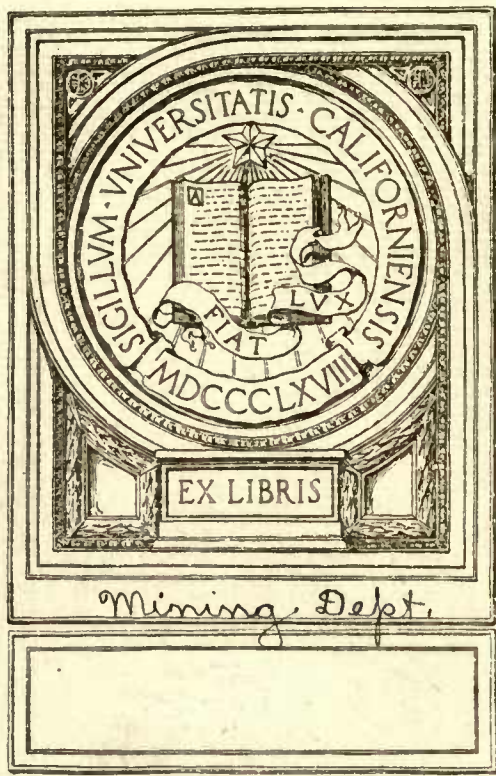


ELECTRICITY IN MINING





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11

WITH PLANS AND ILLUSTRATIONS



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CONTENTS

| Chapter | | Page |
|---------|---|---------|
| I. | Object and Scope of Electric Mining Installations - - - | 1-4 |
| II. | Distribution Systems - - - | 5-22 |
| III. | Choice of Transmission System and Pressure - - - | 23-24 |
| IV. | Electric Power Stations - - - | 25-40 |
| | Steam Engine Stations - - - | 25 |
| | Steam Turbine Plants - - - | 28 |
| | Turbine Installations for Special Purposes - - - | 30 |
| | Gas Engine Plants - - - | 32 |
| | Diesel Engine Power Stations - - - | 36 |
| | Water Power Plants - - - | 39 |
| V. | Switchgear in Generating Stations - - - | 41-46 |
| VI. | Power Transmission - - - | 47-56 |
| | Transformers - - - | 47 |
| | Cables - - - | 51 |
| | Overhead Transmission Lines - - - | 53 |
| VII. | Electric Winding Engines - - - | 57-98 |
| | General - - - | 57 |
| | Driven by three-phase Induction Motors - - - | 61 |
| | Driven by three-phase Commutator Motors - - - | 68 |
| | With Ward-Leonard Control - - - | 70 |
| | With Buffer Batteries - - - | 78 |
| | Siemens-Ilgner System - - - | 80 |
| | Steam and Electric Winders - - - | 94 |
| VIII. | Electrically-driven Pumping Plants - - - | 99-114 |
| | Reciprocating Pumps - - - | 101 |
| | Centrifugal Pumps - - - | 105 |
| | Sinking Pumps - - - | 109 |
| IX. | Electrically-driven Mine Fans - - - | 115-124 |
| X. | Electrically-driven Compressors - - - | 125-130 |
| XI. | Haulages and Hoists - - - | 131-138 |
| | Hoists in Secondary Shafts and Inclines - - - | 131-134 |
| | Main Road Haulages - - - | 135-138 |
| XII. | Auxiliary Machines in-by - - - | 139-142 |
| XIII. | Electric Locomotives - - - | 143-152 |
| XIV. | Electrically-driven Coal Washers, &c. - - - | 153-160 |
| XV. | Machines Specially Designed to Facilitate Transport - - - | 161-164 |
| XVI. | Electrically-driven Rock Drills - - - | 165-174 |
| | Percussion Drills - - - | 169 |
| | Rotary Drills - - - | 171 |
| XVII. | Switchgear for installation below ground - - - | 175-180 |
| XVIII. | Flame-proof Installations - - - | 181-186 |
| | Motors - - - | 181 |
| | Lighting Installations - - - | 184 |
| XIX. | Electric Signalling Systems - - - | 187-194 |
| XX. | Electric Shot Firing - - - | 195-196 |
| | Index - - - | 197-201 |

LIST OF PLANS AND ILLUSTRATIONS

CHAPTER II. DISTRIBUTION SYSTEMS.

| Plan | | Page |
|------|--|------|
| | I. Cie Carbonifera Los Rios de Curanilahue - - - | 5 |
| " | II. The Cambrian Collieries Ltd., South Wales - - - | 6 |
| " | III. The Cambrian Collieries Ltd., South Wales - - - | 7 |
| " | IV. Gewerkschaft "Glückauf," Sondershausen, Germany - - - | 8 |
| " | V. The Nitrate Oficinas (Chili) of H. B. Sloman and Co., Hamburg - - - | 9 |
| " | VI. Rio Tinto Company Ltd., Spain - - - | 10 |
| " | VII. Gewerkschaft Rheinpreussen Homberg on the Rhine (Germany) - - - | 11 |
| " | VIII. Powell Duffryn Steam Coal Co., South Wales - - - | 12 |
| " | IX. Gelsenkirchner Bergwerks A.G., Gelsenkirchen Westphalia (Germany) - - - | 14 |
| " | X. Electric Power Company, Baku - - - | 16 |
| " | XI. Power Distribution System in the Newcastle district - - - | 17 |

CHAPTER IV. ELECTRIC POWER STATIONS.

| | | |
|----------|---|----|
| Fig. .1. | Nord de Charleroi Coal Mines, Roux, Belgium - - - Two horizontal compound steam engines coupled to three-phase generators, each 550 K.V.A., 107 R.P.M., 3,150 volts, 50 cycles. | 26 |
| " | 2. De Wendel Mine, Hamm, Germany - - - Two compound tandem steam engines coupled to three-phase generators of 850 and 800 K.V.A. respectively, 3,000 volts, 50 cycles. | 26 |
| " | 3. Cambrian Collieries, South Wales - - - Two vertical compound engines coupled to three-phase generators, each 1,000 K.V.A., speed 250 R.P.M., 2,200 volts, 25 cycles. | 27 |
| " | 4. Rio Tinto Co., South Spain - - - Two vertical compound steam engines coupled to three-phase generators, each 750 K.V.A., 250 R.P.M., 3,000 volts, 50 cycles. | 27 |
| " | 5. Diagrammatic Sketch showing Ventilation System of Turbo-generator | 28 |
| " | 6. State Mine Wilhelmina, Heerleen, Holland - - - Three-phase turbo-generator sets, output 1,200 and 2,500 K.V.A. respectively, 2,000 volts, 50 cycles, 1,500 R.P.M. | 29 |
| " | 7. Sumitomo Besshi Kogyosho, Nihihama Mine, Japan - - - Two three-phase turbo-generator sets, each 750 K.V.A., 3,300 volts, 30 cycles, 1,800 R.P.M. | 29 |
| " | 8. Lignite Mine, Kauscher Werk, Petershain, Germany - - - Three-phase generator coupled to a "tapped" turbine, 650 K.V.A., 3,150 volts, 50 cycles, 3,000 R.P.M. | 31 |
| " | 9. Rhenish-Westphalian Electric Supply Co., Essen, Germany - - - Turbo-generator, 7,500 K.V.A., 5,000 volts, 50 cycles, 1,000 R.P.M. | 31 |
| " | 10. Rothervale Colliery Company, near Rotherham - - - Exhaust steam turbine with three-phase generator, 625 K.V.A., 3,000 volts, 50 cycles, 3,000 R.P.M. | 33 |
| " | 11. Deutsch Luxemburg Mining and Iron Co. - - - Exhaust steam turbine coupled to three-phase generator, 650 K.V.A., 235 volts, 50 cycles, 3,000 R.P.M. | 33 |
| " | 12. Gewerkschaft Deutscher Kaiser at Bruckhausen - - - Six blast furnace gas engines coupled to three-phase generators, 2,240 and 2,800 K.V.A., 5,500 volts, 50 cycles, 94 R.P.M. | 35 |
| " | 13. Royal State Mines at Bielschowitz, Upper Silesia - - - Two coke-oven gas engines with three-phase generators, 440 K.V.A., 3,600 volts, 60 cycles, 300 R.P.M. | 35 |

List of Plans and Illustrations—(continued).

| | | Page |
|----------|--|------|
| Fig. 14. | German Nitrate Works Ltd., Hamburg - - - Power Station of the Oficina Moreno, Chili. Two Diesel engines coupled to three-phase generators, each 275 K.V.A., 525 volts, 50 cycles, 175 R.P.M. | 37 |
| „ 15. | H. B. Sloman & Co., Nitrate Works Ltd., Hamburg - - Power Station, Rica Aventura (Chili). Three Diesel engines coupled to three-phase generators, output 315 K.V.A., 525 volts, 50 cycles, 175 R.P.M. | 37 |
| „ 16. | Three Diesel engines driving three-phase generators, each 100 K.V.A., 230 volts, 50 cycles, 750 R.P.M. (belt drive) - - | 38 |
| „ 17. | Nagoya Kaisha, Japan - - - - - Three water turbines, each 2,600 gallons per second, 90 ft. head coupled to three-phase generators each 2,500 K.V.A., 2,300 volts, 60 cycles, 360 R.P.M. | 40 |
| „ 18. | Mexican Light & Power Co., New York, Necaxa Station, Mexico Six turbines each 420 gallons per second, 1,650 ft. head coupled to three-phase generators each 6,250 K.V.A., 4,000 volts, 50 cycles. | 40 |

CHAPTER V. SWITCHGEAR IN GENERATING STATIONS.

| | | |
|-------|--|----|
| „ 19. | Generator Control Pillar - - - - - | 41 |
| „ 20. | High-tension Switchgear, Fire-proof Cells - - - - - | 42 |
| „ 21. | Desk-type Switchboard - - - - - | 43 |
| „ 22. | Count Schaffgot Administration Paulus Hohenzollern Mine, Beuthen, Upper Silesia - - - - - Main Board for 2,100 volts | 43 |
| „ 23. | Low-tension Switchboard - - - - - | 44 |
| „ 24. | Typical Diagrams of Connections for Mining Power Plant - - | 45 |
| „ 25. | Cross Section of Switchgear House for Central Station - - | 46 |

CHAPTER VI. POWER TRANSMISSION.

| | | |
|-------|---|----|
| „ 26. | Efficiency curve of a 300 K.V.A. transformer at various loads - | 47 |
| „ 27. | Three-phase oil-immersed self-cooling transformer with radiating ribs | 48 |
| „ 28. | Dutch State Mines, Limburg, Heerlen, Holland - - - Two three-phase oil-immersed self-cooling transformers, output each 640 K.V.A., 10,000/2,000 volts, 50 cycles. | 49 |
| „ 29. | Lübeck Power Station, Germany - - - - - Three-phase oil-immersed water-cooled transformers, output each 2,500 K.V.A., 6,000/30,000 volts, 50 cycles. | 49 |
| „ 30. | Rand Power Company, South Africa - - - - - Three-phase oil-immersed water-cooled transformer, 12,500 K.V.A., 5,000/42,000 volts. | 50 |
| „ 31. | Three-phase cable with single wire armouring - - - - - | 51 |
| „ 32. | Single-conductor cable with double wire armouring - - - - - | 51 |
| „ 33. | Transmission line for 35,000 volts on lattice poles, with spans of 180 to 220 yards - - - - - | 54 |
| „ 34. | High-tension transmission line with suspension-type insulators, for 70,000 volts - - - - - | 54 |
| „ 35. | Safety suspension gear with steel catenary wire - - - - - | 55 |
| „ 36. | Safety suspension gear ; triple suspension - - - - - | 55 |

CHAPTER VII. ELECTRIC WINDING ENGINES.

| | Page |
|---|------|
| Fig. 37. Electrically-driven compressor plant for operating brake gear - | 59 |
| „ 38. The Harton Coal Company Ltd., South Shields, England - | 60 |
| Net load 4½ tons, shaft depth 1,420 ft., speed 41 ft. per second, drums 14 ft. diameter, direct coupled to 5,500-volt 950/1,700 H.P. three-phase motor, 40 cycles. Liquid controller. | |
| „ 39. H. Eckstein & Co., Langlaagte Deep Ltd., Johannesburg - | 60 |
| Net load 3·6 tons, shaft depth 1,000 ft., speed 44 ft. per second. Cylindrical drums 8 ft. diameter, direct coupled to one 2,000-volt 970/1,630 H.P. three-phase motor, 50 cycles. Liquid controller | |
| „ 40. Diagram of Connections for three-phase winder - | 61 |
| „ 41. H. Eckstein & Co., Nourse Mines Ltd., Johannesburg - | 63 |
| Net load 2·4 tons, depth 1,630 ft., speed 48 ft. per second, cylindrical drums 10 ft. diameter, direct coupled to one 2,000-volt 1080/2060 H.P. three-phase motor, 50 cycles. Liquid controller. | |
| „ 42. H. Eckstein & Co., Bantjes Cons. Mines Ltd., Johannesburg - | 63 |
| Net load 4½ tons, depth 4,000 ft., inclination 35°, speed 50 ft. per second, cylindrical drums 14 ft. diameter, driven through single reduction gearing by one 2,000-volt 1,310/2,900 H.P. three-phase motor, 50 cycles. Liquid controller. | |
| „ 43. Diagram of current input to a three-phase winder - | 64 |
| „ 44. Mine Hildasglueck Volpriehausen, Germany - | 65 |
| Net load 1·8 tons, depth 3,300 ft., speed 20 ft. per second, bobbins from 6 ft. 6 in. to 16 ft. 6 in. diameter, driven through double reduction gearing by a 220-volt 210/395 H.P. three-phase motor, 50 cycles. Metallic controller. | |
| „ 45. Richard Mine, Brux, Austria - | 65 |
| Net load, 1·8 tons, depth 124 ft., speed 7½ ft. per second, cylindrical drums 10 ft. diameter, driven through double reduction gearing by a 500 volt 125/200 H.P. three-phase motor, 50 cycles. Metallic controller. | |
| „ 46. Union Mining & Iron Company, Dortmund, Germany - | 67 |
| Net load 6 tons, depth 4,900 ft., inclination 12°, speed 16½ ft. per second, cylindrical drums 6½ ft. diameter, driven by a 1,900 volt 205/360 H.P. three-phase motor, 25 cycles. Metallic controller. | |
| „ 47. Silesian Mining Compony, Lipine, Germany - | 67 |
| Net load 1½ tons, depth 340 ft., speed 23 ft. per second, cylindrical drums 10 ft. diameter, driven through single reduction gearing by 120 volt 80/100 H.P. three-phase motor, 50 cycles. Metallic controller. | |
| „ 48. Diagram of connections of a winding engine driven by 100 H.P. three-phase series commutator motor - | 68 |
| „ 49. Gewerkschaft Burbach Helmstedt, Germany - | 69 |
| Three-phase commutator motor drive. Koepe pulley 13½ ft. diameter. Net load 3·2 tons, depth 1,600 ft. Output of motor 600 H.P. Speed 25 ft. per second, capacity 96 tons per hour. | |
| „ 50. Ward-Leonard system of control - | 70 |
| „ 51, 52. Société des Mines d'Albi dept., Tarn, France - | 71 |
| Ward-Leonard system with separate converter set. Cylindrical drums 10 ft. diameter. Net load 1·6 tons, depth 690 ft., speed 19½ ft. per second, capacity 90 tons per hour. | |
| „ 53. Diagram of the Siemens depth indicator with safety device - | 72 |

List of Plans and Illustrations—(continued).

| | Page |
|--|------|
| Fig. 54, 55. General Mining & Finance Corporation Ltd., Rand Collieries, Transvaal - - - | 73 |
| Ward-Leonard system with separate converter set. Conical drums 10 ft. to 17½ ft. diameter. Net load 5½ tons, depth 3,240 ft., speed 55 ft. per second, capacity 182 tons per hour. | |
| „ 56. Siemens depth indicator with safety gear - - - | 74 |
| „ 57. Gewerkschaft Glueckauf, Sondershausen, Germany - - - | 75 |
| Ward-Leonard system with separate converter set, bobbins from 6½ ft. to 15½ ft. diameter, net load 1 ton, depth 2,460 ft., maximum speed 20 ft. per second, capacity 23 tons per hour. | |
| „ 58. Winder at a Colliery in Durham, England - - - | 75 |
| Ward-Leonard system with separate converter set, cylindrical drum 10 ft. diameter, net load 3,800 lbs., depth 300 ft., maximum speed 5¼ ft. per second, capacity 70 tons per hour. | |
| „ 59, 60. Kaliwerke Friedrichshall Sehnde, Germany - - - | 77 |
| Ward-Leonard system with buffer battery. Koepe pulley 20 ft. diameter. Net load 2.8 tons. Present depth 1,640 ft., to be increased later to 2,950 ft., speed 33 ft. per second, capacity 63 tons per hour. Variable voltage generator and booster generator direct-coupled to the prime mover. | |
| „ 61. Electric Winder at Thiede, near Brunswick, Germany - - - | 78 |
| „ 62. Pirani Booster system - - - - - | 79 |
| „ 63. Siemens-Ilgner system - - - - - | 80 |
| „ 64. Gelsenkirchener Bergwerks A.G., Gelsenkirchen, Germany - - - | 81 |
| Siemens-Ilgner system. Koepe pulley 20 ft. diameter, net load 4.2 tons. Present depth 920 ft., to be increased later to 1,640 ft. Present speed 33 ft. per second, to be increased later to 65 ft. per second. Capacity 170 tons per hour. | |
| „ 65. Current chart of winder and converter motor - - - | 81 |
| „ 66, 67. Gelsenkirchener Bergwerks A.G. Germany - - - | 83 |
| Ilgner system, Koepe pulley 23 ft. diameter, net load 5.2 tons, present depth 1,310 ft. to be increased later to 1,970 ft. Present speed 52 ft. per second, to be increased later to 65 ft. per second. Present capacity 210 tons per hour, to be 190 tons per hour subsequently. | |
| „ 68. Double converter set at the Paulus Hohenzollern Pit of the Count Schaffgot Administration, Upper Silesia - - - | 84 |
| „ 69, 70. Austrian State Coal Mines, Witkowitz, Solomon Pit, Ostrau, Austria - - - - - | 85 |
| Ilgner system, cylindrical drums 16½ ft. diameter, net load, 5.1 tons, depth 3,270 ft., speed 42 ft. per second, capacity 120 tons per hour. | |
| „ 71. General lay-out of Mathias Stinnes Pits, near Essen, Germany - - - | 86 |
| „ 72, 73. Mathias Stinnes Mines, Pit III-IV., Carnap, near Essen, Germany - - - - - | 87 |
| Ilgner system, Koepe pulley 21 ft. diameter, net load 4.8 tons. Present depth 1,640 ft., to be increased to 2,620 ft. Speed 46 ft. per second, capacity 100 tons per hour. Converter electrically coupled with three other winding plants at the same mine. | |
| „ 74, 75. Dutch State Mines, Limburg, Holland - - - - - | 88 |
| Ilgner system, cylindrical drum, 20 ft. diameter, net load 2.2 tons, depth 1,640 ft., speed 39 ft. per second, capacity 70 tons per hour, Converter electrically interconnected with a second winding plant at the same mine. | |
| „ 76, 77. Powell Duffryn Steam Coal Co., Ltd., South Wales - - - | 89 |
| Ilgner system, drums at present cylindrical, to be replaced later by cylindro-conical drums 14 ft. to 22 ft. in diameter. Net load 6 | |

List of Plans and Illustrations—(continued).

| | Page |
|---|------|
| tons, depth 2,190 ft. Present speed 26 ft. per second, to be increased later to 72 ft. per second. Present capacity 180 tons per hour, to be increased later to 360 tons per hour, Converter electrically interconnected with a second winding engine at the same colliery. | |
| Fig. 78, 79. Société Houillère des Mines de Liévin, Dep. Pas-de-Calais, France - - - - - | 90 |
| lgner system, bobbins 12-25½ ft. in. diameter, net load 5·6 tons, depth 2,620 ft., maximum speed 59 ft. per second, capacity 200 tons per hour. Converter electrically-interconnected with a similar winding plant in the same mine. | |
| „ 80. Hausham Pit, Miesbach, Upper Bavaria - - - - - | 91 |
| Example of winder placed in the head-gear directly above the shaft. | |
| „ 81, 82. Upper Bavarian Coal Company, Miesbach, Bavaria - - - - - | 92 |
| lgner system, Koepe pulley 15 ft. diameter, net load 2·8 tons, depth 2,460 ft., speed 52½ ft. per second, capacity 108 tons per hour. The winding engine is mounted in the head-gear. | |
| „ 83. Head-gear to accommodate winding engine - - - - - | 93 |
| „ 84. Different stages in the progressive completion of winding plant - - - - - | 97 |
| CHAPTER VIII. ELECTRICALLY-DRIVEN PUMPING PLANTS. | |
| „ 85. Royal State Mines, Pit Königshütte, Germany - - - - - | 102 |
| Electrically-driven reciprocating pump, 1,320 gallons per minute, total head 475 ft., motor output 280 H.P., 2,000 volts, 161 R.P.M., 50 cycles. | |
| „ 86. Gutehoffnungshütte, Pit Hugo, Germany - - - - - | 102 |
| Electrically-driven reciprocating pump, 1,100 gallons per minute, total head 1,575 ft., motor output 710 H.P., 3,000 volts, 91·5 R.P.M., 50 cycles, | |
| „ 87. Royal State Mines, Pit Waltrop, Germany - - - - - | 103 |
| Electrically-driven reciprocating pump, 660 gallons per minute, total head 2,030 ft., motor output 520 H.P., 3,000 volts, 91·5 R.P.M., 50 cycles. | |
| „ 88. Eschweiler Bergwerksverein, Pit Gouley, near Morsbach, Germany - - - - - | 103 |
| Three electrically-driven reciprocating pumps, each 1,100 gallons per minute. Total head 1,540 ft., motor output 650 H.P., 3,500 volts, 147 R.P.M., 50 cycles. | |
| „ 89. Mines de la Bouble, France - - - - - | 105 |
| Electrically-driven centrifugal pump. Three-phase motor 300 B.H.P., 2,000 volts, 1,500 R.P.M., 50 cycles, with flame-proof sliprings. | |
| „ 90. Gutehoffnungshütte, Pit Oberhausen. Germany - - - - - | 106 |
| Electrically-driven centrifugal pump, 660 gallons per minute, total head 2,100 ft., motor output 650 H.P., 3,000 volts, 1,485 R.P.M., 50 cycles. | |
| „ 91. G. v. Giesches Erben, Cons. Cleophas Mine, Zalenze, Germany - - - - - | 106 |
| Two centrifugal pumps, each 1,540 gallons per minute, total head 1,475 ft., motor output 1,560 H.P., 3,000 volts, 1,490 R.P.M., 50 cycles. | |
| „ 92. Lambton Collieries, Lady Durham Pit, South Durham, England - - - - - | 107 |
| Centrifugal pump, output 2,900 gallons per minute, total head 315 ft., motor output 325 H.P., 600 volts, 1,170 R.P.M., 40 cycles. | |
| „ 93. Charbonnage de Courcelles du Nord, Belgium - - - - - | 107 |
| Three centrifugal pumps, output each 1,320 gallons per minute, total head 950 ft., motor output 625 H.P., 3,000 volts, 1,485 R.P.M., 50 cycles. | |

List of Plans and Illustrations—*continued.*

| | | Page |
|----------|---|------|
| Fig. 94. | G. v. Giesches Erben Mining Company, Cons. Cleophas Mine, Zalenze, Germany Electrically-driven turbine pump, output 2,200 gallons per minute, total head 1,475 ft., motor output 1,560 H.P., 3,000 volts, 1,490 R.P.M., 50 cycles. | 108 |
| „ 95. | Société des Mines de Jarny, France Electrically-driven sinking pump, output 1,100 gallons per minute, total head 737 ft., motor output 400 H.P., 2,000 volts, 1,475 R.P.M., 50 cycles. | 110 |
| „ 96. | Aachener Hütten-Aktienverein, Rote Erde, Germany Two electrically-driven sinking pumps, each 880 gallons per minute, total head 246 ft., motor output 100 H.P., 325 volts, 1,460 R.P.M., 50 cycles. | 111 |
| „ 97. | Royal State Mines, Limburg, Pit Emma, Heerlen, Holland Two electrically-driven sinking pumps, each 660 gallons per minute, head 1,320 ft., motor output, each 400 H.P., 2,000 volts, 1,435 R.P.M., 50 cycles. | 112 |
| „ 98. | Royal State Mines, Limburg, Pit Emma, Heerlen, Holland General arrangement of shaft head-gear and engine room of the sinking plant. | 113 |
| „ 99. | Cable drum for electrically-driven sinking pump | 114 |

CHAPTER IX. ELECTRICALLY-DRIVEN MINE FANS.

| | | |
|--------|--|-----|
| „ 100. | Whitburn Colliery, Harton Coal Company, S. Shields, England Fan motor, output 350 B.H.P., 5,500 volts, 106 R.P.M., 40 cycles. | 117 |
| „ 101. | Carlton Main Colliery, Barnsley, England Fan motor, output 600 B.H.P., 550/530 volts, 500 R.P.M., 50 cycles. | 117 |
| „ 102. | De Wendel Pit, Hamm, Germany Fan for maximum output of 1,150 H.P. Temporary drive from 80 H.P. motor, 3,100 volts, 50 cycles, 730 R.P.M. | 119 |
| „ 103. | Koenig Ludwig Pit, near Recklinghausen, Germany Fan motor, direct coupled, 650 H.P., 5,000 volts, 50 cycles, 245/177 R.P.M. | 119 |
| „ 104. | Bruchstrasse Pit of the Louise Tiefbau Coal Company, Germany Fan with cascade motor, 500 H.P., 5,000 volts, 50 cycles, 245/182 R.P.M. | 121 |
| „ 105. | Werne Mine of the Georg-Marien Bergwerk-und Hüttenverein, Germany Fan with cascade motor, 1,200 H.P., 2,000 volts, 50 cycles, connected to squirrel-cage secondary motor with pole-changing device, speeds 246, 231, 214 and 188 R.P.M. | 121 |
| „ 106. | Diagram of connections of direct-current regulating device | 122 |
| „ 107. | Diagram of connections of frequency converter | 122 |
| „ 108. | De Wendel Pit, Hamm, Germany Fan motor, connected to direct-current auxiliary motor and rotary converter, 1,150 H.P., 3,100 volts, 50 cycles, 270/170 R.P.M. | 123 |
| „ 109. | Deutscher Kaiser Pits, Hamborn, Germany Fan motor, with frequency converter, 1,100 H.P., 5,000 volts, 50 cycles, 295/224 R.P.M. | 123 |

CHAPTER X. ELECTRICALLY-DRIVEN COMPRESSORS.

| | | |
|--------|--|-----|
| „ 110. | Lanchow Mining Company, China Three-phase induction motor driving a two-stage compressor, 500 H.P., 3,000 volts, 147 R.P.M., 50 cycles. | 125 |
| „ 111. | Consolidated Gold Fields, Jupiter Gold Mine, South Africa Three-phase induction motors, driving two-stage air compressors, each 820 H.P., 184 R.P.M., 2,000 volts, 50 cycles. | 126 |

List of Plans and Illustrations—*continued.*

| | Page |
|--|------|
| Fig. 112. Rio Tinto Company Ltd., Spain - - - | 127 |
| Synchronous motor driving two stage compressor, 570 H.P., 125 R.P.M., 3,000 volts, 50 cycles. Pony motor for 125 H.P., 580 R.P.M. | |
| „ 113. Victoria Falls and Transvaal Power Co., South Africa - | 128 |
| Turbo-compressor set driven by two synchronous motors, each 2,150 H.P., 3,000 R.P.M., 1,700 volts, 50 cycles. | |
| „ 114. Compressor Station of the Robinson Central " Deep " - | 129 |
| Twelve compressor motors, each 2,150 H.P., 3,000 R.P.M., 1,700 volts, 50 cycles. | |
| CHAPTER XI. HAULAGES AND HOISTS. | |
| „ 115. Mijnbouw-Maatschappij Ketahoen Lebong-Soelit, Dutch Indies - | 131 |
| Haulage gear, load 1,000 lbs, length 100 yards, maximum speed 2½ miles per hour. Motor output 12 H.P., 220 volts, 50 cycles. | |
| „ 116. Simple double drum haulage - - - | 132 |
| „ 117. Zwickau Oberhohndorfer Steinkohlen-Bau-Verein A. G. Germany | 133 |
| Auxiliary winder below ground, net load 2 tons, depth 290 yards, speed 688 ft. per minute. Motor output 80 H.P., 2,000 volts, 50 cycles. | |
| „ 118. Gutehoffnungshütte Pit Vondern, Oberhausen, Germany - | 133 |
| Auxiliary winder, net load 2 tons, depth 110 yards, speed 590 ft. per minute, motor output 70 H.P., 3,000 volts, 50 cycles. | |
| „ 119. Lockets Merthyr Colliery, South Wales - | 136 |
| Main and tail haulage, motor 250 H.P., 2,000 volts, 500 R.P.M., 25 cycles. | |
| „ 120. Harton Coal Company, South Shields, England - - | 136 |
| Main and tail haulage, motor 60 H.P., 600 volts, 600 R.P.M., 40 cycles. | |
| „ 121. Harton Coal Company, South Shields, England - - | 137 |
| Endless rope haulage, motor 60 H.P., 2,000 volts, 40 cycles. | |
| „ 122. Peases West Colliery, Durham, England - - - | 137 |
| Main and tail haulage, motor 250 H.P., 2,000 volts, 40 cycles. | |
| CHAPTER XII. AUXILIARY MACHINES IN-BYE. | |
| „ 123. Small portable compressor - - - | 139 |
| „ 124. Small compressor for pit installation, 150 H.P., semi-portable - | 140 |
| „ 125. Portable centrifugal pumping set, for pumping out inclined drifts | 141 |
| „ 126. Portable centrifugal pumping set, on adjustable carriage - | 141 |
| „ 127. Portable fan motor, with squirrel-cage rotor - - - | 142 |
| CHAPTER XIII. ELECTRIC LOCOMOTIVES. | |
| „ 128. Mülheimer Bergwerks-Verein, Rosenblumendelle Mine - | 143 |
| Single-phase pit locomotive, 250 volts, 50 cycles, weight 7.5 tons, tractive effort 1,600 lbs., speed 9 miles per hour, two motors, each 18 H.P. | |
| „ 129. Kölner Bergwerks-Verein, Pit Anna, Alten-Essen, Germany - | 144 |
| Rotary converters for pit railway, three-phase current, 5,000 volts, 50 cycles, 1,500 R.P.M.; direct-current 250 volts, output each 80 K.W. | |
| „ 130. Eschweiler Bergwerks-Verein A. G. Nothberg, Germany - | 145 |
| Direct-current mine locomotive, 220 volts, weight 5.5 tons, tractive effort 1,450 lbs., speed 6 miles per hour. Two motors, each 12 H.P., width of locomotive 28 in. | |
| „ 131. Royal State Mines, Zabrze, Upper Silesia, Germany - - | 145 |
| Direct-current mine locomotive, 220 volts, weight 5 tons, tractive effort 2,200 lbs., speed 5 miles per hour. Two motors, each 15.5 H.P. | |

List of Plans and Illustrations—continued.

| | | Page |
|-----------|---|------|
| Fig. 132. | Trolley-wire insulators - - - - - | 146 |
| „ 133. | Gebr. Stumm, Gr. Hettingen, Lorraine, Germany - - - Direct-current mine locomotive, 500 volts, weight 14.5 tons, tractive effort 7,000 lbs., speed 8 miles per hour. Two motors, each 80 H.P. | 147 |
| „ 134. | Société des Mines d'Amersmont et Dommary, France - - - Double mine locomotive for direct current, 300 volts, weight 16 tons, tractive effort 4,400 lbs., speed 6.25 miles per hour. Four motors, each 19 H.P. | 147 |
| „ 135. | Arrangement for protection against contact with the trolley wire - | 148 |
| „ 136. | “Königsborn” A.G. Unna, Germany - - - - - Pit locomotive with battery, weight 6.5 tons, tractive effort 1,100 lbs., speed 6 miles per hour. Two motors, each 11 H.P. Capacity of battery 74 ampere-hours. Discharge pressure 160 volts. | 149 |
| „ 137. | Harton Coal Company Ltd., South Shields, England - - - Direct-current locomotives, 500 volts, weight 15 to 34 tons. Speed 9 miles per hour. Output 93 H.P. to 230 H.P. | 149 |
| „ 138. | Harton Coal Company Ltd., South Shields, England - - - Locomotive with train, weight 40 tons, tractive effort 9,200 lbs. Speed 9 miles per hour. | 150 |
| „ 139. | Lignite Mine, “Kauscher Werk” Petershain, Germany - - - Electrically-driven excavator. The track and the trolley system are moveable. Locomotive 224 H.P., direct current 550 volts. | 151 |

**CHAPTER XIV. ELECTRICALLY-DRIVEN COAL WASHERS,
BRIQUETTE PRESSES, &c.**

| | | |
|--------|--|-----|
| „ 140. | Coal Washery of the Bermannsglück Mine, Germany - - - Motor with starter and control pillar. | 154 |
| „ 141. | Protected-type three-phase induction motor, with totally-enclosed slip-rings, oil-immersed starter and control pillar with fuses under oil - - - - - | 154 |
| „ 142. | Coal Washery of the “Unser Fritz” Mine, Hamm, Germany - - - Induced-draught induction motor with starter and ammeter on the motor casing. Output 28 H.P. | 155 |
| „ 143. | Protected-type induction motor with starter and ammeter mounted on the motor casing. Output 52 H.P. Control board consisting of high-tension pillars with oil-immersed fuses - | 155 |
| „ 144. | Cardiff Washed Coal Co., Cardiff, South Wales - - - - - Protected-type motors driving rockers. | 157 |
| „ 145. | H. B. Sloman & Co., Saltpetre Works - - - - - Individual drive of stone crushers by 25 H.P. motors with flywheel. | 157 |
| „ 146. | Coke oven ram and filler driven by direct-current motors - | 159 |
| „ 147. | Kauscher Werk Lignite Mines, Petershain, Germany - - - Electrically-driven briquette press, with 180 H.P. three-phase commutator motor. | 159 |

**CHAPTER XV. MACHINES SPECIALLY DESIGNED TO
FACILITATE TRANSPORT.**

| | | |
|--------|---|-----|
| „ 148. | Transport of a generator shaft by eight natives - - - - - | 162 |
| „ 149. | Transport of machine parts on bullock carts - - - - - | 162 |
| „ 150. | Winding a generator on site - - - - - | 163 |
| „ 151. | Power Station of the Redjang Lebong Gold Mines, Sumatra - | 163 |

| | | Page |
|--|--|------|
| CHAPTER XVI. ELECTRICALLY-DRIVEN ROCK DRILLS. | | |
| Fig. 152. | Vertical percussion drill with water flushing arrangement | 165 |
| „ 153. | Percussion drill mounted on pillar support - - - | 166 |
| „ 154. | Percussion drill mounted on tripod - - - | 167 |
| „ 155. | Percussion drill working as cutter ; making a vertical cut | 169 |
| „ 156. | Percussion drill working as cutter ; making a horizontal cut | 170 |
| „ 157. | Rotary drill in an iron ore mine - - - | 171 |
| „ 158. | Rotary drill in a coal mine - - - | 172 |
| „ 159. | Rotary drill in a potash mine - - - | 173 |
| „ 160. | Cable drum with contact for wall fixing - - - | 174 |
| CHAPTER XVII. SWITCHGEAR FOR INSTALLATION BELOW GROUND. | | |
| „ 161. | Cast-iron switch box, 550 volts, 200 amps. - - - | 176 |
| „ 162, 163. | Cast-iron switch pillar - - - | 177 |
| „ 164. | Distribution switchboard consisting of cast-iron switch pillars | 177 |
| „ 165. | Distribution board consisting of sheet-iron switch pillars | 178 |
| „ 166. | Flame-proof switch pillar, with fuses under oil, for pressures up to 3,000 volts - - - | 179 |
| „ 167. | Flame-proof switch pillar, for pressures up to 6,000 volts | 180 |
| CHAPTER XVIII. FLAME-PROOF INSTALLATIONS. | | |
| „ 168. | Totally-enclosed flame-proof motor - - - | 182 |
| „ 169. | Flame-proof motor with plate protection - - - | 182 |
| „ 170. | Testing station for flame-proof motors - - - | 183 |
| „ 171. | Oil-immersed controller - - - | 184 |
| „ 172. | Iron-clad lamp fitting - - - | 184 |
| „ 173. | Combined lamp fitting and cable dividing box - - - | 185 |
| „ 174. | Armoured cable distribution boxes with fuses - - - | 185 |
| „ 175. | Oil-immersed transformer - - - | 186 |
| „ 176. | Rotary switch with plate protection - - - | 186 |
| CHAPTER XIX. ELECTRIC SIGNALLING SYSTEMS. | | |
| „ 177. | Diaphragm-type alarm - - - | 188 |
| „ 178. | Oil-immersed contact - - - | 188 |
| „ 179. | Pit bank and level instruments - - - | 189 |
| „ 180. | Engine room instrument - - - | 189 |
| „ 181. | Diagram showing arrangement of luminous mine-signalling apparatus - - - | 191 |
| „ 182. | Recording indicator - - - | 192 |
| „ 183. | Telephone installed underground - - - | 193 |
| „ 184. | Telephone with hinged gear pieces - - - | 193 |
| „ 185. | Electric hooter - - - | 193 |
| „ 186. | Loud-speaking telephone - - - | 193 |
| „ 187. | Winding engine room with recording signal indicator and loud-speaking telephones - - - | 194 |
| CHAPTER XX. ELECTRIC SHOT FIRING. | | |
| „ 188. | “ Dynamo ” type shot firing apparatus - - - | 195 |
| „ 189. | “ Magneto ” type shot firing apparatus - - - | 196 |

PREFACE

Electricity was first brought into use as a motive power in mining work soon after it was realised that electrical machines could be employed as motors, and the earliest electric motors installed in mines were used in connection with small hoists, pumps, fans, and locomotives, and have now been in operation for nearly thirty years.

Since those early days electricity has been introduced into mining work to an extent which was then undreamed of, and to-day the problem of driving electrically all the various machines used in or about a mine is completely solved.

Even winding engines for the most severe duty are now electrically driven, and the experience of a number of years has proved conclusively that electrical driving of the largest machines is absolutely reliable.

In most civilised countries, therefore, there is now no question as to the motive power which is to be adopted when opening up a new colliery or other mine, as electric driving has shown itself to be superior to all other forms of drive for every class of mining plant.

But although it is the general practice abroad, when a new pit is sunk, to equip the whole installation electrically, yet in this country there still appears to be some doubt as to the advisability of adopting this form of motive power, and it is indeed remarkable that at the present time in this country there are to be found extreme examples of mining equipment. On the one hand we find some collieries worked on the most antiquated methods, and with old machinery, while on the other hand we find others equipped with the newest and most economical plant, and worked on the most modern lines. In this latter connection it is beyond all question that England can show instances in which the greatest enterprise has been displayed and in which the progressive spirit and energy exhibited in attacking the problems that arise, excel anything that is to be found in any other parts of the world. In support of this statement we need only direct attention to work carried out in the Newcastle district, where power is generated in the most economical manner in large Generating Stations, and distributed to the various collieries throughout the whole district by the Newcastle-upon-Tyne Electric Supply Co. Limited, and to the large and complete electrical installation in South Wales owned by the Powell Duffryn Steam Colliery Company Limited.

In the following pages we wish to indicate the various purposes to which electricity can be applied in mining work, and to give a general idea of the design and lay-out of such installations, and further to describe the manner in which all classes of mining machinery, up to the very largest and most important, are now driven electrically.

As has been remarked above, the progress of electric driving in mines abroad has been very great, and in view of the fact that the Siemens Companies have Branches in practically every country, we are able to refer to the most varied examples of mining machinery in all parts of the world.

In the section Power Distribution Systems, where we give typical examples illustrating the extent to which electricity is already used in mining, we have, for the sake of completeness, included some large systems where the plant was supplied by a number of different makers. In the other sections where a machine or installation is illustrated or described in detail, the plant has been supplied by a firm of the Siemens Concern.

Our thanks are due to the numerous Owners and Managers of mines or their Consulting Engineers who have placed at our disposal the plans and particulars given in this book.

We give in the appendix, a list of the various Siemens Companies, and their dependents, and from this list it will be seen how the various countries are supplied with plant from the respective Works.

The guiding principle adopted by the Siemens Companies as a whole is that labour should be employed, and salaries and wages paid in those countries where the plant is to be installed, provided always that the turnover in those countries justifies the erection of manufacturing works.

On the other hand, the co-operation between the various allied Companies, and between their electrical staffs is so intimate, that the experience gained in any country, and the inventions made by any one Company, are immediately available to all the others.

February, 1913.

Siemens Brothers Dynamo Works Limited.

CHAPTER 1

OBJECT AND SCOPE OF ELECTRIC MINING INSTALLATIONS

The special conditions of mining work render it necessary that the various kinds of plant used, such as winders, pumps, fans, washing and screening plant, haulages, hoists, drills, etc., should be situated in places much further apart than is usual in other industries, and methods have therefore had to be devised of transmitting to considerable distances the power required.

The first methods of power transmission which call for consideration are those employing steam or compressed air, that is, where gas under high pressure is conducted in pipes to the place where it is to be used. Such pipe systems have, apart from their high first cost, the additional disadvantage that the efficiency of transmission is very considerably reduced as soon as appreciable distances, even of a few hundred yards, have to be covered. This loss in efficiency is due to friction and heat losses in the pipe line itself, and to small leakages from the pipes, particularly at the joints. These losses are practically constant so long as pressure is maintained in the pipes, whether energy is being used or not, and the overall efficiency of such a system is still further reduced by the very low efficiencies of the small machines supplied from it, such as small steam engines or compressed-air motors. The maintenance cost for such a pipe system is also excessive. The transmission of energy by compressed air is only suitable for the supply of comparatively small units and can only be considered as an auxiliary to a steam system. Steam pipes installed below ground have the very undesirable effect of heating the drifts or the shafts.

Hydraulic systems have also been installed in mines, but have not been adopted very widely, as they are no more efficient than compressed air or steam.

The disadvantages of the systems mentioned above are not shared by electricity, and it is, therefore, not surprising that it has rapidly come into general use in mines. Electric power can be transmitted to practically any distance without excessive increase in cost, provided that a suitable pressure is used for transmission. The losses for a given distance and quantity of power are dependent only on the pressure and the size of the conductor, and can be readily calculated in advance for any part of the distribution system; they diminish as the amount of energy to be transmitted decreases, and are nil when no power is being used. The conductors, especially transmission cables, take

up very little space, develop no appreciable heat, and require practically no attention. Portable machinery, such as sinking pumps, small dip pumps, compressors, drills, etc., can easily be arranged to take a supply from the electric system through flexible cables, which can be accommodated on comparatively small drums in lengths up to several hundred yards.

One of the great advantages attaching to the use of electricity is that the power supplied to the different workings can easily be measured by suitable meters and instruments, and it is thus possible to keep a check on the power consumed in each district or by each machine, and also to detect any increase in power taken, such as might be due to careless working or to defects in the machines.

There is also the great advantage that electric motors are highly efficient, even down to the smallest outputs, that the motors themselves are very simple and thoroughly reliable, and that they take up but little space, especially if alternating current is employed. They are also more adaptable than any other form of motor in that they can often be built into or bolted to the machine that is being driven; and that the insulated conductors supplying the current are quite flexible and easily arranged. The use of electric motors has had a marked effect on the design of several classes of plant, as in the case, for instance, of high speed machinery such as centrifugal pumps, turbo blowers, etc., the use of which was rendered possible by the introduction of electric driving; this has caused a considerable reduction in the first cost of new plant. Electric motors are now made for speeds up to 3,000 R.P.M., and these share with the motors of medium speeds the advantage of great ease in speed regulation.

Electric power can be generated most cheaply when it is produced on a large scale, and new installations should, therefore, be so arranged that all the machines in the colliery, from the main shaft winder to the smallest auxiliary pumps, are electrically driven. A number of older pits which have already been equipped with steam or compressed-air systems are adopting electrical driving, and in such cases it is advisable to provide a generating station of ample capacity, so that as far as possible all the machines in the mine may be driven electrically; a large increase in the capacity of the station requires a comparatively small increase in capital outlay, so that it is more economical to convert the whole of the plant than to retain some machines driven on the old system. Where an old system is being converted, those districts which are most distant from the power station should first be driven electrically, as it is in such districts that the losses are greatest when compressed-air or steam-driven systems are used.

The introduction of modern mechanical plant, which is only made possible by the use of electricity, is not only a means of reducing the actual operating costs, but also of increasing the output of a mine. Many pits which are now working with a profit would hardly have been able to hold their own unless they had installed electrical plant as an aid to operation.

The installation of large power stations, and especially of large units, materially reduces the costs of electrical energy. Increase in the size of the single generating units not only raises the efficiency, but also reduces the first cost, the space required and the cost per unit for maintenance, attendance, stores, etc. The load fluctuations of the different machines on the power system such as winders, haulages, etc., will, to a certain extent, be evened out if the whole plant is supplied from one large station, and, consequently, the total load on the station is more constant, and the load factor of the generating plant more favourable. The expenses for the necessary spare plant also become proportionately lower as the size of the power plant is increased.

The economy of large units and large power stations naturally leads to concentration of power production, so that a group of collieries possibly spread over a considerable area is supplied from the same point, and the tendency of recent years has consequently been to supply larger and larger districts from the same centre. It frequently happens, naturally, that a system of this kind develops where a number of collieries are connected by financial interests; if in a case of this kind the collieries already have their own power stations, it is possible to connect them together electrically, so that if any one station is too heavily loaded as the colliery develops, the other stations in the group can supply it with power.

Considerations of this kind have led to the formation of large Public Supply Corporations such as the combination of Power Stations in the Newcastle district, the Victoria Falls and Transvaal Power Co. in South Africa, and the Rhenish-Westphalian Electric Supply Co. in the Westphalian Industrial District. These Supply Companies have developed extensively, and some of them show handsome profits. The extremely low cost at which stations of this kind can produce energy has placed them in a position to supply many pits, especially those of comparatively small requirements, with electricity at prices considerably below those at which any one pit could generate. The mines are the more ready to adopt this supply, as it relieves them of the necessity of tying up the capital which would be required for a power station of their own. In order to reduce the costs of electric power as far as possible, it is necessary to utilize all forms of energy which can be obtained cheaply, either from the mining or from allied industries, such as the unsaleable waste small coal, and the waste heat and gases from coke ovens which are especially suitable for conversion into electric energy. Blast furnace plants in the neighbourhood of mining districts are nearly always in a position to produce electric power under favourable conditions, as the utilization of the blast furnace gases in modern, efficient gas engines produces more power than is required in the blast furnace plant or the steel works themselves, and the excess can be sold at a low price. The introduction of exhaust-steam turbines made it possible to utilize the exhaust steam of old non-condensing steam engines in an advantageous manner. Those industries which require large amounts of steam for heating or drying purposes can easily obtain energy at low cost by utilizing their steam in steam turbines, where it does work by being expanded from a high pressure to the pressure required for the remainder of the plant.

It should be the object of a large Supply Corporation to utilize sources of supply similar to those described above wherever possible. An examination of the distribution plans which are given in the following pages shows how such power systems are gradually extended to embrace a number of generating stations operating in parallel on the same supply.

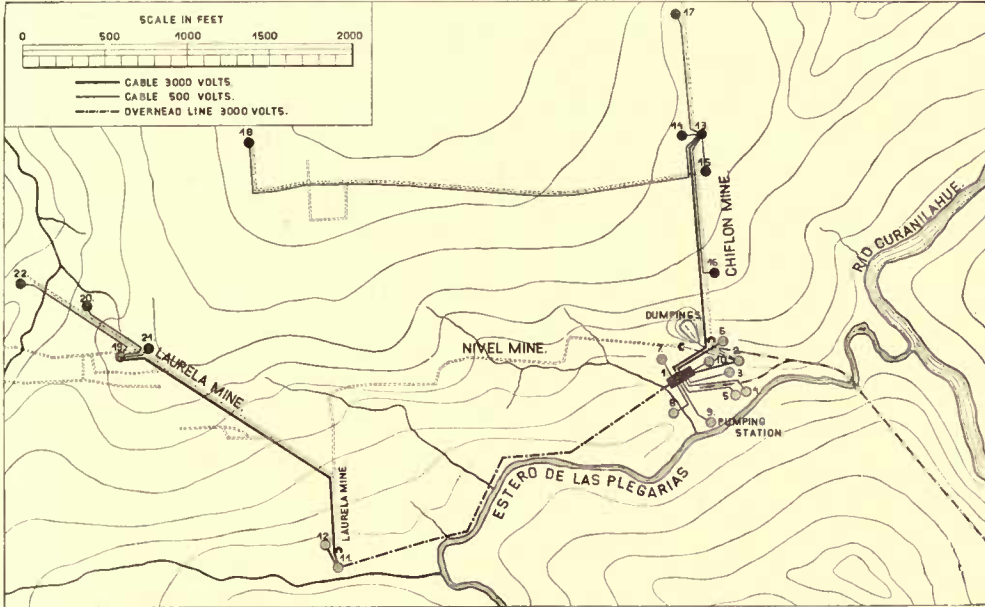
Those countries which are fortunate enough to possess suitable water power will naturally utilize it for the production of electrical energy, and the electric power generated can easily be transmitted to even very distant mines. In a number of oversea countries, where the mines are situated in mountainous districts, the use of mechanical aids to mining is only feasible if the existing water power is utilized, as the consumption of the available firewood and the excessive cost of transporting coal or other fuel prevent the extensive use of machinery otherwise than in connection with a supply of electric energy.

The examples given in the following chapters are intended to show how the distribution of electrical energy for mines has been carried out in practice, how far the transmission systems for single pits, or groups of pits belonging to the same Company, have been extended, and finally how large Public Supply Corporations have grown, and in what manner the available sources of energy in a district have been put to use.

CHAPTER II
DISTRIBUTION SYSTEMS

Cie Carbonifera Los Rios de Curanilahue

The Cie. Carbonifera Los Rios de Curanilahue operates a number of coal mines in the southern part of Chili. The coal is brought out through drifts. The power station generates three-phase current at 3,150 volts, 50 cycles. The larger motors above ground are all supplied direct from the high-tension line, while for the smaller motors the pressure is transformed down to 500 volts. All the motors underground are operated at 500 volts. The power is transmitted at 3,000 volts to the two transformer sub-stations installed below ground in the Mina Chiflon and the Mina Laurela.



Plan I.
Generating Plant

2 condensing steam turbines, output, each 1,000 K.V.A., 3,150 volts, 50 cycles.

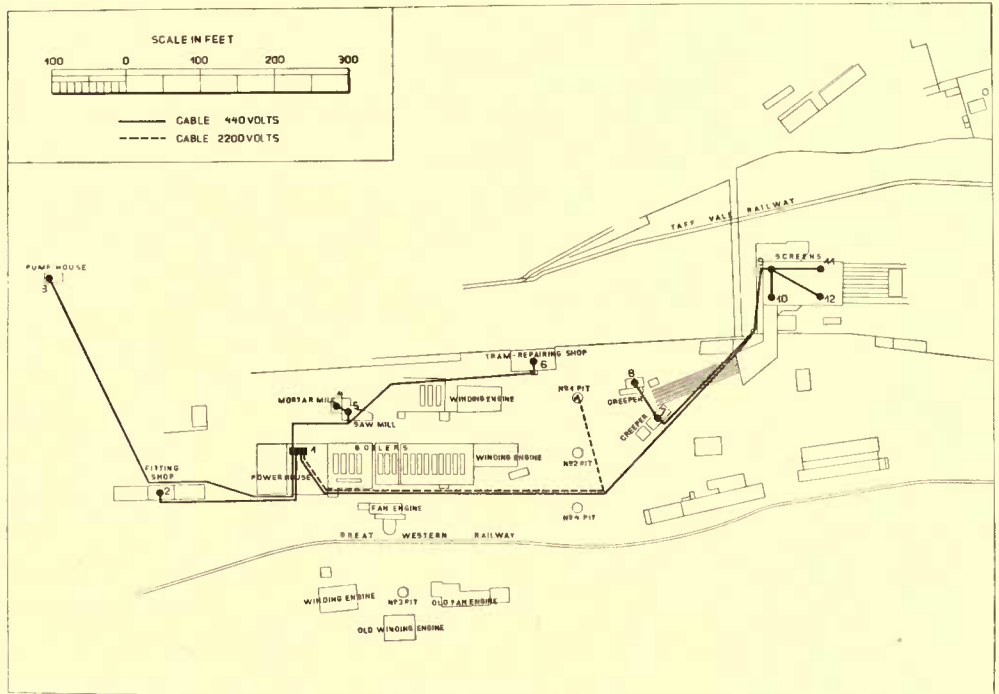
| | | Power Users | | | | |
|---------------------|----------------|-------------|-----------------------|-----------------|----------------------|--|
| | No. on Plan | Machines | | | Total Output H.P. | |
| Haulage House | - 2 | 1 | Endless Rope Haulage, | Mina Chiflon | - 135 | |
| | | 1 | " | Mina Nivel | - 135 | |
| | | 1 | " | for Rubbish Tip | - 35 | |
| Concentrating Plant | 3 | 3 | Motors | | - 104 | |
| Washery | - 4 | 3 | " | | - 76 | |
| Briquette Plant | - 5 | 3 | " | | - 120 | |
| Mina Chiflon | - 6 | 1 | Fan | | - 90 | |
| Shops | - 7, 8 | 2 | Motors | | - 64 | |
| Pumping Station | - 9 | 2 | Centrifugal Pumps | | - 25 (each) | |
| Spill | - 10 | 1 | Motor | | - 21 | |
| Mina Laurela | - 11 | 1 | Endless Rope Haulage | | - 135 | |
| " | - 12 | 1 | Fan | | - 90 | |
| Mina Chiflon | - 13 | 1 | Transformer | | - 450 K.V.A. | |
| " | - 14 | 2 | Centrifugal Pumps | | - 100 (each) | |
| " | - 15 | 1 | Endless Rope Haulage | | - 32 | |
| " | 16, 17, 18 | 3 | Pumps | | - 96 (each) | |
| Mina Laurela | - 19 | 1 | Transformer | | - 235 K.V.A. | |
| " | 20, 22 | 2 | Pumps | | - 132 (each) | |
| " | - 21 | 1 | Endless Rope Haulage | | - 32 | |

The Cambrian Collieries Limited, South Wales

C. P. SPARKS, ESQ., M. INST. C. E., LONDON, CONSULTING ENGINEER.

This Company possesses a very complete electrical installation, power being generated in the Company's own station and supplied to the various motors and machines above and below ground. The general lay-out of the distributing cables and feeders for the plant on the surface is shown on the following plan, and for the underground workings on the page opposite.

Coal is wound from three pits, and at the present time three seams of coal are worked, as will be seen from the illustration opposite. The depths of the pits are : No. 1, 510 yards ; No. 2, 430 yards ; No. 3, 530 yards.

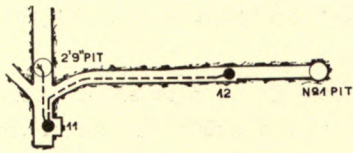


Plan II.
GENERATING PLANT.

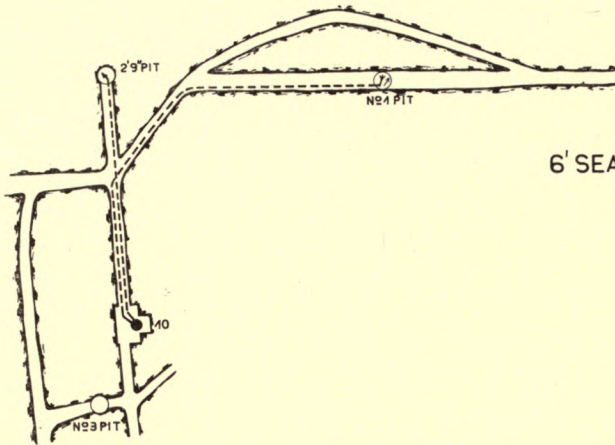
| No. of Units | Type of Prime Mover | Output each |
|--------------|---------------------|-------------|
| 1 | Steam Engine | 750 K.W. |
| 1 | Steam Turbine | 1,250 " |

POWER USERS.

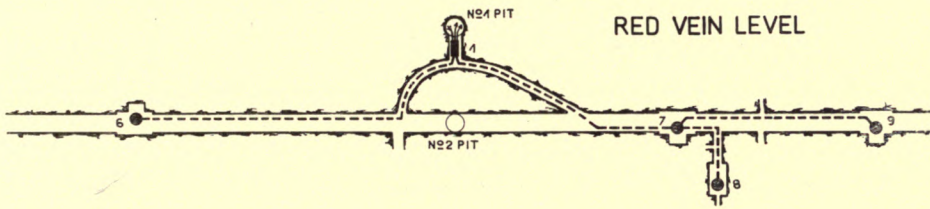
| Position | No. on Plan (Fig.) | Machines | Output H.P. each |
|-----------------|--------------------|----------------------|------------------|
| 2'9" Seam | 11 | 1 Haulage | 150 |
| " | 12 | 1 Air Compressor | 100 |
| 6" Seam | 10 | 1 Haulage | 220 |
| Red Vein Level | 6 | 1 Haulage | 220 |
| " | 7 | 1 Haulage | 220 |
| " | 8 | 1 Motor | 150 |
| " | 9 | 1 Haulage | 300 |
| Coronation Seam | 2 | Distribution Station | — |
| " | 3 | 1 Haulage | 150 |
| " | 4 | 1 Haulage | 150 |
| " | 5 | 1 Haulage | 220 |



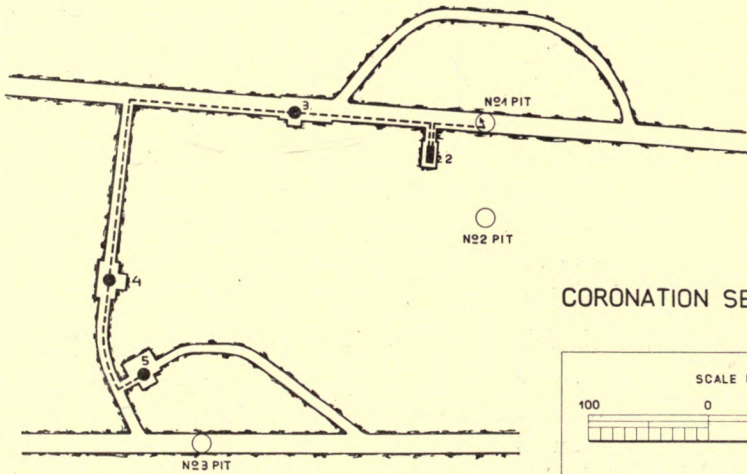
2'9" SEAM



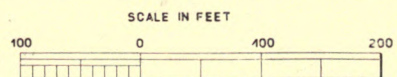
6' SEAM



RED VEIN LEVEL



CORONATION SEAM

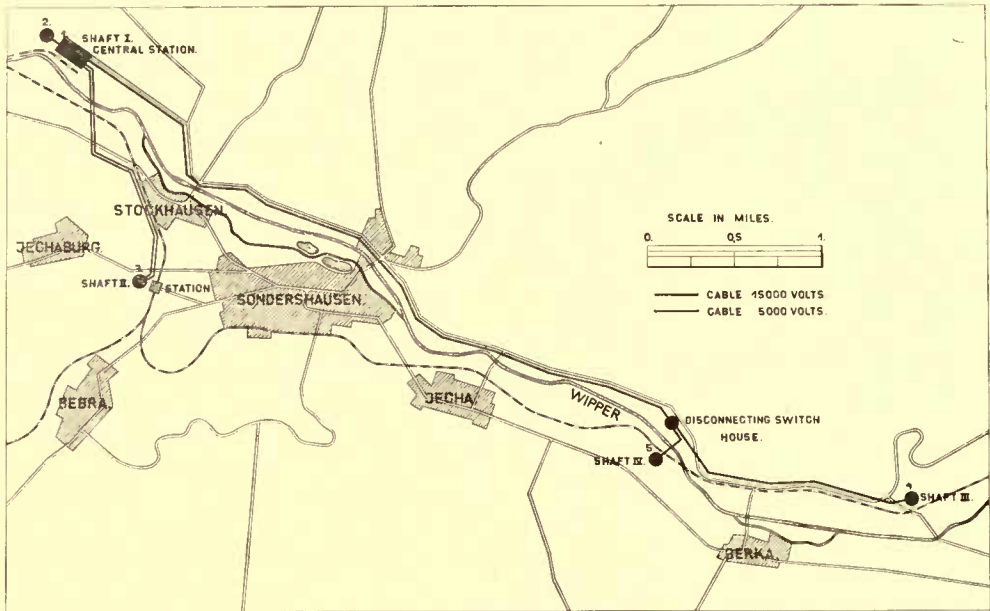


--- CABLE 2200 VOLTS

Plan III.

Gewerkschaft "Glückauf," Sondershausen (Germany)

The "Glückauf" concern consists of a number of single companies, mining potash salts. All of the mines are equipped with electric installations, which are supplied with energy from a single central station. The power is transmitted through cables, at 5,000 or 15,000 volts.



Plan IV.

Generating Plant

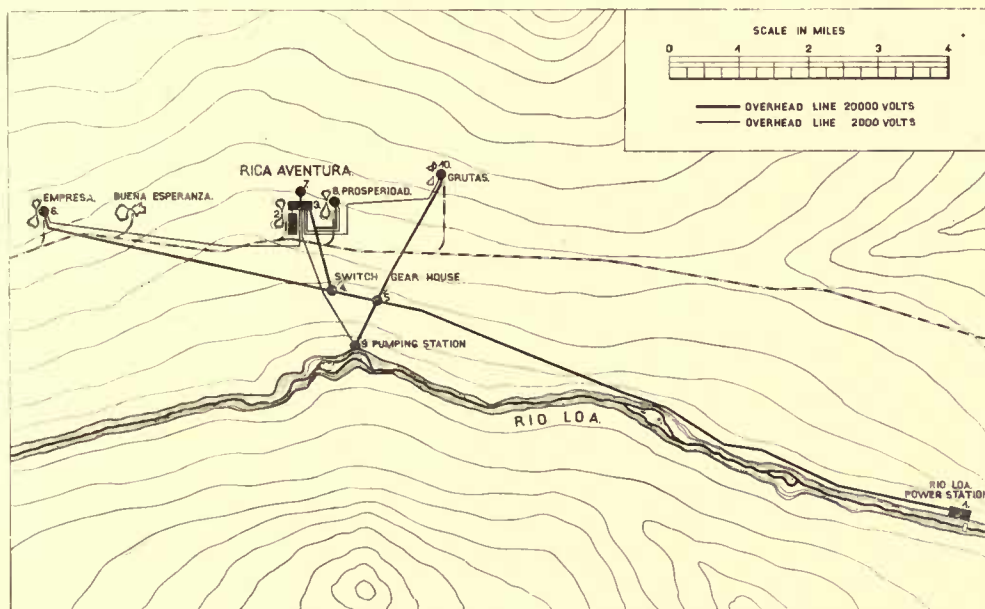
- | | |
|-----------|---|
| 1. Pit I. | 2 Condensing Steam Turbines, output, each 2,000 K.V.A. |
| | 4 Condensing Steam Engines, output, together, 1,100 K.V.A., 500 volts, 50 cycles. |

| | | Power Users | | | | |
|----------|-------------|-------------------------|---|---|-------------------|--|
| | No. on Plan | Machines | | | Total output H.P. | |
| Pit I. | 2 | 105 Motors | - | - | - 1650 | |
| Pit II. | 3 | 1 Siemens-Ilgner Winder | - | - | - 1100 | |
| | | 1 Ward-Leonard Winder | - | - | - 250 | |
| Pit III. | 4 | 60 Motors | - | - | - 900 | |
| | | 2 Ward-Leonard Winders | - | - | - 1425 | |
| Pit V. | - | 23 Motors | - | - | - 200 | |
| | | 2 Ward-Leonard Winders | - | - | - 1530 | |
| | - | 25 Motors | - | - | - 200 | |

The Nitrate Oficinas (Chili) of H.B. Sloman & Co., Hamburg

The Nitrate Oficinas of the above concern are situated near Tocopilla, in Chili, in a district where coal can only be obtained with great difficulty, and at great cost. The required electrical energy is, therefore, obtained by utilizing the water power of the Rio Loa. Quite recently a modern Diesel engine station has been erected, the old steam plant merely serving as a reserve.

The electrical power is distributed to the different points through overhead transmission lines at 2,000 or 20,000 volts, and serves to drive stone breakers, pumps, hoists, etc.



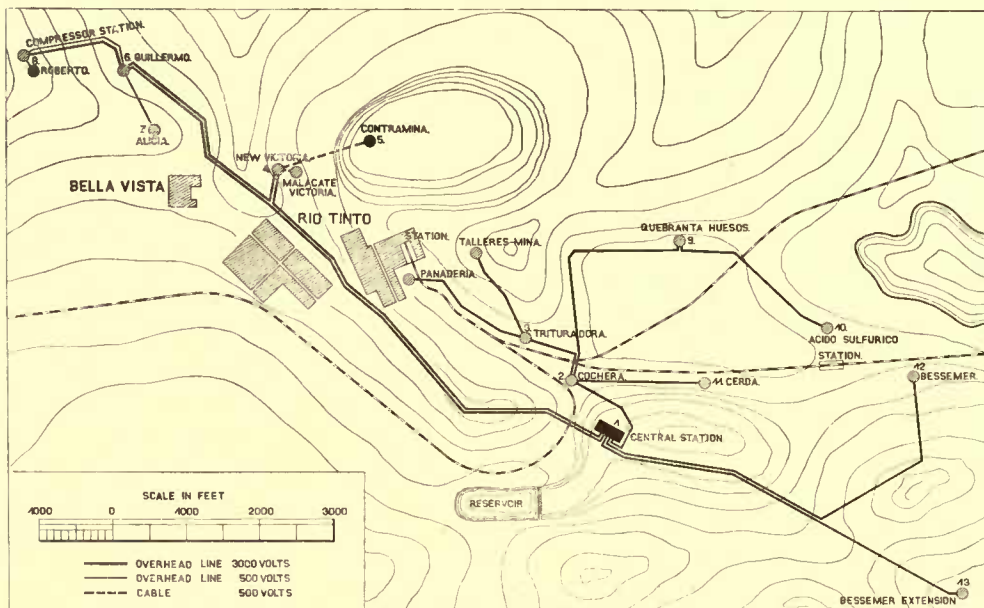
Plan V.

| | | Generating Stations | | | Output | | |
|-----------------------------|-------------|--------------------------|-------|----------|--------------|-----------|--|
| | No. on Plan | Type of Prime Mover | | K.V.A. | Pressure | Frequency | |
| Rio Loa | - 1 | 3 Water Turbines | - | 270 each | 525 | 50 | |
| Rica Aventura (old Station) | - 2 | 4 Non-condensing Engines | Steam | 125 | 525 | 50 | |
| Rica Aventura (new Station) | - 3 | 3 Diesel Engines | - | 275 | 525 | 50 | |
| | | Power Users | | | Total output | | |
| | No. on Plan | | | Machines | H.P. | | |
| Switch Stations | - - | - | - | 4 & 5 | | | |
| Oficina Empresa | - - | - | - | 6 | 34 motors | 500 | |
| Oficina Rica Aventura | - - | - | - | 7 | 47 | 950 | |
| Oficina Prosperidad | - - | - | - | 8 | 57 | 1,150 | |
| Pumping Station, Rio Loa | - - | - | - | 9 | 5 | 300 | |
| Oficina Grutas | - - | - | - | 10 | 27 | 350 | |

Rio Tinto Company Ltd., Spain

J. ANGUS, ESQ., M. INST. C.E., LONDON, CONSULTING ENGINEER.

The Rio Tinto Co. operates a number of copper mines in Southern Spain, which were equipped electrically by the Siemens Concern a few years ago. The power is generated in a single power station by steam-driven sets, and is distributed to the different mines through overhead transmission lines at 3,000 volts. The numerous electric winders are all operated on the Ward-Leonard or the Siemens Ilgner system.



Plan VI.

Generating Plant

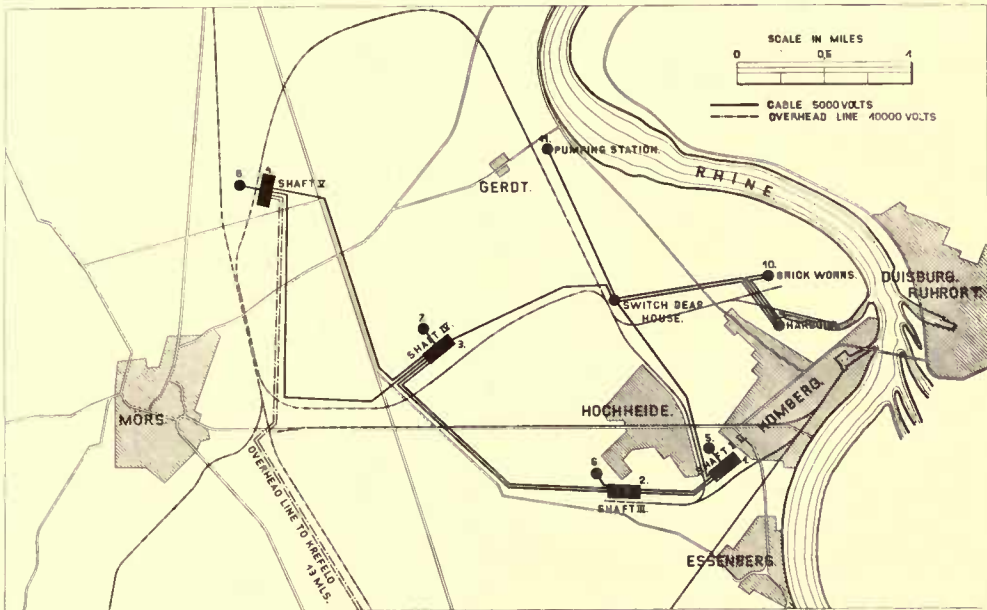
| No. of units | Type of Prime Mover | Output each K.V.A. | Pressure volts | Frequency |
|--------------|--------------------------|--------------------|----------------|-----------|
| 2 | Condensing Steam Engine | 760 | 3150 | 50 |
| 1 | Condensing Steam Turbine | 1500 | 3150 | 50 |

Power Users

| No. on plan | Name | Machines | Output |
|-------------|--------------------|-------------------------------------|----------------|
| 2 | Cochera | 2 Transformers | 37 K.V.A. each |
| | " | 2 Motors | 30 H.P. total. |
| 3 | Trituradora | 1 Transformer | 65 K.V.A. |
| 4 | New Victoria | 1 Ward-Leonard Winder | 270 H.P. |
| | " | 1 Fan | 260 H.P. |
| 5 | Contramina | 1 Ward-Leonard Winder (underground) | 275 H.P. |
| 6 | Guillermo | 1 Siemens-Ilgner Winder | 325 H.P. |
| | " | 1 Compressor | 570 H.P. |
| 7 | Alicia | 1 Ward-Leonard Winder | 270 H.P. |
| 8 | Roberto | 1 Ward-Leonard Winder | 60 H.P. |
| 9 | Quebranta Huesos | 1 Motor | 25 H.P. |
| 10 | Acido Sulfurico | 3 Motors | 20 H.P. total |
| 11 | Cerda | 1 Motor | 20 H.P. |
| 12 | Bessemer | 3 Motors | 200 H.P. total |
| 13 | Bessemer Extension | 3 Motors | 265 H.P. total |

Gewerkschaft Rheinpreussen, Homberg on the Rhine (Germany)

The Gewerkschaft Rheinpreussen owns a considerable number of large coal mines near Homberg on the Rhine. The five pits are provided with complete electrical equipments, and are supplied with power from four different central stations which are inter-connected by cables operating at a pressure of 5,250 volts. The waste heat of the coke-oven plants is employed to produce steam, while the gases are used in gas engines. The power station near Pit V also supplies energy to the Rhenish-Westfalen Supply Co. for supplying the city of Krefeld with light and power.



Plan VII.
Generating Plant

| No. on Plan | No. of Units | Type of Prime Mover | Output each K.V.A. | Pressure Volts | Frequency |
|-------------|--------------|----------------------------|--------------------|----------------|-----------|
| 1 | 2 | Condensing Steam Engines - | 3250 | 5250 | 50 |
| 1 | 1 | Coke-oven Gas Engine - | 1300 | 5250 | 50 |
| 2 | 1 | Condensing Steam Engine - | 900 | 5250 | 50 |
| 3 | 1 | Condensing Steam Engine - | 1300 | 5250 | 50 |
| 3 | 3 | Coke-oven Gas Engines - | 1300 | 5250 | 50 |
| 5 | 2 | Condensing Steam Turbines | 2600 | 5250 | 50 |

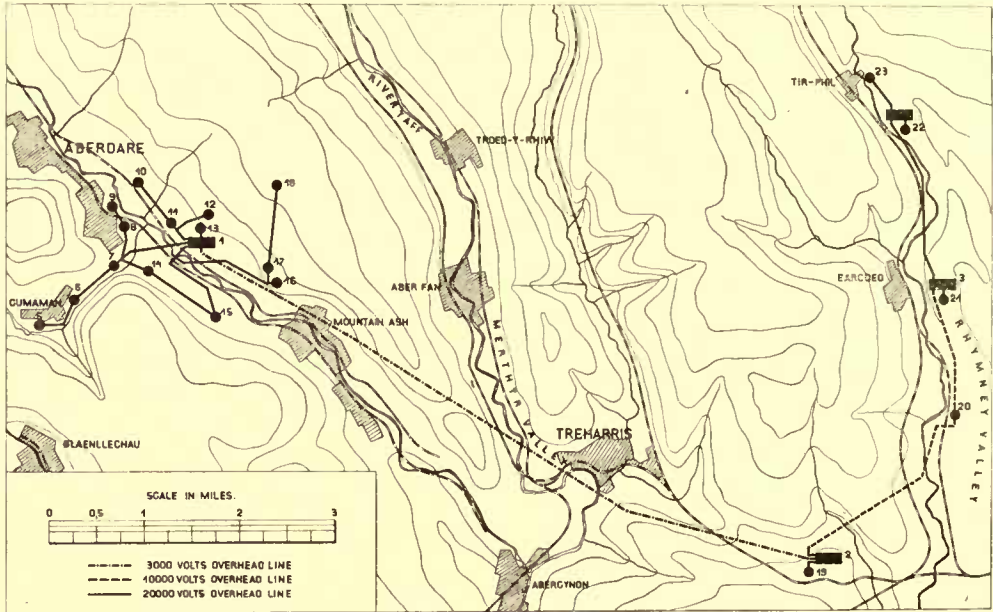
Power Users

| No. on Plan | Machines | Output H.P. |
|-------------|-----------------------------|-------------|
| 5 | 1 Siemens-Ilgner Winder | 3800 |
| | 45 Motors for Washery, etc. | 950 total |
| 6 | 3 Centrifugal Pumps | 2850 total |
| | 2 Reciprocating Pumps | 150 total |
| | 1 Fan | 650 |
| 8 | 8 Motors | 450 total |
| | 1 Siemens-Ilgner Winder | 980 |
| 7 | 2 Fans | 1625 total |
| | 44 Motors for Washery, etc. | 1250 total |
| | 2 Siemens-Ilgner Winders | 2000 each |
| 8 | 2 Centrifugal Pumps | 570 each |
| | 56 Motors for Washery, etc | 1650 total |
| 9 | 3 Coal Hoists | 130 each |
| 10 | 2 Presses | 200 total |

Powell Duffryn Steam Coal Co., South Wales

C. P. SPARKS, ESQ., M. INST. C. E., LONDON, CONSULTING ENGINEER.

The Powell Duffryn Steam Coal Co. is one of the largest mining concerns in Great Britain, and owns about 20 pits, situated in the Rhymney and Aberdare Valleys in South Wales. They were one of the first large firms to employ electric power on an extensive scale, and their pits are among the best equipped in the district. The utilization of waste heat plays a large part in the scheme of power supply, and electrically-driven winders and pumps of very large individual output have been installed.



Plan VIII.

The company generates three-phase current at 3,000 volts and 10,000 volts, 50 cycles, in its own power stations. Most of the pits, which are situated in fairly close proximity to the generating stations, are supplied with current at 3,000 volts, but a number of the mines are supplied at 10,000 volts, and a connecting line between two of the different stations also operates at 10,000 volts.

