though a large proportion of carbon is eliminated with the phosphorus, still that, when there is an excess of carbon, sufficient remains to obtain steel with much higher percentage of carbon than has hitherto been found to be practicable with the basic process.

PROGRESS OF THE ENGINEERING WORKS ON THE DANUBE.

THE Danube, the largest river of Europe after the Volga, since it has a length of nearly 1,800 miles from its source in the Black Forest to its mouth on the Black Sea, is navigable starting from Ulm. Although the navigation of it is easy in the greater part of its course, where in places it forms true lakes of considerable width, it is interrupted, at least in part, by great rapids between Drenkowa (Hungary) and Scola-Bladowa (Servia). As may be seen from our engravings, these rapids are produced by the meeting of banks of rocks, through which the furious water flows and produces immense eddies. Flat-bottomed boats are nevertheless able to pass at certain places, but boats of a greater draught than five feet either have to transship their cargo or else await the season of freshets; and at this moment, if the draught of water is sufficient, to how many dangers is not one exposed amid the innumerable reefs then hidden by the sheet of water! The last and largest of these rapids, situated

the violence and irregularity of the current, is in charge of Mr. Hadju, a Hungarian. The removal of the rock under such conditions necessitates, as may well be imagined, special machines. It is to American, French and English engineers that are due the three types adopted. The Lobnitz machine breaks the rock through the impact of a powerful stamp. The Tedesco diamond drill boat and the Ingersoll percussion drills permit of forming holes in the hardest rocks in order that the latter may afterward be blasted.

Up to the present, nearly a quarter of the sum anticipated has been expended, and it will be about three years before the work is entirely finished.—*Illustration.*

LOCOMOTIVE BOILERS.*

By F. W. DEAN.

I BELIEVE it is estimated that there are about 150,000 locomotives in existence, and with few exceptions they have the usual form of staybolt boiler. The inference might therefore be drawn that this is the safest type of boiler in existence, as an explosion is comparatively unknown. There is, of course, an occasional explosion, but this should not be placed to the discredit of the boiler.

Let us glance at the service which the boiler performs, and in order to appreciate it, a comparison of its duty with that of stationary boilers is interesting.

motives send over less than one-half of one per cent. of moisture less than is found in many stationary boilers. This is due to large water service and steam space. No locomotive boiler was ever so large, or is likely to be, for the reason that from the point of view of economical use of fuel the boiler is always over-worked.

The first matter to decide upon with reference to a boiler is the quality of the material. It is easy to obtain good steel from the various makers throughout the country, and it is probable that any maker can deliver good firebox steel if required.

The most valuable quality which boiler plates can possess, provided that it is not at the sacrifice of any other, is a high elastic limit. By elastic limit is meant the greatest stress per square inch to which it can be subjected without injuring its elasticity. If the steel is strained within this limit, it returns to its original length after the load is removed. If the stress goes beyond this limit the steel breaks down, so to speak, is out of shape, and the boiler becomes leaky. A boiler should have its factor of safety determined with reference to the elastic limit and not with reference to the ultimate strength of the plate. This shows how unnecessary and unwise it is to specify the ultimate strength, except the upper limit, in order to prevent an excess of carbon. In other words, if the elastic limit is brought about by working a low carbon ingot and is accompanied by great elongation and contraction of

THE ENGINEERING WORKS AT THE MOUTH OF THE DANUBE—1. THE RAPIDS OF KASAN. 2. THE GREAT GATES.

near Orsava, in Transylvania, has received the name of the Iron Gates, because the Turks, when they owned the two banks of the river, completely intercepted this dangerous pass by means of an iron chain extending from one bank to the other. Attempts have been made from very remote times to free the river from the obstacles that prevent traffic from being given all the importance that it ought to have, and near the Iron Gates there may still be seen traces of the work done by the Romans. In 1874, an international commission was appointed to ascertain the most efficacious means to be employed. This commission, composed of competent men, estimated the expense at \$2,800,000. At that time the matter was not followed up; but the Austro-Hungarian government, desirous of opening up the country to international navigation, not long ago took up the question, and, although the new estimate carried the probable expense up to \$4,000,000, the work was begun. It extends for sixty miles between Alt-Moldava and Turn-Severin. The object of the work is to excavate in the river a channel that shall have a minimum depth of six feet beneath the lowest water for a constant width of twenty feet.

