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Adaptation of diesel rubber-tired loading equipment to a bedded fluorspar mining problem

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ADAPTATION OF DIESEL RUBBER-TIRED LOADING EQUIPMENT TO A BEDDED FLUORSPAR MINING PROBLEM

BY

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A

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Photographs have been furnished from company files.

A special tribute is due Jesse H. Steinmesch, who died December 15, 1952, and who, as general manager and vice-president of Minerva Oil Company, inspired and encouraged the continuous efforts of the staff to improve mine mechanization and mining efficiency.

Permission given by the officers of Minerva Oil Company to use data, photographs, and other facilities is greatly appreciated.

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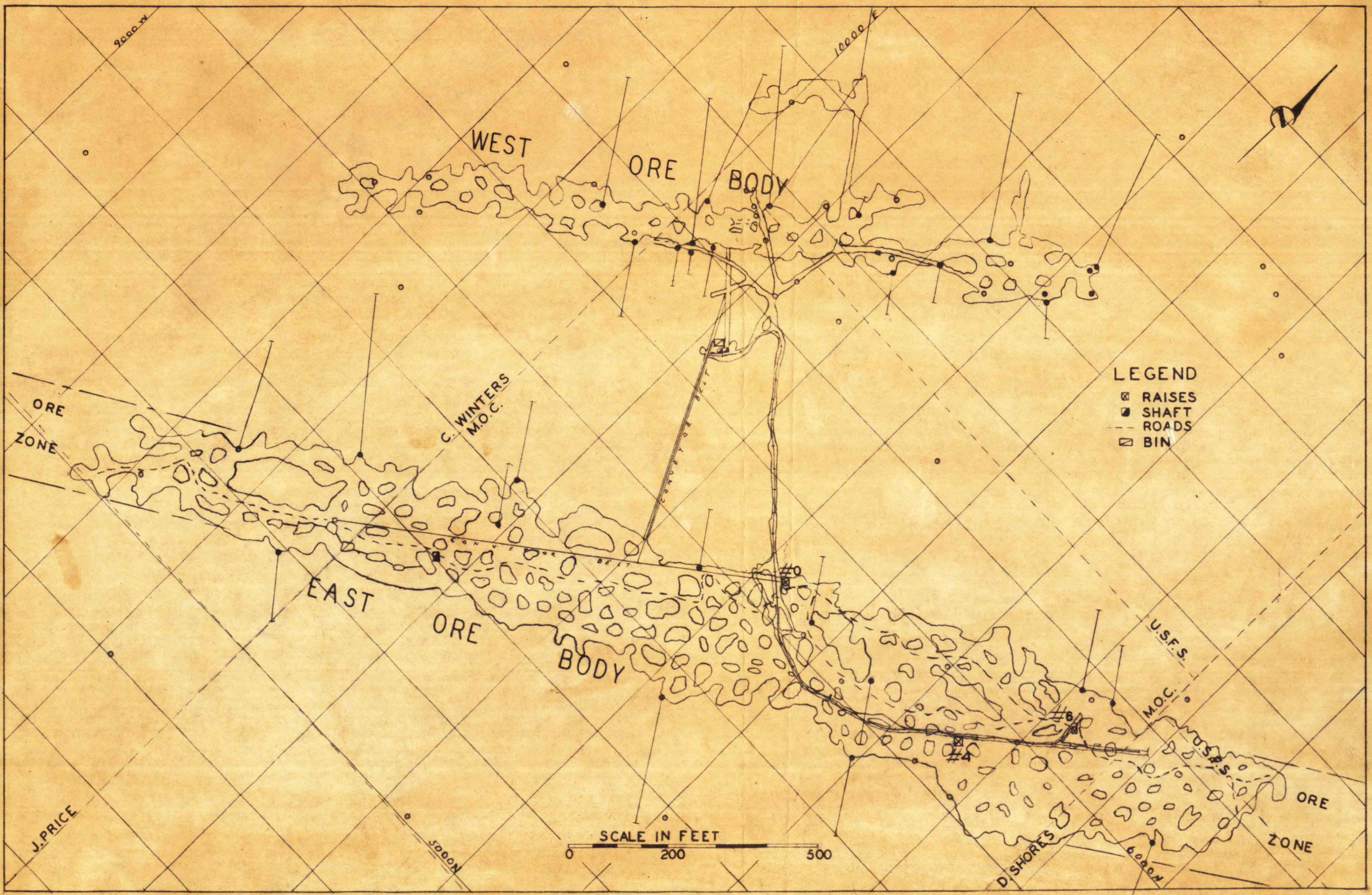

MINE NO. 1 WORKINGS
FIGURE 1

INTRODUCTION

The fluorspar-zinc orebody at Minerva No. 1 mine near Cave in Rock, in Hardin County, Illinois, would have been classed as non-commercial before the days of flotation milling and mine mechanization. The bulk of the ore requires fine grinding for acceptable beneficiation, and the assay of the head feed runs considerably lower than grades thought to be commercial in the fluorspar district prior to 1940.

However, the reserves found by drilling before the decision was made to invest in mine development, and the construction of a two-product, 250-ton, flotation mill, with complete power plant and surface shops, exceeded 600,000 tons. The belief that more than twice this tonnage of additional ore was very probable has been justified by subsequent prospecting. The shaft sinking commenced in 1942, and full plant operation commenced in 1944.

