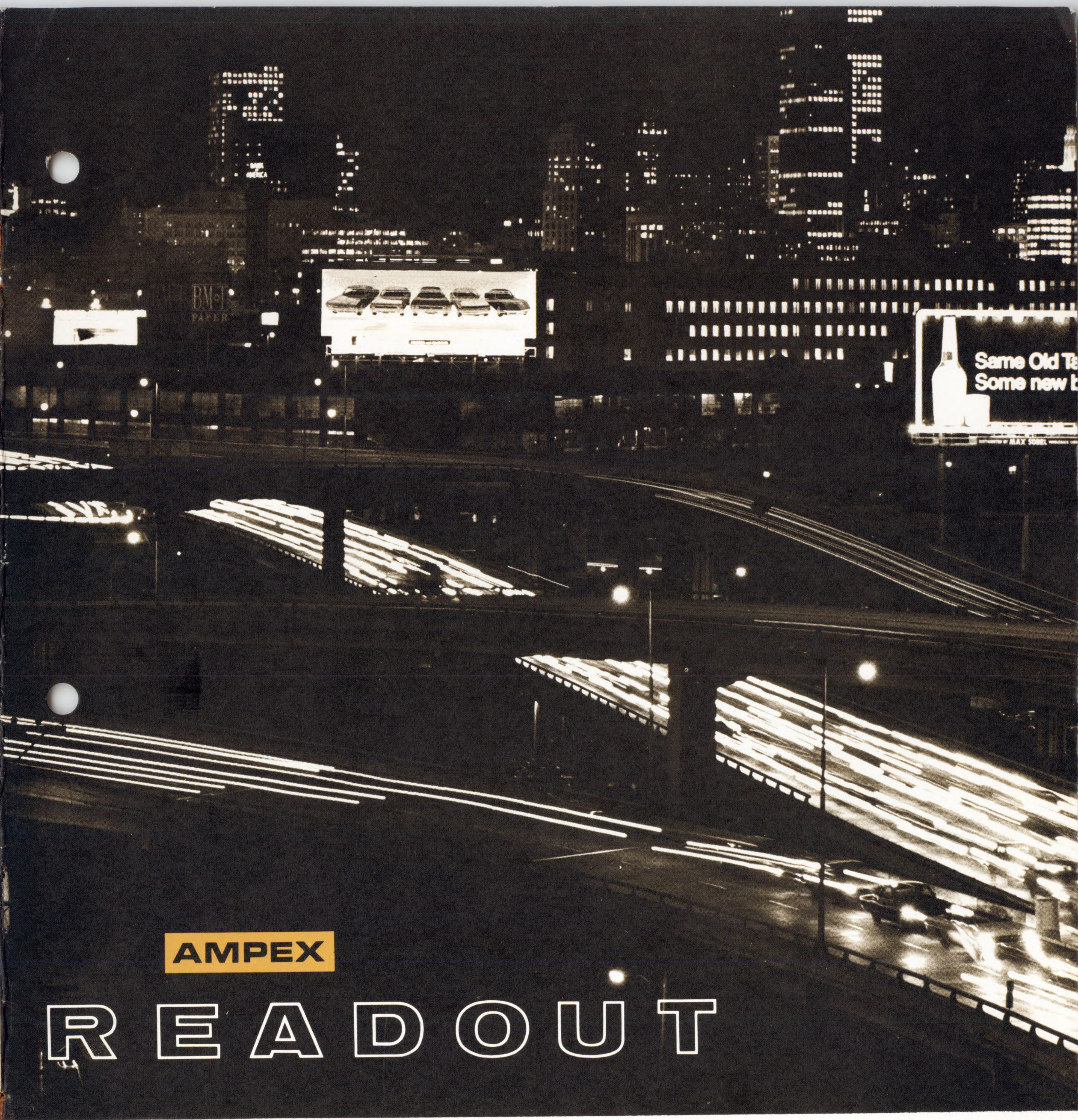


AMPEX

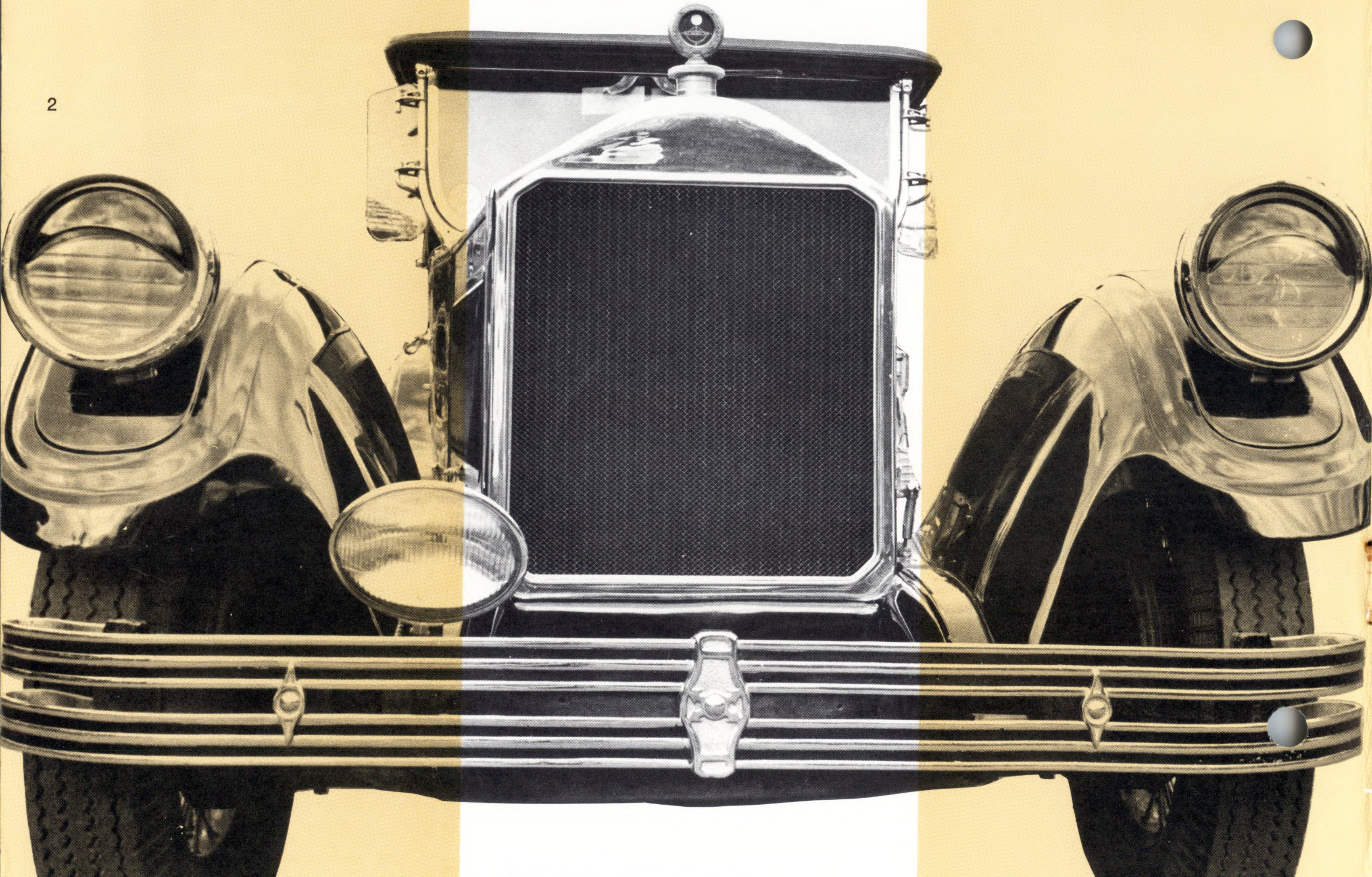
READOUT

In this issue:

- Automobile Safety Programs at Ford
- Television in France
- Italian Space Program
- Ampex Research and Engineering Articles

Ford Mounts Many Pronged Attack to Improve Safety

FORD MOTOR COMPANY has tied together aerospace technology with digital computers in a many pronged attack to improve automobile safety. Ford's latest safety facilities, a new Reliability Laboratory, and a Safety Research Center, push experimental technology forward significantly, bringing to a climax more than ten years of extensive safety testing at Ford. Besides these new space age facilities, Ford reliability and safety research continues in each of the company's basic manufacturing divisions. Speaking generally, automobile safety falls into two interrelated but distinct areas. The first is how to make cars and trucks more reliable and controllable to avoid accidents in the first place. The second is how to protect the driver and the passengers from what is called second collision. This is when the occupants are thrown forward and strike the interior fixtures of the car itself after the impact occurs.



RELIABILITY LABORATORY: Fifteen Million Test Miles per Year

Ford's new (1966) Reliability Laboratory contains some of the latest and most sophisticated equipment to recreate exactly the day-in, day-out use of everything from the smallest chassis parts to the giant tandem highway tractor/trailer combinations. The new multi-million dollar facility represents the third step in the history of reliability testing that grew up with the automotive industry.

Automotive testing began when Henry Ford and other automotive pioneers furtively drove their first cars under the cover of night in the deserted streets of small Michigan and Indiana towns. This grew into testing on the proving ground, and most recently in reliability laboratories. Just around the corner is testing by mathematical models in large computers.

Ford's Reliability Laboratory offers two basic advantages over proving ground testing. It significantly cuts down test time and gives better information about how long the individual parts and overall vehicle will last. Every pre-production model of a Ford vehicle must meet a grueling proving ground durability run, equivalent to 100,000 customer miles for many of the components. The job of the proving ground itself has been gradually shifting. It is being used more and more to show how well simulated testing in the laboratory mirrors actual usage by drivers.

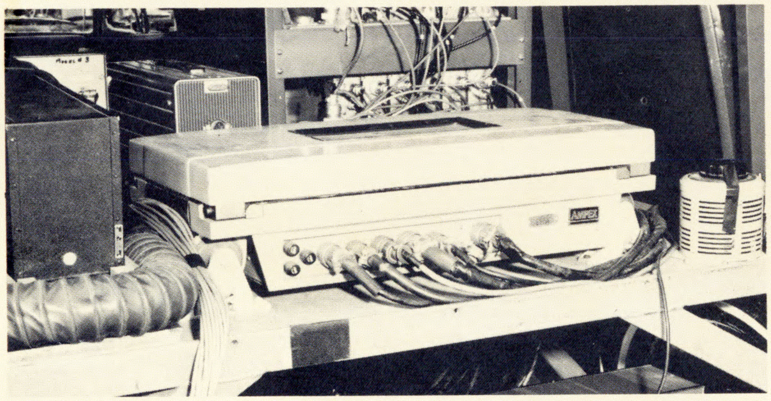
The step beyond the Reliability Laboratory is running tests by computers using mathematical models. Ford is right at the threshhold of testing by computer analysis now. In 1965, it installed a giant Philco 212 scientific computer. In late 1966, an extensive time-sharing system was added. This is one of the largest, if not the largest, non-government computer facility in the world, according to William A. McConnell, director of Systems Research for Ford's Engineering Staff. Ford's time-sharing system was the first major application of this concept in U.S. industry. It can make the giant capability of the computing center available to Ford engineers throughout North America, Britain and Germany.

