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PRINCETON PLASMA PHYSICS LABORATORY
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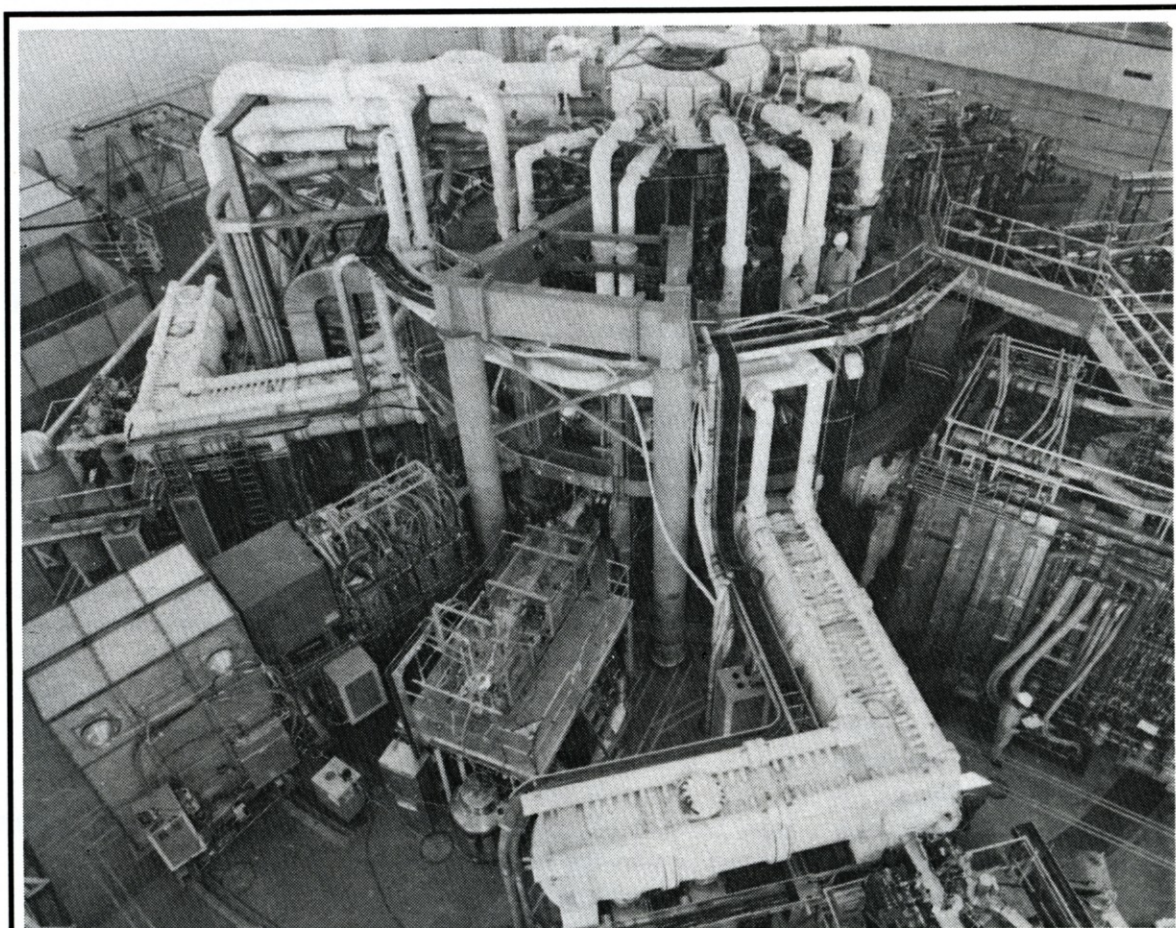
TFTR Sets Fusion World Record

"**TFTR** set a world record of more than three million watts of controlled fusion power during the first approximately 50-50 deuterium-tritium (D-T) experiment," according to PPPL Director Ron Davidson. "The first high power shot occurred at 11:08 p.m. on Thursday, December 9. This record was broken with more than six million watts on Friday, December 10."

"We're all delighted that the TFTR has so readily surpassed the goal of reaching five megawatts of power in 1993," observed Davidson. "The TFTR team is to be congratulated for this superb accomplishment. We now look forward to the rest of the D-T experimental campaign with great pride and anticipation."

