ing algebra SO(8). If we group the single-particle levels into two sets at different energies, we obtain a two-level SO(8) problem which is no longer analytically but still numerically solvable through the diagonalization of matrices of modest size [7, 8]. This is true for the lowest eigenstates of the pairing Hamiltonian which are of low seniority (provided the pairing force is attractive) and for which the necessary coupling coefficients [for SO(8) $\supset$ SU(4) and SU(4) $\supset$ $\mathrm{SU}_S(2) \otimes \mathrm{SU}_T(2)$] are known [7]. The current problem of eight-plus-eight $J = 1/2$ levels is equivalent to a two-level SO(8) description in which each level has a spatial degeneracy of eight, *i.e.*, each level can accommodate 16 neutrons and 16 protons. Exact energies can also be obtained with the Richardson-Gaudin method for the higher-rank algebra SO(8) for non-degenerate levels with equal $T = 0$ and $T = 1$ pairing strengths [9]. These exact solutions provide a very valuable test for the approximate solutions described below.

Case 2. We again set $G^{T=0} = G^{T=1}$ but diagonal matrix elements are now 2.4 times the off-diagonal ones. Our motivation is that the increased value of the diagonal matrix elements explains the Wigner energy anomaly [5] and also the discrepancy between 'observed' single-particle gaps and those obtained from Woods-Saxon potentials in $N = Z$ nuclei [10]. In the SO(8) model of Refs. [7, 8] it is also possible to take unequal diagonal and off-diagonal pairing strengths, if only two levels are considered. However, in the current application we have 16 levels. In this case, the unequal diagonal and off-diagonal pairing strengths suggested by physical arguments, no longer permit the same solution technique as in Refs. [7, 8].

Cases 3 and 3'. We set diagonal matrix elements to be 2.4 times the off-diagonal ones and we change the relative strengths of $T = 0$ and $T = 1$ pairing, *i.e.*, in case 3 we set $G^{T=0} = 0.9 \times G^{T=1}$ and in case 3' we interchange the pairing strengths. Case 3 suggests the sorts of differences to be expected in heavier nuclei where odd-odd $N = Z$ nuclei have a 0^+ ground and a 1^+ excited state. Case 3' suggests light nuclei where the 0^+ state is not the ground state in odd-odd $N = Z$ nuclei. The energies are the same in cases 3 and 3' but the (J, T) labels of the states are interchanged.

For the even-even systems considered here, we use a variational wave function of the form

$$\Theta_i = \mathcal{P} \prod^{k} \psi^{\dagger}_{i,k} |0\rangle, \tag{2}$$

where $|0\rangle$ is the physical vacuum and $\psi^{\dagger}_{i,k}$ is a creation operator of the form

$$\begin{aligned} \psi^{\dagger}_{i,k} \;=\; & \Big[1 + U_i(1,k)A^{\dagger}_k + U_i(2,k)B^{\dagger}_k \\ & +U_i(3,k)C^{\dagger}_k + U_i(4,k)D^{\dagger}_k \\ & +U_i(5,k)M^{\dagger}_k + U_i(6,k)N^{\dagger}_k \\ & +U_i(7,k)W^{\dagger}_k\Big], \end{aligned} \tag{3}$$

with $W^{\dagger}_k = A^{\dagger}_k B^{\dagger}_k$. This is an extended version of the variational wavefunction used in previous studies [3, 5, 10] by virtue of the addition of the $M^{\dagger}_k$ and $N^{\dagger}_k$ terms which are needed because all j_z values are the same and these modes are collective. The operator $\mathcal{P}$ projects definite neutron number, proton number, number parity of $T = 0$ n-p pairs [5] and now also J_z. We project before carrying out the variational procedure.

The variational trial wave function, Ξ^{n+1}_m, is [3]

$$\Xi^{n+1}_m = \Phi^n_m + \Theta_{n+1}, \tag{4}$$

where Φ^n_m, the starting wave function, is

$$\Phi^n_m = \sum_{i=1}^{n} t^n_{i,m} \Theta_i, \tag{5}$$