RELIABILITY TESTING: Months are Compressed into Days or Weeks

Ford's laboratory testing is done on individual chassis components (frame, brakes, suspension, and steering) as well as the complete vehicle (chassis, power train, body, and electrical components) as it operates in a total system.

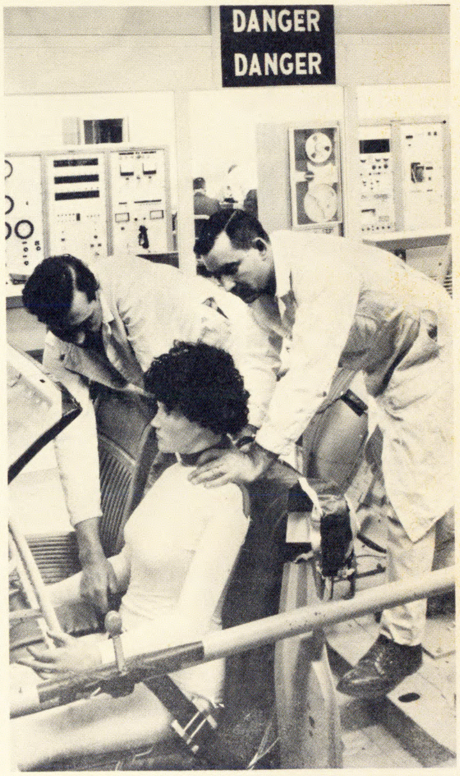
The new generation of equipment differs from earlier equipment in that it can be programmed to recreate real-life road environments. Any situation that can be measured and recorded, Ford's test and development engineers can duplicate in the laboratory with amazing accuracy. The important thing is to recreate the random quality of actual customer usage, as represented by up and down, back and forth, twisting and torqueing of the road surface.

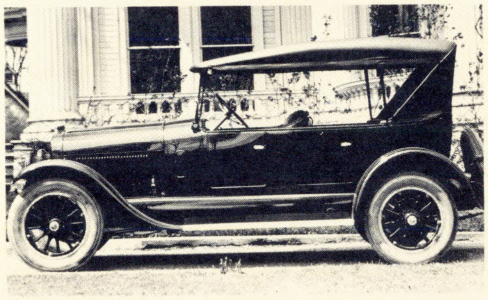
The first step is to instrument the car or truck and send it over a road representing the test conditions. Accelerometers, strain gauges, temperature transducers, and related measuring devices are mounted on the wheels, tires,



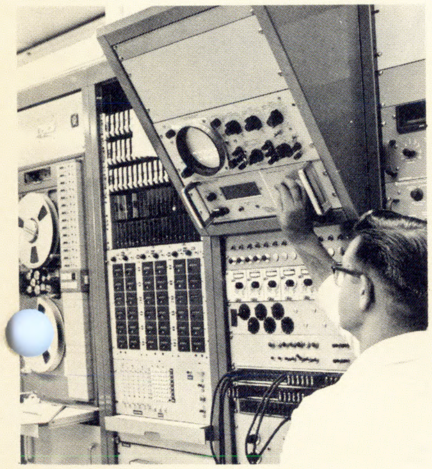
Ampex AR-200 instrumentation recorder in rear of Ford Econoline test instrumentation van. The van connects to the test vehicle via an "umbilical cord."

Crash simulator in Ford's Automotive Safety Research Center uses a track 120 feet long. Results of the impact on dummies from the main collision forces are recorded on the Ampex FR-1800 instrumentation recorder in the background.

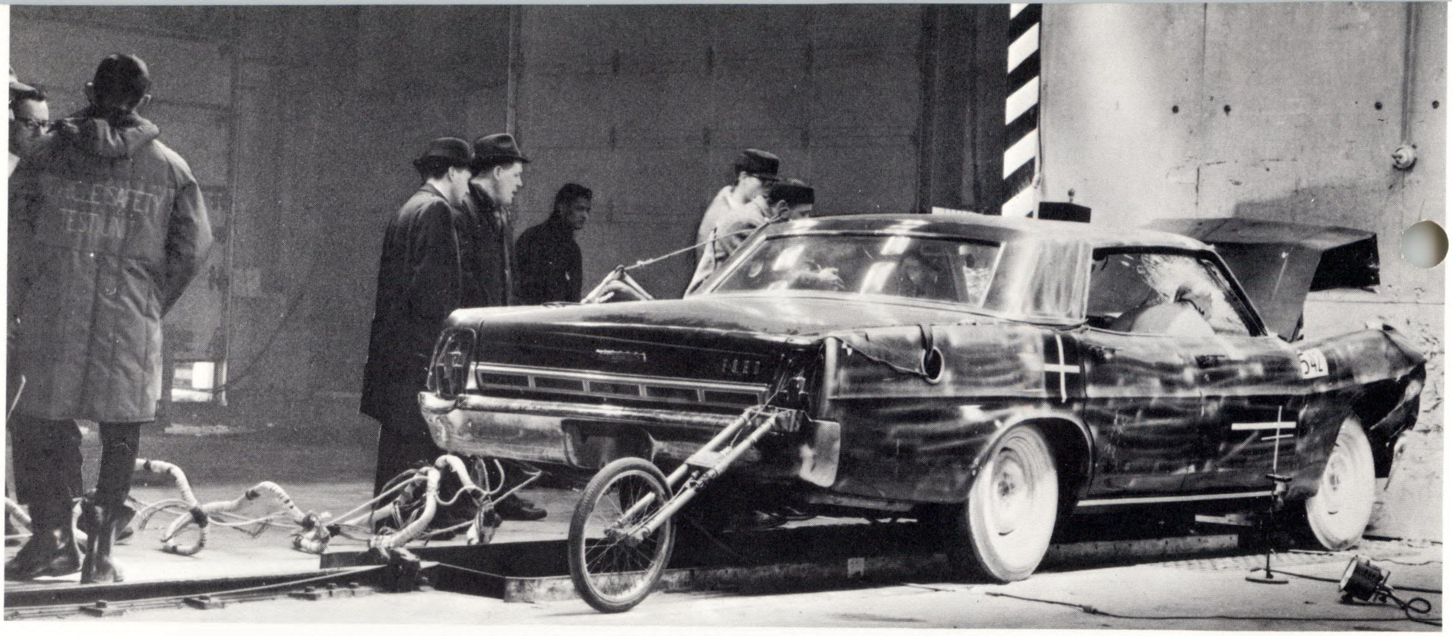




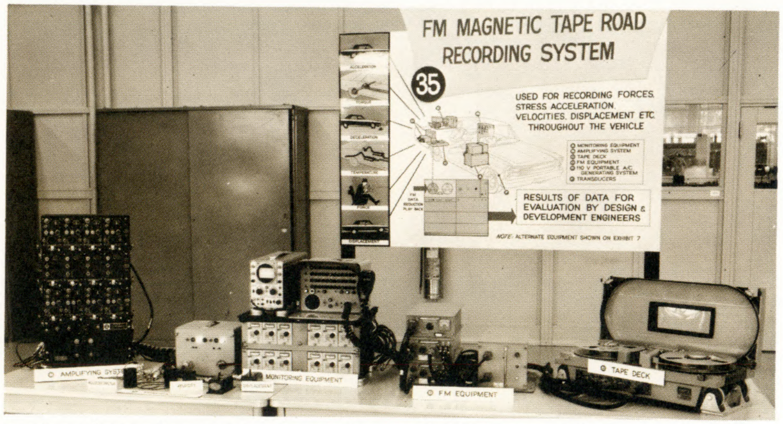
1921 Leland Lincoln touring car.



Data reduction equipment with 14-channel Ampex CP-100 instrumentation recorder for use with tandem axle road testing.



Ford engineers examine a 1967 Ford after it has impacted a 200-ton concrete barrier at 30 mph.



Ford road recording system uses an Ampex AR-200 to record forces, stress, acceleration, velocities and displacement throughout the vehicle.

brakes, suspension components, and body structure to determine the magnitude and direction of the stress and vibrational forces applied by the road. These signals are recorded on 14-channel Ampex AR-200 mobile instrumentation recorders, either at Dearborn, Michigan or Ford's Desert Test Center in Kingman, Arizona. The recorder is mounted in the car along with transducer, power supplies and signal conditioning equipment.

Recording is done at 1⅞ ips which provides up to six hours of recording. Signals are recorded using the FM mode which means that even very slow moving vibrations (down to dc) can be recorded while still maintaining good amplitude stability. As many as fifty or sixty different variables with tens of thousands of data points may be recorded in several test runs on a single reel of tape. Twelve channels are used for data, one for voice or time code, and one for control voltages to turn on analytical devices during playback at significant portions of the data.

Prior to using magnetic tape recording, vehicle mounted paper tape recorders (oscillographs) and galvanometers were used. Magnetic tape has speeded up data analysis and increased significantly the amount of data that can be captured in each test.

Back in the laboratory these recordings are played back for several types of analysis. One method is to control hydraulic rams which recreate with great accuracy the actual road motions. From this test, Ford engineers study suspension dynamics, vehicle noise, and vibration characteristics. Because magnetic tape can be replayed as many times as needed without signal degradation, a particular road condition can be repeated over and over again. In this way, many design alternatives can be evaluated in a much shorter time than on the track, and far more efficiently.

Other types of analysis is commonly done using meters, oscilloscopes, and graphic recorders. By speeding up the playback recorder (an Ampex CP-100) to 15 ips, low frequency vibrations can be compressed into a minimum linear space and still be within the bandpass of a strip chart recorder. For more detailed studies the tapes are played back into an analog computer which pulls out only those portions of the road test which stress the chassis mounts. Frequently, the recorder is run at an even higher speed, up to 60 ips, to take full advantage of the high input rate of the computer. By speeding up the data on playback and using only the peaks, Ford can compress laboratory time to a fraction of road time. For example, it takes about twelve weeks to evaluate spring durability on a proving ground. In the laboratory, it can be cut to only one day.

Similar vibration and stress studies are done in Ford's Tractor Division. Here an Ampex CP-100 instrumentation recorder is mounted on tractors to acquire actual field data on structural members and other components.

Sound level and noise analysis studies are also carried out in the Reliability Laboratory. Tests are run both in the laboratory and on the proving grounds. Recording is done using four Ampex 600 series professional audio recorders. Analysis consists of spectrum and power density studies, and audible tests with loudspeakers. Ford's claim to be the quietest car on the road owes its validity to the experimental work done by the noise analysis group.

AUTOMOTIVE SAFETY RESEARCH CENTER

The second new research facility at Ford is concerned with occupant protection, and with human performance factors that can help avoid accidents.

Experimental crashes are a key part of an impact dynamics study. Currently, Ford crash tests seven to ten vehicles outdoors every week, in addition to dozens of indoor impact tests on components. Ford has been crash testing vehicles since the early 1950's. It has now carried this type of test to a high level of sophistication.

