LIBRASCOPE | TECHNICAL REVIEW

FALL | 1959

Inside | *A computer joins the flight crew*

A NEW PHILOSOPHY

The tremendous growth of scientific and technical knowledge in the past two decades has led to substantial advances in virtually every field of technological endeavor. In the computer field alone, the avalanche of new ideas and techniques has been overwhelming even to those most intimately concerned.

How to keep abreast of these developments is a matter of vital importance to a broad segment of industry and the military, for prompt utilization of state-of-the-art advances can provide the user with significant economic and strategic advantages.

The problem is essentially one of communication, of disseminating information to the proper audience in time to be of value.

Librascope, Inc. has been active in the computer field for more than 20 years, and its programs over that period have embraced every phase of computer technology. We believe that portions of our work are of sufficient interest and importance to warrant presentation to a rather sizeable technically oriented audience.

The Librascope Technical Review, which makes its debut with this issue, is being published to keep its readers informed on noteworthy research, development, design and production activities of Librascope, particularly as they apply to the computer field.

Lewis W. Imm

President

LIBRASCOPE TECHNICAL REVIEW

FALL 1959 VOLUME I NUMBER I

CONTENTS

The LIBRASCOPE TECHNICAL REVIEW is published quarterly by Librascope, Inc., a subsidiary of General Precision Equipment Corporation.

Send communications to Editor, Librascope Technical Review, 808 Western Ave., Glendale 1, Calif.

KENNETH J. SLEE *director, public relations and advertising*

COMPANY OFFICES:
808 Western Ave.
Glendale, Calif.

333 W. First Street
Suite 452
Dayton, Ohio

211 Wyatt Building
777 14th Street N.W.
Washington, D. C.

LIBRASCOPE — A GENERAL PRECISION COMPANY

THE GPE COMPANIES: GPE CONTROLS, INC. • GENERAL PRECISION LABORATORY, INCORPORATED GRAFLEX, INC. • THE GRISCOM-RUSSELL CO. • THE HERTNER ELECTRIC CO. • KEARFOTT CO., INC. LIBRASCOPE, INCORPORATED • LINK AVIATION, INC. • NATIONAL THEATRE SUPPLY CO. • SHAND AND JURS CO. • SOCIETY FOR VISUAL EDUCATION, INC. • THE STRONG ELECTRIC CORPORATION

art direction by Robert Thompson

ON THE COVER ... *Boeing's 707 jet passenger transport is typical of the modern jet fleet now being introduced by world airlines. This exclusive color photograph shows a 707 cockpit during flight. At left is the captain, on the right, the first officer. The flight engineer is right, foreground. The empty chair at the left is for the 2nd officer (3rd pilot). The tiny ASN-24 electronic digital computer, described in the feature article on Page 4 , is an invaluable tool for navigation, especially on trans-polar and oceanic flights of this type of airplane.*
Photograph by Librascope, Inc., courtesy of American Airlines.

A COMPUTER JOINS THE FLI

AT 35,000 feet and just one hour and fifteen minutes out of Idlewild, the navigation computer finished over 4,500,000 computation steps . . .

It had been performing navigation calculations from the moment the Paris-bound jet airliner had started its flight check-out. Now the miniature electronic digital computer presented the Navigator with the requested range and bearing to the alternate destination, Santa Maria in the Canaries, and continued monitoring the navigation aids and maintaining a continuous fix on the airliner's position.

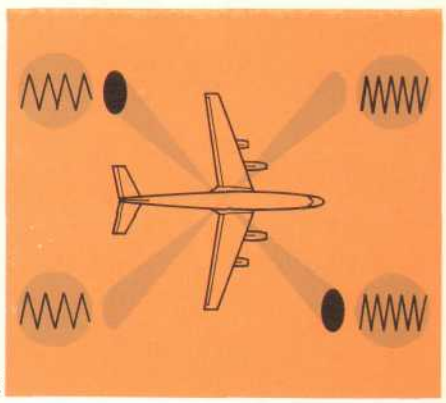
Freed of the routine but highly complex computations required to navigate the aircraft from New York to Paris, the jet's Navigator continued his most important duty, using information received from the computer to make decisions that would insure his airliner's safe arrival at Orly Airport in France.

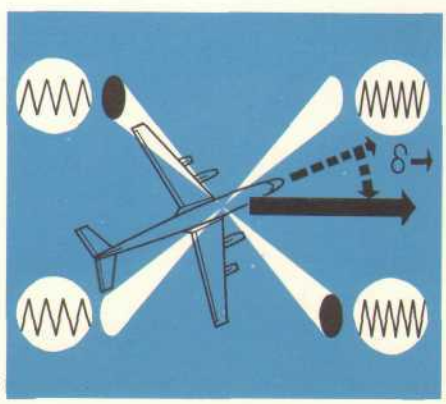
The performance and capabilities of commercial airliners have changed radically with the introduction of the jet engine. Aircraft now fly higher and farther at speeds approaching that of sound forcing changes in the activities of the flight crew to match improved aircraft capabilities.

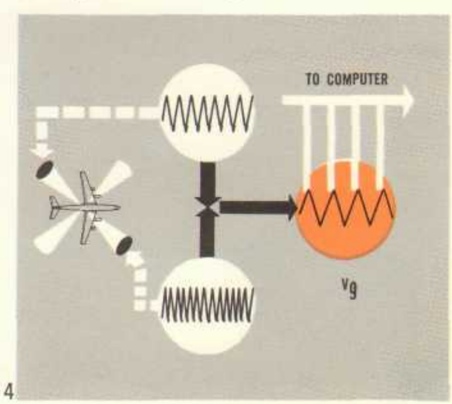
More than ever before, flight crews must possess the ability to make high-speed decisions based on information gained through rapid observation and evaluation of flight conditions from flight aids. Air speeds approaching Mach 1 leave jet crew members little time to ponder and weigh flight decisions. This

HT CREW
U N I O N
URAL MOUNTAINS
Kara Sea
Barents Sea
Queen Victoria Sea
FRANZ JOSEF LAND
SVALBARD
FINLAND
Gulf of Bothnia
SWEDEN
NORW
Baltic Sea
Leningrad
Moscow
Helsinki
Stockholm
Copenhagen
Warsaw
Kiyev
Murmansk
Arkhangelsk
ICELAND
Reykjavik
Denmark Strait
GREENLAND (DEN.)
Baffin Bay
Davis Strait
Atlantic Ocean
ELLESMERE
BAFFIN ISLAND
VICTORIA ISLAND
Lincoln Sea
Foxe Basin

1


2


3


4


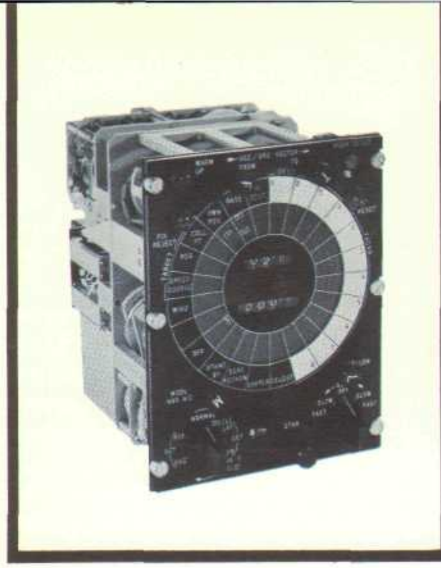
1. *Weather dictates flight path.*
2. *Doppler radar furnishes ground speed and drift angle.*
3. *Cross wind drift causes Doppler frequency changes.*
4. *Doppler determined ground speed is fed to computer.*
5. *Computer uses time delay information from LORAN to make position fix.*
6. *Computer determines probable error in dead reckoning, and LORAN position fixes.*
7. *Computer applies credibility criteria and weighting function to LORAN fix to arrive at best estimate of position.*

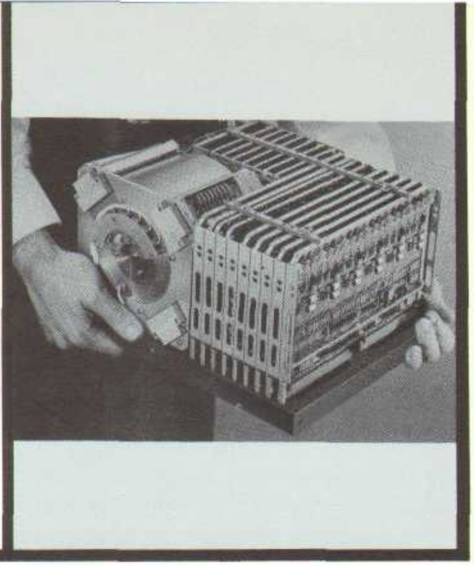
is critically true in the case of the Navigator where each second lost in unnecessary deliberation means one-sixth of a mile difference between the actual position of the aircraft and the calculated position. With the extended ranges and increased fuel consumption of jet aircraft the smallest delays can seriously effect the economy and safety of the flight. These factors will assume even greater import as commercial aircraft speeds push beyond Mach 1.

