Optel's ebullient founder, Zoltan Kiss (it's pronounced *Kisch),* often arrives by bicycle at the stone-faced plant near Princeton, New Jersey. Framing the photograph are some of Optel's liquid-crystal watch displays, greatly enlarged.

Optel's (Mis)adventures in Liquid Crystals

A false start and a boardroom revolt put the fledgling company through an exciting thirty-three months (only two profitable).

by Charles G. Burck

When Zoltan J. Kiss left RCA's laboratories four years ago to start up his own venture in new technology, he read up on the great successes and failures of similar endeavors. He believed that small companies have certain inherent advantages over giants, and he reasoned that he could beat out the RCA's by making decisions with dispatch and using his resources more efficiently. He also felt confident that he could avoid the kinds of mistakes that had undone others—spending too much money, for example, or clinging to technologies that had no practical future.

But none of this wisdom spared Optel Corp. the unpleasant surprises that attend the launching of a new venture. Optel has become a leader in the development of liquid crystals, an infant technology that has dramatic possibilities for use in displaying information—from time on the face of a clock to speed on an automobile dashboard. The company has a solid market for its current products, a substantial backlog of orders, and several tantalizing possibilities down the road. But during its four years of operation, it has also suffered wrenching production problems, devastating supply shortages, the threat of a potentially crippling lawsuit from its largest customer—and a bitter boardroom split over its management and goals. As of August, Optel had enjoyed only two profitable months. It has spent all its original private venture capital, most of the $4,794,000 it raised in a public offering, the funds it got from numerous development contracts, and a fair chunk of a $2-million revolving credit—all together, about $6 million.

Headaches from a new technology

Optel's difficulties reflect not only its own errors but also the turbulent state of the emerging liquid-crystal industry. Liquid crystals are important new competitors of such display devices as light-emitting diodes, gas-discharge tubes, and electromechanical dials and gauges. While they are relatively simple and low in cost, they have proved difficult to make. Liquid-crystal materials are so susceptible to impurities that a little too much humidity in the workshop has been known to wreck production. Sealing the displays is a particularly delicate undertaking: there are almost as many sealing systems as companies in the business, and all of the seals have given their makers headaches. A visitor to just about any of the liquid-crystal companies will sooner or later be told about the recent dramatic failure of some competitor's display in the hands of a customer.

Research associate: Peter Schuyten

Development and production difficulties have bedeviled even the giants of the electronics industry. Texas Instruments recently shelved an unsuccessful effort to make liquid crystals for watches. RCA announced at the beginning of 1972 that it would be in full-scale production by year's end, but the company says it is only now reaching that stage. All in all, the industry, if it can be so loftily described, is stumbling through all of the expected and unexpected pitfalls that strew the path of a developing technology.

Science is safer

Optel's own circuitous path has been largely influenced by the singular personality of Zoltan Kiss, forty-one. Besides being the founder, main stockholder, and chief executive, Kiss is the company's super-salesman. He is knowledgeable, persuasive, and, as even his opponents concede, charming—with just enough of a Hungarian accent to underscore his credentials as a European man of science. He raised capital and secured development contracts by limning seductive pictures of technological possibilities at a time when Optel had little more to offer than promises and a nucleus of talented people.

Back in 1950, at the age of eighteen, Kiss fled Hungary and lived for a time by taking odd jobs in Austria and Switzerland. He soon found his way to Canada, where, after working several months in a lumber camp, he enrolled in engineering at the University of Toronto. His choice of a specialty was a striking exercise in political pragmatism. "I came from a deeply Catholic peasant family," he says, "and in my studies I wanted to pursue the ideal, the theoretical. [He had, in fact, once contemplated becoming a priest.] My choice was between philosophy and science. But I had seen, in my country, men in the liberal professions destroyed by politics. In science, I felt, I would be relatively immune to ideological pressures."

Kiss earned his doctorate in physics at Toronto, spent a year in postgraduate work at Oxford, and in 1960 joined RCA as a researcher at its laboratories in Princeton, New Jersey, where he was regarded as a first-rate physicist. He won a patent for a solid-state laser design, and after five years he was named head of quantum-electronics research.

