Discharge, Prickwillow.

Suction, Prickwillow.

Engine, Wisbech.

Suction at Wisbech.

Modern Pumping Machinery*

As Employed for Drainage of the Fens, England

By Richard W. Allen

THE drainage of that large tract of low lands known as the Fenland (Lincolnshire, England), comprising over 450,000 acres, is generally but little understood. That the subject is full of interest, and the mechanical devices so varied, will be acknowledged, when it is mentioned that to-day the following methods are employed for carrying out this great work, without which the land would be entirely unproductive:

- (a) Windmills driving scoop-wheels.
- (b) Beam-engines (single and compound cylinder) driving scoop-wheels.
- (c) Beam-engines and horizontal engines driving vertical-spindle pumps through gearing.
- (d) Vertical steam-engines driving horizontal-spindle centrifugal pumps.
- (e) Horizontal oil-engines driving horizontal-spindle centrifugal pumps.

To describe in detail the mechanism under each of these headings would be quite beyond the scope of this paper, and the author therefore proposes to deal chiefly with those which are included under headings (d) and (e).

(a) *Windmills driving Scoop-wheels.*—This type of machinery is rapidly disappearing; the largest example now working is situated on the banks of the River Ouse at Harriermere, Middle Fen District, near Ely, the scoop-wheel being 30 feet in diameter with 5 feet by 14 inches ladles, Fig. 1. The dip of water on the ladle is 1 foot 9 inches and the maximum lift to which the wheel is capable of working is 10 feet. This mill has four sails, 40 feet long by 7 feet wide, and the ratio of gearing gives four revolutions of the sails to one of the scoop-wheel.

(b) *Beam-engines driving Scoop-wheels.*—This class of machinery is gradually being replaced by more modern pumping engines, due in many cases to the fact that the subsidence of the land has been so great, varying from $\frac{1}{2}$ inch to 1 inch each year, that the present level of the various main drains is too low to allow sufficient dip on the ladles of the scoop-wheels.

(c) *Beam and horizontal Engines driving geared vertical-spindle Pumps.*—A difficulty now being experienced with many of the existing vertical-spindle pumps, is that, in order to charge the pumps, the water in the drains has to be raised to such a level that there is grave danger of some of the lowest lying land being flooded before the machinery can be set in operation. The cost of lowering the scoop-wheel or the pump, as the case may be, is such an expensive matter and the efficiency under the most favorable conditions so low, that it is more economical to

remove the old plant and replace by more modern machinery.

(d) *Vertical Steam-engines driving horizontal-spindle centrifugal Pumps.*—During the past fifteen years a number of pumping plants have been installed, in the majority of cases new machinery included under clause (d) replacing existing appliances for raising water.

Engine House, Prickwillow.

Discharge, Soham Mere.

For purposes of illustration, the author has chosen some of the following stations in which he has been interested, representing some of the most recent work in the district; but, at the same time, he wishes it to be understood that there are many other stations, such as those erected at Laneham, Puddock Bridge, and in the North Level, which are doing excellent work:

- I. Prickwillow, Middle Fen Commissioners.
- II. Wisbech, Waldersea District Commissioners.
- III. Soham Mere, Dunn Gardner Estate.
- IV. Mr. Martin's Farm, Hilgay.
- V. Ten-Mile River Bank, Littleport and Downham District.

Before describing the pumping stations in detail, it may be interesting to give in condensed form the main points to be considered in the design and construction of drainage machinery suitable to the conditions obtaining in this area:

(1) In the wettest season the machinery only works five to six months during the year, and in a dry season only three to four months, and sometimes less.

(2) Initial cost has to be kept as low as possible, as the Fen Commissioners have seriously to consider their drainage tax.

(3) Plant to be so designed as to run continuously for at least a month.

(4) The machinery will generally be run by a skilled laborer, not a mechanic. Simplicity is therefore essential.

(5) Water for boilers and for condensing purposes always contains a large percentage of mud in suspension, and this particularly so during the wettest time of the wet season.

(6) Efficiency to some extent must be sacrificed to initial cost and simplicity of design.

(7) Cost of maintenance and renewals must be reduced to a minimum.

(8) All calculations must be based upon amount of coal consumed to the water horse-power discharged.

(9) When new plant is installed, the old foundation must be utilized as far as possible.

(10) All new foundation work, unless well stepped into existing foundations, must be placed upon piled ground, or reinforced concrete employed.

(11) The maximum quantity of water has to be always discharged upon the highest lift.

