

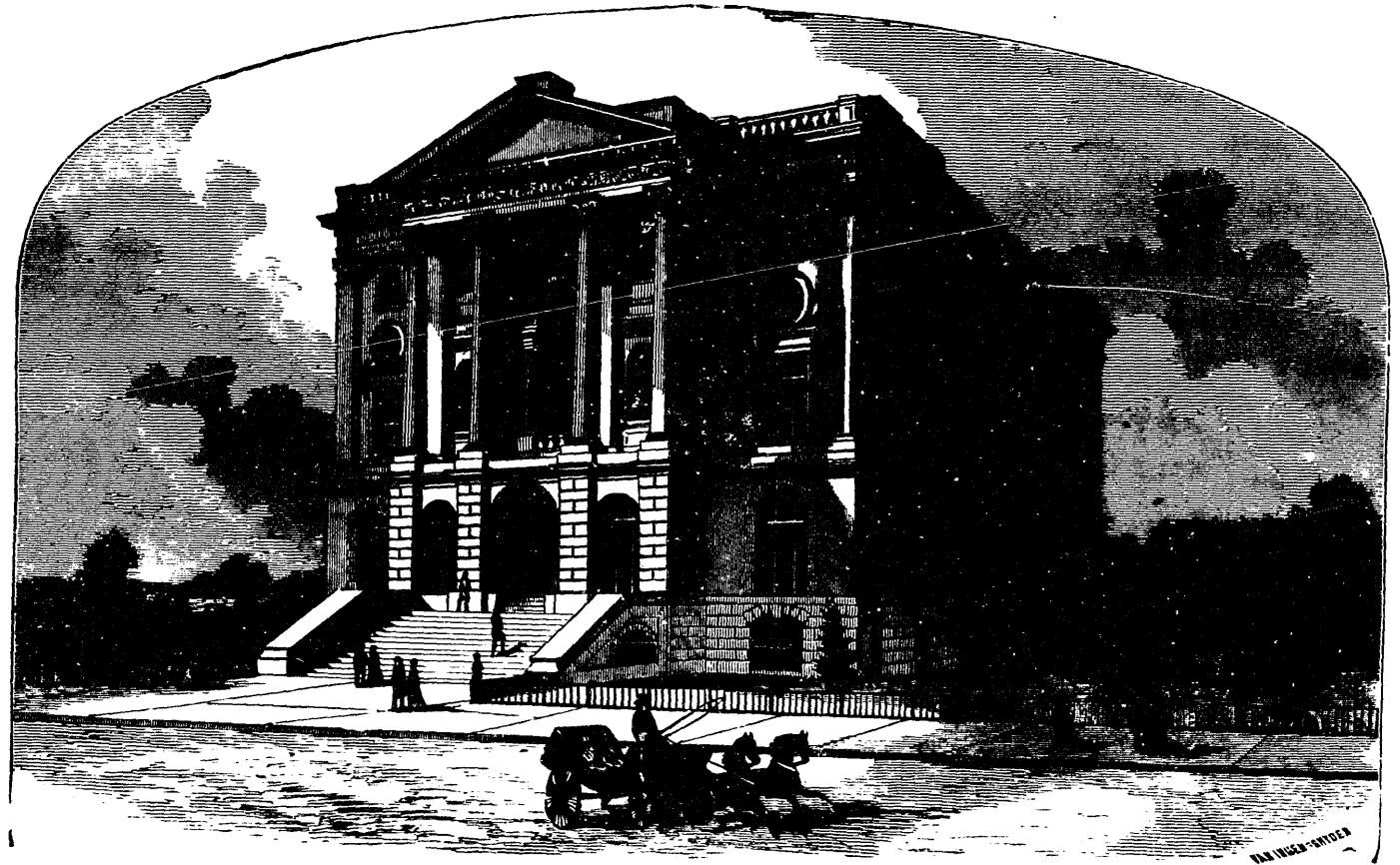
MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

PRESIDENT'S REPORT

FOR THE

Year ending Sept. 30, 1877.

BOSTON:
PRESS OF A. A. KINGMAN.
1878.



INSTITUTE BUILDING.

W. H. WOODS - BOSTON

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

PRESIDENT'S REPORT

FOR THE

Year ending Sept. 30, 1877.

BOSTON:
PRESS OF A. A. KINGMAN.
1878.

Extracts from Acts of the General Court of Massachusetts, in relation to the Massachusetts Institute of Technology.

Act of Incorporation. "William B. Rogers [and others named], their associates and successors, are hereby made a body corporate, by the name of the MASSACHUSETTS INSTITUTE OF TECHNOLOGY, for the purpose of instituting and maintaining a Society of Arts, a Museum of Arts, and a School of Industrial Science, and aiding generally, by suitable means, the advancement, development, and practical application of sciences in connection with arts, agriculture, manufactures, and commerce."

Chapter 188, Acts and Resolves of 1861.

Grant of Public Lands. "When the Massachusetts Institute of Technology shall have been duly organized, located, and established, . . . there shall be appropriated and paid to its treasurer, each year, on the warrant of the Governor, for its endowment, support, and maintenance, one third part of the annual interest or income which may be received from the fund created under and by virtue of the 180th chapter of the Acts of the 37th Congress, at the second session thereof, approved July 2, 1862 [giving Public Lands to the States in aid of instruction in Agriculture, the Mechanic Arts, and Military Science and Tactics]. . . . Said Institute of Technology, in addition to the objects set forth in its Act of Incorporation [as above quoted], shall provide for instruction in military tactics."

Chapter 188, Acts and Resolves of 1868.

Power to confer Degrees. "The Massachusetts Institute of Technology is hereby authorized and empowered to award and confer degrees appropriate to the several courses of study pursued in said Institution, on such conditions as are usually prescribed in universities and colleges in the United States, and according to such tests of proficiency as shall best promote the interests of sound education in this Commonwealth."

Chapter 247, Acts and Resolves of 1868.

CONTENTS.

	<i>Page.</i>
President's Report	vii-xvi
Secretary's Report of Society of Arts	1-29
New By-Laws	1
Uses of Corundum	3
Agriculture in Massachusetts	4
Industrial Education	6
The Russian System	6
Trade Schools	8
Combustion	8
Fuels	9
Natural and Artificial Draughts	9
Covering of Pipes and Boilers	10
Bridge Walls	10
Dignity and Necessity of Labor	10
Automatic Register	11
Combustion	11
Self-Testing Gauge	13
Steam Regulating Valve	13
Household Sanitary Science	14
Proper Moisture in the Air	14
Co-ordinate Surveying	15
Chase Governor	16
Hydraulic Elevator	17
Improved Orrery	17
Merrimac Lead Mine	17
Magnetic Motor	18
Electric Clock	18
Copying Designs	19
Improvements in Telephony	20
Membership of Society of Arts	21
School of Industrial Science	21
Lowell Free Courses	23
Meetings of the Corporation	23
Report on School of Mechanic Arts	24
List of Graduates in 1876-77	28
Department of Philosophy	30
Department of Military Science and Tactics	31
Department of English and History	33
Department of Modern Languages	41

	<i>Page.</i>
Lowell Free Courses for 1876-77	48-52
General and Qualitative Chemistry. Prof. Nichols's Report	48
Elementary Geology. Prof. Hunt's Report	49
The Philosophy of Government. Prof. Howison's Report	49
Practical Mechanics. Prof. Lanza's Report	51
Abstracts of Theses by Graduates of 1876-77	53
The Central Avenue Bridge, Dorchester, Mass., by H. H. Carter	53
Sea Walls of South Boston Flats, by Martin Gay	54
The Lowell Water Works, by Joseph P. Gray	55
The Charles River Bridge at Newton Upper Falls, by Edward Grover	55
The Double Lattice Parker Iron Bridge across the Merrimack River at Lowell, by Richard A. Hale	60
Highway Bridge across the Merrimack River, between Groveland and Haver- hill, by George W. Kittredge	61
The New Bedford Water Works, by C. F. Lawton	61
The Lawrence Water Works, by B. C. Mudge	62
The Newton Water Works, by A. L. Plimpton	64
Design for an Iron Railway Bridge, with a consideration of the Principles determining the Design, by George F. Swain	66
The Ashtabula Bridge, by Frank E. Wiggin	67
A Review of a Continuous Brake Trial, by William H. Beeching	67
The Westinghouse Air Brake, by George W. Chapman	68
Double Valves as applied to the Rider Engine, by Linus Faunce	69
The Construction and Use of a Mercury Column, by Chas. H. Fisher	69
Boiler Incrustation, by Joseph Kirk	70
On Link Motion, by Cecil H. Peabody	72
The Vershire Copper Ore and its Metallurgical Treatment, by George Bartol	73
Investigation of the Institute Ore-Washers, by W. C. Flint	74
On some methods for the Extraction of Nickel and Cobalt from their Ores, by John E. Hardman	76
On the Smelting of a Silver-lead Ore from the Merrimac Mine, by Henry D. Hibbard	76
Report on the Working, for Silver and Gold, of a Middle Grade Product from Ore of the Merrimac Mine, by Walter Jenny	79
Treatment of Vershire, Vt., Copper Ore, by H. C. Southworth	81
Investigation into the Working of the Institute Ore-Concentrating Machines, by Thomas F. Stimpson	82
Experimental Working, by Wet and Dry Methods, of a Low Grade Silver and Gold Ore, from Newbury, Mass., by F. W. Wood	85
Design for a Steam Fire Engine House, by J. Williams Beal	87
A Town Hall, by Geo. W. Capen	87
A Design for a Steam Fire Engine House, by W. E. Chamberlin	88
Design for a Railroad Station, by Pierce P. Furber	89
On an Impurity found in Commercial Acetone, by John Alden	90
The Relations of Carbon to Iron, and its Determination by the Chlorine pro- cess, by Charles S. Bachelder	91
Lowell Department of Industrial Design for 1876-77	92
Members of the Society of Arts	95

THE PRESIDENT'S REPORT.

To the Corporation of the Institute : —

I have the honor to submit my report for the year ending September 30, 1877.

The following resignations have taken place during the year :

Edward C. Pickering, S. B., Thayer Professor of Physics, and Director of the Rogers Laboratory.

William E. Hoyt, S. B., Instructor in Civil Engineering and Stereotomy.

William Foster, Assistant in the Mining and Metallurgical Laboratories.

Lewis M. Norton, Assistant in Quantitative Analysis.

Charles C. R. Fish, Assistant in General Chemistry and Qualitative Analysis.

James B. Stanwood, S. B., Assistant in Mechanical Engineering.

Clarence L. Dennett, S. B., Assistant in Mechanical Engineering.

Thomas W. Robinson, S. B., Assistant in Quantitative Analysis.

In the resignation of Professor Pickering the Institute has sustained an exceptional loss. His connection with the School, as Assistant and Professor, extended over a period of just ten years, an account of which will be found in his report for 1876. This historical sketch so plainly states the origin and growth of the laboratory method of teaching physics in the Institute, and is so full a summary of what the department has accomplished under Professor Pickering's direction, that I need only again ask your attention to it.

We are fortunate in having a Professor and Assistants who have been educated in the department, and are familiar with its spirit and methods, to continue the work. •

I wish here to express, in behalf of the Corporation and Faculty, the indebtedness of the School to Professor Pickering, and to wish him every success in his new field of labor.

The following are the appointments for 1877-78.

Silas W. Holman, S. B., Assistant in Physics.
 John B. Henck, Jr., S. B., Assistant in Physics.
 Edward A. Handy, S. B., Assistant in Civil Engineering.
 Henry M. Waitt, S. B., Assistant in Civil Engineering.
 W. Bugbee Smith, A. B., Assistant in Mechanical Engineering.
 Charles T. Main, S. B., Assistant in Mechanical Engineering.
 Frederick A. Emmerton, S. B., Assistant in the Mining and Metallurgical Laboratories.

John Alden, S. B., Assistant in Quantitative Analysis.
 Albert H. Low, S. B., Assistant in Quantitative Analysis.
 John E. Hardman, S. B., Assistant in General Chemistry and Qualitative Analysis.

Henry K. Burrison, S. B., Assistant in Mechanical and Free Hand Drawing.

George F. Underwood, Assistant in Architecture.

Attendance and Graduation. The whole number in attendance during the year was 315, an increase of 16 over the previous year. For classification and other items, see page 21 of the Secretary's report. The following table shows the attendance of each year since the organization of the school, properly classified, together with the number of graduates for each year. The last two columns give the percentages of those classified as regulars during the first and second years who graduated. Many students enter the school and take the full course during the first year without intending to graduate, and others fail from various causes. The last column probably more nearly represents the true relation between those who have graduated, and those who entered with the intention of so doing.

Of 202, the whole number of graduates, 81 have graduated in the department of Civil Engineering, 34 in Mechanical Engineering, 41 in Mining Engineering, 7 in Building and Architecture, 21 in Chemistry, 1 in Metallurgy, 2 in Natural History, 4 in Physics, 9 in Science and Literature, and 2 in Philosophy.

Year.	Total.	Special students.	Regular students.				No. of graduates.	Percentage of 1st year.	Percentage of 2d year.
			1st year.	2d year.	3d year.	4th year.			
1864-65	27								
1865-66	72	9	32	31					
1866-67	137	27	64	24	22				
1867-68	167	43	56	37	14	17	.52	.52	
1868-69	172	63	57	23	22	7	.16	.21	
1869-70	206	54	68	45	24	15	.16	.27	
1870-71	224	77	73	36	17	21	.30	.74	
1871-72	264	84	91	38	33	17	.19	.24	
1872-73	375	140	115	61	27	32	.37	.69	
1873-74	310	128	68	59	34	21	.25	.47	
1874-75	288	117	36	55	45	35	.28	.46	
1875-76	299	117	66	30	43	43	.37	.71	
1876-77	315	180	36	42	24	33	.47	.58	

Abstracts of the theses by graduates of 1876-77 will be found on pp. 53-91.

There have been no radical changes during the year in any of the departments which call for an extended statement. It will be sufficient briefly to note a few points, referring to the Catalogue and past Reports for full details concerning courses of study and appliances.

In the department of Architecture there is a steady increase in the number of students who enter upon and continue the regular course to the end of the four years, and take the degree. This full course involves the theory of construction as well as of design, and it is noteworthy that in all the theses of graduates the engineering side of the problem selected for discussion is treated with care and completeness. There is a growing feeling among this class of students that any deficiencies on the

side of design can be more readily made up after graduation than on the side of construction. It is to be hoped that the time is not far distant when a large proportion of the students in this department will prefer, and be able, to take the full course.

The Steam Laboratory of the department of Mechanical Engineering has been increased by the addition of a mercury column and other appliances, and is in excellent condition. The student has now the means of practically solving all the important questions upon the nature and use of steam which arise in his course of study, or practice.

The Mining and Metallurgical Laboratories have been gradually increased in capacity and efficiency. Iron ores have at last been included in the course of practical metallurgy. The processes in ore-dressing have been made almost wholly automatic, and these laboratories are now able to handle ores in large quantities.

Besides the education of our own students, they are beginning to be used by the public for the solution of problems in which New England, through the discovery of new mining localities, has a rapidly growing interest. It is but simple justice to refer to the untiring zeal, energy and skill with which Professor Richards has developed this element of his professional work, without in the least sacrificing or lowering the scientific side of the course. He has the satisfaction of knowing that no other mining school offers its students equal practical facilities.

The Chemical department, with its increased space in the new building (see cut, page 98), is in a very satisfactory condition; but the main building would be much improved if the department had one of its own, better adapted to its wants; and it is my duty to repeat that it should not be permitted to remain in the present building any longer than can be avoided.

The Women's Laboratory has been in all respects a gratifying success, due to the high attainments of its students, and to the time and attention which Professor Ordway has devoted to it,

assisted by the zeal and able co-operation of Mrs. Professor Richards.

The Department of Military Science and Tactics, in the charge of Lieut. Hubbell, continues to be entirely satisfactory to both Faculty and students. So far as we can learn, it is only in those colleges where this instruction has been made compulsory and efficient, that it has not been a source of annoyance and demoralization.

It will be seen from Mr. Kastner's report that the students in the Lowell School of Design, through the kind aid of several loom manufacturers, have now the opportunity to learn how to weave their own designs. This will improve the chances of those who succeed, to secure desirable situations.

The new School of Mechanic Arts. It was at first supposed that the general aims of this school could be fully accomplished, and that at the same time the course of studies would be a proper preparation for those wishing to enter the higher departments of the Institute. A brief experience, however, and further consideration, soon showed that the two aims were incompatible. A large proportion of the pupils, who enter this school, have no intention of pursuing an extended course of engineering studies, but desire in the shortest time to prepare for entering upon some industrial pursuit. It has been found best to keep the wants of such students solely in view, and not attempt to provide for the few who may wish to continue their studies. Its exact relation to the advanced work of the Institute may be learned from the report of the Faculty, to be found on page 24. The only aid which this school can render to those wishing to enter the regular courses of the Institute, will be the opportunity to make up special deficiencies in studies embraced in its course of instruction.

The Mechanic Art Shops. The plan announced in my last report, of building up a series of shops in which to teach the

students in the department of Mechanical Engineering and others the use of tools, and the fundamental steps in the art of construction, in accordance with the Russian system, as exhibited at Philadelphia in 1876, has been carried steadily forward; and I have now the pleasure of announcing its near completion. The proposed shops are:—

In wood, I, Carpentry and Joinery; II, Wood Turning; III, Pattern Making: in iron, I, Vise Work; II, Forging; III, Foundry Work (moulding and casting); IV, Machine Tool Work. A full report upon the course of instruction in each of these shops will be given hereafter.

In my last report I had the pleasure of informing you that the Director of the Imperial Technical School of Moscow had been instructed by his Government to duplicate the exhibit of that school at Philadelphia, for the Institute of Technology. This very valuable gift has arrived in excellent order, of which the following is a summary. The catalogue which accompanies the collection will be printed in detail in connection with my report upon this system of instruction as carried out here, up to and including 1877-78.

SUMMARY OF CATALOGUE.

I. Collection of samples for the successive learning of wood turning. Part I. Exercise models of various channelings and other simple forms. (Ten samples.) Part II. Casting-mould models of machine details. (Thirty-six samples.)

II. Collection of samples for the successive learning of joinery and pattern making. (Thirty-six samples.)

III. Collection of patterns for iron castings. (Sixteen samples.)

IV. Samples for the successive learning of blacksmiths' manipulations. (Seventy-seven samples.)

V. Collection of samples for learning metal-turning. (Fifty-three samples.)

VI. Models of drills and countersinks to six times the ordinary size. (Fourteen samples.)

VII. Cutting parts of files increased to twenty-four times the ordinary size. (Eight samples.)

VIII. Collection of samples for the successive learning of vise work. (Forty samples.)

IX. Collection of samples of riveted joints. (Eighteen samples.)

X. Collection of samples in iron welding. (Twenty-four samples.) Each sample consists of two parts; the first represents the details of the piece prepared for welding, and the second is the welded piece.

The whole collection contains 320 pieces of exquisite workmanship, the educational value of which can hardly be overestimated.

Legation of the United States,

St. Petersburg, June 11, 1877.

Prof. J. D. RUNKLE,

Technological Institute, Boston.

SIR:— Referring to your letter of October 16th, I now have the honor to enclose you a translation of a letter received from the IV Section of His Majesty's Chancellery, which explains itself.

I have made, in behalf of your Institute, a proper acknowledgment of the kindness both of Prince Pierre d'Oldenbourg and of His Majesty the Emperor.

I am, Sir, your obedient servant,

HOFFMAN ATKINSON,

Chargé d'affaires.

St. Petersburg, 24 May (5 June) 1877.

IV Section of the Chancellery of His Majesty the Emperor.

Prince Pierre d'Oldenbourg has the honor to inform Mr. Boker, Envoy Extraordinary and Minister Plenipotentiary of the United States, that the wishes of the Technological Institute of Boston, to introduce the system of instruction in Practical Mechanics adopted by the Technical School of Moscow, was placed before the Emperor.

It has pleased His Imperial Majesty to order to be made a collection of different models at the Technical School of Moscow, and to make a present of them to the Technological Institute of Boston.

Profiting by this opportunity to tender his respects to Mr. Boker, Prince Pierre d'Oldenbourg believes that he should add, that the Honorary Curator directing the Technological School of Moscow has been informed of this supreme order to take the necessary measures for its execution.

Legation of the United States.

St. Petersburg, October 29, 1877.

JOHN D. RUNKLE, Esq.,

President Mass. Institute of Technology.

DEAR SIR:—Yesterday I received from the Moscow School of Technology eight cases of models intended for the Institute over which you preside. These cases I have shipped to you by the Wilson Line, Messrs. Sanderson & Co., agents, directly to Boston. I congratulate you on the fact that they reached me before the closing of the navigation, so that you will receive your models shortly after the arrival of this letter.

I am, Sir, your obedient servant,

GEORGE H. BOKER.

The following, properly engrossed, has been transmitted to the Legation of the United States at St. Petersburg:—

To His Imperial Highness,

Prince PIERRE D'OLDENBOURG,

St. Petersburg, Russia.

At a meeting of the Corporation of the Massachusetts Institute of Technology, held November 20, 1877, a communication from his Excellency, Hon. George H. Boker, American Minister at St. Petersburg, was read, announcing the gift to this Institute of eight cases of models, illustrating the system of Mechanic Art education, as devised and so successfully applied at the Imperial Technical School of Moscow. The undersigned have been charged with the agreeable duty of transmitting to His Imperial Highness the following resolutions:—

Resolved, That the Corporation of the Massachusetts Institute of Technology takes this opportunity to cordially congratulate His Imperial Highness, Prince Pierre d'Oldenbourg, that, at the Imperial Technical School of Moscow, education in the Mechanic Arts has been for the first time based upon philosophical and purely educational grounds, fully justifying for it the title of the "Russian system."

Resolved, That this Corporation hereby tenders its grateful thanks to His Imperial Highness for his most valuable gift, with the assurance that these models will be of the greatest aid in promoting Mechanic Art education not only in the School of this Institute, but in all similar schools throughout the United States.

We have the honor to be

His Imperial Highness'

Obedient servants,

WILLIAM B. ROGERS,

JOHN D. RUNKLE,

SAMUEL K. LOTHROP.

The Restaurant. In the year 1874-75 the experiment of fitting up a lunch room in the gymnasium was tried, which was so successful that better accommodations were provided early in the following year.

It has been continued, and is now in a satisfactory condition. Besides our own students, and others connected with the Institute, it is patronized by students of the school connected with the Museum of Fine Arts, and some others, and this patronage aids in its support without incommoding those for whom it was especially established.

It has largely diminished the practice on the part of our students of bringing a lunch from home, and has in proportion promoted their health. It is almost impossible for a student, who lives far from Boston, and must reach the Institute by nine o'clock and remain all day, to depend upon a cold lunch, almost always taken at irregular times, to preserve his health in its full vigor. I am satisfied that this restaurant has been an important means in improving the health of many of our students; and for this reason, if no other, it should secure the interest and support of the Corporation, so far as necessary to its continued success.

In conclusion, I will say that as a whole the school has never been in a state of higher efficiency than at the present time. Our great and pressing need is additional funds; and without

immediate relief, we must either discontinue some of the departments, or cut down the salaries already too small, or more probably both. The fee for those taking the full course is \$200 per annum, and it is clearly out of the question to think of increasing the income by raising the tuition. It is even now far beyond the means of many deserving students.

The value of the Institute as an agency in developing and diversifying the industries of the State can only be maintained by increasing its funds. I can not think that the large sums which have already been contributed towards the establishment of our school, and particularly the large educational facilities and experience gathered together, shall be allowed to fail of the highest results for the want of additional means.

