Cyclic pneumohydraulic treatment by means of nitrogen may be regarded as a development of the method of coal-bed hydrodisintegration in which one of its most challenging stages is intensified: the removal of the working liquid and gas from the degassed bed after treatment.

The aim of nitrogen-based disintegration is to improve coal-bed degasification by increasing the phase permeability of the bed for methane. This is accomplished by intensifying borehole extraction after hydrodisintegration of the coal bed.

In pneumohydraulic treatment, essentially, the working liquid and gaseous nitrogen are introduced in the bed alternately, to create additional pressure in the cracks within the bed until hydrodisintegration and saturation with water are complete, facilitating the extraction of water through the borehole to the surface.

The effectiveness of borehole extraction is increased as follows. Prior to bed disintegration, a gas cushion is created in the perforation zone, and in the subsequent water injection the nitrogen mixes with the hydrodisintegration liquid in the borehole. The solubility of nitrogen in water is fairly low: around 2:1 at 20 MPa and 30°C, in volume units reduced to standard conditions. This means that excess nitrogen remains in the bed in the form of bubbles.

At the end of hydrodisintegration, the pressure in the borehole is reduced; correspondingly, the nitrogen bubbles expand, pushing the working liquid out of the bed and back into the borehole. In the borehole itself, the expanding nitrogen bubbles force the liquid to the surface.

The ratio of the injected water and nitrogen volumes required depends on many factors: the depth of the bed, its hydropermeability, and its elastic properties. The minimum volume of gas per m³ of water for the conditions of the Karagandinsk field varies in the range 20-50.

A volume ratio of less than 20 cannot ensure expulsion of the working liquid, since, even disregarding frictional forces at the borehole wall, the propulsive force is less than the gravitational force on the liquid. The wide range of nitrogen/water ratios is due to the wide range of applications of the method, especially the range of treatment depths, which influences the hydrostatic pressure and hence the gas-bubble volume and the expelling force, and also to the variation in bed pressure, which helps propel the working liquid to the surface despite the friction at the crack walls.

The piston effect allows nitrogen volumes equal to 20-50 times the water volume to be attained, as follows.

Nitrogen is injected into the bed under a pressure close to the hydrodisintegration pressure of the bed. The nitrogen temperature is close to the bed temperature.

After opening the borehole, the bed pressure falls to the pressure of the water column in the borehole

$$P_2 = P_0 + \gamma \cdot H,$$

where $P_0$ is the atmospheric pressure, Pa; $\gamma$ is the density of water, N/m³; H is the bed depth, m.

Correspondingly, the nitrogen expands and forces the working liquid from the borehole and bed to the surface.

Before the borehole is opened, the nitrogen in the bed is at a pressure

$$P_1 = P_{st} + \gamma H + P_0,$$

where $P_{st}$ is the steady pressure when pumping the water, Pa.
In these conditions, the volume occupied by nitrogen in the bed is

\[ V_1 = \frac{V_{N_2} \cdot P_0}{P_{st} + \gamma H} \text{ m}^3; \]  \hspace{1cm} (3)

and the work done in expelling the water is

\[ A = \int P(V) dV = P_1 V_1 \ln \frac{V_{N_2}}{V_1} = P_1 V_1 \ln \frac{P_{st} + \gamma H + P_0}{P_0 + \gamma H}. \]  \hspace{1cm} (4)

Suppose that all the work done by the expansion of nitrogen is consumed in expelling water from the borehole

\[ A = V_d \cdot \gamma \cdot H \text{ J}, \]  \hspace{1cm} (5)

where \( V_d \) is the volume of the displaced water, m\(^3\), and thus

\[ P_1 \cdot V_1 = P_0 \cdot V_{N_2}. \]  \hspace{1cm} (6)

Substituting Eq. (6) into Eq. (4)

\[ P_0 V_{N_2} \ln \frac{P_{st} + \gamma H + P_0}{P_0 + \gamma H} = V_d \cdot \gamma \cdot H. \]  \hspace{1cm} (7)

Hence

\[ \frac{V_{N_2}}{V_d} = \frac{\gamma H}{P_0 \ln \frac{P_{st} + \gamma H}{P_0 + \gamma H}}. \]  \hspace{1cm} (8)

However, the aeration of the water must be taken into account, since the pressure drop on opening the borehole is not to \( \gamma H \) but to \( \gamma_1 H \)

\[ \gamma_1 = \frac{V_d \cdot \gamma + V_{N_2} \cdot \gamma_{N_2}}{V_d + V_{N_2}}, \]  \hspace{1cm} (9)

where \( \gamma_{N_2} \) is the density of nitrogen (standard conditions), N/m\(^3\).

Taking into account that the method is used at depths of 500-1000 m, where \( P_{st} \) may vary from 10 to 25 MPa, it follows that

\[ \frac{V_{N_2}}{V_d} = 20 - 50. \]

In specific geological and hydrological conditions, this parameter is refined by calculation.

The first exploratory experiments on coal-bed disintegration by means of gaseous nitrogen, conducted at boreholes 35 and 41 in the Kostenko field of the Karagandaukol' Production Combine, confirm the effectiveness of the technological setup and the fundamental strength of the engineering approach.

These experiments confirm that the injection of a relatively insoluble gas with the hydrosdisintegration medium intensifies the displacement of the liquid from the bed through the borehole and increases the gas yield from the bed. This follows from a comparison of the water and gas yields from boreholes 35 and 41 with those from other hydrosdisintegration boreholes in the same field at which nitrogen was not injected: in the 15 months after the opening of borehole 35, the water extraction was 22% greater than the mean extraction in an analogous period from boreholes 30-44 in the same part of the field; for borehole 41 in a 6-month period, the corresponding figure was 131%.

Nitrogen injection increased the mean methane yield from boreholes 35 and 41 by a factor of 2.5 in comparison with other boreholes in the same section of the field where nitrogen was not injected. On the basis of the initial data obtained, recommendations have been developed on the optimal treatment parameters. The experimental program also includes studies of hydrosdisintegration at boreholes 26 and 27 of the Skourskaya mine in the Karagandaukol' Production Combine.

The aim of the experiment at borehole 26 is to test cyclic hydrosdisintegration using gaseous nitrogen with increase in the number of cycles to increase the effectiveness of borehole extraction; this is facilitated by a more uniform distribution of the liquid and gaseous agents over the treatment zone.