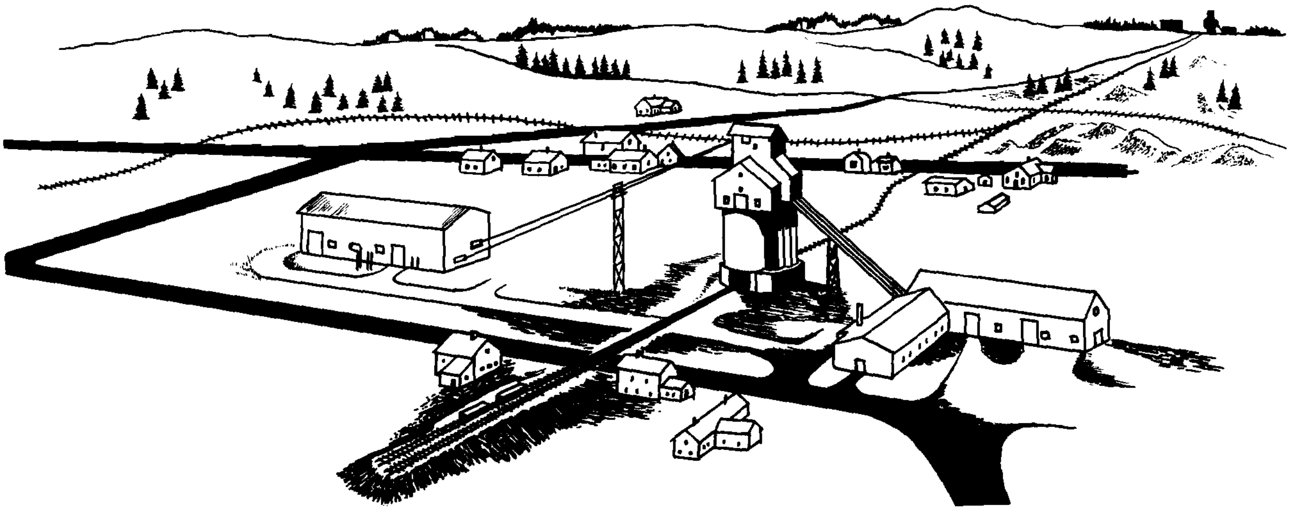

Unwatering the Osceola Lode

by A. S. Kromer, R. J. Marcotte, C. A. Campbell,
R. R. Spencer, and P. H. Ostlender

The objective in unwatering the Osceola was to make available the known ore reserves. These reserves, which exist above the 6000-ft incline depth, include millions of tons of ore. Hoisting equipment has been designed to sink an additional 1000 ft to suspected reserves below the 6000-ft mark.

CALUMET Div. of Calumet & Hecla Inc. is engaged primarily in mining, milling, and smelting the native copper ores of northern Michigan. The copper occurs in fragmental tops of lava flows and in certain interbedded felsitic conglomerates of Pre-Cambrian age. The most famous native copper orebody in world history is the Calumet conglomerate, which outcrops between the villages of Calumet and Laurium for a distance of about 2 miles. The Osceola lode parallels the conglomerate lode and is mineralized for about 3 miles. Horizontal distance between the two is 750 ft.

In 1932 the price of copper dropped to 5¢ per lb. Coupled with the high cost of obtaining copper from extreme depths, this low price made the venture unprofitable, and the mining unit was abandoned. After the shaft pillar copper was removed from several of the conglomerate shafts in a retreating operation, the mine was allowed to fill with water. In post-depression years, when the price of copper stabilized at about 12¢, Calumet Div. found it profitable to operate its remaining mines on other lodes, as well as its tailings reclamation plants.

At the close of World War II several factors forced management into a major decision concerning activity in the district: 1) Reserves in some of the operating mines were nearing depletion. 2) Ore grade was becoming progressively lower. 3) Mining depths were increasing and mining costs were growing. 4) The price of copper was rising, and it was evident that price stabilization would occur at a higher level.

It was expected that several of the operating mines would reach economic depletion by 1956. Remaining operations, in absorbing a greater share of the overhead burden, would then become unprofitable, and unless some other activity was substituted Calumet would be forced into liquidation. In 1950 a committee was established to review all geological and mining records of the region, to appraise the possibilities of opening new properties. The committee realized that any new mining venture must meet certain basic requirements: The new mine would have to be ready for production as the depleting mines closed. Production should largely offset that of the closing mines. The new mine should be located to employ Calumet's existing treatment

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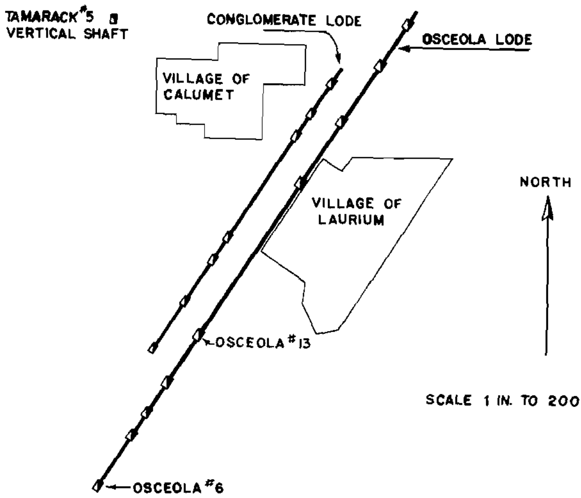
A. S. KROMER is Vice President and General Manager, R. J. MARCOTTE is Technical Assistant to the General Manager, C. A. CAMPBELL is Director of Mining, R. R. SPENCER is Project Engineer, and P. H. OSTLENDER is Project and Specifications Engineering Manager of the Calumet Div. of Calumet and Hecla, Inc., Calumet, Mich.



