

## Development origin of hoisting equipment for a transportation of personnel and tourists in selected shafts of Wieliczka Salt Mine

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Abstract:

The article presents interesting examples of technical activities realized in the past years, having a significant impact on a development of hoisting systems in mines. An increasing number of visitors to the underground workings of the Wieliczka Salt Mine, including foreign tourists, caused a technical development of the vertical transport devices mainly used by visitors. It should be mentioned that an exploitation of underground seams is not conducted any more, but simultaneously a continuous increase of monumental underground objects availability occurs. There is no doubt about the fact that at the turn of the XX and XXI centuries a number of visitors, including foreign guests increased significantly and at present is reaches about 10 000 visitors per day (till March 2020). Such a situation caused a need of modernizing the transportation system and making considerable investments, ensuring a realization of vertical transport tasks, enabling a presentation of continuously developed and modernized exhibits of the underground mining exposition. However, these changes were mainly oriented onto a modernization of the vertical transport means for visitors. This requirement was met due to a development of cage winders in selected shafts, adapted for these purposes, mainly in the result of technical changes in the existing Daniłowicz Shaft and in the result of implementing an innovative solution in the completely rebuilt Regis Shaft. As regards the last one, in the place of the former winder with a winding machine, installed on the pit-bank, an innovative solution for the underground mining transport was used. It has been in operation since 2012. It is a passengers-goods hoisting device used so far only in high buildings on the ground and in technical - view towers. The article contains a compact description, giving an image of a certain technical development origin of cage winders - from horse gears to cabin passengers-goods devices.

Streszczenie:

Wzrastająca liczba zwiedzających podziemia Kopalni Soli w Wieliczce, w tym turystów zagranicznych spowodowała przy zaniku eksploatacji złóż podziemnych, a równocześnie ciągłym rozwojem udostępniania turystom zabytkowych podziemnych obiektów – były powodem istotnego rozwoju technicznego urządzeń transportu pionowego przeznaczonego głównie dla zwiedzających. Niewątpliwie na przełomie XX i XXI wieku liczba ta, w tym także gości zagranicznych znacznie wzrosła, obecnie dochodzi do około 10000 na dobę (do marca 2020 r.). Spowodowało to konieczność modernizacji i znacznych inwestycji zapewniających spełnienie zadań, także w transporcie pionowym, stale rozwijanych i unowocześnianych zasobów podziemnej ekspozycji górniczej. Podstawowym jednak celem tych zmian było unowocześnienie transportu pionowego dla zwiedzających. Spełniono to poprzez rozwój wyciągów klatkowych w wybranych i dostosowanych dla tych celów szybach górniczych, głównie poprzez zmiany techniczne w istniejącym szybie Daniłowicz oraz zastosowanie innowacyjnego rozwiązania w całkowicie przebudowanym szybie Regis. W tym ostatnim w miejsce dawnego wyciągu z maszyną wyciągową zabudowaną na zrębie szybu, zastosowano funkcjonujące od 2012 roku innowacyjne rozwiązanie w transporcie górnictwa podziemnego, to jest urządzenie zjazdowe osobowo-towarowe stosowane dotychczas jedynie w wysokościowych budynkach naziemnych oraz wieżach techniczno – widokowych. Bardzo zwięzły opis stanowiący obraz pewnej genezy technicznego rozwoju wyciągów klatkowych – od wyciągów kieratowych do urządzeń kabinowych osobowo-towarowych stanowi przedmiot niniejszego opracowania.

## 1. Introduction

The main problem in underground mines technology is a technical development of vertical transport devices used not only for hoisting minerals, but also personnel, materials, machines, equipment and in some cases a big number of tourists.

It concerns, among others, the Wieliczka Salt Mine, having a multi-century tradition, known all over the world, where the daily number of visitors reaches 10 000 people.

Aiming at presentation of problems, experienced within recent years as regards a development of cage winders, the Authors concentrated mainly on the technical development during the period of nearly 70 years, realized together with the employees of AGH – University of Science and Technology in Cracow, in collaboration with selected employees of the Mine. Several times they presented and published their papers in conference proceedings [1, 2, 4].

## 2. Vertical transport of Wieliczka Mine visitors

In the end of the XVIII century Wieliczka, and mainly the Salt Mine became a very popular tourist attraction in the world scale due to a multi-year tradition of mining salt. According to the first visitors' books from 1774 the number of visitors reached a hundred people per week.

Until the XVIII century descending into mine took place in the Seraf Shaft which does not exist anymore.