JOHN D. RUNKLE, *President.*

SECRETARY'S REPORT FOR 1876-77.

There have been held during the year thirteen meetings of the Society of Arts.

NEW BY-LAWS.

Nov. 23, 1876. This meeting was taken up by a discussion of the best way to correct certain informalities in the preparation of new By-Laws for the Society, arising from the complicated relations existing between the Corporation and the Society. The proper committee was finally chosen, which, with the committee of the Corporation, reported a new code, which was adopted by the Society March 22, 1877, and by the Corporation April 11, 1877.

The principal differences from the old code are: that the organization and administration are much simplified, and that the funds of the Society are to be held and used for its objects, under the direction of its executive committee, with the approval of the President. It is believed that, with this simpler organization and extended powers, a greater interest will be excited in the objects of the Society, and that the number of members actively engaged in mechanical pursuits will be considerably enlarged.

The objects of the Society are to awaken and maintain an active interest in the practical sciences, and to aid generally in their advancement and development in connection with arts, agriculture, manufactures, and commerce.

The Society invites all who have any valuable knowledge of this kind, which they are willing to contribute, to attend its meetings, and become members. Persons having valuable inventions or discoveries, which they wish to explain, will find a suitable occasion in the Society meetings, under certain regulations; and while the Society will never indorse by vote or diploma, or other official recognition, any invention, discovery, theory, or machine, it will give every facility to those who wish to discuss the principles and intentions of their own machines or inventions, and will endeavor at its meetings, or through properly constituted committees, to show how far any communications made to it are likely to prove of real service to the community.

The Members may be enrolled in divisions, under the following heads; according to the taste or preference of the individual; each division to constitute a committee upon the subjects to which it appertains:—

- (1.) On Mineral Materials, Mining, and the Manufacture of Iron, Copper, and other Metals.
- (2.) On Organic Materials, — their Culture and Preparation.
- (3.) On Tools and Implements.
- (4.) On Machinery and Motive Powers.
- (5.) On Textile Manufactures.
- (6.) On Manufactures of Wood, Leather, Paper, India-Rubber, and Gutta-Percha.
- (7.) On Pottery, Glass, Jewelry, and works in the Precious Metals.
- (8.) On Chemical Products and Processes.
- (9.) On Household Economy; including Warming, Illumination, Water-supply, Drainage, Ventilation, and the Preparation and Preservation of Food.
- (10.) On Engineering, Architecture, and Ship-building.
- (11.) On Commerce, Marine Navigation, and Inland Transportation.
- (12.) On Agriculture and Rural Affairs.
- (13.) On the Graphic and Fine Arts.
- (14.) On Ordnance, Fire-arms, and Military Equipments.
- (15.) On Physical Apparatus.

Any member may belong to more than one of the above-named Committees of Arts.

USES OF CORUNDUM,

Dec. 14. Mr. C. W. Jenks read a paper, illustrated by charts and specimens, on the uses of the mineral corundum in the arts.

Corundum, in its granular and gem forms, has been long known, having been used as an abrasive second in cutting qualities only to the diamond; and in gems, as sapphire, ruby, emerald, etc., of more value even than the diamond. The corundum emerald is specially rare and valuable, being pure alumina, much harder than the silicious emeralds. It was well known to the ancient Hebrews, Persians, and Hindoos.

Extensively used as an abrasive, and widely spread over the earth, it has not been legitimately mined until within the last five years; it has been chiefly found on the surface after rains. Every one of its varieties is extensively mined in the islands of the Ægean sea, in Asia Minor, and in an impure form in this country.

He suggested that the hieroglyphics worked upon the Egyptian monuments, of a stone so hard as to speedily blunt the hardest steel, were made by tools of corundum; at any rate, this mineral will cut the Egyptian granite and the hardest diamond. If it be true that one mine of emery is worth more to a manufacturing people than many mines of gold, this substance owing its value as an abrasive to its forty or fifty per cent. of corundum (which has a hardness of 7, the diamond being 10), what must be the value of pure corundum, which stands at 9? In the rapidly-increasing field of labor for which emery is used, the diamond is too expensive for extensive use; and this the corundum, by its pure quality and better mode of application, will accomplish cheaply and well in the case of granite, steel, the harder alloys for gun-metal, rolls for paper-making machinery, and finishing steel surfaces.

He exhibited a new sapphire wheel of nearly pure corundum. This works wet or dry, heat and acids having no effect upon it; it brings a steel tool rapidly to a cutting edge without heat or

loss of temper, as it cuts so rapidly that the slight friction has no time to develop heat. In this way it does 30 per cent. more work than the best emery, much work that emery can not do at all, and much now done by the diamond.

The corundum gems, all with the prefix of "oriental," are the sapphire, ruby, asteria, emerald, topaz, amethyst, girasol, chatoyant, and white sapphire (the last often used for the diamond). All of these have been found, of more or less purity, among the Blue Ridge mountains of western North Carolina. Both forms, the massive and the gems, are found there in the same mountain, showing that the mineralogical and geological conditions of the two are not unlike, as was supposed from their occurrence in different localities in the old world. There corundum is found in the beds of streams, or in or near their banks, as water-worn pebbles, in a secondary formation of a clayey conglomerate. It is found here also in a native matrix of ripidolite, between hanging and foot walls of serpentine, apparently undisturbed, and yet with all the appearance of water action. He had never seen any specimen in this country or in Europe which he could not duplicate from the North Carolina mine. The discovery of corundum in place is a matter of great scientific interest.

The material is stamped in the usual manner, and afterward roughly or finely ground, according to the use to be made of it. It is only about 15 per cent. more expensive than emery, and apparently does a better and more extended work.

AGRICULTURE IN MASSACHUSETTS.

Dec. 28. Mr. Albert L. Murdock, of Boston, made a communication on the "Decline and Redemption of Agriculture in Massachusetts and the United States," illustrated by maps and charts, and an extensive series of grains, especially wheats, from all parts of the world.

It is a general belief and statement that the agricultural lands of Massachusetts are exhausted; this he thought was not founded on fact. It is true that 148 towns have lost, during the last

twenty years, from 2 to 61 per cent. of their population, and from 8 to 60 per cent. of their products; the people have gone to the manufacturing centres, and our manufactures have increased at the expense of our agriculture, with a consequent large decrease in the value of farms. And yet, with all this decline, there is a production, per acre cultivated, of 35 per cent. more than twenty years ago, and 20 per cent. more in money per bushel or ton is obtained from the products of the farm.

Could three-tenths, even, of these abandoned lands be cultivated, the importation of grain from other States would be stopped. When it is remembered that a million dollars is sent out of the State every week for food that we might easily produce ourselves, and that every sixth man is out of employment, the importance of the question is evident.

The redemption of our agriculture may be brought about in various ways:—by the redemption of our salt marshes by dyking; he instanced a remarkable case in this connection at Marshfield. We do not realize this decline, being deceived by the greater yield from a few acres from superior methods of cultivation; we want more acres under cultivation, and then the modern superior methods would produce all we require. He advocated the establishment by each town of a scholarship in the Agricultural College at Amherst, with the understanding that the incumbent after graduation should reside in the town, and give one afternoon each week for the information of his townspeople, for three years, or else pay back to the town half the cost of his tuition.

He also advocated the establishment of experimental stations by the State, to be cultivated in the best and most economical manner, paying special attention to the relations of the chemical constitution of grains, etc., to the characters of soils, developing thus the best methods of cultivation and the value of fertilizers. Increased production and the employment of idle hands would then be united for the material advantage of the State.

Mr. C. L. Flint, while admitting the general accuracy and importance of Mr. Murdock's remarks, stated that farming was still profitable in the State, not in the production of the cereal grains, but in raising the vegetables and small fruits which find a ready and remunerative sale in the numerous manufacturing centres which have sprung up all over the State, crowding out the old farm agriculture. It is only labor diverted into other and perhaps more profitable channels.

INDUSTRIAL EDUCATION.

Jan. 11, 1877. A paper by Rev. Dr. Bartol was read on the "Social and Political Economy of Universal Industrial Education." Industrial education is economy of health; exercise, motion of body and soul together, is a law which is punished by debility and disease, when broken. Industrial education would make the whole people honest, open generous livelihood to all, turn the State into a bee-hive of industry, relieve the charitable societies, depopulate the prisons, abolish poverty and the alcoholic desire, and substitute the enjoyment of music and the fine art gallery for the haunts of vice. It would detect and render available the mechanical and artistic genius, which is now often lost to the world, or accidentally discovered. Labor has been considered an equivalent of drudgery and degradation too long; industrial education would convert it into interest, dignity, honor.

THE RUSSIAN SYSTEM.

President Runkle then explained the Russian system of Shop-work education, as far as it had been adopted by the Institute. The object is to educate the *hand* as well as the *mind*, without which no system of technical education is complete. The difference between *in*-struction shops and *con*-struction shops must be borne in mind, as most of the adverse criticisms of the system have arisen from ignorance or misapprehension of this vital point. The hand is instructed by the use of tools just as the mind is disciplined by mathematics, chemistry, etc., for develop-

ment, for *education*, without reference to the money value of the immediate products. The purpose here is to instruct as an *art*, and not to establish *manufacturing* shops and teach *trades*. The skillful hand can afterward readily adapt itself to any manufacture.

The *con*-struction part of the great Russian schools is not to be introduced here, and the *in*-struction shops are modified to suit American needs. Though the work done be more quickly and cheaply and better done by machinery, and even though Russian shops are fitted with American-made tools, the system may properly be called Russian, as it embraces the central idea of *class* instruction of the *hand*. It makes no difference whether the forms selected can be made by machinery or not, or whether they are of any money value; the question is, whether the making of these forms is well calculated to give the pupil the skill in the use of his hands which will be a great advantage to him whether he is to make use of it in after life as a mechanic, or whether he never touches a tool again. The time spent in this teaching is so small compared to that devoted to other studies, that the pupil has all the advantages of the regular school courses, plus the manual skill which he can use, or not, as circumstances require.

Prof. Whitaker stated that the instruction in the use of the file — an instrument acknowledged by experts as one of the most difficult to use as well as one of the most important of tools — even on useless forms, would give a manual skill to these lads which was of marketable value. He exhibited specimens of work made at the Rotterdam school, showing that as an educational system this and other *con*-struction shops were of no value, and never could be; these specimens, exhibited at Philadelphia, showed a deficiency in design and detail, of money value perhaps, but useless to make a skillful workman. In his judgment, from experience in the workshops, the two years' course at the Institute, of which the filing occupied a very small portion, would save five years of apprenticeship, and make a better workman.

Mr. H. P. Langley, a mechanic of thirty-five years' experience, expressed his surprise at the excellence of the work done in so short a time, and said that he believed it would be hard to find a mechanic who, after two years' work in the machine shops, could make such accurate fitting with the file as these lads have made after a week's instruction.

Prof. Whitaker explained that the skill so rapidly acquired was due to *class* instruction by a skillful mechanic, who taught how to do the work and how not to do it; they are not left to blunder into the right way, or to pick up the necessary knowledge accidentally, or by observation of their fellow workmen; no time is lost in making mistakes, and the pupils *start* from the standpoint of an expert's knowledge and skill.

TRADE SCHOOLS.

Mr. Newell read portions of the report of Mr. S. P. Ruggles's plan, as presented to the Social Science Association. This plan proposes to take boys at the proper age, as after passing through the grammar schools, introduce them into a developing school, and then teach such of them as show an aptitude therefor the various trades. This plan, however excellent it may be, has nothing antagonistic to the Institute system, and does not pretend to effect the same educational purpose.

COMBUSTION.

Jan. 25. Mr. H. P. Langley read a paper, illustrated by diagrams, on "Combustion and the Economical Production of Steam, with results of experiments on natural and artificial draughts, and methods of preventing smoke."

The necessity for the introduction of a considerable amount of air through the grate bars, and also into the combustion chamber of a furnace, for the complete utilization of the coal gases, seems to have received too little attention in the ordinary setting of boilers. He exhibited drawings, from the work of C. Wye Williams, of various devices for the introduction of air, mostly through perforations in the bridge walls, preventing

smoke, increasing the energy of combustion, and economizing fuel. According to this author, it makes no difference in what part of the furnace or flues this air is introduced, provided that the mixture of air and gases be continuously effected, before the temperature is reduced below that of ignition, not less than 800° Fahr.

He believed that the use of *heated* air was a fallacy, unsupported either by theory or practice; by heating the air we increase its volume, but diminish the weight of oxygen in each cubic foot, and so lessen its efficacy. The use of hot air in the blast iron furnace involves quite different principles. On the contrary, combustion may be increased by condensing the air supplied to a furnace. Of course, judgment must be used to avoid the indiscriminate supply of cold air at every stage of combustion; to secure uniformity in this respect, a mechanical is better than an artificial draught.

FUELS.

The following general rules he considers as established in regard to fuels: 1. Where a strong fire is necessary, with a large and regular supply of steam for heavy work, anthracite is without doubt the best; when boilers are large and firemen numerous, this may be changed for hard coal dust mixed with soft coal, with the use of a blower; — 2. Where the amount of steam required varies much, with corresponding heavy and light fires, Cumberland, or some soft coal would be better, with a sufficient supply of air; — 3. Dust coal has the advantage of lower price, but ten per cent. more is required to do a given amount of work, more labor is necessary to feed the fires, and generally a fan or blower must be used to get the due proportion of air; when used, the fire should be very thin, three or four inches deep, the supply being put on often and in small quantities.

NATURAL AND ARTIFICIAL DRAUGHTS.

According to Pecelet, one fourth of the combustible used is expended in producing the natural draught; if this heat can be

used for making steam, and a mechanical draught will cost less, the latter is to be preferred. According to Prideaux, one pound of coal expended through mechanical agency, is capable of producing a stronger current of air than five hundred pounds expended in heating a column of air to act by a chimney thirty-five feet high; on this principle, the expense of tall chimneys may be dispensed with, and complete and smokeless combustion effected in a very simple manner.

COVERING OF PIPES AND BOILER.

At a foundry in South Boston a trial for twelve weeks was made with Pictou coal, with boiler and pipes uncovered, and covered with felt; the result was 6010 pounds of coal in favor of the felt covering. He described the "Hinkley" boiler, in which the fire is entirely surrounded by water, so that no heat can escape by radiation; in a trial of nine days with hard coal, with steam at 60 lbs., 13.94 lbs. of water were evaporated per pound of coal; with Cumberland coal, in five days, with same pressure, 13.76 lbs. of water were evaporated per pound of coal. He also explained figures of the Bonta furnace, and the Jarvis, Smith, and Walker settings.

BRIDGE WALLS.

Prof. Whitaker mentioned that an engineer of this city, having used for six months a bridge wall under his boilers, beginning at nine inches distance and going up to six, at great cost of coal, had been able to make a daily saving of two hundred and fifty pounds of the hardest Lehigh coal, by raising the bridge wall up to within five inches of the boiler, or four inches with the coating of ashes on it. He believed that the bridge wall should be within four to six inches of the boiler, and with a similar curve.

Mr. Birch advocated the use of an automatic steam damper for regulating the supply of air, claiming to have evaporated fourteen pounds of water per pound of coal, and to have saved thirty tons of coal per month by the proper mechanical introduction of air.

This subject was continued at the meeting of March 8th — see bottom of page.

DIGNITY AND NECESSITY OF LABOR.

Feb. 8 and 22. Mr. Horace McMurtrie read a paper "Labor in its relations to the human organization," and on "its Dignity, Happiness, and Pleasures."

He showed that in the very structure of the human body we find proofs that labor is a blessing and not a curse; active exercise is necessary for the development of the muscles; children at play in this way exercise their muscles more than does the hardest working laborer, and this play is necessary and natural for the development of all young animals. The functions of digestion, circulation, and respiration, require active exercise for their perfect performance. Mental labor is also necessary for the development of the brain, but unfortunately has been separated from bodily labor, as of a higher grade; man endeavors to secure happiness without labor, upon the labor of others, and is prone to look with contempt upon the very means whereby he lives. The harmonious and vigorous action of all our organs is accompanied by pleasure, and any disturbance of this harmony by pain and disease.

AUTOMATIC REGISTER.

Mr. N. M. Lowe exhibited an automatic register for mechanical motions, invented by himself. The registering is effected by the action of two levers upon a train of wheels so weighted that an index will be moved by vibration, or by eccentric or concentric motions. As it may be sealed up in any movable piece of machinery, it can not be tampered with, and is therefore reliable.

COMBUSTION.

March 8. Mr. Charles W. Birch read a paper on combustion of coal, as effected by a boiler furnace of his invention, in which what he regards as warm air is introduced by a swinging per-

forated plate over an air chamber behind the bridge wall. He had previously tried, without success, a perforated plate hung at the back of a small door cut through the bridge wall from the ash pit to the air chamber, the door being kept open.

The perforated plate is placed at an angle of about thirty degrees, sloping toward the combustion chamber, the highest edge of the plate about four inches below the centre of the bridge wall; the plate set over a chamber fourteen inches long and as wide as the boilers (four feet), the sides of the chamber sloping toward a door, twelve inches square, opening into the ash pit. The air passes through the ash pit, being thus slightly warmed, then through the door into the conical chamber, and is further heated there; thence through the perforated plate to ignite the gases under the boilers.

The following were the savings of coal in the months of 1876 over the corresponding ones in 1875, when the boilers were set on the old plan: in July, 16,300 lbs.; in August, 13,000 lbs.; in September, 17,960 lbs.; in October, 12,100 lbs.; in November, 33,540 lbs.; in December, 43,790 lbs.; or a total saving, in the six months, of 136,690 lbs. The boilers were four feet in diameter, tubes fourteen feet long and of size of three inches, and forty-nine in each boiler; floor of combustion chamber on a level with that of the ash pit; bridge walls twenty-six inches thick, and built on a seven foot sweep; distance from top of centre of bridge wall to bottom of boiler five inches. He claims that with this setting he has been able to save ten per cent. of fuel, and to furnish steam for one-eighth more work. It can be easily put under most horizontal boilers, without disturbing the setting or the piping.

Mr. McMurtrie remarked that, in his opinion, the distance between the grate bars and the bottom of the boiler was, as a rule, too small; and that the cubical contents of the furnace ought to be considered quite as much as, if not more than height of bridge walls, introduction of air, etc. From above fourteen to forty inches, and the last the best, he thinks should be the distance from the grate bars to the bottom of the boiler.

Mr Langley said that, in his judgment, the best distance was, for bituminous coal thirty inches, for anthracite twenty-four inches, and for a moderate combustion twenty inches.

SELF-TESTING GAUGE.

Mr. B. B. Keyes explained, by the instrument and by drawings on the board, his self-testing gauge for steam and other pressures.

Since steam came into general use, an instrument for indicating its varying pressure has engaged the minds of inventors. Piston gauges were first introduced, but these soon gave place to the diaphragm in various forms; then Bourdon accidentally discovered that an oval-shaped tube, bent in the form of a curve, would, when pressure was exerted on the interior, tend to straighten; from this arose the spring gauge which bears his name, familiar to all engineers.

To obviate the defects arising from unavoidable accidents which render this gauge sometimes unreliable, Mr. Keyes has devised a simple attachment whereby any hollow spring gauge may be made self-testing; he utilizes not only the horizontal but the perpendicular motions of the springs, uniting them by proper mechanism, so that these motions are transmitted to the pointers; this permitted and required firmer or stiffer springs for measuring like quantities of steam than any before used, and by no pressure, within the amount indicated on the dial, can their elasticity be affected. This device prevents vibration of the pointer under action; and the springs, being held to their lowest points, and not extending beyond a line perpendicular to this point, allow no water to remain in them, subjecting them to the danger of freezing.

STEAM REGULATING VALVE.

March 22. Mr. Joseph E. Watts, of Lawrence, exhibited a steam-regulating valve, of his invention, which had been successfully tried in several manufacturing establishments during

the past year, and upon the steam-tables in the Chemical Laboratory of the Institute.

HOUSEHOLD SANITARY SCIENCE.

April 12. Mr. H. P. Langley read a paper on "Household Sanitary Science," dwelling particularly on the impurities of air, and the necessity for a certain amount of moisture in it. He described a simple device for ventilation by the windows, and exhibited several hygrometers.

PROPER MOISTURE OF THE AIR.

Mr. Chester B. Merrill then made a communication on the condition of air in rooms heated by steam, and explained his invention for regulating the moisture in the same. It is found by actual tests that the temperature in such rooms is kept much too high, ranging from 70° to 80°, and that the hygrometer shows only from twenty to thirty per cent. of moisture, while it should indicate sixty per cent. When steam was introduced for heating purposes, it was said that the air would be too damp; the reverse is the fact.

At zero a cubic foot of air will hold 1.8 grains of watery vapor, at 32° 2.35, at 50° 4.24, at 100° 19.12 grains. The heating of air does not dry it in the sense of taking moisture out of it; it only renders it capable of holding more, and it drinks up moisture from everything that it comes in contact with, whether our furniture or our bodies.

He exhibited in operation a steam air-moistener, invented by himself, by which he claims that the dryness of the air in our houses, one of the principal objections to heating by steam, is overcome — the humidity of the air being regulated in this way, and shown by the hygrometer as accurately as is the temperature by the thermometer.

From remarks made by various persons, it appeared that sixty per cent. of moisture was obtained with great difficulty, and would be accompanied in very cold weather with the double disadvantage of ice on the windows and cold surfaces,

and its subsequent melting and injury to dwellings. Fifty per cent. seems to be the best degree of saturation, and air of this moisture need not be so warm as is generally considered necessary in our hot and dry rooms; double windows, with a space between them of a foot, are necessary for this purpose in cold weather.

CO-ORDINATE SURVEYING.

April 26. Mr. Henry F. Walling read a paper, the object of which was to point out a simple method in which the high degree of precision of the "Coast Survey" work may be made available in the ordinary operations of surveyors where the Coast-Survey triangulations have been carried, and to call attention to the importance of these triangulations over the entire country.

In land conveyances permanent landmarks, position of boundary lines relative to each other, and accurate statements of dimensions are generally omitted; fences, walls, hedges, ditches, streams, shore lines, boundary stones, etc., do not remain unchanged; the compass is liable to great uncertainty from the irregular action of the magnetic force and local disturbances; the theodolite and surveyor's transit afford no greater precision in retracing obliterated boundaries unless one or more well-defined lines remain for reference; the solar compass is more accurate, but its use is limited to bright or slightly cloudy days; the direct measurement of distances by the usual rod, tape or chain, is attended with even more difficulties than the measurement of directions. In a trigonometrical survey, or the measurement of angles, on the contrary, the accuracy is such that the error is reduced to a little less than two feet in one hundred miles, which would not vitiate any measurements even in the most valuable localities.

Instead of defining the position of a point by its terrestrial latitude and longitude, he would give its "latitude and departure," or its co-ordinates, from the zero point or origin of co-ordinates for the containing areas. The advantages of this

method are, he claims : 1. The highest practicable degree of accuracy, in small or large operations ; 2. Great simplicity of notation, with ease and convenience of field work and computation ; 3. Facility in graphic representation ; 4. Absolute certainty of locations in descriptions for conveyances, and consequent removal of a fruitful cause of litigation and dispute.

Buyers and sellers of land, lawyers and conveyancers, are familiar with the defects of the prevalent modes of surveying ; scarcely one deed in a hundred contains such a description of the land as would fix its location with certainty, if its fences, walls, or other boundary lines, should be obliterated ; a large part of the litigation of the country arises from the imperfect surveys, or no surveys at all, upon which such conveyances are based.

