or recorded; these anomalies might have occurred. Some of these apparent causes could not be seriously entertained. The others were more likely to have acted, and it was determined to ascertain by further experiment whether the thermometer was dilatory; whether the steam was superheated; or whether the errors of observation need be very large.

The first new experiment was arranged on the supposition that the thermometer was dilatory. It was easy to make the indicated pressure vary about one and one-fourth pounds by changing the circumstances of the experiment.

A second new experiment was arranged to show still more clearly that the thermometer was dilatory. The gauge was taken as a standard and a slight current of steam was made to pass through the drum for three-quarters of an hour. During this time the pressure in the producing boilers was pretty constantly twenty-eight ponnds, and the pressure in the drum very precisely twenty-five pounds by the test gauge. The temperature of the steam as indicated by the thermometer with its bulk in steam was very constantly 269.25° F. This temperature is what would have been expected, had the pressure been about twenty-six pounds per square inch.

As there was no water in the drum, a relief valve was suddenly opened, reducing the pressure as quickly as possible to one pound per square inch. Observations were then taken every five seconds. A slight current of steam passed constantly through the drum, while the pressure was maintained at one pound per square inch by throttling the admitted steam. The first temperature observed was 252° F. After about one minute, the temperature rose to 253.5°. This is the temperature of saturated steam of a pressure of about seventeen pounds per square inch, while the real pressure was only one pound. This dilatory behavior became exc ting. The readings taken every five seconds became monotonous. The students became hoarse with calling readings. After ten minutes the thermometer had fallen only to 240°; after thirty-eight minutes, to 221°; after forty-six minutes to 219.25°. To hasten the cooling still more, if possible, cold water was pumped into the drum. It did not cover the orifice through which the steam was entering. The temperature remained at 219.25° so long that our time and patience became exhausted. We then increased the pressure as rapidly as was considered safe, to 24.5 pounds per square inch, and the thermometer then read 268°. Throughout the remainder of the experiment, when the gauge indicated twenty-five pounds per square inch, the thermometer indicated 269°. We anticipated 269.25°, but as one-quarter on the scale was a small quantity, this difference was not suprising.

It was concluded from this experiment that the record of the thermometer was approximately true, but that the steam was superheated during the time that the gauge indicated one pound pressure. It was finally concluded that we should get the most reliable experiments by starting with steam at about atmospheric pressure in both boiler and drum, and gradually increasing the pressure at a very slow rate, comparing the indications of each of the instruments before mentioned with an accurate mercurial column, so arranged that its indications could be corrected for the temperature of the mercury in the column.

An extended series of experiments on cylinder condensation at different grades of cut off, with a pressure of seventy pounds of steam in the boiler, has been partly concluded. The records of these experiments show not only the total heat of the steam which left the boiler, but also, approximately, the total heat in the steam at different points of the stroke, between the cut off and release, and, finally, the heat rejected by the engine and carried by the exhaust steam into the calorimeter. Each experiment with saturated steam at a given point of cut off, is supplemented by an experiment with superheated steam having the same initial pressure and cutting off at the same point. The results already arrived at are very interesting, and when the series is concluded I shall have valuable information to report to you. I am

Very respectfully yours,

CHANNING WHITAKER,

In charge of the Mechanical Engineering Department.

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Ordway, John M.	W. Roxbury.
Page, Edward	Boston.
Page, W. H.	"
Parsons, Wm.	"
Paul, J. F.	"
Peabody, O. W.	"
Perry, O. H.	"
Philbrick, Edward S.	"
Philbrick, John D.	"
Pickering, E. C.	"
Pickering, H. W.	"
Pierce, S. S.	"
Plumer, Avery	"
Pope, Edward E.	"
Prang, Louis	"
Pratt, George W.	"

Pratt, T. Willis . .	Boston.
Putnam, J. P. . .	"
Quincy, Edmund .	Dedham.
Quincy, Josiah . .	Boston.
Revere, Joseph W. .	"
Rice, Alexander H. .	"
Richards, R. H. . .	"
Ritchie, E. S. . . .	Brookline.
Robbins, James M. .	Milton.
Robinson, J. R. . .	Boston.
Rotch, Benj. S. . .	"
Royce, H. A. . . .	"
Ruggles, John . .	"
Runkle, John D. .	Brookline.
Russell, LeBaron .	Boston.
Salisbury, D. Waldo	"
Sawyer, Edward .	Newton.
Sawyer, Timothy T.	Charlestown.
Sears, Philip H. . .	Boston.
Shedd, J. Herbert .	"
Sherwin, Thos. . .	Dedham.
Shimmin, Chas. F. .	Boston.
Shurtleff, A. M. . .	"
Sinclair, Alex. D. .	"
Smith, Chauncy . .	Cambridge.
Snow, S. T. . . .	Boston.
Sprague, Chas. J. .	"
Stackpole, G. W. .	"
Stevens, Benj. F. .	"
Storer, H. R. . . .	"
Storer, Jacob J. . .	"
Strater, Herman, Jr. .	"
Stuart, Chas. F. . .	"
Sturgis, John H. .	"
Sullivan, Richard .	Boston.
Thompson, Wm. H.	"
Thornton, J. Wingate	"
Tufts, John W. . .	"
Tuxbury, Geo. W. .	"
Upham, J. B. . .	"
Urbino, S. R. . . .	"
Walworth, J. J. . .	"
Ware, Chas. E. . .	"
Ware, Wm. R. . .	"
Warren, Cyrus M. .	Brookline.
Warren, Geo. W. .	Boston.
Warren, Joseph H. .	"
Warren, Sam'l D. .	"
Waters, C. H. . . .	Clinton.
Waterston, R. C. .	Boston.
Watson, R. S. . .	Milton.
Watson, Wm. . .	Boston.
Weld, Stephen M. .	"
Weston, David M. .	"
Whipple, Edwin P. .	"
Whitaker, Channing	Lowell.
Whitman, Herbert T.	Boston.
Whitmore, Wm. H. .	"
Whiton, David . .	"
Wilder, Marshall P.	Dorchester.
Williams, H. W. . .	Boston.
Winthrop, Robert C.	"
Wood, John F. . .	"
Wright, John H. . .	"
Wyman, Morrill . .	Cambridge.
Zalinski, E. L. . .	Boston.