UNITED STATES

DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION

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MEMORANDUM TO CHIEF DESIGNING ENGINEER

SUBJECT: COMPILATION OF TUNNEL DATA

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by

E. W. LANE

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Under direction of

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TECHNICAL MEMORANDUM NO. 196

Denver, Colorado

1930

(PRICE $1.00)

| Name and Locality | Use | Reference | Length | Section | Material | Water | No. of Headings | Method | Progress | Shifts | Drills | Drill Holes | Explosives | Pull per Round | Muckin |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **RAILWAY TUNNELS, ROCK PREDOMINATING** | | | | | | | | | | | | | | | |
| Arthur's Pass (Otira) New Zealand | Railway | | 5.3 mi. | 15½'x15½' | Alternating slate and graywacke | A great deal. Max. 2000 gpm | 2(?) | Bottom heading 10' wide, 8' high | | | | | | | |
| Cascade, Washington | " | 632,636,638, 640,647,648, 661,776,890, 881,851,838. | 7.78mi. | 20'-10"x16' | Granite, quartz diorite | Max. 10,000 gpm | 4 | Center heading 10'x10' with ring drilling, 8'x9' pioneer heading outside main tunnel part of length | Pioneer bore 1157' per month. Enlarging 1220' per month. | | Drifters mounted on carriage | Center heading 27 - 8' to 10'. Enlarging 29 - 8'x9' drift 22 to 36 | 25¼ 60% NG dynamite center heading, [illegible] per cu.yd. [illegible] many delay periods | 7' to 9' for 8'x9' drift | Meyers-Whaley shovels for d shovels for e |
| Central Railway - Peru | " | 663 | 1640' | 19.7'x13.8' | Very hard granite | | 4 | Top heading enlarged to arch section for whole tunnel, then bench removed | | | Drifters on columns | 16 to 20 in heading 6' deep | Heading 50% of 75% dynamite. Max. 21lb. of 75% per c.y. | | Hand and powe |
| Moffat Colorado | " and water | 625,637,630, 651,1022,771, 783,861,747. | 32160' | Railroad tunnel 16'x24'; water tunnel 8'x8' | Granite gneiss and schist bad conditions at west end | Considerable flows, one reaching 3,000 gpm | | Water tunnel driven first, with cross connections to 8'x8' center bore, enlarged by radial drilling. Main bore enlarged by top heading and bench | 25' per heading in east end | 3 - 8 hrs. | Many varieties | Various lengths | 40% - 60% dynamite | Variable | C Conway muck shovel and ha |
| Musconetcong New Jersey | Railway | 655 | 4840' | 30'x25' | Syenite and limestone | 300 gpm | 2 | Heading and bench. In soft ground crown drift and 2 wall plate drifts | | | Leyner-Ingersoll drifters on columns & tripods | 42-474' heading per round; 25-245" bench per round | | | Air shovels a |
| Ozark Hills, I.C.R.R., Southern Illinois | Railroad | 635,664 | A-800' B-6900' C-2600' | 18'x26' | Sedimentary rock? Some shale | Some in B. | A-2 B-4 C-2 | A- top heading B- center heading C- wall plate heading near S portal, then top heading, then top center heading with 2 benches | 14' per day for 10'x10' heading (max.16'). In C heading max. 52f'; bench average 317'. | 3 - 8 hrs. C - 2 of 10 hrs. | 11' for center heading | | 4-7½# 40% dynamite per cu.yd. in center, 10'x10' heading | | Air shovels |
| Rodger's Pass (Connaught) (Shelkirk) Canada | Railroad | 606,831 | 26400 | Double track | | | | Two pioneer, 7'x8' tunnels | | | | | | | |
| Shimizu Japan | Railroad | 629 | 31831 | 19.7'x16.0' | Diorite | Little | 2 | Bottom heading in soil, two benches in rock. Also modern Austrian method | 20' per day after getting organized | 2 | Air drills of many makes | Benches 25-30 of 5'-6'. | 90% blasting gelatin and 60% dynamite | | Hand and pow |
| Tanna Japan | Railway | 613, 630 | 5 mi. | 28'x22½' | Agglomerate containing andesite, several dikes | Very bad 28 cfs | 2 | Usually bottom heading | During 1924; 7 ft. at one heading, 4.1 at other | 3 of 7 hrs. | Air driven | | Dynamite | | |
| **HIGHWAY, STREET CAR AND SUBWAY TUNNELS. ROCK AND EARTH.** | | | | | | | | | | | | | | | |
| Armstrong Pittsburgh | Highway | | 1299' | Double tube: one 22' wide, other 22' plus 4' wall. Both 23' high | Probably limestone and shale | Not mentioned | 2(?) | | | | | | | | |
| Beaucatcher Asheville, N. C. | " | 916 | 920' | 39'-2"x22' net. 48'x27' gross. | | | | Lined section, 2 drifts 5'x8' Rock, center heading, widened and seconed | | | | | | | Power shove |
| Hollywood-Glendale-San Fernando Valley, Los Angeles, Calif. | Street-cars | | 4225' | 28' wide, 21.2' high | Blue shale clay | Not mentioned | | Two side drifts, two upper drifts | | | | | | | |
| Liberty Pittsburgh | Highway, street-cars and side-walk | 901, 961 | 5715' | Two tubes 26½' wide | Horizontal, slightly fissured shale, clay, soft and hard sandstone | None | 2(?) | Top heading with very short bench | 250'-260' per month | 2 | One-man drills Heading 6 Bench 4 | Headings 20-45 of 11'-15'; bench 12-16 of 12' | 40% dynamite 2½-3½ lbs. per hole in heading 6# in bench # per cu.yd. | | Hand on pe led by 1½ shovel |
