Part III.

17. Mining Engineering in Victoria.

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A story of progress in mining and engineering applied to mining in Victoria can go back only about 83 years to 1851, when a reward of £200 was offered by the Government for the discovery of a goldfield within 200 miles of Melbourne. Prior to that year, coal had been found by the explorers Hume and Hovell at Cape Patterson in 1825, and gold in the Pyrenees in 1849; in neither case had commercial exploitation resulted. In 1851, discoveries of rich alluvial material were made in turn at Clunes, Hiscocks, Ballarat and Bendigo; in 1852, there were camps of 40,000 men at Ballarat, 25,000 at Castlemaine, 40,000 at Bendigo, and the gold yield for that year was 2,286,535 ounces.

Early Years of Gold Mining.

Gold has been the outstanding feature of the State's mineral industry. The recorded gold production to the end of May, 1934, is 71,527,544 fine ounces, worth over £304,000,000 in gold coin. Nearest in value to gold but a very long way off, comes black coal, of which, to the end of 1933, 16,127,000 tons had been mined, and valued at £12,709,000.

A windlass and bucket to haul alluvial material from shallow depths, and a cradle, successor to the tin dish, to wash out the gold, formed equipment worthy of press notice and adequate for the gold-worker's earliest requirements. When, very soon after the alluvial gold discoveries, auriferous veins and lodes were found, a hammer, or pestle and mortar, and a tin dish, were the first appliances available for the separation of the gold from its matrix. As depth of working increased, the windlass gave way to a horse-worked whip or whim; primitive forms of hand-worked pumps were installed to keep workings clear of the increasing volumes of ground water; with larger-scale treatment of wash-dirt, the cradle was succeeded by toms, box sluicing, ground sluicing, and, when pressure could be conveniently obtained, by hydraulic sluicing.

Serious work on the gold-bearing lode outcrops quickly followed the winning of the easily-obtained riches of the shallow alluvial and "surfacing." The alluvial deposits were traced deeper and deeper into ancient river courses covered by hundreds of feet of sands, clays, gravels or lava-flows. Lodes were followed downward in so many places that a shaft depth of 500 ft to 600 ft. was soon commonplace. The steam engine displaced the horse for hauling power. Single hemp winding ropes gave place to three or more flat ropes sewn together; single, double and treble link chains were used; and finally came flat and round wire ropes. Early cages were boxes with links at each corner; these were followed by a framed cage and by kibbles transported to the working face on rails. Next came a framed cage running on guides or skids. Steel cages with safety grips, typical of the cage of to-day, were in general use in Victorian mines 50 years ago. Hand drilling underground received an early ally in a steam-driven machine rock-drill; and not much later the air compressor and air-driven drill became standard on all mines boasting a reasonable equipment. Loose eccentric winding engines, geared engines and first-motion engines took their place in turn. Baling having been found quite inadequate to deal with the heavy water inflow of many mines, particularly the deep alluvial ones, many Cornish pumps were installed, driven by low-pressure steam beam engines, often mounted and housed in such a substantial manner as to suggest that the mines were expected to last for a hundred years at least.

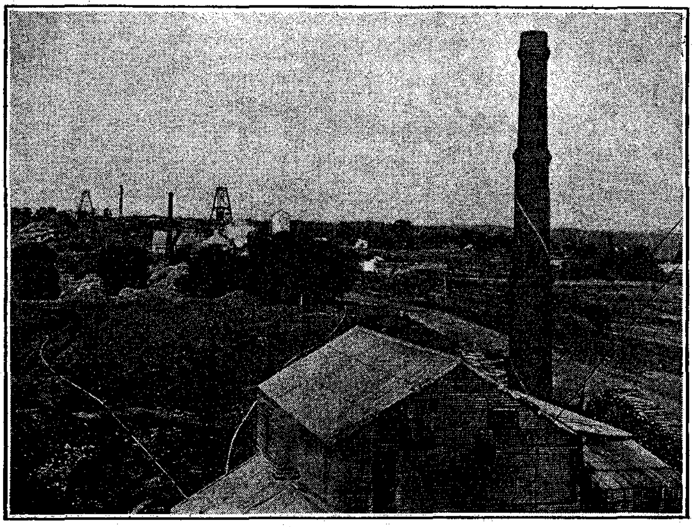
Less than 10 years of gold mining in Victoria was necessary to show that the industry could not be maintained on a substantial scale on rich deposits alone, whether alluvial or lode. Prior to 1865 a mass of quartz-veins and enclosing strata had been worked by open-cut at Black Hill, Ballarat, for 100 ft. deep, for 240 ft. down to 150 ft. wide, and for a length of about 650 ft., for an average yield of gold, from 147,639 tons of ore, of only 2 dwt., 5 gr. per ton. Crushing was done by 60 stamps each of 700 lb. weight, with self feeders; a double 18 inch × 36 inch cylinder horizontal engine, supplied with steam from four 25 ft. × 5 ft. 6 in. Cornish boilers, drove the crushing mill, two 13 inch plunger pumps to raise for battery purposes from the adjoining Yarrowee Creek, 500 gallons of water per minute, a smith's fan and blast for the mine foundry, amalgamating barrels and sundry machines. Black Hill open-cut ore cost 4s. 2d. per ton, underground ore with shaft haulage 8s. 6d. per ton, and milling 4s. per ton. Also in 1865, at the Port Phillip company's Clune, works, probably at the time the most extensive in the States ore was raised to the surface for 13s. per ton; 80 head of stamps crushed in 12 months 54,413 tons of ore for 7 dwt., 13 gr. of gold per ton. From 1857 to July, 1866, this company had mined 308,661 tons of ore for 180,723 oz. of gold.

In 1868, the deepest shaft in Victoria, 713 ft., was being sunk at Creswick, where the Victoria company was pioneering deep lode mining on Robinson's reef for yields of 10 dwt. per ton; the engineer was solidly established as indispensable to the continuance and orderly development of mining operations; the steam engine was in general use for hauling gold-bearing alluvial and lode material to the surface, for the working of mine pumps, and for power supply to the batteries of crushing stamps and a variety of minor reduction and concentrating appliances.