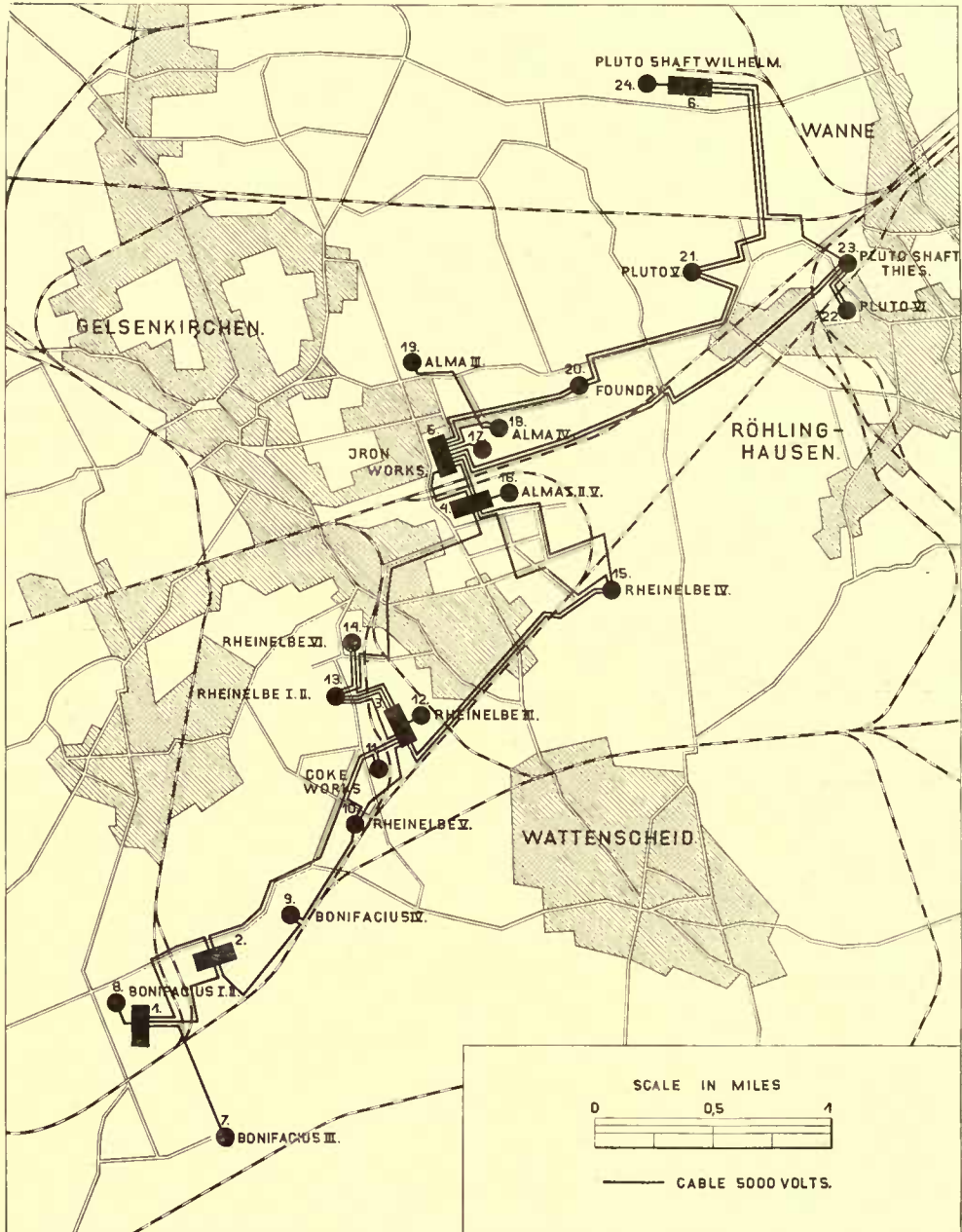
The generating stations are equipped with steam-driven reciprocating sets, live steam and exhaust turbo-sets, and coke-oven gas generators. The power is required for driving numerous pumping plants, winders, fans, haulages and other machinery.

| Pit | No. on Plan | Generating Stations | | | | Output each K.W. | Power Factor 0.7 |
|----------|-------------|---------------------|---|------------------------|---|------------------|------------------|
| | | Type of Prime Mover | | | | | |
| Aberaman | - | 1 | 3 | steam turbines | - | - | 2,000 |
| " | - | 1 | 1 | steam engine | - | - | 1,500 |
| Penallta | - | 2 | 2 | steam turbines | - | - | 3,000 |
| " | - | 2 | 1 | steam engine | - | - | 750 |
| Bargoed | - | 3 | 2 | coke oven gas engines | - | - | 1,650 |
| " | - | 3 | 1 | coke oven gas engine | - | - | 850 |
| " | - | - | 1 | steam engine | - | - | 750 |
| Elliott | - | 4 | 2 | exhaust steam turbines | - | - | 500 |
| " | - | 4 | 1 | steam engine | - | - | 750 |

| Pit. | No. on Plan | Power Users | | | | | | Total Output H.P. |
|----------------------------|-------------|-----------------------------------|---|---|---|---|---|-------------------|
| | | Machines | | | | | | |
| Forchaman Pit | 5 | Haulages | - | - | - | - | - | 1,250 |
| | | Motors for different purposes | - | - | - | - | - | 215 |
| Cwmneol Pit | 6 | Haulages | - | - | - | - | - | 560 |
| | | Fan | - | - | - | - | - | 250 |
| | | Motors for different purposes | - | - | - | - | - | 200 |
| Aberaman Pit | 7 | Haulages | - | - | - | - | - | 1,350 |
| | | Pumps | - | - | - | - | - | 775 |
| | | Motors for different purposes | - | - | - | - | - | 50 |
| Treaman Pit | 8 | Haulage | - | - | - | - | - | 160 |
| Abergwyr Pit | 9 | Winder | - | - | - | - | - | 75 |
| | | Fan | - | - | - | - | - | 75 |
| | | Motors for different purposes | - | - | - | - | - | 60 |
| | | Pumps | - | - | - | - | - | 450 |
| High Duffryn Pit | 10 | Haulages | - | - | - | - | - | 350 |
| | | Winder | - | - | - | - | - | 200 |
| Old Duffryn Pit | 11 | Haulages | - | - | - | - | - | 250 |
| | | Fan | - | - | - | - | - | 400 |
| | | Haulages | - | - | - | - | - | 750 |
| Letty Shenkin Pit | 12 | Motors for different purposes | - | - | - | - | - | 240 |
| | | Motors for different purposes | - | - | - | - | - | 260 |
| Washery | 13 | Motors for different purposes | - | - | - | - | - | 140 |
| Brick Works | 14 | Haulage | - | - | - | - | - | 140 |
| Abercwmbai Pit | 15 | Winder | - | - | - | - | - | 400 |
| | | Compressor | - | - | - | - | - | 560 |
| | | Pumps | - | - | - | - | - | 1,470 |
| | | Motors for different purposes | - | - | - | - | - | 80 |
| | | Fans | - | - | - | - | - | 200 |
| Lower Duffryn Pits 16 & 17 | | Haulages | - | - | - | - | - | 995 |
| | | Motors for different purposes | - | - | - | - | - | 210 |
| | | Winder | - | - | - | - | - | 250 |
| George Pit | 19 | Compressor | - | - | - | - | - | 400 |
| | | Fan | - | - | - | - | - | 100 |
| | | Pumps | - | - | - | - | - | 1,980 |
| Penallta Pit | 19 | Haulages | - | - | - | - | - | 500 |
| | | Fans | - | - | - | - | - | 200 |
| | | Motors for different purposes | - | - | - | - | - | 500 |
| | | Winders | - | - | - | - | - | 1,750 |
| Pengam, Britannia Pits | 20 | Compressors | - | - | - | - | - | 1,050 |
| | | Fan (to be increased to 750 H.P.) | - | - | - | - | - | 250 |
| | | Pumps | - | - | - | - | - | 400 |
| | | Motors for different purposes | - | - | - | - | - | 230 |
| | | Washery | - | - | - | - | - | 800 |
| Bargoed Pits | 21 | Coke oven | - | - | - | - | - | 380 |
| | | Pumps | - | - | - | - | - | 2,400 |
| | | Haulages | - | - | - | - | - | 1,500 |
| | | Motors for different purposes | - | - | - | - | - | 900 |
| | | Haulages | - | - | - | - | - | 1,025 |
| Elliott Pit | 22 | Pumps | - | - | - | - | - | 3,100 |
| | | Motors for different purposes | - | - | - | - | - | 310 |
| | | Haulages | - | - | - | - | - | 850 |
| New Tredegar Pit | 23 | Pumps | - | - | - | - | - | 175 |
| | | Motors for different purposes | - | - | - | - | - | 275 |

Gelsenkirchner Bergwerks A.G., Gelsenkirchen Westphalia (Germany)

The Gelsenkirchner Co. is one of the largest industrial concerns in Germany, and is the result of a combination between a number of coal mines



Plan IX.

and iron and steel works. All the works are equipped with modern electric installations. The available heat existing in the form of blast-furnace and coke-oven gas, waste heat, etc., is utilized for the production of electric power. The different stations, with a total output of approximately 32,000 K.V.A., generate power at 5,000 volts and 50 cycles, and are interconnected

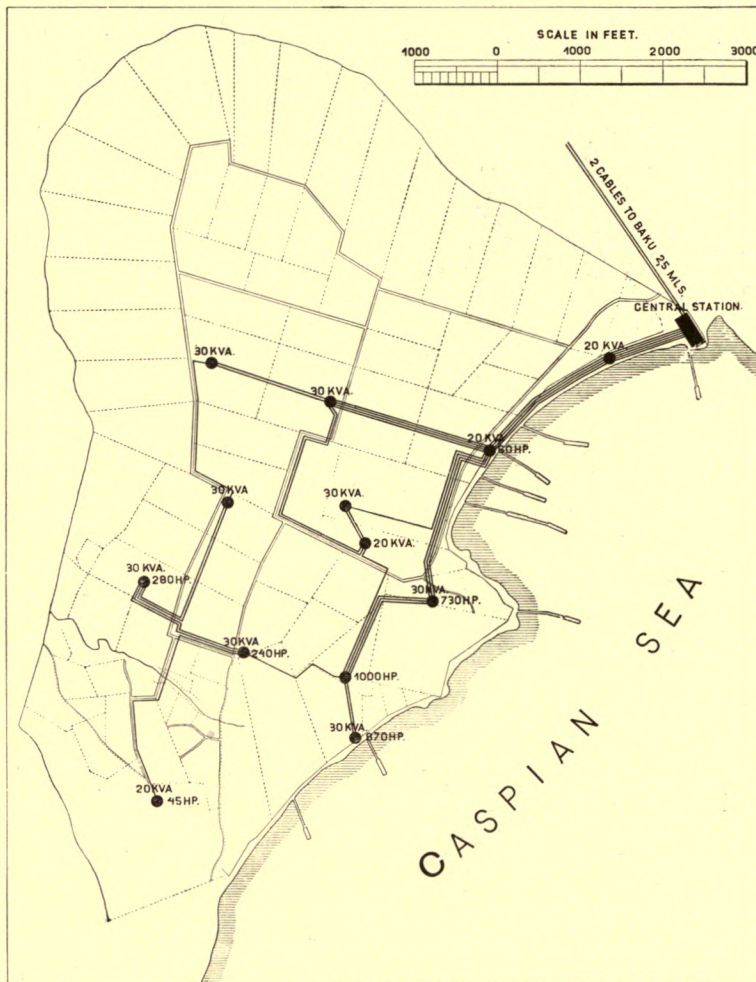
by suitable cables. Further, the blast-furnace power station and the Pit Bonifacius are provided with emergency connections to the Rhenish Westfalian Supply Co., in Essen. Connection has also been made, as a reserve, between the Pluto Mine to the power station "Westfalen."

| Pit | No. on Plan | Generating Plant | | Output each K.V.A. | Pressure | Frequency |
|----------------------------|-------------|---------------------|---------------------------|--------------------|----------|-----------|
| | | Type of Prime Mover | | | | |
| Bonifacius I/II | - 1 | 2 | Condensing Steam Engines | 610 | 2,000 | 50 |
| | - 2 | 2 | Coke-oven Gas Engines | 4,000 | 5,250 | 50 |
| Rheinelle III. | - 3 | 2 | Condensing Steam Engines | 4,500 | 5,250 | 50 |
| Alma I/II/V. | - 4 | 1 | Exhaust Steam Turbine | 625 | 5,250 | 50 |
| | - 5 | 2 | Blast Furnace Gas Engines | 1,250 | 5,250 | 50 |
| Pluto Mine, Wilhelm Pit | - 6 | 2 | Coke-oven Gas Engines | 1,400 | 5,250 | 50 |

| | No. on Plan | Power Users | | Total output H.P. |
|---------------------------------|-------------|----------------------------|---------|-------------------|
| | | Machines | | |
| Pit Bonifacius III. | - 7 | 1 fan | - - - - | 250 |
| | | 1 haulage | - - - - | 50 |
| Pit Bonifacius I/II. | 8 | 1 Siemens Ilgner winder | - - - - | 4,200 |
| | | 1 compressor | - - - - | 1,000 |
| | | 2 reciprocating pumps | - - - - | 620 |
| | | 1 centrifugal pump | - - - - | 650 |
| | | 120 motors | - - - - | 3,200 |
| Bonifacius Pit IV. | - 9 | 2 fans | - - - - | 1,000 |
| Rheinelbe Pit V. Coke Ovens, | - 10 | 1 fan | - - - - | 80 |
| Rheinelbe I/II. | 11 | 8 three-phase transformers | - - - - | 900 K.V.A. |
| Rheinelbe Pit III. | - 12 | 1 centrifugal pump | - - - - | 760 |
| | | 1 haulage | - - - - | 125 |
| | | 66 motors | - - - - | 1,525 |
| Rheinelbe Pit I/II. | - 13 | 1 Siemens Ilgner winder | - - - - | 3,170 |
| | | 1 Siemens Ilgner winder | - - - - | 3,600 |
| | | 67 motors | - - - - | 2,200 |
| Rheinelbe Pit VI. | - 14 | 2 fans | - - - - | 850 each |
| | | 2 haulages | - - - - | 150 each |
| Rheinelbe Pit IV. | - 15 | 1 compressor | - - - - | 1,300 |
| | | 1 fan | - - - - | 525 |
| | | 1 haulage | - - - - | 125 |
| | | 12 motors | - - - - | 150 |
| Alma Pit I II/V. | - 16 | 1 Siemens Ilgner winder | - - - - | 4,300 |
| | | 2 centrifugal pumps | - - - - | 530 |
| | | 3 haulages | - - - - | 210 |
| | | 88 motors | - - - - | 2,625 |
| Blast Furnaces | - 17 | 136 motors | - - - - | 5,500 |
| Alma Pit IV. | - 18 | 1 haulage | - - - - | 140 |
| Alma Pit III. | - 29 | 1 fan | - - - - | 275 |
| Foundry | - 20 | 2 cascade converters | - - - - | 1,000 |
| | | 265 motors | - - - - | 5,500 |
| Pluto Pit V. | - 21 | 1 fan | - - - - | 600 |
| Pluto Pit VI. | - 22 | 1 fan | - - - - | 1,200 |
| Pluto Pit Thies. | - 23 | 3 centrifugal pumps | - - - - | 2,000 |
| | | 1 fan | - - - - | 400 |
| | | 8 locomotives | - - - - | 200 |
| | | 23 motors | - - - - | 700 |
| Pluto Pit Wilhelm | - 24 | 1 fan | - - - - | 900 |
| | | 5 locomotives | - - - - | 120 |
| | | 50 motors | - - - - | 2,000 |

Electric Power Company, Baku

The Electric Power Co., Baku, is a public supply co., which provides current for lighting and power both for the city of Baku and for the different oil producing plants on the coast of the Caspian Sea. The power is distributed by a three-phase system at 2,000 volts and 50 cycles. Transformer stations have been erected near the various oil fields, which, for lighting and



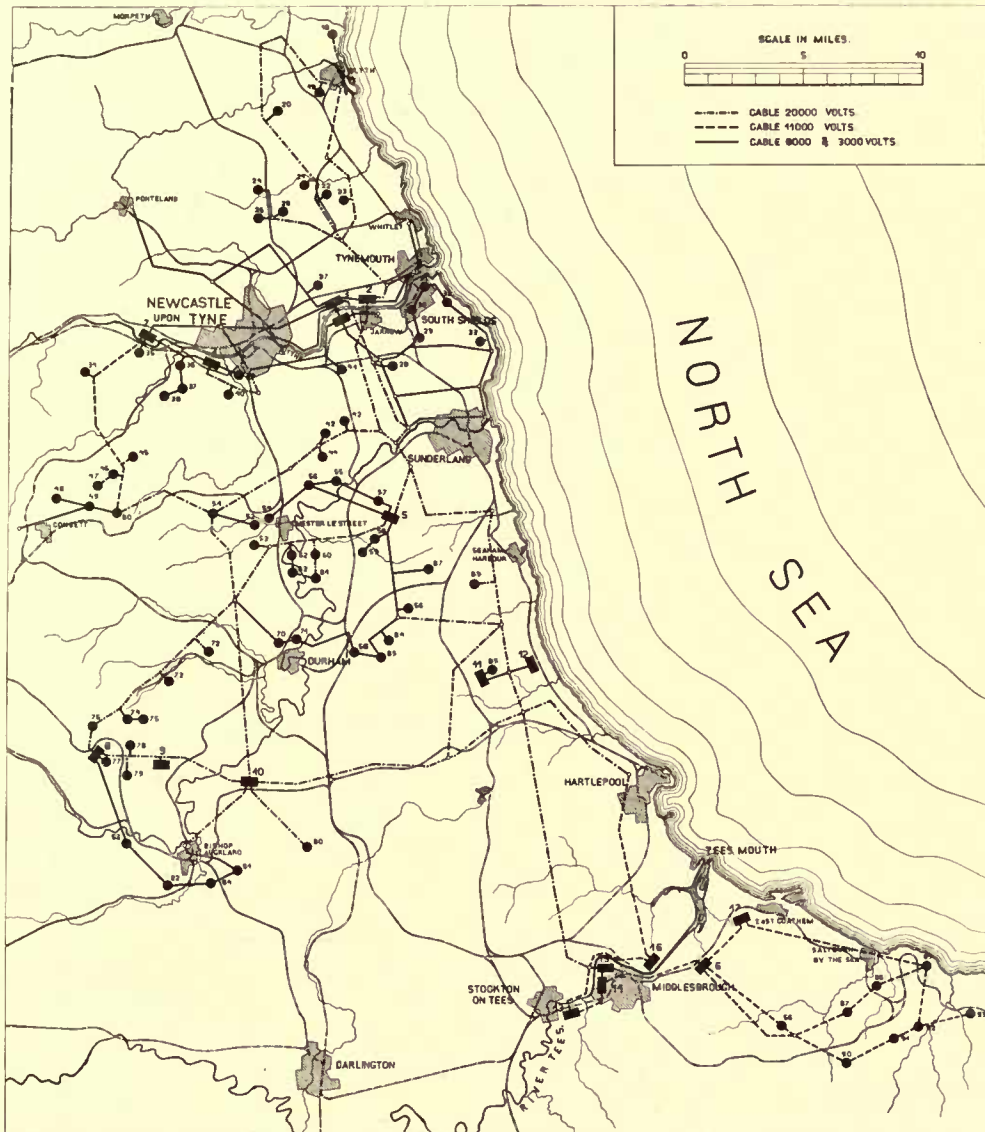
Plan X.

small power requirements, transform the pressure to 110 volts. A large number of motors connected across the 2,000 volt mains are employed for driving pumps, small hoists, etc. The various substations in the Naphtha district supplying current for lighting and power users, are marked respectively K.V.A. and H.P. on the plan.

Power Distribution System in the Newcastle District

MESSRS. MERZ & MCLELLAN, LONDON AND NEWCASTLE-UPON-TYNE, CONSULTING ENGINEERS

The Supply Companies in the Newcastle-on-Tyne District, viz., the Newcastle-upon-Tyne Electric Supply Co., Ltd., The County of Durham Electric Power Supply Co., The Northern Counties Electricity Supply Co., Ltd., and the Cleveland and Durham Electric Power Ltd., supply the whole North-East coast district of England with electric power.



Plan XI.

The industries carried on in this district are mining and the production and utilization of steel and iron.

All these industries require, on the one hand, considerable quantities of electric power, and on the other hand, have a large amount of waste

power in the form of gases or waste heat at their disposal. This waste heat contains a large supply of energy ; moreover, the situation of the power companies in the midst of one of the largest coal fields makes it possible to procure fuel at very low cost. These circumstances made it possible to form a public supply on a very large scale, producing power at an extremely low cost. A huge network of distribution lines covers the whole district, and is supplied with energy from a number of generating stations situated at the most favourable points.

The power is generated and distributed in the form of three-phase current at 40 cycles. The pressure in different parts of the system varies with the distances between stations, and the whole network is interlinked at different points by transformer substations. The total output of the different power stations is about 160,000 H.P., and serves a district covering approximately 1,500 square miles. The total number of consumers is about 15,200, and the total connected load about 170,000 H.P. Generally the smaller consumers are supplied from centrally situated substations, while large consumers are provided from separate substations, working under the control of the power company. Most of the consumers receive current at 2,750 volts, but power is also distributed at pressures of 440 and 220 volts.

In the accompanying plan, only the purely mining consumers are indicated.

| Pit | No. on Plan | Generating Stations | | | | | | Output, each H.P. |
|---------------|-------------|---------------------|---|----------------|---|---|---|-------------------|
| | | Type of Prime Mover | | | | | | |
| Dunston | - | 1 | 2 | Steam Turbines | - | - | - | 10,500 |
| " | - | 1 | 1 | " | " | - | - | 9,000 |
| Carville | - | 2 | 6 | " | " | - | - | 6,666 |
| " | - | 2 | 2 | " | " | - | - | 6,000 |
| Neptune Bank | - | 3 | 1 | " | " | - | - | 2,400 |
| " | - | 3 | 4 | " | " | - | - | 1,100 |
| Hebburn | - | 4 | 2 | " | " | - | - | 1,300 |
| " | - | 4 | 1 | " | " | - | - | 1,600 |
| Philadelphia | - | 5 | 2 | " | " | - | - | 2,660 |
| " | - | 5 | 5 | " | " | - | - | 1,300 |
| Grangetown | - | 6 | 3 | " | " | - | - | 1,780 |
| " | - | 6 | 1 | " | " | - | - | 2,660 |
| " | - | 6 | 1 | " | " | - | - | 3,200 |
| Blaydon | - | 7 | 2 | " | " | - | - | 1,850* |
| Bankfoot | - | 8 | 2 | " | " | - | - | 2,600 |
| " | - | 8 | 2 | " | " | - | - | 2,500* |
| Bowden-Close | - | 9 | 2 | " | " | - | - | 3,200 |
| " | - | 9 | 2 | " | " | - | - | 2,500* |
| Weardale | - | 10 | 4 | " | " | - | - | 1,833 |
| " | - | 10 | 2 | " | " | - | - | 2,500* |
| Shotton | - | 11 | 1 | " | " | - | - | 1,600† |
| Horden | - | 12 | 1 | " | " | - | - | 1,600† |
| Teesbridge | - | 13 | 1 | " | " | - | - | 1,500† |
| Newport | - | 14 | 2 | " | " | - | - | 1,666 |
| " | - | 14 | 1 | " | " | - | - | 666§ |
| Ayresome | - | 15 | 1 | " | " | - | - | 3,200 |
| Port Clarence | - | 16 | 1 | " | " | - | - | 3,200§ |
| Redcar | - | 17 | 1 | " | " | - | - | 3,200§ |

*Coke-oven waste heat and waste gases.

†Exhaust steam.

§Blast Furnace gas.

Power Users

Supplied by the Newcastle-upon-Tyne Electric Supply Co., Ltd.

| | No. on Plan | Machines | Total output H.P. |
|---|-------------|--|-------------------|
| Backworth Coal Co., | | | |
| Algernon Pit - | | Fan - - - - - | 200 |
| Church Pit - | 22 | Fan - - - - - | 100 |
| | | Screens - - - - - | 50 |
| Burradon & Cox-lodge Coal Co., | | | |
| Burradon Pit - | 26 | Pump - - - - - | 150 |
| | | Fan - - - - - | 250 |
| | | Compressor - - - - - | 100 |
| Burn Pit - | | Pumps - - - - - | 660 |
| | | Winder - - - - - | 176 |
| | | Miscellaneous - - - - - | 200 |
| Hazlerigg Pit - | | Pumps - - - - - | 210 |
| | | Fan - - - - - | 100 |
| | | Haulage - - - - - | 100 |
| | | Miscellaneous - - - - - | 220 |
| Weetlade Pit - | | Generator - - - - - | 100 |
| | | Compressor - - - - - | 100 |
| Cramlington Coal Co., | | | |
| Dudley Pit - | | Fan - - - - - | 100 |
| | | Haulage - - - - - | 90 |
| Hartford Pit - | 20 | Fan - - - - - | 100 |
| | | Compressors - - - - - | 300 |
| | | Pumps - - - - - | 230 |
| | | Haulages - - - - - | 180 |
| Lamp Pit - | | Washing Plant - - - - - | 200 |
| | | Brick Plant - - - - - | 100 |
| East Holywell Coal Co. - | 23 | Haulage, Pumps, Screens, &c. - - - - - | 350 |
| Jos. Laycock & Co. - | 21 | Coal Cutter 30, Pumps 100 - - - - - | 130 |
| Wallsend & Hebburn Coal Co., | | | |
| Wallsend Pit - | | Pumps - - - - - | 175 |
| | | Haulages - - - - - | 300 |
| | | Miscellaneous - - - - - | 75 |
| Rising Sun Pit - | 27 | Screens - - - - - | 80 |
| | | Haulages - - - - - | 100 |
| | | Compressor - - - - - | 120 |
| Edward Pit - | | Fan - - - - - | 300 |
| Walker Coal Co., | | | |
| Jane Pit - | | Haulages - - - - - | 220 |
| | | Compressor - - - - - | 110 |
| | | Pump - - - - - | 50 |
| Seaton Burn Coal Co., Seaton Burn Pit - | | Haulages - - - - - | 550 |
| Priestman Collieries Ltd. | | | |
| Bessie Pit - | | Fan - - - - - | 20 |
| | | Pumps - - - - - | 30 |
| | | Crusher - - - - - | 60 |
| | | Miscellaneous - - - - - | 10 |
| Milner Pit - | | Fan - - - - - | 15 |
| Otto Vale Pit - | | Disintegrators - - - - - | 160 |
| | | Creepers - - - - - | 60 |
| | | Miscellaneous - - - - - | 150 |

Power Users—continued.

| | No. on Plan | Machines | Total output H.P. |
|---|-------------|--|------------------------------|
| Preston Coal Co. John Bowes & Partners | | Pumps 65, Screen 50, Belts 60 | 175 |
| Old Fold Pit - | | Pumps - - - - - | 185 |
| Follingsby Pit - | | Screens 50, Pump 10 | 60 |
| Dunston Garesfield Coal Co. Swalwell Pit - | 36 | Winder - - - - - Pumps - - - - - Haulage - - - - - | 150 170 50 |
| Norwood Pit - | 40 | Fan - - - - - Haulage - - - - - Pump - - - - - Winder - - - - - | 150 150 100 100 |
| Framwellgate Moor Coal Co. Cater House Pit | 70 | Pumps - - - - - | 240 |
| Framwellgate Pit | 71 | Compressor - - - - - | 150 |
| Harton Coal Co. Harton Pit - | 29 | Pumps - - - - - Winder - - - - - Haulages - - - - - Miscellaneous - - - - - | 800 1,700 900 600 |
| Harton No. 2 Pit | 30 | Winder - - - - - Compressor 50, Miscellaneous 50 Miscellaneous - - - - - | 400 100 50 |
| Benthouse Pit - | 32 | Sinking engine - - - - - Rotary converter - - - - - Miscellaneous - - - - - | 240 460 150 |
| Boldon Pit - | 28 | Haulages - - - - - Fan - - - - - Miscellaneous - - - - - | 900 500 700 |
| St. Hilda Pit - | 31 | Pumps - - - - - Fan - - - - - Haulages - - - - - Miscellaneous - - - - - | 250 300 400 500 |
| Whitburn Pit - | 33 | Pumps - - - - - Fan - - - - - Haulages - - - - - Miscellaneous - - - - - | 1,400 350 1,000 400 |
| Boldon Don Pit | | Pump - - - - - | 6 |
| Harton Bogs Pit | | Pumps - - - - - Miscellaneous - - - - - | 40 16 |
| Easington Coal Co., Easington Pit - | | Pump - - - - - | 30 |
| Johnasson Gordon & Co., Usworth Pit - | 42 | Screens - - - - - | 100 |
| Hetton Coal Co., Elemore Pit - | | Compressors - - - - - | 400 |
| Owners of Pelton Colliery Pelton Pit - | | Fan - - - - - | 200 |
| Tribley Pit - | | Haulages - - - - - Winder - - - - - Miscellaneous - - - - - | 72 55 60 |
| Owners of So. Pelaw Colliery - | 54 | Haulage - - - - - | 80 |

Power Users—continued.

| | No. on Plan | Machines | Total output H.P. |
|---|-------------|---|------------------------|
| Pease & Partners - Priestman Collieries Ltd. | 72 | Pumps 90, Haulages 225 | 315 |
| Axwell Park Pit - | 38 | Brickmaking - - - - - Haulages - - - - - Miscellaneous - - - - - | 150 60 250 |
| Whickham Pit - | 37 | Pumps - - - - - Haulages - - - - - Fan - - - - - Miscellaneous - - - - - | 120 120 60 40 |
| Blaydon Main Pit - - - - | 35 | Pumps - - - - - Screens - - - - - | 900 30 |
| North Hetton Coal Co. | | Fan - - - - - | 50 |
| South Hetton Coal Co. | | Pump - - - - - | 140 |
| Redheugh Coal Co. Samuelson, Sir B. & Co. | 39 | Haulages 350, Pumps 20 | 370 |
| Stella Coal Co. - | 34 | Coal Cutter 15, Conveyor 15 Haulages 200, Miscell. 150 | 30 350 |
| Washington Coal Co., Glebe Pit - | 44 | Fan 60, Pump 48, Haulage 75 | 183 |
| Washington Pit - | 43 | Fan 160, Haulages 50 | 210 |
| Heworth Coal Co., Fanny Pit - | | Bulk - - - - - | 200 |
| New Brancepeth Coal Co. - - - | | Bulk - - - - - | 530 |
| Ryhope Coal Co. - | | Bulk - - - - - | 500 |

Supplied by the Northern Counties Electricity Supply Co.

| | | | |
|-------------------------------|----|--|-----|
| John Bowes & Partners. | | | |
| Felling Pit - | | Haulages 500, Screens 100, Pump 9 | 609 |
| Wardley Pit - | | Pumps 355, Fan 320, Winder 100 | 775 |
| Cowpen Coal Co. | | | |
| Cambois Pit - | 19 | Pump 140, Miscell. 38 | 178 |
| Mill Pit - - | | Pumps 103, Haulage 70, Screens 100 | 273 |
| North Pit - - | 18 | Haulage 70, Pumps 25 | 95 |
| Heworth Coal Co. | | Haulage 125, Miscell. 80 | 205 |
| Wallsend & Hebburn Coal Co. - | | Pumps 560, Haulage 200, Miscellaneous 40 | 800 |

Supplied by the Durham Collieries Electric Power Co.

| | | | |
|---------------------------|----|---------------------------------------|-----|
| Lambton & Hetton Coal Co. | | | |
| Eppleton Pit - | 67 | Haulage 130, Compressor 70, Pump 30 | 230 |
| Elemore Pit - | 68 | Haulages 330, Compressor 110, Pump 60 | 500 |
| Herrington Pit - | | Haulages 510, Pumps 170, Miscell. 80 | 760 |
| Philadelphia Works - - | | Miscellaneous - - - - - | 170 |
| Lady Ann Pit - | | Haulages 170, Pump 350, Fan 30 | 570 |
| Lumley 6th Pit - | 60 | Haulages 400, Fan 130, Miscell. 240 | 770 |
| Coke Works - - | | Haulage 40, Miscell. 40 | 80 |
| N. Biddick Pit - | 55 | Haulage 130, Pump 420, Miscell. 110 | 660 |
| Harraton Pit - | 56 | Haulages 300, Miscell. 140 | 440 |
| Nicholson Pit - | | Pump 500, Miscell. 20 | 520 |

Power Users—continued.

| | No. on Plan | Machines | Total output H.P. |
|---|-------------|---|-------------------|
| Margaret Pit - | 62 | Fans 300, Miscell. 240 - - - - | 540 |
| " " - | 63 | Haulages 110, Cutters 260, Miscell. 140 - | 510 |
| Lumley 3rd Pit - | 61 | Winder 450, Cutters, 130, Miscell. 240 - | 820 |
| Houghton Pit - | 59 | Haulages 400, Pumps 400, Miscell. 30 - | 838 |
| Sherburn Group (Pumping shaft) | | Pump 1,070, Miscell. 70 - - - - | 1,140 |
| Littletown Pit - | 64 | Haulage 140, Miscell. 80 - - - - | 220 |
| Sherburn Hill Pit | 65 | Haulage 140, Pump 80 - - - - | 220 |
| Sherburn Pit - | 66 | Pump 400, Fan 100 - - - - | 500 |
| North Pit - | - | Fan - - - - | 70 |
| Dorothea Pit - | 58 | Haulages 750, Miscell. 30 - - - - | 780 |
| South Hetton Coal Co. | | | |
| Murton Pit - | 69 | Fans - - - - | 1,070 |
| | | Haulages - - - - | 2,270 |
| | | Pumps 530, Miscell. 800 - - - - | 1,330 |
| Lambton & Hetton Coal Co. | | | |
| Lyons Pit - | - | Surface (Shops) - - - - | 100 |
| Pea Flatts Pit - | - | Transformer - - - - | 100 |
| Supplied by the Bankfoot Power Co. | | | |
| Pease & Partners | | | |
| Sunnyside Pit - | 76 | Haulages - - - - | 600 |
| | | Pumps 250, Miscell. 75 - - - - | 325 |
| Roddy Moor Pit | 78 | Miscellaneous - - - - | 120 |
| Washery - | - | Pumps - - - - | 240 |
| | | Disintegrator 100, Miscell. 150 - - - - | 250 |
| Otto Ovens - | - | Rams 200, Conveyors 70, Miscell. 75 - | 345 |
| French Ovens - | - | Rams - - - - | 50 |
| | | Miscellaneous - - - - | 50 |
| Lucy Pit - | - | Generator - - - - | 80 |
| | | Miscellaneous - - - - | 100 |
| Brickworks - | - | Fireclay side - - - - | 150 |
| | | Stone br. - - - - | 30 |
| Jobs Hill Pit - | 79 | Haulage 120, Fan 25 - - - - | 145 |
| Wooley Pit - | 75 | Winders - - - - | 220 |
| | | Haulage - - - - | 150 |
| | | Miscellaneous - - - - | 250 |
| Stanley Pit - | 74 | Miscellaneous - - - - | 200 |
| Bowden Close Pit | | Haulages - - - - | 300 |
| | | Miscellaneous - - - - | 115 |

CHAPTER III

CHOICE OF TRANSMISSION SYSTEM AND PRESSURE

There are at present only two systems available for the distribution of electric power in mines, viz., with alternating current or with direct current.

The restrictions imposed by the commutators of direct-current generators and motors limit the voltage of direct-current systems to a maximum of about 500 volts. The pressure which is in use in any one part of a direct-current distribution system predetermines the working pressure of the entire plant, as pressure transformation of direct current is only possible by means of rotary transformers, and is accompanied by appreciable losses. A working pressure of 500 volts only suffices for mines whose workings above and below ground have a maximum extent of a few hundred yards. On the other hand, a pressure of 500 volts is as high as is advisable for small motors, lamps, etc., working below ground, compatible with the safety of the attendants.

The use of alternating current for distribution permits the pressure to be transformed up or down as may be desired in static transformers, operating at a very high efficiency. It is, therefore, possible on the one hand to transform up to such values that the transmission can be carried out economically for any practicable distance, while, on the other, the pressure can be reduced to any extent necessary for safe use in small motors, and for lighting, etc.

Alternating-current motors are better suited to operation under mining conditions than direct-current machines, because they lend themselves readily to robust construction, while the commutator of the direct-current machine requires somewhat skilled attention. Small alternating-current motors can be so built that the rotating part consists of a "squirrel-cage" with practically no winding, ensuring the greatest possible reliability and safety of operation. A direct-current motor never offers absolute safety against open sparking, while alternating-current motors with squirrel-cage rotors are absolutely sparkless, and even motors with slipping rotors are only liable to sparking when the slip-rings or brushes get out of order. If, therefore, the mine is one of those in which fire-damp or other explosive gases are likely to occur, an alternating-current motor presents a greater degree of safety than a direct-current motor; moreover, it is possible to make all parts of alternating-current motors explosion proof, while direct-current motors cannot be so built.

Finally, direct-current motors are more sensitive to the presence of moisture than alternating-current motors, especially if the air is slightly charged with acid fumes. In this case the insulation of the direct-current machine is quickly destroyed by the electrolytic action of the direct current, while the insulation of an alternating-current motor remains unaffected, as the continual reversal of the current allows no electrolytic effects to accumulate.

The advantages outlined in the preceding paragraphs have caused the almost universal adoption of alternating current in Continental mining installations, and only a few of the older pits form an exception to this rule. In England, where the number of direct-current installations is still comparatively great, there also exists a strong tendency towards the use of alternating current.

The choice of voltage is determined by the extent of the district which is to be supplied. For single pits, where the maximum distance through which energy has to be transmitted does not exceed 500 yards, it is quite feasible to operate the system at 500 volts. Usually, however, mining installations require the power to be transmitted over considerably greater distances, especially if electric power is used to any extent in the outlying workings below ground. The usual pressures for single pits are, therefore, between 2,000 and 3,000 volts. These pressures make it possible, on the one hand, to transmit energy economically up to distances of 2 or 3 miles, and on the other, permit the use of motors down to an output of about 25 H.P. without a transformer.

If the power supply is to extend to a number of pits, so that distances of, say 10 miles or so have to be traversed, a pressure of about 10,000 volts becomes necessary. If the transmission system covers a still larger supply area, a correspondingly higher pressure must be used. There are a number of power transmission lines in operation at pressures of 100,000 volts transmitting energy over distances of 100 miles, or even more.

These very high pressures cannot be generated directly in the dynamos. Considerations of safety make it customary to limit the generator pressure to about 5,000 volts, and to transform from this up to the transmission pressure in static transformers. The secondary or distribution stations usually transform down to the pressure adapted to the condition of the district which they supply.

If the current is to be used in small motors, and especially if lighting installations are to be supplied, the pressure can be still further reduced. It is usual to reduce the pressure for lighting installations in damp mines to 100 volts or even less in order to obviate any danger to the workmen.

CHAPTER IV

ELECTRIC POWER STATIONS

Steam Engine Stations

The introduction of electrical transmission of energy in mines forced the steam engine into other fields of activity ; while it had formerly been used for driving pumps, compressors, or other machinery, it is at present employed chiefly in connection with the generation of electric energy. The large number of small steam engines in use at the different places where power was required, were replaced by a few large units situated in the power station. This change necessitated greater care in the design and manufacture of steam engines than had formerly been necessary. From the single cylinder slide-valve engine exhausting into the atmosphere, the modern multiple expansion engine with condensing plant and driven by superheated steam was developed. The slide valve itself was improved or replaced by poppet or rotary valves of different kinds, which can be more closely regulated and are more accurate in operation. Rope or belt-driven dynamos were gradually replaced by direct-coupled machines. The rotating parts of alternating-current generators of this type were provided with sufficient weight to reduce the cyclic irregularity to a small value as required for good parallel running.

Two modern installations of this class are shown in Figs. 1 and 2. Horizontal steam engines require a large amount of space, and large and therefore expensive engine rooms ; further, they can only be built for comparatively slow speeds, for which large generators are necessary. These disadvantages are not shared by vertical engines, types of which are shown in Figs. 3 and 4. These can be built for speeds up to 350 r.p.m. and above, and, as a consequence, the first cost of the power station would be considerably reduced. For this reason vertical steam engines have found considerable favour for power stations in mines, especially in England.

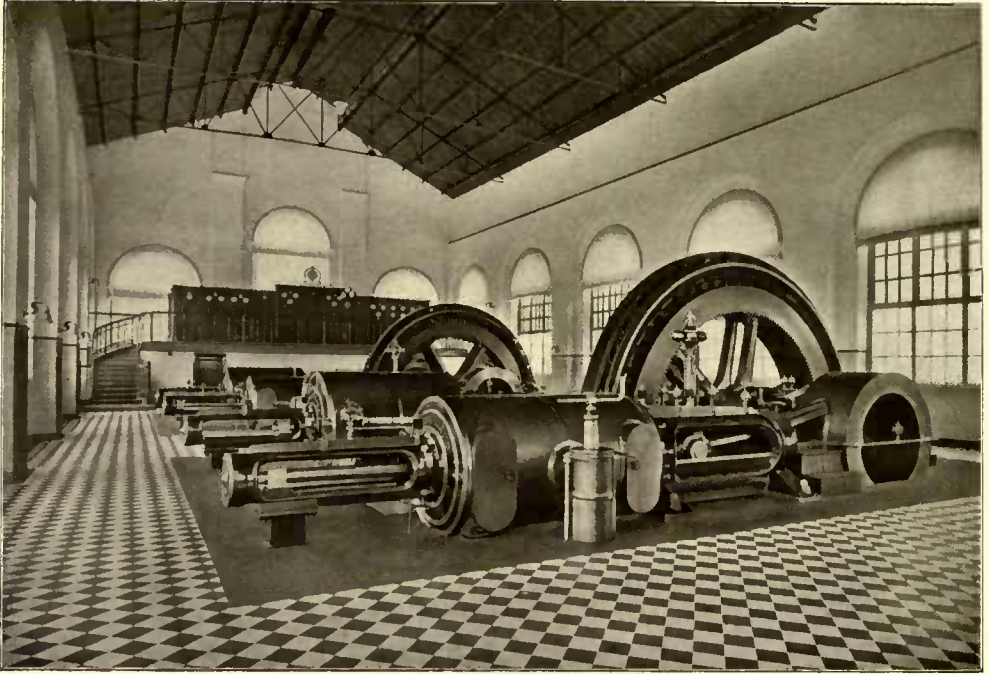


Fig. 1
Nord de Charleroi Coal Mines, Roux, Belgium.

Two horizontal compound steam engines coupled to three-phase generators, each 550 K.V.A.
107 R.P.M., 3150 volts, 50 cycles.

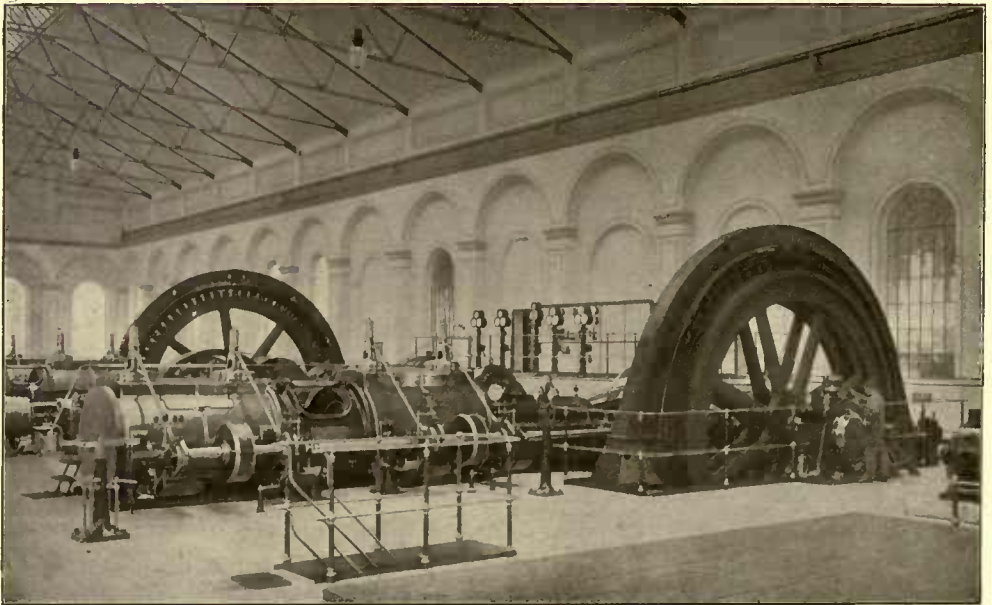


Fig. 2
De Wendel Mine, Hamm, Germany.

Two compound tandem steam engines coupled to three-phase generators of 850 and 800 K.V.A. respectively,
3,000 volts, 50 cycles.

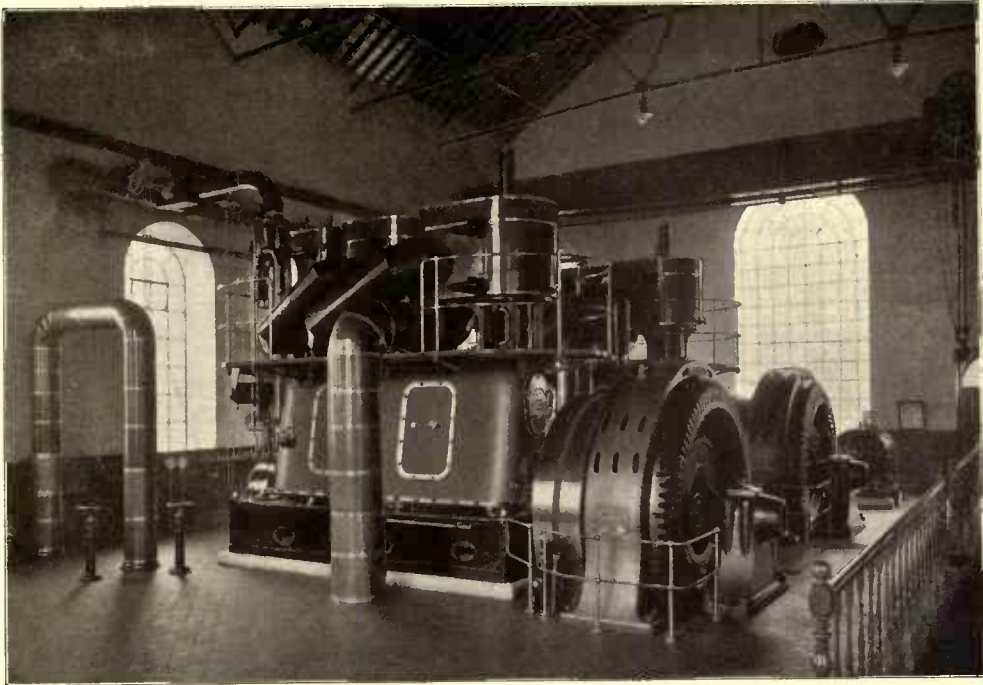


Fig. 3

Cambrian Collieries, South Wales.

Two vertical compound engines coupled to three-phase generators, output each 1,000 K.V.A., speed 250 R.P.M., pressure 2,200 volts, frequency 25 cycles.

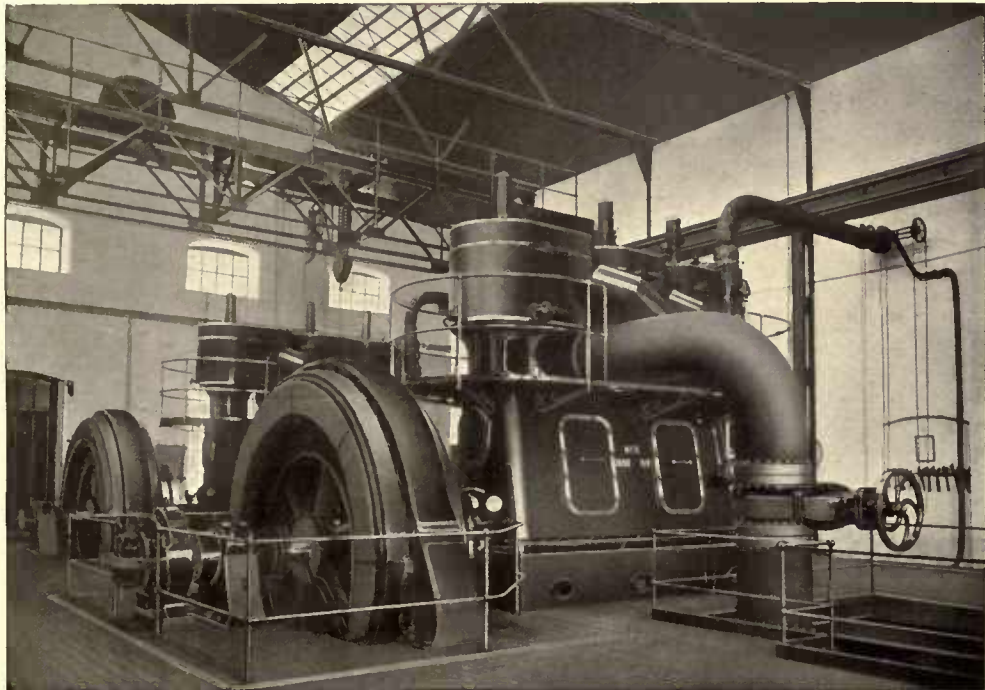


Fig. 4

Rio Tinto Co., South Spain.

Two vertical compound steam engines coupled to three-phase generators, output each 750 K.V.A., speed 250 R.P.M., pressure 3,000 volts, frequency 50 cycles.

Steam Turbine Plants

The steam engine has recently found a rival in the steam turbine, and at the present day it is unusual to instal reciprocating sets for outputs above 500 K.W., while for units with outputs exceeding 1,000 K.W., turbo sets are almost exclusively used. Single units of 20,000 K.V.A. output have already been built, and it is very probable that the size of the units will be still further increased. The capital cost per kilowatt installed is, of course, reduced very much by the employment of these large machines.

The steam consumption of a 1,000 K.W. turbo-generator, running at 3,000 r.p.m., at a steam pressure of 195 lbs. per sq. in., and a temperature of 660°F. at the stop valve, is about 13.5 lbs. per Kilowatt hour. If the size of the units is increased, the steam consumption is even less. The steam consumption at partial loads is comparatively little more than at full load, so that the turbine cited above will only require about 15 lbs. of steam per K.W. hour when running at half load, providing that the same amount of cooling water is available for the condenser.

The Siemens Concern are not themselves manufacturers of steam turbines, but construct their generators suitable for coupling to turbines of any manufacture.

The construction of generators for direct coupling with steam turbines has to be carried out with considerable care, owing to the fact that the high speeds of these sets induce large centrifugal stresses in the rotors. In order to withstand these successfully, the rotors are constructed of open hearth steel, pressed in the molten state and forged in one piece with the shaft. The slots into which the field winding is placed are machined out of the solid metal. The slots are closed with metal wedges, ensuring an absolutely rigid and solid bedding of the winding, even at the highest speeds. Particular care is paid to the insulation and stiffness of the stator winding. The stresses which may arise from a heavy short circuit are met by mechanically stiffening the overhang of the windings, where they project from the slots.

The small surface available for radiating the heat generated in a machine of this type, renders the provision of some system of artificial ventilation necessary. The rotor is provided with fans, which cause an efficient circulation of the air (Fig. 5), the cool air being drawn into the machine through a special dust filter.

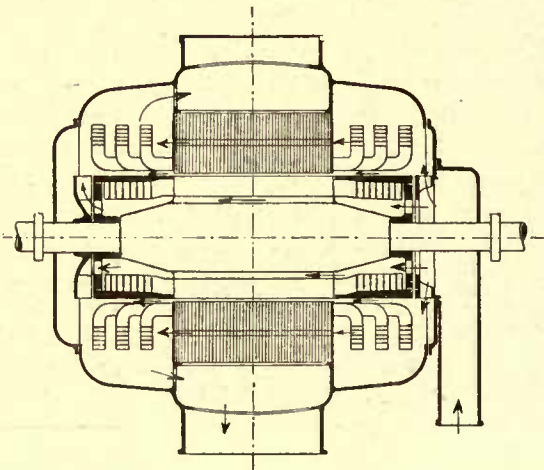


Fig. 5.

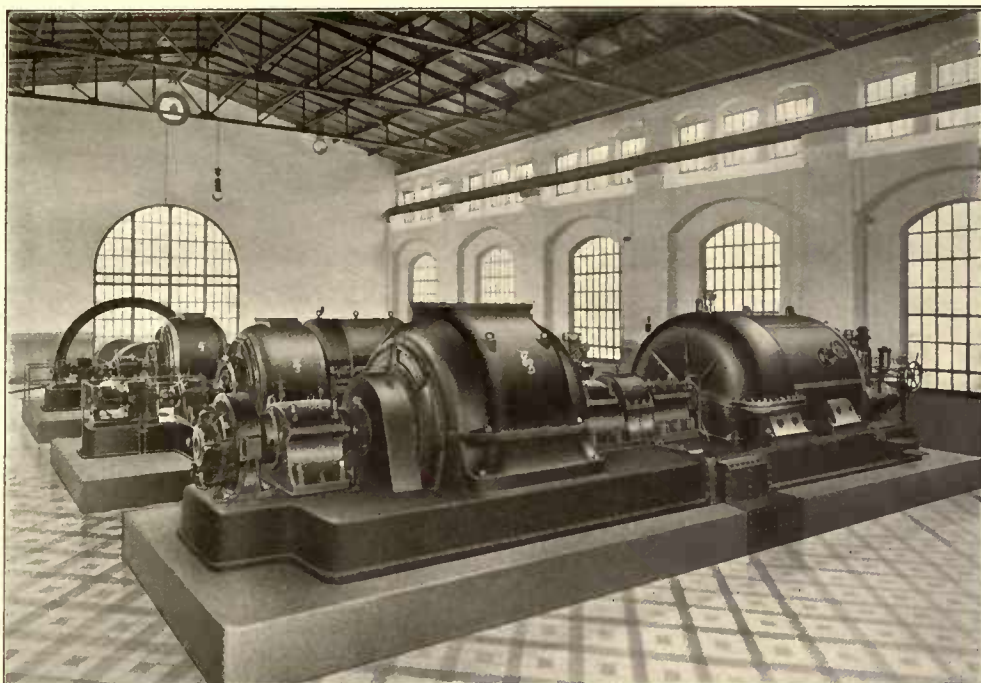


Fig. 6.

State Mine Wilhelmina, Heerlen, Holland.

Three-phase turbo-generator sets. Output each 1,200 and 2,500 K.V.A. respectively, pressure 2,000 volts, frequency 50 cycles, speed 1,500 R.P.M.

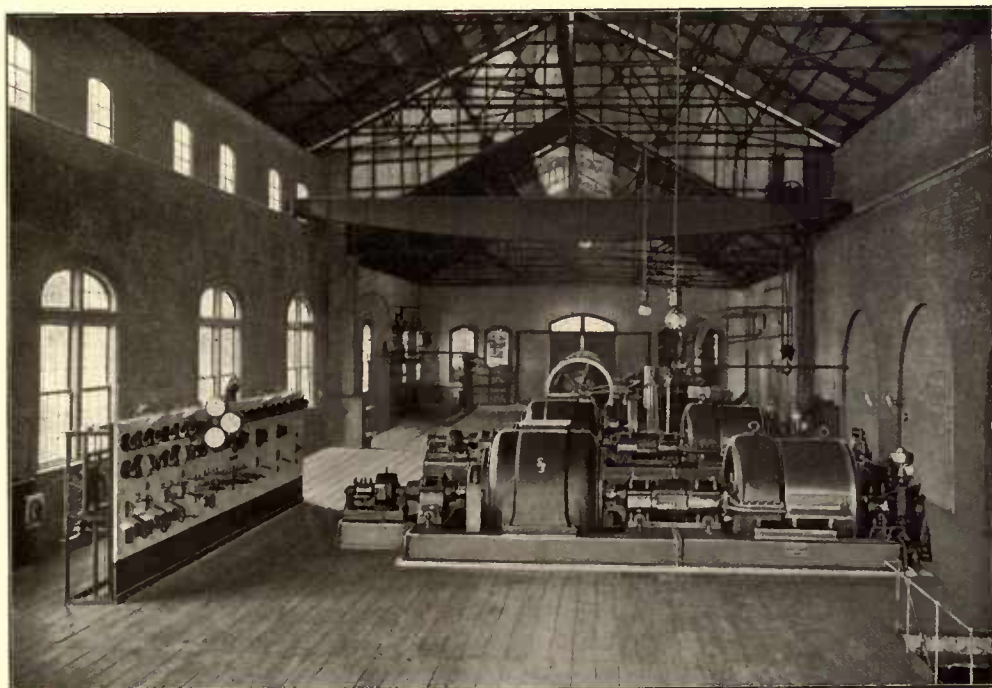


Fig. 7.

Sumitomo Besshi Kogyosho, Niihama Mine, Japan.

Two three-phase turbo-generator sets, output each 750 K.V.A., pressure 3,300 volts, frequency 30 cycles, speed 1,800 R.P.M.

Turbine Installations for special purposes

In some mines steam is required for heating, boiling or drying purposes. The heating installation requires steam at low pressure, whereas the power plant operates on high-pressure steam. It is consequently necessary either to generate all of the steam at the high pressure necessary for operating the power plant, and to reduce the pressure for heating to the required value by means of throttle valves or similar devices, or, if preferred, to instal a separate low-pressure boiler for heating purposes. The total efficiency of the plant can, however, be considerably increased if all the steam required is generated in high-pressure boilers, and the heating steam, instead of being throttled to the required pressure, is expanded in steam engines or steam turbines, and the exhaust from these machines used for heating purposes. Non-condensing steam turbines, known as "back pressure turbines," are specially suitable for this purpose. They are usually equipped with an automatic device for keeping the back pressure constant. Their essential qualities are small space requirements, simple construction, and consequent low cost.

If the demand for steam for heating purposes is so small that the power obtained from its expansion is not sufficient to supply the whole demand for electric energy, it is preferable to use a "tapped" turbine, as shown in Fig. 8. This is a turbine operating with a condenser, so arranged that the steam necessary for heating purposes can be taken from one of the different expansion stages in the turbine itself. When no steam is required for heating or drying purposes, the turbine operates with a condenser in the ordinary way. When steam is required for special purposes, the necessary quantity is taken from an intermediate stage and the remainder goes to the condenser through the low pressure part of the turbine. If the load on the generator is small, so that the expansion energy of the steam required for heating or other purposes is sufficient to drive it, the turbine runs as a back-pressure turbine, that is, all the steam passing through the high pressure section goes into the heating apparatus, while the low pressure part runs without load. If the load on the turbine is still further reduced, while the heating requirements remain unaltered, the necessary steam for the latter must be taken from the boiler feed pipe. This type of turbine is readily adaptable to all conditions of service.

The overall efficiency of old existing plant can be considerably increased by the use of exhaust-steam turbines coupled to electric generators, supplied with steam from the existing non-condensing engines employed to drive the winders, compressors, &c. In this connection the characteristic quality of the turbine, the ability to utilize even the highest vacuum to a great advantage, is specially valuable. If the supply of exhaust steam is not continuous or steady, a heat accumulator can be interposed between the engine and the turbine, and if this is not feasible, mixed pressure sets are used, consisting of an exhaust steam turbine, fitted with one or two high-pressure wheels which can be automatically brought into action if required. If the supply of exhaust steam fails entirely, it is possible to run the whole set as an ordinary steam turbine. Exhaust steam turbines are shown in Figs. 10 and 11. The outputs of these sets show that if the exhaust steam is carefully utilized, a large amount of energy can be obtained with practically no increase in the amount of fuel required.

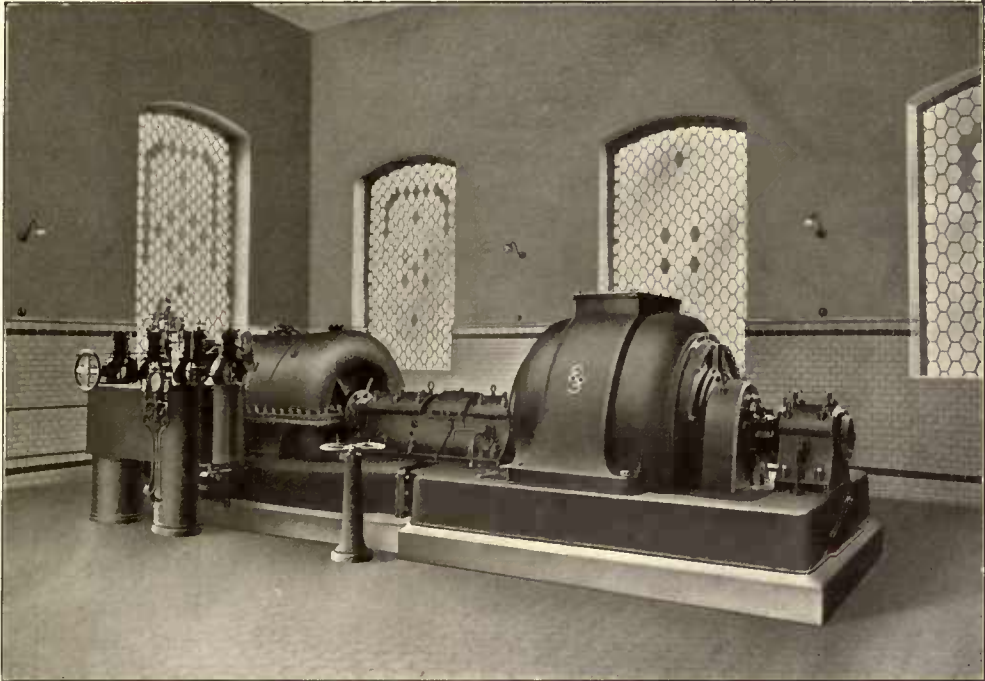


Fig. 8

Lignite Mine, Kauscher Werk, Petershain, Germany.

Three-phase generator coupled to a "tapped" turbine. Output 650 K.V.A., pressure 3,150 volts, frequency 50 cycles, speed 3,000 R.P.M.

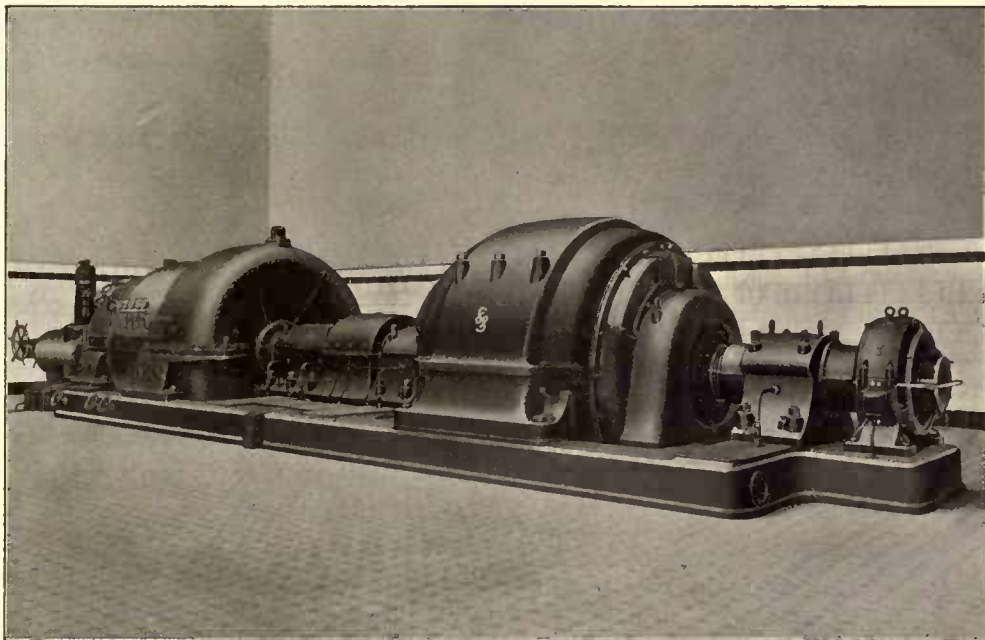


Fig. 9

**Rhenish-Westphalian Electric Supply Co., Essen, Germany,
Reisholz Station.**

Three-phase turbo-generator, output 7,500 K.V.A., pressure 5,000 volts, frequency 50 cycles, speed 1,000 R.P.M.

Gas Engine Plants

The large amount of energy contained in the waste gases from blast furnaces and coke ovens has only been used to a comparatively small extent, although quite recently considerable progress in this direction has been made.

Statistics which were published recently showed that the power which could be generated from waste gases, and the power actually generated from such gases in the different countries of the world is as follows:—

Table of Gas Powers. *

| Country. | Total H.P. available. | Total H.P. utilized. | Percentage utilized. |
|--------------------------------------|--------------------------|-------------------------|-------------------------|
| Germany including Luxemburg - - - | 2,075,000 | 481,428 | 23·2 |
| Belgium - - - - | 225,000 | 46,714 | 20·8 |
| France - - - - | 448,000 | 55,050 | 12·3 |
| Austria-Hungary - - | 260,000 | 25,500 | 9·8 |
| United States - - - | 2,620,000 | 337,490 | 12·9 |
| Great Britain and Ireland | 1,720,000 | 24,986 | 1·5 |
| Other Countries - - | 815,000 | 64,541 | 7·9 |

But even to-day the greater part of the gases from furnaces and coke ovens still escapes without being utilized, or is only burnt under boilers where not more than one half the energy that could be obtained by the use of gas engines is recovered.

The doubts which were raised only a few years ago against the reliability of large gas engines have been dispelled. Conclusive evidence of this is the great increase in the manufacture of gas engines in the last few years. The waste gases of a blast furnace, with an output of 250 tons of iron per day, are sufficient to operate gas engines of approximately 10,000 H.P. continuously. The blast furnace plant itself requires only about 2,500 H.P. for driving blowers, hoists, and other auxiliary plant, so that a total of 7,500 H.P. remains available for other purposes.

This power is usually in excess of the requirements of the iron works for driving the rolling mills, lighting, etc., so that such installations are in a position to sell large amounts of electrical energy at a low price. This cheap power supply is, of course, in the first place at the disposal of those mines which operate in conjunction with steel and blast furnace plants. An example of

* "Stahl und Eisen" and "Glückauf."

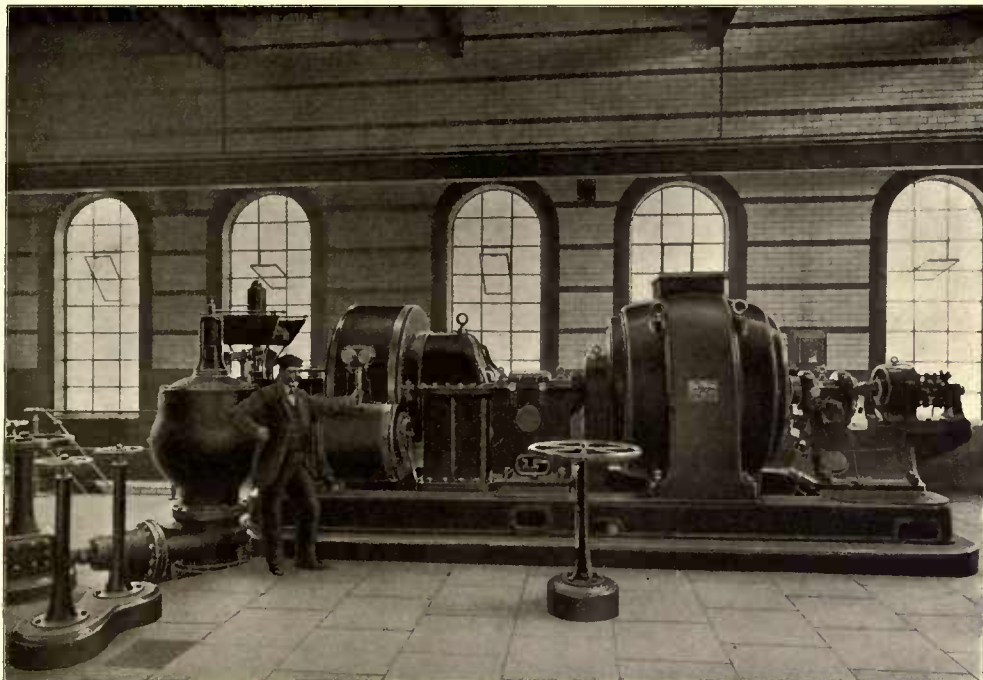


Fig. 10.

Rothervale Colliery Co., near Rotherham.

Exhaust-steam turbine with three-phase generator. Output 625 K.V.A., 3,000 volts, 50 cycles, 3,000 R.P.M.

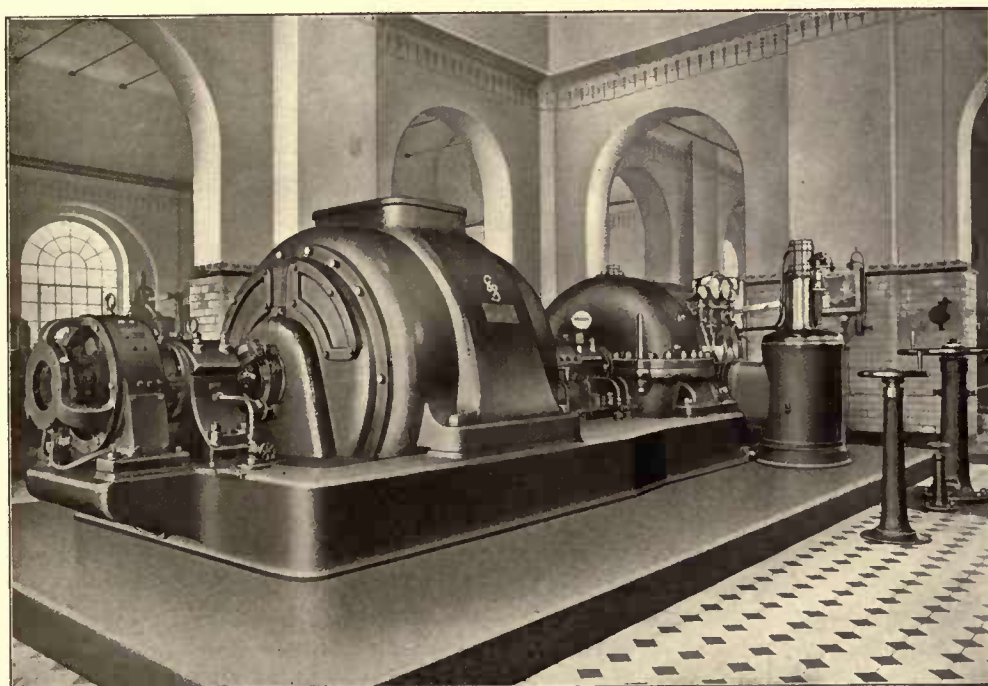


Fig. 11.

Deutsch Luxemburg Mining and Iron Co., Pit Dannenbaum II., near Bochum.

Exhaust-steam turbine, coupled to three-phase generator. Output 650 K.V.A., pressure 235 volts, frequency 50 cycles, speed 3,000 R.P.M.

this type of concern is the Gewerkschaft Deutscher Kaiser at Bruckhausen, whose gas engine power station, shown in Fig. 12, supplies power not only to the steel works, but also to a number of the mines connected with this concern. Usually, however, independent mines which are situated in the neighbourhood of blast furnace plants can also obtain the energy produced from blast furnace gases at comparatively cheap prices, either direct from the producers, or through the agency of one of the large public supply corporations.

The waste gases from coke ovens are also suitable for driving gas engines. An installation of this type is shown in Fig. 13. Coke ovens of the older type give off waste energy only in the form of heat suitable for heating steam boilers. Coke ovens in connection with by-product recovery plants, which have recently been adopted to an increasing extent, leave waste gases for disposal, which can be used to great advantage in gas engines. The non-regenerative by-product coke ovens produce both waste heat and waste gases, while those of the regenerative type give only waste gases. These latter are, therefore, specially suitable for a gas engine power plant.

As a reserve in case of stoppage of the coke ovens, it is usual to provide gas-producers suitable for working on coke. These gas producers can also utilize the coke dust and grit, and if this is done the output of the power plant may be increased by about 50%.

A battery of coke ovens of the regenerative type, with an output of 200 tons per day, corresponding to an input of 10 tons of coal per hour, supplies sufficient gas for operating gas engines with an output of 1,800 to 2,100 H.P., depending on the quality of the coal. This output can be increased to 2,700/3,000 H.P. if the coke dust and grit is also utilized in gas producers.

Gas engines permit of a more efficient utilization of fuel than steam engines. This has occasionally led to their use, even if waste gases are not directly available. In plants of this type the gas is generated in producers, and either forced into the gas engines or drawn into them by their own suction. An installation of this type is, however, only economical if the reduced costs for fuel compensate for the extra capital outlay on the plant. Such an installation is, therefore, only to be recommended when the price of fuel is very high.

Practically all generators driven by gas engines are of the direct-coupled type, the necessary weight for producing the requisite low degree of cyclic irregularity being embodied in the rotating field system of the generator. The difficulties which formerly occurred in connection with parallel operation have been overcome by making due allowance for resonance effects when designing the rotating parts. The experience gained in large power stations during the last few years demonstrates that generators driven by gas engines not only run well together in parallel, but will also run satisfactorily in parallel with generators driven by reciprocating steam engines, or by steam turbines.

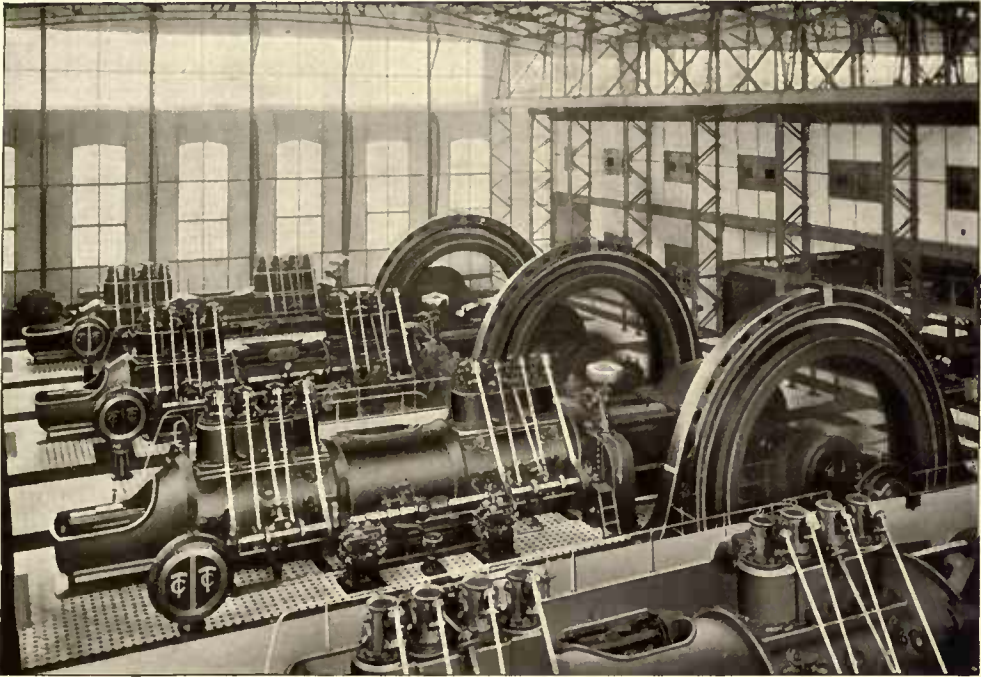


Fig. 12.

Gewerkschaft Deutscher Kaiser at Bruckhausen.

Six blast furnace-gas engines, coupled to three-phase generators, 2,240 and 2,800 K.V.A.
5,500 volts, 50 cycles, 94 R.P.M.

Supplying collieries and steel works.

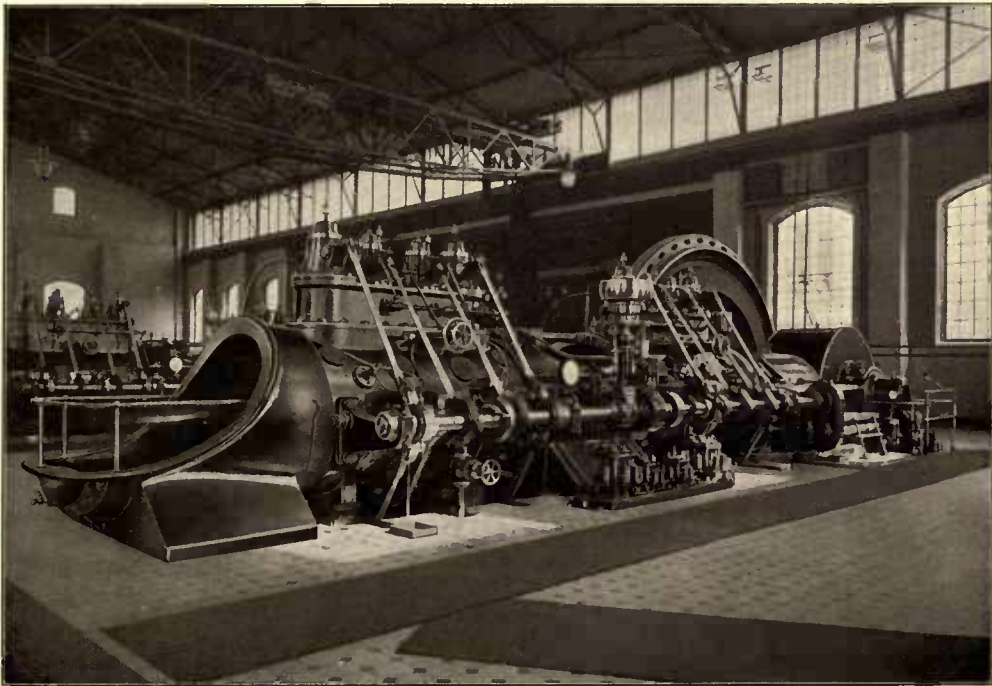


Fig. 13

Royal State Mines at Bielschowitz, Upper Silesia. Power Station at the Delbruck Pits.

Two coke-oven gas engines, with three-phase generators. Output 440 K.V.A., 3,600 volts.
60 cycles, 300 R.P.M.

Diesel Engine Power Stations

One of the most important and successful advances in the construction of power machinery within the last ten years has been the invention of the internal combustion motor of the Diesel type. The first difficulties which occurred with these machines have been overcome, with the result that Diesel engines for outputs up to several thousand horse power have been successfully constructed.

The greatest advantage of this type of engine is its efficient utilization of the fuel. While up-to-date steam installations have a total efficiency of about 16%, and the best gas engines of 28%, the Diesel engine shows an efficiency of about 34%. The latter is, therefore, far ahead of other classes of prime mover as regards thermal efficiency. Internal combustion engines of the Diesel type can be run on practically all kinds of liquid fuel. In those countries where oil is very plentiful, as in America, Russia, Austria, Roumania, etc., it is the usual practice to use the crude oil in its natural state. In countries which have to import their oil fuel, it is usual to employ heavy so-called power oils, which are waste products of the distillation for the lighter oils, and are consequently very cheap.

In Germany, paraffin oil, a by-product of lignite tar distillation, is extensively used, and, in addition, gas oil, a by-product of the distillation of crude oil for the lighter fuels is very largely employed. The oil obtained from the distillation of coke oven by-products, so called coal-tar oil, is also suitable for operating Diesel engines. The constantly increasing amount of crude oil produced, and the discovery of new oil-fields ensure a sufficient supply for Diesel motors for practically all time to come.

In addition to the advantage of extremely low consumption of fuel (about 0.19 to 0.24 lbs. per B.H.P. hour, at full load, with slightly increased consumption at fractional loads), the Diesel engine has the further advantages that no boiler or gas generating plant is required, so that the size of the power station is reduced to a minimum; further the engines are always ready to start, and no fuel is required when the plant is shut down for a short time, as between shifts, etc. Their manipulation is safe and simple, and the regulation excellent.

The advantages enumerated above have opened the door to the Diesel engine for mining plants. It has come into use especially in those districts where large quantities of crude oil are available, and also in those districts where the cost of freight of solid fuel is excessive. The nitrate producing district in Chili is an example of this type of mining district, and many other mining districts abroad are similarly situated.

Generators driven by Diesel engines are usually coupled directly to them in a manner similar to that employed in the case of steam engines and large gas engines. Generating sets of this type are shown in Figs. 14 and 15; when the outputs are smaller, the dynamos can also be driven by belts, as shown in Fig. 16.

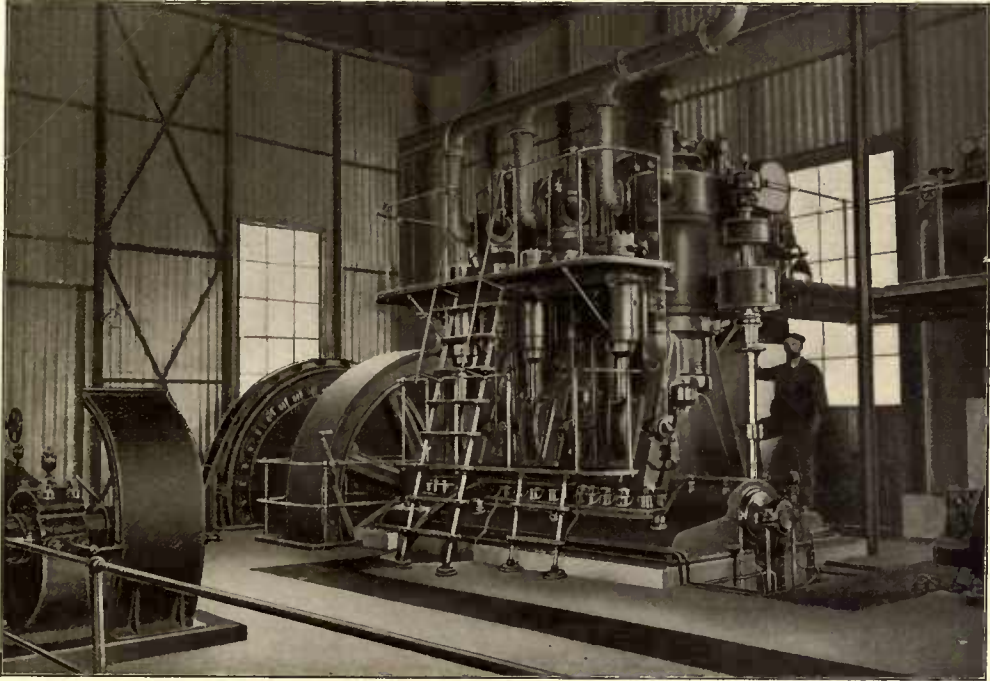


Fig. 14

**German Nitrate Works Ltd., Foelsch & Martins Successors, Hamburg.
Power Station of the Oficina Moreno (Chili).**

Two Diesel engines coupled to three-phase generators, each 275 K.V.A., 525 volts, 50 cycles, 175 R.P.M.