There are no important excavations to be made in the bed of the river except at the Stenka, Kozla, Tachalia, Greben, and Inez cataracts. At the Iron Gates, the river bed is left for an instant and the channel is excavated in dry earth upon the right bank. The work as a whole includes no less than 14,120,000 cubic feet of very hard rock to be blasted and 35,000,000 cubic feet of dikes to be constructed, without counting the rock work. This work, rendered difficult by reason of

A stationary boiler when working at an economical rate evaporates some two or three pounds of water per square foot of heating surface per hour, but the locomotive evaporates seven to fifteen, more commonly ten to twelve. The stationary boiler is allowed eight to fifteen feet of heating service per horse power, but the locomotive boiler has but one to four. The temperature of the escaping gases of stationary boilers is not much over 400 degrees, while those of locomotives have ranged from 600 to 1,200, very commonly 800. If the pressure is 150 pounds per square inch, a pound of steam occupies a volume of 2.75 cubic ft., and 15 pounds occupies 43.75 cubic ft. Such a rapid formation of steam calls for a full opportunity to escape and points to the undesirability of overhanging furnace side sheets. The heat from the fire is transmitted into the water by the staybolts, and the larger the heads, the more efficiently this is done.

The severe service to which the locomotive boiler is subjected is more apparent when we consider the amount of coal burnt per square foot of grate per hour. In stationary boilers it is from five to 20 pounds, in locomotive boilers from 60 to over 200. With these consumptions the evaporation per pound of coal is low, with good coal five to seven pounds of water. The boiler is subjected to great and sudden extremes of temperature, for if it steams too freely the door is opened wide. Recent tests of the quality of steam show that even when working hard the boilers of loco-

area upon being tested, it should be the most important quality of steel. It is well known that it is easy to secure a high elastic limit in thin plates on account of the amount of work which is put upon the ingot by the rolls. This points to the importance of having thick ingots for thick plates, and an ingot some twenty-five times as thick as the plate to be rolled gives good results.

Besides tests for elastic limit, elongation and contraction of area, it is well to have quenching and bending tests. This is done by heating a piece of plate to a cherry red, plunging it in water and then bending it over a cylinder whose diameter is twice the thickness of the plate. Most steel will, however, bend down flat under a hammer after quenching, without fracture.

For fire plates it is best to be content with a low elastic limit, say 30,000 to 32,000 pounds to the square inch, and to secure strength by thickness of plates and frequency of stay bolts. Test pieces should be long enough to give the elongation in no less than eight inches in order to enable us to judge better of the material, for if the length is restricted we compel the elongation to take place in too small an area to be representative. Every effort should be made to prevent any part of boiler plates being strained up to the elastic limit. Plates can be so strained by punching and flanging. If holes are punched $\frac{1}{8}$ in. small and reamed to size, the injured material is mostly removed, but the proper way is to drill all holes in place. When a boiler shop is once fitted for this work the expense is but little greater than for punched work. If reaming

* Read at a recent meeting of the New England Railroad Club, Boston, Mass.

is done it would be better to drill the holes of an inner plate with the outer punched hole as a guide. This assures fairness of holes and avoids eccentric reaming. If both holes are punched the reamer will become inclined and cause eccentric reaming in both holes and remove only a part of the injured material from each.

A plate-closing ram of a riveting machine, unless used with care, overcomes the elastic limit by making a circular indentation around the rivet hole. Considering that this is the weakest part of the boiler, viz., the joint, it should be particularly avoided. The elastic limit is often overcome by flanging and this indicates the importance of annealing plates after flanging. This would probably delay the almost inevitable cracking that takes place in the throat sheets of boilers when they are spread out to join the circular part of the shell. The inner sheets without doubt become annealed in service, so that if they do not crack when new, they are not likely to do so.

