The freight pneumatic elevators as a new form of transport

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Abstract. This article addresses the problem of ensuring high reliability and safety performance of freight elevators. Rope elevator hoists exist more than one hundred years and have become very common, but it is very difficult to achieve their operational efficiency. The authors propose a solution to the problem - the introduction of a fundamentally new type of transport - pneumatic lifting, which capable provides high technical and economic performance. At the specialized enterprise «Pnevmopod”yem» a small-lot manufacture of new import-substituting equipment for hoisting in building sestablished. The authors present the advantages and the principle of operation of the developed pneumatic elevator. Essential advantage of this machine is the safe work which is incorporated in its design. Considerable attention is paid to the results of tests of cargo pneumatic elevator. The authors come to the conclusion that the design of a freight pneumatic elevator makes it possible to use it successfully for transporting cargo in buildings and structures for various purposes, to reduce capital investments in construction, installation and operating costs. The absence of foreign analogs will allow selling pneumatic lifts not only in Kazakhstan, but also in the countries of the former USSR.

1. Introduction

Current issue of ensuring high reliability indexes and safety operational of freight elevators is not solved in full, since the popular rope hoists have a number of design defects and their further improvement only leads to complicacy and in-crease in the cost of their design. Rope elevator hoists exist more than one hun-dred years and have become very common, but it is very difficult to achieve their operational efficiency and reduce energy consumption, because it is necessary to hoist an excessive weight of ropes. It is naturally affects the economic perfor-mance of the elevators. It is also necessary to maintain and periodically change the ropes, which is accompanied by significant material expenses while operating the elevators. Delivery costs, customs clearance and traveling expenses, compos-ing sometimes a cost of acquiring freight elevator, are the serious burden on the cost of construction and reconstruction of objects [1–7]. The customer of such equipment bears the significant costs for the construction of machine rooms, shafts and also finishing, erecting and commissioning works. In addition, mainte-nance of rope, hydraulic and other elevators demand highly-skilled and highly-paid professionals. The lack of freight elevators manufacturing in the Republic of Kazakhstan leads to the to the need to acquire these machines (rope, hydraulic, etc.) abroad and pay their value in foreign currency. One of the problem solution is implementation of a fundamentally new type of transport - pneumatic elevat-ing, which capable provides high technical and economic performance. Funda-mental principles of theory and
calculation methods of pneumatic elevating formulated by the professor of the Karaganda State Technical University, Yu. A. Nikolayev and discussed in detail in the above sources [6, 7].

At the specialized enterprise «Pnev mopodiyem» (Karaganda city) a small-lot manufacture of new import-substituting equipment for hoisting in buildings established. Manufacture of pneumatic elevators with a carrying capacity of 110, 250 and 500 kg disbursed. Factory and production tests of pneumatic elevators demonstrated working ability, reliability and service life of these machines, their ecological safety. At the present time, freight pneumatic elevators are successfully used in the shopping malls, schools, kindergartens and other facilities in the cities of Astana, Karaganda, Petropavlovsk, Aktau. Production of pneumatic elevators can be established in other cities of Kazakhstan, which have machine-building plants. This development is completely ready for industrial production: design and technical documentation prepared, “Know-how”. The absence of foreign analogs will allow selling pneumatic lifts not only in Kazakhstan, but also in the countries of the former USSR.

2. The principle of operation and design development

The essential advantages of pneumatic elevators (as compared with the existing freight elevators) are:
- simplicity of embodiment;
- reliability and safety in operation;
- ease of installation and maintenance;
- reduction of costs for the purchase, installation and operation of the pneumatic lift (at 2–5 times);
- a small pressure of compressed air (0.003–0.007 MPa) in the cavity of the shaft creates favorable and safe dynamic conditions for the operation of the pneumatic elevator.

Figure 1 shows the freight pneumatic elevators of three modifications with a carrying capacity of 110, 250 and 500 kg.

![Figure 1. The freight pneumatic elevators of three modifications with a carrying capacity of 110, 250 and 500 kg.](image)

Pneumatic elevator works as follows. After loading the loading platform, the hatch closes, and the closures are blocked, excluding their opening. The “Start” button is pressed, the fan turns on, and compressed air begins to flow into the cavity under the loading platform. When a certain pressure is reached, the loading platform on the hovercraft rises to the upper mark, where it braked and stops by stop blocks. A green light comes on at the control point, indicating the possibility of opening the hatch and unloading the platform. All the time of unloading at the upper level, the platform is supported by the pressure of the operating fan. After unloading the loading platform, the hatch closes, the hatch locks are locked, the “Stop” button is pressed and the fan is turned off. In this case, the compressed air in the shaft begins to escape (throttling) through the calibrated nozzle into the atmosphere, as a result of which
the loading platform at a given speed on the hovercraft sinks to the lower stop blocks. The green light comes on, the hatch opens, the platform is restarted and the work cycle repeats. During the movement of the loading platform in the shaft, a red light is on, indicating that the opening of the hatches is prohibited.

Figure 2 shows the design schemes of freight pneumatic elevators, their technical and economic characteristics, and also information for ordering these machines.

