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SCHEME AND TECHNICAL MEANS FOR AUTOMATED CONTROL OF THE COMPRESSOR STATION IN QUARRY FIRST OF MAY – MARBLE AND GRANITE CORPORATION

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ABSTRACT
The paper treats the means for automated control of the compressor station exploited under the conditions of quarry FIRST OF MAY - MARBLE AND GRANITE CORPORATION

Until recently a large dimensions extraction of granite blocks has been realized in the quarry FIRST OF MAY of the MARBLE-GRANITE ltd., which is situated in the western slopes of the VITOSHA MOUNTAIN. For next machining (cutting into slabs and grinding) the blocks have been transported in the stone cutting and grinding workshops built in the village VLADAJA.

Considerable amounts of sets, free stone and elements for granite lining have been produced on the quarry territory.

Drilling and blasting operations has been carried out for uncovering and partially for extraction realization and for separation from the mass - drilling operations providing hydraulic wedges use.

The quarry has had several production sections, its own transformer station and pneumatic management including an air conduit long about 2-3 km and compressed air consumers (jack hammers and pneumatic picks, set presses and sharpener).

Initially, the compressor station has been equipped with five two-stage reciprocal compressors type BORETZ 10/8, which have fed a shared air tank (receiver) with a blow valve by a manifold pipe.

Each compressor drive consists of a tree-phase squirrel-cage induction motor AM-92-6 (power75kW, rotation frequency 950 min^{-1} and voltage 380V) and a V-belt transmission.

The compressors cooling are provided by a shared water tank in an open scheme with gravitation liquid flow.

The manual motors control (start and stop) and their overload protection have been realized by automatic oil-filled star-delta starters АПМ3Т - 500/200.

The participation of the input, medial and executive starter elements in the power and driving circuit is respectively shown in figures 1a and 1b.

In principle, the motor-compressor unit basic configuration is shown in fig. 2.

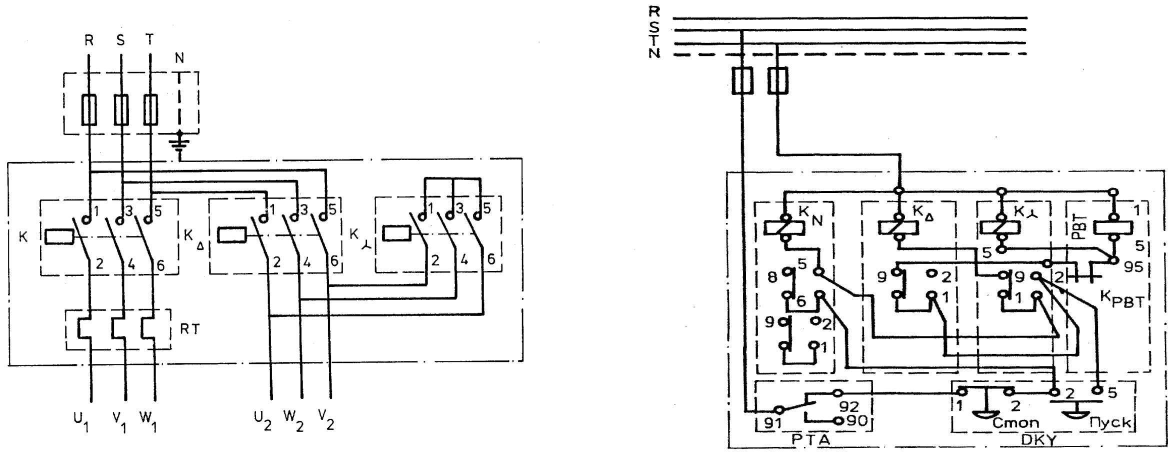
The manual start of each compressor is realized as follows:

A. At no excessive pressure of the air in the tank (i.e. after a long pause of the pneumatic energy consumers operation or after a compressed air deliberately emission in the atmosphere through the cocks K_2 and K_1) the motor starting process goes off at closed cock K_1 and opened K_2.
B. At a high (i.e. close to the operational) air pressure in the tank the motor starting process is preceded by the cock K_2 closing and K_1 opening. After the end of the process closing of the cock K_1 and opening of K_2 have to start simultaneously.

Usually, the compressors have been in continuously operation during the whole shift and the compressed air high consumption and the possibility for the number of the compressors in use to be changed have prevented the blow valve 8 (adjusted for bound pressure 0,65MN/m^2) actuation as well as the rise of the respective undesirable pneumatic energy losses.

For several years quarry FIRST OF MAY lands in the extended borders of the NATIONAL PARK VITOSHA, so the production and extraction activities have got more complicated due to the intolerable realization of blasting operations.