It was apparent from the beginning that full advantage of mine mechanization practices would have to be taken to keep mining costs as low as possible. The advantage of a large reserve opened the way for justifying the expenditure of capital for mechanical equipment, costs of which could be depreciated over many tons and years. Selection of equipment types developed and used with some measure of success in other mining districts, having similar mining conditions, was based upon the need to lower unit mining costs per ton, within the limits imposed by milling capacity, 250 tons, later raised to 325 tons, per day.

This thesis describes the attempts to achieve the best applicable types of loading and hauling equipment to keep mining costs low in a mine where output is held down.

Other factors governing this trend toward utmost mechanization were (1) a desire to limit the size of the manpower requirements during a period of skilled mine labor shortage, (2) adopt equipment types of the operation of which could be taught to new employes, who lacked any mining experience, and (3) adopt equipment types which would help the mine achieve a better safety record than had been experienced in the fluorspar district.

Fig. 2 Mobile electric slusher ramp, mounting a 20 h.p. 3-drum electric hoist which pulls a 42-inch scraper, loading into a two-ton Chevrolet dump truck converted to diesel.

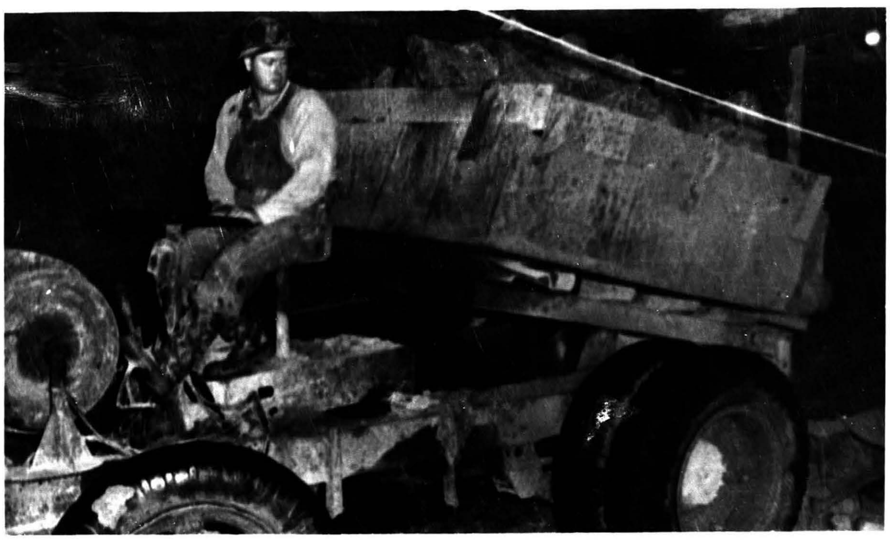

Fig. 3 Electric dump truck discharging an 8-ton ore load. The cable-reel spools 500 feet of 3-conductor No.6 cable for the 15 h.p. induction motor which is mounted below the reel. A Model 55 White truck chassis has been shortened by three feet. Two truck transmissions are used as speed-reducers, coupled directly to the motor, which has a speed of 900 rpm.

MINING ENVIRONMENT

The bedded replacement-type fluorspar deposits of the Cave in Rock District of Hardin County, Illinois, lend themselves to types of mechanized mining evolved in the "sheet-ground" zinc mines of the Picher District of Oklahoma, and room and pillar mining systems applied in many ore, limestone and coal mines.

The ore at Minerva Oil Company's Mine No. 1, six miles north of Cave in Rock, consists of a partial replacement of Renault limestone (Mississippian) by fluorite, zinc and minor amounts of lead, barite and calcite. Orebodies typically lie along either or both sides of minor, northeasterly trending faults, which have displacements of from one to ten feet, and which parallel and lie southeast of the Peters Creek fault, the major structural feature of the district. (1)

The lengths of the orebodies vary from about one-fourth mile to over two miles. Some orebodies as narrow as 25 feet are mined, but most vary from 50 to over 350 feet in width, normal to the strike of the control fractures or minor faults. Ore faces near these fractures may be as high as 18 feet, but most stopes being mined have faces of ore from 3 to 9 feet exposed vertically. Margins may be either gradual pinch-outs against the roof, or abrupt cutoffs.

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(1) Weller, J. Marvin et al Geology of the Fluorspar Deposits of Illinois; Illinois State Geological Survey, Bulletin 76 (1952) - pp 53, 102-103

The roof at Minerva No. 1 is hard, cross-bedded Bethel sandstone of Mississippian age. This sandstone, over 200 feet thick, is usually sound enough to span 50 feet between pillars. Locally, however, the lower portions making the mine roof are weakened by cross-bedding, or are made up of thin, shaly laminations. Air-slacking of shaly partings causes roof failure after a few months of exposure. In some places, multiple jointing has contributed to poor roof. With these adverse conditions, whether structural or stratigraphic, spans between pillars are sometimes limited to as little as 16 feet.

The entire district has a regional dip of about $7\frac{1}{2}^{\circ}$ N, 10° E, and the haulage grades parallel the long axis of the northeasterly trending orebodies, which are usually on a 5° slope - a little too steep for track haulage.

Mine water is a minor problem in all seasons, and the entire mine makes only from 100 to 150 gallons a minute, insufficient for mill supply. About one-third comes from updip faces, and the balance is developed in down-dip mining. Water is fresh and non-acidic, but contains traces of hydrogen sulphide.

