

The
COLORADO
Engineer

Is Four-Channel Stereo
Garbage?

. . . see page 14

May 1974



CHECK OUR SPECS BEFORE YOU BUY THEIR 4 CHANNEL RECEIVER.

	Sylvania	Pioneer	Sansui	Fisher	Harman-Kardon	Marantz
Model	RQ 3748					
Continuous (RMS) Power ¹ 4 channels Stereo Bridge	50Wx4 125Wx2					
THD at rated output	<0.5%					
IM Distortion at rated output	<0.5%					
FM IHF Sensitivity	1.9 μ v					
50 db signal to noise ratio	2.8 μ v					
Capture Ratio	1.5db					
Price	\$549.95 ²					

¹All power measurements taken at 120 volts/60 cycles, 8 ohms, 20Hz-20kHz, all channels driven simultaneously.
²Manufacturer's suggested list price which may be higher in some areas.

If you're in the market for four channel, you already know you've got to spend a good bit of cash for a receiver. So it'd be a good idea to spend a good bit of time checking specs on everything available just to make sure you get the most for your money.

To make your search a little easier, we've prepared the blank comparison chart above with spaces for some of the best-known brands and most important specs. Just take it with you to the store, fill it in, and you'll be able to tell at a glance what you get for what you pay.

We took the liberty of filling in the Sylvania column with specs for our RQ3748 four channel receiver. We did it because we know we're not the best-known name in four channel, and we didn't want you to overlook us for that reason.

Because we think the RQ3748's specs are really worth remembering.

50 watts of RMS power per channel at 8 ohms, 20-20kHz, with all four channels driven. 125 watts per channel in stereo bridge mode. A THD and IM of less than 0.5% at rated output. An FM sensitivity of 1.9 microvolts. A discrete four channel receiver with

matrix capabilities so you can use either type of quadraphonic material. And much, much more.

We can offer so much because we have so much experience. We were one of the first in the audio field. And now we're applying all our knowledge, all our engineering skill to four channel.

Once you've proven to yourself which receiver has the best specs, move on down to that last line in the chart and compare Sylvania's price with all the others. Find out which one gives the most for your money.

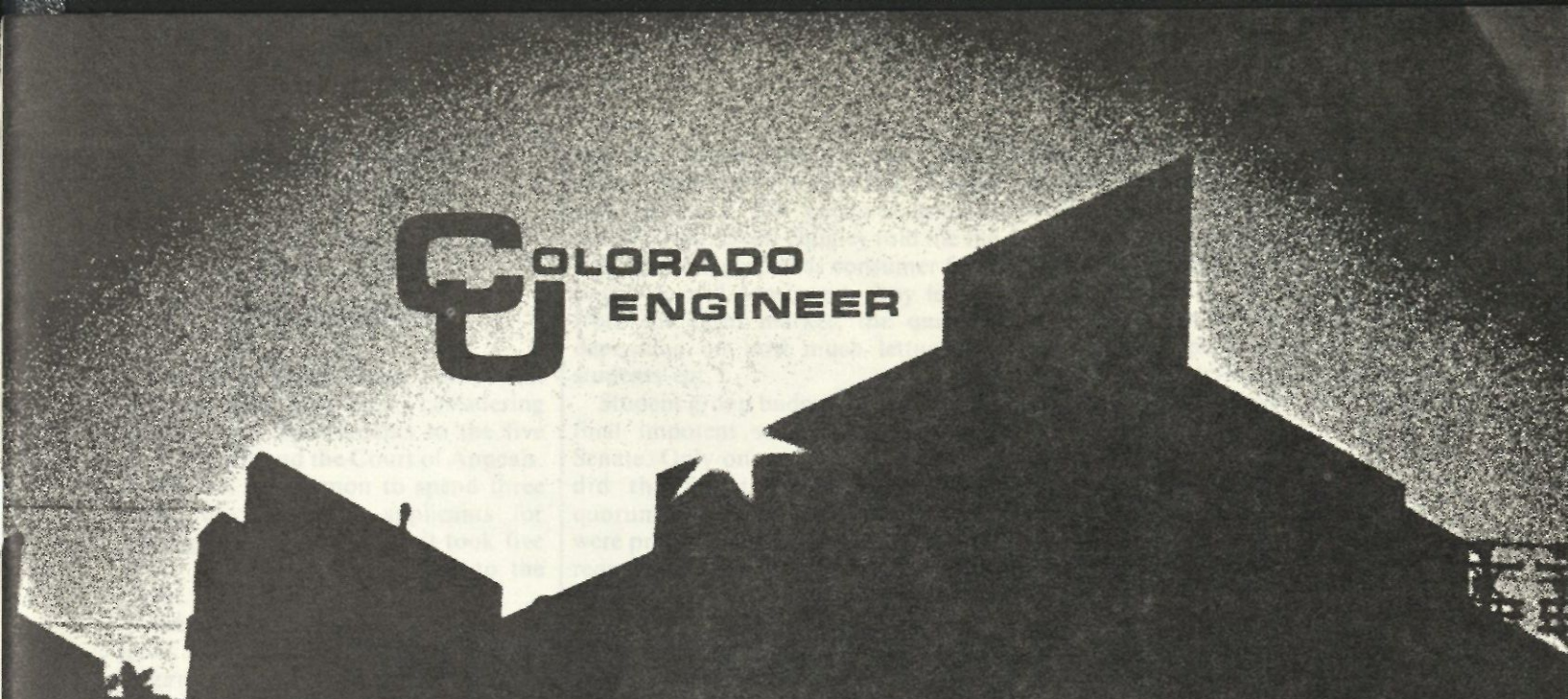
We feel pretty confident you'll discover that the best-known names aren't necessarily your best buy.

³So much more that it won't all fit here. So send us a stamped, self-addressed envelope and we'll send you a four-page brochure on our four channel receivers.



GTE SYLVANIA

Sylvania Entertainment
Products Group, Batavia, N.Y.



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LETTERS

Final Breathes

The ASUC Senate spent a great deal of time this past year considering students for appointments to the five Joint Boards and the Court of Appeals. It was not uncommon to spend three weeks discussing the applicants for each appointment. In fact, it took five weeks to appoint two Justices to the Court.

The past year began with a walk-out from the meeting by Student Rights Organization (SRO) members and their sympathizers, which included both engineering senators. This was prompted by the Senate's refusal to count the votes of seven referenda which appeared on last Fall's student ballot. A legal battle followed and the Court of Appeals decided to give the ballots to SRO. They were permitted to count the ballots and use the results as an unofficial opinion poll. The results of the poll were inconclusive.

The next milestone of the Senate was the endorsement of the Boulder Abortion Clinic. The endorsement saw three weeks of debate by both Senators and interested students who sat in and watched the show. Based on the idea that abortion is an individual question which only the individual can answer, the endorsement was approved.

Perhaps the most constructive action of the Senate was changing the voting system from "bullet balloting" to single transferable voting. Senator Joel Davis spent many months researching several voting systems, and the latter seemed the fairest. Instead of just marking an "X" on the ballot, a student ranks each candidate in order of preference. The winners are determined from a detailed tallying system, which is clearly defined in the Election Code.

The concept of non-mandatory funding for student groups, ASUC, and other fee grabbers brought student government back into the interest of the student. The Senate meeting room was packed with members of most student groups. Verbal jabs were exchanged for more than an hour before the voting finally began. The result was a continuation of status quo; the student has no direct control over fee allocations, the student government will continue to distribute them.

The last constructive action the Senate took was to put a lettuce

boycott referendum on the Spring ballot. However, the vote has no legal significance, it just becomes another opinion poll. Dean Quigley told me the poll can be regarded as consumer feedback. He will continue to buy lettuce from the open market, the quantity depending on how much lettuce the students eat.

Student group budgets consumed the final impotent weeks of the ASUC Senate. Only once in its last six weeks did the Senate manage to reach quorum, and both engineering senators were present. Consequently, the budget requests were sent to the small group of people who compromise the Finance Board. The members had been appointed to this Board by the Senate last year. They will send their budget recommendations to the Board of Regents for final approval.

ASUC died on May 2, 1974. It was replaced by the University of Colorado Student Union (UCSU), which was accepted by the students in the Spring elections. THE UCSU Executive Council replaced the ASUC Senate. The Constitution still has a few holes in it, and the new government should have some fun with it.

Perhaps student politics is not too productive, which is a claim we have all

made. Getting personally involved can become depressing when you finally realize that you cannot change all those screwed up obstacles. Everyone cannot share the same opinions. If you can keep your sense of humor, student government can become an unmatched experience in personal interaction. It has been very trying many times this past year, but I survived and I think it was almost worth it.

Charlie Czarniecki
ASUC Engineering Senator

Kudos

I wish to compliment you and your staff on the excellent job that was done on the March issue. The format, layout, article content and even the advertisements strike me as being that of a first-class professional magazine. Please keep up the outstanding work, especially the high quality of your articles.

Jeffrey Scott
Baker Hall

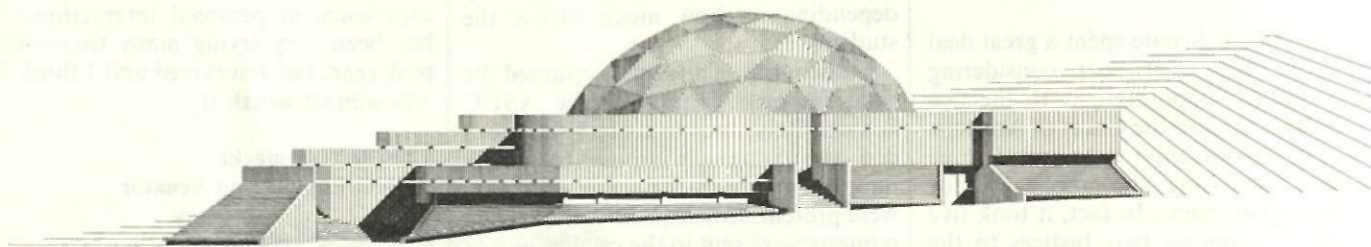
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FISKE PLANETARIUM



by Walt Cranor

Back in March of this year the west end of Observatory Hill suddenly moved around to the north side of the ridge. This earthmoving marked the beginning of one of the most exciting projects on the University of Colorado campus - the new Fiske Planetarium. This facility promises to be one of the finest in the nation; an architectural landmark with a geodesic dome topping wide public terraces.

The late Wallace Fiske, 1917 history graduate of CU, gave 1.3 million dollars to the University to build and operate the planetarium. Fiske attended the University of Denver law school and was a practicing attorney for many years. Fiske's gift to CU also included \$450,000 for the College of Music.

The planetarium was designed by the architectural firm of Marvin Hatami and Associates. The principal contractor is the Newstrom-Davis Construction Company. Several other area engineering firms will have roles in the project including McFall and Konkell, Swanson-Rink, and KKBNA.

The screen for the Fiske Planetarium will be a hemispherical dome 65 feet in diameter, which will be the sixth largest planetarium screen in the United States. The star projector is a Zeiss Model VI from the Carl Zeiss Co. The Model VI is the top model made by Zeiss, one of six in the United States. The planetarium will contain between four and five hundred slide projectors as well as several motion picture projectors, capable of producing an ex-

citing range of visual effects. The sound system will feature an elaborate discrete four channel sound from speakers custom designed for the planetarium. Sound tracks will be prerecorded on professional studio tape machines enabling maximum flexibility with minimum setup time. Perhaps the most unique feature of the Fiske Planetarium will be the instrument elevator. The star projector will be mounted on a hydraulic platform that will disappear below the floor.

The excavation for the Fiske Planetarium has prompted much speculation. The excavated material was hauled around to the north end of the ridge on Observatory Hill for two reasons. The first consideration was financial—it was less expensive to move the dirt than to haul it away and sell it as fill. The second purpose for placing the dirt on the ridge was to provide a base for landscaping. Since the earth removed contains shale, which expands and contracts with changes in moisture content, it was unsuitable for backfill needed at the building site. So, fill dirt was purchased and is being stored in a large pile on the top of the ridge. When construction of the walls is complete, the fill dirt will be used to return the profile of the hill to approximately its original shape.