The pursuit of the theoretical at RCA, however, left Kiss unsatisfied. An egotistical man, as he disarmingly admits,

Young alumni of RCA predominate in Optel's management, including the company's key officers: from left, Nunzio A. Luce, head of liquid-crystal and watch-component development and manufacturing; Richard Corbin, finance; Douglas Bosomworth, watch manufacturing and general troubleshooting; and Kiss, president and chairman.

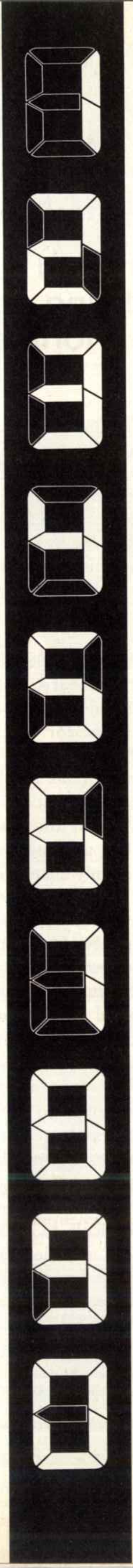
he felt RCA was not letting him use his abilities fully. "Call it ambition or greed or whatever, but it's not really that; you need a sense of a rate of growth in some area, real or imagined." He felt, too, that research at RCA was too remote from product areas—that significant new inventions languished because their sales potential did not seem big enough to division heads who were accustomed to thinking in terms of $100-million and $200-million markets.

One way Kiss might have sought to advance at RCA would have been to try to get into the administrative hierarchy, but he rejected that notion. "This avenue requires in a large corporation, like a government agency or a dictatorship, not only talent and accomplishment but, uh, let me just be kind and call it a compatibility with your superiors. And usually the most creative and inventive people don't have that." In the summer of 1969 he left to set up his own company, where any compatibility with superiors would be the duty of others.

Less than a black box

Kiss quickly recruited three former RCA associates to help him establish the company. Douglas R. Bosomworth, thirty-five, a specialist in infrared spectroscopy whom Kiss had introduced to RCA, signed on as head of component research and development. Richard M. Corbin, thirty-eight, an engineer and graduate of the Wharton School, became Optel's financial officer. Edward Kornstein, forty-four, manager of RCA's Optical Physics Group, led the effort to incorporate Optel's components into finished products. To head marketing, Kiss recruited an old Toronto friend, Theodore C. Grunau, forty, from Hewlett-Packard's Canadian branch, where he was marketing director. The five started out in a bare building near Princeton—an area smaller than but similar to Route 128 near Boston or "Silicon Valley" south of San Francisco, in that it is heavily populated by little electronics companies.

Many entrepreneurs beginning new ventures in technology start off with functioning hardware—"a black box," Kiss says, "which is somewhat better than their 'parent' company's, and somewhat cheaper." But Optel's task was considerably more difficult. It had no hardware, only a scientific phenomenon and the hope of fashioning it into a business reality.

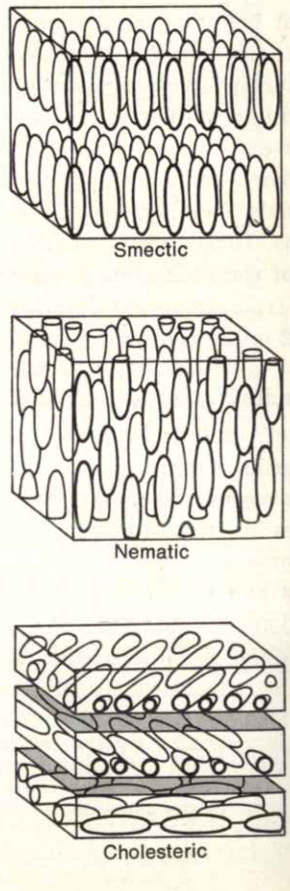


What Makes Liquid Crystals Shine

In the past few years a collection of organic compounds called liquid crystals has emerged as a brand-new technology with enormous possibilities for science, industry, and the consumer. The name sounds like a contradiction in terms: crystals are usually thought of as solid. Liquid crystals are indeed liquids, but they are endowed with highly ordered molecular structures akin to the more familiar solid crystals. When they are spread in thin films, they also have the optical properties of crystals: they reflect, refract, or scatter light.

