estimates of n_a by means of formula (5).

The values of n_a obtained in this manner for typical T-3 regimes in the period of time when $dT_i/dt = 0$ fall in the range $n_a \approx (1.5 - 3) \times 10^8$ atoms/cm^3. We note that for the TM-3 machine, calculations of this kind yield $n_a \sim 10^9$ atoms/cm^3, which is in good agreement with the corresponding quantities obtained by spectroscopic methods. Using the values $\langle\sigma v\rangle_i = 1.5\times10^{-8}$ cm^3/sec (for T_e = 1000 eV) and $\langle\sigma v\rangle_c = 4\times10^{-8}$ cm^3/sec (for T_{deut} = 300 - 400 eV) we obtain from formulas (3) and (4) a value of τ_d in the range (0.22 - 0.45) sec, and a value of τ_c in the range (0.085 - 0.17) sec. A comparison of these quantities with the value of τ_{Ei}, which amounts to ~17 nsec near the maximum of T_i, shows that the diffusion and charge exchange in the axial region of the plasma pinch in the T-3 accounts for not more than 20% of the total thermal loss, and that the bulk of the heat is lost by the ions through heat conduction.

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EXPERIMENTS WITH LARGE VALUES OF β_I IN TOKAMAK-3

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Experiments aimed at studying the plasma in the Tokamak devices have usually been performed under discharge conditions when β_I, the ratio of the mean gas-kinetic pressure of plasma $\bar{P}$ to the pressure of the magnetic field of the discharge current, $H_\phi^2/8\pi$, is much smaller than unity.

The only exception is a narrow region on the decreasing section of the current, where it turns out that H_ϕ^2 decreases more rapidly than $\bar{P}$ and regimes with $\beta_I > 1$ become possible.

One such regime of the T-3 apparatus was presented, for example, in [1].

There is nonetheless a widely held opinion that all the experimental results obtained with Tokamaks pertain to regimes with $\beta_I < 1$, and that when $\beta_I > 1$ the plasma pinch should be magnetohydrodynamically stable.

On the other hand, the existing magnetohydrodynamic theory of the equilibrium of a plasma pinch [2, 3] imposes limitations on the value of β_I only at the level of R/a (R is is the major radius and a the minor radius of the torus), amounting usually to 7 - 10.

A check on this assumption was of interest and was undertaken with the Tokamak-3 apparatus [4] with r = 10 - 15 cm and R = 100 cm.

Attention was paid to the fact that, strictly speaking, the theory imposes a limitation not on β_I, but on the sum $L/2 + \beta_I$ (L - inductance of plasma pinch per unit length), which in this case plays the role of the effective β_I^*. On the other hand, L breaks up into two parts, external $L_{ext} = 2\ln(b/a)$ b - radius of copper jacket) and internal, ℓ_i, characterizing the fraction of the energy of the magnetic field of the current, contained in the volume of the plasma pinch.

If the change of current I occurs within a time shorter than its skinning time in the plasma pinch ($\tau_{sk} = 4\pi\sigma a^2/c\mu_1^2$, $\mu_1^2 = 3.83$), in other words, if the magnetic energy is frozen in its volume, then the new value of the inductance is $L' = L_{ext} + \ell_i(I_1/I_2)^2$; ($I_1$ is the initial value of the discharge current, and I_2 is its value after the change).

On the other hand, if the plasma internal energy does not have time to change in this case, then the new value is $\beta' = \beta_1(I_1/I_2)^2$, and the effective value is

$$\beta_I^* = L_{BH}/2 + (l_i/2 + \beta_I)(I_1/I_2)^2.$$

Naturally, this relation can be valid only under conditions when the change occurs within a time Δt that is shorter than the time τ_E of containment of the energy in the plasma [2].

As follows from the foregoing expression, a pulsed decrease of the discharge current, by a factor 3 - 4, can increase β_I by approximately one order of magnitude.

In the investigated regimes of the T-3 discharge, the values of τ_E and τ_{sk} were ~2 - 4 msec. Accordingly, the chosen characteristic time of variation of the discharge current was ~ 1 msec.

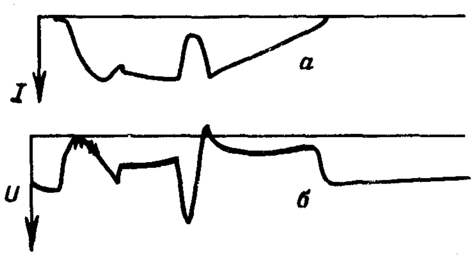

Fig. 1

Figure 1a shows an oscillogram of the discharge current I(t) with a negative pulse Δt. The sweep duration is about 50 msec, and the maximum current is 56 kA.

Recognizing that the quantities τ_{sk} and τ_E do not remain constant when the current is varied, and a certain fraction of either the thermal or the magnetic energy of the plasma pinch may be lost, it is necessary to employ an independent method of determining β_I^*.

This can be done on the basis of readings of magnetic probes placed along the external and internal circuits of the plasma pinch [5]. The difference U_- and the sum U_+ of the readings of such probes (Fig. 1b) are connected with L and β_I as follows [6]:

$$\frac{R}{b}\frac{U_-}{U_+} + 1 = L/2 + \beta_I + C(H_\perp) ,$$

where $C(H_\perp)$ takes into account the influence of the external applied transverse magnetic field $H_\perp$ on the position of the plasma pinch in the discharge chamber, and is equal to $RH_\perp/0.1I$ if this field is not measured directly by the magnetic probes, and to $RH_\perp/0.2I$ if it is measured.