CHASE GOVERNOR.

Mr. L. E. Chase exhibited his new form of governor, prefacing his explanation by a statement of the defects of all the common forms of this instrument.

The two great enemies against which the inventor has to contend here, are friction and lost motion ; since, in proportion as these are overcome, will the governor valve coincide, in time and amount, with the variations of speed in the engine. All systems of jointed arms, levers, swivels, valve stems, etc., are fatal to the required conditions, since any train of the above must engender friction and lost motion, whether the governor be centrifugal, pneumatic or hydraulic. The governor valve must be as delicate and accurate as the best spring balance, and must act with the utmost nicety through minute distances.

To remedy these difficulties, this governor is made without balls, fans, paddle wheels, jointed arms or valve stems ; the valves are hung upon a spring made to revolve, and are actuated directly by the centrifugal force, without the intervention of supplementary parts ; friction is thus reduced to a minimum, and lost motion is entirely avoided. He exhibited it in section and by diagrams, which would be necessary for a complete

understanding of its merits. Beside its great simplicity, the following advantages are claimed for it: no revolving balls, throwing of oil, nor gears to strip or wear out; readiness of application, as it need not be taken apart, will run in any position, or either way, and can be attached to any form of engine; perfect governing power, great uniformity of speed, and complete control over the steam pressure, whether high or low; economy, as it allows no waste of steam; durability and ease of repair.

HYDRAULIC ELEVATOR.

Mr. Joseph H. Lewis exhibited in operation a model of a new hydraulic elevator for dwellings and stores. It was noted as easy of operation, economical of water, and easily adapted for variation in load, when running up or down. It differed somewhat from those in common use.

IMPROVED ORRERY.

May 10. Mr. N. M. Lowe explained a new form of orrery, of his invention. It was very ingeniously contrived to show, in a single instrument, what otherwise has hitherto required complicated and expensive apparatus. It exhibited the orbital motions of the planets in their respective planes; the seasons, months, signs of the zodiac, solstices, and equinoxes; the inclination of the earth's axis; the motions of Jupiter; the direction of the sun's rays on the earth; the places of rising and setting, and the apparent path of the sun in the heavens at the different seasons of the year; the phenomena of the midnight sun; and many other astronomical phenomena, which it is important to exhibit in schools.

MERRIMAC LEAD MINE.

This mine was discovered in 1874, when a pit was dug, and four tons of very fine smelting lead ore were taken out; the vein was found in November 1874; the ore has hitherto been shipped to New York.

Last January a lot of the poorest ore was sent to the Institute Laboratory for the experimental work of the mining students; from their experiments the value of the lead, silver, and gold per ton was carefully estimated. This was done for the double purpose of giving the students practical experience in handling work, and of trying to find a process whereby low grade ores at Newburyport could be treated with profit.

MAGNETIC MOTOR.

Mr. W. W. Gary exhibited in operation a new magnetic motor of his invention, utilizing the power of permanent magnets. He claims to have demonstrated: 1, that the polarity of an iron bar, when magnetized by induction from permanent magnets, is changed by increasing or diminishing the distance between the iron and the magnets: 2, that, according to this law, one small cell of battery may be made to operate an engine of sufficient power for sewing machines or dental engines, by using in combination with an electro-magnet powerful permanent magnets: 3, that the power of the engine is increased by the addition of permanent magnets, without additional battery power or consumption of material.

ELECTRIC CLOCK.

Mr. Thomas Hall exhibited what its inventor, Mr. Clark, of Kentucky, calls the "Perpetual Electric Clock," from its running a year and a half or two years without changing the battery or touching the clock.

In the ordinary electric clock, the swinging of the pendulum of another clock makes and breaks the circuit which sends the hands forward. In this, the weight or mainspring of the common clock is replaced by the electro-magnets; by a simple modification the hair-spring and the magnets effect the reciprocating movement, the circuit being made and broken while the wheel is travelling in the same direction. The clock, once accurately adjusted, will go without variation for about two

years, the weakening of the spring and the deterioration of the battery being about equivalent. A battery, costing about two dollars, may be placed in a closet or in the cellar, and will suffice for a clock in every room in a house, without any attention.

COPYING DESIGNS.

May 24. Mr. Thomas Hall exhibited his apparatus for copying and enlarging designs, opaque or in colors, illustrated by the lantern; the apparatus may be placed in any room ten feet high.

He compared the old, tedious, and expensive process with his rapid, cheap, and accurate method. Now the camera is used for enlarging the design on zinc or paper for the pentagraph machines, and it has many advantages over the old methods. In the old process it was necessary to make a fine outline tracing in black, on transparent paper, of all the shapes and colors in the design; this tracing was put in a camera, and the light taken from above the tracing, casting a shadow on the paper or zinc below. It took from half an hour to a week, or more, to get one of these tracings prepared for the camera, according to the size and amount of work to be traced.

In the new process, the design itself is put in the camera, and an enlarged shadow of the design is obtained on the paper or zinc in the colors in which it is painted, thereby getting a much better shadow to trace, the colors being just as they are drawn, instead of the mere outline of the colors as in the old way. By the new process are saved all the valuable time and labor necessary to make a transparent tracing, often a very important item. He had saved on one pattern some thirty to sixty dollars, and this is a specimen of what is done every day.

The advantages claimed for the new process, then, are: First—It saves much time on every pattern, thus enabling one man to do the work of two. Second—It saves the wages paid to a sketch-maker, while making transparent tracings. Third—The work is more correct, being taken from the de-

sign. Fourth — The shadow is better and more convenient to work from, as the workman can see at once just what colors he is tracing.

IMPROVEMENTS IN TELEPHONY.

Prof. A. Graham Bell gave a brief sketch of the history of telephony, and of the various ways in which he had simplified the apparatus employed. He described the original instruments, in which a battery current was used, in one of three varieties, which he called a year ago intermittent, pulsatory, and undulatory currents, characterized respectively by the alternate presence and absence of electricity upon the circuit, sudden changes in the intensity of a continuous current, and gradual changes of intensity like those in the density of air occasioned by simple vibrations. His receiving instrument then resembled a human ear, in connection with electro magnets and coils, each terminal apparatus being different from the receiving. He had ascertained that it was simply necessary to have a permanent magnet, with a simple coil with magnetized iron core, without a battery. The larger the plate the better the sound seemed to be; he had tried every size and thickness, from that of the thumb-nail to a sheet of iron four feet square, and from the thinness of tissue paper to boiler plate a quarter of an inch thick, with nearly the same results; gold-beater's skin and similar membranes in imitation of the drum of the ear were entirely unnecessary. The vibration is certainly not that of a membrane, and may be called, for want of a better name, molecular. The essentials for the telephonic apparatus, as at present constructed, are a permanent magnet, a coil, and a plate in front so placed as to vibrate freely without touching; and all these parts he has varied in many ways as to size, shape, thinness, material, etc. He finds that the thinner the coil the better the results, and he has had the best effects from a plate of soft iron, four inches in diameter and one thirty-second of an inch thick.

He exhibited a new and portable telephone, having the magnet and coil in the handle; this was passed round among the audience, who were thus enabled to hear music and conversation in a far distant room in the building. He had made a serviceable instrument which he could carry in his vest pocket.

He spoke of the social and business uses to which the telephone might be put, and drew an amusing picture of its future applications, as a time and labor saving apparatus at a moderate cost and for domestic uses.

He concluded his experiments by passing a voice through the bodies of twenty persons, standing side by side on the platform and taking hold of each other's hands. This was overcoming an immense resistance, much greater than that offered by the Atlantic cable; suggesting that, if this resistance be the chief thing to overcome, telephony may yet be substituted for telegraphy across the oceans, as it soon will be across the continents.

The meetings of the Society were then suspended till the autumn.

Of Life Members, Mr. E. B. Bigelow resigned during the year, and Messrs. J. Wiley Edmands and James McGregor died.

Mr. John Newell was elected an Associate Member. Messrs. Isaac Ames, Charles E. Buckingham, J. J. Dixwell, William Munroe, and Edmund Quincy have died during the year; fourteen have resigned, and twelve have been dropped for non-payment of fees and removal from the State. There are now on the list 59 Life, and 154 Associate Members.

SCHOOL OF INDUSTRIAL SCIENCE.

The attendance at the School of Industrial Science for the year has been 315, as follows: Graduate students, 22; Regular students of 4th year, 33; of 3d, 24; of 2d, 42; of 1st, 36; — Students not Candidates for a Degree; 4th year, 11;

3d, 7; 2d, 25; 1st, 12; Architectural students, 21; Students in School of Mechanic Arts, 23; special students in Chemistry, mostly women, 25; students in Practical Design, 47, of whom 38 were women; deduct 13, who were counted twice: = 315. Of these about five-sixths were from Massachusetts, principally from Boston and its vicinity;—from other New England States, 18: viz.; from Maine and New Hampshire 7 each, from Rhode Island and Connecticut 2 each. From other States, there were from New York 8; Illinois, 7; Ohio and Iowa, 4 each; Missouri, Texas, and California, 2 each; Georgia, Minnesota, Wisconsin, Pennsylvania, and Kentucky, 1 each; Japan, 4; Canada, 2; New Brunswick, Cuba, and the Hawaiian Islands, 1 each.

In accordance with a vote of the Corporation, the laboratory for advanced instruction in Chemistry and allied subjects for women was opened at the commencement of the year, and more than twenty, principally teachers, availed themselves of its privileges, for various periods of time and in such departments as each one felt special need. This class was under the superintendence of Prof. Ordway. A vote of the Corporation also authorized the opening of such departments of the school, as the Committee on Instruction see fit, to advanced special students of either sex, or to special classes, where it can be done without interfering with the regular work of the school. In the Department of Philosophy, Prof. Howison had a class of seven ladies, who pursued a thorough and most satisfactory course, extending through the year.

The class in "Practical Mechanism" has also been most successful.

The class in "Practical Design" has been very large, and the character of the work, fully exhibited in Philadelphia last year, has not fallen off. Decoration of tiles and table ware, and work on a loom, have been added to the course, as will be described in the Report of the Instructor, on a subsequent page.

During the year the school has lost the services of Prof. Pickering, who resigned his position as Thayer Professor of Physics to accept the post of Superintendent of the Harvard Observatory at Cambridge. Prof. Zalinski, to whose energy and perseverance the present efficient condition of the Military Department is due, was ordered back to his regiment, the time of his detail to the Institute having expired.

Thirty-two professors and teachers have been connected with the school, who have been assisted, as is customary, by several advanced students in the laboratories and in field work. The fees from students have amounted to about \$45,000.

LOWELL FREE COURSES.

The Lowell Free Courses for the year were as follows :

I. *General Chemistry*. Twenty-four laboratory exercises of two hours each, on Wednesday and Saturday afternoons at 2½ o'clock, by Professor Nichols, beginning Nov. 8.

II. *Qualitative Analysis*. Twenty-four laboratory exercises of two hours each, on Wednesday and Saturday afternoons at 2½ o'clock, by Professor Nichols, beginning Nov. 8.

III. *Geology*. Eighteen lectures on Tuesday and Friday evenings at 7½ o'clock, by Professor T. Sterry Hunt, beginning Tuesday, Nov. 7.

IV. *The Philosophy of Government*. Eighteen lectures, on Monday and Wednesday evenings at 7½ o'clock, by Professor Howison, beginning Monday, Nov. 6.

V. *Practical Mechanics*. Eighteen lectures, on Tuesday and Thursday evenings at 7½ o'clock, by Professor Lanza, beginning Tuesday, Nov. 7.

These were open to both sexes over eighteen years of age, and were, as usual, well attended.

The Corporation has held ten meetings during the year.

At the meeting of May 9, 1877, the President made a detailed statement in regard to the progress, condition, and purposes of the new School of Mechanic Arts, based upon the report of the Faculty in relation thereto.

The following is the Report of the Faculty on this subject, which had received the full consideration of the Committee on the School:—

THE Committee appointed by the Faculty to consider the condition of the newly constituted Department of Practical Mechanism beg to submit the following

R E P O R T.

The new Department of Practical Mechanism established last year, by vote of the Corporation, is of a different character from the other departments of this school, inasmuch as the standard of age and attainments exacted of applicants is lower, the studies pursued are of inferior grade, and the course of study is shorter, no degree, of course, being given at its conclusion. In conformity with this vote, and with certain agreements entered into with the Massachusetts Mechanics' Charitable Association, workshops have been built, in which a successful course of instruction in vise-work has been carried on. This instruction has been followed by the students in the Department of Mechanical Engineering as part of their regular school work, and by volunteers from other departments of the school; by special students from outside, among whom are some of our own graduates; and by a large class of younger students, attracted by the new opportunities, for whom special instruction of an elementary character in English, French, Drawing, and Mathematics has also been provided, forming, with the shop work, a two-years' course of study. This instruction has been given in the drawing-rooms and lecture-rooms of the Institute, by some of our own number. It has been suggested that this two-years' course may prove of service in fitting boys to pass the entrance examinations of the regular course.

Your Committee have accordingly considered this work under its relations, first, to the regular students in the Department of Mechanical Engineering; second, to special students in that department; thirdly, to those younger students for whom the two-years' course is designed; and, lastly, to boys proposing by-and-by to enter our professional courses.

I. So far as relates to regular students in the course of Mechanical Engineering, or to those in any other department who may take part in it, the shop-work presents no difficulty. It obviously stands

on the same footing as any other laboratory work. The workshops are in fact and in intention one of the laboratories of the Department of Mechanical Engineering, where manual skill is acquired at the same time that a practical acquaintance with the subject-matter of the science is attained, just as in the laboratories and drawing-rooms of other departments. They are solely for instruction, and are to have no manufacturing or mercantile character whatever.

The value of this work to these students, and the amount of time properly to be given to it, are matters which your Committee have not felt themselves called upon to consider. The decision of these points lies with the head of the department, acting, of course, as in any other laboratory work, with the advice and consent of the Faculty and of Committee on Instruction.

II. Special Students may, of course, be received into this laboratory, so far as convenience permits, just as into other laboratories or drawing-rooms; and these Special Students may, agreeably to the custom in other departments, take part in such other instruction as they are qualified to profit by, under such rules as may be established. Their case, also, presents no difficulty.

If the interest that has already been shown in this work is ultimately warranted by its success, we may expect a considerable number of young men to come to us to learn the methods here pursued, in order to become teachers in similar instruction-shops elsewhere. All such students, also, would be classed as Special Students in the Department of Mechanical Engineering.

III. It might seem at first as if the students who pursue the two-years' special course above described might also be classed as Special Students in this department, their work in the instruction-shops being the same as that of the Regular Students. They are younger and more ignorant; but it might be considered, and your Committee were at first disposed to consider, that the difference was one of degree, not of kind. In the Department of Architecture, a special two-years' course has been established for the somewhat miscellaneous body of young men who appear in the catalogue as Special Students in that department, and this seemed at first to furnish a precedent applicable to the case in hand; but the difference of the two cases is an essential one. The important question is the question of age. The students

in the special course in Practical Mechanism are boys, and it is for boys that that course is intended. They need the care and discipline that school-boys require. Experience shows already that the methods adapted to our own students do not meet their case. Their studies, outside their shop-work, should be conducted in separate rooms, under the constant supervision of special instructors and disciplinarians.

Moreover, although the shop-work is the characteristic, and, in a sense, the most important part of such a course, since it is the element that distinguishes it from ordinary schooling, it by no means occupies the chief part of these boys' time. The greater part of the day must be occupied, as with other boys of their age, with reading, writing, arithmetic, and drawing, with something of natural science, and perhaps some one of the modern languages. And these studies, if judiciously chosen, need not be any less practical in character than the exercises in the workshops. The arithmetic of mensuration, for instance, with the computations involved in the elementary phenomena of physics and mechanics, would enable the student of any of the mechanic arts to cover a great deal of ground in a way at once entirely practical and eminently scientific. This is the sort of training which, in the decay of the system of apprenticeship, the intelligent workman needs. It is a training that the High Schools and Academies cannot supply, and it is entirely different from anything needed by the students in our professional courses. What is wanted is something which shall come after the Grammar School, and shall put boys in the way to become master mechanics. They need a schooling, but one neither literary nor mercantile in character; a training which, though based upon the the applied sciences, shall be entirely practical in its methods, and it is something of this sort that the instruction in practical mechanism already organized undertakes to supply.

But it seems to us a matter of regret that this instruction should have been organized exactly in the shape that it now presents. As a department in our own school it holds, as has been intimated, an entirely anomalous position, resembling the other departments only in name, and, while its real importance is obscured, tending to disparage the professional courses by its presence among them. To have ranked these students as Special Students in Mechanical Engineering would have been, in terms, more consistent with the rest of our organization; but the consistency here again would have been only nominal. These

students are not really what we mean by Special Students; besides, it would not have been fair to throw upon that department the burden and responsibility of such a charge, especially if, as may well happen, this instruction should come to include other practical arts not specially related to the work of that department, and involving the fitting up of instruction-shops with which its own students would have nothing to do. We cannot but regret that the Corporation did not establish the new work at once on a more independent footing, giving it a position so distinct from the professional training previously undertaken that we should not appear to be changing our policy or lowering our standard, while the new work should clearly appear to be a new one. If the Corporation should, even now, see fit to revise their action, and, instead of establishing a new department in this school, create a separate school, of a subsidiary character, though under the management and direction of the same Faculty, it would seem to your Committee to be the best statement of what they have in fact already done.

If this view should commend itself to the Faculty, we would recommend that the President be requested to signify the same to the Corporation.

This would not necessarily involve any increase of the work beyond its present dimensions, while it would put it on a juster footing, and one more favorable to its natural development. But whatever extension may ultimately be in store for it, the character of the work done in the instruction-shops must, for some time to come, be fixed by the requirements of the several professional departments, as it is at present by those of the Department of Mechanical Engineering; and any other instruction-shop that may hereafter be added must be, as the filing-shop is now, primarily a professional laboratory.

What experience has been already gained would seem to show that such work, being absolutely new to all, is equally well adapted to all classes of students.

IV. As to the serviceableness of such studies to young men proposing afterwards to enter the Institute as Regular Students, we do not see that it can well be made to answer the general demand for such preparatory schooling. Such a school would differ too much from the High Schools and Academies from which our students come for us to expect from it the same class of students; and even the

High Schools and Academies hardly meet our demands. But special cases may constantly arise of students ready or nearly ready to enter our classes, to whom a year of practical instruction would be of great service; and this may prove the best practicable course for some of those who apply for admission to the Institute, but are not quite prepared to pass our entrance examinations. Besides, it does not seem to us desirable that the Institute should be understood to maintain a Preparatory Department.

WILLIAM R. WARE.

JOHN M. ORDWAY.

GEORGE H. HOWISON.

Boston, Feb. 21, 1877.

After considerable discussion, it was voted that this instruction be given in separate rooms—that the department be known as the “School of Mechanic Arts”—that it be not regarded as preparatory to the regular school of the Institute—and that it be under the control of the Committee on the School as are all other departments of instruction in the Institute.

DEGREES CONFERRED.

At the meeting of June 5, it was voted that the Degree of Bachelor of Science be conferred on the following students, who had fulfilled all the requirements for the Degree, and who had been recommended by the Faculty and the Committee on the School:—

Henry H. Carter . . .	Roxbury	Civil Engineering
Martin Gay	Staten Island, N. Y.	“ “
Joseph P. Gray	Lowell	“ “
Edmund Grover	E. Walpole	“ “
Richard A. Hale	Lawrence	“ “
Geo. W. Kittredge	N. Andover	“ “
Charles F. Lawton	New Bedford	“ “
Benj. C. Mudge	Lynn	“ “
Arthur L. Plimpton	Boston	“ “
Charles E. Stewart	Boston	“ “
Geo. F. Swain	San Francisco, Cal.	“ “
Frank E. Wiggin	Boston	“ “

William H. Beeching . . .	Boston	Mechanical Engineer'g.
Geo. H. Chapman . . .	Winchester	" "
Linus Faunce	Kingston	" "
Charles H. Fisher . . .	Canton	" "
Joseph Kirk	Dorchester	" "
Cecil H. Peabody . . .	Chicago, Ill.	" "
George Bartol	Lancaster	Mining Engineering.
William C. Flint	Salem	" "
John E. Hardman	Lowell	" "
Henry D. Hibbard . . .	W. Roxbury	" "
Walter Jenney	Boston	" "
Harry C. Southworth . .	Stoughton	" "
Thomas F. Stimpson . .	Swampscott	" "
Fred. W. Wood	Lowell	" "
J. Williams Beal	S. Scituate	Architecture.
George W. Capen	Canton	" "
Wm. E. Chamberlin . . .	Cambridgeport	" "
Pierce P. Furber	Cottage Grove, Minn.	" "
John Alden	Randolph	Chemistry.
Charles S. Bachelder . .	Brookline	" "

The subjects of the Theses and the abstracts of the same will be found in subsequent pages.

The progress and present condition of the school in its various departments, will be stated in the reports of the President and Professors.

SAMUEL KNEELAND, *Secretary.*

Boston, Sept. 29, 1877.

DEPARTMENT OF PHILOSOPHY.

To the President :—

The programme, as now established and printed in the catalogue for the current year, has been duly carried out. The work assigned for all regulars has been accomplished by them in a satisfactory manner.

In the Department proper of philosophy, there have been no *regular* students this year; but the opening of special courses to persons of either sex, in accordance with the Government's vote of May 10, 1876, resulted in the entrance of a number of young women (seven) upon the Introductory Course in Philosophy, — that laid down for the Second-year students in the Department. Their work proved to be a signal success, and four of them will continue in the Department the coming year, to take a course upon Hume and Kant.

In June last, as the contribution of the Department to the general exhibition (then contemplated, but afterwards given up) of the Institute's School of Industrial Science, an "Account of the Department of Philosophy in the Massachusetts Institute of Technology" was printed, making a pamphlet of 72 pages. It included (I) an account of our various doings from 1872 to the date of publication, fully illustrated by specimen examination-papers, (II) the theses by the men who were graduated in 1876, and (III) the *verbatim* examination-papers produced at the last Annual by the young women mentioned above. The Government are respectfully referred to this "Account" for full details of our operations during the year just closed.

Respectfully submitted,

GEO. H. HOWISON.

DEPARTMENT OF MILITARY SCIENCE AND TACTICS.

President J. D. Runkle :—

SIR, I have the honor to submit herewith my report of the Department of Military Science and Tactics for the School year ending September 30th, 1877.

I assumed charge of the Department at the beginning of the year, and finding the status of the Military Course to have been the result of careful deliberation and experiment on the part of the Corporation, the Faculty and my predecessor Lieut. Zalinski, I instituted no changes and have none to recommend. A new element however, has been added to the School during the past year, viz. ; the Department of Mechanic Arts, and I respectfully recommend that the students attending this Department be required in their first year to attend drills. I think the exercise so obtained would be of benefit to them in counteracting any injurious tendency of their confined shop work, which necessitates more or less labor while in a stooping posture.

These students, should they subsequently enter the regular first year's course, would be able to pass the required examination in tactics and so omit drill for that year, while some of them, as volunteers, would be useful as officers and non-commissioned officers. The small size of the First year class during the past year, averaging about forty for drill, made it inexpedient to form a battalion. I therefore organized the Corps as a Company, retaining, however, the offices of Adjutant and Quartermaster, the duties of which were mainly clerical. During the regular drill hours instruction was given in Infantry drill, including skirmishing, and during recreation hours, volun-

teer detachments were instructed in Artillery drill, rifle practice, and military signalling. The discipline of the Corps has been good and the officers zealous and efficient. I consider them well qualified to perform the duties of their respective grades in any volunteer organization in the country. They were as follows :—

Staff Officers ranking as First Lieutenants.

