Technical Paper No. 219.

Technical Education
in relation to
Railways in America

BY

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April 1921.

G. RICHARDS,
Chief Engineer with the Railway Board.

Technical Education in Relation to Railways in America.

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TECHNICAL EDUCATION IN RELATION TO RAILWAYS IN AMERICA.

I. The broad term "technical education" may be used to cover and include the entire range of instruction extending from the craft training for a particular trade to the scientific study of the engineering and economic problems which concern the executive and administrative grades of the railway service.

Drawing a certain distinction between "training" as connoting instruction combined with practice in a given employment, and "education," as referring here more specially to mental development, and the spread of knowledge as distinct from direct personal experience, we may classify the main divisions of the process under the four headings:—

(*i*) Craft Training,
(*ii*) Elementary Technical Education,
(*iii*) Specialised Technical Training and Education,
and
(*iv*) Higher Technical Education.

This classification needs some further explanation—

(*i*) By "craft training" is meant the ordinary manual practice and workshop experience afforded to apprentices, apart from the technical school courses.

(*ii*) By "elementary technical education" is meant, here, the Technical school, teaching mechanical drawing and the rudiments of practical mathematics, mechanics, heat and steam.

(*iii*) By "specialised technical training and education" is intended a form of instruction and improvement that has not yet developed to any material extent in India. It might be described as an extension of the Technical School course, more especially for the benefit of employés past the apprenticeship stage, and it is applied to the practical development of intelligence and skill in every-day operations.

Illustrations of this process may be found in the special instruction of firemen on the road, or of men working machine tools in the shops—but these are merely casual examples of a system that may be applied obviously to almost any occupation. "Training" and "education" are combined in this case, because the imparting of certain elementary scientific facts and natural laws at this stage necessarily proceeds to a great extent concurrently with the improvement of manual or mechanical efficiency. The specific object is in fact to exhibit the practical application of certain knowledge to the common daily operations of the workshop, the running shed, and the road.

(*iv*) By "Higher Technical Education" we mean generally, on the engineering side, those deeper and more exacting studies in modern science and its applications that are necessary for the professional engineer as distinct from the skilled mechanic.

In the case of railways, however, we must include in "Higher Technical Education" additional provision for subjects not normally comprised in the studies of the civil and mechanical engineer, and we must further extend these studies to include specialised branches of enquiry which are peculiar to railways.

It might reasonably be added that there is no branch or department of the railway service from which the science of railway economics and railway operation as a whole should be excluded. Railway location is a problem that is dealt with but once in the existence of most lines; but it is one which involves data which can be derived only from open-line experience and deductions, and it governs all subsequent operation and development.

In the actual operation of open lines of railway, however, traffic conditions are subject to alteration ; and the efficiency of operation is determined on the material side, by a correct appreciation of the same principles that guide the location engineer—with this difference, that where the latter adjusts his line to suit a hypothetical set of traffic conditions, the operating officer must take his road as he finds it and regulate his equipment to suit the changes in traffic demands as the country developes.

These illustrations, however, merely indicate the fringe of a variety of elated problems that are within the province of the railway officer as such, and not simply as a civil or mechanical engineer or as a traffic officer.

It is proposed in the following pages to sketch the lines upon which progress is made in the training and education of railwaymen, from the apprentice grades upwards, in the United States and in Canada.

II. The problem of devising an effective system of training and education for railway apprentices and employés commenced to receive very serious attention on certain Canadian and American lines some years ago, the outcome, in some cases at least, of the fact that the supply of skilled men was failing in proportion to the development of new lines and heavier demands. This was the position by which the Grand Trunk Railway was faced; and the apprenticeship system that was then re-organized and developed on that railway was specifically designed to cope with the difficulty.

The form of apprenticeship adopted on the Grand Trunk Railway was the result of much careful examination of the whole question—the need to be met, the material to be worked on, and the means likely to be effective. The results are said to have been very satisfactory on both sides. The system is described briefly hereunder.

All apprentices are indentured to Machinist's trade for five years' and to Blacksmith's, Boiler-maker's, or other trades for four years. It was arranged some years ago for a sum of 5 cents per day to be deducted from the wages of each apprentice, and the total amount to be returned to him at the expiration of his apprenticeship, with an addition of $ 25 as a bonus if his services had been entirely satisfactory.*

Candidates must be within the ages of 15 and 18 years, and are required to make their applications direct to the Master Mechanic or to the General Foreman, as the case may be, and they are medically examined to assure the head of the department that they are healthy and likely to be able to follow up the trade on completion of their term of apprenticeship.

Each candidate has then to pass a simple examination in the Master Mechanic's or General Foreman's Office. At this, he must be able to read extracts from instructions at the end of the working time-table, at a distance of 30 inches, and he must be able to hear the ticking of an ordinary open-face watch at a distance of 4 feet.

He is further required to write a letter from dictation, applying for employment in the shops; this as a test of handwriting and spelling. He is also given an arithmetical test involving multiplication and division.

The applicant is required to write this examination out on foolscap paper, and if satisfactory it is copied by him into the record book kept in the Master Mechanic's or General Foreman's Office, so that a complete record of the boy's ability is on the file from the day he first enters the service.

After passing this preliminary or entrance examination the apprentice is sent out to the boiler, blacksmith or coppersmith shop, or other shop as may be required. He stays there from six to nine months, and "is taught to be active and obedient and to prepare himself for future promotions." The words quoted are from a note over the signature of the Superintendent of Motive Power of the Grand Trunk Railway.

III. Concurrently with improvements in the selection and craft training of apprentices, however, a scheme of education was presently evolved such

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*The figures given relate to the pre-war period. The corresponding rates of pay were 8, 10, 12, 15 and 17 cents per hour for 1st; 2nd; 3rd; 4th; and 5th year apprentices, respectively.

that practically the whole staff organization of the Grand Trunk Railway Motive Power Department centred on the Railway's apprenticeship system, with the result that, after it had been steered through a few years of nursing and development, the numbers of new posts created by the rapid expansion of the railway system were being filled practically entirely from the ranks of its own employés, and filled by competent men.

Passing briefly over the evolutionary period, it may be noted that in 1899 a compulsory drawing class, two nights per week, from October to April each year, was first instituted for apprentices by the Company. In the following year the apprentices were graded into classes for this purpose, and special evenings were set apart, in addition, for the instruction of apprentices in the principles of valve-setting, screw-cutting, and so forth.

In 1901, a system of examinations was introduced, that each boy had to pass before promotion from one machine to another or from one part of a shop to another, as well as before receiving an advance in pay. A small text-book was issued in this connection with practical questions and answers on all the different classes of work in the shop, practically taking the boy through a five years' course.

About 1904 this system, which had hitherto been applied only locally, was extended over the entire Motive Power Department of the Grand Trunk System and was then handled entirely by the Company from rules drafted by the Superintendent of Motive Power.

Up to this point, it will be observed, action had been confined to compulsory instruction in mechanical drawing, and examinations in workshop processes and practice.

In 1905-6, practical mechanics was introduced, one night per week being given to each subject by every apprentice instead of two nights to mechanical drawing. The examination system was expended accordingly, a unified system was applied to the whole railway, inter-station competition was introduced, with prizes, and to prevent any doubts about possible favouritism outside examiners were obtained to prepare the papers and correct the results.

A "capital prize" of $ 25,00 is awarded, and a second of $ 7,50, in each of the two subjects for the whole line, in addition to which a prize of $ 4,00 is awarded in each station for each of the two subjects, for each year of apprenticeship, 1st ; 2nd ; 3rd ; 4th ; and 5th. In addition to these cash prizes, certificates are given to successful classes and individuals at different stations. Finally there are awards of a certain number of free scholarships in engineering at McGill University.

The competition for these awards is held at a different place each year, and the boys who enter have all expenses paid.

The subjects now taught in the Grand Trunk Railway Schools extend from simple arithmetic and mechanical drawing, to machine design, mechanics, and fairly advanced mathematics. The courses have been carefully graded; and the Railway is legitimately proud of the fact that numerous requests have been received from other railways, and from some of the largest technical colleges, for complete sets of the Grand Trunk Railway instruction books.

The entire cost of education at these training schools is borne by the Grand Trunk Railway, who furnish all equipment and engage the instructors.

The Grand Trunk Railway Apprenticeship training and educational system described above may serve as an example of the general lines on which some of the best railways in Canada and the United States are approaching the question of the supply of efficient men.

IV. We may turn now to a further development, dealing with the problem of improving the personal efficiency of men at a later stage, when they have become actual full-wage-earning employés.

This phase of instruction falls under two heads (i) instruction carried out by selected railwaymen as part of the railway's own internal organization and (ii) instruction by agencies supported and encouraged by, but independent of

the railway official organization. The former class of instruction is more or less imposed on employés; the second is sought voluntarily by those who are keen to learn more about their work, and ready to pay to do so.

Under the former heading, on certain American lines definite provision is made within the departmental organization for instructing firemen on the road, for air-brake instruction, and for workshop, more particularly machine-shop operations. The men employed on such practical educational work need to be specially selected for personal intelligence and tact as much as for their actual skill, and it is necessary that they should be capable also of imparting instruction in such a manner as to reach and to stir the intelligence of others. Unless the right men are picked for this work their pay is money mis-spent.

Their designations vary. In the shops they are known generally as Demonstrators, and their job is to go into details and to devise better methods of doing jobs, where possible, as well as to instruct men on machines, or at the bench how to get out the maximum of good work with the minimum of wasted effort, and to explain the principles underlying good workshop practice.

On the road, on many lines the Road Foremen of Engines, Travelling Engineers, and Travelling Firemen, are expected to train enginemen in the practical arts of engine-handling and firing for safe and economical operation, and to instruct men in the elements of combustion and the why and the wherefore of methods and duties.

On some of the larger railway systems, well-equipped Instruction Cars are doing good service. These tour the system periodically, in charge of competent lecturers, in pursuance of a definite policy aiming at the improvement of the general standard of knowledge and skill of the employés.

Such instructional services as this, it may be noted, come under the third head of our preliminary classification "Specialised Technical Education and Training." Their main design is to increase manual or mechanical efficiency by the development of observation and intelligence in the case of the younger men, and to maintain the interest and mental alertness of older men, and thus as far as possible to check the tendency to get too much into a groove.

V. Working on similar lines, on the same material, and with the same objects, but more through special text-books and often with the valuable aid of the motion-picture, there is an institution known as the Railway Educational Bureau. This was first organized by the Union Pacific Railroad Company in 1909, and later extended to others of the Harriman Lines. In 1914, directed by Mr. D. C. Buell at the Union Pacific Headquarters, Omaha, Nebraska, it was operating under contract with some two dozen railway administration in the Western and Southern States.

It is barely possible in a note of this character to indicate at all adequately the work which this organization is tackling on the various railways with which it is connected, or the equipment which it has got together for its educational purposes. At its uttermost extensions it links in with the organizations of the individual railways, through their workshop Demonstrators and Travelling Engineers, thus getting down not only to whole groups of men but to the particular needs of individual employés, to the fireman or the man working at a machine in the shops.

It is to be observed that the Railway Educational Bureau is not a substitute for local apprenticeship schemes, but is designed to meet the needs of both older men and men of less skilled grades than those dealt with, for example under the Grand Trunk Scheme already described. Perhaps the special feature of the Bureau is the recognition of the necessity of a text-book of quite a different class from that of the ordinary "Technical School" production, in order to reach certain grades of employés. With this in view the Bureau's pamphlets* have been "written down" and illustrated to meet the special needs of the brakeman, the station helper, the telegraph messenger, the trackman or the office boy, and in fact bi-lingual and well illustrated instructional pamphlets have been issued for the use of Japanese and Chinese labour.