At this stage, the quarry extraction is brought to oversized blocks dragging out of its own old dumps and the production activity - to production of sets and free stone. This has also led to a sharp decrease in the quarry pneumatic management, which is now presented by two compressors (an operating and a reserve), an air conduit long about 600m and several jack hammers and pneumatic picks. The maintenance personnel number has been reduced as well and the only man, who is in charge of the compressor, is also responsible for the pneumatic management rest components maintenance.



a) *b)*

Figure 1

The attempt for decrease in the electric power consumption for the compressed air production by reduction of the compressor operation time (t_1) during the working shift to tree hours has not brought acceptable results because at the restricted consumers number and comparatively high compressor output (30 m^3/min) even small changes in the operating pneumatic picks number lead to the blow valve actuation and the compressed air emission to the atmosphere.

At the state of affairs, worsen by the continuous increase of the electric power price in the country, the governing body of MARBLE-GRANITE has assigned (by a contract with the Scientific-research Sector of the University of Mining and Geology “St. Ivan Rilski”) to the team of the authors the implementation of automatic control of the quarry FIRST OF MAY compressor station.

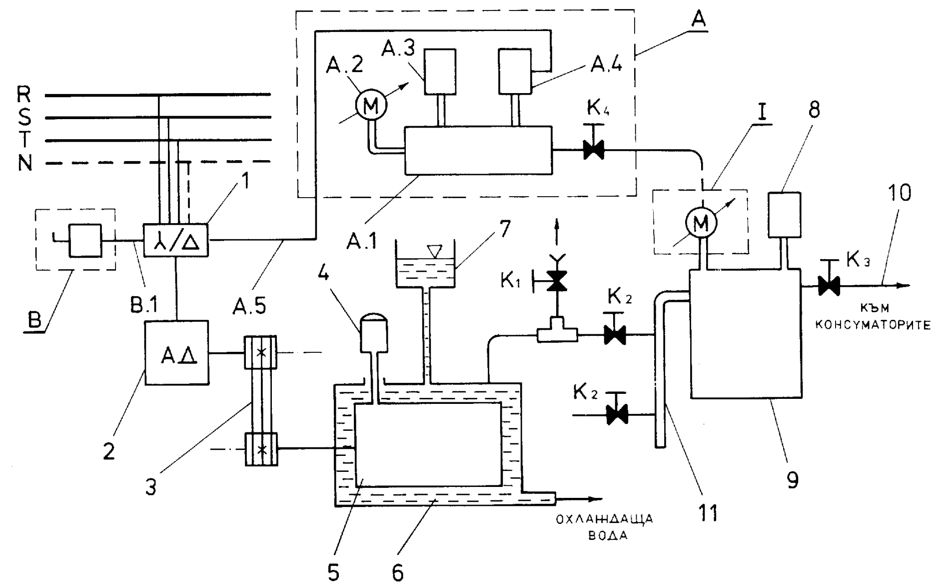


Figure 2. 1 - starter АПМ-3Т-500V/200A; 2 – induction motor; 3 – V-belt transmission; 4 – air filter; 5 – compressor; 6 – cooling water jacket; 7 –water tank; 8 – blow valve; 9 – air tank (receiver);10 – main air conduit; 11 – manifold pipe; A – control-measuring pneumatic device; A.1 – body-distributor; A.2 – manometer; A.3 – blow valve; A.4 – pressure regulator; B – duty switch changer; A.5 and B.1 – lines supplying control electric signals to the starter 1; I – manometer; K_1, K_2, K_3 and K_4 – manually controlled stop cocks.

The restricted corporation finances predetermined the realization of partial (in accordance with the criterion of compressed air pressure) compressor control automation at a maximal preservation of the existing compressor station configuration. The restricted contract price did not allow the transmission reconstruction by implementation of starting clutches, respectively the back valves delivery or remote controlled cocks substitution for the cocks K_1, K_2 and K_3 as well as the basic starting electric equipment replacement.

Under these circumstances the following changes (fig. 2) have been done in the motor-compressor set configuration:

1. The manometer I (see fig. 2) is removed;
2. Two new units supplying control electric signals to the АПМЗТ – 500/200 are implemented:
   - A duty switch changer B (fig. 2) consisting of medial relay and two-position switch;
   - A control - measuring pneumatic device A (fig. 2) consisting of a body-distributor A.1, manometer A.2, blow valve A.3, pressure regulator A.4 and stop cock K_4.