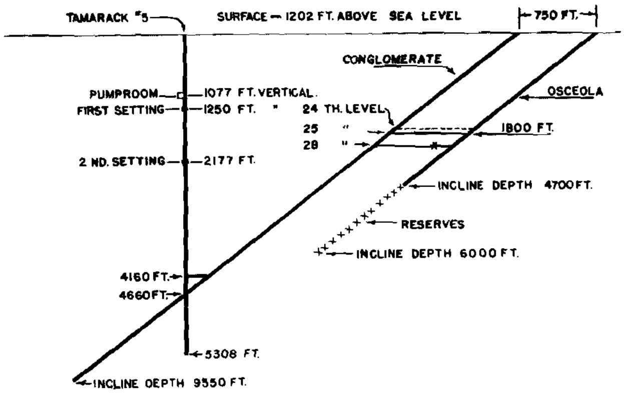
Surface plan of the Osceola area, where the Calumet conglomerate outcrops between the villages of Calumet and Laurium.

facilities. It must be brought into production at a capital cost the corporation could afford and must be capable of profitable operation.

Problems of unwatering and reactivating the Osceola are divided into four major areas: 1) unusual properties of the water, 2) operations of unwatering and rehabilitation, 3) major engineering problems, and 4) coordination of activities.

Water

In 1932 a retreating operation was begun in the conglomerate lode. The old backs and shaft pillars were removed and water was allowed to accumulate in the lower levels. In March 1937 the rising water threatened to overtake the working crews, and pumping was begun to permit working out of the shaft pillars. Pumping facilities were conveniently available in No. 13 Osceola shaft at the 28 level crosscut, and the water was held at this level. In October 1939 the conglomerate operations ceased and both lodes were allowed to fill with water, which was at swamp level by 1943.



Vertical section showing the Calumet conglomerate overlying the Osceola. Interconnected by crosscuts, the two lodes form an integral mining unit.

During the 1937-1939 pumping, much valuable experience was gained concerning the nature of the water accumulating in the conglomerate lode:

1) The water was very corrosive. Cast iron pump parts failed in 10 to 30 days, being converted to graphite by the complete solution of the contained iron. Heavy duty galvanized steel column pipe had to be replaced in less than one year; two complete lines were corroded in the two-year period. Brass was subject to severe dezincification. Galvanized iron, aluminum, and rubber parts failed. The only metallic material then in use which seemed to withstand corrosion satisfactorily was a tin bronze.

2) As the water was spilled into the underground dams, a gas was liberated producing a persistent froth. The gas was combustible, and when ignited, the bursting froth bubbles burned.

3) A red mud, analyzing 88 pct copper, and presumably cuprous oxide, collected in the dams in such quantity that 28,000 lb of copper were recovered. The water being pumped at the time carried copper in concentrations reported at 3 to 10 ppm.

In 1944 a proposal to reclaim copper from the accumulated mine water resulted in an intensive sampling program, which extended through 1945 and was repeated in 1948. It was concluded that the water did not contain sufficient copper to make extraction commercially profitable. Indeed, all of the samples taken analyzed less than one part copper per million. This was truly amazing in view of the reported condition.

With a management decision to unwater the Osceola, it was recognized that the characteristics exhibited by the water during the 1937-1939 pumping would be of utmost importance, not only in the selection of pump and pipe materials adequate for the job, but also in formulating the general operational scheme of unwatering. It was deemed necessary not only to establish the exact chemical composition of the water, but also to identify the combustible gas which produced frothing in the Osceola dams and to determine the extent of liberation.

Water Sampling: Sampling water in these lodes presented a problem. The Osceola underlies the conglomerate, to which it is connected by crosscuts. Tamarack No. 5 is a vertical shaft intersecting the conglomerate lode 4660 ft below surface; its highest connection to the lode is at 4160 ft. It was impossible to secure samples at depth from any of the incline shafts, and all sampling was done through the vertical shaft.

Apparatus employed was a multiple affair, consisting of slender, tubular chambers, fitted at their upper ends with a high-pressure valve to control release of gas in collection of samples, and at their lower end with a ball check to prevent escape of water as the sampler was raised to surface. Sampling assembly was 3¼ in. diam and nearly 12 ft long. The slender streamline shape minimized the possibility of its becoming ensnarled in any obstruction in the shaft.