Liquid crystals can be made to respond to almost any stimulus—heat, light, ultraviolet radiation, sound, pressure, magnetism, electricity, and even traces of chemical vapor. These stimuli

MOLECULAR STRUCTURE OF THREE LIQUID CRYSTALS



cause the ordered ranks of molecules to realign themselves. The realigned molecules, in turn, either reflect light in different directions or break it down into its wavelengths.

Hot blues and cool reds

There are three basic types of liquid crystals, each with a somewhat different molecular structure. Smectic liquid crystals are the most rigidly ordered and—to date—the least used. Cholesterics respond to changes in temperature and pressure by producing colored patterns. A typical cholesteric film spread on a surface with temperature variations will turn blue over warmer areas and red over cooler ones.

Nematic liquid crystals have become the most important family because they respond to electric stimuli, and electro-optical displays account for the largest share of the liquid-crystal business today. Fully compatible with semiconductor circuitry, they can serve as displays in virtually any solid-state device, such as the watches Optel makes, or in any kind of electromechanical instrument.

In a nematic display, a layer of organic fluid six to twelve microns thick is sealed between two pieces of glass. The inward-facing surface of each glass is coated with transparent electrodes. These electrodes are placed in a pattern of letters, segments of numbers (as in the strip at the left), or whatever other information is to be displayed.

When electricity charges the electrodes, it affects the liquid crystals in one of two ways, depending on whether the display uses the "dynamic scattering" or "field-effect" technique. When a dynamic scattering display is quiescent, the liquid-crystal molecules form ordered ranks. Light passes between them and is reflected by a mirror on the rear glass. But when current is applied to the electrodes, ions plow through the fluid between them, disrupting the molecules. Light that hits the scattered molecules is itself scattered and reflected at random. The result is that the charged segments become milky and opaque, in contrast with their clear surroundings.

Field-effect displays are more complicated. The liquid crystals are sandwiched between two polarizers placed at right angles to one another. The layers of molecules in the fluid are arranged in a helical stack—something like a spiral staircase. Because the light coming through the front polarizer is rotated 90 degrees as it travels down the staircase, it passes through the rear polarizer and is reflected by the mirror. But when current is applied, the molecules between the electrodes are themselves rotated 90 degrees, so they are perpendicular to the front polarizer. Light that passes through them is *not* rotated, and therefore is absorbed by the rear polarizer. The result is a darkened digit that contrasts with the light surroundings. (The contrasts can also be reversed—i.e., the digits made light and the surroundings dark.)

Both types of displays have some compelling advantages over competitive products—including light-emitting diodes, incandescent displays, and gas-discharge tubes, all of which generate