The nature of the pamphlets must be left with that indication of the principles on which they are drafted. The following list of general headings will give an idea of the scope of the Bureau's syllabus, it being understood that

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*For list of these pamphlets kept in library of Railway Board, Simla, see Appendix VIII (page 46).

each of these headings stands not for a single book but in many cases for a graduated and classified series of pamphlets dealing in simple terms with the elements and groundwork of each subject:—

Air Brake.
Locomotive.
Mechanical Drawing.
Machine Design.
Mechanical Engineering.
Gas Engine.
Shop Practice.
Tool Making.
Pipe Fitting.
Plumbing.
Railroad Operation.
Block Signal.
Interlocking.
Station work.
Refrigeration.
Traffic.
Track Work.
Concrete.
Surveying.
Mapping.
Mathematics.
Electrical.

Ambitiously comprehensive as some of these general headings may appear the actual contents of the individual pamphlets seem to be admirably drafted and arranged to suit those grades of employés for whose use each pamphlet is primarily intended.

VI. We may turn now to the higher technical education, or graduates courses, intended to provide a sound basis upon which to build up experience to fit men for executive and administrative appointments.

The University of Illinois is considered to provide more complete and more adequate facilities for instruction for railway service than are available elsewhere, and it offers opportunities for research that are possibly unrivalled. It is proposed briefly to describe what is being done at Urbana in the State of Illinois.

The University of Illinois includes Colleges of Literature and Arts, Engineering, Science, Agriculture, Law, Medicine and Dentistry, and Schools of Music, Pharmacy, Education, and Railway Engineering and Administration. There is an Agricultural Experiment Station attached to the College of Agriculture, and an Engineering Experiment Station in connection with the College of Engineering "to promote engineering research and to further the engineering and manufacturing interests of the State."

The total number of students at the University is rather over 5,000, and of instructors about 550. These figures are mentioned in order to give an idea of the general scope and importance of the University as a whole.

The College of Engineering first offered a course in railway mechanical engineering in the year 1900. It has since organized laboratories, devised equipment, and developed lines of investigation suited to the needs of students who wish to specialise in work common to the practice of steam railways.

In January 1906, in further recognition of the necessity for specialised training, there was established a School of Railway Engineering and Administration, the function of which is defined as the co-ordination of the various agencies of the University which by instruction or research contribute to the railway interest, and to develop new lines of work. The activities of the School include a series of courses in railway engineering, administered by the College of Engineering, and of courses in railway traffic, railway accounting, and railway administration, administered by the Department of Economics of the College of Literature and Arts. The School of Railway Engineering and Administration thus provides for those who wish to prepare themselves for work in the engineering equipment, financial, traffic or operating departments of either steam or electric railways.

The following five courses are offered:—

1. Railway Civil Engineering.
2. Railway Electrical Engineering.
3. Railway Mechanical Engineering.
4. Railway Traffic and Accounting.
5. Railway Transportation.

Each course occupies four years, of which, in the case of all three classes of engineering student, the first two years are devoted to the fundamental sciences, and the two latter years to the more specialised study of the particular branch which each student is intending to follow, the fourth year being that of practically complete specialisation in railway subjects. The time is divided between the class-room, the laboratory and field practice or road tests.

The courses in railway traffic and accounting and in railway transportation aim to prepare men for service in all departments of railway work other than the engineering and legal. The course in traffic and accounting may be considered the general course in railway administration. A knowledge of the fundamentals of political economy and finance is required in this course, and the student is familiarised also with the leading features of modern industrial and commercial organization. An adequate training in cost and industrial accounting, trustee and railway accounting and auditing is required. It is in this course that the student without any special predilection for the operating side of railway service will naturally register.

The course in transportation, while still demanding considerable economic training, includes certain courses of the College of Engineering. Theoretical and applied mechanics, and short elementary courses in chemistry and physics, steam engineering, surveying and graphic statics are included, not as a training in engineering but with the object of making students acquainted with general principles underlying the work of the maintenance of way and motive power departments. Train Masters and division Superintendents, men not necessarily trained engineers, it is claimed will be able to discharge their duties all the more efficiently by reason of such training.

The more specialised railway work of both the traffic and accounting and the transportation courses commences in the third year, with the history of the development of the railway system of the United States, and a review of the present methods of internal organization. This is followed by a course dealing with important economic problems connected with railway finance, traffic and political relationship. This training is made use of in studying the railway situation in certain foreign countries. Concurrently with these courses, the student takes up in class the study of the organization and methods of the freight and passenger traffic and operating departments.

In the fourth year each student concentrates on a particular problem of railway policy or operation, and embodies his work in the form of a thesis. In the transportation course the student is required to include a course on locomotives and one on railway tests.

Degrees are granted to successful students in each of the three railway engineering and two railway administration courses.

Advanced courses dealing with locomotive design and operation, electric railway practice, and the economics of railway location, are provided for graduates of Illinois University and of other institutions. Further provision is made in the Department of Economics for those who have the time and ambition to proceed to the Doctor's degree.

VII. It will not perhaps be considered out of place to detach the question of Experimental and Research Work from the general description of the

University work, in order to include the valuable work done in the University Laboritories and test cars with the corresponding investigations that are being carried out elsewhere.

Research work, it may be objected, does not strictly come under the heading of Technical Education as usually understood, and any description of what is being done in that direction in America or elsewhere should on those grounds no doubt be dealt with in a separate Note.

The plea is advanced here, however, that "technical education" is a process which continues throughout our active service, unless we stagnate. Essentially are the results of practical researches a necessary study for technical officers even of senior standing. It is only logical, therefore, to include in this Note on Technical Education a reference to systematised experimental work such as is being carried out by various agencies in America, so far as such work relates to railway problems.

Research work is the care of three distinct kinds of interests; (i) the railways, who require the results for their own immediate purposes, (ii) the technical institutions whose function it is to promote investigations and to collate and disseminate their results; and (iii) the Universities whose primary object is instructional.

In the end, all the results, or all such results as he cares to utilise, come to the railwayman, whose work it is to apply them to the improvement of his methods or of his equipment as the case may be.

He is concerned with various problems, but—whether it be the question of what a locomotive can pull under any given set of conditions, and all that that question implies, or whether it be the holding power of a dog-spike, the best way to use a given class of fuel, or the velocity of discharge from a water column, or any other of the numberless questions bearing on the cost of building and running a railway—outside his own limited experiences, when it comes to facing new conditions he must depend on the measured observations of others, if obtainable, or failing that, must guess.

Of the three interests referred to above, experimental plant is directly operated only by the first and third; the railways themselves, and the Universities. There is no need to describe the commoner classes of equipment for testing materials or carrying out ordinary "heat balance" tests, and so forth. But special plant in connection with specifically railway problems may be mentioned, and a reference to some of the published results also may not be out of place.

The latter can best be indicated by a selected list of Bulletins and Papers which will illustrate the general nature of the investigations taken in hand from time to time by various agencies. Such a list is given herewith:—

1. Effect of Scale on the Transmission of Heat through Locomotive Boiler Tubes.	(University of Illinois, 1907.)
2. Dry Preparation of Bituminous Coal at Illinois Mines	Ditto 1916.)
3. An Investigation of Twist Drills.	Ditto 1917.)
4. Resistance to Flow through Locomotive Water Columns	Ditto 1911.)
5. Effects of Storage upon the Properties of Coal	Ditto 1917.)
6. A Study of the Forms in which Sulphur occurs in Coal	Ditto 1919.)
7. Steaming Tests of Coals, and Related Investigations	Ditto 1904-08.)
8. Locomotive Tests, Louisiana Purchase Exposition	(Penn. Railroad 1904.)
9. Brake Tests	(Penn. Railroad 1913.)
10. Test of a Class K 2 S A. Locomotive	(Penn. Railroad 1914.)
11. High Steam Pressures in Locomotive Service	(W. F. M. Goss, 1908).
12. Superheated Steam in Locomotive Service	(Ditto 1912).

13. A New Analysis of Cylinder Performance	(University of Illinois, 1912.)
14. Passenger Train Resistance	(Ditto 1918.)
15. Resistance on Curves of a 28-Ton Electric Car	(Ditto 1916.)
16. Effects of Cold Weather upon Train Resistance and Tonnage Rating	(Ditto 1912.)
17. Steam Consumption of Locomotive Engines	(Ditto 1913.)
18. Laboratory Tests of a Consolidation Locomotive	(Ditto 1915.)
19. Tests of Oxyacetylene Welded Joints in Steel Plates	(Ditto 1917.)
20. Tests to determine the Rigidity of Rivetted Joints of Steel Structures	(Ditto 1917.)
21. Analysis and Tests of Rigidly Connected Reinforced Concrete Frames	(Ditto 1918.)

VIII. Amongst an infinite variety of engineering problems open to exhaustive research for the analysis and isolation of data, there are a number which relate specifically to railways, as for example the hauling capacity of locomotives, the resistance of rolling stock under various conditions, the deterioration of coal in transit, handling and storage, the effects of unbalanced forces in locomotives of different types on track and bridgework, and so forth.

There are other problems of interest to mechanical and civil engineers in a broader sense, and yet others that affect the practice and interaction of engineers, metallurgists and chemists. And in most of these problems, one or other branch or department of the railway engineering services is interested. The number and variety of such problems, however, as are of interest to us as engineers irrespective of whether we are railway engineers or not is very great, and needs no attempt at any sort of summary here. They are matters which are normally provided for at most important technical colleges and in many commercial and government laboratories all over the world.

We may confine our attention here, therefore, to a brief review of certain distinctively railway experimental plants; and as the basis equally of effective location and of efficient operation is a correct appreciation of conditions which govern the hauling capacity and economical working of locomotives, we may consider the development and utilisation of locomotive testing plants in particular, as an outstanding example of what is implied by railway research work.

In the early days of railways, locomotive tests had for their primary object as a rule simply the investigation and improvement of various mechanical details. More recently, the endeavour has been rather to secure more accurate information about the performance of the locomotive boiler and engine and of the machine as a whole.

Road tests, however, were conducted as long ago as 1835–1840; and for certain purposes they will never be superseded by laboratory work. But road tests are expensive, and are invested with very great difficulties especially in respect of accurate measurements and observations. Conditions of the first importance are variable and uncontrollable; conclusive evidence can seldom be obtained and the isolation of different factors is impossible.

In the laboratory—for the locomotive testing plant is, in fact, a laboratory—conditions can be controlled and accurate measurements, records and observations can be made, and various component factors in engine performance can be quite definitely isolated, studied, and valued.

The first locomotive testing plant was built to the designs of Dr. W. F. M. Goss at Purdue University, United States of America in 1891. This was followed in 1894 by a temporary plant erected by the Chicago and North Western Railway under the direction of Mr. Robert Quayle, at South Kankanna, Wisconsin. The temporary plant at Kankanna was succeeded by a permanent plant erected by Mr. Quayle at the Chicago and North Western Railway Shops at Chicago.

In 1899 Columbia University followed suit with a locomotive testing plant in their mechanical engineering laboratory.

In 1904 the Pennsylvania Railroad installed what was at that time the largest and most elaborate locomotive testing plant yet produced at the Louisiana Purchase Exposition at St. Louis. This was afterwards removed to Altoona, Pennsylvania, where it is still in regular operation both for the immediate purposes of the Pennsylvania Railroad, and very often for the investigation of problems offered by other railways.

Also in 1904 there was erected a similar plant designed by MM. V. Golobolott and S. T. Smirnott, in the Putiloff Works at what was then St. Petersburg, Russia. The following year Mr. G. J. Churchword of the Great Western Railway erected a plant at Swindon. The latest plant is that at the University of Illinois, Urbana, erected in 1912-13.

The locomotive testing plant consists essentially of (i) mechanism for supporting the locomotive while permitting the wheels to revolve, (ii) means for absorbing the power developed and (iii) a dynamometer for measuring the pull exerted and serving also as an anchor. The capacity of the Illinois University dynamometer is up to a pull of 125,000 lbs. That of the Pennsylvania Railroad is up to 80,000.

