The Chemical Handlers

Part One

U.S., state probe danger of working in electronics

When Marta Rojas turns down the detergent aisle of a grocery store she begins to feel light-headed and slightly nauseated. Sometimes her tongue and the insides of her mouth burn.

Other everyday activities, such as reading the newspaper, give her the same reaction.

Mrs. Rojas believes her sensitivity to chemicals in cleaners, ink and other substances was caused by a faulty ventilation system that she believes allowed noxious chemical fumes to enter the area where she worked at Signetics Corp. of Sunnyvale.

"I can live with the discomfort," she says. "However, I cannot forget I have been exposed to carcinogens. Every time I have that feeling (burning sensation), I remember I get upset. I worry."

An investigation of Mrs. Rojas' claims by the National Institute for Occupational Safety and Health found that a "significant, occupationally related health hazard" exists at Signetics -- a charge that the company disputes because it claims "the scientific data concludes exactly the opposite."

The Signetics case was the first such investigation of a Santa Clara County electronics firm by NIOSH, the federal government's research branch for occupational safety and health.

In recent months, other federal, state and local groups have begun looking into the health and safety of workers in the electronics industry that dominates the Santa Clara Valley. More than 160,000 people -- a quarter of the county's workforce -- are employed by the 500 or so electronics firms in the county. Another 150,000 are employed at companies that depend directly on business from those firms.

The question of overall health and safety in the highly competitive industry that provides electronics components to power televisions, calculators and computers is not easily answered. Government and health officials say little research has been done on the subject.

Industry officials who were contacted said their safety controls are more than adequate. Officials from two of the five largest companies refused to discuss safety controls.

However, in interviews with current and former employees, industry officials, doctors, lawyers, government officials and a check of government agency records, these facts emerge:

-- The industry uses some of the most hazardous chemicals that exist -- including corrosives such as hydrochloric and hydrofluoric acids, toxic solvents such as

Continued on Page 3
Worker safety probed
Federal, state and local agencies are investigating the health and safety of workers in Silicon Valley's electronics industry, while some employees - such as Cathi Hee - have taken matters into their own hands with lawsuits.

It's a chemical industry
Hundreds of chemicals are used by the thousands of gallons in Silicon Valley each year. Some are poisonous. A few can cause cancer. These dangerous ingredients are necessary parts of what is essentially a chemical industry.

A question of priorities
Electronics companies in Silicon Valley spend millions of dollars every year to protect two things: the product and the worker. Which of the two takes priority is debatable, industry sources say.

About the authors
San Jose Mercury News reporters Susan Yoachum and Michael Malone spent more than a month researching this report, interviewing industry representatives, government officials and private citizens.
Yoachum, 24, is a municipal government reporter in the Mercury News' North Santa Clara County Bureau. Before joining the Mercury News in 1978, she worked 2½ years at the Dallas Morning News as a general assignment and suburban government reporter.
She received degrees in journalism and political science in 1975 from Southern Methodist University.
Malone, 26, is a business reporter for the Mercury News. Before joining the paper in 1979, Malone spent nearly four years at Hewlett-Packard Co. in Palo Alto, where he directed publicity for that company's pocket calculator and small computer operations.
Malone holds a bachelor's degree in interdisciplinary sciences and a master's degree in business from the University of Santa Clara and is a graduate student in the philosophy of science at Stanford University.

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Copies may be obtained by writing the Public Relations Department, the Mercury News, 750 Ridder Park Drive, San Jose, CA 95190.
The supply is limited.
We don’t know much about what they’re being exposed to

— Dr. Richard Wade

Electronics a leader in state’s highest rates of work-related illness

Continued from Page 1

xylene and dangerous poisons such as arsine gas and cyanide. Because of their unique electrical properties, these chemicals cannot be replaced by safer substances.

The industry has one of the highest incidences of occupationally related illnesses of any industry in California. According to statistics compiled in 1978 by the state Division of Labor Statistics and Research, the industry has 1.3 occupationally related illness cases per 100 workers. Work-related illness for industry as a whole occurs at a rate of .5 cases per 100 workers.

Evacuations, chemical spills, acid burns and fires occur repeatedly. The increasing frequency of chemical spills and fires has prompted the Santa Clara Fire Department to ask for more manpower to cope with the problems of hazardous chemicals.

Nicknamed “Silicon Valley” because the computer chips that serve as the industry’s building blocks are made of silicon, the Santa Clara Valley has been the site of many of the world’s major technological advances for the past two decades.

The local economy is dependent on the industry.

General Electric’s electronics industry is composed of three groups: semiconductor companies, chip manufacturing companies, and systems companies that make computer systems and related devices.

Toxic chemicals are used by each sector, but semiconductor companies, where electronic circuitry is etched onto silicon chips, use the greatest volume.

“We deal with pretty bad stuff,” said Jim Cochran, facilities manager of TeleDyne Semiconductor of Mountain View. But he stressed that those chemicals are used in small quantities.

“As a general rule, the amount of toxic gas workers are exposed to are safe,” said Dr. Linda Cash, a medical consultant for Cal-OSHA, the state agency responsible for investigating the health and safety of workers. “My main concern was the potential for exposure.”

Workers, dressed much like surgeons in their white gowns, gloves and caps, must work in “clean rooms” where the air is constantly filtered because even microscopic dust particles can cause imperfections that spoil the chips.

It is in these clean rooms where workers are most often exposed to dangerous chemicals, primarily through skin absorption or inhalation.

Ed Sawicki, corporate safety engineer for Intel Corp., of Santa Clara, said companies try to control skin absorption through the use of protective equipment such as gloves and boots. He said inhalation is kept to a minimum through the use of air sight processes for dangerous substances like arsine gas and the use of ventilation to take chemical fumes away from the workers’ breathing zones.

However, according to the files of Cal-OSHA and area fire departments, these safety controls do not always work.

In January 1978, 400 gallons of hydrochloric acid leaked from a storage tank at Dyna Craft, a subsidiary of National Semiconductor Corp., of Santa Clara, forcing evacuation of the plant. There were no injuries.

In May 1978, an acid explosion at Fairchild

Cameras and Instrument Corp., in Mountain View, hospitalized three employees and sent 14 workers home after they inhaled acid fumes. The acid was a mixture of hydrochloric, acetic, nitric and others.