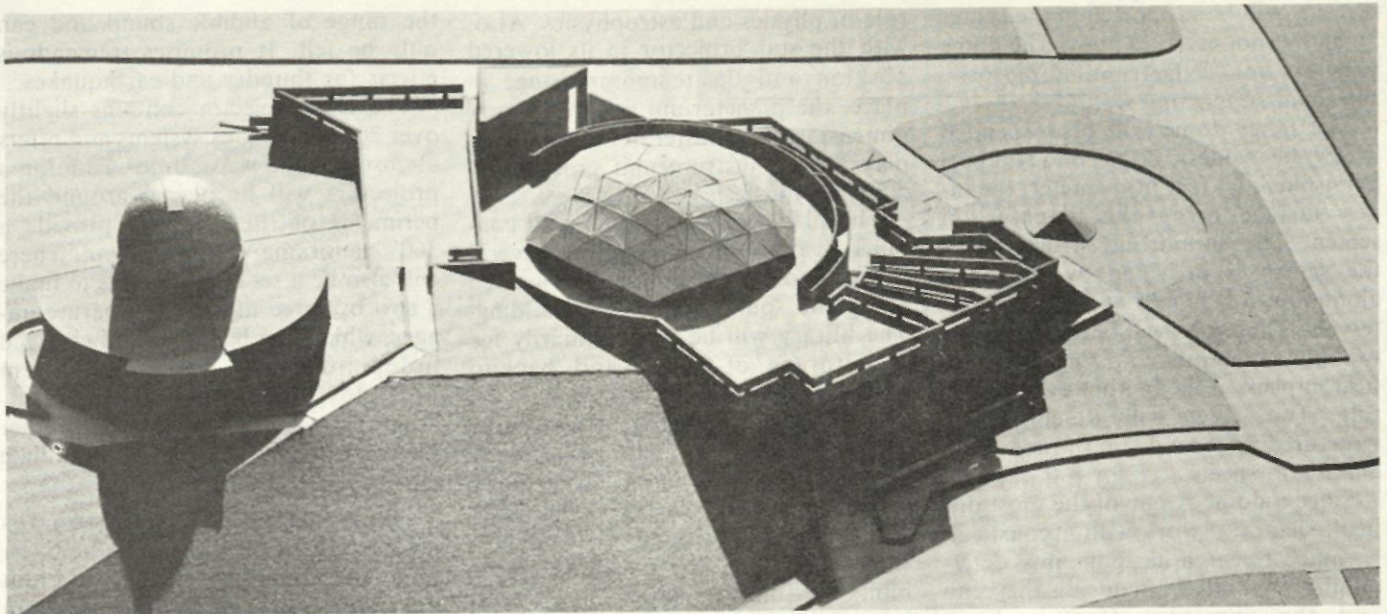
Beneath the soil, the bedrock is a layer of harder shale between 6 and 18 feet down. The shaft for the instrument elevator goes into bedrock to a depth of 24 feet. The casing for the lift cylinder penetrates bedrock to a depth of 48 feet. Since the soil at floor level is insufficiently hard to be considered bedrock, caissons were placed reaching 6 feet into bedrock to attain sufficient load bearing capacity to carry the supporting walls and columns. The

primary supporting wall a circular wall 25 feet high, forming a circle 75' 4" in diameter and resting on caissons placed every 22 feet around its circumference. Caissons were also utilized to form a temporary retaining structure for the excavation of the elevator shaft.

The body of the planetarium will be reinforced concrete cast in place. A massive single set of forms will be used to pour the circular wall which encloses the planetarium chamber. Following the pouring of the walls and columns, the beams and ceilings will be poured. The form work for this step is a rather formidable task, since a temporary superstructure must be provided under the forms capable of carrying the load of the uncured concrete plus any additional load applied before the concrete is cured. The finish floor will be poured on the level of the current excavation. A portion of the building has a second story, and this slab will be poured along with the ceiling slabs on top of the beams after the beams have cured.

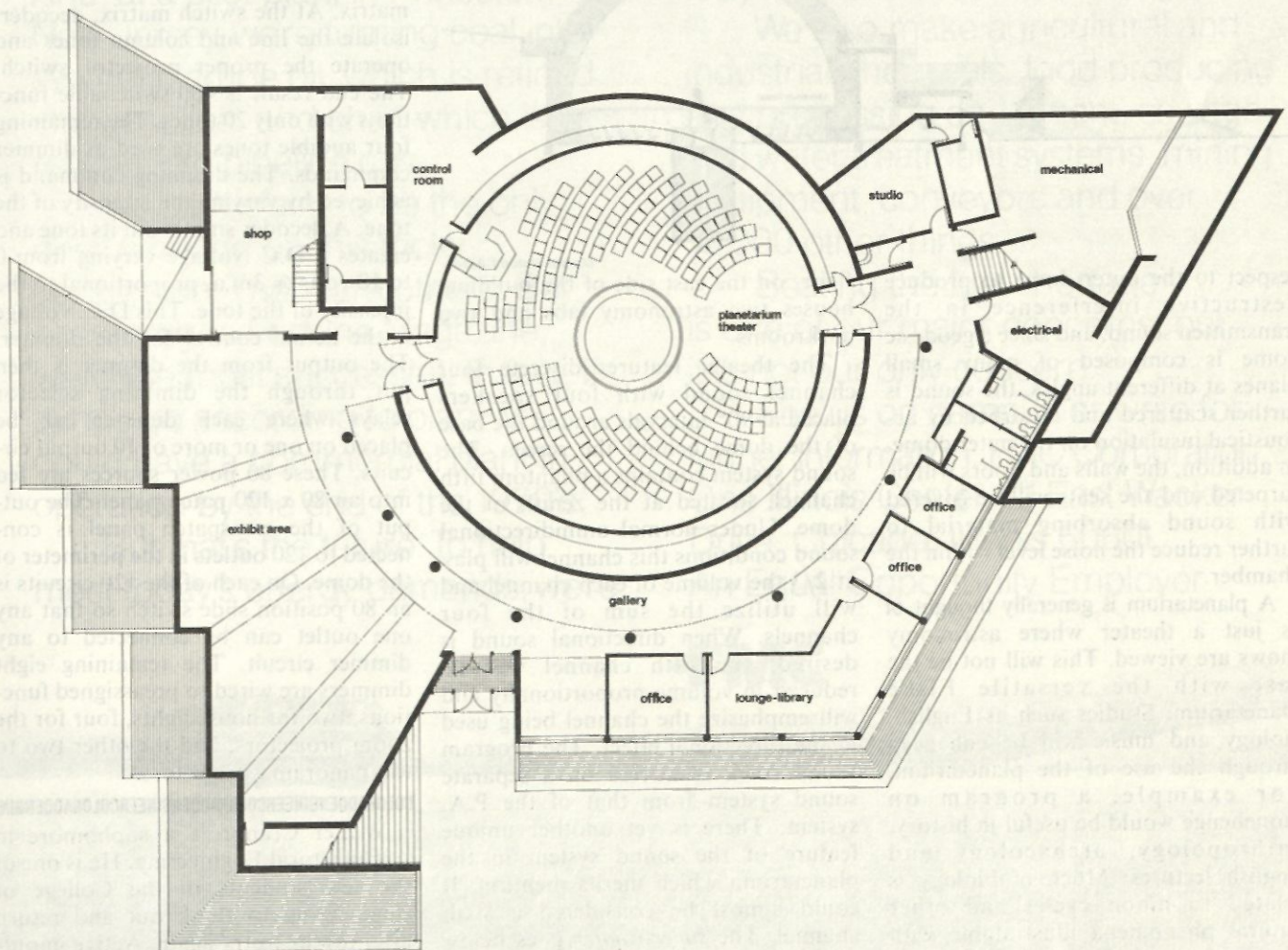
Construction of the instrument elevator shaft and placement of the lift cylinder pose another unusual construction problem. The elevator shaft will be built in a hole 20 x 20 feet and 25 feet deep. When construction of the shaft is complete, a 6 foot deep caisson will be poured in the bottom of the lift casing. The lift cylinder will be set on top of this and anchored in place by sand placed around the cylinder. The platform which forms the base for the star projector will then be constructed on the lift cylinder.

The outer dome is an aluminum geodesic dome being manufactured in California by the Tencor Co. It will be shipped to the site in sections and assembled on site. Until complete, the



This photograph of the model shows the Fiske Planetarium as it will appear when completed.

Marvin Hatami Assoc.



Floor plan for the planetarium.

Marvin Hatami Assoc.

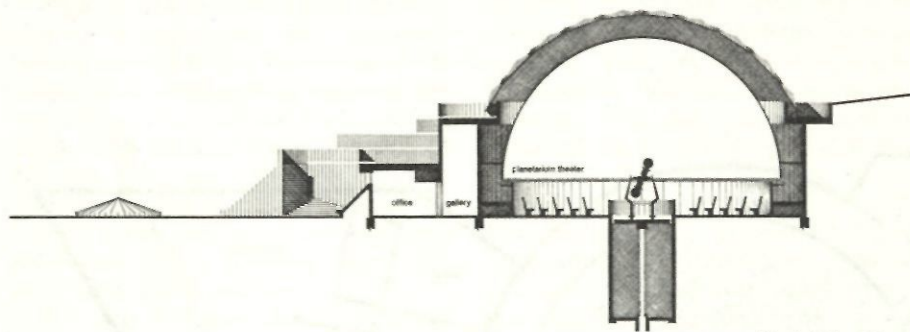
sections will be supported in the center by an 80 foot erection mast. The dome will rest on a ledge cantilevered from the main supporting wall.

The inner dome will be suspended below the geodesic dome, and will be a hemisphere 65 feet in diameter, the inner surface being the planetarium screen. The supporting structure for the screen is provided by 52 radial aluminum fins placed at $6^{\circ} 54' 24''$ intervals. These ribs will be joined at the top by a compression ring, and are held in place at the bottom by a tension ring. The screen will attach to this structure and is made up of perforated aluminum sheets.

Since a dome is one of the most difficult shapes to work with acoustically, much research has gone into determining methods of reducing the echo and the focusing effect a dome produces. The perforated screen allows 90% of incident sound to pass through, reducing the echo inside the inner dome. Also, the inner dome is deliberately placed off center with

role in physics and astrophysics. Also, with the star projector in its lowered position and the temporary stage in place, the planetarium assumes a new dimension as a theater in the round for plays, small instrumental groups and chamber music.

The planetarium building also contains a variety of other spaces. Several offices and a small library are located along the south side of the building. The library will be used primarily for the storage of shows and backup material. The offices will house the director and his technical assistants. The west side of the building is primarily a multipurpose lobby. This lobby will be equipped to serve as one large gallery or partitioned into several smaller galleries for planetarium exhibits or fine arts displays. The full potential of this area will only be realized after the building is in use. Adjacent to the planetarium chamber on the north are workshops to assemble equipment, slides, and visual effects which make up a show. The second



respect to the outer dome to produce destructive interference in the transmitted sound, and since a geodesic dome is composed of many small planes at different angles, the sound is further scattered and absorbed by acoustical insulation on the outer dome. In addition, the walls and floors will be carpeted and the seats will be covered with sound absorbing material to further reduce the noise level within the chamber.

A planetarium is generally thought of as just a theater where astronomy shows are viewed. This will not be the case with the versatile Fiske Planetarium. Studies such as English, biology and music will be enhanced through the use of the planetarium. For example, a program on Stonehenge would be useful in history, anthropology, archaeology and English lectures. Much of biology is related to moon cycles and other natural phenomena illustratable with planetarium shows. Naturally, the planetarium will play an important

role in physics and astrophysics. Also, with the star projector in its lowered position and the temporary stage in place, the planetarium assumes a new dimension as a theater in the round for plays, small instrumental groups and chamber music.

The theater features discrete four channel sound with four speakers placed at 90° intervals around the base of the dome behind the screen. The sound system contains a phantom fifth channel, located at the zenith of the dome. Under normal omnidirectional sound conditions this channel will play at $2/3$ the volume of each channel and will utilize the sum of the four channels. When directional sound is desired, the fifth channel will be reduced in volume proportionally and will emphasize the channel being used in the directional effect. The program sound track is carried on a separate sound system from that of the P.A. system. There is yet another unique feature of the sound system in the planetarium which merits mention. It could almost be considered a sixth channel. The *super-woofer* goes below 19 Hz and provides an omnidirectional bass which, at its lowest, goes below

the range of audible sound and can only be felt. It promises tremendous effects for thunder and earthquakes.