These experiments are the world's first on a tokamak to use a plasma made up of equal parts deuterium and tritium in a tokamak—the mix required for practical fusion power reactors.❖



It's Our Star—TFTR!

Watch for a special edition of HOTLINE in January highlighting events before, during, and after these first historic experiments.

Spheromak Research for Solar Physics

MRX Experiment Exemplifies Diversification

A new, exciting experiment is about to get underway at PPPL. Early next year, Masaaki Yamada will bring the Proto S-1C* spheromak** out of mothballs for reconfiguration as a double spheromak, to be retitled the MRX (Magnetic Reconnection Experiment).

This new thrust of research will focus on magnetic reconnection—the breaking and rapid reconnection of magnetic field lines in a plasma medium.

According to Principal Research Physicist Masaaki Yamada, who will direct this research, "Magnetic reconnection is one of the most important fundamental processes of plasma physics which can dominate plasma confinement characterisitcs. The MRX is regarded as a very important laboratory experiment to find the answers to the sun's unresolved puzzle—the physics of solar flare evolution."

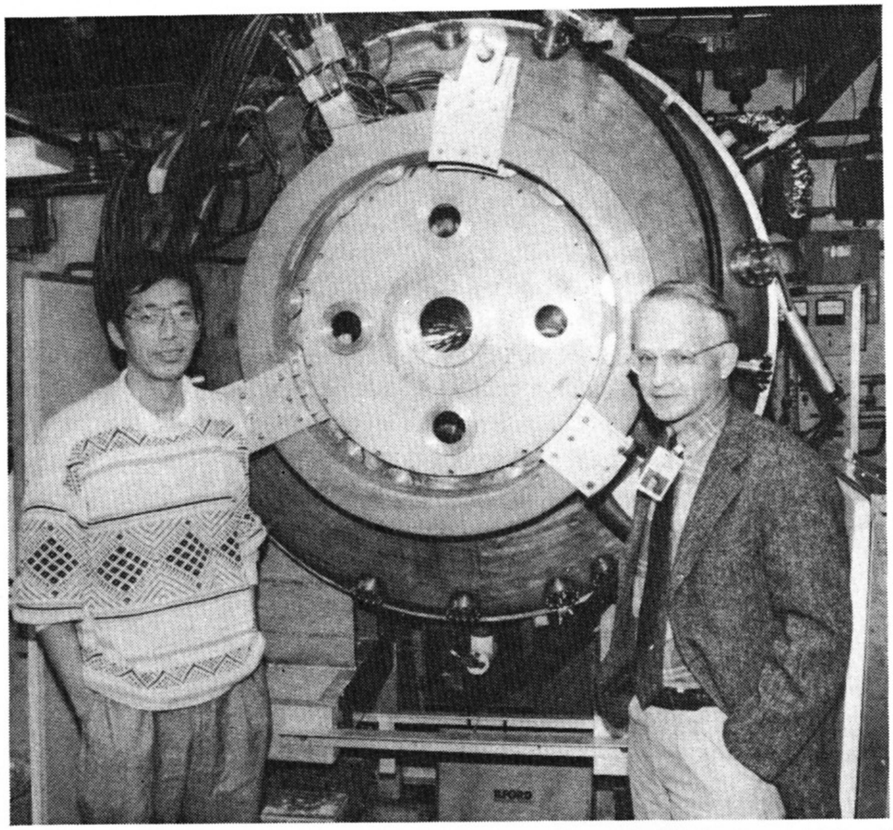


Photo: Dietmar Krause

Masaaki Yamada (left) and Rip Perkins with the Proto S-1C device, which will be reconfigured and renamed the Magnetic Reconnection Experiment (MRX).

Noted PPPL Director Ron Davidson, "The MRX project is a technically exciting basic plasma physics experiment. It is also an excellent example of the diversification of research being encouraged at the Laboratory."

Yamada became convinced that this line of research could prove fruitful in 1988 after PPPL physicist Francis (Rip) Perkins encouraged him to look into the importance of three-dimensional magnetic reconnection for solar physics research. (Astrophysical and solar physics research has generally analyzed it as a two-dimensional phenomenon.)