More frequently, accidents involve only one or two workers.

In September 1978, Marion Shaw, a 54-year-old acid cleaner at Fairchild Cameras and Instrument Corp., was badly burned on her right arm, legs, feet and buttocks by sulfuric acid. She is alleging in a workers compensation claim that the accident occurred when a wheel on an acid cart jammed on a broken tile floor, causing six one-gallon acid bottles to fall from the cart onto her.

Acid burns such as these topped the list of occupational illness complaints in the electronics industry, according to Esther Boginsky, the state Division of Labor Statistics and Research’s analyst for occupational illnesses. She said the other common occupationally related complaints were skin problems and eye irritations.

One of the most frequent sources of burns in hydrochloric acid, a colorless liquid which can burrow through the skin and embed itself in the underlying bone hours after exposure.

Dr. David F. Dickey, head of occupational medicine at the San José Medical Clinic, estimates that hydrofluoric acid burns requiring surgery occur about once a month at each of the large semiconductor companies in the area.

Cal-OSHA records show that chemical burns — particularly from hydrofluoric acid — accounted for almost half the work injuries in recent years at both Spectroscopic and National Semiconductor Corp.

Dr. Sherrwyn R. Baker, an ophtalmologist who serves as a consultant for some Silicon Valley firms, said that eye problems in the valley are a two-fold problem — carelessness of the employee and poor design of safety glasses.

Baker, a specialist in contact lens research, also advised that employers who work around chemicals should use protective glasses because a “soft lens absorbs things” such as chemical fumes.

Skin problems such as dermatitis — a condition where the skin is red, dry and itchy — occur most often in the packaging areas where epoxy resins are used to bond the integrated circuit to a board. But the problem also occurs where chemicals are not directly involved.

Valerie Freitas, a former signer for Intersil Inc. of Cupertino, won a $3,700 workers compensation settlement from the company for a dermatitis condition that developed under eye glasses.

While acid burns, eye problems and skin irritations are the most common electronics industry complaints, public and private agencies also are concerned about other problems that aren’t so visible.

“We get calls from workers with headaches, dizziness, nausea and respiratory problems,” said Robin Baker, director of PHASE (Project on Health And Safety in Electronics) in Mountain View.

PHASE, funded under a grant from federal OSHA, received more than 100 calls in a six-month period on a confidential hot line for electronics workers. In addition to those complaints, other workers reported of nosebleeds, rashes and burning tongues. Ms. Baker said. Still others wanted more information on the effects of the chemicals they use.

“There is a potential for health problems in the industry,” said Dr. Richard Wade, deputy chief of health for Cal-OSHA. “It affects thousands of workers in California and we don’t know much about what they’re being exposed to.”

Cal-OSHA has made the electronics industry a top priority. A special task force has been formed to study the industry for possible target compliance efforts similar to those now under way in the pesticide industry.

Part of the reason for Cal-OSHA’s concern are incidents of worker illness that cannot be explained.

Six years ago, a Fairchild vice president and his staff complained of dry and bitter-tasting mouths, severe headaches and nausea and unexplained emotional outbursts.

In a confidential medical report, a Cal-OSHA medical officer said a number of chemicals, including toxic gases such as diborane, arsine and

Signetics Corp. is at lower left intersection of Wolf Road and Arques Avenue in aerial view of Silicon Valley.
The area of greatest concern... is the long-term effect

— Dr. David P. Discher

Cal-OSHA task force puts top-priority focus on electronics industry

Continued from Page 3

phosphine and nitrogen oxides, could produce such symptoms and could be carried to the executive offices through a common ventilation system.

However, none of those chemicals was measured in levels above the state standards, and Cal-OSHA ruled that the problem was psychological.

Last May, 35 workers at Varian Corp. of Sunnyvale complained of headaches, dizziness and nausea, but Cal-OSHA could find no workplace cause and dismissed the problem as "mass psychogenic illness."

Again, chemicals measured in the work areas were well below exposure levels permitted under state law.

In its task force study, Cal-OSHA will be scrutinizing itself as well as the electronics industry in trying to determine whether some of the state standards for chemical exposure are too high.

The fear that exposure under present standards may cause chronic disorders years from now has many health professionals worried.

"The area of greatest concern to me is the long-term effect," Discher said. "It's easy to miss that type of problem because it's so subtle."

"Heightened awareness" of problem

When the National Institute for Occupational Safety and Health released a February report citing a significant, occupationally related health hazard at Signetics Corp., company officials responded that the agency had "thrown out of proportion" a 2-year-old incident that involved only three of its 4,000 employees.

Yet, according to a company memo, the research and development area where the women worked was shut down for a month beginning in December 1977, and outside environmental and medical consultants were hired. Subsequently, Signetics Vice President Don Lidde said, the company spent $500,000 to alter the ventilation system in that area.

"We wouldn't have spent $500,000 if we didn't think there was a problem," Lidde said.

Although Lidde said there was no longer a problem, several other workers recently asked NIOSH, part of the U.S. Department of Health, Education and Welfare, to investigate current health and safety conditions at Signetics.

In March, the California Occupational Safety and Health Administration ordered Signetics to conduct a ventilation study within six months.

In a press release, Dr. Gerald Pieters, an industrial psychologist on Signetics' executive staff, attributed the new investigation requests to "heightened awareness" of a potential problem.

At least five workers have filed workers' compensation claims against Signetics, alleging that their exposure to chemical fumes has left them with a hypersensitivity to everyday chemicals. An hearing has been scheduled in August on the workers' claims.

Three of those workers, Cathy Banerji, Carol Hee and Cathi Hefley—asked for the NIOSH investigation after they experienced continual headaches, nausea, nasal irritation, chest tightness and burning tongue and eyes.

They were joined in filing a lawsuit seeking $25 million in damages by Betty Colgin, a former drafter for the company who also is seeking workers compensation for similar symptoms.

"The fifth employee seeking workers compensation is Dr. Gene Lemons, a physician and former supervisor in the research and development area," Lemons said. "Some of his problems may be due to exposure to a specific gas—phosphine—while the women believe their problems are due to a mixture of gases."