There is of course a quantity of minor laboratory equipment for weighing and supplying water to the boiler and brakes, collecting and measuring waste products, means for determining accurately the total fuel lost in the exhaust gases, and so forth.

The researches carried out in these locomotive laboratories have been the means of providing much useful information respecting the causes of differences in the performances of locomotives of different types and designs, and of the relative values of different arrangements for various classes of fuels. The Pennsylvania Railroad has carried out a valuable series of experiments on superheater arrangements amongst other investigations, and that administration has applied observations obtained from their testing plant at Altoona to improvements in the design of recent classes of locomotives with very satisfactory results.

The investigations carried out by students under the direction of the professorial staff at the University of Illinois, also, has been not only of material benefit in affording the students themselves a good insight into the essential factors governing engine performance, and, by reason of road tests as well as laboratory work, an appreciation of the various conditions which bear upon the efficiency and capacity of locomotives in actual service, but those investigations have been the means of providing railways with much more complete and accurate data than was hitherto available, and have thrown light on various problems that have always presented difficulties and apparent inconsistencies in the practical results obtained in actual operation.

On the use of dynamometer cars it is unnecessary to dwell; but it is worth noting that at Illinois the students are fortunate in the possession of an electric car for experimental purposes in addition to a good dynamometer car of normal design.

In respect of other important testing equipment, the College of Engineering at Illinois University has installed a drop-testing machine, built to the specifications of the Master Car Builders Association and under those of the American Society for Testing Materials. It is designed for use in testing such material as axles, car couplers, knuckles and knuckle pins, draft gear, and rails, and is of course suitable for making impact tests of other materials.

There is installed also a Brake Shoe Testing Machine by means of which the co-efficient of friction of any shoe can be determined under different conditions of speed and pressure as well as the amount of both shoe wear and tyre wear.

It remains only to note that the results obtained from the more important investigations carried out at the Engineering laboratories is published by the University from time to time in the form of Bulletins or technical papers, each dealing with a particular series of experiments. These Bulletins are carefully prepared, and include complete descriptions of the equipment used, the methods employed, the observations made, and the conclusions arrived at.

University of Illinois Buildings, Urbana, U. S. A.

Transportation Building, University of Illinois.

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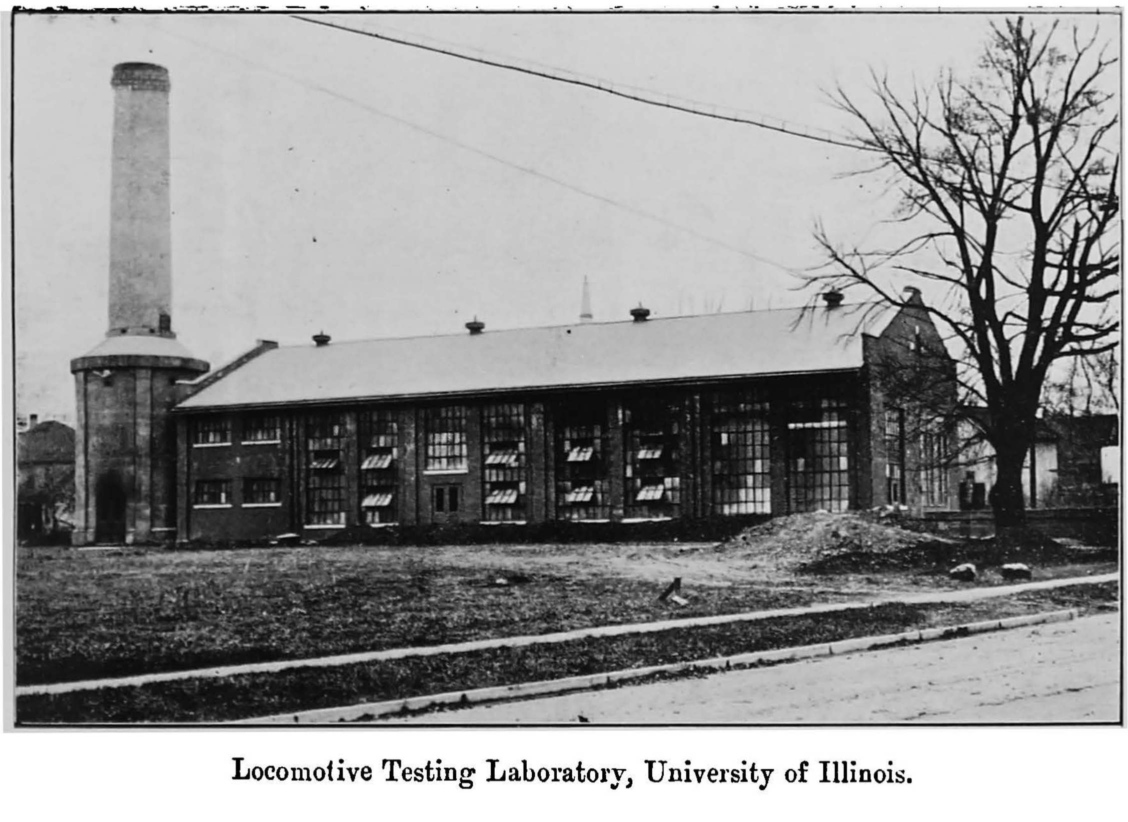
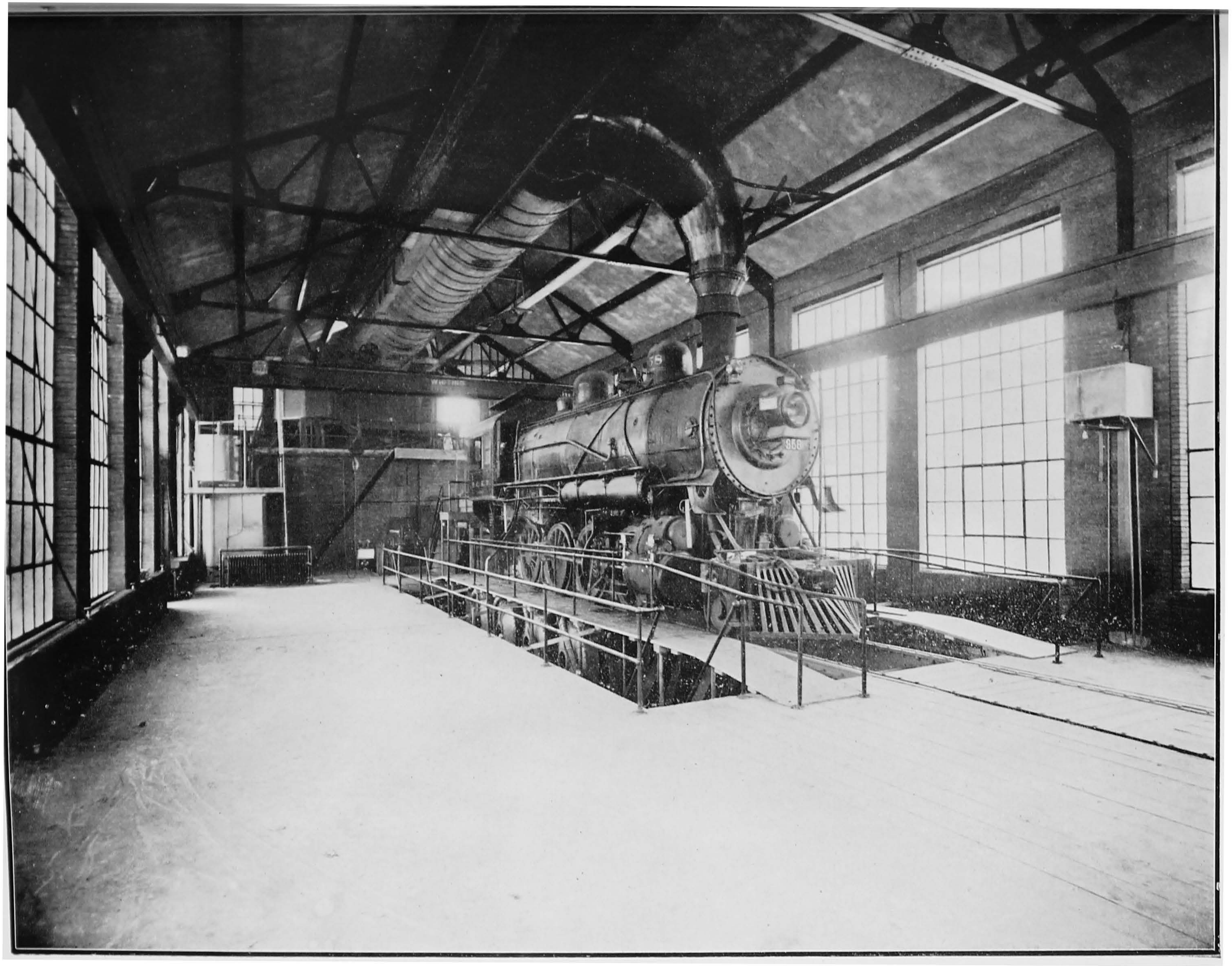
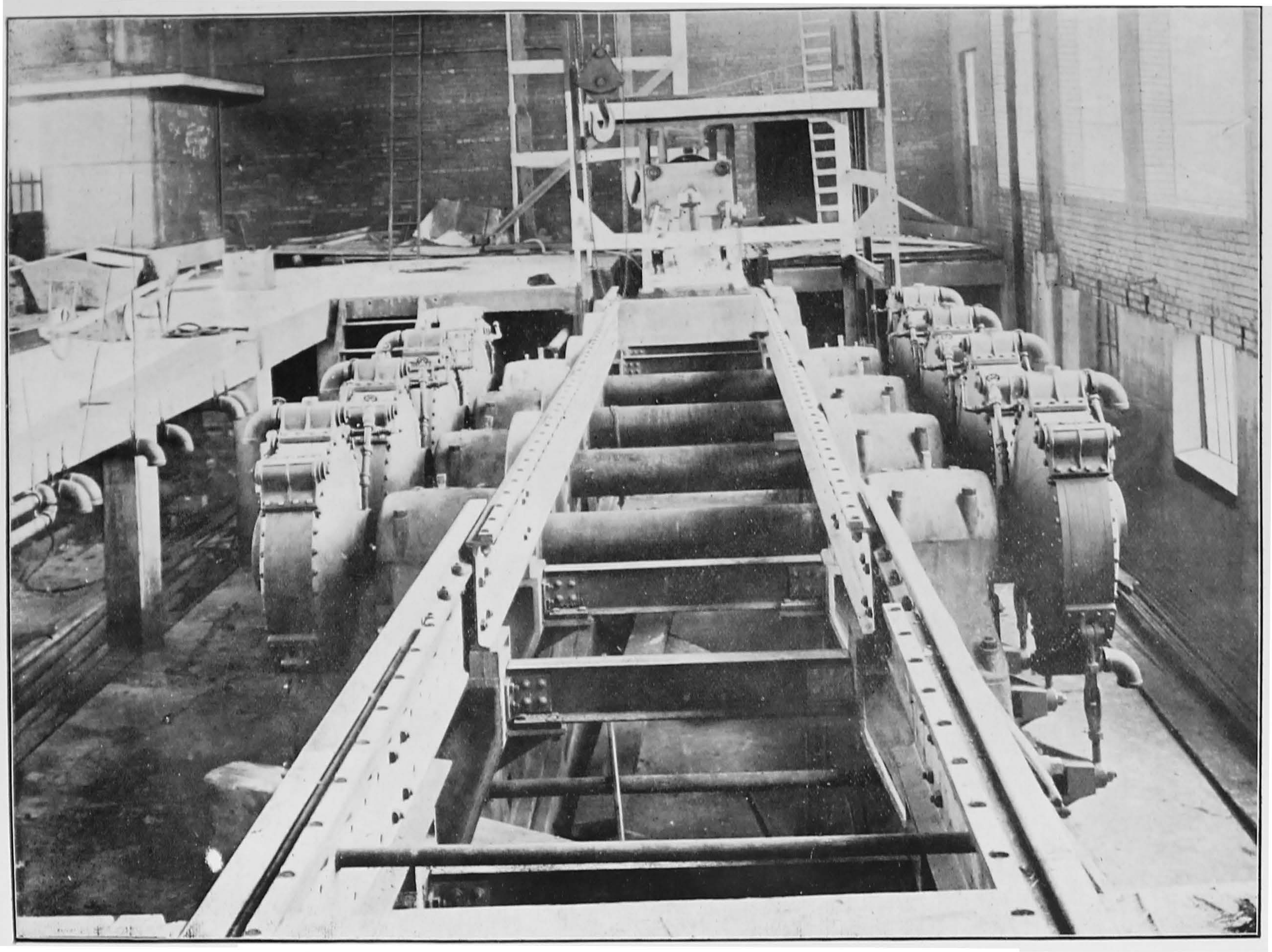
13 No. 219