Radio ranges, LORAN, TACAN, doppler radar, celestial tracking devices, and gyro compasses have been developed to boost the speed and accuracy of aircraft navigation, but the final responsibility for interpreting data from these aids and the use of the information to keep the plane on course still rests with the Navigator. Also, while navigation aids can be relied on to provide the right information they do little to reduce the total number of computations required to solve navigation problems.

The computer's role

The role of the electronic digital computer as a member of the flight crew of modern airliners is that of assisting the Navigator in the performance of his





vital functions. With the computer doing time consuming routine work, the Navigator is freed to make decisions without distraction. He has time to keep up with navigation problems as speeds increase and tolerances decrease. And he can utilize a number of more sophisticated navigation techniques.

At the crew briefing session, the Navigator receives the information from which he prepares his navigation flight plan. This information includes weather data, reporting points, ADIZ corridors, and alternate destination, which changes from flight to flight. The Navigator notes data needed by the computer.

During the preflight check-out the Navigator feeds the data from the briefing into the computer. Already locked in the computer's memory are the equations it must use in making the navigation computations. It also stores tables of magnetic variation and deviation, for the entire Earth, as functions of aircraft position and heading, LORAN station coordinates, TACAN station positions, and the hour angle and declination of 57 stars to be used in celestial navigation.

As the Navigator feeds the new information into the computer, the computer itself is already sampling the various navigation aids and entering the data into the temporary storage portion of its memory. At the same time, it has begun the important self-checking of its myriad of logic circuits. Should any portion of the computer fail to respond correctly to the self-checking, the computer flashes a warning to alert the Navigator. The computer continues to check itself automatically throughout the flight.

Passing over the marker beacon after take-off, the Navigator sets the computer to give him dead reckoning positions. In this mode of operation the computer samples true airspeed continuously and uses the data, together with compass readings and wind information, to compute ground speed and true course.

The computer figures true ground speed and drift angle due to cross wind by using data from the Doppler radar. The Doppler radar transmits signals along four beams to the ground. The frequency of the signals reflected back to the radar vary in accordance to how rapidly the aircraft passes over the terrain. Drifting caused by cross winds causes frequency changes in the signals. The computer uses these changes to figure out the force of the cross wind and the drift angle.

The drift angle and the true heading are combined to furnish the plane's true course. The ground speed is calculated and North and East velocity components are determined. These velocity components are integrated with respect to time to give the aircraft's position in latitude and longitude.

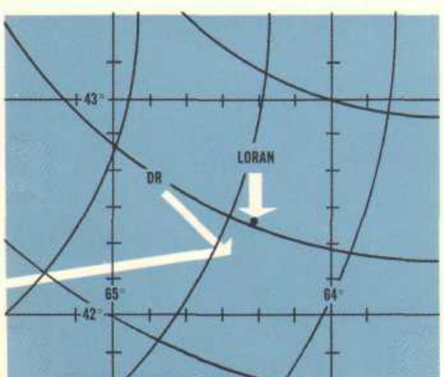
The wind speed and direction determined by the computer are stored, and in case the Doppler signal fails, they are used to calculate the ground speed and course.

The Navigator can examine the wind data at any time by querying the computer. Wind information is used by the Navigator for locating jet streams, comparing forecast with actual wind conditions, and for making wind reports.

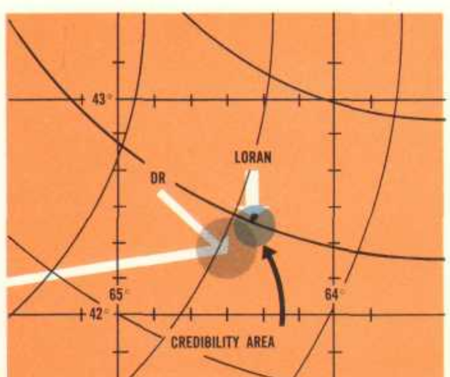
As a constant check on the dead reckoning calculations, the computer uses several radio navigation aids. Out over the middle of the Atlantic, LORAN is highly accurate and convenient to use. The positions of the LORAN stations to be used during the trans-Atlantic flight have been stored in the computer's memory and the Navigator can add the coordinates of additional stations at any time.

LORAN fixes the aircraft's position by determining the time delay between the receipt of radio signals from two ground based stations. A hyperbola represents

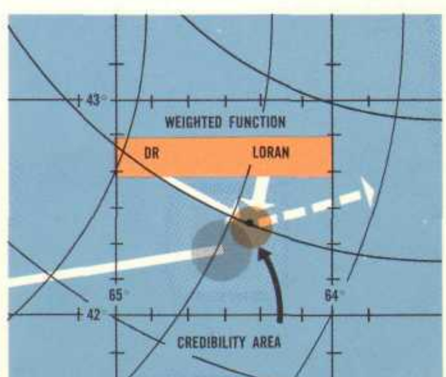
5



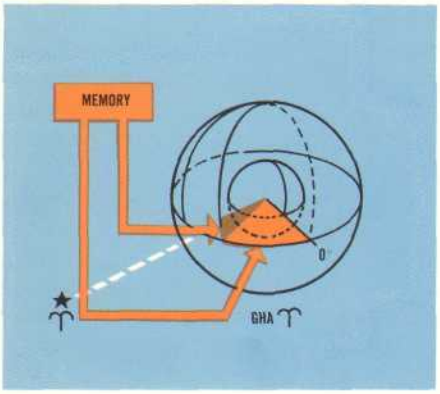
6



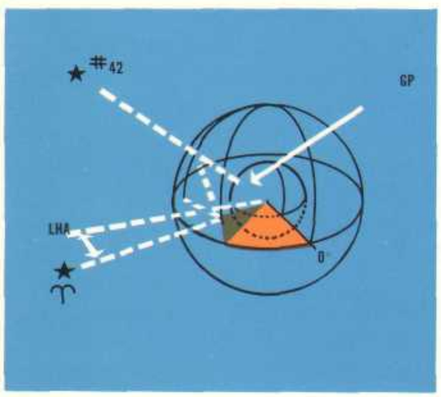
7



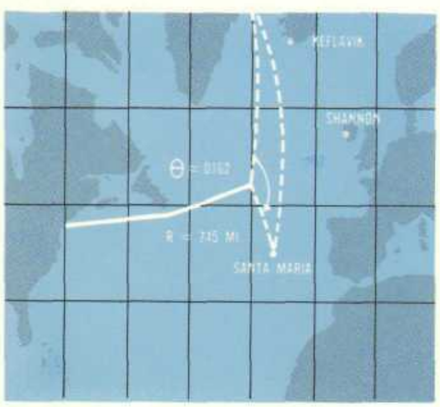
8



9



10



the locii of all positions that would have the same time delay. Operation of LORAN requires that two pairs of stations be used. The time delay for the first pair of stations is measured and the hyperbola representing this time delay determined. The representative hyperbola for the second pair of stations is also determined. The intersection of the two hyperbolas is the position of the aircraft since it is the one position that satisfies the condition of being the point where the two measured time delays exist simultaneously. Previously the hyperbolas representing incremental time delays were drawn on a map of the flight area and the Navigator had to determine the two time delays and find the intersection of the particular hyperbolas. With the computer to aid him the Navigator only needs to take time delays from the Loran equipment and feed them to the computer. The computer solves the problem mathematically, using the basic equations for hyperbolas, and quickly presents the aircraft's position to the Navigator.

When all these calculations were performed by the Navigator, he had to evaluate the possibility of errors in the readings; then decide between the accuracy of different positions given by alternate methods, such as dead reckoning and LORAN. The Navigator, from his experience with the accuracy of the navigation equipment and how it was working at the time, had to decide which position was right. Or he might have to make a compromise between the two to estimate the plane's true position.

This whole process of deciding between different position fixes is now done by the computer. Each of the position fixes (one from dead reckoning navigation and the other from LORAN) has some expected error which is a function of the distance and direction traveled and other variables according to the principle of navigation involved. The computer considers the peculiarities of each navigation technique, figures out the probable error in each position and checks for gross errors. It finds gross errors by examining whether the positions fall within the allowable error (statistically this is the 2 σ area) area of both the techniques. If the second position is beyond the allowable error for the first one, the computer continues to use the old position data, alerts the Navigator, and awaits his decision to accept or reject the new position information.

When both navigation techniques provide acceptable answers, the computer weighs the accuracy of the techniques and arrives at an improved position. The equations that govern this decision apply regardless of what navigation technique is used.

Far out over the ocean, the Navigator calls for a celestial fix by setting the number of the desired reference star into the computer. The computer maintains a store of the hour angle and declination of Aries and of 57 stars with respect to Aries.

Using the present position it has already determined, the computer estimates the star's altitude and azimuth, corrects for Coriolis force and atmospheric refraction and directs an automatic sextant to the star. When the automatic sextant locks on and begins to track the star,

8. *Hour angle and declination of Aries and 57 stars with respect to Aries are stored in computer memory.*

9. *Computer uses present position and chosen star's altitude and azimuth to direct automatic sextant.*

10. *Range and bearing to alternate landing spots are available upon demand.*

the altitude and azimuth of the star are fed back to the computer.

The star's altitude and azimuth are used by the computer to make another estimate of the aircraft's position which is checked against the positions fixed by the other navigation techniques. For further assurance of the position, the procedure can be repeated for another star.