Adjutant— F. R. Loring.

Quartermaster— J. H. Tibbetts.*

Line Officers.

Captain— E. C. Miller.

First Lieutenant— W. T. Miller.

Second Lieutenants— L. R. Millen and N. B. Morton.

The Second Year Class attended lectures on Discipline, Administration, Camps, Marches, Outpost duty, Military Hygiene, and the principles of Field Fortification.

Through the liberality of a gentleman interested in Military education, I was enabled to offer a prize for the best essay on a given subject. The subject discussed was;—“In this country, with a small standing army, how best to apply the maxim, ‘In time of peace, prepare for war.’” There were seven competitors, all of whom evinced thought and originality in their papers. The prize was awarded to Mr. F. B. Knapp.

I am, very respectfully, yours,

H. W. HUBBELL, JR.

1st Lieut. 1st Arty.,

U. S. A.

* Mr. Tibbetts left the Institute after the semi-annual examination. The duties of the Q. M. Dept. were faithfully performed during the remainder of the year by Q. M. Sergt. L. P. Howe.

DEPARTMENT OF ENGLISH AND HISTORY.

President Runkle : —

SIR : — I hereby present through you to the Government of the Institute of Technology, the following account of the condition and work of the department of English and History.

The Freshman Class spend two hours per week in exercises in "Rhetoric and Composition." The first object of these lessons is an elementary one; namely, to supplement the usually great deficiencies of their school education by a review of the rudiments of the subject. To this end, that part of the manuals of Rhetoric is gone over which contains the rules for the construction of sentences, the definitions of figures, and other elementary matters, and this review is accompanied by class exercises, and the requirement of a considerable amount of written composition. This, however, is but the least part in the real work needful for the formation of a good style. That object can never be accomplished through the mere learning of rules and the correction of the crude performances of beginners; but requires, as a necessary element, much and careful reading of good writers. I therefore begin as soon as possible the much-needed labor of teaching our young men *how to read*, by the critical study of selected texts, and the practical application to them of the rules and principles laid down in the Rhetorics. The recent publication in a cheap form of various series of specimens of standard writers in

rose and poetry,¹ will hereafter enable me to read with the class a varied series of complete texts without overburdening the student with the expense of costly editions of the whole works of the different authors. It also puts within our reach for critical study, typical specimens of *modern* writers.

This series of exercises seems to me to be exactly in place in the first year, and experience has proved their necessity to the great majority of the students who attend our school. In proportion to its importance, the time allowed it on our schedule is necessarily short, and it is greatly to be desired that the preliminary review of elementary rules could altogether be dispensed with. I purpose hereafter to "condition" somewhat rigorously all candidates for admission who do not show real familiarity with such practical exercises as are contained, for instance, in the first four chapters of Hart's "Rhetoric and Composition," to require the making-up of such exercises, and to begin the critical reading of texts, as well as the practice of composition immediately. Nothing is more important than to teach such students as ours how to read; for, more than all rules of Rhetoric, the habit of careful reading will lead to accurate thinking, and therefore to clear writing; while a comparison of the different styles of the real masters of composition — a comparison which, whatever may be the imperfections of their school training, our students are quite mature enough to begin — is the only method by which life can be infused into the abstractions of the rhetorical manuals, and the surest way to correct the crudities in their own attempts at composition.

A course in English Literature is assigned me with the class of the Second Year. A "course in English Literature" is usually understood to mean a course of lectures embracing a general survey of English literary history; but such a survey must, from the necessity of the case, be extremely superficial, and can hardly do more than follow in the beaten track of printed "com-

¹ The Oxford "Clarendon Press Series"; The "Vest-Pocket Series" of Osgood & Co.; Harper's "Half-Hour Series."

pendiums" and "manuals." There is, to be sure, ample room for a diligent instructor who could afford to give his whole time to the subject, to make each a course highly instructive to students of sufficient maturity of thought; but such instruction should be the completion, not the beginning, of the course in Literature, and would find its appropriate place in the last year, where, at present, there is no room for it; neither, if there were, would the multiplicity of my present duties allow me sufficient leisure for the thought and study required to do it justice. A more appropriate course for second-year students is to give a practical example of the way in which such studies should be pursued, by confining the student's attention to a limited period, combining History and Literature together, as only two sides of the same subject, and continuing the critical reading of texts begun in the first year. A step further, however, may be taken, and the laboratory method of research may be imitated, by setting the student simple problems to work out in Political History, and in Literature and Criticism, with the help of my own and the City Library. This gives room for the only practice in advanced composition which is good for anything, the writing of papers on subjects which the student has actually investigated, and in which he feels a genuine interest. By a method of study of this kind, accompanied by a carefully prepared course of lessons from the instructor, both the inner and the outer life of a limited period, that is to say, the history of thought and the history of action, may be investigated in a tolerably satisfactory manner within the assigned limits, and the true nature of historical and literary study can be pretty well illustrated. A course so managed will be very sure to give birth to an interest in such intrinsically interesting subjects, even where that interest had been previously kept in abeyance by bad school teaching. Of this I have evidence in the application of portions of classes for leave to continue such studies voluntarily with me after the regular course is over.

It seems to me extremely important to the real success of

our school, that the cultivation of such tastes should be encouraged. The question is sometimes raised by superficial thinkers who pride themselves on being "practical" in their views of education, what place has the study of Belles Lettres, and even of History, in a course of study intended to prepare young men for a practical scientific profession. I observe with satisfaction that the uniform tenor of the discussions on education among practical scientific men themselves, is in favor of enlarging rather than narrowing the general literary element in their education.¹ Their almost unanimous opinion, drawn from practical experience, seems to accord with that of all the best theorists on the subject, that it needs an enlarged and many-sided culture of the intellectual powers to make a man successful even in the speciality to which he devotes his life, and that an engineer who is nothing but an engineer, cannot be, in the highest sense, even a good engineer. An English man of business² has recently made a striking plea for the culture of the *imagination* as a necessary element in any good preparation for business life, and has urged, with much ingenious and forcible illustration, the importance of historical and literary studies, as forming an essential part of the education of practical men. In the necessary absence of classical study from our course of instruction, the study of the English language and of English Literature and History, becomes from this point of view doubly important. In the sharp competition for pupils, which is beginning to arise between the various scientific schools of this country, those only will gain any permanent footing, or meet the approval of that minority of competent judges in the community on whose favorable verdict the success of such institutions must sooner or later depend, which have arranged their courses of study on really sound views as to what constitutes a good scientific liberal education. And it

¹ See particularly "Discussions on Technical Education, at the meeting of the Am. Inst. of Mining Engineers and the Am. Society of Civil Engineers," Easton, Pa., 1876.

² Mr. Goschen, M.P., the eminent London banker. See the Liverpool Daily Courier, Nov. 30, 1877.

will not do to say that the general element in such an education can be equally well represented by any and all kinds of general study, and that, beyond his strictly professional tasks, it is quite a matter of indifference whether the future engineer exercises his mental faculties on Greek or Hebrew, or any modern study which may be the prevailing educational fashion of the moment. In my judgment, the general studies of a professional man should be selected with quite as much care as his strictly technical studies, and it is not a matter of indifference whether the mental habits they create are in harmony or in antagonism with those generated by the professional part of his curriculum. Making allowance for peculiar idiosyncracies which may occasionally give a strong individual bent in the direction of some favorite bye-study, it may be said that the general element in the education of a young man destined for an active profession, should consist of those ingredients which will supplement the narrowness of his technical training in the direction of making him first a good citizen, next a good man of business, and next in the direction of opening to him a source of pure and elevated pleasure, by arousing in him a taste for what is beautiful in Literature and Art. The first object will be gained by the teaching of history and political science, the second by exercising his mind in the examination and discussion of economic subjects, and the last by opening to him the resources of one or more foreign literatures, while his taste is cultivated to appreciate all that is excellent in what is perhaps the richest of all modern literatures, his own. This surely is enough, and more than enough, for the surplus time and mental energy left from the demands of a rigid professional training in mathematical and physical science.

And in my judgment these non-professional studies should be conducted, — indeed in the present condition of our school they *must* be conducted, — in a different spirit and with different aims from those which must govern the professional. They should not be merely hard and disciplinary. The work should be done, as all intellectual work should be done, with care and

accuracy but it should be so conducted as to be a pleasurable relief rather than an additional burthen. The aim should be to implant tastes, to create new interests in subjects to which justice can be done only in the leisure and maturity of after life. The technical studies of our young men constitute a mental drill of the severest kind; but it is the foolishness and falsest of all narrow views of education the notion that it should be all drill. I have yearly cause to lament that this truth is not better understood when I see in our entrance examination-papers in History and Literature the barren results of so much honest but misdirected school labor.

There is at present but little room and less preparation for the systematic study of the moral and political sciences of which History and Literature are but the illustration. These would draw too largely upon the time and brains of students already exhausted by the demands of their professional work; but lighter courses in History and Literature may by judicious management be made a preparation for the more systematic prosecution of such studies in the leisure and maturity of after life. For one of the historical sciences, the Science of Government, a small opportunity is given in a short course on "Constitutional History" in the third year. I think it is very much to be desired that room should also be found in the course of study of all regular students for a part at least of the instruction which — in the absence of any regular provision — I have thus far volunteered to give the students in the department of Science and Literature in Political Economy. This is another of those studies, some knowledge of which is a necessary foundation to all profitable reading of History, and it seems almost an absurdity that in a practical school like ours some attention to this, one of the most important of all practical subjects, should not be required of all students.

It is very true, as I have already said, that our professional students can spare but a very inadequate portion of their time to these general studies. That is an evil for which there is but one remedy, a better preparation for admission, and I judge, as

one of the examiners, that it is an evil which is lessening year by year, and one which will lessen very rapidly as soon as better methods of elementary scientific preparation shall penetrate our High Schools. As soon as our young men bring to us that equipment of elementary mathematical and scientific knowledge which, with good training, they should possess at the age of seventeen, there will be far better opportunity for the higher English studies after their admission; and I think that time is not far distant. Instead therefore of narrowing the scope of the historical and literary instruction given in the Institute, I respectfully urge upon the Government the necessity for more liberal provision, in anticipation of a fast-approaching time when our students can afford to devote a larger share of attention to the element of general culture. That that general element should with us largely take the form of the study of History and Literature, and more particularly of the study of English History and the English Language and Literature seems to me beyond question.

I desire again earnestly to call the attention of the Government to the unsatisfactory condition of the so-called "Science and Literature" department. While it is never without just enough students to make my position a very laborious one, it yet adds nothing to the strength or the resources of the institution. I am confident that by a reorganization it might add to both. While we are not in a position, and it will never be our proper function to attempt to cover the wide field of general education embraced by our colleges, there is one special department of education quite germane to the purposes for which our institution was founded, which is nowhere well provided for, and which we might undertake with every prospect of success. I mean the preparation of young men for active business life by an education in the study of the modern languages, the experimental study of natural and physical science, and in English subjects, including History and Literature, the elements of Law and Political Science, Political Economy and Statistics, and Commercial and Industrial Geography. There is a large and

rapidly increasing class of young men in the community who, for various reasons, are not prepared, on the one hand, to invest their school years in the study of the ancient languages which is required for admission to our colleges, and on the other hand, have no taste or talent for engineering, or the other technical professions, but who yet do desire something beyond the education which our high schools give. By a not expensive addition to our teaching force, as at present organized, and by proper modifications in the course in "Science and Literature" — such modifications as shall give it a character as distinctly individual as the course in Chemistry, or the courses in Engineering — that course might be made to meet exactly this want. As at present arranged, it fully meets no want, and consequently attracts few students.

All which is respectfully submitted.

WM. P. ATKINSON,
Professor of English and History.

DEPARTMENT OF MODERN LANGUAGES.

President Runkle:—

DEAR SIR, Permit me to present herewith the report of the department of Modern Languages for the school year 1876-77.

FRENCH REQUIREMENT FOR ADMISSION.

The following shows the result of the last examination for admission, including that of the autumn of 1877.

1877.

52	{ No. of students in First Year.
58	{ Average mark at Entrance Examination.
0	No. admitted without French.
41	{ No. admitted without conditions.
65	{ Average mark.
11	{ No. admitted with conditions.
31	{ Average mark.

By comparing the above with the results of previous years, as given in my last report, it appears that there continues to be a gradual improvement in the manner in which the requirement is fulfilled. There was still, however, such an inequality, that it was found necessary to form, of those who were behind-hand, a class which has recited oftener and apart from the rest. The number in this Elementary class was nine throughout the year. The French required for admission is now, as indicated in the Annual Catalogue: "French grammar, through regu-

lar and irregular verbs, and the first two books of Voltaire's 'Charles XII' (about seventy pages)".

From blanks filled out at the examination, it appears that of the sixty-seven candidates for the First Year, fifty-eight stated that French was a regular study in the school where they prepared, and forty-two that Latin was, while forty-four reported that they had studied Latin.

WORK OF THE PAST YEAR.

The number of exercises per week in the department were thirty the first term, and twenty-seven the second. The following shows what has been read, and the amount.

FRENCH.

FIRST YEAR. Voltaire — "Charles XII," 80 pages. Tissandier — "L'eau," 172 pages. Töpfer — "Nouvelles Gênoises," 58 pages.
 THIRD YEAR (Sc. and Lit.). Brueys — "L'Avocat Patelin." Molière — "Les femmes savantes," "L'Étourdi," "Le médecin malgré lui."
 FOURTH YEAR (first half). Mémoires — extracts from de Retz, St. Simon, 59 pages. Molière — "Le bourgeois gentilhomme," 3 acts.

GERMAN.

SECOND YEAR. Whitney's Reader, 26 pages. Selections, 20 pages. Andersen's "Märchen," 16 pages.
 THIRD YEAR. Whitney's Reader, 39 pages. Pfaff — "Das Wasser," 158 pages. Putliz — "Das Herz vergessen." Benedix — "Eigensinn."
 FOURTH YEAR (Sc. and Lit.). Portions of Schiller's "Wallenstein."

Exercises in composition, written and oral, and on the forms and principles of the languages in question, have accompanied the above work in translation.

During the first term there was an optional class of eight students, that commenced the study of Spanish, using Sale's grammar, and reading twenty-five pages in Don Quijote. During the second term there was an optional class of six students, that attended a course of French readings, consisting of Victor Hugo — "Ernani," Beaumarchais — "Barbier de Séville," De Musset — "Un Caprice."

Following, are the examination papers at the Annual of the

First Year in French, and Third Year in German, with the average mark of the whole class on the same.

Respectfully submitted,
CHARLES P. OTIS.

[EXAMINATION PAPER OF THE FIRST YEAR AT THE ANNUAL.]

Number of students 27. Average mark 66.

1. Il se peut que les glaces amoncelées au pôle Nord amènent, comme le veut Agassiz, un mouvement subit dans l'axe de la terre, qui, par suite du changement de position de son centre de gravité, serait soumise à une terrible secousse, causant la mort de tout être inanimé, en déplaçant brusquement les océans. Il se peut que la terre, se refroidissant toujours par son rayonnement à travers l'espace, voie son épiderme, qui n'est en définitive qu'une croute figée par l'action du froid, augmenter d'épaisseur, et qu'un jour vienne où l'abaissement de la température soit tel, que l'eau n'existe plus sur notre sphère qu'à l'état de glace. Ajoutons toutefois que, si ces prévisions se réalisaient jamais, ce ne serait que dans une suite de siècles considérables.

1. Point out and explain the subjunctive forms in the above.
2. Explain the force of *se réalisaient*, and turn the sentence into any form it may take without a change of meaning.
3. Tell what you know about *en* in *en déplaçant*.
4. Give in full the present indic. of *peut*, the future of *voie*, the pres. subj. of *veut*, and the compound present of *se refroidissant*.

Render in French: The snow has been falling for several days, and the fields are covered with it; yet, although the cold is sharp,¹ it is not believed that the ice can bear.

¹*perçant*.

II. En 1816, un paysan de Silésie, nommé Priessnitz, revenait de son champ, quand un cheval emporté le renverse, imprime ses fers sur son visage et lui brise deux côtes. Il n'y avait pas de médecin dans le petit village de Freivaldau; Priessnitz veut se guérir lui même. Il fait peu à peu reprendre à ses côtes brisées leur direction première, en s'appuyant constamment la poitrine contre l'angle d'une chaise; pour tout bandage, il se sert d'un linge mouillé; il boit abondamment de l'eau froide, et bientôt il retourne à ses travaux.

— Quelques années après, le paysan Priessnitz fonde un vaste établissement, où de tous les points du globe accourent une foule de malades, venant demander à l'art empirique la guérison que leur a refusée la médecine.

1. Analyse the last sentence, beginning with *guérison*.
2. Point out instances of imperfect and compound of present in the above, and explain the relation of those tenses to the preterit, respectively.
3. Explain the form of the participle *refusée*, and make a sentence which requires it to be written *refusé*.
4. Give the literal meaning of *lui brise deux côtes, en s'appuyant la poitrine*, and give the rule for such forms.

Render in French : In Greece¹ there was a fountain of which it was said that those who had bathed in it were cured of their love. It is a virtue² that it has since lost.

¹ Grèce. ² la vertu.

III. Et si vient la pluie, croyez-vous que je perde mon temps ? Jamais je n'ai tant à faire. Voilà mille petites rivières qui se rendent au gros ruisseau, lequel s'emplit, se gonfle, mugit, entraînant dans sa course des débris que j'accompagne chacun dans ses bords avec un merveilleux intérêt. Ou bien quelque vieux pot cassé, ralliant ces fragments derrière son large ventre, entreprend d'arrêter la fureur du torrent.

— C'était la première fois que, la voyant de près, je pouvais me repaître du charme que je trouvais en elle. Que ne puis-je le répandre en ces lignes et la peindre comme elle m'apparaissait. Et encore semblait il que la bibliothèque de mon oncle Tom lui fût comme un cadre merveilleux qui rehaussait son éclatante beauté. Sur les rayons poudreux, ces livres vénérables, représentant la suite des âges, ce parfum de vétusté, ce silence de l'étude, et, au milieu, cette jeune plante toute de fraîcheur et de vie . . . Ce sont choses qui ne se peuvent enclore dans des mots.

1. Explains the forms *perde, s'emplit, fût*.
2. Point out the relative pronouns in the above, commenting on the form of each.
3. In *ce sont choses qui, etc.*, why is not *ce* in the plural ? Explain that word.
4. Give the principal parts of all irregular verbs in the passage above.

Render in French : This is the house in which we used to live and that I have so often described to you. My uncle's was situated on the same street.

Write a few lines in French about each of the following topics: *Les vendanges. Les pommes de terre. Les bateaux à vapeur.*

IV. *Passage not read before.* Qui trouverait dans une île déserte et inconnue à tous les hommes une belle statue de marbre, dirait aussitôt: Sans doute il y a eu ici autrefois des hommes; je reconnais la main d'un

habile sculpteur; j'admire avec quelle délicatesse il a su proportionner tous les membres de ce corps, pour leur donner tant de beauté, de grâce, de majesté, de vie, de tendresse, de mouvement et d'action. Que répondrait un homme, si quelqu'un s'avisait de lui dire: Non, un sculpteur ne fit jamais cette statue. Elle est faite, il est vrai, selon le goût le plus exquis, et dans les règles de la perfection, mais c'est le hasard tout seul qui l'a faite. Parmi tant de morceaux de marbre, il y en a eu un qui s'est formé ainsi de lui-même; les pluies et les vents l'ont détaché de la montagne; un orage très-violent l'a jeté tout droit sur ce piedestal qui s'était préparé de lui-même dans cette place.

FÉNELON.

FIRST YEAR. MAY, 1877.

[EXAMINATION PAPER OF THE THIRD YEAR AT THE ANNUAL.]

Number of students, 24. Average mark, 59.

I. Während des Winters lagen die Kreuzfahrer zerstreut zwischen Philadelphia und Konstantinopel; allmählig zog sie Friedrich aber immer näher an die Hauptstadt hinan, ließ die Befestigungen von Philadelphia zerstören, und gab den Gesandten der Königin Sibylle von Jerusalem und des walachischen Fürsten Kolopetros Gehör. Jene behaupteten (obgleich ohne weitere Beweise), die Griechen wären gesonnen, alle Kreuzfahrer durch Wein und Mehl zu vergiften, und Kolopetros versprach ein Hülfsheer von 40,000 Mann, wenn Friedrich, der römische Kaiser, sich auch die griechische Krone aufsetzen wolle. Noch einmal wies der besonnene Feld, um seiner ursprünglichen Zwecke willen, diese einladenden Anträge zurück; aber schwerlich hätte er sich länger allen Launen der Griechen unterworfen.

von Raumer.

II. Von allen Seiten drangen jetzt die Türken auf die Pilger ein, und die Größe der Gefahr preßte selbst dem standhaften Kaiser den Wunsch ab: „er wolle gern jede andere Noth ertragen, wenn nur das Heer ungeschädigt in Antiochien wäre.“ Als aber die Seinen wirklich anfangen zu weichen, rief der Greis mit lauter Stimme und durch seinen Heldemuth wunderbar verjüngt: „Warum zögert ihr? Weßhalb seid ihr niedergeschlagen? Gottlob daß die Feinde endlich eine Schlacht wagen! Um den Himmel mit eurem Blute zu gewinnen, verlißt ihr das Vaterland; jetzt ist die rechte Zeit, folgt mir, Christus steigt, Christus herrscht!“ Mit diesen Worten sprengte Friedrich in die Feinde, es folgten ihm seine Mannen, und in demselben Augenblicke gewahrte man die christlichen Fahnen auf den Thürmen von Konium.

von Raumer.

III. a. Seine Afer und sein Grund bestehen aus kaltem Wasser, während seine Strömung warm ist. Der Golf von Mexiko ist seine Quelle, und seine Mündung liegt in den arktischen Meeren. Es ist der Golfstrom. Es giebt in der Welt keine zweite Wasserfluth, die ihm an majestätischer Größe gleich käme. * * *

b. An Wasserfülle stehen jedenfalls alle dem Amazonenstrom nach, wie er auch der Ausbreitung seines Stromgebietes nach alle anderen weit hinter sich läßt, indem er einen Flächenraum von 112,000 q. M., also ungefähr die zehnfache Ausdehnung von Deutschland einnimmt.

c. Auch die reinste Quelle enthält mineralische Bestandtheile, welche das durch die Sonnenwärme aus dem Meere distillirte und als Regen herniederkommende Wasser auf seinem unterirdischen Laufe aus der Erdrinde ausgezogen.

d. Auch aus heißen Quellen setzen sich oft sehr beträchtliche Massen von kohlensaurem Kalk ab. Es geschieht dies noch rascher, als aus kaltem Wasser, weil aus warmem die zur Lösung des kohlensauren Kalkes nöthige Kohlensäure viel rascher entweicht. Eines der bekanntesten Beispiele für solche Absätze liefert der Karlsbader Sprudel, der eine ungeheure Menge von verschieden gefärbten Massen, unter dem Namen Sprudelsteine, vielfach verschliffen und verarbeitet, absetzt.

Pfaff.

