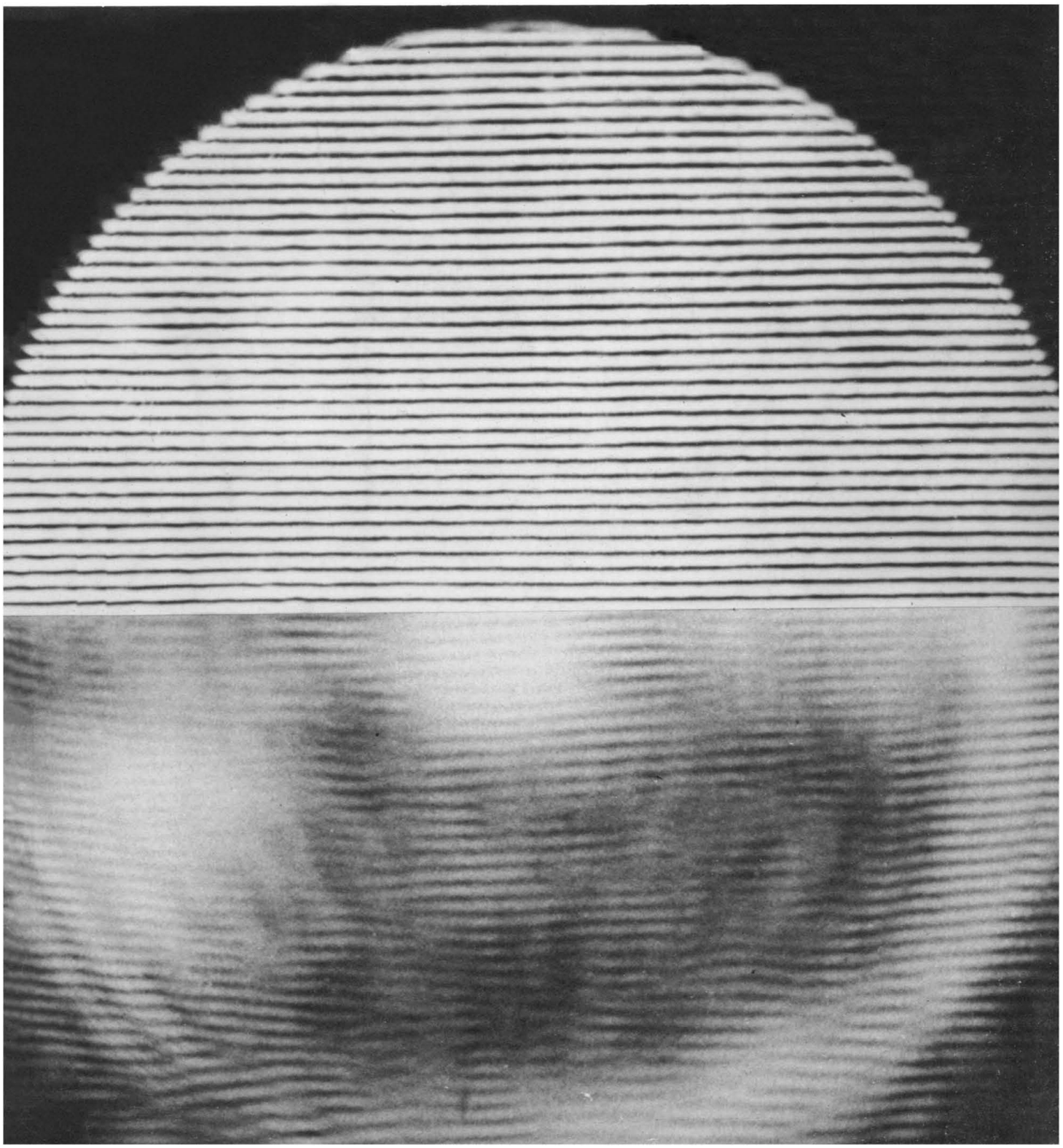
SCIENCE

5 June 1970

Vol. 168, No. 3936

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE



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COVER

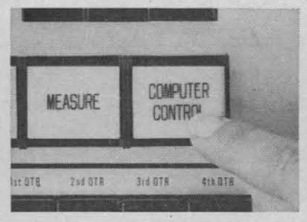
Interference fringes as they appear normally (top) and with double images focused on tissue paper placed over the camera lens (bottom). Cataract patients may see continuously changing fringe patterns similar to those patterns shown on the bottom. See page 1240. [Daniel G. Green, University of Michigan]

FABRI-TEK 1070

...more than just a signal averager

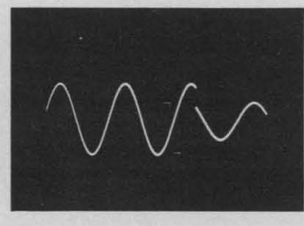
NUMERICAL DISPLAY

Both the address number and data value are displayed on the CRT for any selected coordinate point. The selected coordinate point is clearly intensified on the analog CRT display so that the numerical values of ordinate and abscissa can be associated with a particular position on the analog plot. Changes in the position of this intensified point are made with three pushbuttons for fast, slow and single step allowing movement to the left or right.



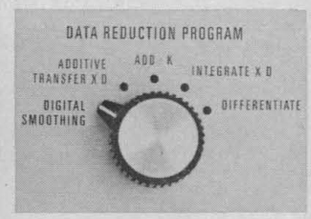
COMPUTER INTERFACE

The 1070 Signal Averager may be interfaced to a general purpose (GP) computer to exploit the best features of both units. The hard-wire programmed 1070 is easy to operate since it needs no programming except switch selection, uses memory storage more efficiently, and provides rapid data collection and display. The GP computer provides additional memory and flexibility, especially in arithmetic processing. A software package for taking the fast Fourier transform of stored data is available from Fabri-Tek.



CONTINUOUS DISPLAY

Slow sweep speeds or infrequently occurring fast sweeps make it difficult to view the memory contents in order to monitor an experiment's progress. With the SW-71 Continuous Display Sweep Control plug-in, the memory contents are always displayed on the CRT regardless of sweep speed or sweep repetition rate. Any small segment of the display may be expanded as much as desired even while acquiring data.



BUILT-IN DATA REDUCTION

The 1070 permits integration of memory contents, addition or subtraction of stored data between memory subgroups, and baseline correction through addition or subtraction of a constant to (or from) any selected memory subgroup. Baseline correction aids in integration since the integral curve might otherwise be distorted by input signal baseline drift. Digital smoothing by three-point running averages and differentiation are useful options that can be added at any time.

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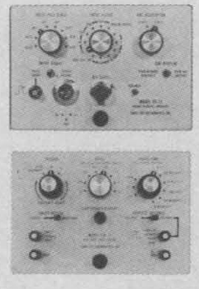