| Missionary Ridge Chattanooga, Tenn. | Highway | 965 | 1000' | Two 22' bores with 25' pillar between | Limestone and earth mixed | Not mentioned | 2 | Top side headings enlarged to top heading and bench | | | | | | | |
| Sidney Australia | Subway | | 740' | Two 15' bores | Shale, large building near | Not mentioned | 1 | 3 bottom headings, then top headings, then removed center core | | | Compressed air picks. | | | | |
| Sunset (Duboce) San Francisco | Street-cars | 914, 951 | 4232' | 25'x23' | Serpentine, sandstone and earth | Considerable at times | 2 | Crown and wall plate drifts | | 3 excavating 1 concreting | | | | | Air shovel |
| **MISCELLANEOUS TUNNELS.** | | | | | | | | | | | | | | | |
| Rove Ship Tunnel Marseilles, France | Ship Canal | 8, 72, 393, 386, 600F | 4½ mi. | Arch 72'x32½' Invert 59'x15' | Marly, fine grained limestone, no faults | Flooded out one heading, grouted | 3 | Two side headings, top heading enlarged to complete the arch. Center core removed after lining placed | Max. 450 cu.yds. per day for 450 men. 15 to 18' per day | 3 of 8 hrs. | Air drills | | 72# dyn. in headings & hard rock. 57% in soft rock. Headings | | Hand |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Moffat<br>Colorado | " and water | 625,657,650, 651,1022,771, 783,861,747. | 32160' | Railroad tunnel 16'x24'; water tunnel 8'x8' | Granite gneiss and schist and conditions at west end | Considerable flows, one reaching 3,000 gpm | | Water tunnel driven first, with cross connections to 8'x8' center bore, enlarged by radial drilling. Main bore enlarged by top heading and bench | 25' per heading in each end | 3 - 8 hrs. | Many varieties | Various lengths | 75% per cu.yd. 40% - 60% dynamite | Variable | Conway mucker shovel and hand |
| Musconetcong<br>New Jersey | Railway | 655 | 4840' | 30'x25' | Granite and limestone | 500 gpm | | Heading and bench. In soft ground crown drift and 2 wall plate drifts | | | Leyner-Ingersoll drifters on columns & tripods | 42=474' heading per round; 26=245" bench per round | | | Air shovels and |
| Ozark Hills, I.C.R.R.<br>Southern Illinois | Railroad | 635,664 | A-800'<br>B-6900'<br>C-2600' | 18'x26' | Sedimentary rock. Some shale | Some in B. | A-2<br>B-4<br>C-2 | A- top heading<br>B- center heading<br>C- wall plate heading near B portal, then top heading, then top center heading with 2 benches | 14' per day for 10'x10' heading (max.16'). In C heading max. 52'; bench average 31'. | B - 8 hrs.<br>C - 2 of 10 hrs. | 11' for center heading | 1 | 4-7½-40% dynamite per cu.yd. in center, 10'x10' heading | 8' | Air shovels in |
| Rodger's Pass (Connaught) (Shelkirk)<br>Canada | Railroad | 606,831 | 26400 | Double track | | | | Two pioneer, 7'x8' tunnels | | | | | | | |
| Shimizu<br>Japan | Railroad | 629 | 3183 | 19.7'x16.0' | Diorite | Little | 2 | Bottom heading in soil, two benches in rock. Also modern Austrian method | 20' per day after getting organized | 2 | Air drills of many makes | Benches 25-30 of 5'-6'. | 90% blasting gelatin and 60% dynamite | | Hand and power |
| Tanna<br>Japan | Railway | 613, 630 | 5 mi. | 28'x22½' | Agglomerate containing andesite, several dikes | Very bad 28 cfs | 2 | Usually bottom heading | During 1924; 7 ft. at one heading, 4.1 at other | 3 of 7 hrs. | Air driven | | Dynamite | | |
| | | | | HIGHWAY, STREET CAR AND SUBWAY TUNNELS. | | ROCK AND EARTH. | | | | | | | | | |
| Armstrong<br>Pittsburgh | Highway | | 1299' | Double tube; one 22' wide, other 22' plus 4' walk. Both 23' high | Probably limestone and shale | Not mentioned | 2(?) | | | | | | | | |
| Beaucatcher<br>Asheville, N. C. | " | 916 | 920' | 39'-2"x22' net. 48'x27' gross. | | | | Lined section, 2 drifts 8'x8' Rock, center heading widened and lagged | | | | | | | Power shovel |
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| Missionary Ridge<br>Chattanooga, Tenn. | Highway | 965 | 1000' | Two 22' bores with 26' pillar between | Limestone and earth mixed | Not mentioned | 2 | Top side headings enlarged to top heading and bench | | | | | | | |
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| | | | | MISCELLANEOUS TUNNELS. | | | | | | | | | | | |
| Rove Ship Tunnel<br>Marseilles, France | Ship Canal | 8, 72, 393, 385, 6007 | 4½ mi. | Arch 72'x52½' Invert 59'x15' | Marly, fine grained limestone, no faults | Flooded out once, grouted | 3 | Two side headings, top heading enlarged to complete the arch. Center core removed after lining placed | Max. 450 cu.yds. per day for 450 men. 15 to 18' per day | 3 of 8 hrs. | Air drills | | 72% dyn. in headings & hard rock. 57% in soft rock. Headings 1.6 kg. Excavating of arch 0.5 kg., center core 0.5 kg. per cu.meter | | Hand |
| Duwamish Waterway<br>Seattle, Washington | Water Pipes | 68 | 414' | 8' diameter, 60' below water | Sand | Kept dry by compressed air | 1 | Compressed air | 4 ft. per day | 3 | | | | | Hand |

