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Rock Displacement at Underground Coal Gasification

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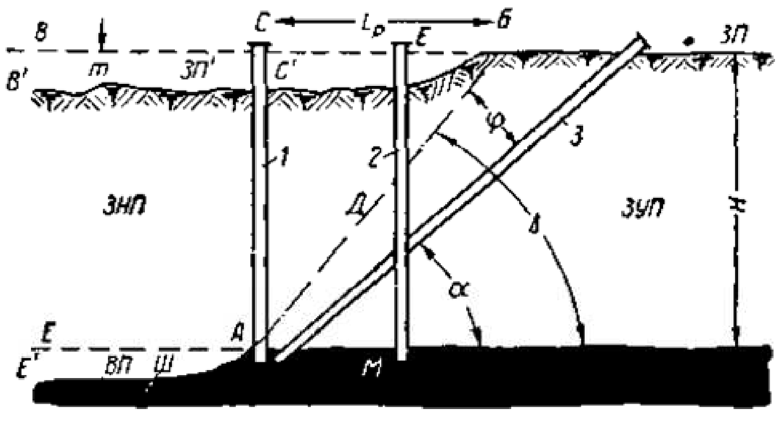
Annotation: In this article the process of underground coal gasification, its impact to the rock displacement and methods for controlling the roof stability is described.

Keywords: coal, mining, gasification, degassing, rock, displacement, filling, roof, bore hole, stability.

Degassing of a coal seam leads to surface subsidence. Magnitude and character of this subsidence in the core depend on thickness of degassed seam, depth of its bedding, an angle of incidence and properties covering a rock bed. Ruptures of mucks it is passed round under some angle from degassed spaces. Thus each vertical hole, which bottom-hole is on boundary line of degassed spaces, exposed to falling rocks and can be destroyed (Pic. 1).



Pic. 1. The circuit design of subsidence and failure of mucks above the degassed space of the underground gas generator and a working condition of holes of baring:

1,2-vertical holes of baring, a baring 3-inclined well;

Δ - an break angle of mucks;

φ - a borehole stability angle;

ЗНП - a zone of failure of mucks;

ЗУП - a zone of resistant rocks.

To ruptures of mucks over degassed space the surface placed in the area of В'С'Б ', and after subsidence of mucks over degassed space it already places in the area of В'С'Б. Magnitude of subsidence of a surface is characterized by a vertical size - m.

If in a coal seam being degassed space terminates, for example, in at point A, on a surface of land the termination of extending of subsidence, goes to a point removed on distance (L ρ) from a vertical projection of a point A on a surface (point C).

Line АБ connecting points of developing process of mucks ruptures in a coal seam A and on a surface of land Б, is called as a line of caving of mucks, it places under some angle to horizon (<Δ – an break angle) and is conditional boundary line between a zone broken or broken-down rocks and a zone of undisturbed rocks.

Thus the vertical hole 1 taken on boundary line degassed spaces A, at the approach through degassed spaces to borehole bottom will be in a zone of failure of mucks.

If the vertical hole is built up in caving zone boundary lines above ground, i.e. between points C and Б, for example in point E the part of its shaft, surveying will be also in caving zone. In that case when the hole will be go up outside of caving zone boundary line above ground to the right from a point all shaft will be in a zone of undisturbed rocks. Thus the borehole bottom will settle from degassed spaces on distance not less СБ. This distance with other things being equal will be that more than seam H and than less break angle Δ more deeply lies down: $Lp=H/tg\ \Delta$

In practice this distance is not always comprehensible for joining operations realization, i.e. For the joint of borehole bottom with degassed space.

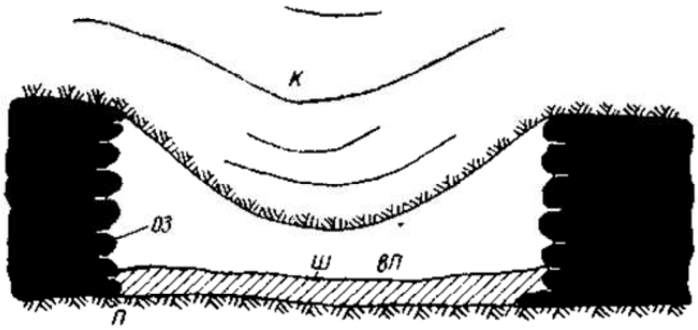
Besides, in the pic. 1 it is obvious, that shafts of vertical holes 1, 2 will always be in caving zone at boundary line approach degassed spaces to borehole bottom.