The possibility of bad weather and other emergency conditions makes it necessary for the Navigator to keep in mind alternate destinations. For this reason the computer stores the positions of the alternate landing spots and can furnish the Navigator with the course and distance to these points at any time.

In the vicinity of Paris, the computer enters the final stages of the flight, continuing to monitor the position of the aircraft over France. Even as the airliner enters the landing pattern and starts its letdown, the computer is still watching the aircraft's exact position. The Doppler radar is still being monitored to determine wind speed and direction, in case weather conditions cause poor visibility. Like any other member of the flight crew, the computer stays at its job until the engines are silenced and the passengers begin to disembark.

Speed plus accuracy

In the six hours, or less, it takes to fly from Idlewild to Orly by jet, the computer will perform some 21,000,000 computation steps. In each computation the computer continually monitors the aircraft's position and determines distance and bearing to flight check points and alternate destinations. A typical computation is completed by the computer in one second. This includes sampling the navigation aid used as source for the information, performing the arithmetical portions of the problem, and presenting the information to the Navigator. The computer performs these calculations with errors as little as one part in 32,000,000.

By way of contrast, the same calculation would take several minutes of the Navigator's time and to match the computers' accuracy the Navigator would have to express his numerical data out to the sixth or seventh place. This is impossible on the basis of time alone. Using a slide rule, or even a desk calculator, the Navigator's probable error would exceed that of the computer by more than ten times.

The general purpose character of the digital computer is of special significance for it provides the flexibility and versatility needed to keep up with projected advances in commercial aircraft performance as well as with new developments in radio and general navigation techniques. All that is required to make the computer compatible with improvements or new developments is a change in the computer program directing it to perform the new computations needed to utilize the latest equipment and methods. The computer circuitry and elements remain unchanged. No one can appreciate the computer's speed, accuracy, and flexibility, more than the Navigator himself.

The ASN-24

The computer on this trans-Atlantic flight is no science fiction dream. It exists today and has been flying for more than a year. Designated the AN/ASN-24, the electronic digital navigation computer is the result of a development program co-sponsored by Librascope, Incorporated, and the Air Force.

Weighing only 31 pounds, the ASN-24 easily wins the title as the world's smallest general purpose digital computer. Volume is a mere 0.6 cubic feet.

The ASN-24 employs "general purpose" computing techniques which permit changing its computing functions simply by changing the internally stored program. The computer uses a magnetic storage drum memory, and employs only silicon junction circuits. Already life tested at 110° C for over 16,000 hours, the computer is highly reliable and has a mean free time to failure of over 500 hours.

As navigation aids become more sophisticated, the ASN-24 will be able to provide even more rapid and accurate calculations. The computer, as a member of the flight crew, brings airline flight even nearer to achieving clearly marked highways in the sky.

A. KERECHUK

COMPUTERIZING THE PROCESS INDUSTRY

Colorado utility uses LIBRATROL-500 for increased efficiency and profits

Processing requirements have become so complex and precise in many industries that the human operator no longer can produce the results dictated by quality standards and operating economies.

As a result, a swing to automatic process control is developing as the processors seek new ways to improve quality and increase production while reducing costs.

One concept that is attracting increasing attention from process industry managements is that of "computerized" process control. The LIBRATROL-500 industrial process control system, built by Librascope, Inc. and marketed by GPE Controls, Inc., embodies this concept.

The LIBRATROL-500 is designed for all three of the presently used computer control techniques: monitoring, computer-direction, and automatic closed loop control. In its basic mode, the LIBRATROL-500 monitors the processing operation. It compiles the various data from transducers, performs the required computations and presents the information to the process operator who then takes appropriate action. Specific data for management and accounting use are also tabulated.

The first computerized system ever used in on-line gas dispatching control utilizes the LIBRATROL-500 in this basic monitoring mode. The system will monitor gas flow meters at purchase points throughout the greater Denver area and the State of Colorado for the Public Service Company of Colorado and its subsidiaries.

It will compute the total hourly and accumulated demand for each hour of the day. The utility company is charged for gas on the basis of a fixed commodity charge, combined with a demand charge based on the highest daily peak demand recorded during a 12-month period. The computer information from the LIBRATROL-500 system will be used by the Gas Load Dispatcher to control these peaks to avoid higher demand charges than are absolutely necessary to serve the utility's requirements.

In addition to this on-line duty in the dispatching center, the computerized system will provide additional engineering calculations for other divisions of the Public Service Company.

Establishing supply charges

The cost of gas to the Public Service Company of Colorado is computed on a two-part rate. The two portions of the rate are the commodity component and the demand component. Each and every cubic foot of gas carries the commodity rate. The demand component is based on the peak demand established during any one day in a year and is then applied over the next eleven months.

If a higher peak demand is recorded during the next eleven-month period, the demand component is revised upwards to account for this increased peak demand. This revision would increase the charges to the utility over the following eleven months, or until a higher peak demand was recorded.

As operating expenses are adversely affected by increased demand charges, it is necessary to insure control of the peak usage within the gas system. The Public Service Company monitors their demand on a twenty-four hour basis throughout the year. Adjustments are made by interrupting service to certain industrial customers. To obtain preferential rates, these industrial customers must agree to curtail use if the demand to the area approaches the condition of exceeding the pre-established peak usage.

The Gas Load Dispatcher must monitor the hour-by-hour demand, anticipate unusual demand due to weather conditions, and evaluate the hourly load increase in terms of necessary industrial curtailment. By monitoring the static pressure, temperature, and differential pressure data telemetered in from the various purchase points in the gas system, the Dispatcher is able to compute the flow at each point and add these to determine the total system demand.

At the present time, the utility requires the monitoring of 44 different telemeters. The instruments from which the Dispatcher determines the flow at each point must be read hourly and the value of the flow computed. The number and complexity of the calculations involved consumes from 30 to 45 minutes of each hour's time. This is an extreme burden upon the dispatcher, who must also devote a large portion of his time to making decisions which will control the demand and maintain adequate gas supplies in the several systems under his supervision.

Computerized process control

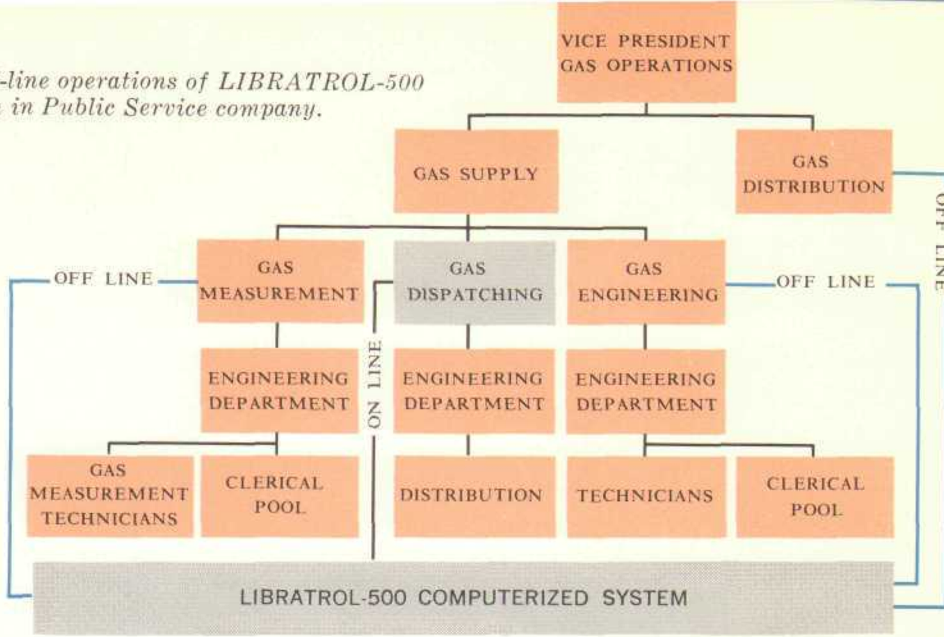
In optimizing process control, the key to success is matching data processing with the time-control requirements. Vast amounts of data, which reflect variations in the process, must be collected, analyzed and displayed to permit control decisions to be made in time to effect corrective and optimizing action.

When large numbers of variables with rapidly changing values are involved, the factor of time is especially important. Time lost in the preparation of data suitable for making decisions results in possible losses in quality, reliability, efficiency and safety.

The primary advantage of computerized process control is that it permits control decisions to be made at rates which match the time constants of the process and system involved. Since these time factors vary from process to process, and each process control situation requires control elements custom tailored to particular specifications, the LIBRATROL-500 system was developed to cope with the large number of variables and rapid computation common to the majority of process problems.

In assisting the Gas Load Dispatcher, the computerized system assumes the responsibility for monitoring the flow information, performs the calculations, and presents the demand data to the

On-line and off-line operations of LIBRATROL-500 system in Public Service company.



Dispatcher. This permits the Dispatcher to devote the major portion of each hour to the critical decisions affecting proper study and distribution of the gas.

The flow data for the computer is provided from circular chart recorders. Each recorder is fitted with a retransmitting potentiometer which generates an output voltage proportional to the value of the flow parameter being monitored by the recorder.