According to workers compensation records, Dr. H. Worwin Hinshaw, a San Francisco physician, examined the five people and found no medical evidence to support the claim, but Dr. Charles Becker, head of the University of California occupational health center in San Francisco, diagnosed the four women as "sensitive to chemicals resulting from overexposure to the workplace."

"The NIOSH report supports Becker's diagnosis," Discher says in a series of prepared statements and one telephone interview.

Signetics officials have taken sharp issue with the NIOSH report because NIOSH has not been able to find objective evidence of any health hazard.

"The report says that 33 air samples were taken and all of the chemicals were found in much lower concentrations than the NIOSH-recommended criteria and the California Occupational Safety and Health Administration standard," company officials said in one statement.

"In spite of that—ignoring what their own scientific data had found—NIOSH has continued to speculate that there might be a problem at Signetics that they may or may not be able to substantiate upon further investigation."

However, an outside consultant's measurements in early 1978 showed that "significant quantities (slightly exceeding Bay Area Air Quality Management District standards) of trichloroethylene, butyl acetate and xylene" were identified in the filters of the building's air conditioning intake.

The consultant, Environmental Research Co. of St. Paul, Minn., was hired by Signetics in 1978 to determine the cause of employee sickness. The consultant concluded that "the problem appears to be due to ventilation," based partly on the air filter measurements.

Jim Melius, chief of the health evaluation and technical assistance branch of NIOSH headquarters in Cincinnati, said the medical complaints of the three women, along with medical records examined by the investigators, were the reason for the conclusion that a health problem existed.

Cathi Hee has filed a claim

Signetics officials criticized the NIOSH investigators for relying on the medical records of eight employees because the investigators had obtained the eight employees' names from the three women and other employees interviewed.

"In our view, the report concludes that Signetics is a safe place to work," Lidde said.

However, Signetics has refused to allow NIOSH investigators to return to the plant to continue the investigation or to begin new investigation. NIOSH, Melius said Thursday, will take Signetics to court if necessary to continue its health and safety studies.

In response, Signetics general counsel William Dana said the company refuses to let NIOSH in without a warrant because Signetics does not want to set an opening precedent that could be used "in all of these harassment lawsuits" by present and former workers.
It's sneaky stuff because it has delayed effects

— James Fordenwalt

Part Two

Safety standards don't cover all chemicals used in industry

“The electronics industry is misleading. People think of it as wires, soldering and transistors. But when you get to the semiconductor industry, you're really talking about chemical reactions. It's a chemical industry.”

— Hamilton Fairburn, assistant regional administrator, U.S. Occupational Safety and Health Administration

Hundreds of chemicals are used by the thousands of gallons in Silicon Valley each year.

Many of these chemicals are hazardous. Some are poisonous. A few can cause cancer.

“Those chemicals are very un forgiving of carelessness,” said James Fordenwalt, a Silicon Valley consultant and a professor at the University of Arizona. “If you do your homework and treat them right, there's no reason why anybody should get hurt.

“But you've got some dangerous stuff in there,” he said. “If it's not used properly, all bets are off.

The danger of those toxic chemicals has prompted the federal government's National Institute for Occupational Safety and Health to begin a nationwide study of the health hazards in the electronics industry. Santa Clara County's Silicon Valley, a part of the country with the highest concentration of electronics firms, will be a prime target.

Two of the most dangerous poisons used in U.S. industry, arsine and phosphine, and one of the most hazardous chemicals, hydrofluoric acid, are considered indispensable to the semiconductor manufacturing process.

Arsine, a colorless, arsenic-based gas with a mild garlic odor, is the most acutely toxic form of arsenic,” according to a report issued in 1979 by the national safety agency.

According to the report, arsine in large doses can kill instantly and in small doses can destroy red blood cells and damage the liver and heart. Arsine is so poisonous that the legal limit for the gas in the workplace is 5 parts per 100 million parts of air, averaged over an eight-hour day.

But the agency fears that even this is too much and has recommended cutting the legal limit to 5 parts per 10 million.

Phosphine, a colorless, phosphorus-based gas with a faint odor, is slightly less toxic than arsenic, but causes greater respiratory damage. Its permissible level is 3 parts per 10 million parts of air.

These dangerous chemicals are necessary parts of the semiconductor manufacturing process.

“We use arsine gas and phosphine gas because of their unique electrical qualities,” said Roger Borey, a senior industrial hygienist at SRI International, a Menlo Park consulting firm.

But accidents still occur.

“I have seen temporary blood-count damage from arsine. I have had people exposed to phosphine leaks. Maybe eight or 10 people who breathed phosphine gas got bronchitis or pneumonia,” said Dr. Bruce Dickerson, medical director for Fairchild Camera and Instrument Corp. of Mountain View.

While arsine and phosphine-related illnesses are rare, burns and other accidents resulting from the use of hydrofluoric acid are among the most common in the industry, according to state statistics.

Hydrofluoric acid, a colorless chemical with an irritating odor, is used as a cleaning fluid for silicon wafers and for etching integrated circuits onto the wafers. The acid has no substitute in the manufacturing process, according to Intel's Borovoy, because it is the only one that can etch glass.

Injuries to workers from hydrofluoric acid most often occur from splashes and spills in the dipping process.

“It's sneaky stuff because it has delayed effects,” said Fordenwalt, Silicon Valley consultant and director of the semiconductor laboratory at the University of Arizona.

Unlike many acids that burn the skin, hydrofluoric acid "penetrates the skin and seeks for the bone," according to SRI's Salazar.

The human body has no resistance to hydrofluoric acid, which will burn away tissue until it is neutralized by bone calcium. Symptoms do not appear until minutes or even hours afterward, when, according to Salazar, it "gives a horrible pain, like being on fire.

Arsine, phosphine and hydrofluoric acid are only three among scores of hazardous chemicals used by the electronics industry. For example, cyanide, a well-known poison, is used by the industry as a catalyst in plating precious metals such as gold onto circuits and connectors and as a reclaiming material for those metals.

In January 1979, cyanide was among four chemicals involved in a chemical spill at Varian Associates in Santa Clara. Santa Clara Fire Marshal Bill Fleming said in a memo that the company "did not have the proper materials on hand to neutralize and contain the chemicals" in the spill that took 21/2 hours to contain. According to Fleming, one employee was injured and the entire plant was evacuated.