Ore is hoisted on one shift in a single two-compartment shaft 645 feet in depth, in two 2-ton skips in balance. Skips are loaded through air-gates from a 300-ton storage pocket on the west side of the shaft. The pocket can be bypassed by direct dumping from 1.7 ton Koppel mine cars on the east side of the shaft.

These cars serve parts of the mine not serviced by conveyor belt, and are hauled to the shaft by 4-ton Mancha storage battery locomotives. Use of track haulage will be discontinued upon completion of a stope conveyor belt, which will serve the northeast or down-dip extension of the east orebody. (See mine map, Figure 1.)

All mining is currently confined to the east orebody, and all mechanical equipment is in use there. This orebody is served by a 555 foot ventilation and supply shaft. This shaft is circular, 5½ feet in diameter, inside concrete. Ventilation through this shaft is furnished by a 4-foot Jeffrey Aerodyne Junior fan installed on the surface, with a sliding access hood. This fan is operated to develop 15,000 cubic feet per minute at the shaft bottom, upcast. The fan is reversible when it is desirable to keep haulageways clear of powder smoke.

EVOLUTION OF MECHANIZATION

In considering the most economical type of mechanical equipment to use, the most limiting factor was the mill capacity: 300 tons per 24-hour day, all flotation, operating seven days per week, except for occasional repair shut-downs. The total surge capacity, until recently, consisted of a 150-ton crude ore bin in the headframe at the surface, a 250-ton fine ore bin, and a 300-ton rolls feed bin. When these were full, the mill could operate through the Saturday-Sunday weekend without mine production. A 300-ton underground storage bin at the hoisting shaft, receiving ore from the "mother" conveyor belt from the East orebody, has just been put into service.

Whenever business justified, the management has preferred to provide all employes with a six-day work week, including an overtime shift, to maintain a high take-home pay, but reserved the right to drop back to the five-day week when business slackened. Only for a short period in 1949 has the company seen fit to do this.

Therefore, the trend has been to condense, as much as possible, the number of working places, and to work them with minimum men and as few as possible items of drilling, loading and hauling equipment.

The ideal strived for, to yield approximately 350 tons per shift, working day-shift only, consists of a single highly mobile drilling unit, a highly mobile and versatile loading machine, mobile and speedy short-haul units, and a long-haul plan utilizing minimum man-power.

Recoverable values of combined fluorspar and zinc in the ore range from $12 to $17 when face-heights of 9 to 11 feet are mined. There is little incentive to mine more selectively in order to raise the grade of feed to the mill, because if lower height faces were mined, the use of many available types of standard loading and hauling equipment, designed to operate in head rooms of 9 to 11 feet, would be barred.

Consideration has been given low head-room modern coal-mine type loading and haulage equipment of trackless types, as popularized by Goodman, Joy, Jeffrey and other firms, but these have been ruled out for two principal reasons:

1. Their comparatively high initial cost and resultant high annual depreciation figure applied to the low daily tonnage requirement results in an unattractive high mining cost.

2. The character of the ore is unsuitable. Variations in thickness of the ore are on the floor side, with the top of the ore nearly always flat against the even Bethel sandstone roof. (2) If none of the waste is taken, the stope floor will undulate erratically, with many potholes, trenches and "horses" of waste. As higher grades of fluorspar ore are friable, shatter badly when blasted, and associated shale partings are earthy, many fines are inevitable. Also, the ore faces make sufficient water that muck piles are usually muddy, and the mine floor sloppy. Although there have been reported recent successes in adapting coal loading and hauling equipment to rocky ores, the company, after some experimentation and observation, has not considered it suitable for conditions found here. (3)

Also, this equipment requires highly skilled maintenance service, an even pattern of pillar spacing, and well-maintained haulage roads to operate efficiently. The company tried a shuttle-car for a few months in 1950, but found it lacked maneuverability and could not operate well on rough bottom. The company, unfortunately, had no facilities at the time to smooth stope bottoms or maintain roads.

(2) Weller, op. cit., pp 105-129.

(3) Three case histories of ore production increases through modernized loading and haulage (Unsigned feature article) Engineering and Mining Journal - Vol. 152 No. 7 pp 113-114 (1951)

Before diesel-powered loading and haulage equipment was successfully developed in the zinc and lead mines of Oklahoma and Missouri, and prior to 1950, which was the first time the State of Illinois would approve diesel underground equipment of any kind, Minerva No. 1 mobile equipment was powered either by compressed air or 3-phase, 440 volt, 60-cycle alternating electric current. (4)

Drill jumbos were adapted from used Model 20 or 30 Caterpillar tractors, either by converting the engine to compressed air, or installing a 10 h.p., 1200 r.p.m. induction motor, with two truck transmissions serving as speed reducers. One had two air-motors operating the main tractor drive sprockets, through a Liberty truck rear end. All such jumbos were largely conceived and built, after making observations in other mines, in the company's own mine shop. All had a single boom for a single 11-foot wagon drill sash, which handled either Ingersoll-Rand D-505 4" drifters, or Gardner-Denver CF-79 3½" drifters. Booms were raised by air-tugger winch. Company experience with two machines mounted on the same jumbo was not satisfactory, when the slab round was used to break the ore face. Observations showed the second machine to be out of efficient position over 50 percent of the time. All these machines, which were in use from 1946 until 1951, shared the same disadvantage to a similar degree: they were too slow and cumbersome. Several are still in the mine for stand-by service.

