Irrigation is an important process in the production system employed for well development; approximately 30% of total expenditures are directly, or indirectly associated with this process. When the flow rate of flushing fluid is less than ideal, the face of the well is not cleaned in the required manner, secondary pulverization of the rock separated from the mass occurs, hammer-operating indicators are appreciably degraded, and the number of hammer impacts and the volumes of descending-ascending operations and the consumption of materials and energy resources are increased. The wiring of wells at minimum cost to the design depth without emergencies and complications is impossible when the formula for flushing agents is inappropriate, or their circulation parameters are irrational.

Powering of mechanical drilling with hydraulic face motors depends entirely on the irrigation parameters. The required irrigation supports the productivity of the drill rig as the wells are deepened. Slush pumps are the largest power consumers and the most massive subassemblies of the drill rig; they therefore affect the capacity of its main drive, and its mobility and technical level on the whole. Use of rigs with excess pump-rating parameters, which are actually impossible to realize, lead to an increase in the net cost per meter of bore and outlays for well development (operating expenditures, assembly and transport costs, and depreciation charges). Equipment parameters that are inadequate as compared with production demands increase time-dependent expenditures. It is therefore necessary to ensure a certain optimal combination of pump-group parameters, which corresponds to a minimum of direct and indirect expenditures associated with irrigation.

Methods employed to determine pump-group parameters for drill rigs can be conditionally divided into production [1-4] and standard [5-9] parameters. In developing and supplementing them, Mironov [10] devised a statistical method based on world experience with the production and use of drill rigs. It was assumed, moreover, that the developers and manufacturers of slush pumps build their product with the aim of maximum fulfillment of requirements established by consumers with allowance for active specifications.

The following parameters were selected for the investigation: the number of slush pumps \( Z_p \) as component parts of the drill rig (in the manufacturer’s complete set); the rated unit \( N_{sp} \) and total \( N_{sp}Z_p \) capacities of the slush pumps; and the rated maximum operating pressure \( P_{\text{max}} \) developed by the pumps. The purpose of the research was to determine the pump-group parameters that best satisfy modern requirements of consumers in well development.

According to standard [5], Class 1 and 2 rigs are furnished with a single pump (from considerations of maximum mobility), and rigs belonging to Classes 3 through 7 with two pumps. Three pumps are furnished on rigs in Classes 8 through 10 (the third is considered a reserve pump); three pumps are basic equipment on Class 11 and 12 rigs. The standard regulation concerning the number of slush pumps \( Z_p \), which differs somewhat, but is sufficiently close to the regulation described, is established by standard [7]. These standards have not been expanded to include air-transportable rigs in which rigid restrictions on the weight of the unit being air-lifted require that a large number of pumps with a lower unit capacity be used.

According to [6], the standard unit capacities \( N_{sp} \) of the pumps represent a discrete series – geometric progression with a denominator of 1.25 and terms ranging from 375 to 1,180 kW. The last four terms of the series agree with established stan-
Twenty empirical equations were derived as a result (Table 1). To come by replacing the parameters of the functions with extrema automatically assumes the existence of an optimum for certain values of the argument. The effect of their argument on the numerical values of the functions, the latter were calculated for boundary values of the argument; the construction of the well and the shaft, regulation of the solid-phase content in the flushing agent (restricts an increase in its concentration), and power transmission to the hydraulic face motor, generation of the required hydraulic power, and the velocity of the outflow and the pulsation of the flow of flushing agent at the outlet from the orifice of the jet hammer.

The maximum pressure $p_{\text{max}}$ corresponds to the maximum energy delivered to the circulation system from the slush pumps per unit volume of flushing agent. The hydraulic resistance of the circulation system is proportional to the depth of the well; the pressure $p_{\text{max}}$ therefore limits the conditional drilling depth $L_{\text{con}}$ of the wells, for the irrigation of which a pump group is suitable (with other conditions equal). It follows, therefore, that the parameters under consideration are those assigned for the purpose and productivity of the drill rigs.