In the pic. 1 also it is visible, that under certain conditions all shaft of an inclined well 3 will be out of caving zone even at extending degassed spaces to a bottom-hole of such hole. That the inclined well shaft was in a zone of undisturbed rocks to the approach degassed spaces to its bottom-hole, it is necessary, that the angle of a location of well was less break angle i.e. that the condition $\Delta = \alpha$ was observed.

The angle making a difference between the break angle of mucks and an angle of a location of well φ, characterizes borehole stability extent: $\varphi = \Delta - \alpha$

At baring of coal seams of a heavy pitch and small thickness for conservation of a wellbore from destruction the angle of a location of well should come nearer as much as possible to an amount of inclination, and at a high thickness of a coal seam the angle of a location of well should be less amount of inclination, i.e. The formation exposing should be carried out from its soil.

For realization of process of an underground gasification of coals in the channel extremely the great value has character a roof caving, a floor quelling, quetch of a coal seam and its crushing under the influence of temperatures and a rock pressure.

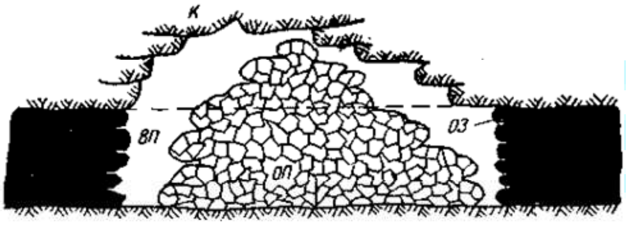


Pic. 2. Character of filling up degassed spaces as a result of a bending flexure of a roof rock.

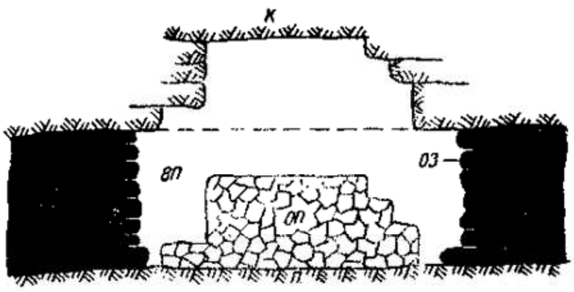
Discriminate three aspects of a change of state of a roof rock.

The first aspect - a bending flexure at which a roof rock caves in without essential rupture of a continuity and fill degassed space and by that maintain about constant value of a specific reactionary surface of coal in the gasification channel that promotes some constancy of character of traffic of blasting and gas (Pic. 2).

The second aspect - ruptures of a roof rock with partial filling up degassed space which occurs owing to crushing of a roof rock at ruptures. Thus the part degassed spaces is filled with fragments of these mucks and by that considerable resistance for blasting and gas pass is created. Finally it can promote also to development of the factors positively influencing a current of process of gasification in the channel, as well as at a roof deflection (Pic. 3).



Pic. 3. Character of filling up degassed spaces as a result of a bending flexure of a roof rock



Pic. 4. Character of filling up degassed spaces at ruptures of a roof rock: ОП - collapsed mucks

The third aspect - ruptures of the roof rock, not leading to maintenance approximately on a fixed level of value of a specific reactionary surface of coal in the channel of gasification and calling emersion of roundabout channels for blasting and gas pass (Pic. 4).

Naturally one aspect of a roof caving can develop in other aspect and on different sections of length of the channel various aspects of strain and ruptures of adjacent strata can occur.

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On character of affecting the bulging of mucks of soil on coal gasification process in the channel should be equated to a bending flexure of a roof rock.

Thus, filling up degassed spaces of the underground gas generator occurs as a result of various aspects of strain and ruptures of adjacent strata, the rests from gasification of a coal seam, drosses and underground waters. Specific gravity of the resulted factors in filling up the degassed spaces is various and depends not only on geological conditions and properties of adjacent strata and a coal seam, but also from system of flame operations and features of conducting process of gasification.

In development degassed spaces of the underground gas generator are discriminated by two stages:

First stage - development degassed spaces without ruptures of adjacent strata;

Second stage - development degassed spaces in conditions ruptures of adjacent strata.

Mucks deprived of a support from a coal seam, on the square degassed spaces get out a stage existing before balance and under the influence of a rock pressure in the beginning cave in, and then in them there are fractures and, at last, they break and cave in, filling thus degassed space.

The termination of the first stage of development degassed spaces for various geological conditions steps at different width degassed spaces, i.e. at different value of an original roof-caving increment of mucks.