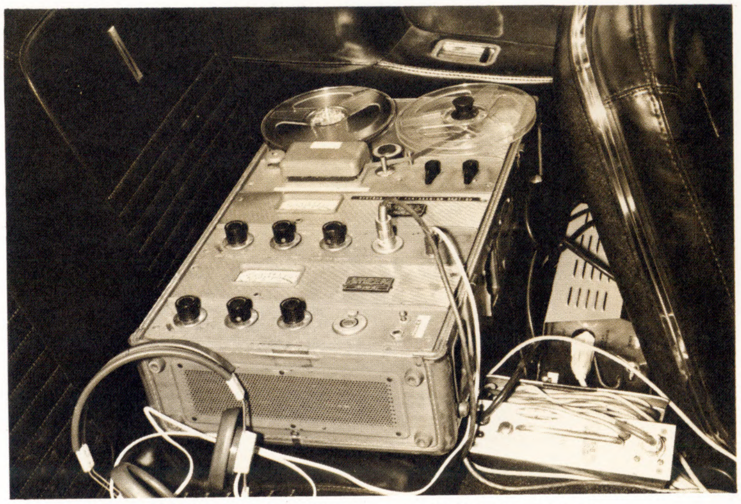
In some of the experimental crashes the test vehicles are connected to an instrumentation van by an umbilical cord through which the data is carried for recording on Ampex CP-100 magnetic tape recorders in the van.

Borrowing from Ford's Philco Division experience with various aerospace programs, telemetry is being used in several tests. Telemetry (literally, remote metering or measuring) allows data to be transmitted by radio from a vehicle out on the proving grounds to an Ampex FR-1800L instrumentation recorder in the lab.

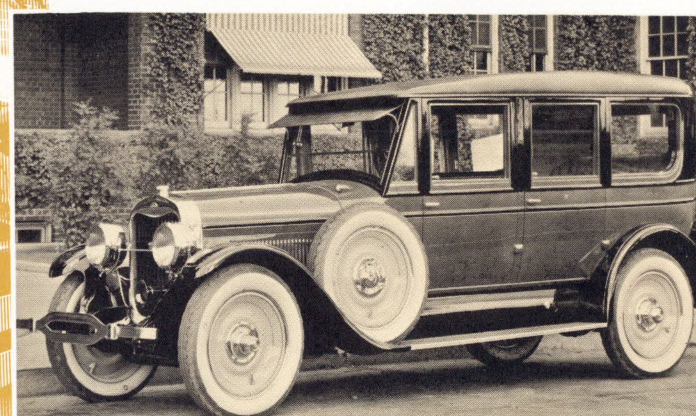
Crash vehicles are usually occupied by one or more 165-pound dummies that approximate the size of an adult male. Smaller dummies representing female adults and children are also used. These dummies, costing several thousand dollars each can be opened for installation of sensitive measuring and telemetry instruments.

Similar impact tests of vehicle components take place in the Dynamic Test Laboratory. Principal tools here are the pendulum, the inclined sled, and a new crash simulator. Adult and child dummies, mounted on the 120-foot crash simulator, are thrown forward by a massive ram to see how new ideas and materials can make car and truck interiors safer. Accelerometers on the dummies, dash board, and steering column measure the g forces and loads at impact. Up to 36 transducer signals are time division multiplexed, then sent by telemetry to three channels of the Ampex FR-1800L recorder. A time code, recorded on another channel is also used to synchronize with high speed motion picture cameras that records visual data on the test.

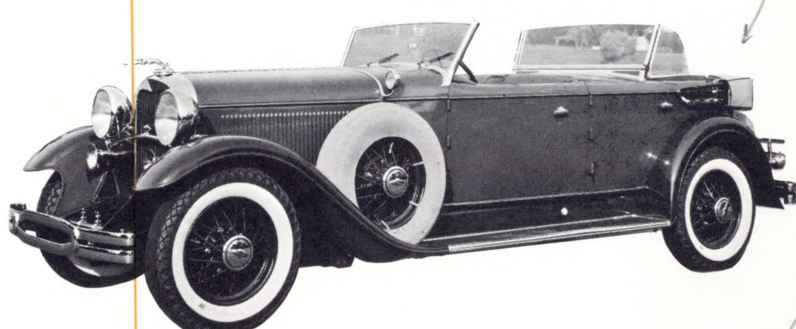
Recording speed is 60 ips. For data analysis, 7½ ips is used to match the lower bandpass of graphic recorders. Additional analysis is done using oscilloscopes, analog, and digital computers, depending on the type and quantity of data.



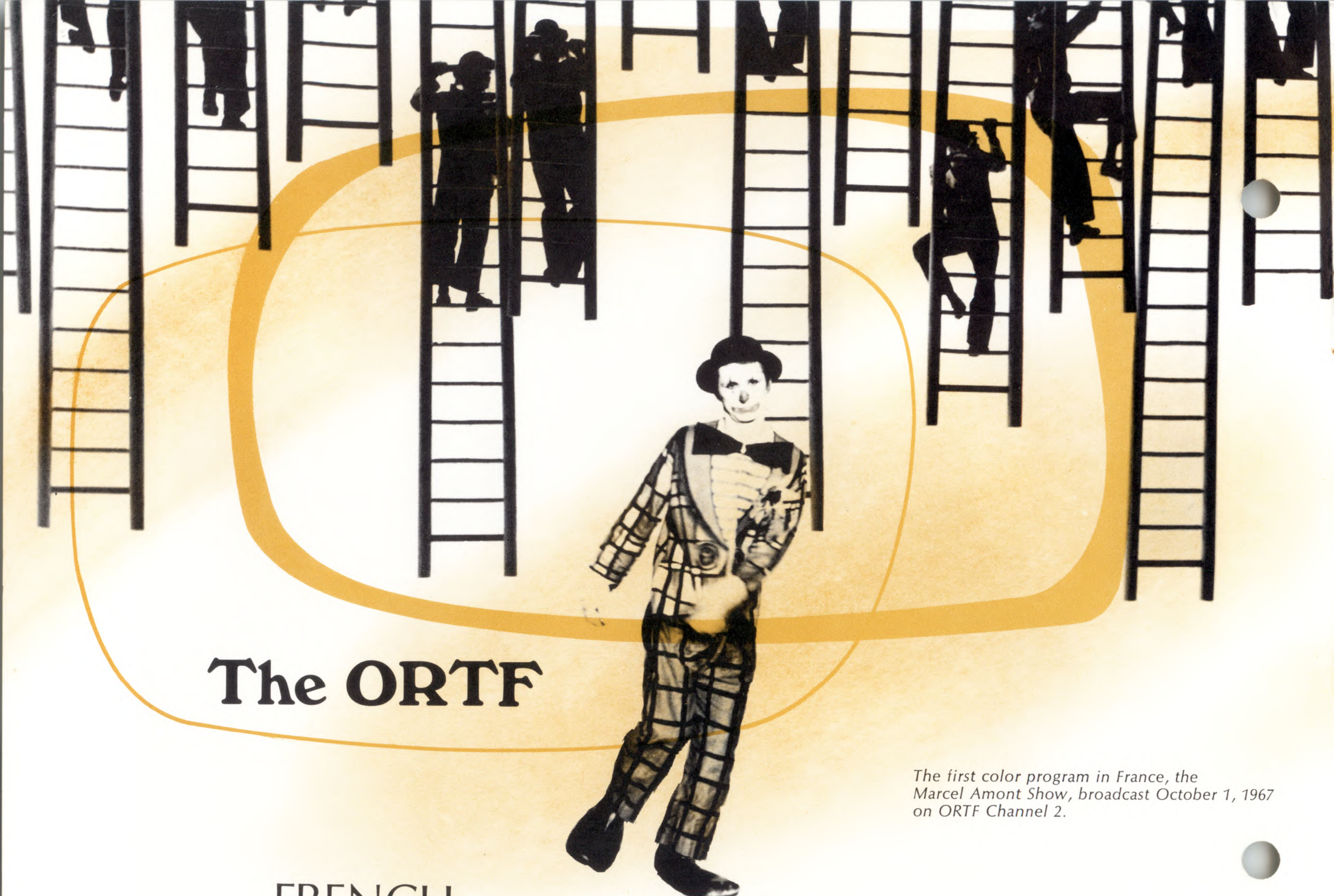
Ampex 601-2 audio recorder in rear of Mustang test car during sound level testing.



1931 Model K Lincoln, dual cowl phaeton with body by Murphy.



1924 Model L Lincoln limousine with body by Fleetwood.



The ORTF

The first color program in France, the Marcel Amont Show, broadcast October 1, 1967 on ORTF Channel 2.

FRENCH TELEVISION: *TV with a pinch of Gallic seasoning*

ALTHOUGH outwardly similar to television in other countries, French television mixes just a pinch of Gallic seasoning into its television programs and production. Even one of the test patterns could only be French: in its center a shapely woman blowing a trumpet stands proudly astride a lunging white stallion. Television in France is operated by the Government. No commercial advertising is carried. Dramatic and news programming is designed to appeal to a mature audience, but popular material, sports, and children's programming have an important place, too.

REMOTE COVERAGE: The Gallic Flare
The French excel in remote coverage. Some 10 percent of total production time users remote pickup. Here is where the Gallic flair is most obvious. Coverage of sporting events, for example, is frequently turned into a near virtuoso exercise with cameras catching the action dynamically from every angle. French crews have installed cameras in helicopters, motorcycles, automobiles, vans — in fact, almost any kind of conveyance that can mount a camera to bring back important scenes from soccer, rugby, auto racing, or skiing.

Similarly in remote coverage of news, immediacy with multi-camera pickup and on-the-spot videotape recording is the key to French coverage. At the 1967 Paris Air Show, the French staged an impromptu demonstration of their remote propensities. Television newsmen took an Ampex VR-3000 back-pack videotape recorder aloft in a borrowed Soviet helicopter (on display at the show) to prepare an insert for that evening's news program.

ORTF: Two Channels, VHF and UHF. French television goes under the formal name of ORTF (Office of Radio and Television, France). It is very much the official voice of France. The ORTF functions as part of the French Secretary of State for Information. It has a committee overseeing television programming, on which sit representatives from the ministries of cultural affairs, foreign affairs, economic affairs, justice, interior, public health, plus journalists and public representatives.

Total budget for the ORTF is $200 million. Television gets 42 percent or $82 million. Income is derived from a licensing fee of $17 paid by set owners. There are about eight million television sets in France, plus an estimated quarter of a million additional unlicensed sets. Group viewing is still very common in rural areas. (Radios total nine million. The radio only fee is $5.)

ORTF broadcasts on two channels, in the evenings on weekdays and beginning about noon on weekends. Channel 1 uses an 819-line standard in the VHF band. Channel 2 uses the new European standard of 625 lines in the UHF band. Total broadcast hours on Channel 1 average about 77 hours a week, not including school broadcasts in the morning. Chan-

nel 2 averages about 35 hours a week. Channel 2 tends to put on more popular programming, with many feature movies.

Channel 1 will continue to operate on 819 lines for another ten years or so. Typical of the Gallic spirit, the French originally picked 819 lines because it produces a much sharper and cleaner picture than other standards.

All programming and transmission originates in Paris (except for a 15-minute local news program on regional stations). From there it is carried via microwave to 100 primary transmitters and more than 1,000 secondary transmitters throughout the country. Each of these stations beams into adjoining areas on several frequencies so that nearly every village in France is covered by television.