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(4) Needham, A. B., Methods and Costs of Mining Fluorspar Deposits at Cave in Rock, Ill. IC 7514 U. S. Bureau of Mines, (1949)

Floyd Callahan, Mine Superintendent, in 1952, designed and built two rubber-tired jumbos, by cutting out four feet of the wheel-base length of used Model 55 White 12-ton trucks. He used an electric induction motor with two transmissions as on previous jumbos. The boom, however, was pivoted nearer the center of the chassis. Although these rigs lacked the short turning radius of the tractor-mounted jumbos, they more than made up for it in greater mobility near the drilling face, and were adapted to be towed great distances rapidly by either a haulage dump-truck or a front-end loader. Their cost, less drifter and sash, was approximately $1500 each. To facilitate their climbing over muck-piles and cutting down excessive tire wear, heavy skid chains were fashioned for the rear wheels.

From 1946 until 1951, all stope loading was done by Ingersoll-Rand 20 MNM 2D electric 3-drum slusher hoists. Before stope haulage was developed, these slushers pulled ore to mill holes connected by chutes to an undercut haulage drift, and the slushers were mounted on used crawler tractor chasses, powered either by electric or air-motors, one motor to each track. The ore available by this satisfactory method was soon exhausted, however, because of the dip and width of the orebody in relation to the haulage drift.

The first stope conveyor belt, 500 feet in length, was installed in 1946, up-dip from the most southwesterly mill-hole raise. It consisted of a single 10 h.p. Barber-Greene drive pulley, with 30" 5-ply belt, on standard 8-foot portable

Fig. 4 Feeding fluorspar ore onto a 30 inch belt conveyor. Dump trucks discharge onto a portable 15-ton steel hopper, which is covered with a grizzly with 8-inch bar spacing. The slope to the top of the hopper is built from waste rock. The hopper can be dragged ahead when the belt is extended.

conveyor frame sections. It was eventually extended in the next two years to about 1000 feet, where it encountered the edge of the orebody, and had to be moved to its present location. As the ore descends on it on a 5° grade, this belt may be extended a very long distance. When trougher and return idlers are well maintained, the weight of the ore on the belt is almost enough to maintain movement at 200 feet per minute, once the belt has been started. The belt line is presently 950 feet long at its second location, and it is planned to extend it to at least 2000 feet. (Figure 4). Its original installed cost is $16.50 per foot. Some of the original rubber belt is still in service, and all of it could have been except for rough belt-loading practices and accidents to the rubber, resulting from improper precautions during the first year of use, as noted below.

After installation of the original belt, Rogers-type loading slusher ramps were installed, using the same electric slushers, with 48" Rogers scrapers. (Figure 2). The loading tails of two of these slushers discharged into small feed-hoppers placed over the belt. Drifts at right angles to the belt were slushed with some efficiency, but mucking of cross-cut rounds to these drifts forced double-dragging, with higher loading costs and slower production.

This factor, plus the discovery that the orebody was wider by over 100 feet than first believed from drilling results, brought about the introduction of the first stope dump trucks in 1948. The first two, built from used equipment in the company's shop, were Model 55 White 12-ton dump trucks, formerly used in coal strip-pit hauling. A 15 h.p. induction motor, with two truck transmissions, was installed on the original motor mounting, similar to application on the first jumbos as described above, plus a cable-reel, motor-operated and synchronized with the speed of a front wheel, and spooling 500 feet of No. 6 3-conductor rubber-covered cable. The dump-beds, as modified, carried 8 tons. These trucks had plenty of power for the required load, and they moved the ore from the slusher ramps to the conveyor belt at a reasonable cost, up to distances of 300 feet. However, they were slow, and of limited maneuverability because of their electric cable attachment. Their cost was about $2000, complete with cable, and were definitely not vehicles of comfort or beauty. (Figure 3.)

These trucks could haul either to the mill-holes, now too remote from ore faces for direct slushing, or to a portable short 48" belt conveyor, which acted as a feeder to the stope haulage belt. Boulders were a problem on the belt as the grizzlies were installed over the raises only. From 1948 to 1951, by using two portable slusher ramps, and two electric dump trucks, production requirements were met with fair regularity, although a third source of ore in the west orebody of the mine was operated about half time to fill in the lapses.

About this time (1948), an experimental rubber-belt conveyor bottomed truck was built and used for a brief period.

It, too, was built on a used heavy truck chassis, and powered by electric motor and cable-reel. Its capacity was low, (3 tons), and it was much less maneuverable because of its length, (22 feet), although its lower overall height (4 feet, 8 inches) permitted it to serve lowered Rogers-type ramps, operating in thinner ore along stope margins. If such a type unit were dieselized and further perfected, the company believes the principle would be competitively adaptable to short-haul problems, involving slusher loading in headings too low for shovels or end-loaders.

By 1949, company engineering personnel was impressed by mining cost and efficiency records being made in the Picher district of Northeast Oklahoma, where diesel loading and hauling had been introduced.[5] The company had long been dissatisfied with the poor floor clean-up characteristics of slusher loading, with resultant loss of rich fines, overly wet and slushy ore from the lower end of the stope, and bad haulage conditions resulting from slusher furrows and windrows of ore, the slushers could not economically pick up. The limited mobility of the slushers and their set-up time for smaller muck piles was also unsatisfactory.