The water contained little or no salt from surface to a depth of 2000 ft, and had a specific gravity very nearly equal to 1.0. Near the 2000-ft depth and within the short distance of about 100 ft, the chloride and specific gravity values changed very abruptly to 33,000 ppm and 1.04 respectively. From there to the bottom of the shaft both the gravity and chloride increased gradually to values of 1.082 sp gr and 62,000 ppm. Thus the water was divided into two distinct layers, an upper layer of relatively salt-free water, and a lower of rather high salt content. Although testing was confined to Tamarack No. 5 shaft, it was assumed that this same condition extended throughout the mine. This assumption is substantiated both by the Alfred C. Lane report of 1911,[1] and by the corporation's present pumping experience.

In all samples the copper content was less than 1 ppm. The deep water, on standing, formed a brownish precipitate, which was essentially iron oxide but also contained grease or oil equivalent to 100 ppm of water.

When poured into a container, samples from below the 1600-ft depth effervesced violently, releasing gas identified as: CH_4, 49.0 pct; H_2, 5.5 pct; CO_2, 1.5 pct; N_2, 44.0 pct; and H_2S, 0.005 pct. The quantity of gas expelled, obviously in excess of the solubility limit at normal temperature and pressure, amounted to 14 pct of the water volume. During collection of samples, gas evolution was greatly assisted by agitation, as when the water was spilled into a container or the side of the sampler was struck a blow with a hammer. These actions seemed to induce the necessary nucleation and produce violent evolution. Without this agitation pressure in the sampler could be decreased below atmospheric by means of an atomizer bulb, without effecting gas release. A subsequent sharp hammer blow would cause instantaneous release and create sufficient pressure to blow the tubes from the gas collection apparatus assembly. Gentle tapping resulted in the desired gradual release.

Gas Problem: The evolution of gas presented two major problems. First, there was the imminent danger of explosions if gas were released in the mine without adequate ventilation, since it contained over 50 pct combustibles. Second, gassy water causes cavitation in pumping.

Originally it had been planned to employ normal suction-type sinking pumps and to unwater through the incline shafts of the Osceola. A pump with a suction lift, though theoretically capable of lifting gas-free water approximately 33 ft, is normally designed for a maximum lift of about 15 ft; beyond that efficiency falls off rapidly and there is an increasing tendency to develop cavitation. With gassy water the maximum lift decreases, and it was agreed that in this situation serious cavitation would develop for any amount of lift. Use of a submersible pump seemed imperative, and it was further believed that to avoid operational difficulties, the pump would have to remain submerged a minimum of 60 ft at all times. It is fortunate that a decision to employ submersibles was reached, because later operating experience has indicated that the use of suction lift pumps would have been impractical.

It now became apparent that unwatering through the incline shafts would present almost insurmountable problems. There was the probability that shaft obstructions would make it impossible to maintain necessary submergence of the pumps. Also, there would be space limitations and resulting congestion, since it was desired to rehabilitate the shaft and unwater simultaneously.

The decision was made, therefore, to unwater through the vertical shaft, which has no openings to the lode above a vertical depth of 4160 ft. Unwatering through this shaft effects the removal of the lower gassy and saline water from under the upper gas-free protective layer. Water flows from the Osceola lode through the 25 level crosscut to the conglomerate and thence to the vertical shaft via the 4160-ft crosscut, maintaining at all times the protective layer in the Osceola and greatly minimizing, if not completely eliminating, a serious gas problem.

The gas issuing from the water has a distinctive odor, attributable to the presence of 0.005 pct hydrogen sulfide. This low concentration, though difficult to detect chemically, produces noticeable corrosion of copper and copper alloys. It is sufficient to cause sub-acute toxicity, but this is not alarming because a minor amount of ventilation will dilute it to harmless values. A check for its presence is regularly made, since hydrogen sulfide deadens the sense of smell and toxic concentrations are odorless.

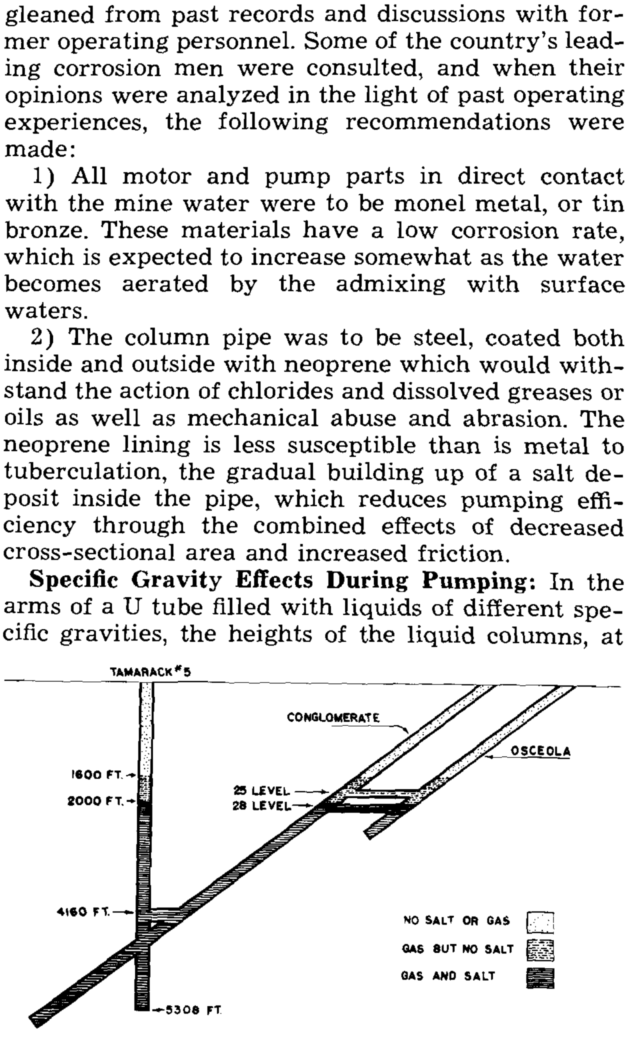
- **The unwatering of the Osceola is, to the best of the authors' knowledge, the largest underground unwatering program ever undertaken by a mining company. The operation involved pumping more than 8.8 billion gal of highly corrosive water, supersaturated with methane gas, potentially a serious safety hazard.**
- **Specially designed submersible pumps in a unique unwatering scheme have nullified the gas condition. Continued testing of the mine air has failed to detect gas, even though, at the surface discharge, the violent foaming and effervescence reveals its presence.**
- **Motor and pump materials of special metallurgy have withstood the corrosion. The neoprene-coated pipe has given excellent resistance to corrosion and the complete absence of tuberculation in the pipelines has contributed much to pumping efficiency.**