These considerations have been met to a very large extent by the machinery installed at the stations already referred to, due especially to the fact that the centrifugal pump applies itself so well to differences in level of the water in the drain and river. The suction and discharge pipes of the centrifugal pump with a horizontal spindle are laid in the old race of the scoop-wheel with very little cutting away or filling in, and, by extending these pipes outside the building, little or no alteration is required to be made to the main walls of the engine-house. The foundations necessary for the engines are small and easily made in the original engine-house, and further, the

Engine room, Soham Mere.

Main drain, St. Martin's Farm.

Engine and pump, St. Martin's Farm.

Suction, Soham Mere.

* Paper read at the Cambridge meeting of the Institution of Mechanical Engineers (England).

extra length of suction pipe can be readily added when required to meet any lowering of the main drain, due to subsidence of the land.

From experience gained, the machinery most suitable is that consisting of Lancashire boilers, vertical double-acting enclosed forced-lubrication engines running at a moderate speed driving direct centrifugal pumps with horizontal spindles, the condensing plant of the jet type having the injection water well strained before reaching the condenser, and the air-pumps driven either direct from engines or by gearing running in an oil-bath. It is upon these lines that these pumping stations have been designed, with the exception that engines of the open type have been supplied in place of those of the enclosed. This has been brought about by hesitation of the Fen Authorities to depart from the exceptionally low revolution engine, although in many cases the piston-speed of the enclosed engine proposed has been less than that of the open-type engine, yet permission to install the former has not so far been granted.

Water-tube boilers, steam-turbines and surface condensing plants have on occasions been suggested as an alternative, but the author ventures to think that their

condensing engine of 60 nominal horse-power, erected in 1833, using steam at 6 pounds per square inch, and driving a scoop-wheel 33 feet 6 inches in diameter.

The machinery, Fig. 2, consists of a vertical compound double-acting condensing open engine, driving direct a horizontal centrifugal pump. The steam-cylinders are 21 inches and 35 inches diameter, each having a stroke of 1 foot 8 inches. The engine is capable of developing 300 indicated horse-power with steam-pressure at 75 pounds per square inch. The diameter of the suction and delivery pipes is 43 inches, and the pump is capable of delivering 150 tons of water per minute upon a 16-foot lift at 130 revolutions. The revolving disk is 5 feet 6 inches diameter, and is made of cast-iron and keyed to a steel shaft, running in white-metal bearings. The

209 days (of 12 hours duration), the maximum non-stop run being 372 hours during the latter part of August. The average coal consumption was 3½ tons for the 12 hours, including the raising of steam in boilers.

This district has a taxable area of 11,000 acres and about 25,000 acres to be drained, and to-day the drainage is mainly carried out by this pump, assisted by a 60 horse-power compound condensing beam-engine driving a vertical spindle pump, the engine being supplied with steam at 65 pounds pressure. The main drain is 30 feet wide and 7 feet deep at starting level, and there are about 30 miles of drains connected thereto.

The capacities of the old and new machinery may be of interest, and are tabulated below. It will be noted

Map of the Fen District, Lincolnshire, England.

claim does not show sufficient merit to warrant their acceptance, as the slight gain, if any, in efficiency would not show sufficient return to cover the interest upon the increased initial capital expenditure; further, it might be necessary to duplicate the machinery to enable the cleaning of the boilers and condensers to be carried out efficiently; and, lastly, the unsuitability of the feed and cooling water for this class of machinery.

I. PRICKWILLow, Middle Fen District.—This pumping engine was installed in 1897 replacing a side-lever

Old beam engine, Ten Mile River Bank, Littleport.

Compound condensing engine and centrifugal pump installed in 1912.

Suction

Discharge.

Fig. 2.—Middle Fen drainage commissioners Prickwillow pumping station.

Fig. 3.—Waldersea drainage district Wisbech pumping station.

Fig. 1.—Windmill at Harrier Mere driving 30 feet diameter scoop-wheel. Middle Fen District.

that, owing to the subsidence of the land, the lift of the pump has increased in 16 years from 13 feet 4 inches to 15 feet, and in 80 years it has increased practically 6 feet.