The general direction of the circulation in locomotive boilers is upward at the firebox and forward in the upper part of the boiler, downward at the forward end and backward at the bottom. It is obvious that the more freely this natural movement takes place, the more freely the steam escapes. The escape is undoubtedly facilitated by the jar of the engine, and this is an advantage which the locomotive boiler possesses over stationary boilers of any kind. Now let us see what

where. The long stay bolts would render this unnecessary, or if more strength of stays is necessary at that point, a larger diameter of bolt can be used. Another advantage of the narrow crown sheet is that fewer crown stays are needed; shorter bars can be used if they are transverse, and fewer if they are longitudinal. The longitudinal bars, besides interfering with the horizontal circulation less than the others, permit the longitudinal tie rods to be placed where they are needed for properly staying the back head. I have seen some boilers that have these rods dangerously far apart. In order to properly support the longitudinal bars, the outer crown sheet should be stiffened with two heavy T irons from which the bars can be supported at two points in each, as in English practice.

Next let us examine the form of the boiler about the fire box. The circular form of a flexible thin shell is the form which it takes when subjected to uniform internal radial pressure, and therefore if it is circular it is in equilibrium and will maintain its circular form when subjected to such pressure, and not otherwise. Let us examine what occurs with a crown boiler under pressure. There are in many cases as much as 200 tons of pressure tending to force the inner fire box downward out of the boiler. How is this pressure resisted? It is resisted by the base or mud ring at the bottom, which tends to rotate (and this points to the advisability of double riveting this ring), by the stiffness of the stay bolts, and by connections from the

stresses in the parts are concerned. When the boiler is under pressure the stays are in unequal and unknown stresses, and many parts must be dangerously strained. The Wootten variety of this form is an extreme case, and its weakness is more apparent. If we take a cross section of this we shall see that the pressure acts upon the sides as it does upon a Bourdon tube in a steam gauge, and it tends to straighten out as the tube does. It is easy to see that the tendency is to pull the stay bolts out of the thinner sheet. This shows the necessity of tying the sides of the mud rings to each other at intervals. My own opinion of all the forms of boiler thus far described is that they are unsafe. Any structure in which the stresses cannot be computed is likely to be unsafe.

Now let us see if there is not some form of boiler which is free from all these defects, in fact, a boiler which possesses nothing but virtues. If we had a boiler which tends to lift up the crown sheet as much as that sheet tends to go down, it is evident that there would be no pressure tending to force out the fire box, to rotate the base ring, to bend the stay bolts, to render computation useless, and to distort the outer shell. The Belpaire fire box, named after its distinguished inventor, has these qualities, and the principle of its design is this, that any flat surface of the inner fire box has a companion equal flat surface upon the outer. This permits the corresponding surfaces to be stayed together by stay bolts of various lengths, and all pres-

THE ENGINEERING WORKS AT THE MOUTH OF THE DANUBE—THE IRON GATES—1. THE RAPIDS OF DOBRO. 2. THE WHIRLPOOL OF KASAN.

obstructs circulation. It would be obstructed by an insufficient feeding of the water spaces, and for this reason I advocate a very wide front water space in order to properly feed the side spaces. I advocate side sheets which do not follow the form of the outside sheet, but which are slightly inclined inward, provided no disadvantage follows. When the firebox is between the frames, as is generally the case in New England, this makes a narrow firebox at the top, but it can accommodate a wide tube sheet by being flanged out forward. This has been the practice on the London, Brighton & South Coast Railway for many years.

Circulation can be facilitated by abandoning transverse crown bars, as they obviously interfere with the upper horizontal current of water. The general circulation in the barrel can be facilitated also by using a large shell and placing the tubes far apart, and by placing the tubes farther apart horizontally at the front end than at the other. The inclination of the tubes to the tube sheets is so slight that the tubes are as tight as usual. The writer has practiced this method for several years in stationary boilers. Inclining the side sheets of the firebox not only promotes better circulation but gives greater elasticity to the upper stay bolts by making them longer, and this prolongs their life. The usual method of accomplishing this desirable end is to use enough stay bolts at the top to make the structure in that vicinity sufficiently strong and rigid to throw relative movement between the plates else-

crown bars to the shell above. The crown sheet, of course, tends to go down, and actually does so, as I have found out by experiment. In doing this it bulges out the curved sides of the inner fire box. In depressing, the crown sheet seeks assistance from the outside crown, but this being in equilibrium from internal pressure, and thin, is as unable to resist distraction from this cause as a distended toy balloon is unable to resist the pressure of the finger. It therefore depresses and the sides bulge out. The inner crown sheet surely goes down, the sling stays are in unequal and absolutely unknown stresses, the upper and other stay bolts are bent, and all conditions for over-straining and breakage are present.

