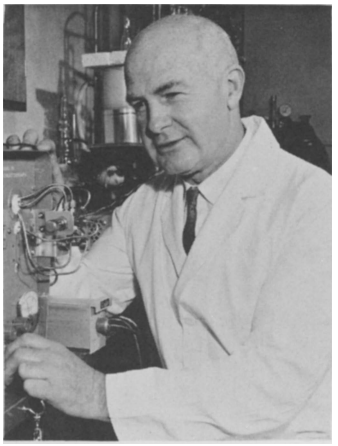
COMMENTARY

EDWARD CREUTZ is Vice-President of Research Development for the General Atomic Division of General Dynamics Corporation.

ATOMIC ENERGY — A LINK BETWEEN REFLECTION AND ACTION



John W. Gardner, Secretary of Health, Education, and Welfare, in an editorial in *Science* (November 18, 1966) entitled "The Worlds of Reflection and Action," says, "A society that aspires to creativity has urgent need of its detached scholars and critics, as well as those who will become deeply involved in the world of action. Our society must have the wisdom to reflect and the fortitude to act." He states that although the university is the principal home of men of reflection it should not fail to prepare some young people for lives of action. Finally he hopes "that the universities will persuade a reasonable proportion of their graduates to move back and forth between the two worlds."

In the area of atomic energy, universities and industries are establishing an essential link between the two worlds, and this may serve as a useful pattern for other fields of human activity.

Traditionally, imaginative engineers are likely to be found in industry, while creative scientists tend to stay in universities, although to be sure there are outstanding engineers in education and distinguished scientists in industry. This prevalent tendency towards institutional separation of the two kinds of technical leaders might be compared with the historical separation in time of man's interest in *understanding* the physical world, and his imaginative *application* of this understanding to make himself more comfortable and secure. And just as this separation in time of *understanding* and *application* is rapidly disappearing, we are beginning to find the tendency for more communication and interchange between Gardner's men of reflection and men of action.

There are numerous early examples of practical devices having been developed quite independently of understanding of the phenomena involved. Spectacle lenses were used many years before the theory of optics was sufficiently understood for the telescope and microscope to be conceived. Magnetism was known as a phenomenon found in some crystals and applied to navigation centuries before there was any theory to describe it or its relation to electricity. Watt's steam engine was not based on any knowledge of the Carnot cycle or on Joule's work on the relation of heat to mechanical energy.

It was not until the middle of the 19th Century that a clear causal relationship began to develop between technology and the science underlying it. Thus Maxwell developed his electromagnetic theory in 1873, Hertz generated waves for experimental communications in 1888, and Marconi made these ideas practical for radio in 1898. Pasteur stated the germ theory of disease in 1866, and Koch isolated and identified many disease-causing bacteria a few years later.

The close partnership of science and technology in the atomic energy field is well known and is undoubtedly related to the fact that its great founders, Rutherford, Einstein, Bohr, Fermi, Wigner, Szilard, and others, during most of their lives fit Gardner's classification of men of reflection, but (except for Rutherford) became action men during World War II. What more action could Einstein have effected than that which resulted from his letter to President Roosevelt?

The response of American industry, in adapting to the situation requiring a large participation in active scientific thought as well as thoughtful applied action, is good. Several industries in the United States now have research laboratories contributing to understanding of phenomena such as the basic physics of nuclear interactions, energy exchange between neutrons and molecules, fission product diffusion, material properties in radiation fields, and behavior of plasma.

Well-known results of this industrial research in atomic energy are: the detailed control of nuclear resonance absorption phenomena in complex systems, use of zirconium hydride as a thermal-neutron moderator-control material, design of high-temperature reactors depending on the interaction of neutrons with phonons in crystalline moderators, nuclear fuel particles coated with materials of controlled crystalline properties, materials and systems of improved resistance to radiation, and progress in confining and heating deuterium plasmas. These accomplishments, and the forward-looking spirit in which they are brought about, are building a sound technology for the continual decrease in the cost of atomic energy which already is competing strongly in our economy.

The realization by industry that atomic energy development requires the closest coupling between the true understanding and the application of recently discovered phenomena, has produced some progress in changing the traditional isolation and separation of men of reflection from men of action. Let us hope that this fruitful mixing of reflection and action as found in the atomic energy field will influence other areas of endeavor.

The men of reflection in the universities, whose responsibilities encompass the need to re-examine knowledge and assumptions continuously and to dissent, criticize, and improve understanding, should not fail to communicate to young people an appreciation of those needs of our society that can be fulfilled by men with the zeal, vision, and perseverance to apply knowledge. Concurrently the men of action in industry must participate in questioning the *status quo* and must accept change as a principal sign of viability and as the only state consistent with the existence of an enduring and creative society.