In the second stage of development degassed roof rock spaces hang on them not in the form of "beam" with points of support on its ends, and in the form of the "console" fixed by one end at a flame bottom-hole.

On a measure degassing of a coal seam the flame bottom-hole moves, the gasification channel extends and the length of overhang from a roof rock increases. Thus the roof-caving increment of mucks is less, than in the first stage of development degassed spaces.

Owing to dissimilarity of properties of rocks and a granularity in advancing of flame bottom-hole ruptures of a console from mucks occurs not at once on all length of the channel of gasification, and on separate sections of its length.

As a result of it at the channel of gasification of considerable length its width lengthwise the channel is various and fluctuates in limits from magnitude of a roof-caving increment of mucks at bracket support to the minimum value of a console after its ruptures.

The roof caving in is more depends on structure of the layers making a roof rock, i.e. from their thickness and a cleavage.

Character ruptures of a roof rock on a measure degassing of a coal seam differs a little from character their ruptures at a getting of a coal seam - mine mining.

At an underground gasification occurs gradual degassing of a coal seam by its thickness and at mine mining bed separation occurs along all its thickness. In this connection at underground gasification development of process of rock deformation of roofing occurs gradually, increasing while degassing coal seam by thickness.

Ruptures of a roof rock at degassing a coal seam are promoted also by the thermal factor under which act of muck can delaminate, crack, distend and is flashed off.

On separate sections of the channel of gasification where heats dominate, the bottom layers of roofing can be flashed off, and then the roofing hangs down over a flame bottom-hole in the form of a plastic shell. The shell from the softened roof rock lengthwise the gasification channel in separate places is broken off by collapsed

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pieces of muck which in different stages of operation of the channel of gasification to a miscellaneous fill its cross-section.

At gasification at Lisichensk station a seam is degassing by a total output and degassed space is densely enough filled with a roof rock and drosses. The volume of hollows in degassed space fluctuates within 20-30 %. In region blowing holes it fluctuates within 10-35 %, and in region gas discharge holes accordingly 8-12 %.

Not all hollows among the collapsed mucks are interconnected among themselves. Forms and sizes of hollows in degassed space are various. In region blowing holes the volume of separate hollows fluctuates from 0,5 to 1 $м^3$, attaining sometimes 3-5 $м^3$.

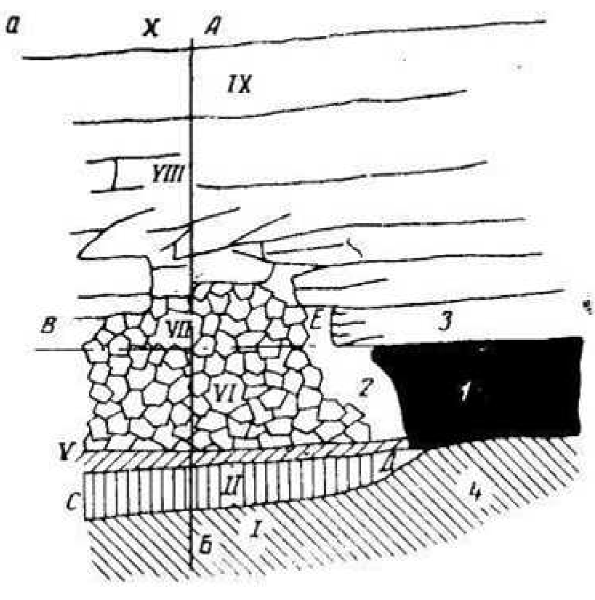
In region degassing holes the volume of separate hollows does not exceed holes 0,5 м3, attaining sometimes 1 $м^3$. The filling up extent degassed a solids makes spaces for region blast holes of 80-85 % and for region gas discharge holes of 60-65 %.

Except the collapsed mucks, the volume part degassed spaces is filled with drosses. Drosses in degassed space are formed as a result of alloying of a roof rock with ashes and charks the rest of a coal seam.

Mining by underground gas generators at South-Abinsk station of “Podzemgas” it was discovered that only in blowing hole area there is a channel With diameter 1,5 m, and after by the stream gas being moved by a system of channels of smaller diameter, which are a result of roofing crush and smashing of coal seam. [4].

Degassing of brown coal seam with a difficult structure proceeds on separate members with drawing in process of gasification of members of a seam with ash content even to 70 %.