It was sank to Level I (-64 m) in 1442 and was equipped with a stairs compartment and a winder, consisting of a horse gear and a shaft with a brake disk, on which a rope was wound.

The horse gear was moved by four pairs of horses. The vertical wheel drove the shaft on which the rope was wound. The shaft was equipped with one caliper brake started manually by the brake operator. A descent of miners and tourists was carried out in saddles made of lime phloem or hemp cord, fixed to the rope with belts.

Usually, 5 or 6 pairs of people were hung on the rope end. Such a trip was very dangerous as quite often attachments of saddles to the rope came off, which made the people fall down the shaft. In 1661 a new shaft, called Leszno, also not existing at present was sank to the Level I. It was equipped with sinuous stairs to be used by visitors.

Since the XVIII century tourists have been able to descent to the Level III using the Daniłowicz Shaft, sank in 1635, using saddles hung on the rope or stairs in the Leszno Shaft or Paderewski Shaft, using stairs to the Level I. The monumental underground part of the Wieliczka Mine served for tourist purposes.

Some parts near the shaft were separated, initially on the Level I and since the middle of the XIX century also on the Levels II and III. In the end of the XIX century a double cage winder in the Daniłowicz Shaft was used for visitors' descending and ascending, but till 1939 they descended only to the Level I and after having visited this part, they walked along galleries and chambers to the Level III, from which they were transported to the surface.

At present visitors, in general, walk down the stairs in the Daniłowicz Shaft to the Level I at the depth of 64 m and after having visited the monumental part (workings, chambers, chapels, lakes etc.) they continue walking until they reach the Level III (at the depth of 135 m). Then they take the cage winder to the surface. A small double cage winder, driven by a double drum winding machine with a steam engine, used to be operated in the Daniłowicz Shaft.

In the end of the fifties a development of tourism in the Wieliczka Mine was limited by a possibility of ascending visitors from the Level III, using the Daniłowicz Shaft. The winder, operated there, was considered to be out-of-date. Its transport capacity using two-floor cages moving at a small speed of 2 m/s and carrying a small number of people in the cage (10 persons), was limited due to the fact that the winder was small.

There were also other disadvantages of the equipment design, among others of the head-frame, so the Mine management decided to modernize the winder and to up-date and partly rebuild elements of the Daniłowicz Shaft, which enabled a significant increase of the winder capacity to even 4000 persons per day at a simultaneous exchange of the winging machine drive, replacing the steam engine by an electric motor. This change was introduced in the sixties of the XX century.

### 3. Planed reconstruction of the winder in the Daniłowicz Shaft

In 1958 a modernization and improvement of the vertical transport means for tourists, visiting the Wieliczka Salt Mine, were conducted under the supervision of Prof. Zygmunt Kawecki from the Department of Shaft Equipment at the Division of Mining Machines and Equipment at the AGH University of Science and Technology in Cracow [1].

The project embraced a series of alternative solutions, but in all of them a change, among others, of the shaft cross-section together with a significant increase of the winder traffic capacity, due to an application of advanced solutions of the shaft equipment, was planned.

As a transport of people in the Daniłowicz Shaft is of a specific character, a solution to the problems could not be in a stereotyped fashion similarly to the case of the workers' everyday descend (as well as in the case of additional materials and also the run-of-mine ascend) in underground mines. Tourist descending or ascending this Mine, usually use such means of transport for the first time in their lives and that is why they must be instructed at their each step, how they should behave and the winder should be constructed in such a way that visitors feel safe.

In the Daniłowicz Shaft it is characteristic that the majority of tourists walk down the stairs to the Level I and all of them ascend from the Level III, taking the shaft winder. As far as technical and economical conditions were concerned it was right to install a cage winder with a counterweight. A single cage system also simplified the shaft signaling system considerably. It should be mentioned that in the case of the Daniłowicz Shaft there is a big irregularity of the winder operations in the case of sight-seeing tours.

#### Suggested design solutions

In the framework of the AGH project, mentioned above, two different solutions were suggested [3]: **Solution I** consisting in taking advantage of the Daniłowicz Shaft reconstruction which was indispensable all the same and an installation of a single cage winder with a counterweight reaching the Level IV, driven by different winding machines. It was decided to present the following alternative solutions:

- **Alternative I** – double drum winding machine with drums of 3 m. dia., driven by a DC motor of 62 kW power at the speed of 4 m/s. The motor operated in the former Okrzeja (Regis) Shaft before, also in the Wieliczka Salt Mine. A two-floor cage was suggested as a conveyance, assuming that a traffic capacity of this type device will be about 3500 persons within 10 hours.
- **Alternative II** – with the winding machine as in Alternative I, but with a new asynchronous motor of the power about 110 kW, typical for this winding machine. Four –floor cage with a counterweight - a traffic capacity of about 4300 persons within 10 hours.
- **Alternative III** – with a four-rope winding machine with a friction pulley of 2 m. dia. Installed in the head-frame, driven by an asynchronous motor of the power about 100 kW at the travel speed of 4 m/s. Single cage winder as in Alternative II.