Deep Lode Mining.

Long before 1900, shafts half a mile deep were common on many different Victorian gold fields—Bendigo, Ballarat,

Stawell, St. Arnaud, Walhalla and others. At Bendigo to-day scores of shafts are over 2,000 ft. deep; a depth of 3,000 ft. is so common that it does not excite comment; two shafts are



Group of Mines on the Sheepshead Line of Reef Bendigo.

over 4,000 ft. deep. Typical equipment on any of these deep mines (which mostly were closed down 20 or 30 years ago, but are now being re-opened in rapid succession) was Cornish or Lancashire boilers, wood-fired, with steam pressure usually not much exceeding 100 lb. per sq. in.; a pair of first-motion winding engines; one or more 6 in. to 8 in. cylinder double steam or air winches for shaft or winze sinking and subsidiary operations; steel baling tanks, with Cornish pumps for heavy-water mines; wooden or steel shaft-head gear 60 ft. or 70 ft. high; round wire ropes and steel safety cages; compound air compressors and air drills; stamp crushing mill with the usual accessory plant for free-milling gold ores; and a small machine shop for small or urgent maintenance of plant. Bendigo's largest mill, Lansell's "Big Blue," had 105 stamps.

Mining and tunnelling for water supply, railways, subways, city drainage and sewerage and for many other purposes have often called for the best that is in the surveyor and the civil engineer. The surveyor and the mining engineer likewise have frequently to collaborate in high class work in the winning of minerals. A notable example in Victoria is the incline and vertical shaft (not now in use) of the former Long Tunnel gold mine at Walhalla. Here, a westerly underlie and flat pitch of the ore-body had resulted, after about 40 years of work, in ore-winning from blind shafts, long manual underground haulage and double handling, with consequent high mining costs. A tunnel had been driven 600 ft. westerly into a steep hillside; there a large chamber was excavated, winding and pumping machinery erected, and a shaft sunk 900 ft.; from the bottom of this shaft a level was driven close to the course of the ore-body for about 1,700 ft., at which point another large chamber was erected and a second shaft sunk 1,400 ft.

To continue work at reasonable cost below the bottom of the second shaft an incline shaft was sunk at an inclination of 49° 3′ from the horizontal for a length of 4,040 ft., at which point, owing to an unexpected change in the course of the ore-body, its inclination was changed on a curve of 80 ft. radius and continued vertical for another 600 ft., a total length of about 4,600 ft. To save time, sinking was started simultaneously from two points, one at the surface, the second from the 900 ft. level, and 1,275 ft. down on the line of the new shaft. An intricate survey guided the work so well that the lines, set out from above and below, met within about a quarter of an inch. The first section was commenced on 15th December, 1902, the second, at 1,275 ft. down, on 24th February, 1903; the two sections were connected on 24th February, 1904, when the total length of shaft was 2,228 ft. The mining of ore was then resumed. Thereafter, the sinking needed only to be intermittent; the depth of 4,040 ft. was reached in September, 1908, the bottom of the vertical shaft in 1914. The notable features of this achievement—for such it was—are the combined incline and vertical shaft, the sinking of 2,880 ft. in 20 months, and the sinking of nearly 3,000 ft. before opening out for the ore-body.

Apart from its shaft-sinking feat, the Long Tunnel was typical of progressive Victorian lode mines in taking advantage of improvements in plant design. More than 35 years ago it had the then latest type of compound steam driven air compressor. In 1907 it added a 20-head mill of 1,250 lb. stamps, with rock breakers, concentrating tables and accessories, driven by a 475 r.p.m., 165 h.p. compound engine; a 200 kW., 3-phase, 50 cycle, 500 volt generator direct-coupled to a 430 r.p.m. compound engine for stage pumping and general use. Steam superheater, economizer, and condenser with cooling tower, new engines to haul from a mile in depth, and water-tube boilers were additional equipment added at about the same period.

Plant Equipment of Major Deep Leads Mines.

Nearly 30 years ago, there were on the Berry-Moolort lead system, on each of two shafts of the Loddon Valley Goldfields Co., triple expansion pumping engines operating in each case two sets of 26 in. Cornish plunger lifts. The pumping engines were $17\frac{1}{2}$ in. × 26 in. × 40 in. by 5 ft. stroke, and 17 in. × 26 in. × 42 in. by 5 ft. stroke. In each case the vertical depth of the lifts was 460 ft., and the engines 900 h.p. Galloway-tube boilers were used at one shaft, multitubular boilers at the other. Other equipment for this mine included double 18 in. × 42 in., 70 h.p. winding engines, air compressors, puddling machines with engines, Roots blowers, small electric generators, feed pumps, capstan engines and machine tools. With auxiliary pumping plant, the total pumping power provided for the two shafts was 2,598 h.p.

Not far from the Loddon Valley Goldfields, at about the same date, and on the same lead system, three other deep alluvial mining companies—the Charlotte Plains Consolidated Co., Victorian Deep Leads Co. and Junction Deep Lead Co.—combined under the name of the Deep Leads Electric Transmission Company, to establish a generating station of three 400 kW. sets driven by 600 h.p. compound condensing engines running at 150 r.p.m., producing 3-phase, 60 cycles, 6,600 volt energy. This station supplied the Havilah and Pioneer shafts of the Charlotte Plains Co. with energy to operate in all, four 3-throw double acting plunger pumps with a maximum output from over 300 ft. deep of 8,500,000 gallons per 24 hours; and to operate also at each shaft a motor-generator furnishing energy to a 10 h.p. electric locomotive, installed to haul 60 loaded trucks for 5,000 ft. underground at 6 miles per hour. The power plant also provided power for 4 puddling machines and for

electric lighting, both underground and on the surface. Underground electric haulage was used also 30 years ago at the Chiltern Valley mine, where 3 small 220 volt electric locomotives of only 6 h.p. hauled each shift, about 4,000 ft. to the shaft, 1,200—6.5 c. yd. trucks, equal to a weekly output of 6,200 tons. A sidelight on the economy of mechanical haulage is contained in estimates made for this mine, showing 0.66d. (including 10% depreciation), 2.05d., and 5.48d. for electric locomotive, horse and manual haulage, respectively.

