# NATIONAL HISTORIC MECHANICAL ENGINEERING LANDMARK

**The First Air Conditioning of the**

**Magma Copper Company**

**Mine**

**SUPERIOR, ARIZONA**

**1937**

**Designated By**

**THE AMERICAN SOCIETY**
**OF**
**MECHANICAL ENGINEERS**

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# COOLING THE LOWER REGIONS

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The title sounds both ominous and awesome -- it is borrowed from a magazine article printed in 1937 which described the initial installation of refrigerated cooling equipment in the Magma Mine at Superior, Arizona.

Quoting from an article written at that time by Mr. William Koerner, General Manager, Magma Copper Co.:

"The Magma Mine, on account of its high rock temperatures, is a warm mine. Below the 2000-foot level, the increase in rock temperature is approximately 1½ degrees F. per 100 feet of depth. The rock temperature on the 2000-foot level is 109° F.

"In the early part of 1935, a crosscut on the 4000-foot level, from a winze, crosscut the vein. The rock temperature on this level was 140° F. From the results of this work and the conditions found on this level, it was evident that provisions must be made for artificial means of cooling and air conditioning the lower levels of the mine. It was evident that this was necessary if the levels below the 3200-foot level were to be developed and gotten in shape for stoping the ore as it was needed.

"Our previous practice at Magma had been to open up a level and let it stand for several years to drain and cool off from the air sent through it from the ventilating fans placed on the level. The 3200-foot level required about three years of cooling by this method before it was cooled off so stope development could be carried on with any degree of efficiency.

"Work for the installation of the refrigerating units was started in the first part of 1937 and the first unit was placed in operation on July 19;

the second unit on August 3. They have been in operation now for a little over a month. Temperature changes that have been effected on the 3400 and 3600 levels have been gratifying. From a comfort standpoint, conditions on these levels are better now after six weeks of air conditioning than on the 3200 level after three years of ventilation by fans without air conditioning. From results to date, it appears as if our stope development work will be hastened by several years over our old practice, and it will be done more efficiently and with more comfort. As air conditioning is carried on and the rock temperatures lowered, conditions in the upper workings of the mine will also improve. It is also expected that in time the temperature of the rock downward will be lowered."

The problems presented by this mine were unique, so the management called for assistance from one of the leading air conditioning experts of that time.

Dr. Willis H. Carrier, Chairman of the Board of Directors of the Carrier Corporation, Syracuse, New York, came to the mine and made a survey of all the unusual features which would have an effect on the installation of the air conditioning. After he made his recommendations, the Carrier Corporation designed the first underground mechanical air conditioning system in North America.

The mechanical refrigerating units, which were installed in the mine during the first half of 1937, were located on the 3600-foot level -- the lowest working level at that time.

All equipment had to be lowered through shaft compartments 40 inches by 60 inches in size. For this reason, two units of 140-ton capacity, rather than one larger unit, were selected. This also gave the plant an added flexibility, as one unit could be operated while the other was shut down to

have the condenser tubes cleaned. By changing valves, either set of cooling coils could be connected to either refrigeration unit.

Each chiller unit was powered with a 200-hp, 2200-volt, three-phase, 25-cycle induction motor operating at 1440 rpm, which was stepped up to 6750 rpm by speed-increasing gears to drive the compressor (See Figure No. 1).

When each unit was furnished with 200 gallons per minute of 95° F condenser water, it would cool 350 gpm of chilled water to 60° F. The chilled water was piped in a closed circuit through cooling coils, one set on the 3400-foot level and another set on the 3600-foot level. The refrigeration station was located on the 3600-foot level (See Figure No. 2).

The source of condenser water was the natural mine water that drained into the working levels from underground sources. At various points where it emerged from the rock, it was from 109° F to 130° F in temperature. A total of 400 gpm was available for condensing purposes near the chiller installation. This water was actually at a temperature of 95° F, having cooled off while flowing along various levels and being in contact with ventilation air. The leaving water temperature from the condensers was 117° F.