The star projector contains slightly over 200 projections systems and offers almost limitless possibilities. Panorama projectors will be placed around the perimeter of the dome to provide a 360° panorama of the horizon. There will also be a set of projectors to make a two by three matrix of separate images, which can be faded and changed independently. Another system provides images projected randomly anywhere on the dome. Another system of zoom projectors will simulate moving objects.

The design of the control system was the most difficult problem to be overcome. After several months of brainstorming, James Sharp, planetarium technical director, devised a recording system using a matrix of audible tones. In each of the four channels, 24 audible tones are used, 10 for the rows, 10 for the columns, and 4 for dimmer controls. Thus when any one of the 100 buttons of the 10×10 matrix is pressed, two audible tones are sent to the matrix. At the switch matrix, decoders isolate the line and column tones and operate the proper projector switch. The end result is 400 switchable functions with only 20 tones. The remaining four audible tones are used as dimmer commands. The dimming command is achieved by varying the intensity of the tone. A decoder singles out its tone and creates a D.C. voltage varying from 0 to 10 volts @ 3m.a. proportional to the intensity of the tone. This D.C. voltage is the actual control for the dimmer. The output from the dimmer is then put through the dimming selector relays where each dimmer can be placed on one or more of 10 output circuits. These 80 power sources are fed into an 80×120 patch panel. The output of the crosspatch panel is connected to 120 outlets in the perimeter of the dome. On each of the 120 circuits is an 80 position slide switch so that any one outlet can be connected to any dimmer circuit. The remaining eight dimmers are wired to preassigned functions, two for house lights, four for the zoom projectors, and the other two to the panorama projectors.

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Walter Cranor is a sophomore in Architectural Engineering. He is one of the few students in the College of Engineering to flunk out and return after a year to try again. Active in outdoor sports, his latest project was building a concrete canoe for E-Days.

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FACULTY RECEIVES AWARDS

An award from the Rocky Mountain Chapter of the National Electric Contractors was conferred upon a civil and environmental engineering professor in observance of National Electric Week.

The engineer is Dr. Ronald N. Helms, whose illumination laboratory is one of the very few of its kind in universities anywhere. The laboratory is unique in that it deals with lighting from the point of view of eye comfort and effective vision rather than of light-emitting devices.

Five other Coloradoans who also received the "big ring" award of society all were either electrical engineers or involved in industry.

The President's Award of the University of Colorado chapter of Tau Beta Pi, national engineering honorary society, was conferred April 21 upon Associate Dean of Engineering George J. Maler. His award cites him for his outstanding guidance and counselorship.

BUS TIRE RESEARCH

A University of Colorado engineering research team will be racing against spring weather in the high country in an effort to gather data about the skid characteristics of school bus tires.

A 60-passenger bus will be tested both for stopping power and for pulling power, using conventional tires, mud and snow tires, and chains on dry, wet, snowy, and icy road surfaces. Its performance on both paved and graveled surfaces will be checked.

The study is being undertaken at the request of the Board of Education of Boulder Valley School District RE2, which is supplying the vehicles and drivers and paying the costs of the research. Dr. Don R. Mosher of the Department of Mechanical Engineering and Professor Richard H. Crawford of the Department of Engineering Design and Economic Evaluation are directing the work, with the cooperation of Dr. Barnard D. Ryan, superintendent of schools, and Lawrence Skinner, the district's director of transportation.

Explained Dr. Mosher, the principal

investigator, "The major volume of pupil transportation in the district is in the high plains. A small fraction, however, involves students who live in the mountains and foothills at elevations up to 9,000 feet. A bus serving these areas may in a single run encounter a near-complete spectrum of road conditions: dry pavement or gravel, wet snow, packed snow, powder snow, and ice."

"The object of the district and our project is to facilitate the safe operation of buses under these diverse conditions. This depends in large part on the use of tires with the correct tread or with effective chains. Good data on what constitutes correct equipment has not been generally available. Some experienced bus drivers, for example, have expressed the belief that at lower temperatures the use of chains may actually be disadvantageous."

There is a compelling need to conduct such tests with typical school buses," said Professor Richard H. Crawford, co-investigator of the project.

"There have been limited tests to evaluate passenger car performance on glare ice at temperatures somewhat below freezing, but, although they provide valuable guidelines, there is reason to question their broad applicability," Professor Crawford said.

The tests will be carried out with specially instrumented drawbars, linking the bus to a six-wheel-drive truck owned by the school district. The bus will be weighted to simulate a full load of passengers. As the truck drags the bus forward, recording instruments in the cab will measure the amount of force required to make the wheels skid under various combinations of conditions. With the bus pulling the truck, the amount of resistance needed to make the wheels spin can be measured.

The project is designed to produce a report that will give school transportation directors like Lawrence Skinner better grounds for deciding when to have chains mounted, to what extent studs improve the performance of mud and snow tires, and under what weather conditions buses might be expected to have serious difficulties.

SOME SOLAR HEATING OBSOLETE

The sun's energy can become an important source of heat for buildings, and the heat pump will probably play an important role in utilizing it, but "there are a lot of people trying to sell systems that didn't work very well in the Fifties; you should require a performance bond for any system you install."

That assessment is made by an engineering faculty member of the University of Colorado who serves as a consultant on solar energy to the RANN Division of the National Science Foundation. The NSF's RANN Division is concerned with research applied to national needs. Dr. Frank Kreith, professor of chemical engineering, is internationally recognized for his work in heat and mass transfer. He is currently revising his book, written in 1963, on the design of solar energy systems.

"A standardized acceptance code for solar heating units and heat pumps is urgently needed," Dr. Kreith said. "When you buy a gas furnace it is labeled 'this is a 60,000 B.T.U. unit.' It's not quite that simple for solar systems, but an acceptance code is needed."

There is a "Catch-22" situation now holding back solar installations, he explained. "Often you can't borrow money on a solar heated building because it doesn't conform to the building code, and there is no building code for it because there are not enough solar heated buildings on which to base one."

Dr. Kreith is working with city officials of Boulder, Colorado, on plans for a building code for solar heating systems, and hopes that engineers and architects can develop nationally recognized acceptances and codes.

In those areas of the nation that receive average sunlight, Dr. Kreith believes that partial solar heating with flat-plate collectors can become economically feasible. "My hope is that a stationary reflector type system can be evolved," he said. A unit providing a temperature of 500 degrees fahrenheit could supply heat to power a properly designed absorption refrigeration system for air conditioning, and 500 to 550 degrees

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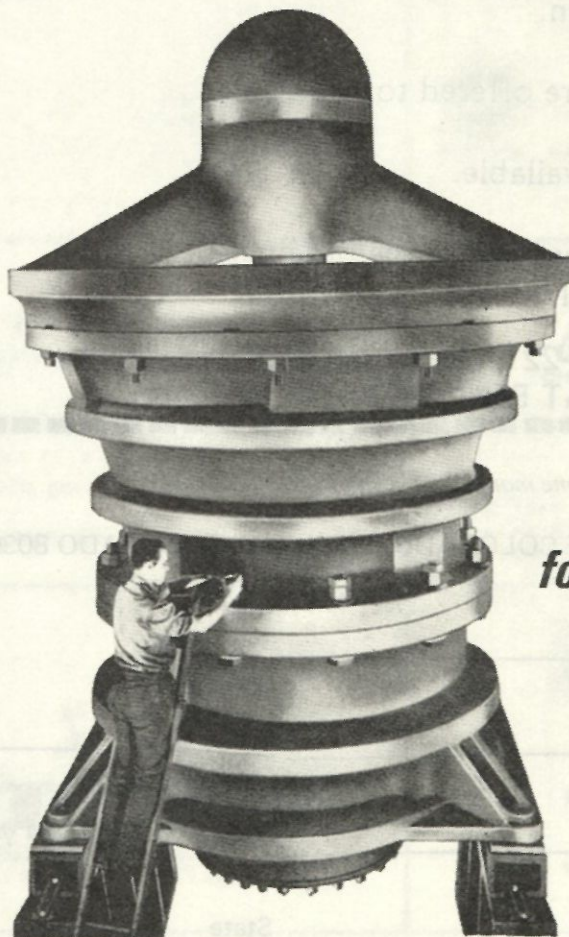
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would handle space heating, he said. In the Rocky Mountain area, however, where there are many clear, sunny days, Dr. Kreith believes that solar heaters which use stationary reflector-concentrator systems are economically superior to flat-plate collectors. "It is my hope that such stationary concentrators can be mass produced soon," he said.

In order of importance, the urgent engineering problems to be solved are cost, service lifetime, construction methods, and upkeep, he said.

There are three basic types of solar heat collectors. One is the flat-plate unit, usually using a black surface to absorb heat and using circulating air of fluid to transfer the heat. The other two employ either lens or reflector systems to concentrate the sun's heat. They can achieve very high temperatures. In one of these the optical system is moved to follow the sun and keep the concentrated beam focused on the heat collector. This type is in limited use for cooking and industry. The other type would employ a stationary optical system that concentrated the light where needed without itself moving. One way

suggested for doing this is with fresnel lenses made of plastic. (The fresnel lens is a thin sheet of optical material having small triangular corrugations on its surface. Each corrugation functions as if it were a small slice from a large lens. Viewed end-on, a cross section forms a saw-toothed pattern.) Heat at the focus of lens systems usually is either removed as steam or used directly.

Working on solar heating recently during three months at the University of Negev, in Israel, Dr. Kreith examined the rooftop solar water heaters which are universally used in Israel. These usually consist of wide black plastic channels topped by glass. Sun shining through the glass heats water flowing over the black plastic. They heat water to about 180 degrees fahrenheit, and are the only water heating device in most Israeli homes.

"The chief problem these encounter in Israel is dust," Dr. Kreith commented. "The glass must be cleaned frequently, and people neglect this."

Such units can be purchased in the United States, and would be effective in most parts of the nation if they were modified to avoid damage from freez-

ing when they are covered by snow. Most U.S. users would want a conventional water heater as an auxiliary supply, Dr. Kreith believes.

CHEMICAL ENGINEERING FACULTY ACTIVE

Dr. Klaus D. Timmerhaus, associate dean of engineering, delivered the Omega Chi Epsilon lecture to chemical engineering faculty members and graduate students of the University of Oklahoma Friday (March 8). After speaking on "The Strange but Exciting World of Cryogenics," he left for Tulsa, where he conducted a series of meetings in connection with the 76th national meeting of the American Institute of Chemical Engineers. Dr. W. F. Ramirez, chairman of the Department of Chemical Engineering presented a paper in a symposium on process control and estimation at the national meeting. It was titled "On-Line Computer Control of a Stirred Tank Reactor."

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DISTINGUISHED ALUMNI AWARDS

by Jim Wood



EDUCATION

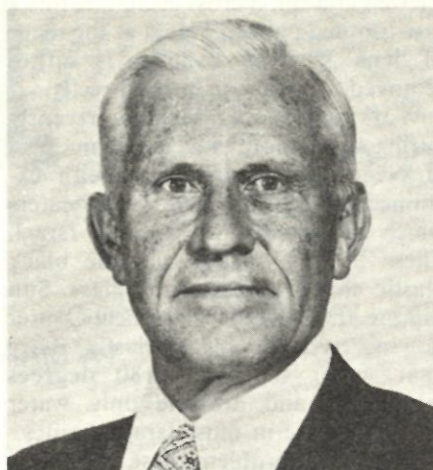
Irene Carswell Peden

A noted engineering educator and a main advocate in the effort to involve women in engineering careers, Dr. Irene Carswell Peden is the 1974 recipient of DETA for Education. Dr. Peden received her DS in Electrical Engineering from CU in 1974 and also holds an AS from Kansas City Junior College with MS and PhD degree from Stanford University.

After successfully entering engineering in industry Dr. Peden was appointed to the engineering faculty at the University of Washington at Seattle in 1961, where she now resides with her attorney-husband Neo J. Peden. In August 1973 she became associate dean of engineering at Washington.

Dr. Peden's outstanding work in education and radio research have earned her many coveted honors. She holds The Society of Women Engineers Achievement Award, for "contributions to radio science and her activities in education." In 1972 she received a similar national honor from Alpha Chi Omega. In 1971, Peden was named Woman of the Year by the Seattle Chapter of Quota International.

In addition to her duties as member of the National Advisory Drug Committee of the United States Food and Drug Administration, Dr. Peden has a seat on the Advisory Council for Stanford's School of Engineering and is active in the America Society for Engineering Education.