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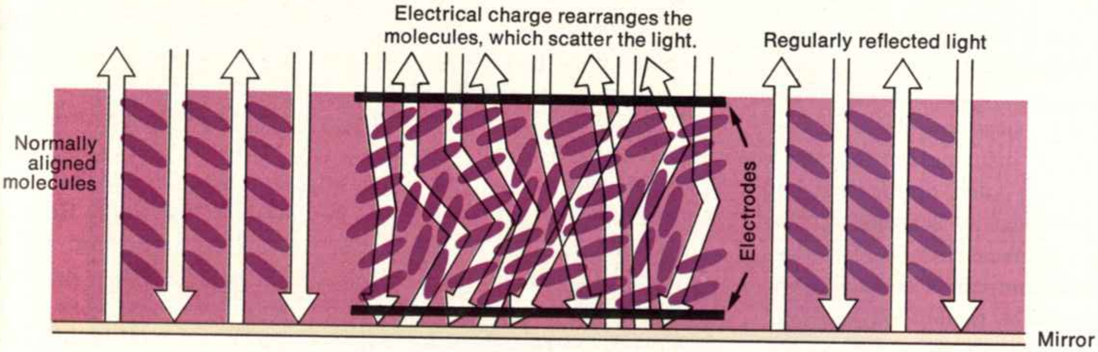
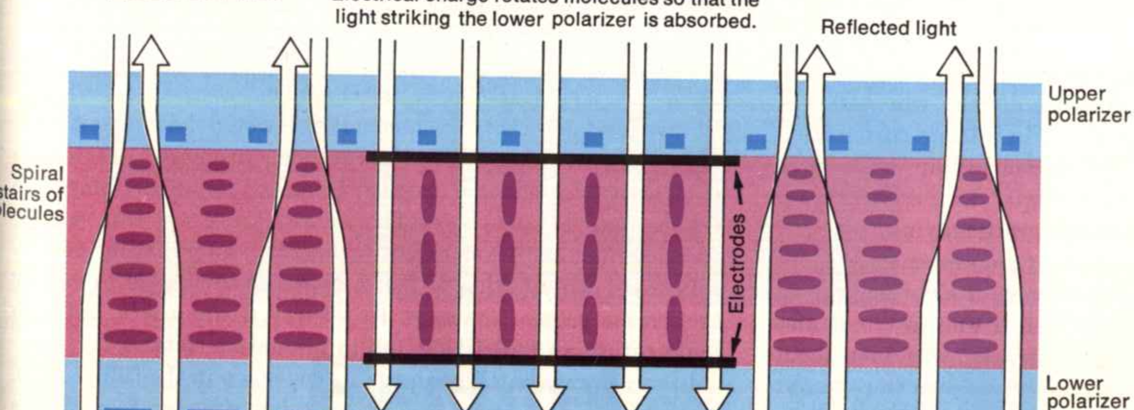
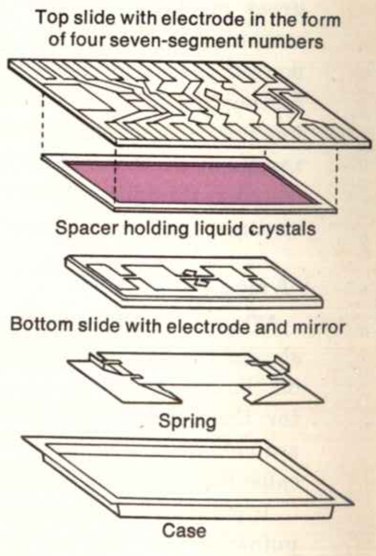
DYNAMIC SCATTERING



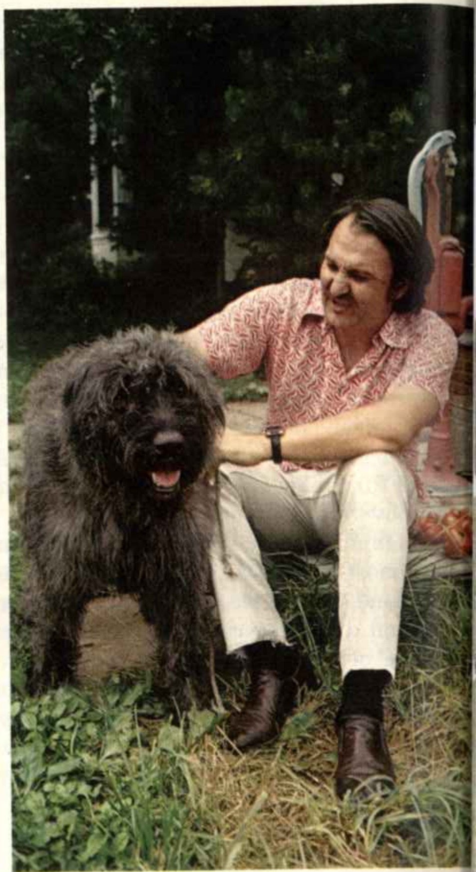
FIELD EFFECT



LIQUID-CRYSTAL WATCH DISPLAY



Through the greenery of rural New Jersey, Kiss rides fifteen miles home to his thirty-acre farm, where he lives with his Swiss bride, Cornelia, twenty-one, and a large Bouvier des Flandres named Zog, who is affectionate to a fault. In inclement weather, he abandons his ten-speed bike for his Toronado or Jaguar XK-E. During the company's boardroom upheaval, one of the complaints lodged against Kiss by his critics was that he spent too much of his time down on the farm.



Optel's early life was further complicated by the fact that it had *two* phenomena to develop. While others in the company were experts in liquid crystals, Kiss's own specialty was cathodochromics, a technology that uses specially coated cathode-ray tubes to store and display information. Kiss saw great markets for cathodochromics in such applications as computer terminals and airport information screens, and he poured the major part of Optel's resources into it. But perfecting the tubes proved beyond the company's technical and financial resources, and cathodochromics generated little enthusiasm in the marketplace. Nevertheless, Kiss refused to abandon the idea, and his refusal contributed to increasingly strained relationships among the founders.