Inspired by solar observations, Perkins, who was teaching plasma astrophysics at the time, had asked the question, "Can we create in the laboratory a plasma wherein a small amount of reconnection will cause a large release of stored magnetic energy and plasma heating?" The double spheromak proved to be just such a configuration.

Said Perkins, "We found that the double spheromak is a flexible concept for investigating magnetic reconnection. It can be used to simulate the way the sun's magnetic fields are constantly being pushed around by the photosphere."

An example of an issue that may be studied during the MRX project is, why the corona (the outermost atmosphere of the sun) gets so much hotter than the sun's surface. (The corona reaches temperatures of 2,000,000 degrees Celsius—dramatically hotter than the surface temperature of 6,000 degrees Celsius.) The explanation may lie in the study of magnetic reconnection, which many believe to play an important role in heating the plasma in the sun's corona.

Because magnetic reconnection is such a basic phenomenon in solar physics, MRX results could play a key role in interpreting data from satellites such as Yohkoh, which has captured many pictures of the sun and interactions with solar flares and arcades.

Preliminary Experiments and Funding

During a year-long leave in 1989, Yamada was able to test some ideas that he and Perkins had developed on TS-3, a Japanese spheromak located at the University of Tokyo. The invited talks Yamada gave regarding these initial experiments

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Spheromak

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were well-received at both the American Physical Society and Solar Physics meetings this year.

Because so much interest had been generated in their work, Yamada and Perkins were encouraged to apply for funding. To increase the likelihood of funding, they have divided their requests for support equally among three agencies—the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), and the Office of Naval Research (ONR). Partial funding of $100,000 for each of three years has now been approved by the National Science Foundation (NSF).

Says Yamada, "NSF funding began December 1 for fiscal year 1994. NASA and ONR have both given high ratings to the proposal, but a final funding decision has yet to be made. PPPL also would support the project by refurbishing equipment, performing safety inspections, and providing power supplies. If full funding is not approved, we will still be able to proceed at a modified level."

Observed Perkins, who has played a key role in promoting the project, "The MRX would be a cost-effective way to provide innovative, meaningful opportunities to do new research with high-temperature toroidal plasmas. The scale of MRX and the anticipated richness of its plasma physics make it an ideal facility for student Ph.D. thesis research."

How MRX Would Work

The goal of MRX is to simulate the way the sun pushes magnetic fields around and thus produces magnetic reconnection. The present machine, Proto S-1C, will be reconfigured into a double spheromak that will do just that.

To accomplish this, two rings of plasma, carrying identical toroidal currents and having the same poloidal-field configuration, will be produced within the double spheromak. One plasma ring will be positioned above the other. Although the external magnetic field will initially be configured to hold the two plasmas apart, configurational changes, which simulate photospheric motions, will cause the attractive force arising from parallel toroidal currents to prevail over external fields. The spheromaks collide, inducing magnetic reconnection. This process abstracts what is thought to happen in the solar corona.

Notes Yamada, "We will use a very flexible double-spheromak configuration with six different operating regimes that should have quite different flow patterns."❖

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*The **Proto S-1C** was originally completed in 1981 and was designed by fusion researchers as an alternative to the tokamak. It was one of three spheromaks built at PPPL.

The name **spheromak—spherical tokamak—was coined by Harold Furth to describe the spherically shaped plasma. A spheromak has a toroidal configuration, as does a tokamak, but in the spheromak the toroidal magnetic field is produced entirely by plasma currents. Thus, there is no toroidal field outside the plasma and no need for toroidal-field coils. The poloidal fields are produced by toroidal plasma currents and external field coils.

Kulsrud Wins Maxwell Prize

"For his pioneering contributions to basic plasma theory, to the physics of magnetically confined plasmas, and to plasma astrophysics," Professor Russell Kulsrud has been awarded the 1993 James Clerk Maxwell Prize in Plasma Physics. For Kulsrud, who has been at PPPL and Princeton University 39 years, the citation reflects the fact that he has consistently maintained his interest in both plasma physics and astronomy.