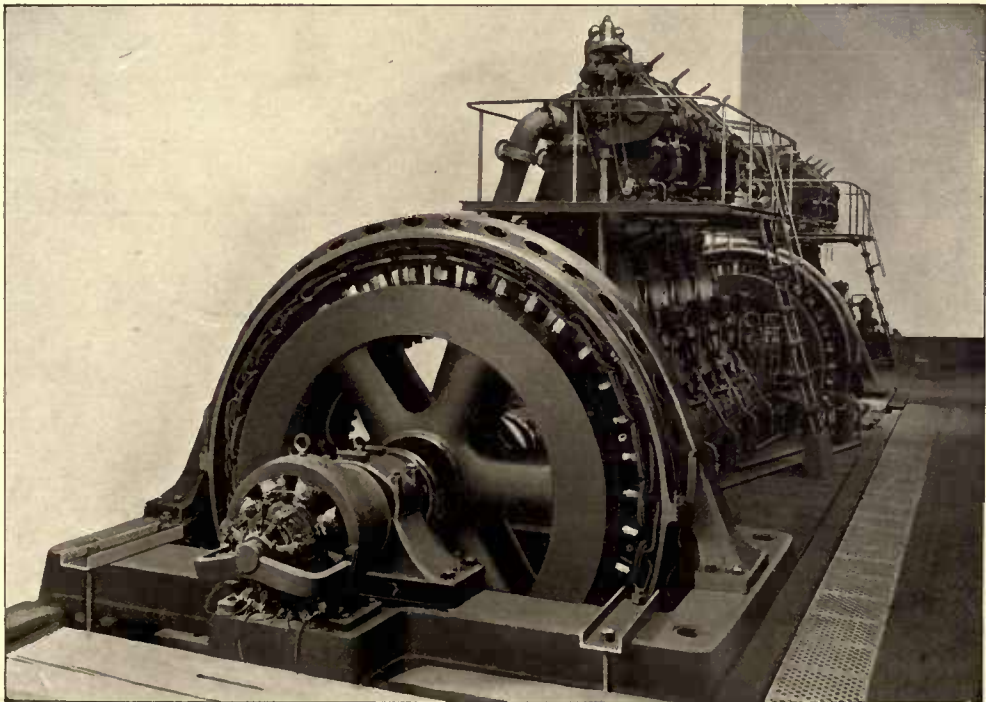


Fig. 15

**H. B. Sloman & Co., Nitrate Works Ltd., Hamburg.
Power Station, Rica Aventura (Chili).**

Three Diesel engines coupled to three-phase generators. Output 315 K.V.A., 525 volts, 50 cycles, 175 R.P.M.,
(engines on the test bed at the builders' works).

There is no difficulty whatever about parallel operation, provided that the flywheel effect is suitably chosen.

The generating plant for Messrs. Sloman & Co., illustrated in Fig. 15, which was one of the first of its kind to be built, and was intended for operation at a very distant point of the Chilian Nitrate district, was tested at the Works of the Augsburg-Nürnberg Co., and it was found that the parallel running of the generators was satisfactory in every respect.

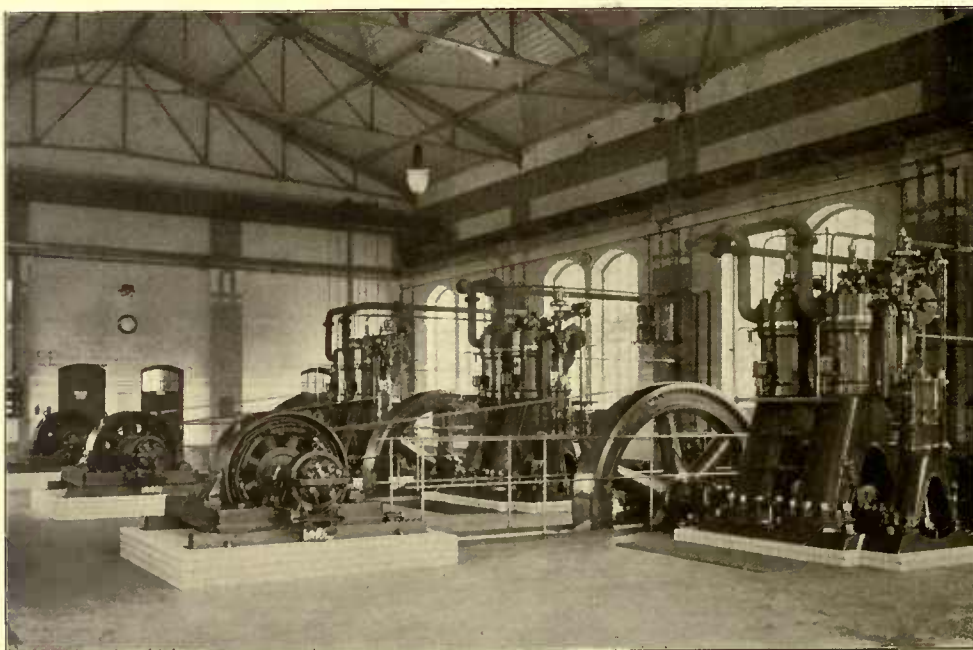


Fig. 16

Three Diesel engines, driving three-phase generators, each 100 K.V.A., 230 volts, 50 cycles
750 R.P.M. (Belt-drive).

Water Power Plants

The large amount of water power available in many districts can only be fully taken advantage of if arrangements are made to distribute it over large areas in the form of electrical energy. The electrical transmission of power is the only possible means of placing the energy of waterfalls, situated in inaccessible mountainous districts, at the disposal of industries and communities settled in more favourable localities. Frequently the available water power is of tremendous commercial importance to mining districts, which were formerly obliged to obtain their fuel supply from great distances, and in some cases, for instance, in districts where it is commercially impossible to procure fuel, a mining industry depends on the utilization of water power for its existence.

The increasing value of water power was accompanied by a simultaneous improvement in the means employed for its utilization. Improved water turbines have been evolved, those of the Francis type having found the greatest field of application. Francis turbines differ from other types in that the water enters radially, that is, perpendicular to the axis of the turbine, and leaves in a direction parallel to the axis. After leaving the turbine runner, the water nearly always enters the tail race through a suction or draught pipe. This arrangement makes it possible to place the turbines at heights up to about 25 ft. above the tail water level, without decreasing the effective head.

Turbines for driving electric generators, must be so arranged that the speed remains constant under all practical conditions of load and water supply. Nearly all modern Francis turbines are fitted with guide vanes which can be rotated on pivots, and are automatically adjusted by a suitable governor. These governors are so sensitive and reliable in operation that it is possible to run water turbine plants in parallel with steam engines, and with steam or gas generating stations.

The turbines are built with vertical or horizontal shafts, according to the requirements of the situation. In the first case the generators are occasionally driven through bevel gearing, but if the output is large, it is usual to couple them direct to the turbine, and to arrange them with a vertical shaft. An installation of this type is shown in Fig. 18.

For horizontal turbines the generators are almost invariably of the direct-coupled type, as shown in Fig. 17. No difficulty is experienced with this arrangement, as the speed of the turbines can readily be accommodated to the requirements of the generator.

If only a small quantity of water at a very large head is available, turbines of the Pelton wheel type are especially suitable. These wheels have the greatest efficiency which can be obtained with water power plants, transforming from 80% to 85% of the available power into mechanical energy. In addition, they can be built for any desired speed. They can also be fitted with automatic governors, to keep the speed constant within very narrow limits.

The economy of water power plants is dependent to a large degree on the extent to which earth and water works must be carried out to make the necessary head available, and to produce a sufficient water storage capacity. The question of the economy can, therefore, only be determined by a detailed investigation into all the existing conditions of each separate case, and a discussion of the points involved would lead too far for the purpose of the present publication.

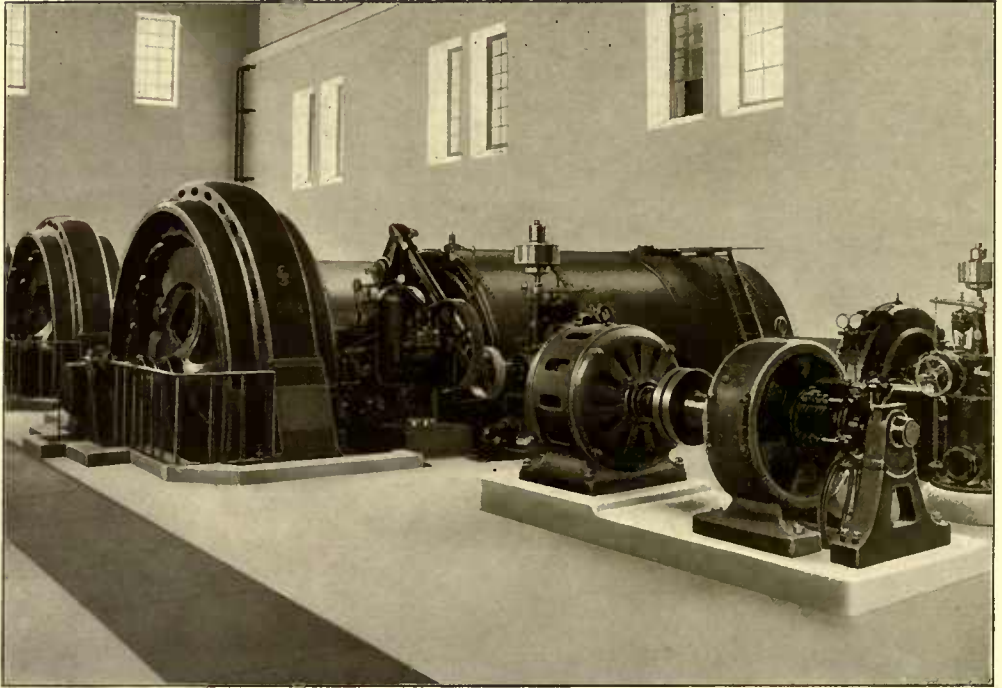


Fig. 17

Nagoya Kaisha, Japan.

Three water turbines, each 2,600 gallons per second, 90 ft. head, coupled to three-phase generators, each 2,500 K.V.A., 2,300 volts, 60 cycles, 360 R.P.M.



Fig. 18

Mexican Light & Power Co., New York, Necaxa Station, Mexico.

Six turbines, each 420 gallons per second, 1,650 ft. head, coupled to three-phase generators each 6,250 K.V.A., 4,000 volts, 50 cycles. Transmission pressure 60,000 volts. Distance 94 miles.

CHAPTER V

SWITCHGEAR IN GENERATING STATIONS

The construction and installation of switchgear must be carried out with the greatest care, as a breakdown in this part of the plant would be liable to lead to serious interruption of the service. It is, therefore, of considerable importance to provide sufficient accommodation for the switchgear, especially high-tension switchgear, which requires a large amount of space. All the operating mechanism of the switches, the instruments and the indicating and recording apparatus must be so arranged that it is impossible to touch any parts which are at a high potential, and all danger to the switchboard attendants must be prevented. It is, therefore, usual to place the operating mechanism for the switches and the regulators, and the requisite measuring instruments on special control panels, on desk-type boards, as shown in Fig. 21, or on switch-pillars, as shown in Fig. 19. The two latter arrangements have the advantage that the attendant faces the engine-room when manipulating the switchgear. A combined arrangement of switch boards with switch-pillars or desk or bench boards can also be used. In such cases the usual method is to instal the gear for the generators on the pillars or on the desk board, and that for the outgoing feeders on the control panels.

The separation of the control handles and instruments from the rest of the gear not only obviates the possibility of the attendant coming into accidental contact with high-tension circuits, but also has the advantage that these handles and instruments can be grouped together in a comparatively small space, and consequently can be more readily watched and manipulated. The fact that the instruments are arranged within a small compass is of particular importance, as, when this is so, mistakes and oversights on the part of the attendants are much less likely to occur.

All parts of the switchgear installation which carry high-pressure currents are accommodated in cells placed underneath the switchboard gallery, or at a distance behind the control panels. These cells are constructed of moulded



Fig. 19
Generator Control Pillar.

stonework slabs with sheet or expanded metal doors, each cell being arranged with a number of compartments in which are placed the high-tension oil switches and the transformers used in conjunction with the measuring instruments and relays. By this arrangement fire and damage to one piece of apparatus is confined to that piece and cannot spread and injure the apparatus in adjoining compartments, thus ensuring the continuity of the supply through the remainder of the switchgear.



Fig. 20

High-tension switchgear.
Fire-proof cells.

distance between the operating board and the switchgear is very great, or where there are other reasons against the installation of mechanically-operated gear, a remote control type of oil switch can be employed, in which the movement of the switch is effected by electro-magnets or by small electric motors controlled from the operating panel, desk, or pillar, as the case may be.

The arrangement of low-pressure switchboards is considerably simpler, as shown in Fig. 23. The switches and instruments are usually placed on panels, which consist either of marble or slate, while the bus-bars, etc., are placed on a comparatively simple framework at the rear of the board. If the pressure is so high that contact with the current-carrying parts entails danger to the operators, all the switchgear, etc., can be accommodated at the back of the board, so that only the operating handles are within reach of the attendant.

In the case of a large installation in which current has to be transmitted at extra high pressure to a mine or number of mines situated at a long distance from

The connections from the generator to the bus-bars are provided with the necessary instruments for measuring the current, the voltage, the output and the frequency, with suitable gear for running each generator in parallel with the rest of the plant, and with an automatic oil switch which separates the generator from the supply system in the case of an overload or a defect. The outgoing feeders, whether they be overhead transmission lines or cables, are also invariably provided with oil switches with automatic overload releases.

The operating mechanism for the switches is usually of the direct mechanical type. This has the advantage that the operation of the actual switches is effected through a positive system of link-work. Where, however, the distance

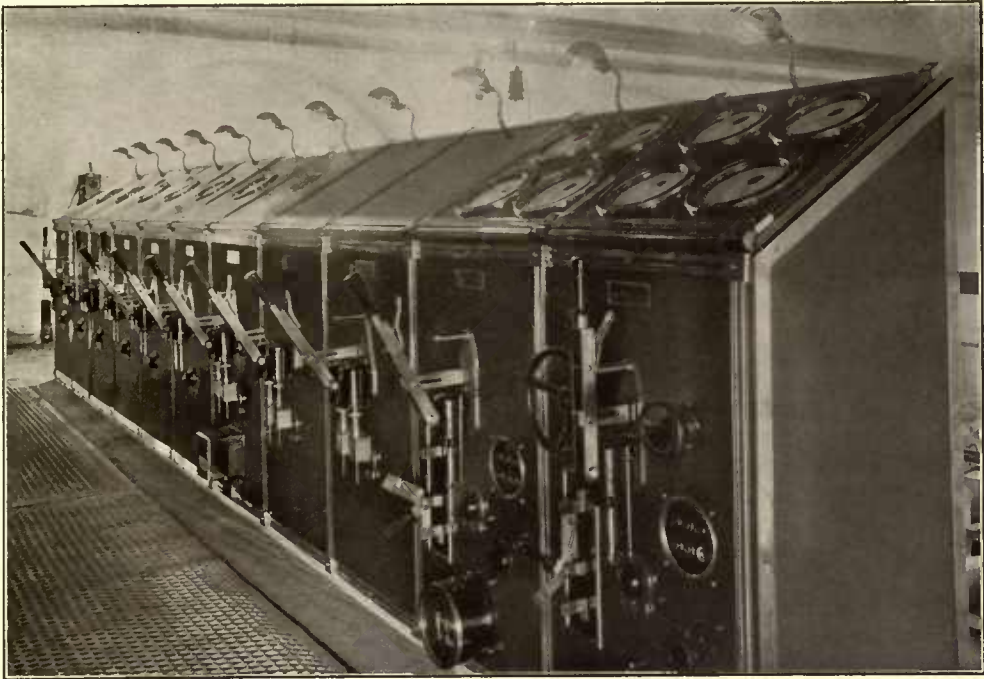


Fig. 21.
Desk-type Switchboard.

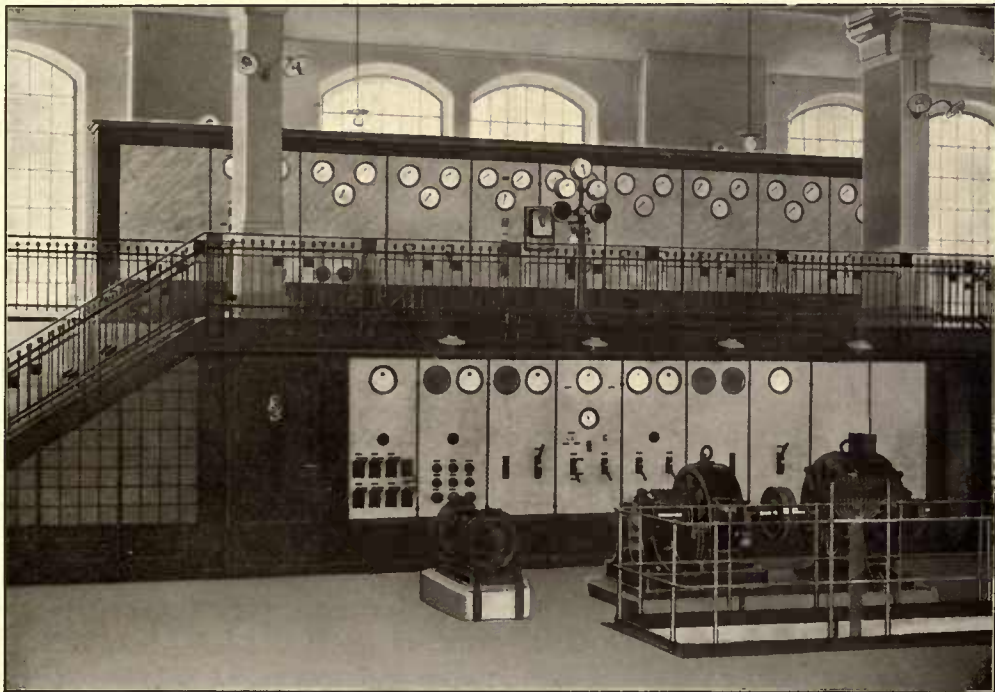


Fig. 22.
Count Schaffgot Administration Paulus Hohenzollern Mine, Beuthen,
Upper Silesia.
Main Board for 2,100 volts.

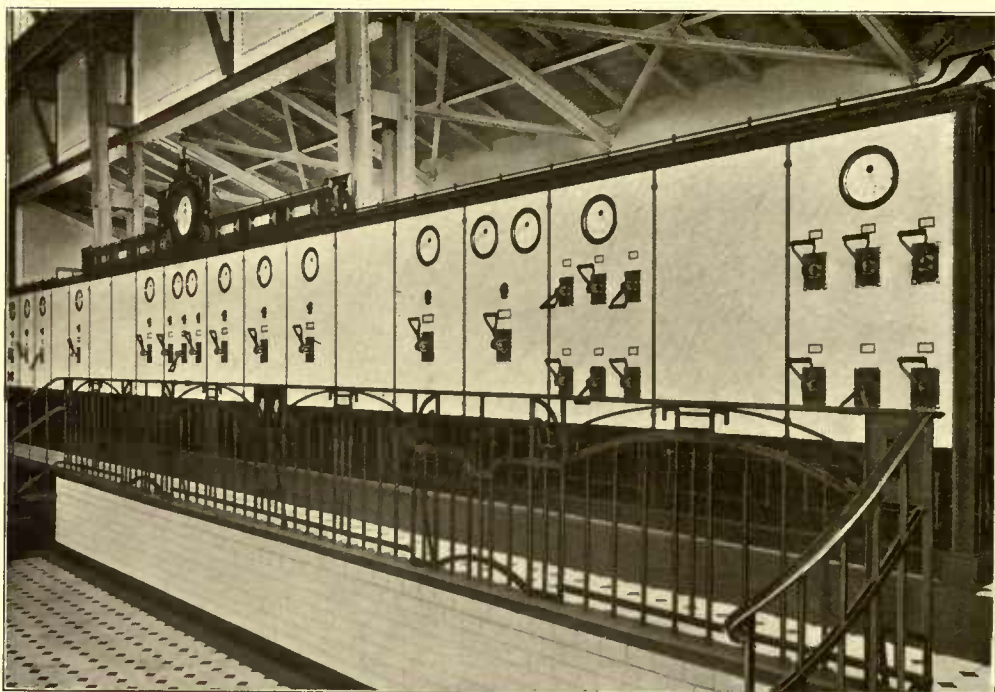


Fig. 23

Low-Tension Switchboard.

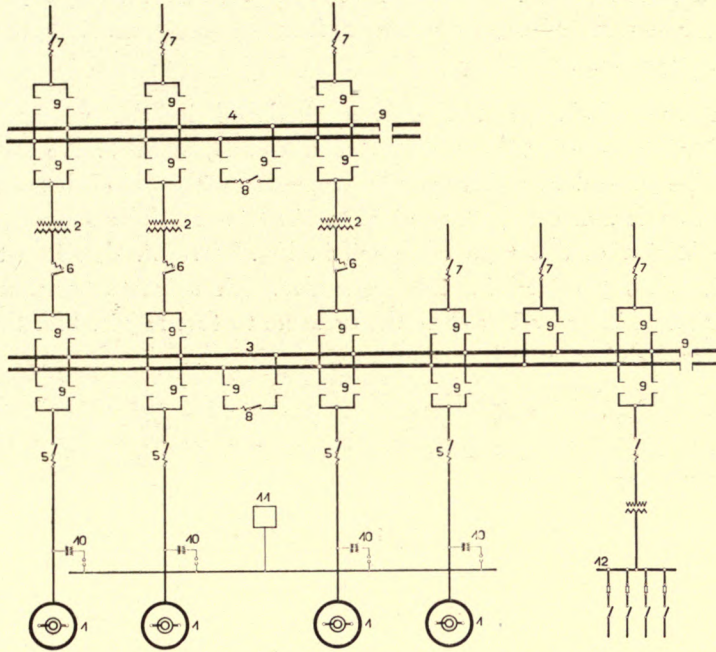
the generating station, the main switchgear is frequently arranged as shown in Fig. 24(a).

The current produced by the generators, usually at a pressure of from 500 to 5,000 volts, depending on the size of the plant, is partly transmitted directly to the consumers in the immediate neighbourhood of the station, and is partly transformed in step-up transformers to the pressure required for the transmission to more distant stations. As a rule the lighting of the station and the small motors and auxiliary plant in the station require a lower pressure than that generated directly, so that it is usual to instal a step-down transformer and a small internal distribution system for this purpose.

As a measure of safety in the case of large installations, it is desirable to provide double sets of bus-bars, both for the generators and for the distribution circuits, so that by connection through suitable isolating or linking switches, both the generators and the transformers can be connected to either set of bars. This arrangement makes it possible, not only to isolate any part of the bus-bar system for the purposes of repairs or extension, but also to run any one generator at a different pressure or frequency from the remainder of the plant. This possibility is of considerable value when, for instance, new cable lines have to be put in service or transformers have to be dried out.

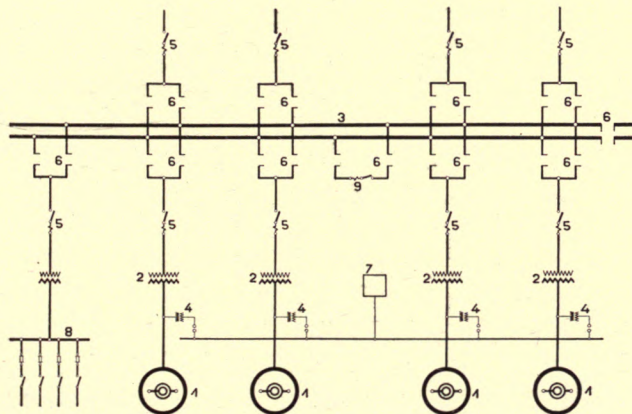
Where the cost or extra complication of a double set of bus-bars is objected to, a single set of bus-bars may be used with isolating switches provided at intervals throughout their length to permit of any section being isolated for inspection, or for the purpose of running one portion of the plant independent of the other portions. By the adequate use of such isolating switches, a very high degree of safety and flexibility may be attained.

Transformers of large output and operating at high pressures are usually provided with oil switches, fitted with protective or buffer resistances. These are connected in series with the transformers for a fraction of a second whenever the transformers are switched on or off, and they prevent too sudden rushes of current and too sudden interruptions of the circuit, and further obviate



(a) Distribution at high and low pressure.

- | | |
|----------------------------|---|
| 1. Generators. | 7. Outgoing feeders. |
| 2. Transformers. | 8. Coupling switch. |
| 3. Low-tension Busbars. | 9. Isolating Switches. |
| 4. High-tension Busbars. | 10. Potential Transformers (for synchronising). |
| 5. Automatic Oil Switches. | 11. Synchronising Gear. |
| 6. Buffer Switches. | 12. Distribution Lines for supply in Station. |



(b) Distribution at high pressure only.

- | | |
|--|--|
| 1. Generators. | 5. Automatic Oil Switches. |
| 2. Transformers. | 6. Isolating Switches. |
| 3. Busbars | 7. Synchronising Gear. |
| 4. Potential Transformers (for synchronising). | 8. Distribution Lines for supply in station. |

Fig. 24.

Typical diagrams of connections for Mining Power Plant.

the danger of excessive pressures arising from switching operations. The generator and feeder oil switches which are provided with overload releases are also usually fitted with time limit devices, and these are generally set in such a manner that in the case of short circuits on the line, the circuit breakers on the feeders open first, and the generator switches only come into operation if the feeder switches fail to act. This arrangement prevents interruptions of service in the power station whenever a small fault or short circuit occurs on any part of the system.

When the whole of the energy produced in the power station is to be transmitted over a long distance, a simplification of the switchgear is possible. The generator bus-bars can be dispensed with, and each generator with its step-up transformer can be treated as a single unit. The simplified arrangement for a station of this type is shown in Fig. 24b. A double set of feeder bus-bars is often provided in this case also. A separate transformer is, of course, necessary, in order to reduce the pressure to that required for the auxiliary plant such as lighting, small motors, etc.

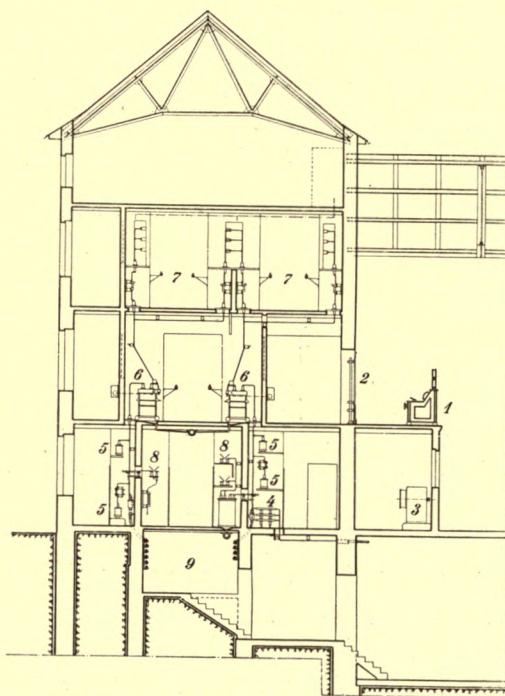


Fig. 25

- | | |
|---|-------------------------|
| 1. Generator Control Board (desk type). | 6. Oil Switches. |
| 2. Feeder Control Board. | 7. Bus-bars. |
| 3. Field Regulators. | 8. Lightning Arresters. |
| 4. Choking Coils. | 9. Cable Subway. |
| 5. Instrument Transformers. | |

Cross section of Switchgear House for Central Station.

CHAPTER VI POWER TRANSMISSION

Transformers

For the economical transmission of electrical energy over long distances, it is customary to employ high pressures, which, in many instances, are not generated directly by the station dynamos, but are obtained by means of static transformers. The latter permit the pressure at which alternating current is generated to be transformed to any desired value. This transformation involves certain unavoidable losses, consisting of the iron or hysteresis losses, and the copper losses. The former are due to the magnetisation of the iron changing under the influence of the alternating current, and are constant for all loads, occurring even when the transformer is supplying no energy. The copper losses are caused by the resistance of the windings

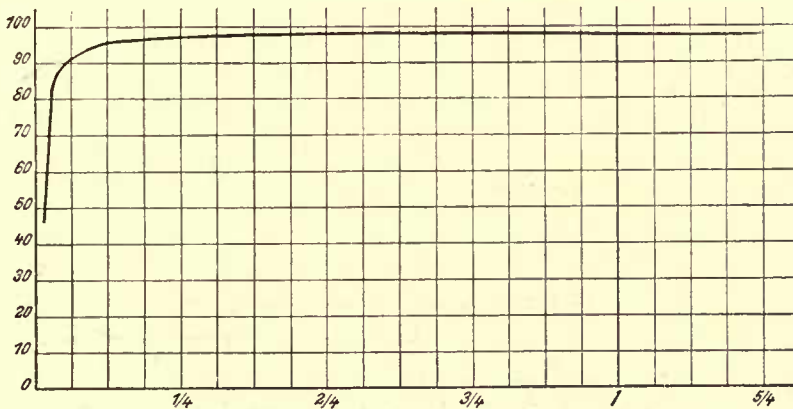


Fig. 26

Efficiency curve of a 300 K.V.A. Transformer at various loads.

to the passage of current, and increase in proportion to the square of the current. As a result of long-continued efforts, the Siemens Concern has made it possible, by careful design and by a choice of suitable material, to reduce the losses to such an extent that efficiencies of 98% or even higher in the case of large transformers are obtained at full load. Even on partial loads the efficiency is very high, as may be seen from Fig. 26, which shows the efficiency curve of a 300 K.V.A. transformer at various loads.

When determining the ratio of transformation, the ohmic pressure drop, due to resistance in the transformer, must be taken into consideration, especially

if the power factor of the system is low. In order to provide for different pressures at different points of the supply system, it is advisable to fit the primary winding of the transformer with several tappings, which make it possible to vary the transformation ratio within certain limits.

The excellent insulation and sound construction of modern transformers make service interruptions very rare. The absence of all moving parts increases the reliability of transformers, but makes it difficult to disperse the waste heat generated in the apparatus itself. For this reason the rooms in which air-cooled transformers are installed require to be specially well ventilated. On account of the difficulty of obtaining such rooms below ground, air-cooled transformers are seldom employed for mining installations, and such systems are usually equipped with oil-immersed transformers.

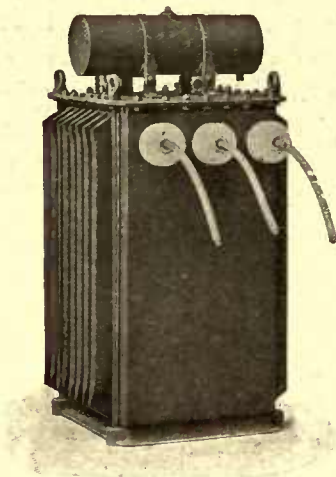


Fig. 27
Three-phase oil-immersed
self-cooling transformer,
with radiating ribs.

transformers. For this reason it is usual, in the case of large units, to immerse in the oil coils of piping through which water is allowed to circulate.

The reliable operation of transformers depends to a large extent on the quality of the oil. The latter must, under all circumstances, be absolutely free from acid or mineral ingredients and water. It is advisable to order the transformer complete with oil to ensure that a suitable quality is provided. But oil even of the best quality will decompose when in contact with air while hot, and will then tend to clog the windings. In the Siemens transformers provision is made against this by the employment of an "oil preserver," consisting of a small vessel connected to the main tank by means of a U-tube, and placed above the level of the transformer oil. Sufficient oil is provided to fill the tank entirely and the preserver partially, so that as the oil expands with an increase of temperature, the level in the preserver will change. This arrangement makes it possible to keep the

In this type of apparatus the actual transformer is placed under oil in a tank. The oil acts as an insulating material, and at the same time assists to carry off the waste heat generated during operation. The windings are so arranged that an adequate circulation of the oil itself can take place.

To increase the cooling area, the transformer tank is entirely or partially constructed of corrugated sheet-metal; in some cases the cooling area of large units is further increased by the provision of pockets, as shown in Fig. 28. The cover of the transformer tank must be absolutely tight, so that no dust, water, or other substances can enter.

Natural radiation is not sufficient to re-

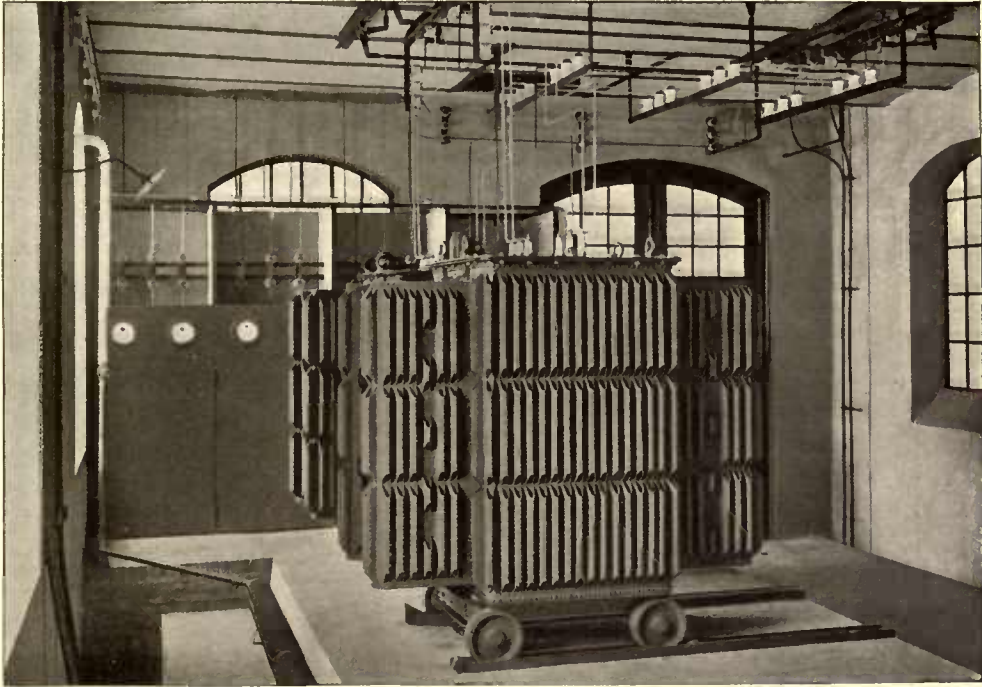


Fig. 28

Dutch State Mines, Limburg, Heerlen, Holland.

Two three-phase oil-immersed self-cooling transformers. Output, each 640 K.V.A., 10,000/2,000 volts, 50 cycles per second.



Fig. 29

Lübeck Power Station, Germany.

Three-phase oil-immersed water-cooled transformers. Output each 2,500 K.V.A., 6,000/30,000 volts, 50 cycles per second.

transformer tank itself always completely full of oil, so that no moisture can accumulate inside. Moreover, the decomposition of the oil is prevented because the warm oil can no longer come into contact with the air except only at the small surface in the preserver, where the temperature of the oil is only slightly above that of the surrounding atmosphere.

The air-tight cover of the tank makes it possible to deliver small and medium size transformers ready filled with oil, so that they are ready for use immediately after installation.

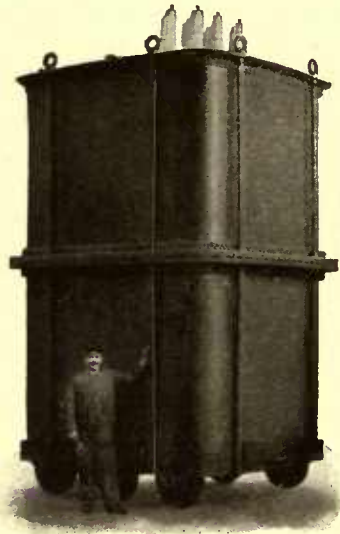


Fig. 30
Rand Power Co., South Africa.
Three-phase oil-immersed water-cooled
transformer.
Output 12,500 K.V.A. 5,000/42,000 volts.

If the transformer is erected and filled with oil on site, either on account of transport difficulties or because of the large size of the apparatus, it is necessary to boil the oil for some length of time after it has been poured into the tank in order to remove all traces of moisture which may have accumulated during transport. The Siemens Concern has designed a portable drying-out apparatus for this purpose.

Oil-immersed transformers can be installed in the open without further protection, and small transformers are frequently mounted on the poles of the transmission lines. In mines, however, it is usual to provide separate rooms, which should be efficiently ventilated. To facilitate removal, transformers are frequently mounted on wheels. In the case of stations containing a number of transformers, the provision of a suitable truck, as shown in Fig. 29, is sometimes considered advisable.

In order to reduce the number of spare parts required for a three-phase system, three single-phase, instead of one three-phase, transformers are sometimes provided. The spare plant would then consist of one single-phase instead of the one three-phase transformer; the former deals with the output from one phase only, and is therefore smaller and cheaper than the three-phase transformer.

Cables

Electrical energy can be transmitted either through insulated cables or by means of bare overhead lines. Cables are preferable in thickly populated districts, where overhead transmission lines for high-pressure current would require extensive protection at the numerous telephone, railway, and other crossings, entailing a considerable and often prohibitive expense. Cables are also immune from service interruption due to atmospheric causes, such as storms, ice, and lightning effects. On the other hand, the cost of cable makes its universal adoption impossible, and its use is further restricted by the limited voltage for which it can be constructed. Three-phase cables of considerable length have so far been installed for pressures up to 25,000 volts, and unarmoured single-core cables are already in use for pressures up to 60,000 volts. Improvements in the manufacture of cables are constantly being introduced, and it is probable that these limits will be exceeded in the near future.

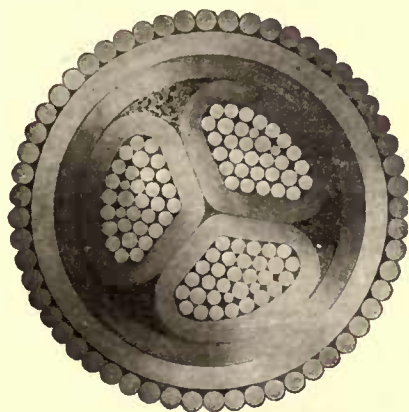


Fig. 31
Three-phase cable,
with single-wire armouring.

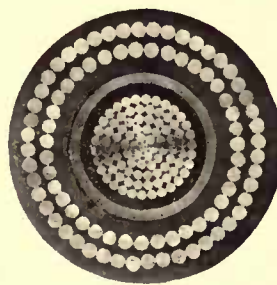


Fig. 32
Single-conductor cable,
with double-wire armouring.

The cable systems installed in mining districts have occasionally suffered from the settling of the ground, which tears the cables away from the connecting boxes. The design and installation of these cable connecting boxes should therefore be the subject of special attention, and the cable itself should be so arranged that slight alterations in the length will not place undue strains on the connecting boxes. Circuits, in which the continuity of the supply is of prime importance, require the provision of a second parallel cable or of a ring connection, so that in the event of interruption at one point of the line, the

remainder of the supply is unaffected. Double cable lines can be so protected by reverse current and overload relays, that a defect in any one section will only cause that particular part to be disconnected from the line, without affecting the remaining portion of the system.

These devices are of little use on ring mains, but several protective systems, such as the Merz-Price balanced relay gear have been devised, affording complete selective protection for ring circuits. A description of these systems would, however, lead too far for the purposes of the present publication.

The cables usually employed for a long distance transmission and high-pressure line are of the three-core lead-covered armoured type. For mining installations, and especially for the transmission down the shaft, it is usual to employ wire-armoured cables, as shown in Figs. 31 and 32. The wire armouring can consist either of round or of segmental wire as used for "locked coil" winding ropes, and can be single or double. In the latter case an extra layer of jute as a protection between the two layers of armouring is recommended. The wire armouring of mine cables should be carefully galvanized in order to withstand the effects of the pit air and water.

The pilot wires and telephone conductors are best installed as separate cables, which can be taken down the shaft parallel to the main cable, but at a sufficient distance from it to avoid the influence of short circuits or other defects which may occur in the latter.

Overhead Transmission Lines.

The fact that overhead lines for the transmission of electric energy have the advantage of lower capital cost than cables, has led to their adoption wherever possible. For pressures exceeding 60,000 volts, the overhead system is exclusively used. Such a system is perfectly safe and reliable even for very high pressures, if proper care be exercised in its design and construction, and efficient apparatus be provided for protection against lightning.

The size of the conductors of such lines is determined not only by considerations of cost, but also by the requirements of safety, and the strength of the wire. The supporting poles can be either of steel or wood. Wooden poles are cheaper than those of steel, but their life is shorter, and in most tropical countries their use is out of the question, because they are quickly destroyed by insects. The life of wooden poles, suitably impregnated, is usually about 15 years, whereas that of steel poles is practically unlimited. The distance between poles varies from 40 to 80 yards. The height and dimensions of the poles depend on the span, the total cross section of the conductors and the working pressure.

Steel poles are either tubular or of the lattice type. The use of tubular poles is becoming more restricted, as they are more expensive than lattice poles, and present no advantages in comparison to the latter. When lattice poles are used, the span may be increased to 200 yards or more, reducing not only the first cost of the line, but also the number of points where leakages or faults are likely to occur.

In the case of very large spans, strains due to wind pressure, and frost or snow must be taken into account. High-pressure transmission lines which cross inhabited districts, railway lines, telegraph or telephone lines, etc., must be fitted with protective devices, which should comply with the regulations of the district. Some of the devices for this purpose either make a broken wire "dead" at once, or bring it into electrical connection with earth, while others are intended to prevent a breakage of the wire altogether. The former consist of relays or of earthing arms on the pole itself. The latter so reduce the strain in the wire that a break is practically impossible. Frequently it is sufficient to design the line with a very high factor of safety, that is, the spans are so arranged as to reduce the stress in the conductors to a very low value. Practically absolute protection against breakage of the wires can be attained

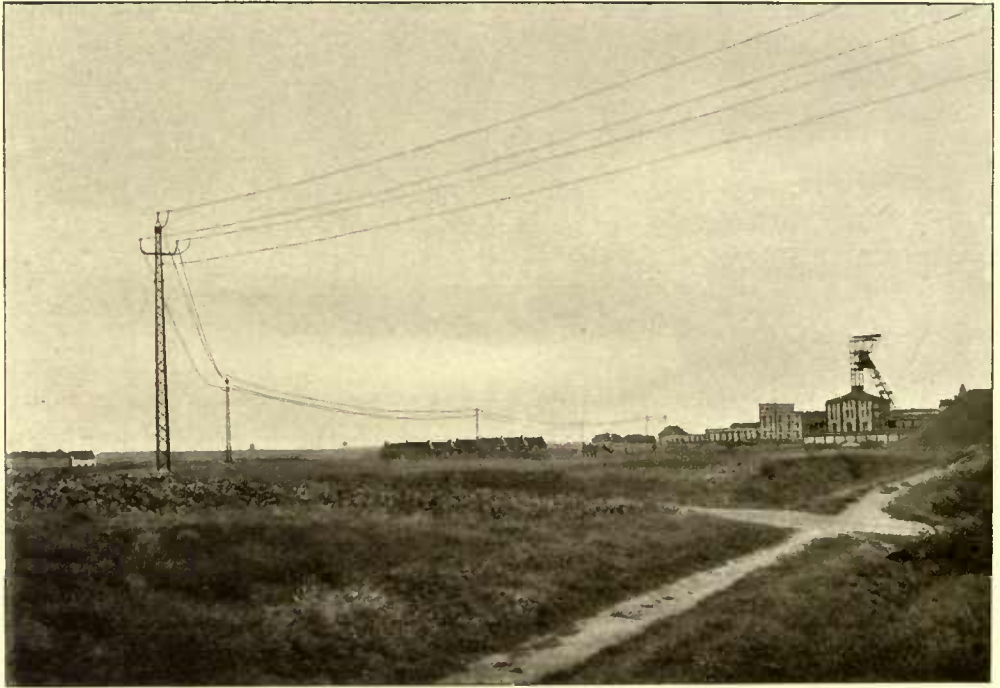


Fig. 33.

Transmission Line for 35,000 volts
on lattice poles with spans of 180 to 220 yards.

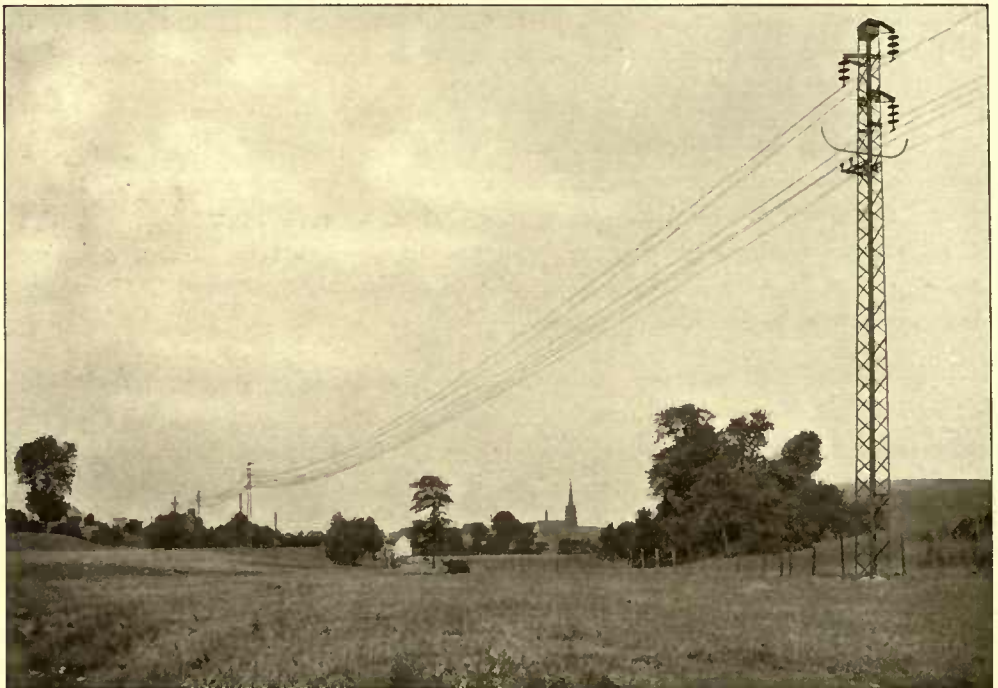


Fig. 34.

High-tension Transmission Line with Suspension-Type Insulators.

For 70,000 volts.

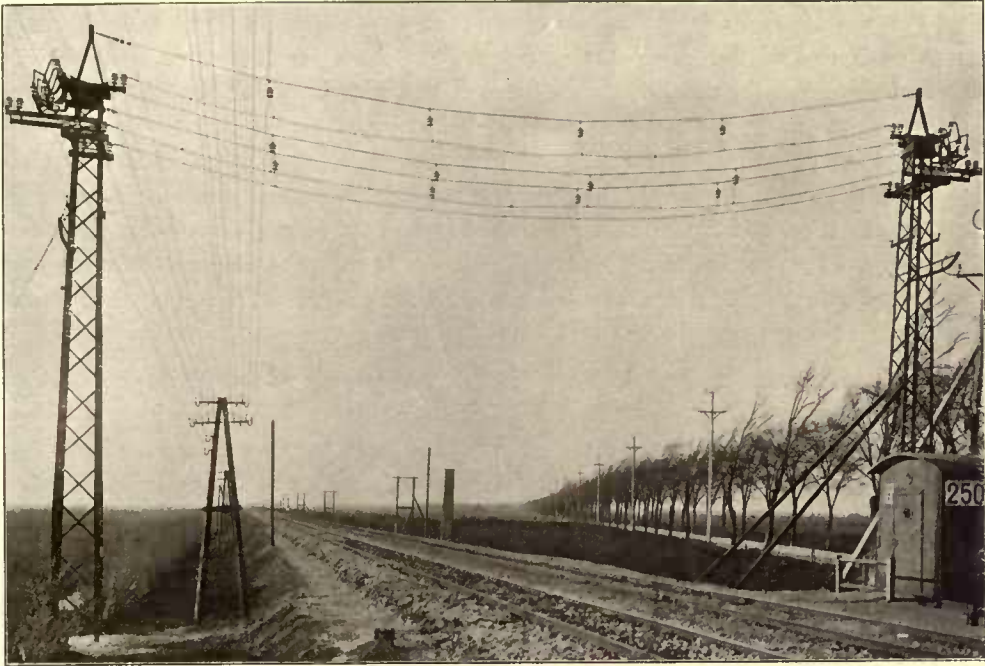


Fig. 35.
Safety Suspension Gear
with steel catenary wire.

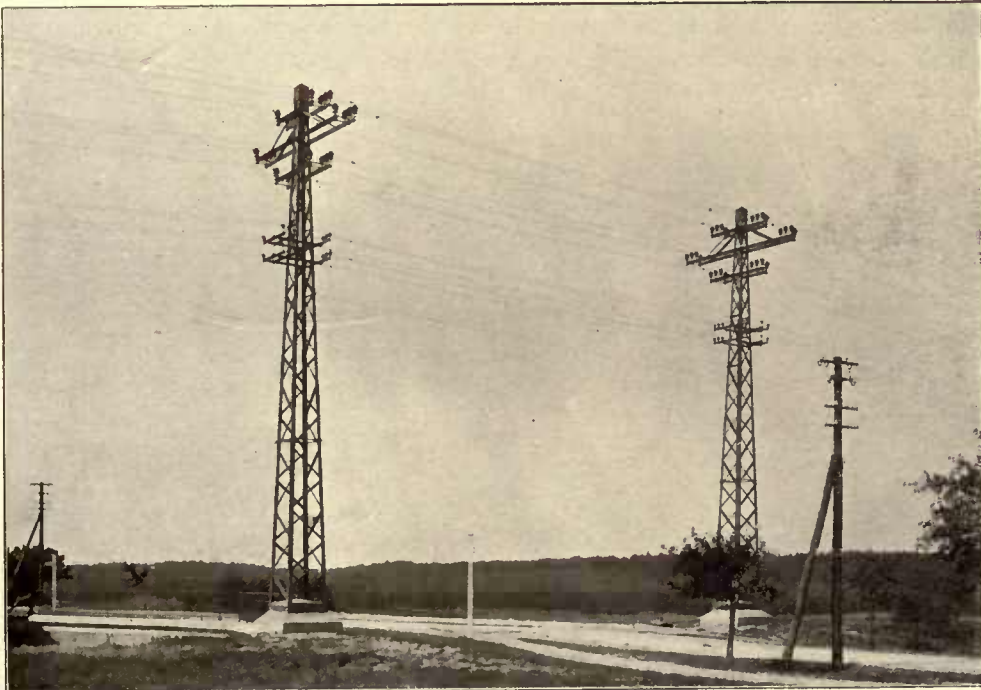


Fig. 36.
Safety Suspension Gear
Triple Suspension.

by the use of the safety suspension gear as illustrated in Fig. 36. In this case each end of the conductor is fastened to three insulators, so that should one of these break, the other two prevent the wire from falling. At the same time, the stress in the conductors must be reduced by keeping the span itself as small as possible. The safety suspension gear, shown in Fig. 35, is designed to fulfil the same purpose. In this case an insulated steel cable is suspended above the wire, and the latter is supported from it by means of suitable hangers. This type of protective arrangement has been found to satisfy all the demands of actual practice, and the cradles, which were in universal use a few years ago, are now entirely dispensed with.

The high-pressure insulators are nearly always made of porcelain, and consist of two or more parts, according to the line pressure. The dimensions of these insulators, and consequently their weight and cost become excessive with increasing pressures, and they cannot be used above certain pressures. It is, therefore, usual, when the transmission pressure exceeds 70,000 volts, to employ so-called "suspension" insulators, consisting of a number of single disc-shaped insulators, which can be put together in any desired number (Fig. 34). The chains so formed are so arranged that the conductor cannot fall to the ground even if one member breaks. The chains are suspended on cross arms, fastened to the poles. They can be constructed for practically any desired pressure without their weight or cost becoming excessive.

Telephone lines can be installed on the same poles as the high-tension lines, but suitable precautions must be taken to neutralize the inductive effects of the main line. This is done by arranging the telephone wires in twisted fashion. Further, it is necessary to equip the telephone apparatus itself with suitable protective devices against high pressures.

CHAPTER VII

ELECTRIC WINDING ENGINES

General

The first electrically-driven winding engines were installed as late as the year 1900, that is, long after electric power had been extensively adopted in mines for driving pumps, fans, etc. This appears to have been due to the very special requirements of winding plants, and to the difficult conditions which had to be met. There was also considerable reluctance on the part of mine owners to change over to a new and untried system, especially as in the case of winders they had to depend on the reliability of the plant, not only for the regular working of the whole mine, but also for the safety of the men. In the end, however, the high cost of working by steam made a trial of the electrical drive compulsory, with the result that even in the earliest installations of any considerable size it was clearly demonstrated that electric winders were quite capable of competing successfully with those driven by steam. Since then some 400 large electric winders have been installed by the various Siemens Companies, and the extensive experience gained has led to such improvements in design that their latest winding plants are as near perfection as the present state of engineering permits.

Such wide experience has also enabled them to perfect every part of the mechanical equipment, and they therefore lay great stress on the importance of obtaining the contract for the complete plant, so as to ensure giving complete satisfaction on the mechanical as well as on the electrical side. The manufacture of the mechanical section is placed in the hands of the best firms which make mining gear a speciality, and the work is constantly supervised during the progress of manufacture.

The mechanical arrangement of winding engines depends in each case on the prevailing conditions. Very different views as to the value of particular systems have gradually developed in the various mining countries, and it is instructive as well as interesting to touch briefly upon this phase of the subject.

The oldest type of winder is, without doubt, that equipped with a plain cylindrical (parallel) drum, as illustrated in Fig. 38. It is specially applicable to moderately deep pits, and if provided with a suitable arrangement for rotating the drums relatively to each other, can be easily and quickly adapted to changes in the winding levels. It also permits the initial acceleration to be increased to any desired amount. In the case of deep pits, especially if

the rope is unbalanced, the difference between the static loads at the beginning and end of a wind frequently leads to the use of conical drums (Fig. 54). Both systems have the disadvantages of high capital cost and great masses, frequently requiring very large motor outputs for acceleration; the space requirements of both systems are also considerable.

In France and Belgium bobbins with flat ropes are preferred (Fig. 78). If the radii are suitably chosen it is possible, with this type of winder, to obtain equal static moments at the beginning and end of a wind. The low capital cost of bobbins is partly counterbalanced by the higher cost of the flat winding rope. The bobbins can be readily arranged so that they can be moved relatively to each other, and are so adapted to winding from varying levels. For this reason they are especially suitable for sinking winders. On account of the small inertia of the bobbins, and the small diameter on which the loaded rope is wound at the beginning of the wind, it is possible to keep the peak loads smaller than with any other system.

On the rest of the Continent, and particularly in Germany, the Koepe pulley (Fig. 66) has found many adherents. It requires the use of a tail rope and permits winding from one level only. The Koepe pulley, like the bobbin, is characterised by low initial cost, small space requirements, and low inertia of the rotating masses. It is specially suitable for the great shaft depths which are becoming necessary in many mining districts, where drum winders would attain huge dimensions. The Koepe pulley is usually employed only for depths of more than 350 yards, because at depths less than this there is danger of rope-slipping. In the case of greater depths, however, the rope-slip can easily be kept within very small limits, provided that the acceleration and retardation are not too high. Under certain circumstances, however, the slipping of the rope is a decided advantage, for instance, in the case of overwinding, or when the cage jams in the guides, etc., i.e., in all cases where there would be danger of a rope failure if a drum were used, and it is a fact, that statistics on winding accidents are in favour of the Koepe pulley.

In the case of steam winders, the brakes are also operated by steam. With electrical winders, the steam can be advantageously replaced by compressed air, obtained from a separate electrically-driven compressor plant, (Fig. 37). In some cases two brakes are provided, both acting through the same system of levers; one is the ordinary brake, operated directly by compressed air, the other is an emergency brake, operated by a weight, which is held in suspension by compressed air, so that the brake is kept in the "off" position until the air can escape from the cylinder. The latter is provided with a small stop valve which is controlled either by hand or automatically by means of an electromagnet. Should the air pressure become too low to hold the weight up, the winder cannot be run at all, so that a sure check on the reliability of the brakes is provided. The two air cylinders for operating the working and emergency brakes respectively are clearly seen in Fig. 66. In other cases only one air cylinder is used, and the levers are so arranged that both the working and the emergency brakes are operated by the same brake weight.

Electric winding engines should conform to the following requirements. The motors must be readily reversible and capable of rapidly accelerating and retarding the moving masses. Speeds of 65 ft. per second and more are frequently demanded, but when winding men the speed must frequently be reduced, and usually must not exceed 30 ft. per second. Moreover, it must be possible to reduce the speed to about $1\frac{1}{2}$ ft. per second for inspecting the rope and the shaft.

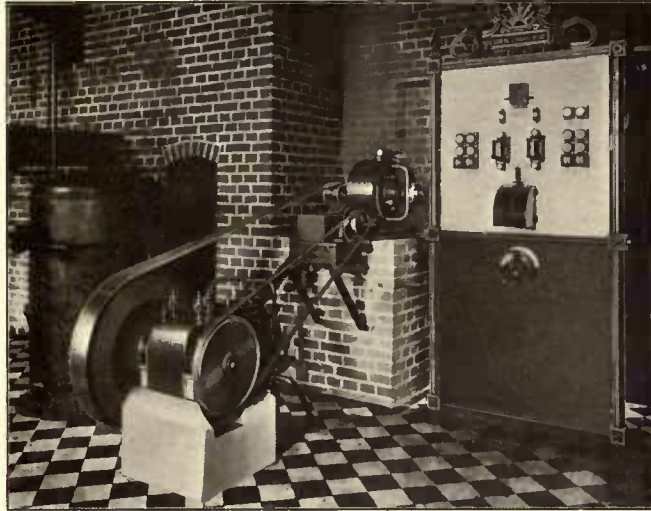


Fig. 57.

Electrically-driven Compressor Plant for operating Brake-gear.

The greatest attainable degree of safety against accidents and interruptions of service, due either to faults of the electrical plant or to the contingencies of the winding service, must be provided.

Load fluctuations due to the winder must not be too great as compared with the total capacity of the power plant ; otherwise special means must be adopted to reduce the peak loads to a permissible value.

The following pages contain brief descriptions of the most important systems of electric winding, and the discussions on their respective qualities should enable an intending purchaser to make the most suitable selection for any particular case.

The systems chiefly considered are as follows :—

- (1) Three-phase induction motor drive.
- (2) Three-phase commutator motor drive.
- (3) Direct-current motor drive on the Ward-Leonard system with or without a separate converter set.
- (4) Installations in which the load fluctuations are met by a buffer battery.
- (5) Installations in which the load fluctuations are met by flywheels (Ilgner system).

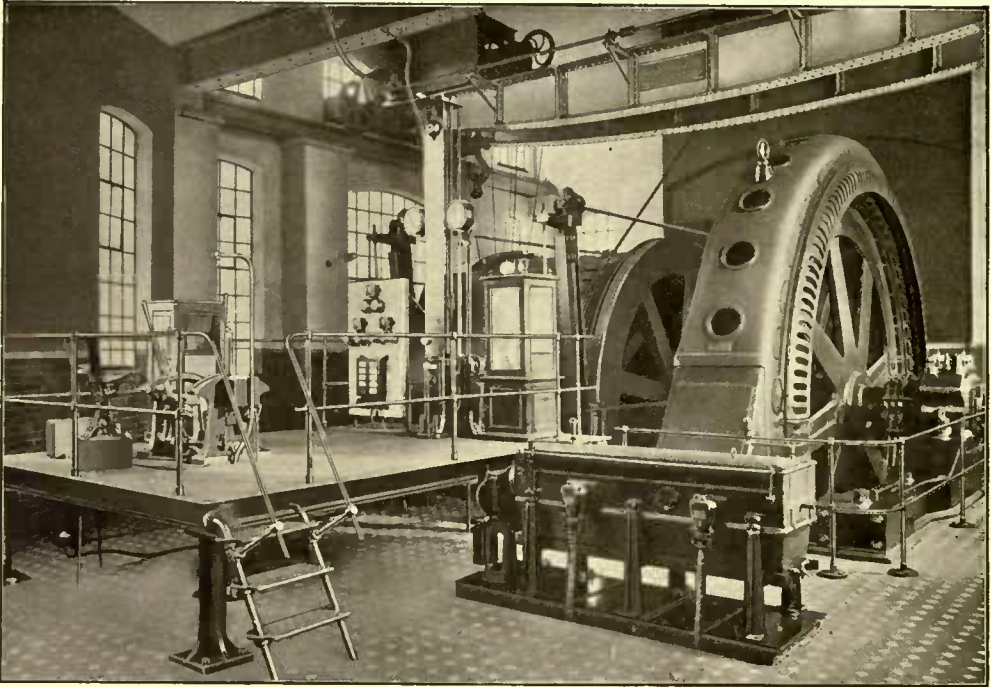


Fig. 38.

The Harton Coal Company Limited, South Shields, England.

HARTON MAIN SHAFT, TYNE DOCK.

Net load $4\frac{1}{2}$ tons. Shaft depth 1,420 ft. Speed 41 ft. per second. Drums 14 ft. diameter, direct coupled to 5,500 volt 950-1700 H.P. three-phase motor, 40 cycles. Liquid Controller.

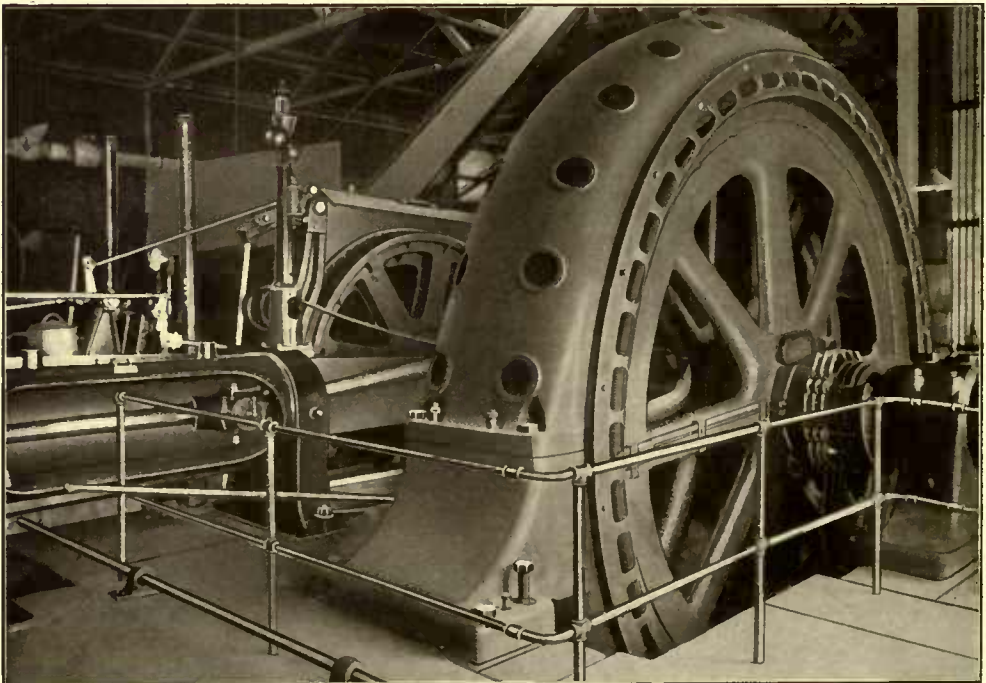


Fig. 39.

H. Eckstein & Co., Langlaagte Deep Ltd., Johannesburg, Transvaal.

SHAFT II.

Net load 3.6 tons. Shaft depth 1,000 feet. Speed 44 ft. per second. Cylindrical drums 8 ft. diameter. Direct coupled to one 2000 volt 970-1630 H.P. three-phase motor, 50 cycles. Liquid Controller.

Winding Engines driven by Three-phase Induction Motors

The direct coupling of three-phase motors to the drum shaft is only possible in the case of large winders, as there are practical difficulties in the way of building three-phase motors of small output for the low speeds usually required in these cases. Such slow-speed direct-coupled induction motors are employed, for instance, for driving the winding engines of the Harton Coal Company Ltd., South Shields, England (Fig. 38) and of the Eckstein Companies in South Africa (Figs. 39 and 41). In the latter case the steam winder originally installed was subsequently converted to electric drive. The efficiency of these slow-speed three-phase motors is considerably lower than that of high-speed motors, and the power factor, more especially, leaves much to be desired. Reduction gearing has therefore come into considerable favour lately even for large winders, and its use is steadily increasing, especially as the manufacture of reliable gearing for transmitting 3,000 H.P. or more is now quite possible. The gears are of the double helical type, and are cut so accurately that manufacturers making a speciality of this work will guarantee efficiencies up to 98%. An example of such an installation is the winding engine at the Bantjes Consolidated Mines Limited (Fig. 42), belonging to the Eckstein Concern, Johannesburg. This motor develops 2,900 H.P. at the end of the period of acceleration.

A typical diagram of connections for a large three-phase winder is shown in Fig. 40. The electrical energy, in the form of high-tension three-phase current is supplied directly to the stator of the winding motor. An automatic oil switch is provided to protect the motor against dangerous overloads. The direction of rotation of the motor can be changed by means of a primary reversing switch which is connected to a buffer-resistance in order to prevent excess voltages contingent on the switching operations. A liquid controller, connected to the rotor, accomplishes the starting and speed regulations. The operating gear for the controller and the reversing switch is so arranged that both are manipulated by a single lever. The very heavy currents and high voltages to be dealt with in the case of large winding engines entail the use

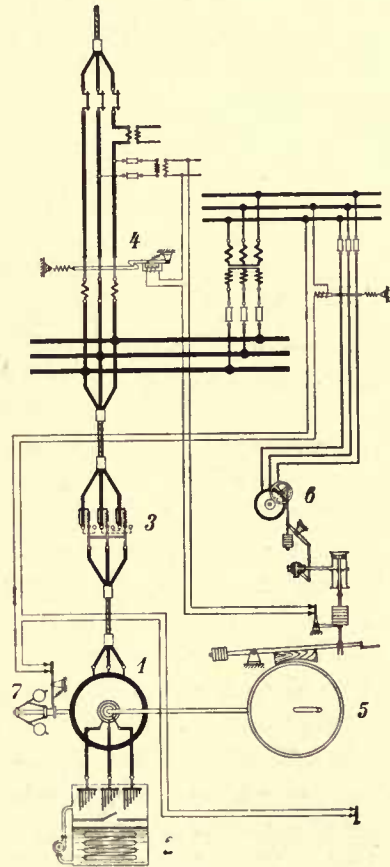


Fig. 40.

Diagram of Connections for three-phase Winder.

- | | |
|-----------------------------------|---------------------|
| 1. Winding Motor. | 4. Circuit Breaker. |
| 2. Liquid Controller. | 5. Emergency Brake. |
| 3. Reversing Switch. | 6. Brake Magnet. |
| 7. Centrifugally-operated Switch. | |

of a very large reversing switch, which can no longer be hand-operated, but requires compressed air or electricity for its working. The starting resistance, which is shown clearly in Fig. 41, consists of a tank divided into two parts by a horizontal partition ; the upper part contains the fixed resistance plates, while the lower one contains the cooling arrangements for the solution. A small rotary pump is provided for pumping the solution from the lower into the upper part, the resistance diminishing as the liquid rises in the upper chamber. The level of the solution can be regulated by adjusting a valve in the horizontal partition, and this can be done by hand without difficulty, even in the case of the largest starters.

For small winders, where the motor output does not exceed 250 H.P., the starting arrangements are simpler. Controllers with metallic resistances are usually employed, the reversing switch being connected mechanically to the starter (Fig. 44).

The speed regulation of an induction motor by means of resistance inserted in the rotor circuit is technically and economically inferior to the speed regulation of a direct-current motor, more particularly when the Ward-Leonard system, as described later, is used. The speed of the induction motor depends not only on the resistance in the rotor circuit, but also on the torque which the motor has to exert at the moment. In order, therefore, to wind to the same diagram at different loads, the control lever must be manipulated in entirely different ways. The manipulation is very similar to that of a steam winder, and depends on the skill and attention of the driver ; there are no reliable means of automatically controlling the speed at every point of the shaft, as is the case with the Ward-Leonard system, and three-phase winding engines cannot, therefore, fulfil more stringent conditions as regards safety than a modern steam engine. Protection against accidents or mishaps, due to wrong manipulation of the control lever by careless drivers, or to other causes, is obtained by bringing the emergency brake into operation, and stopping the winder. To this end, the emergency brake is connected with the brake magnet in such a manner that it is instantly released when the current to the brake-magnet is interrupted. The general arrangement is clearly shown in the diagram of connections (Fig. 40). The current to the brake magnet is automatically interrupted when the supply fails ; by a centrifugal contact on the motor shaft if the speed exceeds a given limit ; by a switch on the depth indicator or at bank in the case of an overwind, and, finally, at the will of the driver by an emergency switch placed at his disposal. The release of the emergency brake simultaneously interrupts the current supply to the winding motor as indicated in the diagram of connections. In some installations, for instance, in that of the Bantjes Consolidated Mines, illustrated in Fig. 42, a number of further safety devices are provided with the object of preventing excessive speeds when approaching the bank, but a detailed description of these would lead too far.

The sudden application of the brake of large winders at full speed may be dangerous, so that suitable damping arrangements must be provided to protect the different parts from excessive stresses.

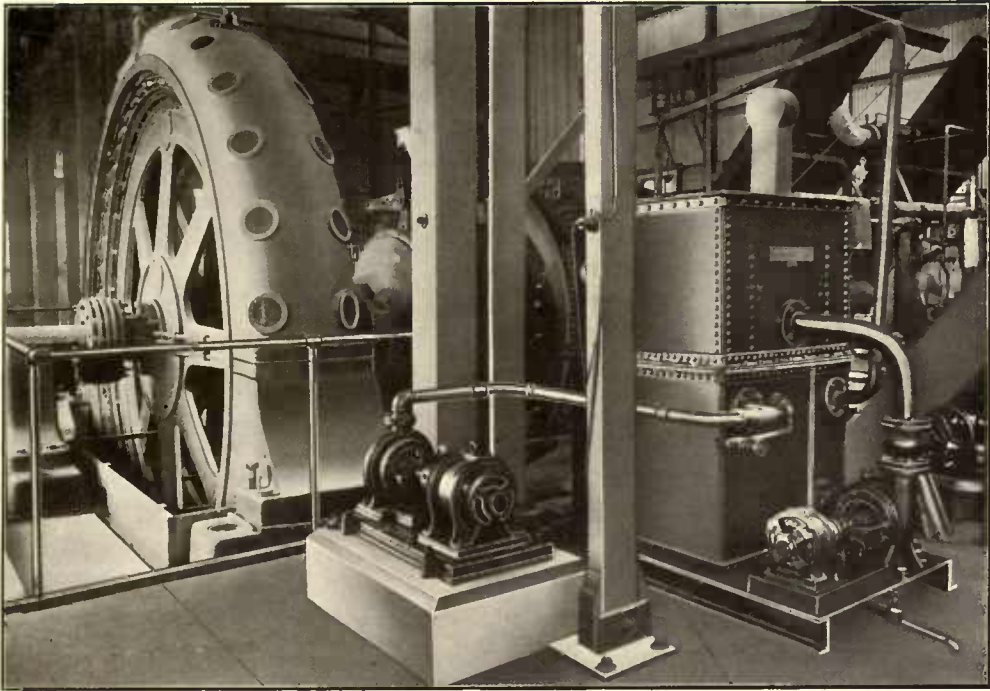


Fig. 41.

H. Eckstein & Co., Nourse Mines Ltd., Johannesburg, Transvaal.

SHAFT II.

Net load 2.4 tons. Depth 1,630 feet. Speed 48 ft. per second. Cylindrical drums 10 ft. diameter.
Direct coupled to one 2,000-volt 1080-2060 H.P. three-phase motor, 50 cycles. Liquid controller.

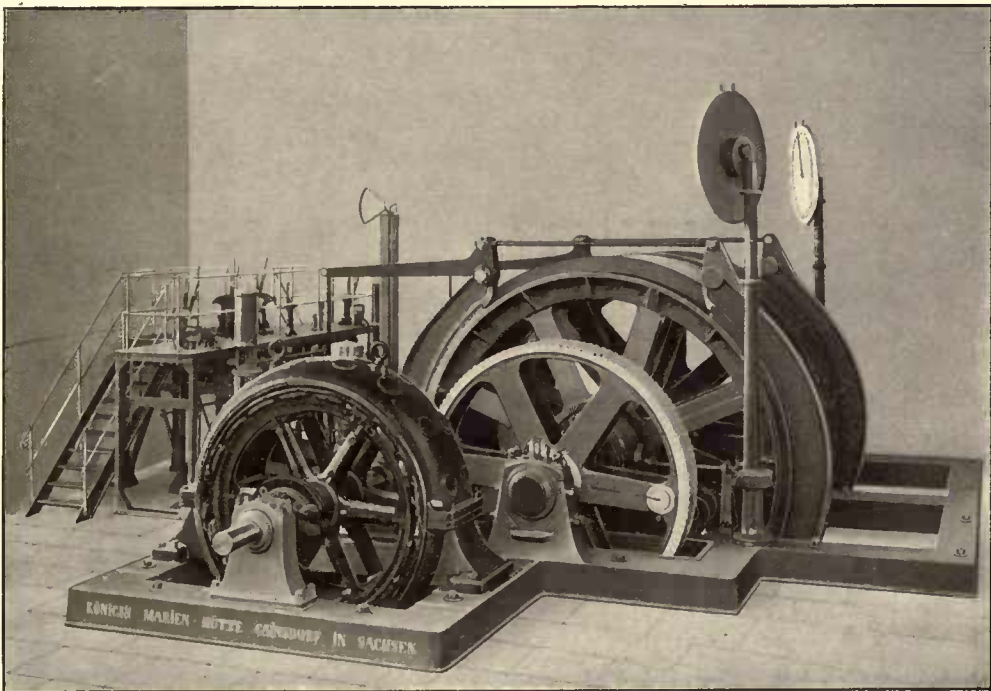


Fig. 42.

H. Eckstein & Co., Bantjes Cons. Mines Ltd., Johannesburg, Transvaal.

CENTRAL SHAFT.

Net load 4½ tons. Depth 4,000 ft. Inclination 35°. Speed 50 ft. per second. Cylindrical drums 14 ft. diameter,
driven through single reduction gearing by one 2000-volt 1310-2900 H.P. three-phase motor, 50 cycles. Liquid controller.

Fig. 43 is a diagram of the current input to a three-phase winder, and is plotted on the assumption that a certain load is raised during the first cycle, the same load being lowered during the next cycle with reverse current. The full lines indicate the energy taken from the supply circuit, while the dotted lines represent energy supplied by the motor to the drum or returned from the latter to the motor respectively. Both when raising and lowering load, energy is taken from the supply circuit, the energy consumption depending solely on the value of the torque no matter whether positive or negative, and on the speed of the motor. At the moment of starting, the motor consumes the greatest amount of energy although the speed is very low and the actual output is practically nothing. The energy consumption is practically constant during the whole of the acceleration period; the difference between the energy supplied to the winder and the work it performs is, apart from insignificant losses in the motor itself, absorbed in the starter. As the motor works at a high efficiency during the full-speed run, the difference between the energy consumed and the work performed is small. In the present instance electrical braking only takes

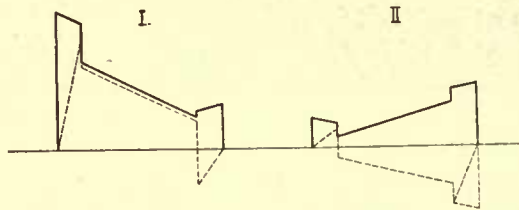


Fig. 43.

Diagram of Current Input to a three-phase Winder.

I. Normal Winding. II. Lowering of load with reverse current.

place, without any application of the mechanical brakes. The moving masses are brought to a standstill by reversing the current, that is, the electric motor exerts a counter-torque, and the energy returned by the winder, as well as the energy taken from the supply circuit, must be absorbed in the controller. When lowering a load without the use of the brake, the motor is also made to exert a counter-torque in order to prevent an excessive speed. The power required for this operation is approximately equal to the energy of the masses being lowered, and the sum of both must be absorbed in the controller. The latter must therefore be capable of converting a considerable amount of energy into heat, and this can only be achieved by providing very elaborate methods of artificial cooling. While the method of operation outlined above is, of course, inefficient, it should be borne in mind that the raising of loads is the rule while their lowering is an exception. It is possible to avoid the losses incident to lowering loads by allowing the motor to run above synchronous speed, when it will act as an induction generator, returning energy to the line. There are, however, objections to this method, especially when men are being wound, because the driver has not the same control over the winder as when operating with reverse current. As a rule, therefore, the latter method is preferred, in spite of the greater losses, in order to increase the safety. Under ordinary conditions, i.e., when loads are being raised, the controller losses become relatively smaller

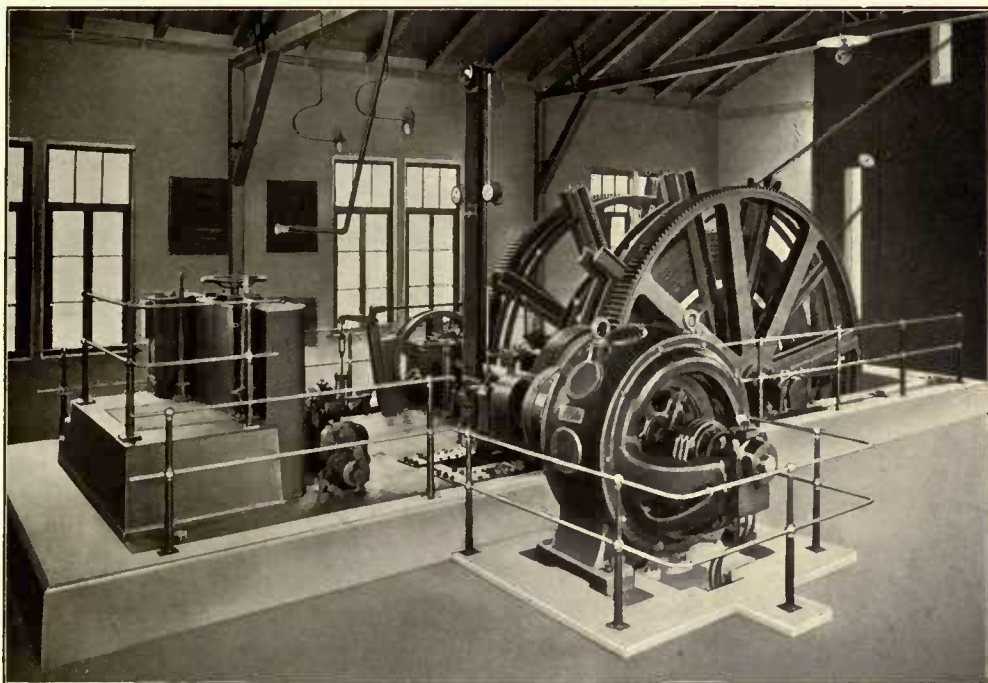


Fig. 44.