The general view of the unit A is shown in fig. 3 and the subunit A.4 (pressure regulator PH) mechanical diagram – in fig. 4. Both of them (i. e. A.3 and A.4) are components of the German industrial locomotives EL-2 pneumatic brake system. The former subunit A.3 has been calibrated and adjusted in laboratory conditions for bound pressure 0,67 MN/m^2, so in case of failure to repeat the action of the basic blow valve 8. The latter (A.4) has been subjected to a reconstruction, which founds expression in replacement of the coil spring $П_1$ (see fig. 4) and readjustment of the regulating screws B_1 and B_2, respectively of the left supporting plate 4. As a result the pressure regulator PH maximal switch range is increased from 0,2MN/m^2 to 0,4 MN/m^2. By the regulating screw B_2 and the adjustable right supporting plate 4 an upper bound of PH actuation exceeding to 0,6 MN/m^2 (PH allows p_{max}=0,9 MN/m^2) is measured in laboratory conditions.

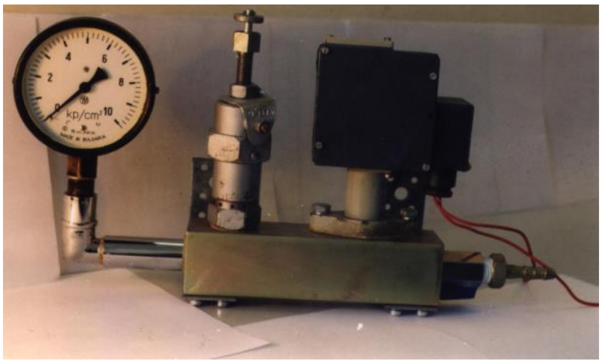


Figure 3

By the compressor test starts, carried out in industrial conditions by the available starter АПМЗТ – 500/200, but at different excessive pressure values in the receiver, has been ascertained that the upper pressure bound at which the starting process still ends successfully is 0,35 MN/m^2.

The changes in the starter АПМЗТ – 500/200 driving circuit and the whole compressor control circuit diagram are shown iin fig.5.

The diagram provides two control regimes – manual and automatic, which could be chosen and switched by the switch II.1.

At a choice of the first regime the switch has to be put in position “0” (this diagram position is shown in fig. 5) and the connection between the clamps 4 and 5 is restored by the movable contact $ПК_1$ of II.2. In manual control regime the compressor start and stop are realized by corresponding starter АПМЗТ – 500/200 buttons regardless of the III.1.1 and III.2 contacts condition. At this control regime a normal compressor operation is provided in cases, when preventive maintenance or repair works in the rest of the diagram components are carried out.

At a choice of automatic control regime the switch II.1 has to be put in position “I”. At this, the АПМЗТ – 500/200 buttons Start and Stop are shunted by the movable contact $ПК_2$ of II.2 and the compressor start and stop are transferred to the pressure regulator III.1.

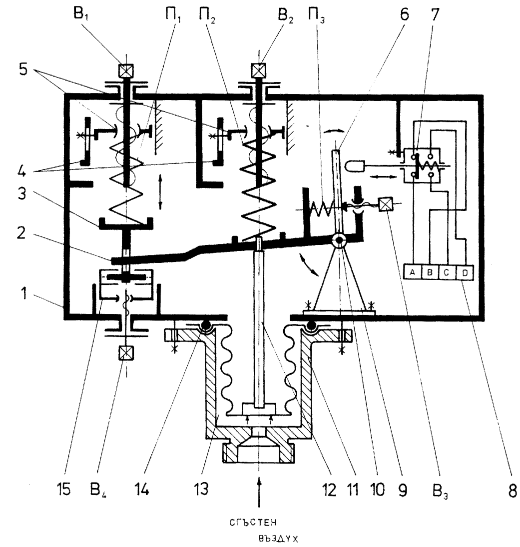


Figure 4. 1 – body; 2 – hinged frame; 3 – adjustable thrust; 4 – restrictive adjustable supports; 5 - tightening movable cross arms; 6 – hinged arm; 7 – limit switch; 8 – clamps; 9 – hinged prop; 10 – hinged axle; 11 – nipple-inlet for the compressed air; 12 – a stem transmitting the compressed air pressure to the hinged frame 2; 13 – corrugated metal sleeve; 14 – sealing ring; 15 – a movable frame changing the thrust 3 position; B_1, B_2, B_3 и B_4 – regulating screws; $П_1$, $П_2$ и $П_3$ – coil springs with adjustable pressure force.