The potentiometer output feeds to a voltage-to-digital converter of the successive approximation type. The converter translates the input voltages into digital signals which feed directly to the computer. The time to convert the voltage from the retransmitting potentiometer into digital signals representative of the data value is only one millisecond. The digitizing process is initiated on command from the computer.

Computing demand data

A 72-channel commutator permits the computer to obtain data from any of the data sources on command. The 72 data sources consist of 55 retransmitting potentiometers, which provide static pressure, differential pressure and temperature data from the recorders. There are also twelve retransmitting potentiometers providing data from the telemetry system which monitors the Western Slope Gas District, and two channels which indicate that parallel runs at a given meter station are in operation. There are three spare channels for future metering operations.

During the sixth minute of each six minute interval in an hour, the computer samples each of the data sources for the differential and static pressures recorded at the flow meter. The square roots of the two pressure measurements are determined and stored. These values are used to form the square root factor of the flow equation. At the end of each hour period, the computer averages the square root values for each flow meter and checks the flow temperature. The averaged square root values and the temperature are used in the computation of the flow during that hour. In addition, at the end of each hour, the hourly flow and accumulated flow is presented to the Dispatcher. The flow accumulation cycle is repeated every 24 hours.

Basic to the calculation of the flow is the orifice factor which defines the relationship between the pressure measurements and the flow on the basis of the characteristics of the gas, of the flow meter, and the flow itself. The computer determines the value of this factor in accordance with the "Gas Measurement Committee Report Number 3" of the American Gas Association.

This formula for the calculation of gas flow from orifice meter measurements is:

$$Q_h = C'\sqrt{h_w p_f}$$

where:

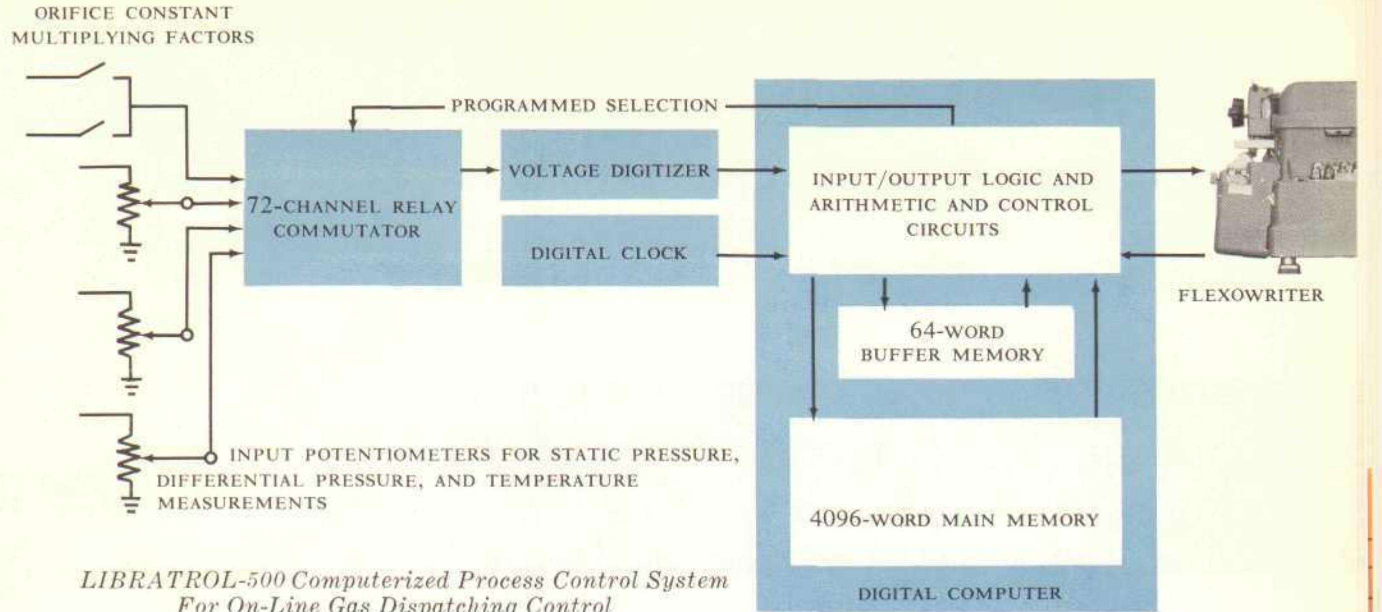
Q_h = quantity rate of flow at base conditions, ft^3/hr

C' = orifice flow constant

h_w = differential pressure in inches of water at 60° F.

p_f = absolute static pressure in psi.

This equation is solved by the computer each hour for each of the metering points. The values of differential pressures and static pressures are telemetered from the orifice meters at the purchase points. The square roots of the differential pressure and the absolute static pressure are determined by the computer



LIBRATROL-500 Computerized Process Control System For On-Line Gas Dispatching Control

for each metering point every six minutes and the average of the values over an hour period is used to compute the flow.

The orifice flow constant, C′, is defined as the rate of flow in cubic feet per hour under base conditions when the $\sqrt{h_w p_f}$ equals one. The orifice flow constant is a function on some nine flow and orifice parameters, all of which must be considered in computing the values of the constant.

The nine parameters affecting the value of the orifice flow constant are basic orifice factor, Reynolds number, expansion factor, pressure base, temperature base, flowing temperature, specific gravity, super-compressibility, and manometer factor.

These factors influence the value of the constant in rather complex ways and the computer has been programmed to compute the effects of the factors and the final value of the constant.

"Doubles in brass"

The extreme speed at which the computer can complete the monitoring and calculations involved in determining the demand leaves it with approximately five minutes out of every six free to accomplish additional computing tasks. To take full advantage of this, the utility is programming the computer to carry out the prime objective of demand calculations, and in addition, perform valuable engineering calculations for several other divisions of the Public Service Company.

A "time box" program has been established to set up a priority sequence of programs for the computer to follow. This program makes it possible for the computer to perform the monitoring and calculation during each sixth minute and again at the end of the hour. It then takes up additional computational work in the vacant five minutes between sampling periods.

One of the most important engineering problems which the computer aids in solving is the analysis and design of the gas distribution system. The multitude of various main sizes, which carry the gas to all points of the system, present a maze of paths, intersections and return paths which must be continuously analyzed to determine the effects of new service areas and new supply points on pressure and demand.

A mathematical technique called the Hardy Cross method formerly enabled the distribution engineers to analyze the overall system, but the method required a tremendous number of trial and error cycles of computations. On a time basis alone, the performance of these computations by the human dispatcher was virtually impossible.

While the computer cannot display the originality or creativity of its human operators, it does excel in the area of rapid and accurate calculation. For this reason the Hardy Cross technique is used quite successfully in the computer. Rapid and accurate analysis of the distribution system performance aids the Denver area by providing increased and more reliable gas service.

Ability to "grow" with demand

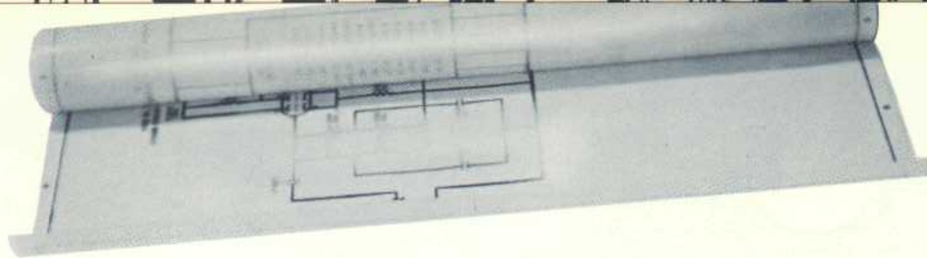
One of the big advantages of the LIBRATROL-500 system is that management may install the equipment at early and less sophisticated stages of process plant development, and utilize the results to install more fully automatic control as the process requirements are evaluated. In many cases, such a system could be utilized to monitor pilot and short runs to establish basic operating criteria.

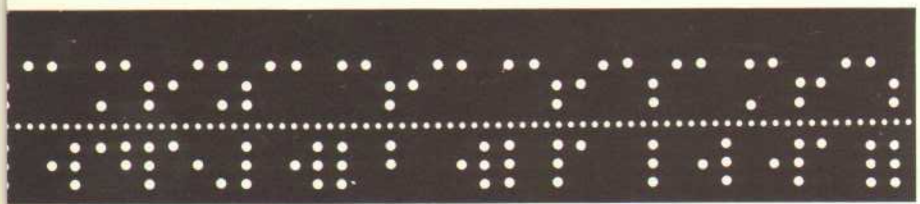
The system is used by the Public Service Company for the basic mode of monitoring and calculating. It may also be used for the more sophisticated computer-directed control. In that mode, the system is used to calculate, on the basis of data monitored by the instrumentation and information stored in the computer, what the optimum set-points in the process should be to realize maximum efficiency, maximum output, or to reach a desired condition in minimum time. This information is presented to the operator to permit him to alter the controls manually to meet the conditions directed by the computer.