II. WISBECH, Waldersea District Commissioners.—This machinery, Fig. 3, was erected in 1900. It consists of a vertical compound double-acting open engine driving

Fig. 4.—Soham Mere pumping station.

direct a horizontal-spindle centrifugal pump. The engine has cylinders 18 and 29 inches diameter by 16 inches stroke, and is capable of developing 200 horse-power, when running at 130 revolutions per minute. It is supplied with steam at 90 pounds per square inch from two Lancashire boilers, 29 feet by 7 feet 6 inches diameter. The diameter of the suction and discharge pipes is 36 inches, and the pump is capable of discharging 100 tons of water per minute against a total lift of 15 feet, the diameter of the disk being 4 feet 6 inches. A jet-condenser is provided giving a constant vacuum of 26 to 27 inches. The air-pump, 16 inches diameter by 9 inches stroke, is worked from the high-pressure crosshead.

This district consists of 5,000 acres and its waters are discharged into the River Nene about 5 miles above Wisbech. It was originally drained by two engines, one erected in 1832, a Cornish beam-engine of 70 nominal horse-power working a bucket-pump 62 inches diameter with 7 feet 6 inches stroke, and the other erected in 1883, a single cylinder condensing engine driving a vertical-spindle centrifugal pump. The former plant was removed in 1900 and replaced by the machinery described above, the old well being used for the suction pipes of the pump. Practically no alteration was required to be made to the foundations or building.

III. SOHAM MERE, Dunn Gardner Estate.—This pumping plant, Fig. 4, was erected in 1910, and replaced an old beam-engine working with 10 pounds of steam, driving a 36-foot scoop-wheel. The engine is of the open compound type driving direct the centrifugal pump. The engine has cylinders 9 inches and 15 inches diameter by 9 inches stroke, and it is capable of developing 65 brake horse-power when running at 250 revolutions per minute, steam being supplied from a Lancashire boiler, 20 feet by 6 feet 3 inches diameter, at 120 pounds per square inch.

The diameter of the suction and delivery pipes is 22 inches and the pump is capable of delivering 35 tons of water per minute against a total lift of 17 feet. The condensing plant is of the ejector type capable of maintaining a vacuum of 26 inches. The injection water centrifugal pump is driven by belting from the main engine shaft, this water being carefully strained on the suction side.

The pump was placed in the old wheel-house and the suction and discharge pipes laid in the wheel race, no alteration whatever being made to the suction and delivery culverts. The engine stands in the old engine-house upon the old foundations, the foundation work being therefore reduced to a minimum. The coal burned is from 2½ to 3 tons in 24 hours. The main drain is about 20 feet wide and 6 feet deep at starting point, altogether 5 or 6 miles of drains connecting thereto, the discharge culvert being 6 feet by 4 feet 6 inches wide.

This district consists of about 2,000 acres and discharges its waters into Soham Lode about 4 miles above Ely. It was, as its name implies, an inland lake and was originally drained by windmills and the steam-driven scoop-wheel previously described. The strata of the soil consist of about 4 feet of silt, 3 to 4 feet of peat and then the clay. About 650 acres are held by small holders, the land, in quantities of 50 acres each holding, being let by the Cambridgeshire County Council.

IV. MARTIN'S FARM, Hilgay.—This plant, erected in 1909, is one admirably suitable for landowners wishing to have, or compelled to have, their own drainage plant. It consists of an open double-acting single cylinder non-condensing engine driving direct a horizontal-spindle pump. The diameter of the cylinder is 10 inches with a 9-inch stroke, and when supplied with steam at 60 pounds

pressure per square inch and running at 275 revolutions per minute is capable of developing 30 brake horse-power. The pump delivers 13½ tons of water per minute against a lift of 17 feet, the main suction and delivery pipes being 14 inches diameter. The end of the discharge pipe which is water sealed is fitted with a balanced flap valve to

Fig. 5.—Mr. Martin's farm pumping station.

Fig. 6.—Littleport and Downham District. Ten Mile River pumping station.

prevent siphoning back of the river water when the pump is not working. The boiler is 20 feet by 5 feet diameter.

This estate, which is situated in Hilgay Fen, discharges its water into the River Ouse about 5 miles above Denver sluice. The area is 750 to 800 acres, and was formerly

drained by a single-cylinder beam-engine driving a 34-foot diameter scoop-wheel. Beyond deepening the suction and discharge culverts for a short distance, and partially removing the division wall between the engine-house and wheel-house, no foundation work was necessary, the pump being placed on girders directly over the old wheel race. Fig. 5 shows the arrangement of this plant.

V. LITTLEPORT AND DOWNHAM DISTRICT, Ten-Mile River Bank Pumping Station.—This installation, which is one of the largest drainage stations in the Fens, was erected in 1912. It consists of two double-acting open compound condensing engines driving direct horizontal-spindle high-efficiency centrifugal pumps. The engines have cylinders 14 inches and 22 inches diameter by 13 inches stroke, and are each capable of developing 200 brake horse-power with steam at a pressure of 120 pounds per square inch.