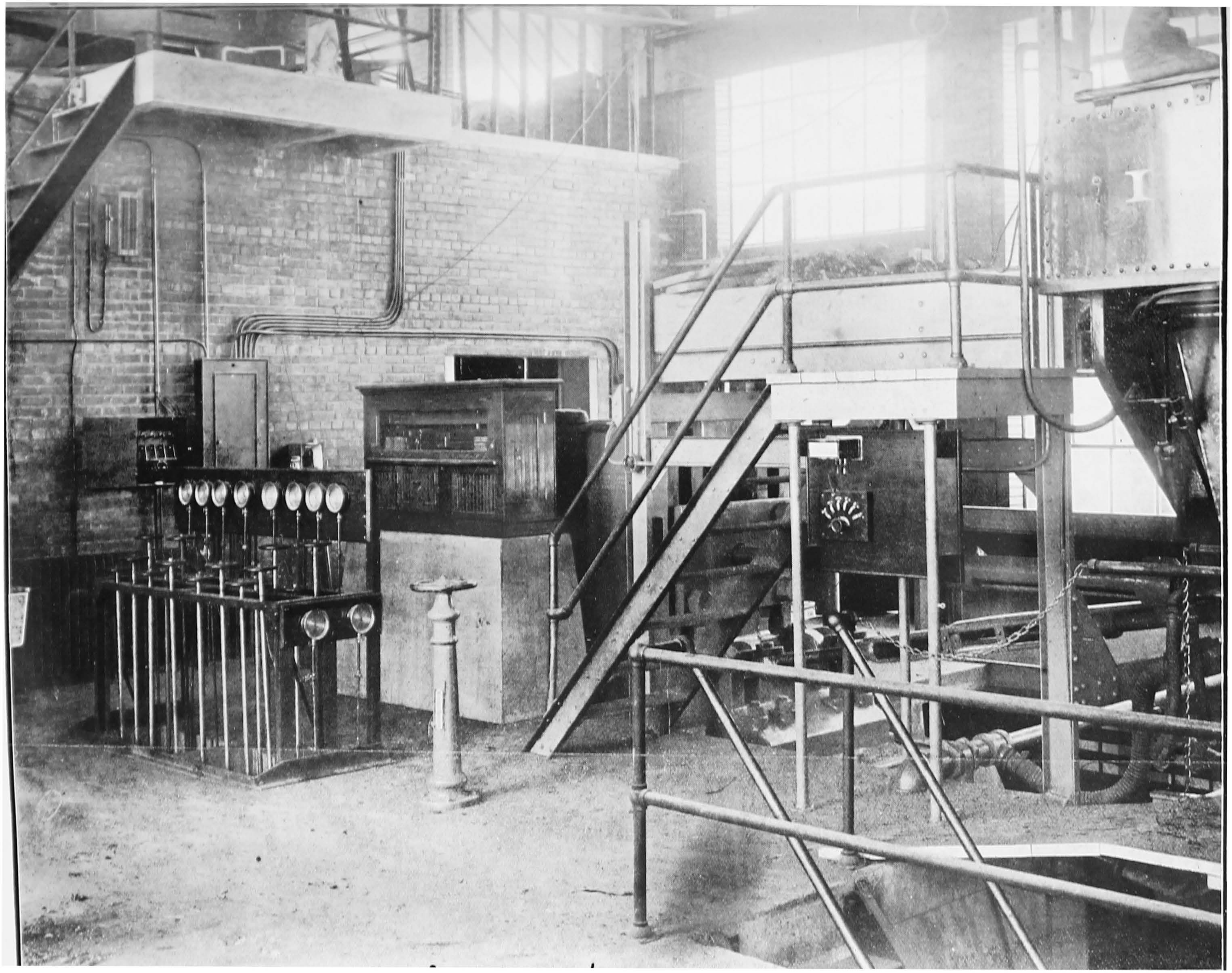
Locomotive Testing Laboratory, University of Illinois.



Interior of Locomotive Laboratory, University of Illinois.



Locomotive Testing Plant, University of Illinois.



APPENDIX I.

Sheet 1

GRAND TRUNK RAILWAY SYSTEM

(Form 460)
A. 1

MOTIVE POWER DEPARTMENT. ....SHOPS

Apprentice.. *Examined*..............................

EXAMINATION FOR PROMOTION OF MACHINISTS' APPRENTICES

FIRST YEAR

Q. What is the weight of a standard shop hammer (Machinists' Hand)?

A. ....

Q. At what point should hammer be held for efficient service?

A. ....

Q. What is the standard length of a hammer handle?

A. ....

Q. How many classes of drills are in general use in this shop?

A. ....

Q. At what degree is cutting end of twist drill ground?

A. ....

Q. What is the speed of a 1" high speed drill in drilling cast iron?

A. ....

Q. What is the speed of a 1" drill in drilling steel or wrought iron?

A. ....

Q. What is the speed of a 1" high speed drill in drilling hard or tough material?

A. ....

Q. What is the speed of a 1" carbon steel drill?

A. ....

Q. How do you find the speed for drilling brass?

A. ....

Q. What is the speed of a 13/16 high speed drill? Show method.

A. ....

Q. What size should holes be drilled for tapping various sizes?

A. Diameter of tapping holes.	Diameter of screw.	Number of threads per inch.
....	.... 5/16............	....

			Sheet
	1/4		
	5/16		
	3/8		
	7/16		
	1/2		
	5/8		
	3/4		
	7/8		
	1		
	1 1/8		
	1 1/4		
	1 3/8		
	1 1/2		

Q. What lubricant is used for drilling wrought iron or steel?

A. ....

....

Q. What is a centre punch used for?

A. ....

....

Q. What is a round nosed chisel used for at drilling machines?

A. ....

Q. What side of a belt should be run next to pulley or cone?

A. ....

Q. What are the general rules to be observed regarding cleanliness and care of machines?

A. ....

....

....

....

....

Q. Apprentice will explain the reading of an ordinary standard measuring rule practically from rule?

A. ....

Q. How many and what are the names of the different classes of calipers in general use on drilling machines?

A. ....

....

Q. What tools are necessary for laying off or measuring work at drilling machine?

A. ....

....

Q. What is a jig?

A. ....

....

....

....

Q. What are its advantages?

A. ....

....

Make a drawing of a main crank pin for a Class A Engine from model. Drawing to be full size and inked in.

Time allowed for examination ten hours.

GRAND TRUNK RAILWAY SYSTEM.

(Form 460, A2).

MOTIVE POWER DEPATRTMENT. ....SHOPS.

Apprentice.. *Examined*..

EXAMINATION FOR PROMOTION OF MACHINISTS' APPRENTICES.

SECOND YEAR.

Q. How should work to be planed or shaped be secured?

A. ....

....

Q. What are the usual tools in connection with shaper or planer?

A. ....

Q. What is the cutting speed per minute for the following classes of material?

A. Steel....................................Feet.

Wrought Iron..............................Feet.

Cast Iron..................................Feet.

Brass.......................................Feet.

Q. What tools are used in setting up work?

A. ....

Q. At what angle should lathe centres be ground?

A. ....

Q. How should shafting, axles, piston rods, crank pins, etc., be centred?

A. ....

....

Q. What measuring tools are in general use on lathe?

A. ....

Q. Give number of threads per inch on Whitworth and American Standard taps?

A. ....

....

Q. What degree of angle is Whitworth Standard thread?

A. ....

Q. What degree of angle is American Standard thread?

A. ....

Q. What is thread pitch and how is it measured?

A. ....

....

Make a drawing of a big end strap with brasses complete for a Class "A" engine, from model. Drawing to be half full size and inked in.

Time allowed for examination ten (10) hours.

GRAND TRUNK RAILWAY SYSTEM.

(Form 460, A3).

MOTIVE POWER DEPARTMENT. ....SHOPS.

Apprentice.. *Examined*..

EXAMINATION FOR PROMOTION OF MACHINISTS' APPRENTICES.

THIRD YEAR.

Q. How would you calculate gear wheels to cut threads in lathe?

A. ....

....

....

....

Q. What centre are used on lathes other than ordinary lathe centre?

A. ....

Q. In turning for pressure shrinking fits, what are the general principles and allowances?

A. ....

....

Table of Allowances.

....

....

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....

....

Q. What is our rule for steel tyres?

A. ....

Q. What is the cutting speed per minute for turning the following classes of material?

A. Commercial Steel..Feet per min.

Wrought Iron..Feet per min.

Brass..Feet per min.

Cast Iron..Feet per min.

Make a drawing of a Balanced Slide Valve complete for a Class "A" engine from model. Drawing to be half full size and inked in.

Time allowed for examination twenty (20) hours.

GRAND TRUNK RAILWAY SYSTEM.

(Form 460, A4).

MOTIVE POWER DEPARTMENT. ....SHOPS.

Apprentice.. ...*Examined*..

EXAMINATION FOR PROMOTION OF MACHINISTS' APPRENTICES.

FOURTH YEAR.

Q. How many classes of chisels are in general use by fitters?

A. ....

Q. How should cutting edge of chisel be dressed?

A. ....

Q. Why?

A. ....

Q. What is the standard length of an ordinary flat chisel when new?

A. ....

Q. How long should the forged part be?

A. ....

Q. How should cutting edge of chisel be ground?

A. ....

Q. At what point should chisel be held?

A. ....

Q. At what angle should cutting edge of chisel (flat chisel) be ground?

A. ....

Q. Give names of files in general use?

A. ....

Q. What are the distinct classes of files?

A. ....

Q. Under ordinary conditions how would work be held in a vise?

A. ....

....

....

Q. How should the file for heavy work be held?

A. ....

....

....

Q. What kind of marking is used to indicate bearing surface in fitting?

A. ....

How should it be applied?

A. ....

....

Q. For what use and when is a scraper used?

A. ....

....

Q. Explain the proper method of setting up a set of guide bars?

A. ....

....

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....

Make a drawing of a piston complete for Class "A" engine from model. Drawing to be half full size and inked in.

Time allowed for examination twenty (20) hours.

GRAND TRUNK RAILWAY SYSTEM.

(Form 460, 15

MOTIVE POWER DEPARTMENT. ....SHOPS.

Apprentice.. *Examined*..

EXAMINATION FOR PROMOTION OF MACHINISTS' APPRENTICES.

FIFTH YEAR.

Q. How should wrist pin fit little end bushings?

A. ....

....

Q. How should big end brasses be fitted?

A. ....

....

....

Q. What is our rule for fitting side rod and intermediate bushings to crank pins?

A. ....

....

....

Q. What are the relative positions regarding height of crown sheet of inside fire box and tapping holes of bottom water gauge mounting in boiler heads?

A. ....

....

....

Q. What distance should bottom try cock be above crown sheet of inside firebox, highes point?

A. ....

Q. What is our shop practice for applying driving axles ? ....

A. ....

....

....

....

....

....