When $H_\perp$ remains constant with changing discharge current, it is possible to obtain for β_I^* the following expression:

$$\beta_I^* = \frac{R}{b}\left[\left(\frac{U_-}{U_+}\right)_2 - \frac{I_1}{I_2}\left(\frac{U_-}{U_+}\right)_1\right] + \left(\frac{L}{2} + \beta_I\right)_1 \frac{I_1}{I_2} + \frac{\Delta I}{I_2} .$$

Attention is called to the fact that $H_\perp$ does not enter in the final expression for β_I^*. Nevertheless, the use of such transverse fields turns out to be experiments for the performance of the described experiments.

The point is that the realization of the discharge regimes with large β_I^* involves large outward displacements of the plasma pinch relative to the center of the discharge chamber ($\Delta \approx (b^2/2R)\beta_I^* = 3.1\beta_I^*$ cm). When account is taken of the real dimensions of the plasma pinch and of the discharge chamber, this imposes additional limitations on β_I^*.

The use of transverse fields (up to 50 or 60 Oe) to shift the pinch inward has actually made it possible to eliminate this limitation.

As follows from the foregoing expression, to determine β_I^* it is ncessary to know not only the parameters I, U_-, and U_+, but also the quantity $(L/2 + \beta_I)_1 = L_{ext}/2 + (\ell_i/2 + \beta_I)_1$. The value of $L_{ext}/2$ was determined by sounding the plasma pinch with an electric voltage pulse [7]. This value was 0.8 - 0.9, corresponding to a plasma-pinch radius $a \approx 10 - 11$ cm. The value of $\ell_i/2 + \beta_I$ was determined in the following manner: Assuming that no energy is lost from the pinch if the discharge current is changed sufficiently rapidly by small amounts, and using the fact that $U_+ \sim I$, we can write

$$-\frac{R}{b}\frac{\Delta U_-}{\Delta U_+} - \left(1 - \frac{L_{ext}}{2}\right) = \left(\frac{\ell_i}{2} + \beta\right)_1 .$$

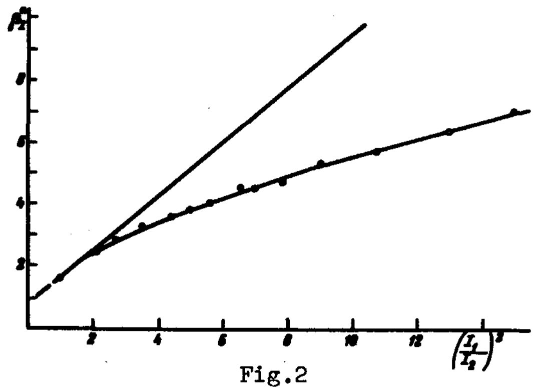

Fig.2

By measuring now $\Delta U_-/\Delta U_+$ in experiments with small ΔI, we determine $(\ell_1/2 + \beta)_1$, which turns out to range from 0.8 to 0.9. It can, in principle, be determined directly from probe measurements, provided $H_\perp$ is known exactly. The corresponding estimates are in good agreement.

Figure 2 shows the experimental plot of β_I^* vs. $(I_1/I_2)^2$. The straight line is calculated:

$$\beta_I^* = \frac{l_{ext}}{2} + \left(\frac{l_i}{2} + \beta_I\right)_1 (I_1/I_2)^2.$$

On the basis of the foregoing data we can conclude that although the energy in the plasma pinch is not fully conserved when a negative current pulse is applied, it is possible to obtain maximal $\beta_I^* \sim 7$. It has been shown with the aid of magnetic probes that there are no disturbances of magnetohydrodynamic type on the surface of the plasma pinch.

Further increase of $(I_1/I_2)^2$ leads to the appearance of such disturbances and to development of a "stalling" instability similar to that described in [6].

The available data do not allow us to ascertain whether this instability is connected with the attainment of the critical value of β_I^* or whether it constitutes a unique instability of the plasma pinch with a negative current flowing on the periphery. A definite answer will apparently be provided only by experiments with toruses having different slopes. It must be stated, nonethele-s, that the plasma pinch in the Tokamak can be stale also at large values of β_I^* approaching R/a. When it comes to β_I, this experiment still has a model character.

The author considers it his duty to thank V. D. Shafranov for valuable discussions.

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INVESTIGATION OF THE ROTATIONAL-VIBRATIONAL TRANSITION OF THE METHANE LINE FOR THE STABILIZATION OF AN He-Ne LASER FREQUENCY AT λ = 3.39 μ

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In [1 - 3] it was proposed to use the effect of saturation of the absorption of a low-pressure gas in the light field of a standing wave to obtain narrow power resonances within a Doppler line, and to stabilize against these resonances the frequency of a laser. Narrow power resonances in the saturation of the absorption of the P(7) rotational-vibrational transition of the ν_3 band of methane by He-Ne laser radiation at λ = 3.39 μ were observed in a laser with a Fabry-Perot resonator [4, 5, 6] and in a laser with a ring resonator [6, 7]. The shift and broadening of the methane line by pressure, and also results on the reproducibility of the frequency of a laser stabilized against a power peak, are described in [8]. The amplifying medium used in [8] was the isotope Ne^{20}.

Our present purpose was to investigate experimentally the stability and reproducibility of the frequency of an He-Ne laser opwerating with the isotope Ne^{22} and stabilized against the narrow Lamb dip of the 2947.906 cm^{-1} line of methane. Since the line of the Ne^{22} isotope lies about 63 MHz closer to the methane absorption line than the line of Ne^{20} [9], a coincidence of the amplification and absorption lines can be obtained at lower pressures of the