Essential advantage of this machine is the safe work which is incorporated in its design. In the event of an emergency (power outage, breakdown of the electric motor, etc.), the loading platform does not fall to the bottom of the shaft, but first stops and then begins to descend due to air throttling, squeezing the hovercraft.

Thus, there are all the necessary prerequisites (low cost of the machine and the cost of its maintenance, safety and reliability of work, transportation and customs costs are excluded, no highly qualified service personnel are required) for the use of freight pneumatic elevators at the enterprises of Kazakhstan and other countries. This makes it possible to eliminate the dependence of Kazakhstan on foreign suppliers of such equipment, to organize reliable technical servicing and repair of machines to solve the problem of load lifting to the future.

![Diagram of freight pneumatic elevators](image)

**Figure 2.** Constructive schemes of freight pneumatic elevators and their technical characteristics.

### 3. Test results

We have conducted tests of freight pneumatic elevators, which allowed us to experimentally set the following parameters:

- kinematic (speed of raising and lowering of the loading and empty platform along the pitshaft, hourly productivity of the pneumatic elevator);
- pneumatic (pressure and flow rate of compressed air during the ascent and descent of a loading and empty platform);

| Parameter                          | 110  | 250  | 500  |
|------------------------------------|------|------|------|
| Carrying capacity, kg             | 110  | 250  | 500  |
| Shaft diameter, mm                | 1020 | 1420 | 1620 |
| Compressed air pressure, MPa      | 0.003| 0.004| 0.0045|
| Installed fan power, kW           | 3    | 5    | 7    |
| Lifting speed, m/s                | 0.3  | 0.3  | 0.3  |
| Cost, depending on the number of floors, thousand KZT | 1117-1405 | 1532-1846 | 1788-2088 |
- electrical (power and energy consumption for lifting the loading and empty platform).

The resistance forces to the movement of the loading platform along the pitshaft (with dry friction and with lubrication of the walls) were determined.

Justification of the required number of repetitions is made in order to ensure sufficient reliability of the experimental studies results.

The required number of repetitions of experiments is determined on the basis of the coefficient $K_{\text{var}}$ and the required degree of accuracy.

The value of the coefficient of variation is determined by the formula $K_{\text{var}} = \frac{100 \cdot \delta}{\bar{x}} \%$, (1)

where $\delta$ – the average square deviation; $\bar{x}$ – arithmetic average.

The value of the standard deviation is calculated by the formula:

$$\delta = \sqrt{\frac{\sum \delta_i^2}{N - n}}$$

where $\delta_i$ – deviations of individual results from group means; $N$ – the total number of experiments; $n$ – the number of groups of experiments.

To establish the necessary number of experiments are given a valid value of $K$ in percent. Knowing the coefficient of variation $K$ for a given test method, it is possible with a reliability of 0.95 to determine the required number of experiments. According to the results of numerous experimental data, $K = 12\%$ is taken, with $K = 11.5\%$. This coefficient corresponds to (at a confidence probability of 0.95) the required number of experiments, equal to 4. Figures 3–5 shows some test results, the dependences of the pressure change in the working cavity of a loaded loading platform on the lifting time of PPG-110, 250, 500.

![Figure 3](image1)

**Figure 3.** Dependence of pressure in the working cavity of the loaded loading platform from the time of lifting PPG-110.

![Figure 4](image2)

**Figure 4.** Dependence of pressure in the working cavity of the loaded loading platform from the time of lifting PPG-250.
Figure 5. Dependence of pressure in the working cavity of the loaded loading platform from the time of lifting PPG-500.

Figure 6 shows the parameters of the current consumption of a three-phase electric motor with a voltage of 380 V when lifting a loaded platform PPG-110, PPG-250 and PPG-500.

Figure 6. Experimental data on operating current during lifting loaded platform PPG-110, 250, 500.

Experimentally obtained values of air flow when lifting the loading platform of pneumatic elevators PPG-110, PPG-250 and PPG-500 (Table 1).

The following equipment and instruments were used to measure the parameters:
- pressure gauge of the type NMP-52UZ with a measurement limit of 0–5 kPa;
- dynamometer;
- measurement of power and consumption of electrical energy is made by electric measuring pliers ARRA-30R with a flexible system for measuring operating voltage and current;
- time is measured by a chronometer;
- load when testing the freight pneumatic elevator is created by reference weights.

| Type      | Speed of movement when lifting, m/s | The area of the shaft, m² | Air flow, m³/s |
|-----------|-------------------------------------|---------------------------|----------------|
| PPG-110   | 0.178                               | 0.785                     | 0.137          |
| PPG-250   | 0.18                                | 1.54                      | 0.28           |
| PPG-500   | 0.193                               | 2                         | 0.386          |

Also, when conducting the study, the methods of analysis proposed by Kazakh and Russian authors were used [8–12].
4. Conclusions
Freight pneumatic elevator is simple structurally, has no restrictions on the lift height, has a low tare ratio, low electrical energy costs for one cycle of lifting the loading platform, which allows it to be successfully used to transport goods in buildings and structures for various purposes, to reduce capital investment in construction, installation and reduce operating costs.

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