In processes where the relationship between the primary and secondary effects of control variations are understood, the LIBRATROL-500 system is used in full automatic control of the process. With the control loop closed through the computer, automatic trimming operations are carried out by monitoring set-points and changing them as required.

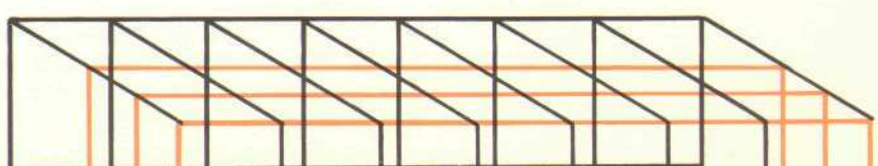
The LIBRATROL-500 computerized process control system incorporates a high-speed digital computer which was designed to handle three factors: a large number of variables, the requirement for intermittent information storage, and the rapid computation of process problems.

Backing up the computer is a wide range of input-output equipment which creates a logical controls system without excessive instrumentation. The control system is especially suitable for use in petroleum and chemical industries, gas and electric utility plants, in steel mills and the aircraft industry. A new, and growing, use is in atomic energy plants where remote control is a necessity.





Computer



The LGP-30 is manufactured for the Royal Precision Corporation by Librascope, Incorporated. It is sold and serviced by Royal McBee Corporation. Royal Precision Corporation is jointly owned by Royal McBee Corporation and General Precision Equipment Corporation.

-Planned Vacationland

ACROSS THE BARREN, sunbaked slopes at the edge of an inland sea, a caravan of trucks fanned out to predetermined positions. Surveyors, stakemen, graders and construction crews started work in the midst of orderly confusion.

Slowly from the rock punctuated landscape, a pattern of roads, utility lines and residential lots began to take shape. More than 20,000 acres began the almost overnight transformation from wasteland into an all-year residential and vacation resort.

The surveying crews, staking out the first units of 50,000 lots at California's immense Salton Sea project, were working from data supplied by a computer, 172 miles away in Los Angeles. The entire new California resort subdivision, including marinas, luxurious hotel and motel areas, bustling shopping centers and varied recreational facilities, has been computer planned and directed.

The Salton Sea project is the culmination of a cooperative effort of major Southern California real estate developers. Ten years will be required before construction is completed on the last building of the self-contained city located at the edge of one of America's only two inland salt water lakes.

At Treadwell Engineering Co., in Arcadia, at the edge of the sprawling greater Los Angeles metropolitan area, a Librascope-developed LGP-30 computer is daily performing the computations that would ordinarily require hundreds of engineering manhours to complete.

Awarded the contract for planning the giant subdivision, Treadwell was called upon to produce huge quantities of survey maps, grading and construction plans, and legal real estate descriptions. Vernon Jones, vice president in charge of Treadwell's electronic computer division, estimates that to turn these out manually would be almost impossible, especially with today's shortage of qualified engineers.

Treadwell must compute the area of each new tract in the subdivision and determine the most desirable size of individual residential and commercial lots. The Salton Sea project is a complete city, with industrial areas as well as business centers, schools and shopping areas conveniently planned for central access.

To make the most efficient use of the land, the computer adjusts lot boundaries and sizes to fit the master plan. After deciding how large each lot will be, the computer then insures that all survey markings agree with the government bench marks or monuments, the master references which dot the country.

Grading and construction plans are prepared by the computer from the designer's drawings. An important consideration is drainage. Even desert land is subject to short but heavy downpours that must be drained away without muddy pools or erosion.

Finally, county authorities require subdivision maps and legal descriptions for each tract. All of this computation is performed by a desk-sized LGP-30 general purpose digital computer.

The big advantage of using a computer for the engineering problems involved in subdividing such a large tract is first of all a savings in time. In dividing up a tract into 5,500 lots, for example, over 30 engineers would have been required to perform the computations. In the same time, 5 engineers and the LPG-30 did the same job—without the necessity for extra supervisory time to check for ordinary mathematical errors.

Treadwell switched over from manual solution of engineering problems to the computer operation in a few days. Information required by the computer is exactly the same that an engineer would need. The only special training for the engineers who work with the computer was a short instruction on punching tape for the computer. An LGP-30 uses punched tape for its instructions, although it typewrites the solutions.

Each engineer has his own tape typewriter right at his desk. As he figures out the physical dimensions he punches them onto the tape. Most of the engineers are so skilled at this now that they can prepare the punched tape as rapidly as they formerly prepared worksheets for manual computation. When the tape is finished, it is taken to the LGP-30.

As the tape is fed into the computer, all the mathematical operations are performed by the machine. Once all of the data is in the computer, it calculates the unknown values and prints the correct solution on an output form, or tape. The computer can be programmed to give the answer in columns, lines, or to fill certain blanks in a form.

Calculations handled with ease

The computation of lot traverses is one of the most demanding engineering problems in subdivision layout. It requires the highest degree of skill and the most time. Using the LGP-30 to solve traverse unknowns has reduced the time and eliminated the inevitable risk of human errors in calculation.

Treadwell is computing a number of different traverse problems for the Salton Sea project. Some require calculation of the length and bearing of an unknown side of a lot; others require finding two lengths when all bearings are known; or finding two bearings when all the lengths are known. Other problems solved by the computer are finding the length of one course and the

Computer-Planned Vacationland (continued)

Treadwell's Vernon Jones checks results typed out by the LGP-30

bearing of another. Error of closure (EOC) of a closed traverse, or the area of a lot must be calculated in many cases. All of these problems required many hours of painstaking hand figuring, then hours of patient checking to be sure there were no calculation errors.

The only hand operation needed in the figuring of traverse problems with the LGP-30 is the transfer of actual physical dimensions from a map to a tape. Where engineers once had to spend a lot of time looking up angular function values, working manual calculators and recording the results on special worksheets, the LGP-30 now does the entire job, and in only a fraction of the time.

In a typical problem at Salton Sea, the engineer starts out with a map of the area on which are recorded the measurements made by a surveying team. This includes data on the number of sides of the lot, the direction, bearing and length of each side.

The engineer types these out on his tape typewriter, which punches the symbols onto the paper tape in a language the computer can understand. He uses the same accuracy that was formerly required for hand calculations. Angles are recorded to the nearest second, and length is put down to the nearest hundredth of a foot. At the end of each complete problem instruction, he types a stop code which instructs the computer to hold the answer for use in a subsequent problem.

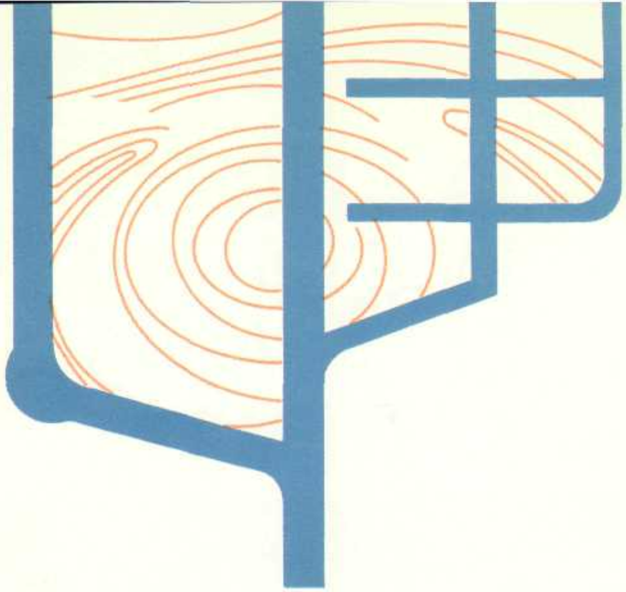
The typewriter produces both a typewritten page and the punched tape. The punched tape not only feeds the problems into the computer, but may also be filed for recalculation of the same problem at any later time.

The computer then computes all of the answers, and retypes the information on the original sheet, under the data which was typed while preparing the punched tape. This gives problem and answer on the same page and permits instant cross checking of the results.

Area can also be computed on a traverse, and this is usually given to the nearest hundredth of an acre for plots larger than one acre, and are given to the nearest tenth of a square foot for plots smaller than an acre.

Treadwell has programmed the LGP-30 to give answers to problems concerning traverses with as many as 64

Programmers translate information from drawings to tape for computer



sides. This number is sufficient for the largest and most complex tract found in subdivision work. With this type of program, Treadwell engineers may work with side lengths up to 8,192 feet and side bearings up to 90 degrees.

In one problem recently the time taken to prepare a punched tape for the LGP-30 was about five minutes. It then took about two minutes to feed the tape through the computer, and for it to complete its calculations, including printing the output. Although this is only seven minutes from the beginning of the problem to the printed solution, former hand methods by a skilled engineer would take about an hour, and still require additional supervisory time for checking the hand-calculated figures.

One of the biggest advantages has been the increase in accuracy of all solutions. By reducing the number of errors, the time required for rechecking the computer's figures has been reduced to almost nothing. The only check required is to be sure the taped instruction data to the machine has been prepared correctly.

Jones noted that morale in the Engineering Department has risen to a new high since the computer was installed. During rush jobs, engineers formerly had to work nights and weekends to finish mountains of calculations in time for engineering deadlines. Use of the LGP-30 has eliminated this by permitting more efficient scheduling, and by transferring the bulk of calculation time to the computer itself.