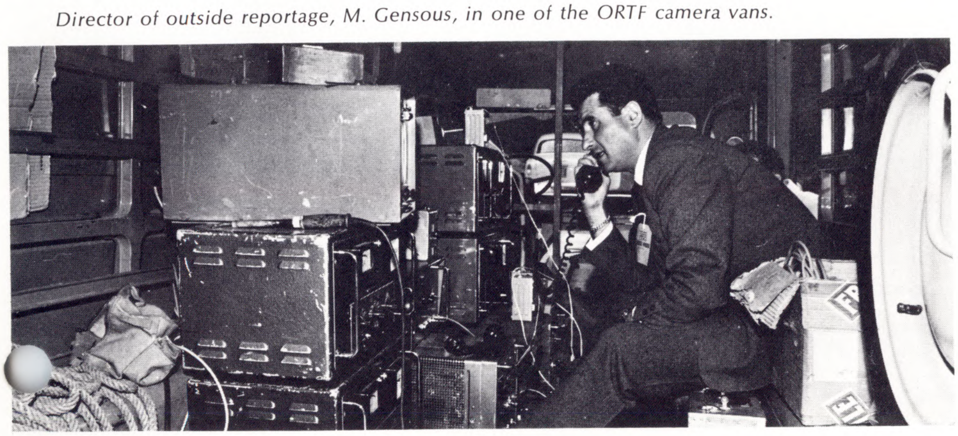
About one-third of the programs on Channel 1 are live and two-thirds are recorded. Recorded material divides about equally between film and tape. On Channel 2, more material is recorded. About one-third of the recorded material is on video tape, the remainder on film, much of it feature movies.

PROGRAMS: Diversity with Cultural Emphasis. ORTF attempts to have a wide diversity of programming with an emphasis on cultural programming for mature audiences. It includes classical and avant garde drama, popular variety programs, news and news magazines, excellent science programs, and children's programs. In addition, educational broadcasting covering all school levels is put out during the morning. An ambitious ORTF adult educational project broadcasts five to six hour courses once a week. The 1967-68 course, aimed at assembly workers and electronic technicians, covers transistors and color television. Preprinted program and course material are carried in the French magazine, *Television*.

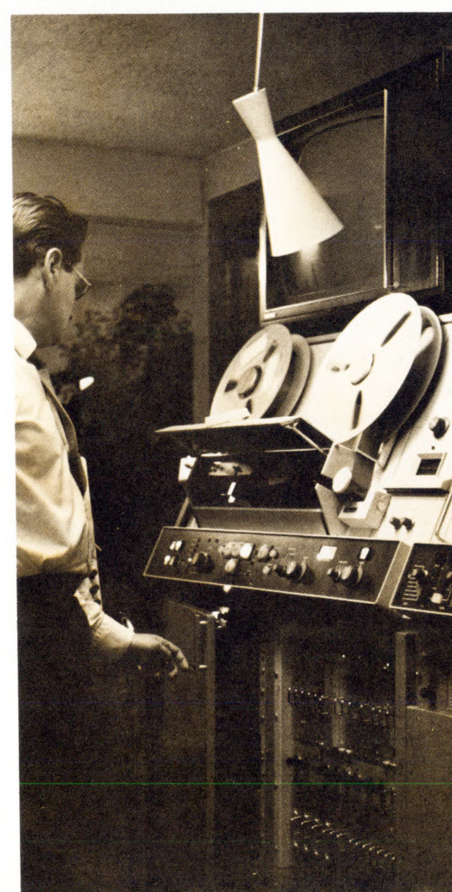
Because of the language difference, American programs are not as common in France as in Britain, although *Bonanza* and *The Untouchables*—Le Incorruptibles—(with dubbed dialog) have been currently running as regular series. In general, French television does not have as many repetitive series as the Uni-

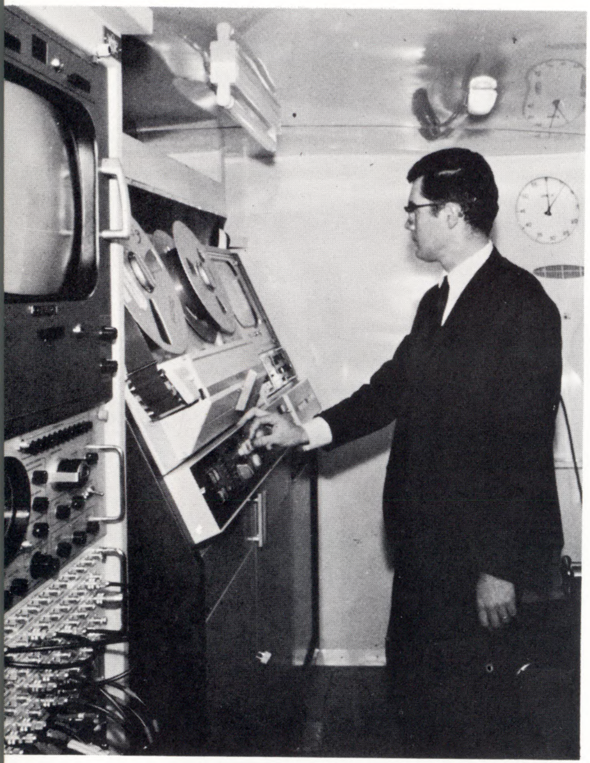
ORTF's unique circular Radio and Television Center, located on Avenue du President Kennedy near the River Seine in Paris.

Director of outside reportage, M. Gensous, in one of the ORTF camera vans.



Recorder station at ORTF facility in Paris with Editec equipped Ampex VR-2000 high band videotape recorder, one of eight VR-2000's now in operation. Four additional VR-2000's will be installed soon.





One of the two new vans especially built by ORTF for use at the Winter Olympics in Grenoble in February 1968. Recorders are Ampex high band VR-2000. ORTF also used at Grenoble an Ampex HS-100 slow/stop motion disc recorder, two VR-650's (VR-660) in small vans, and four VR-2000's in a studio. The United States network ABC, had a similar complement of the portable equipment for its coverage.

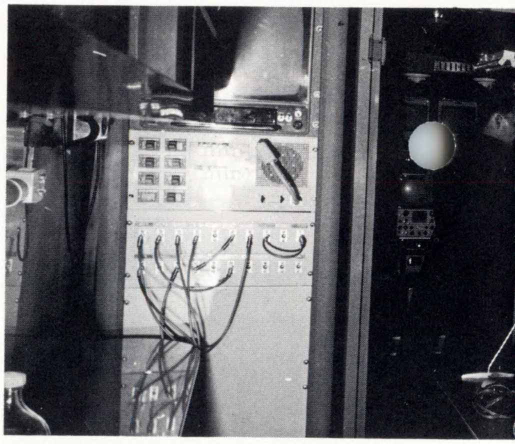
At the Paris Air Show (June 1967), an Ampex VR-3000 back-pack recorder worked in conjunction with an ORTF television camera in a helicopter to produce an insert for an evening news program.

ted States and Great Britain. The emphasis is more on dramatic programming complete in one or possibly two evenings. American movies are standard fare on Channel 2.

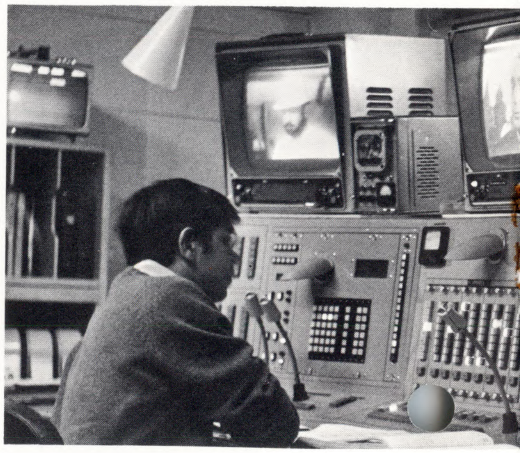
NEWS BROADCASTS: In Depth with Many Remotes. News broadcasting in depth characterizes French television. It's quite common to have not just one or two, but four or more newsmen on a 30 or 45-minute program. The news is usually broadcast live with several taped inserts from remote vehicles. The ORTF news service uses five small Citroen vans, two equipped with Ampex VR-650 recorders and cameras, which record news events in the Paris area for immediate playback and three vans equipped with UHF cameras. Five additional VR-650's have been ordered to expand this service in Paris and throughout France.

Political debate, second nature to the average Frenchman, has not been a feature of French television until recently. An edict has now been passed by the French Parliament that Government and opposition political parties will share television time equally before elections. Also, a new program called Face to Face (much like our Meet the Press) has stimulated a great deal of fresh viewer interest.

THE SMALL WHITE SQUARE: Signals Adult Programs. A good example of the French flair in television both in instant news and remote coverage, was a kind of "Candid Camera" program several years ago which documented the activities of the ladies of the street. This program caused quite a stir. In fact, it resulted in a successful lawsuit against the Government for invasion of privacy. Shortly afterwards, the famous small white square started appearing in the lower right hand corner of the screen to indicate controversial or adults only programs. A second use of inserts is a small "2" on Channel 1 when a program is about to start on the second channel.



Above: *Interior of videotape mobil van equipped with an Ampex VR-1000 recorder.*

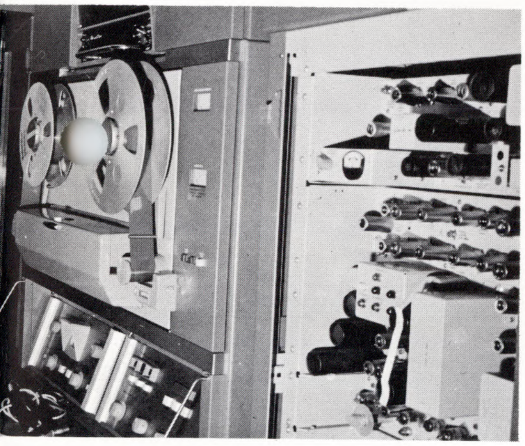


Scene from the first episode of a new 18th century series, Lagardere, *based on a popular historical novel.*

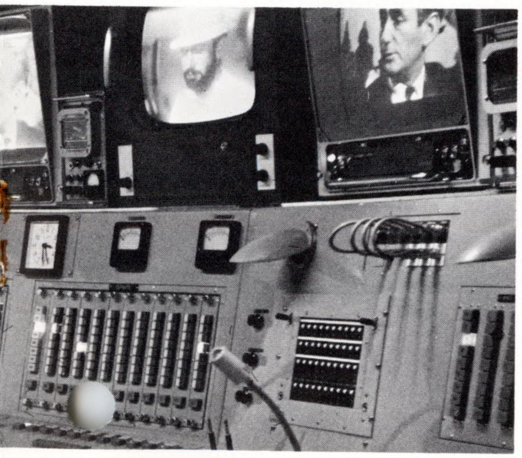
ADVERTISING: Only National Associations. On both channels, national advertising from trade associations is carried, of the type— drink more milk, eat more bread. Recently the press reported two different groups interested in setting up a third channel which would derive its income from the sale of advertising time. It remains to be seen whether either of these schemes will actually develop, although there has been talk for several years about accepting commercial advertising on the second channel to increase ORTF revenue.