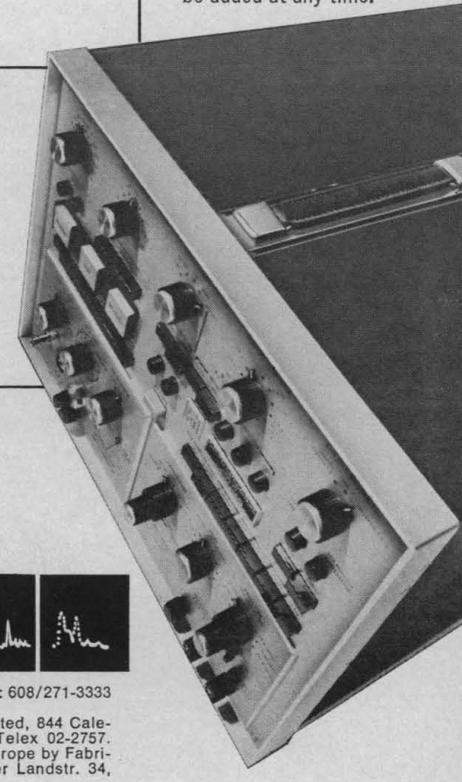

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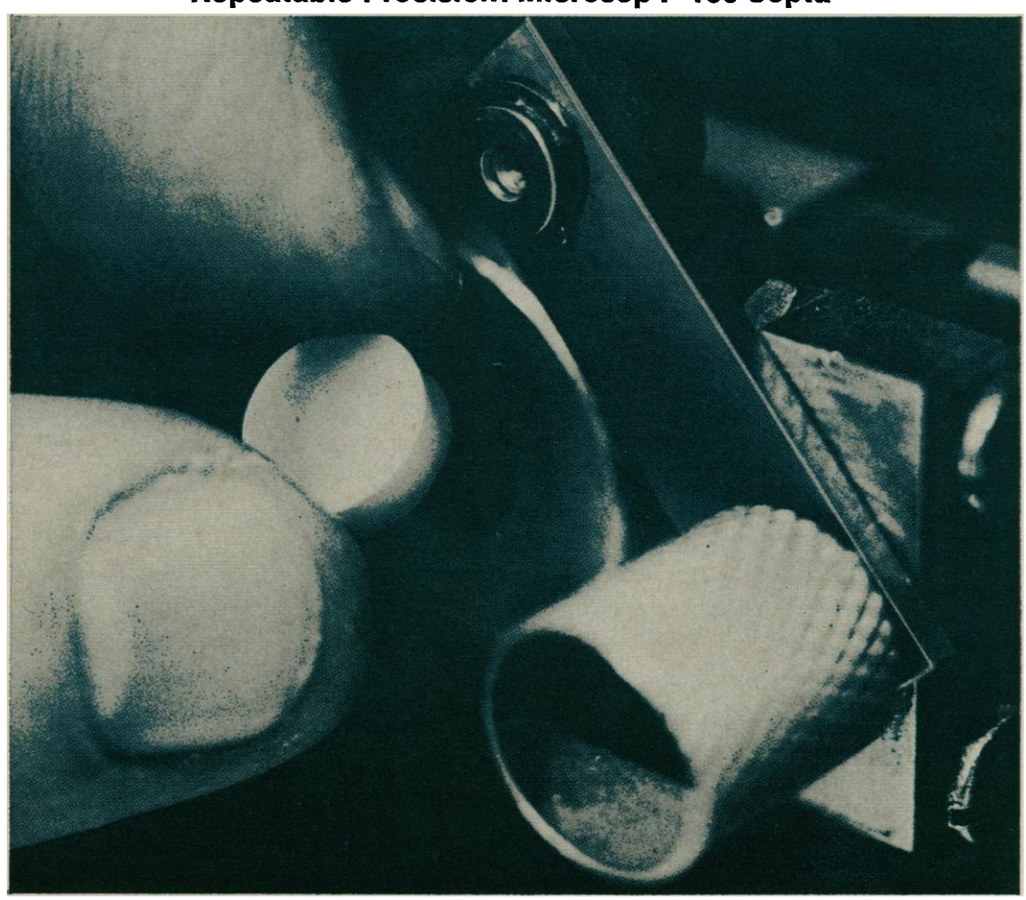

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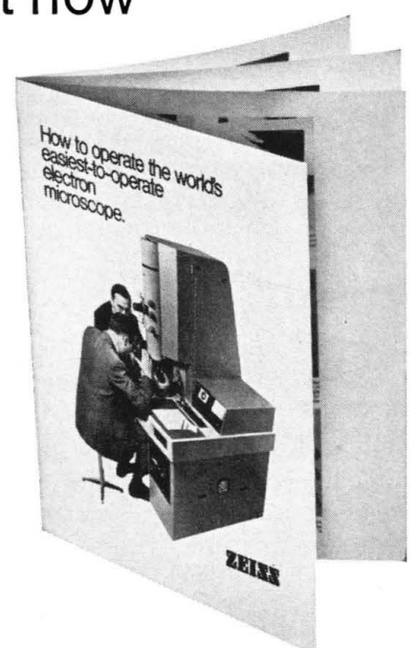

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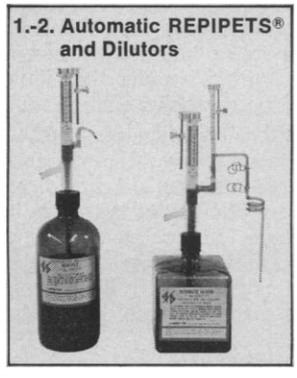

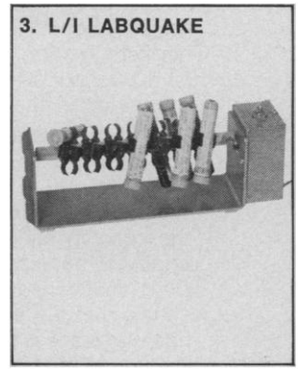

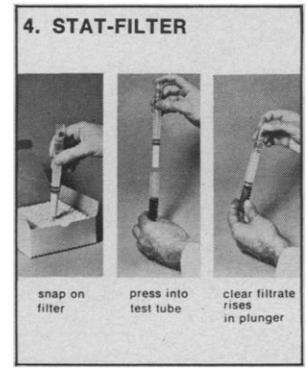

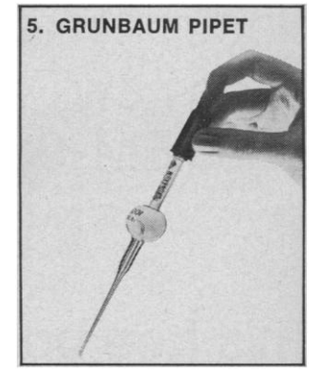

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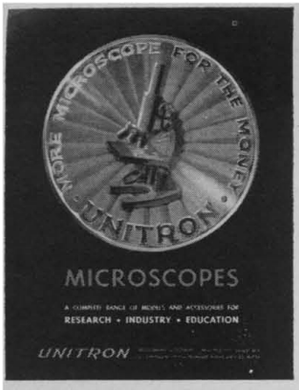

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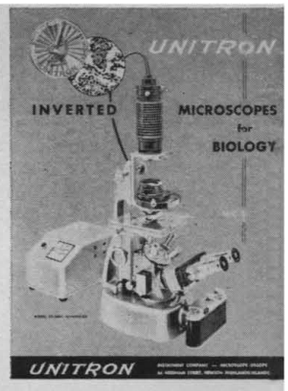

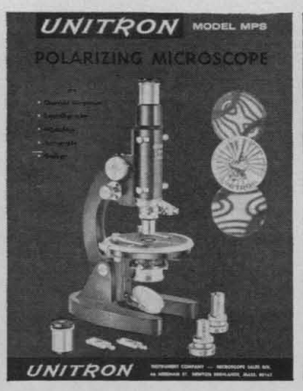

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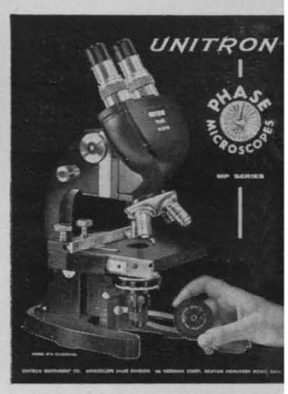

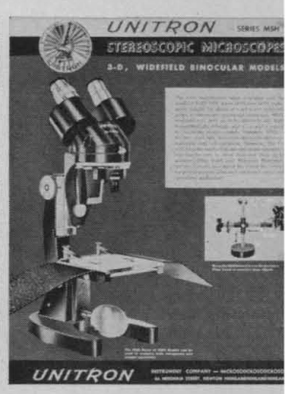

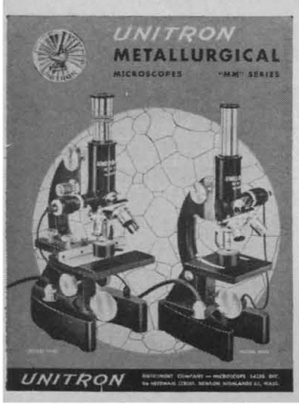

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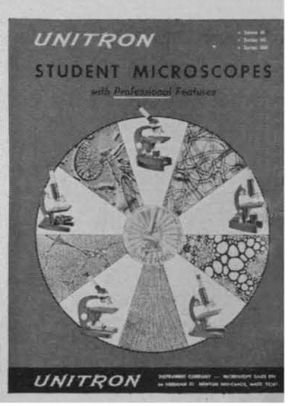

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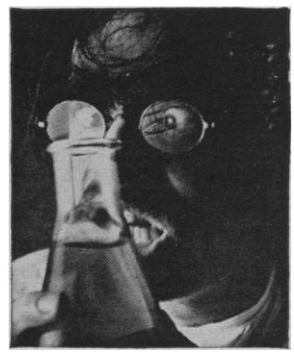

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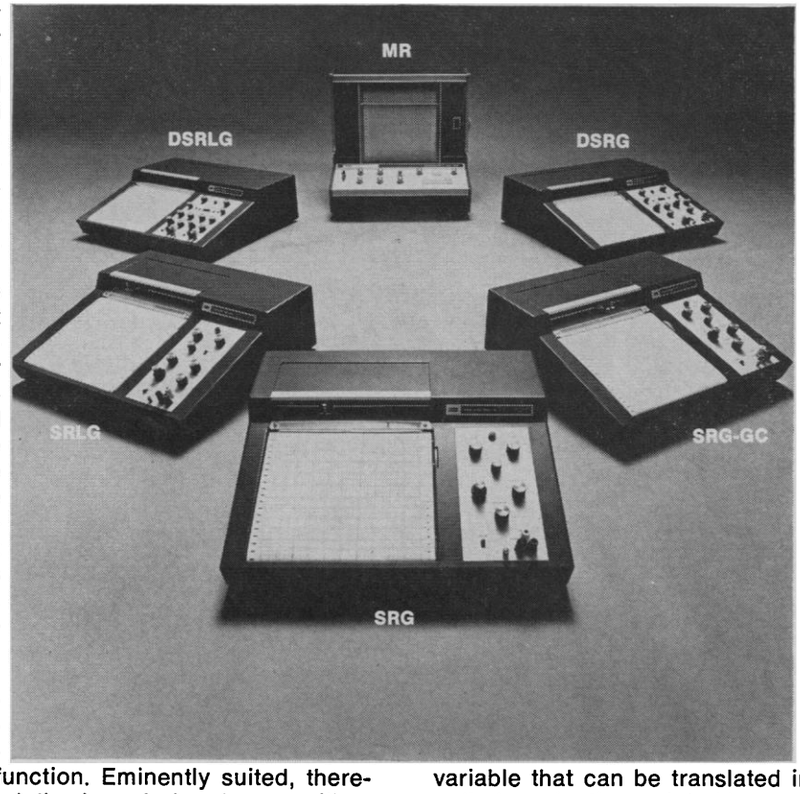

Model DSRLG: Another logical move. Two SRLG's in one dual-pen recorder. Think of what that means if you work with a spectrophotometer, photometer, or densitometer — simultaneous recording of both transmittance *and* absorbance. Or linear/log recording of any two time-synchronized variables. Basic price: $2075.