"A nice, happy family"

When they started out together in early 1970, the partners shared the excitement and camaraderie of men who had cast off the constraints and comforts of life in a large corporation for the adventure of scientific entrepreneurship. "We were a nice, happy family working in a garage," Kiss wistfully recalls. But by summer, the familial bonds were fraying.

It was clear to Kiss's partners that cathodochromics was not going to pan out, and Optel's starting capital of nearly $1 million, put up largely by private investors and by companies that had given Optel development contracts, was just about exhausted. Kornstein and two other directors who were major investors—Lawrence Goldmuntz, a scientist, and Edwin Robbins, a venture capitalist—began to suspect that Kiss couldn't manage the business, and others in the company gradually came around to a similar view.

An intuitive thinker, with a good eye for concepts but a casual attitude about mundane details, Kiss seemed to be going his own way without listening to his colleagues. "Zoltan expected a loyalty that prohibited any dissent," says one. He was doing an excellent job of drumming up contracts and small parcels of financing, but his partners worried that he was overreaching, making promises to potential customers that could not be met. He also appeared to be neglecting his administrative duties, spending too much time on the road, often in Europe, and amidst the bucolic pleasures of his nearby farm. Meanwhile, Ted Grunau quit to return to Canada and become Hewlett-Packard's general manager for that country, and some of the other partners felt Kiss took too lightly the loss of an important member of the team.

Kiss concedes that "in hindsight, I would have spent only 60 percent of what we did on cathodochromics." As to the charge that he was too frequently absent from the office, he argues that he had to devote much of his energy to raising money, clinching development contracts, and enlisting people. "My main contribution to the company is to be able to gather around me people," he says. He's sorry Grunau left, but who could refuse an irresistible job in his native country?

In any event, matters came to a showdown in the fall of 1970. As Kiss tells it, he was in Europe, raising money from Swiss

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watchmakers, and had expected to return on Sunday, November 29. He finished work on Friday—having got a commitment from a combine of three companies to buy 70,000 shares of Optel stock—and he was planning to stop over in Paris the next day for a visit to Versailles ("which is particularly lovely in the fall"). But he was tired and he decided instead to catch an early plane home. He arrived Saturday evening to find a telegram apprising him of an extraordinary board meeting scheduled for the following day. The purpose of the meeting was to remove him from office.

Kiss was astounded. The partners who sent the telegram knew he was in Europe, but they had sent it to his farm. It seemed clear that they hoped to act before he got back. Under Delaware law, a majority of a company's board can change the bylaws. Kornstein, Goldmuntz, and Robbins had by this time been joined in their opposition to Kiss by Bosomworth, and the four constituted a majority of the six-member board. They planned to abolish the voting rights of Kiss's stock and give themselves control.

But Kiss appeared at the meeting on Sunday and informed his opponents that he had held, as one of them puts it, "a meeting with himself" as main stockholder. He fired the board and reconstituted it without his opponents. Since Kiss needed his foes more than they thought they needed him, however, he then commenced to negotiate. With Corbin and several other steadfast supporters at his side, Kiss and his opponents bargained until well past midnight before a compromise was reached. Kiss kept his job and control, though he surrendered about a quarter of his stock, bringing his ownership down to 45 percent. Kornstein left the board, and Kiss eventually fired him. Goldmuntz also left, but later came back as a consultant and a director, serving as a friendly critic and representative of his holdings, plus those of Robbins and several other early investors. Bosomworth made, as he says, "a certain peace with the situation," and out of an almost idealistic devotion to the company, he stayed on.

The orders roll in

After the insurrection, Optel pushed cathodochromics into the background and focused on liquid crystals. A strong market for liquid-crystal displays had emerged with the electronic-watch boom, and Optel was sending out "engineering samples" to potential watchmaking customers. Kiss developed ties with a number of Swiss watch consortia, whose members were anxious to gain a foothold in electronic-watch technology.

Optel was still uncomfortably short of money, though. It was counting on a public offering in the fall of 1971, but had to abandon the plan in the face of a poor market for new technology issues. So the $700,000 Kiss had raised selling stock to the Swiss, along with the income from a few development contracts, had to tide the company over for the year.