**Solution II** - an application of two identical hoisting devices with two-floor cages with a counterweight, one servicing the Levels I and III; the other one – the Level III, assuming that the first one would reach the Level IV, whereas the other one – the Level VI.

These systems were to be driven by two identical four-rope winding-machines with pulleys of 1.25 m. dia. installed in the head-frame, with driving motors of the power about 50 kW. The traffic capacity at the steady-state speed of 4 m/s was 4000 persons /10 hours. It was recommended to implement an automatic control of these machines, eliminating a winding- machine operator. The drive start-up could be realized by a shaft banksman.

### 4. Present condition of hoisting equipment in the Shafts: Daniłowicz and Regis at the Wieliczka Salt Mine

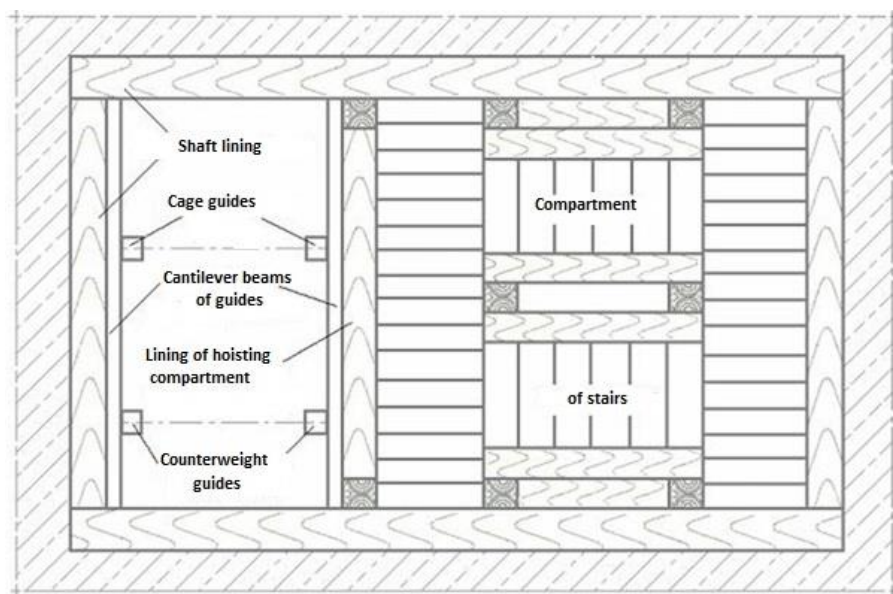
Basing on multi-alternative solutions of design changes in selected shafts of the Wieliczka Salt Mine in the case of continually increasing number of visitors, also caused by a development and availability of new underground resources of monumental workings and exhibits, it was decided to

undertake a multi-year modernization and development of the winder in the Daniłowicz Shaft in the sixties of the XX century.

Besides, due to increasing interest in the Wieliczka Mine in the world scale, at the turn of the XX and XXI centuries, a totally innovative reconstruction of the Regis Shaft was realized.

Significant changes in the Daniłowicz Shaft were undertaken in 1959. They improved sight-seeing conditions underground. These changes concerned not only the shaft itself, but also an exchange of the winder, i.e. an installation of a single cage winder with a counterweight (four-floor cage), a replacement of a steam engine by an electric drive and an overhaul of the existing landing together with a construction of a new engine room and an exchange of a pine wood shaft lining for an oak one down to the Level II.

After the overhaul the visitors' means of transport consisted of walking down the stairs compartment to the Level I as ascending from the Level III by a cage winder (Fig.1).



**Fig. 1.** Present cross – section of the Daniłowicz Shaft [4]

The following overhaul of the Daniłowicz Shaft was conducted in the years 1987-1989. Its scope included a control of geological hazards and a possibility of two-level getting on and off the cage on the Levels: I and II. The repair and investment work, together with a modernization of landing and an installation of air – conditioning aggregates drying the air directed to the tourist route, was realized in the end of nineties. Then another change was introduced, the BB-3000 machine was replaced by the BB-2500 machine with supply and control systems.