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Concepts from Union Carbide:

Cryogenic freezing of red blood cells

Probably no single problem has received more attention from cryobiologists than the preservation of the human red cell. And with good reason. Procedures that extend the supply of erythrocytes for transfusion have meaning in terms of human lives.

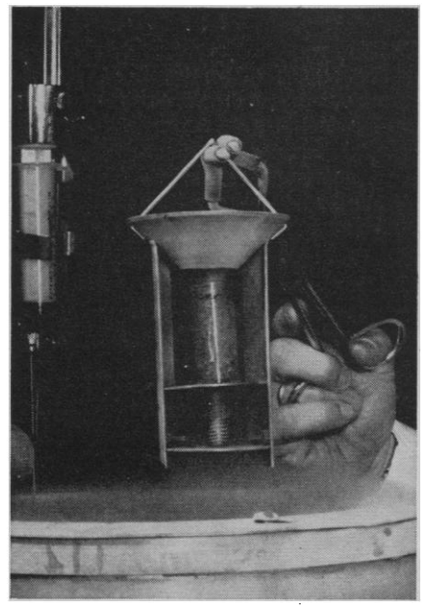
The prospect of a frozen blood reserve has been a matter of intensive interest to the blood banking agencies for the past twenty years; some have played a major role in the scientific attack on the problem. It has not been easy. It was observed in 1941 that red cells (suitably protected with additive substances) could survive the drastic environmental changes induced by freezing. Since then, processes have been sought for the preservation of blood in the frozen state that would provide a useful and acceptable product for transfusion. As evidenced over the past decade by the successful transfusion of thousands of units of blood preserved in the frozen state, that goal seems to have been reached.

The current limitation of twenty-one to twenty-eight days for blood preserved by conventional methods in the liquid state has often taxed the resources of the organizations that undertake to provide our communities with supplies of this indispensable agent. The relatively short shelf life of the cellular components of blood adds to the problem of coordinating supply with demand. The less common blood types sometimes are difficult to procure, but even the more common types may vary in supply at any given time.

Red cell wastage is an inevitable consequence of the dating period necessarily imposed on blood stored at 4°C. A primary objective of agencies interested in preserving blood at low temperatures is to prevent this wastage. Another, of course, is to assure adequate reserves of all types of blood at all times for each community. Conceivably then, as frozen blood banks become established in various parts of the country, an integrated and computerized inventory system could be developed that would result in an effective national reserve.

Several practical approaches to the preservation of blood at low temperatures have evolved. All have some elements in common. A solution of additives, often called cryoprotective agents—glycerol is the outstanding example—is combined with the red cells from which most of the plasma and much of the other cellular components of blood (leukocytes and thrombocytes) have been removed. This is done in special containers in which the erythrocytes are cooled and placed in long-term storage. When needed, the erythrocytes are withdrawn from storage, warmed, and subjected to a washing procedure to remove the protective agent before transfusion.

The heart of a frozen blood reserve is the storage facility. Storage equipment is of two general types: cryogenic and noncryogenic. The latter provides temperatures down to about −85°C and depends on electric power. The cryogenic equipment is independent of a power source and provides lower storage temperatures—down to −196°C—with liquid nitrogen, the most commonly used refrigerant. Associated with such storage equipment are cryogenic shipping units that permit transport of blood in the frozen state without danger of a destructive rise in temperature that might render the blood cells unfit for transfusion.



Small quantities of blood are instantly frozen for long-term storage in the droplet freezer. A mechanically vibrated syringe releases droplets into a revolving drum of liquid nitrogen. The frozen droplets are collected in the base. Thousands of droplets can be collected from each sample for use as reference specimens.

The banking of frozen blood with longer shelf life should considerably enhance the ability of the blood supply agencies to meet demand and might influence current procurement practices. The use of cryogenic storage equipment would provide a margin of safety for autologous blood banking in which individuals of rare blood type would establish a reserve of their own blood in anticipation of later need. Probably most important in terms of medical need, the availability of banks of frozen red cells would seem likely to lead to the development of banks of the other cellular components of blood. With current liquid state storage procedures, platelets and leukocytes—far less stable than the red cell—are without transfusion value within about three days or less after donation. At present, the only prospect for establishing a large-scale reserve of these invaluable components is to preserve them in the frozen state. Although low temperature preservation procedures for these cells are not technically as far advanced as for the red cell, several blood laboratories are fully aware of the need and are attacking the problem vigorously.

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concluded) over the signatures of 135 members of the Michigan faculty senate. The purpose of this reply was to express our profound concern over our colleagues' short-sighted response to violence.

Few, if any, on the faculty either advocate or condone the use of violence. Indeed, we are all equally agonized by its increasing frequency of occurrence, not only at Michigan, but on campuses across the nation. However, a more adequate response than the mere condemnation of violence is required. Violence cannot be viewed in isolation. We must examine the context in which it occurs if we are to understand the forces that drive some individuals and groups to perform such acts. The omission of these concerns from our colleagues' statement was sufficiently serious to cause us to publish our statement. . . .

SYLVAN KORNBLUM
Mental Health Research Institute,
University of Michigan,
Ann Arbor 48104

Carter lauded the establishment of a 10 percent admission quota for Negroes at the University of Michigan. No doubt many other ethnic and racial groups are underrepresented at that and many other universities. For instance, students of Polish, Italian, and Irish extraction constitute a smaller proportion of the student body than that in the United States or the state of Michigan. On the other hand, Jews, who constitute 2.5 percent of total population, probably constitute over 25 percent of the student body and faculties of many universities. Why not establish ethnic and racial quotas similar to the immigration quotas based on the composition of the U.S. population, as we had not so long ago? Also, why limit quotas to undergraduate admissions? Why not graduate and professional schools, and why not quotas for degrees, including the doctorate? And why not for faculties? Quotas for university admission based on race or social origin have been common in many fascist states and are now in force in communist countries. It is ironic that today's liberals have embraced this concept.

At present the doors of most of our universities are wide open for any Negro with a minimum of ability and motivation. Special programs for the underprivileged student are extensive and should be further developed. On the other hand, racial quotas serve only to recruit the unsuited and unmotivated. These students will obviously fail any normal curriculum, and special programs and degrees for this category will be required. The regents and president of the University of Michigan, having capitulated to the Black Student Union and their allies, will have to grant more and more concessions. The introduction of racial quotas is ominous and a dangerous precedent for all American universities. Vice President Agnew had some cogent comments on this issue, and it would have been fair and proper for *Science* to print his statement in that issue. . . .

JOSEPH KATZ
Cedars of Lebanon Hospital Division,
Box 54265, Los Angeles,
California 90054

With varying degrees of success, many writers have attempted to define what it is that "turns off" a large segment of the university student population. However, none has succeeded so well, albeit unwittingly, as Lieberman in "The university is not a highway department" (Letters, 17 Apr.). If Lieberman's point of view is shared by even 25 percent of university faculty members, then one can easily understand the disenchantment of our young people. It is pointless to comment on the specifics of his letter. Suffice to say that in the age in which we are now living, *all* of our intellectual resources must be brought to bear on social problems. Intellectuals, as typified by university faculties, can, and must, be socially responsible—and responsive—"men of action."

If Lieberman's opinions are correct, then socially responsible-responsive teachers and students *should* depart from the university and leave it to the pedagogues and their disciples. Then the university would, indeed, become analogous to a highway department, dealing as it would with pedestrian issues. Lieberman has performed a service by clearly illustrating the very essence of what makes the university nonrelevant to the student.