The diameter of the suction and delivery pipes is 48 inches, and the ends of the discharges are fitted with multiple flap valves. Each pump is capable of delivering 150 tons of water per minute upon a lift of 15 feet, or 190 tons of water per minute upon 10 feet lift, when running at a speed of 210 to 220 revolutions per minute; each pump is fitted with outside bearings and steam-ejector for charging purposes.

The condensing plant is of the jet type, each engine driving, through gearing enclosed in an oil bath, twin air-pumps, which run at 90 revolutions per minute. The diameter of each barrel is 8¾ inches diameter by 11 inches stroke, and they maintain a constant vacuum of 26 inches. The injection water is drawn from the main discharge culvert, passing through a twin strainer which can be cleaned without causing any cessation in the flow of the water. The air-pumps discharge into a hot-well, from which the feed-pumps draw their water. Steam is supplied by three Lancashire boilers, 25 feet by 7 feet 3 inches diameter, the feed water having its temperature raised by means of a live-steam heater. The pumping machinery, Fig. 6, is so arranged that each unit is quite independent of the other.

The following records of the working of these pumps have been kindly supplied by the officer of this district:

From October 30th, 1912, to April 9th, 1913, the total hours of running were 1,458. Total fuel consumed, 600 tons. Total average lift, 11 feet 8 inches. Total water discharged, approximately, 170 to 180 tons per minute. The main drain is about 23 feet wide, and in all approximately 26 miles of drains connect thereto. At starting point of pumping there is 6 feet of water in the drain, and at stopping it is lowered to about 2 feet.

This district has a taxable area of 26,000 acres, but a total area to be drained of 35,000 acres, which was originally carried out entirely by windmills. At present the whole area is drained by two pumping stations, 7 miles apart, one at the Hundred Foot River and the other at the Ten-Mile River. The first steam plant erected in the district was a 30 horse-power engine and scoop-wheel at the Ten-Mile River in 1818.

In 1829 an 80 horse-power beam-engine, having a cylinder 3 feet 6 inches diameter by 8 feet stroke driving a scoop-wheel 41 feet in diameter, was installed. This

wheel was, in 1882, increased to 50 feet diameter with 60 ladles, 8 feet long by 3 feet wide, and is working to-day. At the Ten-Mile River Bank Station, in 1843, the original steam-plant was removed, and an 80 horse-power condensing beam-engine was erected driving a scoop-wheel

of 42 feet 8 inches diameter, which was increased to 43 feet 8 inches diameter in 1880. The wheel had 50 scoops 7 feet 6 inches radial length by 3 feet wide, and made $4\frac{1}{4}$ revolutions per minute, the gearing being 7 of engine to 1 of wheel, and at that date had an average dip of the scoops of 3 feet. Owing to the subsidence of the land, this dip was gradually lowered to 1 foot 10 inches, and in 1912 this plant was removed, and the centrifugal pumps previously described were installed.

The rainfall recorded in this district since the year 1901 is as follows:

1901.....14.81 inches.	1907.....20.23 inches.
1902.....17.86 "	1908.....16.16 "
1903.....27.65 "	1909.....25.38 "
1904.....16.85 "	1910.....21.85 "
1905.....18.87 "	1911.....20.65 "
1906.....21.32 "	1912.....31.01 "

(c) *Horizontal Oil-engines driving horizontal-spindle Centrifugal Pumps.*—This class of machinery has been

installed especially for small plants in several districts, the first to be erected being at Denver Parts in 1897, and consisting of a 9 brake horse-power oil-engine driving an 11-inch centrifugal pump. Mention should also be made of a 24-inch pump driven by a 40 brake horse-power oil-engine in the March Third district, and an 18-inch pump driven by a 40 brake horse-power engine at Willingham. The author understands that a plant capable of delivering 100 tons of water per minute has just been installed in the Methwold and Feltwell district. This type of machinery has not, however, met with as much support from the Fen Commissioners as was at one time anticipated, the efficiency for plants of large capacity having yet to be determined and the danger of fire being points which may have been the cause of the slowness of development in this direction. The interior and exterior of some of the pumping stations referred to are shown in the accompanying photographs in the hope that they may be of some interest.

