Control and Telemetry for Oil and Gas Production

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The application of control and telemetry techniques to operational procedures is a well established engineering discipline. Most plant operational procedures have been reviewed for potential replacement by special purpose or standard, control or computer equipments. All have been tried with varying degrees of success. This measure of success was established by elimination of personnel, improved efficiency of personnel, improved quality of products, increased quantity of products, less operational down-time, or any number of at least twenty other qualifying statements.

Before going into the specifics of Lease Automation we should review three items related to the question, "Should we automate and to what extent?" These three items are:

1. Operation procedures
2. Replacement by equipments
3. Measure of success

The simplest approach to automation of any kind is to take a single mantype operational procedure; devise a machine to replace the man; establish the measure of success by one-for-one comparison of upkeep and operational ability of the machine to that of the man. The problem with this approach is that any future total system objective is subordinated to these equipments and the evolved procedure.

A more complex approach to automation is necessary. It involves system methods related to operations research. (Handbook of Automation, Computation, and Control, Volume I, pages 15-04 through 15-08 titled, "Phases of Operational Research," Reference #5). The phases of operations research can be summarized as follows:

1. Analyze the operations of both men and machines; the tasks involving control, communication, and decision.
2. Determine the decision making and evaluative procedure of management, and the effect of contiguous operations on this decision-making.
3. Formulate the research problem by listing objectives, assumptions, and measures of effectiveness.

The difficult tasks in performing the three phases are, first, the psychological limit of subjectiveness when a company or group performs a self-inspection, second, the problem of recognizing the typical system or norm which in turn prevents the study team from reaching agreement, or, third, the tendency of team members to use the exception to prove the rule.

The objective of this presentation is to outline an approach to complete systems automation of a major oil and gas production facility, with emphasis on telemetry and the fundamentals of digital coding as they apply to telemetry. The task to be outlined is, first, to define automation, telemetry, and digital coding; second, to answer the question, "Should each of these approaches be applied to your problem?"; and, third, to answer the question, "How can these methods be applied?"

What is automation? The basic definition of automation is, "to make automatic." This can be applied in its most elementary form by permitting a float switch to stop input flow, to the other extreme of complete automation of an entire facility. This complete automation can be designed on a self-contained local lease basis or on a community of lease production facilities communicating with a central point. The central station then provides the automatic function of programming, analysing, and controlling these community facilities.

What is telemetry and control? Telemetry and control are subordinate to total systems automation. Fundamentally, telemetry is the transmission, from one point to another, of information or intelligence related to the status, condition, state, or numerical value of the physical system under surveliance. Control is the timely commanding of the operations of a facility so that it meets the prescribed technical, legal, and economic restrictions established by the company and government. This control can either be local to an individual lease or group of leases, or remote to a community of leases controlled from a central location. It should be obvious that if control of a community of leases from a centralized remote point is to be accomplished, then telemetry will be required. This telemetry will provide the information or intelligence to the centralized point so that preprogrammed commands can be applied in an intelligent manner.

What is digital coding? Digital coding is a means of representing status, data, or controls in a discrete form. This should be done in the shortest most reliable form adaptable to communications in a noisy transmission media. Some of the terms which apply to digital coding are quantizing, digitizing, cyclic code, weighted code, binary code decimal, straight binary, gray code, excess 3 code, teletype code, CW code, ternary code and bi-quinary code.