IV. a. Analyze in full the following, stating in the case of each, as also of the parts composing it, whether it be derived or compound: Kreuzfahrer, Befestigung, behaupten, Antrag, Selbennuth, beträchtlich, Unentschlossenheit.

b. What is the difference between compound and derived words? When a noun is the first part of a compound word, what variations in its form may there be? What are the two modes of forming derived words; the relative frequency of their use? What is the force of the inseparable prefixes *ver-* and *zer-*?

c. Give the English *historically* connected with the words ziehen, fahren, bringen, fangen, schlagen, Zeit, Theil; with the suffixes *-schaft*, and *-thum*.

V. a. Case and construction of Befestigungen, Kaiser, sich (I); Ausbreitung (III, b); wälsche (III, c)? What is the difference in the use of während in I and III, a? What is the difference in *meaning* and *construction* between von verschieden gefärbten Massen (III, d) and von verschiedenen gefärbten Massen?

b. To what class of the subjunctive belong wären (gesonnen), hätte unterworfen (I); wolle, wäre (II); käme (III, a)? What is noticeable in the *tense* of wären (gesonnen)? What is the difference between the force of käme and the indicative (as would be used in English)?

c. Principal parts of lagen, gesonnen (I); weichen (II); verschliffen (III, d). Is unterworfen (I) a separable or inseparable verb, and why? How does sich ihr niedergeschlagen (II) differ in *form* and *meaning* from habt ihr niedergeschlagen?

VI. a.

LEIPZIG, March 24.

Dear Sir: — Your letter was received last week. I beg pardon for not answering the same at once, but was prevented by pressing business.¹ The books of which you speak we have on hand. We will sell them to you at a discount of ten per cent. If you wish the same, please inform² me, and I shall take pleasure in filling your order. Yours respectfully.

¹bringende Geschäfte. ²benachrichtigen.

b. I overheard¹ this morning our Henry requesting² Elizabeth to say: "Heaven be thanked, the table is set," and falling³ into a violent⁴ strife with her when she would not do so. Laughing, I related that to my wife; with flattery⁵ I said to her that she would not be so obstinate, and, in jest, begged her to speak those words. She however refused⁶ with such decided obstinacy, with such striking⁷ stubbornness, that we had a serious altercation.⁸

¹belauschen. ²verlangen; who requested. ³gerathen. ⁴heftig. ⁵schmeicheln.
⁶oft weigern. ⁷auffallen. ⁸Wortwechsel.

c. Write in German the second stanza. of „Die Lorelei.“ Schreibe kurze Aufsätze über die folgenden Gegenstände: „Die Vögel im Winter;“ „Die Windmühlen.“

VII. (Passage not read.) Gehen wir noch einmal auf den Vergleich des Auges mit der *Camera obscura* zurück, so fällt uns noch ein besonderer Vorzug des Auges auf, den dasselbe vor jener voraus hat. Er besteht darin, daß die Hinterwand des Auges kugelförmig gewölbt ist, während in der *Camera* die matte Scheibe,¹ welche das Bild auffängt, eben ist. Dadurch erhält aber das Auge zwei wesentliche Vorteile, die jedem leicht auffallen werden, der einmal das Bild einer *Camera* betrachtet hat. Bernstein.

¹ disk.

THIRD YEAR. May, 1877.

LOWELL FREE COURSES FOR 1876-77.

General Chemistry. Twenty-four laboratory exercises.
Qualitative Analysis. Twenty-four laboratory exercises.

President Runkle ; —

DEAR SIR:— The Lowell Course in Chemistry the present year, although conducted on the same plan as in previous years, has been unusually satisfactory. Many of the applications were made in person, and were from those having a strong desire to avail themselves of the opportunities offered, and the number of really earnest workers seemed to me to be larger than usual. The entire number of persons attending the exercises was fifty-four; the largest number at any one time members of the two classes was forty-eight; the average attendance was 36.5. This average may seem rather small, but several circumstances account for it: the weather on two of the days was so very severe that many were prevented from coming, and the school holidays coming during the course caused the absence of many of the teachers who were at the time out of town. The smallest attendance was twenty-seven; the largest forty-one.

The following statistics may be of interest:—

Number of students in General Chemistry	34
Number of students in Qualitative Analysis	20
Number of male students	32
Number of female students	22

Occupations as far as recorded :

Teachers	26
Physicians	1
Pharmacists	10
Engaged in other business . . .	8
Unknown and Students	9
Total	<u>54</u>

Yours, very respectfully,

WM. RIPLEY NICHOLS.

Elementary Geology. Eighteen lectures.

These lectures began by defining the general principles of dynamical and historical geology, and then proceeded to consider the history of the great geological divisions, as illustrated by the rocks of North America, regard being had both to their geographical relations and to their economic mineralogy.

T. STERRY HUNT.

The Philosophy of Government. Eighteen lectures.

This course was attended by some fifty persons, the majority being men, and a large part of them students of law, or young lawyers. The following is an outline of the topics :—

Lecture I. The Nature of the State:—It is not a contingent combination of individuals, resulting from (a) the pressure of external evils, or (b) the accident of descent or juxtaposition.

Lect. II. The Nature of the State:—It is not a voluntary organization of individuals for ends merely special, either (a) the maintenance of private rights, or (b) the promotion of Economics.

Lect. III. The Nature of the State:—It is the investiture of Rational Man with institutions,—the organization of Universal Personality considered in its progressive entirety.

Lect. IV. The Foundations of Sovereignty, as given in the Logical Origin of the State:—Theory of the “Social Contract”; sovereignty not from it.

Lect. V. The Foundations of Sovereignty:—Theories of the "Natural" Origin of the State; it is not (a) from Conquest, or other forms of Force; nor (b) from the Family; nor (c) from the Collective Will of the People.

Lect. VI. The Foundations of Sovereignty:—Theory of Divine Right; the State is founded in Human Nature, *i. e.*, comes from God.

Lect. VII. The Foundation of Rights:—The State is their only sufficient basis.

Lect. VIII. The Nature of Rights and, especially, of Citizenship:—Rights are simply conditions of Personality legalized, and their possession is conditioned upon the actualization of Personality; Citizenship is investiture with Rational Freedom, *i. e.*, with Obedience to Law from Conviction.

Lect. IX. The extent of the State's realm in Human Life, (a) by the Social Process, (b) by Formal Administration.

Lect. X. The function of the State in Education, Morals, and Religion.

Lect. XI. The Form of the State, as distinguished from its Substance; the Medium of the Form, as distinguished from its Sovereignty. The two main Forms,—the Realm and the Commonwealth.

Lect. XII. The Liability of the Realm to antagonize the State, (a) as Autocracy, (b) as Empire, Tyranny, or Cæsarism, (c) as Oligarchy, (d) as Democracy.

Lect. XIII. The nature of Constitutions; the Hereditary Principle as the basis of distinguishing the Kingdom from the Republic.

Lect. XIV. The ultimate Distinct Functions in the State.

Lect. XV. The true nature of Representative Government: the Representative stands for the Civil Idea, not for Constituents.

Lect. XVI. The basis of Suffrage:—Three questions: (1) What warrants the vote as a right? (2) To whom does the right belong? (3) By what polity shall the right be kept with those to whom alone it belongs?

Lect. XVII. The Statutes and the "Higher Law."

Lect. XVIII. The Literature of Political Philosophy.

GEO. H. HOWISON.

Department of Mechanics. Eighteen Lectures.

President J. D. Runkle : —

DEAR SIR: — Before determining upon the subjects of the separate lectures in the course on Practical Mechanics, given by me in the autumn of 1876, I consulted a number of gentlemen who conduct manufacturing establishments in this vicinity, and who have large numbers of workmen under their charge, so that I might make use of the light thus obtained to select such subjects as seem most suitable for mechanics, for whom the lectures were specially intended. I received from many of these gentlemen not only advice, but also the loan of specimens and working drawings. I have to thank, especially, Mr. Boyd, Engineer of the Atlantic Works, E. Boston, Mr. Leach, General Manager of the Hinckley Locomotive Works, Mr. Fairbairn of the Hartford Insurance Co., and Messrs. Richards and Crooker of the Bay State Iron Works. I also took pains to inform the Superintendents of a number of shops of the projected lectures, and to request them to call the attention of their employees to them. The largest number present at any one lecture was eighty, the average attendance being twenty-five or thirty. The subjects actually selected were as follows :

I. Strength of shells, tubes, flat and cambered ends of Steam Boilers, Copper and Cast Iron as used in Boiler Making.

II. Wrought Iron and Steel.

III. Riveting and Welding.

IV. Description of main types of Steam Boilers and essential differences.

V. Construction of Boilers.

VI. Furnaces and Boiler Setting.

VII. Furnace and Boiler Fittings.

VIII. Wear and Tear and Incrustation.

IX. Boiler Explosions.

X. Boiler Power and Combustion of Fuel.

XI. Steam Engine Indicator.

XII. " " "

XIII. Governors.

XIV. "

XV. Belting. — Materials used — Forms of Pulleys — Crowning of Pulleys — Lateral Stiffness of Belt — Engaging and Disengaging — Fast and Loose Pulley — Quarter Twist — Guide Pulleys, etc.

XVI. Velocity ratio in Belting — Speed Cones — Eccentric Pulleys — Wire ropes.

XVII. Strength of, and Power transmitted by Belts and Wire ropes.

XVIII. “ “ “ “ “ “ “ “
 Very Respectfully,
 GAETANO LANZA.

ABSTRACTS OF THESES PRESENTED BY GRADUATES OF 1876-77.

DEPARTMENT OF CIVIL ENGINEERING.

The Central Avenue Bridge, Dorchester, Mass. Abstract by the author, H. H. Carter.

This bridge, which is built in two spans of 94 ft., and 63 ft. 6 in. respectively, crosses the Neponset River at Central Avenue, Dorchester, Mass. Each span consists of six wrought iron, single intersection, lattice girders, placed 8 ft. 4 in. apart on centres; the girders being connected at the top and bottom chords by lateral bracing, and at the ends and intermediate points by vertical cross bracing. The girders in both spans are 6 ft. 5 in. in depth, resting at their abutment ends on wrought iron rollers, and at their pier ends on cast iron bearing plates.

Both chords are of T-shaped section, built up from wrought iron plates and angle irons. The web members consist of angle irons riveted to the vertical web plates of the chords, and also to each other at intersection points. The floor timbers rest on the top chords of the girders, and are of yellow pine, fifteen inches deep at the centre of the roadway, and twelve inches deep at the sidewalk curbs. Alternate floor timbers project over the outside girders in order to support the sidewalk, and are six inches in width, the remaining timbers being four inches in width. The roadway planking is in two courses; the lower course is of yellow pine four inches thick, spiked to

the floor timbers; the upper course is of spruce two inches thick, spiked to the lower course.

The long span was taken for detailed investigation, and the stresses arising from a live load of 100 lbs. per sq. ft. and a dead load of 50 lbs. per sq. ft. were calculated; also the stresses produced by a 20 ton wagon placed in various positions upon the bridge.

The maximum stresses in the different parts of the girder having been found, the necessary dimensions have been calculated and compared with the actual dimensions used in the construction of the bridge. Accompanying the description and calculation of the bridge are two sheets of drawings, showing the details of construction and the manner of connecting the various parts.

*Sea Walls of South Boston Flats. Abstract by the author,
Martin Gay.*

Accompanying this thesis are two sheets of drawings, one showing the location of the walls, and their relation to the harbor and wharves of Boston, and the other showing on a larger scale the shape of the dock which the walls enclose, and sections of the different kinds of wall used.

I have explained that this project was intended only as an improvement to the navigation of the harbor, and the reasons for its being undertaken, and that it was finally extended into a scheme for reclaiming the useless flats of the Commonwealth; also the methods of filling the flats with the material dredged from the harbor.

Next, I have described the form and materials, and have calculated in turn each wall; investigating first, whether the wall of itself is strong enough to resist the forces acting upon it, and second, if the foundation upon which the wall rests will bear the load put upon it.

The Lowell Water Works. By Joseph P. Gray.

(Abstract not received.)

The Charles River Bridge at Newton Upper Falls. Abstract by the author, Edward Grover.

The subject was treated under the following different headings:

I. The Location and general description. II. Materials and Construction; with explanation of drawings. III. Calculation. Strength and Stability. IV. The Centering.

The Sudbury River Aqueduct for bringing an additional supply of water to Boston was begun in July 1875, and at the time of writing was in different stages of construction. The line from Farm Pond in Framingham to Chestnut Hill reservoir is 15.61 miles long, and is an interesting example of construction in swamp and quicksand, of rock and earth tunnelling, and of cuttings and embankments.

The most important structure on the line is the bridge which carries the conduit over the valley of the Charles River at Newton Upper Falls. This bridge is 475 ft. long between the terminal chambers. At the westerly end is a semi-circular arch of 37 ft. span, partly cut off by the slope of the hill which is quite steep. Next is a segmental arch of 130 ft. span and about 45 ft. rise, radius 69 ft. Then there are on the east side of the river, four semi-circular arches of 37 ft. span and lastly, a flat arch having a span of 28 ft. over Ellis St., a town way. In making the surveys there were two schemes for crossing the river under consideration; namely, by a bridge as located and by means of a siphon about a mile from the former. The cost was nearly the same for each and the Water Board decided to build the bridge. The river at this point is quite narrow, a little over 100 ft. wide and the slopes of the valley, especially the westerly bank, being abrupt and the river bed and banks of firm rock, making a good foundation for the piers and abutments. The springing of the large arch is considerably above

the water-level which latter varies but slightly during the year; accordingly there is no obstruction of the water way. The width of the bridge just below the conduit is 18 ft., the face walls having a straight batter of one in twenty-four, except for the great arch which has a curved batter, being the curve of pressures. It is the largest stone bridge in the country, with one exception, and is a model of strength and beauty.

The construction is next described in the following order. (1) Foundations, (2) Piers, (3) Voussoirs, (4) External Spandrel walls, (5) Interior Spandrel, filling, &c., (6) The Conduit, dimensions and construction, (7) Terminal chambers, manholes, (8) Approaches, including a description of the materials and their composition and a description of the accompanying drawings.

The foundations consist either of the natural rock or of large blocks of granite laid at such depth as to be sufficiently firm. The steep western slope and the river bed are composed of a compact granitic rock. The western slope was prepared by removing the soil and loose rock and dressing the solid rock with the hammer to plane surfaces perpendicular to the thrust of the arch at the springing, and level or vertical elsewhere, thus forming sets of steps. The bed of the river was prepared as follows to receive the vertical timbers which supported the centring: The mud was removed and blocks of stone laid on the natural rock; levels were then taken at each point of support and the top of those blocks were made as nearly level as possible; timbers were next laid horizontally, the lower surfaces being cut to fit the stone so as to bring the upper surfaces exactly level. The slope on the easterly shore was neither so steep nor so rocky, and the earth was simply excavated a few feet to receive the large rectangular blocks of stone laid as above mentioned, each block being smaller than the one below it to distribute the pressure over a larger area.

The piers are composed of very large rectangular blocks of ashlar with dressed beds, builds, and vertical joints and well bonded together. The faces are built with a batter and the

caps are of a little lighter colored stone. The foundations, piers and centring having been completed the arches were begun and carried up, keeping at the same height on each side, so as to keep the load on the centring symmetrical. The keystone has a depth of five feet and the springing stones a depth of six ft. for the great arch.

The voussoirs are hammered smooth, the intrados to the curve and the ring and coursing joints to plane surfaces, leaving no cavities. In the large arch the faces of the voussoirs are bounded by neat lines three inches distant from the plane of the spandrel wall, and the projection is chamfered off at 45°. The voussoirs of the roadway are also chamfered, the projection being two inches.

The exterior spandrel walls are twenty inches thick at the top and increase to twenty-four inches at the springing of the small arches, below which they are twenty-four inches. The face stones are quarry faced and a certain part of the walls are of split stone, all well bonded together. Between the two exterior spandrel walls are two walls of brick laid in mortar. These are eight inches thick and are tied together and to the exterior walls by long bond-stones. They are also covered on top with split stone which supports the conduit. Near the top of these walls, the spaces between are arched over, thus forming continuous passages between the arches by which access may be had under the conduit. These passages are lighted and ventilated by narrow openings in the spandrel under the lower string course. Part of the space between the spandrels is filled with cement concrete. Great care was taken in the designing and construction to make the conduit as nearly as possible water-tight, and also to provide for the thorough drainage of any water which might leak through. The floor of the passages above mentioned is cemented, and then in order that any percolation may not effect the spandrel walls the water is conducted over the concrete filling, which is covered with a coating of coal-tar concrete, to gutters in or near the centre of the piers and runs out at "weeping holes" at the springing of

the arches. The cross section of the bridge is like that of one of the bridges on the Croton Aqueduct in New York.

The conduit is of good size, much larger than the old Cochituate conduit, the sectional area being equivalent to a circular section of $8\frac{1}{2}$ ft. diam. It is estimated that it will deliver at the rate of seventy millions of gallons in twenty-four hours. In the thesis was a sketch of the section showing the curves of the inside, etc., as also a sketch of the Croton aqueduct, with which it was compared. The manner of building the conduit on forms was described. The whole of the curved brick lining was coated both inside and outside with coal-tar concrete, and when finished, an additional coating of pure Portland cement one-fourth inch thick was applied over the inside. The side walls outside the curved brick lining are of brick having an air space running through the centre of each. These walls are covered with a coping of smooth cut granite. This coping or upper string course together with the lower string course of similar stones just below the conduit are a great addition to the architectural beauty of the bridge. The side walls of the conduit are covered with these coping stones between which and the top of the covering arch the filling is of cement concrete with a layer of coal-tar concrete. This with the coping forms a water-tight roof and a splendid promenade for moonlight nights. There is an ornamental iron fence over the whole length. The exterior of the conduit walls is of face brick formed into panels which gives a very pleasing effect.

The terminal chambers are somewhat different in construction and contain a manhole in each for access to the interior of the conduit. The internal passages of the bridge are entered by a trap-door at the foot of the roadway arch. The bridge is terminated by a series of steps, of the smooth light granite like the coping, which will prevent the bridge being used as a drive. The accompanying drawings consist of a side elevation and different sections, cross and longitudinal, at different points through the large and small arches. Also plan elevation, and sections of the terminal chambers.

Calculation. In designing an arch of masonry, many points have to be considered in order to assure sufficient strength and stability. The load to be supported is generally known, to which, having assumed the form, we have to proportion the rise and span which are both somewhat limited, and also to determine the thickness of the arch-ring both at crown and at springing, the height to which the backing must be carried, etc. In this class of structures there is almost always some similar work already in existence which may be imitated or modified to suit the requirements, but we ought to know, especially in any new case when we may not obtain from experience and analogy the necessary information, exactly what are the actions which are produced in an arch by different manners of loading, etc. In other words we want to know the form of the curve of pressures. This we may do by means of a graphical construction, or by analytical formulæ we may obtain the point in the arch ring where the line of pressures passes near or beyond the edge of the voussoirs. In the present case where the relation between the form of the arch and the load could not be easily expressed, the point of rupture and maximum horizontal thrust was found graphically according to the method of Rankine. The method of Dr. Scheffer was also used and compared with Rankine.

The Centring. In calculating the greatest normal pressure that can come on any segment of the arch, with exactness, friction ought to be taken into account, as also the fact that the normal pressure of any voussoir upon the centring is decreased the more the arch stones are laid above it, since the normal component of the tangential thrust due to the voussoirs above acts outward and opposite to the normal component of the weight of the voussoirs considered. According to Rankine friction should be disregarded, as the action of the voussoirs when completely laid to the keystone is nearly the same whether friction acts or not. But what is required is to find the greatest normal thrust on any one segment which would not occur when the whole arch was complete. However for practical purposes,

neglecting the friction, the calculations, as Rankine says, would err on the safe side. Then the only way to proceed appears to find the normal thrust for each stone separately which process must be omitted in the abstract. A drawing of the centring of the large arch was inserted in the body of the thesis. The whole cost of the bridge was \$174,105.75.

The Double Lattice Parker Iron Bridge across the Merrimack River at Lowell. Abstract by the author, Richard A. Hale.

A brief sketch of the old bridge and reasons for changing are given, and then a description of the abutments and new bridge.

The present bridge consists of two iron Parker girders, each of about 150 ft. span, 40 ft. wide, and 20 ft. in height in the centre, with curved upper chords and horizontal lower chords. The girders are commonly known by the name of "Hog-back." One span was taken for discussion. As no drawings were available, complete measurements were made of the bridge, from which the weight of the structure was calculated.

From this data the dead load was taken as 20 lbs. per square foot, and the live load as 60 lbs. per square foot. The methods of obtaining the maximum stresses in the chords, diagonals and uprights, were explained, and the maximum stresses of all the parts given in tabular form. The sectional amount of material in each piece was compared with the sectional amount required to resist the stress, and the strength of all the rivet and pin connections were calculated. The cross girder for sustaining the road-way is an iron Pratt truss, with projecting ends for sidewalks. The method of finding the maximum stresses in all of the parts were given, and the stresses were arranged in tabular form, together with the sectional areas required, and the actual sectional area. The strength of the connections were also calculated. In the calculation for the floor stringers, a concentrated load of twelve tons was taken on each stringer, and the resistance computed. For sway bracing the wind was

considered as acting uniformly on 500 square feet with a force of 20 lbs. per square foot, and the strength of the rods calculated.

Two drawings were made, one containing the plan and elevation of the bridge, and the second containing the details and connections on an enlarged scale.

Highway Bridge across the Merrimack River, between Groveland and Haverhill. Abstract by the author, George W. Kirtledge.

The thesis begins with a short history of the unsuccessful attempts in 1834, 1835 and 1836 to obtain a charter to build a bridge where the present one stands.

The bridge, as erected, consists of six spans of 124 ft. each, besides a draw span of 48 ft. It is a bowstring girder in form, and was built by the King Bridge and Iron Manufacturing Company of Cleveland, Ohio. The different parts of the structure are next described in the following order: (1) The cribs upon which the piers rest; (2) The piers; (3) The abutments and wing-walls; (4) The superstructure. The calculations are made and explained upon the supposition that when a bowstring girder is uniformly loaded over its entire length, the load is transmitted directly to the arch through the verticals. A table accompanying the calculations gives the total load, the required sectional area, the actual sectional area, the safe intensity of stress and the actual intensity of stress on each of the pieces calculated. In the conclusion are set forth some of the greatest objections to the structure, and the manner in which they might have been obviated to a certain extent.

The New Bedford Water Works. Abstract by the author, C. F. Lawton.

The advantages furnished by an abundant supply of fresh water, on the score both of health and economy, are first spoken of. I have then entered into many general questions of

water supply—the portion of rain-fall available, the measurement of the same, the quality of water, methods of analysis, etc. I have then given a short history of the New Bedford Water Works, and noticed particularly the questions of which a general discussion has previously been given. The construction of many parts of the works, such as the dams, waste-weirs, aqueduct, etc., has been explained minutely, and has been accompanied by drawings.

The discussion of the pumping engines has been left, as being more suitable for the mechanical engineer; and the subject of the distribution of the water requires too much space to be treated of in this thesis.

*The Lawrence Water Works. Abstract by the author,
B. C. Mudge.*

The supply of water to large towns has become a subject of so great importance, and involves problems of so extensive and complicated a nature that the best skill and attention of scientists and practical engineers have been called into requisition in its treatment.

In supplying this indispensable element of health and comfort to a large city, water is drawn, in many cases, many miles distant; it has to be purified and filtered for domestic use; elevated often to a height of hundreds of feet above its original level, and finally distributed through nearly every street, and into the interior of almost every house. It will therefore be easily conceived that the operations accomplishing these objects require in arrangement and adaptation no small degree of scientific and technical skill.