| Explosives | Drill per engine | Mucking | Hauling | Timbering | Character | Lining Repair | Placing | Power | Compressors | Ventilation | Dust | Miscellaneous |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Trolley locomotives with reels. 2'-6" gage | Temporary timbering thrust | Precast concrete blocks | | | Electric | | Exhaust, 4,000 cfm at each end | | |
| [illegible] | 7- to 9-ft. per [illegible] | Shovels, Shaley and air shovels for drift. Air shovels for enlargement | 6 and 20-ton trolley locomotives. 6-yard mine. trolley/rail car near headings. | | Concrete | Steel and wood | Pneumatic and gravity | Electric Steadly, oil | E.portal 2850 cfm; Mill Creek 3898 cfm, W. portal 4750 cfm | W. portal 20,000 cfm | | Mill Creek shaft 22,000 gpm in pumps |
| [illegible] | | Hand and power rockers | | | | | | | 2000 cfm | | | |
| [illegible] | [illegible] | [illegible] | Battery and trolley locomotives. [illegible] and 4-cu.yd. cars | Heavily timbered in places. Steel used in places | | | | Electric | | 2- 4000 cfm blowers at 4-lb. 2 [illegible] 12,000 cfm at 1/2 oz. | | |
| [illegible] | | Air shovels and hand | | Required in places, usually 12"x12", also 12"x16" and steel beams for high pressures | Reinforced concrete. Steel forms used in places for reinforcing in concrete | Wooden | By gravity from lining traveler. Hay pneumatically | Electric | 4- 250 h.p. 2000 cu.ft. after coolers | 4,000 cfm blower | | |
| 4-[illegible] [illegible] | Oil | Shovels in D. | 2- 12-ton 1-yd. cars with battery locomotive | A large portion of B and C | 4- Concrete 12" min. thick. 6 drills, power, mill plates and 2-cap. crab | Steel | Gravity, pneumatic in [illegible] | Oil engines | 2-100 h. p. 2-2-200 h.p. Diesel with 270 cfm free air delivered at 125#/sq. in. | 5000 cfm for D. | | 2-75 kva. and 1-150 h.p. generators operated by 2-250 h.p. Diesels used for fans, lighting and locomotives. 100 h.p. Diesel for hoist. |
| | | | | | 20,000 lin.ft. concrete | Collapsible steel | Pneumatic from car | | | | | |
| [illegible] | | Hand and power | Hand and electric | Steel and wood with iron ribs | Concrete block. Full section in soil. Arch only in rock. Block in [illegible] | | | Electric | 2 compressors, 440 cfm at each portal | | | |
| Dynamite | | | 30" gage cars. Hand and electric hoists | Temporary system. Bad earth pressures | Concrete and brick | | | Steam replaced by electric | | Fans 75 h.p. | | |
| | | | | Probably steel beams used | Concrete reinforced with rods and structural steel | | | | | | $1,540,000 incl. property damage | Begun in Jan., completed in Oct., 1926 |
| | | Power shovel | 6-yd. std. gage cars. Eleven steam dinky | 120' timbered | Concrete | | | | W. portal 400 cfm with 100 h.p. electric motor. E. portal 220 cfm with 60 h.p. | | | |
| | | | | | Concrete 1:2:4 reinforced | | | | | | | |
| [illegible] | [illegible] lbs. per hole in heading [illegible] in bench [illegible] per cu.yd. | Hand on bench, all bench ld by [illegible]-yd. air-shovel | 4-yd. cars, 5-car trains, electric locomotives | Steel with wood lagging [illegible] I-beam, [illegible]'-[illegible]' c.c. | Concrete, grouted | Footings wood; remainder sectional steel | Pneumatic | | | Exc. [illegible] Conc. [illegible] Contract price $722 per lin. ft. | Overbreak 11% | |
| | | | | Heavy 12"x12"-12"o.c.; in some places further bracing required | Concrete 1:2:4 - [illegible] thick | | Hand | | | Bid $547,212. | | |
| | | | | Curved steel rails for arch with lagging between | Walls brick, arch 18" concrete | Lagging suspended from curved rail timbering by bolts | Hand | | | | | |
| | | Air shovels | For concreting, gasoline locomotives and trucks | Practically entire length 7-segment arch 10"x12" timbers close together | Reinforced concrete | Steel | Pneumatic | | | | | |