BERNARD J. FINE
Woodside Road,
Harvard, Massachusetts 01451

Removing Sulfur from Coal

Abelson's editorial "Progress in abating air pollution" (20 Mar., p. 1569) includes a well-authenticated statement: "It is possible to remove some of the sulfur from coal by mechanical

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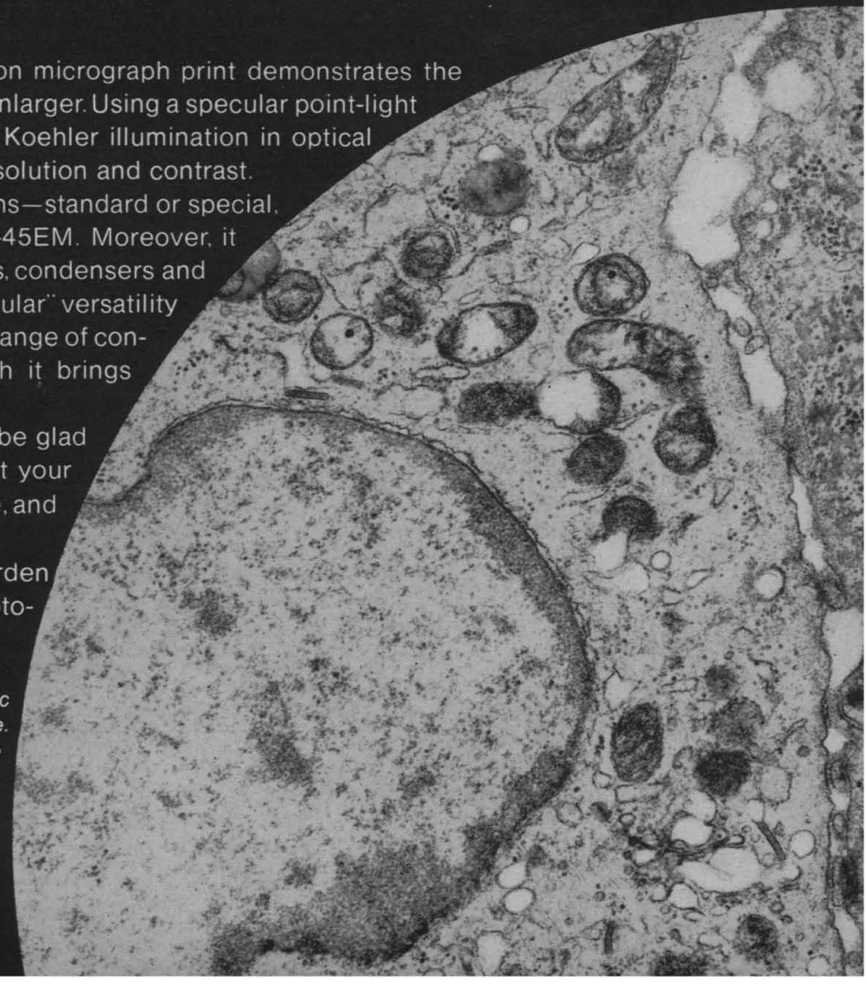

Section of human epidermis taken from a site of allergic eczematous contact dermatitis due to mercuric chloride. Parts of a Langerhans cell and of a keratinocyte are shown. Photographed at 6,000x in a Siemens Elmiskop 1 A electron microscope; enlarged to 16,000x with a Durst S-45 EM.

(Courtesy of Dr. Inga Silberberg, New York University School of Medicine, Department of Dermatology).

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SNAP CRACKLE, INSTRON A major chemical company which we fondly regard as forward-thinking just installed one of our PACE analytical data systems with its several GCs and INSTRONS for simultaneous operation and automatic data acquisition. INSTRONS produce stress/strain signals on materials; PACE then makes these signals into meaningful, efficient, and reliable reports. Material-makers rejoice in better testing, better quality of their products. More illuminating details from "INSTRON", Dept. 206C. Please mention tests you have in mind.

LITTLE BLACK-BOX SCHOOLHOUSE The root sense of "education" is: to lead out of. The Chemistry Department at Northwestern University is using analog computers, not to answer questions mindlessly but to raise new ones by offering deeper insights into the problem. In short, by education. In the pursuit of understanding second-order chemical reactions, graduate students are encouraged to use an EAI desk-top analog computer to find rate constants by matching reaction peaks with a computer model and thus read the reaction value from control knobs' settings. Such hands-on exercise gives student show-and-tell understanding completely unmatched by more abstract manipulation of formulae. Doubtless, too, results in diminished feeling by student that he is only a punch-card in today's educational system. And who today faults this feeling? Insights added by writing "Primer", Dept. 206C.

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means, but most cannot be eliminated except by costly chemical processing." While generally correct, this statement is subject to some qualification.

There is no magic wand or "thiomagustic" device that can draw sulfur out of a lump of coal without changing its physical structure. But it is quite possible and practical to destructively desulfurize coal without seriously penalizing total fuel value of the resulting char, condensable liquids, and combustible gas. These low sulfur product fuels can be efficiently burned together in modern powdered fuel steam generator fireboxes with minor modification, or the char alone can be efficiently burned in fluidized bed stream generators.

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HENRY C. MESSMAN
Post Office Box 267, Mamaroneck, New York 10543

Reproduction in a Finite World

Szabo asks "Do we hate our own species so much that it is regarded as a crime if people want to have at least three children?" (Letters, 3 Apr.). . . . Those who favor the limitation of population do so because of concern for humanity, not hatred. Granted only that our world is finite, and that mass migration away from it is impossible, then the conclusion that the birthrate must inevitably equal the death rate follows with mathematical certainty. At that point in time each person, on the average, can at most reproduce himself; any excess offspring must die before maturity. Surely then it would be a crime, particularly against the children, for the size of the average family to be as high as three children.

One point should be obvious: The numbers refer to averages. If some couples want large families they may still be able to do so provided others want smaller families or no families. We should be able to keep such options open provided we recognize the overall constraints.

This simple philosophical argument does not tell us *when* the limitation of family size becomes of such vital importance. The answer to that depends on which aspect of the world's finiteness is or should be most important: is it food, space, or something else? Basically it involves human *values*. If we could all address ourselves to the question of human values and desires we might begin to make some headway toward a better life for all.

W. J. HEIKKILA
Division of Atmospheric and Space Sciences, University of Texas at Dallas 75230

Szabo fails to recognize that it is because we love our species that some of us advocate voluntary tubal ligation and vasectomy. In a period when we are plagued with overpopulation and environmental pollution, the assumption that it is permissible, if not desirable, to have more than two children seems to be archaic. At one time this attitude was probably appropriate to the species because it was desirable to increase the population. Now, however, it is inappropriate, and man's attitudes must be altered in order for him to adapt to these conditions: overpopulation and environmental conditions.

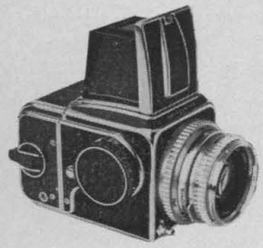
JOHN H. MOORE
Department of Sociology and Anthropology, Wisconsin State University, Stevens Point 54481

Predicting Ovulation—Precisely

In spite of all the discussion of the medical, mechanical, and social drawbacks of contraceptives which are currently available, I wonder if we are not missing the point. What we really need is not the "ideal" contraceptive, but the "ideal" predictor—of ovulation. Is anyone working on the development of effective means of telling precisely when ovulation is about to occur in a woman? If they had 2 or 3 days accurate warning, women would have a much better chance of avoiding problem pregnancies, with none of the added physiological or psychological strains which attend current contraceptive methods. With a really effective Distant Early Warning system, even the rhythm method ought to work!

H. GHIRADELLA
Department of Biological Sciences, State University of New York at Albany, Albany 12203

Hasselblad's idea of a Hasselblad may be different than your idea of a Hasselblad.



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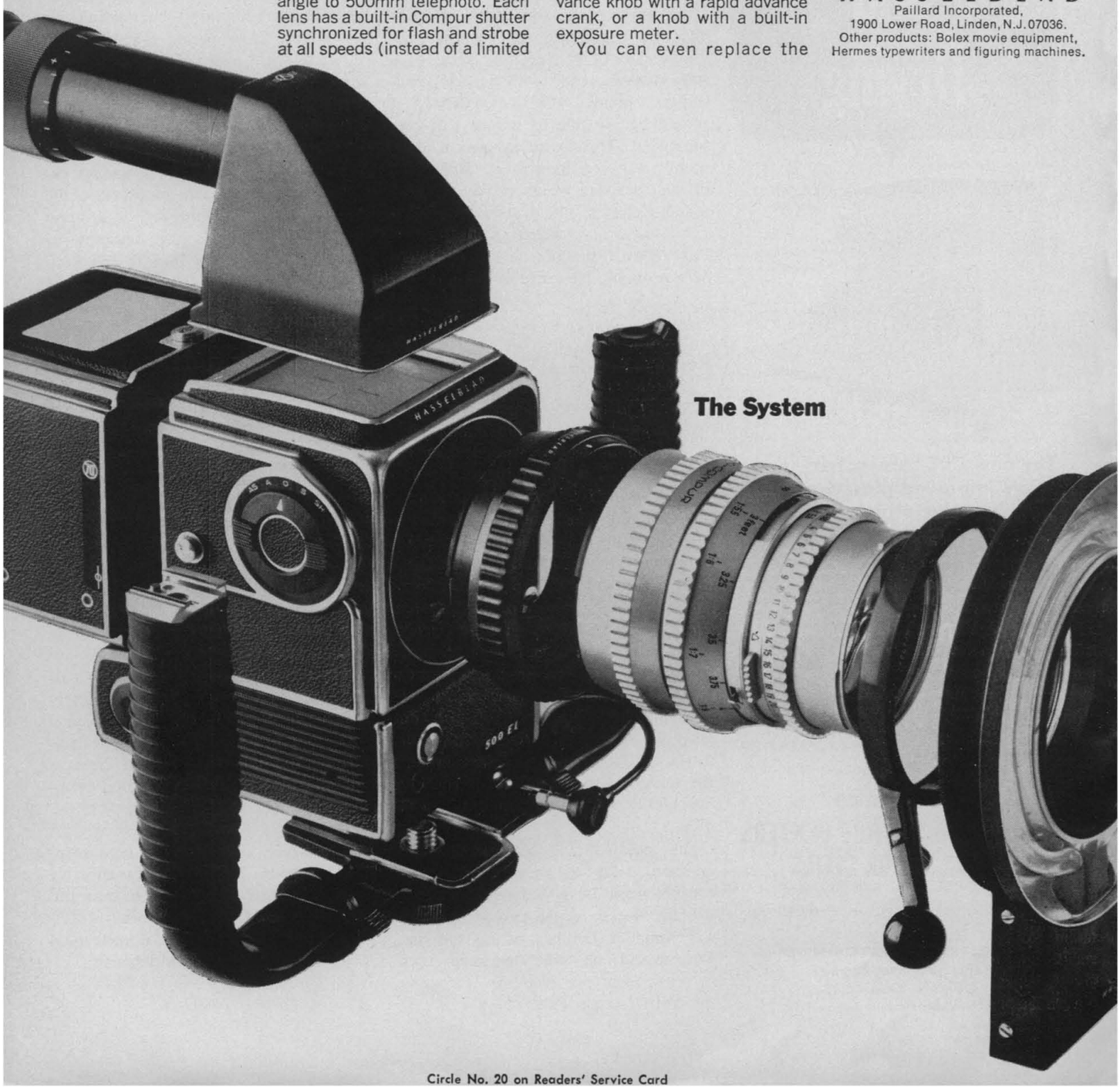