Prospects brightened in 1972. Optel moved from its "garage" to a relatively opulent-looking stone building a few miles away on Route 1, the region's main artery. And in June it finally did go public. Buoyed by their rising prospects, Kiss and his colleagues decided they could put themselves in the best marketing position if they supplied watchmaking companies not only with displays but also with whatever else they might want—completed watches, watch movements including everything but the cases, or modules consisting of the basic circuitry and the display.

This strategy required the development of special solid-state circuitry, and Optel joined forces with Solid State Scientific Corp. to design the two requisite semiconductor chips—an oscillator-countdown chip and a decoder-driver. Solid State contracted to build and deliver 100,000 of these pairs of chips by the end of 1973. Convinced that the company was primed and ready to produce, Kiss spent much of the year drumming up business. By year's end, Optel's staff had expanded to nearly 100, and was set to assemble, in semi-automatic fashion, as many as 5,000 watches a month. The company had orders for more than 150,000 watches, movements, and modules. One order alone, from Waltham Watch Co., was for 100,000 watches over a three-year period.

"In retrospect, I guess I was naive"

Unfortunately, the orders could not be met. Solid State had problems making the circuits; it has actually delivered fewer than 35,000 pairs of chips to date that have met Optel's specifications. Optel rejected many chips for failure to perform properly, and the ones that could be used soon escalated to almost twice the contract price—from $5.50 a pair to $10. Optel was helpless; there was simply no other supplier.

"In retrospect," says Kiss, "I guess I was naive" in expecting a steady price and reliable deliveries from a sole supplier that was producing a new and tricky semiconductor. Anybody with experience in the electronics business could, in fact, have anticipated the problem, and planned accordingly. "I would have accepted an order for 10,000 units on the Waltham contract rather than 100,000," says a colleague. But Kiss, as an enthusiastic salesman, assumed that Optel could perform up to its best imaginable production capability, and he simply trusted that supplies would prove equal to demand.

The company lost several contracts because it couldn't deliver (though it won some of them back later), and it was soon bickering with Waltham, which had become its biggest customer. Kiss had promised to ship 25,000 watches to Waltham before the Christmas selling season of 1972, and apparently had hoped that he might ship as many as 75,000 during 1973. Instead, Waltham received only some 2,000 watches in 1972; as of August, it had received only an additional 6,000. Worse yet, Optel had based its price to Waltham on the original costs of the components it bought; after the price of Solid State's chips doubled, the best Optel could do was break even. At one point, Waltham was seriously contemplating suing Optel, but later dropped the idea.

Even when it got enough chips to keep production lines moving, Optel ran into the kinds of problems with its displays that are fairly common in the industry. The worst of these developed last spring. Before then the number of watches sent

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Optel *continued*

back by customers for failure to meet quality criteria had been running at an average of 20 percent (which is typical in the business). Suddenly the return rate leaped upward. Part of the difficulty was in the quality of purchased components—"virtually every part of the watch," grumbles Kiss—but the liquid crystals themselves also began failing. The chief villains were, in a manner of speaking, April showers. Moisture in the air was finding its way into Optel's liquid crystals during assembly, and the displays began to fail in disheartening numbers after they left the plant. Kiss and his colleagues spent much of the summer, to use Kiss's less-than-appropriate phrase, "putting out fires" in the plant. They are disinclined to say exactly how they solved the problems, but by August return rates were back down to normal. And, says Kiss, what really counts is that "field returns"—i.e., those from watches already sold by retailers—have generally stayed below 10 percent.

Kiss and his partners are fully confident that the semiconductor shortages will be over with by year's end. Optel now has one other supplier, Solitron Devices, which (after long delays) will deliver in quantity, and two others are striving to perfect semiconductor chips for the company. Optel should also get a better yield of useful chips as an indirect benefit of producing more and more "field-effect" liquid-crystal displays, as opposed to the "dynamic scattering" displays that Optel (and most of the industry) started out producing. Of the semiconductor chips that Optel had rejected, many had failed because of minute current leakages. But by their nature, field-effect displays use less current than the dynamic scattering type, and leakages are less of a problem. Optel should therefore be able to use a few thousand chips it had shelved.