| [illegible] | | Hand | Narrow-gage railways, air and steam locomotives | Little required | Limestone blocks in calcareous natural cement mortar, designed for 44# per sq. in. | Wooden forms held by metal frames | | | | | Labor 84¢ hr. Cost probably Fr. 185,000,000 | Excavation 60,000,000 cu.ft. Largest tunnel excavation in Europe. |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | Electric | 2000 cfm | 2- 4000 cfm blowers at 4-lb., 2 fans 12,000 cfm at 1/2 oz. | | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | Reinforced in places, usually 12"x12", also 12"x16" and steel beams for high pressures | Reinforced concrete. Steel forms used in places for reinforcing in concrete | [illegible] | By gravity from lining traveler. Key pneumatically | Electric | 4- 200 h.p. 3000 cu.ft. after coolers | 4,000 cfm blower | | | |
| 4-[illegible] dynamite [illegible] | [illegible] | Air shovels in B. | 2 - 12- 1-yd. cars with battery locomotive | A large portion of B and C | In Concrete 12" min. thick. C Stills, posts, mill plates and 2-cog. arch | Steel | Gravity, pneumatic in crown | Oil engines | 2-100 h. p. 2-2-200 h.p. Diesel with 870 cfm free air delivered at 125#/Sq. in. | 5000 cfm in B. | | 2-75 kva. and 1-150 h.p. generators operated by 2-100 h.p. Diesels used for fans, lighting and locomotives. 100 h.p. Diesel for hoist. | |
| | | | | | 24,000 lin.ft. concrete | Collapsible steel | Pneumatic from car | | | | | | | |
| 70% [illegible] gelatin and 30% dynamite | [illegible] | Hand and power | Hand and electric | Wood and rod with iron ribs | Sandstone block. Full section in drill. Arch only in [illegible] | | | Electric | 3 compressors, 466 cfm at each portal | | | | | |
| Dynamite | | | 50" gage cars, hand and electric hoisting | Compressed air system. Rock and earth pressures | Concrete and brick | | | Steam replaced by electric | | Fans 75 h.p. | | | | |
| | | | | Probably steel beams used | Concrete reinforced with rods and structural steel | | | | | | | $1,540,000 inc. property damage | Begun in Jan., completed in Oct., 1925 | |
| | | Power shovel | 6-yd. std. gage cars. 21-ton steam dinky | 120' timbered | Concrete | | | | W. portal 400 cfm with 100 h.p. electric motor. E. portal 220 cfm with 60 h.p. | | | | | |
| | | | | | Concrete 1:2:3 reinforced | | | | | | | | | |
| [illegible] | | Hand on bench all hand led by 1-yd. air shovel | 4-yd. cars, 5-car train, electric locomotives | Steel with wood lagging [illegible] I-beam, [illegible] | Concrete, grouted | Footings wood; remainder sectional steel | Pneumatic | | | | | Exc. [illegible] Conc. [illegible] Contract price $722 per lin. ft. Mid $847/lin. | Overbreak 11% | |
| | | | | Heavy [illegible] in some places further bracing required | Concrete lined - [illegible] thick | | Hand | | | | | | | |
| | | | | Curved steel rails for arch with lagging between | Brick, arch 16" concrete | Lagging suspended from curved rail timbering by bolts | Hand | | | | | | | |
| | | Air shovels | For concreting, gasoline locomotives and trucks | Practically entire length 7-segment arch 10"x12" timbers alone [illegible] | Reinforced concrete | Steel | Pneumatic | | | | | | | |
| [illegible] | | | Hand | Narrow-gage railways, air and steam locomotives | Little required | Limestone blocks in calcareous natural cement mortar, designed for 440 per sq. in. | Wedge forms held by metal frames | | | | | Labor [illegible] hr. Cost probably Fr. 185,000,000 | Excavation 60,000,000 cu.ft. Largest tunnel excavation in Europe. | |
| | | | Hand | Hand | Timber lagging. No sets required | Concrete | Steel ribs with timber lagging. Collapsible. | Hand | | | | | Bad air leakage. 4000 cfm used. | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] | | | | 14' diameter | Hard plastic, [illegible] gravel, clay | | 7 | | Max. [illegible]' per month | | | |
| [illegible] | [illegible] | [illegible]. 450 | [illegible] | [illegible] horseshoe | Horizontally bedded limestone, generally [illegible] | Very little | 2 | Top heading and [illegible] bench | [illegible]ft. per shift in 15 ft. tunnel | [illegible] of [illegible], [illegible] of [illegible] | [illegible] | [illegible] |