For circulating the chilled water from the refrigeration plant to the cooling coils on the two levels, four-inch pipe was installed. This, along with the six-inch and eight-inch pipe that was used to complete the condenser water circuit resulted in a total of 9,579 feet of pipe being installed. This proved to be a much greater job than the actual erection of the refrigeration machinery (See Figure No. 3).

Mr. J. F. Kooistra, an engineer of the Carrier Corporation, writing in The Mining Journal, Phoenix, Arizona, December 15, 1941, says in part:

"The average temperatures of eight working places on the 3600-foot level, taken the day before the air conditioning plant was started, were 101° F dry bulb and 93° F wet bulb. After 28 days of operation of the plant these same places averaged 93° F dry bulb and 84° F wet bulb.

"After four months of air conditioned ventilation, the average of all working places on the 3,400 and 3,600 foot levels was lowered to 80° F dry bulb and 72° F wet bulb. The maximum benefit was derived from the cooling system after about seven months of operation when, aided by cooler incoming air due to surface temperatures, the average was brought down to 81° F dry bulb and 71° F wet bulb. According to the effective temperature chart this condition corresponds to an effective temperature of about 71° F, which is a condition close to the comfort zone. These records are sufficient proof that the efficiency of the workers in this particular area of the mine must have been improved considerably.

"By the middle of 1939 when the first plant had been in operation for nearly two years, the management of Magma decided to increase the capacity of the underground cooling plant. The 4,000-foot level was far enough along with its development that it was felt necessary to install air con-dicioning for that level to permit immediate stoping operations, so a third chiller identical to the first two was installed.

"In order to provide condenser water for this third chiller, an underground spray cooler was placed at the 3,600-foot level at the foot of an exhaust shaft. The air leaving through this shaft was at approxi-mately 100° F dry bulb and when the 200 gpm of hot condenser water was circulated through the three-stage spray cooler, the leaving water tem-perature was within 2° F of the air wet bulb temperature.

"This third machine also cooled 350 gpm of cooling water to a

temperature of 60° F and circulated it through air-cooling coils installed at the fan station on the 4,000-foot level. 30,000 cfm of air was circulated through the working of this level.

"The results obtained with air conditioning on the 3,400, 3,600, 3,800 and 4,000-foot levels has been most satisfactory, so that all future development work of the mine is being planned with the thought in mind of immediate cooling after a new level is opened up.

"The Magma Copper Company purchased three additional centrifugal refrigeration machines, each again having 140-tons of capacity, so that toward the middle of the summer of 1941 a total of six machines with a total capacity of 840-tons were installed to provide comfortable working conditions for the miners, improve operating efficiency, and provide a means of getting immediate returns from new development investments."

These units were the last that were installed using mine water for condensing. The new units were placed on lower levels, along with the moving of the original chillers to the new areas. The arrangement provided for one old unit and one new unit at each of three locations. The original 400 gpm of condenser water, stretched to 600 gpm by use of a spray cooler, was pumped to each of the old units at 95° F, leaving at 117° F. This higher temperature water was then introduced into the new chillers nearby, and left at 135° F. This high temperature water was then pumped to the surface and wasted.

Since that time Magma has installed a number of other air conditioning systems in the mine at Superior. A change in the basic method of providing condensing water capacity came about in the late 1940's, when a regenerative-type cooling tower was installed (See Figure No. 4). Much of the research work on this tower was done in the Mechanical Engineering Department,

University of Arizona, under the direction of M. L. "Baldy" Thornburg. A number of now well-known engineers in Arizona were employed in this research when they were students at the U. of A.

The area of the mine where the first refrigeration units were installed has had all of the ore removed. For the most part, the equipment was moved to new mining areas and later abandoned in place -- it would be too costly to bring those chillers back to the surface.

For a time, though, it was the first and only air conditioned mine in North America.

