Much information is available in the literature on the increases in gasoline octane number that can be obtained by adding water in the form of an emulsion or by injecting water into the intake pipe [1-5]. When we consider that the yield of A-76 gasoline from crude oil is 10% greater than the yield of AI-93 gasoline, it becomes clear that the addition of water may be regarded as one of the means for expanding the resources of fuel for spark-ignition engines through the use of gasolines with lower octane numbers. It has been noted [1-6] that the use of water does not reduce the power of gasoline engines, whether the water is injected separately or whether it is supplied in the form of a water/gasoline emulsion (WGE) all the way up to a 1/1 gasoline/water weight ratio.

A calculation based on the assumption of instantaneous combustion at top dead center, with a number of other simplifications [7], showed that with a compression ratio of 8, a drop in power begins when the concentration of water in the WGE is increased above 70%, and that with a water concentration of 58%, a 4% gain in power is observed. As the compression ratio is increased, the point at which the indicator power starts to drop off is shifted toward higher concentrations of the WGE. In experimental studies in single-cylinder units [1-3, 5-7], a 2% increase in power has been observed. The work reported here represents a test of the above concepts in modern full-scale carburetor engines, one with a displacement of 1500 cm$^3$ and a compression ratio of 8.8, and the other with a displacement of 7000 cm$^3$ and a compression ratio of 6.5. This work was also aimed at determining the optimal content of water in the WGE and evaluating the feasibility of increasing the engine efficiency, i.e., improving the fuel economy by the use of the WGE.

The 1500-cm$^3$ engine was tested on AI-93 gasoline and on WGEs with the following compositions: a) 10% water, 1% nonionic surfactants, remainder AI-93 gasoline; b) 20% water, 2% surfactants, remainder AI-93 gasoline; c) 40% water, 3% surfactants, remainder A-76 gasoline. The 7000-cm$^3$ engine was tested on A-76 and AI-93 gasolines and also on WGEs formulated from A-76 gasoline with water contents from 0 to 40% by weight. In calculating the engine efficiency, the added surfactants were considered as fuel. Although the stoichiometric ratios for the particular surfactants that were used were different from those for gasoline, the effect of the surfactants on the excess air coefficient was less than 1%. This effect can be neglected in plotting the "adjustment" characteristics as functions of the mixture composition. The effect of the surfactants on the knock resistance of the gasolines was also quite small, and can be neglected within limits of ±0.5 octane number.

The test stands were instrumented for measurements of the fuel consumption rate, air intake rate, torque, engine speed, spark advance angle, and concentrations of toxic components in the exhaust gas. For the 1500-cm$^3$ engine, "adjustment" characteristics were determined for the WGE at three speeds (42, 58, and 75 rps) under constant-power conditions. For the 7000-cm$^3$ engine, the characteristics were determined at five speeds (30, 35, 40, 45, and 50 rps) at constant throttle.

Typical "adjustment" characteristic curves are shown in Fig. 1. Under other speed and load conditions, these characteristics for the two engines were analogous. When operating on emulsions with 20% water, the engine efficiency on rich mixtures was practically the same as on straight gasoline. For the 1500-cm$^3$ engine on lean mixtures with the emulsion containing 20% water, the efficiency was 1-3% below that obtained on straight gasoline. Operation on 40% WGE gave much lower lean-mixture efficiencies in both engines. The specific fuel consumption on the emulsions was inversely proportional to the content of gasoline in the emulsion.

Since the efficiencies on the emulsions and on the straight gasoline are practically identical within a certain range of adjustment, it is obvious that the specific consumptions of these fuels (gasoline plus surfactant) will also be identical. The narrowing of the adjustment limits on lean mixtures is accompanied by a sharp
Fig. 1. "Adjustment" characteristics ($\eta_e$ is the engine efficiency; $g_e$ is the specific fuel consumption) relative to mixture composition: a) 1500-cm$^3$ engine, speed 75 rps, torque 44.2 N-m; b) 7000-cm$^3$ engine, speed 30 rps, full throttle; $\eta_e=f(\alpha); \quad \eta_e=f(\alpha); \quad g_e=f(\alpha); \quad g_e=f(\alpha); \quad c_{CO}=f(\alpha); \quad c_{NO}=f(\alpha); \quad c_{CH}=f(\alpha); \quad 1)$ Al-93 gasoline; 2) WGE (20% water + Al-93); 3) WGE (40% water + A-76); 4) Al-93 and A-76 gasolines; 5) WGE (17% water + A-76); 6) WGE (33% water + A-76).

Fig. 2. Load characteristics: a) 1500-cm$^3$ engine, speed 58.5 rps; b) 7000-cm$^3$ engine, speed 30 rps; $\eta_e=f(N_p); \quad \eta_e=f(N_p); \quad \eta_e=f(N_p)$; $1)$ Al-93 gasoline; 2) WGE (20% water + Al-93); 3) WGE (40% water + A-76); 4) A-76 and Al-93 gasolines; 5) WGE (24% water + A-76).

increase in the discharge of unburned hydrocarbons (CH) on lean mixtures as the water concentration in the WGE is increased. With rich-mixture adjustment, the increase in unburned hydrocarbon discharge is 20–50% for the 20% emulsion and 100–200% for the 40% emulsion (compared to straight gasoline). The dependence of the carbon monoxide (CO) concentration in the exhaust from these engines is the same for all of the emulsions and gasolines. The nitric oxide (NO) concentration is lower by a factor of approximately 2 for the 40% emulsion.

Data on the effect of water in the WGE on the concentrations of toxic components in the exhaust for other speed and load regimes are listed in Table 1. It can be noted that when the load is changed on an engine operating on 10% or 20% WGE, the engine efficiency is very similar to that obtained when operating on straight gasoline. On the 40% WGE, however, when the load is reduced, the change in efficiency of the engine amounts to 15–17%. The concentration of hydrocarbons in the exhaust is higher with the emulsions than with the straight gasoline, by average factors of 1.5 on the 10% WGE, 2.2 on the 20%, and 4.0 on the 40%. At low loads, the hydrocarbon concentrations are much higher in operation on the 40% WGE, by a factor of 8–17. The lean-mixture limit (the composition at which the amount of hydrocarbons in the exhaust is minimal) is lowered by 4–5% for the WGE with 20% water, and 7–8% for the WGE with 40% water.