In 1954, when he completed his thesis in astrophysics and graduated from the University of Chicago with a Ph.D. in physics, little did Kulsrud know he'd be participating in a project that has been described as "creating a star on earth." While casting about for challenging job possibilities, he heard that astronomer Lyman Spitzer had something interesting going on at Princeton, but the specifics of the project were top-secret. An interview with Spitzer convinced

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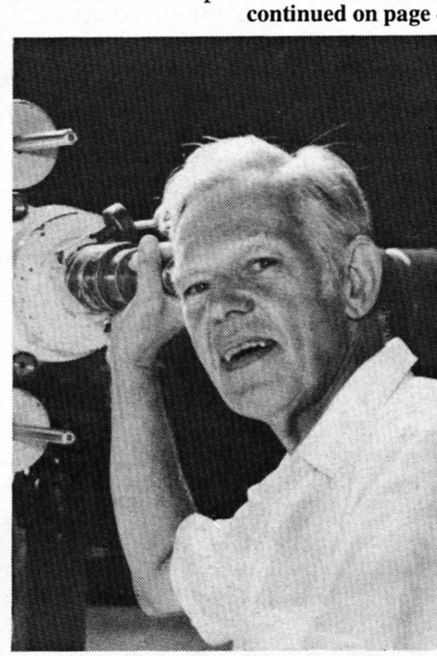
Photo: Dietmar Krause

Russell Kulsrud adjusts a telescope for some star-gazing.

Kulsrud

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Kulsrud that this project, intriguingly titled Project Matterhorn, was interesting and important, and he signed on—still not knowing the nature of this secret mission.

He was kept in the dark until his security clearance came through. "When I found out we were going to attempt to make energy through fusion, as the sun does, I was greatly surprised and excited," recalls Kulsrud.

"During the first few months after I joined the project, we were still very optimistic about how quickly we could develop a workable fusion reactor, because we hadn't yet recognized the stumbling blocks instabilities in the plasma would cause," Kulsrud remembers. "Once we realized the importance of instabilities, we knew the work would go much more slowly than we first expected. It has taken a long time, but over the years we have gradually learned to stabilize the plasma at more and more subtle levels."

Ten years after he joined Project Matterhorn, Kulsrud became the Head of the Theory Division. "By that time," notes Kulsrud, "I had the bigger picture of what was going on and I was in a position to play a useful role in guiding the research."

With a sense of satisfaction, he notes, "Back in 1954, we had no concept of a burning plasma. We've now solved the problem of fusion as we saw it then and gone far beyond those goals. Now, with the deuterium-tritium experiments, we are moving on to other key issues—how to convert neutrons to power and how to handle instabilities at a new level."

In 1960, as a Lecturer in the Astronomy Section of the Astrophysical Sciences Department, Kulsrud began to share his expertise in both astronomy and plasma physics with graduate students. With the exception of a year as a professor at Yale in 1966-1967, he has been teaching at Princeton ever since. Now a professor in the Astronomy Section of the Department of Astrophysical Sciences, Kulsrud maintains his role as senior physicist at PPPL.

The Maxwell prize citation goes on to describe some of Kulsrud's specific accomplishments over the years. "His important work encompasses plasma equilibria and stability, adiabatic invariance, ballooning modes, runaway electrons, colliding beams, spin-polarized plasmas, and cosmic-ray instabilities." He is now planning a book that will summarize some of his accomplishments.

Kulsrud was presented with the $5,000 prize awarded by Maxwell Laboratories Incorporated at the American Physical Society meeting in November. He and his wife Helene have three adult children, Peter, Pamela, and Suzanne, who live in New York and Boston.❖

Science on Saturday

Come one, come all, to an exciting, informative, entertaining, *free* series of lectures geared towards high school students, but open to everyone. Lectures begin at 9:30 a.m. and usually finish by 11:15 a.m. Hint: come early—last year, overflow crowds had to be accommodated via video in the cafeteria. Refreshments are provided by the local chapters of the American Vacuum Society.