The automatic control aims at the compressor operation discontinuation when the air pressure in the receiver has reached to 0,6 MN/m^2 and switches it on again, when the latter has fallen to 0,25 MN/m^2 (the bounds have been coordinated with the corporation specialists). The compressed air emission from the receiver to the atmosphere is prevented by a choice of the upper pressure bound with 0,5 MN/m^2 lower than the actuation level of the air tank blow valve and corresponds to the compressed air rated pressure for the manual pneumatic tools in use.

When the switch II.2 is in position "I" the contactor PM is actuated because 0 is supplied to the clamp 3 and to the clamp 2 – the phase R along the circuit : point 92 from I, the clamps 4,1, B, the closed switch of PH, clamps A and 2. The contactor PM closes its contact K_{PM} connected with the clamps4 and 5. The phase R reaches the point 5 from I through the clamp 4, the contact K_{PM}, the clamp 5, the movable contact $ПК_2$ and clamp 6 as a result of that the motor starts.

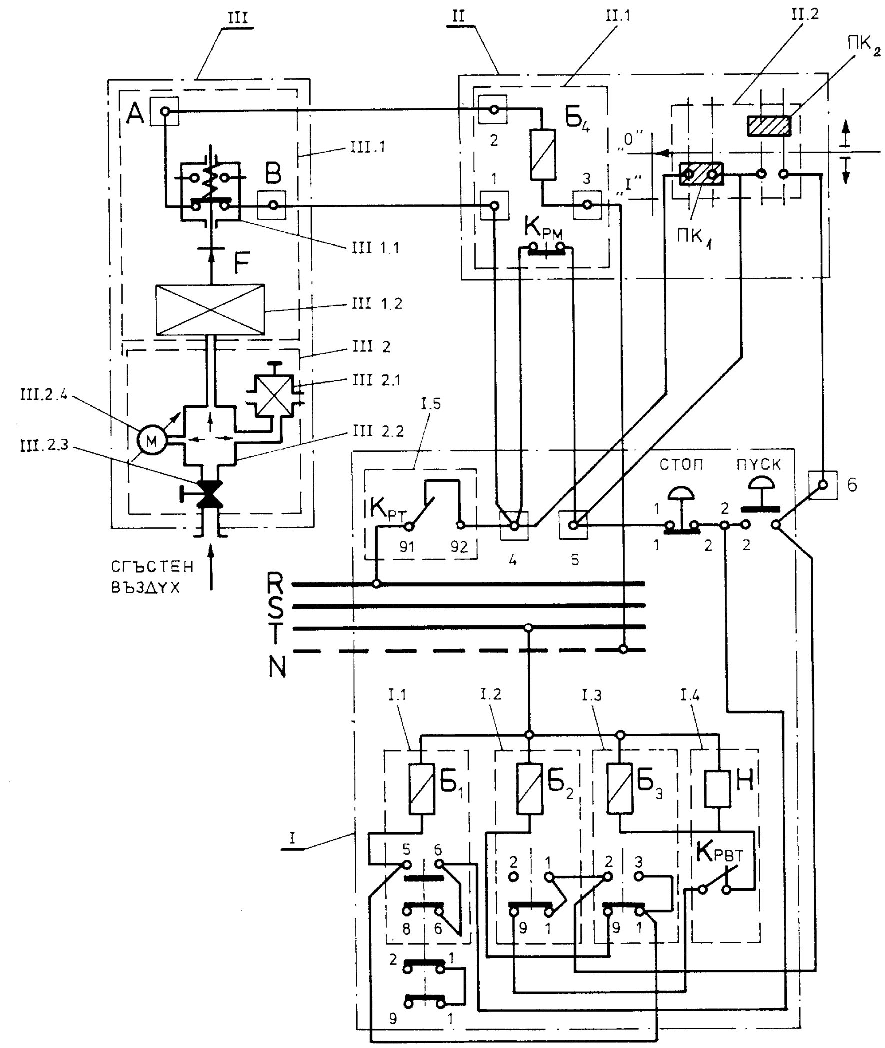


Figure 5. I – star-delta starter АПМ3Т – 500/200; I.1 – main starter contactor(K_N); I.2 and I.3 – starter switching contactors (K_S and K_D); I.4 – thermal timer (PBT); I.5 – thermal relay; II – duty switch changer; II.1 – medial relay(PM); II.2 – bistable switch; III. – control-measuring pneumo-electric block; III.1 – pressure regulator(PH); III.1.1 – limit switch; III.1.2 – regulator mechanical part; III.2 – pneumatic part of the block III; ; III.2.1 – blow valve; III.2.2 – body-distributor; III.2.3 – cock; III.2.4 – manometer; $Б_1$, $Б_2$, $Б_3$ u $Б_4$ – coils of the contactors K_N, K_S, K_D and PM; H – PBT heating element; - clamps of the clamp-rows II and III; F – total force created by the pressure regulator mechanical part.