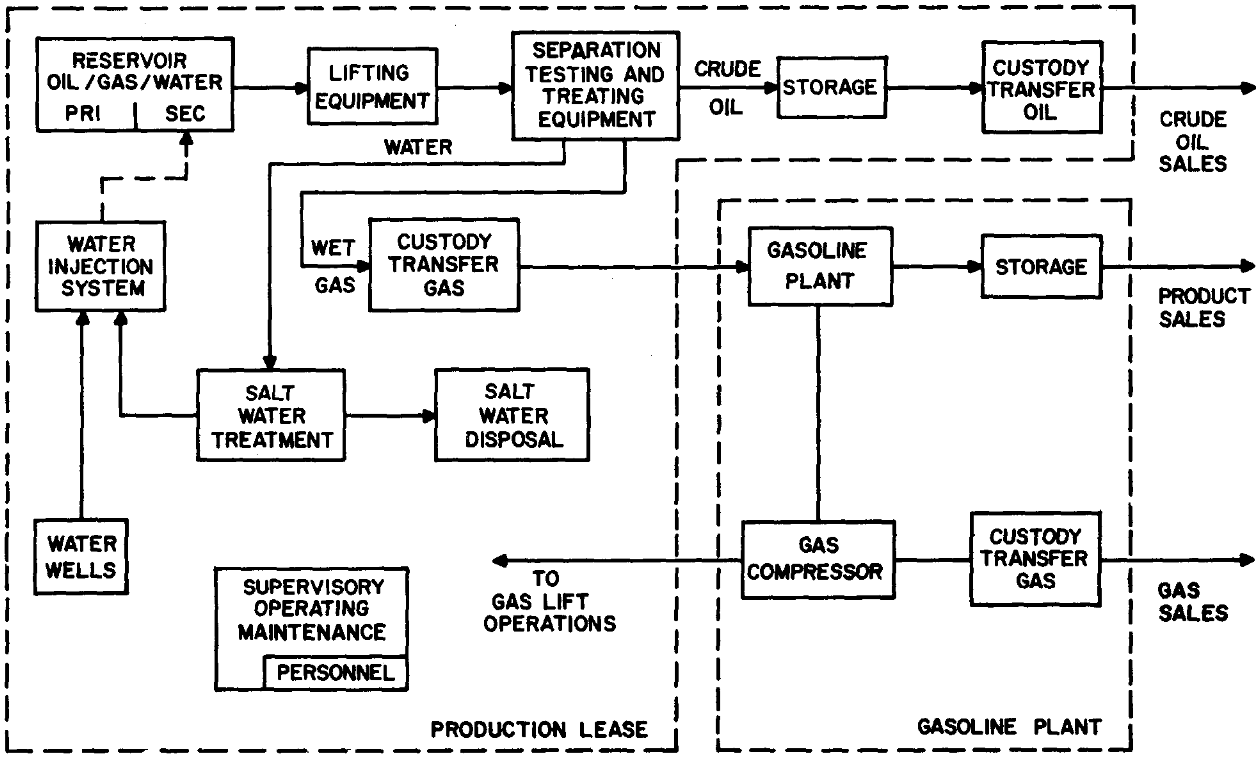
Why should we apply automation, telemetry, or control to our oil and gas production facility? The most obvious objective would be to lay the groundwork for increased net income from oil and gas production. However, in today's consideration for complete systems thinking, many of the so-called intangible benefits will provide an improvement of overall company operation. The increase of net income can be realized on the basis of improved maintenance, improved data handling, and improved supervision. Also, more reliable information is available for expansion and improvements in the future as a result of relief through changes in laws and regulations as imposed by the government or by our industry. As a minimum, we should apply operations research methods to our system for potential application of the latest methods to our current problems. We should plan now for the future since these methods would be difficult to apply if we have not installed today the kind of equipment adaptable to tomorrow's methods.

How can we apply these automation, telemetry, or control methods? Again, I must answer in a general sense because there are many solutions to the same system. Even though a typical oil and gas production facility can be described in such a way that it might fit 80% of all leases for any company, one cannot describe the "how" since such boundary conditions as geographical distribution, money available, age of the present equipment, and many other criteria would prevent one solution from satisfying all problems.

A logical approach to applying automation, telemetry, and control would be to study a total system including the equipment, the people, the operations, the maintenance, and the supervision, through an operations research type program. An approach directed specifically to lease production is reference #7 titled, "Automation Program for Lease Production", published in the Canadian Oil and Gas Industries magazine of October, 1961.

Oil production, as you know, can be divided into five primary functions: lifting, treating, testing, storage, and transfer (Figure 1-1. Typical Production Lease). These primary functions can then be reconstructed into combination man-machine functions such as production control, test control, status and alarm surveliance, and custody transfer. They may then be divided into subcategories of function such as recirculation, bad oil diversion, or vapor recovery.

With a good operating facility, why do we visit a lease? First, we visit the lease to inspect for problems, to guarantee that there is no overheating or overflowing, and that there is proper production. In other words we do a form of surveliance of status and alarm conditions. The second reason why we would visit a lease is to control the process of oil production, or those items of the lease which require modification in operation on a periodic basis. This consists of switching over the manifolds, setting wells on a different production schedule, controlling the choke setting, and controlling the transfer of oil. Third, we go to the lease to collect data; that is, to read our instruments, change our charts, take readings from the tank levels, and generally to review and transcribe the quantities of oil and/or gas produced. If we are to substitute machines for any of these tasks, then we must describe these tasks either in their present form or redesign them to suit a new or efficient configuration.



TYPICAL PRODUCTION LEASE

FIG I-I

BASIC TELEMETRY SYSTEM

FIG 1-2

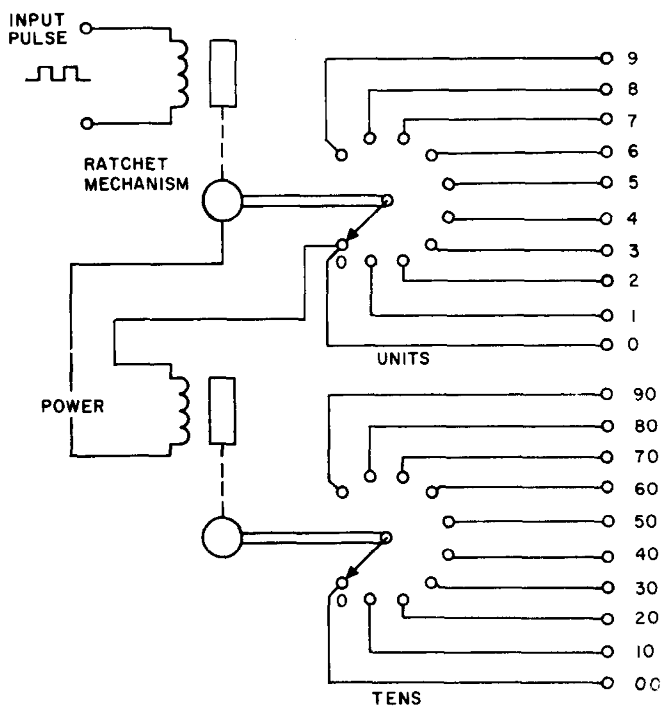
A simplified version of a telemetry system is shown in Figure 1-2 (Basic Telemetry System). The transceiver at the field location must either periodically transmit the status and data information, or it must be instructed from the office by a command function to "send data and/or status". The office transceiver must be capable of accepting the data or status and then translate this information into a form useable for display and printout.