A major benefit to the company has been the ability to use a smaller staff of engineers more effectively. This small staff of highly skilled engineers utilizes the work capacity of a group of draftsmen that formerly required almost double the number of engineers feeding in data from which to prepare drawings and maps. The number of errors which were formerly encountered between the designers and the final maps have been cut to almost nothing.

As these maps are finished at the Treadwell offices in Arcadia, they are sped by messenger to the construction site on the edge of the Salton Sea. Here, graders and construction men turn the maps and plans into reality—a modern new all-year resort city on the edge of an inland sea, teeming with sport fish and providing year-round recreation—the city planned by a computer.

The LGP-30

DIGITAL EVALUATION OF ANALOG SYSTEMS

A new technique of digital data recording, for use in performance evaluation of complex analog computing and control systems, records data directly from analog devices within the system. Developed by Librascope, Incorporated, for acquisition of performance data during simulated "trial runs" of various analog systems built by the company, the technique involves recording the condition of a large number of variables in near simultaneous reference.

The analog system being considered here will generate a staggering amount of data during relatively short (20-30 minute) operating periods. A detailed evaluation of the data must then be made to determine the system's performance characteristics accurately.

A number of different approaches have been taken in collecting analog information for evaluation. Pen recorders and similar devices can be used to provide continuous records of the different variables within the system. However, arithmetical processing of the data is required for complete evaluation of the performance in respect to time, making the extraction of data from oscillograph records impractical for complex systems.

The most desirable technique for obtaining the information needed to assess performance is to convert analog signals directly to digital form, and to record, in virtually simultaneous reference, the digital data for the requisite number of variables. The recorded digital information can then be fed into a general purpose computer for rapid evaluation.

Such a recording technique, capable of monitoring up to 100 variables, has been developed by Librascope, Inc.

Data recording can be accomplished within a fraction of a millisecond. When considered with respect to the speeds at which the variables undergo change, the event and its recording are, for practical purposes, simultaneous.

To provide a finite number of discrete

data recordings, a sampling rate is establishing which will provide close tracking of the control system being monitored. The analog variables are converted to digital form by positioning binary-coded decimal shaft converters. A scan matrix is programmed to sample the data at the specified times and store it temporarily on a magnetic drum. The data is maintained in this buffer memory until readout circuits feed it to a high-speed tape punch. After the trial run is completed, the paper tape data may be converted to printed form by an electric typewriter, or may be used to prepare punched cards or magnetic tapes.

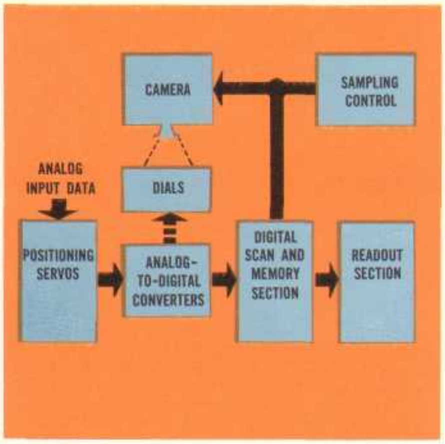
The technique is suitable for use with analog computers, and with analog control systems such as those used in missile control and guidance, flight simulation, autopilots, and in process control for the chemical, petroleum and petrochemical industries. Digital data recording has been used at Librascope as a method of gathering development information on new analog systems prior to finalizing designs for production.

Fire control evaluation

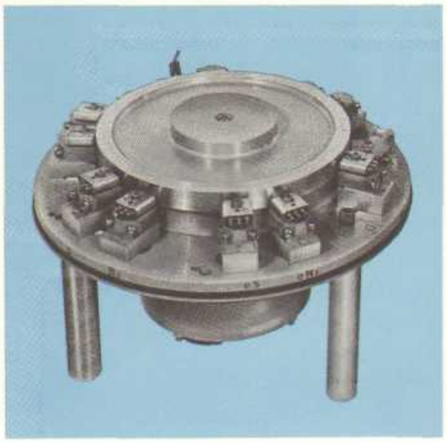
An excellent example of the potentials of such a recording technique exists in a special data recorder designed by Librascope to assess the performance of a U. S. Navy fire control system.

In order to evaluate the fire control system, a printed record is made of 20 analog variables at specified times during a trial run. Twelve of these variables are scanned and recorded at three-second intervals, and the remaining eight are recorded at the random occurrence of two events during the test.

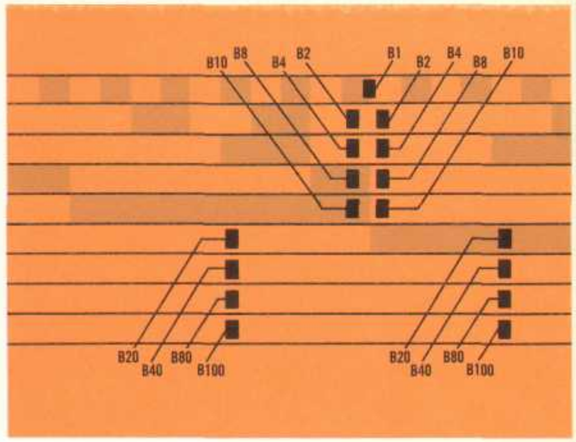
Twenty binary-coded decimal shaft encoders are used. A scan matrix samples the data from these at specified times. The data is then stored temporarily on a magnetic drum. Recirculating and readout circuits operate a high-speed paper tape punch to record the data



Block diagram of system



Memory drum turns at 3450 rpm



Commutator segment

from the drum. Following the trial run the punched tape is fed through a tape reader and put into printed form by an electric typewriter.

The twelve variables, monitored every three seconds, are scanned and recorded on the magnetic drum in approximately 0.8 millisecond. This interval, considered in relation to the speed at which the variables undergo change, is essentially simultaneous.

The analog variables are converted to a binary-coded decimal form for recording. This is accomplished with commutator-type, shaft-to-digital encoders. The values of 17 functions are transmitted by synchros, two are step-motor functions and time is generated with a synchronous motor.

Servos position both the analog-to-digital encoders and display dials. A camera photographs the dials at the same instant that the converters are scanned electrically. The camera provides an alternate record in case of malfunction in the digital scan and memory unit during a test.

To obtain the 17 synchro variables, the stator terminals of synchro generators in the fire control system are connected in parallel with the stator terminals of synchro control transformers in the recorder. The input signal to each servo amplifier is then taken from the rotor winding of the appropriate control transformer.

The amplifiers may be used in either 60-cycle or 400-cycle servo loops. Each amplifier has a crossover network for two-speed use. Each module of four amplifiers has its own separate, regulated power supply.

Four amplifier modules are used for 16 of the synchro signals. A special amplifier is used for the 17th, which is transmitted at 1100 cycles. This signal is demodulated and is converted to half-wave 60-cycle pulses, phased with the 1100-cycle signal.

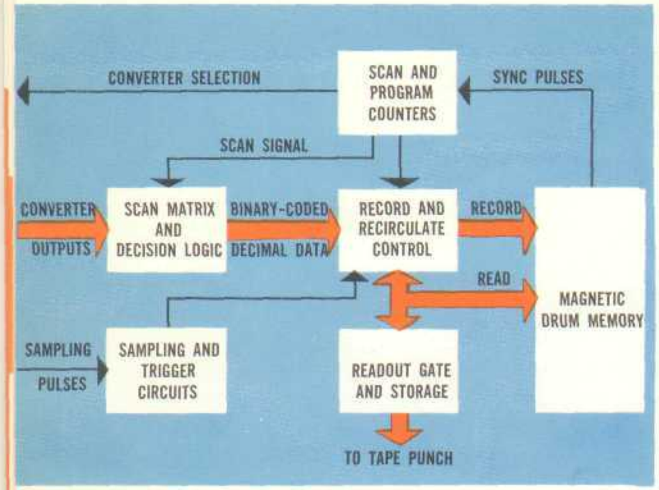
A disc-type shaft-to-digital encoder is used. The commutator-type disc consists of concentric rings which correspond to the weighted values of the brush locations. A binary-coded decimal (1-2-4-8) code is used. A two-brush pickoff system eliminates ambiguity. Each disc is divided into 200 divisions to produce coded numbers from 000 to 199. Encoders with larger output ranges are used for the time conversion in the system.

The encoder outputs are sampled by a high-speed scanning technique to provide parallel binary-coded decimal data. The scan and memory circuits are all packaged in the form of printed plug-in circuits. (Each circuit "card" is color coded for rapid identification.)

Input sampling and selection of signals from each of the 20 encoders must be maintained in a predetermined sampling sequence. A program counter designates 44-word intervals through a circuit of six flip-flops.

The scan and program counters operate continuously during a run. They are synchronized with the memory drum. Whenever a data sample is made, a record-recirculate flip-flop provides the time period required to locate the right data storage point in the memory.