The pumping plants of the deep leads mines were required to deal with vertical lifts generally of 300 ft. to 400 ft., but occasionally approaching 600 ft., and with quantities frequently of 2,000,000 to 3,000,000 gallons per 24 hours for an individual shaft. The Spring Hill and Central Leads mine had 2,000,000 gallons and 525 ft.; the Berry United 3,500,000 gallons. The Loddon Valley Goldfields, with a badly located shaft, pumped $2\frac{1}{2}$ million gallons per day while it was driving 6,000 ft. to reach the lead, and later had to increase its pump capacity to about 4,000,000

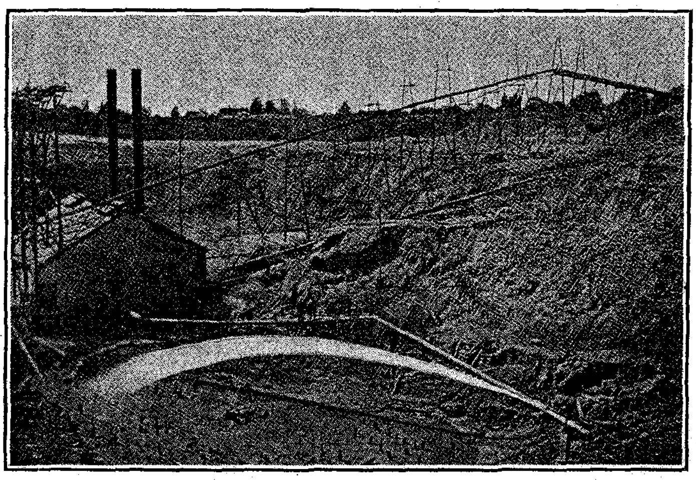
Morning Star Gold Mine, Woods Point, a typical View in the Mountains.

gallons, having at this stage spent £202,000 on its venture. The Duke and Main Leads Consols mine near Havelock had 3,000 h.p. provided for operating electrically-driven centrifugal pumps (quite a notable plant 30 years ago), and, as well, two 18 in. plunger pumps. The Prentice and Southern mine, near Rutherglen, for 8 years prior to 1909 had pumped about $3\frac{1}{2}$ million gallons per day from two shafts.

Sandy drifts, combined with heavy water inflow, have in more than one case called for caisson sinking. In one such case, that of the Junction Deep Leads mine, where steel cylinders were used, the water is so heavy that it is estimated that pumps to lift 10,000,000 gallons per day will be necessary if the mine is to be re-opened.

Dredging and Sluicing Plants.

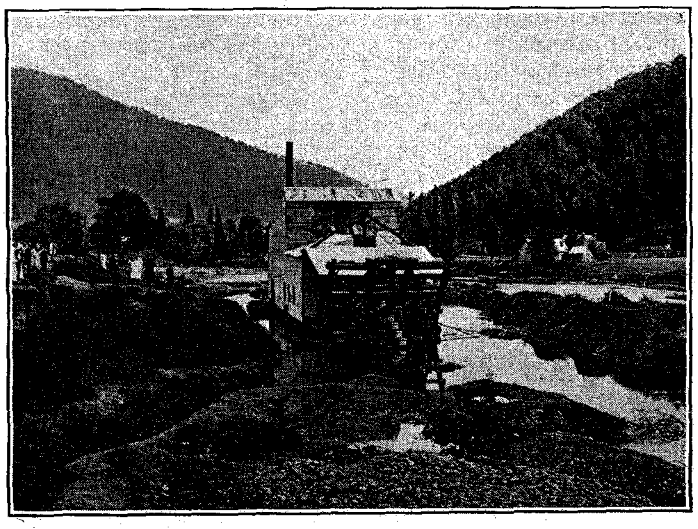
Near the close of the last century, there were in Victoria large unworked areas of more or less friable auriferous gravels, sands and sandy clays, which were suitable neither for deep lead mining methods nor for the primitive methods



Pump Sluicing Plant, Creswick.

of the alluvial fossicker or miner, although the latter had in many cases done his best to pick the eyes out of such deposits. At Cobungra, Mitta Mitta and a few other places in the State, where water could be harnessed to give, by gravitation, a high nozzle pressure, hydraulic sluicing had been resorted to for the purpose of exploiting deposits of this character, but for the most part such natural water power was not available.

Methods that had come into use for similar situations in North America were then introduced into Victoria under the name of hydraulic dredging or pump sluicing, for which purpose a moderate water supply for hydraulicing or washing away the ground is repeatedly returned and forced to the nozzle through a water pump, while the sluiced material is pumped through a sand or gravel pump to elevations of 80 ft. or more, thence to gravitate to a tailings dump. The sand pump, gravel pump, boilers and all accessory plant are mounted on a shallow barge, which sits on solid ground during a sluicing period, and is then floated from time to time to new positions by suitable damming at the bottom of the excavation. This method was first introduced in Victoria about 1898 at and around Beechworth and Yackandandah.



Bucket Dredge, Bright District.

Somewhere about the same period, taking the cue from successful operations in New Zealand and a number of installations in New South Wales, bucket dredges were introduced, the first location being on the Goulburn River. The bucket dredge, unlike the pump sluicing barge, floats continuously, washing the auriferous gravel on the dredge and depositing the tailings in the pond behind the dredge.