Mine Hildasglueck Volpriehausen, Germany.

Net load 1.8 tons. Depth 3,300 feet. Speed 20 feet per second. Bobbins from 6 ft. 6 in. to 16 ft. 6 in. in diameter. Driven through double reduction gearing by 220-volt 210-395 H.P. three-phase motor, 50 cycles. Metallic Controller.

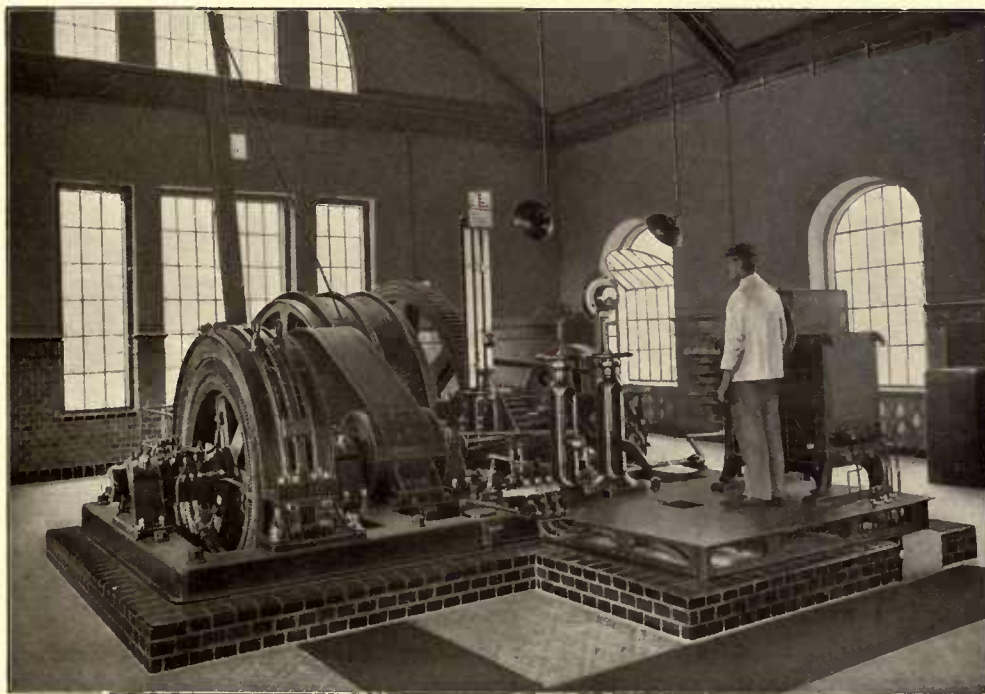


Fig. 45.

Richard Mine, Brux, Austria.

Net load 1.8 tons. Depth 124 feet. Speed $7\frac{1}{2}$ feet per second. Cylindrical drums 10 ft. diameter, driven through double-reduction gearing by a 500-volt 125-200 H.P. three-phase motor, 50 cycles. Metallic Controller.

as the periods of acceleration and retardation are decreased and the peak-loads reduced. The efficiency of a three-phase winder will therefore be particularly high in those cases where large loads are wound from great depths at low speeds, and when the masses to be accelerated and retarded are small. Occasionally, the condition is imposed that when winding men, the speed must be permanently lower than when winding minerals. With three-phase winders this requirement can only be met by inserting resistance in the rotor, thus reducing the motor speed. The excess energy, corresponding to the slip, must then be permanently absorbed in the starter, unless it is preferred to provide a second motor of lower speed expressly for winding men, which can be coupled up when required. The efficiency of this mode of operation is very low, so that this requirement has frequently led to the use of direct-current motors with Ward-Leonard control. The low speed required for rope inspection also causes considerable difficulties. The only reliable method of keeping the speed of the three-phase motor at the required low value is to load the cage. This entails heavy overloading of the starter, and unless the latter has been amply dimensioned for this special purpose, it becomes necessary to interrupt the inspection at intervals so as to give the solution time to cool.

The diagrams in Fig. 43 show that the use of three-phase winders entails large and sudden fluctuations of load. These re-act momentarily on the power station so that there is no time for the regulators of the prime movers to follow the load. Three-phase winders can therefore only be used where the capacity of the power station is very large compared with the peak load of the motor, and as a matter of fact large winding engines operating on this system have only proved successful in those districts where large power stations are available, as in South Africa in the district of the Victoria Falls and Transvaal Power Co., and in England in connection with the supply from the Merz Power Companies near Newcastle (The Newcastle-on-Tyne Electric Supply Co., Ltd.; The County of Durham Electric Power Supply Co., Ltd., and Cleveland and Durham Electric Power, Ltd.). On the Continent the number of three-phase winders in operation with a maximum output of more than 300 H.P. is very small.

The first cost, and the interest and depreciation charges, of a three-phase winding plant are smaller than for any other system. On the other hand, the costs for the feeder line may be higher because the characteristic of the induction motor—that the torque diminishes with the square of the voltage—limits the permissible pressure drop. The simplicity of the equipment reduces maintenance costs to an item of minor importance.

The above remarks show that three-phase winders are suitable in those cases where a current supply from large power stations is available and where low first costs are of primary importance. In all cases, however, where the electric winder is preferred to a steam winder on the score of its greater safety, the three-phase motor is not to be recommended.

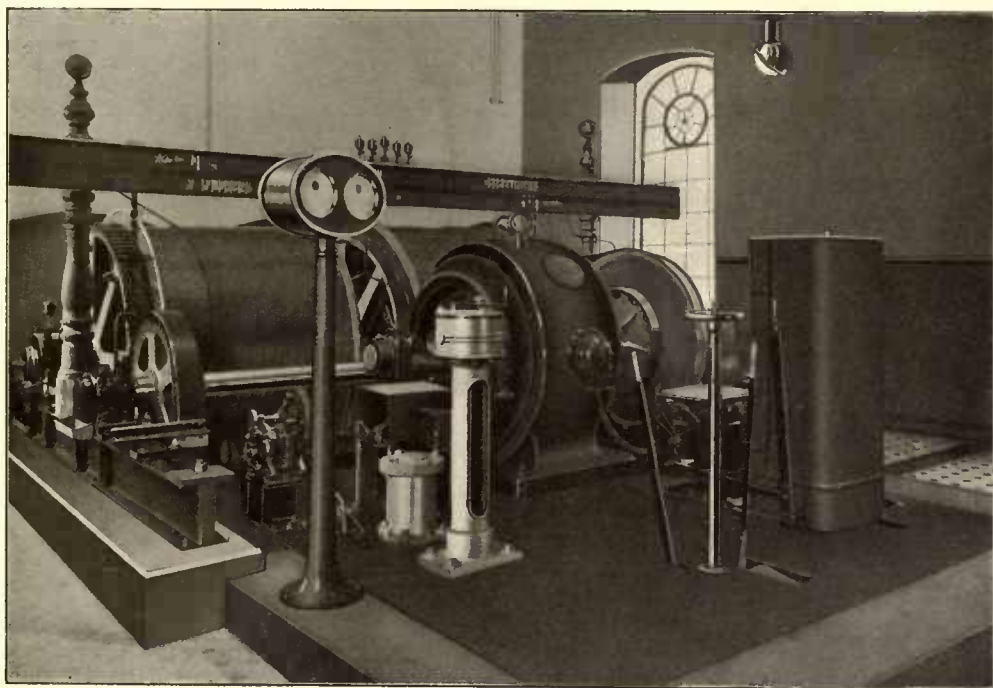


Fig. 46.
Union Mining & Iron Company, Dortmund, Germany.

WOHLVERWAHRT PIT, KLEINBREMEN.

Net load 6 tons. Depth 4,900 feet. Inclination 12°. Speed 16½ ft. per second. Cylindrical drums 6½ ft. diameter.
 Driven by a 1,900-volt 205-360 H.P. three-phase motor, 25 cycles. Metallic Controller.

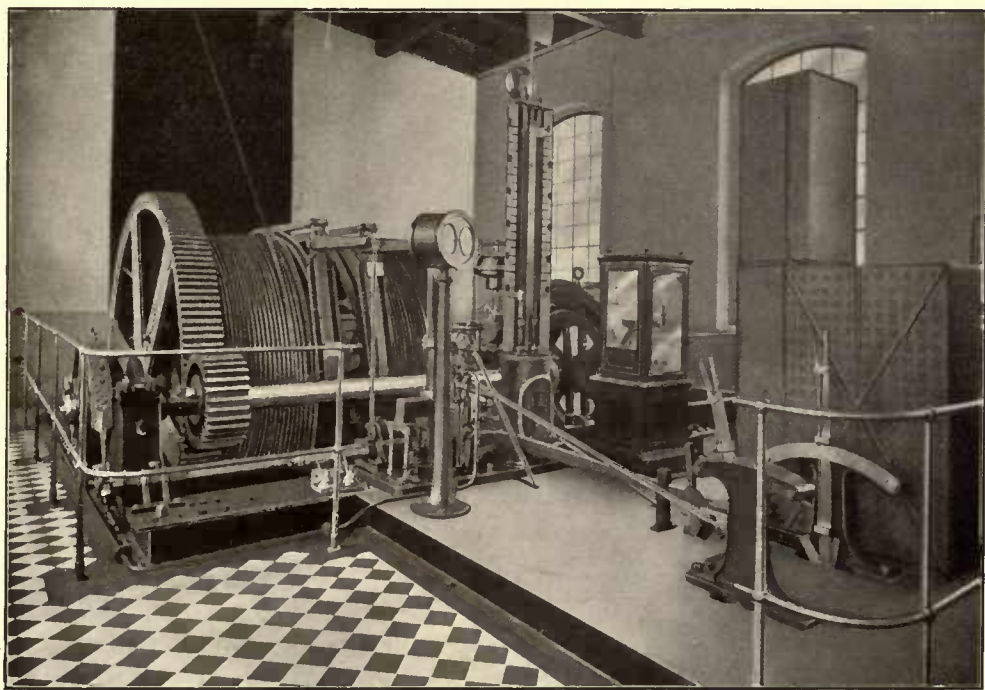


Fig. 47.
Silesian Mining Company, Lipine, Germany.

FIEDLERSGLUECK PIT, BEUTHEN.

Net load 1½ tons. Depth 340 ft. Speed 23 ft. per second. Cylindrical drums 10 ft. diameter driven through single-reduction gearing by 120-volt 80-100 H.P. three-phase motor, 50 cycles. Metallic Controller.

Winding Engines driven by Three-phase Commutator Motors

Great attention has recently been paid to the equipment of winders with three-phase commutator motors. The Siemens' commutator motor has a series characteristic, that is, it behaves exactly like a direct-current series motor with the following salient properties :—

It develops a large torque at starting. As the load decreases, the speed rises, until at no load the machine reaches a dangerous speed as is the case with a direct-current series motor. The speed can be closely regulated within wide limits by shifting the brushes on the commutator, and both efficiency and power-factor are high throughout the whole range of speed regulation. The motor has a large overload capacity, and does not stop, even under very heavy overloads, but only slows down. Further, a powerful and easily-regulated braking effect can be obtained electrically by moving the brushes back through the neutral position. When braking in this manner, and especially when lowering loads, the motor acts as generator and returns energy to the line. The direction of rotation can be reversed by moving the brushes to the other side of the neutral position, but in order to prevent sparking at the commutator, the stator current must also be reversed.

Since the best design of commutator is only practicable for low voltages up to about 100 volts, the supply pressure must first be reduced to this value in a static transformer, unless such pressure is already available.

Constructional limitations make it impracticable to design commutator motors for very large outputs at present, so that their use is still confined to small and medium-sized winders. The same causes prevent these motors being used for low speeds, say below 300 R.P.M., so that in those cases reduction gearing must always be provided. In all other respects the arrangement of a winder with a three-phase commutator motor is very simple. The diagram of connections for such an installation is shown in Fig. 48, while Fig. 49 shows a complete winder with commutator motor. The motor is controlled solely by shifting the brushes on the commutator and operating the change-over switch, both movements being performed by a single lever. The commutator motor shares with the three-phase induction motor the disadvantage that, for any one position of the control lever, its speed depends on the torque, i.e., on the load in the cage. Consequently, only the same safety

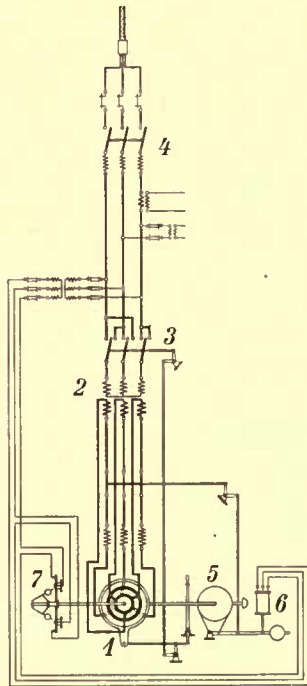


Fig. 48.

Diagram of Connections of a Winding Engine driven by 100 H.P. Three-phase Series Commutator Motor.

- | | |
|-----------------------------------|-------------------------------|
| 1. Winding Motor. | 4. Automatic Circuit-Breaker. |
| 2. Transformer. | 5. Emergency Brake. |
| 3. Reversing Switch. | 6. Brake Magnet. |
| 7. Centrifugally-operated Switch. | |

devices as used on three-phase winders are available, and protection is confined to the release of the emergency brake and the interruption of the supply in all cases where the motor is over-loaded or any other danger arises.

Since the power taken by the series commutator motor rises gradually from the moment of starting to the end of the acceleration period, there is sufficient time to enable the prime movers and generators in the power station to follow the load fluctuations. Winders driven by three-phase commutator motors may, therefore, be supplied with current from comparatively small power stations, provided that the generating sets are fitted with modern voltage regulators.

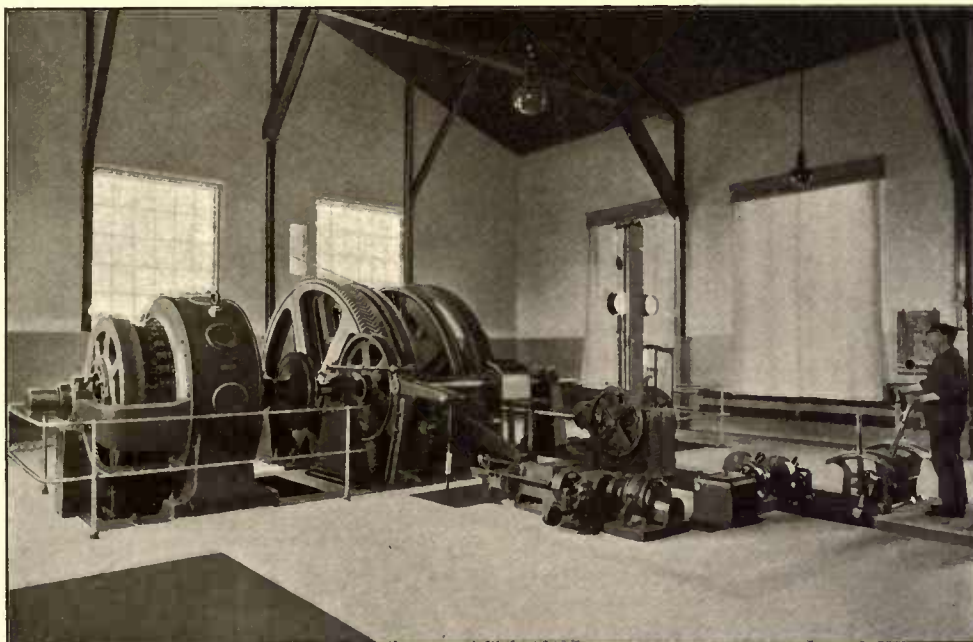


Fig. 49.

Gewerkschaft Burbach Helmstedt, Germany.

BARTENSLEBEN PIT.

Three-phase Commutator Motor Drive. Koepe pulley 13½ ft. diam. Net load 3·2 tons. Depth 1,600 ft.
Output of motor (2 in tandem) 600 H.P. speed 25 ft. per sec. Output 96 tons per hour.
For sinking, the winder is at present equipped with one motor and bobbins.

The full-load efficiency of a commutator motor is about 5% less than that of a similar induction motor, but as the losses during the starting and braking periods are practically negligible, and as, further, the speed can be permanently reduced without loss, and as energy will be returned to the line, even at low speeds (as when lowering loads), the total efficiency of such a winder may under certain conditions be better than that of a corresponding three-phase winder. A great advantage of the commutator motor over the induction motor is that its power-factor at full load is unity, and hardly varies from this value throughout the whole range of regulation. The first cost of a commutator motor is at present considerably higher than that of an equivalent induction motor, and the expenditure on attendance and maintenance is somewhat higher, owing to the wear on the brushes. A separate consideration of each case is, therefore, required to determine whether the increased efficiency compensates for the higher interest, depreciation and maintenance costs.

Winding Engines with Ward-Leonard Control

The introduction of the Ward-Leonard system of control marked the beginning of a new era in electric winding engines. The absolute control and the degree of safety which this system first rendered possible constitute one of the chief claims of superiority of electric over steam winders. The principle of the Ward-Leonard control is shown in Fig. 50. It is based on the fact that the speed of a separately-excited direct-current motor is directly proportional to the pressure supplied. Such a motor can, therefore, be made to assume any desired speed or direction of rotation, according to the pressure and direction of the current impressed on it. The motor current is supplied by a separate generator usually called the converter or variable-voltage generator. The speed and direction of rotation of the winding motor can be controlled in any way desired by regulating and reversing the excitation, i.e., the pressure, of the converter dynamo.

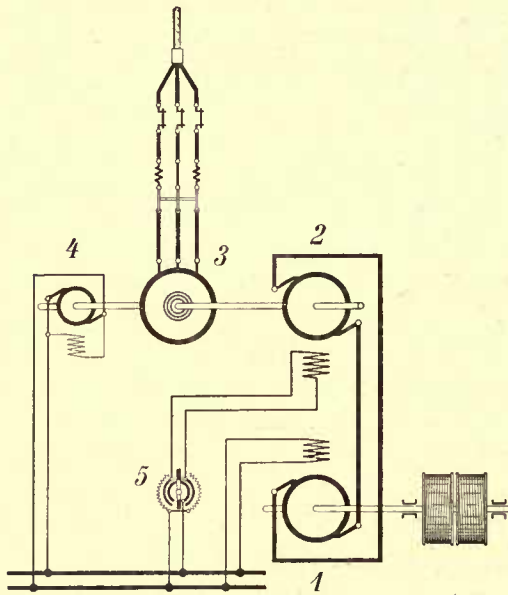


Fig. 50. Ward-Leonard System of Control.

- | | |
|-------------------------|---------------------|
| 1. Winding Motor. | 3. Converter Motor. |
| 2. Converter Generator. | 4. Exciter. |
| 5. Controller. | |

The most important feature of this control is that the speed and direction of rotation of the winding motor are determined solely by the regulator, that is by the position of the driver's control-lever. This holds true, irrespective of the load in the cage, or of the direction of the torque, whether positive or negative, that is, whether loads are being raised or lowered.

Moving the operating lever towards the "off" position induces a strong electrical braking effect, the motor acting as a generator, and returning energy through the converter generator to the line. Energy is also returned to the line when loads are lowered. The low speed required for inspection purposes can be readily obtained with the Ward-Leonard system by moving the

operating lever only slightly from the "off" position. The controllers are only called upon to deal with the energy in the exciting circuit of the converter generator (about 2—3% of the energy consumed by the winding motor) and can be small and simple; they can, therefore, be readily operated by the control lever, without the use of auxiliary gear, even in the case of the largest winders.

The fact that any given position of the operating lever corresponds to only one speed and direction of rotation, makes it possible to provide safety appliances of absolute reliability. Fig. 53 shows diagrammatically the Siemens patent safety gear, while Fig. 56 is an illustration of the apparatus itself.

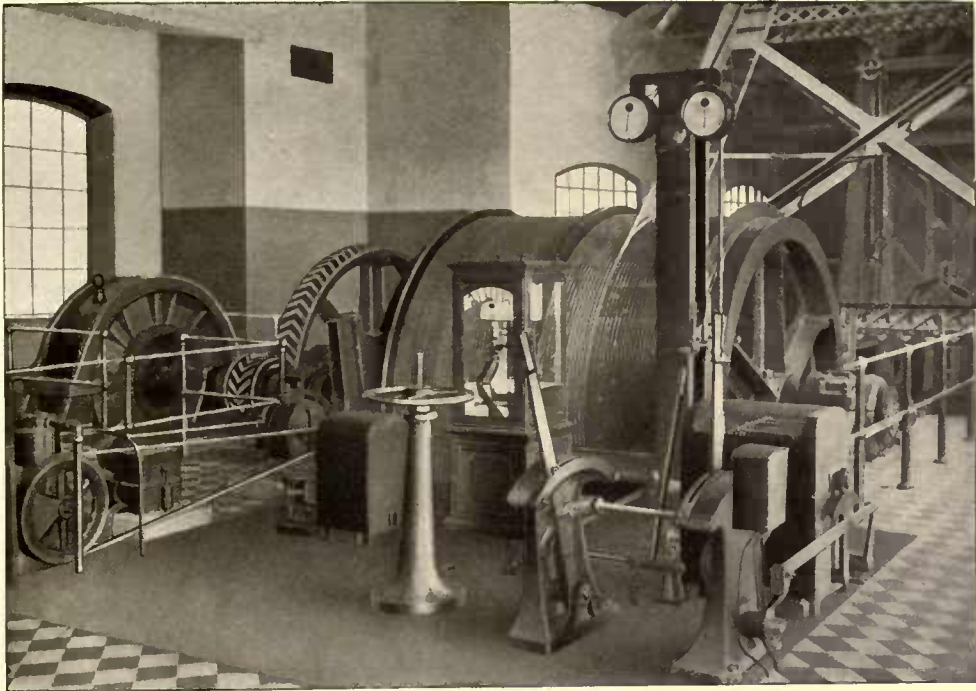


Fig. 51.

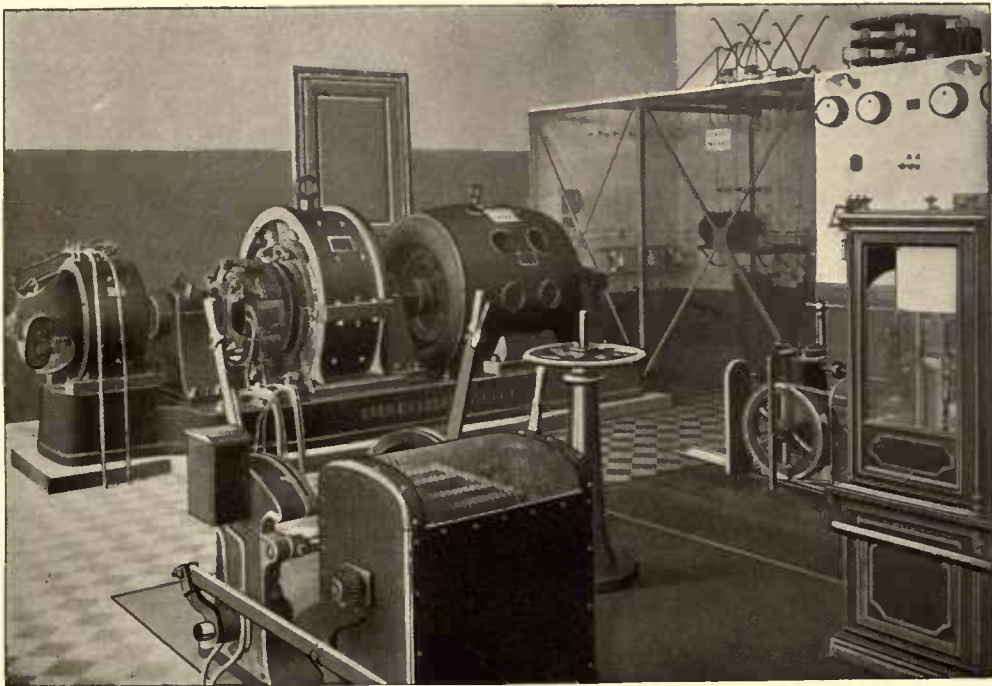


Fig. 52.

Société des Mines d'Albi dept. Tarn. France Shaft 1, Albi.

Ward-Leonard system with separate converter set. Cylindrical drums 10 ft. diameter. Net load 1'0 tons.
 Depth 690 ft. Speed $19\frac{1}{2}$ ft. per second. Capacity 90 tons of material per hour.

The spindle of the depth indicator drives two control cams (one for each cage) through suitable gearing so proportioned that the cams make nearly one complete revolution for each wind. These cams act on the control lever through a system of links in such a manner as to limit the maximum throw of the operating lever at every point of the cage travel. When starting a wind, the control lever is gradually released by the cams, and when stopping it is gradually forced back into the "off" position; the cages are thus brought to rest at the pit bank and over-winding is impossible. During the wind, acceleration, retardation and speed of winding are completely within the driver's control, provided always that he does not exceed the limits given by the cams. But however the control lever may have been operated the cams finally come into action as the cages approach the bank; the speed is thus automatically reduced to a very low value. The emergency brake is automatically released by a special trip operated from the cam shaft, the cages are brought to rest and overwinding prevented. In addition to the above safety devices a further trip switch is provided, mechanically operated by the cage itself, so that if an overwind were to take place the cage would open this switch and also cause the emergency brake

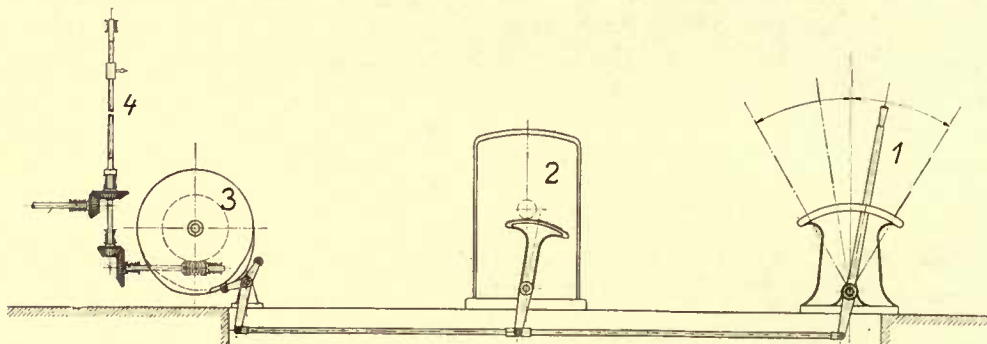


Fig. 53. Diagram of the Siemens Depth Indicator with Safety Device.
 1. Operating Lever. 2. Controller. 3. Control Cam. 4. Depth Indicator.

to act. The sudden application of the brakes in this case presents no danger, because the speed of the cage is already considerably reduced by the return of the controller to the "off" position through the cams.

With the pure Ward-Leonard control, the speed of the motor is not determined absolutely by the position of the controller, because of the ohmic drop in the converter generator, and the motor armatures. The resulting small discrepancies may be neutralised by means of auxiliary apparatus.

Such an arrangement (Osborn system) has been evolved and successfully used by the Siemens Companies. A detailed description of this system would, however, lead too far. Tests carried out with the winder at Zollern Pit II, (Fig. 64) showed that the winder, if left entirely to itself when winding men at a speed of about 35 feet per second, stopped automatically when the cage had overrun the pit bank by about 6 ft., a result which could hardly be attained with a steam engine.

It is also possible with this type of control to limit the maximum speed of the winder when raising men. An electrically-operated interlocking device on the control-frame, which can be actuated from the pit bank, limits the effective throw of the control lever to the required degree.

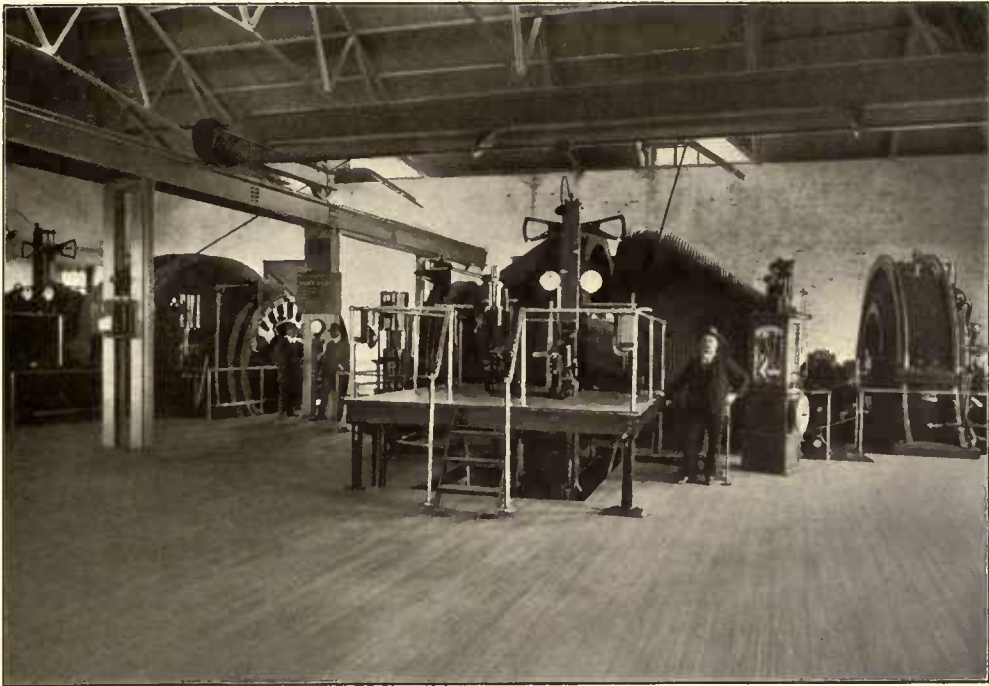


Fig. 54.

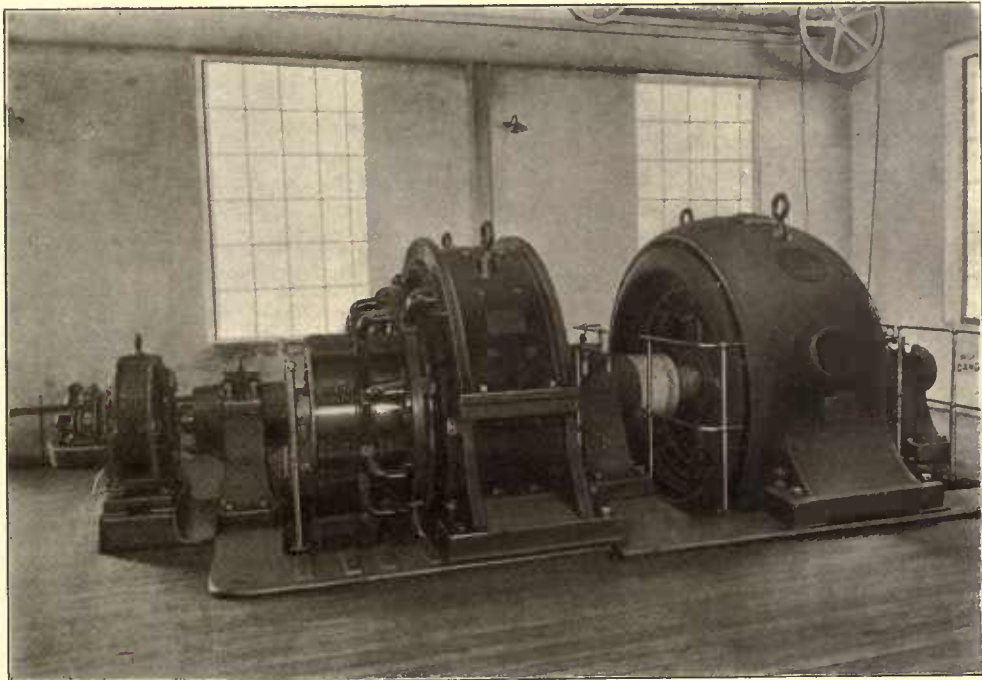


Fig 55.

General Mining and Finance Corporation Ltd. Rand Collieries, Transvaal.

Ward-Leonard system with separate converter set. Conical drums 10 ft. to 17½ feet diameter.
Net load 5½ tons. Depth 3,240 ft. Speed 55 ft. per second. Output 182 tons of material per hour.

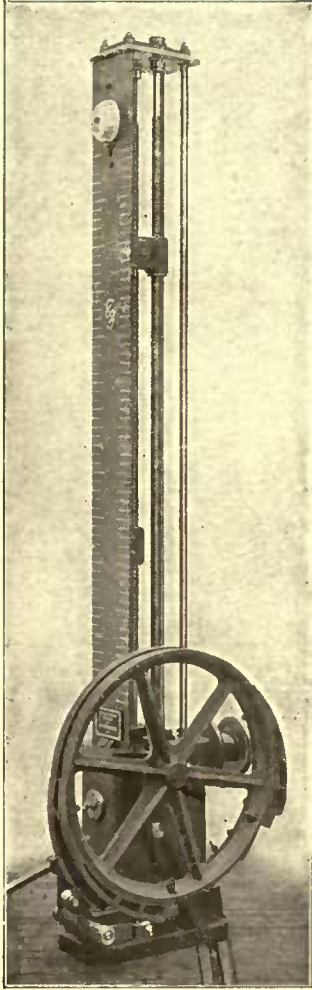


Fig. 56.
Siemens Depth Indicator with
Safety Gear.

The consumption of energy with the Ward-Leonard control rises slowly during the starting period, exactly as in the case of the commutator motor. The maximum is, therefore, only reached at the end of the time for acceleration, i.e., after about fifteen to twenty seconds. The energy consumption at bank for decking or lifting off the keps etc., when the speed of the winding motor is very low and the output small, is inconsiderable, so that no peak loads occur. For these reasons it is possible to supply Ward-Leonard winders from power stations of comparatively small total output, provided that the machines of the station have a sufficient capacity to maintain their speed during the peak loads, and that the generators are provided with modern voltage regulators.

The converter generator can be driven in a number of ways. In the majority of cases the winding engines will be connected to a three-phase supply, involving the use of a three-phase induction motor, the so-called converter motor, to drive the generator. It is usual to add an exciter to the converter set, unless a direct-current supply is available. Winders operating on this system are shown in Figs. 51, 52, 54, 55, 57 and 58.

It is also possible to couple the converter generator to a prime mover, as is shown, for instance, in Fig. 60. Steam turbines have lately been found to be specially suitable for this purpose. The load fluctuations are in these cases transmitted direct to the prime mover, and though it is possible to fit very sensitive regulating devices, it will always be necessary to provide for a certain continuous minimum load, because otherwise the prime mover would operate too unfavourably and would race when energy is returned to the line. The best method of providing this load is to couple a three-phase generator (which can provide the energy for the other machines throughout the mine) to the prime mover, in addition to the variable-voltage generator. While this arrangement presents some great attractions, it also has some disadvantages which confine its use to comparatively few cases. To begin with, it is necessary to have a boiler plant in close proximity to the winding engine. Further, it is not always possible to provide a constant and sufficient minimum load and finally the arrangement makes the winding engine dependent on a single prime mover and violates the principle of centralized production of energy.

If the converter generator is coupled directly to the prime mover, the losses

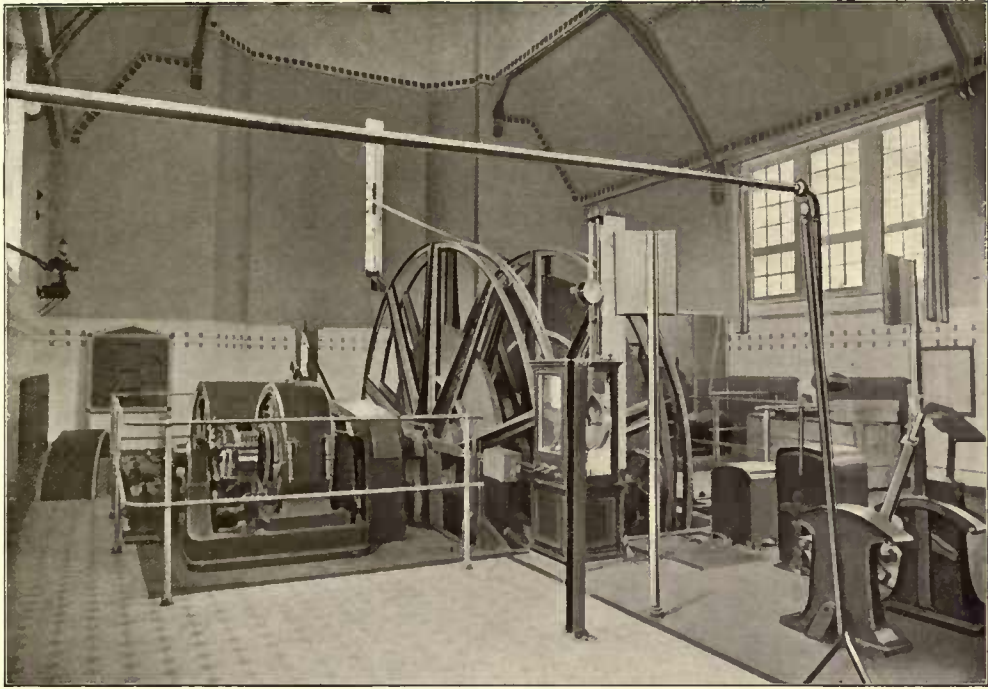


Fig. 57.
Gewerkschaft Glueckauf, Sondershausen, Germany.
PIT II.

Ward-Leonard System, with separate converter set. Bobbins from $6\frac{1}{2}$ ft. to $15\frac{1}{2}$ ft. diameter. Net load 1 ton. Depth 2,460 ft. Maximum speed 20 ft. per second. Capacity 23 tons of material per hour.

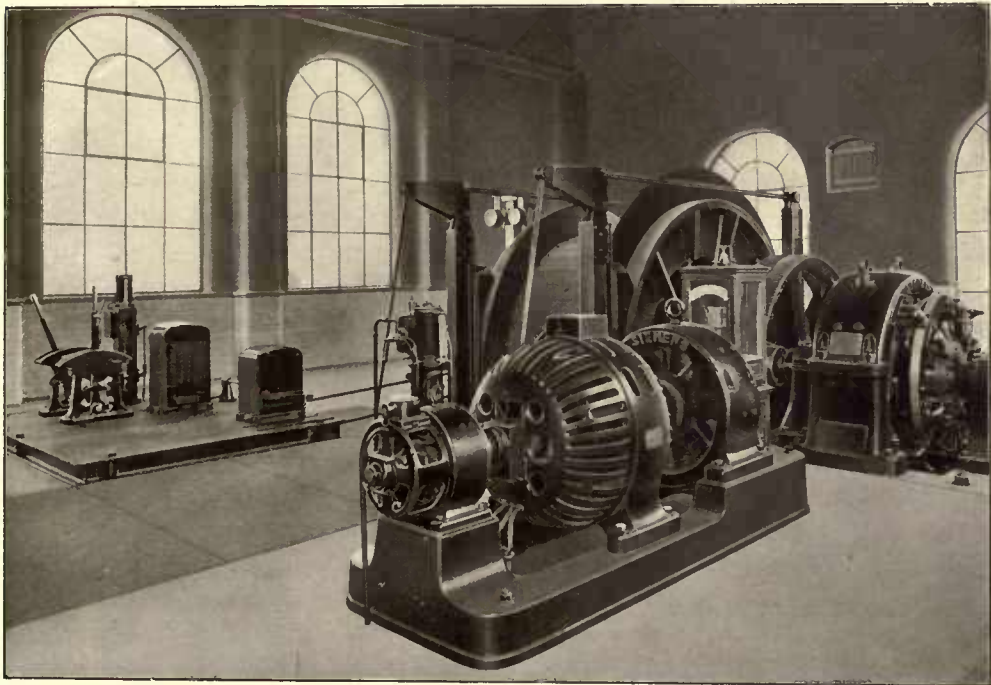


Fig. 58.
Winder at a Colliery in Durham, England.

Ward-Leonard system with separate converter set. Cylindrical drum 10 ft. diameter. Net load 3,800 lbs. Depth 300 feet. Maximum speed $5\frac{3}{4}$ ft. per second. Capacity 70 tons of material per hour.

of conversion are avoided. Nevertheless, it is doubtful whether this arrangement really makes for any actual economy. The prime mover working with varying load has a considerably higher steam consumption than one of similar size operating on constant load and, moreover, the efficiency of the boiler plant is also reduced by the fluctuations of load. The high steam consumption not only increases the generating costs of the power for the winding engine, but also of all that energy which is produced by the generator and forms the minimum load. The extra cost of the energy utilized in the auxiliary equipment of the mine must therefore be charged to the winder.

Since it is possible to build even small direct-current motors for low speeds with high efficiencies at reasonable cost, it will nearly always be possible to couple the winding motor direct with the drum shaft, so that the losses incidental to reduction gearing are avoided. While the conversion of electrical energy in the converter from three-phase to direct current is accompanied with appreciable continual losses, the starting and speed regulation of the motor entails practically no losses whatever, and it is possible to regain the energy stored in the moving masses by electric braking and also to utilise the power returned when lowering loads. A Ward-Leonard winding engine will, therefore, be preferable to a three-phase winder in all cases where it is necessary to wind at high speed from comparatively small depths and where large masses have to be accelerated and retarded, that is, in all cases where the three-phase motor would be inefficient on account of the large starting losses. The Ward-Leonard control is further to be preferred in those cases where a slower speed for winding men is prescribed; these winders are practically as efficient at slow speeds as at full speed. Finally, the Ward-Leonard system possesses the great advantage that the energy consumption of the winder is practically independent of the skill of the driver, while in the case of three-phase winders, as with steam winders, much depends on whether the manipulation is skilful or unskilful. The choice between the Ward-Leonard system and a three-phase commutator motor must be considered for each individual case.

The capital costs of a winding plant with converter are higher than those of a plant with three-phase motor or with commutator motor on account of the larger number of machines involved. The direct coupling of the converter generator with a steam turbine will hardly effect a reduction of the capital costs, because the turbo-generator will be considerably more expensive than the ordinary converter generator working at lower speed. The maintenance costs of the Ward-Leonard winders are hardly greater than those of three-phase winders because, although the larger number of machines require more oil and stores, and the wear and tear on the brushes is greater, the simple control gear requires practically no supervision. In many cases the actual operating costs of the Ward-Leonard system will be found smaller than those of the three-phase winder; in all other cases it will be necessary to decide whether the lower efficiency will be compensated for by the greater safety of the Ward-Leonard system.

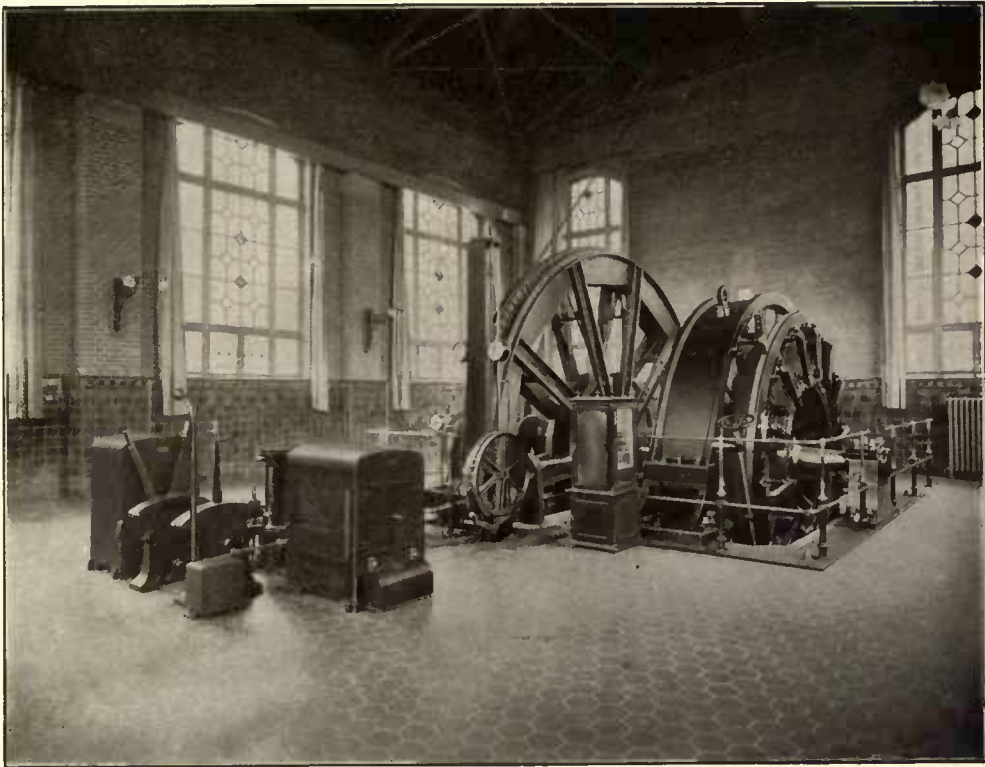


Fig. 59.

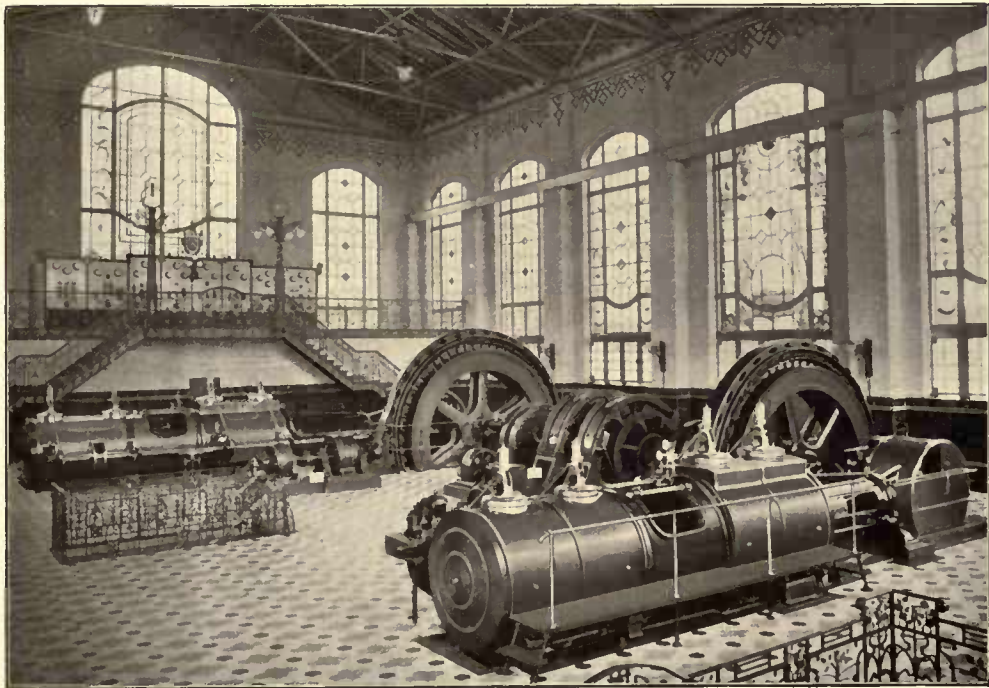


Fig. 60.

Kaliwerke Friedrichshall Sehnde, near Hanover, Germany.

Ward-Leonard system with buffer battery. Koepe pulley 20 ft. diameter. Net load 2.8 tons.
 Present depth 1,640 ft., to be increased later to 2,950 ft. Speed 33 ft. per second. Capacity 63 tons
 of material per hour. The variable-voltage generator and the booster generator are direct-coupled to the
 prime mover.

Winding Engines with Buffer Batteries

The greatest impediment to the introduction of electric winders was the disturbing influence of the violent fluctuations of the demand on the prime movers in the station. To overcome these difficulties, even the earliest winders of considerable size were equipped with some means of energy storage which could be drawn upon during peak loads and replenished during periods of low load, and particularly in the intervals of winding. A storage battery was naturally the first solution which presented itself, and as far back as the year 1900 the Siemens Companies equipped the winder at Thiede near Brunswick (Fig. 61) belonging to the Thiederhall Company, on this system. The winder itself is placed below



Fig. 61.
Electric Winder at Thiede, near Brunswick, Germany.

Installed in the year 1900.

ground, and winds mineral from the 1,640 ft. to the 980 ft. level. The battery and prime mover are installed above ground. As will be seen from the illustration, the two direct-current shunt-wound winding motors are direct coupled; their speed can be regulated by connecting the armatures in series or in parallel, together with a resistance. The buffer battery is connected across the terminals of the generator, and as the voltage of the latter drops with increasing current, the battery assists automatically in supplying the energy. This plant is still working to-day with every satisfaction.

The variation of the voltage of the prime generator is a disturbing feature if electric current is to be supplied for other purposes from the same source. It is, therefore, necessary when connecting winding engines to direct-current supply circuits to introduce a special auxiliary machine to induce effective operation of the buffer battery. One of the means adopted for this purpose is known as the Pirani Booster System. In this system, an extra boosting voltage is added either to the battery or to the line voltage, according to whether the

battery is to be discharged or re-charged. The booster voltage is made to vary in value and direction in accordance with the current in the main circuit. This arrangement offers the advantage that the battery can meet all the fluctuations which may occur when a number of winders and other machines taking varying power supplies are operating off the same circuit. A disadvantage of this system is that its use is confined to direct-current supply systems, which form the exception among modern mining installations.

Quite recently buffer batteries in conjunction with Ward-Leonard winders have been repeatedly installed, both for plants with and without converters. A plant of this type, consisting of a converter set for operating from a three-phase supply and a battery in connection with it, was recently installed, among others, for the Potash Mines "Amélie" in Alsace-Lorraine. This plant operates with a net load of 2.5 tons, winding from a depth of 2,000 ft. at a maximum speed of 33 ft. per second. A notable feature

of this plant is the simple arrangement installed to ensure proper operation of the battery. A voltage regulator is actuated by the current taken by the converter motor, and influences the excitation of a booster generator in such a manner that its pressure rises or falls according to whether the battery is to be charged or discharged. The voltage regulator replaces the Pirani system described above, and in actual operation has been found to be fully as good as the latter.

An example of a winding plant on the Ward-Leonard system, but without converter, and in which the fluctuations in the power demand are also compensated for by the use of a battery, is that of the Friedrichshall Co., Sehnde, near Hanover, shown in Fig. 60. In this instance the steam engine not only drives the variable-voltage generator and the booster generator, but also two alternating-current generators which furnish the power required for other plant about the mine.

The buffer battery has a considerably larger capacity as energy storer than, for instance, the fly-wheel used with a converter set. While the latter arrangement only permits of one, or at the most two winds, being made with the energy stored in the flywheel, the buffer battery is usually large enough to complete twenty or thirty winds without the assistance of the prime mover. Further, the battery retains its store of energy for a considerable time without appreciable losses, while the fly-wheel requires a constant supply of power to keep it in motion.

It follows that plants equipped with buffer batteries are ready for operation even when the generating station is temporarily out of service. They present, therefore, certain advantages for those mines where the power station is shut down during the night and during holidays, and where it is necessary to make a few winds for the purposes of shaft inspection, repairs, etc. Moreover, the battery offers a considerable advantage as temporary reserve in the case of a breakdown in the power station.

In spite of these advantages, the buffer battery has not been used to any great extent in connection with winders. This is undoubtedly due to its high cost, the large amount of space required, and the rapid deterioration, involving considerable provision against depreciation. Moreover, in most modern mines the power station is required to be in operation both day and night, so that one of the chief advantages of the buffer battery is not utilised.

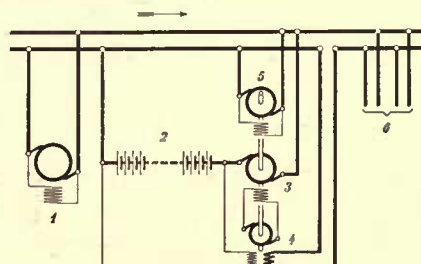


Fig. 62. Pirani Booster System.

- | | | |
|--------------------|-------------|---------------------|
| 1. Main Generator. | 3. Booster. | 5. Motor. |
| 2. Battery. | 4. Exciter. | 6. Feeder circuits. |

Siemens-Ilgner System

The large increase in the use of electric winding plants which has taken place within the last ten years must be ascribed to the introduction of the Ilgner system, which made it possible to reduce the energy fluctuations to practically any desired degree without the use of a battery.

The principle of the Ilgner system is diagrammatically shown in Fig. 63. Its essential feature is the use of a fly-wheel as buffer between the supply and demand, in connection with the Ward-Leonard system of control.

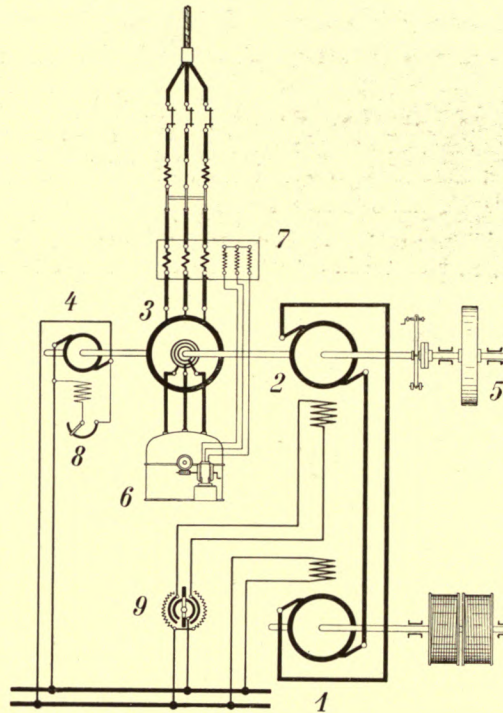


Fig. 63.

Siemens-Ilgner System.

- | | |
|-------------------------|-------------------------------|
| 1. Winding Motor. | 5. Fly-wheel. |
| 2. Converter Generator. | 6. Automatic Slip Resistance. |
| 3. Converter Motor. | 7. Current Relay. |
| 4. Exciter. | 8. Automatic Shunt Regulator. |
| 9. Controller. | |

The Ilgner system was first used for the electrification of the winding plant at the Pit Zollern II of the Gelsenkirchener Bergwerks A.G. Merklinde, near Gelsenkirchen, in 1902, shown in Fig. 64. Since that date, the Siemens firms alone have installed about 150 winding plants on this system, and the continually increasing demand for these plants may be taken as the best evidence that they meet the demands of modern engineering in every way.

In order to utilise the energy stored in a flywheel, it is necessary to reduce its speed, and, conversely, it is necessary to increase the speed of the flywheel



Fig. 64.

**Gelsenkirchener Bergwerks A.G., Gelsenkirchen,
Germany.**

PIT ZOLLERN II, MERKLINDE.

Siemens-Ilgner system. Koepe pulley 20 ft. diameter. Net load 4.2 tons. Present depth 920 ft., to be increased later to 1,640 ft. Present speed 33 ft. per second, to be increased later to 65 ft. per second.
Capacity 170 tons of material per hour.
Installed 1902.

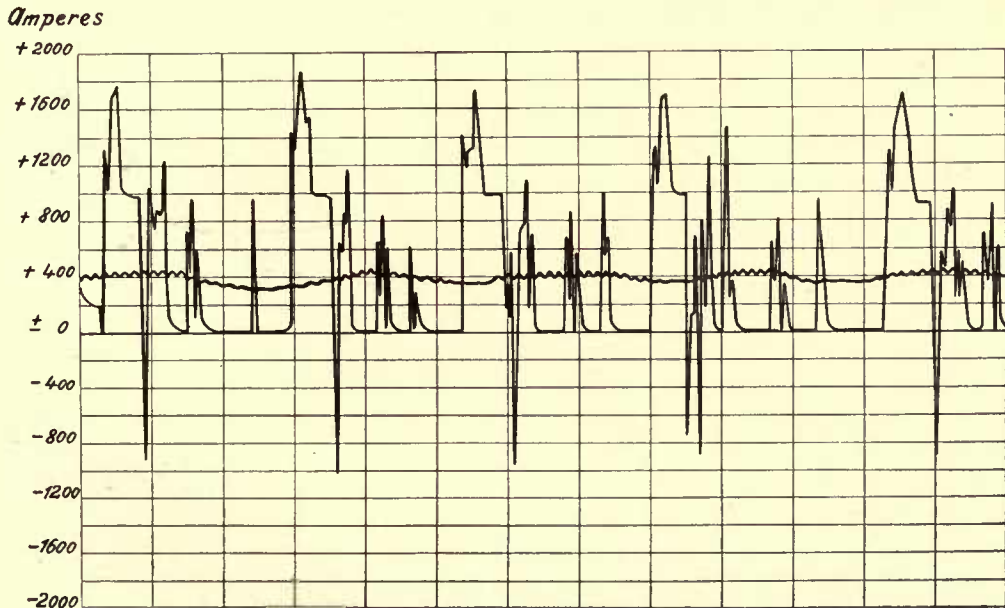


Fig. 65.

Current chart of Winder and Converter Motor of the above.

in order to store energy in it. This speed variation is accomplished by means of an automatic slip resistance connected in the rotor circuit of the converter motor. The slip resistance is almost invariably made in the form of a liquid controller, and the movement of the blades is accomplished by means of a gear drive with auxiliary electric motor, or by means of a small direct-coupled relay motor, operated in either case from a current relay in the stator circuit of the converter motor. The arrangement is such that when the stator current increases, resistance is added in the rotor circuit, thus reducing the speed of the set, and vice versa.

The actual operation of this arrangement is exemplified by the current diagram, Fig. 65, taken from the winding engine at the Zollern II Pit. The current taken by the winder varied between +2,000 and -1,000 amperes, while the converter motor had a practically steady demand of 400 amperes.

The operating characteristics of a winding plant on this system, especially as regards ease of manipulation and safety, are fully described in the section dealing with the Ward-Leonard control system, to which it is essentially similar. The great advantages of this method of control in connection with the Siemens' safety gear also hold good for the Ilgner system. Moreover, the energy stored in the flywheel forms a certain temporary reserve, which usually makes it possible to complete one or two winds if the supply fails; in all cases, however, it is possible to complete a wind which has just begun or is under way. The economy of an Ilgner plant can be judged on the same basis as that of a Ward-Leonard plant. In addition to the losses entailed by the Ward-Leonard system of control, the Ilgner system introduces additional losses, caused by the friction of the flywheel and the slip resistance. It is usual to calculate the flywheels for a maximum speed reduction of 15% at the peak load. The average continual loss, therefore, in the slip resistance will be about $7\frac{1}{2}\%$ of the converter input.

Considerable improvement has recently been made in the manufacture of flywheels. The peripheral speed has been increased from about 250 ft. per second in the first flywheels to about 450-500 ft. per second in the nickel steel wheels which are at present being employed. This increase in speed has made it possible to reduce considerably the weights required for given conditions. A peak of 60,000 H.P. seconds, for instance, which formerly required two flywheels of a total weight of 80 tons to compensate it, is now met with a single flywheel of 22 tons weight. The friction losses have been reduced from 150 H.P. to approximately 100 H.P., thus effecting a considerable annual economy.

In order to reduce the losses incidental to the running of the flywheel during long intervals of winding, a clutch is placed between the flywheel and the converter, which can be disengaged at full speed. It is then possible to perform isolated winds, required for the raising of men or of material, by the aid of the converter set without the flywheel. These winds must, however, be carried out at a lower speed in order to avoid overloading the converter motor. An automatic interlocking device operating on the control frame prevents the

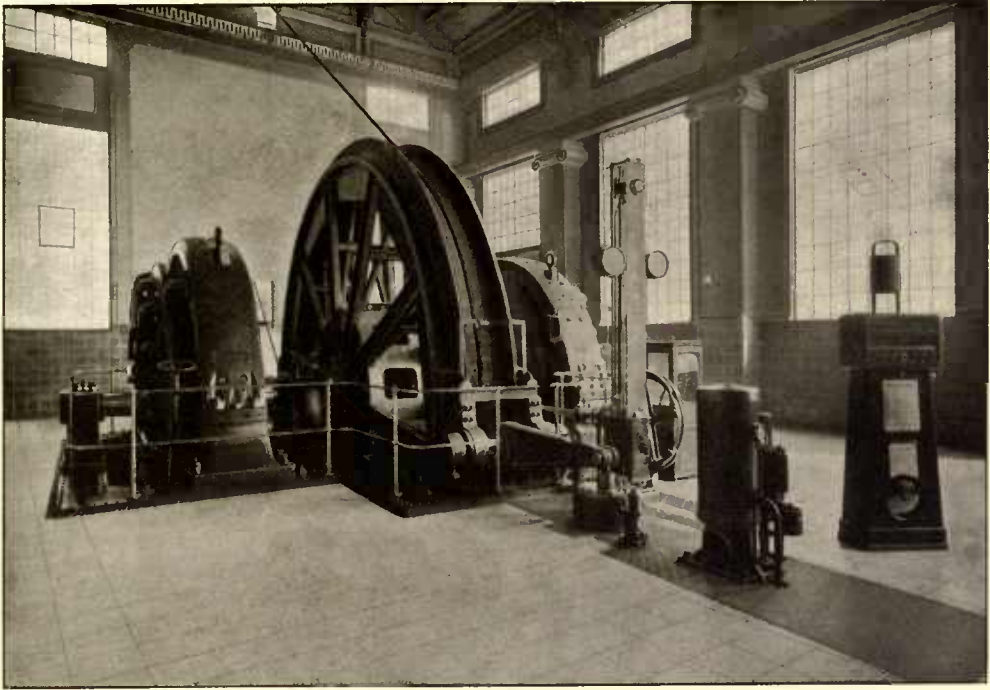


Fig. 66.

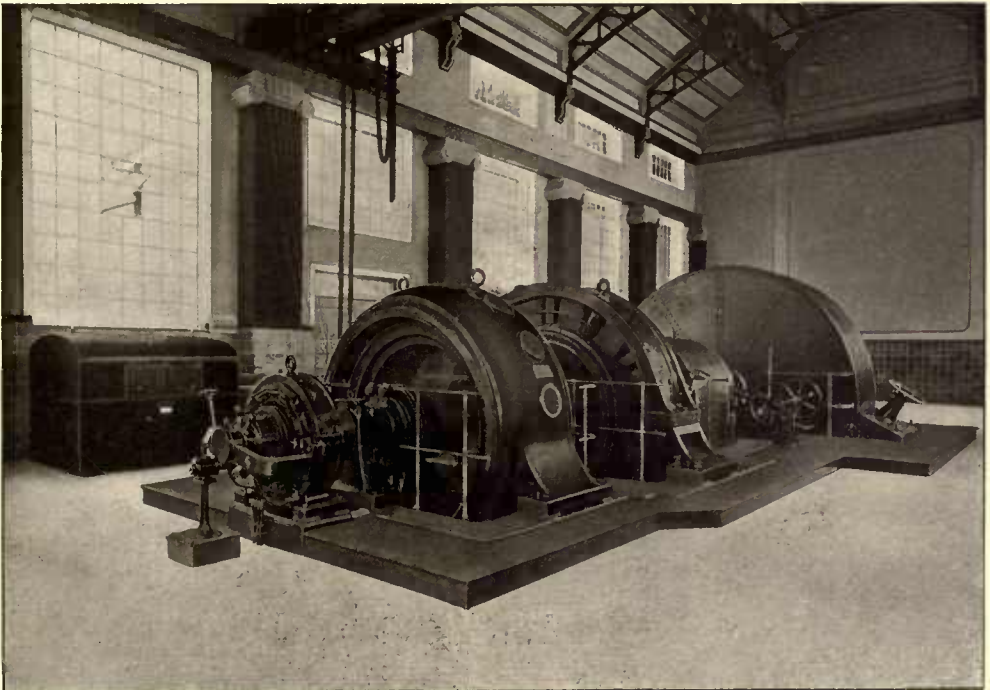


Fig. 67.

Gelsenkirchener Bergwerks A.G., Gelsenkirchen, Germany.

BONIFACIUS PIT KRAY NORD, NEAR ESSEN.

Illgner system. Koepe Pulley 23 ft. diameter. Net load 5.2 tons. Present depth 1,310 ft. to be increased later to 1,970 ft. Present speed 52 ft. to be increased later to 65 ft. per second. Present capacity 210 tons of material per hour, to be 190 tons per hour subsequently.

driver from exceeding a predetermined speed limit as long as the flywheel is disconnected.

A comparison between the economy of an Ilgner plant and that of other systems of electric winding should not take into consideration the winding plant only, but also the effect of the winder on the economy of the power system as a whole. Winding plants without means of compensating for the energy fluctuations throw widely and rapidly varying loads on the power station, and thus affect the efficiency of the prime movers and the boiler plant unfavourably. On the other hand, the power demand of an Ilgner plant is very steady, and therefore, the power station will operate at a comparatively high efficiency, so that the cost of energy production will be reduced, not only for the winder itself, but for all the other plant about the mine.

It is possible to reduce the losses in the slip resistance where two winding engines are situated in proximity to one another by coupling the flywheel converters, in accordance with patents granted to the Siemens Concern. This arrangement induces a certain equalization of the loads, so that the average speed reduction of the common converter set is reduced by approximately one-half, provided the flywheel for each plant is made as heavy as if the converter sets were not coupled.

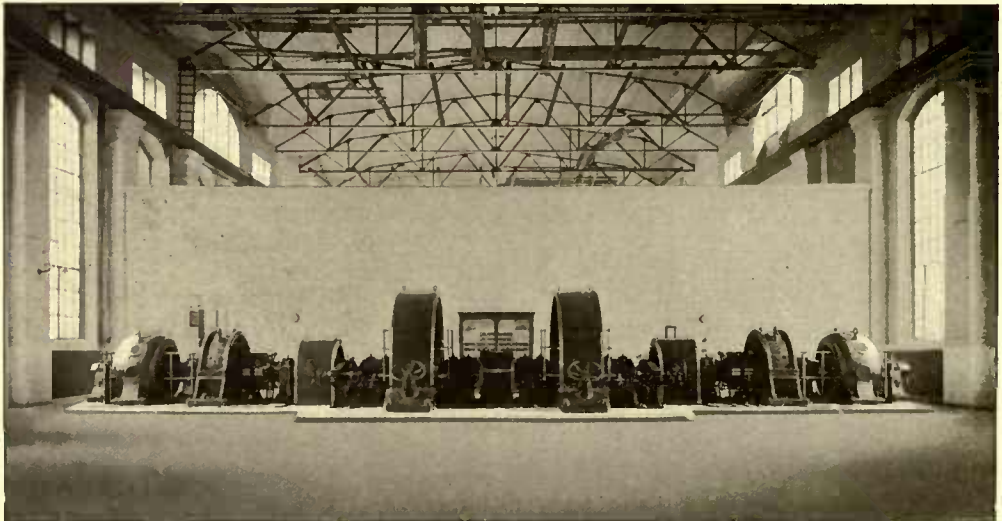


Fig. 68.

Double Converter Set at the Paulus-Hohenzollern Pit of the Count Schaffgot Administration, near Beuthen, Upper Silesia.

As examples of this arrangement the following plants may be mentioned :—

The double converter set for the Paulus-Hohenzollern Pit of the Count Schaffgot Administration, near Beuthen, Upper Silesia, Fig. 68, and the double converter sets of the Powell Duffryn Steam Coal Co., Britannia Colliery (Fig. 77), and the Markham Steam Coal Co., both in South Wales.

In the case of the winding plant at the Mathias Stinnes Pits near Essen, Fig. 73, the converter sets are connected in couples mechanically, and they

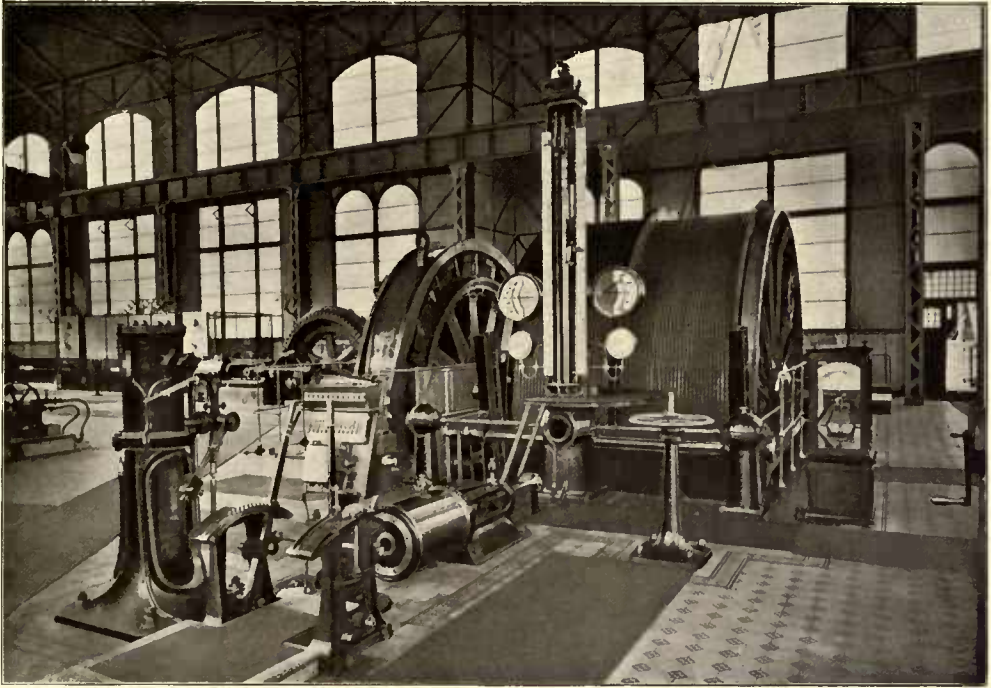


Fig. 69.

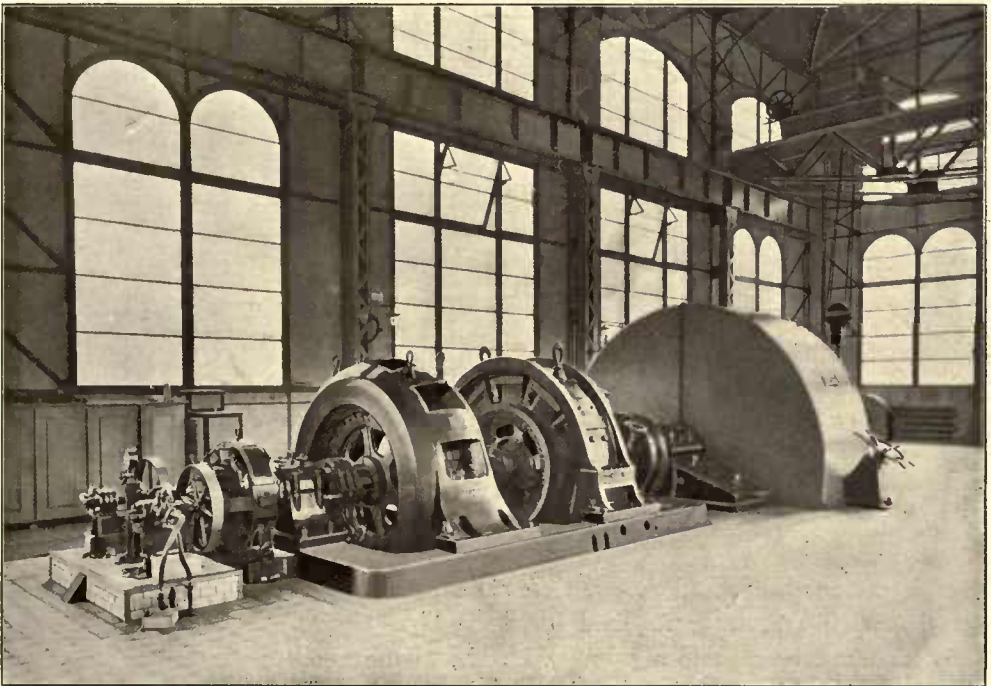


Fig. 70.

Austrian State Coal Mines, Witkowitz, Solomon Pit, Ostrau, Austria.

Illgner system. Cylindrical drums $16\frac{1}{2}$ ft. diameter. Net load 5.1 tons. Depth 3,270 ft. Speed 42 ft. per sec.
Capacity 120 tons of material per hour.

may be further interconnected electrically, so that all four flywheels are in use for compensating the energy fluctuations, and the loads of the four different winders are averaged. The general lay-out of this plant is shown in Fig. 71, while one winding engine and one double converter set are shown in Figs. 72 and 73.

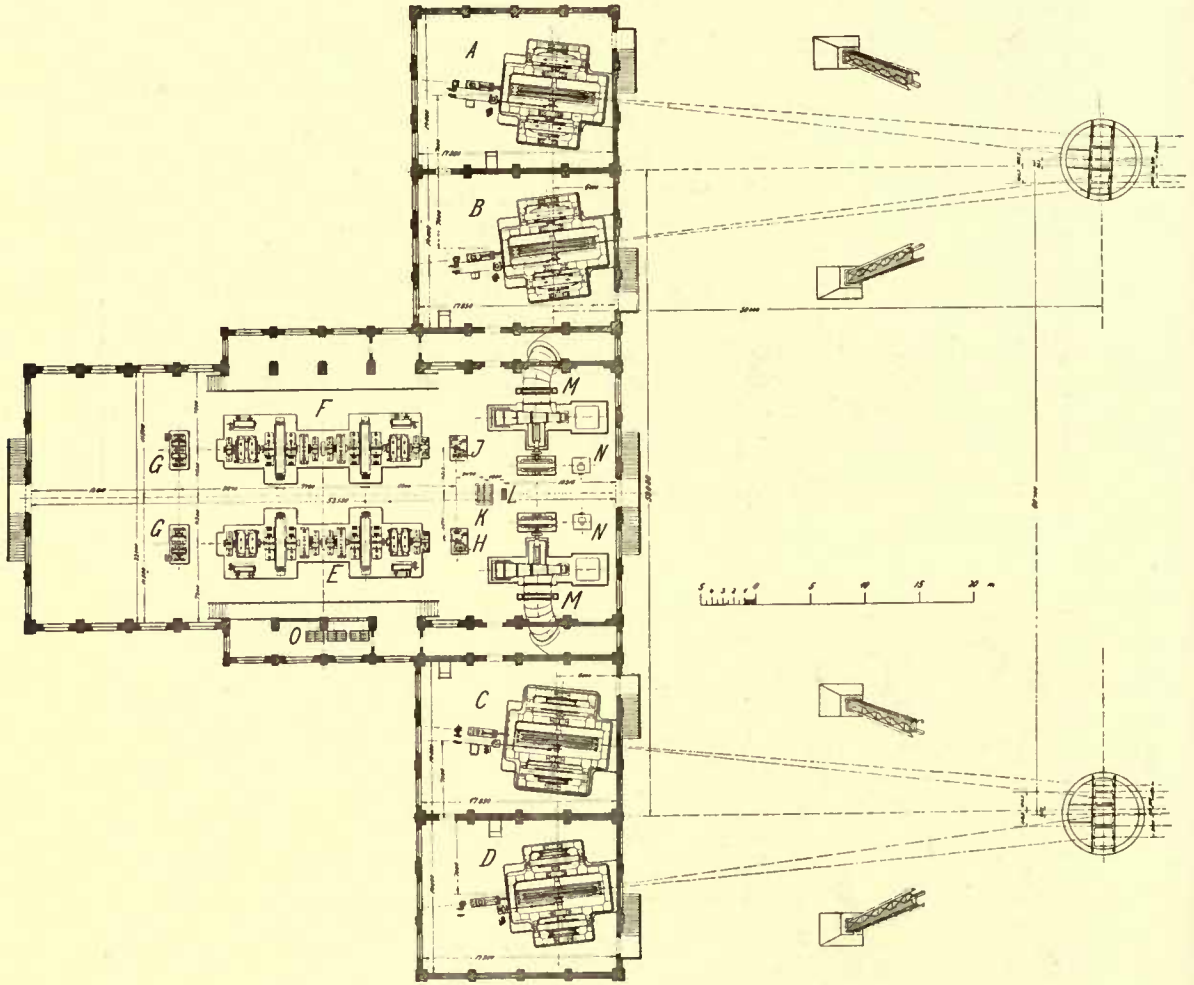


Fig. 71.

General Lay-out of Mathias Stinnes Pits, near Essen, Germany.

- | | |
|------------------------------|--|
| A, B, C, D Winding Engines. | K Inter-connecting Gear for armature circuits. |
| E F Flywheel Converter sets. | L Inter-connecting Gear for exciting circuits. |
| G Exciter sets | M Fans. |
| H J Air Compressors. | N Starter. |
| | O Switchgear. |

If preferred, a double converter set can be installed with a single flywheel of the same weight as required for a single converter. An arrangement of this kind can be seen in Fig. 79, which shows the winding plant of the Société Houillère des Mines de Liévin, France. In this case the mean speed reduction of the converter set is the same as for a single winding plant, but the coupling of the two converter sets effects considerable reductions in the friction losses. Under all circumstances, therefore, the coupling of the converter sets presents considerable advantages.



Fig. 72.



Fig. 73.

Mathias Stinnes Mines, Pit III-IV., Carnap, near Essen on the Ruhr, Germany.

Illgner system. Koepe Pulley 21 ft. diameter. Net load 4·8 tons. Present depth 1,640 ft. to be increased later to 2,620 ft. Speed 46 ft. per second. Capacity 100 tons of material per hour. The above converter is electrically coupled with three other winding plants at the same mine.



Fig. 74.

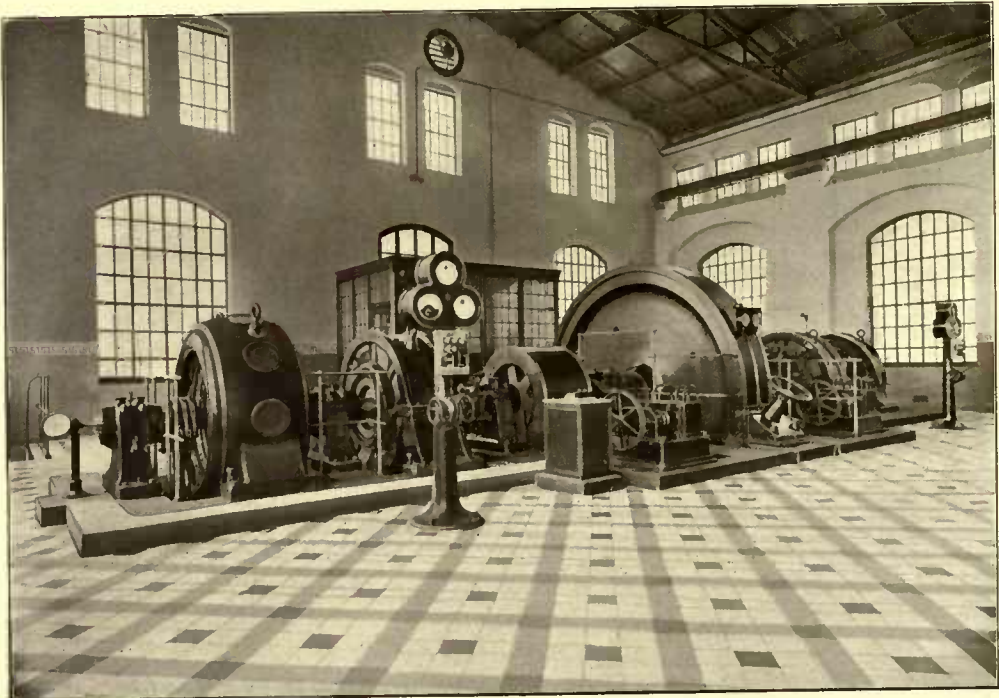


Fig. 75.