Corrosion Problem: Past experience had indicated that the water was potentially very corrosive to certain metals. There was an instance in which a ½-in. section of cast iron was corroded through in a period of ten days. Because it was impossible to conduct any corrosion test that would simulate actual pumping conditions, selection and specification of pump and pipe materials had to be based on theory bolstered by whatever reports and experience could be gleaned from past records and discussions with former operating personnel. Some of the country's leading corrosion men were consulted, and when their opinions were analyzed in the light of past operating experiences, the following recommendations were made:

1) All motor and pump parts in direct contact with the mine water were to be monel metal, or tin bronze. These materials have a low corrosion rate, which is expected to increase somewhat as the water becomes aerated by the admixing with surface waters.

2) The column pipe was to be steel, coated both inside and outside with neoprene which would withstand the action of chlorides and dissolved greases or oils as well as mechanical abuse and abrasion. The neoprene lining is less susceptible than is metal to tuberculation, the gradual building up of a salt deposit inside the pipe, which reduces pumping efficiency through the combined effects of decreased cross-sectional area and increased friction.

Specific Gravity Effects During Pumping: In the arms of a U tube filled with liquids of different specific gravities, the heights of the liquid columns, at



Schematic representation of water analysis. From surface to a depth of 2000 ft, the water contained little or no salt.

the balance point, are inversely proportional to their gravities. When pumping was begun on March 18, 1953, with a special pump set at 400-ft depth, heavy water moved in from the conglomerate lode through the 4160-ft crosscut into Tamarack No. 5 to replace the low gravity water which was being removed from the top of the shaft. It required but a short time, about a day, for the heavy water to reach the pump intake. At this time the existing conditions simulated a U tube in which Tamarack No. 5 shaft represented one arm filled with water having a specific gravity of 1.072, while the other shafts and the two lodes represented the second arm, the bottom half of which was filled with water ranging from 1.04 to 1.072 sp gr and the top half with water of 1.0 sp gr.

The water level in Tamarack No. 5 was actually lowered 160 ft before any lowering of the lighter water in the Osceola was detected. This point of initial motion in the Osceola justified precisely the assumption that the interface between the heavy saline water and the light water was at a uniform level throughout the mine and was located 2000 ft below surface. Failure to take this specific gravity effect into account during initial pumping might easily have led to the conclusion that caving in the mine was preventing the flow of water to Tamarack No. 5 and that unwatering through this shaft was impossible. This would have been especially true had the initial attempt been made with a suction lift pump and the inherent necessity of moving to new settings at 15 to 20-ft intervals.

Unwatering and Rehabilitation

Unwatering: To unwater the Osceola it was also necessary to unwater that upper portion of the conglomerate which exists above the lowest interconnecting crosscut at the 28 level. The amount of water thus involved was more than 5 billion gal.

In the first stage of pumping, six submersibles were set 1250 ft below the collar of Tamarack No. 5 shaft, the motors being controlled from an electrical substation at surface. The water was lowered 1177 ft, which was 100 ft below a small former pump station. This pump room was enlarged to accommodate six stationary booster pumps as well as the transformers and electrical control equipment for all 12 pumps.

The submersibles were then lowered to a new setting of 1100 ft below the level of the pump room, or to a depth of 2177 ft below the collar. Each of the submersibles discharged directly into the intake of one of the station booster pumps, which in turn delivered the water to surface. With this arrangement, the water in both lodes was lowered to the 25 level crosscut, at which time natural drainage from the Osceola to the conglomerate ceased. To unwater the Osceola further, it would be necessary either to pump via the incline shafts or to transfer the water to the conglomerate through one of the crosscuts. The 25 level crosscuts are too far removed from No. 13 shaft to be available for such use.

Originally it had been planned to unwater the remainder of the Osceola through No. 6 shaft. Incline submersibles with mechanical seals would be used as sinkers, delivering to booster stations at the 36, 24, and 11 levels. Caving encountered in this shaft was so severe, however, that rehabilitation was considerably behind schedule and the original pumping plan could not be employed. It appeared that the project would be seriously delayed.