RESEARCH AND INVENTION

Joseph S. Alford

Joseph S. Alford, winner of the DEAA in Research and Invention is a distinguished employee of General Electric's Aircraft Engine Group. He was one of the primary contributors to the development of jet engine superchargers, used on the 747 Jumbo jet and has participated in jet aircraft engine development for many years.

Alford graduated with special honors from CU in 1934 as a mechanical engineer. He joined General Electric and a year later enrolled in GE's Advanced Engineering Program. During World War II, Alford transferred to GE's Supercharger Division where he organized engineering instruction, designed superchargers, and did analysis on aircraft engines.

Alford is the author of several professional papers and holds 27 U.S. patents. He has received numerous awards for outstanding achievements, including General Electric's Charles S. Steinetz Award. In 1965, Alford was named Engineer of the Year by the Technical and Scientific Societies Council of Cincinnati for his work in jet engines and his contributions to the Engineer's Council on Professional Development.



GOVERNMENT SERVICES

Wade H. Taylor

Hydroelectric energy expert Wade H. Taylor is this year's distinguished alumni in the Government Service Category. A 1934 engineering graduate of C.U., he later received his M.S. here in electrical engineering. In a 35 year career with the United States Bureau of Reclamation, Taylor compiled an impressive service record and has received many Reclamation awards for his dedicated work. As one of the Bureau's top hydro-electric production and transmission authorities, Taylor directed activities in Region 3 which includes California, Nevada and Arizona. His strong leadership assisted in the negotiations and planning for the 800,000 volt Pacific Northern-Pacific Southwest power network. Taylor was responsible for the development of a Denver simulator which trains power plant operators for 17 western states.

For his outstanding service, Taylor received the U.S. Department of Interior Distinguished Service Award in 1966. Beside holding the grade of Fellow in the IEEE, Taylor has membership in the International Conference on Large Electric Systems (CIERE), located in Paris. He also has a seat on the Engineering Development Council at C.U.

The University of Colorado College of Engineering has quite an outstanding and successful group among its graduates. To commemorate this proud heritage the University of Colorado

Engineering Development Council began a program in 1966 to honor prominent graduates. Distinguished Engineering Alumnus Awards are given in six categories: Education,

Research and Invention, Government Service, Industry and Commerce, Private Practice, and Special.



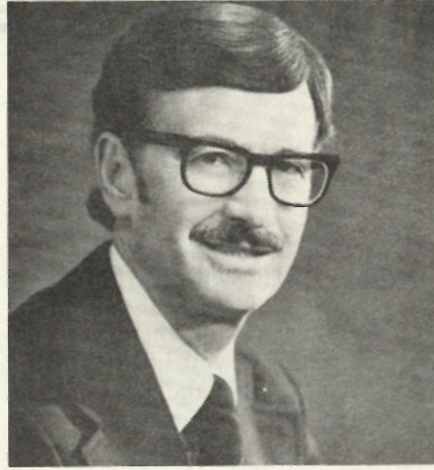
INDUSTRY AND COMMERCE

Robert J. Wolf

Robert J. Wolf graduated from CU in 1937 and is an executive vice president for Kaiser Engineers. Wolf directs designing and construction activities currently valued at over one billion dollars.

Following graduation, Wolf joined a Detroit firm specializing in the design of structural steel and concrete projects. He became involved in a series of designs as a project engineer, valued at nearly \$50 million. Wolf was later promoted to assistant chief engineer responsible for a number of major industrial construction projects.

Wolf began his career with Kaiser in 1956 as a division manager supervising the work of 400 engineers. Two later, he was named vice president of the Kaiser Engineers Division when the firm was constructing the National Aeronautics and Space Administration mission control center in Houston. In 1973 Mr. Wolf was named executive vice president in charge of all the activities of Kaiser's Engineering Division. Wolf is also a vice president or director of sixteen Kaiser subsidiaries and is a director of the Universal Dredging Corporation.



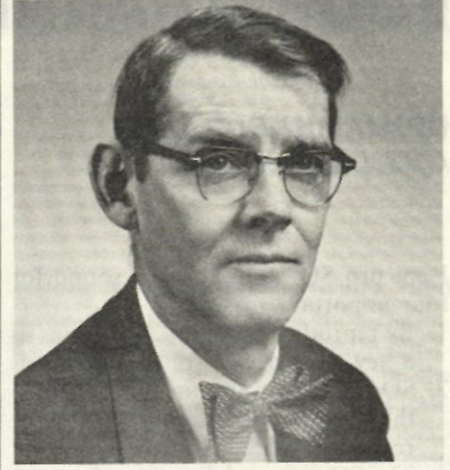
PRIVATE PRACTICE

Arthur M. Krill

It must have been hard to find a category large enough to cover the wide variety of activities of Arthur M. Krill recipient of the award for distinguished achievement in Private Practice. An accomplished business man Mr. Krill also has shown competence in both academic and research pursuits.

Krill graduated with honors from the CU College of Engineering in 1943, and took his skills in mechanical engineering to Pratt and Whitney Aircraft Corporation. Four years later, he was appointed to teach at the University of Denver. While at D.U., Krill became an associate professor of mechanical engineering, coordinator of the cooperative engineering plan and director of administrative engineering. Krill did an intensive study of management and psychology at D.U.

In 1961, Krill left the University of Denver to form the Falcon Research and Development Company of Denver. Two years later he became the president of the Ken R. White Company, one of Denver's largest engineering and architectural firms. Concerned primarily with improving man's environment, the White Company has projects around the world.



SPECIAL

Jackson F. Fuller

This year's recipient of the DEAA Special award is a familiar face around the Engineering Center—Jackson Fuller is a CU professor of electrical engineering.

Fuller graduated from CU in 1944 with honors in electrical engineering. He joined General Electric soon after graduation and became involved in many projects. Fuller was responsible for the first applications of a hydroelectric project in the Rockies.

In 1948, Fuller was stricken with polio and was told that he would never walk again. However, in a determined and dramatic recovery Fuller conquered the illness and returned to work, travelling 80,000 miles a year in his duties with GE. During his industrial career, Fuller was awarded several patents for his inventions.

Fuller returned to CU in 1969 to become professor of electrical engineering. He introduced several new projects in the College of Engineering including a student investigation into electric autos and a computer controlled electric generator.

FOUR CHANNEL SOUND? YES!

BENJAMIN B. BAUER

CBS Laboratories

I am pro SQ* four-channel sound for four important reasons:

1. By reproducing reality, SQ brings us a new measure of sonic enjoyment.
2. SQ opens new artistic dimensions to the composer, the performer, the record producer, and the listener.
3. The SQ system delivers a solid four-channel sound without obsoleting any of the present-day stereo equipment, and retaining the full high-fidelity values of the disc record; and it does so in a practical and economical manner.
4. By synthesizing a credible ambience with the existing stereo recordings, the SQ system improves and extends the value of existing stereo record collections.

Now, let's examine these premises. We live mostly in a world of 2π steradians—or perhaps, a bit more when we climb to the top of tall buildings. Sounds come from all around us, and we have learned in real life to recognize their direction. There is little argument that if technology and cost were no object, we would wish to give to the artist and the producer the ability to recreate this full surround-sound potential. Let's look at a similar art. Still photography is great—it built Kodak's fortune. Motion pictures are even better—they help us to identify with the performers. Sound plus motion adds to a new dimension, as does color—and all at a small incremental cost we cheerfully pay.

QUADRAPHONY ADVICE

I take the liberty of already observing that you have come to my point of view. But then, I see you thinking it over and saying: "But Bauer has a vested interest in Quadraphony—how do I know that his advice is unbiased?"

Then, don't take my advice. Use your own common sense. Think of a real-life sonic experience. Like when you went to a symphony concert or a

rock festival. The sounds arrived from all sides—first from the stage, then after each crash-bang there was ambience enveloping you in a delightful sonic cocoon. Later the applause was all around you. Or, imagine yourself playing in a string quartet—the second violin is at your left, the cello is at your right, and the viola in front. Can you identify yourself with these space experiences, or would you rather have all this sound come at you through two holes in the wall? Or, use your ears. Go to the nearest quadraphonic salesroom and ask for a demonstration. Be sure that your supplier has good equipment, which is set in a livingroom-like environment. If the dealer plays a matrix system, be sure to ask if this equipment has an "SQ Full-Logic" Decoder. Then, decide for yourself.

We find that most people who oppose quadraphony have not heard it, or if they have heard it, it was with primitive or counterfeit equipment or under abominable surroundings—a noisy store, a hard-walled classroom, or a cavernous studio. In a typical livingroom for which the records are produced, using good equipment, quadraphony is almost unbelievably satisfying. Friends who experience it in my home for the first time literally flip. They must have it in their own homes at once. I was flabbergasted when the day following such an experience, one of my visitors called me at the office and asked if I had an "in" with the equipment manufacturer. "Another one of those 'moochers' who want me to get it for them wholesale!" I groaned to myself. Oh no, this was not the purpose of his call! His dealer was out of stock for the particular brand and he wanted to use my good offices with the manufacturer to deliver him a set as soon as possible!

But, let us say that you won't trust your own mind or ears. Whose advice should you take? The answer is so simple that I am willing to wager that you



*SQ is a trademark of CBS, Inc.



QUADRAFIZZLE

J. ROBERT ASHLEY
University of Colorado

A quadrifizzle* is a program that has four areas of foolishness caused by poor engineering. A recent quadrifizzle is the current fad in audio gadgeteering called 4-channel stereo. This idea has been brewing in most audio equipment marketing manager's offices for about four years and the engineering has been done after the fact. It is not surprising that the engineering has been shoddy and the results very unsatisfactory. Consumers are asking better questions about 4-channel and the salesmen get caught in their own confusion in giving answers. The result is that the only 4-channel sales come as the result of high pressure marketing tactics and I have a sad feeling that the buyer ends up with a very sour taste in his mouth after living with his 4-channel for more than four weeks.

FOUR CHANNEL HISTORY

The 8-track tape cartridge playback system using 2-tracks at a time was modified in the late 1960's to play back 4-tracks at a time. (This is now considered to be the prototype of the discrete 4-channel system.) Some pre-recorded tapes were marketed for this system. The problem of compatibility with existing 2-channel stereo systems and the well-known convenience of the disk phonograph record motivated the development of the 4-2-4 matrix system that became available to consumers in 1970. Looking for commercial alternatives to the 4-2-4 matrix as well as the need for increased band width for transmission of four independent channels of information led to development of several kinds of "discrete" disk recording methods* and associated demodulation techniques. Through all of this, I have sensed that the development has been fragmented, cloaked in

*Note that the correct Latin prefix is *quadri*— those who coined the words "quadraphonic" and "quadrasonic" knew as little Latin and Greek as they knew about engineering.

secrecy of commercial rivalry, and supplied with more marketing razzle-dazzle than engineering common sense. Although this is the tradition in the audio field, I think there are long term economic consequences that demand that engineers apply some common sense to 4-channel.

I became interested in the consumer's side of this development when I heard the demonstrations at AES conventions that invariably started with over \$2,000 worth of loudspeakers and included another several kilobucks worth of amplifiers, turntables, decoders, professional 4-track tape recorders, etc. Although the sound was great, my ear told me that the reason was the excellent equipment and not the number of channels. What little effect I could hear was limited to very narrow regions in the demonstration rooms. Nowhere have I seen or heard a discussion of how much a 4-channel home system should cost in comparison to the usual 2-channel systems and how the performance differences relate to the price differences.

THE FIRST FOOLISH IDEA

Going from one to two channels in the late 1950's made a significant improvement in home music systems; thus, further improvement will require more channels.

This seems to me to be the underlying assumption behind the current 4-channel developments. Those of us who have "mono" or "right plus left" mode controls on their systems can use these controls to demonstrate that stereo does sound a lot better than mono. Most people accept the results of this experiment without really understanding why, but to evaluate the worth of adding more channels, we do need to understand why stereo is better than mono.

If we look at the history of the mono-to-stereo developments of 1955 to 1960, we find several other

continued on page 22

have overlooked it. Visit any self-respecting record store and browse through the quadraphonic bin. A good record store should have several hundred SQ quadraphonic albums in the bin, about half the currently available quadraphonic repertoire, divided about equally between the classical and the popular titles. Look through the titles. Who are the people who perform or produce these quadraphonic records? I will tell you who: Bernstein, Biggs, Boulez, Ormandy, Simon and Garfunkel, Percy Faith, Santana, McClure, Frost, Kazdin—men whose international reputations draw universal acclaim. . . men with unmatched credentials in the world of music—in short, the people who know what good sound is all about. These are your best sources of recommendation of the virtues of quadraphony, and of the SQ system.