Both these methods made rapid advances, and were the most striking feature in the application of engineering to mining between 1900 and 1910. By 1907, the State had 84 pump sluicing plants in operation and, by 1912, 56 bucket dredging plants. With very few exceptions, all these plants were designed by Victorian engineers, and manufactured and built by engineering firms within the State. The average cost of treatment for a pump sluicing plant was about 8d. per solid cubic yard treated, and for a bucket dredge about 3d. per cubic yard; the advantage of the pump sluicing plant, as a set-off to its higher costs, was that, with a hard bottom, with much of the gold concentrated in crevices in the rock, a complete cleaning-up by hand could be effected. With the bucket dredge, provided the bottom were reasonably soft, excavation of sufficient of it could be effected to ensure the recovery of most of the gold; but this was impracticable with a hard bottom.

The bucket dredge broke up the working face, generally 20 to 30 ft. deep, with a chain of buckets, sometimes assisted by strong grabs or hooks, lifted the dislodged material in the buckets to a height of 40 or 50 ft. to sluice boxes supplied with 2,500 to 3,000 gallons per minute of water raised 25 to 30 ft. from the pond in which the dredge floated. A pump sluicing plant treating ground at the same rate had to deliver 3,000 to 3,500 gallons per minute to a nozzle at a pressure equivalent to a head of 100 to 150 ft., and then raise this water, together with the sluiced material, usually to a height of 40 to 50 ft. to sluice boxes. The boiler and engine power of the pump sluicing plants was 5 to 6 times that of the bucket dredges on similar ground. The pumps of the sluicing plants in Victoria ranged in size from 10 in. to 16 in.

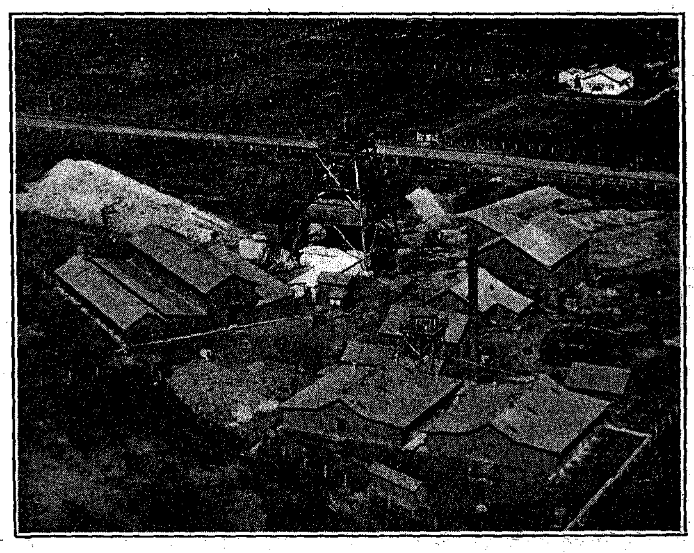
One of the most powerful sluicing plants built up to that time was supplied in 1908 by a Melbourne engineering firm for working stanniferous ground at Billiton, in the Dutch East Indies. It carried over 1,000 h.p. on a steel pontoon, 70 ft. × 35 ft. × 6 ft., drawing 5 ft. of water, and had independent vertical compound condensing engines respectively of 375 h.p. and 760 h.p. to drive 16-inch gravel and nozzle pumps, the former lifting its burden to a maximum height of 120 ft. One Victorian pump sluicing company, the Cock's Pioneer, working for gold and tin at Eldorado, established in 1914 a stationary power plant, providing electric energy for its barge plant. The power plant included two 575 h.p. triple-expansion condensing engines, each direct-coupled to a 400 kW., 6,600 volt, 3-phase, 50 cycle alternator. Steam was provided from wood-fired water-tube boilers, with economizer. Three-phase motors of about 6,100 volts operated gravel pumps; one was a primary gravel pump, the remaining three elevating to the stacking area in three successive lifts. The motors were 250, 340, 175 and 165 h.p.; the respective lifts being 55 ft., 80 to 90 ft., 50 to 55ft. and 50 ft. to 60 ft. At the same voltage a motor of 130 h.p. worked a tail-water pump, and a motor of 280 h.p. forced water to the sluicing nozzle. From a permanently fixed transformer close by 450 volt 50 cycle energy was provided to an aggregate of 50 h.p. in small motors on the barge. This plant at its peak dealt with 6,000 gallons per minute of water and its burden of gravel; it operated from 1914 to 1929. The high voltage pump motors came from Germany, Sweden and from a Melbourne workshop, which must have been well abreast of world design at the time. Work is being resumed this year on this mine, but electrical energy is to be provided from the mains of the State Electricity Commission instead of from the former power plant.

Very large volumes of ground were treated by these dredging and sluicing plants. One bucket dredge alone in one year treated over 700,000 solid cubic yards of material. In 1907, about 10,000,000 cubic yards were treated by pump sluicing, and about 10,000,000 cubic yards by bucket dredging. Activity with both types of plant waxed quickly and waned quickly. In 1918, only 21 bucket dredges and 12 pump sluicing plants were operating. In 1930, bucket dredges had disappeared, and there were only 3 hydraulic sluicing plants. At the present time, there is promise of a slight revival in the form of 2 buckets dredges added to the 3 pump sluicing plants.

Black Coal Mining.

The black coal discovered by Hume and Hovell in 1825 at Cape Patterson is not far from the present Wonthaggi State mine. Later, small seams were found at other localities in the same region, but it was not until 1859 that coal mining was actually started. In that year the Victorian Coal Company, operating near Cape Patterson, raised about 2,000 tons and sent it to Melbourne, carting it in bullock drays to the beach, loading it into whaleboats and transhipping it to small vessels in the open roadstead. Efforts to mine the Cape Patterson coal ceased in 1864; but, following on surface prospecting and boring by private persons and by the State, coal mines, which continued on a comparatively small scale of production for many years, were opened about 20 years later at Korumburra, Jumbunna, Outtrim, Kilcunda and other South Gippsland localities.