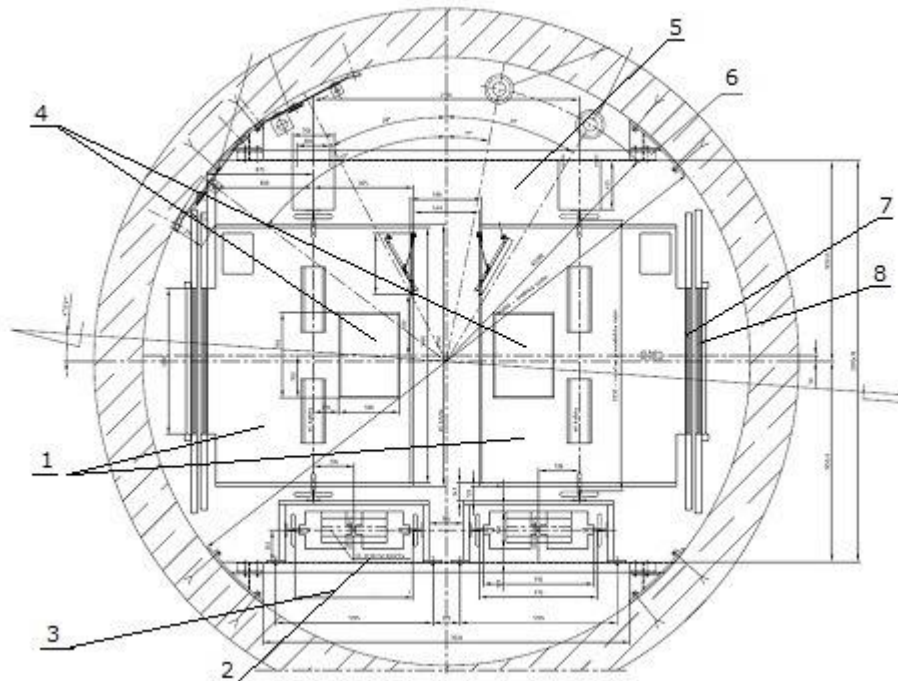
In the end of the XX century an exploitation of salt in the Wieliczka Mine was stopped completely. A chance for a development of the Mine and of the town consisted in a development of tourism, so the enterprise management of that time took a decision about a reconstruction and modernization of the Regis Shaft. An increasing number of visitors in the second half of the XX century from 3500 to about 5000 guests, whereas at present it reaches 10 000 tourists per day, confirmed the rightness of earlier decisions concerning a broad development of the vertical transport system in the Regis Shaft.

A detailed description of the shaft modernization as well as of the investments made in the shaft surroundings, similarly to the Daniłowicz Shaft, is presented in monographs elaborated by the employees of the Wieliczka Salt Mine and the AGH University of Science and Technology in Cracow [1, 6].

Looking for safe and economically feasible as well innovative solutions of vertical transport, the Wieliczka Salt Mine management decided to implement passengers-goods elevators, commonly used in transport systems, mainly in high buildings, observation and view towers. To a certain extent this solution is similar to the Solution II, which has already been mentioned, suggested for the Daniłowicz

Shaft and for multi-rope winders installed in the head frame. However, such solutions are not commonly used in underground mines. A difference consists in a replacement of typical multi-rope winding machines, installed in the head-frame, by elevators. After having conducted technical analyses it was possible to select a solution which guarantees a high level of safety. It was decided to choose an elevator for a transport of 20-person groups of visitors interested in visiting a newly available area of the Mine through the Regis Shaft. An assembly of two passengers-goods elevators was conducted by the Kone Company from Warsaw.

In the Regis Shaft each elevator has the hoisting capacity of 1600 kg (21 persons) - Fig 2. In July 2012 the device was commissioned and obtained a permit for operation in an underground mine, i.e. the Wieliczka Salt Mine [5].