COLOR BROADCASTING: SECAM System. Color broadcasting began on ORTF in November 1967 on Channel 2. It uses the SECAM color system (also adopted by the Soviet Union and several East European countries) which stands for "Sequential and Memory." Earlier, ORTF had been sending out experimental SECAM broadcasts for some time. Initially about 20 hours a week are in color, or about 60 percent of total program time on Channel 2.

About 25 to 30 percent of this color is produced and broadcast on tape using the eight high band Ampex VR-2000's located in Paris. ORTF color production facilities include four color studios, two outside broadcast vans and 12 Telecine chains (16/35 mm), which provide 25 to 30 percent of the color programs. The SECAM color system has permitted ORTF to microwave color programs over a distance of 6,000 Kilometers (about 3,700 miles). Color transcoding from SECAM to PAL, and vice-versa, is commonly done, especially for the use within the Eurovision network.



Below: *Control console at ORTF News and Distribution Center in Paris.*



INTERNATIONAL PROGRAMMING: Produced For French Speaking Areas. France has always been active in promoting French culture via television. About ten hours a week of foreign programming in French comes out of ORTF studios for use in Luxembourg, Belgium, and other French speaking areas such as former colonies, French Canada and parts of the Middle East. ORTF will also supply technical and production advisors on request to help set up a television system.

At Expo 67 in Montreal, French television programming was an important part of the exhibit in the French pavilion. The ORTF brought over a color television studio including a high band Ampex VR-2000 recorder to tape remote coverage at the Fair and for color program demonstrations.

VIDEO STUDIO FACILITIES: Fifteen of Various Sizes in Paris. According to Michel Oudin, Video Production Director for ORTF, "We have some 15 studious of varying sizes for teleproduction within the Paris area." The largest is 900 square meters. Twelve of these are monochrome, three are color. A color studio is also located in the ORTF research department which has been experimenting with color transmission and evaluating color recorders for several years.

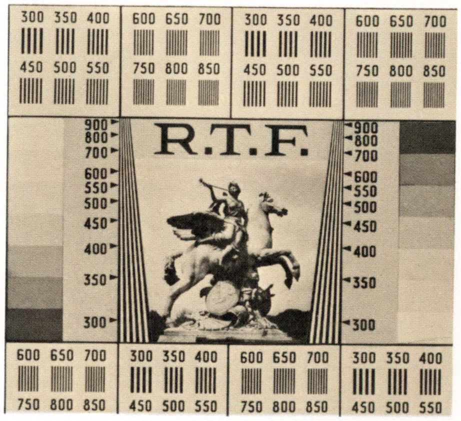
Each studio is equipped with four or more cameras, and a full range of control, monitoring, and recording equipment. Eight VR-2000's are installed for studio use in the Cognacg-Jay Center; four additional ones are being added now. Other equipment in the Buttes de Chaumont Center includes 15 VR-1000C's. ORTF uses the VR-2000's especially for its high band monochrome and color recording.

A typical one-hour program will have 30 or 40 mechanical splices. Two of the eight VR-2000's are equipped with Editec which is being increasingly used for splice-free electronic splicing.

REMOTE RECORDING FACILITIES: Small and Large Vans. About 10 percent of all production is done outside by 11 vans or other vehicles. About half of this is news and sports, the other half for insert into dramatic programs. ORTF now has five videotape vans, three equipped with low band videotape recorders (such as the VR-1000) and two with the helical scan Ampex VR-650 recorders. Five more VR-650's are on order now to step up the coverage of news, accidents, parades, and other fast breaking events. In addition, several small vans with monochrome and color cameras and microwave equipment transmit back to the studios for recording or live broadcast.

For the Winter Olympics at Grenoble in 1968, two fully equipped color vans with high band VR-2000 recorders have been constructed.

FILM FACILITIES: Ten Studios plus Complete Processing Equipment. ORTF film facilities consist of ten production studios with 30 operator crews for film production and 80 crews for news reporting. Film facilities include all conventional production equipment, plus complete development and splicing labs, a post synchronization studio and a preview studio.



DATA RECORDING WITH THE LASER

By Samuel Bousky, Ampex Corporation

INTRODUCTION

Present day technology is forcing an increasing need for data storage at greater bandwidth and for data retrieval in shorter access time. The answer to both appears to be a requirement to reduce the spatial storage area per bit on the recording medium; or in other words, to increase the data packing density in terms of bits per square inch. A typical high quality magnetic data recorder capable of 6 megahertz (MHz) bandwidth and better than 40-dB signal-to-noise ratio (SNR) utilizes an 0.0100-inch track width, 0.0025-inch space between tracks (guard band), and an 0.00016-inch (4-micron) bit length. Such a system is capable of spatially storing about 0.5 megabits/inch^2 of tape surface. New equipment of about the same bandwidth and SNR, now being readied for product status, has increased the packing density to 1.3 megabits/inch^2.

Recent work at Ampex in electron beam recording on high resolution photographic film has shown that SNR of 40 dB can be attained with round spots of about .0002-inch (5-micron) diameter. Allowing a guard band width equal to a spot diameter, the spatial packing density would then be 12.5 megabits per inch^2 or about an order of magnitude greater than attainable in magnetic recording.

Data recording with light on photographic film is almost as old as photography itself. The ability to record at large bandwidth with small spots has been limited by available light sources and source brightness. The advent of the CW laser suddenly changed this situation and made available not only sources of significant brightness but also output light beams of good monochromicity and collimation. Laser sources permit the attainment of optical systems operating at the diffraction limit. Thus very small spots of light of the extremely high brightness necessary for large bandwidth and high packing density, are now attainable.

While the laser has opened new vistas in data recording it has brought with it problems of its own. The technical areas require careful evaluation before such instrumentation can enter into reliable product status. The more important problem areas include: spot formation, scanning, modulation, recording, and readout.

THE RECORDING SPOT

The theoretical basis for the formation of diffraction limited spots was worked out about 100 years ago. The impetus for this analysis was provided by the problems in astronomy wherein collimated light (starlight) of uniform intensity distribution filled a finite aperture to form a spot (star image). Such a spot is an "Airy disc," that is, a bright central maximum surrounded by a series of diminishing concentric rings as shown in Figure 1. The x and y coordinates are spatial, the z coordinate is light intensity. The size of the spot is determined by the f number of the optical system, that is, focal length divided by aperture. The size is defined as the diameter of the first dark ring.

The light from a laser source does not have uniform intensity distribution across the beam but is ideally gaussian. The spot which is formed also has gaussian distribution and therefore has no dark rings for specifying spot limits. A more practical definition in laser work is to define the spot size at the points where the intensity falls to 10% of maximum. Thus even though the distribution is not of ideal gaussian shape, the size definition is practical.

The envelope of the ray bundle forming a diffraction limited spot may be represented by a hyperbola of revolution as shown in Figure 2. The effective spot diameter d_e (at the waist) is given by:

$$d_e = k\lambda f = \frac{k\lambda F}{A}$$

where f is the working f number at the lens (or focal length, F, divided by beam aperture, A), λ is the wavelength of light, and k is a constant depending on intensity distribution and method of defining spot size. If size is specified at the 10% points, then $k = 1.33$ for an Airy disc and 1.27 for a gaussian input beam the size of which in turn is specified at the e^{-2} points.

In a scanning system, however, the spot is in motion. The recording medium observes an integrated effect of spot distribution in the direction of scan. The cumulated exposure in the center increases thus *reducing* the effective spot size (i.e., the 10% points shifted closer together). On the other hand, the spot size may be *increased* if the lens aperture is not sufficiently larger than the input beam size to avoid excessive cutting of the distribution skirts. Consideration must also be given to depth of focus when working with small spots. The focal depth is proportional to the square of the spot size. A spot as small as 40 μinches may increase by about 10% in a distance of 20 μinches whereas a spot of 200 μinches has a focal depth of 5000 μinches for a comparable change.

The light power in the spot required to effect a recording exposure depends upon spot size, recording bandwidth, and sensitivity of the medium. Spectrographic type films at 50 megahertz bandwidth require about 0.1 to 2 milliwatts in a 200 μinch (5-micron) spot to develop a density of 1.0. Present direct print-out photochromic materials on the same basis would require 2 to 5 watts of light power.

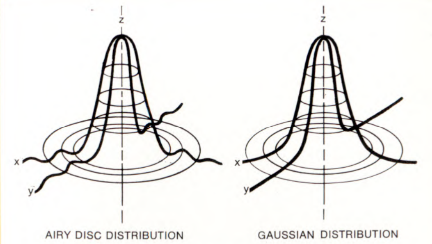


FIGURE 1

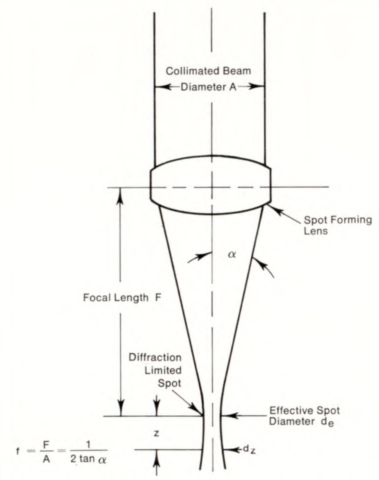


FIGURE 2. Spot Forming Schematic

SCANNING

The most effective present method for wideband recording is that of successive scans across the width of the recording film while it moves lengthwise. Each scan line may include several thousand spots or bits; a 5-micron (200-μinch) spot would produce over 10,000 spots per scan line on 70-mm film, and over 22,000 on 5-inch film.

Several electrical methods for producing scan line deflections of light beams have recently been demonstrated on a laboratory basis. These include electro-optical methods employing changes of refractive index or birefringent switching, acoustic interaction with light, and interferrometric techniques. All such methods are presently limited to a few hundred spot diameters deflection; none seems yet feasible for thousands of spot deflections.

Mechanical scanning methods presently show the greatest promise. Such scanning is effected by mechanical rotation and may be classified into three fundamental categ[illegible] based upon the location within the spot forming ray bundle that scanning deflection is introduced. The method found to be the most capable of long scan lines at large bandwidth with the least optical and mechanical scan line distortion is entrant scanning, in which the ray bundle enters a fixed lens in such a way that the bundle always passes through the lens pupil while the entrant bundle scans through an arc. A typical system capable of 50-MHz bandwidth on 70-mm film may employ an octagonal mirror rotating at 67,000 rpm and supported on air lubricated bearings to insure positional accuracy.

MODULATION

A successful method of modulating laser beams utilizes the linear electro-optical effect of suitable crystalline materials. Suitable configurations of such crystals will produce a rotation of light polarization with applied voltage as a beam traverses the crystal. The polarization rotation may be made linearly proportional to applied voltage. To convert to an intensity change requires passage of the output beam through a polarizer. This latter conversion, however, is not linear but follows a sine-squared function. By biasing the modulator crystals at the midpoint of the sine-squared curve, a region of adequate linearity for data recording may be obtained. Figure 3 shows the harmonic distortion introduced by the modulator as a function of peak signal amplitude normalized to the half-wave voltage. Modulation of 60%, which corresponds to a factor of four from minimum to maximum light, introduces 4% distortion.