Transverse tie rods just above the crown sheet simply modify the unknown stresses, but do not simplify the chaotic condition of them. This is enough to cause stay bolts to break, and in my opinion is the great cause, rather than the expansion of the side sheets. The depression of the outer shell forcing out the sides assists in cracking the upper part of the throat sheet. Another common feature of construction assists in this last phenomenon. I refer to the common practice of not using a circular form to the outer crown sheet, not that this would do any good to this sheet, but it would give circular cross sections to the conical part of the shell immediately in front, thus avoiding a flat place on each side. This flat place tends to bulge out, and assists in cracking the throat sheet.

The radial stay system has the same faults as far as

sures are perfectly balanced. Moreover, as the stayed plates are flat, they are elastic and yield to movements produced by changes in temperature. Every part can be properly stayed, the stresses properly computed, and the conditions of stress are not changed when the boiler is hot.

This boiler is safe with any pressure for which it is designed. As the crown sheet does not go down, stay bolts will break less than in any other boiler. Circulation is free over the crown sheet, water surface and steam space is great, and longitudinal tie rods can be placed where needed. The weight is a minimum because every part is proportioned for its stress.

With this boiler carefully worked out, I should not anticipate any cracking of the extremities of the throat sheet.

Of course boilers of this kind can be imperfectly worked out, and trouble will follow, but what I mean to say is that if this boiler is properly designed, most boiler troubles will disappear. Flat places should be carefully sought out, and there should be no staying between the back head and this outer crown sheet.

Of course there is no difference of opinion as to the superiority of the butt joint for boilers with inside and outside covering plates. The circular form is preserved best by it, and it gives the strongest joint. In case an extra strong joint is wanted—and who does not desire it?—the inside plate can be extended beyond the outside, and one or more rows of wide-pitched rivets placed through it and the shell proper. In this case

the inside plate should be as narrow as is consistent with the object in view, because any inside plate tends to straighten out between the rows of rivets, and thus be ineffective in a measure. This plate should be as thick as the shell, in order to minimize such a tendency, but it should be pointed out that this tendency would not exist if the inside plate should be calked, and thus the steam prevented from getting between it and the shell. The calking cannot be done, however, unless the covering plate is very thick and scalloped around the rivets. Whenever a joint is made in this way, and it is not uncommon in foreign marine works, the narrow plate is placed inside and the wide scalloped plate outside. This makes the strongest possible joint and probably has an efficiency of nearly 95 per cent. of the boiler.

While upon this point I wish to point out the deceptive nature of a joint that is frequently seen on locomotive boilers. I refer to the lap joint with an inside bent covering plate. I have watched the behavior of large sections of this joint in the Watertown testing machine, and can testify to the all but uselessness of the weld. Its action is to straighten out and allow the main part of the joint to be ruined before it is pulled taut, at which time, of course, its own elastic limit is passed at the bend. Such a weld should always be thick and the rivets nearest the bend should be as close as possible to it.

Concerning tubes, many people believe that long tubes are objectionable. It should only be remembered that the smoke box temperatures of our locomotives are between 600 degrees and 1,200 degrees, while the temperature of the steam is not usually much above 300 degrees. We either want longer tubes or more tubes of the present length. In other words, in the usual type of bituminous coal burning locomotives the heating surface should be more than 73 times the grate surface, which is the common ratio. In France this matter of tube lengths has received much attention, and tubes 16 feet long have been used for years.

In conclusion I wish to call attention to the device of a Frenchman for increasing the heat-absorbing surface of tubes—the Serve tube, which has longitudinal internal ribs, thus increasing the inside surface some 90 per cent. These ribs not only possess more surface, but the ribs slice up the gases and abstract the heat from the center. It seems to me that this provides a most promising means of cooling down the gases in locomotive boilers. Tests have shown an increase of evaporation per pound of coal of some 10 per cent. to 15 per cent.