In conclusion, the author ventures to express the opinion that at no time has the problem of efficient drainage of low lands been of more importance than it is to-day. The abnormal rainfall of 1912, and the amount of damage done to so many thousands of acres, has brought this important question more prominently before the Drainage Commissioners of the whole Fen District. That it is necessary to drain these lands more efficiently may be due to the increased difficulty of getting rid of the water owing to the constant subsidence of the land, and also to the fact that to-day a different class of produce is grown, in many cases vegetables of various kinds, in place of cereals. That pumping machinery of larger power and capacity are being installed is evident, but at the same time it is quite as essential that the drains leading to these pumps should be deepened and widened so that the water can reach them easily, as unless this is done the maximum efficiency of the pumping plants can never be obtained.

The Cost and the Advantages of Using Electrically Melted Ferromanganese*

ELECTRIC steel furnaces of various types have found a new field of application in recent years, as they are being widely used in Europe to keep a molten supply of ferromanganese on hand at the converter plant. The use of molten ferromanganese instead of solid ferromanganese not only results in a saving of alloy, but makes the deoxidation more efficient and the steel better; and the cost of melting the ferromanganese electrically is more than counterbalanced by these advantages.

This method has been widely introduced during the last few years in Europe. The first plant to take up this practice in this country has been the Illinois Steel Company, which at its converter plant at Joliet, Ill., employs a 4-ton Heroult furnace to keep on hand a supply of molten ferromanganese from which 150 pounds are taken every seven minutes. It is the experience of this company that besides the saving in alloy there is a clear advantage in quality, the soft steel produced being decidedly better for wire purposes.

In Europe various types of electric furnaces have been employed for the same purpose, and the induction furnace has found particular favor in several plants. As very few exact figures have been published in the past on this subject, the following results obtained in three European plants employing induction furnaces for melting ferromanganese should be of timely interest:

The three plants in question use for this purpose a 3-ton, 350-kilowatt furnace, a 4-ton, 500-kilowatt furnace, and a 4-ton, 500-kilowatt furnace respectively, all being of the 3-phase, 50-period, 3-ring Roechling-Rodenhauser type, the design of which is very well known to our readers.

In the plant using the 3-ton, 350-kilowatt ferromanganese-melting furnace, some 30 to 50 tappings, ranging each from 90 to 120 kilogrammes (198 to 264 pounds), are made every 24 hours, depending upon the demands of the steel plant. For the first five weeks the average energy consumption, excluding the energy required for burning in the lining, was 721 kilowatt-hours per ton for an output of 220 tons of ferromanganese.

To maintain the furnace hot during long intermissions 200 to 250 kilowatts are required.

As a result of using molten ferromanganese, an average saving of 30 to 40 per cent of weight of ferromanganese required is recorded. With cold ferromanganese from 7 to 8 kilogrammes are used per ton of steel, and during a year some 2,100 tons of cold ferromanganese are required. With molten ferromanganese this amount is reduced to less than 1,400 tons, representing a saving of more than 700 tons, which at \$55 per ton represents a saving of \$38,500 per year.

In one of the plants with a 4-ton, 500-kilowatt furnace ferromanganese has been melted at the rate of 10 tons per 24 hours with an energy consumption of 750 kilowatt-hours per ton. The furnace, however, is capable of melting a considerably higher tonnage of ferromanganese per day, and when the demand of the steel works increases it may be expected that the specific energy consumption will be reduced.

At the same time the amount of ferromanganese used per ton of steel has been reduced at this plant from 7.5 or 8 kilogrammes (for cold metal) to 4 kilogrammes (for molten metal), which is a saving of from 45 to 50 per cent.

If the results of these two furnaces are used on which to base an estimate of the power requirement and savings to be expected in new installations, it seems safe to figure on a saving of 30 per cent in weight of ferromanganese and a power consumption of 675 kilowatt-hours per metric ton of ferromanganese for a 3-ton furnace in regular operation. For burning in the lining and heating up a 3-ton furnace about 3,500 kilowatt-hours are required, and a life of 12 weeks, or 84 days

of 24 hours, may be expected for the lining. From these data a figure for an additional small power consumption may be deduced. As stated, all these figures refer to induction furnaces. It would be interesting to get for comparison data from arc-furnace installations.

Electric furnace for melting ferromanganese at Krupp plant.

The use of molten ferromanganese has, however, additional advantages which cannot be stated as easily in figures. Owing to the rapidity with which molten ferromanganese becomes distributed through a steel charge, much time is saved owing to the fact that the steel may be teemed at once. Further, low-grade ferromanganese, containing large percentages of fines, may be easily melted in an electric induction furnace.