Q. After wheels are pressed on axle and quartered, what is the shop practice in laying off the forward and back eccentric keys ?

A. ....

....

....

Q. Supposing you have an engine requiring a new driving axle and you have no gauge as above described, explain how you would make a staff from the sheaves on old axle so as to place eccentric sheaves on new axle in same position ?

A. ....

....

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Q. Explain the method of squaring an engine, as practiced in the shops ?

A. ....

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Q. What is lead?

A. ....

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Q. What is lap?

A. ....

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Q. Explain the method of setting valves, as practiced in the shop?

A. ....

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....

Make a drawing of a crosshead complete for a Class "A" engine from model.
Drawing to be half full size and inked in.

Time allowed for examination thirty (30) hours.

APPENDIX II.

EXAMINATION FOR PROMOTION OF BOILERMAKERS' APPRENTICES.

First Year.

1. Q.—What class of material is now used in the construction of boilers?

A.—Principally steel.

2. Q.—Why is steel used?

A.—Because it has great tensile strength, ductility, homogeneity, toughness, freedom from blisters and internal unsoundness.

3. Q.—What are the faults usually found in wrought iron plates?

A.—Blisters and unsoundness are frequently met with.

4. Q.—What is our practice on the Grand Trunk in regard to selection of boiler plates?

A.—These are manufactured to our specifications and when received are tested to see that our specifications are complied with.

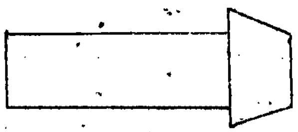
5. Q.—How are steel plates fastened together in boiler work?

A.—By means of rivets.

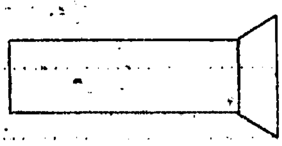
6. Q.—How many kinds of rivets are there in general use?

A.—Three kinds: Conehead, countersunk, and buttonhead. Show sketch.

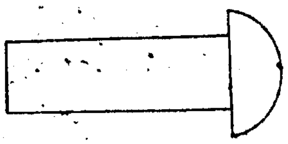
Cone Head



Countersunk Head



Button Head



7. Q.—Should rivet holes in boiler work be drilled or punched?

A.—They should always be drilled. It is considered good practice, however, to punch holes smaller in diameter than required and ream them out to the proper size. This removes the fractured metal that the punch creates.

8. Q.—How are rivets made?

A.—Rivets are made from forging from round iron bar or mild steel in blacksmith shop.

9. Q.—How much larger should rivet holes be than the shank of the rivet?

A.—One-sixteenth-inch for ⅝-inch diameter rivets and over.

10. Q.—What methods of rivetting are in general use?

A.—Hand, hydraulic, air and steam rivetting.

11. Q.—What are the disadvantages of hand rivetting?

A.—Slowness and a tendency to form a shoulder on the rivet before it fills the hole.

12. Q.—Why is machine rivetting preferable?

A.—It is done more quickly. The pressure coming gradually on entire rivet compresses it completely into the hole before head is formed.

13. Q.—Before rivetting, what care should be exercised with plates?

A.—They should be close together, so a shoulder will not be formed between the plates and prevent them making a good joint. The holes should also be true with each other.

14. Q.—Why is hydraulic rivetting generally preferred to steam rivetting?

A.—The pressure is more gradual: The steam rivetter gives sudden blows and does not allow time for the rivet to completely fill the hole.

15. Q.—Which rivets are the stronger, cone buttonhead, or countersunk?

A.—Cone or buttonhead rivets are always stronger than countersunk, and should always be used wherever possible. Countersinking weakens the plate and the head of a countersunk rivet is liable to pull through hole.

16. Q.—How can rivets be tested in the boiler shop?

A.—Bend the rivet cold in the form of a hook around another rivet of the same size, and it should not show any fractures or cracks if of good material. Rivets can also be tested by heating and bending back over itself in the shape of a "U" and should not show any fractures or cracks if of good material.

17. Q.—If plates have been punched and reamed, how should they then be treated?

A.—They should then be annealed in furnace.

18. Q.—How should steel rivets be heated?

A.—It is important that the heat be uniform and they should only be brought to a white heat but not beyond this.

Make a drawing of a main crank pin for a class "A" engine, from model, drawing to be half full size and inked in.
Time allowed for examination Ten (10) hours.

EXAMINATION FOR PROMOTION OF BLACKSMITHS' APPRENTICES

First Year.

1. Q.—What are the most important tools used in the blacksmith shop?

A.—Hand-hammer, sledge-hammer, anvil, tongs, swages, flatters, drifts, fullers punches, calipers, rule, square and chisels.

2. Q.—Of what material are anvils made?

A.—Wrought iron faced with steel or cast steel.

3. Q.—Describe an open-hearth blacksmiths forge.

A.—The modern practice is to make them of cast-iron with a tuyere to admit blast to fire with a smokejack to carry away smoke and gases.

4. Q.—What pressure is usually used?

A.—About eight ounces per square inch.

5. Q.—How is this obtained?

A.—By means of a rotary fan, hand-bellows being used only in small shops.

6. Q.—When the valves are closed at a fire or a number of fires what prevents the accumulation of gas pressure in the blast pipes?

A.—Safety valves are placed on the main blast pipes.

7. Q.—Are there any other designs of blacksmith's open-hearth forges?

A.—Yes, there is what is called the down-draft forge. With this class of forge an exhaust fan is used to carry away smoke and gases and an overhead smokejack is not necessary.

8. Q.—What are the ordinary metals worked upon by a blacksmith?

A.—Wrought iron and steel.

9. Q.—What is the length of the standard hand hammer handle used by blacksmiths and why should it be this length?

A.—Usually 20 inches. To prevent his hand coming in too close contact with the hot iron.

10. Q.—What is the length of the sledge hammer handle?

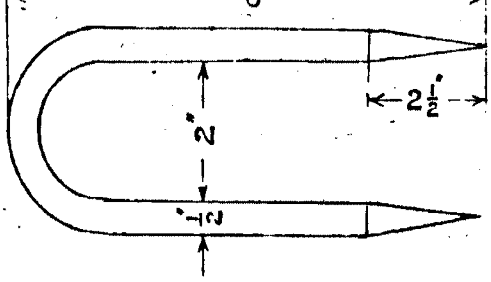
A.—Usually 36 inches.

11. Q.—How would you make an ordinary staple 6 inches long, out of ⅜-inch diameter material?

A.—First cut the iron to a suitable length. Then heat one end and draw it to a point, then treat the other end in a similar manner. As pointing draws the metal out, it will be necessary to cut the bar a little shorter than length required of finished article in order to allow for the drawing. After pointing both ends, then draw it to its final shape over the horn of the anvil, that is, when doing it by hand, by holding same with a pair of flat tongs and striking with the hand hammer until it is bent to the desired shape.

12. Q.—A staple is to be made of ½-inch round iron and is to be 8 inches long over all and taper is to extend back 2½ inches from each point. What length of material must be cut to make this, as per sketch?

A.—Fifteen inches.



Staple

13. Q.—What is the floor of a blacksmith shop usually composed of?

A.—Cinders or ashes, well tamped.

14. Q.—How many kinds of fuel are used in a blacksmith shop?

A.—Charcoal, coke, fuel oil, gas, and bituminous coal.

15. Q.—What kind is used in an open-hearth forge?

A.—Fine bituminous coal.

16. Q.—Why is this used?

A.—On account of being free from sulphur and earthy matter.

17. Q.—Why is sulphur not desirable?

A.—Because it gives out choking fumes and has an injurious effect upon the iron, and renders good welding difficult.

18. Q.—How would you go about preparing and maintaining a fire in an openhearth forge for ordinary work?

A.—First heap coal all round tuyere to a depth of two or three inches, leaving tuyere free. A handful of shavings or oily waste is put on fire and placed near top of tuyere and a small quantity of fuel is piled over it. As the fire burns more fuel is added. The fire is kept from spreading by sprinkling water around the edges of it.

19. Q.—How high should the top of the fire be from the tuyere?

A.—High enough to prevent the cold blast from the tuyere striking the hot metal.

20. Q.—Should hot iron come into contact with fresh coal?

A.—No: When the fire requires to be replenished coal should be taken from the side of the fire, and fresh coal placed on the side to become gradually heated and coked.

21. Q.—How should fire be kept?

A.—Always clean, clinkers, scraps of metal, etc., being removed.

Make a drawing of a main crank pin for a class "A" engine, from model, drawing to be half full size, and inked in.

Time allowed for examination Ten (10) hours.

EXAMINATION FOR PROMOTION OF TINSMITHS' AND PIPE-FITTERS' APPRENTICES.

First Year.

1. Q.—What is the weight of a tinsmiths's hammer?

A.—One and one-quarter pounds.

2. Q.—What is the length of a hammer handle?

A.—Fourteen inches.

3. Q.—What hand tools are used?

A.—Straight and circular snips, hammer, soldering copper, firepot, rivet sets, groovers and files.

4. Q.—What is the weight of soldering coppers?

A.—1¼ and 3 pounds.

5. Q.—What are the commercial names and sizes of tin most used?

A.—IX (14 x 20), 1C (14 x 20), IX (20 x 28), IXX (20 x 28).

6. Q.—How is solder made and what are the proportions?

A.—Solder is composed of tin and lead in equal parts.

7. Q.—Preparatory to applying solder to tin work, what class of acid are the parts coated with?

A.—Muratic acid, and a small quantity of zinc dissolved in same.

8. Q.—Are there any other materials used?

A.—Yes. Soldering salt and resin.

9. Q.—Is the same preparation of acid used when soldering galvanized iron as is used when soldering tin?

A.—No. Muratic acid alone is used on galvanized iron.

10. Q.—Why should not pure acid be used when soldering tin work?

A.—Because it blackens the tin and the solder does not adhere as well.

11. Q.—What are the tools in general use in ordinary pipe-fitting work?

A.—Stocks and dies, pipe wrenches, pipe cutters, pipe vises, taps, reamers, hand hammers, chisels and files.

12. Q.—What is known in pipe-fitting as a stock.

A.—The stock is the tool used for holding the dies.

13 Q.—What is a die?

A.—A die is the name given to the tool which cuts the thread.

14. Q.—In using a die what care should be observed?

A.—Plenty of lubricant should be used otherwise the die will run hot and spoil the thread on pipe and probably the die.

15. Q.—What classes of dies are used in pipe shop?

A.—Two: Right and left.

16. Q.—Give the number of threads per inch on wrought iron pipes from ¼ inch to 6 inches in diameter?

A.—

⅛"	pipe,	27	threads	per inch.
¼"	„	18	„	„
⅜"	„	18	„	„
½"	„	14	„	„
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1 "	„	11½	„	„
1¼"	„	11½	„	„
1½"	„	11½	„	„
2 "	„	11½	„	„
2½"	„	8	„	„
3 "	„	8	„	„
3½"	„	8	„	„
4 "	„	8	„	„
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5 "	„	8	„	„
6 "	„	8	„	„

17. Q.—What is the taper on threaded end of wrought iron pipe?

A.—One-thirty-second of an inch to one inch.

18. Q.—What is a pipecutter?

A.—A tool used for cutting pipe, being made adjustable for the different diameters of pipe.

19. Q.—What care should be observed in using this tool?

A.—Cutter should be well lubricated or it will run hot and break cutting edges.

20. Q.—What is the proper way to use a pipe wrench?

A.—Always take a square hold and do not pull sidewise. If pulled sidewise it is apt to break wrench.

Make a drawing of a main crank pin for a class "A" engine, from model, drawing to be half full size, and inked in.

Time allowed for examination, Ten (10) hours.

EXAMINATION FOR PROMOTION OF PATTERNMAKERS' APPRENTICES.

First Year.

1. Q.—Give definition of a pattern?

A.—In connection with the foundry and machinary business a pattern is understood to be a form by the use of which a mould is made.