Above ground around the underground gas generator the pipelines network for blasting and gas and a number of other land constructions places. Therefore surface conservation in region degassing of a coal seam as one of the important factors, able accordingly to influence parameters of process of an underground gasification of coals and on conditions of its industrial service has an important mining.



Pic. 5 Zonality in failure of rocks around degassed space.

At gasification of a flat-lying coal seam. 1 coal seam, 2 channel of gasification. A 3-seam roof. 4 - seam floor 1-1-characteristic areas or zones in structure of adjacent strata around degassed space. I - a zone of bases in a natural condition, II - a zone warmed up bases, III - a soil zone of rock fracture, IV - a zone of decayed rocks of soil. V - a zone of drosses, VI - a zone of mixture of the rests from gasification of a coal seam with roofing and soil decayed rocks. VII - a zone of decayed rocks of a roofing. VIII - a zone of a cleaved burden. IX - a zone of a burden in a plastic deformation condition. X - a zone of a burden in a natural condition.

In the pic. 5 extending of separate areas - zones of a different rate of decay of adjacent strata over degassed space is shown.

Therefore those from zones of destruction of mucks which attain in the produced conditions of a surface, will characterize as well extent of failure of a surface. In region degassed coal seam's behavior it is possible to discriminate four aspects:

1st type - the surface practically does not change the rule at degassing of a coal seam;

2nd type - a surface by a way of coal seam degassing smoothly caves in over degassed space without visible failures of a continuity of soil;

3rd type - surface depressing over degassed space calls emersion of fractures;

4th type - over degassed space occurs depressing of a surface of land with the advent of fractures and craters. A crater in this case name a funnel formed in a surface which is connected with degassed space through a layer of randomly collapsed mucks.

Character of destruction of a surface over degassed space mainly depends on a relationship of a stratum of a burden and thickness, on which coal seam is degassing, and also properties of a burden and bedding conditions.

In the conditions of Angren station Podzemgaz at average thickness of installed gas coal seams and a considerable stratum of a burden over degassed space the first two aspects of failure are above ground observed.

In geological conditions of basin near Moscow where a relationship between a burden and thickness of an installed gas coal seam make 10-15, fractures in soil are manifested not only a surface bending flexure over degassed space, but also and.

One of prominent features of depressing of a surface over degassed space in the conditions of a coal field Situated near Moscow is slow and smooth developing process of this process in comparison with surface subsidence over seam sections at its mine mining (pic 6).

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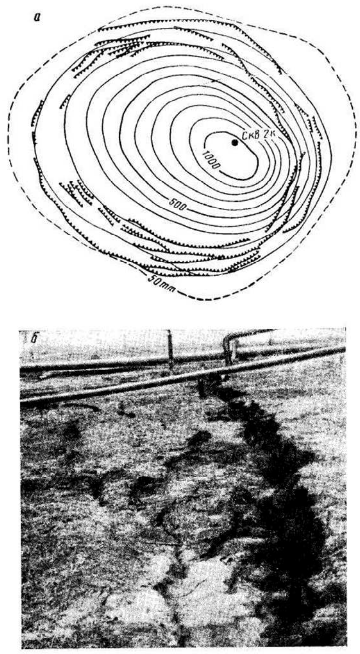

Pic. 6. Shifting of a surface in region of degassing horizontally lying down section of a seam of a brown coal with flawing: *and - the plot of a surface of land with hypsographic curves around - the vertical hole 2 to, - fractures above ground; - appearance of subsidence of a surface over degassed space of the underground gas generator with flawing.*

For example, at mine bed separation there is a rough subsidence of a roof rock, and the surface cakes almost on magnitude, equal to a seam thickness, with velocity to 300 mm/day. On coal seam degassing, magnitude of subsidence of a surface attains 30-40 % of a seam thickness and proceeds with velocity of 40-80 mm/day.

In geological conditions of South Abinskiy station Podzemgaz (the gas generator № 1) the surface over degassed space manifests all four aspects of strains. The surface rate of subsidence in an observed case made no more than 25 *mm/day*. Formation of craters on a land surface was preceded for 5-10 days by increment of rates of subsidence of a surface. Emersion on a surface of land of craters called sharp accretion underground losses of gas which decreased to initial after filling up craters muck and clay and fillings up with a clay mud.

For conditions of Angren station also as well as at other stations shifting a roof rock it is caused by process of degassing of a coal seam not at once on all thickness, and gradually have been degassing in the following sequence (Pic. 6). Taking into consideration laws of distribution of temperature in a coal mass round the channel, the temperature in which lengthwise fluctuates from 1100 to 600°C, there is as though a layering machining of coal (Pic. 7). At a development of a part of coal and an exposure of the squares exceeding resistant to exposures of coal, it is observed coal ruptures in degassed space (the second stage, Pic. 7).