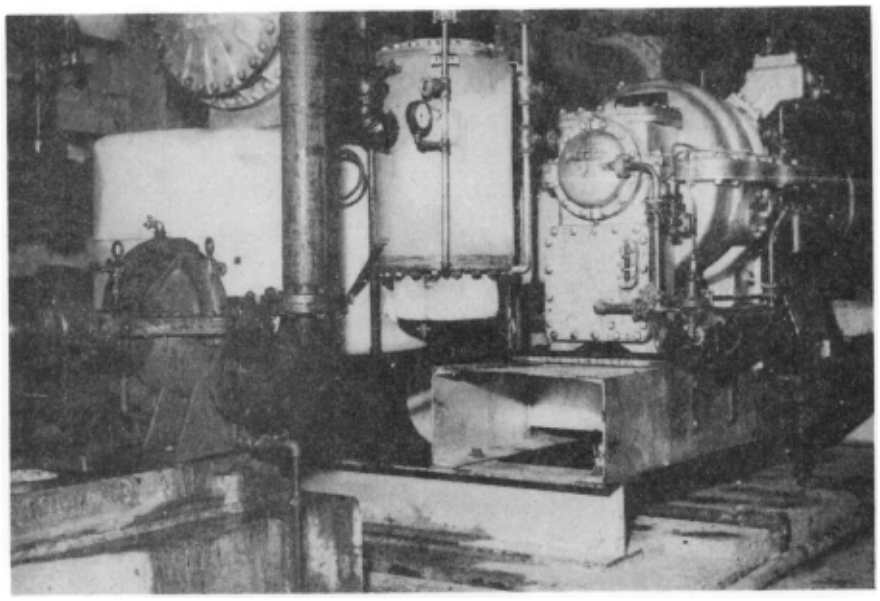

Figure No. 1

140-TON Centrifugal Chiller Unit No. 1
Installed on 3600-ft. Level

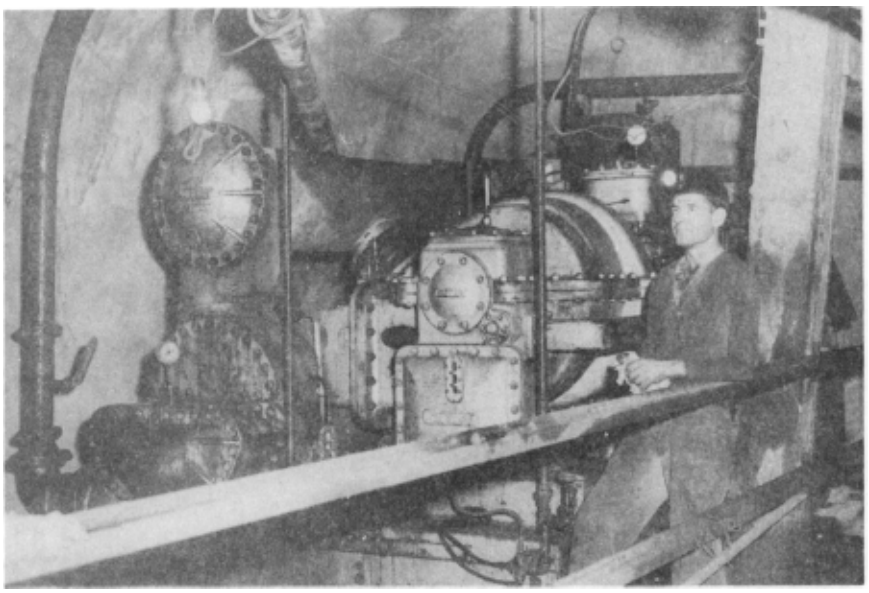

Figure No. 2

140-Ton Centrifugal Chiller Unit No. 2
Installed on 3600-ft. Leve l

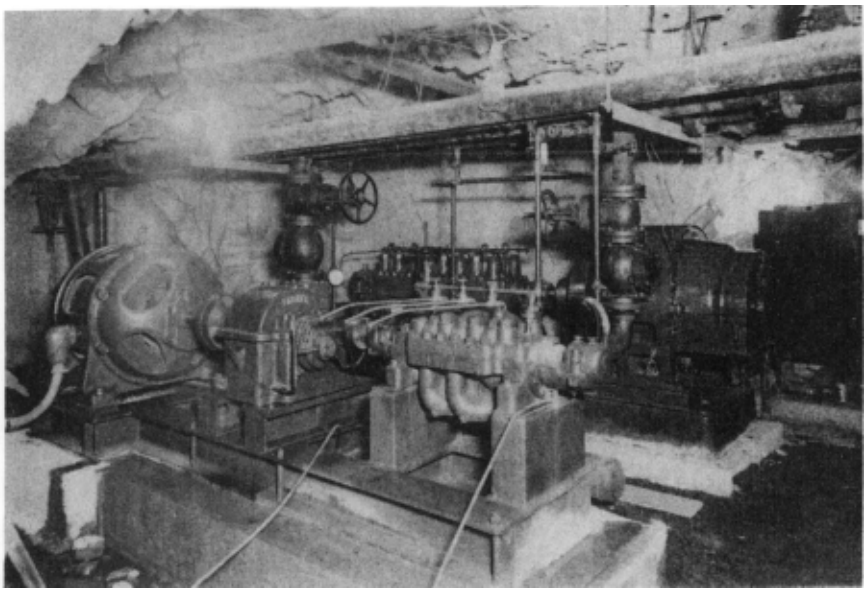

Figure No. 3

Condenser Water Pumps for Refrigeration
Units No. 1 and No. 2
Installed on 3600-ft. Level

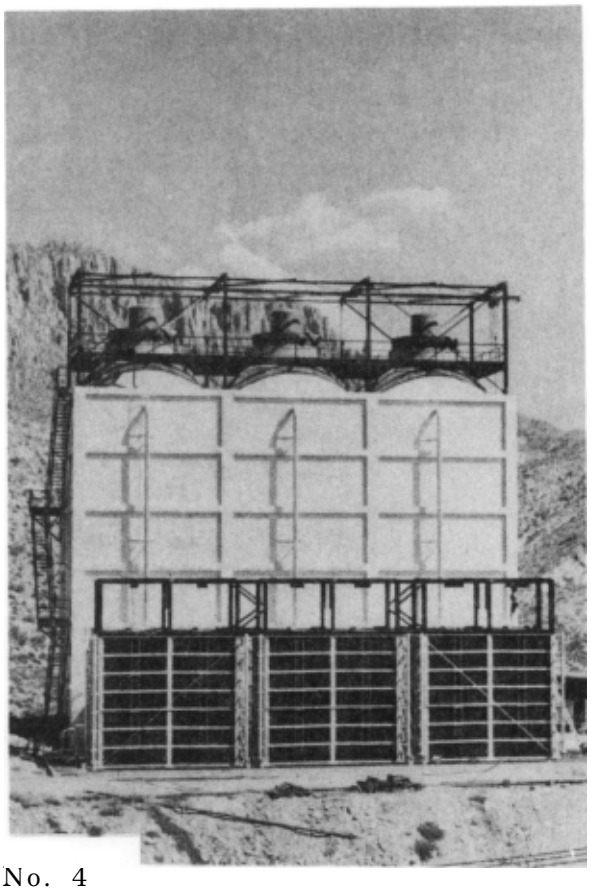

Figure No. 4

Cooling Tower--Installed in Late 1940's

FIGURE NO. 5: FIRST CENTRIFUGAL -- Dr. Willis H. Carrier, whose invention of air conditioning dates back to July 17, 1902, is shown (at center) with the machine which made large-scale air conditioning feasible -- the centrifugal refrigerating machine. This first unit was demonstrated at the Carrier plant in 1922. Dr. Carrier was so unsure that engineers would attend the showing of his invention that he added a six-round boxing match to the program. The machine later was installed at the Onondaga Pottery Company plant in upstate New York where it served until 1960. It was removed for permanent exhibit at the Smithsonian Institution in Washington, D. C. in 1964.

FIGURE NO. 6: CARRIER DESIGNED -- Dr. Willis H. Carrier personally designed the Magma Copper installation and supervised the manufacture of the machinery involved. Magma is one of the principal mines of its type in the world and the first to be air conditioned by Carrier in the U.S. Six centrifugals were installed 3600 to 4600 feet underground to cool miners so that they could work complete shifts without coming to the surface.