In a Lithium Niobate modulator developed at Ampex, correction circuits in the driving amplifier maintain total harmonic distortion to within 1½% for the 4:1 intensity range. This modulator takes 130 volts to cover the 4:1 range, is flat within ±½ dB from dc to 6 MHz, and requires driving power of 0.4 watts per megahertz of bandwidth. The modulator has been driven at bandwidths of over 100 MHz. The state of the art of electro-optic modulators is such that they are no longer a limitation in recorder design.

RECORDING

In the data recording process we consider the storage of electrical signal information for later retrieval and linear conversion to substantially identical electrical signal information. The recording medium (photographic film) is, however, not linear. A typical transfer characteristic for photographic film is the D – Log E curve (i.e., density, versus log exposure) as shown in Figure 4. The straight line portion of this curve may be represented by:

$$D = \gamma \log E$$

where γ is the slope of the straight line portion. Now if we consider the exposure E to be proportional to the input signal e_i, and the transmittance T of the recording to be

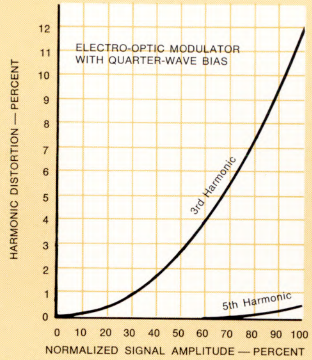


FIGURE 3. Distortion for Biased Electro-optical Modulation

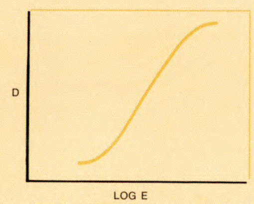


FIGURE 4. Film Transfer Characteristic D-Log E Curve

proportional to the readout signal e_o and since:

$$D = \log \frac{1}{T}$$

then:

$$\frac{1}{T} = E^{\gamma}$$

and we may write:

$$\frac{e_i}{e_o} = k\frac{E}{T} = k\,E \cdot E^{\gamma} = k\,E^{\gamma+1}$$

From which it is apparent that to make e_o linearly related to e_i, γ must be –1. The negative value of γ dictates that the recording be a positive rather than a negative process. The curve of Figure 4 represents a negative process which would require making a print to attain a positive. The record/readout process has higher quality if the recording is made on a direct positive film.

The size of the spot limits the spatial bandwidth of the recording medium. The spatial bandwidth is measured in line pairs per millimeter (or cycles/mm). Figure 5 shows the modulation transfer factor for square wave response of the product of spatial frequency and spot size. Thus at a modulation transfer of 70% (3-dB attenuation) the $d_e\,f_s$ product is 470. This shows that a 10-micron spot would be down 3 dB at a spatial frequency of 47 line pairs/mm. The reciprocal of the $d_e\,f_s$ product (times 1000) gives the number of spot diameters per cycle for a given attenuation. Thus at 3-dB attenuation there are 2.1 (i.e., 1000/470) spots per cycle. These basic relationships are important in recording system design.

It is also important that a high degree of uniformity in spot size, shape, and intensity be maintained during recording. These factors are affected by variations in the amount of light reflected during the scan, by variations in the angle at which the spot arrives at the film, by the thickness of the emulsion layer, and by the precision of film positioning at the focal surface.

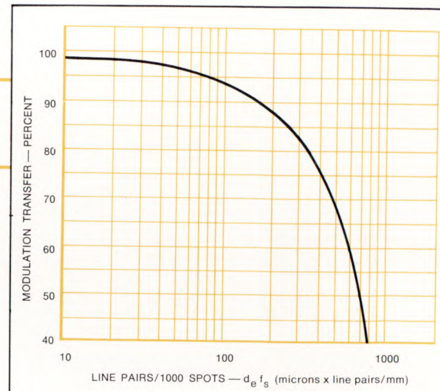


FIGURE 5. Square Wave Aperture Response

READOUT

Recorded data, to be of value, must be capable of retrieval. Considerable work on data readout by line tracking has been done by electron beam and many of the techniques developed are applicable to laser beam readout. Besides the ability to lock-on and track the recorded line during readout, errors caused by changes in the film due to processing, errors caused by variations in film transport, and errors caused by optical inaccuracies must be handled by the line tracking system. This requires means for small rapid spot deflections both in the longitudinal and transverse directions.

Certain electro-optical materials such as Lithium Niobate, Barium Sodium Niobate, etc. enable beam deflections through 3 to 5 spot diameters to be made at megahertz rates. In the film travel direction, however, deflections of perhaps 30 to 50 spot diameters at much lower bandwidth are required to maintain synchronization between the transport servo and scan line position. This can be obtained by electromechanical means. A combination of the two is indicated.

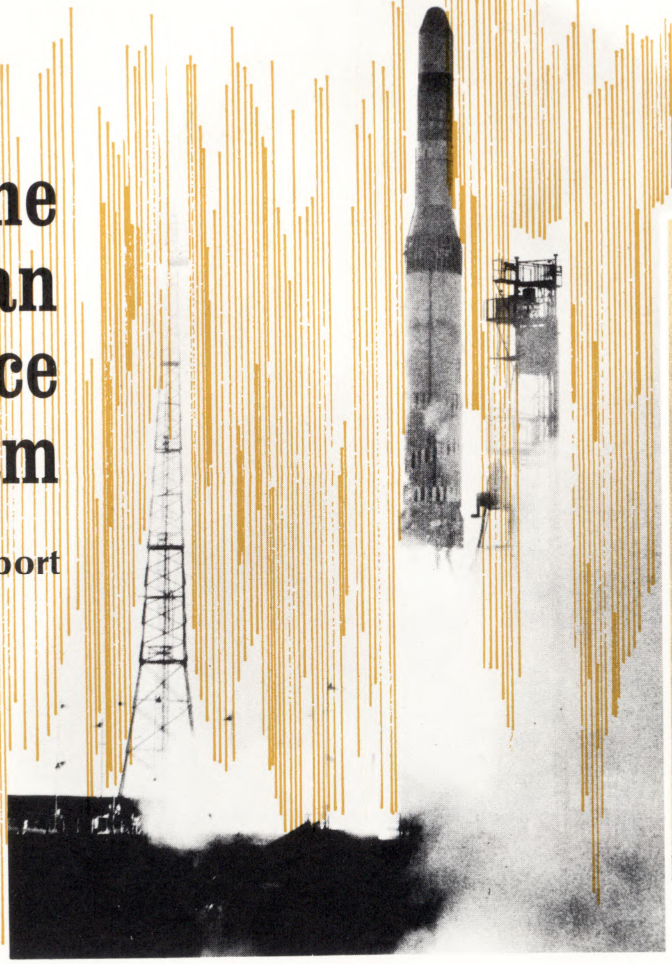
In order to maintain data continuity during readout, a small amount of data overlap can be provided at the line start and end, but then a switching function is required similar to that employed in magnetic recording. In laser readout however, two switching operations per line are required. One photodetector observes the start and a little more than the first half of each line, while another observes a little more than the remaining half and the end of the line. Switching between them then takes place in one direction at the line center and the other direction at the line end. Techniques for time base correction through the use of pilots and delay lines can be employed which are similar to those used in magnetic recording.

CONCLUSION

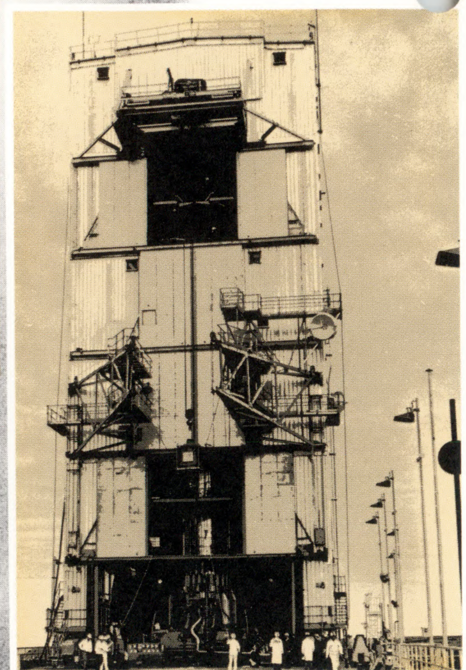
The added availability of light coherency from a laser permits the use of a new dimension in laser readout. Special techniques of data recording and readout utilizing the interference of light similar to that employed in holography is already showing great promise in faster data access, data analysis, and data processing. Instrumentation for data storage, retrieval, and analysis by laser beam is still in its infancy but it appears destined to occupy a significant position in future systems.

The Italian Space Program

An Introductory Report



The ELDO Europa I Vehicle during the first phase of the F6/1 Launch from Woomera Range in Australia.



The tower at the Woomera Range.

IN ITALY, the descendents of Galileo and Schiaparelli are carrying on the rich tradition of advanced research in astronomy and astrophysics. Today, Italy is engaged in several major and a host of smaller space research projects. It has created its own national program, the San Marco Satellite Project. For the multi-national ESRO and ELDO space programs, Italy designs and instruments the satellites. It was among the first nations to cooperate with the United States on several important programs, particularly on communications satellites.

Italian space research is not coordinated by a single agency. Instead, private companies, government agencies, and universities work together in a cooperative effort. In the private sector, LABEN in Milan (Laboratory for Electronics and Nucleonics), supplies on-board and ground PCM telemetry equipment and reduces data from the ELDO program. For its data reduction, LABEN has developed a telemetry processing system using an Ampex FR-1200 recorder and two TM-7 digital tape transports. Final output of the system is a tape containing test data in a computer ready format.

ITALIAN SPACE PROGRAM: National and International

Italy's tradition in space research goes back many centuries: in 1966 the city of Florence celebrated the 500th anniversary of Galileo's birth. While boasting Galileo's genius, Italy also takes pride in the work of other scientists and astronomers. Schiaparelli discovered the "channels" of Mars. Cassini and Fontana first observed the stripes of Venus.

Italian research is now going forward in many areas: satellite design, launching, orbital and re-entry physics, telemetry, balloon flights, weightlessness, celestial mechanics, solar wind and plasma, radio propagation, auto modulation in the ionosphere, communications theory, a joint study with the Mt. Wilson Observatory on solar corona, radio telescopes, and optical tracking of satellites.

Besides its extensive cooperation in multinational space programs, Italy has mounted its own San Marco Project, an equatorial orbiting satellite. This ambitious effort is carried on as a joint venture with the United States space agency, NASA, and the Italian Commission for Space Research. Primary scientfic mission is a unique method of measuring upper atmosphere density at the edge of space.