Have these artistic luminaries been conned into quadraphony? Don't kid yourself! One does not become a successful recording artist or producer by being naive in the ways of the musical world. If the producer thought that quadraphony was not a worthwhile contribution to the recording arts he would not bother to produce the record. Remember, he has his own reputation to uphold, and quadraphony for him is not a snap. First, he produces the stereo version of the record. He does so because he knows there is a public there waiting for it, and he knows how to mix for stereo backward and forward (he has been doing it for 15 years). Next, he has to go to work again to bring out the quadraphonic version. He is not elated about the prospect. It is a new art form, he must learn its intricacies; it takes more time to mix because it has to sound good both in quad and in stereo; the added studio time costs him money. But, he buckles down and finally turns out a great quad disc. Why does he do it? Because he can do so much more with quadraphony; because it's the wave of the future and he wants to be part of it; because it's an opportunity to work with new spatial dimensions; and because, increasingly, the public is clamoring for it.

QUADRAPHONY PIONEER

As a matter of credit or blame, the man most responsible for pushing us into quadraphony is John McClure, former director of Columbia Masterworks, and now personal recording director for Leonard Bernstein. Several years ago, John traveled to Venice to record Gabrielli *in situ*, where, 400 years ago the Master had

performed his four-choir magic from the inner balconies of St. Marco's Church. Back in New York after the "takes" John worked for weeks trying to produce a stereo record, but to no avail—the sound was flat. Then, he had an inspiration—he reproduced the tapes over four loudspeakers placed in the corners of the editing room. The magic returned! The first thing I knew of this was when the president of Columbia Records called me and asked what would it cost to develop a four-channel disc. Other record producers joined the chorus. So you can see, the pressure to come out with quadraphony came from the artistic people who know what good sound is all about.

ARTISTS AND PRODUCERS

Are all the artists and producers in favor of quadraphony? Of course not. Musicians are notoriously conser-



vative. Even the modern ones. Ask the man who is an expert on the Moog synthesizer of his opinion about the Bookla synthesizer. The idea of learning a new art is frightening to some people. Others simply don't want to bother. They will wait until the field develops before making a decision to enter it. Yet, the most talented people in the business are among the many now working extensively in quad.

EVERYONE'S FAVORITE?

Are all producers as enthusiastic about the SQ system as I am? Of course not. Some prefer the alternative (so-called "discrete") CD-4 System. Remember, I said that the SQ system allows you to produce solid four-channel sound using your present stereo pickup and stereo equipment by adding a decoder, two amplifiers, and two loudspeakers. New sets are out with the decoder and the added amplifiers already built into the set.

The SQ records are cut pretty much like ordinary stereo records, but with stereo, there is no attempt to utilize phase information, with SQ suitable phase relationships are provided. The difference between a stereo record and an SQ record may be likened to the difference between a photograph and a hologram. A hologram reconstructs three dimensional images because phase information is retained. The SQ record has the same frequency response, the same level, the same signal-to-noise ratio, the same playing time, and the same freedom from distortion and noise we have become accustomed to expect from all high-fidelity records.

The first quadraphonic record we developed was called a "discrete" system which we discarded as impractical, before we invented and finally adopted the SQ system. The CD-4 system preserves the directional information by adding ultrasonic carriers to the audio modulation. This means that a new pickup and stylus with 45 kHz capability are needed (an expensive requirement). The presence of a carrier diminishes the available output level and the available recording time. The overall response is diminished to 15kHz. Carrier noise invariably is introduced, and if the disc is played with an ordinary pickup and an ordinary stylus, the carrier is promptly wiped out converting the quad disc into stereo. Because of its limited signal-to-noise ratio and the presence of the ultrasonic carriers, the music must be compressed and recorded at half speed, and the producer must review the compressed version at half speed, which quadruples the recording time. The pressing compound must contain anti-static fatty acids which have a tendency to ooze out, crystallize, and cause more noise. The pressing time is lengthened and quality control problems are maddening. Thus, the discrete record with all its good intentions has less fidelity and musical value than an SQ record—in essence it's a brute-force method of achieving quadraphony. There is much R&D work going on to improve CD-4 however, and only the future will tell with what success.

What are the advantages of CD-4? For the producer, the mixing process is somewhat simpler. He doesn't have to know as much about the system as he does when he produces an SQ record. But when you compare the two there simply is no doubt that the SQ system is the better higher-fidelity product. Nevertheless, some producers prefer the discrete system. After you are

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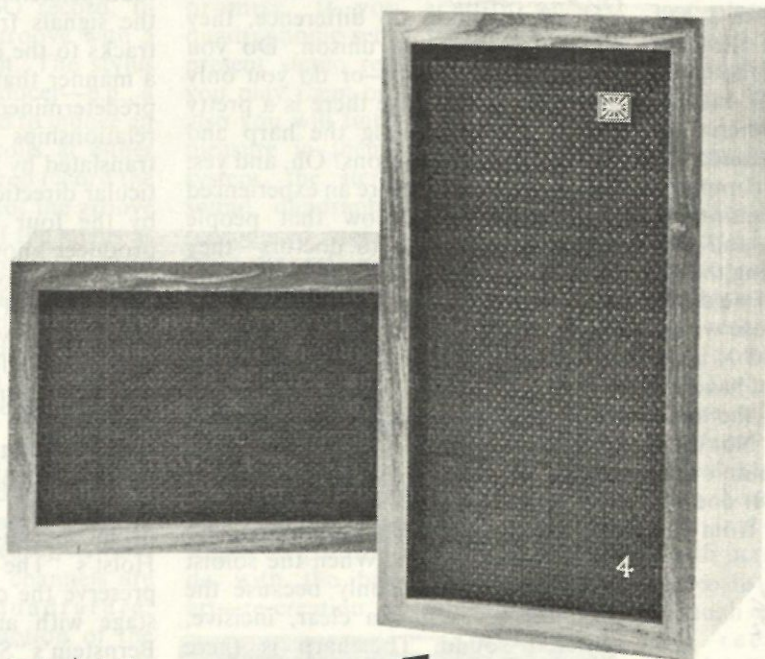
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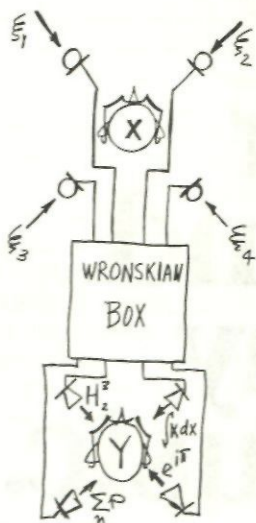


**We make our
speakers by hand.
The same way
people make music.**

equipped for SQ you can always purchase a specially-designed pickup and a CD-4 demodulator to reproduce discrete records also.

With this weight of evidence in favor of quadraphony, why is there a body of otherwise reasonable and even mathematically-minded people who are so dead set against it? I think that some of their antiquadraphonarianism comes from a confused cerebration as to what the sound recording arts are all about. The mathematicians are the ones who most often fall into this trap. Are they not, after all, the spiritual inheritors of Pythagoras and Zeno? Isn't sound merely a summation of pressure phasors and velocity vectors at a point in space?

The mathematician places himself mentally in the 10th row center of a concert hall with four microphones clustered about an imaginary point centered in his head X. The mikes are connected to some sort of a system of matrices, attenuators, gyrators, phase-shifters, recorders, transmission lines, disc recorders, etc.—placed inside a mathematical black box which I call the Wronskian Box. Out of the Box come our lines connecting to four loudspeakers directed to a "Y-marks-the-spot" point in space where the listener's head might be located. Lo and behold, after a few computer manipulations, the mathematical wizard defines the necessary and sufficient conditions for replicating the X-field at Y. Then he gets mad if we don't follow his prescription. Suppose we do as he says—replicate the field X at Y and listen to it. What will you have? A glorious record? Nothing of the sort! You'll have a dreadful mess. Not only couldn't you sell it—you couldn't give it away. People have tried it. It doesn't work. What then is missing from the equation?



MATHEMATICIAN'S CONCEPT OF QUADRAPHONY

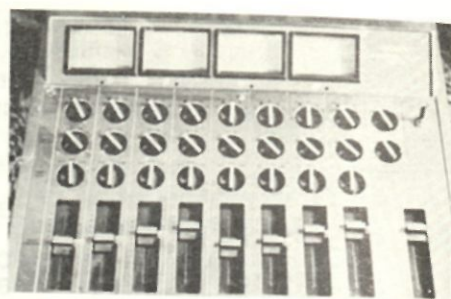
ARTISTRY IN QUADRAPHONY

Attend a recording session run by experienced recording professionals with top recording artists on the stage. Remember, someone is paying \$50,000 for this record so it had better be right the first time. What do you see? Not a cluster of microphones in the tenth row center, but a veritable forest of microphones in between the instrumental groups, spot mikes for the soloist and the accent instruments, and a few more interspersed through the hall for reverberation. All of these lead to a control console where the sounds are balanced and grouped into 16 channels which are recorded on a 2"-wide, 16-track tape. The tape goes to the studio for editing. This is where the real work of the producer or the musical director begins.

Why the difference between the mathematical reveries and the real-world approaches? As a concert-goer, you should have no trouble figuring this out. What do you hear when you are in the 10th row center? Is the theme being carried by the soloist or the first violins? It makes no difference, they move their arms in unison. Do you really hear the harp—or do you only think you do because there is a pretty girl up there fondling the harp and making with the motions? Oh, and yes, the coughing! If you are an experienced concertgoer, you know that people with colds don't go to doctors—they come to concerts, but your mind and your eyes shut out the coughs. The magic of the concert hall, the rapport of musicians with the audience, and the conductor making wild gyrations—all this forms part of the illusion you enjoy so much.

This magic is gone when you listen to the record. There is no sight, no concert hall, no audience, no conductor to support the illusion. When the soloist plays you know it only because the producer gives him a clear, incisive, centered sound. The harp is there because the accent microphone let you hear it, since you can't see it. The coughing is not there, because there is no audience—remember each symphonic movement will have had at least three "takes" to catch any slight errors—so that the reverberation time has changed and, acoustically speaking, you are in a different hall. What's more, the record has to sound good not only where Y marks the spot but over a wide area in the room.

During the editing session, the producer works along with a studio engineer in the editing room which has the size and the acoustics of a small liv-

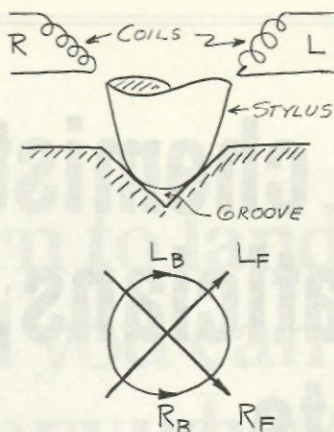


ing room. There are four loudspeakers in the corners. In front of him is a console with hundreds of controls—switches, attenuators, meters, knobs, and the like. In the back, under full remote control, is the tape machine playing the 2-inch, 16-track tape, which is to become a record (stereophonic or quadraphonic, the process is very similar). If quadraphonic, the 16-tracks go to the mixing console, and then to a device known as an SQ encoder, resulting in two encoded channels. Thence to an SQ Full Logic Decoder—much like the one you heard at your dealer's except perhaps more refined, and finally into the four loudspeakers. The encoder allocates the signals from each of the 16-tape tracks to the encoded channels in such a manner that the signals therein have predetermined amplitude and phase relationships which subsequently are translated by the decoder into the particular directions of sound, reproduced by the four loudspeakers. Thus, the producer knows precisely what the SQ record will sound like when played in the home. The producer begins by planning how most effectively to present the performance to the record-playing audience. Is the intention of the conductor to portray a full surround-sound format (like when Boulez conducted Bartok's Concerto using two podiums and the orchestra in a circle) or in a semi-circular format (like in Holst's "The Planets") or should he preserve the classical orchestra on the stage with ambience format (like in Bernstein's "Swan Lake")? Or, perhaps the performers should appear to arrive from the particular loudspeakers (like the solos in "A Little Night Music"), or the solo at center-front with the accompaniment in the back (as with Loggins and Messina). Then he begins to mix the channels according to plan. With classical music, he usually follows as closely as possible the format used by the conductor. With popular music, he often is more avant garde. He may move an instrumental group from side to side for more effective balance and emphasize the weaker instruments to compensate for the missing visual aspect. Using the reverberation

channels, he perhaps will increase or diminish the perceived size of the hall. If the producer has done his job effectively, you will be completely convinced that you are there, in the 10th row center. The best seat in the house. As soon as the mix is finished, the engineer makes a master tape of the encoded signals which subsequently is used to cut the record. Thus, the musical director or producer is as much a part of the creative process of bringing art to your home as is the conductor and the musician. And the reverie of the mathematician who plays the role of the God of Arts is merely hallucinogenic. You can also see how unfounded and malicious are the bad mouthings of those who would tear down one quadraphonic system in favor of another. The fact is that each quadraphonic record is approved by someone with credentials in the field of musical arts. Zeno may be right about the arrow, but with respect to the musical arts he is likely to be a callow ignoramus.