The System

Circle No. 20 on Readers' Service Card

5 June 1970, Volume 168, Number 3936

SCIENCE

The Cambodian Crisis: Reason and Emotion

The invasion of Cambodia was a step backward in the struggle of today's youth to find a new humanness. President Nixon's decision was a product of reason and, once again, reason has failed.

We can ill afford to reject reason for emotion. But we must accept the place of emotion in individual life and human affairs. We must learn to let emotion play its proper role in the reasoning process and must find the ways to channel the force of emotion appropriately. We have been taught that the emotions, especially what we call negative emotions, are dangerous and bad. But each of the emotions, like any other significant part of the human being, has an inherently adaptive function.

Distress can lead to personal discouragement and crippling depression. But unless we feel something of the personal distress of the loved ones of the wounded or dying man, whether friend or foe, we cannot have an adequately human perspective on this or any war.

Disgust with yourself can lead to alienation and aloneness, and disgust with the world can lead to dangerous indifference. But unless we experience some disgust with ourselves for the complacency over the miseries and massacres of war we cannot have an adequately human perspective on this crisis.

Contempt of self can lead to the disaster of self-rejection, and contempt of others can sustain prejudice, misconception, and conflict between peoples. But unless we have some measure of contempt for killers of men and contempt for the act of killing, we cannot have an adequately human perspective on war's destruction of humanity.

The shame of defeat would strike deep at the heartstrings of a proud nation. But unless we can find greater shame in inflicting suffering and death than in a lost or stalemated war, we cannot have the kind of perspective that can lead to peace and progress in a search for a new humanness and a new humanity.

Anger can make a mockery of man's hope for reasoned negotiation and can increase the likelihood of destructive aggression. But a little anger properly channeled can defend a new kind of personal integrity and a new kind of integrity for humanity that disallows war's miseries and massacres.

Fear is the most toxic of all the emotions. This is not a time for panic, but, unless we have some fear of war, we cannot see the Cambodian crisis in true perspective.

I am not asking that you let distress lead to depression, disgust to indifference, contempt to aloofness, shame to withdrawal, anger to destruction, or fear to panic. I am asking you to be sad over war-inflicted suffering and death. I am asking you to be a little disgusted with complacency and a little contemptuous of the forces and conditions that lead to war. I ask us all to be a little ashamed of the inability of the most powerful nation on earth to accept defeat—or simply to redefine it as a colossal mistake.

I ask you to be a little angry at the grave threat that deepening and continuing commitment to war poses to our humanness and to our very survival. I ask you to be a little afraid of the horror of becoming extinct or, perhaps even worse, of becoming less and less human. I ask you to respond to each of these emotions with constructive effort before the emotion is dissipated and comes to nought or before it goes awry and wreaks destruction.—CARROLL E. IZARD, *Vanderbilt University*

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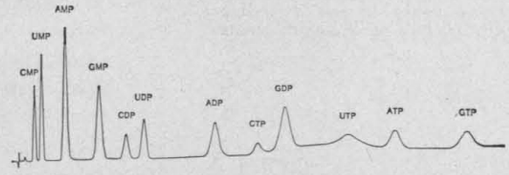

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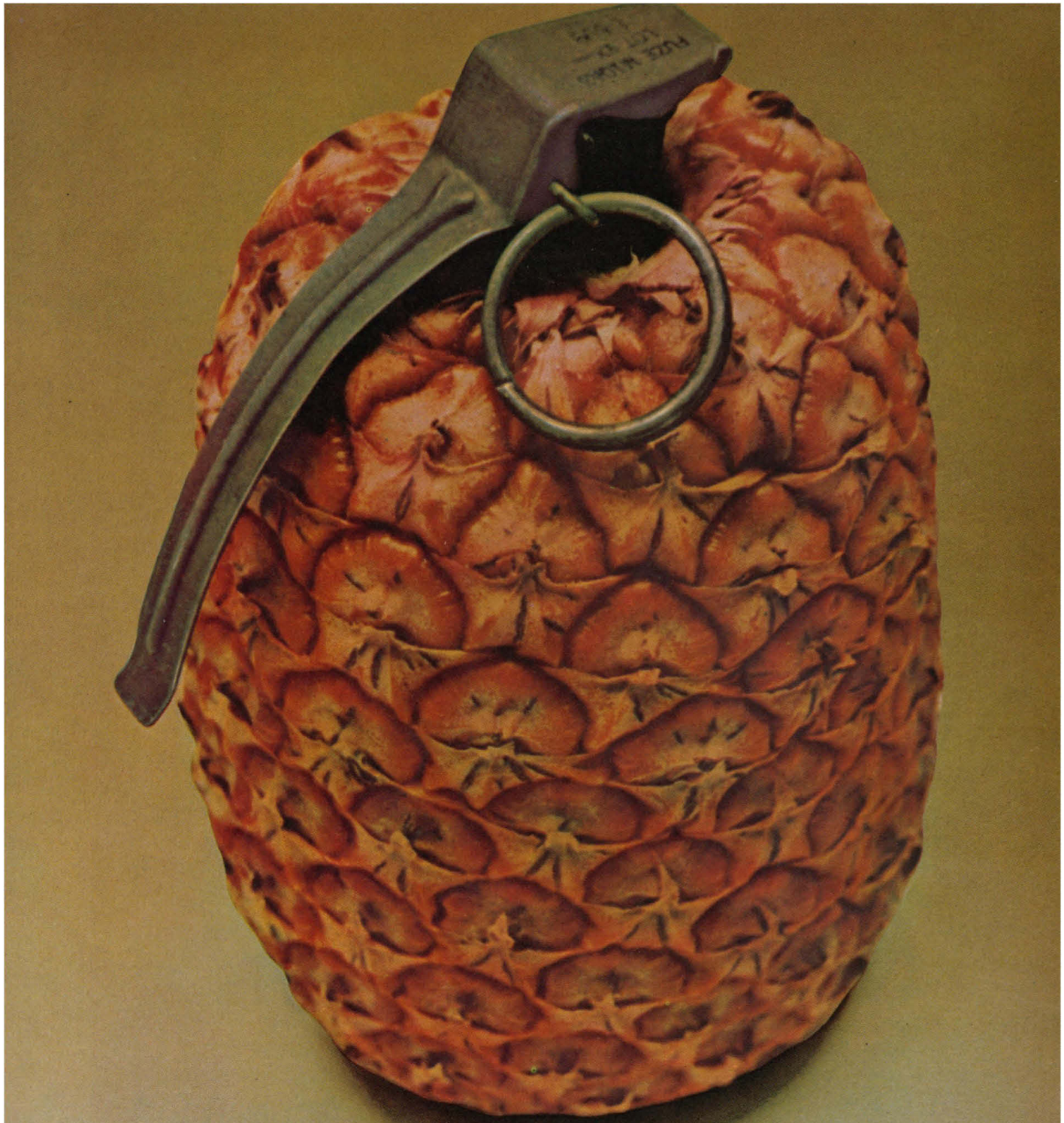

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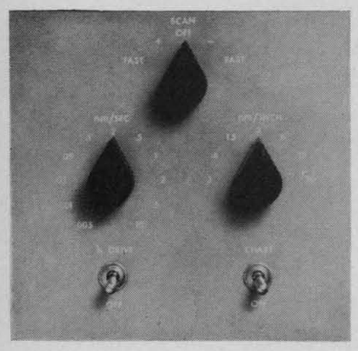

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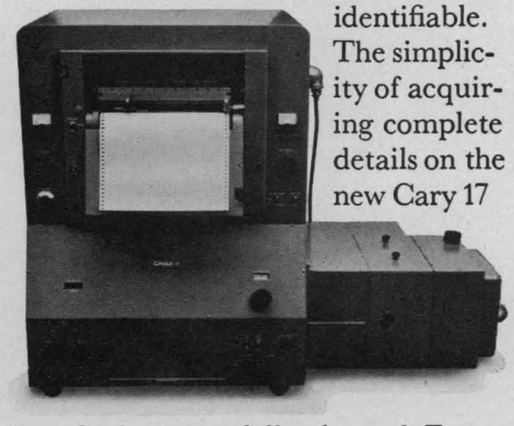