FIGURE NO. 7: TWO MILES DEEP -- Several years before the Magma Copper installation, Carrier gained valuable experience in mine air conditioning at the Robinson Deep Mine in Johannesburg, South Africa, the world's deepest mine. The mine stretched almost two miles below the earth's surface where temperatures reached 130° F.

All three photos courtesy of the Carrier News Bureau, Syracuse, N.Y.

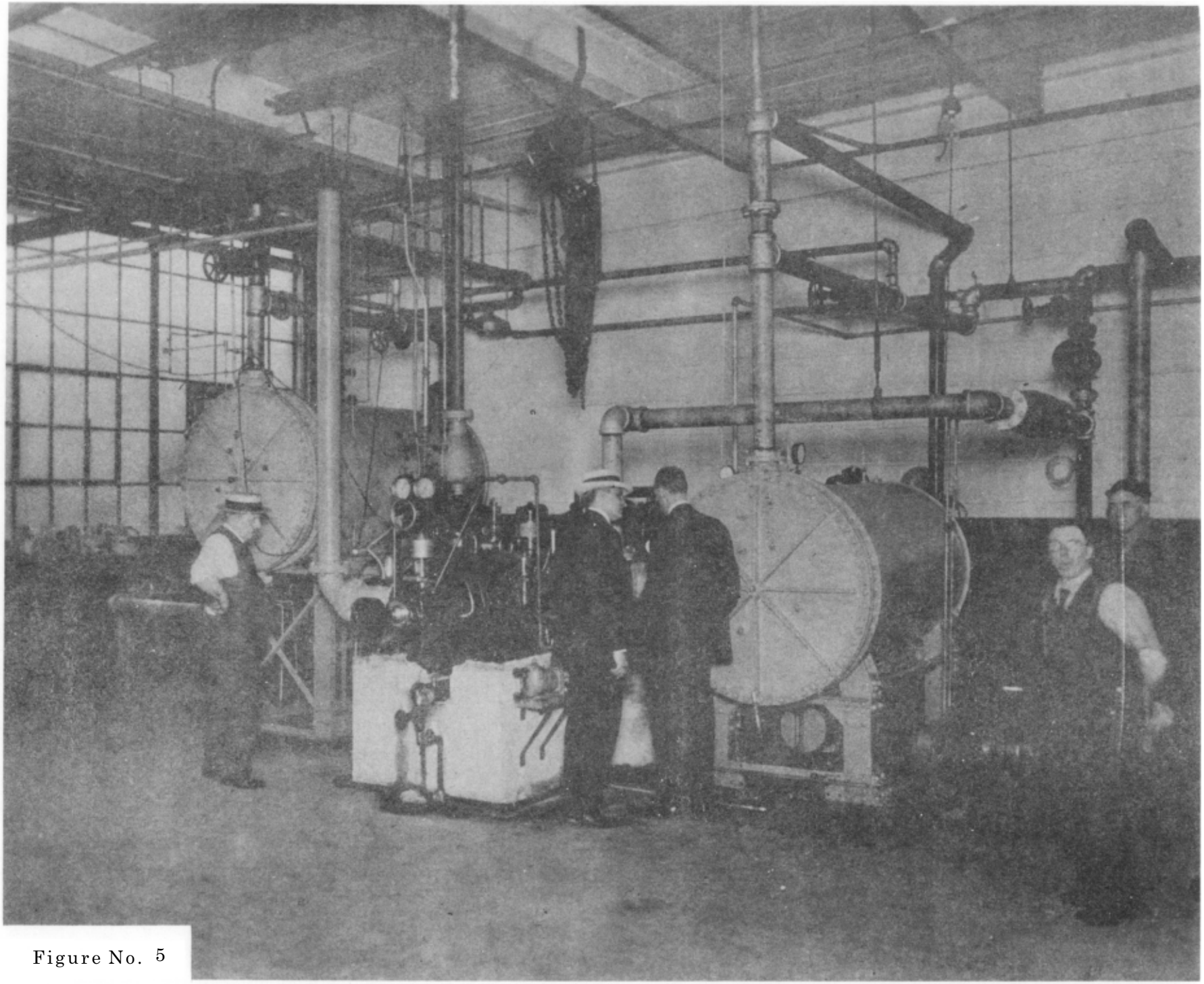

Figure No. 5

Figure No. 6

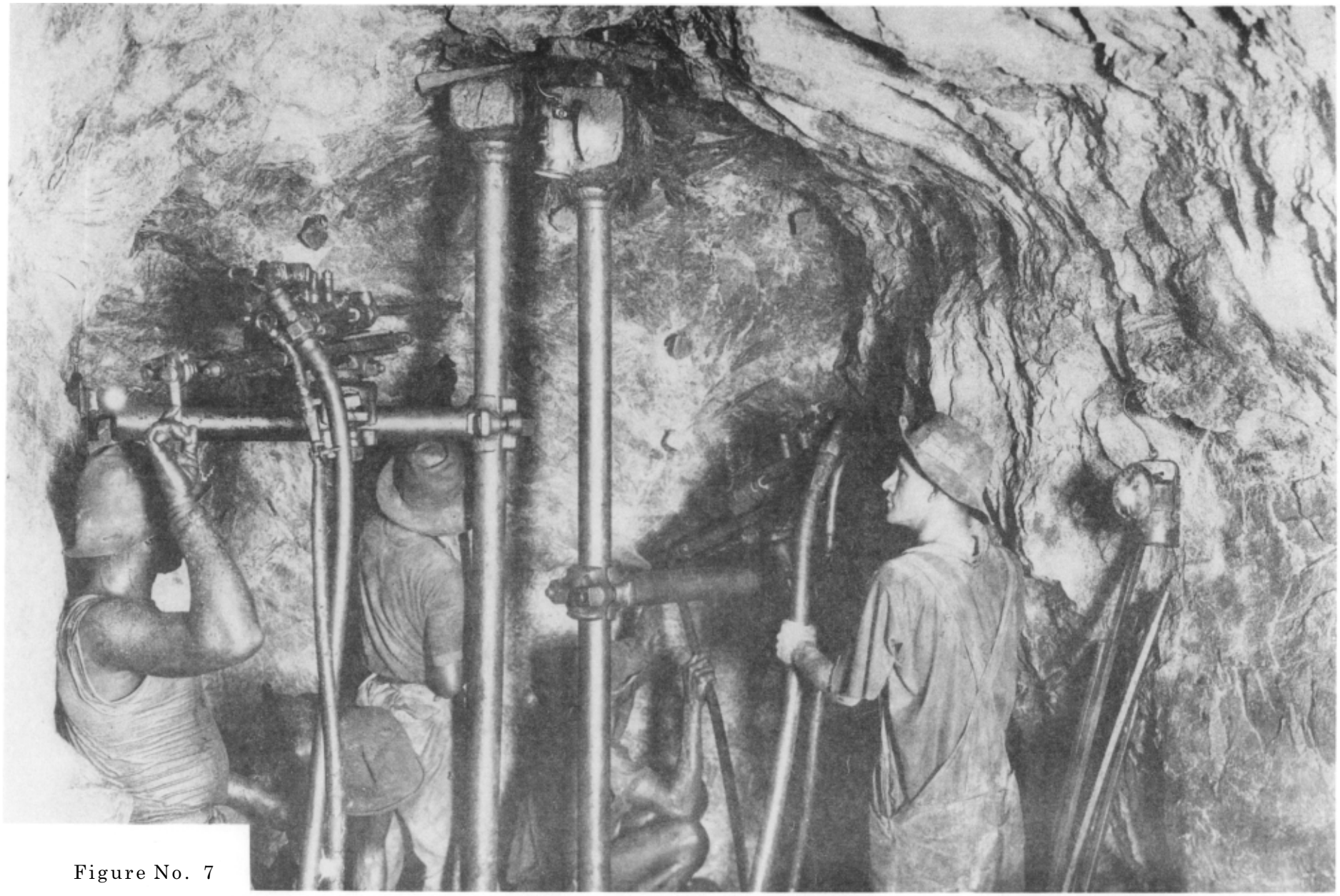

Figure No. 7