Because of the restricted and faulted character of the coal seams, black coal mining in this State has never assumed very large proportions; but the development of the State mine at Wonthaggi to a capacity of over 500,000 tons per



Surface Workings of one of the Several Pits of the State Coal Mine, Wonthaggi.

annum is a striking example of successful perseverance under great difficulties. So irregular are the Wonthaggi coal seams in thickness and broken in continuity by faulting that in 5 years, 1913 to 1918, there were sunk no less than 570 bores, aggregating 218,749 feet, at a cost of £27,630. The low cost of 2s 6.31d. per foot is a tribute to the men and machines responsible for this boring. It is doubtful if any other coal mine in the world has had to face such intensive boring as a preliminary to setting out underground workings as has been necessary at Wonthaggi. Many smaller mines than Wonthaggi—at Korumburra, Jumbunna, Kilcunda—had come and gone before the State mine was opened. There are still two or three small mines turning out a few hundred tons a week in the South Gippsland black coal measures; but to-day, as for many years past, black coal mining in Victoria without Wonthaggi would be scarcely worth mention.

The Wonthaggi mine was started in November, 1909, to supply coal to the railways and industries of Victoria during a strike on the New South Wales coal fields. From several shafts with primitive equipment established within a few weeks coal was won from a depth of about 50 ft., and 3,526 tons carted 10 miles by horse and bullock teams over bad roads to the small port of Inverloch, whence it was shipped to Melbourne. In 3 months the railway line from Nyora to Woolamai had been extended 14 miles to Wonthaggi; by 30th June, 1910, 41,274 tons of coal had reached Melbourne, a general manager had been appointed, and all steps taken to place operations on a permanent basis. At this date about 2,500 persons were living under canvas, the camp was reticulated with a temporary water supply, a sanitary system had been provided, a town drainage scheme started, and streets laid out. The short period of work prior to coal winning and the rapidity of railway construction were both quite notable achievements.

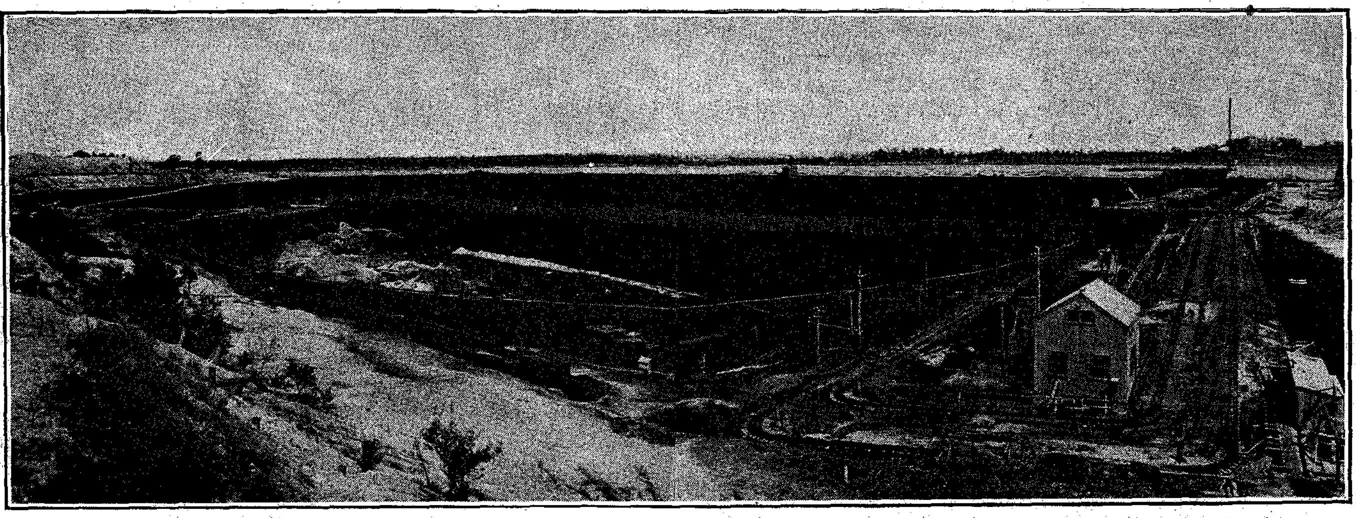
Up to the present time Wonthaggi has produced from seams averaging only about 3 ft. thick over 11,000,000 tons of coal; its peak annual output, in 1929-30, was 662,159 tons; and it has proved reserves considered capable of producing half a million tons per annum for the next 20 years. The coal has been won from numerous shafts and incline tunnel workings to a vertical depth from the surface of over 1,500 ft.

The mine has taken advantage of all modern plant adaptable to its own special features. Coal-cutting machines, introduced in 1911, were in due course found unsuitable, and coal is now won by hand. Rope-haulage underground is electrically-driven with remote control. Electricity is the general motive power throughout the works. The power station, recently modernized with water-tube boilers, pulverized coal equipment and a geared turbo-generator, supplies energy to the township as well as for mining operations. Bath-houses, drying rooms and well-equipped rescue stations, are provided in effective locations to ensure, as far as is possible, the comfort, health and safety of about 2,000 employees.

Brown Coal.

Perhaps the most striking application of engineering to mining in Victoria is to be seen at Yallourn, where a seam of brown coal, about 180 ft. thick and overlain by about 30 ft. of sands, sandy clays and gravels, is required to furnish fuel for the boilers of the nearby power station and briquetting works of the State Electricity Commission, as well as coal for conversion into briquettes. Various unsuccessful attempts, started more than 60 years ago, had been made at Lal Lal, Mirboo, Morwell, Yarram, Boolarra, and other Victorian localities to mine brown coal on a commercial basis prior to the establishment of the Electricity Commission's enterprises. The pioneering work of the Mines Department from 1913 to 1920 in open-cut mining, by hand, of coal at what is now known as the old Morwell brown coal mine, and the systematic boring and laboratory investigations by the same department, of the Yallourn coal area furnished the fundamental data necessary for the safe initiation of the State Electricity Commission's undertaking.