Dutch State Mines, Limburg, Holland.

WILHELMINA PIT, HEERLEN.

Illgner system. Cylindrical drum 20 ft. diameter. Net load 2.2 tons. Depth 1,640 feet. Speed 39 ft. per second.
Capacity 70 tons of material per hour.

The above converter is electrically interconnected with a second winding plant at the same mine.

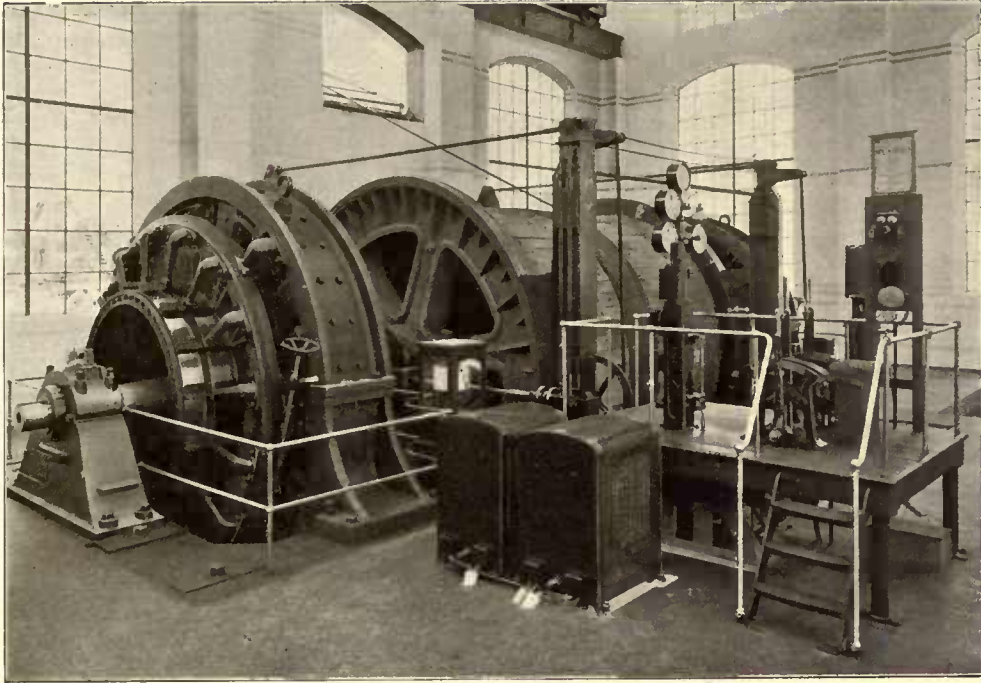


Fig. 76.

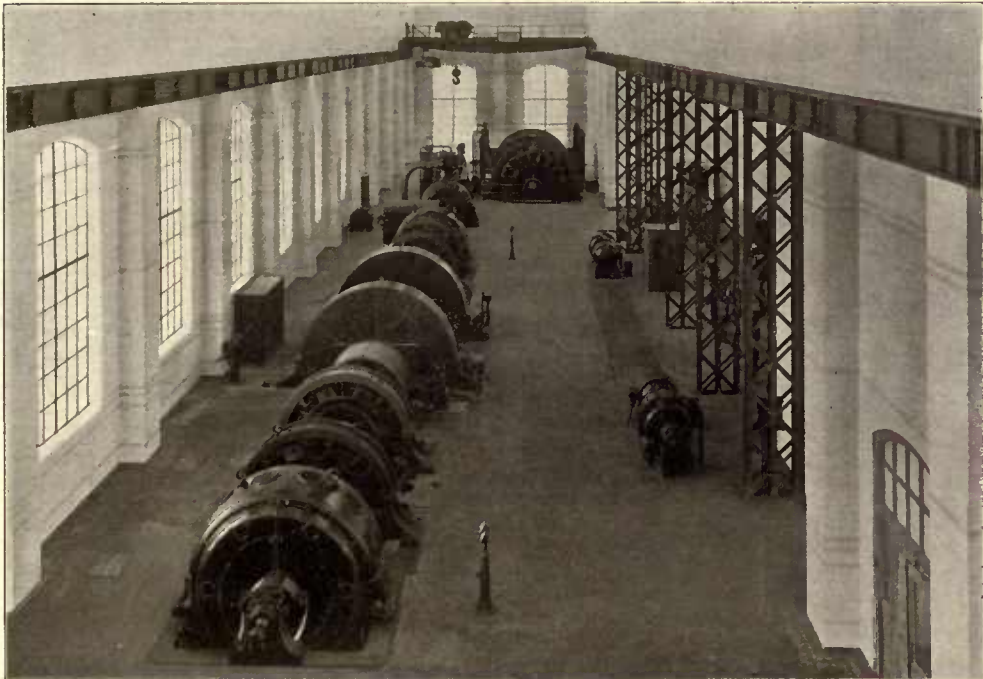


Fig. 77.

Powell Duffryn Steam Coal Co. Limited, South Wales.

Ilgner system. Drums at present cylindrical, to be replaced later by cylindro-conical drums, 14 ft. to 22 ft. in diameter. Net load 6 tons. Depth 2,190 ft. Present speed 26 ft. per second, to be increased later to 72 ft. per second. Present capacity 180 tons per hour, to be increased later to 360 tons per hour. The above converter set is electrically interconnected with a second winding engine at the same colliery.

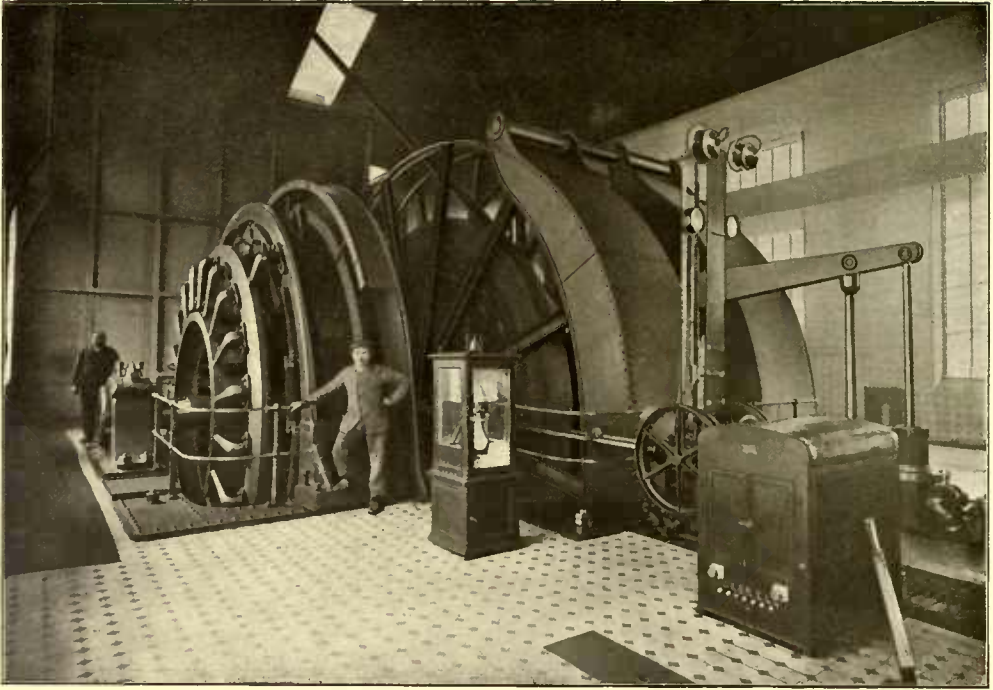


Fig. 78.

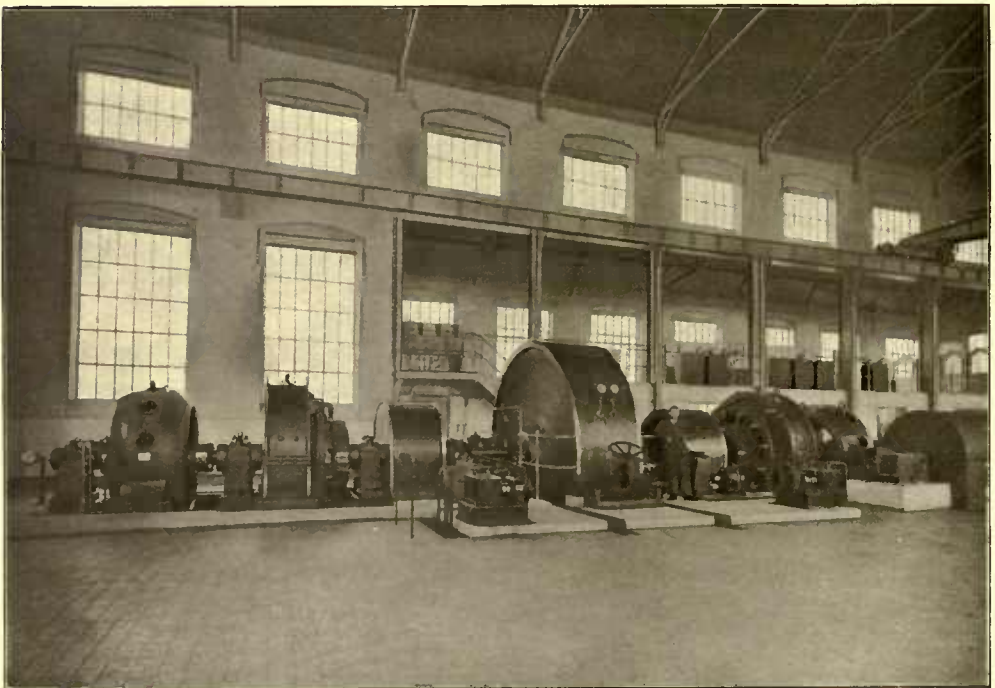


Fig. 79

Société Houillère des Mines de Liévin, Dep. Pas-de-Calais, France.

PIT VI, LENS.

Illgner system. Bobbins 12-25½ ft. diameter. Net load 5·6 tons. Depth 2,620 ft. Maximum speed 59 ft. per second.
Capacity 200 tons of material per hour.

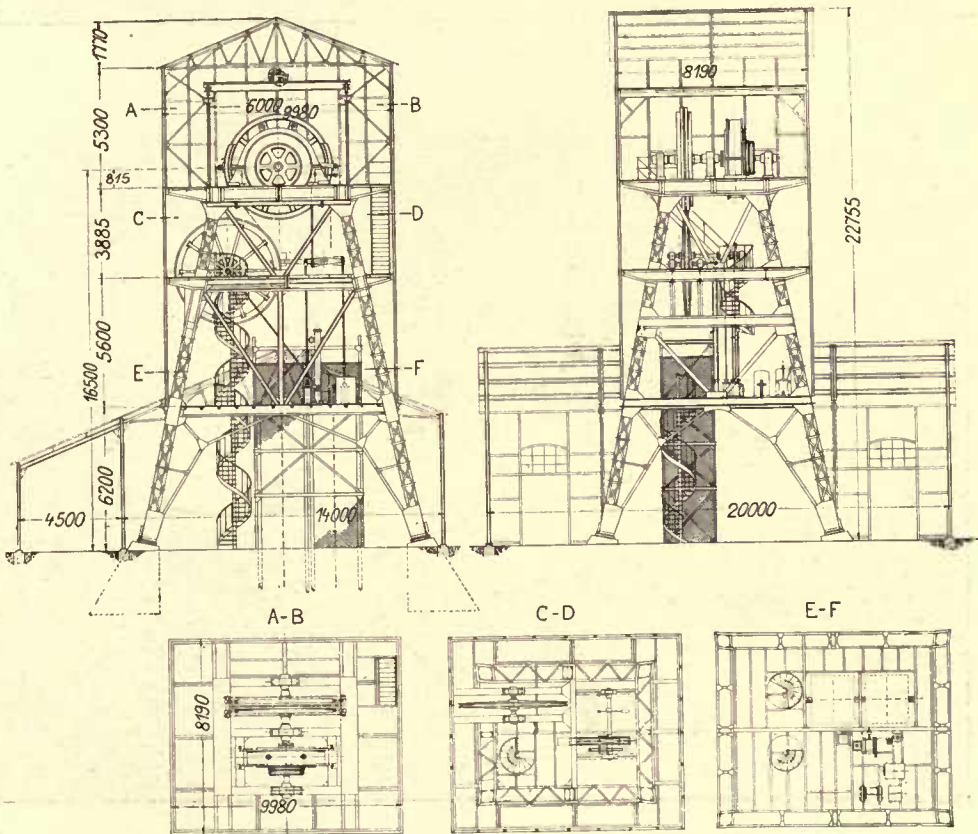
The above converter is electrically interconnected with a similar winding plant in the same mine.

The first cost of an Ilgner plant for large outputs is considerable, but has been appreciably reduced within the last few years by a number of improvements. The flywheels themselves have not only been made smaller and cheaper by the increase in peripheral speed, but the motors and the generators have also been cheapened by better utilization of the material and the adoption of high speeds.

The actual output of the generating plant can be lower in the case of an Ilgner winder than in the case of winders without balancer, because of the practically constant power demand of the former. The decreased expenditure for the power station will, therefore, partially compensate for the greater capital cost of the flywheel converter set.

The costs for maintenance, repairs and stores are so low, even in the case of the largest Ilgner plants, that they need hardly be considered in calculating the operating cost.

Occasionally it is possible to reduce the capital costs considerably by placing the winder in the head-gear directly above the shaft. A plant of this type, supplied for the Hausham Pit at Miesbach, Upper Bavaria, is shown



(Dimensions in millimetres.)

Fig. 80.

Example of Winder placed in the head-gear directly above the shaft, Hausham Pit at Miesbach, Upper Bavaria.

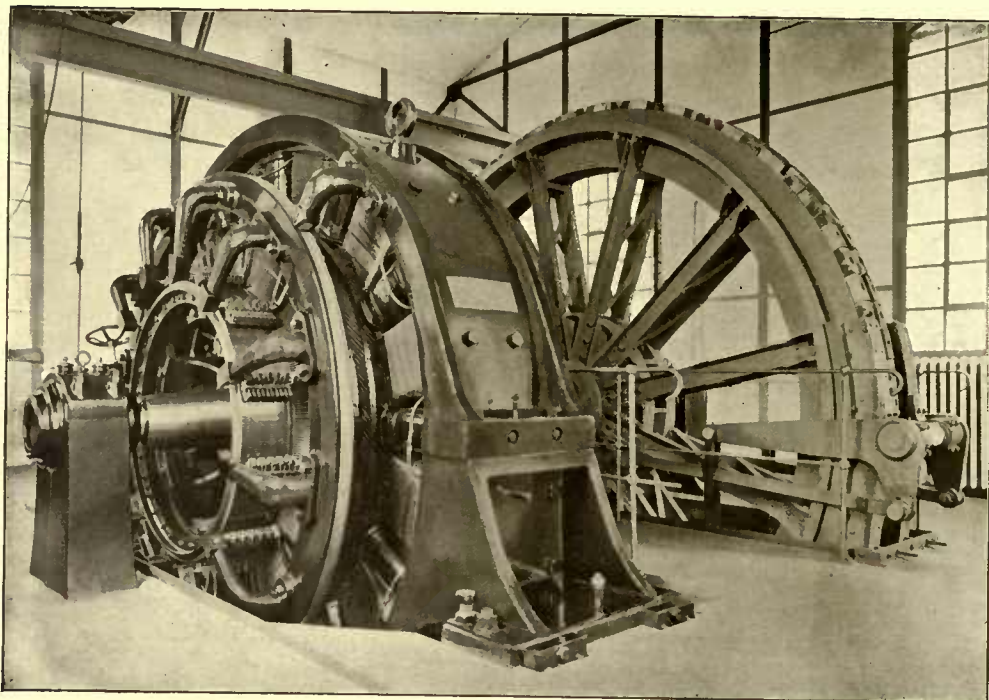


Fig. 81.

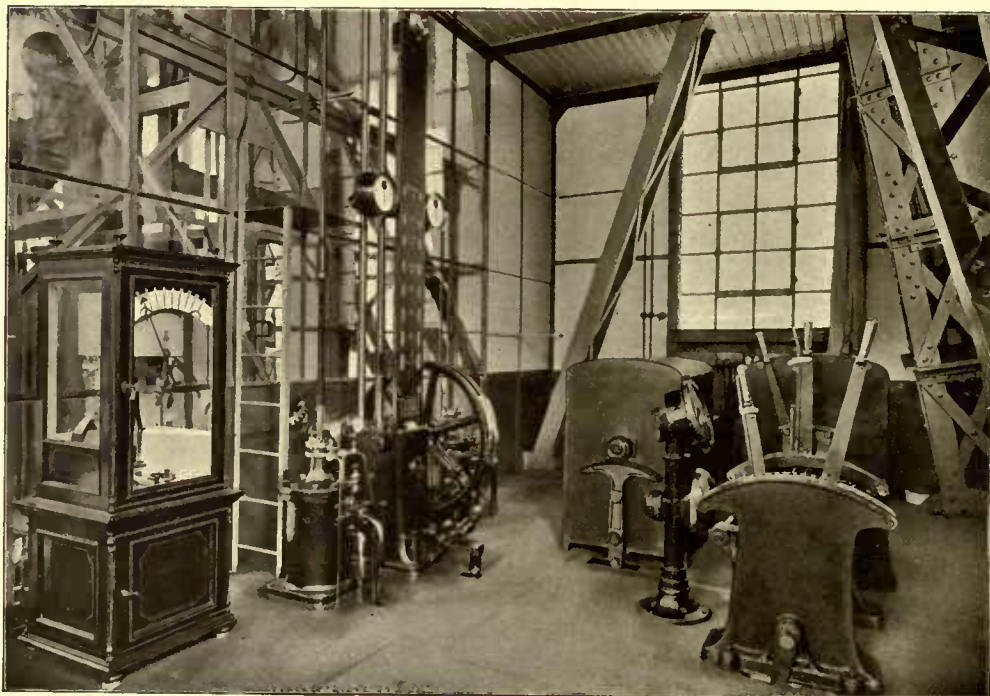


Fig. 82.

Upper Bavarian Coal Company, Miesbach, Bavaria, Germany.
HAUSHAM MINE.

Illgner system. Koepe pulley 15 ft. diameter. Net load 2.8 tons. Depth 2,460 ft. Speed $52\frac{1}{2}$ ft. per second.
 Capacity 108 tons of material per hour. The winding engine is mounted in the head-gear.

in Fig. 80. This winder is to operate with a maximum net load of 36 tons, and a total load on the rope, including the cage, of 12.25 tons, and the maximum speed is to be about 52 ft. per second, so that it may be classed as a comparatively large plant. The actual first cost of this installation demonstrated conclusively that the total capital cost can be materially reduced by placing the winder in the head gear, although this latter has to be made somewhat higher and heavier than would be necessary if the winder were placed on the ground level in the ordinary manner. The general arrangement of the winder, and of the control platform is shown in Figs. 81 and 82. A similar plant is shown in Fig. 83, which is made from a photograph taken during the erection of the head gear.

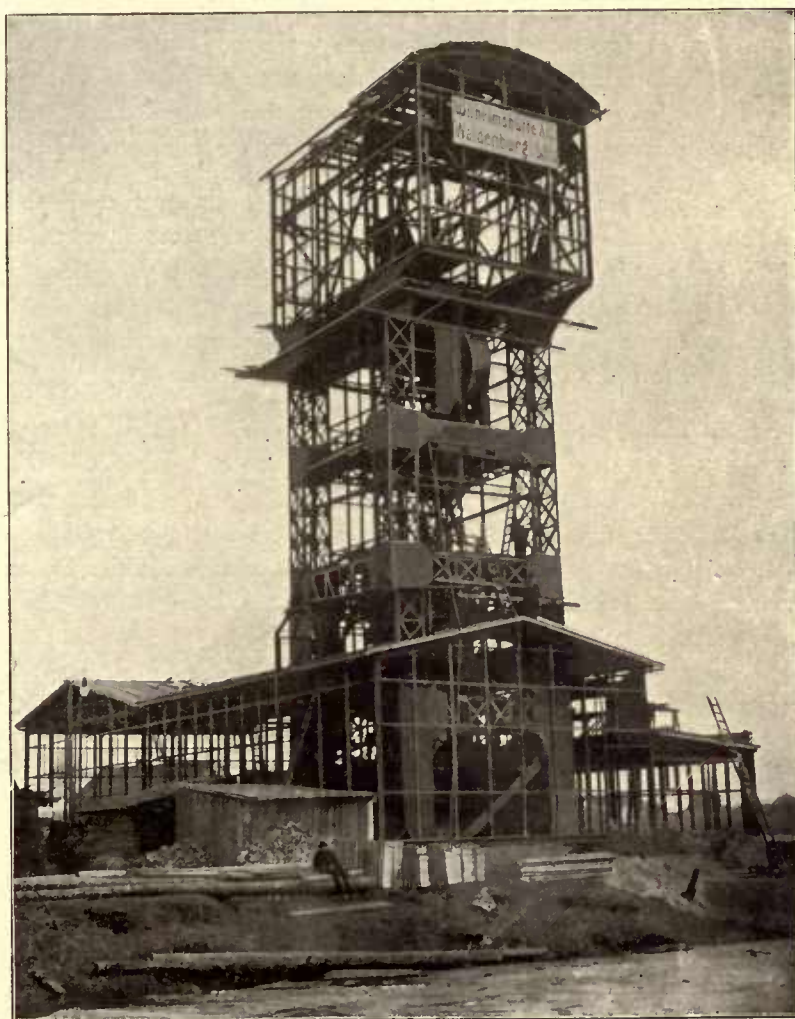


Fig. 83.

Head-gear to accommodate Winding Engine.

(From a photograph taken during erection.)

These installations are naturally confined to winders with Koepe pulleys, as the lead of the rope with drum winders and the varying radii with bobbins would cause considerable difficulty.

Steam and Electric Winders

The great gain in steam economy which was at once obtained by the use of the electric winders led to an increased competition between electric winders and steam winders, and resulted in considerable improvements in the latter.

The guarantees given by the manufacturers of steam winders usually only hold for full load on the winding engines, and cannot be considered correct for ordinary commercial operation. In order to obtain serviceable results as a basis of comparison, the Coal Owners' Institute in the Westphalian district, together with the Boiler Inspection Society in Dortmund, instituted a series of service tests on modern steam winders. These tests were made during the years 1908 and 1909, and extended over periods of from 8 to 24 hours. The results are given in Table I. At the same time comparative tests were carried out on several Ilgner winding plants, the results of which are given in Table II.

In order to reduce these figures to the same basis, that is, the steam consumption per shaft H.P.-hour, it is necessary to take account of the efficiency of modern turbo-generators. This type of machine will generate a kilowatt-hour on 13.5 to 16.5 lbs. of steam. This figure introduced into the calculations gives a steam consumption of the electric winding plants of from 22 to 24 lbs. per effective shaft H.P.-hour over long intervals of time.

It will be seen that the electric winder is superior to the steam winder as far as the actual steam consumption is concerned. Further, it should be borne in mind that the continual leakage losses involved in keeping the steam mains under pressure over night and during holidays were not taken into consideration when determining the consumption of steam winders, while the figures on the electric winders at the De Wendel Pit and at the Kruegershall Mine include the losses of the continually running converter set.

The installation of an electric winder necessitates an increase in the output of the power station, and consequently makes it possible to use larger units throughout the station. This tends to reduce the costs of the whole power for the mine, and is a factor which should not be left out of consideration when making a detailed comparison of the costs.

Quite frequently the main steam winder and the power station which generates electric energy for the remainder of the mine are supplied from a common boiler battery. The modern tendency in respect to power stations is to instal steam turbines, which for their part require highly superheated steam in order to operate at their highest efficiency. The reciprocating winder on the other hand cannot operate on highly superheated steam, and it is therefore necessary to work the whole plant at a lower steam temperature than would be most economical for the turbines. The steam consumption of the latter is consequently increased.

Both the steam winder and the electric winder with the variable-voltage

Table I.

| Installation. | Type of Engine. | Normal load per wind. | Winding depth. | Duration of test. | Total load raised. | Steam consumption per Shaft H.P.-hour. |
|---|--|-----------------------|----------------|-------------------|--------------------|--|
| | | <i>lbs.</i> | <i>ft.</i> | <i>hours.</i> | <i>tons.</i> | <i>lbs.</i> |
| 1. Schuerbank and Charlottenburg Mine. | Twin tandem steam engine cylindrical drums 26ft. dia. | 11900 | 1970 | a) about 8 | 1113 | 36.3 |
| | | | | b) ,, 24 | 1972 | 53 |
| 2. Julia Mine Pit II, near Herne. | Twin tandem steam engine cylindrical drums 26ft. dia. | 9300 | 1340 | a) ,, 8 | 979 | 59 |
| | | | | b) ,, 24 | 1900 | 68 |
| 3. Wilhelmina Victoria Mine. Pit I, near Gelsenkirchen. | Twin tandem steam engine. Koepe pulley 21 ft. 4 in. dia. | 10080 | 1990 | a) ,, 8 | 977 | 46.4 |
| | | | | b) ,, 24 | 988 | 61.1 |

Table II.

| Installation. | Normal load per wind. | Winding depth. | Duration of test. | Total load raised. | Energy consumption per shaft H.P.-hour | Steam consumption per shaft H.P.-hour. |
|--|-----------------------|----------------|-------------------|---------------------------------|--|--|
| | <i>lbs.</i> | <i>ft.</i> | | <i>tons.</i> | <i>KW-hours</i> | <i>lbs. *</i> |
| 1. Emscher Lippe Mine, Pit II. Datteln, near Essen. | 14000 | 2195 | a) 8 hours | 1802 | 1.39 | 20.65 |
| | | | b) 24 ,, | 3511 | 1.56 | 23.4 |
| 2. De Wendel Mine, Pelkum, near Hamm. | 12350 | 2425 | 365 days | 335704.35 | 1.54 | 23.1 |
| 3. Castellengo Pit of Count Ballestrem Mine Administration, Ruda, Upper Silesia. | 5060 | 850 | 11 hours | 1238 | 1.53 | 23.07 |
| 4. Potash Mine Krügershall Teutschenthal, near Halle Germany. | 3300 | 2460 | 365 days | 112647 hoisted 32538 lowered | 1.73 | 25.9 |

All the electrically-driven winding installations in the above table are on the Ilgner system.

* Assuming that the consumption per K.W.-hour is 15 lbs.

generator coupled directly to the prime mover reduce the efficiency of the boiler plant on account of the varying steam demand. They require the installation of flue-type boilers, containing large amounts of water, instead of modern water tube boilers which require less space, and are more efficient.

In comparing the capital costs, the expense of the boiler plant should be taken into consideration. The electric winder requires an appreciably smaller boiler plant than the steam winder, on account of the lower steam consumption. The cost of the power plant for the electric winder should only be taken as that amount by which it is actually necessary to enlarge the existing or the contemplated power station beyond the output required if the winder were not electrically operated. This increase in the station output hardly ever corresponds to the mean power consumption of the winding plant, because it is usually possible to arrange for the pumping plant to operate only during the shifts when the winder is standing still. Consequently, it is very frequently possible to keep the station output nearly the same as would be necessary if a steam winder were installed.

In the case of new mines, it is possible, when installing plant on the Ilgner system, to instal the winding plant progressively, instead of erecting a machine of the maximum output at once, as is necessary with steam winders. For instance it is possible at first to omit the flywheel entirely, and to wind at reduced speed. Then, when the output increases, and more coal has to be raised, the flywheel can be added and the winder speed increased to its maximum. If at a later date a further increase in the output is necessary, a second winding motor and a further motor-generator may be added, so that the net load per wind, and therefore the total output, can be doubled.

It is not necessary to expend the initial capital required for the maximum output at once, and the actual winding costs are therefore considerably lower during the first years than if an engine of sufficient size to wind the whole output had been put down in the first place. The difference in the steam consumption between the electrical winder and the steam winder is also considerably greater during the first years of operation than when the plant is working at full output. The different stages of such a progressive completion of the winding plant are shown diagrammatically in Fig. 84.

The even torque of an electric motor makes it possible to accelerate at a higher rate than is possible with a steam engine, this rate being governed by mechanical safety or, with a Koepe pulley, by the rope-slip. For the same reason the period of retardation of an electric winder can be considerably reduced as compared to that of a steam winder. The result is that for a machine of given output, the total time per wind can be reduced, and the output in material wound per hour increased correspondingly.

The simple operation of an electrical winder has also resulted in the increase of the permissible speed for winding men up to approximately 35 ft. per second, while the maximum speed of steam winders under the same circumstances is hardly more than 25 ft. per second. The consequent reduction in the time necessary for changing shifts is another factor increasing the total output of the mine.

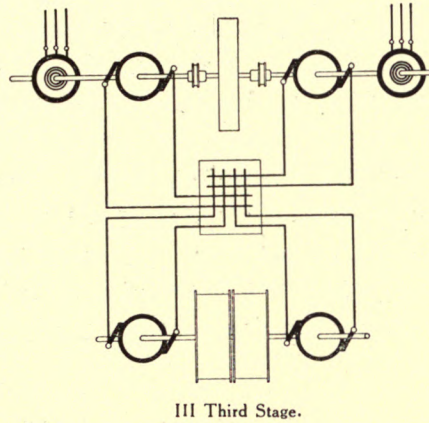
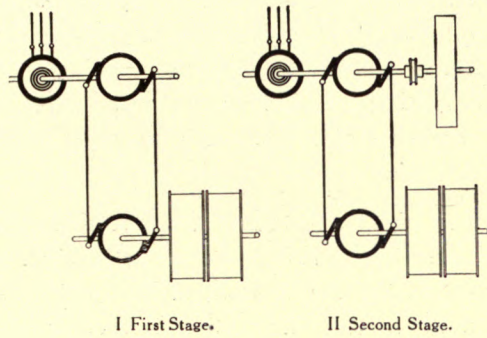


Fig. 84.

Different Stages in the progressive completion of Winding Plant.

Further, the costs for attendance, maintenance and repairs are considerably lower on electric winders than on steam winders.

The experience gathered during the years of operation of electrical winders has shown the fallacy of the former doubts as to the reliability of electric plant. As a matter of fact, none of the numerous electrical winders of all systems which have been installed by the Siemens Companies have ever been subject to a serious defect. The service interruptions are much rarer with electric winders than with steam winders, and are usually more easily remedied. Recent progress in the manufacture of electrical machinery has made it possible to insulate the windings successfully against high pressures, so that breakdowns on this score are becoming very rare. The introduction of commutation poles and compensating windings on direct-current machines has resulted in sparkless operation of the commutator under all conditions of load and speed, so that no difficulties are now met with in this respect.

Finally, the flywheel bearings in Ilgner plants have been so simplified by the introduction of ordinary ring lubrication and similar devices, that they

are practically as simple as the bearings of ordinary machines. Even, however, if a defect of some kind should occur, it is usually possible, when the winding plant is equipped with two motors, to continue working at a reduced output. For this purpose it is usual to provide interconnecting devices which make it possible to connect up each motor with each converter generator singly, or to connect the machines in pairs.

Similar arrangements can be installed in connection with double converter sets so that either winder can be driven from one or both converter sets. A steam winder does not permit the use of such devices so that any serious breakdown results in the complete interruption of the winding service.

The conditions which have been outlined in the preceding pages are all so strongly in favour of the use of electrical winding engines, that a steam winder will only present advantages in exceptional cases. But even in those instances where there is little difference between a steam winder and an electric winder as regards economy, the latter deserves preference because an installation on the Ward-Leonard system introduces a degree of safety unattainable with steam engines in spite of all improvements.

The advantage of the electric winder is placed beyond all doubt if the plant has to be installed below ground or at a pit not equipped with boilers, and supplied with electric energy from a power station operating under favourable conditions. In these cases a comparison of the operating costs will be found superfluous.

CHAPTER VIII

ELECTRICALLY-DRIVEN PUMPING PLANTS

Electrically-driven pumps, installed below ground, were introduced as early as the latter part of last century, and since then have come into nearly universal use. The rapid adoption of this method is the most conclusive evidence of its great technical and commercial advantages over steam drive. In addition to the principal advantages of the electrical distribution of energy, i.e., highly efficient centralized production and transmission, electrically driven pumping installations below ground present further advantages which are described in the following pages.

Steam-driven pumps require the installation of a boiler battery above ground, and necessitate the use of pipe lines of considerable length to supply the steam to the pumps. The unavoidable radiation from the pipes heats the air in the mine unnecessarily, in addition to other undesirable features of such a line. When electrical power is used all steam pipes, both in the shaft and in the drifts and roads, can be done away with. The temperature of the pump room itself can also be kept considerably lower when electrical machines are employed, as the radiation from these is considerably less than from steam machinery. Consequently, the pump rooms may be made smaller, and will be less costly.

The actual coal consumption of an electrically-driven pump set is considerably lower than that of a steam set, because the large losses due to condensation and leakage in the pipe line are avoided. Moreover, the electric motors consume no energy whatever when standing still, while the supply lines to the steam pump must be kept continually under steam in order to avoid damage due to changes of the temperature.

The costs of attendance, maintenance and repairs are also lower for electrical than for steam pumping sets. Electric motors, and especially three-phase induction motors, which are almost exclusively used in connection with these plants, require practically no attendance or maintenance, as they are subject to the least possible wear and require very little lubricating material. Properly installed shaft cables are practically immune from repairs, while steam pipes require constant inspection and frequent repairs, if they are to be kept in good condition. The first cost of an electrical pumping plant is usually lower than that of a steam set; moreover, the electrical drive makes it possible to instal high-speed centrifugal pumps, which are comparatively inexpensive, even for very large outputs.

With regard to reliability, the electrical drive is far superior to the steam drive. A failure of the supply need not be feared, if the power station is suitably designed

and has sufficient reserve power installed, and breakdowns of the shaft cable or of the motors themselves are extremely rare. On the other hand, steam pumps are themselves more subject to defects, and the supply lines are liable to frequent breakdowns, in addition to being a source of serious danger.

The question whether reciprocating pumps or centrifugal pumps are preferable for electrically-driven installations cannot be decided generally. If the amount of water to be pumped is small, say about 110 gallons per minute, or less, and the head is large, up to several hundred feet, the use of reciprocating pumps is almost universal, while when a large amount of water has to be pumped against a comparatively small head, centrifugal pumps are always preferable. Between these limits each case should be decided on its own merits, taking into consideration the following points.

Reciprocating pumps are considerably more expensive than centrifugal pumps, this being chiefly due to the fact that the pump chambers for their accommodation have to be larger ; the costs of attendance and maintenance are also higher than for centrifugal pumps. On the other hand, reciprocating pumps are less affected by gritty water, which causes serious damage to the guide vanes and impellers of centrifugal pumps. The centrifugal pump is designed for an absolutely constant delivery so that no pressure equalizer is required, while the reciprocating movement of plunger pumps requires the installation of some type of equaliser in the rising main ; even the introduction of an air chamber does not always entirely prevent variations of the pressure in the main.

The efficiency of reciprocating pumps is considerably higher than that of centrifugal pumps, an advantage which is partially counterbalanced by the higher efficiency and power-factor of the high-speed motors for centrifugal pumps as compared to the low speed motors employed for driving reciprocating pumps. The wide experience gained in the last few years with pumping plants of all kinds shows that the overall efficiency of electrically-driven reciprocating pumps, measured from the steam input to the prime mover to the actual net work done in lifting the water, is 65-70%, while centrifugal pumps show an overall efficiency of 55-60%. The power consumption of centrifugal pumps is therefore about 10-15% greater than that of reciprocating pumps.

The greater the amount of water, compared to the total head, the more favourable the working conditions for centrifugal pumps, whereas, when this ratio is smaller, reciprocating pumps are found to be more suitable. The final decision as to the choice of system will therefore be influenced mainly by the cost of the current and the average time of operation of the pumping plant, which affects the cost of interest and depreciation per thousand gallons pumped. A very satisfactory solution of the problem is offered by installing a reciprocating pump for continuous operation and a centrifugal pump as a reserve. A large number of pumping sets in continental mines have been installed on these lines during the last few years.

The amount of water is varied in accordance with the fluctuating supply by regulating the speed of the motor. A number of sets have been installed, in which the regulation has been effected by varying the frequency of the supply, but

this arrangement has the disadvantage that a separate generating unit is required for the pumping plant, an undesirable feature on account of the decentralisation of the power production. It would of course also be possible to vary the speed of the pump motors by means of some of the devices which have been recently introduced for the speed regulation of induction motors. As a rule, however, these expensive installations are dispensed with in connection with pumping sets, and the fluctuations of the supply are met by varying the time which the set is allowed to run. This mode of operation naturally requires a comparatively large sump, which, however, is usually provided in any case. When centrifugal pumps are used it is also possible to regulate the amount of water delivered by throttling the discharge side. This does not materially decrease the efficiency.

Electrically-Driven Reciprocating Pumps

The adoption of electrical driving introduced new problems in the construction and design of reciprocating pumps. As transmission through belts or gearing hardly comes into consideration, especially for pumps of large output, it became necessary to design the pumps to run at speeds which make it possible for pump and motor to be coupled directly. As a result of the progress which has been made in this direction it is possible to build reciprocating pumps of large outputs operating at speeds up to 150 R.P.M. These pumps are as reliable and otherwise as good as the slower running types, which were formerly in vogue. The rotor of the slow-speed driving motor is usually mounted direct on the shaft of the pump and constructed with sufficient weight to reduce the cyclic irregularity to a minimum. In order to reduce the fluctuation on the power consumption and consequent heating effects, the cyclic irregularity should not exceed 1 : 125.

To facilitate repairs to the pump in any position of the rotor, it is usual to provide the latter with a barring gear, so that it can be moved into any desired position. Adjustment of the air gap is provided for by fitting the stator on sliding feet so that it can be moved laterally. The vertical adjustment of the air gap is accomplished by placing liners under the stator feet. The larger motors are provided with detachable stator feet, so that after their removal, the stator can be turned on the rotor and the lower stator windings made accessible for repairs. In order to arrange for the easy transport of the machine through the shaft and the roadways underground, it is usual to divide the stator and rotor into several parts. When the pump is of the duplex or quadruplex type, this subdivision is specially desirable in order to facilitate erection.

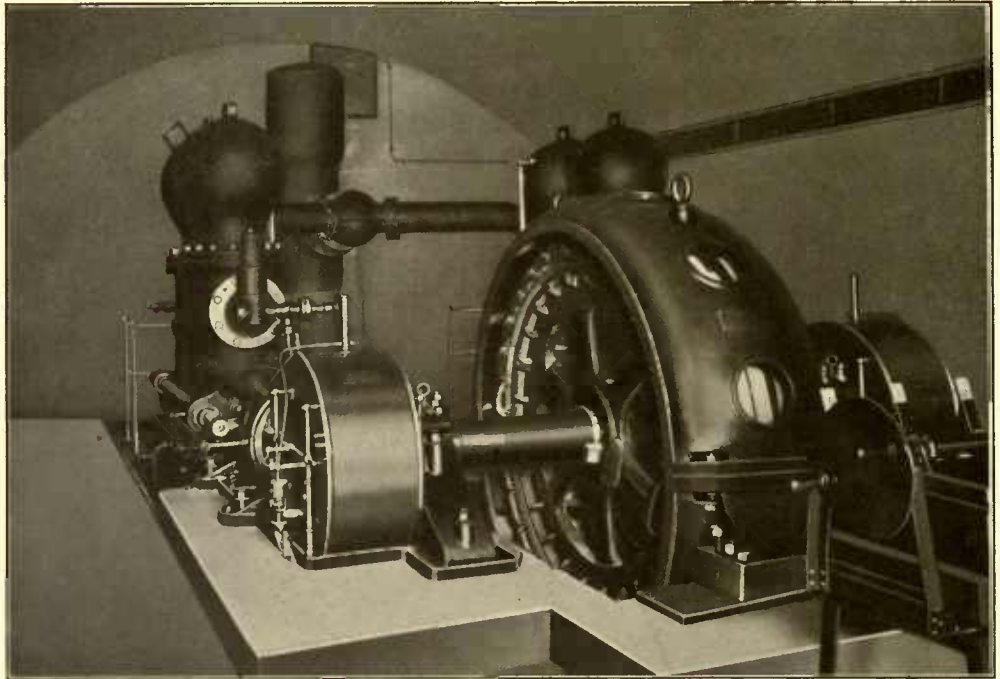


Fig. 85.

Royal State Mines, Pit Königshütte, Germany.

Electrically-driven reciprocating pump. Output 1320 gallons per minute. Total head 475 ft. Motor output 280 H.P., 2000 volts, 161 R.P.M., 50 cycles.

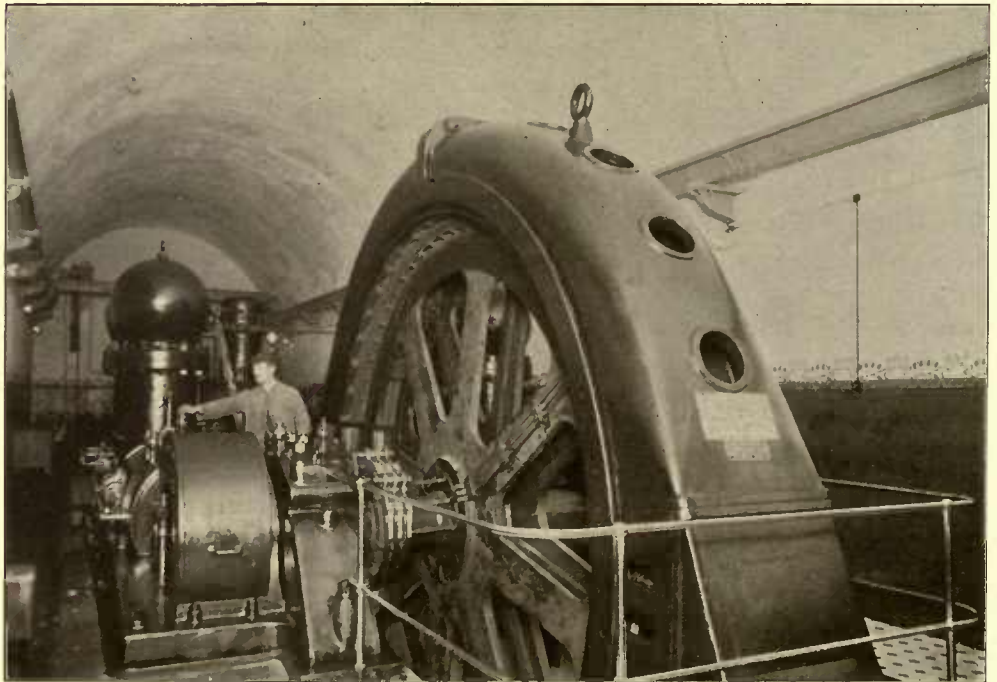


Fig. 86.

Gutehoffnungshütte, Pit Hugo, near Holten, Germany.

Electrically-driven reciprocating pump. Output 1100 gallons per minute. Total head 1575 ft. Motor output 710 H.P., 3000 volts, 91.5 R.P.M., 50 cycles.

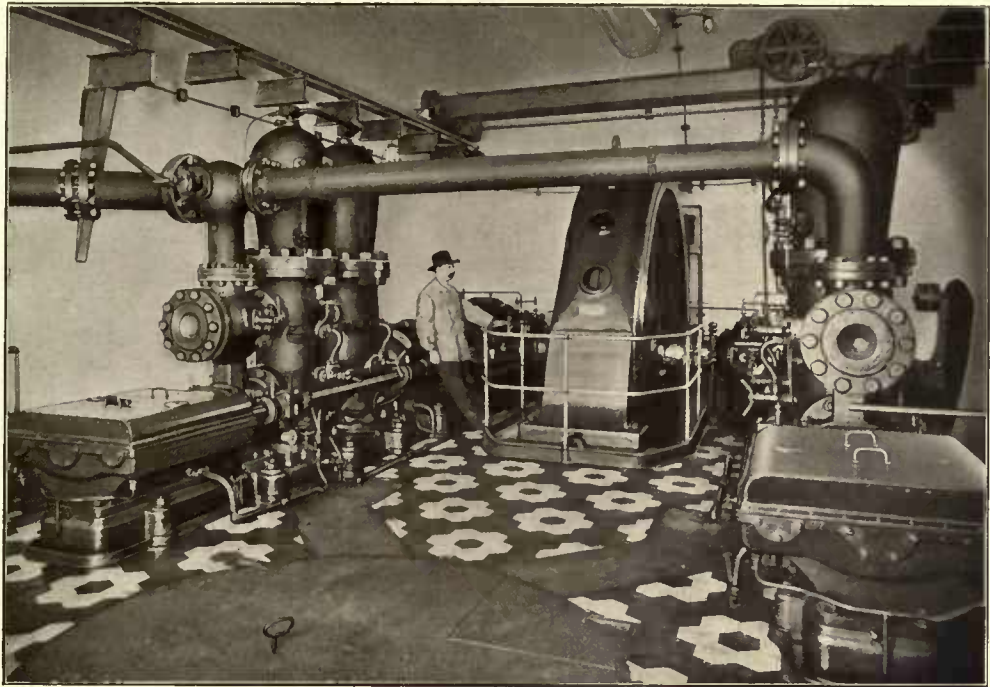


Fig. 87.

Royal State Mines, Pit Waltrop, Germany.

Electrically-driven reciprocating pump. Output 660 gals. per min. Total head 2030 ft., Motor output 520 H.P., 3000 volts, 91.5 R.P.M., 50 cycles.

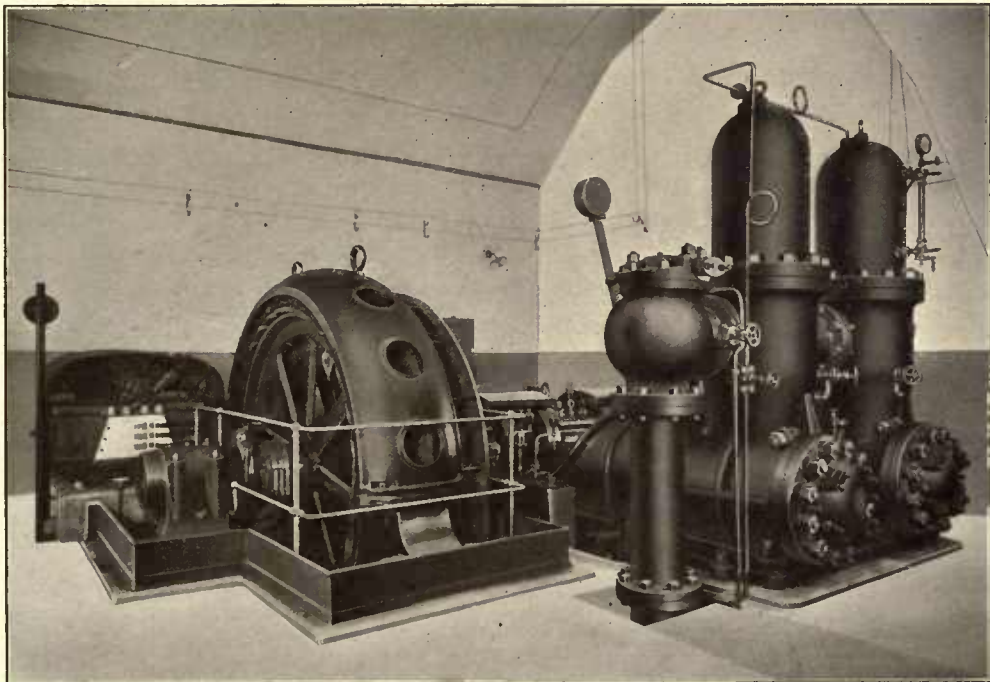


Fig. 88.

Eschweiler Bergwerksverein, Pit Gouley near Morsbach, Germany.

Three electrically-driven reciprocating pumps. Output each 1100 gals. per min. Total head 1540 ft. Motor output 650 H.P. 3,500 volts, 147 R.P.M., 50 cycles.

Pump motors of large output are only constructed in the so-called protected type. They are provided with damp-proof insulation and the sliprings are fitted with brush-lifting and short-circuiting device, so as to reduce the wear to a minimum. In mines where firedamp is likely to occur, it is usual to enclose the sliprings in a flame-proof casing, although as a rule this precaution will not be necessary, because the pump rooms are nearly always located on the intake airway. The motors can be started by means of rotor resistances, which may be either of the metallic or of the liquid type. If the pump has to start against the full head, the starter should be designed for double the motor output, in order to prevent undue heating. The introduction of a by-pass is therefore to be recommended in practically all cases. The pump motors can be always connected direct to the supply line, so that transformers need only be installed in the pump chamber for the small motors driving the air compressors for the receivers, and for the lighting installation.

In order to prevent excess voltages when switching the stator winding on to the line, it is usual to provide large motors with switches equipped with buffer resistances through which the pressure is first applied to the stator. The switchgear for these motors should be placed in sheet-iron or cast-iron pillars, as it has been found that ordinary open switchboards are not desirable below ground.

The reliability of the pumping plant depends to a considerable extent on the general arrangement of the pump room. It is especially desirable that the walls of the pump room be as dry and watertight as possible, so that the motor itself is protected from dripping or splashing water. Further it is advisable to provide the motor pit with a protecting wall of suitable height, as shown in Fig. 88, so that if water should get into the pump room the motor itself is protected for some time. Further it is advisable to introduce a non-return valve in the rising main where it leaves the pump room, in order to prevent the water in the main itself from entering the pump room in case of a break or a leak in the pipe line.

Electrically-Driven Centrifugal Pumps

Centrifugal pumps are specially suitable for direct electrical drive, on account of the high speeds at which they operate. In most cases the supply in mining installations is three-phase current with a frequency of 50 cycles per second, so that only certain speeds, i.e., 3,000, 1,500 and 1,000 r.p.m. are possible. Until recently, motors of these speeds were not built for more than a few hundred horsepower, but at present reliable high-speed motors with outputs of 1500 H.P. and more can be supplied. Such motors naturally require considerable care in their design and construction in order to meet the requirements of the service which they fulfil. They are either of the protected or of the induced draught type; in the latter case, they are protected against splashing water and similar influences. If the local circumstances are especially unfavourable it may be necessary to instal a totally-enclosed motor, but machines of this type for larger outputs must be provided with artificial means of cooling. The necessary cooling water is usually taken from the first pressure stage of the pump. For small and medium outputs the motors are provided with end-shield bearings, while for motors of larger outputs pedestal bearings are the rule. The bearings themselves are usually of the ring-lubricated type, but in cases where the service is specially severe, water-cooled bearings are provided. In order to facilitate erection and dismantling of the pump, it is advisable to mount the motor on slide rails, which permit movement either in an axial or in a transverse direction (Figs. 93 and 90). The latter arrangement is usually preferred if the motor is provided with two shaft extensions and is connected to a centrifugal pump at each end.

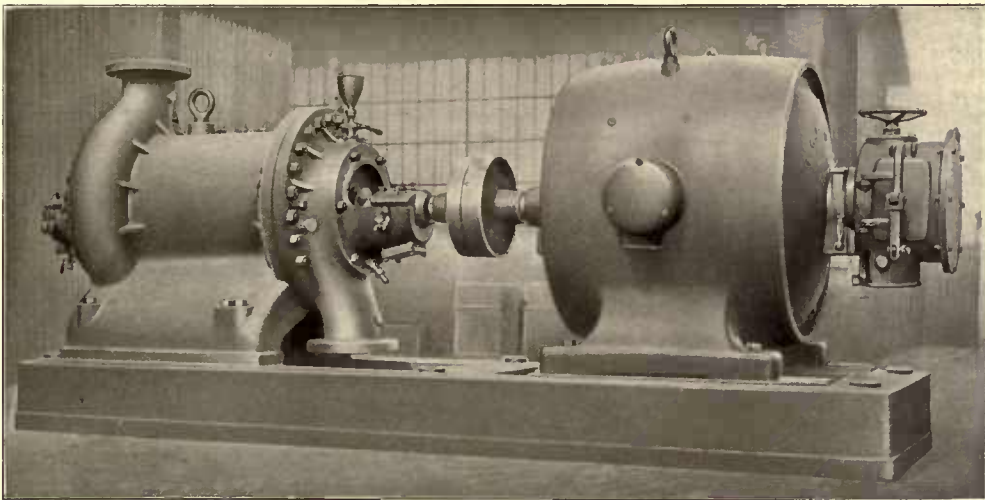


Fig. 89.

Mines de la Bouble, France.

Electrically-driven centrifugal pump. Three-phase motor, output 300 B.H.P., 2,000 volts, 1,500 R.P.M., 50 cycles. With flame-proof slippers.

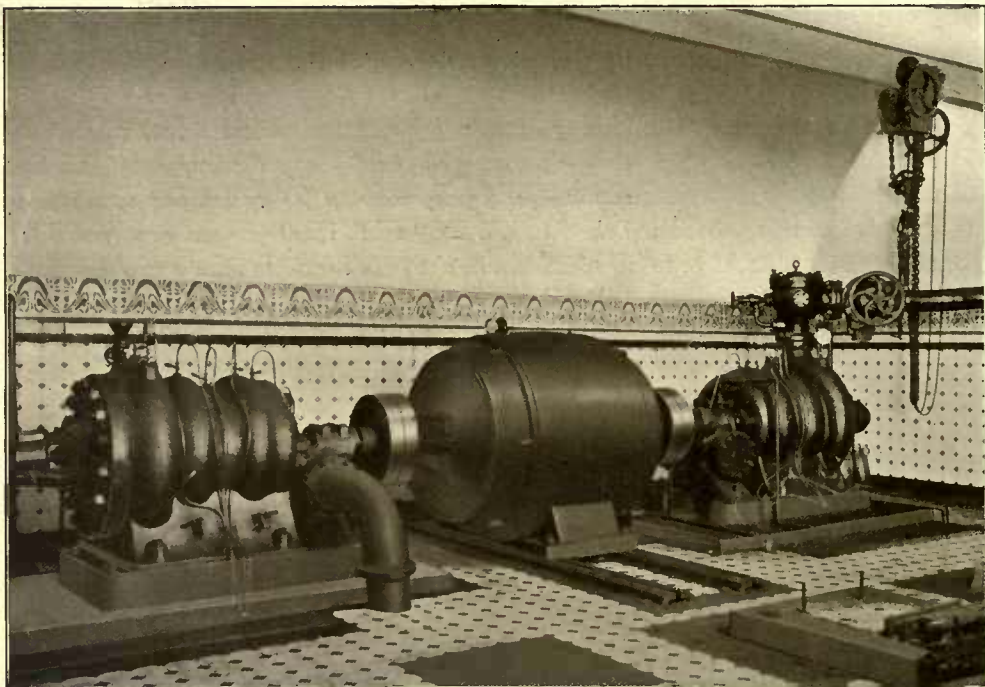


Fig. 90.

Gutehoffnungshütte, Pit Oberhausen, Oberhausen, Germany.

Electrically-driven centrifugal pump. Output 660 gals. per min. Total head 2100 ft. Motor output 650 H.P., 3000 volts, 1485 R.P.M., 50 cycles.

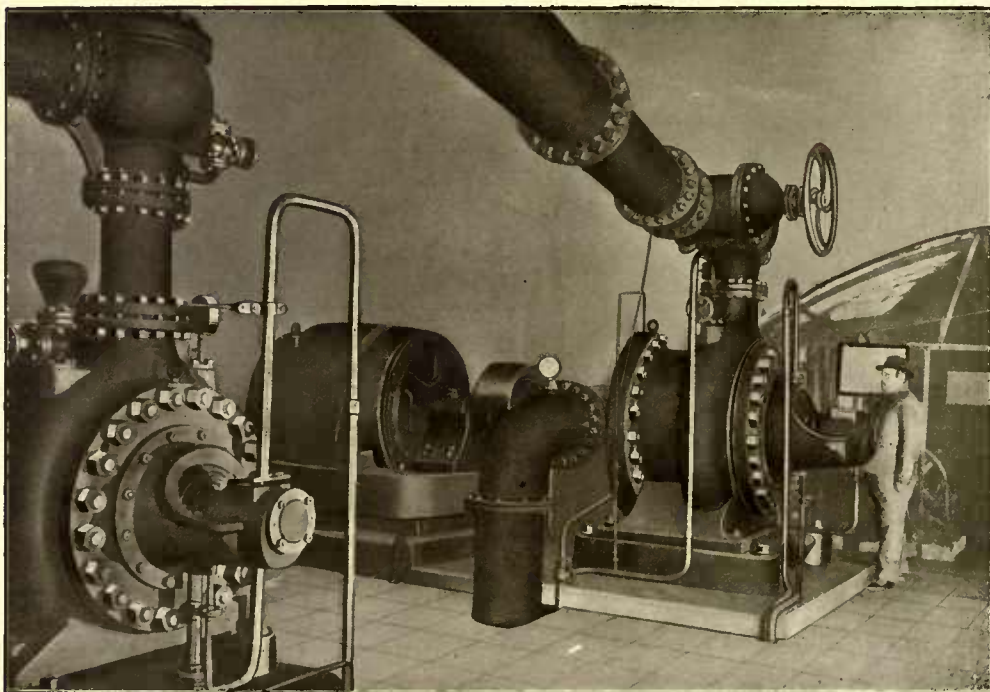


Fig. 91.

G. v. Giesches Erben, Cons. Cleophas Mine, Zalenze, Germany.

Two centrifugal pumps. Output, each 1540 gals. per min. Total head 1475 ft. Motor output 1560 H.P., 3000 volts, 1490 R.P.M., 50 cycles.

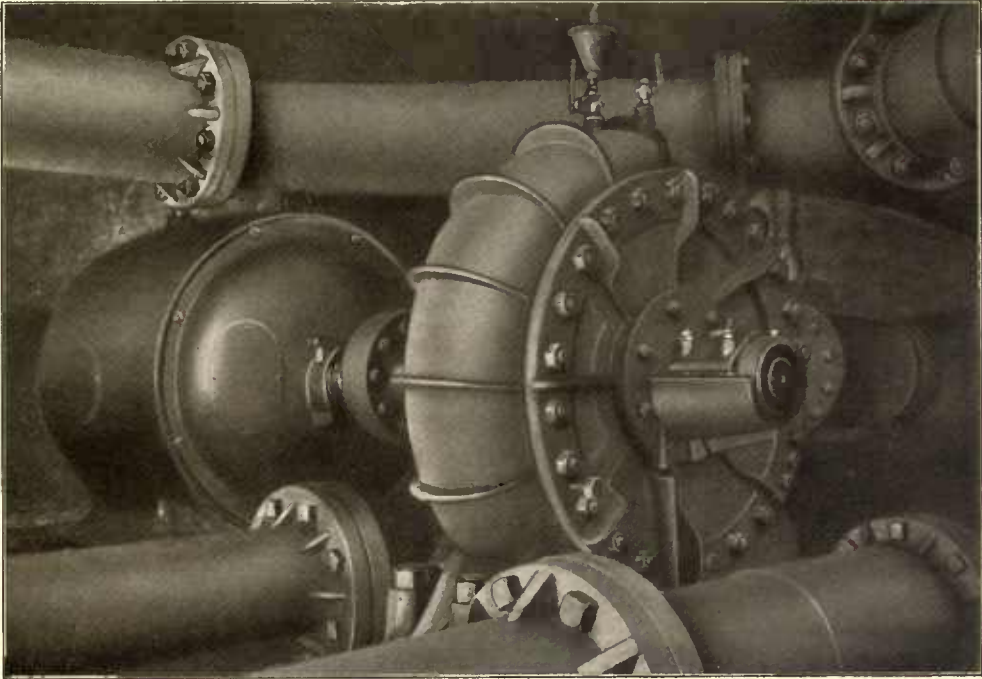


Fig. 92.

Lambton Collieries, Lady Durham Pit, South Durham, England.

Output 2,900 gals. per min.

Total head, 315 ft. Motor output, 325 H.P. 600 volts. 1,170 R.P.M. 40 cycles.

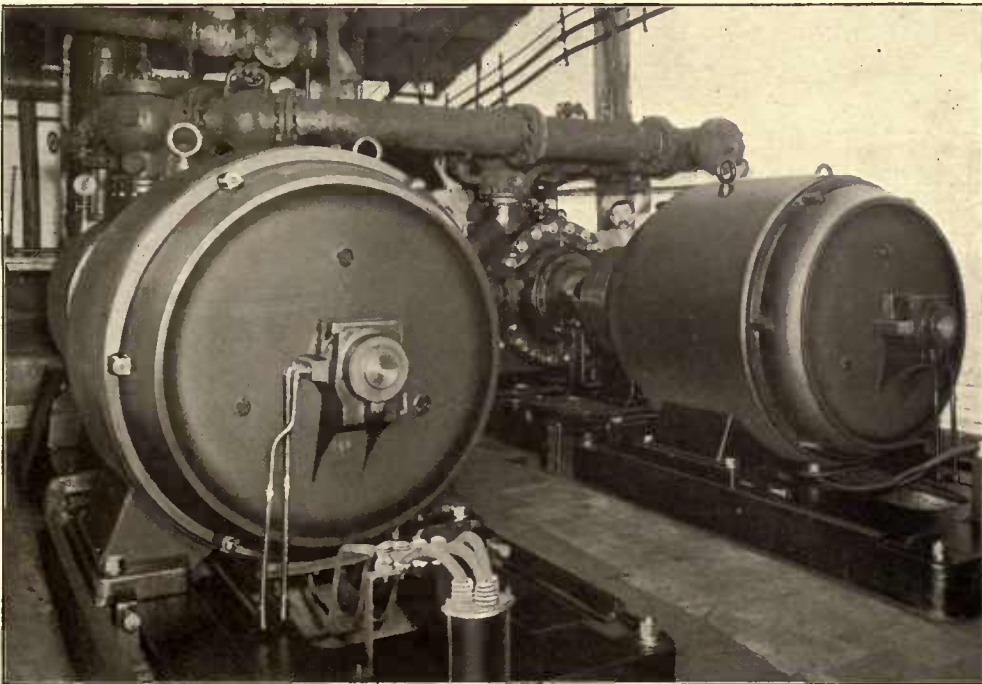


Fig. 93.

Charbonnage de Courcelles du Nord, Belgium.

Three centrifugal pumps. Output, each 1320 gals. per min. Total head 950 ft.

Output 625 H.P., 3000 volts, 1485 R.P.M., 50 cycles.

The motors which drive centrifugal pumps can be connected direct to the high-pressure supply. They can be fitted either with slipping or with squirrel-cage rotors. Motors with slipping rotors, can, as in the case of motors for reciprocating pumps, be started by the aid of either liquid or metallic starters. These starters, however, can be designed for a smaller output, because the pumps usually start with the rising main valve closed, so that the maximum load on the motor at starting will not be more than 40% of the normal. Motors with squirrel-cage rotors are started by means of a starting transformer, which applies the voltage to the stator in two or more steps according to the torque that has to be attained ; it is, however, not quite possible entirely to avoid heavy current rushes, so that large squirrel-cage motors can only be used in connection with power stations of large outputs. A number of electrically-driven centrifugal pumping plants is shown in Figs. 89 to 94. Up to the early part of the year 1912 the Siemens Concern had installed about 250 large pumping sets of this type with a total output of about 150,000 H.P.

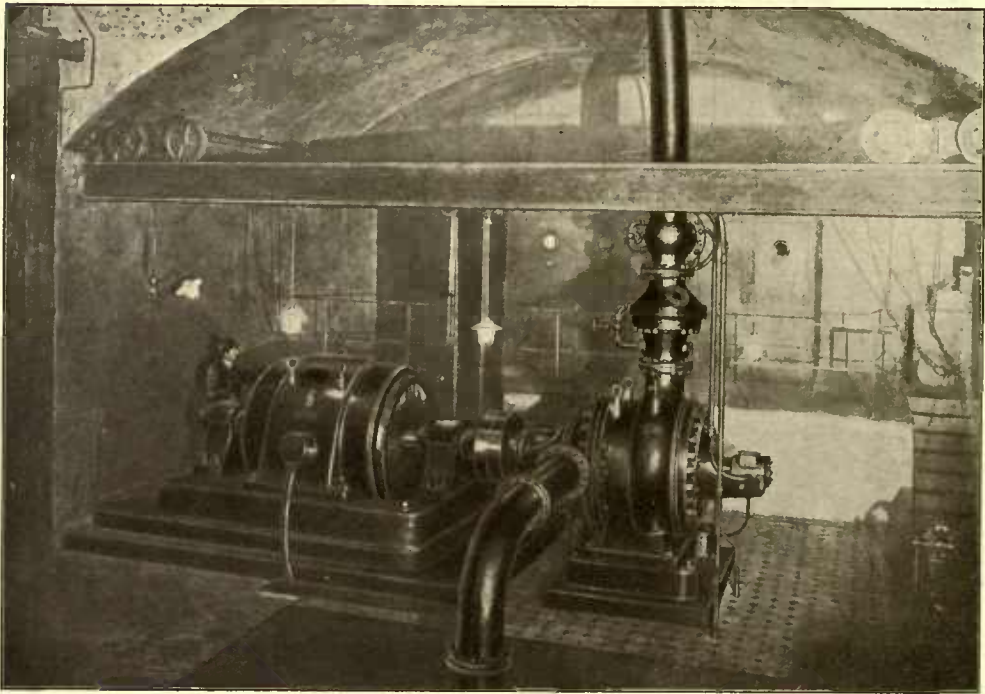


Fig. 94

**G. v. Giesches Erben Mining Company, Consolidated Cleophas Mine,
Zalenze, Germany.**

Electrically-driven turbine pump. Output 2200 gals. per min. Total head 1475 feet: Motor output 1560 H.P.,
3000 volts, 1490 R.P.M., 50 cycles.

Electrically-Driven Sinking Pumps

The advantages of electricity for driving pumping plants are especially evident in the case of sinking pumps. The steam reciprocating pumps, which formerly were used for sinking work, have had to give way to electrically operated sinking pumps, both on account of the general disadvantages of steam operation and those of the reciprocating pump as such for sinking purposes. The steam plant increases the temperature in the shaft to an undesirable degree, causing the working conditions, which in themselves are very unfavourable in pit sinking to become still worse.

The installation of the steam-piping presents considerable difficulties because the pumps have to be movable. The steam consumption of the pumps, which work under very unfavourable conditions is very high, and further, considerable condensation losses occur in the pipes themselves. These are especially heavy for sinking plants because it is nearly always impossible to keep the pipes suitably covered.

Reciprocating pumps have great disadvantages for sinking work in that the reciprocating movements of the plungers make a steady suspension in the shaft impossible, and that the pumps are very heavy and take up much space. These difficulties would not be overcome even by using the electrical drive, and centrifugal pumps are to be preferred.

The introduction of electrically-driven pumps made it possible to use centrifugal pumps with vertical shafts. These are direct coupled to the motor and form very compact sets, which take up very little space in the shaft. The even turning moment of the pump and the motor allows of an entirely steady suspension in the shaft. The current is supplied to the pump motor through a light shaft cable, which requires practically no attention or repairs.

The power consumption of such a set is very low, because both the pumps and motors operate at very high efficiency. Moreover it is possible to regulate the pump output by throttling the discharge. As a result of these advantages the electrically-driven pump has, in some countries, entirely replaced steam sets for sinking operations.

Its most serious competitor is the water winding system of Thomson, in which the water is wound from the pit by means of a winding engine and suitable buckets. But this system has several disadvantages; the winding engine must be built for large loads up to ten tons and consequently is expensive and only in a few instances will it be possible to use it later for winding coal, as the light load at which it would be required to operate would reduce the efficiency materially. The working costs of a water winding plant are also considerably higher than those of electrically-driven sinking pumps. It has been found by tests that the actual fuel consumption of a water winding plant is about double that of an electrical sinking pump for the same duty. The high power consumption of the water winding system will be readily appreciated if the large masses to be accelerated and retarded with each wind are considered, and it is remembered that the energy contained in them must nearly always be absorbed by mechanical braking.

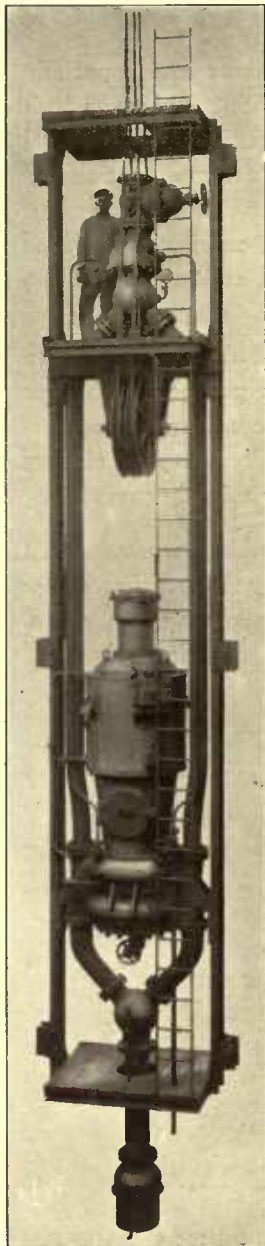


Fig 95
Société des Mines de
Jarny, Jarny, France.
 Electrically-driven sinking pump.
 Output, 1100 gallons per minute.
 Total head 737 ft. Motor output
 400 H.P. at 2,000 volts, 1475
 R.P.M., 50 cycles.

A further disadvantage of the water winding system is the large amount of space which it occupies in the shaft. The large water hoppits, and their guides take up the major part of the shaft section, and the space at the bottom of the pit is very much cramped by the water reservoir, from which the hoppits are filled. The system is further complicated by the necessity of forcing the water into the tanks either with compressed air, steam or electrically-driven pumps.

It is sometimes claimed that one of the disadvantages of electrically-driven sinking pumps is the excessive wear of the guide vanes and impellers through the gritty water, which frequently has to be pumped. It is natural that the life of the moving parts is not as long when the water is dirty, as when it is clean, and it is necessary to keep a sufficient amount of reserve material in stock to prevent serious stoppages. It will always, however, be possible to prevent the worst impurities from entering the pump by the provision of a suitable strainer, and further, the wear of the rotating parts can be reduced by the choice of suitable material. A complete spare set should, if possible, be kept in reserve ready for operation. This allows repairs to be carried out without interrupting the service, and provides also a certain measure of safety against unexpected large influxes of water.

Generally it is advisable to build the pumps for a large output, in order that the water which collects at the bottom of the pit, when the pump has been hoisted up for blasting operations, can be removed in the shortest possible time.

The sinking pumps require to be extremely carefully designed and constructed, in order that they may give reliable service under the extremely severe conditions to which they are subjected. The experience gained by the installation of a large number of sinking plants and the perfection of the design through long co-operation with first class pumping firms have put the Siemens Concern in a position to deliver complete sinking equipments which will conform to all reasonable requirements.

The pumps themselves are built with one or more stages according to the amount of water to be raised and the head. As the centrifugal pumps operate with the stages in series, it is possible at the beginning of the sinking operations to

run the pump against the reduced head, replacing some of the impellers by blank discs. When a greater depth has been reached, the increased head can be met by putting more stages into operation. The weight of the rotating parts is balanced hydraulically in the pump, so that the load on the bearings is reduced to a minimum.

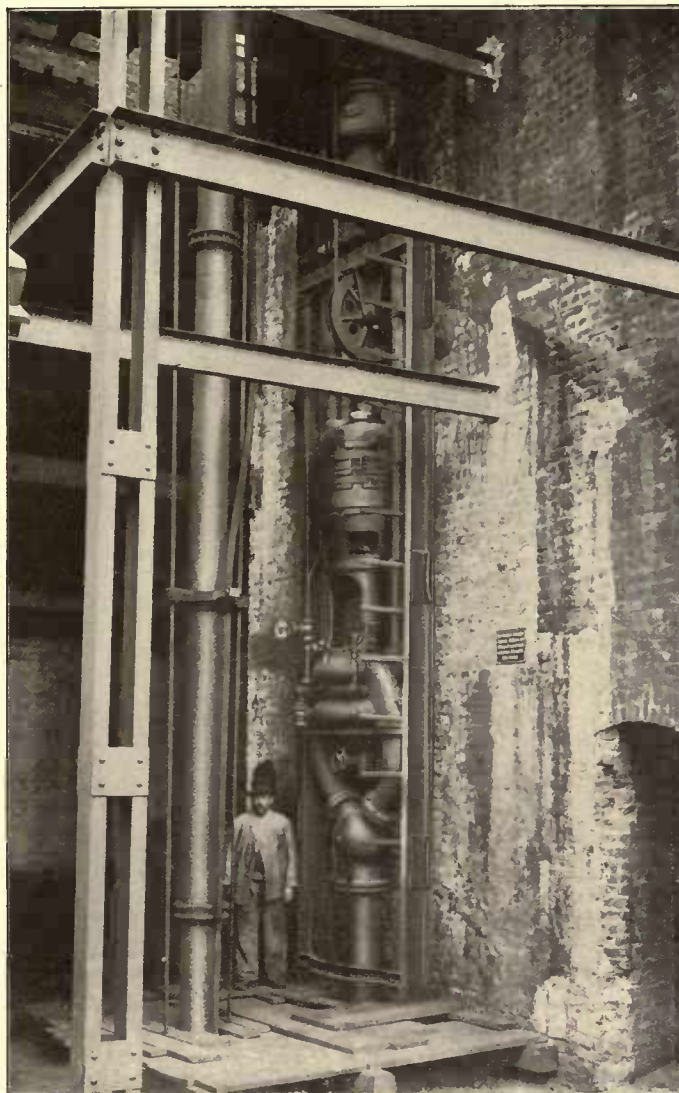


Fig. 96

Aachener Hütten-Aktienverein. Rote Erde, Germany.

Two electrically-driven sinking pumps. Output, each 880 gallons per minute. Total head 246 feet.
Motor output 100 H.P., 325 volts., 1460 R.P.M., 50 cycles.

The motor is placed above the pump and its frame is connected to that of the pump by means of a strong cast-iron connecting piece. An elastic coupling is provided which can be readily disconnected. The pump and the motor are mounted in a frame work of girders provided at the top and at the bottom with a

strong platform of heavy timber as a protection against pieces of stone or other objects falling down the shaft. A frame of this type complete with pump and motor is shown in Fig. 96. It is usual to provide a platform for the necessary inspection of the machines, on which all of the instruments and apparatus for controlling the plant, can be accommodated. The attendant, therefore, need not leave his post, when the set is in operation. A ladder, which is attached to the framework, facilitates access to all parts of the pump.

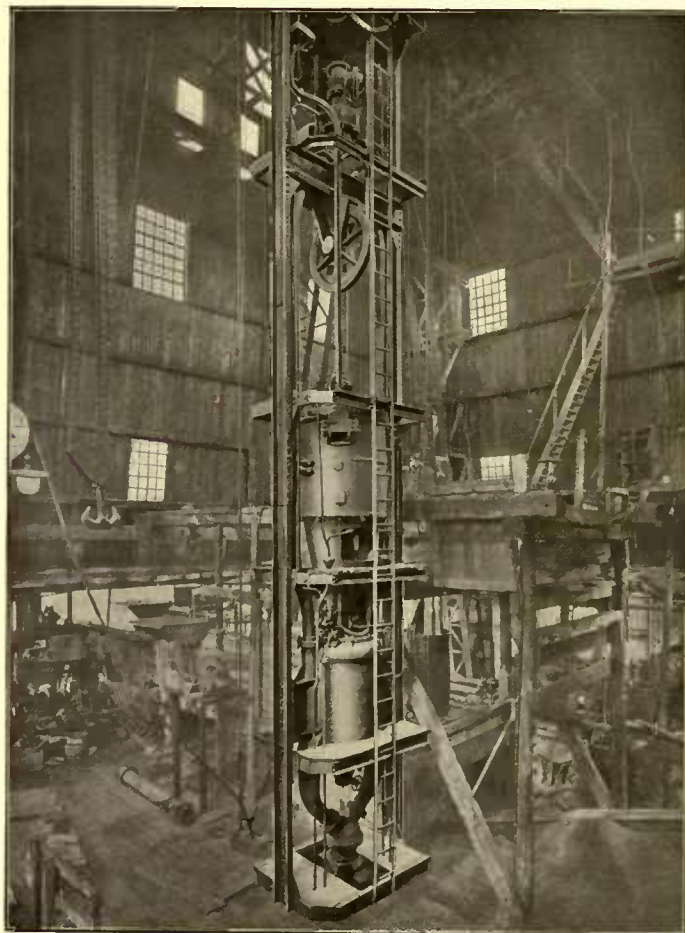


Fig. 97

Royal State Mines, Limburg, Pit Emma, Heerlen, Holland.

Two electrically-driven sinking pumps. Output each 660 gallons per minute. Head 1320 ft.
Motor output, each 400 H.P., 2000 volts., 1435 R.P.M., 50 cycles.

The pump is suspended by wire ropes, which are carried around a cast iron sheave attached to the upper part of the suspension frame. One end of the rope is fastened to the headgear while the other runs over another sheave to a small winch or winder, which is usually electrically driven, and serves to raise or lower the pump. Suitable guides are usually provided, in order to ensure the correct position of the pump in the shaft. The suction pipe should preferably be telescopic so that it can be adjusted to any length desired, and must be fitted with a suitable strainer

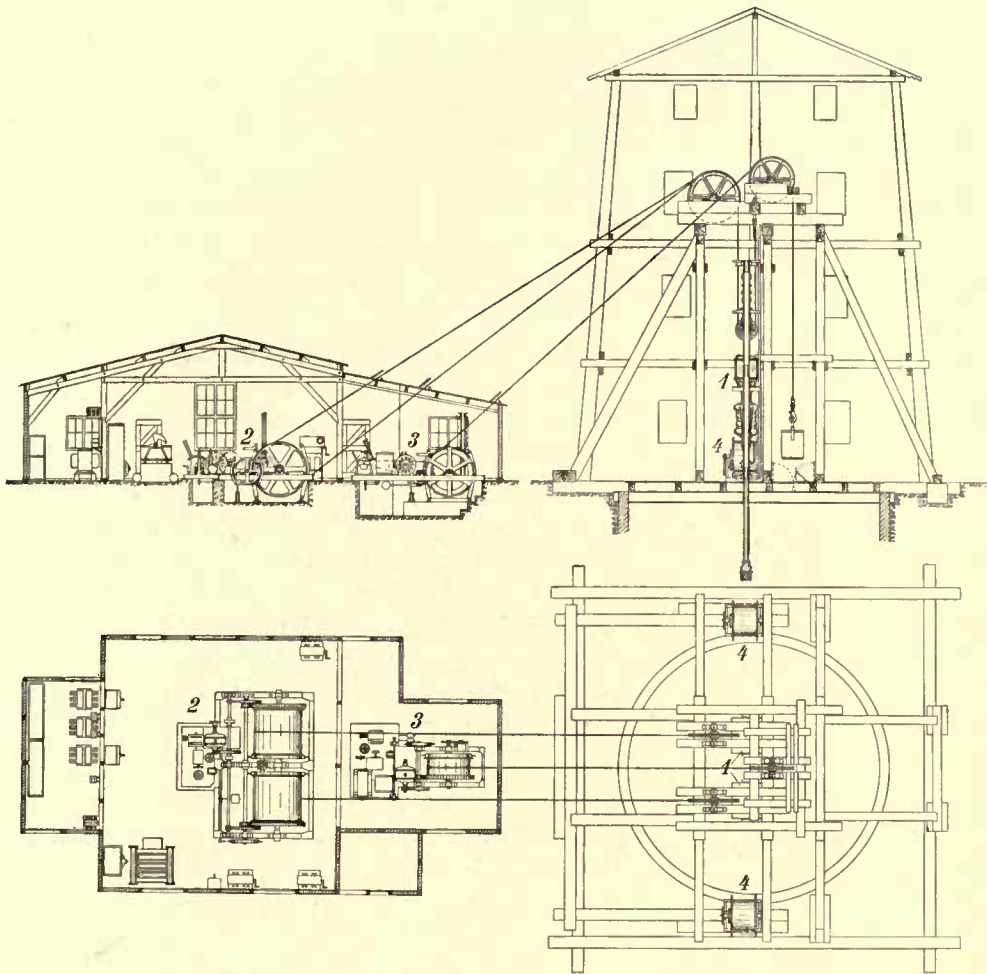


Fig. 98
General arrangement of shaft headgear and engine room of the sinking plant for the Pit Emma, Royal State Mines, Limburg, Pit Emma, Heerlen, Holland.