A short account of the earliest instances of a water supply to cities, other than by natural means, particularly those of Jerusalem and Rome, together with a mention of the Assyrian, Persian and Egyptian peculiarities relating thereto, served to introduce the subject. The hygienic necessity of a disjunction of the sewage waste and water supply, with some facts con

nected with the pollution of the water of the Thames, was urged from many standpoints.

The various sources and qualities, modes of conducting, purifying, pumping, storing and distributing the water, were the chief topics for consideration, each subject receiving separately its due amount of attention. The quantity, quality and methods of rendering the relative values of their determinations in a given district serviceable, were presented. Granting these principles relating to water supplies in general to be in the main correct, a description of the Lawrence Water Works, showing how far they conform thereto, practically illustrating many of the facts adopted, was undertaken, from a knowledge derived by a personal study of the drawings and works themselves.

With the Merrimac River as the source of supply, there seemed to be no limitation to the amount to be obtained, and in the year 1873 the first steps were taken to prosecute the work.

DESCRIPTION.

There is an inlet pipe admitting water directly from the river to the wells of the pumping station, one hundred and seventy feet long, constructed partly of brick masonry and cast iron pipes thirty-six inches in diameter. A filtering gallery was introduced along the bank of the river to provide, in certain seasons of the year, a supply of filtered water whenever the water of the river should become turbid. This is of granite foundation, with an arch of brick masonry. The pumping engines were built by S. P. Morris & Co., from the designs of E. D. Leavitt, Jr., of Cambridge, Mass. They are overhead beam engines, with compound cylinders. The force main is a line of cast iron pipes thirty inches in diameter, extending through a tunnel of brick masonry nine hundred feet in length to the reservoir.

The reservoir is rectangular in form, seven hundred and thirty feet long, four hundred and eleven feet wide, with a division embankment, and capable of containing 40,000,000

gallons when filled to high water mark. Upon this division wall is an over-fall, for the purpose of aerating the water. One peculiar and very valuable advantage these works possess above most others is, that both systems of distribution can be employed at will; that of pumping directly into the street mains the water to be delivered finally into the reservoir; also that of pumping directly into the reservoir through the force main, thence to be delivered to the inhabitants.

The Newton Water Works. Abstract by the author, A. L. Plimpton.

In this thesis the general questions, which always have to be considered before establishing a system of water works, are discussed in the first pages in their important points. They are, namely, the questions of quantity, quality and the most available source or sources of supply. At the same time these questions are applied to the particular case of Newton. Its most available source was the Charles River, which now supplies the city.

In regard to economy, the plan adopted by Newton was the Reservoir and Pumping System, or Gravity Plan.

After these matters, a general description of the works is given. They consist of the Filtering Basin, the Pumping Station, the Reservoir, together with the various pipes and conduits which connect the same, and lastly the Distributing Pipes.

THE FILTERING BASIN.

It is about 1000 feet long, the cross section being 70 feet on top and 10 feet at the bottom. It follows the general direction of the river, and will probably be extended up the river before long.

An iron pipe connects the basin with the pumping station. The plan of the pumping wells is shown by a drawing. The Worthington Pumping Engine is used, and the water has to be lifted about 170 feet.

THE RESERVOIR.

This is of irregular form adapted to its position on a side-hill. The embankments are well built, and are covered with a slope wall of blocks of granite on the inner side. The specifications for the work throughout were very strict and were followed very closely.

The reservoir is partly in excavation and partly in embankment, it being so placed as to make the quantity of material removed about equal to that required for the embankments.

In excavating, the method of "Falls" was used. The gain of this, in regard to the amount of work required, over the old way of working it all with picks, is discussed; and assuming a certain size for the fall which is about that usually taken, the result shows that it does not require quite half the time, with the same amount of labor, to completely break it up ready for the shovellers.

In obtaining the capacity of the reservoir, the area of the bottom was calculated by the method of coördinates. I then found the contents, assuming the sides to rise vertically. But as the sides have a slope of $1\frac{1}{2}$ to 1, there is an additional amount to be taken in, whose cross section is a triangle. As this cross section is constant I used the Theorem of Pappus. The reservoir holds about 14,800,000 gallons.

THE GATE CHAMBER.

The arrangement of the pipes in the gate chamber is such, that while the engine is working, the supply in the distributing pipes is obtained without its passing into the reservoir first. But when it is not working, the supply is again taken from the reservoir. To effect this result a single pipe serves both as the inlet and outlet of the reservoir, arranged with automatic valves.

Iron pipes were used throughout, and the methods for ascertaining the necessary thickness is discussed in the thesis. It is a matter about which there is considerable variance of opinion and many different formulæ are given. The thickness, of

course, depends upon the head and the desired diameter. We find these involved in most of the formulæ and also various constants determined by experiment. Rankine's formulæ are the two following.

$$\left. \begin{aligned} t &= \sqrt{\frac{D}{48}} \\ t &= \frac{HD}{12,000} \end{aligned} \right\} \text{the largest result to be used.}$$

It is found that either of these give a very low result. The formula adopted for the Newton Water Works is the following

$$t = (.00008 H D + .01D + .36) \text{ inches.}$$

H = the head in feet. D = the diameter in inches. As an illustration of the different results obtained by using the above formulæ I give the following. For a 12" pipe with a head of 200 ft, the Newton Formula gives $t = .67$ of an inch. Rankine's Formulæ gives $t = .50$ of an inch. The very systematic way of tabulating the subject adopted at Newton, I have shown in the thesis.

Oftentimes a pipe will be thicker than is necessary because it is better not to have too many classes, and rather than for a small amount of pipe to have a different size, it is placed with the size next thicker.

Design for an Iron Railway Bridge, with a consideration of the Principles determining the Design. Abstract by the Author, George F. Swain.

The purpose of this thesis is to design an iron railway bridge, and to discuss the general principles involved. The total span to be bridged, together with the various local circumstances, being assumed, the economical number of separate spans is first taken up and discussed in its general aspect, and afterwards theoretically, Thurin's formula being explained and applied to the present case. The number of spans having been determined upon, the type of bridge to be employed next engages attention, and the panel length having been assumed in

accordance with the best practice, an extension of "Bramwell's method" is employed to determine the economical depth and the corresponding amounts of iron in all the trusses in common use in the country. This comparison, although made for this particular case only, gives results which are believed to be approximately true for all cases, as regards the order of economy of the different trusses under like conditions. They agree admirably with the best practice, and indicate as the most economical form of truss, the Pratt, with double intersections, a truss extensively used both at home and abroad. This type being adopted, the amount and distribution of the load are next considered, and the accuracy of the usual uniform loads assumed for bridges of this span is tested by comparing the chord stresses produced by them with the actual stresses produced by a heavy train. The details of calculation of stresses and determination of dimensions are then taken up.

Two sheets of drawings accompany the thesis.

The Ashtabula Bridge. By Frank E. Wiggin.
(Abstract not received.)

DEPARTMENT OF MECHANICAL ENGINEERING.

A Review of a Continuous Brake Trial. Abstract by the author, William H. Beeching.

I have considered this subject under two parts:—

Part I gives a description of the trial-ground, the apparatus used, the trains and brakes, the experiments as they took place under the different classes, the statement of the questions to be considered, and, if possible, to be settled by this trial.

Part II deals with the calculations and questions as stated in Part I; also contains tables, with the results obtained, a number of diagrams used in the discussions. We find that the Westinghouse Automatic Brake out-did all the other brakes, in ease of application and running, promptness of action and

apparent durability. We also find that wet rails greatly decreases the coefficient of friction of the brakes, and thus their efficiency when wooden brake blocks are used, and more so than in the case of cast iron blocks.

The Westinghouse Air Brake. Abstract by the author, George W. Chapman.

The Westinghouse Air Brake is a contrivance consisting essentially of a cylinder, fitted with a piston working air-tight within. The piston rod is connected with the brake levers, and on the admission of compressed air, the piston is forced from its normal position at one end of the cylinder to the other. This movement of the piston through about ten inches, and with a pressure of ninety pounds per square inch behind it, is capable of exerting upon the wheels the same, or greater, pressure than is applied by the total weight of the cars resting upon them. The sudden resistance to the train's motion enables it to be stopped under the most adverse circumstances of speed, incline, and weather within a distance of five hundred yards, and ordinarily within five hundred feet. With the old form of hand brake, the train often runs a distance of half or three-quarters of a mile before stopping.

The air pump for compressing the air does not differ materially from the pumps used in physical experiments, but all the appendages are of necessity much stronger. The motive power is a steam engine situated directly over the pump cylinder, so that the same piston rod serves for both. The air is compressed to a pressure of from seventy to one hundred pounds per square inch, and is stored for use in a cylindrical boiler-iron reservoir, situated under the foot board on the locomotive. The details of engine, pump and brake, are numerous, but not complicated for a contrivance of such inestimable value to railroad companies for the safety of the traveling public. It seems to me that in point of simplicity and efficiency in car brakes, the acme has been attained in the Westinghouse Brake.

Double Valves as applied to the Rider Engine. Abstract by the author, Linus Faunce.

The Rider Engine is similar to most stationary engines with the exception of the valves and their connection with the governor. The main slide valve is, on its face side similar to the ordinary D valve except that it has its ends lengthened to admit of ports being formed outside of the valve proper. The ports on the face side are parallel with the ports in the cylinder and at right angles to the motion of the valve. On the back these ports are oblique and at opposite angles to each other. The expansion valve is a sector of a cylinder with its acting ends cut off obliquely in opposite directions corresponding exactly with the obliquity of the ports in the back of the main valve. It is fitted into a semicylindrical recess in the back of the main valve.

These valves are operated lengthwise by separate eccentrics, to which they are attached in the usual manner, except that the expansion valve rod has a swivel joint to permit of partial rotation, and it is so connected with the governor that when the governor rises or falls it will be made to rotate in one direction or the other.

The governor, instead of throttling the steam, regulates the point of cut off, making admission longer or shorter as there is more or less work to be done.

With proper proportioned valves and governor any degree of expansion may be obtained.

The Construction and Use of a Mercury Column. Abstract by the author, Chas. H. Fisher.

It is becoming common as more accurate results are required, for engineers to frequently test the instruments which they use in observing pressures. To do this they must, directly or indirectly, compare them with an open air mercury manometer.

In this paper, the necessary principles of the construction of

such an instrument and the interpretation of its readings, are discussed.

The ordinary pressure-indicating instruments are graduated to even pounds per square inch and may be read to the nearest tenth of a pound by estimating the tenths by the eye.

Therefore if we should, in the use of such a manometer, for the sake of convenience, introduce a small error in our interpretations, we may be certain that our result is as near as the instrument on trial can indicate, if we are sure that the error we introduce does not amount to a half of a tenth of a pound.

In using a mercury column there are two ways in which errors may be introduced. The first is in the graduation and reading of the scale with which we observe the height of the mercury. By care, this error may be kept within almost any limit we desire.

The second way an error may arise, is in the transformation of the pressure, expressed in height of mercury, to that expressed in pounds per square inch.

The pressure, in pounds per square inch, corresponding to a column of mercury h inches high, is $p = hy$, where y is the weight in pounds of a cubic inch of mercury. The value of y may vary either from a change of temperature or from the compression produced in the mercury by pressure.

In this paper are discussed the effects of these variations and the means of correcting them.

Finally, there is described a design for such a column, and a suggestion made concerning an addition, to be made to the design, for the purpose of reading the height of the mercury.

Boiler Incrustation. Abstract by the author, Joseph Kirk.

Incrustation in steam boilers is caused by impurities in the feed-water, which become concentrated in the boiler, and finally form a coating or layer on the plates or tubes. The deposit thus formed, having a low conducting power, hinders the transmission of heat from the fire to the water, involving

the expenditure of more coal than would be used if the plates and tubes are clean. The deposit also acts injuriously upon the boiler by causing the plates to be overheated, in consequence of which they may be burned, or their strength may be made insufficient to resist the pressure of the steam. If the deposit on an overheated plate is suddenly cracked off, or removed in any way, the water in the boiler is brought into contact with the plate, and the result may be a true explosion. Substances forming deposits may be divided into two classes; those dissolved by the feed-water, and those held in suspension. To the first class belong salt, lime, magnesia and iron salts; to the second, sand, mud, and vegetable matter. The method of prevention generally adopted against salt are blowing off and surface condensation. Lime is found as incrustation in two forms; carbonate and sulphate. The carbonate may be precipitated before the water enters the boiler by boiling the water; or by mixing it with lime-water. Sulphate of lime is precipitated by being boiled at a high pressure. Magnesia occurs as the carbonate and acts in a similar manner to carbonate of lime. Iron salts have a corrosive action on the boiler. They can be precipitated by boiling. Members of the second class can be removed from the feed-water by filtering. Chemical substances, especially carbonate of soda, are sometimes used in the boiler for preventing lime incrustation.

Substances having, or supposed to have, a mechanical action in preventing incrustation have been used. They often contain grease, which if present in considerable quantity is injurious to the boiler. Vessels for collecting the sediment and preventing it from being deposited on the plates or tubes are sometimes used in the boiler. When a hard coating of scale has formed it may be removed by being chipped off, or by suddenly heating or cooling the boiler. The first method is inapplicable to multitubular boilers unless the tubes are taken out. The second is liable to injure the boiler by the sudden strains introduced. The general opinion of railway men in regard to the prevention of incrustation, is that it is best to

purify the water before it goes into the boiler rather than to use chemical powders, etc., in the boiler.

On Link Motion. Abstract by the author, Cecil H. Peabody.

The idea pursued in this thesis is to take an example of link motion from actual practice, and by applying to it the different methods of working out the problem, to make a comparison of the methods and of their results, pointing out the advantages and deficiencies of each method. As an introduction, there is given a short sketch of the development of the link motion from earlier forms of reversing motions, together with a description of the form common to American practice.

The three methods applied to the problem chosen are, in order, the algebraic method, based on cinematocal principles, the graphical method, and the method by use of a model with adjustable parts. The algebraic method is that given by Professor Gustav Zeuner in his treatise on Valve-gears, the problem being solved in full, both numerically and by aid of a diagram, thus obtaining an efficient check on the work. The graphical method is that given by Wm. S. Auchincloss in his Link and Valve Motions, only the simplest case being touched upon. A description of a model at the Hinkley Locomotive Works, with an account of an experiment, giving results, closes the discussion.

DEPARTMENT OF MINING ENGINEERING.

The Verehire Copper Ore and its Metallurgical Treatment.
Abstract by the author, George Bartol.

This thesis is divided into six parts.

1. Description of the ore and its constituent minerals. The composition of the ore was found to be :—

Cu	11.29 per cent.
Fe	46.76 "
S	33.98 "
SiO ₂	5.67 "
Zn	1.27 "
Co and Ni undetermined.	
Pb, Al ₂ O ₃ , Ca, Mg, traces.	
	98.95 per cent.

2. A review of the advantages and disadvantages of the principal methods for the extraction of copper. Outline of the process best suited to this ore and of the one finally adopted.

3. A detailed account of the metallurgical treatment of the ore at the Institute. 1019 lbs. of the ore were treated in the following manner—

- a. Roasted in a reverberatory furnace.
- b. Roasted ore smelted in the blast furnace for matte.
- c. Matte roasted in a kiln.
- d. Roasted matte smelted in the blast furnace for black copper and matte.
- e. Matte roasted in a reverberatory furnace.
- f. Roasted matte smelted in crucibles for black copper and matte.

The products were:— 97½ lbs. of black copper and 2 lbs. of matte.

4. Tables giving details of furnace runs, consumption of fuel, losses of copper, etc.

5. Remarks on the size and position of tuyères, deductions from tables, suggestions and conclusions.

6. Description of the methods employed in chemical analysis.

Investigation of the Institute Ore-washers. Abstract by the author, W. C. Flint.

This report is of an examination of the work on a low grade ore from the Merrimac Mine by the ore-concentrators at the Mass. Institute of Technology, being a counterpart to the thesis of Mr. Stimpson, but not covering the same ground.

This thesis is divided into six parts.

Part I. A statement of the object of the thesis. A review of the character of the ore and the difficulties of its treatment, owing to the presence of minerals of every specific gravity, from 2.5 to 7.5. A brief description of the Spitzkasten, also of the Rittinger (side-bump) and end-bump tables and dolly-tub.

Part II. Narrative of the experiments in running the machines. Tables of the records kept, also a table showing the order of operations on the ore. A statement of the final products.

Part III. A consideration of the machines from a business point of view. The proportion of metal-bearing ore saved. The cost of running the machines compared with the assay value of what was saved. The value and amount of ore saved.

Part IV. A discussion of the forces which act on bodies falling in water, also the formulæ deduced for the velocity, path, and time of fall of both spherical and irregular bodies; being the theory of grading. (Translated from Rittinger's "Lehrbuch der Aufbereitungskunde.")

Part V. Investigation of the products of boxes 2, 3, and 4 of the Spitzkasten, and of the overflow of the same, as follows:

Samples were taken and passed through sieves to size them. The sieve products were grouped into a smaller number of divisions, thus: Spitzkasten, box 2, into four: 1, through a 12th sieve on a 40th; 2, through a 40th on a 70th; 3, through a 70th on a 120th; 4, through a 120th; box 3 into three: 1, through a 12th on a 70th; 2, through a 70th on a 160th; 3, through a 160th; box 4 into three: 1, through a 12th on a

120th; 2, through a 120th on a 160th; 3, through a 160th; overflow into two; 1, through a 12th on a 160th; 2, through a 160th.

Construction of curves to show the results of this sizing. The above divisions examined for PbS, S, Fe and CO₂, and the mineral percentages calculated therefrom. Account of the analyses and results. Construction of curves to show these graphically. Tables showing the direct results of analyses, also the mineral percentages.

TABLE OF DIRECT RESULTS.

		Per cent. PbS.	Per cent. S	Per cent. CO ₂ .	Per cent. Fe.
Box 2 of Spitzkasten.	Division 1.	1.96	1.83	{ 6.17 5.96	7.17
	" 2.	2.10	2.33	{ 6.89 6.72	8.25
	" 3.	5.28	5.05	{ 9.73 9.42	12.42
	" 4.	15.42	8.08	{ 9.23 9.31	18.11
Box 3 of Spitzkasten.	" 1.	2.61	1.82	4.85	6.53
	" 2.	4.56	2.68	7.69	8.99
	" 3.	8.63	6.92	9.48	13.32
Box 4 of Spitzkasten.	" 1.	1.69	1.30	4.15	{ 4.64 4.75
	" 2.	2.87	1.97	7.40	8.86
	" 3.	2.90	5.84	9.78	12.65
Overflow of Spitzkasten.	" 1.	4.70	{ 3.895 3.95	6.60	7.62
	" 2.	9.65	{ 3.52 3.49	8.82	9.76

TABLE OF MINERAL PERCENTAGES.

		Per cent. Galena.	Per cent. Pyrite.	Per cent. Siderite.	Per cent. Gangue.	Total per ct.
Box 2 of Spitzkasten.	Division 1.	1.96	2.94	16.27	78.43	99.60
	" 2.	2.10	3.84	17.92	71.70	95.56
	" 3.	5.28	8.14	25.23	69.48	98.13
	" 4.	15.42	11.27	24.44	48.80	99.93
Box 3 of Spitzkasten.	" 1.	2.61	2.76	12.78	77.15	95.30
	" 2.	4.56	3.88	20.80	69.88	99.12
	" 3.	8.63	10.80	24.99	49.39	93.81
Box 4 of Spitzkasten.	" 1.	1.69	2.01	10.94	83.35	97.99
	" 2.	2.87	2.98	19.51	71.69	97.05
	" 3.	9.30	8.46	25.78	53.18	97.32
Overflow of Spitzkasten.	" 1.	4.70	6.17	17.40	70.34	98.61
	" 7.	9.65	4.14	23.26	61.94	98.99
Calculated from the above table and the weights of each product.	Total Box 2.	5.93	6.69	21.45	63.78	97.80
	" 3.	6.38	7.53	22.55	60.66	87.12
	" 4.	8.05	7.02	24.02	58.47	97.56
	Total Overflow.	9.32	4.28	22.86	62.49	98.95

The residue insoluble in HNO₃ and KClO₃ was weighed and called the amount of gangue.

Part VI. Conclusions drawn from the results obtained in Part V, considered together with the theory given in Part IV. Suggestions as to the reasons why the spitzkasten did not do better grading. Changes advisable in the spitzkasten. Changes which would be made in the investigation if repeated.

On some Methods for the Extraction of Nickel and Cobalt from their Ores. Abstract by the author, John E. Hardman.

This paper is divided into five parts.

1. The object of the thesis, showing the increasing importance of nickel and cobalt ores, the scanty knowledge we have of the metallurgy of these elements, and giving a plan of the thesis.

2. A statement, or description, of methods actually in use for the extraction of these metals, so far as the methods are known, on account of the secrecy with which the processes are kept by the proprietors. The details of two methods, one in use at Klefoa in Sweden, and the other at Dillenburg in Germany, are given.

3. A narration of experiments undertaken in accordance with the object of the thesis. Six series of experiments are described in full, and the results tabulated.

4. General deductions from, and applications of the results given in 3.

5. A detailed account of results obtained from an investigation of (1) Fischer's, (2) Rose's, and (3) Fleischer's methods for the quantitative separation and determination of cobalt and nickel, together with some facts regarding the chemistry of the two elements which are not generally noted in text-books; and some analyses of ores used during the whole investigation.

On the Smelting of a Silver-lead Ore from Merrimac Mine. Abstract by the author, Henry D. Hibbard.

A lot of low grade ore weighing $4\frac{1}{4}$ tons, from the Merrimac Mine of Newburyport, was washed by the machines at the In-

This mixture was fed with one seventh its weight of coke during the whole run. The composition of the fluxes was

		Tapcinder.	Limestone.	Slimes.
Silica	SiO ₂	. . 14.55	.5	45.79
Iron oxide	FeO	. . 70.89	.0	21.
Alumina.	Al ₂ O ₃	. . 8.08	.0	8.95
Lime	CaO	. . 2.38	56.	4.01
Lead	Pb	. . .0	.0	7.61
Magnesia	MgO	. . .0	.0	7.72

This smelt gave a slag of the following composition :

Silica	SiO ₂	. . . . .	24.28
Iron oxide	FeO	. . . . .	52.20
Alumina	Al ₂ O ₃	. . . . .	10.48
Lime	CaO	. . . . .	5.30
Lead	Pb	. . . . .	4.44
Magnesia	MgO	. . . . .	1.37

During this smelting 81 $\frac{7}{8}$ lbs. of lead or 32.23 per cent. of all the lead was lost partly in fume, partly in drops in the slag and partly as silicate in the slag, the proportional amounts however, of these several losses were not obtained.

This lead was then melted and desilverized by pouring into it 1 per cent. of melted zinc which rises to the top and carries with it the silver and gold. This addition of zinc and the separation of argentiferous zinc scum has to be repeated several times as follows:

Before 1st addition of zinc the lead contained	64 oz. silver per ton	2000 lbs.
After " " " " rem'n'g "	16 " "	" "
" 2d " " " " "	2.48 " "	" "
" 3d " " " " "	.22 " "	" "

The zinc was now distilled off from this alloy of lead. Zinc and silver and an alloy of lead and silver were left which were separated on a cupel. The loss of lead during the desilverizing was 1 $\frac{7}{8}$ lbs. or 73 per cent. of the whole lead in the ore and in cupelling 3 $\frac{1}{2}$ lbs. of lead or 1.34 per cent. were lost.