| [illegible] | | | 1600 | [illegible] horseshoe | Rock | | | Heading and bench fired, then full face | | | [illegible] | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] horseshoe | Hard, variable | | | | | | | [illegible] |
| [illegible] | | [illegible] | 7800 | [illegible]' diameter | [illegible] basalt | | | Top heading and bench | | | [illegible] | [illegible] |
| [illegible] | | [illegible] | [illegible] | [illegible] | [illegible] and granite | [illegible] 50 g.p.m. | 4 | Top heading and bench | [illegible] ft. per heading per day | [illegible] of 10 hours each | [illegible] | [illegible] |
| [illegible] | | [illegible] | [illegible] | [illegible] | Granite | Considerable wet ground | [illegible] | Heading and bench | One heading [illegible]' April, [illegible] | [illegible] of 8 hours each | [illegible] | [illegible] |
| [illegible] | [illegible] | ? | [illegible] | [illegible]' horseshoe | [illegible] and [illegible] | | 2 | Probably full face | | 2 (?) | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] horseshoe | [illegible] and [illegible] sandstone, [illegible] clay shale | [illegible] installed | 2 | Full face | [illegible]' per mo. in [illegible] | | [illegible] | 7' |
| [illegible] | | | 4000' | [illegible] horseshoe | | | 1 | Probably full face | | 2 (?) | [illegible] on [illegible] | |
| [illegible] | [illegible] | [illegible] | [illegible] | 8' diameter | Hard diorite | | | [illegible]. face | | | | |
| [illegible] | [illegible] | [illegible], 154, 405, [illegible] | [illegible] | [illegible] | [illegible] and granodiorite, [illegible] mostly slate | Considerable in some parts | 10(?) | Full face | 600-700 ft. per mo. Max. 775 | 8 | [illegible] | 22' |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | Hard granite | | 6 | Heading and bench | | | [illegible] | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] diameter | Water-laden gravel, limestone, [illegible] | Water, oil and gas encountered | 6 | [illegible] open pit, open and pneumatic caissons | [illegible] per 8-hr shift [illegible] per [illegible] shift<br>North Portal [illegible]' | | [illegible] | 4' |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] | [illegible] | | 4700' | 6'-8' horseshoe | | | 1 | Probably full face | | 2 (?) | Drifters on Cols. 12" shaft | | | | | Sheet hand belts |
| [illegible] | Tower | 289 | 2576' | 8' diameter | Hard diorite | | | St. face | | | | | | | | Hand |
| [illegible] | Water | 22, 124, 201, 237, 306 | 18.3 mi. | Lined 10'6"x9'-9" hr" 12'6"x11'-4" | 5 mi. hard gneiss, granite and granodiorite, remainder mostly slate | Considerable in some parts | 10(?) | Full face | 500-700 ft. per mo. Max. 776 | 3 | | [illegible] | | | 12' | Machi |
| [illegible] | Tower | 36 | 18.4 mi. | 18'x18' | Hard granite | | 6 | Heading and bench | | | | [illegible] | | | | Air sh shovel |
| [illegible] | Water | 79 | A 18500' B 11000' | A 7½' diameter B 6' | Water-laden gravel, limestone, conglomerate & shale, shaft badly | Water, oil and gas encountered | 6 | Shafts open pit, open and pneumatic caissons | Shafts 8½'-10' diam. per 8-hr. shift. Tunnel 5'-5' per 8-hr. shift | | | [illegible] | | 80% gelatine 4½ | 4' | Hand a |
| [illegible] | Tower | 3, 26, 595 | 16945 | 17'x17' | Granite, hard, coarse, seamless and blocky, prism vertical grain | Weak in north portal | 6 | Top heading and bench. Vertical face with drill carriage, latter probably best | North Portal [illegible]' per day. S. Portal max. [illegible]', Adit 12 max. 12' | | North portal 15'-18' | [illegible] north portal 75-80 adit 21. | | | North portal 10-11' | |
| [illegible] | " " | 26, 56, 595 | 8561 | 13.6'x18.0' unlined. [illegible] lined | Poor granite, very blocky, some slides of rock and earth | Not entirely dry | 10 | Full headings, radial method unsuccessful | 120' per 24-hr. day for last month | Probably 3 | 12-15 of 16' 12 of 12' | | | | | Shove |
| [illegible] | " " | 595 | 1172 | 7.5' diameter | Granite | | | | | | | | | | | |
| [illegible] | " " | 26 | 40000 | [illegible] | Shale, decomposed to hard granite | | 40 | Full face | Max. 470 per mo. | | | [illegible] | | | | Hand |