Because most electronic firms regard the chemicals they use as "proprietary information," a complete accounting of the chemicals used by the industry is not available.

Still, based upon interviews with Salazar; Fordenwalt; Dr. Richard Wade, deputy chief of health GIF CARSSA (Occupational Safety and Health Administration); R.W. King, Santa Clara County's environmental health supervisor, and Robin Baker, director of PRASSE (Project on Health and Safety in Electronics), it is possible to develop a list of five types of chemicals used by the industry: dopania, corrosives, cryogenic gases, epoxy resins and solvents.

Of these groups, dopants — the chemicals used in airight vessels to give the silicon wafer its electrical properties — are considered the most dangerous.

These include arsine, phosphine, diborane, silane, boron tribromide and boron trichloride.

Corrosives include such acids as hydrofluoric, hydrochloric, nitric and sulfuric. They are used to clean the wafer and to etch it, processes that may be repeated half a dozen times before the wafer leaves the fabrication area.

Unlike many chemicals in the electronics industry, the cryogenic (ultracold) gases are found in large volume and usually are stored outside the plant. These chemicals include liquefied hydrogen, oxygen and nitrogen. The first is highly flammable, and all three can freeze skin on contact. They are used to heat and cool furnaces used to bake chemicals into the surface of silicon wafers.

Epoxy resins are among the most "sensitizing" chemicals in the industry — capable of producing, after continued exposure, strong allergic reactions even in minute amounts. These chemicals are used in the process of bonding the silicon chip to the circuit board, and it is in this manufacturing step where contact dermatitis, a skin problem causing redness, dryness and itching, occurs most frequently.

Solvents can be used as a liquid for suspending solid substances, such as photosensitizing chemicals, but they are primarily used as degreasers or cleaners.

Continued on Page 8
The steps in semiconductor manufacturing

1. WAFER PRODUCTION
Thin circular wafers of between 2 in. and 4 in. in diameter are sliced from cylindrical ingots of glass-like silicon. This procedure is usually done at firms which specialize in growing the silicon crystals.

<table>
<thead>
<tr>
<th>CHEMICALS</th>
<th>POTENTIAL HAZARDS</th>
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<tbody>
<tr>
<td>silicon</td>
<td>lung, respiratory irritation</td>
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</table>

2. WAFER CLEANING
Each wafer is cleaned in an acid bath to remove any grease or other alien substance from the surface. This is usually done by dipping the wafer into a bath containing a number of wafers in a bath containing a strong acid kept at a high temperature to increase its corrosiveness. The wafer is then washed with cold, then boiling, ultrapure water.

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<thead>
<tr>
<th>CHEMICALS</th>
<th>POTENTIAL HAZARDS</th>
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<tbody>
<tr>
<td>sulfuric and nitric acids</td>
<td>contact, skin burns, inhalation, eye, nose, throat irritation</td>
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6. DIFFUSION
The wafer is placed in a closed vessel containing an atmosphere of either arsine, phosphine or boron gas, and heated to 1,000°C. This causes the gas (called the dopant) to chemically react with the exposed photochemicals on the surface of the wafer and alters its electrical characteristics. Depending upon the number of layers of circuitry needed on the surface of each chip, the wafer, steps 3 through 6 may be repeated as many as six or seven times.

<table>
<thead>
<tr>
<th>CHEMICALS</th>
<th>POTENTIAL HAZARDS</th>
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<tbody>
<tr>
<td>arsine gas, phosphine gas, diborane gas</td>
<td>blood disorders, jaundice, respiratory problems, tight chest, breathing problems</td>
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</table>

7. METAL MASKING/EVAPORATION
The wafer, now with its complete circuitry deposited in dopant, is again masked with photoresist, exposed and acid etched. This masking is for the deposition of a number of aluminum contacts for connecting to the external wiring. An added step in this process is the placement of the wafer into an oven to evaporate any unwanted metal. The wafer is washed in ultrapure water and then coated with a surface layer of glass at a temperature of 420°C in a process called passivation. This is followed by another acid etching and rinse.

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<thead>
<tr>
<th>CHEMICALS</th>
<th>POTENTIAL HAZARDS</th>
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<tbody>
<tr>
<td>none</td>
<td>same as in steps 3-6</td>
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8. WAFER PROBE and SAWING
Each of the scores of individual integrated circuits on the surface of the wafer is microscopically inspected and those that have been imperfectly fabricated are marked for disposal. The wafer is then sliced up into the separate chips with a diamond saw.

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<tr>
<th>CHEMICALS</th>
<th>POTENTIAL HAZARDS</th>
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<tbody>
<tr>
<td>diamond saw blade injury, eye damage from lasers</td>
<td>none</td>
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'Over 200,000 chemicals are used in the workplace in the United States. We have standards for about 2,000' — Dr. Richard Wade