The Illinois Department of Mines and Minerals, in early 1950, issued an experimental permit to use diesel underground equipment in a zinc mine in the Galena mining district of northwestern Illinois.[6]

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(5) Three case histories of ore production increases through modernized loading and haulage (Unsigned feature article) Engineering and Mining Journal - Vol. 152, No. 7, pp 113-114 (1951)

(6) Allen, V. C., Use of Diesel Equipment in a Zinc-Lead Mine. Mining Congress Journal - January 1953 pp 26, 49

Fig. 5 A Model 102 Eimco diesel over-head loader built on a D-2 Caterpillar tractor chassis, and powered by a 38 h.p. Caterpillar diesel engine. It has a three-quarter cubic yard digging bucket.

With this precedent set, the company immediately started work on the sinking of a ventilation, supply and escape shaft into the open workings of the East orebody, anticipating dieselization. This shaft, 555 feet deep, circular, $5\frac{1}{2}$ feet in diameter, was made by stripping a 14-inch churn drill hole, and gobbing the waste in to worked-out rooms by a slusher. It was completed in December 1950. A Jeffrey, 4 foot Aerodyne Junior fan, producing 15,000 c.f.m., on discharge, upcast, was mounted on the shaft collar.

The first diesel engine used was a 38 h.p. Caterpillar diesel, which powered a Model 102 Eimco front-end shovel loader. (Figure 5). Much of its early work, starting in January 1951, consisted in building a road, surfaced with crushed limestone of road-rock Class X size, lowered from the surface. It's ore loading was done into the electric dump trucks, until the first diesel dump truck was installed in August 1951. The Eimco loader was supplied with an Eimco limestone and copper fume scrubber, which successfully removed virtually all traces of irritating and smoky fumes, including the aldehydes and nitrous oxides, although it had no effect on trapping carbon monoxide.

Regulation of fuel pump and carbueration was depended upon to keep this carbon monoxide count low. An MSA bulb CO detector using "Hoolamite", activated iodine pentoxide as an indicator, was used for all company tests, and both U. S. Bureau of Mines and Department of Mines and Minerals inspectors made frequent exhaust, stope air, and ventilation tests

Fig. 6 A two-ton Chevrolet dump truck powered by a Model DOOD Hercules 85 h.p. diesel engine.

during the first several months of operation. In test after test, on both loader and truck engines, the only detectable traces of CO were found within 6 inches of the exhaust port of the scrubber box, with room tests showing "no trace" even in "dead headings" at shift's end.

To date, no instances of sickness or nausea have been reported that could be ascribed to the effect of carbon monoxide.

A second dump truck was installed in December 1951, and a third truck was placed in service in March, 1953. (Figure 6). All three trucks were modifications of Chevrolet standard 2-ton short wheel-base dump trucks, bought second-hand in vintages ranging from 1946 to 1948. Model DOOD Hercules 85 h.p. diesel motors were installed in each of these trucks. They were purchased with special attachments to fit the bell housings of these particular models of Chevrolet trucks, and occupied the space of the removed gasoline motor without adaptation. Shop mechanics are able to switch motors in a single shift.

Each truck is equipped with a company-built fume scrubber tank, the dimensions of which are 12 x 24 x 26 inches. (Figure 7). Limestone and scrap copper wire were used in early models. Although the use of copper has been discontinued, the limestone gravel is found to counteract the acidity of the fumes, and helps inhibit corrosion of the scrubber tank. Scrubbers are mounted either on the right running board or in the seat space to the right of the driver.