SQ SYSTEM

Examine closely an SQ record. In cross-section there is a groove with a pickup stylus riding in it. The stylus drives some sort of transducer—e.g., a magnet—which is adapted to induce an output voltage in two coils at either side of the stylus. In a stereo record the Left channel modulation of the groove produces a 45° motion of the stylus as shown by the arrow labeled L—because it also represents Left Front modulation of an SQ record. The Right channel modulation of a stereo record is at -45° as portrayed by the arrow marked R, because it also portrays the right-front channel SQ modulation. Therefore, the front channels of the SQ record are identical with stereo. The difference resides in the addition in SQ, of at least two more channels. The Left back channels are recorded in phase-quadrature, resulting in a circular motion of the pickup stylus, as shown by the circle LB. The Right-back signal produces a counterclockwise circle RB. Viewed along the groove, the circular motion results in a helical motion of the groove modulation which the ordinary stereo pickup stylus follows with complete ease—a clockwise helix for the left-back channel, and counterclockwise helix for the right-back channel. All of these modulations sound perfectly normal through a conventional stereo set and when broadcast via FM radio they all come through at identical levels when heard with a monophonic receiver.



SQ BASICS

Thus, the four basic channels of SQ are characterized by specific modulations along the groove, resulting in corresponding voltages in the coils which, upon reproduction through a Full Logic SQ Decoder, result in a virtually complete channel separation, as heard by the listener.

STEREO RECORDS

I promised good tidings for the owners of stereo record collections. Now it's time to make good on that promise. If you acquire an SQ quadraphonic setup, fear not for your present stereo records—not only can you play them on the SQ system, but also you will find a new dimension of pleasure in them. Played on an SQ system, the stereo records will not sound quadraphonic. They will be reproduced normally over the two front channels, but in addition any random sounds, e. g. reverberation, recorded in them will be shifted toward the back channels, creating a unique and delightful ambience. Many listeners feel that this feature alone justifies investment in SQ equipment!

CONCLUSION

Much of the debate about the pros and cons of quadraphony has been waged on grounds that have nothing to do with the basic purpose of this art—re-creation of sonic reality, the

addition of new dimensions to the creativity of the artists and composers, and the musical enjoyment of the listeners. Sophisticated arguments of those who are concerned about reproducing sound pressure phasors and sound velocity at a point in space remind us of the reveries of Zeno about the flight of the arrow. The arrow, said Zeno, could never reach the target because there was always an infinity of half-spaces left for it to traverse. Zeno, of course, was ignorant of infinitesimal calculus, which at the time had not yet been invented. In the same manner, many of the arguments about quadraphony are carried on by people ignorant of the objectives and procedures of the recording arts and sciences.

The art of sound recording has gone through evolutions at intervals each spanning a generation—Edison's tin foil phonograph, Berliner's flat disc, electrical disc recording, electrical sound reproduction, long-playing record, stereo, and now, SQ quadraphony. Each step has created a new plateau of improved values and musical enjoyment. Each step has meant that a new fundamental principle has been added to what now is a century-old fortress of art. The SQ system, by adding phase to amplitude ratios for reproducing the back channels has done for the record what holography has done for the photograph—it has added a third dimension actually enhancing its utility as a record without affecting the fidelity of sound reproduction.

When played through a conventional stereo player, the SQ record will produce stereophonic sound of excellent quality, which many assert is even more pleasing than that of a conventional stereo record—because of the depth perception it affords even to the stereo listener. But, when reproduced through an SQ Full Logic Decoder, the SQ record reveals the full quadraphonic effect.

With the SQ system, the existing stereophonic record collections are not obsoleted. A stereophonic record played through the SQ system of course is reproduced mainly on the front channels; but at the same time, any casually out-of-phase or randomized signals in the record are spread around the four loudspeakers providing a delightful synthetic ambience.

But in the matters of the performing arts we should not limit ourselves to scientific arguments. Visit a friend or a



continued on page 28

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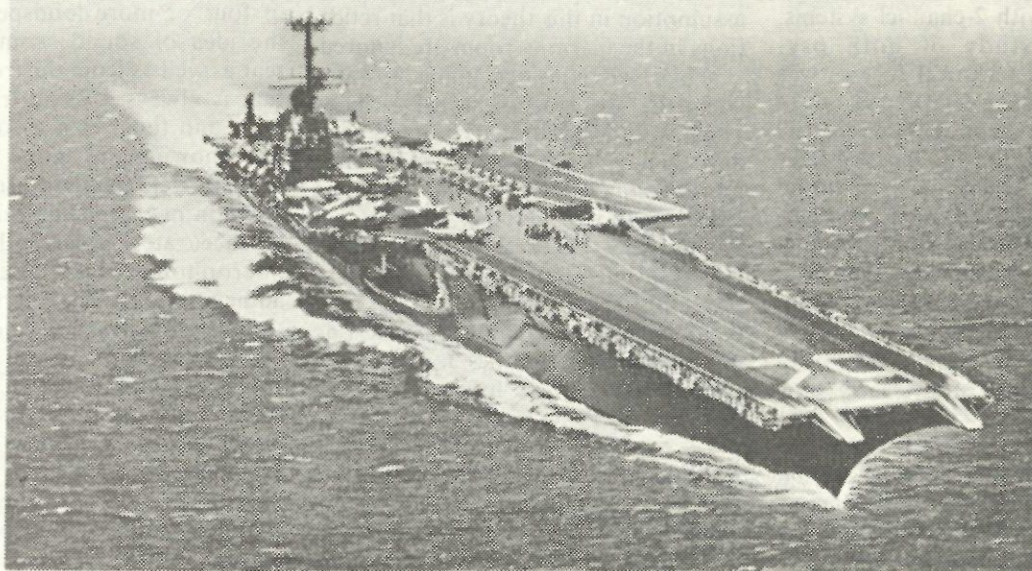
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developments which added to the improved fidelity of the stereo system. The 33 1/3 long playing record, magnetic cartridges, good pre-amps, tape recorders a consumer could afford, availability of the 88-108 MHz fm broadcast band and good engineering made the words "high fidelity" mean something. The most important development occurred in 1955 when Vilchur¹¹ published his paper on the AR-1 woofer—the acoustic suspension revolution of loudspeakers was on its way.

Thus, when the first twin track modifications made tape recorders 2-channel signal systems, it was natural to experiment with 2-channel systems. A feasibility study of both psychoacoustic and technical factors was done in England by Clark¹², et. al. in 1957 and was republished in the U.S.A.¹³ in 1958. On the basis of later psychoacoustic experiments, I would now dispute some of their findings. However, the work was timely, competent, and covered the correct aspects of the subject. One most important finding was the "m-s" microphone technique.

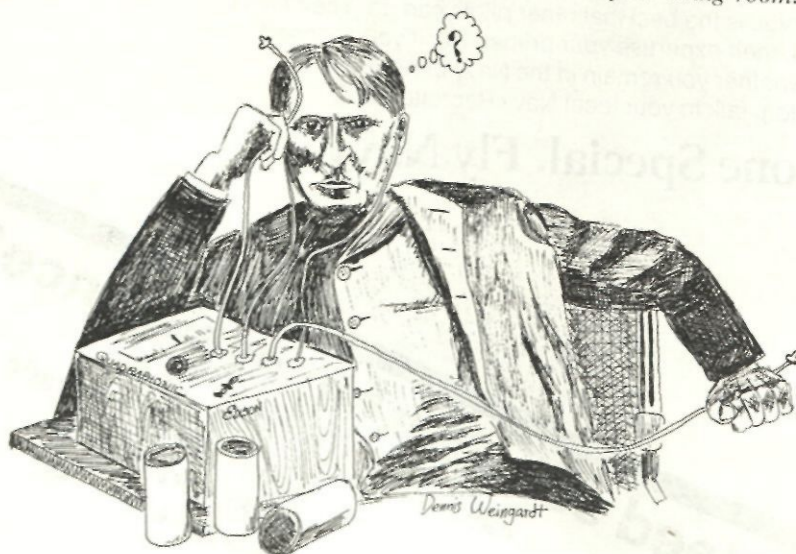
Clark's feasibility study, early standardization of the 45-45 stereo disk (which effectively doubled the system bandwidth in the transmission storage link), and development of the stereo-multiplex system for fm broadcasting (again nearly doubling bandwidth) allowed all workers to develop hardware for a common goal. The loudspeaker revolution lowered the price to the point where a good 2-channel stereo system of 1960 cost about the same as an equivalent quality mono system of 1955. This fact aided consumer acceptance as much as the improved quality.

For music from the concert hall, the 2-channel stereo does improve the simulation in a living room. Using a fairly realistic set of assumptions to make the problem reasonably simple, the Russian scientist Pavel G. Tager¹⁴,¹⁵ demonstrated mathematically that a 2-channel system makes it possible for the home listener to detect the relative locations of instruments in a position along a line between the loudspeakers that is relative to the position of the instruments recorded at the live performance. We must realize that this is a simulation of the normal concert hall situation where the orchestra is in front of the audience. The only questionable assumption in this theory is that reflections in the listening room are ignored.

When we consider going to four channels, we must first ask—How much will the additional channels cost? and then—What do we get for two more channels? Remember that going from one to two channels did not double the cost of a reasonable system. Now, we must look for something like the loudspeaker revolution if going to 4-channel is not to double the cost. I do not see any possibilities for a second revolution in price for loudspeakers nor do I see any portion of a home music system where future technology will make a significant price reduction. Doubling the investment in loudspeakers means that a 4-channel system costs about 1.5 to 1.8 times as much as a 2-channel system. The additional cost is going to have to be justified on the basis of the additional enjoyment provided by the additional channels.

THE SECOND FOOLISH IDEA

The 4-channel system will do a better job of bringing the concert hall listening experience into your living room.



The motivation for going from one to two channels was the improved simulation of the concert hall experience in a living room by the addition of directional information. The false analogy is that since this explanation motivated the mono to stereo developments of the late 1950's, the same reasoning is valid going from stereo to four channel. Two basic reasons are often given for 4-channel systems doing better than stereo systems at bringing the concert hall experience home: (1) enhanced directional effects (2) added ambience. The illustrations in papers advancing the first reason show a listener in the center of four or more loudspeakers to give the idea of sounds coming from the rear as well as from the front. The thing that is always missing from these pictures and theories is a companion picture showing the actual source of the acoustic field being transmitted and the location of the pickup microphones. If you accurately consider the case of four microphones anywhere out in the audience area of a concert hall, coupled to four loudspeakers via completely independent channels (eg. 4-track tape), you may share Tager's¹⁵ description of the result as "confusion-phonetic." Tager comes to a very clear and accurate conclusion that two microphones, two transmission-storage channels, and two loudspeakers are not perfect, but are as good as we can get. Adding more channels makes the results worse.