Between the giants and the garage operators

The company now has a substantial inventory of displays and various watch components, and a backlog of orders from U.S. and Swiss watchmakers big enough to guarantee profitability if it can only build the products. Optel has been working with Chrysler on liquid-crystal displays for use in dashboards, and is negotiating with an auto-industry supplier. It has research expertise not only in liquid crystals but also in electronic circuitry—an important asset because it gives Optel the ability to integrate its displays into end products.

According to the judgments of consultants like Arthur D. Little and various Wall Street analysts, liquid-crystal displays will be a $25-million market by 1975, becoming vastly larger as more and more uses for them are found. But the field is likely to be crowded and competitive—perhaps even on the verge of a shake-out. Despite their early difficulties, big companies like Rockwell, Motorola, and RCA will no doubt become major forces in the market. General Electric and Solid State Scientific have recently launched a joint venture to produce liquid-crystal watches, and some watchmakers may try to produce their own liquid crystals. Semiconductor manufacturers like American Micro-Systems and Intel are also integrating forward into liquid-crystal production. Optel and other small companies could get squeezed between substantial, integrated enterprises and garage operators who can turn out displays at rock-bottom prices.

In the face of this competition, Optel's immediate fate hinges on whether it has finally worked out its supply and production problems and can finish out the year operating in the black. If it can't do that, Kiss will surely have more trouble raising capital than he did in the past, and all sorts of dread scenarios are possible, including a take-over by outsiders.

Barring that sort of development, Optel's long-term future depends largely on how much Kiss has learned. He is admired as a scientist and salesman—but not as an administrator. "The fact of an idea is very different from its implementation," says an associate, implying that Kiss has been slow to grasp the difference. But events appear to have sobered him somewhat, and experience has taught him some lessons he couldn't get from books in those heady days when he was reading up on new ventures. "Zoltan's had a rude awakening in the last six months," says another colleague. "He's becoming less naive about production problems, and learning that you have to kill bugs, not just push them out of sight, or they'll come back to haunt you." He is also putting in more time at the plant.

The old ebullience, slightly tempered

Optel is especially distinguished from its competitors by the talented researchers—including Kiss himself—who are pursuing some exciting lines of inquiry. The company has numerous patents on its work—though the effectiveness of patent protection in liquid-crystal technology is open to some question.

One of the most dramatic prospects lies in an infant solid-state technology called electrochromics, pioneered by Kiss and derived from his research in cathodochromics. Electrochromic materials have "memory"—the ability to store information in electronic or optical form. The prototypes built by Optel are small slivers of inorganic material that respond to the same electric stimuli as liquid crystals, but then retain the images until they are erased or changed. Optel is also working on liquid-crystal materials with similar properties—but Kiss is most excited about the electrochromics. "We have here," he says, stabbing buttons on a black box, "the true electronic analogue of the printed page"—an infinitely erasable and reusable writing slate that would receive information electronically, store it indefinitely, and present it visually.

Kiss's old ebullience wells up as he talks about electrochromics, which he envisions one day replacing magnetic tape and microfilm as information-storage media. He is once again the man of science expounding in theoretical terms on a dramatic new technology of his own. Optel could, he says, be in full production with electrochromic devices before the end of 1974—if all goes well. But then a new note of caution, learned through several years' experience, intrudes upon the enthusiasm. Things might not go entirely well, he allows. In that case "it will be much longer." To those who know Kiss, the admission suggests that he has a much greater appreciation of the gap between "the fact of an idea and the fact of its implementation" than he did four years ago. END

How Liquid Crystals Shine

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light of their own. Since liquid crystals do not generate light, they use much less power. A typical liquid-crystal display in an electronic watch will consume slightly more than one microampere at 15 volts, while a light-emitting diode display in a similar application will need several thousand microamperes. The battery in a light-emitting diode watch will wear out within a month or two if the display is on all the time. The battery in a liquid-crystal watch will last a year or more.