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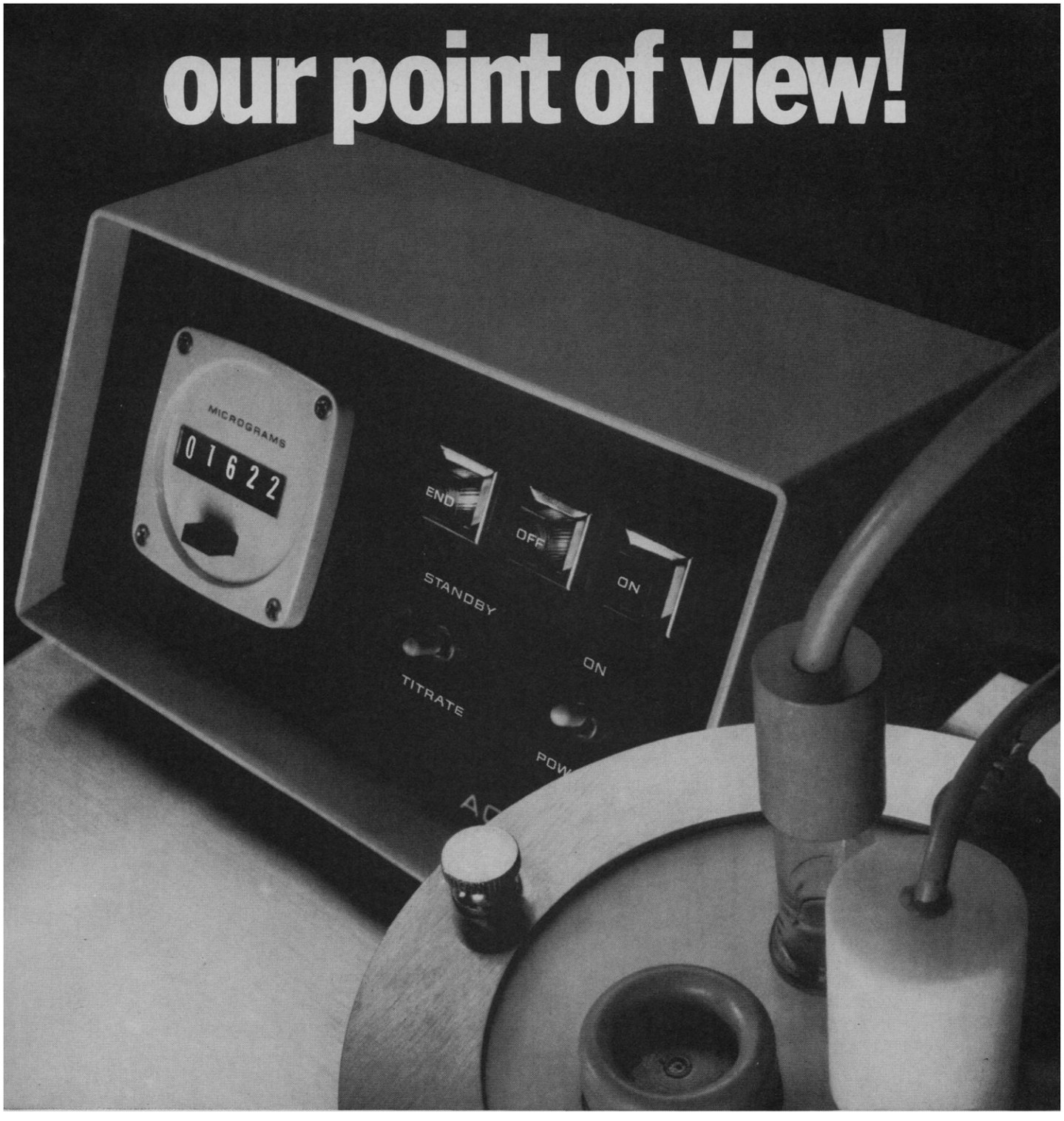

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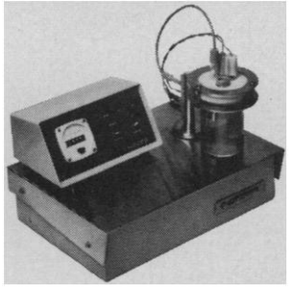

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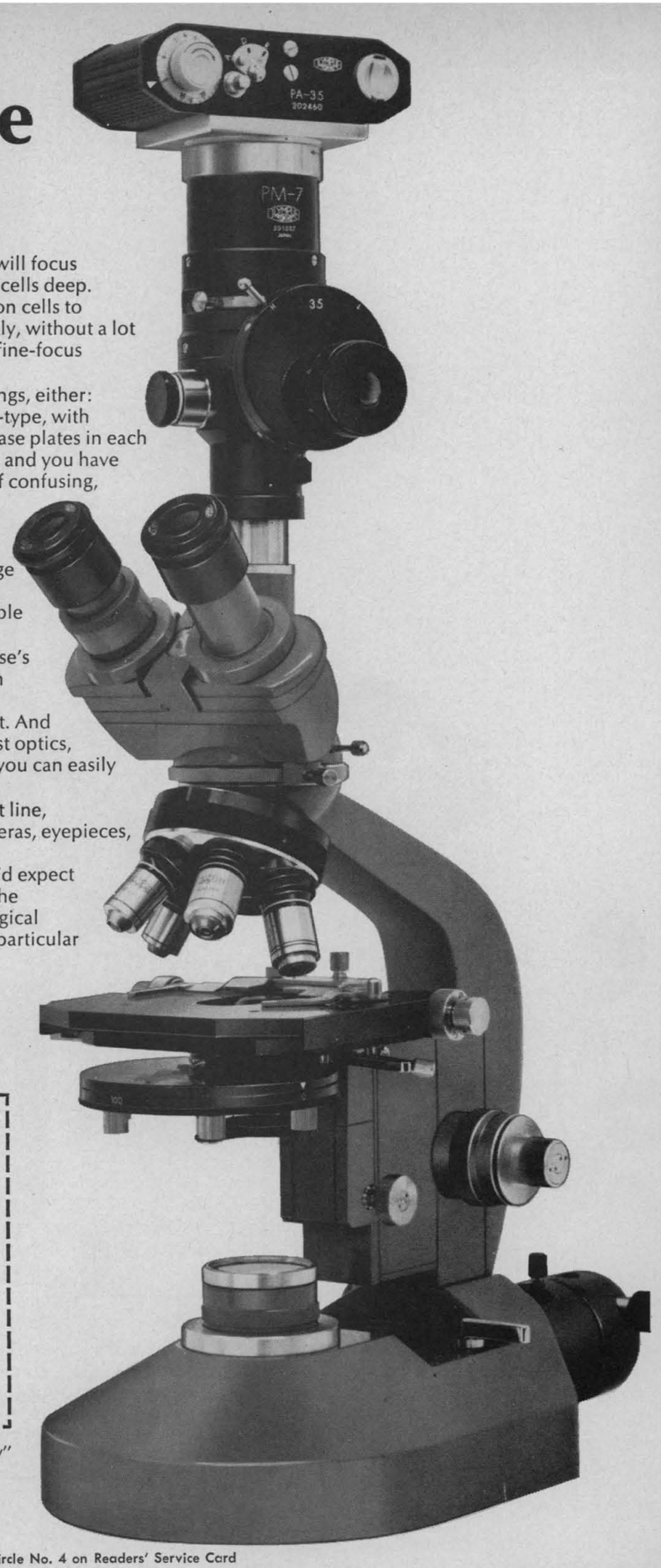