Thus, 4-channel degrades rather than enhances directional effects and we must look for another reason for adding channels. This leads us into considering *ambience* of the concert hall. A full discussion of the artistic and scientific ideas of ambience would be too lengthy here. Briefly however, acousticians usually consider that two kinds of sound reach a listener. Direct sound comes from the performance on a straight line path. Ambience is sound that has bounced around the auditorium several times before it is finally dissipated. If this sound is reflected from a flat surface and reaches the listener more than 40 milliseconds after the direct sound, an echo occurs which is quite undesirable. Good auditoriums have rough walls (hand hewn rock is great), lots of breaks, and ornamentation so that the sound is both reflected and scattered. A good amount of sound energy is contained in this reverberant field but it is diffused in time. If an instrument on the stage emits a staccato note lasting about 100 milliseconds, the listener will

hear the reverberant sound start about 20 to 50 milliseconds after the direct sound. The reverberant sound will build up in a jagged fashion as a result of interference from different reflection paths, scattering at each reflecting surface, and finally die out. The staccato note may have been only 100 milliseconds long, but the reverberant sound energy will not reach the truly negligible level of being down 60 dB until about two seconds later. This time is called the reverberation time of the auditorium.

The reverberant field is a summation of a group of transient sounds that arrive at almost random times with the mean delay time of about $\frac{1}{4}$ second. The individual components of the reverberant field come from all sorts of directions (including the front) and cannot be assigned a direction vector.

What good can 4-channel do in bringing this ambient sound to your living room? Let me follow Eargle³ and use two cardioid mikes placed close enough to the orchestra to pick up direct sound only. Two additional cardioid microphones are placed less than 30 feet further out in the auditorium. Eargle can only suggest experimentation for aiming these rear microphones. If we aim them at the orchestra, we get Tager's "confusion-phonics." If we follow Long¹⁶ and aim them at the rear of the auditorium we get mostly the reverberant sound. As long as no one puts a strong hand on the gain control and tries to make the VU meters for these channels equal the VU meters for the front channels we can bring this reverberant or ambient sound field into the living room.

If you think I have finally gotten to the point where I must admit that 4-channel has at least a feeble reason to exist—don't bet on it. Why are two extra channels needed to carry a rather limited amount of information?

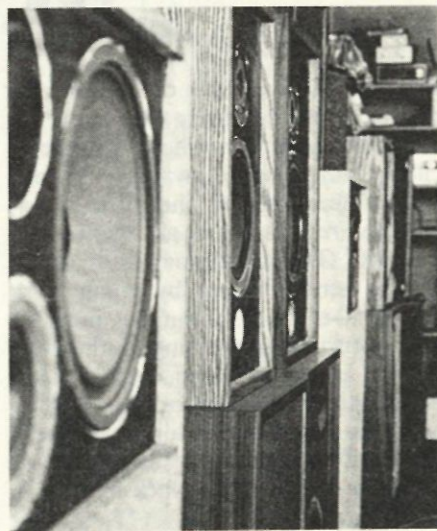
The ambience information is delayed about $\frac{1}{4}$ second and 25 milliseconds plus or minus will not make a bit of difference. Thus, I can take Long's rearward pointed microphones and add their outputs into the direct sound channels to add ambience to the 2-channel system. I can even use just two omnidirectional mikes for the stereo pickup and move them back and forth to achieve balance between direct and ambient sounds. Four channels will do a poorer job of bringing the concert hall experience into your living room and you are better off with 2-channel stereo for this musical reproduction goal.

THE THIRD FOOLISH IDEA

Four-channel systems can and must be compatible with the existing 2-channel stereo equipment.

In discussing the mixing of a 4-channel recording, Eargle³ states—"it is important that the 2-channel and monophonic compatibility of the four signals be carefully checked." There are obvious business reasons behind this since there is a lot of 2-channel equipment in service and developing a market for new recordings means that they must play on existing equipment. Note that a significant key to the switch from mono to stereo was that the stereo record and stereo fm broadcasts would play through the monophonic equipment.

Let us re-examine the compatibility of stereo and mono now that the conversion is essentially complete. There is still a need for mono reproduction of stereo material and it is accomplished



by linearly adding the two signals. Mono playback occurs only in very inexpensive phonographs, table model fm receivers automotive radios, and in am broadcast receivers. Most of these units have such low quality that they cannot display loss of fidelity caused by the linear addition of left and right signals to obtain the mono signal. The loss of quality is caused by the difference in path length between sound sources and the two microphones. The path length causes a relative phase angle between signals, and if the angle is near 180° linear addition results in partial cancellation. The frequency response of the mono signal has a set of minimums where the frequencies of the minimums are determined by sound source and microphone placement.

The idea of 4-channel compatibility also carries another dimension of trouble. The linear sum of the signals for

mono-playback is not important because of the low quality of most mono equipment. This is emphatically not true for the 2-channel case. Adding the left front and left rear signals to get a composite signal for the left side (and doing likewise in the right) will have the same problems as adding left and right to get mono from 2-channel stereo. If the rear channels contain only ambience information, there will not be cancellation of the direct signals and the results will be satisfactory. However, if the rear channels carry a portion of the direct sound, there will be a lot of cancellation because of the front to back spacing of the microphones.

Thus, there is a significant technical reason against 2 and 4-channel compatibility achieved by linear addition. Since there is little understanding of the musical problems involved, I think it is a mistake to worry about compatibility at this state of 4-channel development.

THE FOURTH FOOLISH IDEA

Four signals can be linearly encoded into two channels, recorded and or transmitted, and be decoded into four useful signals.

Yes, I am on my soap box about the 4-2-4 matrix method of achieving poor man's 4-channel. Those of us who know something of communication system theory are appalled by the basic idea of the 4-2-4 system which does not have increased bandwidth in the two transmission channels—this is a flagrant violation of Shannon's channel capacity theory. It makes about as much sense as simultaneously putting equal flows of kerosene and gasoline into a pipeline at Dallas and expecting to separate gasoline and kerosene in Denver.

In the fine print of the matrix theory papers, this problem is politely acknowledged as lack of separation. Scheiber⁹ points out that a symmetrical 4-2-4 matrix system will have a whole 3 dB of separation between channels. By abandoning symmetry, one can trade front to rear separation for left to right separation. The result is about a dB of separation in the unfavored direction and one might as well forget using a decoder on the 2-channel signal.

Does this lack of separation cause musical mischief? Let Walter Carlos answer that one for me in a quote from *Billboard*, August 5, 1972:

"When Rachel Elkind and I began our new *Sonic Seasonings* album, we planned for quadrasonic and recorded all the materials in quadrasonic. That master, like *Clockwork Orange* and most of our

other product, is already mixed in 4-channel. We tried to process this master on all the known matrix systems, and a few not so known. I am most unhappy to report that the results were catastrophic most of the time, and ho-hum for the rest. And this was using the latest state-of-the-art matrix equipment, a magnitude better than home matrix systems. Our *Switched on Bach* was released in the best of the matrix systems, CBS's SQ, and we later discovered that, despite some musical acclaim, it is a pale mirror of the quadrasonic master. Worse, the musical balances are irrevocably bastardized so that, at many times, solo lines are obliterated by accompaniment. Columbia has generously agreed to withdraw this album. If you should come across any remaining copies of the SQ version, avoid it like the plague—a strange sentiment for profit consciousness, but in the long run we believe it is the only valid decision possible."

The proponents of the matrix systems will reply to these criticisms stating that they have done the following sort of experiment. A 4-channel master tape is run through the encoder, two short pieces of transmission line and through the decoder. A quad of amplifiers and loudspeakers is switched back and forth to compare the master with the signals going through the 4-2-4 matrix path. Listening panels proclaim that there is not much difference in the sound and the implication is that the 4-2-4 system being tested is good enough.

What is the flaw in this kind of reasoning? The music used is usually from the concert hall and the listening panels are instructed to listen for loss

of directional effects caused by the matrix. Neither the panels nor the recording engineers who made the 4-channel master are aware of Tager's pronouncement of the discrete 4-channel reproduction as "confusion-phonics." The directional information got all scrambled up by going to 4-channel—there is not much more to lose in further scrambling by the 4-2-4 matrix. If one of Walter Carlos' Moog Synthesizer tapes, or something recorded in an acoustically dead studio were subjected to the same test, the listening panel would black-ball the 4-2-4 matrix.

If you have a limited budget for music reproduction equipment, avoid any and all of the systems which claim to bring you 4-channels via a disk recording. You will invest your money more wisely if you carefully select a 2-channel stereo system.

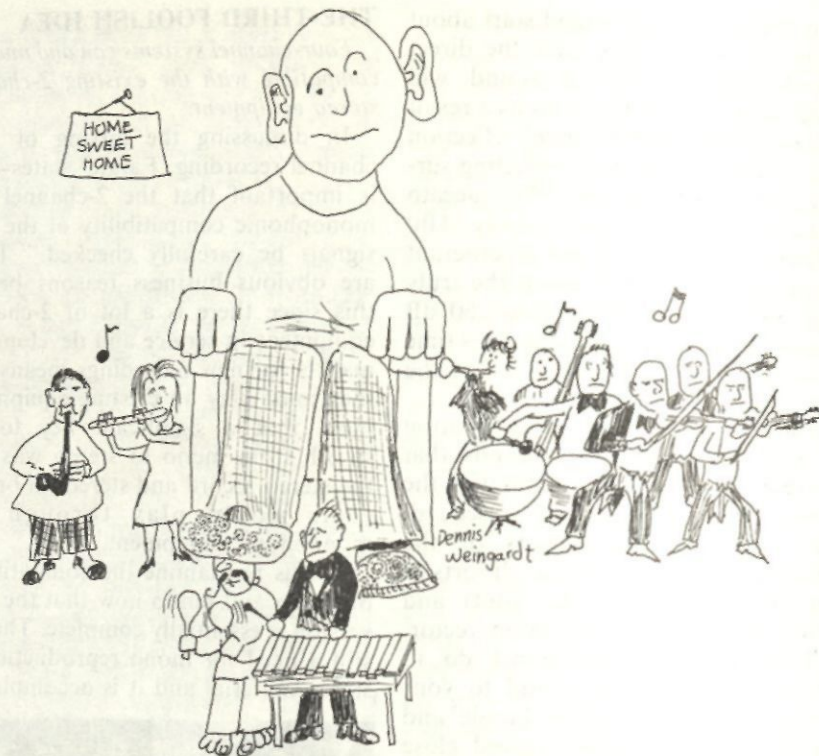
THE ONE GOOD IDEA

On music from the synthesizer or from an acoustically dead recording studio, four independent channels and four carefully placed loudspeakers can add a new dimension of intimacy to contemporary music.

There is a hint of this promise in the quotation from Walter Carlos. If you are not concerned with music from the concert hall you have no traditions of auditorium acoustics to handicap artistic creativity. It is possible for a skilled recording director to plan the performance to have artistic meaning in the dimensions of your living room. The only thing currently lacking in

achieving this promise is standardization of loudspeaker placement so that the listener can place his speakers where the recording director planned.

If you want to experiment with contemporary music reproduction via 4-channels, here are some rules to follow:



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- (1) Thou shall not bother with 4-2-4 matricies.
- (2) Thou shall not worry with concert hall music.
- (3) Thou shall expect to spend twice as much money for 4-channel equipment.
- (4) Thou shall pray for development of a tape system using 1.5 cm or wider tape running at 19.8 cm/sec which will play both sides of the tape.
- (5) Thou shall be careful that your 3-way loudspeaker systems have excellent low frequency response, adequate acoustic output power capability, and low distortion in the tweeter.
- (6) Thou shall try to learn where the music director placed his loudspeakers for the final mix-down.
- (7) Thou shall not be concerned with compatibility.
- (8) Thou shall not expect the results to be twice as good as can be obtained with 2-channel stereo.

I think even the most enthusiastic marketing managers will someday come to learn what Abraham Lincoln meant when he said:

If you once forfeit the confidence of your fellow citizens, you can never regain their respect and esteem. It is true that you may fool all of the people some of the time; you can even fool some of the people all of the time; but you can't fool all of the people all of the time.