In February, 1922, stripping at Yallourn started from the north-western end of the area to be exploited and proceeded in parallel cuts in an easterly direction. The north and south width of the first overburden cut was about 600 ft. clear on the top, 540 ft. on the bottom, and about 2,000 ft. long. On completion of this cut, stripping was continued in parallel cuts of 35 ft. along the full length of the southern face.



Yallourn Brown Coal Mine, 1934. Coal 180 ft. thick, Overburden 35 ft. thick.

In the initial stages of coal winning, large revolving shovels were used to excavate both overburden and coal. Overburden was disposed of by belt conveyors on the north side of the open cut. Overburden stripping commenced with two steam-driven shovels, respectively of 2½ and 3½ c. yd. dipper capacity. When sufficient coal had been exposed, the larger shovel was shifted from overburden to coal. Coal winning for the power station started in August, 1924. The conveyor belts, which transported and dumped the overburden, and which were fed by the shovels, were 48 in. wide, and travelled at 300 ft. per minute. The conveyors were supported on movable steel trusses in 40 ft. lengths. Seven successive trusses were hinged together, permitting the movement necessary to allow for surface undulations. The conveyors provided for an overburden face about 600 ft. long, and delivered at their extremity to the belt of an inclined stacker, which was capable of building a spoil dump up to 60 ft. in height, with a normal width of 435 ft. on the ground surface and 255 ft. at the crest. The required capacity was obtained by swinging the conveyor stacker in an arc of a circle.

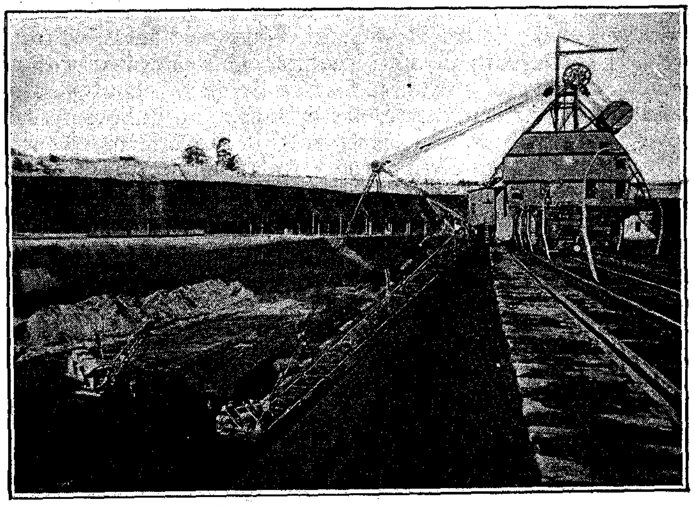
The belt conveyance of overburden subsequently gave way to transport by means of side-tipping waggons drawn by steam locomotives. The stacker and overburden conveyor plant were moved about ½ mile from the open cut, where they are at present in operation, disposing of the truck-transported material.

Following on the preliminary exposure of the coal faces by the 3½ c. yd. shovel, an electrically-operated shovel was installed for coal winning. This machine has a 10 c. yd. dipper, weighs 420 tons, can work on a 75 ft. coal face, and has a capacity of about 2,500 tons of brown coal per 8-hour shift. It excavates about 6 tons with each bite. The electric equipment includes a 350 kVA. synchronous motor generator set, driving 3 direct current generators on a 6,600 volt, 3-phase, 50 cycle supply. Each generator controls one of the three motors required for the digging, racking and slewing operations. For several years this shovel supplied the coal requirements of 3,000 to 3,500 tons per day.

The discharge from the shovel was taken by a travelling hopper, which crushed, weighed and delivered the coal to trucks of an endless ropeway which left the open cut at the south-western corner on a rise of 7½% grade to a screening house. The screening plant delivered coal under 2½ in. in size to the power station, and the oversize and crushed, unscreened coal to the briquetting works. Storage bins, with a total capacity of 2,500 tons, and situated adjacent to the screening plant, provided against irregularities in delivery. The bins were fed from the screening house by inclined conveyors. The power station and the briquetting works received coal from the central screening plant by endless rope haulages similar to that installed between the mine and the screening house. Gable-bottom haulage trucks of 3 ton capacity were attached to the rope by grips which were automatically released and engaged in passing the haulage engine. Each truck was loaded by two automatic loaders.

Prior to the commencement of coal winning, an aggregate of about 11,000 lineal feet of headings, opened from two shafts sunk through the coal seam, were driven near the bottom of the seam, with the object of draining the coal and preventing seepage into the coal from below.

With the growing demand for coal, in 1926 it was decided to modify coal winning methods and develop them according to the latest experience in Germany, where the open cut mining of brown coal has reached a very high state of efficiency. This entailed a re-arrangement of the Yallourn open cut and the application of dredges, locomotive haulage and machinery of a type special to brown coal workings. In conformity with this policy, a revolving bucket dredge was installed on overburden in 1928, working in conjunction with rakes of 20 c. yd. air-dump trucks drawn by electric locomotives. Overburden is transported to the disposal plant previously described, where the whole train or each individual truck may be discharged by compressed air from the locomotive. A result of the improved methods is lower costs for the removal of a c. yd. of overburden. The overburden dredge has a normal output of 2,000 c. yd. place measurement per 8-hour shift. It excavates either 26 ft. below or 29 ft. above the rails on which it travels.



Yallourn Coal Dredge Excavating to a Vertical Depth of 90 ft. below Rail Level.