An additional crosscut exists at the 28 level and in the vicinity of No. 13 shaft. This crosscut is sealed by a concrete dam in which there is a heavy bronze valve, closed when pumping ceased in 1939. If this valve were opened, all water existing between the 25 and 28 levels of the Osceola could drain into the conglomerate, greatly accelerating the project. It would make possible the subsequent unwatering of No. 13 by installing an incline submersible in that shaft and pumping to the conglomerate through the 28 level crosscut.

The big problem was to open the valve. There was the possibility that a diver might be successful. Inquiry revealed that several commercial divers were willing to undertake the job. The operation involved lowering the divers in a man car from the 25 to the 28 level of No. 13 shaft, a distance of 360 ft on the incline. The man car had to be stopped precisely at the 28 level. The diver would then walk 40 ft into the drift, turn into the narrow crosscut, and walk an additional 100 ft to the valve. There he would attach a specially designed reel to the wheel of the valve and return to the man car for surfacing. The valve would subsequently be opened from the 25 level by pulling on the cable attached to the reel. Because of the many unusual factors involved, it was generally agreed that if successful, this would be the most complex and most ambitious dive ever attempted.

After elaborate preparations and rehearsals of details, trial runs were made, which very quickly indicated that the dive was too deep and time-consuming to permit conventional use of compressed air for breathing by the divers. In succeeding attempts, U. S. Navy divers employing helium-oxygen techniques were able to progress toward the entrance of the crosscut. However, what appeared to be insurmountable difficulties made necessary the abandonment of the diving attempt. The diving attempts attracted wide attention and the final dive by Navy divers was nationally televised.

Caving in No. 6 shaft persisted, threatening to delay the project for an indefinite period. It was then decided to drive a new crosscut to the conglomerate from the 24 level of No. 13 shaft. This was accomplished in 25 days. An incline submersible was installed in No. 13 shaft and pumping to the conglomerate was done through the newly driven 24 level crosscut. When the 28 level was cleared, the valve was opened and water from the submersible was routed through this crosscut. No. 13 shaft was completely unwatered in April 1955.

At the time of this writing, rehabilitation of No. 6 is progressing and caving has decreased. It is expected that unwatering the lower Osceola via No. 6 shaft according to the original plan will be complete in July 1956.

Shaft Rehabilition: No. 13 shaft has been generally free of obstructions, and rehabilitation has progressed in an orderly fashion and on schedule. It has been necessary to replace 75 pct of the timber.

In No. 6 shaft, the serious cave-ins encountered have caused considerable delay in its rehabilitation and have required the replacement of 85 pct of the timber.

Major Engineering Problems

Pumps: To keep ahead of the planned rehabilitation schedule in the incline shafts, it was necessary to pump at an average rate of 9000 gpm. It was imperative to keep the water confined at all times, avoiding discharge into underground sumps or dams, to prevent the release of explosive gas within the mining area. Booster or station pumps were placed in series with the submersibles and a positive pressure of at least 30 lb was maintained at the intakes of all pumps. The water was not released until it reached a large open reservoir on surface.

The submersible pumps selected for the job are all-bronze, 12-stage, deep well turbine type, with a rated capacity of 1500 gpm at 850-ft head, and capable of higher heads at reduced output. The pump, measuring 18 in. diam and 15 ft long, is powered by a 450-hp, oil-filled, mercury-sealed, submersible motor, having an all monel outer casing and measuring 15 in. diam and 13 ft long. To maintain the proposed average pumping rate, it was necessary to employ six such pumps operating simultaneously.

The booster or station pumps are conventional two-stage, horizontal-type, bronze-constructed with monel shafts. They are driven by 500-hp, 3450-rpm, 3/60/2300-v, squirrel-cage, line-start motors. Each pump has a rated capacity of 1500 gpm at 940 ft head.

Column Pipe: Testing had revealed that the vertical shaft was free of obstructions and its selection as the pump shaft suggested the possibility of setting the submersibles at great depth, thus minimizing the costs and delays incident to frequent moving to new settings. The plan called for the initial setting of the submersibles at 1250 ft. To the best of knowledge this is the greatest depth at which submersible motors have ever been set. The plan also involved their suspension on the threaded column pipe, from a single support at the shaft collar. The live load of each column line, including motor, power cable, pump, check valves, pipe and water load, was calculated at 112,000 lb, to be supported by the threaded pipe joint. Obviously this was not a job for ordinary standard threaded pipe. The pipe selected was a 9⅝ OD oilwell casing with a tool joint type of thread having a rated pull out strength of 875,000 lb, thus allowing an ample safety factor, provided that both the pipe and threaded joints could be adequately protected against corrosion.

