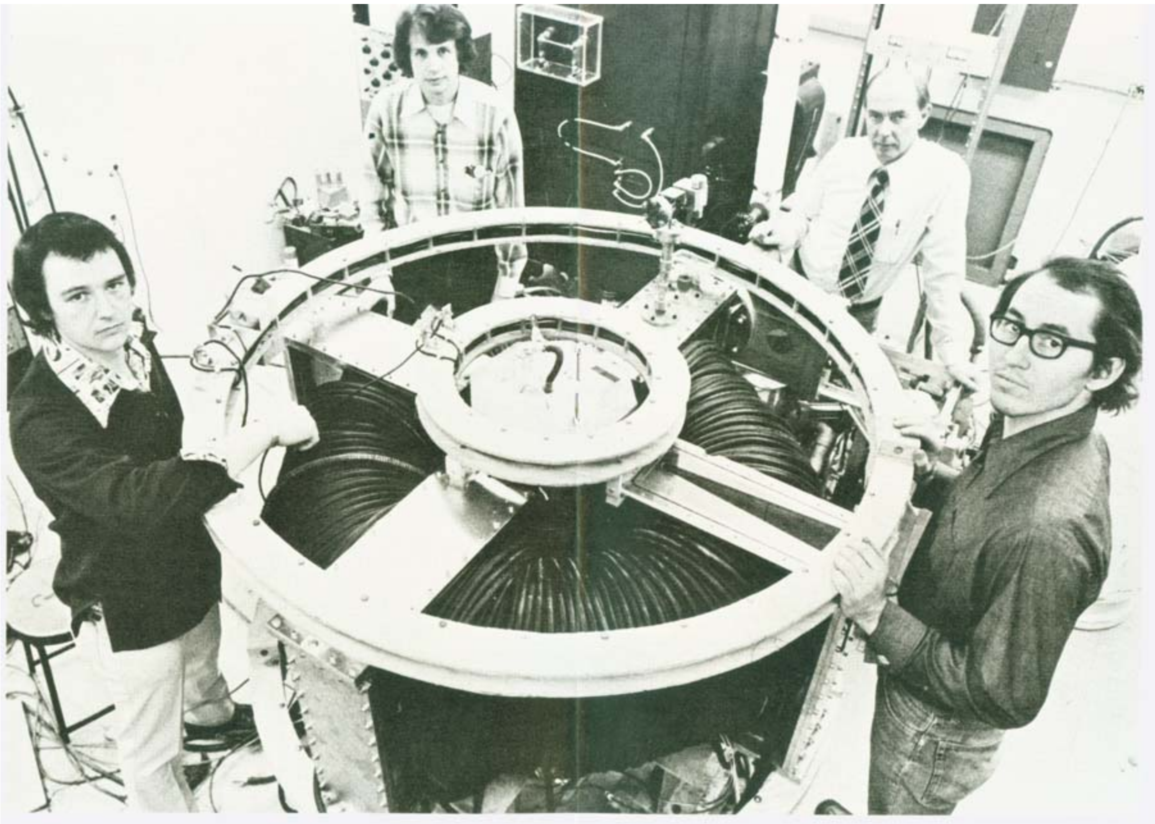


FUSION: THE ENERGY OF THE FUTURE

By Evan L. Holzwasser

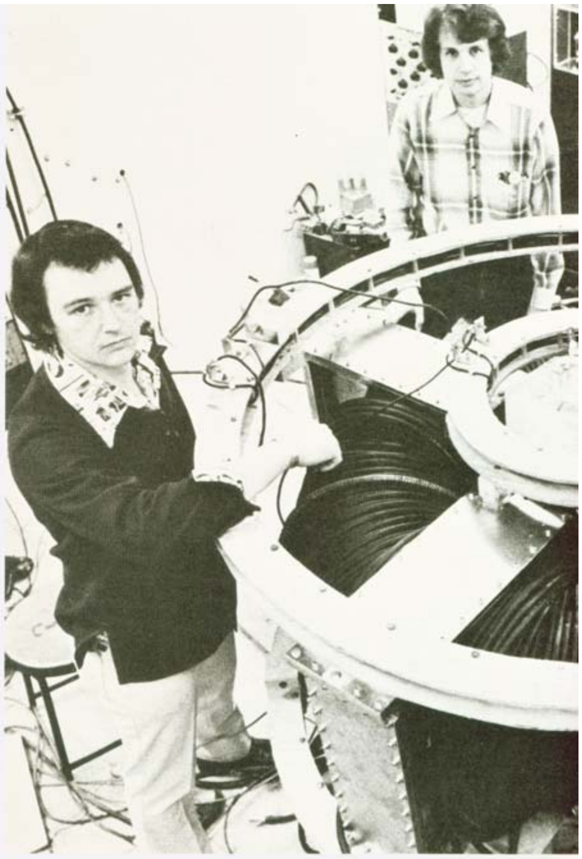
Today we are in the midst of a global energy crisis due in large part to our dependence upon fossil fuels which are limited in their availability, non-replenishable in their supply and predominantly under the control of the OPEC production cartel. We are experiencing the consequence of a technology which has unlocked the potential for much economic development in this century, but which is being asked to deliver more than it can sustain for many more decades at current or projected levels of energy consumption. Faced by the social, political and economic consequences of an over-dependence on this fossil fuel echnology we are seeking alternative sources for our energy.