| [illegible] | Outlet Tower to Reservoir | 595 | 5400 | 12'x12' horseshoe slope 15°[illegible] circle | Hard igneous rock, limestone | No difficulties | 2 | St. face | 7' per day per heading | 2 | | [illegible] | | | 7' | Com |
| [illegible] | Water Tower | 20 | 4500 | 20'x22' horseshoe 475 sq. ft. | Probably limestone | No trouble | 6 | Arch section carried entirely thru, then bench | 9' per day, 180 cu. yds solid rock (250 broken) | 2 of 9 hrs. each. drilling in day; mucking at night. | Headings 18 jackhammers & volumes | Heading 40-[illegible] 20' down | | | 7' (?) | 3/4 typ |
| [illegible] | Siphon Tower | 521-595 | 3400 | [illegible] | Interbedded shale and limestone of varying hardness | None | | Drill carriage with full face | Completed in 8 mos. Max. 1601', max. for [illegible] | | | 25 to 35 | | 60% & 7 gelatin dynamite | | Two shov |
| [illegible] | Tower Valley | [illegible] | 10070 | 1600'-18' diameter [illegible] horseshoe | Hard limestone, solid and heading, soft earth | | 8 | Heading and bench | Max. 534 ft. per mo. | | | Heading [illegible] 20%, Bench [illegible] | | | | Ham |
| [illegible] | " " | [illegible] | [illegible] | [illegible] diameter 20' diameter | Gneiss, schist, conglomerate | | 8 | Shaft plus drift and top heading heading | | 2 of 3 hours | Layer and jackhammer | [illegible] | | | 8' | Tar air co. |
| [illegible] | Tower | 26 | 14500 | Horseshoe, [illegible] | Sandstone, conglomerate, shale | | 4 | Full face | | | | 7 to 10 of 8' [illegible] | | | | Ham |
| [illegible] | " " | [illegible] | [illegible] | Horseshoe, 7'x[illegible] | Hard granite and granite and shale | [illegible] | 8 | | | | Layer layers | [illegible] | | [illegible] | 7.7' | Ham |
| [illegible] | " " | [illegible] | [illegible] | Horseshoe, 11'x[illegible] | Shale, [illegible] | Considerable [illegible] | 10 | Heading and bench | 12 headings 2040 per mo. [illegible] | 2 shots per day in heading, [illegible] 1 in bench | Jackhammers and layers | [illegible] | | [illegible] | 5.6' to 10 | Ham |
| [illegible] | " Tower | 26 | 14000 | 8'x11' | Hard granite | | 4 | Drill face | Max. 350' per mo. | | | [illegible] | | | | Ham |
| [illegible] | " Shaft | 595 | [illegible] | Horseshoe, [illegible] | Drill hard granite & [illegible] | Considerable | 6 | Drill face | Best month 2 headings 1160', one 9 headings 1200' | 1 to 2 | Drifters on [illegible] | [illegible] | | | 2 to 10' Shaft | Ham |
| [illegible] | " Tower | 26 | [illegible] | Horseshoe, [illegible] | Drill granite | | 2 | | | | | | | | | |
| [illegible] | " Tower | 595 | [illegible] | Drill 10'x12', block 8'-9' diam. | Drill granite | | | St. face | | | | | | | | Ham |
| [illegible] | Tower | 107 | [illegible] | 8' diameter | Hard clay, shale, limestone | Considerable | 4 | | | | | In shale 3'-4' | | | | Ham |
| [illegible] | Tower Tower | | 12000 | 8'-9' horseshoe | | | 6 | Probably full face | | 2 (?) | Drifters on [illegible] 12" shaft | | | | | [illegible] |
| [illegible] | Water Tower | 21 | | [illegible] | Horizontal limestone and shale layers | Not troublesome | | Drill section heading with 12' bench | 10 ft. per day | One shaft drill and shoot, other muck | Water layers and jackhammers | Shoot 40 in [illegible] 25 in bench | | | | Ham |
| [illegible] | Water Shaft | 75 | 450' | 9'x9' horseshoe | Sound granite gneiss enough for jointing | Not troublesome | 1-2 | Full face | 55 ft. per week | 2 drilling, 1 blasting and mucking, 8 hrs. each | 2 drills and [illegible] on [illegible] arms. Over [illegible] | [illegible] - 12" layer | | [illegible] | 10% | [illegible] |
| [illegible] | " Tower | | 6.8mi | Horseshoe 14'; 340' of 14' circle; 5 branches 8' diam. | Practically all solid rock | | 4 | Heading and 8' bench shot together | Average 480' per mo. per heading | 2 | Drifters on [illegible] thickness for trimming | Heading [illegible] Bench 6½ all horizontal | | | 7'-9' per shot | [illegible] |
| [illegible] | " " | [illegible] | 455' | 8' diameter | Earth and broken rock | | | St. face | | | | | | | | Ham |