1. Sinking pumps.
2. Winch or winder for hoisting and lowering the pumps.
3. Sinking winder.
4. Cable drums.

at the lower end. The rising main consists of light, flanged wrought-iron pipe and is provided with a regulating and a non-return valve. It is connected to the discharge nozzle of the pump and carried up the shaft between the two suspension ropes ; special clamps are provided to hold it in a vertical position, so arranged that the hoisting ropes can slide through eyes, when the pump is being raised or lowered. The general arrangement of an electrical sinking plant with electrically-driven winches, shewing the head gear, the engine room and the pumps, is illustrated in Fig. 98.

Sinking pumps are invariably driven by three-phase induction motors ; direct-current motors are not suitable for this purpose on account of the inaccessibility of the commutator. The motors are of the squirrel-cage type, and must be totally enclosed on account of dampness and of dripping water in the shaft. The casing is water cooled in order to prevent undue heating and to keep the motors within reasonable dimensions ; the cooling water is taken from the first pressure stage of the pump. The use of induced-draught motors is not to be recommended, as the damp air of the pit, driven continually through the working parts of such

motors, leads to early deterioration of the insulation. Naturally the totally-enclosed motors cannot work under water or remain submerged any length of time, as the water would then enter the motor casing through the openings provided for the escape of water which may have collected inside. Special attention has been paid to the design of the bearings. The upper bearing is a combined thrust and guide bearing of the ball type, and carries the weight of the rotor. Both this and the lower guide bearing are provided with automatic lubrication, the oil being cooled by the circulating water.

The pressure for small installations is usually 500 volts, and that for large plants, 3000 volts, in order to reduce the cross section of the cable, so that its weight and price shall be as low as possible. The cable is usually wire armoured, rubber insulated and without lead sheath; it is usually provided with a number of pilot wires, forming an auxiliary circuit supplying current by means of which the motor may be switched off from the bottom of the shaft, if this should become necessary. The cable terminates at the suspension framing in a trifurcating box provided with an ammeter. It is advisable to mount this trifurcating box near the regulating valve, so that the load on the motor can be watched. The cable is usually led to the head of the shaft parallel to the rising main, to which it is fastened by suitable clamps. A cable drum is placed above ground for the accommodation of that part of the cable which is not in the shaft; a drum of this type is shown in Fig. 99. It is provided with three sliprings for taking current to the motor, and two sliprings for the auxiliary circuit. The cable drum, shown in the illustration, only serves to accommodate the cable, but not to wind it up out of the shaft, and can therefore only be used when the cable is fastened in some manner. If the cable hangs free in the shaft, it is necessary to provide the drum with double reduction gearing and a reliable braking device.

The squirrel-cage motor is started from the head of the shaft by means of a starting transformer, combined with a step switch. It is customary to place these starting transformers and switches in a pillar, which also contains the other necessary switchgear, instruments, etc.

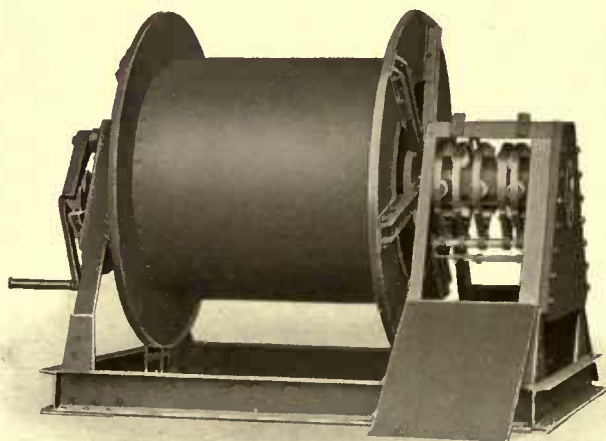


Fig. 99
Cable Drum for Electrically-driven Sinking Pump

CHAPTER IX

ELECTRICALLY-DRIVEN MINE FANS

The ventilation of mines is at present carried out almost exclusively by means of centrifugal fans, driven in most cases by electric motors. The ventilating plant is usually in operation both day and night, so that it forms a constant load on the power station, and makes the use of larger units possible, which in turn reduce the specific steam consumption of the station. A single steam engine for driving the fan would be of comparatively small size, and would, therefore, have a greater specific steam consumption than the prime movers in the station, even if the losses in the conversion of the energy are taken into account.

The three-phase induction motor, which has been adopted to a very large extent for driving fans, is very much less liable to breakdowns than a steam engine, and needs no special attention when running. An interruption of the current supply, which would result in shutting down the plant, is practically impossible in the case of a modern station, where sufficient spare plant has been installed.

In cases where a separate ventilating shaft is provided, electrically-driven fans present special advantages. These shafts are usually situated at some distance from the main shaft and the power station, and are only used in cases of danger as emergency exits for the men; they are usually equipped only with a small auxiliary winding plant in addition to the fan itself. If the fan is electrically driven, no separate boiler plant is necessary, and the auxiliary machinery is always ready for service. The electric motor requires no continual attendance, so that the saving in operating expenses as well as in first cost is considerable.

One of the most important considerations in determining the method by which the fan shall be driven is that of the quantity of air to be drawn through the workings. A considerable variation in this quantity is usually required, as when the workings are extended it becomes necessary to increase the ventilation. These alterations of the air supply take place only at very long intervals, frequently only after years, and, as a rule, considerable time, that is, at least several hours, is available for effecting the change. In those cases where it is desired to increase the ventilation on account of special circumstances, such as an outbreak of fire, gas, or similar accidents the conditions are essentially different, and the quantity of air has to be altered in a few minutes.

The required variation in the air supply can be obtained by two methods, which differ fundamentally from each other. The first method is to throttle the air by means of a valve or a similar device in the fan drift, while the second is by regulation of the speed of the fan. If the former method is adopted, the quantity of air and the power required are reduced in proportion to the diminished area of the drift. If the regulation is accomplished by variation of speed of the fan, the air supply is decreased in direct proportion to the speed, while the power absorbed diminishes with the third power of the speed; for example, if the quantity of air is decreased by 50%, the power required is reduced by 50% if the regulation takes place by throttling, but is reduced by 87.5% if the regulation is effected by reducing the speed of the fan. The latter figure does not, however, take into consideration the reduction in the efficiency of the fan at lower speeds. It follows, therefore, that it is much more economical to regulate the air by varying the speed of the fan than by throttling the drift.

The use of direct-current motors would allow of speed variation with practically no loss, but direct current is very seldom available, and, moreover, alternating-current motors are more suitable for driving fans, as the absence of a commutator makes them more reliable than direct-current machines. The following descriptions will, therefore, be confined to methods of speed regulation, as applied exclusively to alternating-current motors.

If the fan is not required to give its maximum output for a long time, at least a number of years, the best arrangement is that embodying a small standard alternating-current motor, which drives the fan through a suitable belt. The quantity of air can then be increased by changing the pulleys (Fig. 102). When the final large motor has been installed, some use for the smaller machine can usually be found.

The final method to be adopted for driving a large fan should preferably be that in which the fan is direct coupled to the motor. Induction motors can be built at comparatively low cost, and with high efficiency and power-factor for the outputs and speeds in question. In the case of a direct-coupled fan, the variation in its speed must be accomplished by regulating the motor speed. The usual method of changing the speed of three-phase motors is by the insertion of resistance in the rotor circuit (Fig. 100). This entails a continual loss of power, but as the torque of the fan is considerably reduced at lower speeds, the actual losses in the slip resistance are not so great as is generally supposed.

The power required by the fan itself diminishes as the third power of the speed, but when the speed is regulated by the resistance method, the actual input to the motor decreases as the square of the speed. The actual losses are, therefore, comparatively small, and at the same time the simple and reliable arrangement, the low first cost and the possibility of changing the speed in small steps are very much in favour of the resistance method. It has consequently found a very wide application, especially for plants of small or medium output.

For large fans with motors of 2,000 H.P. output or over, which are being more extensively adopted, losses of even a few per cent. are of considerable

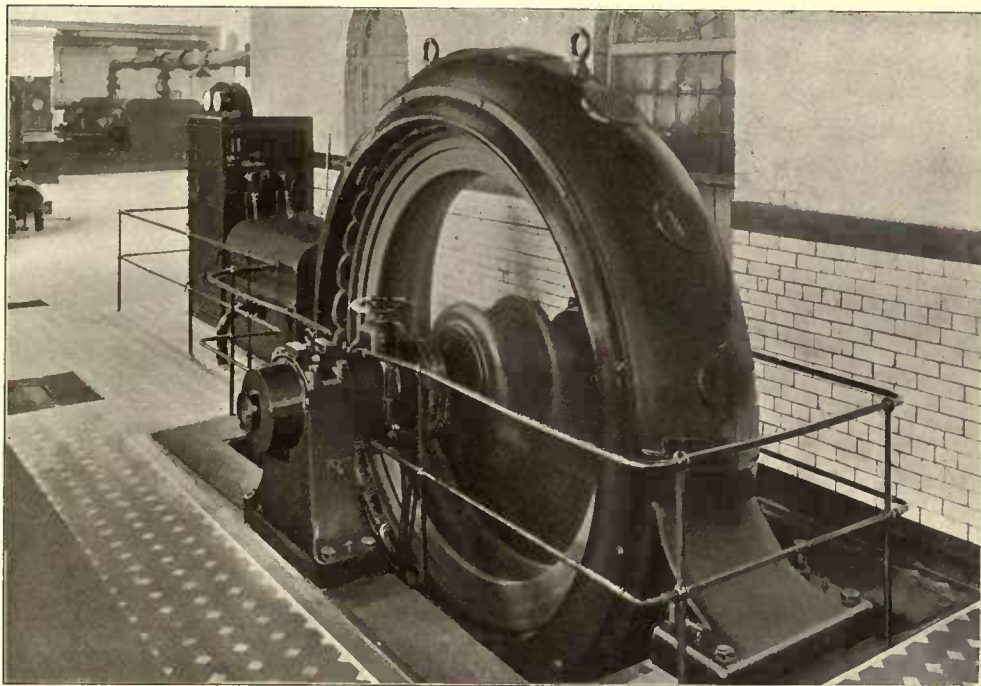


Fig. 100

Whitburn Colliery, Harton Coal Co., S. Shields, England.

Fan motor, output 350 B.H.P., 5,500 volts, 106 R.P.M., 40 cycles.

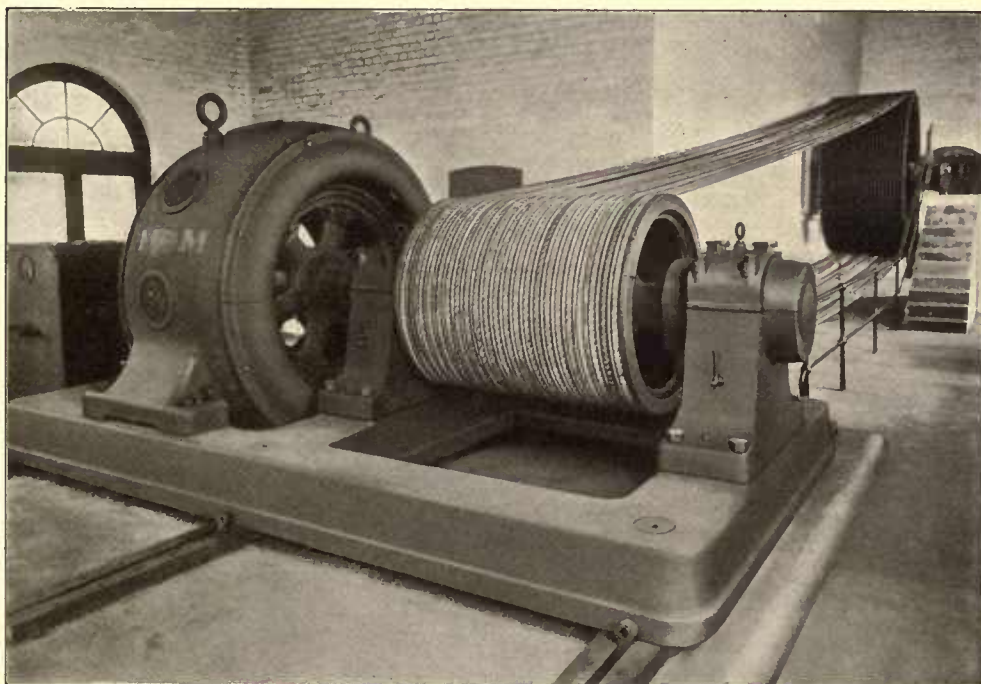


Fig. 101

Carlton Main Colliery, Barnsley, England.

Fan motor, output 600 B.H.P., 550/530 volts, 500 R.P.M., 50 cycles.

importance, especially as the plant is in continuous operation day and night. A comparatively slight improvement in the efficiency frequently justifies the installation of expensive regulating devices, such as are described below.

The so-called cascade connection offers a means of varying the speed of induction motors, with a very slight loss of efficiency. The efficient operation of a cascade motor is, however, confined to a few predetermined speeds. The arrangement itself consists in connecting the rotor terminals of the main motor to the stator of a secondary motor. The two motors are either coupled directly or by means of a belt or gearing. The actual speed of such a set corresponds to that of a motor with a number of poles equal to the sum of the number of poles of the two motors. The two different speeds are then obtained by running the two machines in cascade in the manner described, or by allowing the main motor to run by itself. If required, it is possible to regulate the speed in smaller steps by combining the cascade connection with resistance regulation.

A cascade motor set is illustrated in Fig. 104, which has been in operation at the Bruchstrasse Pit of the Louise Tiefbau Coal Co. for a number of years. Two motors are mounted on the same shaft, the arrangement presenting the appearance of a single machine. The main motor, which has 24 poles, has an output of 500 H.P., at 245 r.p.m. When it is connected in series with the auxiliary motor, which has 8 poles, a speed of 182 r.p.m. is obtained, with a total output of 220 H.P. The efficiency is high in both cases, being about 93% when the main motor only is in operation, and about 89% when the whole set is running.

Another interesting example of a cascade set is the ventilating plant at the Werne Mine, which was designed for a maximum output of about 1,200 H.P. (Fig. 105). In this case the secondary motor is a squirrel-cage machine, and is connected to the main motor through a belt. In order to obtain a number of regulating steps the auxiliary motor is designed in such a way that the number of its poles can be varied, and it can run either as a two, four, or eight-pole motor. The main motor has 24 poles, and runs at a synchronous speed of 250 r.p.m. The other speeds of the set, which can be obtained by means of the cascade arrangement, are 231, 214, and 188 r.p.m., corresponding to a speed regulation of about 25%. By changing the ratio of the belt pulleys between the main and the auxiliary motor, three further speeds, viz.: 223 r.p.m., 201 r.p.m., and 169 r.p.m. are obtainable. This number of regulating steps is ample for main pit fans, and the differences between steps are small enough to permit economical operation under all conditions. The different speeds, with the corresponding values of output, efficiency, and power-factor, are given in the table below. The figures show clearly that plants of this type can be built for a very favourable power consumption at all required speeds. The power factor in these cases is not so good, especially at the lower speeds.

| | | | | | | |
|--------------|---|---|-------|------|------|------|
| Output | - | - | 1,200 | 850 | 700 | 450 |
| Speed R.P.M. | - | - | 246 | 228 | 212 | 185 |
| Efficiency% | - | - | 95.0 | 93.0 | 92.0 | 91.0 |
| Power-Factor | - | - | 0.87 | 0.75 | 0.68 | 0.61 |

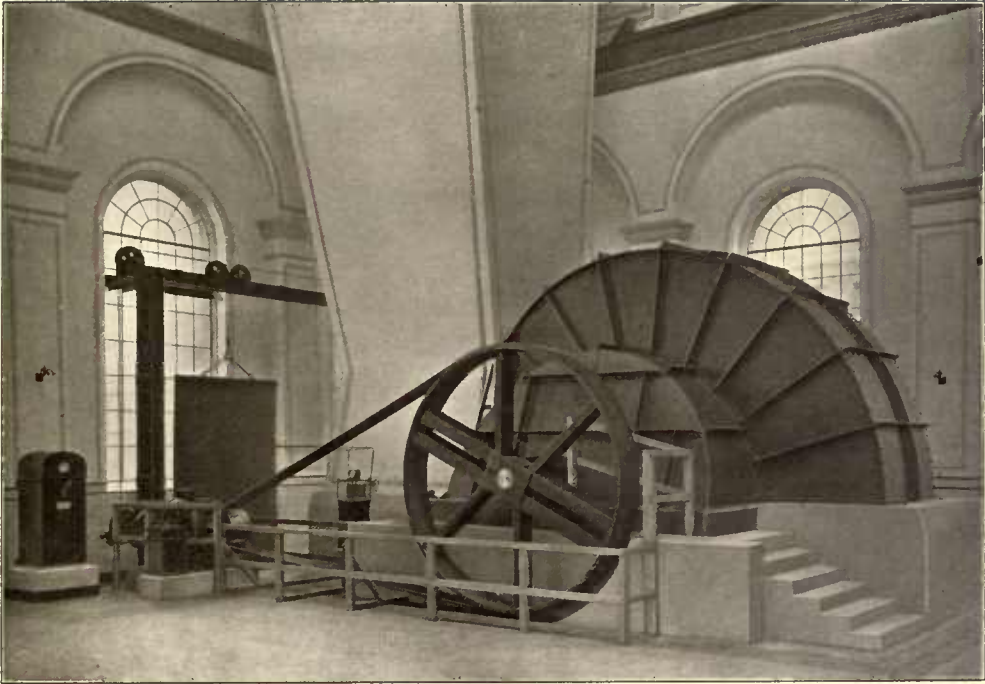


Fig. 102

De Wendel Pit, Hamm, Germany.

Fan for maximum output of 1,150 H.P. Temporary drive from 80 H.P. motor.
3,100 volts, 50 cycles, 730 r.p.m. For final arrangement see Fig. 108.

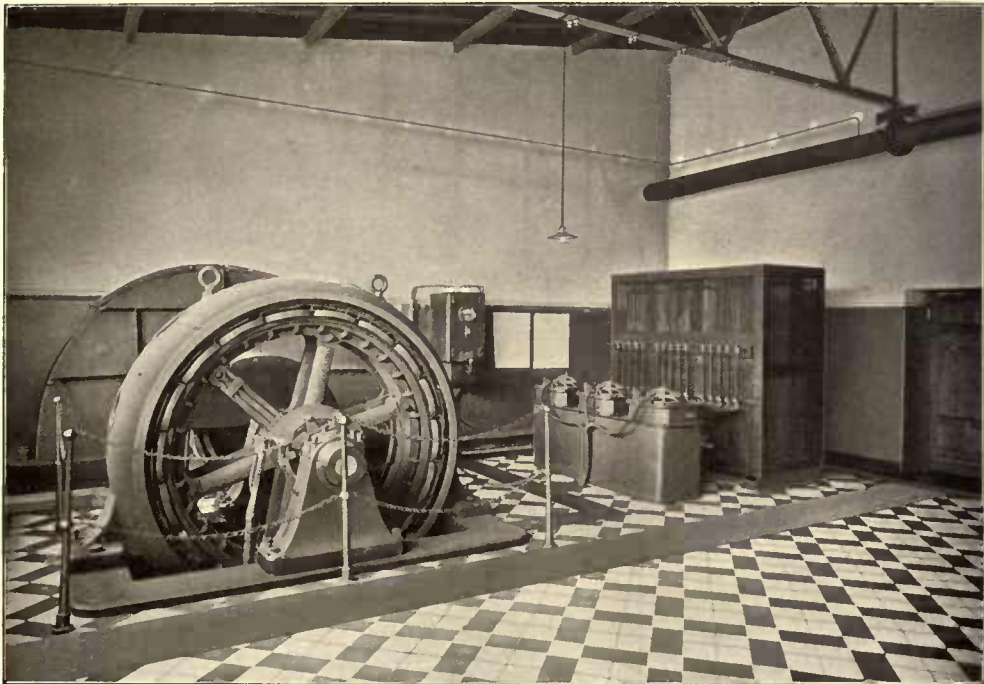


Fig. 103

Koenig Ludwig Pit, near Recklinghausen, Germany.

Fan motor, direct coupled, output 650 H.P.
5,000 volts, 50 cycles, speed variation from 245 to 177 R.P.M.

This arrangement is extremely simple and reliable. The main motor is a standard three-phase motor, with slipping rotor, while the auxiliary motor is an ordinary squirrel-cage machine, so that defects or faults are practically out of the question for either of the two motors. The belt drive between the machines cannot be regarded as an objection, because the power which it transmits is only a fraction of the total output.

Another group of regulating devices is characterised by the attempt to regain the energy which would otherwise be converted into heat in the rotor resistance. A drive of this type, which was installed at the De Wendel pits, near Hamm, Germany, is shown in Fig. 108. The fan itself is direct coupled to a standard three-phase motor; a rotary converter is connected to the slip-rings of this motor and transforms the rotor current into direct current. This slip energy is supplied to a direct-current motor, the so-called auxiliary or secondary motor, which, in its turn, transmits the power through a belt to the shaft of the main motor. A diagram of connections of this arrangement is shown in Fig. 106. The speed is adjusted by varying the field of the auxiliary motor by means of a regulating resistance. As this field is increased, the speed of the auxiliary motor (and consequently that of the main motor) is correspondingly reduced. Both the rotary converter and the auxiliary motor are excited from a separate source of current with constant voltage. Since the losses in both the rotary converter and the auxiliary motor are comparatively small, the greater part of the energy, which would otherwise be wasted as heat in the slip resistance, is converted into useful work, and the overall efficiency of the plant is quite high throughout the whole range of speed. Another advantage of this method is that the power-factor of the whole set may be increased to unity by regulating the field of the rotary converter in a suitable manner. In the particular case under consideration the main motor has an output of 1,150 H.P., at 270 r.p.m., while the auxiliary motor is designed for an output of 210 H.P., at 650 r.p.m. The regulating set makes it possible to adjust the speed between 6% and 35% below the normal, the efficiencies attained varying from 92% to 85%. When the fan runs at full speed, the regulating set is disconnected. Between full speed and a speed corresponding to 6% below normal, the regulation can be accomplished by means of a regulating resistance.

The same purpose, viz., the regaining of the slip energy, can be attained by the aid of another regulating device, shown in Fig. 109, which has been installed at one of the "Deutscher Kaiser" pits, near Hamborn. In this case the low frequency of the rotor current is converted to that of the supply in a frequency converter, so that when the motor is operating at speeds below the normal, it can return energy to the line.

The frequency converter consists of a rotor, generally similar to the armature of a rotary converter, and of a stator of the usual type, which forms the magnetic field, but is not provided with windings. The slip-rings of the armature are connected to the supply circuit, while three sets of brushes on the commutator transmit the current from the rotor of the main motor. The armature is driven at a speed corresponding exactly to that of the main motor,

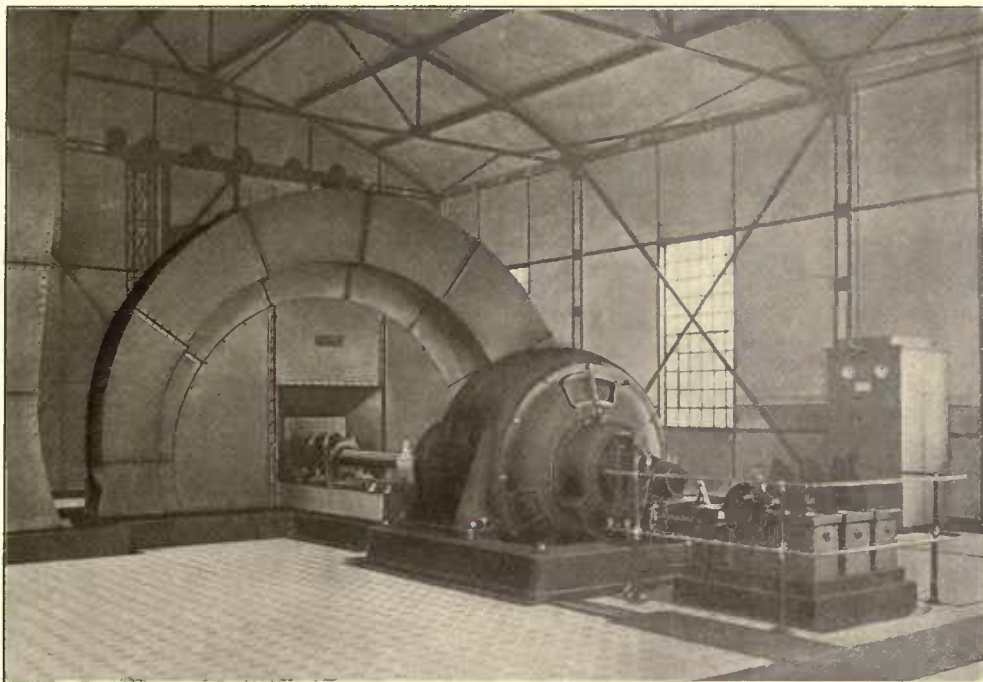


Fig. 104
Bruchstrasse Pit of the Louise Tiefbau Coal Company,
Langendreer, Germany.

Fan with cascade motor.¹ Maximum output 500 H.P., at 5,000 volts, 50 cycles.
 Speed from 245 to 182 R.P.M.

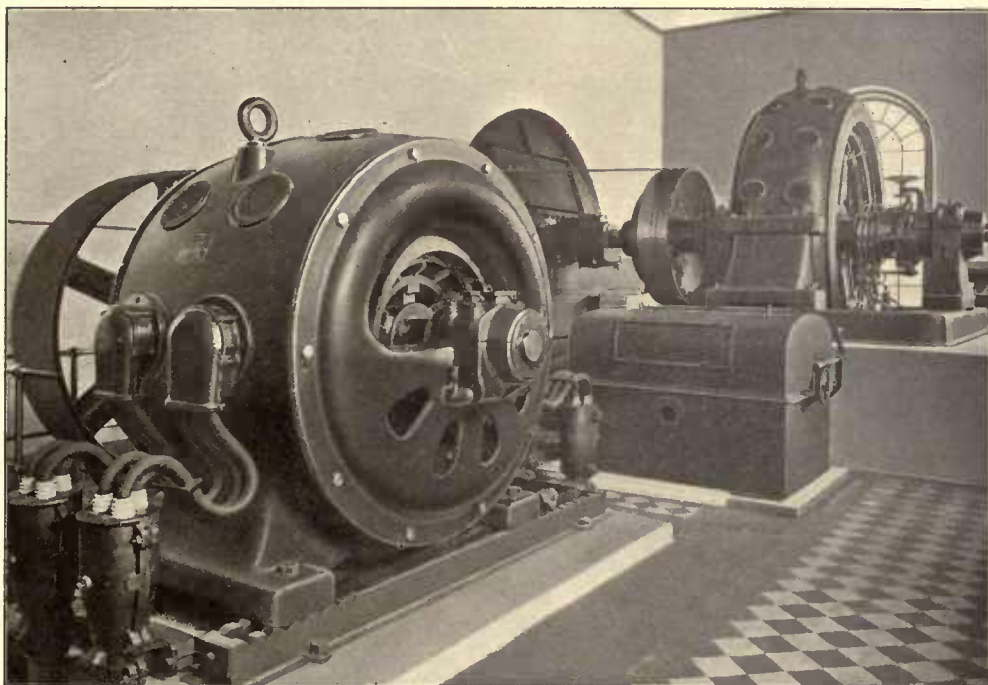


Fig. 105
Werne Mine of the Georg-Marien Bergwerk-und Hüttenverein,
Germany.

Fan with cascade motor. Maximum output 1200 H.P., 2,000 volts, 50 cycles, connected to a squirrel-cage secondary motor, with pole-changing device. Speeds; 246, 231, 214 and 188 R.P.M.

either through gearing or through a synchronous electric drive. (See diagram of connections, Fig. 107.) Since not only the frequency of the rotor current, but also its pressure changes with variations of the speed, it is necessary to arrange for a variable-pressure transformer, in addition to the frequency converter. This transformer raises the low pressure of the rotor current received from the frequency converter to that of the supply circuit, and it is by regulation of the ratio of transformation that the speed of the motor is varied. The overall efficiency of the plant is very high, and the supply to the main motor can be always adjusted to unity power-factor. If desirable, it is even possible to obtain a leading power-factor for the main motor, and thus to improve the power-factor of the whole system. In the Deutscher Kaiser plant, shown in Fig. 109, the main motor has an output of about 1,100 H.P., and the frequency converter permits of a regulation of the speed between 296 and 224 r.p.m.

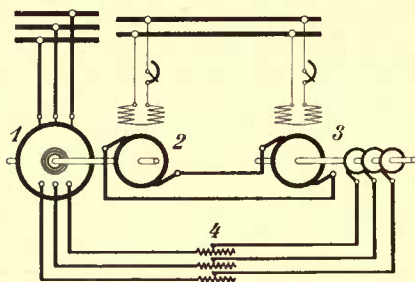


Fig. 106

Diagram of Connections of Direct-current Regulating Device.

- | | |
|---------------------|----------------------|
| 1. Fan Motor. | 3. Rotary Converter. |
| 2. Auxiliary Motor. | 4. Starter. |

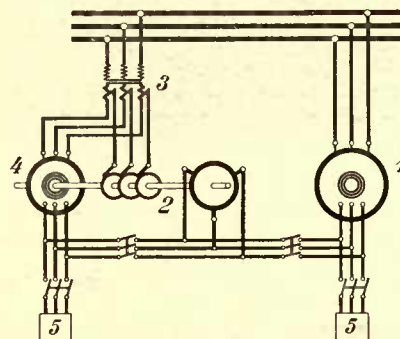


Fig. 107

Diagram of Connections of Frequency Converter.

- | | |
|-------------------------|---------------------------------------|
| 1. Fan Motor. | 4. Motor Driving Frequency Converter. |
| 2. Frequency Converter. | 5. Starter. |
| 3. Transformer. | |

The frequency converter differs from other types of regulating device in that it makes it possible to run the motor above synchronous speed. In this case the extra energy is supplied from the line through the frequency converter and transformer to the rotor.

All the regulating devices so far described, i.e., with rotary converter and auxiliary motor, with frequency converter, and with cascade auxiliary motor, are used in connection with a main motor, which is always a standard three-phase induction machine. Should any trouble occur with the regulating device, it is still possible to keep the ventilating plant in operation at full speed. The reliability of the plant is therefore great. These regulating devices can also be installed in connection with existing standard three-phase motors; if the mine or pit has been extended so far that the fan can work at its full output, the regulating set can be removed and put to use elsewhere.

Recently, three-phase commutator motors have also been used for driving fans. The efficiency of these motors at full speed is somewhat lower than that of standard three-phase motors, but their speed can be varied through a considerable range without the aid of any regulating resistance, by changing the



Fig. 108

De Wendel Pit, Hamm, Germany.

Fan motor, connected to direct-current auxiliary motor and rotary converter. Maximum output 1,150 H.P., 3,100 volts, 50 cycles, speed variation from 270 to 170 R.P.M.

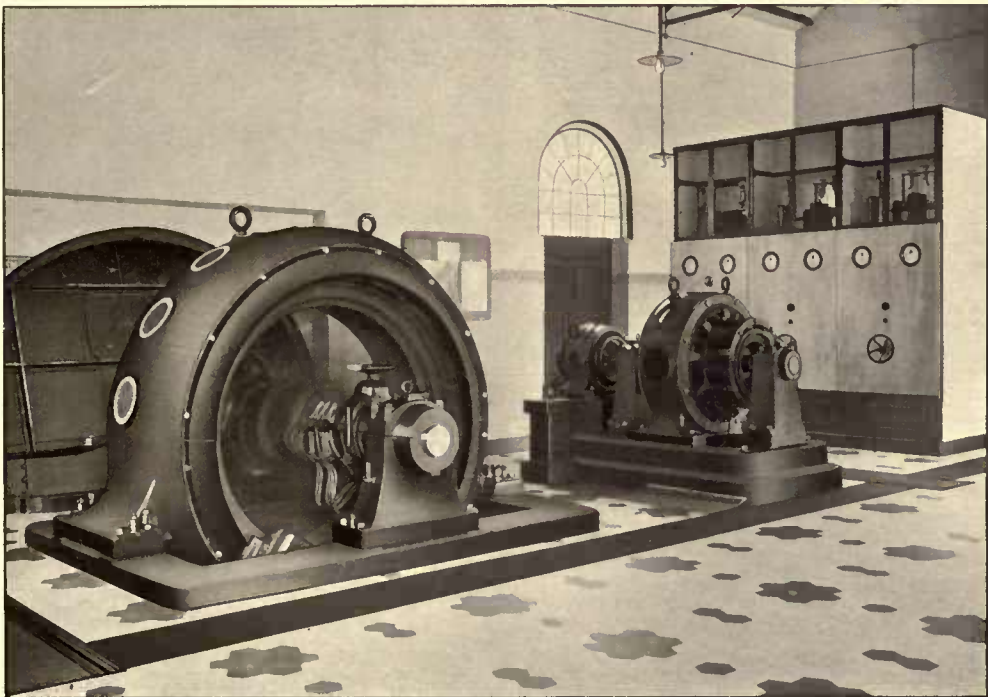


Fig. 109

Deutscher Kaiser Pits, Hamborn, Germany.

Fan motor, with frequency converter. Output 1,100 H.P., 5,000 volts, 50 cycles. Speed variation between 295 and 224 R.P.M.

position of the brushes. Both efficiency and power-factor of these motors are good throughout the whole range of speed. If desired, the motor can be arranged to take current at unity power-factor at all speeds, but a special design is required for this purpose. A certain disadvantage of these motors is the large number of brushes on the commutator. These are subject to considerable wear, especially when the motor runs day and night, and the cost of their renewal is an item of some importance.

When considering the adoption of any one of these devices for a particular case, not only the efficiency, but also the cost of the installation is of importance. If the use of temporary motors is not desired, regulation by means of resistance in the rotor circuit undoubtedly gives the lowest first cost. Installations in which cascade motors are employed are comparatively inexpensive, so that their high efficiency will effect an economy repaying the extra outlay in a short time. Commutator motors, frequency converters, or direct-current regulating sets, cost considerably more, and they are, therefore, only to be recommended where a close regulation and a high power-factor are desired.

CHAPTER X

ELECTRICALLY-DRIVEN COMPRESSORS

The use of compressed air as a means of transmitting energy cannot always be dispensed with, although the losses occurring in the pipe lines and the low efficiency of the small compressed-air machines render this method of power transmission very uneconomical. Frequently the mine authorities object to the use of electricity in workings where fire-damp regularly occurs, and in many countries the use of electricity is either prohibited entirely in such districts, or consent is given on condition that stringent rules and regulations be observed, which are difficult to fulfil in actual practice. Under these circumstances it is often

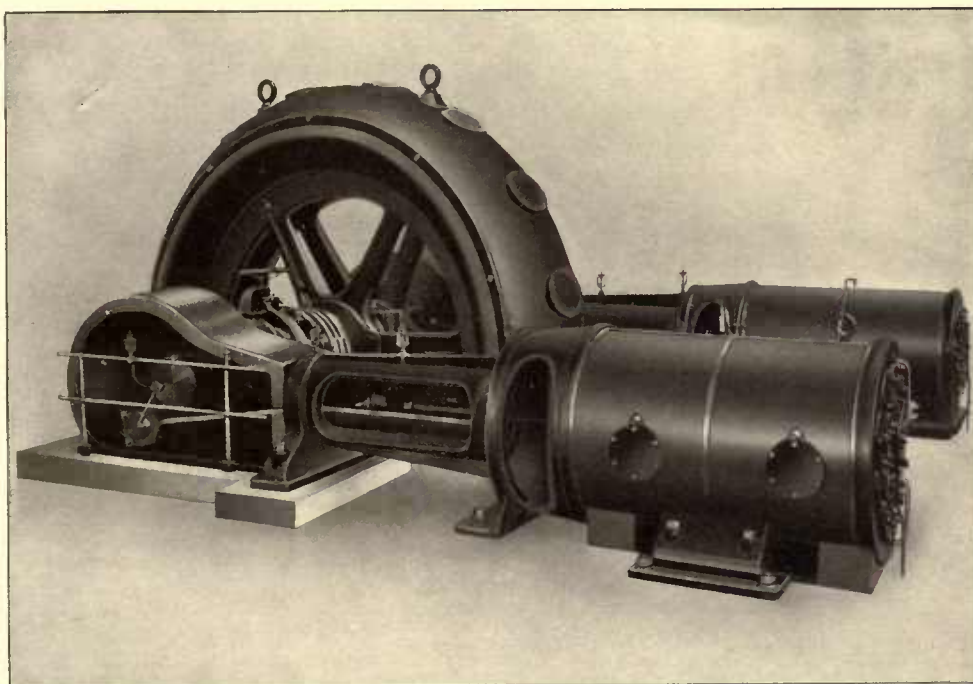


Fig. 110

Lanchow Mining Company, China.

Three-phase induction motor driving a two-stage compressor. Output 500 H.P., 3,000 volts, 147 R.P.M., 50 cycles.

advisable to operate the small machines such as small winches, drills, coal cutters, etc., with compressed air, if they are situated where dangerous gas occurs. The air compressors, especially when the output is not very large, are usually placed below ground in the intake air-way, and are then driven electrically. Large compressors, which supply a whole mine with air, and frequently are of considerable output, are usually installed above ground. These machines can be driven electrically with considerable advantage, especially when the electrical energy is produced in large central stations at comparatively low cost.

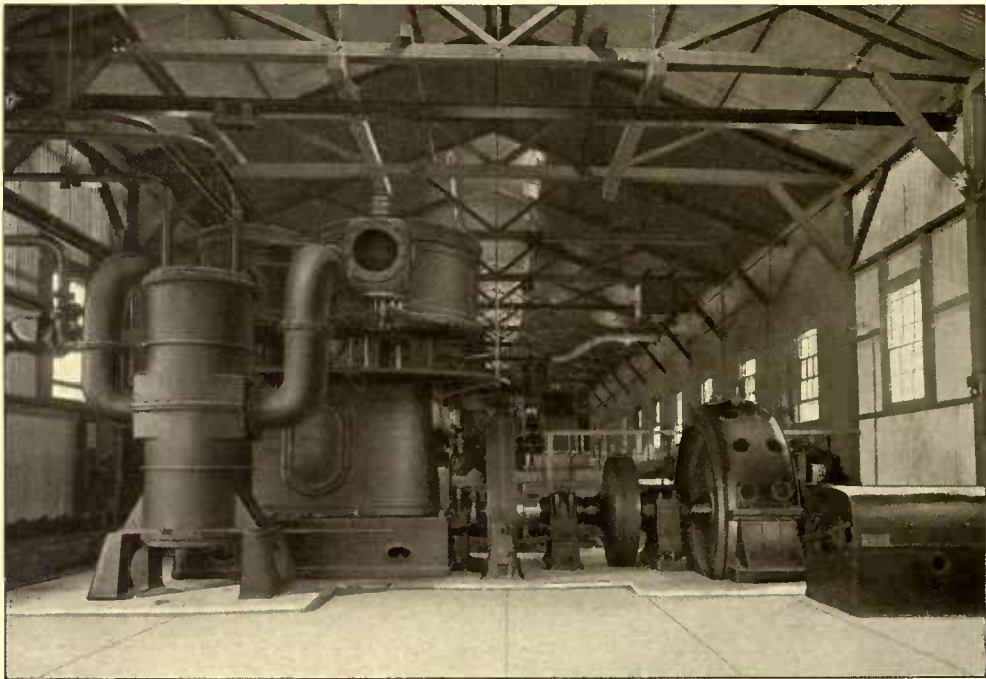


Fig. 111

Consolidated Gold Fields, Jupiter Gold Mine, South Africa.

Three three-phase induction motors driving two-stage air compressors. Output each 820 H.P. at 184 R.P.M., 2,000 volts, 50 cycles.

In order to obtain a constant load on the compressor, in spite of the variable demand for compressed air, it is customary to provide a receiver between the compressor and the distribution pipe system. Fluctuations in the load which are too large to be met by the receiver are provided for by regulating the compressor output in accordance with the air pressure. In the case of small compressor plants the simplest arrangement is to control the compressor automatically, according to the air pressure. Large compressors do not lend themselves to this arrangement, and it becomes necessary either to vary the speed in accordance with the fluctuating demand of air or to equip the compressor itself with a regulating device which varies the quantity of air, while

the speed remains constant. An essential difference between fans and compressors, is that the power required for compressors is reduced in direct proportion to the speed, and consequently the regulation of the speed does not offer such great advantages compared with mechanical regulation as in the case of fans. Occasionally, however, regulating devices by which the speed is varied, offer certain advantages. The resistance method of regulation would be very uneconomical, owing to the constant turning moment required by the compressor, while cascade motors are not to be recommended, because a finer regulation of the speed is usually required than is possible by this means. The solution of the problem is therefore to be found in the use of commutator motors, frequency converters or regulating sets, but an investigation of each separate case is necessary to determine whether the greater efficiency of the plant justifies

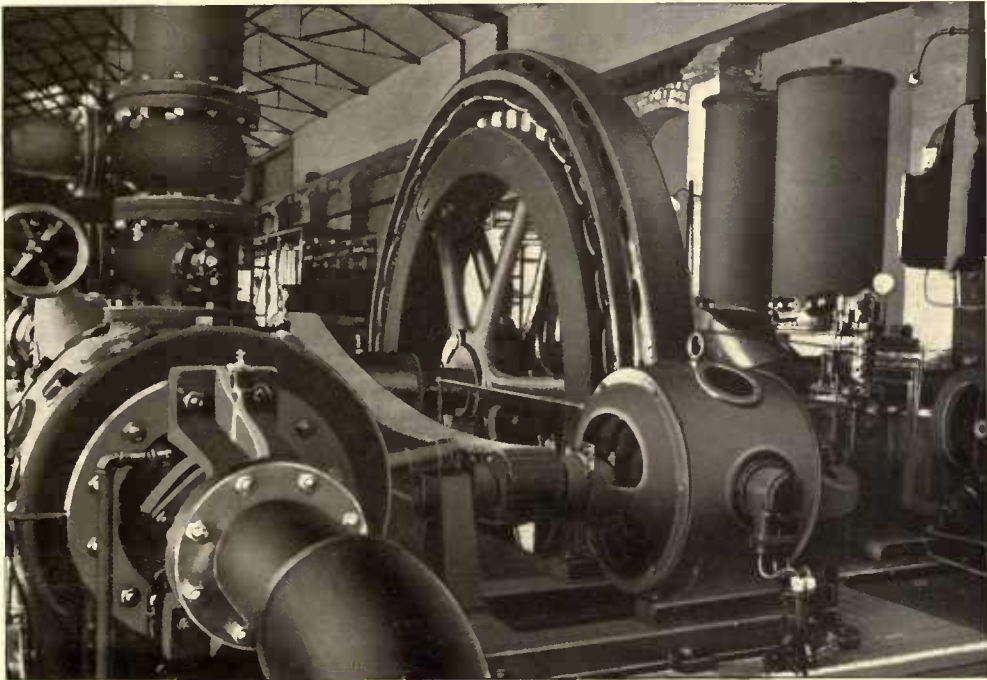


Fig. 112

Rio Tinto Company Limited, Spain.

Synchronous motor driving a two-stage compressor. Output 570 H.P. at 125 R.P.M., 3,000 volts, 50 cycles. Pony motor for 125 H.P., at 580 R.P.M.

the extra cost of the installation. Most compressors are of the constant-speed type, in which the amount of air is regulated by mechanical devices.

Compressors for outputs up to about 600 H.P. are nearly always of the reciprocating type, designed to run at speeds of about 125 to 175 R.P.M. The motors are usually mounted directly on the shaft of the compressor, the necessary flywheel effect being obtained by placing extra weight in the rotor. In order to prevent undesirable heating of the motor and an unfavourable reaction on the power station, the cyclic irregularity should not be less than 1 : 125. Both three-phase induction motors and three-phase synchronous motors are in use for driving compressors.

Compressors with three-phase induction motors are illustrated in Figs. 110 and 111. These motors are started up in the usual manner by a resistance in the rotor circuit. In order to reduce the losses as far as possible, it is usual to fit a by-pass valve or similar device. When the plant is running at full speed and output, the sliprings are short-circuited and the brushes lifted off the rings.

Synchronous motors offer special advantages for driving compressors when it is desired to keep the power-factor high. When these motors are over excited they take a leading current from the line, so that the power-factor of the whole distribution system can be improved. If no separate source of energy

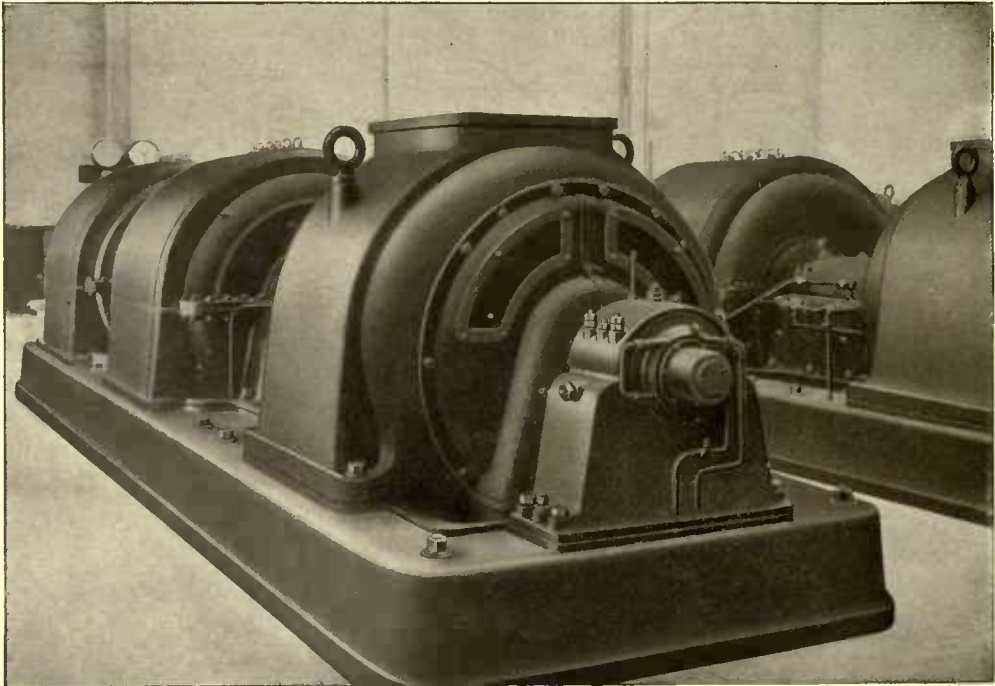


Fig. 113

Victoria Falls and Transvaal Power Company, South Africa.

Turbo-compressor set, driven by two synchronous motors. Output, each 2,150 H.P., at 3,000 R.P.M. 1,700 volts, 50 cycles.

is available for the field excitation, a direct-coupled exciter is usually provided. When starting up synchronous motors it is necessary to bring them up to speed and into phase before connecting them to the supply circuit. For this purpose they are provided with small auxiliary induction motors, termed "pony motors," which are connected to the compressor shaft either through gearing, chain or belt drive, and can be disconnected when the machine has run up to speed. (Fig. 112).

For installations with very large outputs, turbo-compressors have recently come into use. Their high speed and even turning moment make them especially suitable for electric drive. When these compressors are to be installed

to run off a supply circuit with a frequency of 50 cycles, the motors are built almost invariably for a speed of 3,000 R.P.M., and are of similar design to a turbo-generator. It is, of course, possible to use either synchronous or induction motors for this purpose.

The electrical equipment for a very large turbo-compressor plant was supplied by the Siemens Concern to the Robinson Central Deep Mining Company, South Africa. The compressor station supplies a number of gold mines with compressed air, which is required principally for operating rock drills. One of these sets is shown in Fig. 113. It consists of two complete units, each driven by a synchronous motor designed for an output of 2,150 H.P., at 3,000 R.P.M. One half of the set contains the high-pressure stage, the other half the intermediate pressure stage, while the low pressure stage is divided between the two. Each complete set is capable of compressing 1,270,000 cub. feet of free air per hour to a pressure of 132 lbs. per sq. inch. In order to start these synchronous motors, a special starting converter, consisting of an induction motor and a three-phase generator, has been installed. The synchronous compressor motors are brought up to speed together with the fully excited

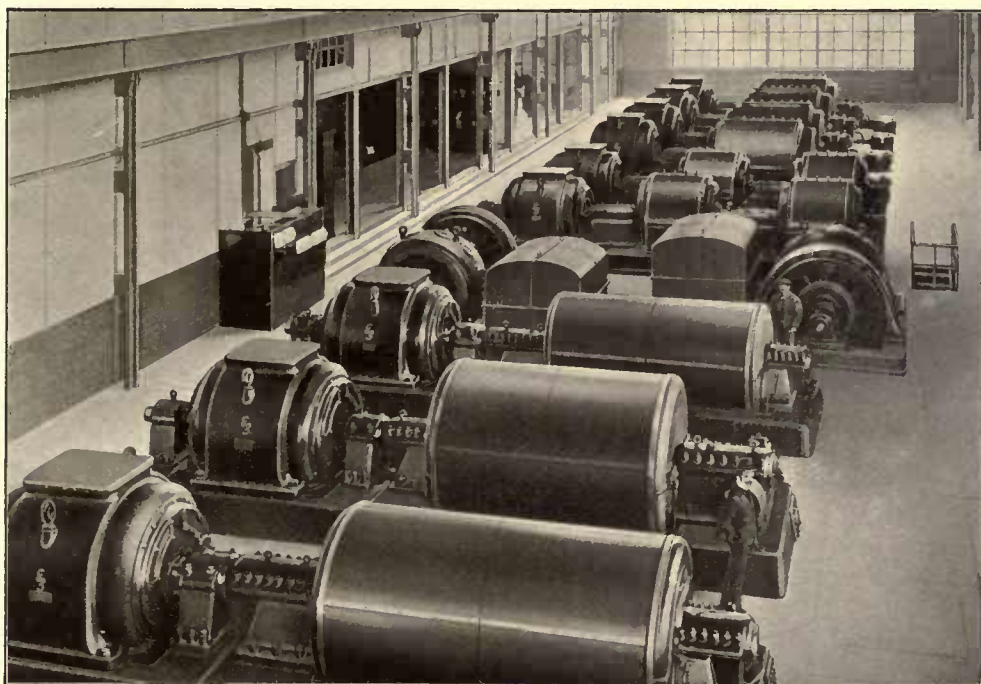


Fig. 114

Compressor Station of the Robinson Central "Deep."

12 Compressor motors. Output, each 2,150 H.P. 3,000 R.P.M. 1,700 volts, 50 cycles.

three-phase generator, and then connected to the line, after which the starting set is shut down again. The possibility offered by the synchronous motor of improving the power-factor of the supply circuit, has been taken advantage of to a considerable degree in this installation. A view of the whole plant, taken during erection, consisting of twelve 2,150 H.P. compressor motors, manufactured by the Siemens Concern is shown in Fig. 114.

CHAPTER XI

HAULAGES AND HOISTS

Hoists in Secondary Shafts and Inclines

Formerly the coal or mineral obtained at the working face was transported to the shaft in small tubs or trucks, which were drawn either by men or by animals. Even at the present time this simple method is in use in the actual workings, and in small side drifts leading to the main road, where the amount of material to be moved does not justify the installation of mechanical haulages. The main haulages, that is, those transporting the material along the main roads to the shaft or drift through which it is to be taken to the surface, are almost invariably operated mechanically, in order to reduce the cost to a minimum, and increase the output.

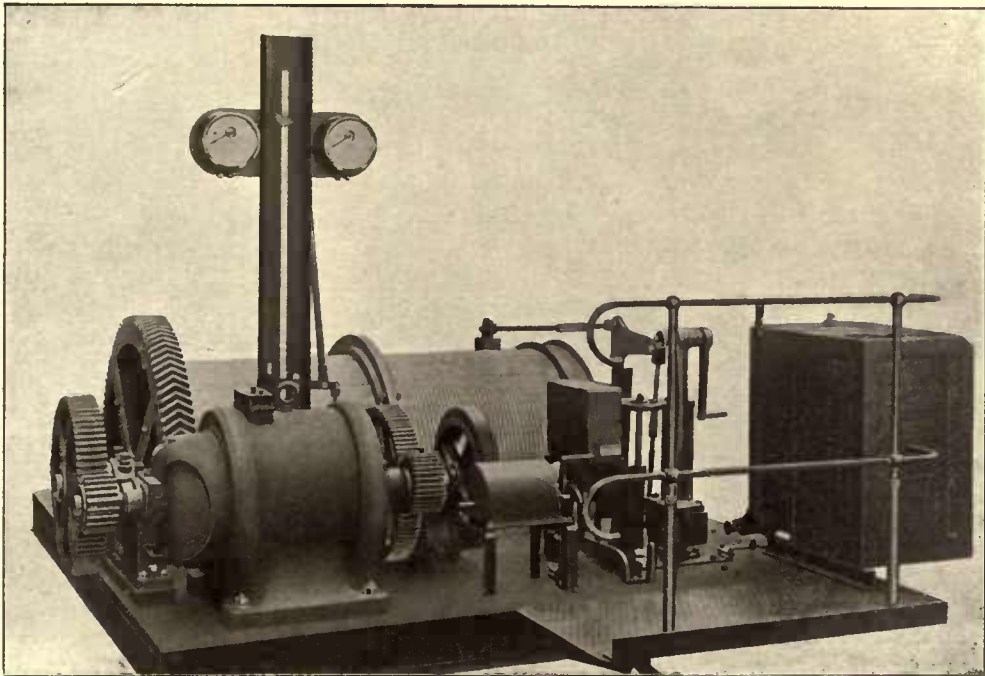


Fig. 115

Mijnbouw-Maatschappij Ketahoen Lebong-Soelit, Dutch Indies.

Haulage gear for a load of 1,000 lbs, length 100 yards, maximum speed $2\frac{1}{2}$ miles per hour.
Motor output 12 H.P. continuously, 220 volts, 50 cycles.

The secondary haulages, which move small loads at comparatively low speeds, must be so simple in their operation that they can be entrusted, not only to an unskilled labourer, but to practically any person working in the mine. As a rule they are not fixed permanently in one locality, but are arranged so that they can be moved from time to time in accordance with the requirements of the mine. For this reason it is necessary to construct

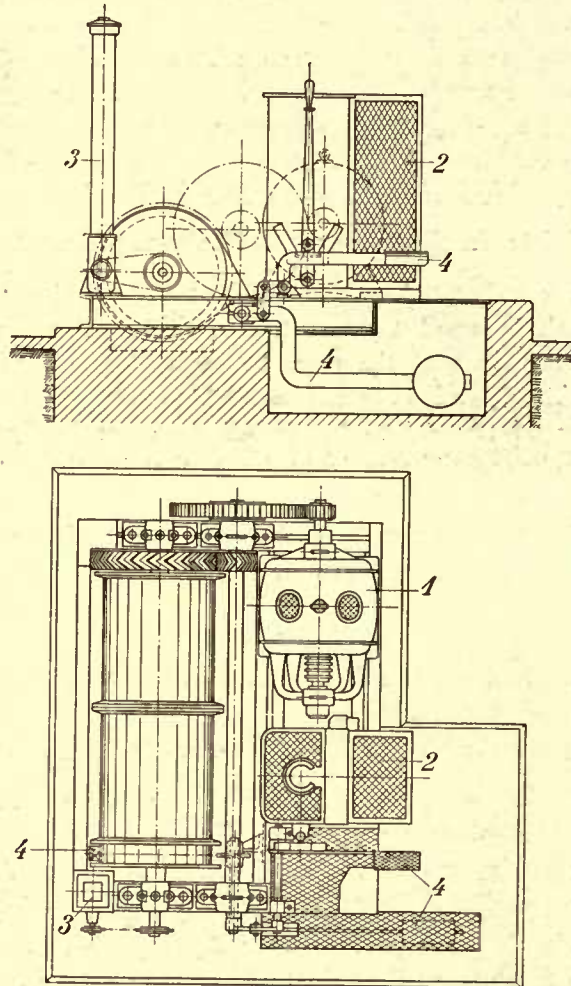


Fig. 116

Simple double drum haulage.

- | | |
|----------------|---------------------|
| 1. Motor. | 3. Depth Indicator. |
| 2. Controller. | 4. Brake Weight. |

them as compact and light as possible. If the haulages are to be moved about very frequently, they can be mounted on a carriage, so that they may be moved along on the mine railways.

On the other hand the haulages must be constructed to withstand the rough handling to which they are subject, and to be comparatively safe from breakdowns and accidents, especially when they are used for taking the men into the workings. The safety appliances which have to be installed depend in each case on the local circumstances, and the regulations of the respective mining authorities.

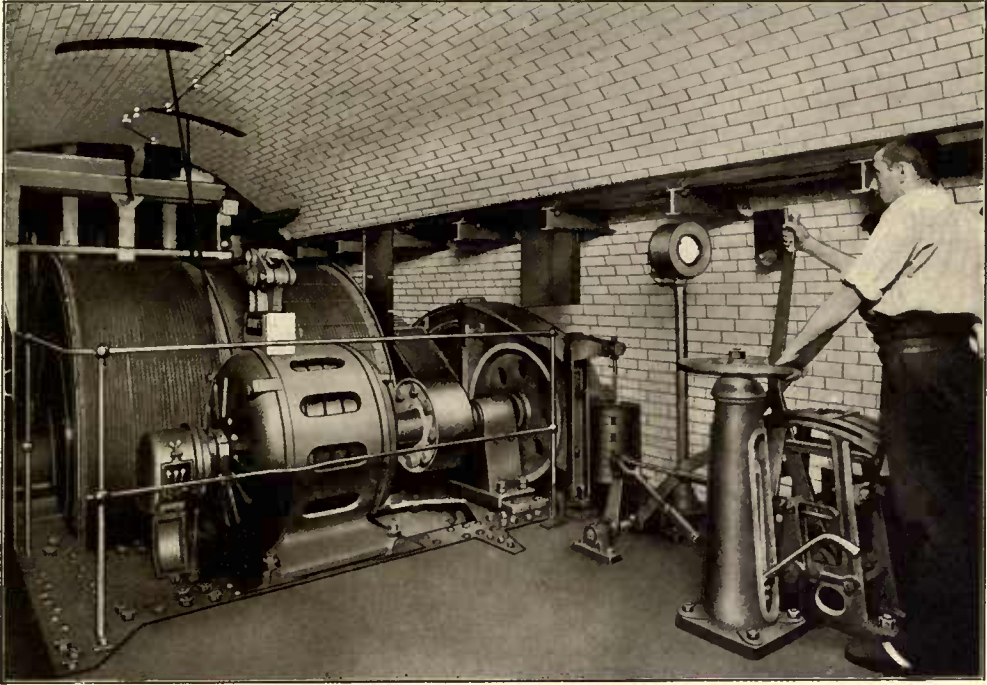


Fig. 117

**Zwickau Oberhohndorfer Steinkohlen-Bau-Verein Aktien-Gesellschaft,
Oberhohndorf, Germany.**

Auxiliary winder below ground. Net load 2 tons. Depth 290 yards. Maximum speed 688 ft. per min.
Normal output of motor 80 H.P., 2,000 volts, 50 cycles.

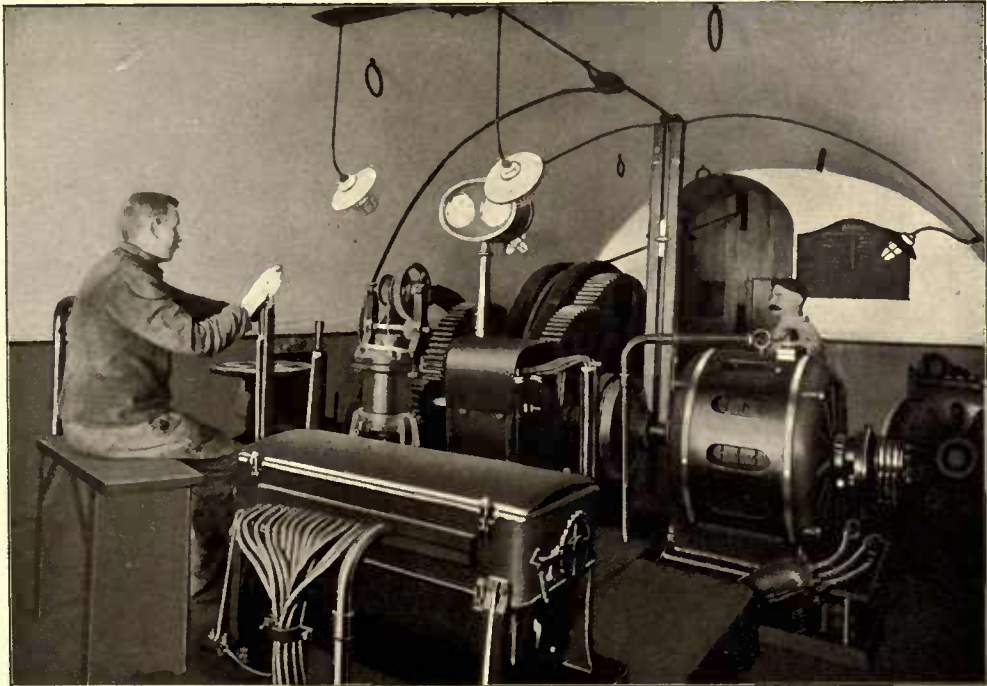


Fig. 118

Gutehoffnungshütte Pit Vondern, Oberhausen, Germany.

Auxiliary winder, net load 2 tons, depth 110 yards. Maximum speed 590 ft. per minute.
Normal output of motor 70 H.P. 3,000 volts, 50 cycles.

Haulages may be either of the single or of the double drum type. A double drum haulage of the simplest type, which is only used for hauling minerals, is shown in Fig. 115. The drums, which can be rotated relatively to each other, are driven by a three-phase motor through double reduction gearing. The motor is controlled by a reversing controller, fitted with carbon contacts, and a metallic resistance. A simple bandbreak acting on the drum shaft is held in the "on" position by a weight, and controlled by the operator. The brake lever and the control lever are so interlocked that the brake can only be applied when the controller is almost in the "off" position, and the controller can only be operated when the brake has been released. A simple depth indicator is provided, driven through a chain from the drum shaft. The whole gear is mounted on a strong steel frame, arranged to facilitate transport from place to place.

A similar haulage is shown in Fig. 116. This also serves to carry men, and is, therefore, equipped with two independent brakes, one acting on the countershaft, and the other, the emergency brake, acting on the drum shaft. The emergency brake is operated by a weight which is held in the "off" position by a brake magnet. If the current supply fails, or an overwind takes place, the brake magnet circuit is interrupted, and the brake released. The depth indicator is provided with two instruments for showing the power used. The motor is of the induced-draught type, and is protected against dripping water.

The hoists shown in Figs. 117 and 118, which are essentially similar in their construction to those described, are also similar to the main shaft winders, on account of the large outputs of their motors. They are driven by three-phase induction motors, supplied with current at 2,000 or 3,000 volts, and are controlled by means of resistance in the rotor.

The controller, which is plainly visible in Fig. 118, consists of a totally-enclosed cast-iron housing, containing the contact drum, which is entirely submerged in oil. The actual resistance elements are quite separate from the controller.

While the ordinary three-phase induction motor is the most suitable machine for small haulages, on account of its simplicity and cheapness, three-phase commutator motors and direct-current motors on the Ward-Leonard system have also been adapted to large haulages and hoists operating below ground. Installations with either a flywheel or buffer battery have also been put down recently for small auxiliary winders below ground. These winders are described in detail in another chapter.

Main Road Haulages

Locomotive haulage is undoubtedly the best system for those mines in which the main roads and side headings have very sharp curves, or the lay-out is very complicated. For level roadways with comparatively few curves, rope haulage of some kind will usually deserve preference, however, as it is less expensive both to instal and to maintain than a locomotive haulage. Rope haulage is permissible, even in mines in which fire-damp occurs in the main haulage road, while locomotive haulage is entirely out of the question owing to the sparking which occurs at the trolley wire. In the case of old mines in which it is desired to change from animal to mechanical haulage, the introduction of locomotives would frequently require the renewal of the whole track to allow for the heavy strains put on it. If rope haulage is introduced, this can usually be avoided.

The haulages for trains of 30 to 50 trucks are usually provided with two drums which can be coupled to the shaft. Two ropes are used, one of which is taken directly from the drum to the train, while the other is carried over a sheave at the extreme end of the haulage road to the rear end of the train. The train is moved in one direction or the other according to the direction of rotation of the drums. The winding drum is coupled to the shaft, while the other drum, from which the rope unwinds, runs loose. Haulages of this type, are illustrated in Figs. 119 and 120. The arrangement of the electrical drive is essentially similar to that described in the foregoing pages. The driving motor, even for very large outputs, is nearly always of the three-phase induction type, which runs at a very high efficiency. The starting losses are of minor importance in view of the long period of continuous operation of these haulages. A continual speed regulation is not usually provided for in the haulages illustrated, but a certain choice of speeds has been secured in that illustrated in Fig. 119 by means of double sets of reduction gearing.

Endless rope haulages always operate in the same direction. The rope is carried in several turns over one or more sheaves, and is moved by friction; at the opposite end of the road the rope is carried over a return pulley. The variations in the length of the rope are compensated for by a stretching device, which can be placed either near the haulage or at the other end of the road. In some instances, chains are in use instead of ropes; the chain is then only carried round one sheave, provided with suitable projections for engaging with the links.

Endless rope haulages are usually employed on double track roads, each track serving for the haulage in one direction. The trucks are brought out of the side tracks into the main road separately, and then attached to the rope or chain. The haulage is, therefore, continuous, so that the driving motor is constantly loaded, and the power demand on the station is subject to very little variation.

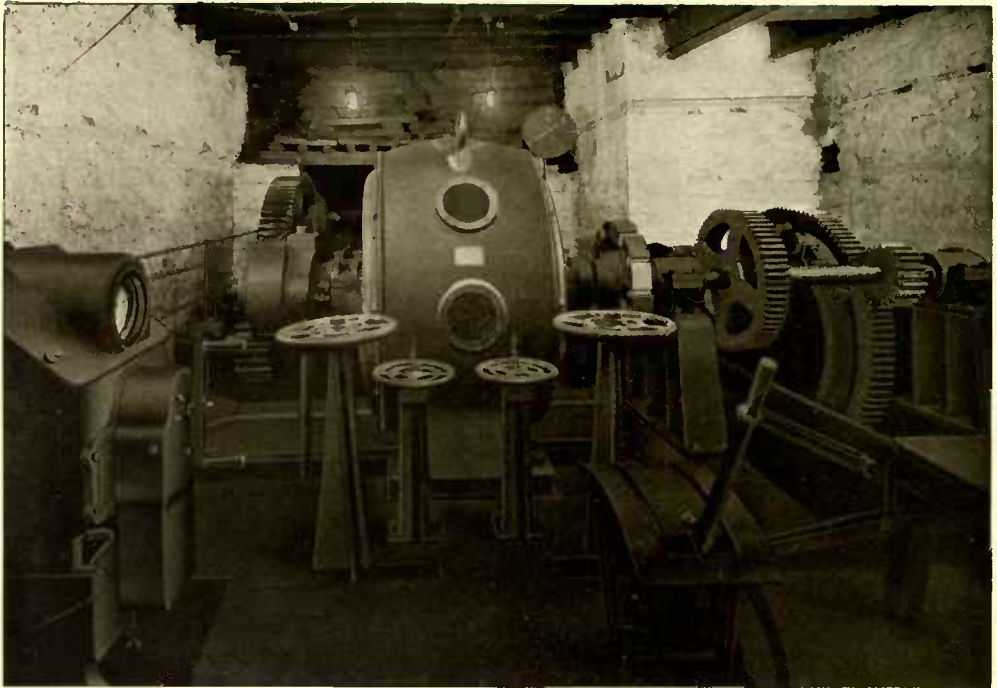


Fig. 119.
Lockets Merthyr Colliery, South Wales.
Main and Tail Haulage.
Motor output 250 H.P. 2,000 volts, 500 R.P.M., 25 cycles.

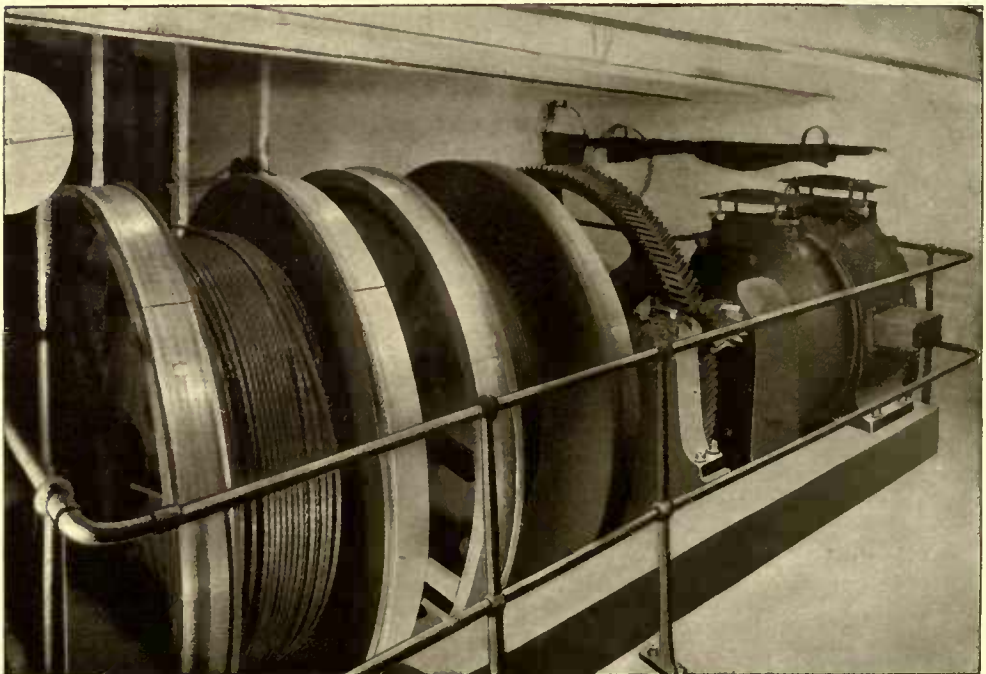


Fig. 120
Harton Coal Co., South Shields, England.
Main and Tail Haulage.
Motor output 60 H.P. 600 volts, 600 R.P.M., 40 cycles.

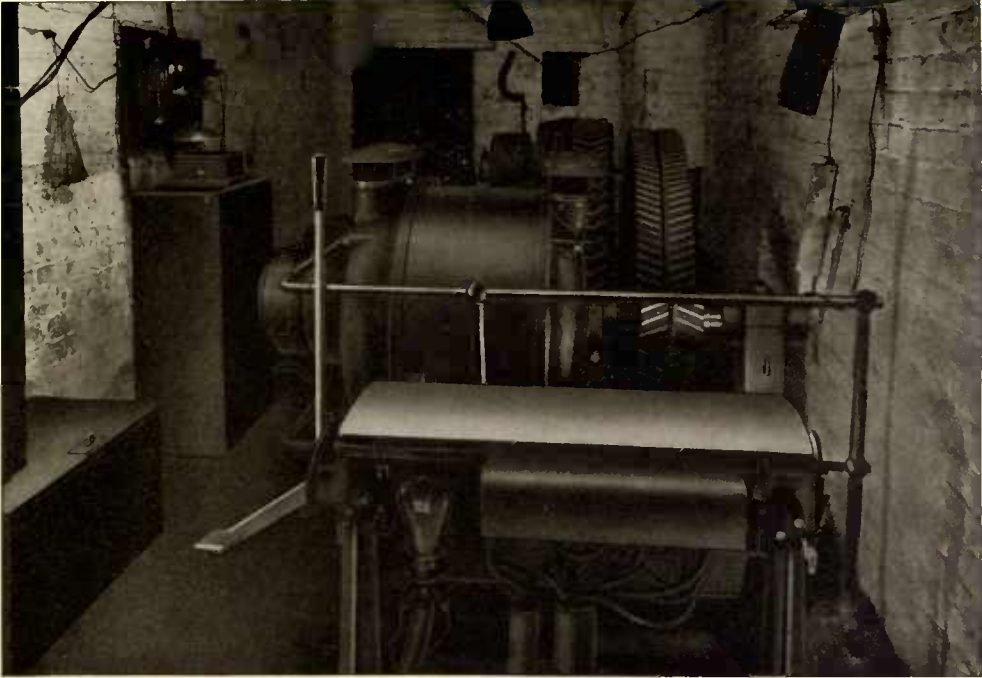


Fig. 121
Harton Coal Co., South Shields, England.
Endless Rope Haulage.
Motor output 60 H.P., 2,000 volts, 40 cycles.

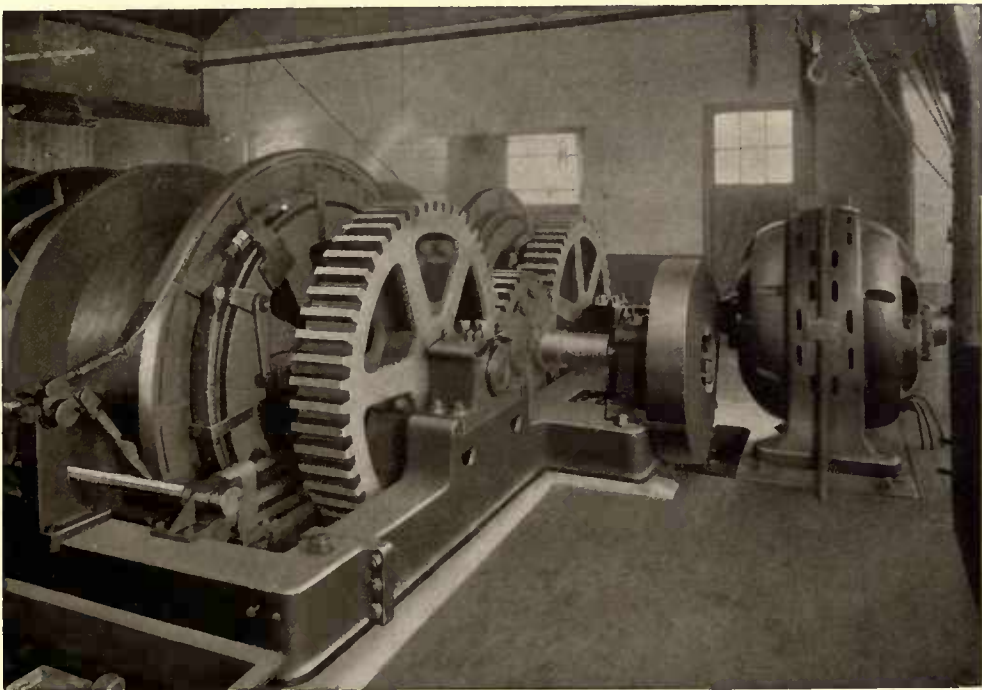


Fig. 122
Peases West Colliery, Durham, England.
Main and Tail Haulage. Converted steam set.
Motor output 250 H.P., 2,000 volts, 40 cycles

The space usually required at both ends of the track for forming and arranging the trains can also be dispensed with. The motor can be started either by means of a controller or an ordinary starter, which should be amply dimensioned so that the haulage can be started several times successively against full load. Continual attendance is not necessary if arrangements are made so that the motor can be stopped or started from any point along the road. In the latter case the starter must be designed for automatic slow starting. In the case of larger haulages and important roads, an attendant should always be provided. The starting and stopping of the haulage are then carried out by the attendant in accordance with signals from points along the road.

CHAPTER XII

AUXILIARY MACHINES IN-BYE

Auxiliary machines for working in-bye have to be moved frequently in order to allow for extensions of the mine. They must therefore be so designed that they can be dismantled and re-erected without difficulty, and hence their weight must be kept within low limits. It is often desirable to mount the machines on wheels, so that they can be transported along the existing pit railways.

These machines are almost exclusively driven by electricity. They can be built for high speeds and if coupled direct to electric motors, form simple and compact sets. The current is supplied to the motors through light flexible cables, which are wound on a cable drum and shortened or lengthened as required in the manner described in the chapter on rock drills (Fig. 160).



Fig. 123
Small Portable Compressor.

Two electrically-driven centrifugal pumps, combined with their motors, are shown in Figs. 125 and 126. These serve to pump out inclined drifts, and for this reason the trucks on which they are carried are so constructed that the pump remains horizontal when on a gradient.

The supporting frame of the pump shown in Fig. 126, is constructed for various inclinations of the road, so that the pump can work in a drift with practically any dip. When the output is very large, and especially where the drift is very steep or the shaft itself has to be pumped clear, sinking

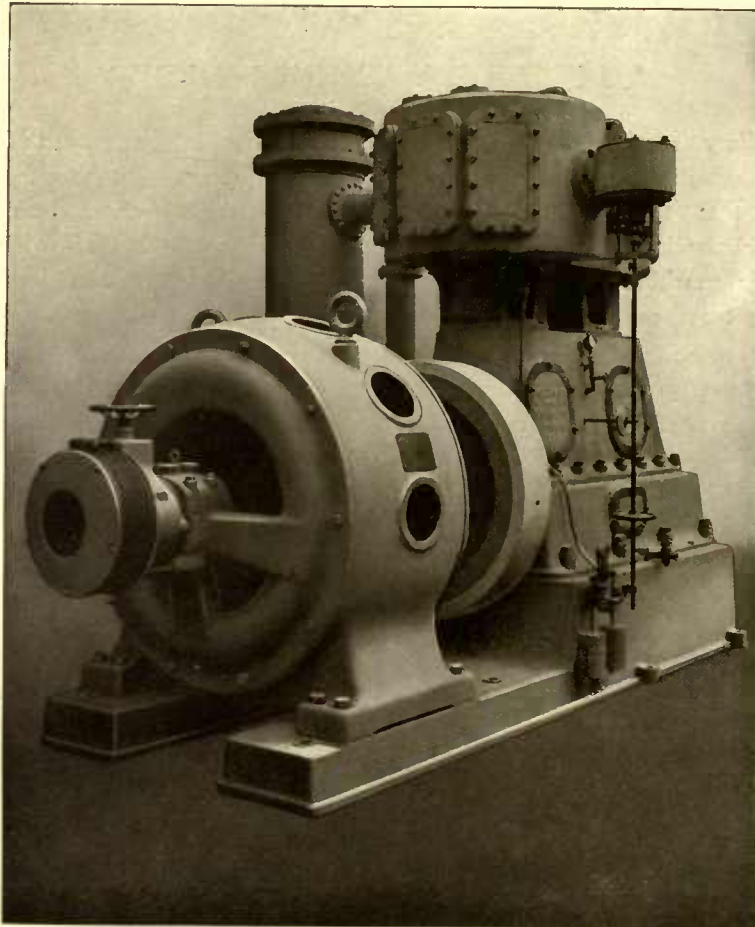


Fig. 124

Small Compressor for Pit Installation.