2. Q.—What is a pattern usually made from?

A.—Wood, metal, plaster of Paris or rubber.

3. Q.—Why is wood most generally used?

A.—Because of its low cost, the ease with which it may be worked into shape, its firmness, lightness and adaptability of surface to withstand the action of the moist sand in the mould.

4. Q.—How many planes are used by a pattern-maker? Name them and explain their use.

A.—Jack plane, try or jointing plane, and smooth or hand plane. The jack plane is used first for roughing, then try plane to take out all irregularities and make a

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2 " „ 11½ „ „
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4. Q.—How many planes are used by a pattern-maker? Name them and explain their use.

A.—Jack plane, try or jointing plane, and smooth or hand plane. The jack plane is used first for roughing, then try plane to take out all irregularities and make a true surface, the hand or smoothing plane is used to smooth surfaces not requiring a true finish.

5. Q.—What is sandpaper and how should it be used?

A.—Sandpaper is ground quartz or sharp sand glued on paper and is graded from numbers 00 to 3. In patternmaking sandpaper should only be used in giving finish to a pattern.

6. Q.—Why is water used on a grindstone and at what speed should it revolve to grind wood-cutting tools?

A.—Water is used on a grindstone to carry off the heat resulting from the friction between the stone and the tool. The surface speed for grinding wood cutting tools should be 600 feet per minute.

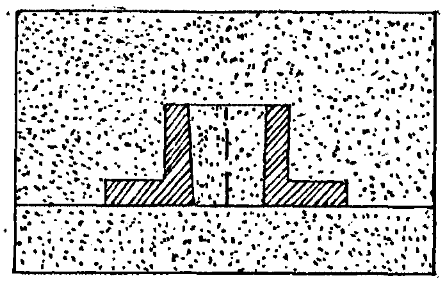
7. Q.—When hollow castings are required, how is it done?

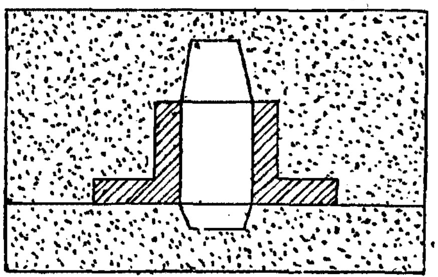
A.—By means of what is called a core.

8. Q.—Explain the meaning of core?

A.—A core is a body of sand projecting into the mould to form an opening in the casting which may be formed by the pattern itself or by a separate device called a core box.

Give sketch showing two examples.





9. Q.—What is meant by a coreprint?

A.—A coreprint is one or more projections on a pattern to form an impression in the mould in which the core is laid.

10. Q.—What are the best woods to use in the manufacture of patterns?

A.—Clear, dry, white pine, but where a large number of castings are required to be made use mahogany or cherry.

11. Q.—How many rules are required in patternmaking?

A.—Two. Standard and shrink.

12. Q.—What are used to keep the two halves of a pattern in position when moulding?

A.—Dowel pins.

13. Q.—Why should raised figures or letters be placed on all patterns?

A.—The impression of such numbers are reproduced on the castings and assist in checking and tracing castings and patterns.

Make a drawing of a main crank pin for a class "A" engine, from model, drawing to be half full size, and inked in.

Time allowed for examination, ten (10) hours.

EXAMINATION FOR PROMOTION OF MOULDERS' APPRENTICES.

First Year.

1. Q.—What are the four branches of moulding?

A.—Coremaking, green sand, dry sand and loam moulding.

2. Q.—What is understood by coremaking?

A.—Cores are used to form the hollow interior of castings.

3. Q.—What is understood by green sand moulding?

A.—Green sand moulding involves the making of moulds that are comprised entirely of sand in a damp state.

4. Q.—What is understood by dry sand moulding?

A.—Dry sand moulding involves the making of moulds with damp sand after which the mould is dried before casting.

5. Q.—What is understood by loam moulding?

A.—In loam mouldings castings are made in moulds constructed with sweeps and skeleton patterns. A mixture of loam sand is used to form the face of the mould, brick-work forming the outside in place of moulding flasks. This class of work, like dry sand moulding, requires thorough drying.

6. Q.—What is a flask used for?

A.—Flasks are used to keep the sand in place while the mould is being made.

7. Q.—What is understood by the drag?

A.—The bottom portion of the flask is called the drag.

8. Q.—What is understood by the cope?

A.—The upper portion of the flask is called the cope.

9. Q.—What is a moulding board used for?

A.—A moulding board is used to place pattterns on while ramming sand into drag.

Make a drawing of a main crank pin for a class "A" engine, from model, drawing to be half full size, and inked in.

Time allowed for examination, ten (10) hours.

EXAMINATION FOR PROMOTION OF ELECTRICAL APPRENTICES.

First Year.

1. Q.—What is an electric light extension?

A.—A portable cord with attachments to be used in pits and other places where general lighting has no effect.

2. Q.—What is an electric switch?

A.—An appliance used to open or close a circuit.

3. Q.—What is an electric fuse?

A.—An appliance used to protect a circuit.

4. Q.—What are fuses made of?

A.—Metals which will fuse at low temperatures: if of the correct size they will melt when the temperature, caused by an abnormal rise in current, reaches the proper value?

5. Q.—What is meant by a cut-out?

A.—A receptacle to hold fuses.

6. Q.—What is to prevent electricity from passing into machines, and other apparatus where wires come in contact with them?

A.—Insulation, a covering of rubber and cotton or other non-conducting material.

7. Q.—What is a cleat?

A.—An appliance used to hold wires in place, usually consisting of porcelain or other insulating material.

8. Q.—How are wires usually joined together in a circuit?

A.—Usually by twisting together and soldering.

9. Q.—Why is it advisable to solder together all joints and terminals?

A.—So that they may carry the current without loss or heating.

10 Q.—Is there any other method of fastening terminals or joints, if so, how?

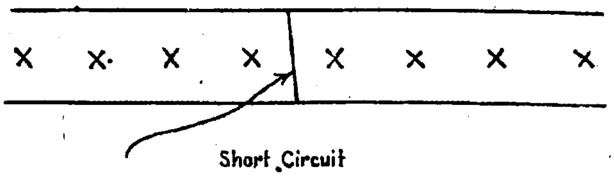
A.—Yes: by sleeves to fit the ends of wire and fastened by screws, or soldered, or both.

11. Q.—What is a circuit?

A.—Usually consists of wires carrying electric current such as the wires conducting current to incandescent lamps, electric bells, etc.

12. Q.—What is a short circuit?

A.—Any shorter path for the current to pass through other than that intended.



Wires of opposite sign or between which a difference of potential electromotive force or electric pressure exists.

13. Q.—What is a volt?

A.—A unit of electric pressure.

14. Q.—What is an ampere?

A.—A unit of current strength.

15. What is an ohm?

A.—A unit of resistance.

Make a drawing of a main crank pin for a class "A" engine, from model, drawing to be half full size, and inked in.

Time allowed for examination, ten (10) hours.

APPENDIX IV.

APPRENTICESHIP RECORD. GRAND TRUNK RAILWAY SYSTEM, STRATFORD SHOPS.

NAME.	SHOP.	MONTH.	WORKMANSHIP.				CONDUCT.				ATTENDANCE.				REMARKS.
			7TH	14TH	21ST	31ST	7TH	14TH	21ST	31ST	7TH	14TH	21ST	31ST	
M. D.	Erecting	Sept.	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	
H. C.	”	”	”	”	”	”	”	”	”	”	”	”	”	”	
C. S.	”	”	”	”	”	”	”	”	”	”	”	”	”	”	
W. C.	”	”	Fair	Fair	Fair	Fair	”	”	”	”	”	”	”	”	Indifferent.
A. H.	”	”	Good	Good	Good	Good	”	”	”	”	”	”	”	”	
H. M.	”	”	”	”	”	”	”	”	”	”	”	”	”	”	
E. R.	”	”	”	”	”	”	”	”	”	”	”	”	”	”	
B. M.	”	”	”	”	”	”	”	”	”	”	”	”	”	”	
C. H.	”	”	”	”	”	”	”	”	”	”	”	”	”	”	
E. W.	”	”	”	”	”	”	”	”	”	”	”	”	”	”	
W. D.	”	”	”	”	”	”	”	”	”	”	”	”	”	”	
J. M.	”	”	”	”	”	”	”	”	”	”	”	”	”	”	
W. P.	”	”	Fair	Fair	Fair	Fair	”	”	”	”	”	”	”	”	Improving.
J. K.	”	”	Poor	Poor	Poor	Poor	Fair	Fair	Fair	Fair	”	”	”	”	Indifferent.
H. V.	”	”	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	

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APPENDIX V.

FRISCO LINES.

MONTHLY REPORT

OF

APPRENTICE SCHOOL AT SPRINGFIELD SHOPS.

Month ending April 30th, 1914, Class No. 6.

NAME.		Times late.	Times absent.	Zeros in lessons.	Attentiveness.	AVERAGE GRADES.				General average.	REMARKS.
						Drawing.	Home Lessons.	Machine work.	Floor work.		
D.	C.	...	1	1	Fair	79	70	...	Fair	75	Boiler maker.
M.	O.	...	...	...	Good	75	65	...	Good	70	Tinner.
A.	J.	...	...	1	Good	74	53	...	Good	64	Carpenter.
T.	L.	...	...	1	Good	81	77	...	Fair	79	Machinist.
H.	J.	...	...	...	Good	80	77	...	Good	79	Machinist.
D.	E.	...	...	...	Good	77	79	...	Good	98	Upholster.
L.	W.	...	...	...	Good	78	70	...	Fair	74	Machinist.
F.	A.	...	...	...	Good	83	63	...	Good	73	Carpenter.
B.	J. P.	...	...	...	Good	85	61	...	Good	73	Machinist.
J.	W.	...	4	...	Good	80	...	...	Good	...	Tinner.
G.	O.	...	...	...	Good	74	72	...	Good	73	Carpenter.
T.	R.	...	...	...	Good	76	82	...	Good	79	Machinist.
W.	A.	B.	...	...	Good	78	80	...	Good	79	Machinist.
N.	C. M.	...	1	...	Fair	76	100	...	Fair	88	Boilermaker.
T.	G. F.	...	...	...	Good	72	80	...	Good	76	Boilermaker.
W.	G. F.	...	...	...	Good	74	75	...	Good	75	Carpenter.
B.	G.	...	...	...	Fair	73	65	...	Fair	69	Boilermaker.
P.	J.	...	...	...	Fair	74	80	...	Fair	77	Machinist.
P.	L.	...	...	...	Good	79	80	Good	...	80	Machinist.
P.	G.	...	...	...	Just entered apprenticeship					...	Machinist.
E.	E.	...	...	...	Just entered apprenticeship					...	Machinist.
G.	W.	...	...	...	Just entered apprenticeship					...	Carpenter.
M.	F.	...	...	...	Just entered apprenticeship					...	Carpenter.
B.	N.	...	...	...	Just entered apprenticeship					...	Painter.
B.	R.	...	...	...	Just entered apprenticeship					...	Machinist.
D.	R.	...	...	...	Just entered apprenticeship					...	Machinist.

APPENDIX VI.

CHICAGO AND NORTH WESTERN RAILWAY'S EXAMINATION FOR FIREMEN.

On the Chicago and North Western Railway system progressive examinations are held to test their firemen. First, Second and Third Examination pamphlets are issued accordingly, to each fireman on the line. An example of the First Year Examination is given below. The Third Year Mechanical Examination follows very much the same lines as our ordinary Driver's Examinations, dealing largely with the conditions set up and action necessary in a variety of machinery failures, and a searching series of Air Brake questions.

The following extract from the First Book describes the method and time of holding these progressive examinations.

When a fireman is employed, he shall be given the First Book, and notified that at the end of his first year's service he will be required to pass a written examination thereon, under the direction of his Master Mechanic.