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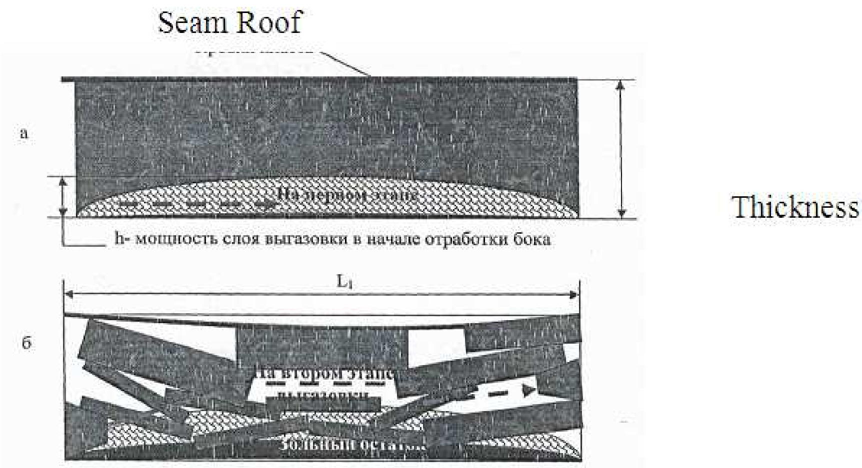
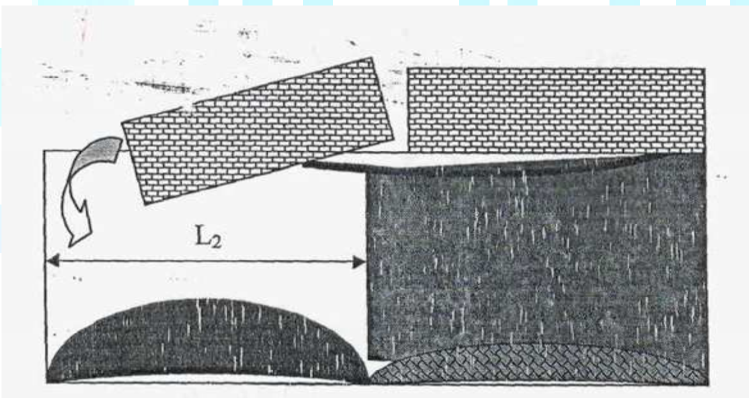


Pic. 7 Destruction of coal at degassing body-section

According to institute "VNIIPodzemgas", carrying out researches at various stations "Podzemgas", and then confirmed with Open Society "YEROSTIGAZ" operational experience, (h) thickness of a layer degassing depends on volumes of submitted blasting (Q). Controlling a delivery volume it is possible to achieve working of a coal seam on all thickness (Pic. 7). It in turn at intensity accretion of degassing will lower a rate of travel of flame bottom-hole $L_1 > L_2$.



Pic. 8. Ruptures of a roof rock while degassing by all seam’s thickness

Way of working of a coal seam - it is body-section or by all thickness influences processes of a straining of a burden.

In case of level-by-level working off as coal less resistant to, coal ruptures occurs at the smaller square of an exposure. However its chaotic ruptures leads to creation of the time basis for a roof rock. And a pliability of the hulled coal predetermines gradual roof caving at a great distance, which reduces a degree of fragmentation. Decrease of a degree of fragmentation leads to acceleration of transfer of vertical strains from a coal seam to a surface that creates conditions to formation of vertical fractures on which gas losses can be observed.

At working of a coal seam by all thickness, it is observed chaotic ruptures of mucks lying down in a seam roof that promotes formation of a zone of broken-down rocks over a goaf and absence of vertical fractures

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connecting a goaf with a land surface. In this case there are no gas losses though in an initial stage of formation of caving zone alterations of quality of gas PGU are possible.

Knowledge of regularity of formation of process ruptures of the earned additionally coal or mucks allows to influence a condition of the earned most additionally rock mass, by application of certain processing methods. Besides this knowledge allows to predict scenarios of behavior of hills and all phenomena accompanied by it - charging box shifting formation on land surfaces, possible water inrushes from water-bearing horizons, losses of gas UCG, leaving of a wash over liquid and drilling assembly undershootings, etc.

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