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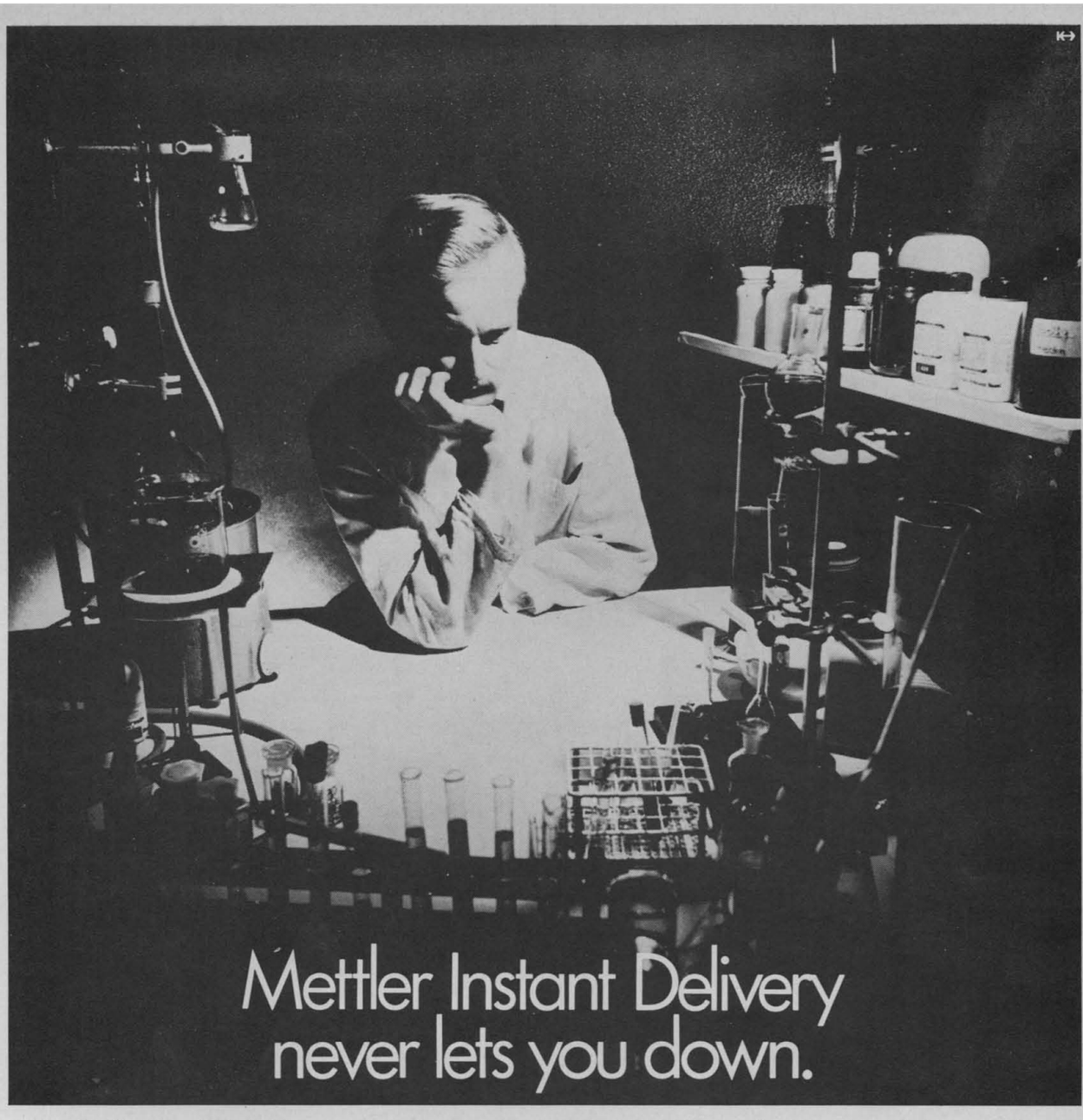

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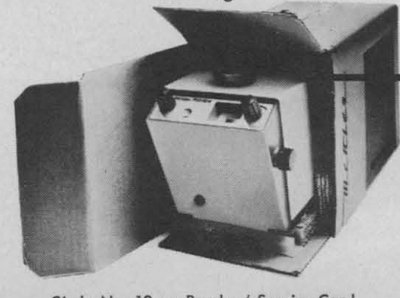

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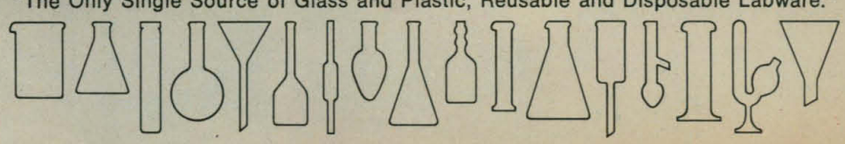

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papers documented the plate boundaries and motions of the recent past as revealed by the locations of spreading axes, the spacing of magnetic anomaly bands, the orientations of transform faults, and the location and behavior of the earth's seismically active regions, which are linear and curvilinear belts along plate junctures. Morgan (Princeton), McKenzie (Cambridge), and Parker (Scripps) described the inferred nature of the geometry of the movements, and related them to major structural features. LePichon, Heirtzler, and their colleagues at Lamont-Doherty (Columbia) amassed the data on magnetic anomalies, their orientation, their correlation, their spacing, and coordinated the whole into an integrated analysis of rates of plate divergence at rises and rates of plate convergence at trenches.

The most convincing confirmation of the idea came when Isacks, Oliver, and Sykes at Lamont-Doherty (Columbia) analyzed worldwide seismological data. Both the locations of earthquake foci and the sense of first motions calculated for representative earthquakes appear to lead to the same conclusions about plate motions as the other lines of evidence. Their plot of 30,000 earthquake epicenters on the globe reveals the outlines of the major lithosphere plates, and shows that most include both continental and oceanic areas. Failure to recognize the latter was perhaps the main factor that led unsuspecting continental drifters and seafloor spreaders into so many theoretical difficulties in the past.

The fundamentally mobilist concept of geology that has emerged from this past decade of research challenges all past orogenic theories that rest upon stabilist concepts. The plate tectonic model explains orogenic belts, where most mountain-building and rock-deformation occur, as the narrow, elongate regions of juncture between moving plates or segments of lithosphere.

These linear or curvilinear junctions are of three kinds. Where the plates are diverging, mantle upwelling and volcanism form new lithosphere with oceanic crust in the wakes of the separating plates to form typically intraoceanic rises, such as the Mid-Atlantic Ridge. Where the plates are sliding laterally past one another along strike-slip transform fault systems, complex deformation near the adjacent plate edges produces linear trends of folded and faulted crust, such as the oceanic fracture zones, or the California Coast

Ranges beside the San Andreas fault. Where the plates are converging, the geometry requires that one overlap the other in some fashion, hence that some crustal rocks which approach the region of collision either disappear from the surface or undergo some drastic lateral crumpling. The plate tectonic model clearly implies that the mechanical energy available to drive orogenic processes, either directly to deform rocks or indirectly by conversion to heat, is greatest along convergent junctures. As Dewey (Cambridge) has shown, the empirical evidence also favors this view.

In strictly kinematic descriptions of relative plate motions, convergent plate junctures can be called sinks with reference to the fact that the areal dimensions of one or both adjacent surficial plates are reduced somehow as lithosphere is, in effect, consumed by overlapping or crumpling of plates, removed by descent into the deeper mantle, or otherwise destroyed as a surficial entity in some unspecified fashion. The dominant real process is thought to be the descent of lithosphere, with a capping of thin oceanic crust, in the vicinity of intraoceanic trenches and trenches marginal to continents. The course of descent is thought to be marked by the inclined seismic zones that reach deep into the mantle beneath the intraoceanic island arcs, like Tonga and the Marianas, and the marginal continental ranges, like the Andes, where chains of explosive volcanoes stand parallel to nearby trenches. In some exceptional cases, however, lithosphere with a capping of thick continental crust may serve as the descending plate of a converging pair, as in the Himalayan region where at least part of the continental crust of the Indian plate appears to have passed beneath at least part of the Tibetan plate.

The complexity of the telescoping and overlapping of crustal rocks observed along ancient convergent plate junctures became evident from discussions at the conference. Most participants, therefore, adopted a general term, "subduction zone," to describe any linear region along which crustal rocks have been led to descend relative to an adjacent block by folding or faulting or both in combination. The term was coined by Alpine geologists, and recently revived, in its English translation, by the Esso (Houston) research group as a term appropriate for a process of broad crustal significance; the term was introduced to the con-

ference by D. Roeder. As used during the conference in discussions of structural relations among ancient rocks, the term subduction zone served to avoid unwanted implications of bathymetric trenches, or of crustal extensions of inclined seismic zones inferred for the mantle, or of any other particular feature possibly, but not necessarily, closely related to the structures observed in the crustal rocks under discussion.

Many specific geologic features of orogenic belts emerged from the discussions in a fresh light in terms of the plate tectonic model. Some of these can be cataloged as follows, with due allowances for complications, exceptions, and atypical situations.

1) Young andesitic volcanic chains and ancient andesitic metavolcanic belts can be taken as the linear surficial eruptive evidence for inclined seismic zones in the mantle beneath, and stand or stood typically above a region of intermediate depth earthquake foci as noted by Wadati a generation ago in Japan. Moreover, the transverse asymmetry in the total alkali, or potash, content of the volcanic rocks in a cross-arc direction reveals the sense of dip of the seismic zone and, therefore, the side of the arc upon which the associated trench or principal subduction zone is or was located. As emphasized by the late Professor Kuno (Tokyo) in a number of papers, the total alkalinity of the lavas increases as the depth to the seismic zone increases. Hatherton and I have shown that the increase in alkalinity is an increase in the level of potash content, with the level of soda content invariant.

2) As argued forcefully by Warren Hamilton (U.S. Geological Survey), many granitic batholith belts can be taken as the plutonic phase of arc volcanism. The plutons of regions like the Sierra Nevada were probably emplaced in the roots of eruptive arcs, and show the same general transverse areal asymmetry in total alkalinity or potash content as the arc volcanics. As noted by Matsuda (Tokyo), the concept of a volcanic front, the line parallel to a trench marking the edge of an eruptive arc, can be broadened to the concept of a magmatic front as a similar line marking the edge of the combined intrusive and extrusive phases of the arc magmatism. In any given arc with a long volcano-plutonic history, the position of the magmatic front can shift with time in response to some changing dynamics or position of the associated subduction zone. In several major batholith belts of the circum-Pacific region, radiometric age dates of the plutons have also indicated a puzzling episodicity of intrusive phases that appear to be coordinated over large regions. The causes of the episodicity of plutonism and the associated volcanism, the size of the areas over which the episodes are correlative, and the question of whether the episodes are truly periodic in some regular pulsing of activity pose significant challenges for future work.