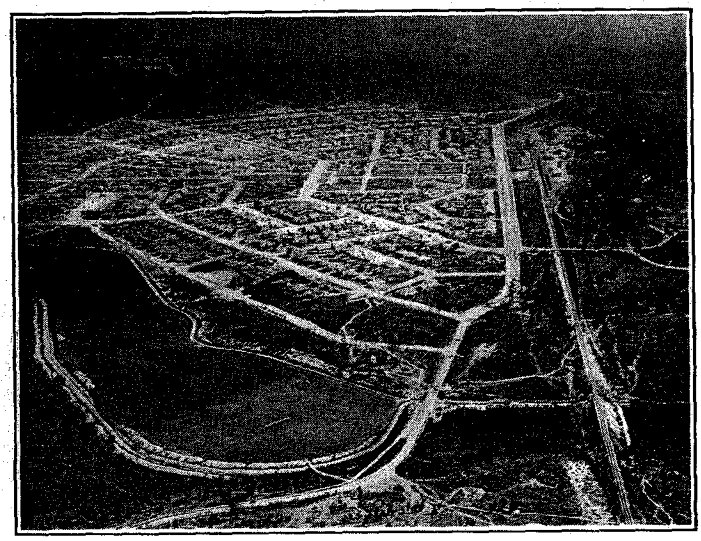
The main coal excavating equipment consists of two double-portal down-dredges, with buckets of 1 c. yd. capacity. These machines are practically duplicates, and were the largest of this type when manufactured. The thickness of the coal on which they operate is about 180 ft. The two machines command the whole depth of the deposit, thus simplifying transport and supervision. The first coal dredge commenced operation in July, 1929; the second in March, 1931. No. 1 dredge works close to the coal surface and removes the coal to a depth of 90 ft., leaving a level surface behind it from which No. 2 machine operates to the bottom of the deposit. Each machine has a capacity of 4,000 tons per 8-hour shift, weighs 411 tons, which includes 60 tons of ballast, and has an installed capacity in motors of about 400 kW. The power supply is 1,000-1,100 volt, direct-current, taken from the trolley wire of the transport tracks. The dredges are mounted on 100 lb. rails, and travel at a speed up to 23 ft. per minute while digging. The total length of the bucket ladder is 126 ft. The coal dredges do not revolve like the overburden dredge, and dig only below their own level. The maximum depth that the buckets can cut into the face is 20 in., but it is usual to take 4 in. or less when working on full face depth.

The transport tracks under the two portals of the machines are placed on the same sleepers as those used for

the dredge tracks, and they come together at a point about which the dredge working faces pivot as coal winning proceeds. After the face has been cut down to the desired batter of 53°, the tracks are shifted back by a mechanical track shifter. A locomotive draws and pushes the track shifter along the rails for the length it is desired to shift them. Tracks, track masts and trolley wires all move together to their new position. In the case of heavy tracks, the lateral distance moved at each pass is about 8 in. but on single line tracks the distance is usually 18 in., and may be as much as 6 ft. or 8 ft. The machine can also be used where it is required to ballast tracks as it can lift the rails 18 in.

The equipment for the transport of coal by electric railway, with the exception of the trucks, is the same as for the transport of overburden. The electric locomotives, which draw rakes of coal trucks of 20 ton capacity, weigh 46 tons. They also collect current from the trolley wire by pantographs having wide cylindrical rollers. Each locomotive is fitted with two large pantographs, set in tandem on the centre line of the track, and also with two pairs of smaller ones arranged on either side. The large pantographs are used on all permanent tracks, the smaller ones being for use on the loading tracks. An air compressor on the locomotive provides air for actuating the brakes and operating the air cylinders on the rolling stock.

The coal won by No. 1 dredge from the upper face is transported on the surface of the coal until it reaches the pivot point of No. 1 dredge track. The coal transport track then rises in a cutting to surface level, whence the coal can be delivered by means of a transfer hopper to the endless ropeway (to be replaced at a future date by locomotive haulage) leading to the briquetting works or to a 1,500 ton transfer bunker at the power station. The transfer hopper and bunker, constructed of reinforced concrete, contrary to the usual practice have no discharge doors, but are each equipped at the bottom with one longitudinal slot, through which the coal flows on to a table. Automatic feeders travel back and forth, scooping the coal from the table on to a belt conveyor situated immediately alongside it.



Yallourn Township from the Air.
[*Courtesy Airspy*]

The difference in level of 160 ft. of the trestleway carrying the surface railway to the power station transfer bunker and the surface of the coal formed by No. 1 dredge is overcome by a steep haulage, up which the coal trains are drawn by a hauling winch. A train of up to 6 loaded trucks, of a gross weight of 200 tons, is hauled up the incline of 1 in 7; an empty train is lowered at the same time. The trains are raised and lowered against pushing trucks. The driving motor of the winch is 650 kW. and operates at 6,600 volts. The hauling ropes are 7$\frac{3}{8}$ in. in circumference and 1,940 ft. long. Elaborate protective devices are installed to guard against accident in case of breakdown. The steep haulage is capable of an output of about 12,000 tons in 15 hours. By adopting a flying shunt at the bottom station and gravity shunting at the top station, this outout could be increased by nearly 100%.

The output from the mine at the present time is about 10,000 tons per day. The total coal mined from the Yallourn open-cut to June, 1934, is more than 16,000,000 tons. Prior to 1917, all the brown coal won in the State was less than 85,000 tons; prior to 1920, it amounted to less than 300,000 tons. In the year 1940 the combined demand for coal of the power stations and the briquetting works will probably be about 14,000 tons per day. The general scheme of mining provides for an expansion to this and to a considerably greater output.

Briquetting of Brown Coal.

Mining and briquetting of Yallourn brown coal are closely allied. The raw coal, containing about 65% of moisture, costs to-day about 2s. per ton delivered at power station or briquetting works, and is likely to cost less than 1s. 9d. in 1940. At these low costs, the raw coal is a remarkably cheap fuel in boiler furnaces at Yallourn, notwithstanding its low net calorific power of 3,000 B.Th.U. per lb.; but it is impossible to find any extensive commercial use for it in other localities where substantial additional costs for rail freight would be incurred. Therefore, for trade external to Yallourn the soft raw coal of 65% moisture is converted by drying and pressing into hard briquettes able to stand handling and a good deal of weathering. The briquettes contain about 15% of moisture and have a net calorific power of about 8,750 B.Th.U. per lb.