WATER CONVEYING AND SEWER TUNNELS, EARTH PRESSURE TIRE

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] | Shaft | 12 | 2000' | Three-barrel, 6½' [illegible] 8' semi. | Sensitive dry blue glacial clay | Little | 1 (?) | Excavated by hand and shoved [illegible] amber layer first. | 20-25 ft. per day | 2 shots. | | | | | | |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Outlet Valves to Penstock | 595 | 4400 | 12'x12' horseshoe also 12'dia circle | Hard igneous rock, Granstone | No difficulties | 2 | Sh. face | 9' per day per heading | 2 | | 15 to 25 ft. | | | |
| | Water Power | 20 | 4900 | 22'x22' horseshoe 375 sq. ft. | Probably limestone | No trouble | 6 | Arch section carried entirely thru, then bench | 9'per day,180 cu.yds solid rock(350broken) | 2 of 9 hrs. each, drilling in day; mucking at night. | Headings 10 Jackhammers & valves | 36 | Heading 40-holes 10' deep | | 9' (?) |
| | Mine Drainage | 531-886 | 3400 | [illegible] | Intersected shale and limestone of varying hardness | None | | Drill carriage with full face | Completed in 8 mos. Max.avg. 1001', max. day [illegible] | | | 28 to 28 | | 40% 1.7 gelatin dynamite | |
| | Water Power | [illegible] | 10070 | 1880'-14' diameter 3870'-12'x12' horseshoe | Hospitals here,sulfur and broken, and earth | | 8 | Heading and bench | Max. 864 ft. per mo. | | | | Heading 8-10 ft 9' to 10'. Bench [illegible] | | |
| | " " | [illegible] | [illegible] | Diameter 14' diameter " | Volcanic tuff, conglomerate | | 6 | Full plate drift and top heater heading | | 8 of 8 hours | Larger and jackhammers | 1 to 11 per heading | | | 8' |
| | " Shaft | 24 | 14500 | Horseshoe,[illegible] | Serpentine, continuous, [illegible], shale | | 4 | Full face | | | | 7 to 10 of 5' dia. 9' | | | |
| | " " | [illegible] | [illegible] | Horseshoe,[illegible] | Sound [illegible] granite [illegible] | A few small [illegible] | 8 | | | | Water layer | 20 per round | | [illegible] | 7.7' |
| | " " | [illegible] | [illegible] | Horseshoe, 11.5'x10.25' | [illegible] | [illegible] | 12 | Sound rock [illegible] heading. Thereafter full face. Between heading first and [illegible] bench | [illegible] rock, max. 12 headings 3540 per [illegible] | 2 shots per day on top heading trouble. [illegible] | [illegible] Jackhammers and bench | [illegible] | [illegible] | [illegible] | 7.5' to 10' |
| | " Tunnel | 24 | 18000 | 9'x11'. | Hard granite | | 4 | Full face | Max. 180' per mo. | | | [illegible] | | | |
| | " Shaft | 225 | [illegible] | Horseshoe, [illegible] | [illegible] | Considerable | 6 | Full face | Best month 2 headings 1160', for 9 headings 1800' | 1 to 2 | Drifters on [illegible] | [illegible] | | [illegible] | 5 to 12' holes |
| | " Tunnel | 24 | [illegible] | Horseshoe, [illegible] | Hard granite | | 2 | | | | | | | | |
| | " Shaft | 225 | 14400 | Diameter 10'[illegible] 15000 [illegible] | Shale granite | | | 24. face | | | | | | | |
| | Shaft | 187 | [illegible] | 9' diameter | Hard clay, shale, limestone | Considerable | 8 | | | | | 24 shots 5'-4' | | 2 shots [illegible] | |
| | Water Shaft | [illegible] | [illegible] | [illegible] horseshoe | | | 4 | Probably full face | | 2 (?) | Drifters on [illegible] 12" steel | | | 240 holes per round | |
| | Water Shaft | 21 | | 24'x24' | Horizontal limestone and shale layers | Not troublesome | | Full section heading with 12' bench | 10 ft. per day | One shift drill and shoot, other muck | Water layer and jackhammers | Shoot 24 in [illegible] 12 in heading | | [illegible] | |
| | Water Shaft | 79 | 660' | 9'x9' horseshoe | Sound granite gneiss except for jointing | Not troublesome | 1-2 | Full face | 55 ft. per week | 2 drilling, 1 blasting and mucking, 8 hrs. each | 2 drills [illegible] 12" long on [illegible] area. Carry [illegible] | 24 - 12" long | | [illegible] | 10% |
| | " Tunnel | | 5,[illegible] | Horseshoe 14';349' of 14'circle;5 branches 6' diam. | Practically all solid rock | | 6 | Heading and 8' bench shot together | Average 450' per mo. per heading | 2 | Drifters on [illegible] Jackhammers for trimming | Heading 8; bench 8; all horizontal | | | 7'-8' per shot |
| | " " | [illegible] | [illegible] | 8' diameter | Earth and broken rock | | | Sh. face | | | | | | | |
| | | | | | | | | | | | | | | | |