After passing the first year's examination, he will be given the Second Book and notified that at the end of his second year's service he will be required to pass a written examination thereon under the direction of his Master Mechanic.

When he has passed the second examination, he shall be furnished with the Third Book and notified later when he will be required to pass an examination before a General Board of Examiners at Chicago Shops.

If a man shall fail to answer correctly eighty (80) per cent of the questions asked, he will be given another opportunity to pass the same examination some time within six months. If he then fails to pass by a percentage of eighty per cent. (80), he shall be immediately dropped from the E. & F. lists.

The General Board of Examiners shall be appointed by the S. M. P. & M. or his assistant, and shall sit in Chicago at a time appointed by the same official, notice of which shall be sent to each Master Mechanic some time previous thereto.

No Master Mechanic shall send a man to take the third examination unless he is satisfied as to the man's qualifications, and would desire to have him as an engineer, provided he successfully passes the examination.

If not in conflict with the Master Mechanic's wishes, as indicated in the preceding clause, he will send firemen in order of their seniority to take the Third Examination.

Engineers for employment shall be required to pass the Third Examination before going into service.

Note.—After passing each examination the applicant will turn in the question books he has previously had, which books are the Company's property.

FIRST MECHANICAL QUESTIONS, June, 1905.

Has there been anything to hinder or prevent you from obtaining the desired information for this examination ?

1. What are the fireman's duties on arrival at enginehouse previous to going out ?

2. Have you acquired the habit of comparing time with your engineer and do you insist on seeing the train orders ?

3. What is the cause of tank sweating, and what effect does it have on the paint ? What would you do to prevent it ?

4. Describe the ash pan and its use. What would be the effect if allowed to fill up ?

5. What advantage is it to the fireman to know the grades of the tracks and location of stations ?

6. Explain the principle upon which the steam gauge works.

7. What do you understand by the pressure registered by the steam gauge? How would you know the gauge registered the correct pressure?

8. How many safety valves are there on an engine and what are they for?

9. (*a*) What is the source of power?
   (*b*) What is steam, and how is it generated?

10. What is the composition of bituminous coal?

11. What is carbon, and whence do we obtain oxygen?

12. What per cent. of oxygen is in the atmosphere.

13. About what per cent. of carbon is there in bituminous coal?

14. What is combustion?

15. What is the igniting temperature of carbon and oxygen?

16. What other heat-giving properties are there in bituminous coal?

17. In what condition should the fire be to consume these gases?

18. What is the appearance of a fire when it is at a very high temperature?

19. How can you maintain your fire in this condition?

20. What is the effect of putting four or more scoops of coal on a bright fire? Is this a waste of fuel?

21. Define black smoke. Is it combustible?

22. Have you made an effort to practise the smokeless method of firing? What degree of success have you attained by this method?

23. How would you build up your fire at stations and avoid black smoke?

24. What is a hollow arch? What advantage has it over the solid arch, and what must be observed to protect its life and effect the greatest fuel economy? What are the other advantages of an arch in a locomotive firebox?

25. What is the estimated waste of coal for each minute the safety valve is open?

26. What should you do to keep the engine from blowing off, and to prevent black smoke, when throttle is closed for station?

27. What effect has opening and closing the dampers on combustion?

28. Why is it necessary to provide for a supply of air through the fuel in furnace combustion?

29. How can you prove this theory of the mixing of air with gases?

30. What is the effect upon combustion if too little air is supplied to the fire? If too much air is supplied?

31. Why are grates made to shake and when should they be shaken?

32. How does the exhaust steam create a draught through the fire?

33. Describe a blower, its use and abuse.

34. Why is it very important that coal should be broken so that it will not be larger than an ordinary sized apple before being put into the firebox?

35. When and why should you wet the coal down?

36. Has improper firing any tendency to cause flues to leak? How?

37. What would you consider abuse of a boiler?

38. How should you take care of a boiler with leaky flues or firebox?

39. What amount of water ought to be evaporated in a locomotive boiler to the pound of coal?

40 What are the advantages of a large grate area?

41. Can you fire an engine more intelligently by watching the water level? Why?

42. What are the duties of a fireman on arrival at terminal, regarding dampers and signals?

43. Do you consider it essential to your success in the business to abstain from the use of intoxicating liquors ? Do you consider it to your interest to work to the best of your ability for the interests of your employers, and be economical in the use of fuel and supplies ?

FIRST AIR BRAKE QUESTIONS.

1. What is an air brake ?
2. What is the purpose of the air pump ?
3. How should the pump be started ?
4. What is the main reservoir used for ?
5. What does the red hand on air gauge indicate ? What does the black hand indicate ?
6. What are the standard main reservoir pressures; the train pipe pressures ?
7. What other appliances are operated by main drum pressure ?
8. What are the bad effects in allowing air pumps to run over ash pits ?

APPENDIX VII.

COURSE OF STUDY.

Required for the Degree of B.S. in Railway Civil Engineering.

FIRST YEAR.

First semester.

Subject.	S. H.
General Engineering Drawing (G. E. D. 1)	4
Trigonometry (Math. 4)	2
Advanced Algebra (Math. 2)	3
French 1, or German 1 or 3 or 4, or English 1, or Spanish 1	4
Shop Practice (M. E. 41)	3
Military Drill (Mil. 2)	1
Gymnasium (Phys. Tr. 1)	1
Total	18

Second semester.

Subject.	S. H.
Descriptive Geometry (G. E. D. 2)	4
Analytical Geometry (Math. 6)	5
French 1, or German 3 or 5 or 6, or English 2, or Rhetoric 11, or Spanish 1	4
Shop Practice (M. E. 41)	3
Military Drill (Mil. 2)	1
Drill Regulations (Mil. 1)	1
Gymnasium (Phys. Tr. 1)	1
Total	19

SECOND YEAR.

First semester.

Subject.	S. H.
Differential Calculus (Math. 7)	5
Physics Lectures (Phys. 1)	3
Physics Laboratory (Phys. 3)	2
Rhetoric 1	3
Surveying (C. E. 21)	5
Military Drill (Mil. 2)	1
Total	19

Second semester.

Subject.	S. H
Integral Calculus (Math. 9)	3
Physics Lectures (Phys. 1)	2
Physics Laboratory (Phys. 3)	2
Rhetoric 1	3
Analytical Mechanics (T. & A. M. 7)	3
Topographical Surveying (C. E. 22)	4
Railroad Curves (C. E. 23)	1
Military Drill (Mil. 2)	1
Total	19

THIRD YEAR.

First semester.

Subject.	S. H.
Engineering Materials (T. & A. M. 6)	1
Analytical Mechanics (T. & A. M. 8)	2½
Resistance of Materials (T. & A. M. 9)	3½
Railroad Surveying (C. E. 4)	5
Chemistry 1 b or 1 a	4
Total	16

Second semester.

Subject.	S. H.
Hydraulics (T. & A. M. 10)	3
Railway Structures (R. E. 32)	2
Graphic Statics (C. E. 20)	2
Steam Engines and Boilers (M. E. 11)	3
Astronomy 3 and 6, or Geology 13	5
Principles of Economics (Econ. 2)	2
Total	17

FOURTH YEAR.

First semester.

Subject.	S. H.
Economic Theory of Railway Location (R. E. 33)	4
Signal Engineering (R. E. 35)	1
Railway History and Organization (Econ. 41)	3
Masonry Construction (C. E. 5)	5
Bridge Analysis (C. E. 12)	2
Tunneling (C. E. 18)	1
Metal Structures (C. E. 24)	1
Total	17

Second semester.

Subject.	S. H.
Thesis (R. E. 30)	3
Railway Yards and Terminals (R. E. 31)	3
Seminary (R. E. 50)	1
Railway Administration (Econ. 42)	3
Masonry and Reinforced Concrete Design (C. E. 6)	2
Bridge Design (C. E. 14a)	3
Engineering Contracts and Specifications (C. E. 16)	2
Total	17

COURSE OF STUDY.

Required for the Degree of B. S. in Railway Electrical Engineering.

FIRST YEAR.

First semester.

Subject.	S. H.
General Engineering Drawing (G. E. D. 1)	4
Trigonometry (Math. 4)	2
Advanced Algebra (Math. 2)	3
French 1, or German 1 or 4, or English 1 or Spanish 1	4
Shop Practice (M. E. 41)	3
Military Drill (Mil. 2)	1
Gymnasium (Phys. Tr. 1)	1
Total	18

Second semester.

Subject.	S. H.
Descriptive Geometry (G. E. D. 2)	4
Analytical Geometry (Math. 6)	5
French 1, or German 3 or 5 or 6, or English 2, or Rhetoric 11, or Spanish 1	4
Shop Practice (M. E. 41)	3
Military Drill (Mil. 2)	1
Drill Regulations (Mil. 1)	1
Gymnasium (Phys. Tr. 1)	1
Total	19

SECOND YEAR.

First semester.

Subject.	S. H.
Differential Calculus (Math. 7)	5
Physics Lectures (Phys. 1)	3
Physics Laboratory (Phys. 3)	2
Rhetoric 1	3
Shop Practice (M. E. 42)	2
Machine Design and Mechanism (M. E. 24)	3
Military Drill (Mil. 2)	1
Total	19

Second semester.

Subject.	S. H.
Integral Calculus (Math. 9)	3
Physics Lectures (Phys. 1)	2
Physics Laboratory (Phys. 3)	2
Rhetoric 1	3
Analytical Mechanics (T. & A. M. 7)	3
Chemistry 1	4
Military Drill (Mil. 2)	1
Total	18

THIRD YEAR.

First semester.

Subject.	S. H.
Engineering Materials (T. & A. M. 6)	1
Analytical Mechanics (T. & A. M. 8)	2½
Resistence of Materials (T. & A. M. 9)	3½
Dynamo-Electric Machinery (E. E. 3)	3
Electrical Engineering Laboratory (E. E. 22)	2
Electrical and Magnetic Measurements (Phys. 4)	2
Chemistry 2 and 3	4
Total	18

Second semester.

Subject.	S. H.
Hydraulics (T. & A. M. 10)	3
Alternating Currents (E. E. 5)	4
Electrical Engineering Laboratory (E. E. 23)	2
Electrical and Magnetic Measurements (Phys. 4)	2
Surveying (C. E. 10)	2
Mechanical Engineering Laboratory (M. E. 13)	3
Integral Calculus (Math. 9a)	2
Total	18

FOURTH YEAR.

First semester.

Subject.	S. H.
Seminary (R. E. 10)	1
Electric Railway Practice (R. E. 64)	3
Advanced Alternating Currents (E. E. 14)	4
Electrical Engineering Laboratory (E. E. 24)	2
Thermodynamics (M. E. 15)	3
Principles of Economics (Econ. 2)	2
Steam Engineering (M. E. 23)	2
Total	17

Second semester.

Subject.	S. H
Seminary (R. E. 10)	1
Railway Laboratory and Road Tests (R. E. 63)	3
Electric Railway Practice (R. E. 65)	3
Electrical Design and Power Plants (E. E. 34)	3
Economic Problems (Econ. 16)	2
Thesis (R. E. 30)	3
Total	15

COURSE OF STUDY.

Required for the Degree of B. S. in Railway Mechanical Engineering.

FIRST YEAR.

First semester

Subject.	S. H.
General Engineering Drawing (G. E. D. 1)	4
Trigonometry (Math. 4)	2
Advanced Algebra (Math. 2)	3
French 1, or German 1 or 4, or English 1, or Spanish 1	4
Shop Practice (M. E. 4)	3
Military Drill (Mil. 2)	1
Gymnasium (Phys. Tr. 1)	1
Total	18

Second semester.

