formation of the $^1S_0$ proton-anti-neutron system.

In recent years, a series of particles have been discovered with mass intermediate between that of nucleons and π-mesons. Such a family of particles may also be considered from the point of view of the Fermi-Yang hypothesis, i.e., as nucleon-anti-nucleon systems in bound states. It is interesting to compare the value of the interaction potential obtained in this case with the enormously strong potential obtained by Fermi and Yang by considering the π-meson as a composite particle.

Fermi and Yang have considered the problem in the two particle approximation. The Schrödinger equation for the proton-anti-neutron system is as follows:

$$[-c\hbar i(\vec{\alpha}_P - \vec{\alpha}_A)\vec{\nabla} \tag{1}$$

$$+ Mc^2(\beta_P + \beta_A) - V(r)(1 - \vec{\alpha}_A\vec{\alpha}_P)]\psi = E\psi,$$

where ψ is a 16-components wave function, r is the relative coordinate and the indices P and A refer to the proton and the anti-neutron. Given an interaction potential $V(r)$ in the form of a well of width r_0 and depth V_0, the continuity condition on the logarithmic derivative of the wave function at $r = r_0$ gives[2] for the state $^1S_0$:

$$k \operatorname{ctg} k_{r_0} = -k_0, \tag{2}$$

where

$$k^2 = \frac{E(8V_0^2 - 2V_0E + 4M^2c^4 - E^2)}{4(\hbar c)^2(2V_0 - E)}, \tag{3}$$

$$k_0^2 = \frac{4M^2c^4 - E^2}{4(\hbar c)^2} \tag{4}$$

The value of the potential depth V_0 can be found from Eq. (2) for various stipulated values of $E = \mu c^2$ and $r_0 = \hbar c/\kappa$ (κ is the rest mass of the composite particle; if it is assumed that the Fermi-Yang force arises from quanta exchange, then the parameter κ corresponds to their rest energy). The value of V_0 is given in the Table below for various values of E and κ. All quantities are given in units of Mc^2. For π-mesons $\mu \approx 0.15\ M$ (i.e., $E \approx 0.15$) and with $r_0 = \hbar/Mc$ ($\kappa = 1$) we have the value obtained by Fermi and Yang $V_0 \approx 26.5$; for τ, κ-, χ-particles for $r_0 = 2\hbar/Mc$ ($\kappa = 0.5$), $V_0 \approx 2.2$, i.e., about 2 bev. The maximum possible value of the masses $\mu = E/c^2$ of the constructed particles diminishes with increasing value of r_0.

$\kappa = 1.2$		$\kappa = 1.0$		$\kappa = 0.8$		$\kappa = 0.6$		$\kappa = 0.4$		$\kappa = 0.2$	
E	V_0	E	V_0	E	V_0	E	V_0	E	V_0	E	V_0
0.15	37.7	0.13	30.5	0.09	31.5	0.12	14.4	0.11	7.8	0.12	2.0
0.72	7.3	0.46	8.7	0.37	7.4	0.83	1.1	0.54	1.2		
1.09	4.5	0.81	4.6	0.96	2.3						
1.25	3.7	1.26	2.4	1.14	1.3						
1.54	2.5	1.43	1.5								
1.66	1.9										

The present calculation was suggested by Prof. Ia. P. Terletskii.

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[1] E. Fermi and C. N. Yang, Phys. Rev. 76, 1739 (1949).

[2] L. D. Landau and E. M. Lifshitz, *Quantum Mechanics*, vol. 1, p. 140, GTTI, 1948.

Translated by M. A. Melkanoff
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On the Development by Means of Leaders of the Process of Breakdown of Liquids

(Reply to the Remarks of G. A. Vorob'ev)

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IN one of the 1954[1] issues of JETP there were published some remarks by G. A. Vorob'ev on my article[2] which dealt with the question of pre-breakdown currents in liquids. These remarks referred to my conclusion that in the absence of a limitation on the discharge current the breakdown of liquids takes place by a single avalanche process without a leader stage. In the above remarks this conclusion was questioned, and it was asserted that, independently of such limitations, the breakdown process must always be of the leader type. In support of his views G. A. Vorob'ev quoted an American article[3] in which, however, something quite to the contrary is stated.

It should be noted that in my article the absence of a leader stage was mentioned in the sense that the development of the breakdown process takes place gradually, without interruptions in time. For such relatively small interelectrode gaps as a few centimeters it appeared to me useful to speak of an avalanche stage which then goes over into streamer stage. In the case of an uninterrupted development of the process a streamer, or streamers traveling in opposite directions, short the electrodes, the principal discharge is formed and the breakdown ends in the formation of a highly conducting bridge. I used the concept of the leader stage in those cases when the process of the development of the breakdown was discontinuous in time.

In my opinion it is shown sufficiently clearly in reference 2 and more particularly in reference 4 that specifically in the absence of resistors *R* to limit the current, the breakdown of certain liquid dielectrics takes place without a leader stage in the sense indicated above.

In investigating the pre-breakdown processes in liquids one could come to the conclusion[2] that the development of the breakdown process in some cases takes place unexpectedly or suddenly. The breakdown begins to form progressively without an appreciable increase in current right up to the moment of the ''collapse'' of voltage. The process itself of the formation of breakdown naturally takes a certain length of time. This time has been determined by me in certain cases[4].

In what circumstances then does a discontinuous development of the breakdown or a leader process occur? On the basis of experimental data described in references 2 and 4 it is possible to assert that when the current in the discharge channel is limited,the temperature of the latter does not rise sufficiently so that the intense thermal ionization and photoionization can make the discharge channel of the first leader highly conducting. There are reasons to believe that this process of formation of a highly conducting bridge (broadening of the channel) grows in a cumulative fashion under favorable circumstances. As the degree of ionization increases, the current flowing through the channel also increases. The temperature of the latter increases in the meantime, and consequently the intensity of thermal ionization and photoionization increases, the broadening of the channel increases still further, etc. Of course it is also necessary to take into account here the processes which oppose the development of the breakdown, such as the capture by the molecules of the liquid of the electrons in the streamer, recombination, excitation of electrons in atoms and molecules of the liquid, radiation, heat being conducted away, collisions of the second kind, etc. When the discharge current is limited, the broadening of the channel must cease at a certain stage, and these opposing processes assume a dominant influence: the discharge stops.

It should be noted that, as experiments have shown, during the statistical delay time, sometimes even without the inclusion of a limiting resistor, the progressive development of the discharge is suppressed by the opposing processes in the stage of formation of avalanches or even of small streamers. However, this takes place only in the case when the applied voltage is somewhat lower than the breakdown value. Therefore such processes should not be confused with the progressive development of the breakdown.

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[1] G. A. Vorob'ev, J. Exper. Theoret. Phys. USSR **27**, 764 (1954)

[2] I. E. Balygin, J. Exper. Theoret. Phys. USSR **25**, 736 (1953).

[3] T. W. Liao, J. G. Anderson, Trans. AIEE **72**, 641 (1953).

[4] I. F. Balygin, J. Exper. Theoret. Phys. USSR **24**, 338 (1954).

Translated by G. M. Volkoff
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Photoelectric Recording of Spectra of Combination (Raman) Scattering of Powdery Materials

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IN the solution of a number of applied problems, and also in the investigation of certain basic problems, such as the question of the influence of the aggregate state on the character of the spectrum of combination (Raman) scattering, one frequently deals with powdered material. Digressing