WATER CONVEYING AND SEWER TUNNELS, EARTH PENETRATING

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sewer | 12 | 5500' | Three-barrel 6', 4.5' and 3' semi-circular | Practically dry blue glacial clay | Little | 1 (?) | Excavated by hand air shovel or mucker, barrel first, then one side, then other | 20-25 ft. per day | 8 hours. | | | | | |
| | " | 130 | 5000' | 10'and 11' diam. [illegible] | Quicksand | No trouble | | Needle beam | | 8 | | | | | |
| | Sewer Shaft | 14 | Dial. | 12' and 14' diam. | Plastic blue clay, occasional sand pockets | Little trouble | | A 3'x6' drift sinked to a bench, hand and power shovels. B Machine excavation | A - 12' per day B - 24,12'-15' per day | 1.5 | | | | | |
| | " " | [illegible] | [illegible] | | Hard clay, shale, [illegible] | | 4 | Heading and bench | Heading 9'-12' per day, bench max. 24' | | | | | | |
| | Sewer | [illegible] | | 20' diameter | Alternating, water-bearing sand, below [illegible] | Cut out by shift [illegible] | | Upper half by one shift, lower by second shift, finish by third shift | 20' per day per heading | 8 | | | | | |
| | " | [illegible] | | 8' and 6' horseshoe | Hard clay with fine sand | Some sand and [illegible] | | | | | | | | | |

Note: This data is compiled from engineering literature. Some items may be inaccurate, due to changes made after the articles were written.

[illegible] in tunnel listing is unknown.

[redacted]

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | [illegible] | | | Concrete throughout | 6 - 20' sections, steel | Invert poured walls [illegible] | | | [illegible] | |
| | [illegible] | [illegible] | Steam battery locomotives, [illegible] side dump cars, [illegible] track | Ordinarily roof segments and lagging | Concrete | | | [illegible] | [illegible] | [illegible] | |
| | | [illegible] conveyor belts | | | Concrete throughout | 6 - 20' sections, steel | Invert poured walls [illegible] | | | [illegible] | |
| | | [illegible] | | | Concrete 8" min. thick [illegible] | | Concrete | | | | |
| | [illegible] | Machines, several types | Battery locomotives, [illegible] | Required only on occasional stretches | [illegible] | [illegible] | [illegible] | | | | |
| | | [illegible] | | None | None | | | | | | |
| [illegible] | [illegible] | [illegible] mechanical | Mules and electric locomotives | | Concrete | Steel | Hand and pneumatic | [illegible] | | | |
| | [illegible] | | Battery locomotives | | | | | | | | |
| | | [illegible] | Steam battery locomotives, [illegible] | [illegible] segment [illegible] lagging | Ribs, floor and part of [illegible] | [illegible] | [illegible] pneumatically | | | | |
| | | | | | Concrete 8" min. [illegible] | | | | | | |
| | | Hand | | [illegible] | Concrete [illegible] | | | | | | |
| | [illegible] | [illegible] | Battery locomotives, [illegible] cars | | [illegible] | [illegible] | Pneumatically | | | | |
| | [illegible] | [illegible] | [illegible] locomotives | [illegible] | [illegible] concrete | [illegible] steel | | | [illegible] | | |
| [illegible] | | [illegible] | Battery locomotives [illegible] | | [illegible] | | | [illegible] | | [illegible] | [illegible] |
| | | Hand | [illegible] locomotives | [illegible] | [illegible] | | [illegible] | | | | |
| | | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | Pneumatically | | | | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| | | [illegible] | | | [illegible] | [illegible] | [illegible] | | | [illegible] | |
| | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | | [illegible] | [illegible] | |
| | | [illegible] | | | [illegible] | | [illegible] | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] | [illegible] (?) | 3/4-cu. yd. crawler type air shovel | Electric locomotives, [illegible] | [illegible] | | | | | [illegible] | | | |
| [illegible] Yugoslavia [illegible] | | Two [illegible] shovels | Battery locomotives and 40 cu. ft. cars | | No listing | | | Electric | | 3000 cfm compr[illegible] | Details given in [illegible] | |
| | | Hand | Battery locomotives | [illegible] of length | [illegible] | | Pneumatic | | | | | |
| | | [illegible] | Battery locomotives | [illegible] | [illegible] | [illegible] | Pneumatically | | | | | [illegible] |