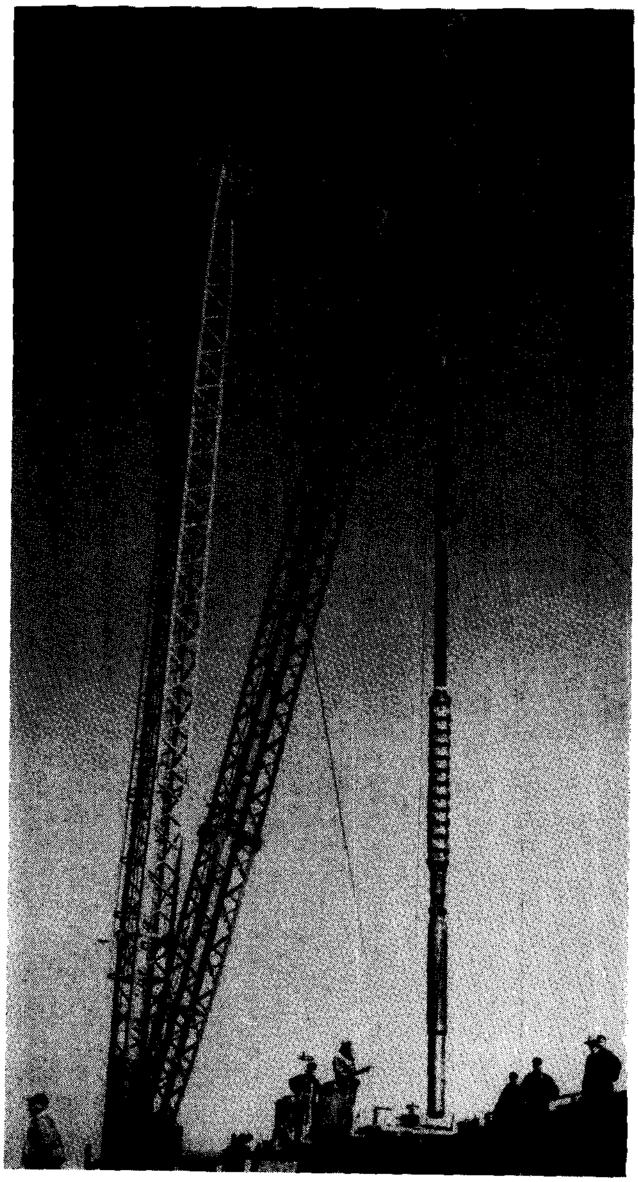
It was recommended that the pipe be coated with neoprene. Because the project called for 2 miles of pipe, because neoprene-coated pipe was available only with coating thicknesses far in excess of that necessary for the job, and because special fittings and flange joints would require on-the-job attention, it was considered advisable for the corporation to do its own neoprening.

Pipes to be neoprened, mostly 40-ft lengths, were first given a thorough cleaning by sand blasting, then placed on a rack at a 45° angle. The liquid neoprene was applied by pouring at a controlled rate into the upper end of the pipe until flow had been established throughout its length. To coat the inside surface completely, the pipe was then rotated very slowly through one complete revolution. Flow from the top was stopped and the excess neoprene allowed to drain. This procedure resulted in application of a coating approximately 0.020 in. thick; three such applications gave a final coating of 0.060 in. For the outside of the pipes, as well as for flanges, special fittings, and threaded ends, the neoprene was applied by brushing. All newly neoprened pipes and fittings were heat cured. Emergency repairs in the field were made with an air curing variety of neoprene.

Flanged joints, which coupled the column pipe to the bronze pump and monel check valves, were fitted with special gaskets to provide complete electrical insulation at the joint and eliminate the electrolytic corrosion that might occur because of the proximity of dissimilar metals.

Setting the Submersible Pumps: To facilitate handling and installing the pumps, a 75-ton guy derrick with a 100-ft boom was erected at the shaft collar and power was supplied by a drawworks. Lowering or raising pumps and disconnecting pipe sections was aided by regular oil field equipment such as slips, elevators, and tightening tongs.

Each pump was suspended at the shaft collar by suitable supporting plates. With the aid of the derrick, the first flanged pipe section was brought into position and bolted to the pump. The entire assembly was then raised slightly in order to free and permit removal of the collar pump supports, and subsequently lowered until the pipe end was about 3 ft above the working platform. The assembly was secured in slips and the derrick was now free to bring in another length of pipe. The threaded joint was spun in with manila rope and bucked up



To facilitate handling of submersible pump and assembly, Calumet and Hecla had this 75-ton, 100-ft guy derrick erected at the shaft collar.

with the casing tongs, using liquid neoprene for thread compound. This procedure was repeated until the column line was complete. As the line was being lowered into place, the armored cable, carrying power to the submersible motor, was attached to the pipe at approximately 10-ft intervals, employing monel band-it. With an experienced crew, the setting of a complete pump line was effected in approximately 12 hr.

It was a major operation to establish supports across the shaft at the level of the underground pump room, for the second setting of the six submersible pump lines, involving a total live load of 336 tons. Sizable hitches were cut into the rock walls of the shaft. Rock bolts were put in under the hitches to insure against slips in the rock formation. Built-up support beams of 6700 lb, measuring 15 in. on the flange face, 45 in. high, and 19 ft, 3 in. long were lowered through the narrow cage compartment of the shaft, and at very close quarters were inched into position across the shaft openings. Two such beams supported three pump lines in each of two shaft compartments. In a third compartment, two similar beams supported the full weight of two 12-in. column lines to surface.