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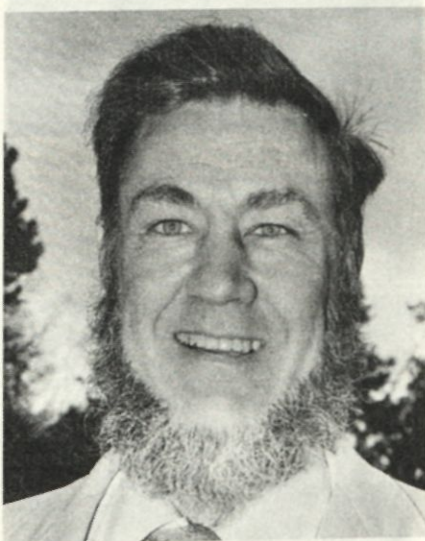
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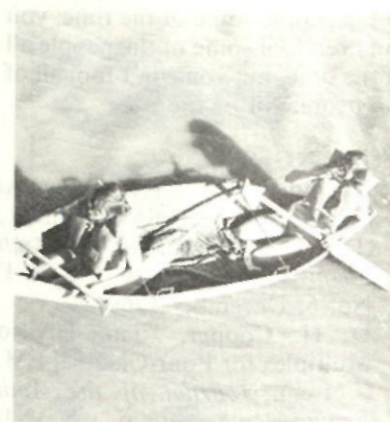
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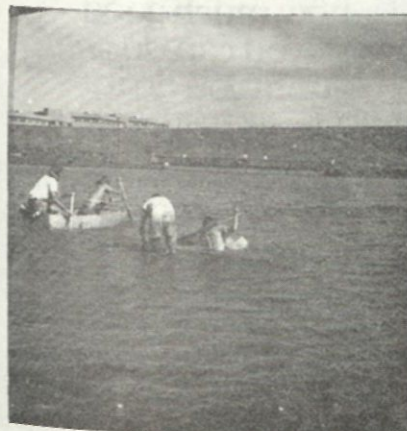
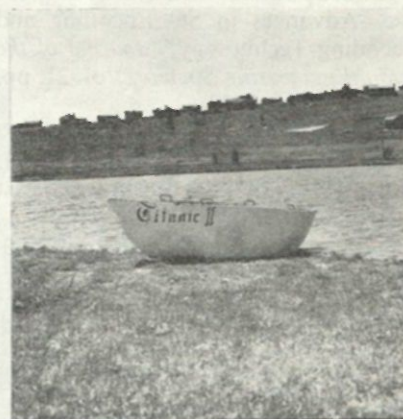
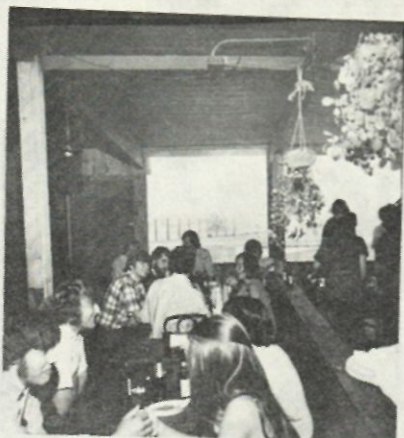


J. Robert Ashley is professor of Electrical Engineering at the University of Colorado, Colorado Springs Center. He did undergraduate and graduate work at the University of Kansas. He spent nine years with Sperry-Rand in microwave electron device research. In 1967, Ashley was awarded a Ph.D. (EE) by the University of Florida. Dr. Ashley then joined the University of Colorado and turned his attention to audio engineering which had always been a hobby. His publication on loudspeakers, crossover networks, and testing audio systems have received international acclaim.

1974 E-Days

Engineering Days (April 26-27) were a big success this year. A wide variety of interesting events allowed many students to get involved. The events on Friday included the awards banquet, paper airplane contest, egg drop survivability contest, and a softball tournament. The main event on Saturday was the picnic at Harlow Platts park. At the picnic, the U.S.S. Poseidon won the concrete canoe race, Professor Phillip Ostwald received the meanest professor "purple screw" award, and everyone ate chicken, drank beer and had a good time.



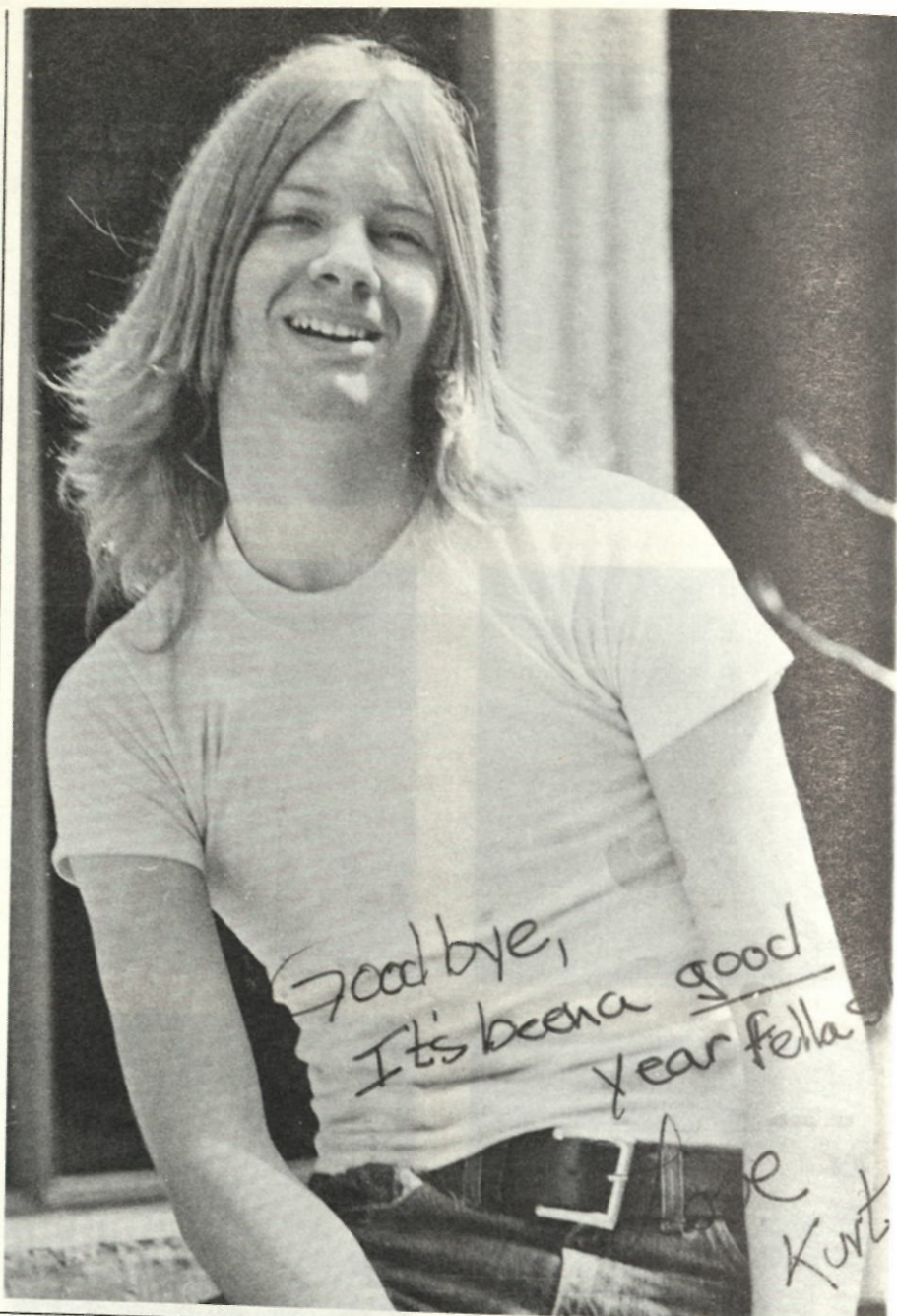


continued from page 19

dealer who has a good quadrasonic reproducer and hear it for yourself. Then make your own decision. I think you will agree with me: Four-Channel Sound? Yes!

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Benjamin B. Bauer is Vice President in charge of research in Acoustics and Magnetics at CBS Laboratories, Stamford, Connecticut, a Division of CBS, Inc. He had spent his whole career in the fields of psycho-acoustics, sound reception, measurements, recording and reproduction. Prior to 1957, he was Vice President in charge of Engineering at Shure Brothers, Inc., in Evanston, Illinois. Mr. Bauer is a Fellow and Honorary Member of the Audio Engineering Society, a Fellow of the IEEE, and a Fellow and an Associate Editor of the Acoustical Society of America.

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to keep people talking. Bell Labs chemical physicist Stan Kaufman invented a material that turns waterlogged underground phone cable into a water-free "jelly roll" that can carry calls again. Pumped through football-field lengths of cable as a liquid, the material forces water out and then turns to jelly—to keep the water out.

Water sometimes seeps into cable damaged by plows, lightning, gophers, or sharp rocks. Phone calls going through the cable become noisy or don't go through at all. Until now telephone companies had to abandon waterlogged cable, or dig it up and replace it, or use acetone to flush out the water. Once the acetone was evaporated, however, there was nothing to prevent water from getting back in again.

We needed an inexpensive water-repellent liquid that would turn into a jelly inside a cable and plug up holes. The material also had to be electrically nonconductive so it wouldn't interfere with telephone signals. Such a material

didn't exist, so we asked Stan Kaufman, a 1970 Ph.D. from Brown University, to tackle the problem.

Drawing on his knowledge of molecular structure and working with telephone company engineers—sometimes in muddy cable trenches—Stan came up with a new compound. A Western Electric engineer modified a pump to force the compound through long lengths of cable. And during field trials, operating telephone engineers suggested installation procedures.

Bell Telephone companies are happy because they don't have to dig up as much waterlogged cable, which often runs under highways and people's lawns, and because restoring an otherwise good cable helps hold down the cost of providing telephone service.



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General Electric employs quite

a few engineers. So we thought a series of ads explaining the work they do might come in handy. After all, it's better to understand the various job functions before a job interview than waste your interview time trying to learn about them.

Basically, engineering at GE (and many other companies) can be divided into three areas. Developing and designing products and systems.

Manufacturing products. Selling and servicing products.

This ad outlines the types of work found in the Sales and Service area of GE. Other ads in this series will cover the two remaining areas.

We also have a handy guide that explains all three areas. For a free copy, just write: General Electric, Dept. AK-3, 570 Lexington Ave., New York, New York 10022.

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Sales engineering is technical marketing. Sales engineers at GE are the important liaison between GE manufacturing facilities and utility, industrial, distributor and governmental customers. Working closely with assigned customers, they use their technical background to recognize customer needs and recommend GE products or systems to fill them. From small AC motors to huge turbine-generator units. Requires a thorough understanding of a customer's business, as well as a wide range of GE products. Plus the ability to work well with people and to recognize a good business opportunity.

Application Engineering

Application engineers are technical experts who work closely with the sales engineer and the customers' engineers. Their job is to analyze special problems and equipment needs of customers, then determine the optimum GE products or systems to meet them. There are two kinds of application engineers. The first works out of a sales operation and is adept at applying a wide variety of products to create a "system" that meets the customers' needs. The second works in a product manufacturing department and is a specialist at applying the products of that one department. Both must have in-depth knowledge of the customers' technical needs. They often consult with product planners and other

marketing personnel to suggest ideas for new or modified products.

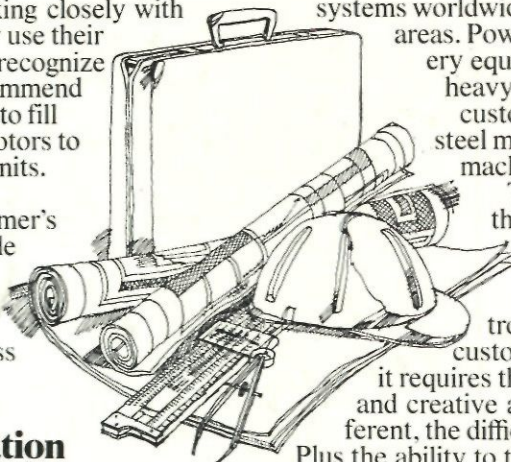
Field Engineering

Field engineers at GE plan and supervise the installation and service of large equipment systems worldwide in two main customer areas. Power generation and delivery equipment for utilities. And heavy apparatus for industrial customers such as paper and steel mills, chemical plants and machine tool manufacturers.

They specialize in either the mechanical/nuclear or electrical/electronic areas. Since field engineers are often called to troubleshoot and correct a customer equipment problem, it requires the technical competence and creative ability to handle the different, the difficult and the unexpected. Plus the ability to take charge, lead people, and make independent, on-the-spot decisions.

Product Planning

Product planning is a marketing function. Product planners make sure a product line offers what customers need at competitive prices. They determine the need for a new or modified product, product availability, market size, cost structure, profitability, specifications and distribution channels. To do this, they work with market researchers, application and sales engineers, finance experts, marketing management, plus design and manufacturing engineers. Their engineering background is a big plus. This work requires self-starters who can coordinate a project and sell their ideas to management.



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