That the quality of the steel is improved by the use of molten ferromanganese will be understood from the following considerations:

The deoxidizing effect is much stronger and more rapid than with solid ferromanganese, as the latter must first be dissolved and exerts a certain cooling effect.

As the ferromanganese is added to the steel while teeming, it does not come into contact with the slag, and rephosphorization by reduction of the phosphates in the slag is entirely excluded.

Frequent analyses in the three induction furnace installations in question have proved that the composition of the steel remains constant from the first to the last ingot for any one charge.

On account of the uniformity of the composition of each ingot, due to the better distribution of manganese and also to the more complete deoxidation, the steel "rolls" extremely well. It has been proven that a section which, when cold ferromanganese was used, could not be satisfactorily rolled with steel containing less than 0.4 per cent Mn, can, when molten ferromanganese is used, be rolled easily from steel containing only 0.29 per cent Mn.

The amount of ferromanganese per ton of steel can be considerably reduced on account of the certainty that the total amount of ferromanganese added is utilized and nothing is retained in the slag or remains undissolved in the steel.

The contents of the ladle can be poured at once, whereas much time is saved, and, moreover, the charge need not be so hot from start so as to be able to heat the ferromanganese to melting temperature. The liquid

steel remains completely quiet, does not boil, and can be poured very satisfactorily.

The lining is put into ferromanganese induction furnaces in about the same way as in steel furnaces; that is, a mixture of magnesite, or dolomite, with tar is rammed in hot. But because the temperature required is not so high as for steel, and also because ferromanganese is usually in particularly convenient form for melting in an induction furnace, the life of the lining is much prolonged. From the results so far obtained it is thought possible when working continuously to average between four and five renewals per year, or even better.

No slag is required. The molten metal is effectively protected from oxidation by a layer of carbon in the form of petroleum coke. The metal being saturated with carbon, no alteration in composition occurs. The fact that such a covering is used proves that the atmosphere in the furnace is non-oxidizing.

While, as stated before, the Roechling-Rodenhauser type of combination induction furnace is used in the three installations here discussed, the Siemens & Halske Company, which made these installations, has developed more recently an improved type of induction furnace which combines the good points of the Kjellin, Roechling-Rodenhauser, and Frick types, and with which it has been possible to reduce the specific energy consumption still further.

While the data given above from European practice refer to plants using induction furnaces for melting ferromanganese, other types of electric furnaces are also used for this purpose in Europe. The adjoining illustrations show a 5-ton Girod furnace recently installed by the Friedrich Krupp A. G., Friedrich-Alfred Hütte, Rheinhausen-Friemersheim, Germany, for the melting of ferromanganese.

The "Day of Rest" and Human Efficiency.

THE refreshing influence of the weekly "day of rest" on a person subjected to the strenuous routine of a busy life is a feature which he himself can duly appreciate in the effects on his "feelings" and "spirits." The efficiency of the working-man, the length of the working-day, the interjection of pauses for rest in the schedule of labor for persons of different ages and stations in life—questions of this sort are constantly arising for solution on a scientific basis. Not only in the field of manual labor, but also in the case of the schoolchild, the office-boy, the factory-girl, the banker and the merchant, efficiency is the key-note of the times.

In view of this, says *The Journal of the American Medical Association*, it is of more than passing interest to know that Dr. Martin and some of his associates in the Laboratory of Physiology at the Harvard Medical School, have been making a careful study of the whole question of fatigue and efficiency from a physiological standpoint. A long series of experiments have been made on first-year medical students who were following a regular routine of school work during six days of each week. The routine was interrupted weekly by the Sunday recess, an interval occupied variously by the students, but in no case in precisely the manner of the week days. The daily observations made on these persons during several weeks show that at the beginning of the week the nerve reaction tends to be high, that from then until the end of the week there is a fairly continuous decline, and that following the interruption of the routine by the intervention of Sunday, it returns to the original high point.

The decline is interpreted as a cumulative result of general fatigue incident to routine. What is even more significant, however, is the added fact that a pronounced break in the routine—such as the "day of rest" occasions—may bring about a return of sensitiveness to a high point or, in other words, it restores the nervous tone. Studies continued in this direction should lead to some useful conclusions regarding the maximum of work, with respect to both its duration and type, that should determine the conditions under which the organism of man may be maintained without depletion.

* Reproduced from *Metallurgical and Chemical Engineering*.