January 15, 1994	Dr. Richard Voss, IBM Research Laboratories "The Practical Fractal"
January 22, 1994	No Lecture (SAT test being given)
January 29, 1994	Prof. Patrick Hanrahan, Princeton University "Computer Graphics in Terminator II and Other Films"
February 5, 1994	Prof. Edward Cox, Princeton University "How Animals Develop their Shape and Form"
February 12, 1994	Prof. Edward Witten, Institute for Advanced Study "The Big Bang and the Beginning of Time"
February 19, 1994	Prof. Richard Lutz, Rutgers University "Amazing Creatures at Hot Water Springs in the Deep Sea"
February 26, 1994	No Lecture (Science Bowl)
March 5, 1994	Prof. Peter Lindenfeld, Rutgers University "Superconductivity—83 Years Old, but Not Yet Grown Up"
March 12, 1994	Prof. Edwin Turner, Princeton University "Looking at the Universe through Gravity's Lenses"
March 19, 1994	Dr. Leslie Johnson, Princeton University "Sex Differences in Animals—What For?"

The First Trace Tritium Shots
TFTR Control Room

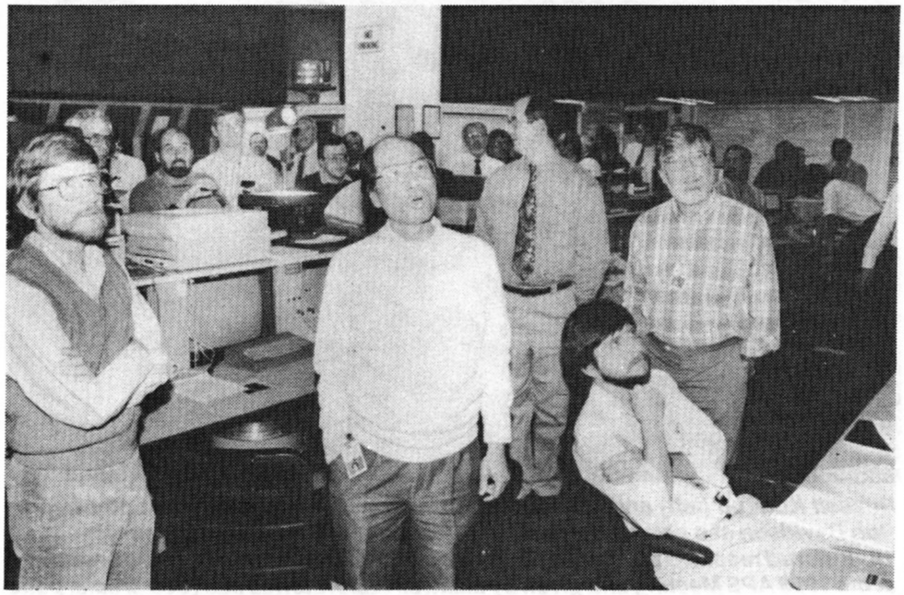

Photo: Dietmar Krause

On Friday, November 12, the TFTR control room was abuzz with excitement as everyone eagerly anticipated data from the very first trace tritium shot. Here, (left to right) Mike Bell, King-Lap Wong, Paul LaMarche (background), Forrest Jobes , and Kingston Owens gaze up at the large screen, awaiting the first results.

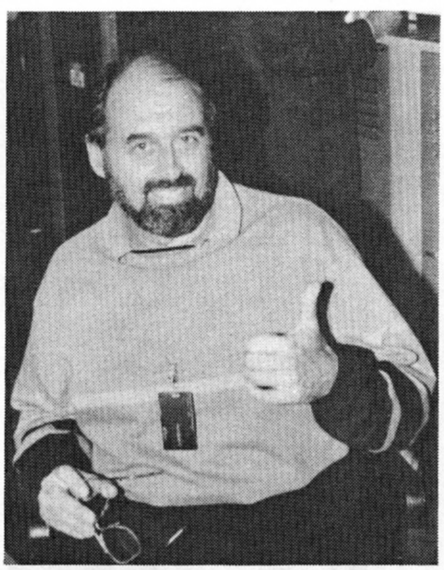

Photo: Dietmar Krause

Jim Strachan gives thumbs up to the success of the first trace tritium D-T shots.

Photo: Dietmar Krause

Mike Williams (left) and Jim Anderson share a jubilant handshake after the first trace tritium shots. In the background, Larry Lagin (center) and George Fleming (rear) consider the new data.

What's Happening at PPPL?