At the pressure increase to 0,6 MN/m^2 the PH switches off the contactor KM coil by the circuit disconnection between the clamps A and B. The contact K_{PM} switches off and breaks the phase to point 5 from the starter I, which causes the motor turning off.

At the pressure fall to 0,25MN/m^2 PH closes its contact and actuates the contactor PM, which by the contact K_{PM}, supplies the phase to the point 5 and the motor starts. The process continues in an automatic regime controlled by the pressure change in the receiver.

In order the operating compressor to be emergency stopped in an automatic regime the bistable switch has to be turned to "0" (i.e. the manual control to be switched over) and next the Stop button to be pressed.

During the November, 2002, 72-hour recording test (by a recording instrument WATTREG 10) of the power consumed by the motor (N) has been carried out in order the technical means and the diagram operability to be determined.

A wattmeter record of the dependence N=f(t)at the compressor drive automatic control and absence of operating compressed air consumers is presented in fig. 6, and fig. 7

shows the graphic expression of the dependence p=f(t), constructed according to the manometer indications, which have been read at the same load and compressor control type. The two curves illustrate the normal operation of the diagram and equipment, realizing the compressor drive automatic control. In fig. 7 it could be seen that the compressor start and stop are steadily realized at reaching respectively the upper (p_{max}=0,6 MN/m^2=6at) and the lower (p_{min}=0,26MN/m^2=2,6at) values of the pressure in the receiver.

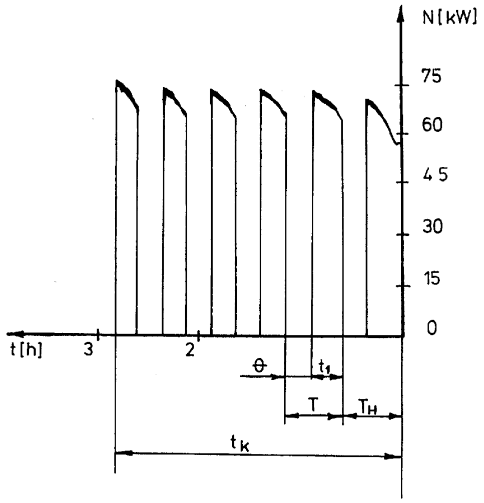


Figure 6

Fig. 7 shows that after the initial cycle (T_H) completion the rest of the time for the compressor use during the working shift (t_k) is divided in equal cycles (T). At this, the relation between t_1 and θ (these are the compressor operation and idle times during a cycle) is unchangeable.

The compressor automatic system has been delivered for exploitation in industrial conditions after the test completion (6th, November, 2002) and it has not shown any defects.

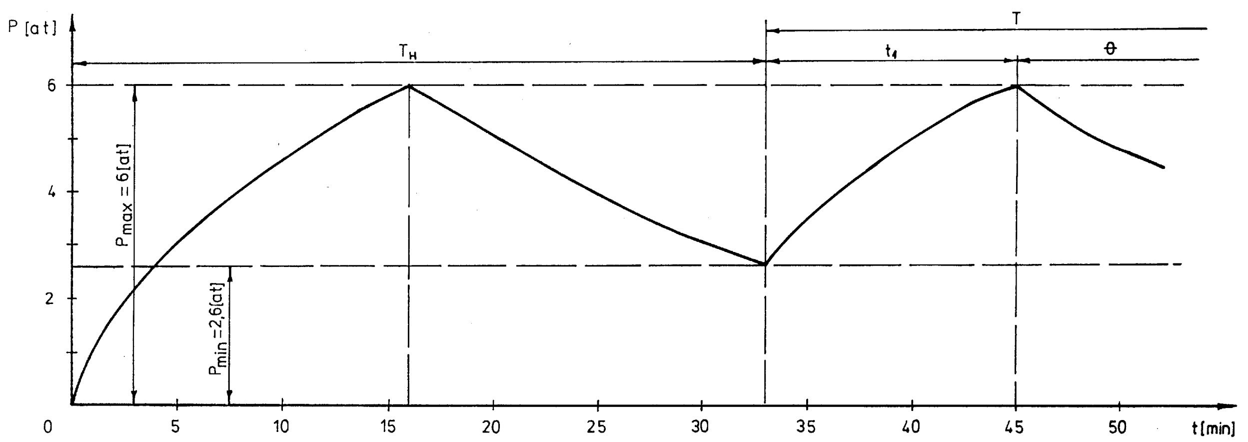


Figure 7

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