The magnetic memory drum has 1584 engraved time points on the clock track. This is exactly six times the number of bits in the 44-word recirculation storage. Record and read heads on the four binary-coded decimal recirculation tracks are placed approximately 264 time points (44 words) apart. This provides an operating frequency of about 100 kilocycles. The access time to the number storage is about three milliseconds when the drum is driven by a



Scan and memory circuit diagram

Readout section showing typewriter and tape punch equipment

3450 rpm motor. This access time is only about 1/15 the cycle time of the paper tape punch, so no time is wasted in looking for new data to be punched. The tape punch operates at a speed of 24 digits per second.

The sampling control unit furnishes timing information for the recorder. A cam-microswitch is geared to the synchronous motor which drives the time converter. This circuit generates the three-second sampling command signals which are gated through the sampling control unit. Special circuits close relays in the unit to record the two random conditions which may occur.

Three sampling flip-flops provide synchronization between the more or less random sampling and the "clocked" electronics in the memory unit.

To get synchronization between the digital scan and memory section and the paper tape punch, an additional 44-word track is provided in the memory. This recirculation track is called the punch readout sync line. It provides one pulse positioned adjacent to each four binary-coded decimal digits punched by the tape punch. After each set of digits has been read into the tape punch, the pulse is stepped to the next set of digits. If the next digit location is blank, the pulse is stepped on until a location is found which does contain numerical data.

In Librascope's data recorder, it was decided to punch out only the continuous three-second samplings onto tape. Provisions were made to have the readout sync pulse to step through only the continuous data section of the memory. At the end of the run, the pulse is stepped through all three data locations to clear the memory.

A flip-flop circuit is provided to clear the readout sync channel and to locate a single pulse. This flip-flop is set high each time it receives an origin pulse. It remains high for one 44-word recirculation period, clearing the readout sync line and passing the single pulse in its proper location.

The numerical data is recorded by the least significant digit first. But the tape punch punches out the most significant digit first. The sync pulse is synchronized with the most significant digit, and then steps back to the least significant. The pulse stepping is controlled at the rate of one digit per step. When it is in line with an unused digit, it automatically steps on so that when the punch is ready for new data, the sync pulse will be adjacent to this data.

In order to print out on the electric typewriter, the punch tape must contain instructions for Tabulate and Carriage Return. This format control is normally used to print columns which will be easily read, with each containing successive values of a single analog variable.

The control signal for Tabulate is placed after each recorded variable except at the end of each group of three-second sampled data, where a signal for Carriage Return is placed. Such control signals are gated into storage flip-flops which correspond to the seven punch channels of the seven-hole paper tape used. Plate circuit relays are used to control the punch magnets according to the flip-flop storage.

When the memory drum is cleared at the end of a run, the special data recorded at the times of random occurrences is read off from those portions of the memory space where it was retained, and this information is punched out last on the paper tape.

The seven-hole paper tape is read by a motorized tape reader and the resulting coded signals are converted to six-hole typewriter code by a relay matrix in the encoder chassis. The output of the relay matrix then operates the electric typewriter. The motorized reader and the typewriter operate synchronously at ten digits per second.

The readout arrangements are not limited to a single tape punch. As many as six punches may be operated simultaneously to permit more frequent data sampling, increased volume of data, or to allow making parallel recordings.

Synchro amplifiers and mechanical follow-up sections may be eliminated where existing electro mechanical devices supply analog information. The analog-to-digital converters can operate directly from any shaft. Inputs to the digital scan and memory sections may be originated by converters or from other digital devices.

The output of the memory readout circuit can be recorded on magnetic tape or on punched cards as well as on punched paper tape.

MARKET RESEARCH

A necessity to keep pace with customer needs

A potential buyer of graphic recording equipment stood up in his office at a West Coast rocket engine facility, looked the visiting vendor in the eye and remarked, "Show me some equipment that's brand new from the bottom up. All you have here is a re-arrangement of circuitry encased in a two-tone painted frame. It won't do our job."

This is the reception greeting some of the nation's electronic sales engineers who try to "sell an old dog in new sheep's clothing."

Company policy which calls for modernization of existing equipment by merely modifying circuit design and mechanical structure leaves the firm's sales force literally "carrying the ball— to the competition's goal."

Naturally this approach isn't working. Sales are diminishing, with the orders going to those firms who specialize in seeking out and answering customer requirements. Positive information must be obtained about improving the capabilities of a product.

Aiding the engineering, sales and production force of any electronics company are marketing specialists who maintain constant surveillance on customer needs for a particular item. Time and expense must be invested in this procedure before a prototype unit can be designed. The competition dictates this principle.

Librascope, a leader in the early development of plotters and graphic recording instruments, keeps up a continual evaluation of the company's entire product line. A new X-Y Plotter is being introduced after marketing research determined that former units would be outmoded by customer requirements in the near future.

Particular procedures were adhered to before the new X-Y Plotter, Model 210, could be developed. An engineering team from Librascope explored the present state-of-the-art and these evaluations were studied and projected into the future plotter design. The team investigated all instruments in the plotter-graphic recorder market, noting advantages and disadvantages of each.

Resulting information was considered by an outside market research group composed of sales engineers familiar with X-Y Plotter user requirements. A special questionnaire, to gain information directly from operators of plotters, was distributed for determination of user requirements.

It was decided that a major operational feature would be a quick, accurate scale changing technique with scale expansion possible between each step. Push button scale switching with vernier control accomplished this.

This technique enables the operator to fill the entire trace area with between scale voltage inputs. The servo control loop gain was designed to be independent of the scale changes, insuring no "jump" when scales are changed.

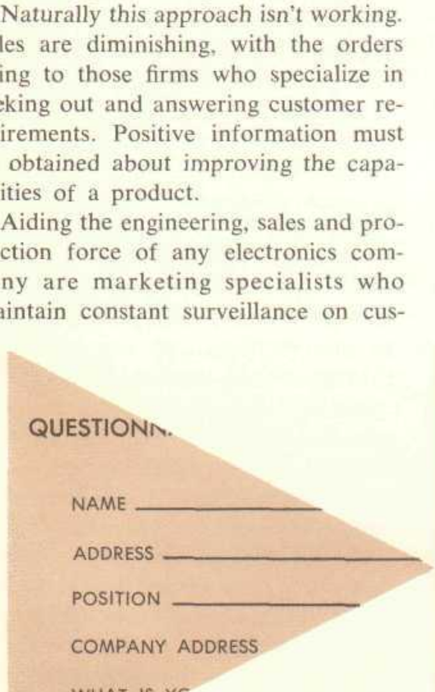
High plotting output accuracy was stressed with a static accuracy of $\pm.1\%$ of full scale, and a dynamic accuracy of $\pm.2\%$ of full scale at 10 inches per second tracing speed. Frequency response was designed to be flat to $0 - 1$ cps $\pm.2\%$ of full scale at 6 inches displacement amplitude.

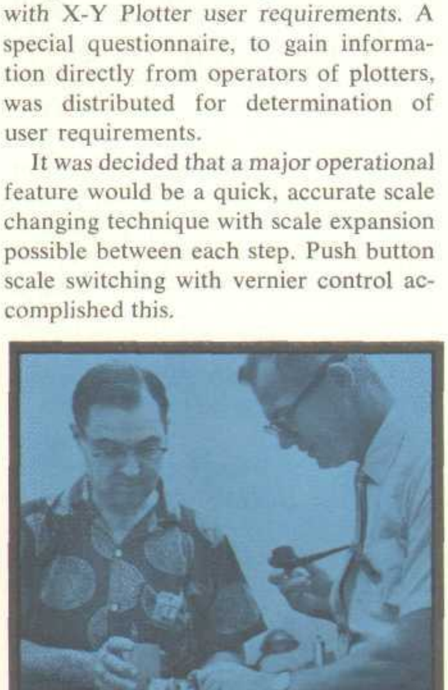
A major complaint in the questionnaires regarding earlier plotters was the difficulty in inserting paper under the plotting arm. Librascope engineers solved this problem by supplying a push-button control which automatically retracts the arm from the paper and moves it completely off the plot area. Simultaneously, input signals are locked.

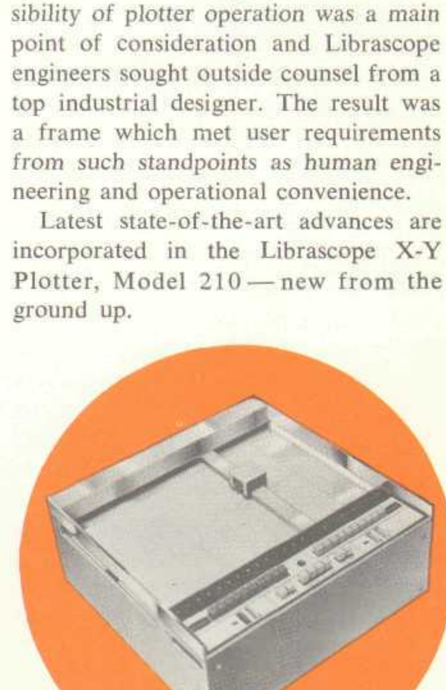
A vacuum platen answers the problem of keeping the graph paper in place with positive hold down characteristics.