To sum up the losses were as follows:

Lead lost in roasting . . .	20½ lbs., or 8.07 per cent.
“ “ “ agglomerating . . .	11 “ 4.30 “
“ “ “ smelting . . .	81⅞ “ 32.23 “
“ “ “ zincing . . .	1⅞ “ .73 “
“ “ “ cupelling, etc. . .	3½ “ 1.37 “
Total . . .	118½ lbs., or 46.70 per cent.

Total amount of lead obtained was 135¼ lbs. or 53.30 per cent.

The record of the silver is as follows:

The ore contained 6.15 oz.			
In roasting and smelting the loss was	1.38 oz., or 22.44 per cent.		
“ refining and zincing	“ 1.09 “ 16.09 “		
“ cupelling	“ .21 “ 3.41 “		
Total lost . . .	2.68 oz., or 41.94 per cent.		
Total amount of silver obtained . . .	3.47 “ 58.06 “		

The record of the gold:

The ore contained \$4.50.

Lost in roasting and smelting . . .	\$.42 or 9.33 per cent.
“ refining, zincing, and cupelling	\$1.28 28.4 “
Total lost . . .	\$1.70 37.73 “
Total obtained . . .	\$2.80 62.27 “

Report on the Working, for Silver and Gold, of a Middle Grade Product from Ore of the Merrimac Mine, Newburyport. Abstract by the author, Walter Jenney.

The object was, to so concentrate the ore as to make a second or middle grade product which should contain minerals whose specific gravity would not allow them to be saved in the “Smelting Ore” without greatly diluting it, but which were supposed to carry quite a quantity of silver. Several processes were to be tried with the intention of finding, if possible, a method by which it would be possible to work such a product profitably.

8500 lbs. of ore from the mine, when so concentrated, gave 1272 lbs. of this middle product, which assayed for gold \$9.23

per ton, and for silver \$11.28 per ton. The finding of so much gold was something of a surprise and caused the methods to be altered somewhat so to extract that also. The product was made up of quartz 20.654 per cent., siderite 37.204 per cent., pyrite 20.377 per cent., galena 11.589 per cent., and smaller quantities of ispickel, chalcopyrite, blende and serpentine. It was roasted in a reverberatory furnace till all odor of SO₂ had ceased coming off, and then ground with salt (5 per cent.) and roasted again. Assays showed that in this first roasting, 38 per cent. of the gold, and 23 per cent. of the silver were lost. Experiments were made by (I) Amalgamating this chlorinated ore in a Washoe Pan—and by (II) chlorinating it with Cl gas, dissolving in brine, precipitating as sulphides, running down with lead and cupelling, with the results shown below.

Amalgamating. Per cent. extracted from *roasted ore* . . Au 17, Ag 23.
 Gas Chlorination I. " " " " . . " 41, " 70
 " II. " " " " . . " 82, " 61.

It will be seen that the chlorination process (with Cl. gas) worked much the best, and it would give much better results if the leaching had been carried on farther.

Assays of the different products are given below:—

	Silver.	Gold.
Raw ore assayed	\$11.28	\$9.23
Roasted ore (before chlorination)	11.91	—
Chlorinated ore	11.06	7.23
Tailings from Amalgamation	6.80	6.03
“ “ Gas chlo. I.	1.70	4.82
“ “ “ “ II.	1.70	3.61

The inference is that on a similar product which would be obtained from a richer ore (this being a *very* poor ore) this process might be made to pay, especially if made to work continuously as could easily be done.

Treatment of Vershire, Vt., Copper Ore. Abstract by the author, H. C. Southworth.

The thesis was divided according to the following outline:

1. The ore, with its ultimate analysis and minerals contained.

2. An account of the treatment of the ore, and a description of the processes used.

3. Deductions from my experience in working the ore, with the modifications of treatment suggested by that experience, and the comparison of the methods, with remarks upon them.

4. Tables relating to blast furnace runs, roasts, analyses, etc.

The result of the work upon the ore, as is stated in Part 2 of the thesis, was a black copper containing about 98 per cent. of copper.

This was accomplished by two roasts in the kiln, and smelting twice in the blast furnace, and then taking the second matte and running it down in black lead crucibles, after roasting as well as possible in the reverberatory furnace.

The most interesting comparison is that of the work of the kiln with the reverberatory furnace, upon the same ore. This is shown by the following table :

	Roasting in		
	Kiln.	Reverberatory.	
Amount of ore roasted	865½	1019½	lbs.
“ “ fuel used	105½ (coke)	739 (coal)	lbs.
“ “ labor	8	52	hrs.
“ “ sulphur lost	131	122	lbs.
Percentage “ “	15.14	about 12.	

As the reverberatory furnace was used by Mr. Bartol, I am indebted to him for a part of the information concerning the above table.

In speaking of modifications of treatment, the view was expressed that, by sufficient roasting — which could be done in the kiln — the ore might be run down at once into as good a matte as was got by smelting twice.

In this way a good black copper would be got with only two furnace runs.

Investigation into the Working of the Institute Ore-concentrating Machines. Abstract by the author, Thomas F. Stimpson.

This subject was divided for study between Mr. Wm. C. Flint and myself. The ore to be experimented upon was a very poor quality argentiferous galena ore from the Merrimac Mine, Newbury, and was found by inspection to consist of the following minerals:— Galena, Chalcopyrite, Quartz, Pyrite, Siderite, Arsenopyrite, Zinc-blende, Tetrahedrite and traprock, associated with the greenish-white gangue composed essentially of Silicate of Alumina. It was broken, crushed, and sifted, by the machine in the Mining Laboratory of the Institute. Of the 8485 lbs. ready for concentration a sample was taken and subjected to chemical analysis, with the following results:—

Lead	5.23 per cent.
Sulphur	5.45 "
Iron	4.24 "
Ferrous Oxide	9.24 "
Copper . . . . .	.32 "
Arsenic . . . . .	.27 "
Alumina	8.30 "
Oxide of Manganese	1.01 "
Zinc . . . . .	.15 "
Lime	1.16 "
Magnesia	1.89 "
Alkalies	1.95 "
Carbonic Acid	7.02 "
Silicic Acid	52.75 "
Water . . . . .	.96 "
Determined	99.44 per cent.

From the above the mineral constituents were calculated as follows:—

Galena	6.04 per cent.
Siderite containing manganese	18.51 "
Pyrite	7.36 "
Chalcopyrite . . . . .	.93 "
Arsenopyrite . . . . .	.90 "
Zinc-blende . . . . .	.46 "
Siliceous gangue	65.24 "
Total	99.44 per cent.

An assay for the precious metals gave : —

Silver020 per cent.; 5.83 oz. to the ton.
Gold00067 per cent.; 196 oz. to the ton.

The subject was treated more or less fully under six headings, viz : —

1. Description of the Ore and Machines.
 2. Narration of Experiments. Final Products made.
 3. Estimation of the Cost of Running the Machines..
- Value of the Final Products made.
4. Theory of Concentration.
 5. Investigation of Results. Comparison with the Theory (not fully completed).
 6. Conclusions.

1. The description of the machines was confined to the Cone, the Spitzkasten and the Jigger.

2. The time occupied in concentrating the ore was about 29½ hours, extending over a period of five days. The object in view, meanwhile, was to make two workable products of ore: (1) One which was rich in lead — a smelting ore; (2) a product which should be poor in lead but carrying silver which was to be extracted either by chlorination or by amalgamation.

The following are the workable products made during the run.

	<i>Weight lbs.</i>	<i>Per cent. Lead.</i>	<i>Per cent. Silver.</i>
Smelting Ore	624½	38.03	.049
Middle Grade Ore	1829½	8.97	.031

3. The object of considering the cost of running the mill in the Laboratory was more especially to gain some idea of the cost of working similar ores on a larger and more practical scale. It is evident that, by increasing the capacity of the machine, the cost of concentrating an ore could be greatly diminished.

The principal data for this purpose are presented as follows:—

	<i>Weight, lbs.</i>	<i>Value Lead.</i>	<i>Value Silver.</i>
The Ore before treatment	8485	\$26.63	\$27.24
Smelting Ore produced	624 $\frac{1}{4}$	\$14.24	\$4.86
Middle Grade Ore produced	1823 $\frac{1}{4}$	9.81	9.23
Waste	6037 $\frac{1}{4}$	4.47	11.38
	<u>8485</u>	<u>\$28.52</u>	<u>\$25.47</u>
Unaccounted for: Lead, 32 lbs. at 6 cts.		— 1.89	
Silver, 1.61 oz. at \$1.10			1.77
		<u>\$26.63</u>	<u>\$27.24</u>

Cost of working ore :

Interest on capital of \$1800, including wear, per day	\$.50
Wages of 2 men at \$2.00	4.00
“ “ 2 boys at .75	1.50
Coal for generating steam . . . . .	.75
Oil for lubricating . . . . .	.25
Cost per day	<u>\$7.00</u>
Total cost for five days	\$35.00

4. In ore-working there are usually two distinct processes :

1. *Sorting*, by which the ore is separated into groups whose particles have a like falling-velocity in water; 2. *Sizing*, by which the coarser grains are separated from the finer, and by which, if the ore had previously been sorted, a concentration takes place.

5. In investigating the results of the experiment the investigation extended to the work done by the Cone, Spitzkasten No. 1, and the Jigger, in order to inquire into the proficiency of these machines as “sorters” or “sizers” — as the case happened to be. The results depended upon the chemical analysis, and the physical examination of the different sizes of grains in each product to be investigated.

6. An examination of some of the products showed that the concentration of the ore, in respect to its silver, was rendered particularly difficult on account of the manner in which that metal was disseminated throughout the whole mass

of ore; and, on the other hand, the concentrations for lead would have been much richer but for the manner in which particles of quartz and siderite were disseminated through the galena giving to it thereby a lower specific gravity. It is thought that a further study of the data already obtained will show that the machines did their work as completely as possible, considering the peculiar physical condition of the ore and the manner in which the process of concentration was necessarily hastened.

Experimental Working, by Wet and Dry Methods, of a Low Grade Silver and Gold Ore, from Newbury, Mass. Abstract by the author, F. W. Wood.

Three principal divisions may be made of this thesis as follows:

1. Description of certain wet and dry processes for the extraction of silver.
2. Description of the ore experimented upon.
3. Description of the experiments conducted in the Metallurgical laboratory, with conclusions drawn from the results.

In Part 1st it is endeavored to give, in as compact form as possible, descriptions of the following named processes with the chemical reactions involved in each:— Washoe amalgamation, Augustin, Ziervogel, Von Patara, and a smelting process used at Freiberg.

It was originally intended to conduct the experiments upon an argentiferous zinc blende, but as this could not be obtained, a middle grade product, separated in the washing of $8\frac{1}{2}$ tons of low grade ore from the Merrimac mine at Newbury, was substituted.

Part 2d gives a scheme of the washing, showing the products making up the ore experimented upon, an analysis of the ore, with some of the methods of determination employed, a calculation of the mineral species, and the results of assays of the ore.

Part 3d is devoted entirely to the description of the experiments which were as follows:—

1. Trial roast and lixiviation to determine the possibility of extracting any of the silver in the above ore by a wet method.
2. The working of 100 lbs. of ore by Augustin's process.
3. Experiment upon 500 grms. to determine the possibility of applying Ziervogel's process.
4. The working of 100 lbs. of ore by Von Patera's process.
5. The smelting of 100 lbs. for matte and the subsequent treatment of one fourth of the matte, for silver and gold, in the dry way.

The following are the results of the different processes:—

	<i>Obtained, per cent.</i>		<i>Lost, per cent.</i>	
	Silver.	Gold.	Silver.	Gold.
Trial Roast . . .	7.8		92.2	
Augustin's . . .	23.7	14.3	76.3	85.8
Von Patera's . . .	24.7	18.6	75.3	81.4
Smelting . . .	33.3	62.9	66.7	37.1

The *per centage lost* includes the silver and gold in the residues from the wet processes.

The loss in Augustin's process was increased by the breaking of a crucible while in the furnace.

In the dry process, the roasting of the matte obtained by the first smelting was carried so far that not enough sulphur for the formation of a matte in the second smelting remained, hence a considerable portion of lead, and with it the silver, went into the slag.

The conclusion drawn from the experiments is, that in order to economically extract the gold and silver, instead of attempting to work such a product alone, it should be smelted with an ore rich in lead.

DEPARTMENT OF ARCHITECTURE.

Design for a Steam Fire Engine House. Abstract by the author, J. William Beal.

It was the object in this thesis to present the subject, not merely from an architectural point of view with regard to design and execution of drawing alone (although these were given the most careful attention), but more particularly from a practical point of view adapting the *theoretical* to the practical requirements of the problem, according to one's best judgment. This course, although it may not present such pleasing results as may have been obtained by selecting some subject involving more architectural design, has nevertheless served to initiate the student into the routine of service in actual work which is of the greatest value. To accomplish this object, thorough examinations were made into the Fire Department of Boston and Cambridge; through the kindness of the officers the practical workings of each branch of the department were shown. The Engine Houses varying from one another, the advantages or disadvantages of each were ascertained. In accordance with the information thus obtained the design was worked out, all points of construction being treated exactly as though it was an actual case of building, in every case the theoretical calculations being compared with work already executed. These calculations embraced calculation of girders and timbers for floors, calculation of foundations and retaining walls, the distribution of strains in the roof trusses and the calculation of their dimensions, also the stability of arches and their effect on walls. The drawings comprised directions, plans and sections, with details and a perspective view of the building.

A Town Hall. Abstract by the author, Geo. W. Capen.

The subject of this thesis, "A Town Hall" was chosen for a variety of reasons, the principal of which were, that there is comparatively little architecture in our country towns, also that

it afforded a good field for architectural composition and design, and lastly a good opportunity for the calculation of strength and stability.

The building was to be built of rough stone and was designed to meet the wants of a town of from five to six thousand inhabitants. It contained on the lower floor, offices for the town clerk (which office was provided with a fire-proof vault), tax collector, selectmen and janitor, besides a large library room and a hall for small public gatherings.

The whole of the second floor was occupied by a large and spacious hall for large public gatherings, which was provided with two suits of dressing rooms, one for ladies and one for gentlemen.

The hall was to be covered by an open timbered roof, with a balcony in the rear, a large and commodious stage in front and a long narrow balcony on either side supported by brackets which form an architectural composition with the roof trusses.

The design is executed in the modern gothic style, and has for its principal exterior feature, a clock tower with a dial facing each of the cardinal points of the compass.

Of the drawings accompanying the thesis, there were a front elevation, a ground plan and a hall plan drawn to a quarter-inch scale — a side elevation, a longitudinal and transverse section and a gallery plan drawn to an eighth-inch scale, besides a perspective drawn to a quarter-inch scale.

A Design for a Steam Fire-Engine House. Abstract by the author, W. E. Chamberlin.

The conditions of the problem were assumed as follows: —

A flourishing suburban town requires a house for a steam fire-engine with its hose-carriage, and accommodations for six "permanent men." The house, which is to be of brick and stone, is to have a tower where the hose is hung to dry.

The principal story is for the most part taken up by the large room where the apparatus stands. In the rear the stalls are arranged, also an office and a workshop.

The second story contains six sleeping rooms as near as possible to the staircase which is in a single run. There is also a parlor, a room for the fire-alarm battery, a bath-room and a grain room.

In the cellar are found the hose-trough, the heating-apparatus, &c., &c.

The tower, which is usually put on the rear of the building, has in this case been put on the front. This position, while detracting nothing from the convenience within, gives an opportunity for making the building more pleasing without.

In order to be assured of the best arrangements for the planning of the problem several of the best houses in Boston and Cambridge were visited, and useful hints obtained.

The drawings accompanying the text consisted of plans of the first and second stories and cellar, the two principal elevations, a longitudinal section, a perspective and a few details on a larger scale.

For mathematical calculations the following were made :

1. Dimensions of floor timbers in engine-room, (assuming the weight of engine ready for a fire as 8000 lbs. The fact that two-thirds of this comes upon the hind wheels was considered.)

2. Truss 32 ft. long in partition in 2d story.

3. Parlor flooring timbers.

4. Roof truss (this was a primary truss of 32 ft. span, each slope being braced by a strut from the bottom of the vertical tie-rod.)

5. The brick arches on the front of the house.

Design for a Railroad Station. Abstract by the author, Pierce P. Furber.

In the design accommodation was afforded for waiting rooms for both ladies and gentlemen, baggage and lunch rooms, freight, telegraph and ticket offices, with the necessary halls, vestibules, and side rooms, in a two story building, 32 ×

44 feet, having a one story wing, 32 × 53 feet, the material used being red brick with brown stone trimmings and blue slate roofs.

The accompanying drawings consisted of two floor plans, a piling plan, two elevations, a section, and perspective, all drawn to a scale of one-eighth of an inch to a foot. Calculations were made as to the number of piles necessary to support the building in a loose sandy soil, and as to the stability of the arch over the main entrance.

A design was made for the roof trusses, the proper dimensions of the different members composing them being determined by the aid of "Greene's Graphical Analysis of Roof Trusses," a load of 12 pounds per square foot of snow, and a wind pressure of 26.5 pounds per square foot being taken into consideration. The strength of the floors was discussed, as was the construction of a trussed partition.

DEPARTMENT OF CHEMISTRY.

On an impurity found in Commercial Acetone. Abstract by the author, John Alden.

In repeating Baeyer's experiments on the formation of Phorone by passing dry chlorhydric acid gas into Acetone, a solid crystalline body was formed, a fact not mentioned by Baeyer, or by those who have since repeated his experiment. The purification and analysis of this body form the subject of the thesis.

From the analysis made the body was judged to have the formulæ $C_4H_{11}N_2O_2Cl$ as the following results show:—

Carbon	31.45	31.07
Hydrogen	7.80	7.12
Nitrogen	17.45	18.12
Chlorine	23.10	22.98
Oxygen	20.55	20.71
	<hr/>	<hr/>
	100.00	100.00

Judging from the reactions the body evidently had an acid structure, and a double arindo-structure. As the body was first formed, both groups of NH_2 were evidently saturated with HCl , but on exposure to the air HCl was given off, till finally only one remained combined.

The formation of this nitrogenous body was evidently due to an impurity in the acetone. Certain tests and analyses led to the conclusion that it was acetonitrile. To verify this conclusion, some pure acetone and acetonitrile were made, and the mixture of the two saturated with HCl , when the same crystalline body was formed, having the same properties and constitution.

The acetone was probably prepared from the by-products of aniline manufacture by Béchamp's process, in which it occurs. This would account for the presence of acetonitrile.

The relations of Carbon to Iron and its determination by the Chlorine Process. Abstract by the author, Chas. S. Bachelder.

The subject is treated as follows:—

I. Relations of Carbon, Silicon and Manganese to Iron:—

In this section is considered the importance of knowledge of the above named ingredients of commercial iron, as seriously affecting its value for different purposes; also the form in which these elements are supposed to exist in the Iron.

II. Methods of determining total carbon and the Möhler Chlorine Process:— Under this head is discussed the various methods for determining carbon, more especially that known as the Chlorine Process.

III. Experiments with the Chlorine Process:— In this section the results of a number of analyses are given, the various defects in the process pointed out, and methods given for avoiding them as far as possible. The conclusion is reached that when properly carried out the Chlorine process affords results, which compare not only with themselves, but also with those given by what are considered to be accurate methods.

LOWELL DEPARTMENT OF INDUSTRIAL DESIGN
FOR 1876-77.

President Bunkle :—

DEAR SIR:— At the close of my fifth year I have the honor of submitting to you the following report. Of the graduates, twenty-two are in situations, besides a number of others who have left the school before the completion of the course, to finish their apprenticeship in mills as they have received offers of places. In my last report, it was stated that designers for silk and woollen goods must understand weaving, and the art of putting a design on the loom, During the past year we have established such a course; and the looms now in possession of the department have been presented, one by the Lewiston Machine Co. of Lewiston, Me; one by the Bridesburg Manufacturing Co. of Philadelphia; one, an English loom, by Mr. Edward A. Brigham of Boston; and two by Mr. George Crompton of Worcester, one a twenty-harness and four-shuttle loom, and one an improved Jacquard pattern-loom, expressly designed, and built for the department. Messrs. Mudge, Sawyer & Co. have also kindly furnished us with the needed cotton and woollen yarns.

The object of this department is not simply to teach weaving, but to give the student a general idea of the way in which all woven fabrics are made, and to teach him to dissect any sample of cloth, and to reproduce it upon the loom, as well as to exhibit his own designs in the woven fabric. The following is a general outline of the course, which is in the immediate charge of Mr. A. D. Blodgett.

The first five lessons are devoted to learning the names of the various parts of the loom, and the function of each, the

drawing in, and mending of, the warp-threads, the filling of the shuttle, the oiling, the starting and the stopping of the loom, and the weaving of a simple cloth with two or three harnesses and one shuttle.

The sixth lesson is devoted to putting the warp into the loom, hanging the harnesses, and setting the reed.

The seventh lesson teaches the running of a loom with eight to twelve harnesses and one or two shuttles.

The five following lessons are devoted to designing and weaving patterns upon an eight-harness loom running four shuttles.

The eight following exercises are upon designing, setting up, and weaving patterns upon a twenty-harness loom and four shuttles.

Two lessons upon drawing in warps from drawing drafts made by the student. The work done in these two lessons is put upon the loom and woven.

The next eight lessons are upon an improved Crompton-Jacquard loom, consisting of designing, setting up, drawing in, and weaving various patterns.

The following is a list of the pupils who are now in situations: —

James L. Folsom . . .	Hartford Carpet Co.	
Alex. Johnson . . .	Pacific Mills . . .	Boston.
Carroll S. Faunce . . .	“ “ . . .	New York.
Sam'l Hudson . . .	“ “ . . .	Lawrence.
Everett Anthes . . .	Manchester Print Co.	Boston.
Mary Jefferson . . .	“ “ . . .	“
Elizabeth Mendum . . .	“ “ . . .	“
Chas. H. Cowdrey . . .	Oriental Print Co. . .	“
Wm. Schroeder . . .	“ “ . . .	“
Edwin Foster . . .	“ “ . . .	“
Addie S. Bartlett . . .	“ “ . . .	“
Caroline Egerton . . .	“ “ . . .	“
Caroline A. Stafford . . .	“ “ . . .	“
Minnie E. Ricker . . .	Hamilton Print Co. . .	“
Harriet A. Parker . . .	Roxbury Carpet Co.	

Howard G. Hinckley . . .	Merrimac Print Co. . .	Boston.
S. R. Eaton	" " . . .	"
Edgar Eames	" " . . .	"
Chas. H. Underwood . . .	" " . . .	"
Henry Symmes	" " . . .	"
Reuben Winslow	" " . . .	"
Frank Hyde	" " . . .	"
Chas. A. Washburn	Sanford's Carpet Mills	New York.
Eva M. Close	Forbes' Lithograph Co.	Boston.
Henry P. Mabile	American Print Co. . .	New York.
Annie D. Stimers	Sprague Print Co. . .	"
John H. Tarbell	Donnell Manufac. Co.	
Edward Williams	Lithographer . . .	Boston.
Henry Morse	Carpet Mills . . .	Maine.

Respectfully submitted,

CHARLES KASTNER, *Director.*

MEMBERS OF THE SOCIETY OF ARTS
OF THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
MARCH 1, 1878.

HONORARY MEMBER.

* Prof. Daniel Treadwell, Cambridge, Mass.

LIFE MEMBERS.