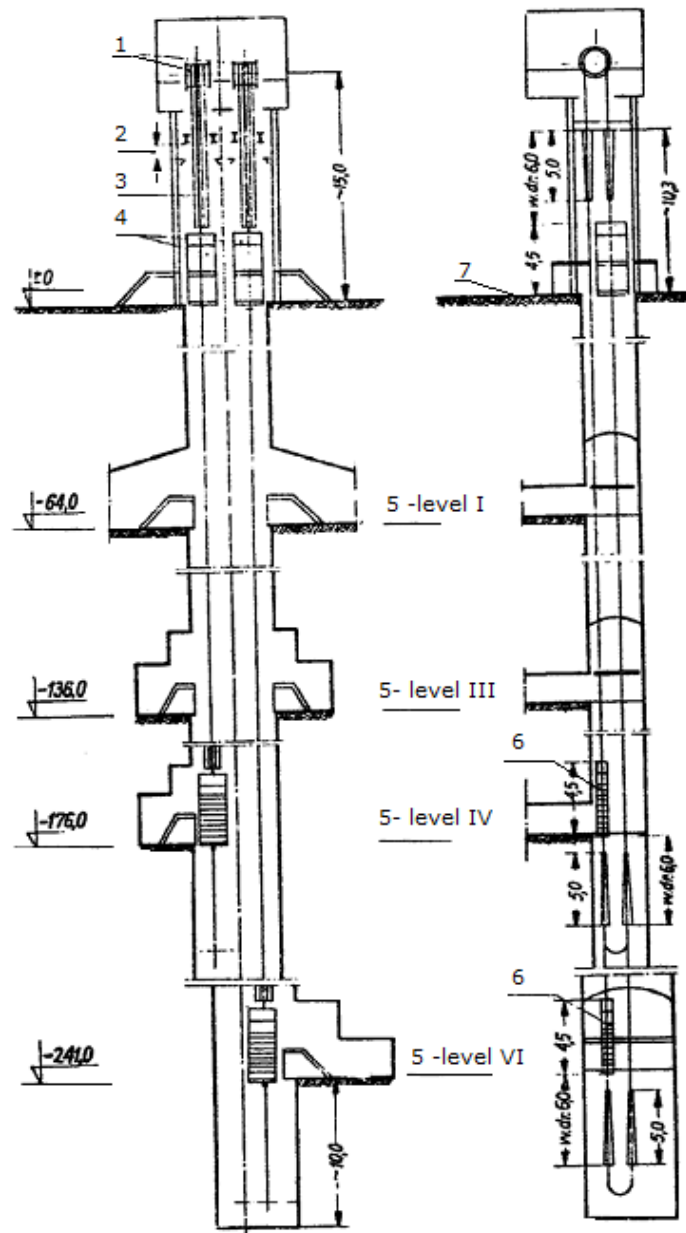


**Fig. 2.** The Regis Shaft cross-section [1]

Explanations to Fig.2:

- 1- Cabin
- 2- Axis of counterweight
- 3- Spacing of counterweight guides
- 4- Roof manhole
- 5- Door for passage from cage to cage in case of failure of one of the compartments
- 6- Reinforcement of Regis Shaft
- 7- Cabin door
- 8- Arrest door

To compare the implemented solution in the Regis Shaft with the suggested Solution II, according to the concept for the Daniłowicz Shaft, from 1858, schematic diagrams of the shaft equipment are presented additionally in Fig. 3 and Fig. 4.



**Fig. 3.** Cross-section of the Daniłowicz Shaft according to the Solution II [3]

Explanations to Fig. 3:

- 1- Two four-rope winding machines  $\Phi$  1.25m
- 2- Bumping beams. Cage keep
- 3- Four load-carrying ropes
- 4- Two two-level cages
- 5- Levels: I, III, IV, VI
- 6- Counterweight
- 7- Pit bank



The passengers-goods elevators, which started their operation in 2012, are characterized by the following technical parameters:

- calculated traffic capacity of passengers from the Level III (-127,7 m), assuming a 10-hour operation, to the surface is 1134 persons/hour, and in the case of 10-hour operation-11340 visitors. The elevators move at the speed of 4 m/s,
- power of 8-rope elevators is 28.5 kW each.

It should be highlighted that both cage winders are characterized by very good technical and economical parameters, they do not require separate, traditional winding machines, special rooms and they can be controlled directly from the conveyance, i.e. from the elevator cabin.

## 5. Conclusions

The history of the Daniłowicz Shaft as well as of the Regis Shaft at the Wieliczka Salt Mine indicates that engineering of mine shafts, but in particular mechanical engineering, which is its integral part, require interdisciplinary technical knowledge and abilities including an out-of-the-box thinking and approach.

An increasing number of visitors to the underground workings of the Wieliczka Salt Mine caused an urgent necessity of improving the hoisting system capacity. At present, after several years of using elevators in the Regis Shaft, it can be clearly seen that the decision about a complete modernization of the hoisting installation was right. At present visitors` transport capacity exceeds 10 000 persons per day. It should be highlighted that the modernized hoisting systems are characterized by a high reliability and very good operational as well as economical parameters.

All the modernization stages of hoisting systems at the Daniłowicz and Regis Shafts contributed to a safety improvement, meeting the requirements not only of regulations but also of thousands of visitors.

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