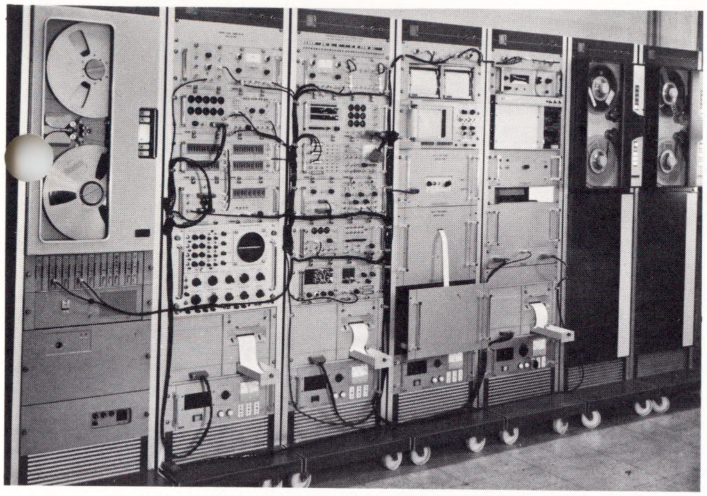
San Marco I was successfully launched in 1964, by a NASA trained Italian crew at Wallops Island, Virginia, on a Scout solid propellant rocket. Italy launched San Marco II in April 1967 (again with Italian crews using a Scout vehicle) from a sea platform located off the coast of Kenya. It scored three significant firsts in satellite research: the first equatorial launching, the first equatorial orbit, and the first launching from sea. San Marco C, to be launched from this site in late 1969 or 1970, will carry both Italian and NASA experiments to measure atmospheric density.

ELDO AND ESRO PROGRAMS: Multi-national Cooperation

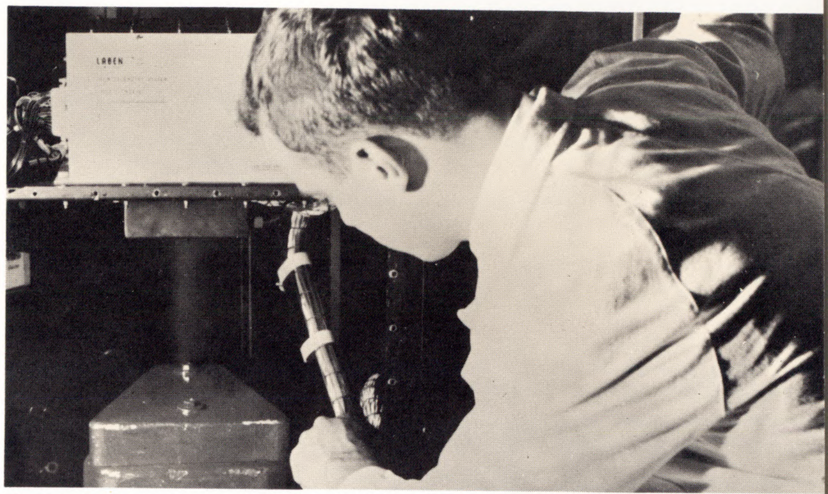
ELDO, the European Launcher Development Organization, was created in 1962 when seven nations banded together to built a three-stage launcher for heavy satellites. Great Britain is responsible for the first stage, the Blue Streak rocket; France the second stage; and the Federal Republic of Germany the third stage. Belgium supplies the ground facilities; The Netherlands the long-range telemetry; Australia the launching site at Woomera. Italy's role is to build and instrument the satellites and related ground telemetry equipment.

The ELDO launcher (to be operational in 1969) is called Europa I. It will place a satellite weighing about 1320 pounds in a circular orbit at an altitude of 344 miles. Being able to launch heavy satellites is important to Europe, particularly in its development program for telecommunications satellites.

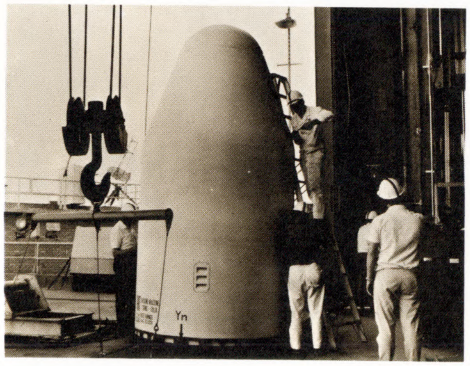
ESRO, the European Space Research Organization, was set up by ten countri in 1962: Belgium, Denmark, France, Ger y, Italy, the Netherlands, Spain, Sweden, Switz-



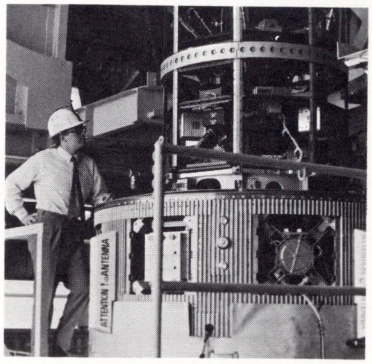
LABEN PCM Data Reduction System—Model DR1-EL—which uses one Ampex FR-1200 instrumentation recorder and two Ampex TM-7 digital tape memories.



Technician completes installation of LABEN PCM Telemetry Encoder in the Satellite of the ELDO Europa I Vehicle.



The fairings on the base of the tower at Woomera Range in Australia.



The Satellite of the ELDO Europa I Vehicle with two LABEN Vibration Analyzers.

erland, and Great Britain. Italy is contributing scientific instrumentation and participating in work on the first ESRO satellites. Projects include the ESRO I, a polar ionospheric satellite, and ESRO II, an astronomy satellite. ESRO II was fired in May 1967 by a Scout vehicle from the Pacific Missile Range in California, but failed to orbit. ESRO A will go up in 1968. ESRO C (TD-1), a stellar satellite, will be launched by a Thor-Delta rocket. These will be followed by additional scientific satellites

ELDO DATA: LABEN Telemetry and Reduction Systems

The first phase of the ELDO program is to develop a launch vehicle, launch communications and tracking technology; the second to orbit a satellite. After several static tests, the first test launch was made in May 1966, at the Woomera Test Range in Australia.

This launching was a test of the first stage Blue Streak rocket. The other two stages and the satellite itself were test dummies. In the test satellite (manufactured in Italy) on the first launch LABEN installed a PCM system, Model TL-64, to gain operational experience and test its check-out system, Model DCO-EL. This same check-out system was used on th[illegible]RO II launching.

[illegible]e next vehicle was static tested in November 1966. LABEN supplied a TL-64 PCM telemetry package, a vibration analyzer, the VA-66, and a check-out system, DCO-EL. Data from the static test was brought to LABEN for initial data analysis. Using an earlier version of its data reduction system, LABEN played these tapes back on an Ampex FR-1200 recorder, then converted the data to punched tapes, a time consuming operation.

For data from the follow-on satellites, LABEN's new reduction system (Model DR1-EL) adds two Ampex TM-7 digital transports which permit simultaneous processing of all parameters. With this system, PCM data is analyzed by playing back the tapes on the FR-1200 through LABEN Signal Conditioning equipment (Model EL135) onto the first TM-7. The serial PCM data and the clock information are recorded together with range timing information which is decoded and converted in BCD format by means of the LABEN Timing Code Translator Model EL235.

The resulting tape is in a digital format without inter-record gaps in it. Time correlated PCM data can be photographed for a quick look at this stage. Then it is played back from the first TM-7 through the LABEN Telemetry Processor onto a second TM-7 in computer compatible format. This processing phase is accomplished through a start-stop operation of the two TM-7's, to allow the gapped format tape to be produced without an interposed Telemetry Processor Memory.

Special tape speeds were provided on the TM-7's to allow such a "synchronous production" of a computer compatible tape. It is remarkable that an operative performance of the two TM-7 strictly within the specification charteristic is requested for this synchronous generation mode. The results were completely satisfactory after two data processings.

Preliminary analysis of the data from future tests will be required within two weeks after launch. According to the Data Reduction team at LABEN, "Magnetic tape recording, analog and digital conversion, and digital recording in computer format permit us to meet this schedule. On future orbital flights the increasing quantity of data involved will be handled by the higher performance and the greater flexibility offered by the new LABEN PCM Data Reduction System (Model DR2-EL) now under development. This new system includes a LABEN 4096x24 Magnetic Core Memory System in its Telemetry Processor."

As in several other European countries, Italy's LABEN has been able to look ahead and use some state-of-the-art developments in electronics and space technology. In the PCM Telemetry supplied for the second launch, the Model TL-66, conventional printed circuit boards are used in the analog section, but integrated circuits are used in the digital section. Latest LABEN PCM electronics, Model ML-67, uses integrated circuitry throughout.

Technical Information:
MANUFACTURING FERRITE CORES

By R. Bravo, A. Horowitz, and D. Webster
Compiled by M. R. Mraz and G. H. Ashbridge

Supplying coincident current ferrite memory cores for computers and related devices poses a broad range of technical problems. Not only have production schedules steadily increased for these devices in the past few years, but also the demand for faster and larger memories has led to sharp reductions in the core's physical size. Each part has to be manufactured to close dimensional tolerances and must meet stringent electrical requirements for several parameters. Thus it is apparent that many technological innovations have been required to permit mass production of several distinct core types each of which requires the close control of several process variables.

POWDER PREPARATION

As in any ceramic process, the first consideration is powder processing. The precise nature of the electrical response required in the final product precludes any deviation in a powder manufacturing procedure. There are about a dozen critical steps in powder processing alone, which places a heavy responsibility on manufacturing. Fortunately, the cost of raw materials is low, and tight screening for high quality powder (98% purity) can be economically maintained. The fact that each core consumes a very small amount of ferrite powder makes it economically feasible to fabricate the powder in relatively small batch sizes. For example, one normal sized production powder batch will produce between two and three million ferrite cores of the commonly used 0.030-inch o.d. and 0.022-inch o.d. sizes. The relatively small size of the powder batch also makes it feasible to have a core product line consisting of a variety of cores each requiring a different powder preparation process. This flexibility of operation then allows cores with a variety of electrical requirements and dimensional configurations to be fabricated economically. Also, the wide variety of memory cores fabricated for different computer requirements makes it more advantageous to have flexibility of operation, in contrast to a single powder process, since as electrical requirements change, and as the size of the core changes, each subsequent operation is affected.

Figure 1 is a typical flow chart for the ferrite memory core fabrication process. In actual operation some of the steps indicated in the flow chart are omitted and in some cases others are added. Typical calcining temperatures are between 450 and 700°C for time periods between one and two hours. Reacting temperatures vary between around 700 and 1100°C for approximately two hours. Press densities are between 3 and 4 grams per cubic centimeter. Sintering temperatures for both firing and refiring are optimized to obtain the best compromise of core properties.

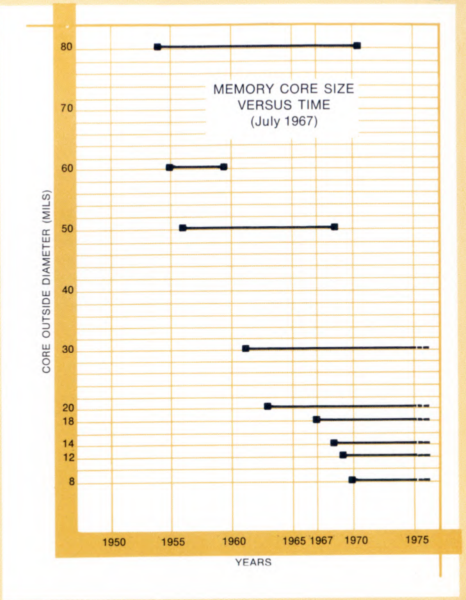
Strict in-process control is required in the following major areas: 1) chemical and physical properties of the raw material, 2) mixing and grinding time, 3) calcining time-temperature relationships, 4) screened sieve size for agglomerate size, and 5) binder and lubricant additions.