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<tr>
<th>3. PHOTORESIST/BAKING</th>
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<tr>
<td>Water is baked at 1,100 degrees Celsius to produce a thin layer of silicon oxide (similar to silica on iron) on its surface. Then, a photosensitive chemical is painted onto the surface and the wafer is again baked — this time at about the boiling temperature of water — so that the photosensitive chemical forms a hard, smooth coating.</td>
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<tr>
<th>CHEMICALS</th>
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<tbody>
<tr>
<td>Photoresist suspending liquid</td>
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<table>
<thead>
<tr>
<th>POTENTIAL HAZARDS</th>
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<tbody>
<tr>
<td>Contact — dermatitis</td>
</tr>
<tr>
<td>Inhalation — dizziness, muscular weakness, mental confusion</td>
</tr>
<tr>
<td>Highly flammable</td>
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<tr>
<th>4. MASKING/ALIGNING</th>
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<tr>
<td>Using ultraviolet light, the photoresist-coated wafer is exposed to the desired pattern of integrated circuitry, which leaves an exposure on the wafer's surface. This exposure is then developed much like a standard photograph, using developer and rinsing. The wafer is then inspected for flaws in the exposure and then baked again.</td>
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<thead>
<tr>
<th>CHEMICALS</th>
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<tbody>
<tr>
<td>None</td>
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<table>
<thead>
<tr>
<th>POTENTIAL HAZARDS</th>
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<tbody>
<tr>
<td>Fumes from photoresist chemicals (see #3); eyestrain from microscope</td>
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<tr>
<th>5. ETCHING</th>
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<tr>
<td>To remove the unexposed material from around the desired circuitry, the wafer is dipped at least twice into a bath of concentrated sulfuric acid maintained at a temperature higher than boiling water. The wafer is then rinsed with ultrapure water.</td>
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<thead>
<tr>
<th>CHEMICALS</th>
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<tbody>
<tr>
<td>Hydrofluoric acid</td>
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<tr>
<td>Hydrochloric acid</td>
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<table>
<thead>
<tr>
<th>POTENTIAL HAZARDS</th>
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</thead>
<tbody>
<tr>
<td>Contact — tissue, blood vessel damage</td>
</tr>
<tr>
<td>Inhalation — nose, throat irritation</td>
</tr>
<tr>
<td>Contact — skin burns</td>
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<tr>
<th>9. ENCAPSULATION</th>
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<tbody>
<tr>
<td>Individual integrated circuit chips are bonded to ceramic frames containing a dozen or more conductive metal legs for attaching to printed circuit cards for applications in computers, calculators, appliances and other devices. The chips are then connected to these legs via tin wires attached to the chip's metal contacts. Finally, the chip and the lead wires are encapsulated by a plastic or ceramic cap bonded in epoxy. To ensure air tightness, the capsules are sometimes placed in radioactive krypton and then sealed for leakage.</td>
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<thead>
<tr>
<th>CHEMICALS</th>
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<tbody>
<tr>
<td>Nickel plating</td>
</tr>
<tr>
<td>Solder</td>
</tr>
<tr>
<td>Acetone</td>
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<tr>
<td>Isopropyl alcohol</td>
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<table>
<thead>
<tr>
<th>POTENTIAL HAZARDS</th>
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</thead>
<tbody>
<tr>
<td>Asphyxiation; deafness</td>
</tr>
<tr>
<td>Dermatitis</td>
</tr>
<tr>
<td>Radiation exposure</td>
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<tr>
<th>10. BOARD LEVEL ASSEMBLY</th>
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</thead>
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<tr>
<td>Different types of integrated circuits and various other less-sophisticated forms of semiconductor circuitry according to need are mounted via their metal legs onto ceramic or plastic printed circuit boards and soldered into place. All parts are cleaned with solvents.</td>
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<thead>
<tr>
<th>CHEMICALS</th>
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</thead>
<tbody>
<tr>
<td>Lead (used for solder)</td>
</tr>
<tr>
<td>Trichloroethylene (cleaner)</td>
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<thead>
<tr>
<th>POTENTIAL HAZARDS</th>
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<tbody>
<tr>
<td>Abdominal pain, anemia, lead poisoning</td>
</tr>
<tr>
<td>Narcotic effects, liver damage, suspected carcinogen</td>
</tr>
<tr>
<td>Narcotic effects</td>
</tr>
<tr>
<td>Shallow, rapid pulse</td>
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<tr>
<td>Low toxicity but high fire risk</td>
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<tr>
<th>11. SYSTEM LEVEL ASSEMBLY</th>
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<td>The printed circuits are combined with other components, such as keyboards, displays and wiring and mounted into the devices for which they were designed. These devices range from &quot;smart&quot; home appliances, such as microwave ovens, to large scale computers. Most of these devices are cleaned and degreased with solvents, and some are epoxied, sealed and painted.</td>
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<tr>
<th>CHEMICALS</th>
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<td>Solvents</td>
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<tr>
<th>POTENTIAL HAZARDS</th>
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<td>Same as above solvents</td>
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'Published standards haven’t been set for all of the chemicals used.'

Continued from Page 5

Chemistry of electronics much more hazardous than one might think

Continued from Page 5

an eight-hour day, while the federal safety agency recommends the same amount of exposure averaged over a 10-hour day.

Other solvents include toluene, methyl-ethyl-ketone and trichlorethylene. Trichlorethylene, commonly known as TCE, is known to cause cancer in animals.

For this reason, the industry is phasing out TCE and replacing it with methyl chloride, which is believed to be safer and can perform the same degreasing functions.

But substitution is not always possible. Proven cancer-causing chemicals even more potent than TCE still are in use by the industry.

In Santa Clara County alone, more than a dozen electronics companies are registered with the state Department of Industrial Relations as users of at least one of the 20 substances identified as cancer-causing under state law.

Inorganic arsenic, vinyl chloride and asbestos are the most common registered substances, according to the registration records, but more unusual and potent carcinogens occasionally are used.

Some companies have been fined by Cal-OSHA for failing to register carcinogens. In February 1978, Raychem Corp. of Menlo Park was fined for failing to register five carcinogens with the state. The company also was given citations for failing to properly label, store and monitor the use of these carcinogens. Raychem responded by disposing of four of the five substances and establishing approved handling procedures for the remaining substance, acrylonitrite.

In November 1978, Fairchild Camera and Instrument Corp. was fined $1,500 for failing to register two carcinogens with the state, for failing to store them properly, and for failing to put a "cancer suspect agent" label on containers of benzidine hydrochloride.

Outside groups have challenged industry statements that employees are adequately informed of the hazards involved in their jobs.

Company officials, including Tom Wrobleski, corporate safety officer and manager of employee relations for Zilog Inc. of Cupertino, have claimed that "safety data sheets" listing health and safety hazards of toxic chemicals always are available for employee inspection.

But a state Assembly bill that would have required companies to give employees written warnings on each chemical they may handle was defeated in January in the Assembly Ways and Means Committee.

At least one state agency is not pleased with the Legislature's actions. Cal-OSHA's Wade said his agency will push for regulations from the state standards board requiring just such written employee warnings from companies that manufacture chemicals in California.

Although some government agencies and many physicians take the position that no exposure to a carcinogen is safe, government standards have been set for permissible exposure levels to carcinogens.

But, such published standards haven't been set for all of the chemicals used in electronics or any other industry, Wade said.

New chemicals are developed at a faster rate than health standards can be developed for them, Wade said. He added that even tightening an existing standard because of new evidence of danger can be a long process, meaning that workers might continue to work under the more relaxed standards for months or even years.