3) The so-called ophiolite complexes, pseudostratigraphic sequences composed, in ascending order, of alpine peridotite or serpentinite, gabbro, basalt pillow lava or breccia, and chert or argillite, can be taken as the outer rind of oceanic lithosphere that has been incorporated tectonically into orogenic belts at continental margins. Some masses of this kind, and principally the most intact and least dislocated ones, have ridden over subduction zones as part of a structurally high block in a thrust complex. Such masses were described by Blake (U.S. Geological Survey) from California, Davies (Australian Bureau of Mineral Resources) from Papua, and Moores (University of California, Davis) from Cyprus. Similar masses, commonly sliced internally or dismembered by shearing, have ridden into trench-style subduction zones to become mingled with other rock types. Although found now within the orogenic belts formed at convergent plate junctures, many of the complexes presumably formed on midoceanic rises at divergent plate junctures where oceanic crust is mainly generated, and moved to their present sites during sea-floor spreading.

4) Blueschist metamorphism in the high pressure part of paired metamorphic belts, as recognized by Miyashiro, can be taken to reflect the rapid descent of cold surficial lithosphere to great depths along trench-style subduction zones. Despite the announced title of the conference, metamorphic processes were not discussed extensively, but Coleman (U.S. Geological Survey), Ernst (University of California, Los Angeles), and others sparked several impromptu discussions of the puzzling tectonic relations of blueschists.

5) Intracontinental thrust belts like those of the Wasatch and Mojave regions can be taken as a secondary inland expression of parallel trench-style subduction zones and arcs with

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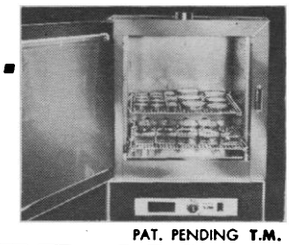

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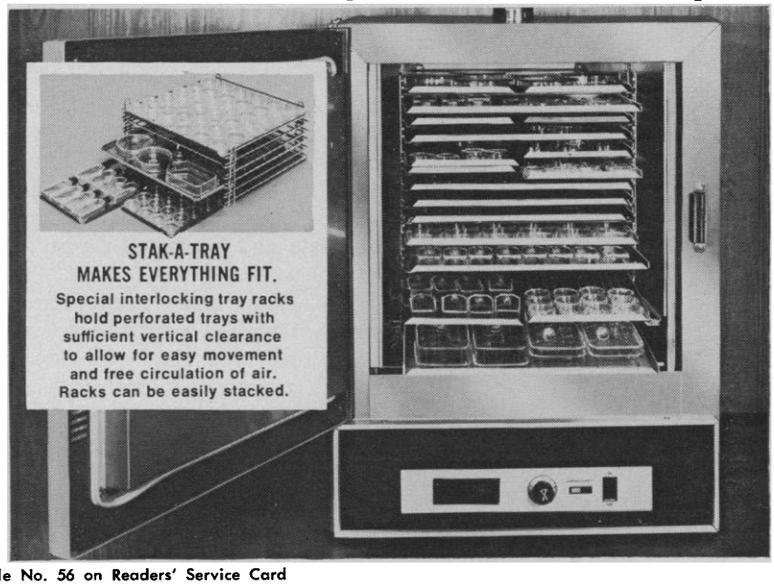

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movements in the opposite sense. Oriel (U.S. Geological Survey) analyzed the geometry and timing of the late Mesozoic and early Tertiary Idaho-Wyoming thrust belt and found them consistent with those of Canadian counterparts but inconsistent with proposed gravitational models. The geometric relation of the thrust belt to the roughly coeval Sierra Nevada, as reconstructed by Hamilton and Myers, resembles that suggested by Hamilton for the late Cenozoic thrust belt in the eastern foothills of the modern Andean volcanic arc. Burchfiel (Rice) and Davis (University of Southern California) showed how opposed thrust systems of this type can form the major structural elements of a two-sided orogen, with a trench on one side and an inland thrust belt on the other.

An important impression that emerged from the proceedings was the realization that the nomenclature of tectonic elements and stratigraphic facies in orogenic belts requires revision and further evolution. The meaning of the geosynclinal theory, which holds roughly that thick sedimentation in a linear belt precedes and predestines orogeny, must be translated into a new conceptual framework. Past usage has relied heavily on the concepts of eugeosynclinal and miogeosynclinal sequences, supposedly deposited side by side in a single large trough or in complex parallel furrows, as the forerunners of orogenic belts. Eugeosynclinal assemblages are commonly conceived to be rich in volcanic rocks and deep-water turbidites, and to undergo early, protracted, and intense deformation capped by metamorphism and plutonic intrusion. Miogeosynclinal sequences, by contrast, lack volcanic rocks and undergo less deformation of a more surficial kind. At least three kinds of each assemblage can now be identified with reference to modern analogs which can be related to current plate geometry.

One kind of eugeosynclinal sequence, that like the Franciscan assemblage of California, can be called a trench complex, and recognized as pervasively sheared, graywacke-bearing melanges in which terrigenous detrital turbidites are mingled depositionally and tectonically with offshore sea-floor strata including pillow lavas of the oceanic crust. Such sequences are not built in ordinary stratigraphic superposition, but are stacked tectonically over a period of time as materials are successively ridden into a trench and under its inner wall. The

pervasive shearing and stratigraphic discontinuity within melanges have been described at length by Hsu (Zurich), who led a preconference field trip to exposures along the coast near the conference site.

A second kind of eugeosynclinal sequence, perhaps the most familiar type, can be called an arc complex, and recognized as largely andesitic and dacitic volcaniclastic strata intruded by partly cogenetic granitic plutons. Such sequences are not accumulated in a topographic trough, but pile eventually to great thicknesses through progressive subsidence as described by Markhinin in the Kurile Islands. Facies range from shallow marine and even subaerial near volcanic centers to deep marine in blocky basins between volcanoes. A third kind of sequence locally called eugeosynclinal is composed of sea-floor lutites and distal turbidites deposited on basaltic crust in deep water beyond the continental slope of stable continental margins.

One kind of miogeosynclinal sequence, the miogeocline of Dietz, can be called a continental terrace complex, and represents the sediment built mainly in shallow water off the edge of a stable continental margin. Such sediment wedges may differ little in facies from platform deposits, but can reach great thicknesses, especially where they are built across the foundering edge of a continent. Rifting associated with the opening of a new ocean causes thinning of the crust where it necks and divides. A second kind of miogeosynclinal sequence, that like the Great Valley sequence of California, accumulates as detritus eroded mainly from an adjacent and parallel magmatic arc, and deposited in an elongate sediment trap between arc and trench. The site of deposition can be a shelf, slope, or trough in this tectonic position, separated from the trench by a bathymetric basement ridge of the type that Karig (Scripps) especially has noted at the top of the inner walls of trenches as a characteristic tectonic element in many modern arc-trench systems. A third kind of sequence, called miogeosynclinal by some and exogeosynclinal by Kay, is the clastic wedge foredeep complex, with the Cretaceous of the continental interior and the Devonian of the northern Appalachians as examples. Such sequences are deposited in variable water depths in troughs apparently associated with secondary subduction zones.

With these interpretations, what be-

comes of the idea that geosynclinal deposition presages the eventual onset of orogenesis and controls its effective extent? In the cases of the first two kinds of eugeosynclinal sequences and the last two kinds of miogeosynclinal sequences, sedimentation is simply a part of an unfolding process in which some deformation of the strata accumulated is an inexorable sequel. Even so, each case is somewhat different. In the case of the continental terrace, or miogeocline, and its offshore facies equivalents on continental rise or abyssal plain, there appears to be no immediate proclivity for deformation of the strata, as the continental margin is stable. In this case, the time dimension of plate tectonics comes into play. Oceans can be shown to have opened and closed. Once isolated continents come to be sutured together by collisions at subduction zones along which intervening oceanic crust is consumed. Hence, given time, any stable continental margin will eventually encounter a subduction zone at a convergent plate juncture, and will ride either over it or into it. In either case, the flanking sediment wedge will be deformed in some fashion; for a thick sedimentary pile simply to exist at a continental margin thus predestines eventual deformation when, inevitably, the margin becomes active.

In a sense, then, the geosynclinal theory of orogeny remains valid if the causative function of a thick sediment prism is replaced by a notion of coincidence or consequence. In another sense, the theory is perhaps more faulty and potentially misleading. A single, sequential orogenic progression is commonly assumed to be the norm. This notion cannot be expected to remain part of the plate tectonic model of orogeny. As oceans open or close and continents rift or join, as arcs and trenches and thrust belts grow and die with migrations and possible reversals of polarity, as one type of tectonic element is superimposed upon or juxtaposed against another, we have no reason to suppose as yet that there is any unique order in which these events may occur in a given region or happen to a given rock mass. Hence, different orogenic belts may undergo different sequences of deformational events. Each step ought to be one of a finite array of types, but the order of the steps should vary from place to place.

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