Of all the choices available, fusion energy is simultaneously one of the most promising, yet difficult energy sources being investigated. Unlike solar energy or nuclear fission, both of which are feasible with current technology (although each has problems of economic practicality, reliability or safety) nobody has yet produced a controlled thermonuclear fusion reaction, much less tamed fusion as an energy source. Like a miniature star here on earth, nuclear fusion may promise the 21st century a plentiful source of energy with very little radioactive waste, no combustion products, no chance of fission runaway and no creation of fission by-products with their weapons threat potential.

But the research stages involved in understanding, replicating, controlling and harnessing this star-like power are proving more intricate and frustrating than encountered in other energy technologies. It is extremely difficult to attain stellar-like conditions on earth, much less control them or unleash their power. RPI's fusion research involvement, directed by Professors Robert L. Hickok, William C. Jennings and Kenneth A. Connor, centers on the most basic levels of the inquiry needed to unleash this power — understanding and measuring what happens in the plasmas that will provide the basis for nuclear fusion.

What Is a Plasma ?

There are three common states of matter on earth — solid, liquid and gas. One or more of these states occurs for any substance depending on such factors as pressure and temperature. But when enough energy is added to a gas, a


From left, Professors Jennings, Connor and Hickok with graduate student James Pipkins and RPI's new tokamak.

point will be reached at which the molecules and atoms of the gas will divide into its component electrons and ions. This process is called ionization, and some ionized gases qualify as plasmas, the fourth state of matter. Examples of plasmas which exist in nature include the Aurora Borealis, the ionosphere, interstellar material, and lightning. Man-made plasmas include those which appear in mercury and sodium vapor lamps, neon signs, arc welders, gas lasers, and explosions. It should be noted that none of these plasmas meet the stringent requirements for fusion to occur.

Nuclear energy can be obtained from a plasma only if a significant number of fusion reactions occur in which light atoms, such as hydrogen, burn to form heavier atoms, such as helium. This fusion reaction requires that the temperature of the plasma be of the order of one hundred million degrees. In addition, the plasma must be dense enough, and last for enough time to allow the reactions to develop. These conditions are going to be tough to meet, and will rely on the basic diagnostic tools now being developed at RPI.

At present there are two different approaches to the problems of meeting the temperature, density and time necessary for fusion to occur. The first is inertial confinement, in which a pellet of deuterium is blasted with high energy lasers or particle beams. The pellet absorbs energy from the beams

and becomes a rapidly expanding plasma. The objective is to inject so much energy in such a short time that the pellet implodes and reaches the ignition point before it has time to expand away.

The second approach is magnetic confinement, in which strong magnetic fields are used as a "bottle" to hold the hot, dense plasma. In this case, the objective is to produce a hot plasma inside the volume contained by the magnetic field and hold it long enough for fusion reactions to occur. The magnetic devices presently being investigated include such exotic closed geometry systems as tokamaks and toroidal theta pinches, as well as open systems employing magnetic mirrors.

The major emphasis of the program at Rensselaer is in the development and application of techniques for measuring plasma density, electron temperature, space potential, and plasma instabilities, as well as for mapping magnetic fields within the plasma volume. The heavy ion beam probe apparatus originally developed by Dr. Hickok, is the only diagnostic technique now available to allow scientists to understand both where and when various behaviors are taking place in the plasma.

RPI's research team consists of Professors Hickok, Jennings and Connor; research associate Dr. Charles Parsons, as well as thirteen graduate students and twenty-two undergraduates.

The Federal Energy Research and Development Ag
(ERDA), which administers almost all controlled
thermonuclear reaction research at the national lab
in industry and at universities, is the primary fundin
source, providing nearly $400,000 each year for
Rensselaer's fusion research, conducted both on a
off-campus.

The off-campus program is divided into two parts.
setup explores the operation of the ion beam probe
diagnostic system on a Laser Initiated Target Exper
device at the United Technologies Corporation Res
Center (formerly United Aircraft) in Hartford, Conne
The diagnostic facility was designed, built and insta
Rensselaer and is operated by Rensselaer staff wh
on-site in Hartford. In this experimental apparatus,
of lithium hydride are blasted with a laser beam to
expanding plasma, which is captured by a magneti

At the Oak Ridge National Laboratories a second re
project features a series of magnetic mirrors shape
form of a torus and employs high power microwave
the plasma. At Oak Ridge, Rensselaer scientists an
engineers are also concerned with the design, cons
and eventual operation of an ion beam probe diagn
system.

RPI, MIT, Caltech and the Tokamak

The on-campus program at Rensselaer is primarily
concerned with refining ion beam probing as a diag
technique using the recently constructed Rensselae
tokamak. RPI's tokamak is one of only three small
tokamaks in existence today in the United States —
other two are at MIT and Caltech.

Presently the leading candidate for a controlled
thermonuclear reaction device, the tokamak consist
toroidal (doughnut shaped) vacuum chamber and t
plasma-confining magnetic fields. Time, temperatu
density are the keys to controlled fusion. Rensselae
tokamak produces these conditions at a sub-fusion
while Dr. Hickok's ion beam probe techniques prov
and his colleagues with a read-out on what's happe
the plasma. These powerful diagnostic tools — the
to produce and control the plasma; the ion beam pr
monitor it — are allowing researchers to gradually i
the power of their plasma machines to the point at
controlled fusion will be practicable. Things need t
much hotter, denser and longer lasting before contr
nuclear fusion will become a reality, and the RPI fus
research team is hard at work finding the answers t
there.

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