Mr. LAUDER: I have heard these matters discussed for the last thirty or thirty-five years by scientific men, practical men, constructors of boilers and users of boilers, and have heard the poor old locomotive boiler sadly abused, yet for sixty years it has done its work, and done it well. I have never been able to discover the weaknesses in the old locomotive boiler that Mr. Dean mentions. He says that the boiler we are using is a dangerous thing, and yet while there are tens of thousands of locomotives in use all over the country, using all kinds of water and fuel, run by all kinds of men, some with good care and some with poor, there is scarcely a case on record where a locomotive boiler has exploded; occasionally there is one, generally an old one. If a boiler is properly built and tested, properly inspected and taken care of, and the repairs looked after when weaknesses are discovered, there is little danger of explosion. I have never discovered any particular merit in the radial stay boiler. With the good water we have in New England, I see nothing wrong with the ordinary type of boiler, with the fire box stayed with crown bars; it has stood the test of service for a good many years. Where the water is bad, impregnated with alkalis, the crown sheets are soon used up, and the radial stay boiler is better for use; but under the circumstances, I should prefer to use the Belpaire boiler. That boiler practically is right, but it has developed some weaknesses, possibly due to not being properly designed. Whether it can be designed to stand the rough usage which most locomotives get, I think is an open question. It has the merit of having flat surfaces both of the inside box and the outside shell. The theory that when a boiler is under high pressure the outside circular crown is flattened by the pull-down of the sling stays I think is largely imaginary; if that occurred to the extent sometimes supposed, the plates forming the outer crown would soon give way. It is true that that has sometimes happened. We have had longitudinal cracks develop in the outside crown of locomotive boilers, but it was always where that outside crown was made in three sheets, with a double riveted lap seam, which invites this trouble. With regard to the supposed want of circulation in the locomotive boiler, I think the circulation of water in a well designed modern locomotive boiler is almost perfect. Were it not so, with the intense heat generated in the furnace, the plates would soon show the effects of over-heating.

Mr. DEAN: Mr. Speirs has shown by direct experiment that the crown sheet does go down on the side; he found it went down over 0.06 of an inch, and it is not unreasonable to suppose that the middle went down further. I remember a 90-inch boiler with a nine-sixteenths inch plate, and the outer crown sheet was stiffened up very much by heavy bars riveted to it. I put a templet on that boiler, making it go over between two certain points, and found the middle of the outer crown sheet fell 3-32 of an inch.—*Nat. Car and Locomotive Builder.*

WORLD'S CONGRESS OF ENGINEERS.

AMONG the various congresses which are being promoted by the "World's Congress Auxiliary," it is proposed to hold in Chicago, during the Columbian Exposition of 1893, an International Congress of Engineers. Its organization has been made a separate department of the "Auxiliary," and has been intrusted to the undersigned committee, assisted by an Advisory Council, which will constitute the non-resident branch of the Committee, and will co-operate with it by means of correspondence.

Moreover, the various engineering organizations of the United States and Canada have formed a voluntary association, for the purpose of providing headquarters for engineers who may visit the Exposition, and of promoting the Engineering Congress. The information already received by this association makes

it evident that there will be a large attendance of both foreign and American engineers.

The principal objects of the Congress will be to enable engineers to inform each other concerning the latest, best and most economical practice in methods of construction and operation, machines, processes, experiments and investigations, including standards of efficiency, tests and measurements, to compare and interchange ideas, and to discuss points of professional interest.

It is expected that the Engineering Congress will take place probably in the month of July or August, 1893, and will last six days, a portion of which may be devoted to visits for the inspection of objects of engineering interest. The "Auxiliary" is to furnish the halls and the rooms for the meetings, and to attend to the subsequent publications of the proceedings and papers, but this will not prevent the various societies holding sessions in the Divisions or Sections of the Department from publishing the papers and proceedings in their transactions.

The Congress is to begin with a joint meeting and appropriate addresses, and in view of the wide scope of engineering specialties, it is then to be divided into seven General Divisions, as follows:

- General Division A—Civil Engineering.
- B—Mechanical Engineering.
- C—Mining Engineering.
- D—Metallurgical Engineering.
- E—Electrical Engineering.
- F—Military Engineering.
- G—Marine and Naval Engineering.

These divisions may be divided into as many chapters or sections as may be found desirable. The Congress may terminate with another joint session.