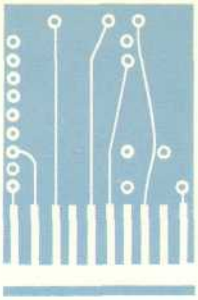
The exterior configuration and accessibility of plotter operation was a main point of consideration and Librascope engineers sought outside counsel from a top industrial designer. The result was a frame which met user requirements from such standpoints as human engineering and operational convenience.

Latest state-of-the-art advances are incorporated in the Librascope X-Y Plotter, Model 210 — new from the ground up.









"Progressive" quality control insures

COMPUTER RELIABILITY

RELIABILITY is one of the foremost considerations both in the design and the manufacture of electronic digital computers. Other considerations such as computer speed, accuracy and capacity lose much of their significance if the computer is subject to frequent operating failures.

This requirement for maximum reliability has led Librascope to institute a program of "progressive" quality control aimed at eliminating defective assemblies at the point of origin. This progressive inspection process permits discovery of defects almost as they occur with a consequent saving of labor and materials which might otherwise have gone into a unit which would not pass final testing.

Particular emphasis is placed on the quality control of the hundreds of etched circuit boards which make up the computer's complex electronic network. Relatively minor defects in the boards can result in intermittent or early operating failure after installation in the computer. With progressive inspection, these defects can be detected and the boards removed from the manufacturing process before additional time and materials are expended unnecessarily.

This sequential quality control has speeded production, produced more reliable computers, and saved thousands of dollars in production costs.

At Librascope's modern Glendale facility, where over 50 types and models of computers are manufactured, highly complex etched circuit boards are assembled with as many as three hundred miniature components. The "wires" that connect components are flat metal ribbons formed by photography and chemical etch processing of a copper-clad plastic sandwich (an epoxy resin and woven glass fibre laminate).

Many computer manufacturers purchase their boards from outside jobbers of etched circuit boards for subsequent component assembly. Librascope, however, in order to maintain high quality standards, purchases only the basic "sandwich" of copper-clad epoxy glass laminate. The manufacture of the etched circuit board is accomplished in Librascope's own newly established production processing facilities.

The manufacture of these is an excellent example of the progressive inspection sequence which has been instituted at Librascope. George Magurean, head of the Etched Wiring Processing Department, maintains a constant control of process conditions, as well as a progressive system of visual inspection of the boards as they proceed through their fabrication and assembly cycle.

Preparing the board

When the boards arrive at Librascope, they are visually inspected for general quality and possible shipping damage. Then they are cut to size and accurately punched in two places with location holes that remain in the board during the entire manufacturing process.

Once the basic boards have been cut to size and punched, the protective vinyl coating applied over the copper surface is stripped away. The boards are cleaned chemically to remove all residuals and surface impurities. Next, the boards are air dried and vapor degreased. At this point, the boards are again inspected visually to assure they are ready for the next process.

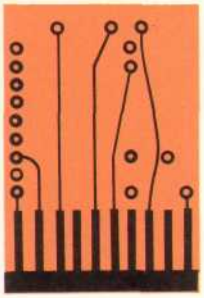
While awaiting further processing, the boards are cooled and stored in dust-free humidity-controlled cabinets. On removal from storage, the boards are dipped in a photo-sensitive emulsion resist which coats them with a film, much the same as in conventional photographic procedures. The boards are then air dried in their "storage" cabinets to a tack-free condition and inspected again to insure that the photo-sensitive emulsion resist coat was properly applied. At this point, the boards are baked in ovens to a maximum temperature of 160°F, and removed for storage in their dust-proof, humidity-controlled cabinets until needed again.

Photo processing

To attain the highest standards of accuracy and quality in its etched circuitry, Librascope uses a recent development in photo-template masters. A translucent paper photoplate is glued to a transparent acrylic plastic. This construction insures that the dimensional characteristics of the paper template will be unaffected by changes in atmosphere and temperature. The plastic backing is equipped with two locating pins that precisely match the two location holes originally punched in the boards to guarantee accurate registration during photo processing and subsequent fabrication operations.

The photo processing is semi-automatic. The photo-templates, together with the sensitized boards, are inserted into a vacuum frame, a timing clock is pre-set for just the right exposure selected for that particular application, and the vacuum frame with its contents is exposed to an actinic light source for the precise period of time required.

When the boards have been developed, they are removed from the vacuum frame and subjected to vapor degreasing techniques which remove the photo resist coating from the unsensitized or unexposed areas. At the same time, the process hardens the exposed areas. The pattern developed on the boards at this point is not readily discernible, since the photo-resist coating



1 *Printed circuit facility at Librascope, Incorporated, Glendale, California.*

2 *Chemical and plastic formulations are continually checked for precise control.*

3 *Each circuit board is painstakingly inspected and circuits are touched up.*

4 *Careful visual inspection is made of each negative at each step of process.*

is somewhat transparent. To provide an easily distinguishable and visual control for subsequent operations, special dyeing techniques are employed to coat the photo printed areas with a black dye, leaving the copper-clad unprotected in the remaining areas. The dyeing technique reveals at this point whether any imperfections have occurred in printing and developing. If any have, they will be clearly visible to the eye.

Solder plating

Now the boards are ready for solder plating in electroplating tanks. The solder plating achieves two major objectives: It provides a durable etching resist necessary for developing the final circuitry pattern, and it facilitates subsequent dip soldering operations.

By chemical procedures, the remaining photo emulsion resist is removed. At the same time the black dye comes off. After the solder plating operation, the boards are again closely observed by the operators to insure that the latest operation has resulted in no imperfections such as pin holes or misetched sections.

Etching

The boards are now ready for the etching process, which resembles chemical milling, or the preparation of engravings by a printer. Each board is mounted in a special fixture made of stainless steel and acrylic plastic. Both are resistant to the etching solution. The etching solution, a chromic-sulphuric acid, then eats away the copper portions of the board, while leaving the solder-coated parts untouched.

Extreme care must be taken in the etching process to avoid undercutting the deposited solder material by over-etching. This is achieved by precise control of the etching solution temperature and strength.

1

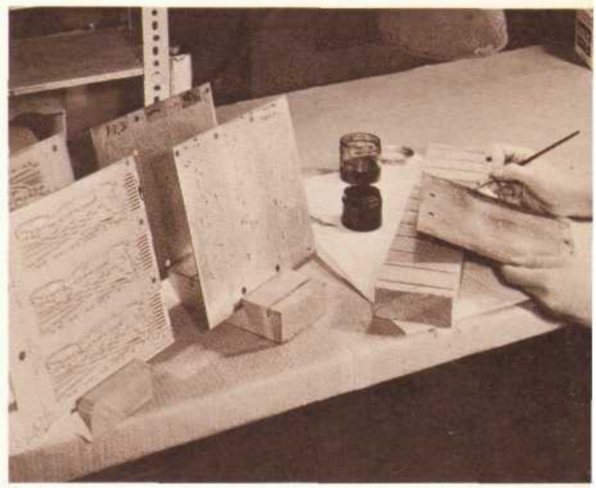
2

After etching, the boards are washed in mechanical rinsers to free them from the solution. Again they are inspected by the operator, after which they are ready for the nickel-rhodium plating.

Any area of the circuit boards that might be subjected to wear or abrasion such as the plug-in contacts is protected by plating with nickel-rhodium metal. This also minimizes corrosion.

Finally, the boards are thoroughly scrubbed with a mild abrasive detergent to remove any foreign matter, finger grease, oil or other foreign deposits. Inspection in detail follows the scrubbing, and the boards are sent to the hole drilling and fabrication operation as final preparation for component assembly.

The boards finally used in the many types and models of computers built by Librascope, may see service in general industry, in process control, in anti-submarine warfare, in photo-mapping, in navigating a jet, a missile or a space vehicle across the skies, or in any one of 50 different fields where Librascope computers perform reliably.



3

4

TODAY'S ANTISUBMARINE WEAPONS CONTROL COMPUTER

THE TIME: *Early 1940.* **THE ACHIEVEMENT:** *A small, compact ballistic computer for the U.S. Navy.* **THE RESULT:** *The beginning of Librascope's leadership in the design, development, and production of weapons and navigation control systems and components.*

Today, Librascope-designed and manufactured electronic and mechanical equipment for the MK 113, MK 111, MK 110, MK 107, and MK 105 underwater fire control systems include computers, attack directors, torpedo and missile angle solvers, attack plotters, depth plotters, position keepers, target motion analyzers, stabilization computers, roll and pitch computers, and various indicators and control instruments. ■ Librascope's simulation laboratories provide the Navy with a means for testing and analyzing the performance of equipment under "real attack" conditions. In the field, our engineers assist in the maintenance and improvement of Librascope systems.

SHIPBOARD COMPUTERS

COURTESY NBC-TV FILMS' "THE SILENT SERVICE"

For information on career opportunities at Librascope, write Glen Seltzer, Employment Manager.

LI 9-8

Librascope's experience creating new concepts in computer—control systems for both military and industrial use can be accurately applied to your specific needs. ■ For detailed information and solutions to your computer problems, write...

LIBRASCOPE

A GENERAL PRECISION COMPANY

LIBRASCOPE, INC. • 808 WESTERN AVENUE • GLENDALE, CALIF. • *A Subsidiary of General Precision Equipment Corporation*