G. A. Askar'yan, I. A. Kossyĭ, and V. A. Kholodilov. *Ray-jet engines.*[4] The development of microwave power engineering and the problem of radiative energy transfer[1] make it desirable to investigate new modes of radiant-energy conversion. One of the possible objects of conversion might be the jet that forms on the surfaces of solids and in gases under the action of high radiation flux densities. The high efficiency of plasma-jet conversion of microwave energy to electric-current energy (efficiency $\gtrsim 15-20\%$) was recently[2] observed and investigated. In Ref. 4 the present authors have reported an investigation of the direct conversion of radiant to mechanical energy with the aid of a jet formed by the radiation in models of three types of engines: turbine, vibration, and piston (Fig. 1). The radiation source was a centimeter-band microwave generator that produces pulses with energy $Q_1 \sim 10$ J, duration 60 μsec with the repetition frequency adjustable from 1 to 100 Hz. A neodymium laser with an energy of ~10 J per pulse was used to investigate the light jet.

1. *The ray turbine.* A rudimentary turbine with blades 10 cm long and a moment of inertia $I \approx 10^4$ cm^2 was built. The turbine was set into fast rotation on focusing of the radiation on an area situated away from the turbine shaft toward the edges of the blades. Recording of the rotation with interrupted light and motion-picture and strobe techniques made it possible to study the acceleration, the steady state and the damping of the rotation when the jet was switched off in various regimes with various repetition frequencies and various gas pressures in the metal chamber enclosing the turbine. The frequency f of the rotation decreased as the gas pressure p was raised from 0.2 to 1 atm and increased on an increase in the pulse repetition frequency (Fig. 2). Using the expression $F \sim \alpha P$ for the force F with which the jet acts on the surface, where $\alpha \sim 10$ dyn/W and P is the radiation pulse power, we obtain from the equation of motion of the turbine $I\dot{\Omega} = F\tau\nu L - (I/T)\Omega$ where T is the decay time of the rotation ($T \sim 1/p$ in the pressure range $p \sim 0.2-1$ atm), we obtain $\Omega_{st} = F\tau\nu LT/I$. Since the mechanical power $\dot{A} = F_{av}v = F_{av}L\Omega = (F\tau\nu)^2L^2T/I \sim P^2$, the efficiency is $\dot{A}/P \sim P$, i.e., should increase with increasing power.

Rotation frequency and efficiency were significantly increased by fitting the turbine blades with chamber attachments that ensured directional outflow of the jet gas and eliminated the effect of the shock wave from the jet on the preceding blade; the efficiency was ~1% with these attachments. Synchronization of pulse delivery with the optimum position of the turbine blade, increas-

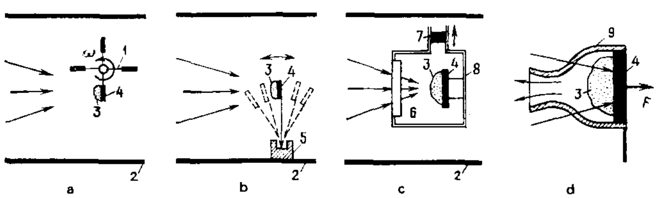

FIG. 1. Schematic representations of turbine (a), vibration (b), and piston (c) engine and turbine blade with chamber attachment (d). 1) rotor; 2) vacuum chamber; 3) jet; 4) blade; 5) mount for vibrating rod; 6) radiotransparent window; 7) piston; 8) combustion chamber; 9) chamber attachment.

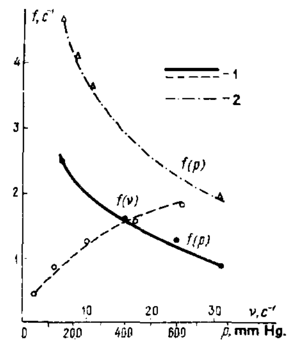

FIG. 2. Turbine rotation frequency f as a function of frequency ν of microwave pulses and of pressure P in chamber (at $\nu = 17$ Hc). 1) turbine without chamber attachments; 2) turbine with chamber attachments.

ing the power, reflecting the gas flow from the attachments or onto the blades, and a more rational design of the turbine would all help to increase the efficiency of the jet turbine utilizing the characteristic properties of the jet—rapid volume heating and high outflow velocities.

2. *Vibration engine*. To demonstrate resonant conversion, we used a flexible steel plate 10 cm long, one end of which was fixed while the microwave beam was focused on the other. The resonant frequency of the oscillations was $f_r \sim 12$ Hz, and the damping time was $T \sim 2$ sec. As the repetition frequency approached the resonant frequency, the vibration amplitude increased sharply, $x_0 \sim F/\gamma\omega$, and the power was $\dot{A} = \dot{x}F \sim F^2/\gamma$ where γ is the coefficient of friction and $F \sim F_1 \tau\omega/2\pi$. It is evident from the above that the efficiency is $\sim P$. It should be noted that drift out of resonance was evidently due to drift of the repetition frequency and to the nonlinear variation of the resonant frequency (the vibration amplitudes exceeded 5–6 cm).

The energy of the vibrating plate can be easily converted to energy of another type of motion.

3. *Piston jet engine*. The microwave radiation was focused into a chamber with a volume $V_0 \approx 500$ cm^3 and produced a jet on the surface. The stroke of a piston with a 100-gram load was measured. A single pulse raised the piston through 10 cm, indicating conversion of $A/Q_1 \sim mgh/Q_1 \sim 1\%$ into work on the piston. The work done on the gas increased with decreasing piston mass and with an increase in energy output. Impulsive motion was imparted to the piston by the application of pulses (radiation gun). Work is done on the piston not only by the average pressure rise on heating $\Delta p \sim Q(\gamma - 1)/V_0$ but also by shock waves that undergo multiple reflection from the chamber walls.

Similar experiments were performed with laser jets, both in the turbine regime and in a closed volume. Specific thrust pulses $F\tau/Q \sim I\Delta\Omega/LQ \sim$ hundreds of dynes · sec/J were registered on the turbine.

The observed jet conversions of radiant to mechanical energy may prove more advantageous than laser engines in which the gas is heated by molecular absorption[3] by virtue of the high efficiency of the microwave ray jet.

This conversion might also be used to measure radiative power at high flux densities.

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