"Over 200,000 chemicals are used in the workplace in the United States," Wade said. "We have standards for about 2,000."
'An employee can tolerate a lot more than the product'

—Bill Sanborn

Workers wear protective clothing in 'clean room' of a semiconductor plant; woman at left dips wafers in acid bath

Part Three

Which standards are safe enough for the semiconductor industry?

By conservative estimates, electronics companies in Silicon Valley spend millions of dollars every year to protect two things: the product and the worker. Which of the two takes priority is debatable, industry sources say.

"There are mixed loyalties. The main reason (for spending money) is to maintain air quality for the product," said Bill Sanborn, senior engineer for safety and facilities at Intel's Inc. of Cupertino.

"The hazardous chemical exposure risk is really that low. An employee can tolerate a lot more than the product."

Many Silicon Valley executives agree with Sanborn that the air purity required to keep products uncontaminated is more than adequate to preserve the health of employees.

Yet, according to the state Division of Labor Statistics and Research, the electronics industry has one of the highest illness rates of any California industry.

Why?

"Probably because they use more chemicals that can cause problems," said Karen Jones, research manager for the state labor statistics division.

Officials at two of the area's five largest semiconductor firms, Fairchild Camera and Instrument Corp. of Mountain View and Advanced Micro Devices Corp. of Sunnyvale, refused to discuss their health and safety programs. However, based upon interviews with officials of the other three largest companies and officials of three smaller companies, health and safety controls in the electronics industry can be divided into five groups: ventilation, air monitoring, protective equipment, training and medical evaluations.

"Like a vented hood above a stove, the ventilation system is designed to pull dust and chemical contaminations from the air. The air then flows into a dry scrubber, which washes it with water to remove impurities. The air then is recirculated into the plant or released to the outside atmosphere."

To check the efficiency of the ventilation system and to locate new leaks, firms periodically monitor the air in work and office areas using a wide variety of products, ranging from simple air pumps that hang on the belt to highly sophisticated
Trade-offs involved in safe manufacture of semiconductors

Computer-based sensors costing thousands of dollars.

Protective equipment includes gloves, arm coverings, rubber aprons, safety glasses and boots. Companies issue these products to employees who work in wafer fabrication areas and most firms require that they be worn at all times.

Many firms also provide training programs designed to give employees an idea of the dangerous chemicals with which they work and to keep employees constantly aware of safety.

Some electronics firms require medical evaluations of their employees who might be exposed to hazardous chemicals. This includes an initial check-up upon hiring and periodic testing thereafter. Intel Corp. of Santa Clara, for example, gives employees who work with arsenic-based chemicals blood and urine tests every six months. Beyond these safety measures, most firms depend upon their employees’ noses—which can detect many chemicals at levels well within safety limits.

"Smell is my best protection," said Jim Cochran, facilities manager at Teledyne Semiconductor in Mountain View.

However, some workers argue that this practice has been carried to extremes. A former employee of Fairchild Camera and Instrument Corp. of Mountain View claims that she was asked to go to other work areas to serve as a "barometer for chemical fumes once the company discovered she was sensitive to chemicals."

Shirley Philipson, a former secretary at a Fairchild vice-president, said company officials asked her to serve as a "canary," meaning that because of her higher sensitivity she might be able to detect chemical fume problems quicker than other people.

Fairchild refused to discuss the women’s claims or any other safety aspect.

Marta Rojas, Caryl Hee and Cathy Bauer—three women who are suing Signetics for their chemical sensitivity—also claim that the company asked them to serve as canaries. Ray Vaden, Signetics’ manager of security and safety, has dismissed the women’s claims as "ridiculous and arbitrary."

Intel corporate safety engineer Ed Savicki said his company will evacuate an area at the first sign of an unusual odor. National Semiconductor corporate safety director Gerard Colletta said his company has a similar attitude toward evacuation.

Safety by smell and evacuation is one of the things that health officials criticize about the industry.

The industry needs better electronic monitoring of the air rather than having to rely on smell, said Dr. Linda Garb, who was a medical consultant for Cal-OSHA, the state agency responsible for investigating the health and safety of workers before she went into private practice at the Palo Alto Medical Clinic.

Such electronic monitoring is now being tested at Intel. Other large companies, including Signetics, are interested in the idea.

It is in areas such as costly electronic monitoring and expensive safety staffs that the small and large companies differ. While the large companies have safety engineers, industrial hygienists, nurses and occasionally physicians on staff, the smaller companies rely on outside consultants to monitor their problems.

Despite the money that is spent on worker protection, some safety engineers say health and safety controls are not foolproof.

For example, ventilation problems will be a key issue in the coming task force study by Cal-OSHA. According to Richard Wade, deputy chief of health for the agency, ventilation and scrubbers can allow different chemicals to be mixed to create unpredictable "synergistic" effects for which there is little research and no static data.

Alfredo Salazar, a senior industrial hygienist at SRI International and a consultant to the industry for the past seven years, also is critical of the design of many scrubber systems.

The best way is to ventilate air through a stack similar to those used by heavy industry, Salazar said. Instead, he said, the scrubbers are contained in aesthetically pleasing pails that can allow contaminants to start accumulating on the roof level, with "occasional re-entry of chemicals into plants."

Problems extend outside semiconductor plants

Some agencies equally concerned with fire, environmental dangers posed by industry.

While most of the government agency attention on the electronics industry has focused on conditions inside the plants, there are some agencies that are just as concerned about conditions outside.

Four years ago, the Bay Area Air Quality Management District installed 13 air filter strips near electronics firms from Santa Clara to Palo Alto to monitor five chemicals, including fluoride and chloro-

Howard James, a biostatistician for the district, said the air monitors were put out after he received reports that apricot trees showed evidence of chemical concentrations. James said the air strips pick up relatively high concentrations of fluoride in the center of the monitoring area, which is bounded by Highway 101, Middlefield Road, Ellis Street and Whisman Road, "but it doesn’t seem to be getting out of that area."

Even if a problem developed,

James said he would have a difficult time curtailing fluoride emissions, since there are no specific regulations on allowable concentrations of fluoride.