Output 150 H.P. Semi-Portable.

pumps are used, which can be transported on wheels attached to the framework. The bearings of the pumps are specially designed in order to allow for the inclined position. In other respects the construction of these pumps is similar to that of the sinking pumps described in another chapter, so that further description is unnecessary.

The loss of pressure which occurs in long air pipes has led to the installation of electrically-driven compressors in the immediate neighbourhood

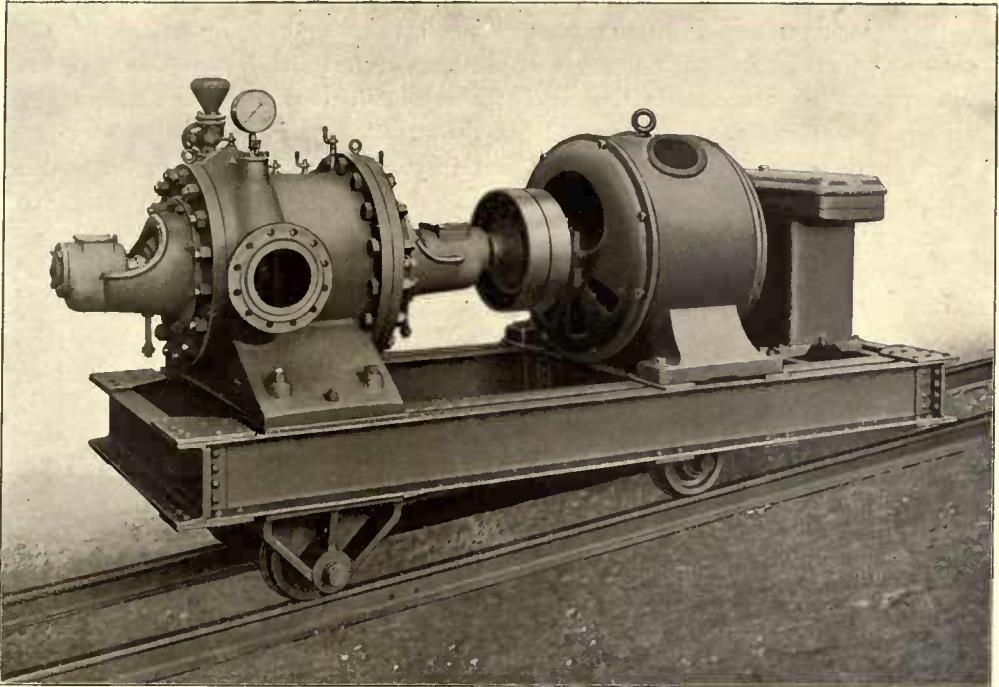


Fig. 125
Portable Centrifugal Pumping Set.
For pumping out inclined drifts.

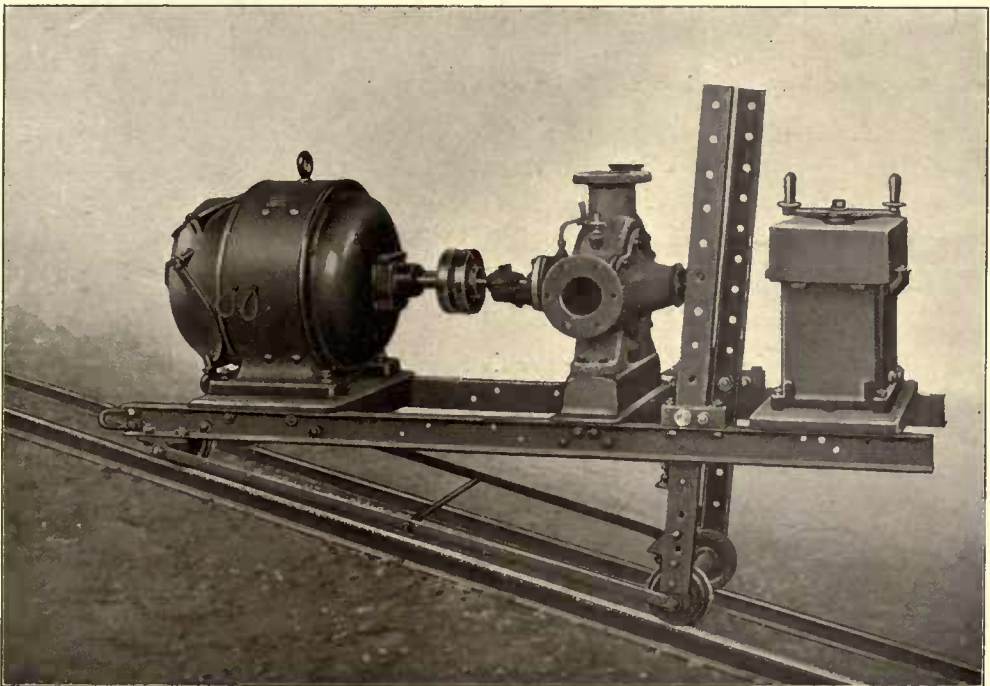


Fig. 126
Portable Centrifugal Pumping Set.
Mounted on adjustable carriage.

of the machines. This arrangement embodies both the advantages of the electrical transmission of energy, and of the compressed air working system. No appreciable increase in the efficiency is obtained by this means, however, as when working with compressed air, the greater part of the losses occur in the actual machines or tools, and not in the piping. The small portable compressor sets are, however, of considerable advantage in mines, when a compressor has not been installed above ground. These small compressors are also desirable when compressed air machines have to be driven at distant points of the mine, so that a long pipe line would be necessary for connecting them to the existing air supply. An electrically-driven compressor of this type, with a 150 H.P. motor is shown in Fig. 124 ;

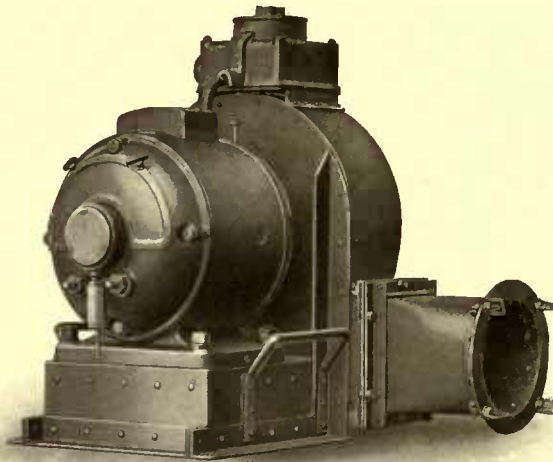


Fig. 127

Portable Fan. Motor with Squirrel-cage rotor.

it serves to supply a number of rock drills with compressed air, and is arranged for installation near the working face. While it is not immediately transportable, its construction is such that it can be removed with comparatively little difficulty. Smaller compressors are frequently mounted on wheels (Fig. 123), and are usually built in sizes of 20 to 25 H.P. suitable for driving two or three drills simultaneously. The compressor is provided with a small reservoir, mounted on a special truck, coupled to the compressor carriage. The greatest advantage of these small sets is the ease with which they can be moved, which makes it possible to bring them into the immediate neighbourhood of the working face, and to remove them to a safe distance again just before firing the blasting shots.

The ventilation of the mine frequently requires a large number of small fans in addition to the main fan. These small fans are used either to supply unfavourably situated districts with air or to remove the gases resulting from blasting operations. In both cases high-speed fans coupled direct to electric motors have proved to be very serviceable.

A portable fan of this type intended to supply a small district with air is shown in Fig. 127. It is so arranged that two workmen can easily move it from place to place. The fan is driven by a direct-coupled squirrel-cage motor for which the starting switch is mounted on the machine.

CHAPTER XIII

ELECTRIC LOCOMOTIVES

The possibilities and the advantages of haulage by locomotives, especially the ability to advance further into the workings, were mentioned in the chapter on stationary haulages. Locomotives are able to travel along roads with numerous and sharp curves and a large number of branches or sidings. Even very narrow single tracks are no hindrance to locomotive haulage. The position of the road can be changed at any time without interrupting the service, and the tracks can be extended right up to the working face ; in fact, there is no limit

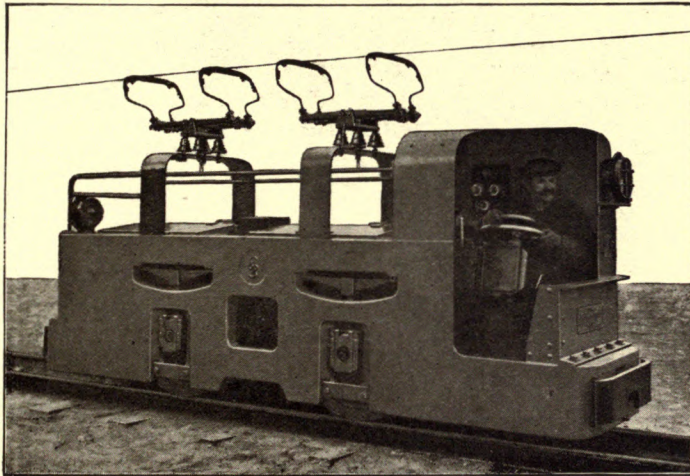


Fig. 128

Mülheimer Bergwerks-Verein, Rosenblumendelle Mine.

Pit Locomotive for single-phase alternating current, 250 volts, 50 cycles. Weight 7.5 tons, tractive effort 1,600 lbs. Speed 9 miles per hour. Two motors, each 18 H.P.

to the length or the distance to which the track may be extended. The output can be increased by adding locomotives as required, and the speed of haulage is nearly double that of rope haulages. This last feature makes it possible to carry the men from the main shaft to the working face in a shorter time than would otherwise be possible.

Underground locomotives can only be operated electrically. Steam locomotives are out of the question on account of the smoke and steam produced by them, and the danger of fire. The use of locomotives driven by internal combustion motors is increasing, but these are also accompanied by the danger of fire, and their operation is not so reliable as that of electric locomotives. Compressed-air locomotives are less economical, and only come into consideration where explosive gases are present in haulage roads. In all cases where the question of firedamp offers no difficulties, the electric locomotive is preferable, especially if a supply of electric energy is already available.

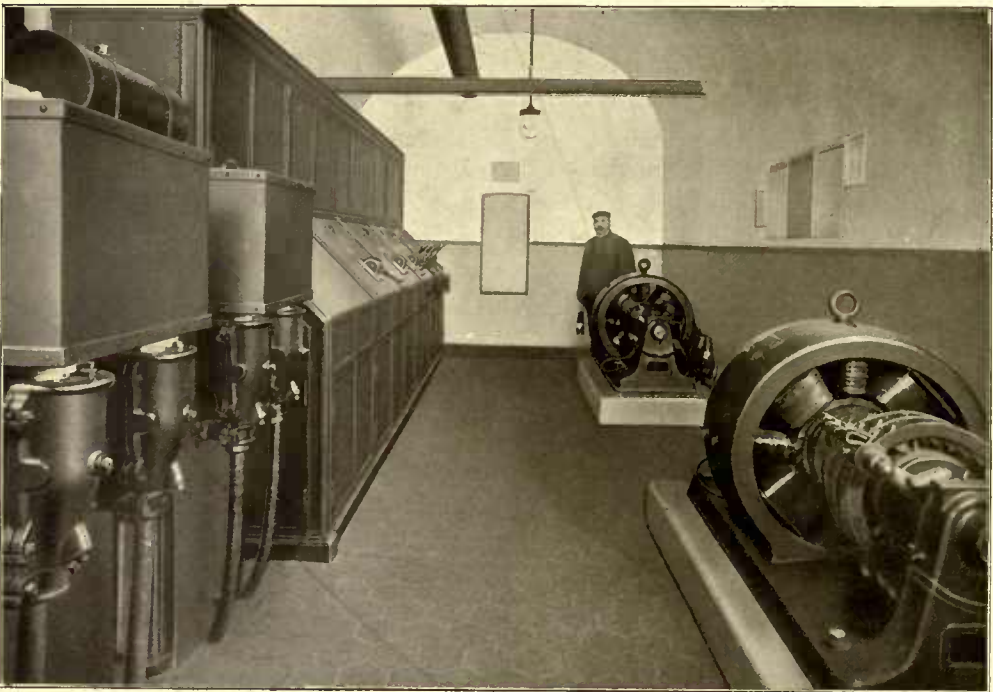


Fig. 129

Kölner Bergwerks-Verein, Pit Anna, Alten-Essen, Germany.

Two rotary converters for pit railway, three-phase current, 5,000 volts, 50 cycles ; 1,500 R.P.M.
Direct current 250 volts. Output of each 80 K.W.

Direct-current locomotives are usually employed, but as most modern mining installations have a three-phase supply system, there is a growing inclination to use single-phase alternating current for the locomotives, the power being taken from one phase of the three-phase system. The use of three-phase current for locomotives is not to be recommended, as in such a case each track would require two separate trolley wires and correspondingly complicated switching arrangements. The unbalanced load, caused by



Fig. 130
Eschweiler Bergwerks-Verein A.-G., Eschweiler Reserve Pit,
Nothberg, Germany.

Mine locomotive for direct current, 220 volts. Weight 5.5 tons. Tractive effort 1450 lbs.
 Speed 6 miles per hour. Two motors, each 12 H.P. Width of the locomotive 28 ins.



Fig. 131
Royal State Mines, Zabrze, Upper Silesia, Germany.

Direct-current mine locomotive, 220 volts, weight 5 tons, tractive effort 2,200 lbs., speed 5 miles per hour.
 Two motors, each 15.5 H.P.

supplying the locomotives from one phase of the distribution system, will not materially affect the average mining power station. In the case of longer railways, it is possible to distribute the different sections among the three phases of the distribution system in such a manner as to produce a practically balanced load. Single-phase railways can be extended to any desired distance without increasing the voltage in the trolley wire, by providing a sufficient number of feeder points at which current is supplied from the high-tension distribution system through static transformers. It is, therefore, possible to keep the pressure in the trolley wire at a low value. Direct current, if employed, is transformed from the three-phase supply through rotary converters, and is supplied direct to the trolley wire. As a rule the pressure should not exceed 250 volts, to avoid danger to the workmen. If the track is of considerable length, it is necessary to provide several converter sub-stations which, of course, materially increase both the capital and maintenance costs. The actual economy of the single-phase, as compared with the direct-current system, can only be decided by a detailed consideration of each particular case; the losses occurring in the rotary converters of direct-current railways, are balanced by the greater losses in the return circuit of single-phase railways, and the lower efficiency of the single-phase motors. A single-phase locomotive, equipped with two 18 H.P. motors, is illustrated in Fig. 128.

The conversion of alternating current to direct current was formerly carried out by means of motor generators, but at present rotary converters are extensively used for this purpose as they possess many advantages over motor generators. Their simple construction and high speed reduce the amount of space required to a minimum. The capital cost and maintenance costs of rotary converters are very low, and the efficiency and power factor is high at practically all loads. They can be started up from the three-phase side without auxiliary apparatus, and synchronising gear can be dispensed with.

Current is supplied to the locomotives through an overhead trolley wire of hard-drawn copper, which is supported from the roof at intervals of 18 to 30 feet on insulators. The latter are of the double porcelain cup type, protected against external damage by a strong iron cap. An insulator for this purpose is shown in Fig. 132. In mines where the haulage roads are very high so that the insulators cannot be fastened directly to the roof, the trolley wires are supported on cross wires in the way generally employed for surface tramways. The trolley wire is supported in clamps in such a manner as to leave its lower surface free for contact. As the wire is not soldered into the clamps, it can be readily removed when timbering has to be renewed. Special

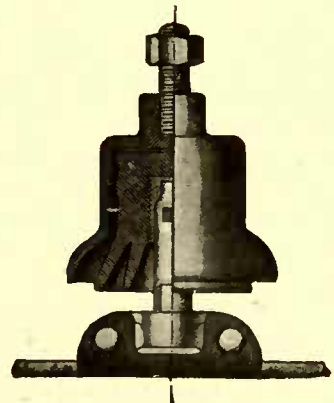


Fig. 132
Insulators for supporting the trolley wire.

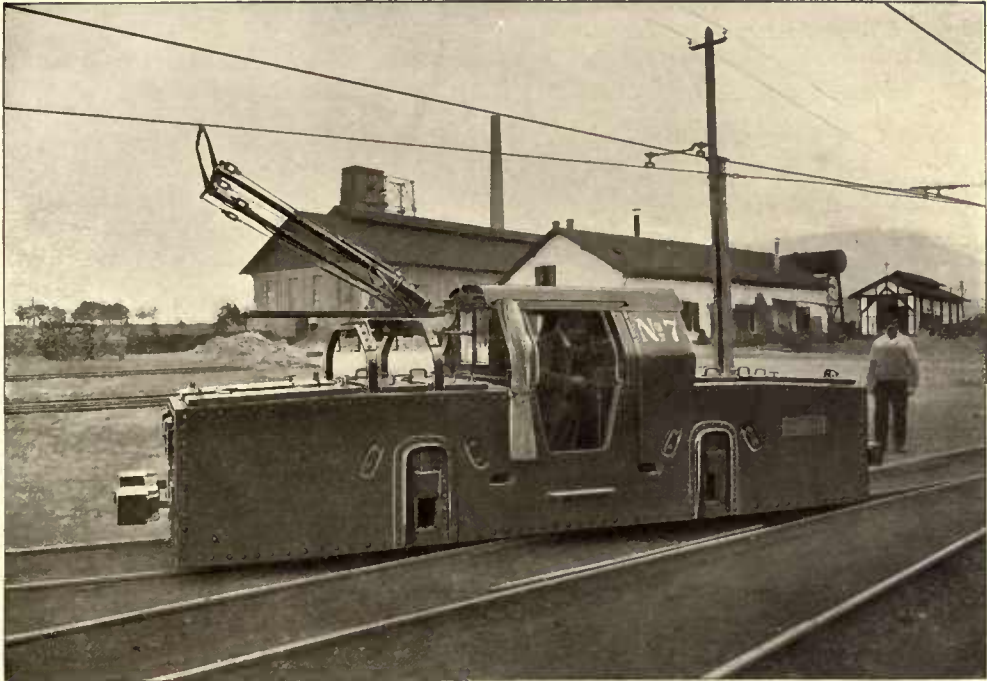


Fig. 133

Gebr. Stumm, Gr. Hettingen Lorraine, Germany.

Mine Locomotive for direct current, 500 volts., weight 14.5 tons, tractive effort 7,000 lb.,
speed 8 miles per hour. Two motors, each 80 H.P.

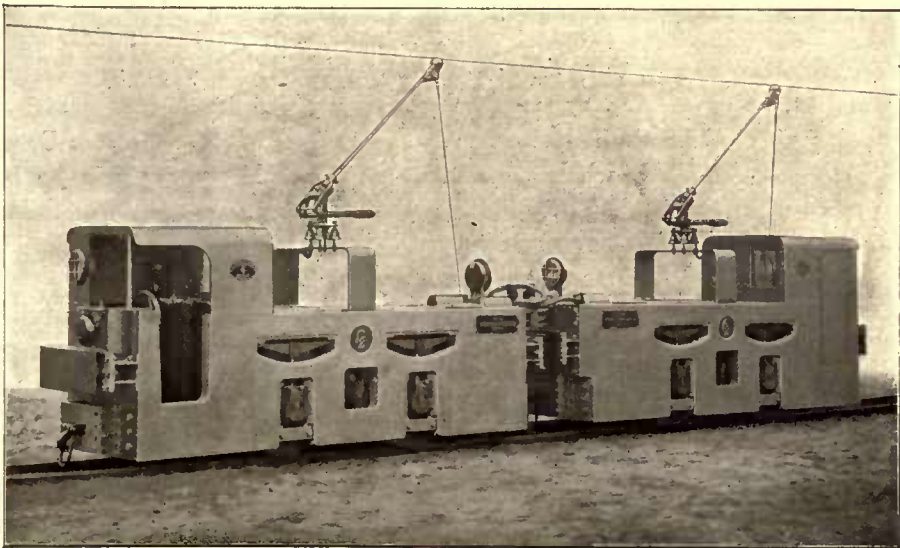


Fig. 134

Société des Mines d'Amermont et Dommary, Bouligny, France.

Double mine locomotive for direct current, 300 volts, weight 16 tons, tractive effort 4,400 lb.,
speed 6.25 miles per hour. Four motors, each 19 H.P.

protection against accidental contact with the trolley wire is not usually required, but if necessary this can be readily arranged by the provision of a vertical board on each side of the wire, as shown in Fig. 135. The trolley wire should, when erected, be as even and level as possible, differences in height of more than 12 inches being avoided, so as to permit the use of a trolley of the simplest design. The current is returned through the rails, which are bonded at the joints by means of copper bonds.

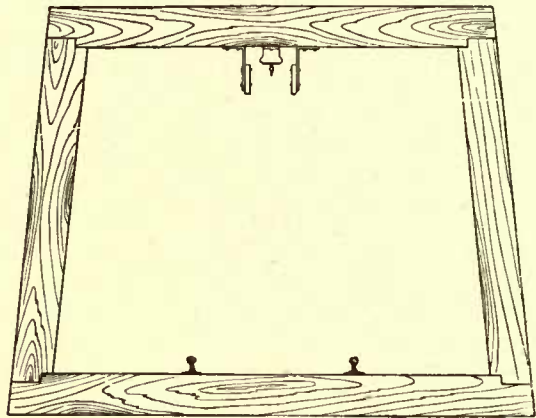


Fig. 135

Showing arrangement for protection against contact with the trolley wire.

The design of the locomotive is usually determined by the gauge of the track, and the height and width of the haulage road; the Siemens type of locomotive is therefore specially suitable owing to its great compactness. In the case of locomotives up to 5 tons in weight, the frame is constructed of steel. For specially heavy locomotives the sides of the frames are of cast iron, and the buffers of cast steel. As these materials, however, can only be used above certain thicknesses, owing to their inability to withstand the shocks due to derailment or similar accidents, built-up frames are frequently used. These enable the locomotive to be of very narrow construction; that shown in Fig. 130, for instance, has a width of only 28 inches for a gauge of 19 inches. The motors, resistances, sand boxes, etc., are easily accessible, the top of the locomotive being provided with openings for this purpose, and the whole superstructure can be readily removed and the motors lifted out of their supports. Accessibility of the motors is of special importance in the case of mine locomotives, as the narrow gauge usually does not permit of the provision of inspection pits. Recently a device has been introduced by the Siemens Concern by means of which the whole superstructure of the locomotive can be lifted by the aid of four simple screw jacks; the motors can then be withdrawn without difficulty. This arrangement, which can, if desired, be electrically driven, greatly facilitates the speedy exchange of the motors.

The driver's cab is usually placed at one end of the locomotive (Figs. 130 and 131). The locomotive shown in Fig. 133, however, is provided with a cab in the centre, so that the driver can see the track equally well in either direction. This locomotive possesses the further advantage that the motors are very easily accessible. Locomotives with two cabs, one at each end, are an exception.

The motors are of the totally-enclosed type, fully protected against damp and dirt. One end is suspended from the main axle by a long bearing,



Fig. 136

"Königsborn" A.G. Unna, Germany.

Pit locomotive with battery. Weight 6.5 tons, tractive effort 1,100 lbs., speed 6 miles per hour.
 Two motors, each 11 H.P. Capacity of battery 74 ampere-hours. Discharge voltage 160 volts.



Fig. 137

Harton Coal Co., Ltd., South Shields, England.

Direct-current locomotives, 500 volts, weight 15 to 34 tons. Speed 9 miles per hour.
 Output 93 H.P. to 230 H.P.

while the other rests through a spring support on a cross piece of the locomotive frame. The power is transmitted through single reduction gearing, which is entirely enclosed in a suitable oil-filled casing. The current is taken from the overhead wire by means of a trolley wheel, which is pressed against the wire by springs.

The locomotives built by the Siemens Concern, however, are usually equipped with a bow collector in place of a trolley wheel. This arrangement has the advantage that it reverses automatically when the direction of the locomotive changes, and is not so apt to leave the wire at curves, crossings, or switches. The use of the bow collector also permits of simpler wiring arrangements at crossings and switches. Each locomotive should preferably be equipped with two collectors, so that an uninterrupted current supply is ensured even if one of the collectors should temporarily break contact with the wire. This arrangement has the further advantage that sparking at the point of contact is reduced to a minimum. The current from the overhead wire passes through an automatic circuit breaker and the controller to the motors, and returns to the generator through the wheels and the rails. The controllers are of the reversing type, so that the locomotives can run in either direction, and they are also arranged to control the speed. The motors are usually arranged for series-parallel control. The locomotives are supplied with electric searchlights, in order that the track ahead may be well illuminated.

The transport of the material along the main roads often requires very powerful locomotives. A locomotive with a total output of 160 H.P. is shown in Fig. 133, and a double locomotive in Fig. 134. The latter type offers advantages in cases where the cross section of the roadway is not sufficient to accommodate a single larger locomotive. The two parts of the locomotive



Fig. 138

Harton Coal Co. Ltd., South Shields, England.

Locomotive with train. Weight 40 tons, tractive effort 9,200 lbs. Speed 9 miles per hour.

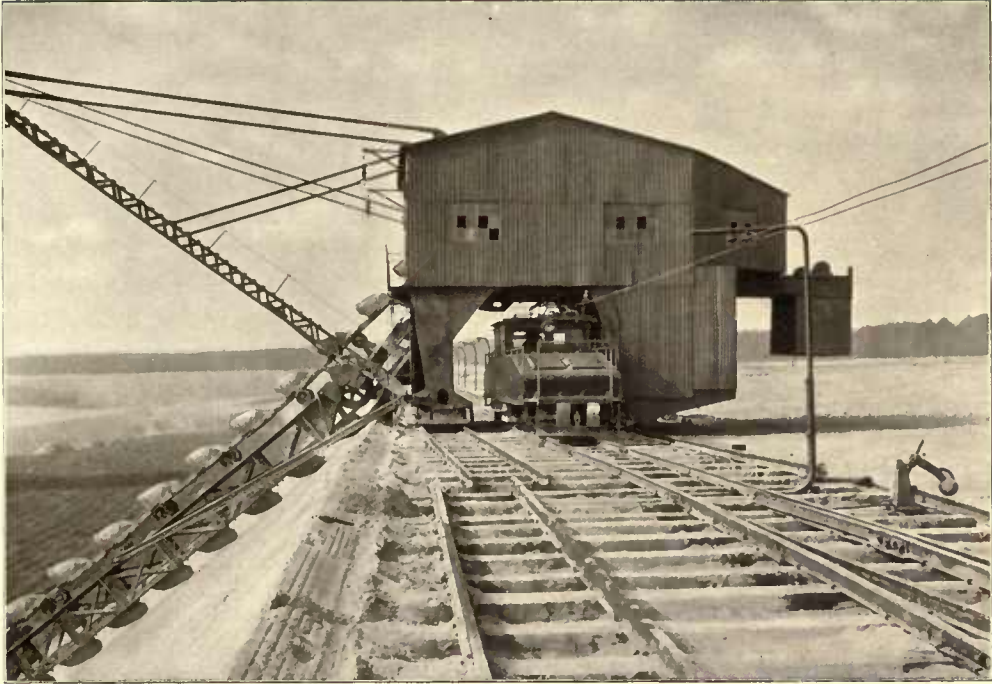


Fig. 139

Lignite Mine "Kauscher Werk" Petershain, Germany.

Electrically-driven excavator with electric railway. The track and the trolley system are moveable. Output of the locomotive 224 H.P., direct current 550 volts.

are exact duplicates of one another, and the motors can be controlled from either of the cabs. The electrical connections between the locomotives are made by means of flexible cables.

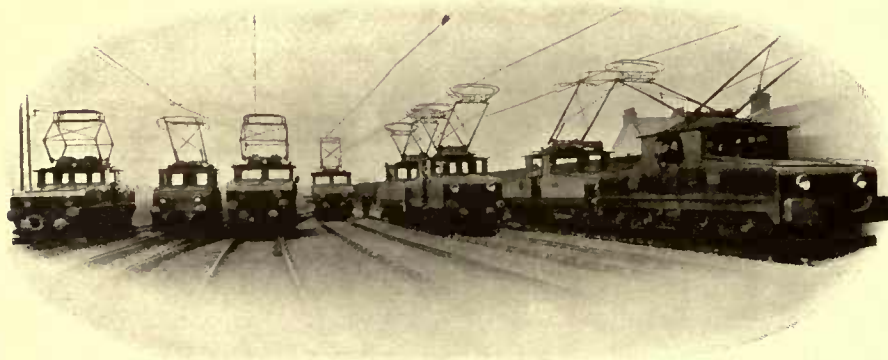
In roads which are so low that a trolley wire cannot be installed, locomotives with storage batteries have proved very serviceable. These locomotives are also very suitable as auxiliaries to bring the loaded trucks from side tracks to the main haulage line.

A type of battery locomotive frequently employed for mine haulage is shown in Fig. 136. The battery is placed in a box, supported on a number of rollers with bearings in the frame. Similar rollers are arranged at the charging station for receiving the battery boxes. When the locomotive comes into the station, the discharged battery is removed from the locomotive and replaced by a newly charged battery from another set of rollers at the other side of the locomotive. The rollers are operated by means of a chain and handwheel. The removal of the battery, therefore, requires very little time. Current for re-charging the batteries is supplied by a motor-generator set installed in the substation.

In addition to the locomotives employed underground or in the headings leading to the surface, many mines require an extensive railway installation above ground. The construction of the locomotives for the latter service is not

subject to the same restrictions as for those in use underground, and they can therefore be designed to draw much heavier loads. The driver's cab is usually placed in the centre of the locomotive, and is high enough to allow the man to stand upright. The collector is placed on the roof of the driver's cab, so that it shall not interfere with the view along the road, or with the accessibility of the motors. Such locomotives are usually driven by direct-current motors, on account of their large outputs, as large alternating-current motors would subject the power station to an excessive out-of-balance load. A number of locomotives belonging to the Harton Coal Co., are illustrated in Fig. 137, and Fig. 138 shows one of the largest of these attached to a train of coal trucks.

Similar locomotives are used in surface workings in connection with bucket or chain excavators. For this purpose moveable tracks are necessary so as to follow up the working field of the excavator; the supports for the overhead line are fastened to the sleepers, so that they can be moved together with the track. The locomotive itself is so designed that it can pass through the openings in the excavator (Fig. 139). A number of installations of this kind have been erected for lignite mines in Germany.



CHAPTER XIV

ELECTRICALLY-DRIVEN COAL WASHERS, BRIQUETTE PRESSES, &c.

So many various types of machinery come into question for the preparation of the material produced by the different mining industries, that it is scarcely possible to describe each one separately. A detailed description of each is unnecessary, however, as the methods by which they are driven are similar.

The demands which are placed on all motors used in connection with mining plant are excessively heavy, both electrically and mechanically. The attendant is usually an unskilled man, so that careful handling of the electrical machinery and apparatus can hardly ever be counted on. This point applies to all apparatus installed in mines. The motors themselves are subject to heavy shocks, due to the varying power demand of the driven machinery, and to unavoidable rough usage, so that ample dimensions and specially strong mechanical design are absolutely essential. Very frequently the motors have to operate in dusty or damp rooms, and require to be protected against splashing water or dust.

As the majority of the machines operate at a comparatively low speed, the transmission is effected through shafts and belting, in which case the motors are fitted with pulleys. Either the individual-drive or group-drive system may be employed. If the latter system be installed, care should be taken to arrange those machines together which operate simultaneously, and may, therefore, be driven by the same motor. If the output is small, the use of squirrel-cage motors is to be recommended on account of their simplicity, and the absence of any winding on the rotating parts; where the starting torque required, however, is very large, it is necessary to provide a fast and loose pulley for starting. Further, the starting current of squirrel-cage motors is very heavy, and may exert an undesirable influence on the power station if the motor output is large. It is possible to reduce this starting-current considerably by using a starting transformer, but this entails a reduction of the starting torque much below the value usually required for this type of drive. The usual practice is, therefore, for medium and large outputs to instal motors with slipping rotor. These motors are started up by the aid of a rotor resistance, and can exert a very large starting torque without undue current consumption. The starters are usually of the metallic type, with oil-cooled resistances, and are provided with tight fitting covers as a protection



Fig. 140
Coal Washery of the "Bergmannsglück" Mine, Buer (Germany).
Motor with starter and control pillar.

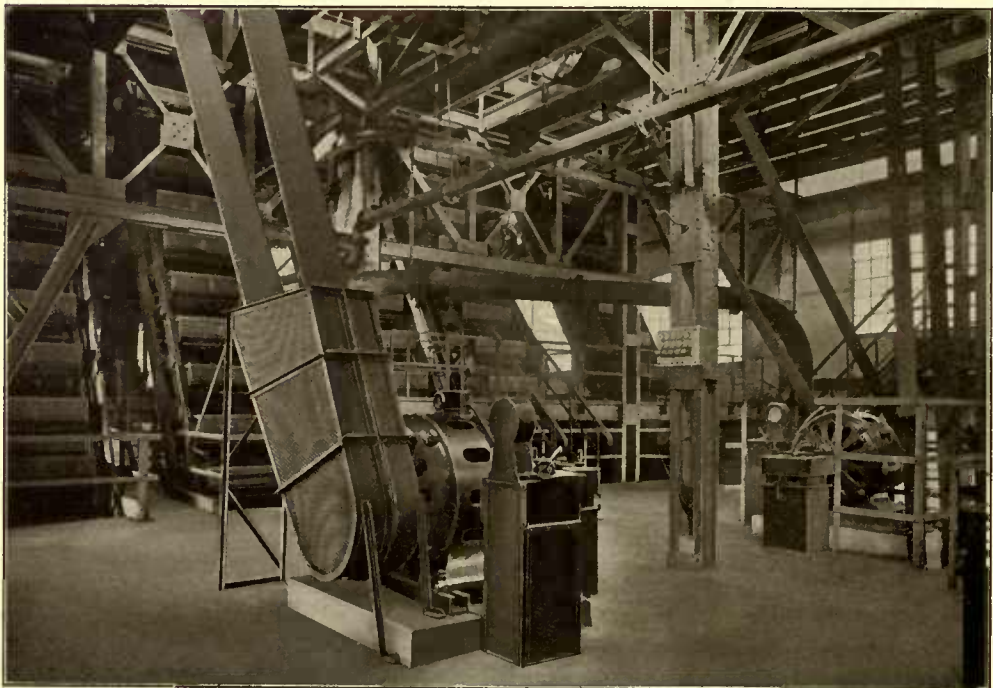


Fig. 141
Protected-type three-phase induction motor.
With totally-enclosed sliprings, oil-immersed starting resistance, and control pillar with fuses under oil.

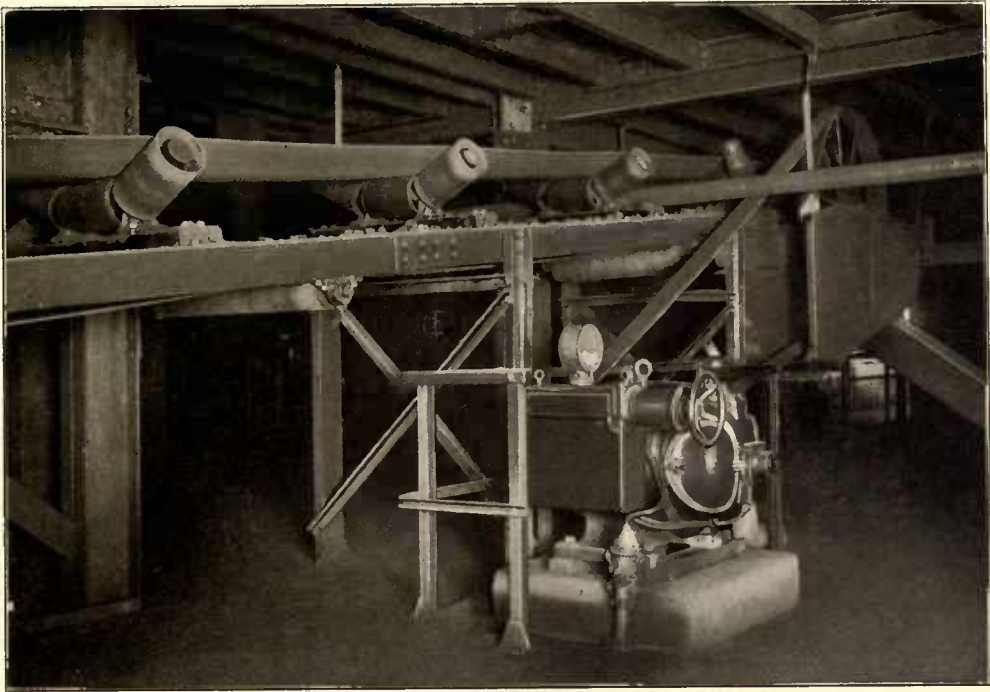


Fig. 142

Coal Washery of the "Unser Fritz" Mine, Hamm, Germany.
Induced-draught type induction motor, with starter and ammeter mounted on the motor casing.
Output 28 H.P.

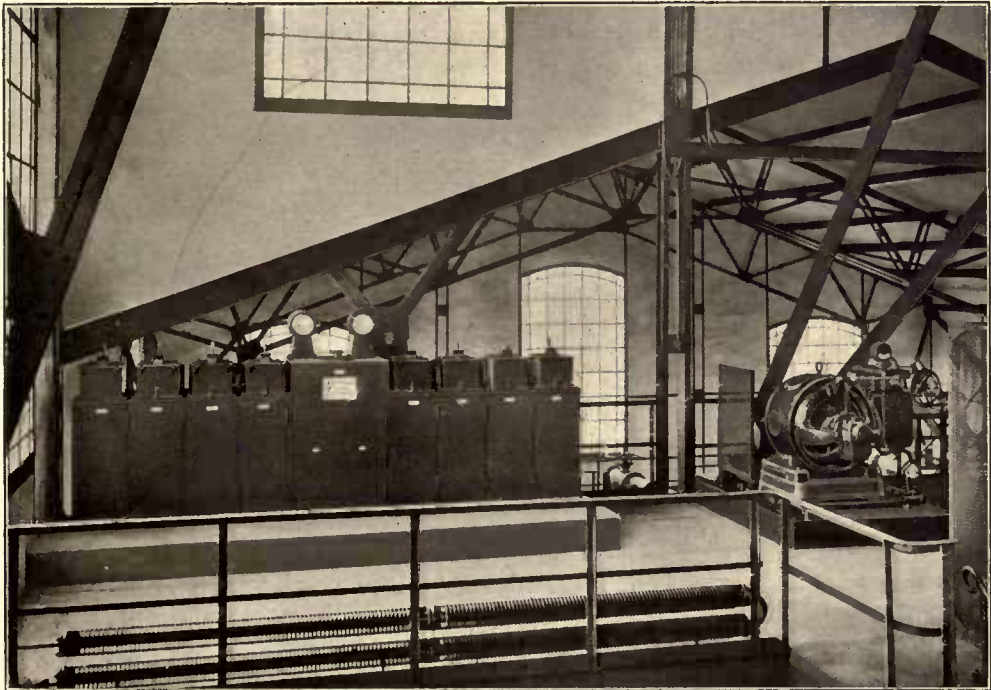


Fig. 143

Protected-Type Induction Motor.
With starter and ammeter mounted on the motor casing. Output 52 H.P.
Control board, consisting of high-tension pillars, with oil-immersed fuses.

against dust or damp. The motors are usually provided with brush-lifting and short-circuiting devices, to reduce the wear of the brushes and slip-rings to a minimum. If the locality in which the motors are placed is very dirty, the use of dustproof slipping covers is advisable (Fig. 140).

The switchgear should be arranged in cast-iron or sheet-iron switch pillars. For high-tension installations, switch pillars with oil-immersed fuses (Fig. 166) have been widely adopted. It is advisable to provide such pillars with an ammeter, so that the current consumption can be controlled. The connections between the motor and the switchgear, and also for the distribution of the electrical energy inside the building usually consist of cable or of rubber insulated wire in conduit, or mounted on insulators.

The motors can be either of the protected or of the induced-draught type. Protected-type motors, fitted with end shields which protect the winding from mechanical injury, are usually considered sufficient. The motor should be blown out with compressed air from time to time to prevent too great an accumulation of dirt in the windings.

The induced-draught motors are totally-enclosed with the exception of ventilating openings provided at two points. A fan is fitted to the rotor which draws in air through one opening and expels it through the other, so that the motor is efficiently cooled. The casing is provided with doors, so that the brushes and sliprings can be inspected. These motors are used in localities where protection against falling debris or splashing water is necessary. If the air in the motor room is very dusty, induced-draught motors cannot be used without slight modification, otherwise the air draught would carry large quantities of dust into the motor and lead to an early clogging and deterioration of the windings. If it is necessary, for some reason, to place induced-draught motors in dusty rooms, the ventilating pipes should be extended to the open air. Suitable flanges are provided on the casing of the motor for these pipes. This arrangement reduces the permissible output of the motor by a small amount on account of the energy lost in overcoming the resistance in the pipes.

Some difficulty is experienced with regard to the disposal of the waste heat in the case of totally-enclosed motors, and therefore, for a given output, a larger and heavier machine would be required than in the case of open-type machines; for outputs above 20 H.P. water cooling must be employed. The use of totally-enclosed motors is, therefore, restricted as far as possible, and they will only come into use where the motors are exposed to the weather, or have to be installed in rooms containing dust or dangerous gas, and where the introduction of cooling air from outside is not possible.

Some years ago the Siemens Concern introduced induction motors provided with starters mounted directly on the motor casing. These motors have been found to meet the requirements of mines in every way. They are fitted with all the requisite starting and switchgear, so that removal is extremely simple, as the whole can be transported bodily from place to place, the only work necessary being to connect the terminals to the supply. The extra cost of these motors is compensated for by the omission of

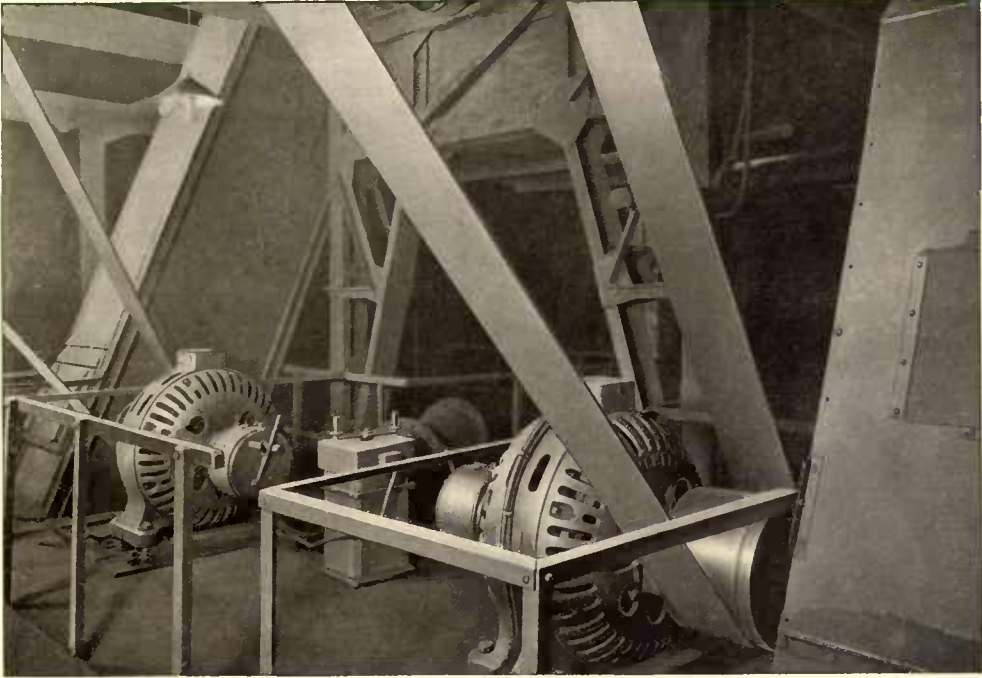


Fig. 144
Cardiff Washed Coal Co., Cardiff, South Wales.
Protected-type motors driving rockers.

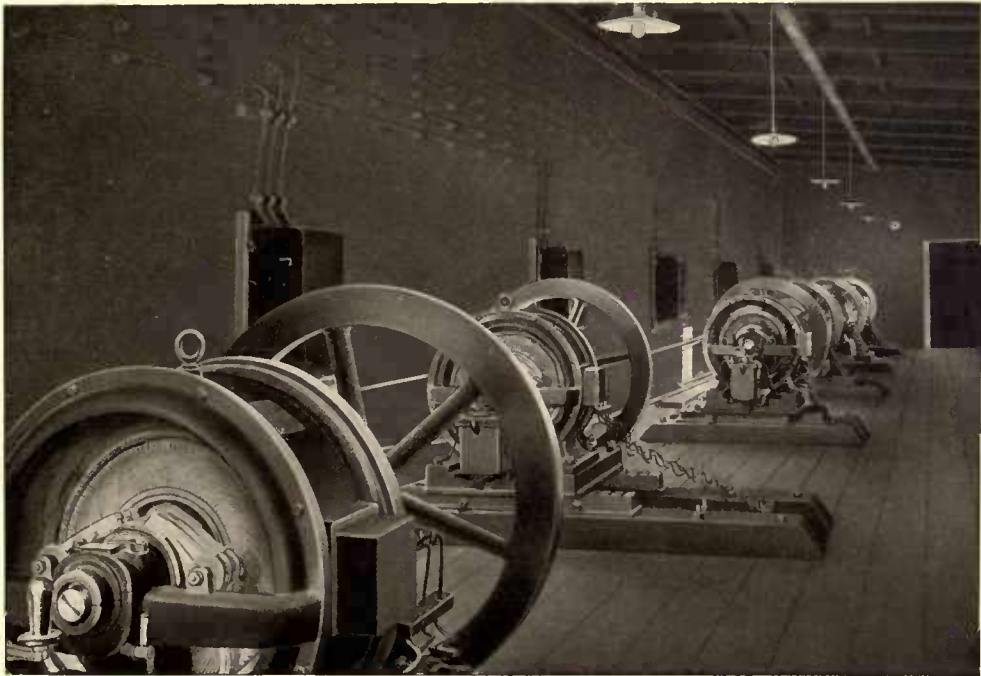


Fig. 145
H. B. Sloman & Co., Saltpetre Works.
Individual drive of stone crushers in a nitrate mine in Chili, by 25 H.P. motors with flywheel.

auxiliary starting and switch gear and connecting cables, and by the lower cost of erection. This type of motor is built for all outputs up to 230 H.P., and pressures up to 5,000 volts. Where the pressure does not exceed 1,000 volts, the primary switch is combined with the starter, but for higher pressures a separate switch is preferable. Motors of this kind are illustrated in Figs. 142 and 143, which represent an induced-draught type, and one of the protected type respectively. The motor and starter are so interlocked as to make it impossible to operate any switch in the wrong order. Breakdowns or accidents in consequence of wrong manipulation of the switchgear are therefore impossible, even if only unskilled attendance is available.

If the machines are liable to heavy shocks and fluctuations of load, as for instance is the case with stone breakers, it is desirable to provide flywheels to overcome the peak loads. Such flywheels, however, can only deliver their stored energy if a speed reduction takes place, and it is, therefore, necessary to provide some means for reducing the speed of the motor at the moment when the energy stored up by the flywheel is to be used. For this purpose, the rotors are connected to a fixed or an adjustable regulating resistance, which causes the speed to diminish when the current rises.

Electrically-driven stone breakers in a nitrate mine in Chili are shown in Fig. 145. Each stone breaker is driven by a 25 H.P. motor.

Large coke oven plants require separate special machines both for filling the ovens and for ramming out the coke. Electrical drive can be applied to these machines to considerable advantage. The machines must be moveable, so that they can work at every point of the oven platform, and must, therefore, receive their current supply from a trolley wire through suitable collectors, similar to those in use on tramways.

Direct current is preferable if it is available, as the arrangements for collecting current are simpler and easier to instal. A machine of this type is shown in Fig. 146. The stamper, which is built into the charging machine, is driven by a separate small motor, with an output of about 3 H.P., the other parts of the machine being driven by a common motor, with an output of about 50 H.P. This motor is mechanically connected through couplings to the different parts of the machine, as desired. A reversing controller is provided for reversing the direction of rotation. This should preferably be fitted with carbon contacts, and the whole switchgear must be of substantial mechanical design. The use of three-phase current presents no considerable difficulties with regard to the current collecting arrangements.

An innovation of considerable importance for the lignite coal industry, is the electrical drive applied to briquette presses. Formerly these presses were driven exclusively by steam engines, which were very uneconomical on account of their extremely high steam consumption. The exhaust steam of these engines was employed to dry the material, but it has been found more economical to produce the steam for heating purposes at a high pressure, and to utilize it in suitable turbines for the production of electrical power to drive the presses.

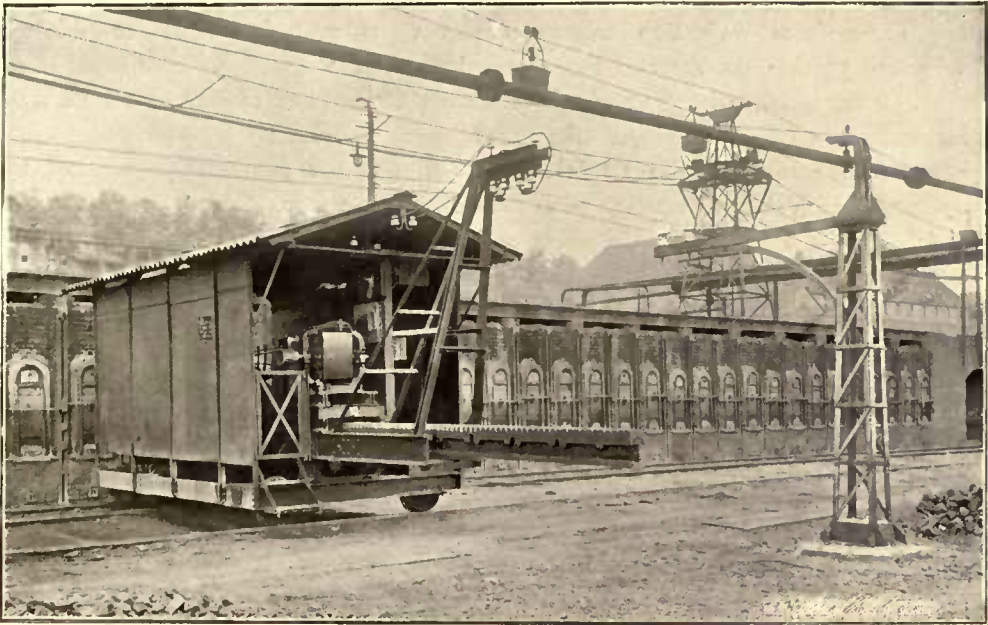


Fig. 146
Coke Oven Ram and Filler.
Driven by direct-current motors.

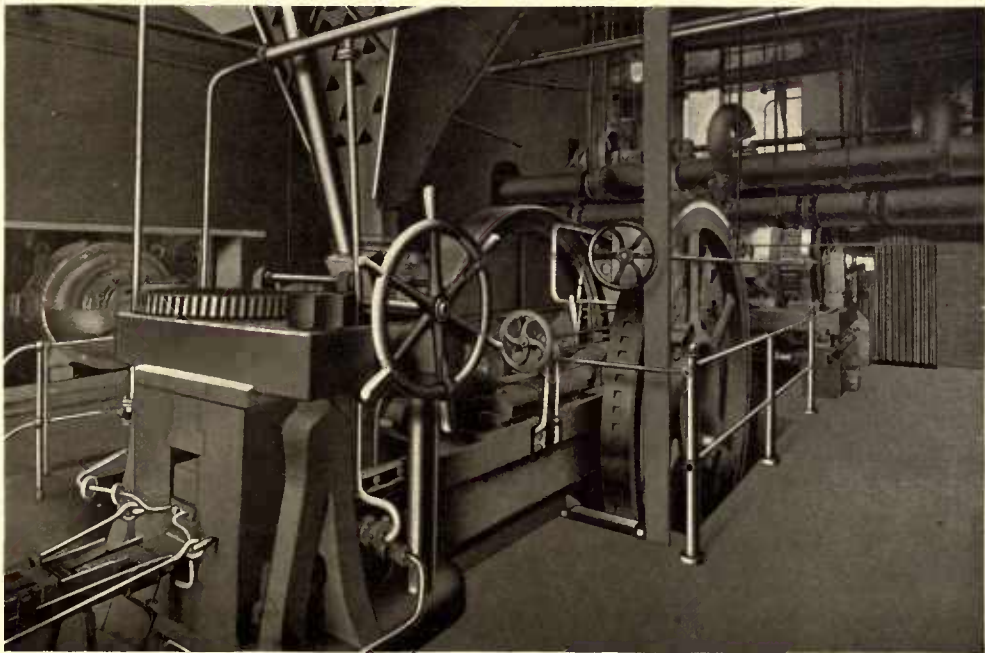


Fig. 147
Kauscher Werk Lignite Mines, Petershain, Germany.
Electrically-driven briquette press, with three-phase commutator motor, 180 H.P.

Three-phase induction motors are not extensively used for driving briquette presses, as most of these machines require speed variation between wide limits, which cannot be obtained with a three-phase motor without serious losses in the rotor resistance. As these losses are directly proportional to the speed reduction for constant turning moment, and the presses are required to operate during long or short periods at lower speeds, this method is not satisfactory. The only types of motor available for this purpose are direct-current motors or special three-phase motors which permit of speed regulation without appreciable losses. Tests made in the year 1909, at a German lignite mine, showed conclusively that briquette presses could be driven by direct-current motors, and direct current is also frequently used at lignite mines for driving the excavators and locomotives. As a result of these tests a large number of different drives have been installed.

There was considerable demand, however, for a suitable three-phase motor for driving the presses of those mines where only three-phase current was available. In order to test a new type of motor, viz., the three-phase commutator motor, the Siemens Concern erected a trial installation at the Kauscher Werk lignite mine, near Petershain, Germany. This plant is illustrated in Figs. 147. The briquette press was formerly driven by steam, and is now operated by a three-phase commutator motor, which has proved itself particularly adaptable to the requirements of such a plant. The speed of the motor can be regulated within wide limits by simply changing the position of the brushes; at starting it exerts a torque up to $2\frac{1}{2}$ times the normal. As the motor has a series characteristic, it is possible to utilize the energy of the flywheel and keep the actual power demand on the station practically constant. The efficiency is very high throughout the whole range of regulation. The power factor is unity at full load, and varies but little from this value, even at reduced speed. The trial plant operated so satisfactorily during the time of the tests, which extended over several months, that four more motors of this type, with an output of 240 H.P. each, for driving similar presses have been ordered.

CHAPTER XV

MACHINES SPECIALLY DESIGNED TO FACILITATE TRANSPORT

The transport of large electrical machines presents difficulties even in civilized countries, and it occasionally becomes necessary to take this into consideration when designing the machine. But this is especially the case when the machines have to be transported on secondary railways, which are only built for comparatively small weights and limited over-all dimensions. The difficulties become even greater when the machines have to be taken underground, as the cross sections of the roads and drifts limit the size of machines. The stators and rotors of large motors intended for use below ground usually have to be constructed of a number of parts which are assembled when the motor is in place.

The worst difficulties of this kind are, however, met with abroad. A good example of this type of plant is that installed by the Siemens Concern for the Redjang Lebong Gold Mine in Sumatra. The Sumatra gold fields are located in the interior of the island, about 60 miles from the coast, in the midst of tropical forests through which there are no paths worthy of the name road. The transport of fuel for boilers was therefore entirely out of the question and only the use of electrical energy generated by the existing water power made it possible to operate this mine successfully.

The owners of the mine, Messrs. Erdmann & Sielcken, in Batavia, entrusted the Siemens Concern with the supply and installation of an electric plant, which raised entirely new problems of construction.

The machines required were, of course, of a very special nature, but it was impossible to avoid using them in this mine, as they were necessary in order to work it on a larger scale. It must be understood, however, that machines of such design are very much higher in price than standard machines, as the price of the latter is based on repetition work, and naturally the cost of manufacture is much greater when, as in this instance, machines have to be built specially in small quantities. Cases may arise, however, where non-standard machines have to be used, and the increase in capital cost may then be fully justified if such machines give greater efficiency and economy in the working of the mine.

At a distance of about one and three-quarter miles from the mines, a water-power plant, consisting of two Pelton wheels, driving generators each

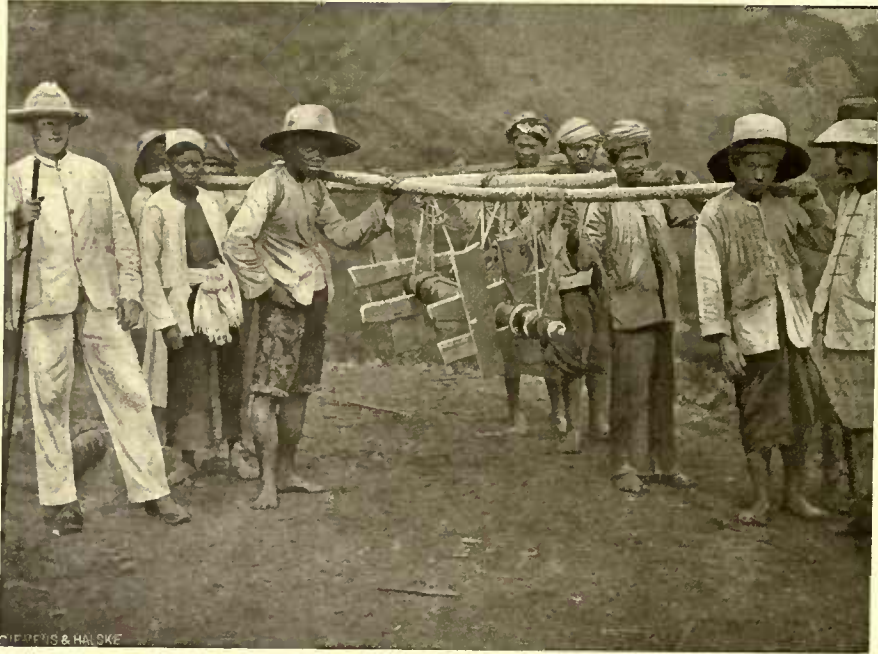


Fig. 148
Transport of a Generator Shaft by eight natives.



Fig. 149
Transport of Machine Parts on Bullock Carts.

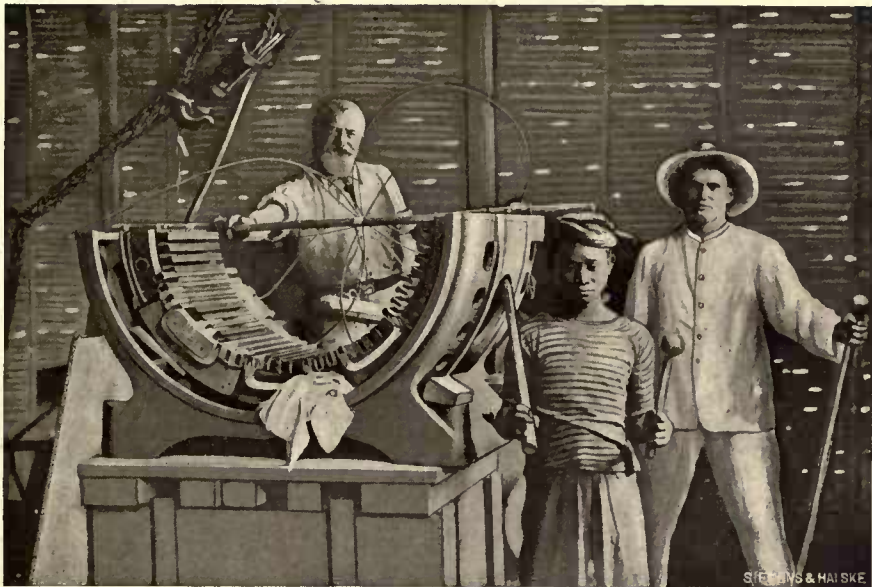


Fig. 150
Winding a Generator on Site.

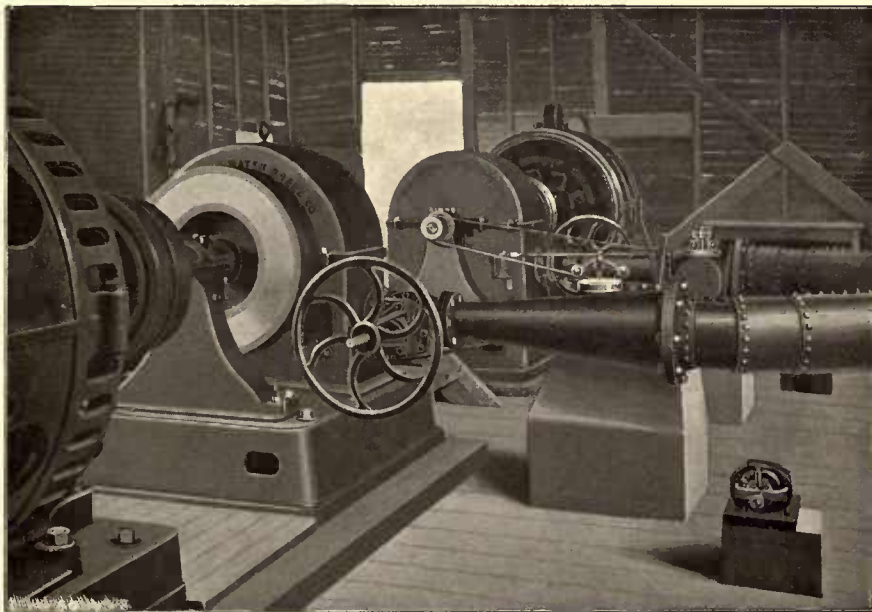


Fig. 151
Power Station of the Redjang Lebong Gold Mines, Sumatra.

of 100 K.W. output was installed. Three-phase current was transmitted at a pressure of 2,000 volts by an overhead line supported on poles, over the jungle to the mines, where it is used for driving small winders, pumps, etc.

The main difficulty was the question of transporting the different machine parts from the coast to the mines. The order was placed on the condition that no single part should weigh more than 1,100 lbs. packed for shipment. This small weight was not attainable by simply sub-dividing the machine parts while retaining the standard construction, but required entirely new designs of dynamos and motors.

The stator frames of the generators and the stator cores were divided into four parts, and arranged so that they could easily be removed from the frame. As the generator had to be wound on site, the winding material was packed and shipped separately. The method of transporting a generator shaft is shown in Fig. 148. Under the most favourable circumstances the pieces were on the road several weeks, but very frequently accidents or interruptions occurred which prolonged this time considerably. The occurrence of an earthquake, which seriously damaged the existing paths was especially unpleasant. The transport of those parts which could be placed on two-wheeled bullock carts (Fig. 149) was comparatively simple.

After all the material had been delivered on site, the erection and winding of the machines had to be done by European erectors, helped by native labour. A large part of the material had been damaged by the heavy rains met with on the road, so that only the spare material which had been sent, made it possible to finish the work without unreasonable delay. The complete power station is shown in Fig. 151. The erection of the whole electrical plant was accomplished in less than four months, in spite of the difficulties to be overcome.

CHAPTER XVI

ELECTRICALLY-DRIVEN ROCK DRILLS

The holes into which the charges for blasting stone are placed can be drilled out either with percussion or rotary drills. In both cases about one horse power is necessary, so that the power consumption may be taken roughly as 1 K.W. An output of 10 H.P. at the shaft of the prime mover is therefore sufficient to drive about six drills simultaneously. If compressed-air drills for the same output are used, the required power is about ten times this amount. The



Fig. 152
Vertical Percussion Drill.
With water flushing arrangement.

power consumption of compressed-air drills is usually stated by the manufacturers as being considerably lower than the above mentioned value, but this higher efficiency may be accounted for by the fact that stationary compressors are usually provided with very large receivers ; the compressor itself can then be built for a considerably smaller output than that corresponding to the actual air consumption of the drills when working simultaneously. Every drill is subject to considerable interruptions due to the changing of the drills, alteration of the position of the machine and other circumstances. During these periods of interruption, which are frequently equal to the time during which the drill is actually working, the compressor charges the receiver and thus compensates for the increased demand during times of actual service

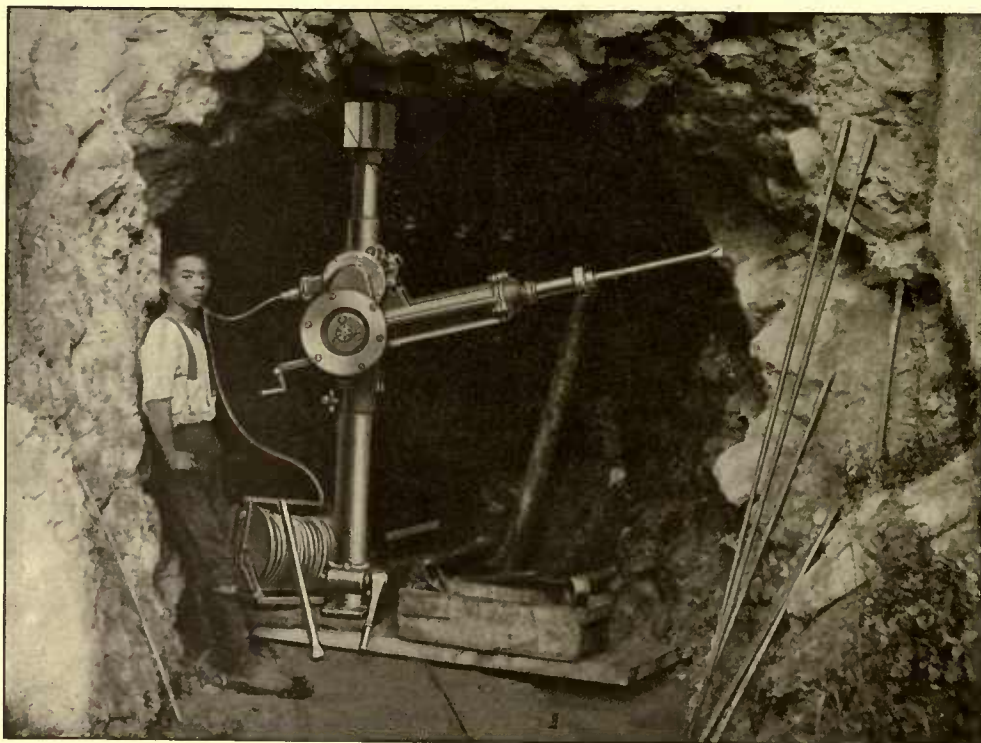


Fig. 153
Percussion Drill (Japan).
Mounted on pillar support.

The compressor, therefore, runs continuously, while each drill is in operation during only about half the time ; for instance, if a compressor for six drills runs continuously with an average power consumption of 36 H.P., the power for each drill is only 6 H.P., but as only three machines, on the average, are in operation, each drill consumes 12 H.P. The motors of electrically-driven rock drills run only when the drills are actually in operation, no power consumption taking place during the intervals. If compressed-air drills are supplied from portable compressors installed underground, a large receiver cannot be provided, so that the compressor motor must be constructed for an output corresponding to the actual power consumption of the drills, that is to say, about 12 H.P. per drill.

One of the chief advantages of electrically-driven rock drills is the ease with which the power may be led up to the point at which it is required. An electric cable can be much more easily and quickly installed, and takes up less space than the air pipe. This latter must be very carefully erected if the losses in the pipes are not to be excessive, whereas an electric cable can be put down in practically any manner.



Fig. 154
Percussion Drill
Mounted on tripod.

The first cost of electric drills appears higher than that of compressed-air drills. The comparison should not, however, be confined to the cost of the drill alone, but should take into consideration the cost of the whole plant for supplying the compressed-air drive as compared to that for producing electric current. If the cost of the compressed-air installation includes the drills themselves, the air pipes and a proportionate part of the compressors, boilers and buildings, while the cost

of the electric drills is taken to include the cost of the drills, the cables and a proportionate part of the station, boiler plant and buildings, it will usually be found that the first cost of the electric drills is not higher than that of the compressed-air drills. This is due to the fact that electric drills need only about one-tenth of the power required to drive a compressed-air drill ; the continual saving in energy is, of course, entirely in favour of the electric drill. The maintenance costs are practically the same for both types of drill so that the total annual expenses, including interest, depreciation, maintenance and power costs are lower for electric drills than for those of the compressed-air type.

Different types of electric drilling machines are described in the following pages.

Percussion Drill

This type of drill is known, owing to the method of its drive, as the crank percussion drill. The motor is fixed to the back part of the drill casing on a supporting saddle and is arranged so that it can be readily removed. The motor drives a crank, supported in two bearings, through single reduction gearing. The rotating motion of the crank is transformed into a reciprocating motion by the usual crosshead arrangement. This crosshead is connected by means of very strong helical springs to the drill chuck ; consequently the drill chuck and the drill itself



Fig. 155
Percussion Drill working as Cutter.
Making a vertical cut.

move in the same manner as the crosshead. The effect of the springs is to make the blow of the drill elastic, and its stroke greater than that of the crosshead. Usually the stroke is about $2\frac{1}{2}$ in. and the speed about 450 blows per minute.

The "return" pull which the machine can exert is about 800 to 1,100 lbs. so that jamming of the drill is practically impossible. A small flywheel is mounted on an extension of the crank shaft to prevent the blows from the drill being transmitted through the gearing to the motor. The gearwheel is connected to the shaft through a friction coupling so that in the event of the crank shaft being suddenly stopped for any reason no damage will result.

The standard size of hole for percussion drills is from 2 to $2\frac{1}{4}$ inches in diameter, but it is possible to drill holes of 3 to 4 inches in diameter in medium hard

rock such as limestone or sandstone, without endangering the machine. The depth of the holes, which was formerly limited to 9 feet can be considerably increased if heavier springs are used. Quite frequently holes 23 feet in depth have been drilled.

When boring deep vertical holes it is possible to remove the grit by flushing with water which is run into the hole through a hollow drill. In this case the machine must be supplied with a so-called flushing head, which makes it possible to introduce the water into the drill without hindering its rotation after each stroke. The flushing head requires a somewhat longer drill support (Fig. 152).



Fig. 156
Percussion Drill working as Cutter.
Making a horizontal cut.

The machine is usually mounted on a pillar when used underground (Fig. 153) and on a tripod if used in the open. It can work in any desired direction both on the tripod and on the pillar, and it is immaterial whether the motor is placed above or below the machine.

These percussion drills have been used with considerable success in connection with the construction of Alpine tunnels. They were employed almost exclusively during the construction of the Jungfrau Railway up to the Eismeer Station, the tunnels through the Tauern mountains, through the Karawanken mountains and through the Wocheiner range in the Eastern Alps.

The machines can also be used for cutting, provided that the machine is mounted on a suitable swivel. A drill in use for making vertical and horizontal cuts at the working face is shown in Figs. 155 and 156.

Rotary Drills

Rotary drills are intended for drilling holes in soft stone such as rock salt, potash, soft coal, iron-ore, etc. They are preferable to the percussion drills in every case where the rock permits of their use, since they are lighter and less costly and

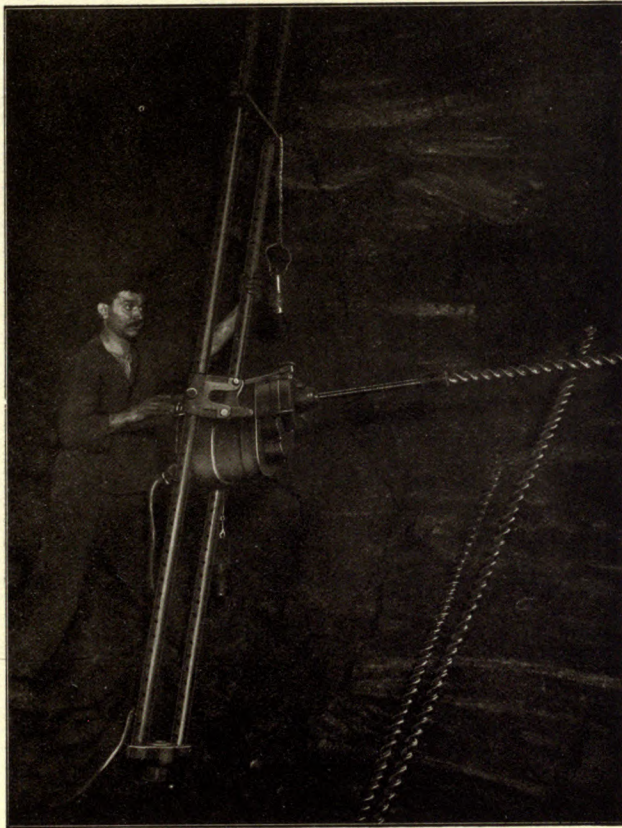


Fig. 157
Rotary Drill
in an iron ore mine.

are subject to less wear and tear. Rotary drills are provided either with a "differential advance" or with a "thread advance." In both cases a motor of one horse-power is used.

The rotary drills with differential advance, which were introduced in the year 1894, were driven from a separate motor by means of a flexible shaft. This

method was also applied to percussion drills. Since 1900, however, these machines have been fitted with direct-coupled motors, as shown in Figs. 157 and 158 and at the present time this type of machine is preferred.

The advance of the drill is regulated automatically by the hardness of the stone, and the return of the drill is accomplished by the motor itself. In the thread type of machine the drill spindle turns in a nut, which is held in position by suitable means, and for each revolution advances a distance equal to the pitch of the thread. If the rock is so hard that the drill cannot advance at the top speed, the nut is turned round by

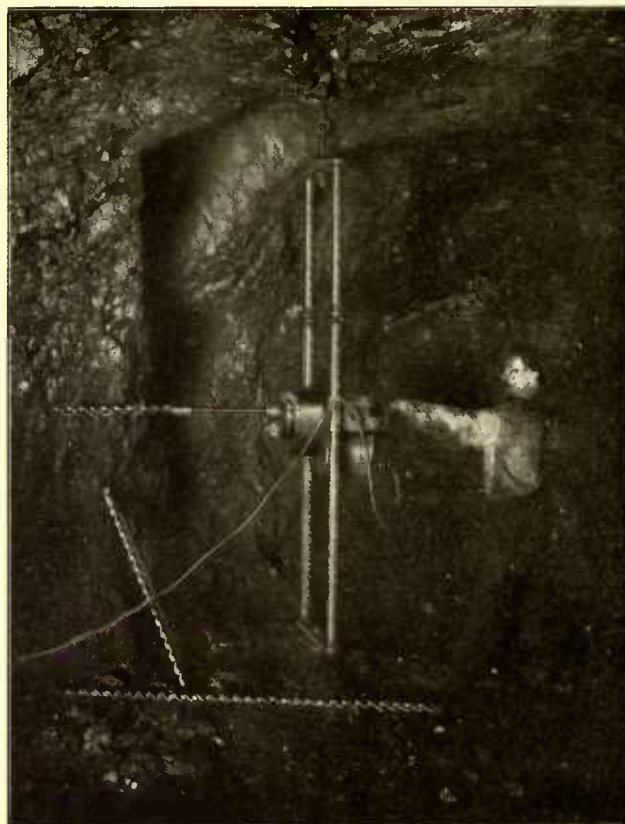


Fig. 158
Rotary Drill
in a coal mine.

friction and the advance is reduced. A brake acting on the nut and controlled by springs provides the retarding force. It is so arranged that it cannot be adjusted by the workmen in the pit. The drill is returned by reversing the direction of rotation of the motor. A small handle serves to move the brake away from the nut to allow it to rotate with the drill. The drill then works without any advance whatever and simply removes the dust from the hole.

Drills with differential advance are fitted with a spindle and nut with left-handed thread, so that if the direction of rotation is clockwise and the

nut remains stationary, the drill is withdrawn. When the drill is in operation the nut rotates faster than the spindle and the drill advances. The speed of advance depends on the difference between the speed of rotation of the nut and the spindle. In this type the pitch of the thread may be larger than in the thread type, and the return is very fast. The return of the drill is accomplished by holding the nut fast, while the drill continues turning in the same direction as when moving forward.

The reduction gearing which rotates the nut is fitted with a friction clutch which causes a reduction of the speed of the nut if the rock is exceptionally hard, and thus diminishes the advance if the resistance to the



Fig. 159
Rotary Drill
in a Potash Mine.

drill becomes too great. This automatic regulation of the advance prevents the machine from becoming overloaded, and the spindle or the supports from being damaged. The standard advances which can be obtained by the use of different combinations of gearing, are: 6 ins., 12 ins., 18 ins., 24 ins., 29 ins., and 36 ins., per minute. The usual speeds for a hole 2 ins. in diameter are: in rock salt 6 or 12 ins., in soft rock salt and pure minette iron ore 18 or 24 ins., and in soft coal 29 or 36 ins. per minute.

If the rock is very damp so that the resulting dust forms into a sticky mass which cannot be very readily removed by the drill, it is advisable to use hollow drills, and flush out the holes with water. These drills are also recommended for drilling in dry rock, if the material is so hard that the drill becomes heated. If the use of water in the latter case does not allow a sufficient drilling speed to be attained, it is advisable to employ a percussion drill.

The rotary drill with thread advance is to be recommended if the hardness of the rock varies considerably in the same hole, or where the machine is frequently called upon to perform different kinds of work. This drill does not, however, possess the advantage of the mechanical return of the drill for the same direction of rotation, and is only built for advances up to 16 ins. per minute. If very slow advance is required or if the rock is of practically the same hardness for some distance, the other type of machine, with differential advance, is preferable. An advantage of this latter type is the quicker return speed of the drill, which exceeds 6 ft. per minute, while the machine with the retarded nut only permits the drill to return at the same speed at which it advances.

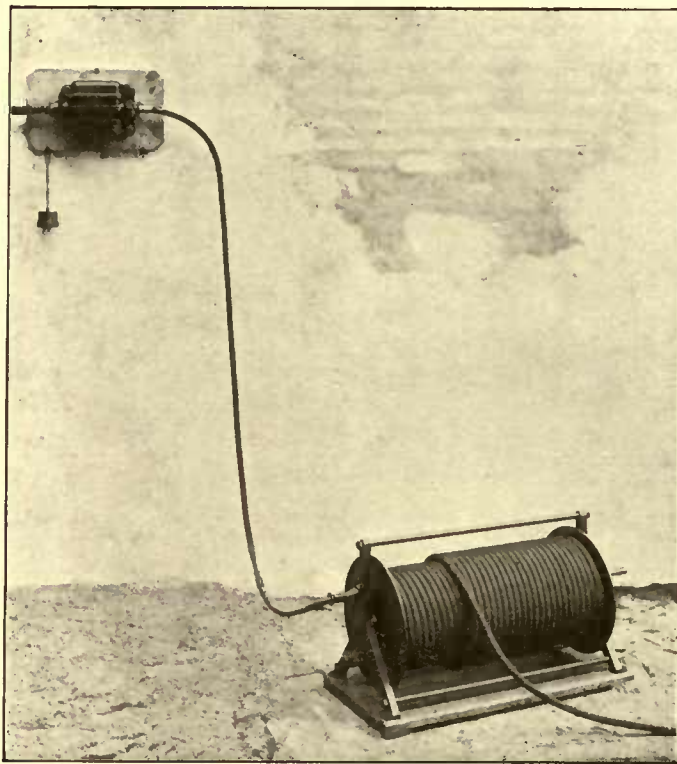


Fig. 160

Cable Drum with Contact for Wall Fixing.