Some overwhelming reflections

Liquid-crystal displays are not without their drawbacks. They are very sensitive to extraneous stimuli—e.g., extremes of temperature and pressure. The contrast between activated areas and their surroundings is limited, and—as with any reflective display—visibility is poor in dim light. The displays cannot be read at wide angles of view, and in a dynamic scattering display, reflections from the mirrored rear glass can be so bright that they overwhelm the displayed information itself. This problem can be ameliorated, but only at the expense of contrast. It can be eliminated if, instead of reflecting light, the display transmits light from a source behind the liquid crystals. With a tiny bulb serving this purpose, a liquid crystal would still use less current than other types of displays. Field-effect displays have no problems with mirror reflections, but the polarizing overlays reduce their brightness and crispness.

A commercially acceptable display today has a lifetime of one to two years, whereas earlier versions lasted only a few months or days. The first displays were also so susceptible to temperature extremes that they wouldn't work satisfactorily—if at all—when they got very hot or cold. Today's standard display operates between zero and 50° centigrade without any important loss of performance for most uses, and the range is steadily being extended. The manufacturers are bending every effort to reduce power requirements still further, and low consumption is one of the advantages of field-effect displays. International Liquid Crystal Co. (Ilixco), a pioneer in the development of field-effect technology, sells displays that operate on 5 volts and only 300 nanoamps—less than a third the requirement for the standard dynamic scattering display. In fact, Ilixco can also make field-effect displays that perform on as little as 10 nanoamps and 1 volt, but to date these displays have required direct current, which has its problems. The steady flow of direct current eventually strips off the conductive coating, shortening the life of the equipment.

If low power consumption is the primary advantage of liquid-crystal displays, potentially low costs of production run a very close second. The raw materials—mainly glass and a drop or two of fluid—cost but a few pennies. An average liquid-crystal display for a calculator comes to around $1 per digit, compared with almost $2 for a similar light-emitting diode display, and more than $4 for an incandescent tube. Volume production and the economies gained by experience are expected to widen the gap within two or three years.

An aid to the oenophile

Liquid crystals were first recognized nearly a hundred years ago; among them are such familiar substances as cholesterol and soap, whose bubbles display the refractive properties some liquid crystals possess. But not until the last decade did researchers begin to see the practical uses for such light-manipulating abilities.

Besides appearing in watches and calculators, nematic liquid crystals should be able to replace electromechanical display devices ranging from computer readouts and electronic test equipment to automobile gauges, highway signs, and billboards. They also may be fashioned into simple, durable camera shutters or windows that become opaque at the turn of a switch.

Cholesteric liquid crystals can be made sensitive to infinitesimally small variations in temperature, pressure, or other stimuli. Although most are still in the laboratory or experimental stage, they have enormous potential. They are beginning to be used in nondestructive testing, where they are either sealed in a very thin sheet of plastic or painted directly over the material that is to be tested. For example, Ilixco has built an experimental turbine-blade tester that will measure the thickness of the metal in the hollow cast blades by mapping the temperature changes on the surface as the blades are heated and then cooled from within.

In a more frivolous vein, liquid crystals have been proposed as aids to the oenophile: a strip of microencapsulated material pasted on a bottle would indicate, by its color, when the wine is at the correct serving temperature.

The memory lingers

Further from current reality, but full of possibilities, are classes of liquid-crystal compounds with memory capacity. Some smectic materials and several mixtures of cholesterics and nematics have the ability to store information both electronically and optically. Information electronically fed into a device using these substances can be displayed optically, as in a conventional liquid crystal; but when the current is turned off, the image remains. The substances have an information density, or ability to store data compactly, hundreds of times greater than magnetic tape or microfilm.

Liquid crystals promise to fill a vast array of uses in the future. Like any technological innovation, of course, they sometimes inspire expectations that soar beyond the confines of reality. They have rekindled old hopes for a flat-screen television, for example, but that development must actually await some rather substantial breakthroughs in electronic circuitry. They will probably not, as some enthusiasts have suggested, rival the transistor in importance. But it is also likely that the multifarious properties of liquid crystals will make them useful in a broad range of applications as yet unforeseen.

Apart from their product and testing applications, they appear also to have very important biological implications. Many parts of the body have been found to be made of liquid crystals—including nerve sheathing, portions of the eye and brain, and the lipid membranes that surround every cell. Recent research suggests strongly that they play a role in smell, sight, and possibly even in the workings of memory and the genetic-coding mechanisms. Medical science has only begun to realize their ubiquity, and in years to come, liquid-crystal research is expected to yield significant and perhaps even profound insights into the workings of the body. END