However, the district can classify companies as "public nuisances" if it receives five or more complaints about odors from a firm in a day.

Since September, Pleasant Merey Science of Mountain View has received three such citations, according to district public information officer Peretz Lee. She said the company had responded by ordering a better air scrubber for one of its processes.

Area fire departments also keep a close eye on the electronics industry.

"The electronics industry commonly uses hazardous chemicals that are flammable, explosive, poisonous and reactive when exposed to other chemicals," Santa Clara Fire Marshal Bill Pfenning said in an internal memo. "This presents a serious hazard to our firefighters and plant employees or anyone in the area when a fire involving chemicals or a spill occurs."

"It is time for us to realize that with a city that is one-half developed industrially and the number of that industry devoted to electronics, that we have been extremely fortunate," Fleming added.

He also wrote that he is concerned about the possibility of an accident while hazardous chemicals are being hauled to and from the electronics firms. "We have yet to have a hazardous material transportation accident," he said. "But as the exposure increases, the risk increases."

While Santa Clara has been the site of two large electronics firms since the first of the year, the other city with a large concentration of electronics companies—Sunnyvale—has had no major emergences.

"We’ve lived a very charmed life," said Sunnyvale fire prevention inspector Gale Bate. "We like to believe it is because we strictly enforce regulations."

From August to November, the Sunnyvale Fire department found 504 fire code violations at Signetics Corp. The violations ranged from blocked access for exits to improper storage of hazardous chemicals.

In a prepared response, Signetics vice-president Don Liddie noted that 90 percent of the violations had been corrected, while "most of the others involve reconstruction and are in progress.

"We’re solving ours all the time, but we’ll never hit 100 percent. No one ever does," Liddie said. "You’re chasing a moving target—employees that put in unauthorized coffee pots or extension cords, changes in the fire regulations and so forth."

Palo Alto Fire Marshal Bob Wall said that "industry is often ahead of the codes."

"They come up with new products faster than we can keep up with them. That is the reason why there is a violation," said Wall.
Most firms depend upon employees' noses to detect danger levels

In a May 1978 report, an outside consultant for Signetics Corp. of Sunnyvale expressed a similar opinion.

"The flat roof of the building is surrounded by a wind screen designed per local regulation to block the vent pipes and thereby improve the building appearance," Environmental Research Co. of St. Paul, Minn., said in its report. The wind screen also reduces the dispersion of the vented vapors under certain wind conditions actually traps the vapors on the roof.

Air-sampling procedures at many firms also have been criticized because they are not continuous. Employee air pumps, for example, "are run to determine concentrations of materials where there is felt to be a problem," Sanborn said. "There is no OSHA mandate that sampling would be continuous.

National Semiconductor Corp.'s Coleta said the company continuously monitors areas where arsine and phosphine gases are used. When the monitors have reached certain levels, Coleta said, it has been a case of a "fishing" done, by a technician.

Industry officials say employee error is one of the greatest sources of accidents in the semiconductor industry. Not all of the mistakes result from poor judgment. It is difficult to remain acutely safety-conscious day after day in a potentially hazardous environment. Protective clothing is designed to guard against such accidents, but when an employee takes an undue risk and makes a garment, proper supervisory personnel can suffer.

In January 1979, National Semiconductor was fined $1,000 because an employee was wearing Sulcina tennis shoes instead of steel-toed boots while working with sulfonic acid.

Coleta said this was in violation of company policy and was apparently allowed to occur because of a supervision problem.

"Because the industry uses hazardous substances, training is emphasized. In the large semiconductor firms, a week of training is not uncommon. "Every employee who is new to us and to the industry, who is hired to work in a fab or fabrication area, undergoes an initial five-day training and orientation," Don Liddle, vice president of Signetics Corp., said in a prepared statement. At the conclusion of the classes, employees must take a safety quiz.

Still, in an August 1979 inspection report, a Cal-OSHA industrial hygiene inspector noted that "Signetics' training course be provided to other employees so they will be more aware of chemical hazards."

In February 1978, a Cal-OSHA inspector noted that National Semiconductor "has a safety program in operation, but its performance is adversely affected by the employee turnover and a lack of training in handling hazardous substances."

Because some people can tolerate chemical exposure better than others, medical evaluations are used to check individuals' exposure levels.

"A "baseline" health and physical study is conducted on an ongoing basis. In his prepared statement, Liddle said, "physical exams are performed on employees who are going to work with certain chemicals, and the employees ever get to their first work stations. Then the workers are monitored periodically so the first sign of a problem would be picked up quickly."

Intel's Sawicki said his company plans to expand its arsenic medical monitoring to include all employees who come in contact with hazardous chemicals.

As is indicated by some companies plans for stepped-up safety controls, the companies themselves are growing increasingly concerned about health and safety issues.

At Applied Technology of Sunnyvale, the safety department is now requiring pregnant women to obtain a signed release from their doctors before they work with about 30 hazardous chemicals and materials.

A group of about 30 safety engineers that has been meeting sporadically for more than a year is considering affiliation with the Santa Clara County Manufacturing Group to solidify its organization. The group was organized by Sawicki, an enthusiastic, outspoken advocate for improved health and safety practices in the industry. He joined Intel's safety department four years ago, after working for a year at Signetics.

He started the group because he felt that "a lot of people were trying to re-invent the wheel."

Since "everybody used the same chemicals and bought the same equipment" Sawicki said, it was time for the industry to share health and safety information.

"We are not in competition on health and safety issues," he said.

Sherril LeRocca, vice president and training officer for the Electronics Association of California, said she has been "pretty impressed that I get phone calls from process engineers who want to know when employees are going to get a certain safety standard."

"The companies have probably been growing so fast that they are taking shortcuts," said Tom Wroblewski, corporate safety officer and manager of employee relations for Zilog Inc. of Cupertino. "We're working quite hard in the area."

Wroblewski was critical of recent suggestions by governmental agencies that the health and safety in the industry may be suspect.

"Maybe it's justified in some companies, but it tarnishes the whole industry," he said.

Tom Hinkelman, executive director of the

Machine monitors factory air

Intel tests measuring device to warn of air contamination

In three months, the wafer fabrication workers at Intel Corp. of Santa Clara no longer will have to depend on their noses to tell them if they need to evacuate an area.