Heat Dissipation: The operation of 3000 hp in pump motors and 6000 kva of transformers liberated into the limited quarters of the underground pump room an estimated 1,300,000 Btu per hr. It was necessary to dissipate this heat properly to prevent the installation from becoming excessively hot. The water being pumped was at a constant temperature of 80°F and, therefore, would not be effective as a cooling medium.

The problem was solved by bratticing the compartment which carries the column lines to surface. The warm water in the pipes helped to create a stack effect, causing a circulation of cool surface air down the other compartments. This was augmented by six 5-hp fans to draw the cool air through the pump room and force it up the bratticed column compartment.

Coordination of Activities

To make the Osceola lode productive required pumping 8.8 billion gal of water, including inflow, building three complete surface installations, and rehabilitating three shafts. All these projects were started at approximately the same time.

Tamarack No. 5: Prior to actual pumping at Tamarack No. 5, much surface preparation was necessary. The guy derrick and drawworks were erected. The surface plate supporting each pump and column carried an ultimate load of 56 tons, and supports, therefore, had to be provided for a total of 336 tons live load. The original shaft was built in a swamp and the fill surrounding the shaft had very limited bearing value. Consequently, the footing for the re-enforced concrete supporting walls had to be set 17 ft below the collar. A large manifold, 6 ft in diam, was constructed to receive the discharge of the pumps. From this manifold a concrete pipeline, 30 in. diam and 2400 ft long, was installed to carry the water to a large open existing reservoir known as the Tamarack dam. The electrical control equipment for the submersibles was housed in a substation erected near the shaft collar. The collar house and the engine house, containing the hoist which would service the shaft, were erected. All of the above were completed in January 1953.

Pumping was started on a limited scale on March 18, 1953. By April 1954 the water level had been lowered to a depth of 1177 ft, which is 100 ft below the existing pump room. The room was enlarged to 35 ft wide, 145 ft long and 12 ft high, involving the blasting and removal of 5000 tons of rock, all brought to surface by the man cage, which had been designed to accommodate a small mine car.

It now became possible to install the six stationary booster pumps in the newly created pump room, and two additional 12-in. neoprene-coated column lines to surface. The electrical substation equipment and all necessary controls had to be so designed that they could now be taken to the underground pump room through the existing cage compartment.

A special armored cable of 350,000 circular mils was purchased to deliver 12,000 v from surface to the station. The cable is 4¾ in. diam, its total weight of 8 tons supported at surface in a special cable support. Lowering the cable presented a unique problem in that the reel was too large for the shaft openings. It was impossible to lower the reel and then pull the cable to surface in the conventional manner. The lowering was accomplished using 3½-in. oil field drill pipe and attaching the cable to the pipe at 60-ft intervals with Kellem's grips.

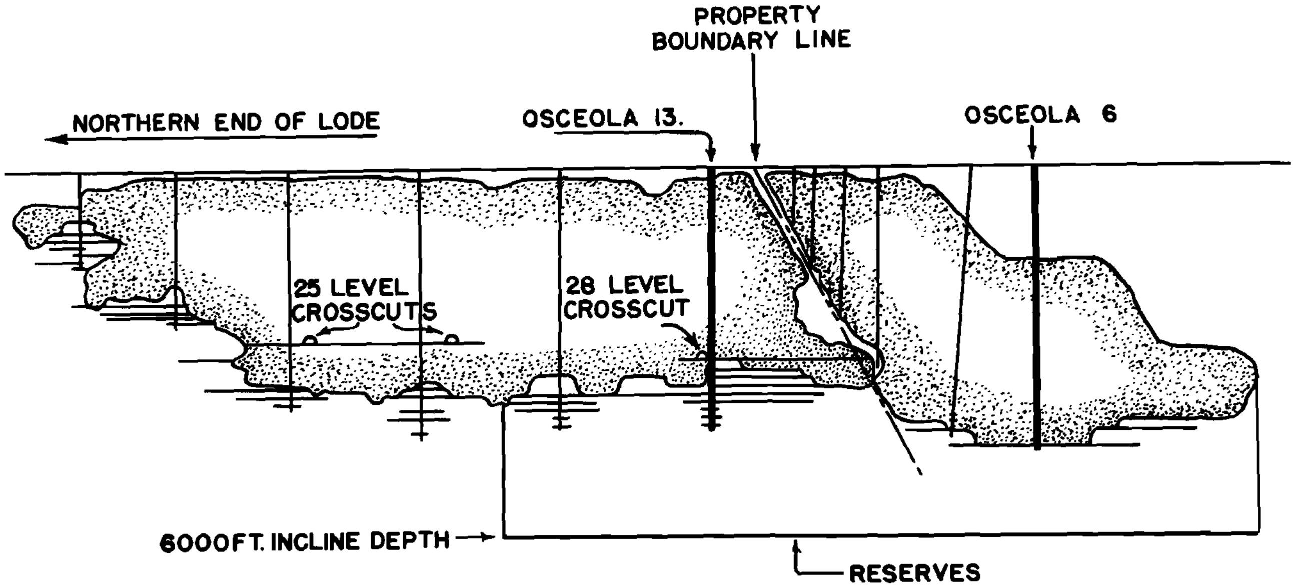
Lowering the submersible pumps from their first setting to the supporting beams at the underground station was accomplished by coupling 3½-in. drill pipe to the pump column and lowering the entire assembly with the derrick and oil field equipment. Completion of the transfer to this second stage of pumping was effected in July 1954.