The first instalment of the Yallourn briquette factory came into operation in November, 1924, with a capacity of about 400 tons per day. A major extension approved in 1927 and completed early in 1931, increased the capacity to 1,200 tons per day.

A modern brown coal briquette factory calls on the engineer for much modern equipment. A battery of 12 revolving tubular steam-heated driers, aggregating 153,600 square feet of drying surface, takes steam at 30 to 40 pounds gauge pressure from the exhaust of steam-driven briquetting presses and turbines generating electricity as a by-product. The steam pressure of the 1924 boiler plant was 260 pounds gauge, with steam-driven presses; of the 1931 extension 600 pounds gauge, with electrically-driven presses. In the next extension the steam will be generated at still higher pressure, and the new turbine or turbines probably will exhaust into the 600 pound range. The 1,500 kW. turbo-generator set of the 1924 plant takes over 35 lb. of steam per kWhr.; the two 10,000 kW. sets (one a spare) of the 1931 extension take about 20 lb. of steam per kWhr.; the new extension will provide a kWhr. for probably about 14 lb. of steam before exhausting to the driers.

The decision to include the generation of by-product electricity in the original factory was made as far back as 1921; and that to raise the boiler pressure to 600 lb. for the extensions was made in 1927. A comparison with progress elsewhere would show that Yallourn has been among the world leaders in reaping the advantages of the use of high-pressure steam for generating electrical energy, before passing the steam on to processing, calling for lower pressures and temperatures. To-day the factory, with a maximum output of about 10,000 kW., produces daily 220,000 kWhr., of which about 50,000 kWhr. are used in the factory and 170,000 kWhr. go into the Yallourn system for general distribution.

The factory contains over 150 motors, aggregating 5,000 h.p. and ranging from small 400 volt units to 6,600 volt alternating current motors of 450 h.p. The installed generating capacity is 21,500 kW., with 8,000 kVA. in transformers.

Belt conveyors automatically handle to and from the crushing and screening section of the factory 4,500 tons per day of raw coal, sending 1,500 tons to the boilers and 3,000 tons to the driers. Encased spiral conveyors transport 1,200 tons of dried coal through the cooling houses to the presses; belt conveyors are again called on to handle the manufactured briquettes to railway trucks. Electrical precipitation plant is used in the drier flues to keep down dust nuisance and danger. Fans exhaust to spray towers fine dust from the dry-coal conveyors which are not under the control of the electrical precipitation plant; these towers discharge to a continuous filter plant to keep down sludge discharge to the Latrobe River. Without all these devices of modern engineering Yallourn brown coal would not be seen beyond the confines of Yallourn; with them, it is making its way in all directions towards the State boundaries and even into adjoining States.

Other Minerals.

The necessity for devising special treatment for extracting gold from Victorian ore-bodies has been comparatively rare. The Bethanga field, with highly arsenical sulphides, after much experimenting, proved amenable to chemical treatment. Cassilis ore, of similar character, was somewhat less troublesome to the metallurgical engineer.

Victorian minerals other than gold and coal have not called on the engineer for any special assistance. In this narrative it is enough to mention that tin oxide worth about £800,000 has been won, mostly from alluvial deposits; that antimony, tungsten, molybdenum, silver, gypsum, diatomaceous earth, marble and other products have been won on a comparatively small commercial scale.

So far, large ore-bodies of the common metals have not been found in this State, but Victorian engineers and manufacturers have taken a very considerable share in developing the high class mining and metallurgical plants of other States in the Commonwealth, notably at Broken Hill and Mt. Lyell. Victorian engineers have played also quite an important part in solving the problems of treatment of gold ore of a special character at Mt. Morgan, Kalgoorlie and elsewhere.

Revival of Gold Mining.

It seems appropriate, as well as fortunate, that Victoria's centenary year is ushering in a very definite revival of interest and investment in gold mining, which only three years ago was rapidly approaching the vanishing point. Almost every gold field in the State was then practically abandoned, insofar as mining was concerned. Even Bendigo, the producer of over £80,000,000 worth of gold, had been reduced to 4 or 5 small mines. To-day every old mine and field in the State is receiving attention; the State Mines Department is issuing leases for gold mining at a rate unknown for at least a quarter of a century; at Bendigo over 60 companies are at work, and some of them are entering on operations more comprehensive than any hitherto planned on the field, and—of still greater importance—with adequate working capital; the unworked deep leads of the State have been acquired to the extent of hundreds of miles in length and are being prospected and equipped with money provided from outside the Commonwealth. It has been axiomatic with those who have studied the history of Victoria that there has always been renewed attention to gold mining in times of depression. But there is no doubt that the chief reason for the present marked revival is the premium on gold arising out of the departure from the gold par standard of most of the world's national currencies. Even an early return to normal currency conditions could not rob this State—or any other Australian gold mining State— of all the benefit to be derived from the reopening of gold mines and the establishment of new ones.

Use of Electricity in Mining.

Small generating units for lighting and for power supply for minor plants have been common on all types of mines for 20 or 30 years. Quite an important departure from the usual wood-fired steam plants was made by the Cassilis Goldmining Company in 1909, when the Victoria River was harnessed to provide power for practically all moving plant, including winders and a 320 h.p. compressor. The head used was 400 feet in a 1,600 ft. pipe line; the transmission line was 16 miles from the power station to the mine. Although a storage dam and other parts of the originally projected scheme were not completed, this power plant, with occasional stoppages due to want of a storage dam, functioned for several years till the mine was closed down.

One of the features of the gold mining revival of special interest to the engineer is the probability that in due course some of the fields, particularly those containing deep leads, will be able to husband their capital resources and perhaps also economize in working costs, by arranging a supply of energy from the continually-expanding State electricity schemes.

THE END.