DIAGRAM OF TYPE OF SCRUBBER USED ON UNDERGROUND DIESEL EQUIPMENT

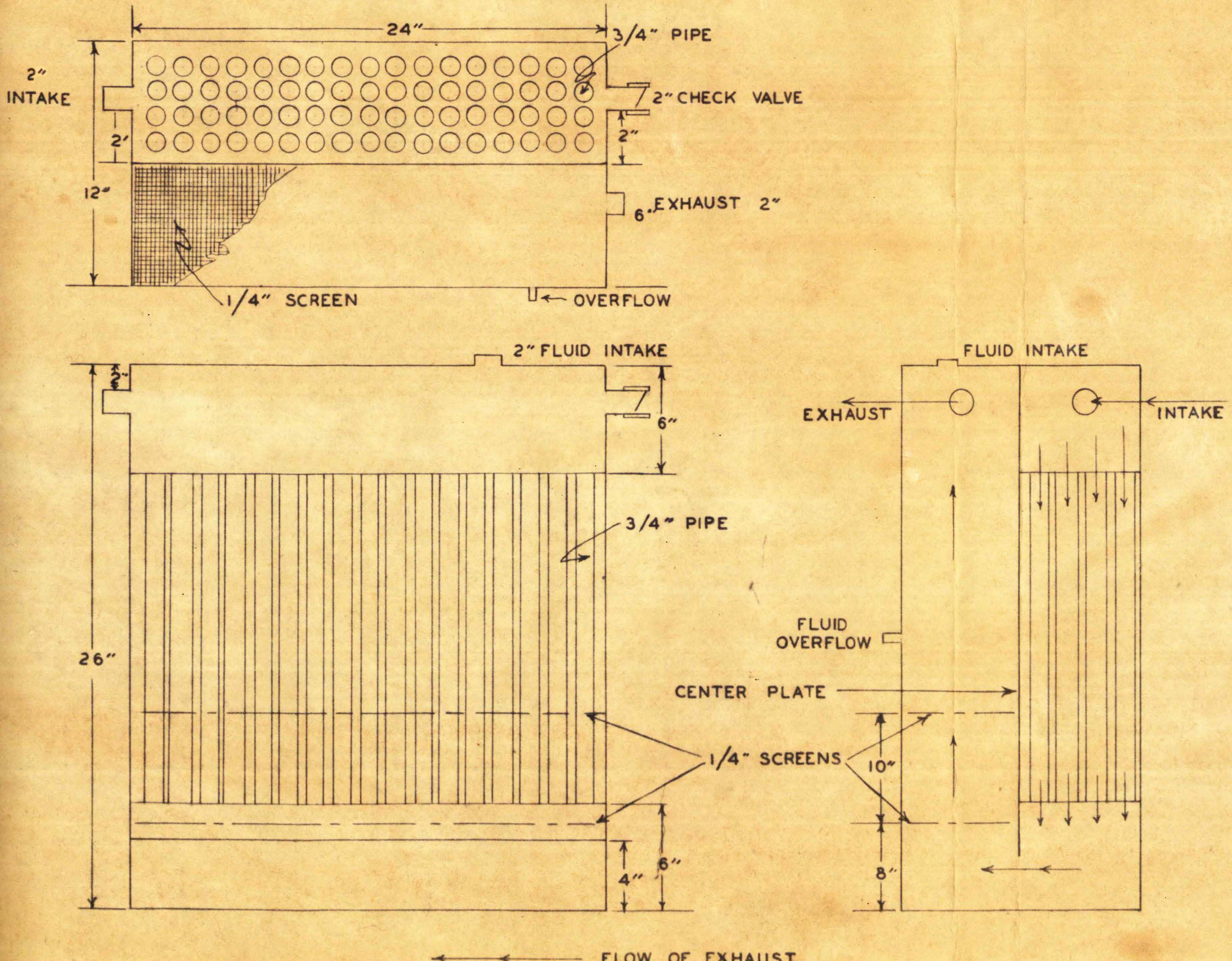


FIGURE 7

These Hercules engines start by battery, and use a 12-volt system for starter and lights. Cabs are cut down to the height of the driver's back rest. The re-inforced dump-beds are partially built on the surface, but welded together electrically in the stope shop area, because their size does not permit their lowering, intact, down any mine shaft. The engine, frame and cab are lowered as a unit, but wheel and axle assemblies are lowered separately. All trucks are equipped with standard highway tread tires, 7.50x20 front, and 8.25x20 duals on the rear.

The experience with the Eimco 102 was unsatisfactory, entirely due to down-time, because of mechanical failure of parts on the tractor, which, being a D-2 Caterpillar construction, was entirely too light for the work demanded. When in running order, the loader had a high output, although its throwing action was hard on truck dump beds. This model is no longer being manufactured.

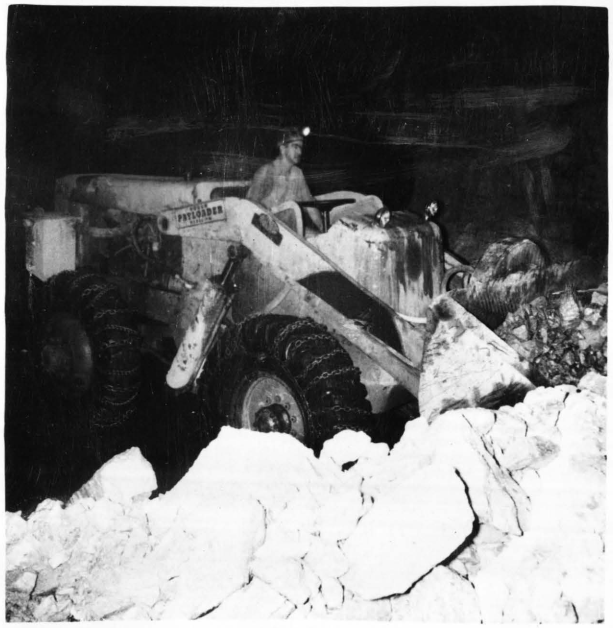
However, the experience with the Eimco 102, when it was working well, convinced the company that the end-loading principal was so far advanced over the portable slusher ramps, that it sought to replace the Eimco with a front-end loader, which would retain the rapid loading and clean-up advantages of the Eimco, plus increased mobility, which would allow use of the machine anywhere in the East stope area, now about one-half mile long, and would be capable of loading the entire milling requirement of 300 plus tons, and also be available for road-making and miscellaneous work.

After studying the successful experience and costs of the rubber-tired Hough Payloaders at the Bilharz Mining Company's zinc mining operations at Treece, Kansas, this type of loader became favored over various other end-loader types available, most of which were on crawler treads.

In August,1952, the company tried out and immediately purchased a Model HMD Hough $1\frac{1}{2}$ yard Payloader, equipped with 4-wheel drive and a 99 h.p. Hercules, Model DJXH, diesel engine. (Figure 8). During the first two months, tire wear was a major expense due to (1) improper selection of tire type and (2) unavoidable slippage of all four tires during the crowding and digging operation. High pressure, 20-ply rock-lug 14x24 tires, were replaced by medium pressure $13\frac{1}{2}$x24, 16-ply tires with a universal tread, thus allowing more traction surface and reducing slippage.