No. 6 and No. 13 Osceola Shafts: At these locations no surface plants remained from the previous operations. Awaiting the delivery of permanent headframes and hoists would have delayed this phase of the project more than a year. To expedite the rehabilitation, temporary headframes and hoists were installed.

Permanent change houses, collar houses, headframes, and engine houses had to be designed and erected. They are of modern design and are exact duplicates for both locations. The change houses, of steel and aluminum construction, can accommodate 208 men and are connected directly to the collar houses. The headframes provide storage for 1000 tons of ore and house the 24x36-in. primary jaw crushers of the overhead eccentric type. The engine or hoist houses are 60x140 ft and are equipped with a 25-ton overhead traveling crane to aid in installation, maintenance, and repair of equipment. The hoists have two drums, 10 ft in diam and with a 110-in. face, each having a capacity of 7000 ft of 1⅜-in. rope. The hoist is driven by two 1500-hp, dc motors which obtain their power from a motor generator flywheel set.

Power: All electrical power generated at the Calumet power plants was 25 cycle. With the obvious advantages of 60-cycle power, careful study confirmed the justification of its use for this project and for the operation of these mines. Accordingly, four frequency changers were installed with a total capacity of 12,000 kw. An estimated 64 million kw-hr of electrical energy were required merely to pump the water.

Ventilation: Unwatering through the vertical shaft permitted maintaining a cap of fresh water in the Osceola, thus reducing the gas hazard during



Horizontal projection of the Osceola lode showing both extent of the mined area and location of the reserves. Note that the 25 level crosscuts are too far removed from No. 13 shaft to be available for pumping.

rehabilitation. At No. 5 Tamarack shaft, the provisions made for heat dissipation were more than adequate to handle the ventilation problem. At No. 6 and No. 13 Osceola, 75-hp suction-type fans were installed over the adjacent No. 5 and No. 14 shaft openings. Thus No. 6 and No. 13 were converted to downdraft shafts, causing fresh air to flow from surface through the areas where men were working on rehabilitation. These ventilating units are equipped with auxiliary gasoline engines arranged for automatic starting in the event of electrical power failure.

Mining: During the prior active life of the Osceola, the ground between the 10 and 11 levels north of No. 13 shaft had been left to act as support for the headframes and engine houses of the conglomerate which were located directly above. The need for this support no longer exists, and as soon as the 11 level had been unwatered, active mining of this area began. The first skip load of rock was brought to surface in July 1954.

Production from the lower levels of No. 13 began in November 1955, and the shaft was scheduled to reach full capacity of 1500 tpd in February 1956. Mining in Osceola No. 6 is scheduled to begin in September 1956 and reach full production of 1500 tpd in December.

Disposal of the Water: One of the important problems associated with the Osceola unwatering was the proper disposal of the water, which contained relatively large concentrations of salt. The Michigan Water Resources Commission was most cooperative in helping solve this problem. After careful study they approved discharge of the water into Lake Superior, provided that disposal was controlled so as to secure maximum protection against pollution injurious to the public water supply. The Commission has required surveys to determine the course of the water as it enters the lake, regular sampling at several stations, and the installation of continuous chloride recorders at the waterworks intakes.

Water from the shaft is pumped through the 30-in. concrete line, to the North Tamarack dam, where it is allowed to spill, releasing the entrained gas. From the dam it enters a small stream, flowing a distance of approximately six miles, and entering Lake Superior at a point 5¾ miles northeast of the waterworks intake.

When the lake is rough, strong wave action causes mixing of the mine and lake water, and subsequent movement is entirely dependent upon wind direction, the concentration of chloride diminishing rapidly with distance traveled from the mouth of the stream. Maximum chloride content detected in the tap water to date was 36 ppm, approximately one eighth of the minimum detectable by taste. This concentration was reached only once, after two weeks of persistent north winds. During the summer, with prevailing westerly winds, the chloride content of the tap water has been 1:2 ppm, normal for Lake Superior.

When the lake is calm, the mine water does not mix immediately with the lake water but, because of its higher specific gravity, follows the bottom contour of the lake, forming an *underwater stream* which seeks out the low spots, moving out into deeper water toward the very bottom of the lake, dispersing itself as it goes along. Under quiet conditions, the layer which hugs the bottom is thin and sharply defined. Its thickness is generally about 1 ft. This segregation tendency is so pronounced that it was not possible to detect chloride in the surface water at distances greater than 20 ft from the mouth of the stream, even though mine water was entering the lake at a rate of 12,000 gpm and at a chloride content of 40,000 ppm. At a point 2 miles directly out into the lake, where the water is 50 ft deep, chloride could be detected in the lower 2 ft only, and the maximum concentration at this point was 500 ppm.

Thus, in spite of the tremendous quantities of salt involved, disposition has been so gradual and prolonged that no difficulty has been encountered in holding the effect on the public water supply to an absolute minimum.

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[1] A. C. Lane: *The Keweenaw Series of Michigan*, Michigan Geological and Biological Survey, vol. 2.