Ferrites are ceramic ferromagnetic materials with the general composition MO Fe_2O_3 where M is any of several metals such as iron, manganese, magnesium, nickel, zinc, copper, cobalt, lithium or (more generally) some mixture of these. During the fabrication process the ferrites are crystallized into the spinel structure which is determined primarily by the oxygen ion lattice. This crystal structure can be thought of as the closest possible packing of layers of oxygen ions with the metallic ions fitting in at either of the two kinds of interstices. Raw material purity is a necessity. A slight content shift in one of the constituents causes difficulty in finding the correct firing temperature, and makes it impossible to obtain the electrical properties required. Physical properties also must be accurately controlled to ensure correct grain structure during subsequent sintering and firing.

After raw material inspection, the next step in the powder prepartion procedure consists of an accurate weighing of the various metallic compounds required in the material formulation. Then, mixing is accomplished either wet or dry, to assure a homogeneous product throughout the operation. Calcining is performed to complete the reduction and dehydration of raw materials, and to begin the first stages of spinel formation. After calcining, the powder is mixed together with solutions of suitable binders and lubricants to form pressable granules. Screening these agglomerates to size completes the powder preparation. The screened size of the particles, as well as the apparent density and powder flow characteristics vary from one core type to another as well as from one core size to another.

PRESSING

Figure 2 shows how the dimensions of ferrite cores have been reduced as fabrication and wiring techniques become more sophisticated. Actually, the first modern ferrite was fabricated in 1946 with memory cores arriving on the scene about 1951 with outside diameters of 0.180 inch or larger. A major portion of present day production is concerned with cores whose dimensions are 0.030 inches o.d. by 0.020 inches i.d. and 0.022 inches o.d. by 0.014 inches i.d. Cores with dimensions 0.018 inches o.d. by 0.012 inches i.d. are beginning to appear in large quantities and one major manufacturer has 0.012 inches o.d. by 0.0075 inches i.d. cores in mass production. The density of the unfired core has a great influence on the optimum firing temperature for the core and a variation in pressed density makes it extremely difficult to find the proper sintering temperature for the core. Relatively fixed mechanical tolerances on pressing height and individual core weight have a greater and greater percentage effect on pressed density variations as cores get smaller and smaller. Pressing tolerances on present core types must be carefully monitored to ±0.0003 inches in height and ±0.010 mg in weight.



One major problem in pressing is high quality tooling. Tungsten carbide tooling is a necessity, but it does not lend itself easily to the thin walls required by core sizes, and the resulting strict dimensional tolerances. Uniform density of the carbide-tool material is a critical factor. Unfortunately, the highest density carbide does not have the best mechanical strength. A compromise is required to ensure adequate tooling life and to maintain dimensional tolerances. Holding good concentricity of the pressed core is also essential. Another requirement which extends carbide-tool fabrication time is that good surface finishes on i.d. and o.d. must be maintained. This is required to eliminate much of the punch breakage, sticking, binding or seizing that normally plague high volume press operation.

During operation, the presses must be extensively monitored. Every 20 minutes, the operator checks random samples of cores for height and weight, to ensure that dimensions are being held within specified limits. A visual microscopic check is also made to inspect for flash, burrs, or any unusual core conditions. It is essential that monitoring equipment be maintained with periodic inspections. Any deviation of the equipment tolerances could lead to the rejection of millions of cores for mechanical or electrical reasons. The pressing operation requires the full support of a tool service department, specifically experienced in maintaining this high caliber of tooling and equipment.

FIRING

The last step is the heat treatment (firing). Firing produces a dense ferrite with the required electrical characteristics. The time and temperature cycle in firing can influence the spinel phase relationships, stoichiometric ratios, grain size and shape, internal strains and density of the device. All of these parameters will affect the magnetic properties of the fired cores.

Typically, cores are fired in either periodic or automatic tunnel kilns. Periodic kilns require the presence of an operator to insert cores at the entrance and to remove them from the exit. Auto-

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matic tunnel kilns utilize limit switches and special rams to automatically cycle the core containers through the kiln. The kiln choice is essentially controlled by the firing cycle requirements of the core. This, in turn, is determined by the core size and the particular ferrite composition involved. Most cores are fired at relatively high temperatures for long periods of time. The majority of cores presently manufactured by Ampex are automatically fired at rates in excess of 2 million cores per day per furnace.

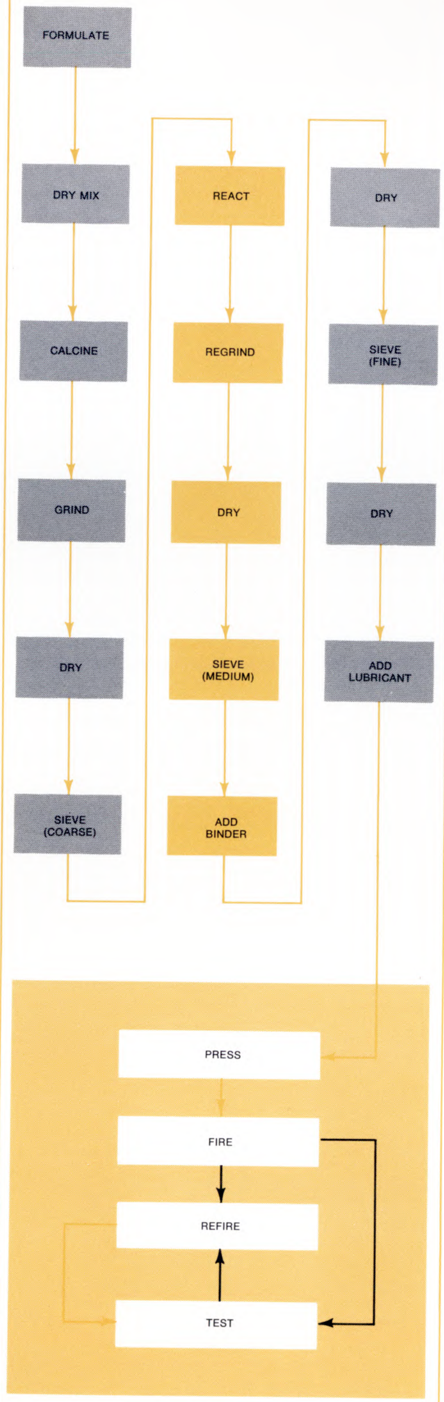
Precise control of furnace temperatures and rate of product travel, must be maintained, since these factors determine the overall temperature profile that the core experiences. A normal thermal cycle consists of a temperature plateau, a temperature decrease, and finally, a rapid quench. The quench takes place in 30 minutes and locks-in the necessary electrical parameters of the core. Severe restrictions are thus imposed on the containers carrying the ferrites through the furnace in order to prevent a high temperature reaction problem and breakage of the containers due to thermal shock.

Actual operation of the high production furnaces begins with test firings. Since the normal temperature profile has been specified in advance, the operator has only to make slight adjustments in the high heat and quench temperatures to produce a high yield product. Periodic electrical test readings are made to estimate the fired core quality once full production operation has taken place. Test equipment has been devised for this purpose which evaluates the fired product distribution, and provides a guide for possible furnace environment corrections. This piece of equipment is used for all core types and it is used to quickly relay large quantities of information to the operator as well as to the engineering staff. When the core batch has achieved optimized yields, the operator concentrates on loading techniques and taking sample dimensional checks on the fired cores. When a large batch attains a high yield quickly, the operator will usually not be required to make any changes during its run.

TESTING

The test operation follows three main steps: 1) pre-grade testing, 2) high speed core grading, 3) acceptable quality level testing.

Pre-Grade Testing. Samples of cores received directly from the firing kilns in fire lots (a group of cores pressed from the same material batch and fired simultaneously in the same container) are hand-tested on static test equipment to determine whether the fire lot has a high enough potential yield to warrant high speed grading. A minimum of 20 cores from each fire lot is individually tested on a pre-grade test station. The test is conducted in accordance with a specific storage core test specification and all data concerning specified output characteristics in order to guarantee that they are reproducible.



TYPICAL FERRITE MEMORY CORE FABRICATION PROCESS

Results of the pre-grade testing are analyzed by a core test supervisor who determines the estimated yield and then decides on the basis of the expected yield and the production requirements whether the fire lot should receive further testing. Accepted fire lots are then cleaned and sized before high speed grading. Cores rejected by the pre-grade test are returned to the firing kiln area for additional firing or destruction.

High Speed Core Grading. Fire lots accepted in the pre-grade test are then subjected to a high speed grading operation. The purpose of high speed grading is to make certain that all cores accepted by the high speed graders meet all of the specification values. Drive current settings and core output discrimination level settings on the high speed grader are at the discretion of the test supervisor. In general, these settings are at values higher than the test specification in order to be certain that grader noise levels do not allow reject cores to be transferred to the "accept" bottle.

As further insurance, the test supervisor periodically samples extracts from the "accept" bottle. Samples are tested on a semi-automatic station during the grading of each fire lot. If an intermediate sample contains rejected cores, grading is immediately stopped and the grader drive current settings or the output level discrimination settings are tightened. All cores from the "accept" bottle are then replaced in the grader input hopper. It is important that every core from every pre-grade accept fire lot passes through a high speed grading station and that the cores in the accept bottle be capable of passing the requirements of the Acceptable Quality Level (AQL) specification. Rejected cores are returned to the firing kiln area for additional firing or destruction.

Acceptable Quality Level Testing. In AQL testing, cores are individually tested at semi-automatic test stations on a special test jig. The operator visually observes the core output characteristics on an oscilloscope screen. All of the cores in the AQL sample must be tested for each characteristic contained in the test specification, which includes at least dV_1, dV_z, t_s, and t_p. In general, this will include more than one set of drive conditions at more than one temperature. Core fire lots accepted on the basis of the AQL test are transferred to the mechanical inspection area for tests. Mechanical tests are made to check the inside and outside diameters of the cores and to perform core fracture strength tests.

All fire lots accepted on the basis of the mechanical tests are then weighed to determine the actual quantity of cores present. The cores are then transferred by fire lot to production control for packaging and shipping. Core fire lots rejected by the AQL test are returned to the high speed grading area for a tightened grading operation. If the anticipated yield is not satisfactory, then the rejected fire lot must be returned to the firing kiln area for additional firing or destruction.

When you buy tape for your own recording uses, be sure it's the kind of tape you'd choose if you were a professional.

What do the pros look for? Quality. Consistency. Dependability. They recognize that the least expensive element of tape recording is the tape. Buying cut-rate tape can blow the sound investment you've made in all your equipment.

Ampex has been the quality standard for tape recording since we perfected it in 1947. Men who make a living doing what you do for fun know that we demand the very top performance from our recording equipment. Same goes for all the magnetic tape we make for you.

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