Beginning in November, almost all tire trouble and excessive wear was eliminated by the installation on all four wheels of shop-made heavy duty tire chains, with cross-chains at 4-inch spacings, all parts made with 3/8 and 1/2 inch standard chain.

At the present time, this loader handles all ore requirements when serviced with either two or three trucks, working available muck-piles in one end of the stope area in the morning, and the other end in the afternoon, always followed to its working place by the trucks. The two portable slushers are kept in reserve, and are set up on reserve muck-



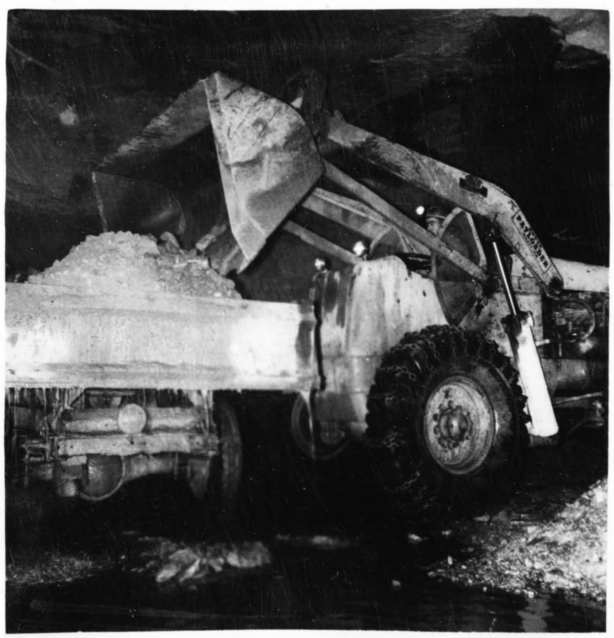


Fig. 8 A Model HMD Hough Payloader with a $1\frac{1}{2}$ cubic yard digging bucket, powered by a 99 h.p. Hercules diesel motor. It is shown digging into the fluorspar ore muck pile, and discharging into the Chevrolet dump truck. Note the fume scrubber near the left margin of the upper picture, and the tire chains on all wheels.

piles for immediate use in case of any down-time on the Hough Payloader. The slushers are also used part-time for loading out thin ore faces along the margins of the ore body.

The chart, Figure 9, compares (1) the percentage of operating availability, (2) loading costs, and (3) loading rates of slushers, the Eimco 102, and the Hough HMD Payloader, operating under comparable conditions during measured periods. The depreciation figure used in each case is based on a five-year life, and the cost includes full initial installation and set-up cost.

In addition to the obvious cost and efficiency of the rubber-tired diesel end-loader, not shown on such a chart, is the factor of it's high usefulness as a miscellaneous tool and roadbuilder. It's costs, while doing this other work, have not been kept separately and are included in the figures given. This loader, when it has loaded the day's requirements, is in demand for any of the following work: towing jumbos to distant set-ups; elevating mine timbers; lifting motors, pumps and other equipment on to trucks; providing a handy working platform for roof-bolting; and cleaning up falls and spillage along haulage roads. When maintenance or repair work is to be done on it, all the parts are easily accessible, thereby shortening expensive tear-down and reassembly time. Being on rubber tires, it can travel and operate over exposed air and water lines, without damaging them as do crawler treads.

Required height of roof for loading on to trucks is about the same on all three units, being approximately 9 feet.

COMPARATIVE COST OF LOADERS

Figure 9

	Rogers Type Loading Ramp	Eimco Rocker-Shovel Model 102	Hough Shovel Model HM	Diesel Truck*
Overall operating efficiency	80%	64.8%	97.8%	96.6%
Hours of demand	804	1957	505	743
Hours of actual operation	643	1272	494	718
Hours of possible operation	1168	2032	872	1168
Total hours down time	525	759	378	450
Repair hours	161	397.5	11.0	25
Hours lost time	364	75.0	367.0	425
Total manhours repair	180	851	17	35
Tons loaded or hauled	14996	21046	14048	17104
Hourly rate in tons	23.3	16.5	28.4	23.7
Cost per ton				
Repairs, labor	$243.00	$1234.00	$67.50	$55.00
Repair parts	1075.00	2748.00	---	65.00
Repairs, tires, tubes	---	---	453.00	---
Chains	---	---	301.14	---
TOTAL	$1318.00	$3982.00	$821.64	$110.00
Cost per ton------------------------	8.8¢	19.0¢	5.5¢	.01¢
Amortization, 5 years	$ 460.00	$1800.00	$1044.00	$450.00 -- 3 yrs.
Fuel, grease	240.00	127.00	78.00	65.00
Operating labor	1887.00	1908.00	750.00	1084.00
TOTAL	$2587.00	$3835.00	$1872.00	$1599.00
Cost per ton-----------------------	17.3¢	18.2¢	13.3¢	9.30¢
Total cost per ton-----------------	26.1¢	37.2¢	18.9¢	9.31¢

*Average distance of haulage -- 455 feet

The slusher, however, can muck out headings as low as four feet, but must be set up under a 9 foot roof. Because of the overhead loading feature, the Eimco 102 is a handier tool for mucking narrow development drifts, which are over 100 feet long, but on shorter headings, the rapid backward travel of the Hough machine soon equalizes this advantage.

Figure 10 shows the operating personnel required to load and haul the ore with the various combinations, as well as utilization of other mine personnel, and tons per mine man shift.