The current is usually supplied to the drills through a flexible cable, which is carried on a suitable drum in lengths of 250 feet. Each drum is provided with a plug for connection to the permanent distribution system (Fig. 160). A terminal box fitted with fuses is placed at the end of the distribution line, from which connection is made to the cable drum.

CHAPTER XVII

SWITCHGEAR FOR INSTALLATION BELOW GROUND

Although mining accidents due directly to the use of electricity have been of extremely rare occurrence, the miner is justified in his demand that all the electrical gear for installation below ground be designed and constructed far more carefully and with a much higher degree of safety than that for use on the surface. The mining authorities share this view and have issued regulations concerning the use and erection of electrical apparatus below ground, which tend to minimise the danger both for the attendants and for the mine itself.

The regulations of the mining authorities of the different countries differ slightly in detail, but in general they lay stress on the following principles which have to be observed in the construction of switchgear for installation below ground :

The apparatus must be so built, that the attendants cannot be exposed to any danger from contact with live parts. It must be suitable for operation in damp or dusty localities without deterioration and must be protected against dripping or splashing water. All parts which are subject to deterioration in service must be readily accessible for inspection and cleaning. Suitable provision must be made on the outside of the casing to indicate the position of all switches.

Owing to the unskilled class of labour available and the rough service to which the workmen are accustomed, all gear must be so built that danger arising from wrong operation is avoided as far as possible and all parts of the mechanism must be of substantial construction, so that damage from rough handling is practically impossible.

Electrically the gear must be suitable for the highest voltages met with in the system and not become unduly heated by the heaviest currents. Each individual switch must be designed to cope with the maximum load which may occur under the most unfavourable conditions.

All switchgear intended for mine installations and for similar plants above ground must conform to the conditions mentioned above. In mines where explosive gases may be present, the additional condition is imposed that the gases shall not be ignited either by open sparking or by arcing inside the switch itself.

The Siemens Concern have designed a series of switches and control gear embodying the above conditions and utilizing the experience gained under various operating circumstances in different countries.

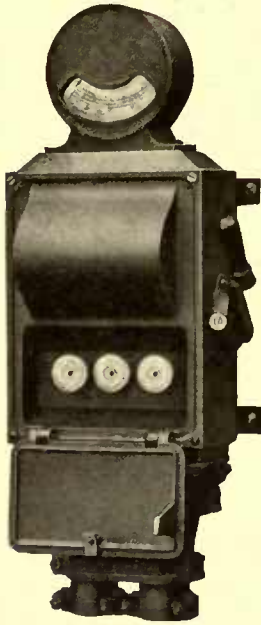


Fig. 161
Cast-Iron Switch Box.

For 550 volts and 200 amps.

Below ground the connections between switchgear and motors are best made by means of cables. The terminals on the motors, starters and switchgear are usually made in the form of cast-iron cable boxes so that the joints can be filled up with insulating compound. The switch pillars are fitted with two cable trifurcating boxes, one for the incoming and the other for the outgoing cables.

Motor control pillars for pressures up to 3,300 volts and for currents up to 200 amperes are illustrated in Fig. 162, and for pressures up to 6,600 volts and currents up to 400 amperes in Fig. 165.

These pillars are equipped with two triple-pole isolating devices and an oil switch, the whole enclosed in a strong cast-iron casing. The oil switch can be equipped with two or three releases, either with or without time limit device, and can, if necessary, be fitted with a no-volt release and also with a buffer resistance. The oil switch is mounted on a moveable carriage, which carries one half of the isolating device. The forward movement of the carriage opens the isolating device, so that all parts requiring inspection can be attended to without danger. A series of interlocking devices ensures against a wrong sequence of operation. It is impossible to pull the oil-switch carriage forward until the circuit is broken or to remove the oil tank or the protecting cover until the carriage is in the forward position. Further, it is impossible to return the carriage into position when the switch is closed or when any of the protecting covers or tanks are out of position. The pillar is shown in Fig. 162 ready for service and in Fig. 163 with the cover removed.

These pillars can further be equipped with voltmeters and ammeters or other instruments, and can be used either singly or combined in any desired number as distribution boards similar to that shown in Fig. 164. When the pillars are used for distribution boards, they are equipped with busbars, placed in a compartment in the upper portion of the case. The pillars are provided with cable trifurcating boxes for the incoming and outgoing conductors.

For voltages above 3,300 volts and all currents the Siemens Concern instal totally-enclosed sheet-iron switch pillars. These pillars can also

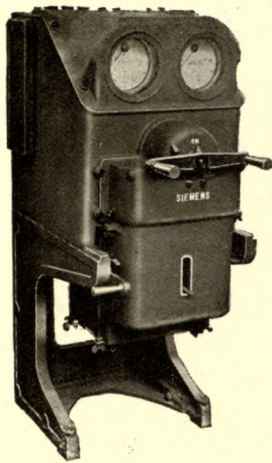


Fig. 162
Complete.

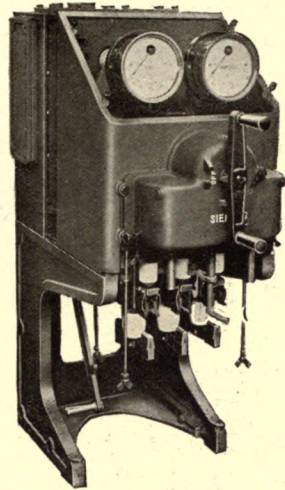


Fig. 163
With cover and oil tank removed.

Cast-Iron Switch Pillar.

be used singly or combined in groups as switchboards (as shown in Fig. 165), and can accommodate all the instruments and switchgear which may be required; they can even be built to provide room for a

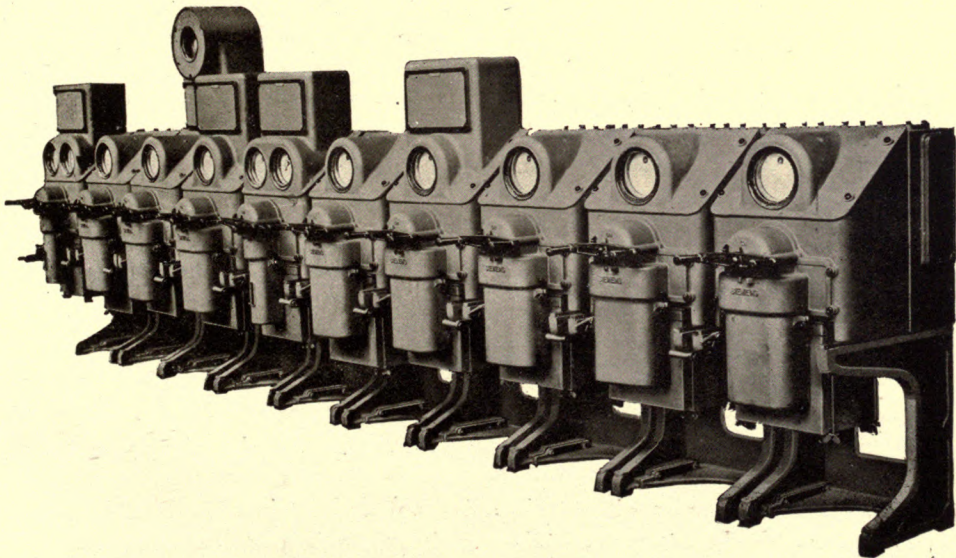


Fig. 164
Distribution switch-board.
Consisting of cast-iron switch pillars

small transformer. Furthermore they are also equipped with interlocking devices which exclude all danger to the attendants.

The switchgear described above is not entirely flameproof. In the case of the pillars shown in Fig. 162, a spark due to the static charge on long cables may occur when the isolating switch is opened, and the enclosing casing is not strong enough to resist an internal explosion.

Pillars which are to be absolutely flame-proof must have all the parts where sparking may occur immersed in oil, or the casing must be strong enough to withstand an internal explosion. Usually, especially where large apparatus is required, the necessary strength for resisting an explosion could only be obtained by the use of a very heavy housing, even if cast steel were employed; consequently the apparatus for this class of service is so designed that all the contacts are under oil, and all the space inside the switch pillar is filled with oil, so that no explosive gas mixture can be formed.



Fig. 165

Distribution board consisting of sheet-iron switch pillars.

A flame-proof switch pillar with oil-immersed switch and fuses is shown in Fig. 166. All the gear is enclosed in a cast-iron housing, which is entirely filled with oil, and above which is placed the necessary operating mechanism. When the cover is removed, the upper contacts, with the fuses, are lifted out of the oil, so that the fuses can be removed without danger. The ammeter is mounted on the casing and is insulated from earth by a base and cover of insulating material. A current transformer for high voltages is unnecessary. The cover is so interlocked that it can only be removed when the switch is open. These pillars can be used in groups, as shown in Fig. 143, which represents a distribution switchboard for a coal washery.

They are suitable for pressures up to 3,000 volts, and have come into extensive use on account of their reliability, easy manipulation, and low price.

A type of pillar which conforms to all the requirements of modern high-tension switchgear for use below ground is shown in Fig. 167. These pillars can be used for pressures up to 6,000 volts, and currents up to 350 amperes. Each switch pillar consists of a strong cast-iron housing which contains all the apparatus and switchgear necessary for a distribution or control panel, including busbars. A complete distribution board can, therefore, be built without providing any further parts. Each casing contains three separate compartments which are entirely filled with oil, in which are immersed all current-carrying parts and the greater portion of the operating gear. One compartment contains the oil switch, the second the relays, instrument transformers and isolating switches, and the third the busbars and cable trifurcating boxes. The first two compartments form a single section which can be electrically connected to the third by means of plug contacts.

The simplest switch pillars are fitted with hand-operated oil switches, isolating links, cable connections, and busbars. The oil switch can be fitted with two or three instantaneous or time limit releases, and, if a potential transformer is installed, with a no-volt release; a buffer resistance can also be furnished. The oil tank of the switch can be lowered by means of a small screw winch, so that the contacts become accessible without further difficulty. The pillar can be fitted with an ammeter and a voltmeter, or with a wattmeter and one other instrument. The triple-pole isolating switch can be operated from the outside by means of a suitable key; it is interlocked with the oil switch so that it can only be operated when the oil switch is opened, and is also interlocked with the tank. In the "off" position the blades of the switch become visible through three windows in the casing, so that its position can be ascertained without opening the casing.

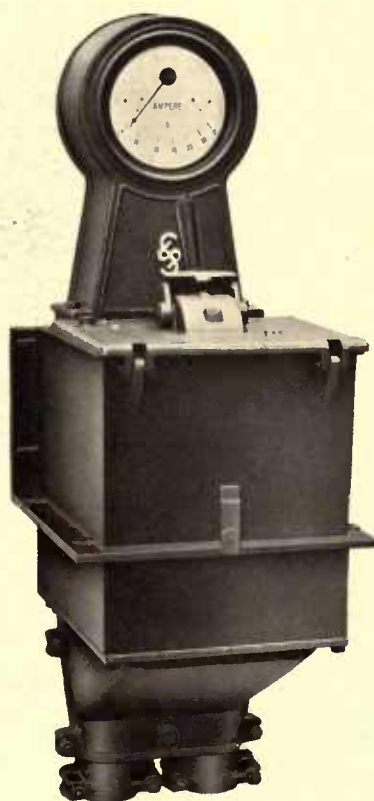


Fig. 166

Flame-proof Switch Pillar

with fuses under oil, for pressures up to 3,000 volts.

The busbars are placed in a separate casing, which is made in one piece for two or three switch pillars, so as to avoid connection boxes. By the use of a light framework to serve as a support for the busbar casing and at the same time to carry the movable part of the switch pillar, erection is greatly simplified. The current at which the releases operate can be adjusted from the outside; the oil gauge is plainly visible, and the position of the switch is shown by an indicator on the outside of the casing.

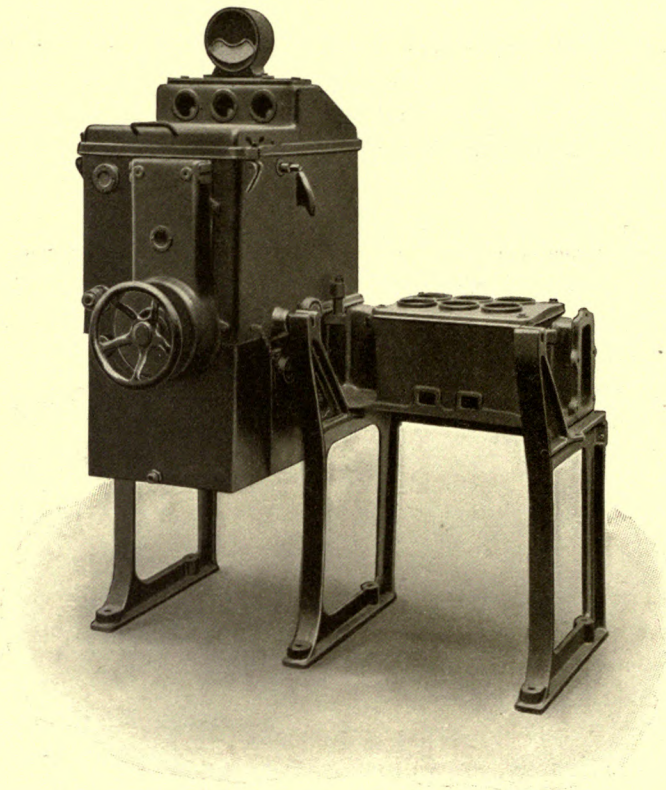


Fig. 167

Flame-proof Switch Pillar

for pressures up to 6,000 volts.

CHAPTER XVIII
FLAME-PROOF INSTALLATIONS
Motors

The design of electric machines and apparatus, which are to be flame-proof requires very careful consideration. In all civilized countries the Mining Regulations are very strict with regard to electric installations in fiery mines, and in Great Britain the use of electricity is entirely prohibited in any part of a mine where on account of the risk of explosion of gas or coal-dust such use would be dangerous to life. The endeavours of the Siemens Concern have been constantly directed toward the construction of motors and apparatus to meet the special requirements of each country, and in the course of the development certain fundamental principles have been evolved, on which the designs are based. The machines, etc., described in the following pages serve as examples of the general class of flame-proof gear. It goes without saying, that these special machines are much more expensive than standard ones, and absolute safety for the mine cannot be guaranteed. It has, therefore, always been the policy of the Siemens Concern not to recommend the use of electricity in such localities where dangerous gases are constantly present, or where the operating conditions make safeguards for the machines impossible, as for instance at the actual working face.

It is not sufficient merely to enclose such motors, because even very careful provision against leakage cannot entirely prevent explosive gases penetrating into the interior of the motor and causing an explosion if a spark were to occur. It is therefore necessary to prevent transmission of an explosion from the interior of the casing to the outside. The simplest and safest method is undoubtedly to make the casing strong enough to withstand the pressure of an explosion inside the machine, which has been found experimentally to be about 110 lbs./sq. in. If the total volume enclosed is small the provision of a sufficiently strong housing presents no difficulties, but in those cases where it is necessary to make the housing large, difficulties of design are met with, necessitating either material of very great thickness or the use of expensive material such as cast steel, etc. The other method of rendering an explosion inside the casing harmless is to provide all the openings in the case with the so-called "plate protection" in which each opening is provided with a large number of thin metallic plates so arranged as to give a labyrinth passage for the gases; in this way the flame is cooled down before reaching the exterior and is rendered harmless. The plate protection consists of very thin metal plates at least 2ins. wide and arranged in cylindrical or rectangular packages so that the distance between plates is not more than 1/50in. (0.5 m/m).

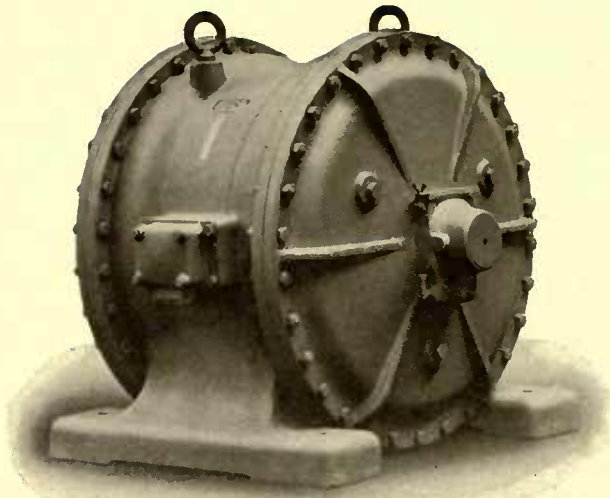


Fig. 168

Totally-enclosed flame-proof motor.

For small motors, the totally-enclosed type has proved the best in practice (Fig. 168). The casing of the motor is so strong that it will not be affected by an internal explosion. The cooling of these motors, however, presents great difficulties so that the machines have to be very large for a given output, and consequently become expensive especially for larger machines. The Siemens Concern, therefore, only build these motors up to outputs of 25 H.P.

Usually, this output suffices for machines installed very far in-by, because larger motors will nearly always be placed in separate rooms located on the intake airways, where the danger of an explosive mixture is small. The motors are in that case not totally enclosed excepting as regards the parts where sparking is most likely to occur, as, for instance, the sliprings, which are made flame-proof. Standard squirrel-cage type motors can be utilised under these conditions without further modification, while on slipring motors the sliprings only need be enclosed. Motors of this type are provided with external sliprings, as it would be difficult effectively to enclose sliprings placed between the bearings.

Motors of this type are, of course, only flame-proof when the winding is in perfect condition. Sparking which might occur through a defect of the winding may cause an explosion if by chance an explosive gas-mixture is present.

Motors in which the entire winding, the active iron and the sliprings are placed

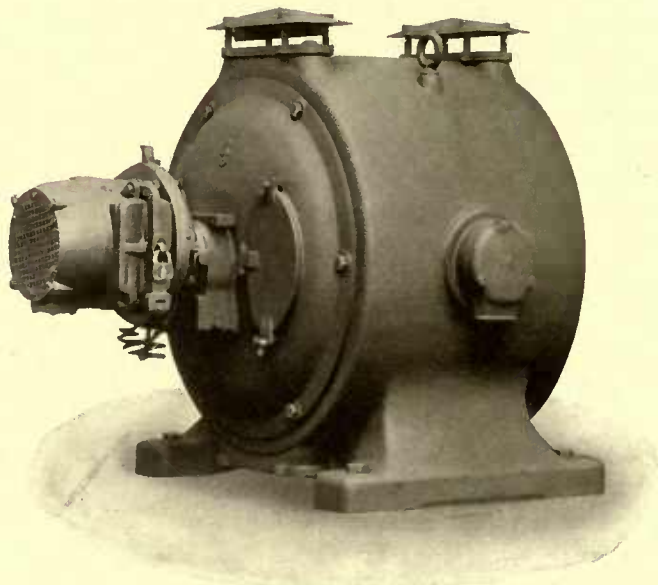


Fig. 169

Flame-proof motor with plate protection.

inside the plate protection have also been built (Fig. 169), but have not proved to be very successful in actual practice. Owing to the resistance offered by the plate protection to the passage of the cooling air the motors have to be built much larger than is the case for ordinary induced-draught motors ; another disadvantage is the possibility of the plate protection becoming clogged with dust, so that after a comparatively short time of service no cooling air can pass through.

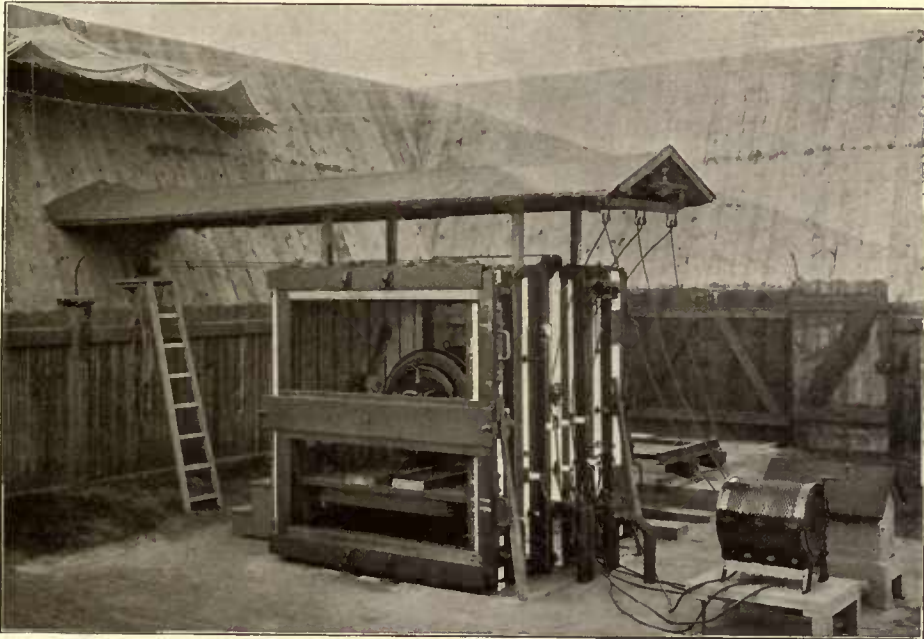


Fig. 170

Testing Station for flame-proof motors

Nürnberg Works of Siemens-Schuckertwerke.

Other means of making electric motors proof against explosion consists in connecting the casing to a fresh air supply, so that the cooling air is entirely free from gas. This arrangement, which in itself is very desirable, is only available in very rare instances, because motors of this kind are usually so far away from the shaft or from galleries with absolutely pure air, that the arrangements for conducting the cooling air to the motor would be expensive and difficult to instal.

For starting motors in localities in which inflammable gas is present, controllers with contacts and resistances immersed in oil, are used. A controller of this type, which is absolutely flame-proof and is in general use for the control of haulage motors for pressures up to 3,000 volts, is shown in Fig. 171. The contacts are under oil so that any sparking which may occur is extinguished at once. The controller is of very rigid construction, to withstand rough handling without danger.

Motors intended for fiery mines are subjected to a very rigorous test before leaving the works. A testing plant which has been built at the Nürnberg Works of Siemens-Schuckertwerke for the special purpose of testing such motors is shown in Fig. 170. The testing arrangement consists of a large box-shaped enclosure built of heavy timber suitably stiffened, and open at both ends. These two ends

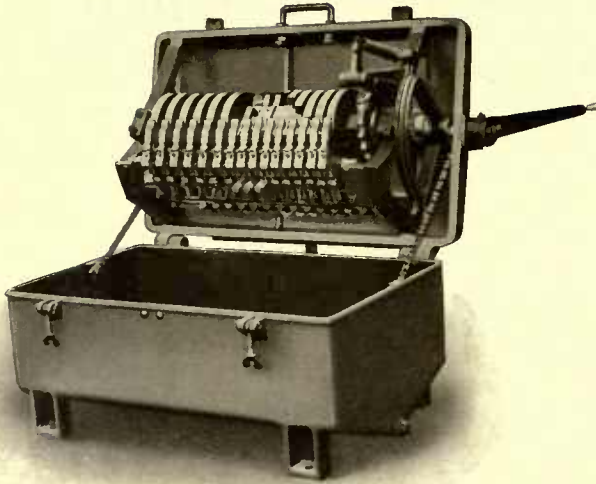


Fig. 171
Oil-Immersed Controller.

or thirty times with different gas mixtures, and the motors are only declared flame-proof if no explosion of the external mixture takes place. If an explosion of the external mixture in the box does actually occur, the paper walls of the box act as safety valves. The switchgear and all the apparatus necessary for controlling the motor and measuring the mixture are located in the test house.

are closed up as gas tight as possible by paper walls. The whole box is filled with a mixture of explosive gases, and great care is taken that the distribution is as even as possible, and that the motor casing is filled with the explosive mixture. The motor is started and the gas mixture inside the housing exploded by an electric igniter. If the casing has been properly built, the explosion inside the motor is not transmitted to the external gas mixture. The tests are carried out twenty

Lighting Installations

Lighting installations underground must be carried out with special care as the fittings hang very low and are thus exposed to possible damage through careless handling.

The fittings must therefore not only be very strong, but must also be so designed that all contact with current-carrying parts is avoided. In mines where explosive gases are present, all parts must be so constructed that in case of a defect there is no possibility of ignition.

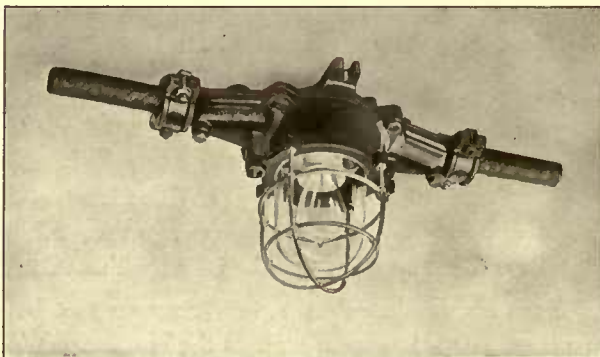


Fig.172
Iron-clad Lamp Fitting
for pit installation.

A very good arrangement can be made by the aid of the lamp fittings shown in Figs. 172 and 173. These fittings are designed for use in connection with armoured cables, which are the safest form of conductor for use underground. The lamp fitting is built

directly into the cable connecting box, so that the cable can be led into the box and connected, and the whole filled with compound. Special end-connectors for the cables are not necessary, when the cheaper paper-insulated cables are used in place of the expensive bitumen or rubber insulated cables. The lamp fittings are equipped with fuses for each pole. The protecting basket and glass are attached to a spring device, which interrupts the contact between the cable terminals and the lamp as soon as the outer protection is taken away.

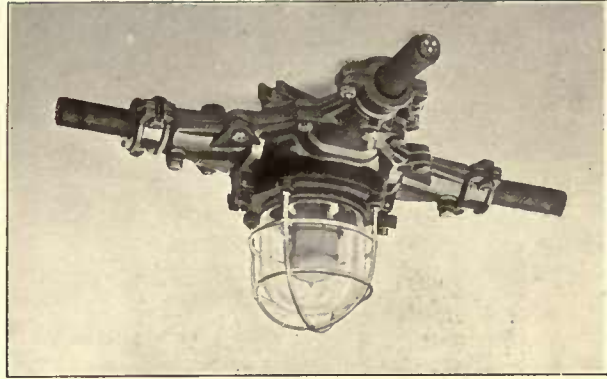


Fig. 173
Combined Lamp Fitting and Cable Dividing Box
for pit installation.

The switches used in connection with these flame-proof installations must be water- and gas-tight. The different contact parts are surrounded by plates, arranged similarly to those for plate protected motors, which prevent an explosion inside the switch from being transmitted to the outside. The

The switches used in connection with these flame-proof installations must be water- and gas-tight. The different contact parts are surrounded by plates, arranged similarly to those for plate protected motors, which prevent an explosion inside the switch from being transmitted to the outside. The

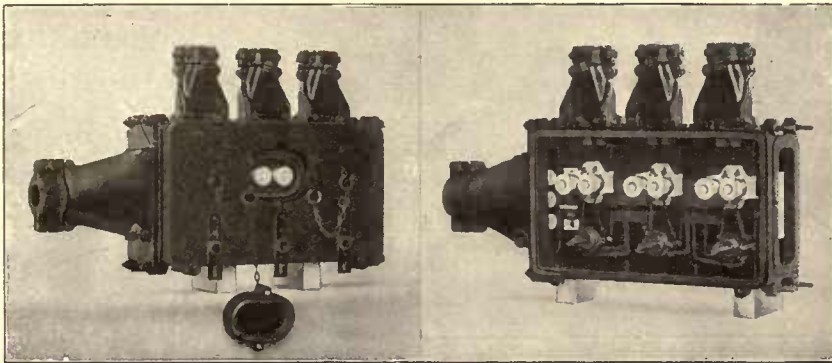
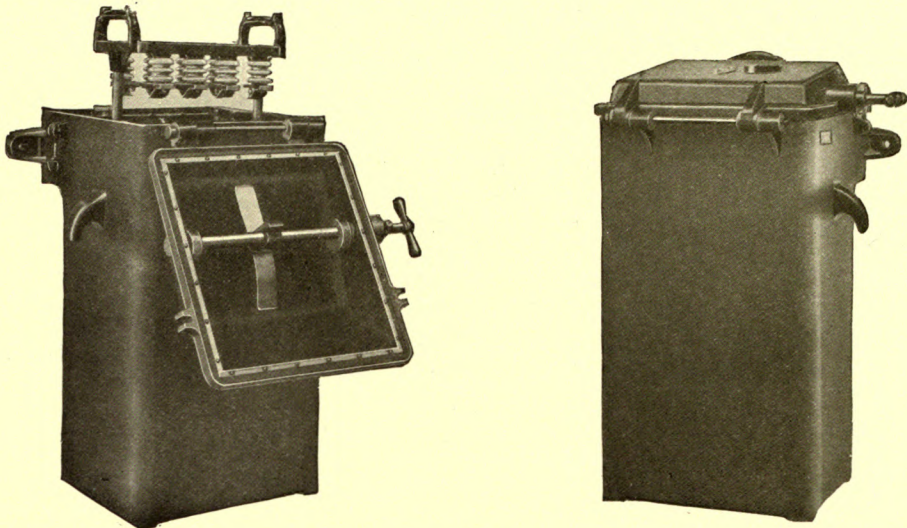


Fig. 174
Armoured Cable Distribution Boxes with Fuses
for pit installation.

whole switch is surrounded by a water-tight case, but even without this it is entirely flame-proof. Distribution boxes built up of these switches and cartridge fuses where the fuse element is completely enclosed in porcelain, are manufactured by the Siemens Concern (Fig. 174). They serve to connect a number of lighting circuits to a common main cable. The boxes are provided with busbars and the number of circuits can be increased to any desired extent by simply adding more boxes. The main cable and the different distribution cables are led in through dividing boxes filled with insulating compound.



Open.

Fig. 175

Closed.

Oil-immersed Transformer

with switch.

It is frequently necessary to transform the pressure available for the motors underground to a lower value for the lighting system. For this purpose special alternating-current transformers are employed which are placed in an oil-filled cast-iron housing containing all the necessary switches and fuses. The cast-iron cases are usually arranged for hanging on the wall or on a suitable framework. The cables are brought into the transformer casing through a dividing box. The whole transformer set is entirely flame-proof and can be built for outputs up to 3.5 K.W. and for primary pressures up to 3,150 volts. This output suffices to supply a very large lighting installation, especially if Tantalum or Wotan lamps are employed.

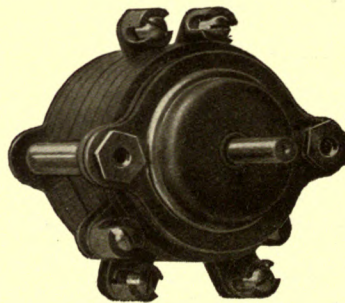


Fig. 176

Rotary Switch

with Plate Protection.

CHAPTER XIX

ELECTRIC SIGNALLING SYSTEMS

In view of the extensiveness of modern mines, it is of the greatest importance to design the signalling apparatus with great care, since the best of equipments will be of little value if the signalling arrangements leave anything to be desired, quite apart from the fact that failure or faulty working of the signalling system endangers the lives of the men. The simple mechanical arrangements which were formerly in common use, and which were quite adequate to meet the requirements in the past, are at the present time considered no longer sufficient. In modern mining plants, therefore, the signals, particularly those for transmitting winding signals between bank, pit levels, and winding engine, are mostly worked electrically. The Siemens Concern have paid particular attention to the design of such apparatus for many years, and they have succeeded, by keeping in close touch with practice, in evolving a large number of designs which meet the extremely stringent requirements of the rough mining service in every respect.

The difficulties in designing practical mine signalling apparatus were not so much of an electrical as of a mechanical nature, as the apparatus, being mounted in damp mines and subjected to rough handling by the men, has to be extremely strong and unaffected by moisture, in order to be able to perform its work satisfactorily and continuously. In addition, its manipulation must be as simple as possible, so as not to impose undue requirements on the intelligence of the operators.

The apparatus is, therefore, provided throughout with substantial casings completely water and gas-tight. After the problem of the most suitable mechanical design of the apparatus had been solved, continual efforts were made to perfect the signalling devices by evolving new and ingenious arrangements.

The following contains a brief description of some of the most important and most extensively used mine signalling arrangements.

The oldest method of communication, which even to-day forms the most common means of signalling in mines, is by a bell which is operated by hand. Each operation corresponds to a certain number of rings of the bell, and when the signals given are of any length, it is usual to divide the message into various parts with a suitable pause between each.

These signals were formerly given by means of a hammer worked by a wire, etc., and arranged to strike bells, or in some cases, plates. The

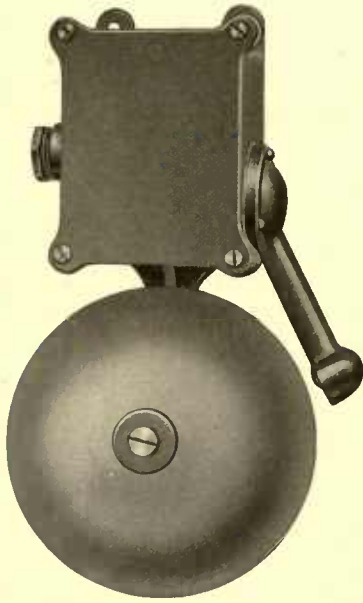


Fig. 177
Diaphragm-type Alarm.

task of the electrical engineer was, therefore, to produce suitable substitutes. The chief difficulty in designing electrically-worked bells or "alarms" was the condition that the apparatus should be absolutely damp-proof, dust-proof, and proof against explosive gases; all these conditions have now been successfully met. Such water and gas-tight bells, in all sizes and designs, both single striking and with continuous action, have been used in large numbers, not only in mines, but also on ships, in railway service, etc., and form a considerable portion of all modern mine signalling installations. In the smaller sizes of bells, the diaphragm type (Fig. 177) has proved very successful. The electro-magnet with armature and interrupter is mounted in a water and gas-tight case, and the movements of the armature are transmitted to a hammer outside the case by means of a diaphragm of metal or rubber mounted over

a suitable opening in the case. This design entirely circumvents the use of glands. Various designs of pull and push contacts are used for giving the signals. They, too, are mounted in substantial water and gas-tight cases, and have quick-break action in order to reduce damage due to arcing. Recently, oil contacts have come into favour where high-tension circuits are allowed, and as the switch mechanism is submerged in oil, arcing is entirely prevented. (Fig. 178).

Current may be obtained from an existing direct-current supply, but in order to be independent of possible disturbances in the supply, a separate accumulator or dry cell battery is recommended for working the signals. In smaller installations magnetos may also be used with advantage; they are then used in place of the signal keys, and in order to obtain sharply defined signals, there is a stop to limit the throw of the magneto handle. An advantage of such installations is that they do not need a separate source of current, and require only very little attention.

These installations, which give purely audible signals, have certainly the advantage of great simplicity, but they also have the serious drawback that errors may easily be made if

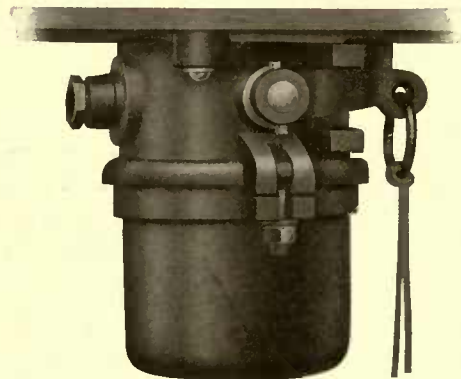


Fig. 178
Oil-immersed Contact.

the signal is incorrectly understood, or only partly heard. This is prevented by supplementing the bell signal by an optical signal of longer duration.

The Siemens luminous mine-shaft signalling apparatus (Rutherford's Patent) consists of sets of indicators and bells for the pit bank, engine room and levels, as shown in Figs. 179 and 180.

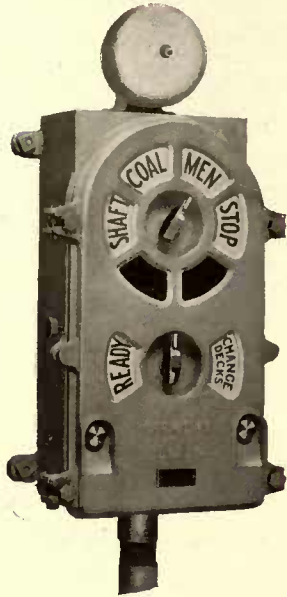


Fig. 179
Pit Bank and Level
Instrument.

When it is required to wind men from the level, the onsetter turns the top switch on his indicator to "men," and then gives the customary rings on the bells at the bank and engine-room by means of the bell switch provided. If the banksman concurs with the signal from the onsetter, he replies by means of the bell and turns his switch to "men," whereupon the signal "men" is illuminated in the engine-room, at the bank, and at the level. This indicates to the engineman that men are to be carried, and this order remains in force for all the subsequent windings until altered for some other operation, such as "coal" or "shaft."

The operations of winding are controlled by the lower switches on the bank and level instruments in the following manner:—

If the cages are provided with one deck only, and are loaded ready for raising and lowering, the onsetter and banksmen turn their respective switches to "ready," and give the usual rings on the bells. When both have turned their switches, the signal appears illuminated at the engine-room, bank, and level. It will be seen that the visual indication of the order does not appear in the engine-room until both the onsetter and banksman are ready for the order to be executed. When the engine has started, a switch is actuated which releases the "ready" switches at both the bank and level, thus extinguishing the lamps and the order on the indicators, and leaving them clear for further orders. In cases where the cages have two or more decks which are loaded from one staging, necessitating the moving of the cage a short distance after one deck has been loaded, the operation is controlled by turning the switch to "change decks," with the same procedure as for "ready." The signal "change decks" is obliterated by the movement of the engine in the same manner as the order "ready." When all the decks are filled, the signal "ready" can be given in the same manner as for one-deck cages, as described above.

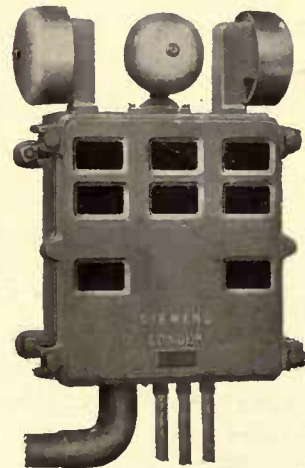


Fig. 180
Engine Room Instrument.

Any system of bell signals can be used in conjunction with the luminous signals. The circuits for illuminating the indicators being separate from the bells, the indicators form independent corroboration of the bell signals, and as it is necessary for both the onsetter and banksman to operate their switches before the orders are illuminated, it is clearly indicated to the engineman that he may proceed without any possibility of doubt as to the bell signals given. The emergency or "stop" signal can, however, be operated independently by either the onsetter or the banksman, to stop the cage at any point.

An important feature of the system is that the signals required by the British Home Office Rules are not interfered with, and can be performed in the ordinary manner.

In addition to the safety provided by having a visual indication of the order, further security is obtained by the arrangement that the visual indication does not appear until both the men concerned, the onsetter and the banksman, have concurred and performed their part of the signalling. It is also impossible for more than one order to appear at the same time, the changing of an order by either man extinguishing automatically the previous indications.

A considerable advantage in the direction of simplification and speed of working is obtained by dividing the visual indications of the orders into two groups, one group comprising such orders as will be standing orders, and are required to be in force for a considerable time, extending over several operations of winding, such as "men," "coal," etc. The other group consists of the orders on which the engineman acts to raise or lower the cage, and comprises "change decks," (when required) and "ready." The indications of the latter group of orders are extinguished automatically immediately the engine is moved to change the decks or to raise the cage, whereby it is impossible for an order which has been executed to remain and thus to cause confusion.

Visual indications are provided by illuminated windows, on which the orders appear as soon as the lamps which are arranged behind them are lit by the operation of the switches at the levels and pit bank.

The apparatus is contained in substantial water-tight cast-iron cases, with separate windows for each order. The press switches and the order-sending switches are securely protected, so that it is impossible for them to be accidentally closed.

In the diagram (Fig. 181), which shows the general arrangement of the apparatus, the luminous and bell signals with "ready" and "change decks" indicators and switches are arranged for shafts having one level only. If required, these instruments can be supplied without either bells or "change decks" order, or with neither of these. In cases where it is necessary to work the cages from either side of the shaft, duplicate "change decks" and "ready" switches can be supplied, as shown on the diagram.

The apparatus has been completely standardized, and is so designed as to permit of any desired arrangement. The Diagram (Fig. 181) shows the

arrangements most commonly required, but special requirements can generally be met without departing from the standard apparatus.

The Bell Indicator consists of a dial instrument which is used in conjunction with bell signalling apparatus to indicate the number of bell strokes

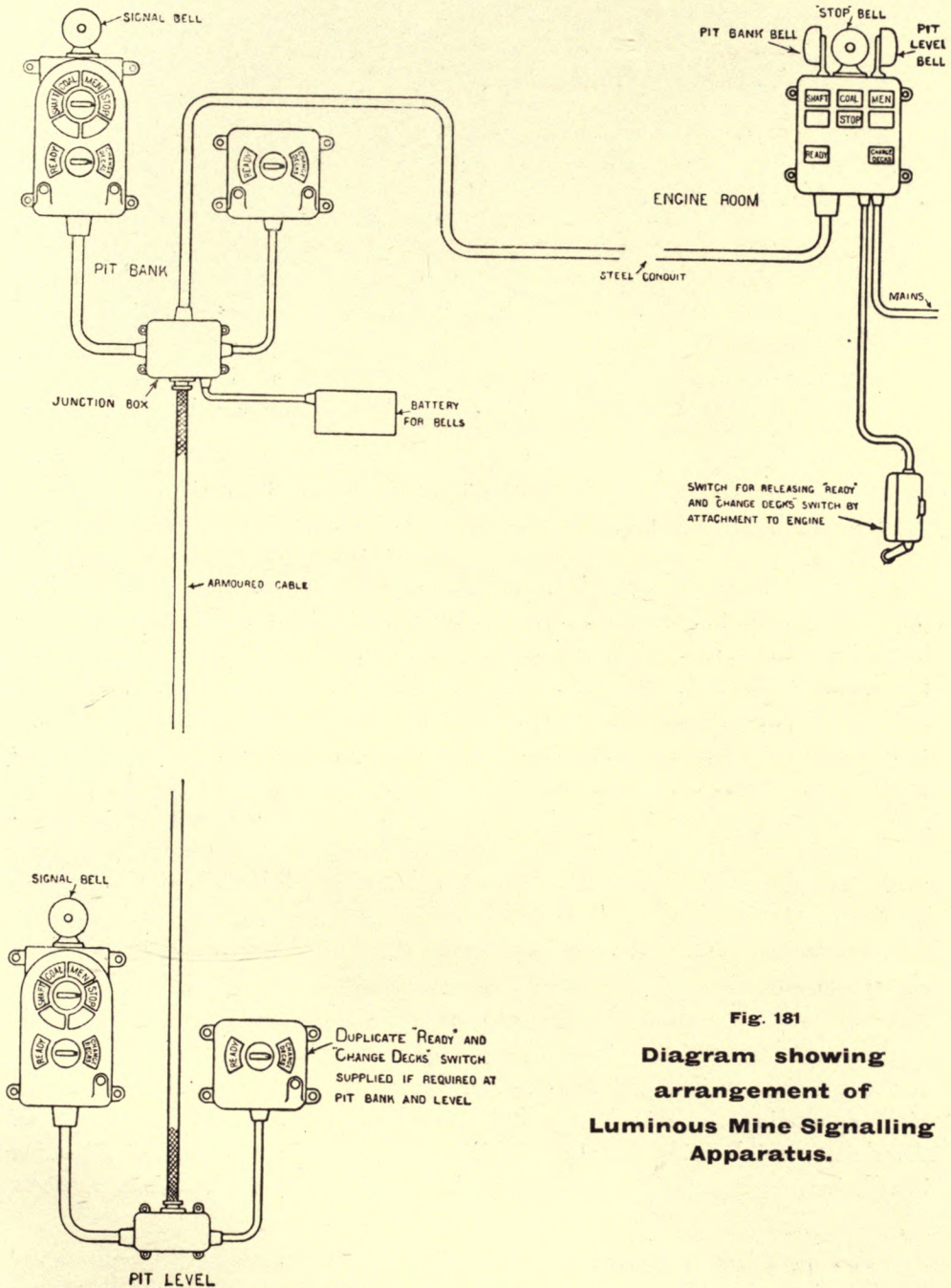


Fig. 181
**Diagram showing
 arrangement of
 Luminous Mine Signalling
 Apparatus.**

given. It comprises an electro-magnet which operates an armature ; the latter actuates a pointer through one section of the dial for each ring so that the number of rings received is recorded by the pointer. It is provided with a

releasing mechanism, by means of which the pointer can be set back to zero. This last operation can be effected either by hand at the instrument by means of a lever provided, or electrically by a press button switch in the engine room. This switch may also be so arranged that it is automatically operated by the engine.



Fig. 182
Recording Indicator.

The Indicator can be applied to any existing electric bell signalling apparatus without any alteration to the latter.

Bell Signal Indicators are less suitable for installations in which groups of signals are in use, since they only indicate the number of bell strokes, and not the grouping of the bell signals, but a satisfactory solution to this problem has lately been found in the shape of Recording Signal Indicators. As indicated by the name, this apparatus has the important advantage of recording the signals automatically. It is characterised by the extremely clear reproduction of the signal groups, which appear as rows of illuminated points on a dark background. The illumin-

ated points correspond to the bell strokes, while the spaces between the various points correspond to the pauses between the strokes. Such an apparatus is shown in the illustration of the winding engine room (Fig. 187). It is mounted adjacent to the operating platform. A signal, consisting of two bell strokes, a pause, and three further bell strokes, has just been transmitted, and this order corresponds to the picture of the illuminated points clearly seen in the illustration. It should be emphasised that both the visual reproduction and the recording of the signals are performed by one and the same device as follows:—The signals are punched in the form of groups of holes in a paper ribbon kept in movement by clockwork, and the signal recorded in this way is projected by a suitable arrangement on a larger scale, and is at once visible to the operator. It is, therefore, impossible for the recorded signals to differ from the visible ones. Each signal remains visible until the next one is given.

There is no difficulty in connecting up this signal apparatus to a single-stroke bell installation, and this without necessitating more conductors in the pit or altering anything at all in the method of manipulation. It is, therefore, possible with the aid of this apparatus to convert older signalling installations to installations which meet all requirements of a modern service.

The signalling arrangements so far described serve solely for transmitting the winding signals, which repeat themselves at regular intervals. Other communications can be made in most cases by means of Loud-speaking Telephones (Fig. 186). It is possible to carry on communication between various points in any manner desired by means of selectors. The telephones

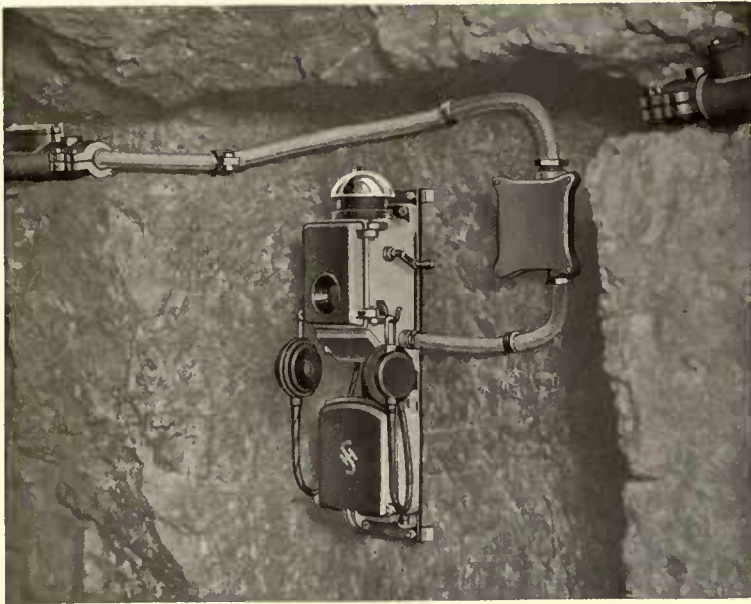


Fig. 183
Telephone installed underground.

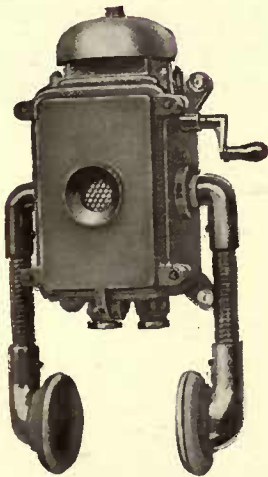


Fig. 184
Telephone with
Hinged Earpieces.



Fig. 185
Electric Hooter.

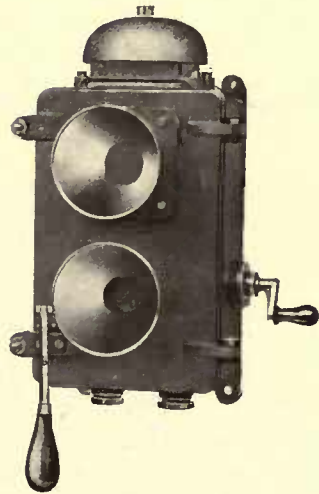


Fig 188
Loud-speaking
Telephone.

at bank and pit bottom may be provided (Fig. 184) with hinged earpieces, which hang down when not in use, but which are raised when in use. The earpiece is provided with indiarubber padding in order to reduce interference from outside noise. In the winding engine room itself, the telephones are usually not provided with earpieces, but with a trumpet. In these cases the apparatus is mounted on a pillar near the operating platform (Fig. 187), being placed in such a way that the sound from the telephone is directed towards the engineman, so that there is no need for the latter to leave his place. The sound emitted by these telephones is so powerful that speech can be clearly understood at a distance of several yards.

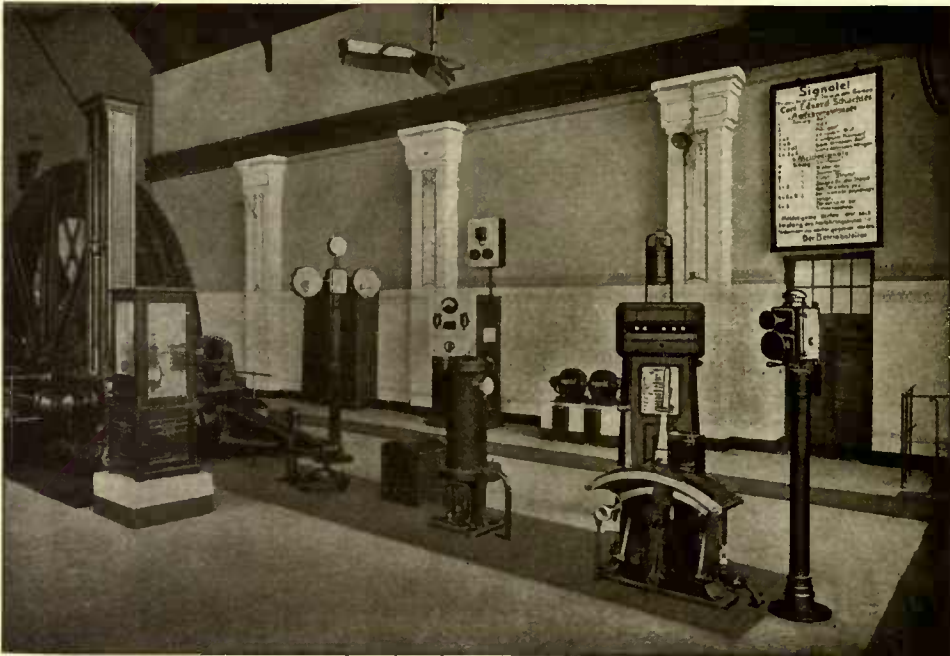


Fig. 187

Winding Engine Room with Recording Signal Indicator and Loud-Speaking Telephones.

Ordinary telephones, suitably modified for mine work, are also largely used in modern mines ; such a telephone mounted below ground is shown in Fig. 183.

Mention may also be made of a new type of alarm, viz., the Electric Hooter (Fig. 185). This meets the want often felt in extensive signalling plants for an apparatus which will give an effective sound quite distinct from the usual alarm bells. The hooter is provided with a diaphragm which is set vibrating by electro-magnetic means, and emits a sharp and penetrating tone, which is very much more effective than bell signals. The hooters are made for connection to accumulators and to the ordinary electric supply.

CHAPTER XX

ELECTRIC SHOT FIRING

Electric shot firing is far superior to the old means still largely in use, such as fuses, etc. In the first case, the electrical method increases the safety of the men, since the explosion can be brought about from any distance. It is further possible to explode a number of shots simultaneously, thus obtaining an increase in the effect. In spite of these advantages, which are acknowledged on all sides, it was comparatively long before electric shot firing was generally adopted. The reason for this was the great amount of work required before the apparatus was sufficiently perfected to meet all practical requirements as regards absolute reliability, ease of manipulation, portability and strong construction to withstand the somewhat rough treatment to which it is necessarily subjected in mining work.

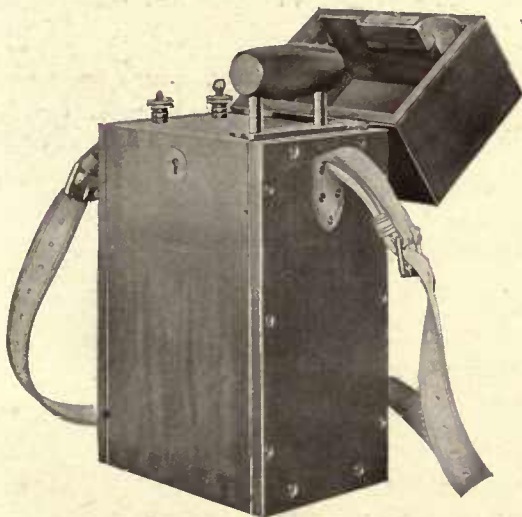


Fig. 188
"Dynamo" Type Shot-Firing Apparatus.

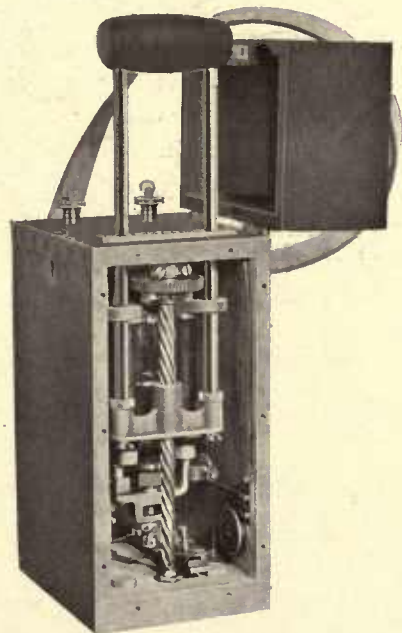


Fig. 189

The firing may be effected by a spark or by a wire rendered incandescent by an electric current. As a rule, the latter method is preferred, the apparatus for which is worked by a low-voltage current, so that the leads need not have

a high insulation, and the danger of misfire due to leakage is reduced. The greatest advantage is, however, that this method enables the firing plant to be easily tested before firing, which is not possible with firing apparatus of the spark type.

The apparatus is made in two types, viz., the "Magneto" type, capable of firing up to about 10 shots, and the "Dynamo" type, capable of firing up to 50 shots, in series. The best construction of the "Dynamo" type is that

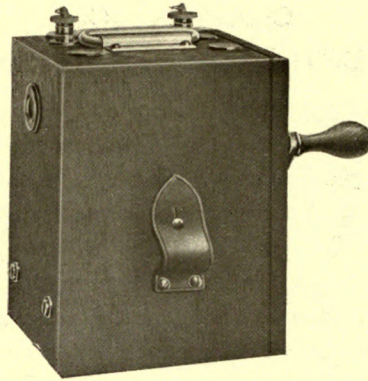


Fig. 190

"Magneto" Type Shot-Firing Apparatus.

known as the "Twist," illustrated in Fig. 189. In the smaller or Magneto type (Fig. 190), the magnet system is composed of permanent steel magnets, whereas in the Dynamo type the fields are provided with windings excited from the armature circuit.

Another type of machine is actuated by a clock spring, which is wound up by a key; when the clockwork is released, the armature rotates rapidly and generates the current required. This type possesses the advantage that its output is always constant, and does not depend on the force put into it by the operator. In all hand-driven machines it is necessary for the force to be put into them rapidly to obtain the necessary current, a switch being provided which is closed when the armature is rotating at its maximum speed.

INDEX.

| | Page | | Page |
|---|-----------|---|---------|
| Acceleration with Winding Engines | 57-59 | Collectors, Bow, for Locomotives | 150 |
| Alps, Eastern Percussion Drills | 170 | Conductors for Overhead Transmission Lines | 53 |
| Alternating Current, advantages of | 23 | Compressed Air for Brakes | 58 |
| Alternators (see Generators, alternating current) | — | " " Rock Drills | 165-166 |
| Angus, J. | 10 | Compressors, Electrically-driven | 125-130 |
| Armoured Cables | 52 | " for working inbye | 140-142 |
| Audible Signals | 188-189 | " Reciprocating Type | 127 |
| Austria Hungary, Gas Power available in | 32 | " Turbo- | 128-130 |
| Automatic Releases for Oil Switches | 42 | Connecting Boxes for Cables | 51 |
| Auxiliary Machines for Working Inbye | 139-142 | Continuous Current (see Direct Current) | — |
| " Back Pressure " Turbines | 30 | Control Gear for Switchboards, etc. | 41 |
| Baku Distribution System | 16 | Controllers, Flame-proof | 183 |
| Battery Locomotives | 151 | Converters, Rotary | 146 |
| Bearings for Flywheels | 97 | Converter Sets, Powell-Duffryn & Markham Coal Co. | 84 |
| Belgium & France, Winding Engines in | 58 | Crude Oil for Diesel Engines | 36 |
| Belgium, Gas Power available in | 32 | Cylindrical Drum Winders | 57 |
| Bell Signals | 187 & 192 | Deutscher Kaiser Fan, Regenerative System for Fan Motor | 120 |
| Blast Furnaces, Power available from | 32 | Depth Indicator for Winding Engines | 72 |
| Blast Furnace Gas, Utilisation of | 3 & 32 | Desk-type Switchboards | 41 |
| Boiler Plant with Winding Engines | 96 | Diagrams of Connections | 45 |
| Booster System, Pirani | 78-79 | " " for Fan Motors with Regenerative Systems | 122 |
| Bow Collectors for Locomotives | 150 | Diagrams of Connections of Ward-Leonard System for Winding Engines | 70 |
| Brakes for Winding Engines | 58 | Diagrams of Connections of Siemens-Illgner System for Winding Engines | 80 |
| Briquette Presses, etc., Electrically-driven | 153-160 | Diagram of Connections for Winding Engine with Three-phase Commutator Motor | 68 |
| Briquette Presses for Lignite Coal | 158 | Diagram of Connections for Three-phase Winding Engines | 61 |
| Buffer Batteries, Winding Engines with | 78-79 | Diagram of Current Input to Three-phase Winding Engine | 64 |
| Buffer Resistances for Pump Motors | 104 | Diagram showing arrangement of Mine Signalling | 191 |
| Busbars, double sets | 44 | Diesel Engines, efficiency of | 36 |
| Cable Connecting Boxes | 51 | Diesel Engine Power Stations | 36-38 |
| Cables, Electric | 51-52 | Differential Advance for Rotary Drills | 172 |
| " for Machines working Inbye | 139 | Direct-current Generators and Motors, Limitations of | 23 |
| " for Rock Drills | 174 | Direct-current Motors for Briquette Presses | 160 |
| " for Sinking Pumps | 114 | Direct-current Motors for Coke Ovens | 158 |
| Cambrian Collieries Distribution System | 6-7 | Distribution Boxes, Flame-proof | 185 |
| Carbonifera, Distribution System | 5 | " Diagrams | 45 |
| Cascade Connection for Fan Motors | 118 | Distribution Systems | 5-22 |
| Centrifugal and Reciprocating Pumps | 100 | " System, Baku | 16 |
| " Pumps, Electrically-driven | 105-112 | " " Cambrian Collieries | 6-7 |
| " " for working Inbye | 140 | " " Carbonifera | 5 |
| Choice of Transmission System and Pressure | 23-24 | " " Gelsenkirchen | 14-15 |
| Coal-tar Oil for Diesel Engines | 36 | | |
| Coal Washers, etc., Electrically-driven | 153-160 | | |
| Coke Ovens and Gas Engines | 34 | | |
| Coke Ovens, Power available from | 34 | | |
| Coke-Oven Gas, Utilisation of | 32 | | |
| Coke Oven Plants, Auxiliary Machines | 158 | | |

Index—continued.

| | Page | | Page |
|---|-----------|---|-----------|
| Distribution Systems "Glückauf" - | 8 | Fittings, Flame-proof - - | 184-185 |
| " " Newcastle District - | 17-22 | Flame-proof Controllers - - | 183 |
| " " Nitrate Oficinas - | 9 | " Distribution Boxes - - | 185 |
| " " Powell Duffryn - | 12-13 | " Fittings - - | 184-185 |
| " " Rheinpreussen - | 11 | Flame-proof Installations - | 181-186 |
| " " Rio Tinto - | 10 | " Lighting Installations - | 184-186 |
| Double Drum Haulages - | 134-135 | " Motors - - | 181-184 |
| Drills, Rotary - - - | 171-174 | " Switches - - | 185 |
| " Percussion - - - | 169-170 | " Switchgear - - | 178-180 |
| Drum Winders, Cylindrical - - | 57 | Flywheel Bearings - - - | 97 |
| Drying & Heating, Steam for - - | 30 | Flywheels for Stone Breaker Motors - | 158 |
| "Dynamo" Type Shot Firer - - | 196 | Flywheels, Limit in speed of - | 82 & 91 |
| Eckstein Company, Winding Engines - | 61 | France, Gas Power available in - | 32 |
| Efficiency Curve of Transformer - | 47 | France & Belgium, Winding Engines in | 58 |
| " of Cascade Fan Motors - | 118 | Francis Water Turbines - - | 39 |
| " " Pelton Wheels - - | 39 | Frequency Converters with Fan Motors | 120 & 122 |
| " " Reciprocating and Centrifugal Pumps - - | 100 | Fuel Consumption with Diesel Engines | 36 |
| Efficiency of Regenerative System for Fan Motors - - | 120 | Gas, Blast Furnace, utilisation of - | 3 & 32 |
| Efficiency of Siemens-Igner Winding Engines - - - | 84 | " Coke Oven, utilisation of - - | 32 |
| Efficiency of Steam, Gas and Diesel Engines - - - | 36 | " Engines driven by coke oven gas - | 34 |
| Efficiency of Steam and Electric Winders - | 94-98 | " " Efficiency of - - | 36 |
| " " Three-phase Commutator Motor for Winding Engine - - | 69 | " " in Ironworks - - | 32 |
| Efficiency of Three-phase Winding Engines - - - | 61 & 66 | " Engine Plants - - - | 32-35 |
| Electric Locomotives - - - | 143-152 | " " Power Stations - - - | 32-35 |
| " Power Stations - - - | 25-40 | " Oil for Diesel Engines - - | 36 |
| " Shot Firing - - - | 195-196 | " Power available in various countries | 32 |
| " Signalling Systems - - | 187-194 | " Gas Producers and Coke Ovens - | 34 |
| " and Steam Winders - - | 94-98 | Gelsenkirchen Distribution System - | 14-15 |
| " Transmission of Power - - | 1 | Generating Stations, Switchgear in - | 41-46 |
| " Winders (see Winding Engines) - | — | Generators, alternating-current, parallel operation - - - | 34 |
| " Winding Engines - - - | 57-98 | Generators for Water Turbines - | 39 |
| Electrically-driven Centrifugal Pumps - | 105-112 | " Turbine driven - - - | 28 |
| Electrically-driven Coal Washers, etc. - | 153-160 | Germany, Gas Power available in - | 32 |
| " " Compressors - - - | 125-130 | " Glückauf" Distribution System - | 8 |
| " " Mine Fans - - - | 115-124 | Great Britain & Ireland, Gas Power available in - - - | 32 |
| " " Pumping Plants - - - | 99-114 | Harton Coal Company Limited, Winding Engines - - - | 61 |
| " " Reciprocating Pumps - - | 101-104 | Harton Coal Company Limited, Locomotives - - - | 152 |
| " " Rock Drills - - - | 165-174 | Haulages and Hoists - - - | 131-138 |
| " " Sinking Pumps - - - | 109-114 | Haulages, Main Road - - - | 135-138 |
| Endless Rope Haulages - - - | 135 | " Single and Double Drum Type - | 134 |
| Exhaust Steam Turbines - - - | 30 | Headgear, Winding Engines in - - | 91-93 |
| Explosion Pressure inside a motor - | 181 | Heating & Drying, Steam for - - | 30 |
| Fans, Mine—Altering the output - | 115-116 | High-pressure Insulators - - - | 56 |
| Fans for Mine Ventilation, Electrically-driven - - - | 115-124 | " Transformers - - - | 47 |
| Fans, Mine, with Three-phase Commutator Motors - - - | 122 & 124 | Hoists and Haulages - - - | 131-138 |
| | | Hoists in Secondary Shafts and Inclines - | 131-134 |
| | | Hooters, Electric - - - | 194 |

Index—continued.

| | Page | | Page |
|---|---------|---|-----------|
| Horizontal & Vertical Steam Engines - | 25 | Motors for Centrifugal Pumps - | 105-112 |
| Hydraulic Systems of Power Trans- | | „ „ Compressors - | 127-128 |
| mission - - - - | 1 | „ „ Mine Fans - - - | 115-124 |
| Induced-Draught Motors for Coal | | „ „ Sinking Pumps, Pressure for | 114 |
| Washers, etc. - - - | 156 | „ Induced Draught - - - | 156 |
| Induction Motors, Three-phase, for | | „ Squirrel-Cage, for Coal Washers | 153 |
| Winding Engines - - - | 61-67 | „ Synchronous, for Compressors | 128 & 130 |
| Insulators for high pressure - - - | 56 | „ Three-phase, for Haulages and | |
| „ Porcelain - - - - | 56 | Hoists - - - - | 134-135 |
| „ Suspension - - - - | 56 | Motors, Three-phase, for Reciprocating | |
| Iron Works with Gas Engines - - - | 32 | Pumps - - - - | 101 & 104 |
| Isolating Switches - - - - | 44 | Motors, Three-phase, for Sinking Pumps | 113-114 |
| Instruments, Measuring - - - - | 42 | Newcastle District Distribution System | 17-22 |
| Jungfrau Railway, Percussion Drills | 170 | „ „ Power Co.'s Electric | |
| Karawanken Mountains, Percussion | | Winders - - - - | 66 |
| Drills - - - - | 170 | Nitrate Districts, Diesel Engines in | 36-38 |
| Koepe Pulley for Winding Engines | 58 & 93 | Nitrate Mine, Electrically-driven Stone | |
| Lead Covered Cables - - - - | 52 | Breakers in - - - - | 158 |
| Lighting Installations, Flame-proof | 184-186 | Nitrate Oficinas Distribution System | 9 |
| Lignite Coal Briquette Presses - - | 158 | Object and Scope of Electric Mining | |
| Locomotives above ground - - - | 151-152 | Installations - - - - | 1-4 |
| Locomotives, Electric - - - - | 143-152 | Oil Drying Apparatus - - - - | 50 |
| „ for Main Road Haulage - - - | 134 | „ for Transformers - - - - | 48 |
| „ Underground, Design of - - - | 148 | Oil-immersed Transformers - - - | 48 |
| „ Underground, Three-phase | | Oil Switches - - - - | 42 |
| and Direct-current - - - - | 144 | Oils for Diesel Engines - - - - | 36 |
| Locomotives, with Batteries - - - | 151 | Operating Gear for Switchboards | 41-42 |
| Machines, Auxiliary for working in | 139-142 | Osborn System with Ward Leonard | |
| Machines Specially Designed to Facili- | | Control - - - - | 72 |
| tate Transport - - - - | 161-164 | Overhead Transmission Lines - - | 53-56 |
| “Magneto” Type Shot Firer - - - | 196 | „ Trolley Wire - - - - | 146 |
| Main Road Haulages - - - - | 135-138 | Paraffin Oil for Diesel Engines | 36 |
| Markham Coal Company Converter Sets | 84 | Pelton Wheel Turbines - - - - | 39 |
| Merz, C. H. & McLellan - - - - | 17-22 | Percussion Drills - - - - | 169-170 |
| Merz-Price Balanced Relay - - - | 52 | Pirani Booster System - - - - | 78 & 79 |
| Mine Fans, Altering the Output | 115-116 | “Plate Protection” for Flame-proof | |
| Mine Fans, Electrically-Driven | 115-124 | Motors - - - - | 181 & 183 |
| Mine Shaft Signalling Apparatus | 189 | Poles, Steel or Wood, for Overhead | |
| Mining Installations, Electric, Object | | Transmission Lines - - - - | 53 |
| and Scope of - - - - | 1-4 | Porcelain Insulators - - - - | 56 |
| Motor Control Pillars for Installation | | Powell Duffryn Steam Coal Company, | |
| below ground - - - - | 176-180 | Distribution System - - - - | 12-13 |
| Motors and Generators, Direct-current, | | Powell Duffryn Steam Coal Company, | |
| Limitations of - - - - | 23 | Converter Sets - - - - | 84 |
| Motors, Alternating-current, Advant- | | Power generated electrically - - | 2 |
| ages of - - - - | 23 | „ required for Rock Drills | 165-166 |
| Motors, Direct-current for Briquette | | Power Stations, Advantages of large | |
| Presses - - - - | 160 | units in - - - - | 3 |
| Motors, Direct-current for Coke Ovens | 158 | Power Stations, Diesel Engine - - | 36-38 |
| „ Electric, Advantages of - - - | 2 | Power Stations, Electric - - - | 25-40 |
| „ „ for Pumps - - - - | 99 | „ „ Gas Engine - - - - | 32-35 |
| „ Flame-proof - - - - | 181-184 | „ „ Steam Turbine - - - - | 28-29 |
| | | „ „ Water Driven - - - - | 4 |
| | | „ „ Water Turbine - - - - | 39-40 |

Index—continued.

| | Page | | Page |
|--|---------|--|-----------|
| Power supply in bulk - - - | 3 | Siemens-Ilgner System for Winding | |
| Power Transmission - - - | 47-56 | Engines - - - | 80-93 |
| " " Electric, Hydraulic, | | Signalling Systems, Electric - - - | 187-194 |
| " " by steam or compressed air - | 1 | Single Drum Haulages - - - | 134 |
| Pressure, Choice of Transmission | | Sinking Pumps, Cables for - - - | 114 |
| System and - - - | 23-24 | " " Electrically-driven | 109-114 |
| Pressure for Sinking Pump Motors - | 114 | " " Three-phase Motors for | 113-114 |
| " Limits for Cables - - - | 51 | Span for Overhead Transmission Lines | 53 |
| " of Explosion inside a motor - | 181 | Sparks, C.P. - - - | 6, 12-13 |
| Producers, Gas, and Coke Ovens - | 34 | Speed of Winding - - - | 59 |
| Protective Devices for Transmission | | " " for men - - - | 96 |
| Lines - - - | 53 | "Squirrel-Cage" Alternating-current | |
| Pump Motors, Switchgear and Buffer | | Motors, Advantages of - - - | 23 |
| Resistances for - - - | 104 | "Squirrel-Cage" Alternating-current | |
| Pumping Plants, Electrically-driven | 99-114 | Motors for Coal Washers, etc. - | 153 |
| Pumps, Centrifugal for working inbye - | 140 | "Squirrel-Cage" Alternating-current | |
| " " Motors for - - - | 105-112 | Motors for Sinking Pumps - | 113-114 |
| " " Reciprocating, Alternating-cur- | | Stations, Steam Engine driven - - - | 25-27 |
| " " rent motors for - - - | 101-104 | Steam and Electric Winders - - - | 94-98 |
| Pumps, Reciprocating and Centrifugal - | 100 | " Consumption of Turbo-generator | 28 |
| " " Electrically-driven | 101-104 | " Driven Pumps - - - | 99 |
| " " Sinking, Electrically-driven | 109-114 | " " Sinking Pumps - - - | 109 |
| " " Steam driven - - - | 99 | " " Engines, Efficiency of - - - | 36 |
| Reciprocating and Centrifugal Pumps - | 100 | " " Horizontal and Vertical | 25 |
| " Compressors - - - | 127 | " " Engine Stations - - - | 25-27 |
| " Pumps, Electrically-driven | 101-104 | " " Turbines for Converter Sets - | 74 |
| Redjang Lebong Gold Mine, Special | | " " Turbine Plants - - - | 28-31 |
| Machines for - - - | 161-164 | " " Power Stations - - - | 28-29 |
| Regenerative System for Fan Motor, | | " " Winders - - - | 94-98 |
| Deutscher Kaiser Pits - - - | 120 | Steel Poles for Overhead Transmission | |
| Regenerative System for Fan Motor, | | Lines - - - | 53 |
| Diagrams of Connections - - - | 122 | Suspension Gear for Transmission Lines | 56 |
| Regenerative System for Fan Motor, | | " Insulators - - - | 56 |
| De Wendel Pits - - - | 120 | Switchboards, Desk-type - - - | 41 |
| Releases for Oil Switches - - - | 46 | " for Low Pressure - - - | 42 |
| Remote Control of Switchgear - - - | 42 | " " High " - - - | 41 |
| Rheinpreussen Distribution System - | 11 | Switches, Flame-proof - - - | 185 |
| Rio Tinto Distribution System - - - | 10 | " " Isolating - - - | 44 |
| Robinson Central Deep Company, | | Switchgear for Coal Washers, etc. - | 156 |
| Turbo-Compressor Plant - - - | 129 | " " Installation below ground | 175-180 |
| Rock Drills, Cost of - - - | 167-168 | " " Pump Motors - - - | 104 |
| Rock Drills, Electrically-driven | 165-174 | Switchgear in Generating Stations | 41-46 |
| " " Power required for | 165-166 | Synchronous Motors for Compressors | 128 & 130 |
| Rolling Mills, Gas Engines in - - - | 32 | System and Pressure for Transmission, | |
| Rope Haulages - - - | 135 | Choice of - - - | 23-24 |
| " Inspection with Three-phase | | Systems, Distribution - - - | 5-22 |
| " " Winder - - - | 66 | "Tapped" Turbines - - - | 30 |
| Ropes, Flat, for Winding Engines - - | 58 | Tappings on Transformers - - - | 47-48 |
| Rotary Converters - - - | 146 | Tauern Mountains, Percussion Drills - | 170 |
| Rotary Drills - - - | 171-174 | Telephones, Loud Speaking - - - | 192 |
| Rutherford's Mine Shaft Signalling | | Telephone Wires and Overhead Trans- | |
| Apparatus - - - | 189 | mission Lines - - - | 56 |
| Safety Gear with Electric Winders | 72 & 82 | Tension, Electric (see Pressure) - - | — |
| Shot Firing, Electric - - - | 195-196 | | |
| Siemens-Ilgner System, Comparison of Costs | 95 | | |

Index—continued.

| | Page | | Page |
|--|-----------|--|-------------|
| Thomson Water Winding System | 109-110 | Visual Signals - - - | 188-190 |
| Three-core Cables - - - | 51-52 | Voltage (see Pressure) - - - | — |
| Three-phase Commutator Motors for Briquette Presses - - - | 160 | Ward-Leonard Control for Haulage and Hoist Motors - - - | 134 |
| Three-phase Commutator Motors for Electric Winders - - - | 68-69 | Ward-Leonard Control for Winding Engines - - - | 70, 66 & 62 |
| Three-phase Commutator Motors for Haulages and Hoists - - - | 134 | Ward-Leonard System with Buffer Batteries - - - | 79 |
| Three-phase Commutator Motors for Mine Fans - - - | 122 & 124 | Ward-Leonard System with Electric Winders - - - | 98 |
| Three-phase Motors for Centrifugal Pumps - - - | 105-112 | Waste Gases in Gas Engines - - - | 34 |
| Three-phase Motors for Coal Washers, etc. | 153 | Water Power Plants - - - | 39-40 |
| " " " Compressors | 127-128 | " " Stations - - - | 4 |
| " " " Haulages and Hoists - - - | 134-135 | " " Turbines - - - | 39 |
| Time Limit Devices for Releases | 46 | " " Power Stations - - - | 39-40 |
| Transformer Oil - - - | 48 | " " Winding System of Thomson | 109-110 |
| " " Tappings - - - | 47-48 | Wendel Pits, Regenerative System for Fan Motor - - - | 120 |
| Transformers - - - | 42 | Werne Mine, Cascade Fan Motors - - - | 118 |
| " " Arrangement of - - - | 46 | Winding Engines, Electric - - - | 57-98 |
| " " Efficiency of - - - | 47 | Winding, Speed of - - - | 59 |
| " " Oil-immersed - - - | 48 | " Engines, Electric, Number Installed - - - | 57 |
| " " Use of - - - | 47-50 | Winding Engine, Acceleration - - - | 57-59 |
| Transmission Lines, Overhead - - - | 53-56 | " Engines, Brakes for - - - | 58 |
| " " Protective Devices | 53 | " " Depth Indicator for - - - | 72 |
| " " Suspension Gear for | 56 | " " driven by Three-phase Commutator Motors - - - | 68-69 |
| Transmission of Power, Electric, Hydraulic, by steam or compressed air - - - | 1 | Winding Engines driven by Three- phase Induction Motors - - - | 61-67 |
| Transmission of Power - - - | 47-56 | Winding Engines, Flat Ropes for - - - | 58 |
| Transmission System and Pressure, Choice of - - - | 23-24 | " " in France and Belgium | 58 |
| Transport, Machines specially designed to facilitate - - - | 161-164 | " " " Headgear - - - | 91-93 |
| Trolley Wire, Overhead - - - | 146 | " " " Newcastle District | 66 |
| Turbine Installations for special purposes | 30-31 | " " Progressive Installa- tion of " - - - | 96 & 97 |
| " Plants, Steam - - - | 28-31 | Winding Engines, Steam and Electric - - - | 94-98 |
| Turbines " Back Pressure " - - - | 30 | " " Three-phase, Diagram of Connections - - - | 61 |
| " driven by exhaust steam - - - | 3 | Winding Engines, Three-phase, on the Continent, Number of - - - | 66 |
| " Exhaust Steam - - - | 30 | Winding Engines with Buffer Batteries | 78 & 79 |
| " Francis and Pelton Wheel - - - | 39 | " " " Koepe Pulley | 58 & 93 |
| " " Tapped " - - - | 30 | " " " Siemens-Ilgner System " - - - | 80-93 |
| " Water - - - | 39 | Winding Engines with Ward-Leonard Control - - - | 70-77 |
| Turbo-Compressors - - - | 128-130 | Winding Engines with Ward-Leonard System - - - | 98 |
| Turbo-generators, Steam Consumption of | 28 | Winding Speed - - - | 59 |
| " " - - - | 39 | " " for Men - - - | 96 |
| " " Design of - - - | 28 | Wood Poles for Overhead Transmission Lines - - - | 53 |
| United States, Gas Power available in - | 32 | | |
| Vertical and Horizontal Steam Engines | 25 | | |
| Victoria Falls Power Company and Three-phase Winding Engines - - - | 66 | | |

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