It is expected that each division will be organized in advance with the active aid and co-operation of the representatives of the National Society or Governmental department corresponding thereto. Such organization will include a chairman, vice-chairman, secretaries and advisory council of the division; and will select the subjects to be discussed, promote and receive voluntary papers, and arrange for discussions thereon, and generally prepare an approximate course of proceeding.

The work of every division will consist in:

First: The discussion of subjects chosen by the officers of the division.

Second: Reading of selected voluntary papers, and discussion thereon.

The officers of each division will be expected to cause analyses of the engineering subjects selected to be prepared by specialists in advance to serve as an introduction to the intended discussion: and also to endeavor to secure the attendance of engineers prepared to discuss them.

Voluntary papers to be solicited from engineers throughout the world, in either English, French or German, not to exceed fifteen minutes in presentation, and not previously published or communicated to any society, are to be sent in advance to the secretary of the division for which they are intended, and passed upon by its officers. Papers or abstracts will be printed and distributed if received in time, and the discussions will be under such rules as may be formulated by the undersigned General Committee of the World's Congress Auxiliary.

The Committee therefore bespeaks the co-operation of all engineers in making this Congress a success. It is only through their aid that its work can be made satisfactory.

The following tentative classification of subjects is submitted, and suggestions are invited in relation thereto, and in regard to all other matters connected with the Congress, to be used in the formation of the final plans.

GENERAL DIVISION A.—CIVIL ENGINEERING.

Subjects.

Railways.—Location, construction, equipment, operation, maintenance, and terminals.
Canals.—Construction and operation.
Water Works.—Dams, aqueducts, filtration, and distribution. Pumping and gravity systems. Reservoirs and aeration.
River Improvements.—Regulation and control.
Harbors.—Jetties, breakwaters, lighthouses and other signals, piers, docks, wharves, and dredging. Removal of obstructions to navigation.
Drainage.—Sewage and sanitation.
Roads.—Highways, streets, pavements, and curbing.
Reclamation of marshes, sand dunes.
Foundations.—Independent piers, piles, coffer dams, caissons, pneumatic and other methods.
Tunnels.—Subways, shafts, and deep wells. Ventilation of tunnels.
Strength and Employment of Materials.—Testing machines, tests.
Surveying.—Land, cities, public works, etc.
Street Railways.—Animal, cable, and electrical, etc.
Instruments of Precision.—Transits, levels, etc.
Masonry.—Viaducts, arches, aqueducts, bridges, walls, etc.
Bridges.—Truss, plate-girder, and suspension. Cantilevers and arched girders.
Construction of buildings and towers.
Handling and storage of grain, coal, ores, etc.
Elevated Railways.—Underground railways.
Irrigation.—Artesian wells, hydrography.
Constructional Appliances.—False works, cranes, etc.

GENERAL DIVISION B.—MECHANICAL ENGINEERING.

Subjects.

Motors.—Steam, air, explosive, hydraulic, and wind.
Machines.—Excavators, dredges, cranes. Planting, cultivating, and harvesting machinery. Animal, steam, and manual power machinery. Brewing and distilling apparatus. Wood-working machinery, pulp-making and wood-preserving apparatus, logging tools and machinery. Tanbark, turpentine, and charcoal manufacture. Hydraulic rams and presses, elevators. Fire apparatus, engines, ladders, standpipes, chemical engines, etc. Sawing, planing, moulding, and veneering machines. Stone-working machines. Ventilating and warming machinery, stoves, ranges, hot air and steam heaters. The phonograph.

Instruments of Precision.—Scales, meters, measures, etc.

Tools.—Lathes, planers, emery wheels, presses, drills, punches, saws, shears, wood-working tools, etc.

Rolling Stock.—Locomotives, traction engines, cars, power brakes.

Power Transmission.—Cables, shafting, belting, compressed air, steam, hot water, hydraulic pressure.

Heat Transmission.—Steam, hot air, and hot water.

Steam Generators.—Boilers and settings, furnaces and grates, mechanical stokers, stacks, forced draughts, fuels, smoke consumers.

Gas Making.—Coal gas, water gas, vapor gas machines. Distribution, consumption, and measurement.

Testing Machines.—Tests.

Refrigeration.—Ice making and cooling machines.

Cable Railways.—Pneumatic railways. Rack railways.

Pumps, filters, blowers, fans, and miscellaneous machinery connected with engineering work.