Allen, Stephen M. . . Boston.	Hemenway, Mrs. M. . . Boston.
Amory, William . . . "	Hoadley, J. C. . . . Lawrence.
Atkinson, Edward . . . "	*Huntington, Ralph . Boston.
Baker, William E. . . . "	Johnson, Samuel. . . . "
*Bancroft, E. P. . . . "	Kidder, Henry P. . . . "
*Beebe, James M. . . . "	Kuhn, Geo. H. "
Bowditch, J. I. "	*Lawrence, James "
Bowditch, Mrs. J. I. . . . "	Lee, Henry "
Brimmer, Martin "	*Lee, John C. "
Browne, C. Allen "	* Lee, Thomas "
Bullard, W. S. "	Lee, Thomas J. "
Colby, Gardner "	Little, James L. "
Cummings, John . . . Woburn.	Lowell, John A. "
Dalton, Chas. H. . . Boston.	Lyman, Geo. W. "
Davenport, Henry "	Mathews, Nathan "
Dupee, James A. "	*McGregor, James "
*Edmands, J. Wiley. . . . "	Mudge, E. R. "
*Eldredge, E. H. "	Nichols, Lyman "
Emerson, George B. . . . "	Norcross, Otis "
Endicott, Wm., Jr. . . . "	*Pierce, Carlos . . . Canada.
Fay, Joseph S. "	Preston, Jonathan . Boston.
Fay, Mrs. Sarah S. . . . "	Pratt, Mrs. William "
Forbes, John M. "	Pratt Miss "
Forbes, Robert B. "	Richardson, Geo. C. "
Foster, John "	*Richardson, J. B. "
Gaffield, Thomas "	Rogers, Henry B. "
*Gardner, G. A. "	Rogers, William B. "
Gardner, John L. "	Ross, M. Denman . . W. Roxbury.
Gookin, Samuel H. "	Ross, Waldo O. "
*Grant, Michael "	Ruggles, S. P. . . . Boston.
Greenleaf, R. C. "	
Grover, Wm. O. "	

* Deceased.

*Savage, James . . Boston.
 Sayles Henry "
 Sayles, Mrs. Willard "
 *Sears David "
 Shaw, Mary S. "
 *Skinner, Francis "
 *Stetson, Joshua "
 Thayer, Nathaniel "
 Thorndike, John H. . . . "

Tobey, Edward S. . . Boston.
 *Turner, J. M. . . . "
 *Upton, George B. . . . "
 Wales, Geo. W. "
 Wales, T. B. "
 Wales, Miss "
 *Whitney, Joseph "
 Wolcott, J. H. "

ASSOCIATE MEMBERS.

Adams, James . . . Charlestown.
 Adams, Joseph H. . . Boston.
 Amory, T. C. "
 Anderson, Luther W. Quincy.
 Appleton, Thos. G. . . Boston.
 Atkinson, Wm. P. . . . "
 Austin, Edward "
 Batchelder, John M. Cambridge.
 Beal, James H. . . . Boston.
 Bender, Richard W. . . . "
 Bigelow, A. O. "
 Bigelow, Jacob "
 Bishop, Chas. J. "
 Bond, George W. . . W. Roxbury.
 Bond, W. S. "
 Bouvé, T. T. . . . Boston.
 Bowditch, Wm. I. . . Brookline.
 Browne, Causten . . Boston.

Cabot, Samuel "
 Carpenter, Geo. O. . . . "
 Carruth, Charles "
 Clapp, Wm. W. "
 Clinch, John M. "
 Cummings, Nath'l "
 Curtis, Frederick "
 Davis, Barnabas "
 Delano, Jos. C. . . New Bedford.
 Denny, Henry G. . . Boston.
 Dewson, F. A. "
 Dix, John H. . . . Boston.
 Dresser, Jacob A. . . . "

Eastman, Ambrose "
 Farmer, Moses G. . . . "
 Flint, Charles L. . . . "
 Foss, L. Bacon "
 Francis, James B. . . Lowell.
 Fuller, H. Weld . . . Boston.
 Gardner, James B. . . . "
 Gibbens, Joseph M. . . . "
 Grandgent, L. H. . . . "
 Guild, Chester "
 Guild, Henry "
 Hall, Thomas "
 Hammond, George W. . . . "
 Haven, Franklin. "
 Hayes, S. Dana "
 Heard, John T. "
 Henck, John B. . . . Brookline.
 Henshaw, John A. . . Cambridge.
 Hewins, Edmund H. Boston.
 Holmes, O. W. "
 Homans, C. D. "
 Hubbard, Charles T. . . . "
 Hyde, George E. "
 Hyde, Henry D. "
 Jackson, J. B. S. "
 Jasper, Gustavus A. . . . "
 Jenks, Lewis E. "
 Kehew, John "
 Kneeland, Samuel "

- Lamson, Chas. D. . . Boston.
 Langley, H. P. . . "
 Lanza, Gaetano . . . "
 Lawrence, A. A. . . "
 Lee, Francis L. . . "
 Leuchars, R. B. . . "
 Lewis, Charles W. . . Charlestown.
 Lewis, Wm. K. . . Boston.
 Lincoln, F. W. . . "
 Little, James L., Jr. . . "
 Little, John M. . . "
 Lothrop, Sam'l K. . . "
 Lowe, N. M. . . "
 Lowell, John . . . "
 Lyman, Theodore . . . Brookline.

 Mansfield, A. K. . . Cambridge.
 Markoe, G. F. H. . . Boston.
 Mason, Robert M. . . "
 May, F. W. G. . . Dorchester.
 May, John J. . . "
 McMurtrie, Horace . . Boston.
 McPherson, W. J. . . "
 Merrill, N. F. . . Cambridgep't.
 Montgomery, Hugh . . Boston.
 Moore, Alex. . . "

 Newell, John . . . "
 Nichols, James R. . . Haverhill.
 Norton, Jacob . . . Boston.

 Ordway, John M. . . W. Roxbury.

 Page, W. H. . . Boston.
 Parsons, Wm. . . "
 Paul, J. F. . . "
 Peabody, O. W. . . "
 Perry, O. H. . . "
 Philbrick, Edward S. . . "
 Philbrick, John D. . . "
 Pickering, E. C. . . "
 Pickering, H. W. . . "
 Pope, Edward E. . . "
 Prang, Louis . . . "
 Putnam, J. P. . . "

 Rice, Alexander H. . . Boston.
 Richards, R. H. . . "

 Ritchie, E. S. . . Brookline.
 Robbins, James M. . . Milton.
 Robinson, J. R. . . Boston.
 Rotch, Benj. S. . . "
 Ruggles, John . . . "
 Runkle, John D. . . Brookline.
 Russell, LeBaron . . Boston.

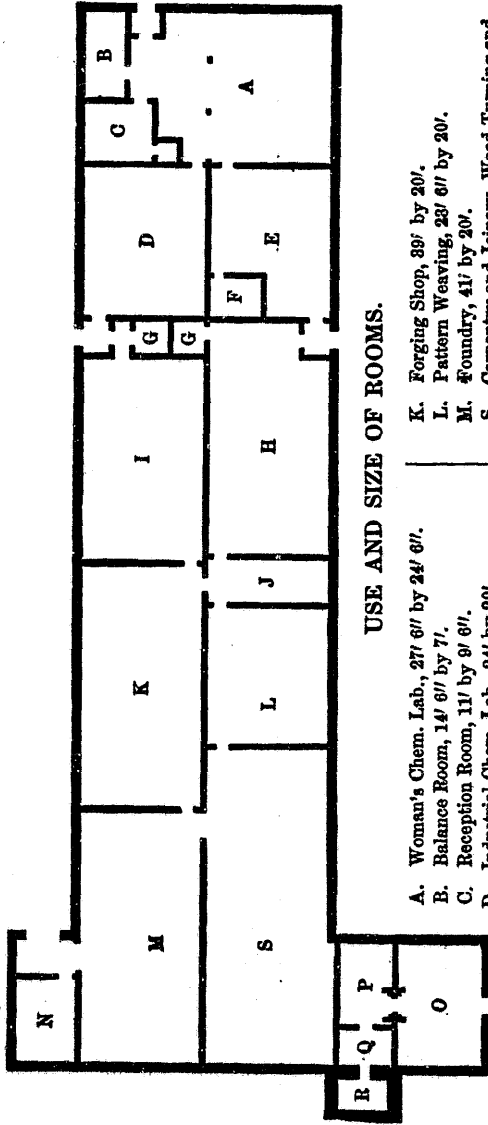
 Salisbury, D. Waldo . . "
 Sawyer, Edward . . Newton.
 Sawyer, Timothy T. . . Charlestown.
 Sears, Philip H. . . Boston.
 Sherwin, Thos. . . Dedham.
 Shimmin, Chas. F. . . Boston.
 Shurtleff, A. M. . . "
 Sinclair, Alex. D. . . "
 Smith, Chauncy . . . Cambridge.
 Sprague, Chas. J. . . Boston.
 Stevens, Benj. F. . . "
 Sturgis, John H. . . "
 Sullivan, Richard . . "

 Thompson, Wm. H. . . "
 Tufts, John W. . . "

 Upham, J. B. . . "
 Urbino, S. R. . . "

 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.
 Watson, R. S. . . Milton.
 Watson, Wm. . . Boston.
 Weston, David M. . . "
 Whitaker, Channing . . "
 Whitman, Herbert T. . . "
 Whitmore, Wm. H. . . "
 Whiton, David . . . "
 Wilder, Marshall P. . . Dorchester.
 Williams, H. W. . . Boston.
 Winthrop, Robert C. . . "
 Wight, John H. . . "
 Wyman, Morrill . . . Cambridge.

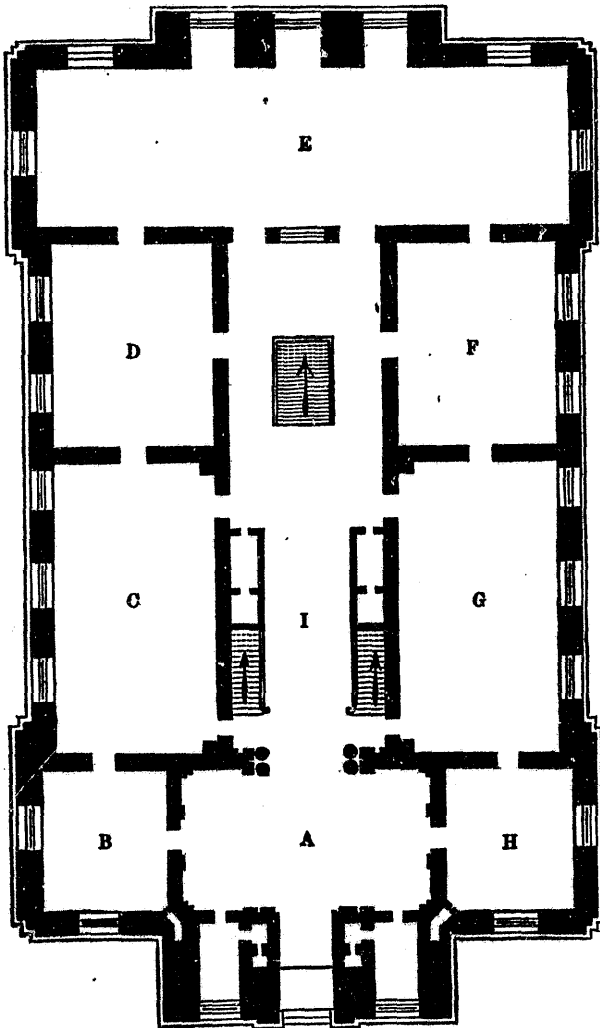
NEW TEMPORARY BUILDING FOR SHOP-WORK AND CHEMISTRY.



USE AND SIZE OF ROOMS.

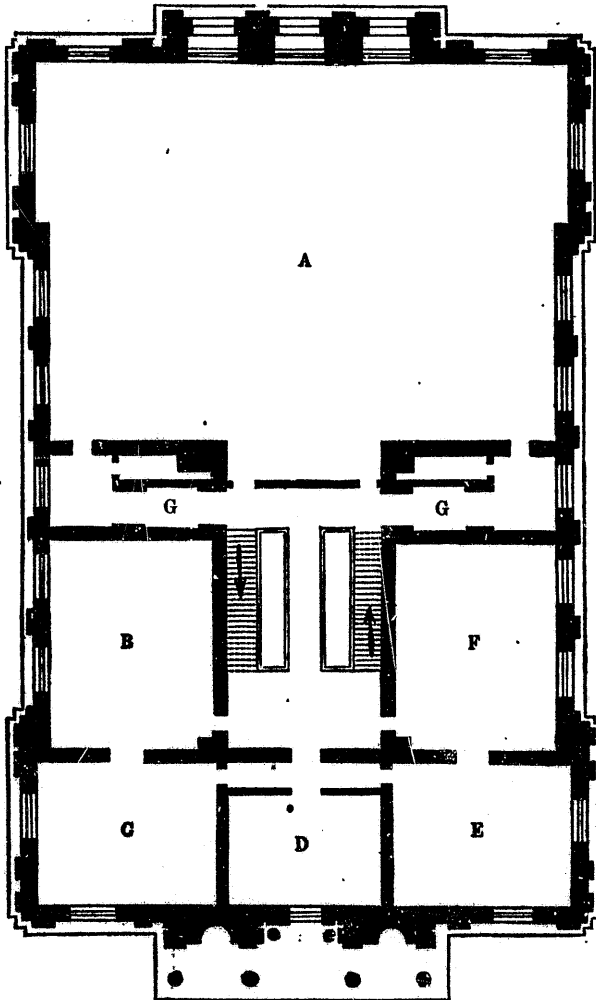
- | | | | |
|------|--|----|--|
| A. | Woman's Chem. Lab., 27' 6" by 24' 6". | K. | Forging Shop, 39' by 20'. |
| B. | Balance Room, 14' 6" by 7'. | L. | Pattern Weaving, 23' 6" by 20'. |
| C. | Reception Room, 11' by 9' 6". | M. | Foundry, 41' by 20'. |
| D. | Industrial Chem. Lab., 24' by 20'. | S. | Carpentry and Joinery, Wood Turning and
Pattern Making, 50' by 20'. |
| E. | Microscopical Lab., 24' by 20'. | N. | Was Room, 18' 6" by 9' 6" |
| F. | Dark Room, Spectroscope. | O. | Organic Chem. Lab., 1' by 14'. |
| G.G. | Tool and Stock Rooms, 6' by 6'. | P. | Special Work Room, 13' by 9' 6". |
| H. | Machine Tool Shop, 37' by 20'. | Q. | Store Room, 9' 6" by 6'. |
| I. | Chipping and Filing Shop, 32' 6" by 20'. | R. | Ice Chamber, 8' by 5'. |
| J. | Engine Room, 20' by 7' 9". | | |

FIRST STORY FLOOR.



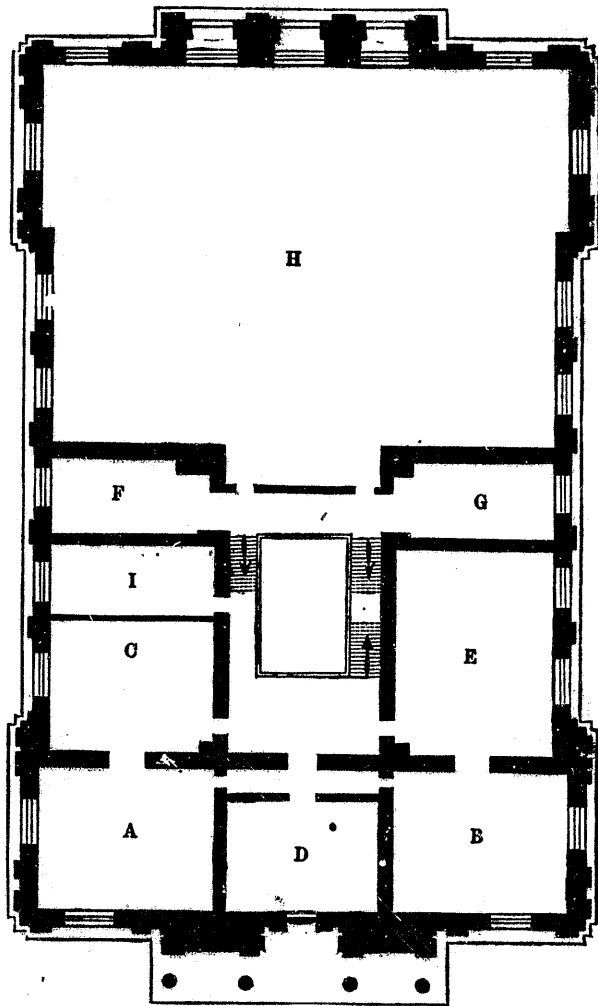
- A. Entrance Hall, 42' 2" by 25' 0".
 B. President's Office, 25' 0" by 22' 11".
 C. Physical Lecture Room, 49' 7" by 28' 3".
 D. Physical Laboratory and Apparatus Room, 35' 8" by 28' 3".
 E. Physical Laboratory and Apparatus Room, 92' 0" by 27' 10".
 F. Geological Lecture Room, 35' 8" by 28' 3".
 G. Society of Arts Room, 49' 7" by 28' 3".
 H. Secretary's Office, 25' 0" by 22' 11".
 I. Stairway Hall, 87' 3" by 28' 10".

SECOND STORY FLOOR.



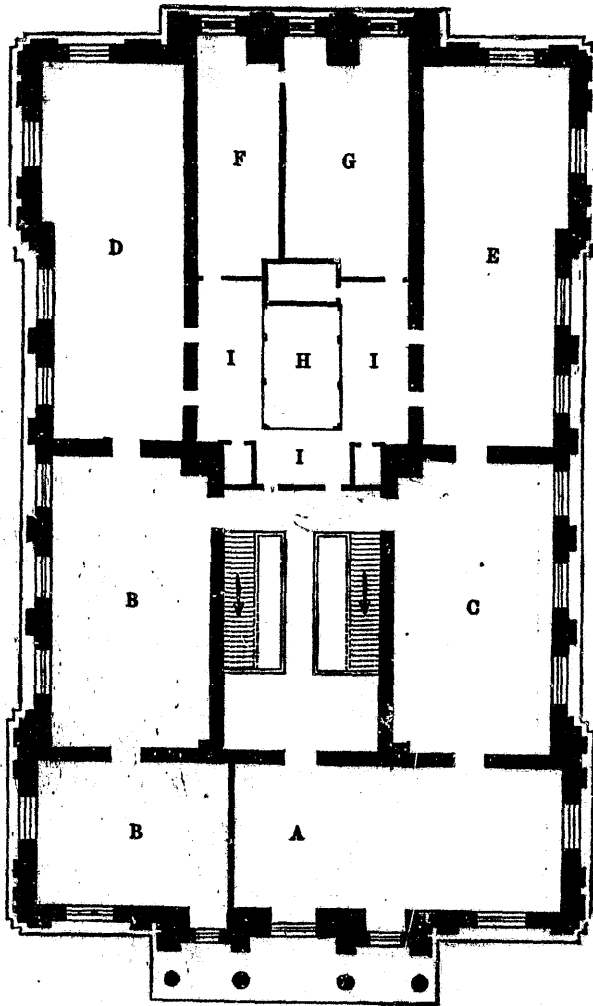
- A. Huntington Hall, 32' 0'' by 65' 5''.
- B. Mathematical Lecture Room, 34' 9'' by 28' 8''.
- C. Civil Engineering Lecture Room, 32' 2'' by 25' 0''.
- D. Modern Language Lecture Room, 28' 2'' by 20' 6''.
- E. English Lecture Room, 32' 2'' by 25' 0''.
- F. Mathematical and Astronomical Lecture Room, 34' 9'' by 28' 8''.
- G. G. Passageways to Huntington Hall.

HALF STORY FLOOR.



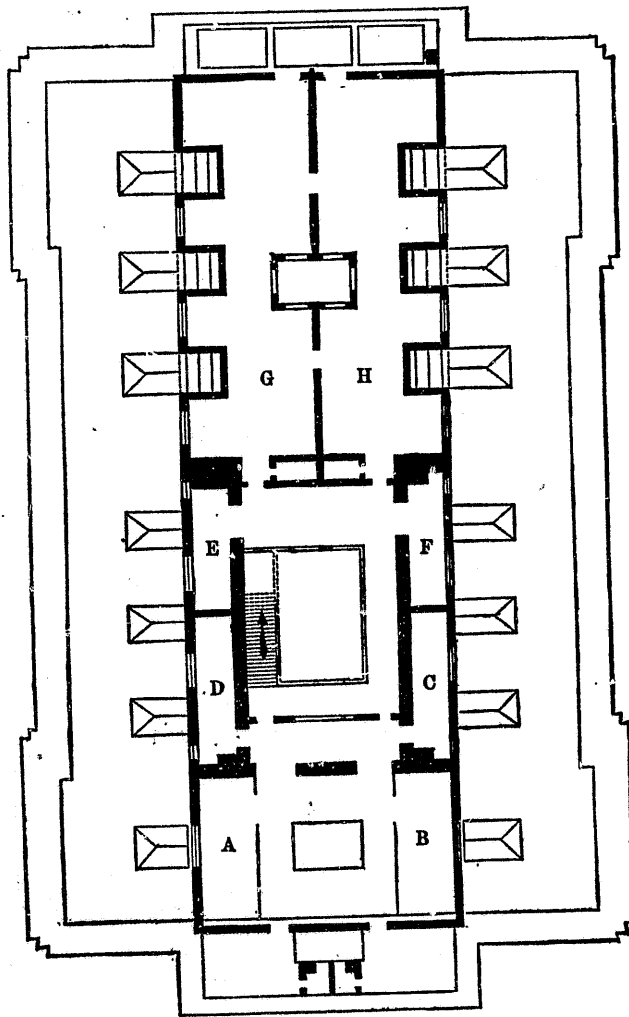
- A. Architectural Museum, 32' 2'' by 25' 0''.
- B. Architectural Library and Study Room, 32' 2'' by 25' 0''.
- C. Architectural Museum, 28' 3'' by 20' 9''.
- D. Natural History Lecture Room, 26' 2'' by 20' 6''.
- E. Prof. Richards' Lecture Room, 34' 9'' by 28' 3''.
- F. Prof. Atkinson's Study, 28' 3'' by 14' 2''.
- G. Prof. Hunt's Study, 28' 3'' by 14' 2''.
- H. Huntington Hall.
- I. Prof. Howison's Study, 28' 3'' by 14'.

THIRD STORY FLOOR.



- A. Reading and Study Room, 62' 0" by 25' 0".
 B. B. Civil Engineers' Drawing Rooms, 49' 7" by 28' 3".
 C. First Year's Drawing Room, 49' 7" by 28' 3".
 D. Mechanical Engineers' Drawing Room, 65' 5" by 28' 0".
 E. First Year's Drawing Room, 65' 5" by 28' 0".
 F. Mechanical Engineering Lecture Room, 37' 0" by 17' 0".
 G. Mathematical and Descriptive Geometry Lecture Room, 37' 0" by 26' 0".
 H. Model Room, 21' 0" by 18' 0".
 I. I. I. Passage way

FOURTH STORY FLOOR.



- A. Prof. Lanza's and Prof. Whitaker's Study, 24' 5" by 11' 6".
 B. Prof. Henck's Study, 24' 5" by 11' 6".
 C. Prof. Osborne's Study, 24' 9" by 7' 6".
 D. Prof. Richards's and Prof. Nichols's Study, 28' 0" by 7' 0".
 E. Instructors Handy and Waitt's Study, 21' 6" by 7' 6".
 F. Prof. Ware's Study, 24' 9" by 7' 6".
 G. Architects' Drawing Room, 65' 5" by 21' 10".
 H. Lowell School of Design, 65' 5" by 21' 10".