Figure 11 is an ore-flow diagram, assembled as a result of average-time-tonnage-cost studies by William Swales, junior mining engineer. It presents data on alternative routes, and methods in use at the mine since 1950.

An important consideration in the successful use of any mining machine or method, is it's popularity with the miners themselves. Aside from a couple of informal talks to the group about the suitability and safety of diesel engines underground, when the first motor was installed in 1950, no particular selling campaign has been waged. Manufacturers' representatives periodically make talks and distribute literature on the importance of proper maintenance to operators and the two mine mechanics. Few of the underground employes have been miners for many years, but many of them formerly operated trucks or tractors. This former experience, therefore, is valuable, and, without dissent, all mine employes like the rubber-tired units, and vie for operating jobs on this equipment.

MANPOWER DISTRIBUTION

Figure 10

	Before Dieselization 1949	After Dieselization 1953
Supervisors	2	2
Hoistman	1	1
Cager	1	1
Motorman	2	1
Bin Drawers	2	1
Loaders		
Loading slusher men	4	
Hough (operator & helper)		2
Truck drivers	1	2
Jumbo drillers & helpers	4	4
General Repairs	4	3
Grizzly & common labor	2	3
Mechanics	4	2
Development	2	
TOTAL	29 men	22 men
Tons ore per year	58762	73696
Tons ore per mine man	6.8	11.1
Average daily tonnage	196	245
Monthly tonnage - average	4897	6141

Ventilation has been no problem, even though the brattice wall building program has lagged several hundred feet behind working headings. The height of ground and fairly wide stoping areas allow for adequate fume diffusion anywhere there is slight air movement. Fresh air is directed toward the stope ends from the air shaft, by building hollow-tile masonry walls, containing burlap-draped concussion windows, between stope pillars.

CONCLUSION

The best mining costs experienced in the Minerva Mine No. 1, to date, have been experienced during the period of use of rubber-tired dieselized loading and hauling equipment.

The several advantages it has over other types previously tried include:

1. Higher mobility, allowing use of the same equipment items over a wide range of mining territory by the same operating personnel.
2. Lower operating and maintenance costs per ton of ore.
3. Fewer operating and maintenance personnel.
4. Better mine-floor clean-up characteristics.
5. Can operate at times of mine electric power failure.
6. Ability to operate at advantage in wet locations and up or down erratic dip changes of the ore base; no track laying.
7. Versatility as a tool of many miscellaneous uses other than in ore handling.
8. Rubber tires less damaging to pipes and conduit on mine floor.
9. Popularity with mine personnel.

The only possible disadvantages that can be cited in the application to this particular type of problem and set of conditions are:

1. Present types used cannot be used if necessary to mine ore faces lower than 8 feet.
2. Rubber-tired equipment does not operate over broken rock surfaces as well as crawler type equipment,

and require road preparation and maintenance.

3. Good ventilation required for diesel equipment.

In development of new mines, the company will favor use of rubber-tired diesel equipment wherever possible.

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VITA

Robert Gill Montgomery, son of Mr. and Mrs. R. T. Montgomery, was born in Newburg, Missouri, September 26, 1910, then lived in Rolla, Missouri from 1917 to 1920. From there the family moved to Bartlesville, Oklahoma, where he completed his grade school and high school education, and attended one year at Bartlesville Junior College.

He entered Missouri School of Mines and Metallurgy at Rolla, Missouri in September, 1930, and graduated with a BS in Mining Engineering, Geology Option, in June 1934.

Thesis work toward his Master's degree, under Dr. C. L. Dake, was completed in the summer of 1934 on the "Geology of the Hart Mountain Overthrust" (Wyoming), but residence requirements were never met.

He was employed in September, 1934, by the Phillips Petroleum Company, Burbank, Oklahoma, in their gasoline division as an oiler, until transferred to their geological department the following March. He served on their various seismograph field crews as computer and party manager at various localities in Oklahoma, Arkansas and Mississippi until August, 1937.

In September, 1935, he married Janet Steinmesch, daughter of Jesse H. Steinmesch, former acting head of the Department of Mining at Missouri School of Mines. They now have a son and daughter.

In August, 1937, he joined the seismograph division of the Indian Territory Illuminating Oil Company at Bartlesville, Oklahoma, and after serving as computer in various localities in Kansas, Oklahoma and Texas, was stationed in Bartlesville as chief computer until December, 1940, at which time the company merged with Cities Service Oil Company.

In January, 1941, he joined the Minerva Oil Company at Eldorado, Illinois, as subsurface geologist for their oil division. Following discovery of a new fluorspar deposit by J. H. Steinmesch in Hardin County, Illinois, he was placed in charge of prospect drilling the fall of that year.

He became chief geologist of the mining division in 1942, and at the completion of the fluorspar mine and mill development in 1944, became general superintendent of the operation. Upon expansion of the fluorspar interests of the company through purchase of the Crystal Fluorspar Company and the Yingling Oil and Mining Company, he was named general manager of the fluorspar division in September, 1952, which position he now holds.

He is a member of American Institute of Mining Engineers, American Mining Congress, American Association of Petroleum Geologists, and MSM Alumni Association. He is an officer of the local Lions Club, and the Eldorado Chamber of Commerce. For several years, he has served as a leader of Boy Scout units, and as a Sunday School teacher in the Baptist church.

His home address is 2300 Illinois Avenue, Eldorado, Illinois.

COMPARATIVE ORE FLOW COST DIAGRAM

FIGURE II