They will be able to rely instead on a machine called the M-80, which constantly measures the level of the most dangerous chemicals in a given area, and sounds an alarm if the levels are too high.

Corporate safety engineer Ed Sawicki boasts that Intel's $38,000 M-80 machine is a one-of-a-kind machine in the electronics industry, although he suspects the chemical component may be purchased from another firm. The alarm system is activated.

The M-80 has been operating on a test basis — without the alarm system — for several months, and Sawicki estimates that it will be another three months before the crucial "early warning" alarm system is activated.

However, the testing has been so successful so far that Intel has already placed an order for seven more M-80s.

The machine essentially is an infrared monitor hooked up to a microprocessor, or tiny computer. Twenty-four white tubes protrude from the ceiling, sensitive heads that resemble microphones and are suspended from the ceiling in 18 separate locations in Intel's semiconductor manufacturing process.

"We put the units in the worst possible locations; the ones most likely to leak a particular gas, such as arsine pipes," Sawicki said.

The machine is designed to measure levels of certain chemicals that are potentially toxic.

The amount of each chemical in the air is measured and printed out each half-hour. That information can then be checked against the parts per million exposure allowed by state law and Intel standards. Sawicki said Intel allows employees to be exposed to half of what the state allows "as an added precaution."

After the alarm system is activated, the machine will let the workers know automatically if the concentrations of certain gases in the air are too high.

The M-80 has other uses as well. The $12,000 portable version can be placed in an area to find the chemical fingerprint of an unknown contaminant in order to identify it, Sawicki said.

"The machine also has its limitations. For example, it cannot monitor levels of concentrations lower than 0.5 parts per million of air. This makes it impossible to measure a gas such as arsine, which has a parts per million level under state law of .53 parts per million.

Sawicki said Intel can compensate for this on a spot-check basis, by having certain employees carry pumps that can measure arsine levels in a small area. "But we can't measure it continuously as with the M-80," he said.

While Intel is marketing the M-80 in the industry, researchers at Stanford University are working on ways of making a similar device smaller.

Dr. Stephen Terry, a senior research associate for the Stanford Electronics Laboratories, says his gas chromatograph, which measures chemical and carbon dioxide levels, will be small enough to place on a worker's belt.

"From an industrial hygiene point of view, that's better since it gets the same exposure that the employee does," Terry said. "It will be portable enough that it monitors individual worker exposure instead of room exposure.

Terry's first prototype will be sent to the National Institute for Occupational Safety and Health before summer, and Terry hopes it will be available for industrial use within two years.
Labor’s role debated in current emphasis on health, safety

Continued from Page 11

Semiconductor Industry Association, is also puzzled by the recent questioning of health and safety standards in the industry.

"The industry has an outstanding record on health," Hinkelmann said. "For over 50 years, it has been operating complex fabrication work systems using chemical systems. It has never had a fatality.

When it comes to health and safety, it is acting at the state of the art." Roy Brant, National Semiconductors vice president for human relations, said he is suspicious that organized labor largely may be responsible for the current emphasis on health and safety in the Silicon Valley.

"Since organized labor has been so unsuccessful (in the Silicon Valley is largely unorganized), they are searching for any and all potential issues," Brant said.

Brant said, however, that because they are government agencies, he does not question the legitimacy of the concern by Cal-Osha, which has formed a special task force to study the industry and the federal government’s National Institute for Occupational Safety and Health, which is investigating worker complaints of possible health hazards.

Mike Nye, business representative of the Central Labor Council in San Jose, said he did not think the "trade union movement made up the problems of headaches and dizziness and the chemicals that are used. It’s an institution that responds to problems.

Cal-Osha’s special electronics task force report will be concluded this summer. If the task force identifies areas where the industry is not conforming to established standards, a more long-term scrutiny of the industry will be made.

Officials of both Cal-Osha and Niosh are careful to say that they do not know what problems may find in the electronics industry.

"Toxic substances are used," said Dr. John Froines, deputy director of Niosh. "But the key question, he says, is, "Are they properly controlled?"

Industry challenged on health matters

2 groups take advocacy role, provide information, education

Amanda Hawes, a lawyer with a background in legal aid, had fought for better working conditions for cannery workers in the East Bay.

Pat Lamborn, a solderer with a large semiconductor company, was concerned about the skin problems she was having.

Robin Baker, a public health worker, believed that occupational health was an emerging need in the public health field.

In early 1976, the three women formed the nucleus of what was to become Ecoshow, the Electronics Committee On Safety and Health, a group that began as an information center for electronics workers who had questions about the hazards of the chemicals they used.

Two years later, Ecoshow has taken on an advocacy role in filing complaints with state and federal agencies on behalf of employees and in questioning the electronics companies’ health and safety practices.

A splinter group called PHASE (Project on Health and Safety in Electronics) has taken over the educational and informational aspects of Ecoshow under a $127,000 grant from the U.S. Department of Labor’s Occupational Safety and Health Administration.

Some industry officials believe Ecoshow and PHASE, which share an office in Mountain View, are fronts for union organizing in an industry that is largely unorganized.

However, Mike Nye, business representative for the Central Labor Council of Santa Clara County, says there is no formal connection between the unions and Ecoshow and PHASE.

Last year, safety engineers from 25 companies asked OSHA officials not to cut off the PHASE grant because they viewed it as federal tax dollars being spent for union organizing, said Ken Larson, special assistant to the regional OSHA administrator.

Larson said the officials also did not think an outside health and safety group was needed.

OSHA officials apparently disagreed, since they later increased PHASE’s grant from $50,000 to $127,000.

Since that time, PHASE director Robin Baker said PHASE avoids any official mention of unions, although she and other staff members have been referred to as a way to guarantee better health and safety conditions for electronics workers.

With no such tax-funding constraints, Ecoshow actively supports organizing efforts in the industry, although it denies the charge that Ecoshow is an organizing committee in disguise.

Ms. Baker organized PHASE after Ecoshow learned that OSHA would have money available for the first time in 1978 for training and education of employees in "high risk" industries.

"The electronics industry has for so long enjoyed the image of a clean, safe industry," she said. "The main problem isn’t safety. It’s health, because of exposure to toxic substances."