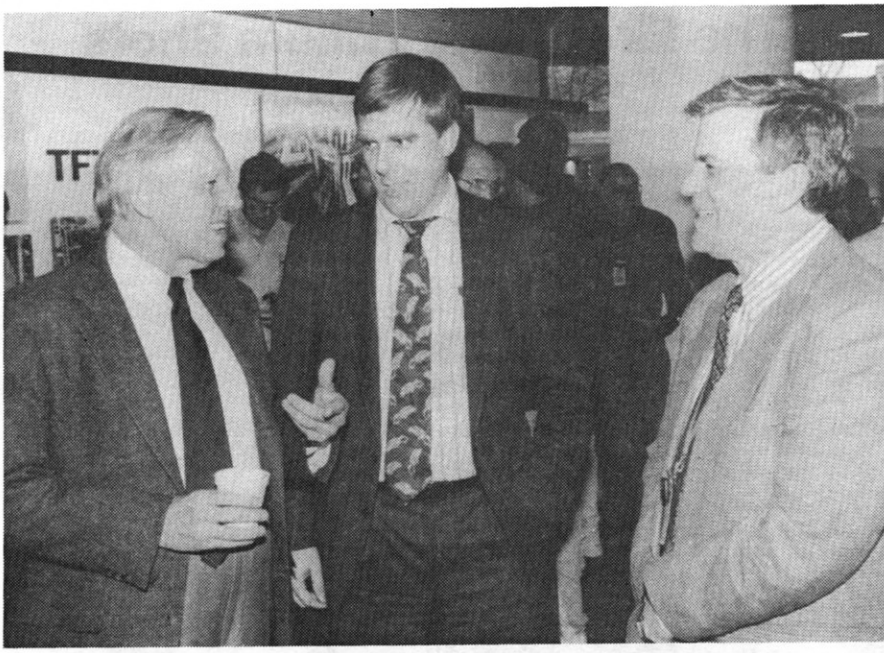

Photo: Dietmar Krause

Russell Kulsrud (left) and Mike Williams enjoy a light moment with Lab Director Ron Davidson at a celebration held in their honor in the LOB lobby on November 18. Kulsrud received the James Clerk Maxwell Prize in Plasma Physics presented at the 1993 APS Meeting and given by Maxwell Laboratories Inc. (See article, page 3.) Williams received the 1993 IEEE Fusion Technology Award. (An article on Williams' award appeared in the November 12, 1993 HOTLINE.)

Photo: Dietmar Krause

PPPL Director Ronald Davidson (far left) and Deputy Director Dale Meade (far right) celebrate with those honored at the FY93 Retirement Award Ceremony and Reception on October 28. Among those present were (left to right) O. Nelson Bowen, Edna Kalmus, Frank Clark, Eugene "Buck" Taylor, and Elizabeth Klank.

Photo: Dietmar Krause

Just in case you needed proof that the graduate program here turns out smart people—John (Bert) Cuthbertson, pictured here during his graduate student days at PPPL, became a five-time champion on the television program Jeopardy during September. He is currently employed at Sandia but is working on loan to General Atomics. Another successful Jeopardy contestant now employed at PPPL is Rush Holt.

Photo: Johanna Van Wert

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Among those from PPPL attending the Fall Open House Information Fair sponsored by the Princeton University Women's Organization were, above, left to right, Martha Redi, Ellen Webster, Dianne Nunes, Gloria Cain, and Ashild Fredricksen. Above right, Carol Phillips explains the mission of PPPL to an interested Princetonian. The Lab provided a van for the convenience of PPPL employees going to the Fair, which was held in Whig Hall on campus.

Photo: Dietmar Krause

Mary Ann Brown displays the Irish Rose Bedspread that won her first place in the Fine Crochet Division at the 1993 Flemington Fair. The U.S. Marine Corps bedspread on the wall won her second place. She also took the blue ribbon last year for fine crochet.

Thank You!

I want to thank all my friends at the Lab for the many cards and well wishes I received upon my retirement. I will miss so many of you, and I wish you all the best. Special thanks to those who attended a dinner and a luncheon for me. The gifts I received were very thoughtful. I am really enjoying my relaxing and carefree days, and I look forward to the future with joy. May God bless you and yours.

Eleanor Schmitt

May this Holiday bring joy and peace to you and those you love.

With very Best Wishes

Ron Davidson