Rated characteristics $(L_{\text{con}}, N_{\text{sp}}, p_{\text{max}}, Z_{\text{p}})$ of 125 series-produced models of drill rigs served as initial information for the investigation; of these models 53, 38, and 34 were manufactured by American, Russian (Soviet), and Roumanian firms, respectively. Parameters established by standards [5, 7] were examined to assess the extent to which standard requirements were fulfilled. The indicated characteristics were subject to mathematical processing using the procedure presented in [11].

For purposes of nomenclature unification and reduction and an increase in production volume, all manufacturers furnish analogous drill rigs (which are distinguished only by the type of main drive) with similar pump models. For certain models, limitation of the parameter $N_{\text{sp}}Z_{\text{p}}$ by the drive capacity of the pumps made it necessary to divide the pumps analyzed by type of drive. The pressure $p_{\text{max}}$ is limited only by the rated value, and can even be realized with the maximum-pressure regime when there is a deficit in drive capacity. In studying the parameter $p_{\text{max}}$, therefore, the set of models under consideration was divided only in terms of features inherent to the different manufacturers. The range of selection of the parameters analyzed was defined by the following boundaries:

- $1600 \leq L_{\text{con}} \leq 15250$ m; $294 \leq N_{\text{sp}}Z_{\text{p}} \leq 5000$ kW; $20 \leq p_{\text{max}} \leq 70$ MPa; and $1 \leq Z_{\text{p}} \leq 3$ for rated values (for their determination, attention was focused on both the basic, and reserve pumps); and
- $1000 \leq L_{\text{con}} \leq 16000$ m; $295 \leq N_{\text{sp}}Z_{\text{p}} \leq 7360$ kW; and $20 \leq p_{\text{max}} \leq 105$ MPa for standard values (for the $L_{\text{con}}$ interval, the larger value was assigned on the basis of standard [7]).

The principal parameter of the drill rigs – the allowable load on the hook – was excluded from the analysis, since its relation to the parameters under consideration is indirect, and the numerical value depends on the construction of the wells and the layout of the drill pipe string. Both rated, and also standard values of the parameters $N_{\text{sp}}Z_{\text{p}}$ and $p_{\text{max}}$ are certain functions of the conditional drilling depth $L_{\text{con}}$, as a result of which their numerical values are incommensurate for the different classes of rigs, and separation of initial-data selections by class deprives them of a degree of representation. This difficulty was overcome by replacing the parameters $N_{\text{sp}}Z_{\text{p}}$ and $p_{\text{max}}$ by their specific values $N_{\text{sp}} = N_{\text{sp}}Z_{\text{p}}/L_{\text{con}}$ and $p_{\text{sp}} = p_{\text{max}}/L_{\text{con}}$ (here $L_{\text{con}}$ is a unit of rated conditional drilling depth). Initial-data selections were verified as to whether their members belonged to a single general set.

The purpose of the mathematical processing of initial information, which was conducted in two successive steps [11], was to establish relationships of the form $N_{\text{sp}} = f(L_{\text{con}})$ and $p_{\text{sp}} = p_{\text{max}}/L_{\text{con}} = \varphi(L_{\text{con}})$, which approximate two-dimensional initial samples with the lowest standard deviations and reflect the mean-statistical level attained with respect to individual manufacturers, plants with monotypic drives, and with respect to the set of drill-rig models analyzed on the whole. Twenty empirical equations were derived as a result (Table 1).

Monotonically increasing (decreasing) continuous functions were selected for the approximation, since selection of functions with extrema automatically assumes the existence of an optimum for certain values of the argument $L_{\text{con}}$. Low-order coefficients served as the argument in parabolic and exponential types of approximating expressions. To assess the extent of the effect of their argument on the numerical values of the functions, the latter were calculated for boundary values of the argument; the impossibility of linearization of the indicated relationships and their reduction to the form $f(L_{\text{con}}) = \text{const}$ and $\varphi(L_{\text{con}}) = \text{const}$ while retaining an acceptable accuracy is demonstrated. For practical use of empirical equations (1)-(20), substitution of known values of the argument $L_{\text{con}}$ in the equations enables us to compare the products of the various manufacturers, estimate the parameters of an arbitrary model, and select an appropriate supplier.