Subject.	S. H.
Descriptive Geometry (G. E. D. 2)	4
Analytical Geometry (Math. 6)	5
French 1, or German 3 or 5 or 6, or English 2, or Rhetoric 11, or Spanish 1	4
Shop Practice (M. E. 41)	
Military Drill (Mil. 2)	
Drill Regulations (Mil. 1)	1
Gymnasium (Phys. Tr. 1)	1
Total	19

SECOND YEAR.

First semester.

Subject.	S. H.
Differential Calculus (Math. 7)	5
Physics Lectures (Phys. 1)	3
Physics Laboratory (Phys. 3)	2
Rhetoric 1	3
Shop Practice (M. E. 42)	3
Machine Design (M. E. 4)	2
Military Drill (Mil. 2)	1
Total	19

Second semester.

Subject.	S. H
Integral Calculus (Math. 9)	3
Physics Lectures (Physics 1)	2
Physics Laboratory (Phys. 3)	2
Rhetoric 1	3
Analytical Mechanics (T. & A. M. 7)	3
Shop Practice (M. E. 42)	2
Steam Engineering (M. E. 16)	3
Military Drill (Mil. 2)	1
Total	19

THIRD YEAR.

First semester.

Subject.	S. H.
Engineering Materials (T. & A. M. 6)	1
Analytical Mechanics (T. & A. M. 8)	2½
Resistance of Materials (T. & A. M. 9)	3½
Power Measurements (M. E. 3)	2
Mechanism (M. E. 5)	3
Integral Calculus (Math. 9a)	2
Chemistry 1b or 1a	4
Total	18

Second semester.

Subject.	S. H
Machine Design (M. E. 9)	3
Thermodynamics (M. E. 5)	3
Seminary (M. E. 29)	1
Analytical Mechanics (T. & A. M. 11)	3
Dynamo Machinery (E. E. 16)	4
Engineering Chemistry (Chem. 16)	3
Total	17

FOURTH YEAR.

First semester.

Subject.	S. H.
Locomotives (R. E. 1)	2
Locomotive Design (R. E. 2)	3
Locomotive Performance (R. E. 4)	2
Dynamometer Car Tests (R. E. 8)	2
Seminary (R. E. 10)	1
Mechanics of Machinery (M. E. 8)	3
Alternating Currents (E. E. 6)	2
Principles of Economics (Econ. 2)	2
Total	17

Second semester.

Subject.	S. H.
Shops and Auxiliary Equipment (R. E. 3)	2
Advanced Design (R. E. 7)	3
Seminary (R. E. 10)	1
Thesis (R. E. 30)	3
Traction (R. E. 61)	2
Surveying (C. E. 10)	2
Economic Problems (Econ. 16)	2
Total	15

COURSE IN RAILWAY TRAFFIC AND ACCOUNTING.

FIRST YEAR.

First semester.

Subject.	S. H.
Commercial Geography (Econ. 26)	3
Advanced Algebra (Math. 2)	3
Trigonometry (Math. 4)	2
Rhetoric 1	3
Foreign Language	4
Military Drill (Mil. 2)	1
Gymnasium (Phys. Tr. 1, 3)	1
Total	17

Second semester.

Subject.	S. H
Econ. Hist. of the U. S. (Econ. 22)	3
Analytical Geometry (Math. 6)	5
Rhetoric 1	3.
Foreign Language	4
Military (Drill Mil. 2)	1
Drill Regulations (Mil. 1)	1
Gymnasium (Phys. Tr. 1, 3)	1
Total	18

SECOND YEAR.

First semester.

Subject.	S. H.
Principles of Economics (Econ. 1)	5
Mathematics 8a	5
Physics Lectures (Phys. 1)	3
Physics Laboratory (Phys. 3)	2
Military Drill (Mil. 2)	1
Total	16

Second semester.

Subject.	S. H.
Money and Banking (Econ. 3)	3
Business Writing (Rhet. 10)	2
Physics Lectures (Phys. 1)	2
Physics Laboratory (Phys. 3)	2
Military Drill (Mil. 2)	1
American State Govt. (Pol. Sci. 3)	3
History of U. S. (His. 3)	3
Total	16

THIRD YEAR.

First semester

Subject.	S. H.
Principles of Accounting (Accountancy 1)	2
Cost Accounting (Accountancy 2)	2
Corporation Management (Econ. 10)	3
Railroad History and Organization (Econ. 41)	3
Traffic Administration (Econ. 43)	3
Political Science 1 or History 3	3
Total	16

Second semester.

Subject.	S. H.
Principles of Accounting (Accountancy 1)	2
Industrial Accounting (Accountancy 3)	2
Industrial Consolidations (Econ. 11)	3
Railway Administration (Econ. 42)	3
Railway Transportation (Econ. 44)	3
Math. of Investment (Math. 23a)	3
Total	16

FOURTH YEAR.

First semester.

Subject.	S. H.
Advanced Accounting (Accountancy 4)	3
Auditing (Accountancy 5)	2
Railway Practice (Econ. 45)	3
Seminary (Ry. Administration) (Econ. 18)	2
Pol. and Social Ethics (Phil. 9)	2
Electives	...
Total	12

Second semester.

Subject.	S. H.
Advanced Accounting (Accountancy 4)	3
Trustee and Railroad Accounting (Accountancy 6)	2
Foreign Railway Systems (Econ. 47)	3
Seminary (Ry. Administration) (Econ. 18)	2
Commercial Law (Law B)	3
Electives	...
Total	13

COURSE IN RAILWAY TRANSPORTATION.

FIRST YEAR.

First semester

Subject.	S. H.
Trigonometry (Math. 4)	2
Advanced Algebra (Math. 2)	3
General Engineering Drawing (G. E. D. 1)	4
Rhetoric 1	3
Foreign Language	4
Military Drill (Mil. 2)	1
Gymnasium (Phys. Tr. 1a, 2)	1
Total	18

Second Semester

	S. H.
Analytical Geometry (Math. 6)	5
Descriptive Geometry (G. E. D. 2)	3
Rhetoric 1	3
Foreign Language	4
Military Drill (Mil. 2)	1
Drill Regulations (Mil. 1)	1
Gymnasium (Phys. Tr. 1, 2)	1
Total	18

SECOND YEAR.

First semester.

Subject.	S. H.
Differential Calculus (Math. 7)	5
Physics Lectures (Physics 1)	3
Physics Laboratory (Physics 3)	2
Principles of Economics (Econ. 1)	5
Military Drill (Mil. 2)	1
Total	16

Second semester.

Subject.	S. H
Integral Calculus (Math. 9)	3
Physics Lectures (Phys. 1)	2
Physics Laboratory (Phys. 3)	2
Money and Banking (Econ. 3)	3
Steam Engines and Boilers (M. E. 11)	3
Analytical Mechanics (T. & A. M. 7)	3
Military Drill (Mil. 2)	1
Total	17

THIRD YEAR.

First semester.

Subject.	S. H.
Corporation Management (Econ. 10)	3
Railway History and Organization (Econ. 41)	3
Traffic Administration (Econ. 43)	3
Resistance of Material (T. & A. M. 9)	3½
Analytical Mechanics (T. & A. M. 8)	2½
Total	15

Second semester.

Subject.	S. H.
Railway Transportation (Econ. 44)	3
Railway Administration (Econ. 42)	3
Mechanical Engineering Lab. (M. E. 13)	2
Electrical Engineering (E. E. 16)	4
Surveying (C. E. 10)	2
Business Writing (Rhet. 10)	2
Total	16

FOURTH YEAR.

First semester.

Subject.	S. H.
Railway Practice (Econ. 45)	3
Seminary (Ry. Administration) (Econ. 18)	2
Accounting (Accty. 1)	2
Locomotives (Ry. Eng. 1)	2
Engineering Materials (T. & A. M. 6)	1
The Labor Problem (Econ. 12)	3
Total	13

Second semester.

Subject.	S. H.
Foreign Railway Systems (Econ. 47)	3
Seminary (Ry. Administration) (Econ. 18)	2
Accounting (Accty. 1)	2
Railway Tests (Ry. Eng. 11)	1
The Labor Problem (Econ. 12)	3
Commercial Law (Law B)	3
Total	14

APPENDIX VIII.

THE RAILWAY EDUCATIONAL BUREAU, UNION PACIFIC RAILROAD COMPANY.

List of instruction pamphlets kept in the Library of the Railway Board, Simla.

Unit.	Subject.
G. A. 1	Station Works, General.
G. A. 2	Glossary of Terms used in Station Work.
L. 26	Railroad Operation, Don'ts for employés.
F. 1	Railway Mechanical Engineering, General.
F. 3	Do. do. Practical Problems in Mechanics.
F. 7	Do. do. Steam.
S. S. 1	Shop Practice, General.
S. S. 3	Reading Working Drawings, Part I.
S. S. 4	Do. do. Part II.
S. S. 9	How to locate defective wheels
F. A. 1	Mechanical Drawing, General Instructions, Instruments, materials and lettering.
F. A. 2	Mechanical Drawing, Geometrical Drawing.
F. D. 2	Boiler Layout Work, the First course.
L. 22	Railroad Operation. The Turning of Power.
N. 1	Practical Locomotive Firing.
N. 2	Combustion and Firing, Theory of Combustion.
N. 3	Locomotive Boilers, General.
N. 6	Locomotive valves.
O. A. 1	The Air Brake—General.
I. A. 4	Track Work, Ties and Tie Plates.
F. T. 1	Principal of the Gas Engine.
F. T. 10	The McKeen Motor Car.
B. A. 1	Arithmetic, Addition and Subtraction.
B. A. 2	Do. Multiplication and Division.
B. A. 14	Trigonometry.
C. 2	Elementary Electricity and Magnetism, Sources of Electricity, Part 2 "B S C O" cells, storage cells, and dry cells.
C. 3	Do. do. Magnetism.
X. 1	Mallet Articulated Compound locomotives.
X. 2	Handling Mallet-type Locomotives.
J. 9	Track Work—Construction of new line and new second track (Translated into Japanese).

Other Educational pamphlets kept in the Library of the Railway Board, Simla.

Unit.	Subject.
...	Carriage and North Western Railway's First, Second and Third Mechanical Examination papers.
...	Circular No. 1 *re* Announcement of Courses of Instruction to be offered to employés of the Illinois Central Railroad Company and the Yazoo and Missisippi Valley Railroad Company.
...	Westinghouse Air Brake Company Instruction Pamphlet No. 5032, April 1917, No. 6 E. T., Locomotive Brake Equipment with Diagrammatic Folders.

SGPI—S28 -183CE RB—6-1-21

BOOKS AND TECHNICAL PAPERS PUBLISHED BY THE RAILWAY BOARD.

BOOKS.

(1) Administration Report on the Railways in India. Published yearly. *Price* Volume I, Report, Rs. 1-8, Volume II, Appendices, Rs. 2-4.

(2) Classified List and Distribution Return of Officers of all Indian Railways. Published half-yearly. *Price* Re. 1.

(3) History of Indian Railways constructed and in progress, corrected up to 31st March 1918 (published quinquennially). *Price* Rs. 1-8.

(4) History of Services of the Officers of the Engineer and Superior Revenue Establishment of State Railways. Published yearly. *Price* Rs. 2-8.

(5) Pocket edition of the Schedule of Dimensions to be observed on all 5′ 6″, 3′ 3⅜″ and 2′ 6″ gauge railways in India. *Price As. 12.*

TECHNICAL PAPERS.

(6) Over 200 papers have been published by the Technical Section of the Railway Board's office. The papers comprise—

(*a*) Original descriptions of Railway Works and studies of Railway problems in India and elsewhere.

(*b*) Reprints of articles from Foreign Engineering Magazines.

(*c*) Reprints or abstracts of reports received by the Government of India on subjects connected with Railways.

A complete list of the papers can be obtained *gratis* from the Chief Engineer with the Railway Board, Simla.

The prices of the papers vary from Annas Four to Rupees Eight.

The books and papers can be bought from the Superintendent, Government Printing, India, 8, Hastings Street, Calcutta.