Sanitary engineering and appliances.

Petroleum.—Pipe lines. Distilling and refining.

GENERAL DIVISION C.—MINING ENGINEERING.

Subjects.

Extracting Ores.—Iron, coal, copper, zinc, lead, tin, nickel, etc.

Drift and Placer Mining.—Gold, silver, diamonds, and other precious metals and stones.

Boring. Petroleum, natural gas, salt water, and prospecting.

Preparation of Ores.—Roasting, concentration, etc.

Extraction, separation, and refining of products.

Explosives.—Gunpowder, nitro-glycerine, and allied explosives. Location, loading, and firing of blasts.

Mine Working.—Timbering, ventilation, and safety appliances. Draining.

Ore-working Machinery.—Boring and cutting, crushing and pulverizing apparatus.

Assaying.—Methods employed and comparison of results.

Surveying.—Prospecting and mapping. Instruments of precision.

Geology.—Mineralogy.

Quarrying and Allied Industries.—Graphite, asphalt, asbestos, clay, building stones, limestone, marble, cement, gypsum, salt, borax, phosphate, slate, etc., quarries and mines.

GENERAL DIVISION D.—METALLURGICAL ENGINEERING.

Subjects.

Smelting.—Furnaces, stacks, stones, direct processes.

Iron.—Manufacture of various grades of cast and wrought iron. Fuel, waste products, economy, etc.

Puddling.—Furnaces, malleable iron processes. Mechanical puddlers.

Steel.—Bessemer, basic, and open hearth processes, etc.

Rolling Mills.—Plates, rails, beams and shapes of various kinds. Long pieces, rolling from fluid metal.

Steel.—Working and tempering of steel for tool and constructional uses.

Wire.—Manufacture, sizes, strength.

Forgings.—Methods of manufacture. Sizes.

Aluminum.—The pure metal and its qualities. Its alloys and their qualities. The manufacture.

Alloys.—Gun metal, type metal, bronzes, etc. Their manufacture and qualities.

Fuels and Fluxes.—Their nature, costs, and effects.

Reduction and Working of Other Metals.—Copper, zinc, lead, tin, nickel, etc.

GENERAL DIVISION E.—ELECTRICAL ENGINEERING.

Subjects.

Telegraphy.—Systems: Duplex, quadruplex, multiplex, etc. Rapid telegraphy. Cable telegraphy and instruments. Batteries and telegraph dynamos. Circuits. Induction and telegraphy.

Telephones.—Systems, transmitters, switch-boards. Automatic apparatus. Magneto bells. Long distance telephony. Induction and retardation.

Lamps.—Arc lamps and carbons, incandescent lamps and filaments. Manufacture and durability. Sockets.

Wires.—Overhead systems, underground systems, cables. Insulation.

Distribution.—High tension, direct; low tension, direct; alternating. Simple circuits, compound circuits. Series and parallel systems.

Batteries.—Primary and secondary.

Generating Machinery.—Dynamoes, alternating and direct. High and low tensions. Armature and field windings. Methods of regulation. Commutators. Mechanical details.

Motors.—Direct and alternating current motors. Armature windings. Regulating devices. Commutators and mechanical details.

Appliances.—For measuring and controlling currents of electricity. Switches, rheostats, meters, safety appliances.

Transformers.—Methods of winding, loss in conversion, heating, designs.

Mining and Metallurgy.—Boring, drilling and firing, pumping. Reduction of ore.

Welding.—Welding, brazing, soldering, tempering and forging.

Transmission of Power.—Short distances, long distances.

Signals.—Bells, annunciators, automatic calls, individual calls, etc.

Railways.—Single and double wire systems, rail transmission systems, geared and gearless motors, generators. Trolley and underground systems. Storage battery systems.

Electro-plating.—Current, solutions, time, etc.

Heating.—Resistance devices. Thermostats.

Execution.—Apparatus for destruction of life.

Photography.—Electrical devices for same.

GENERAL DIVISION F.—MILITARY ENGINEERING.

Subjects.

Fortifications.—Breastworks, arsenals, magazines, pits, mines. Protection of rivers and harbors.

Ordnance.—Light and heavy guns, rifled bores, breech-loading. Small arms, magazine guns.