The performance of the office unit in sending a control from the office and performing the function in the field is similar to the reverse procedure. Thus, the transceivers at the two ends can be quite similar in design. A communications link between transceivers can vary from the simple DC line to the more complex microwave links. The application determines the selection. The basic question is "How much information must be transmitted in a unit of time?" This, in turn, establishes frequency, band-width and ultimately the number of dollars per mile per month to use the links.

The justification of such a system depends not only upon the economics of more efficient operation but also upon the future objectives of the company. If it is desirable for a company to expand its operations and to operate with more efficiency and with the same number of personnel then some form of machines must be used to satisfy the many tasks required. One such machine, the computer, has been effectively used in the accounting and inventory departments of oil and gas producing companies. Justification for a complete system covering as many as two hundred leases would require many months of study by an engineering and accounting team. Assuming that we, as an oil producing company have decided to have a central control and telemetry system and have modified or will modify our operating, maintenance, and accounting to match this new scheme, some form of lease surveillance is required. Some of the items to be surveyed are the flow-no-flow situation of the various kinds of wells, the on-off situation of a crank balance, hydraulic systems, flowing and gas lift wells, the vibration of a crank balance or air balance system that is out of balance, the over temperature conditions of the heater treater or test treater, the high level or overflow situation of a tank, the diversion of bad oil, the low lube-oil pressure, the loss of a prime-mover driving a centralized hydraulic system, the low gas pressure of a gas lift system, and many of the other tasks performed either by some simple device or by an operator (a pumper) as he visits the lease. All the surveillance tasks must be outfitted with a transducer, a device for translating the physical phenomenon into an electrical signal, either DC impulse or AC signals as required by the particular system to be utilized. Many of the signal sensors currently used on oil and gas production leases are adequate as input signals to telemetry and control systems.

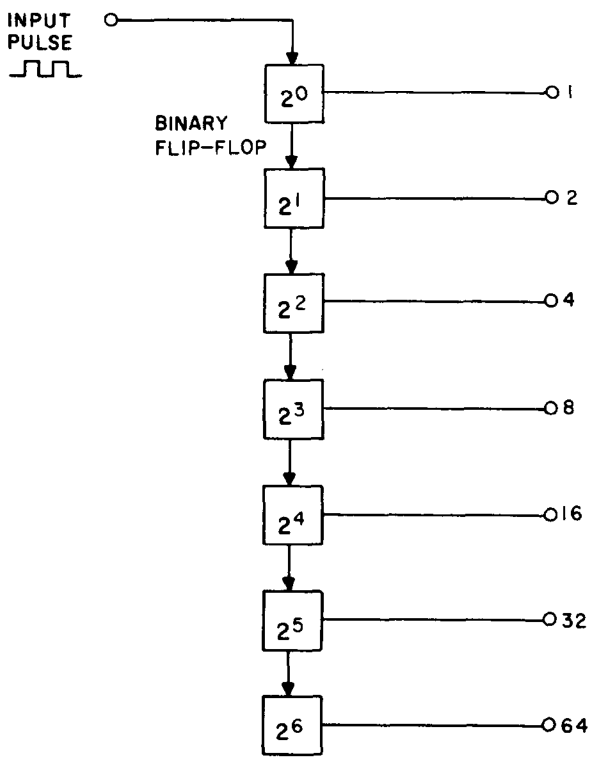
Next is the collection of data much of which is of interest or perhaps required by the Railroad Commission. These may be the oil, gas, and water as measured by a test treater; the amount of oil transferred through a custody transfer system; the amount of gas injected into a gas lift system; the amount of water injected into a water flood scheme; the number assigned to the well; the number assigned to the lease; and many other pieces of data important to the record keeping and accounting system of an oil and gas producing company. In collecting this data it is necessary to convert present information into a form usable by the telemetry system. Here again, we must utilize transducers or converters which will translate units of measure into electrical pulses.

The telemetry system has been shown to be an electronic or electrical means for collecting status and data information and preparing it for transmission to the office for subsequent display or logging. It has also been shown to be a scheme for accepting a control command and preparing it for transmission via the communication link to the field where it is utilized to modify the operation of a lease through the control function. Each of these status data or control



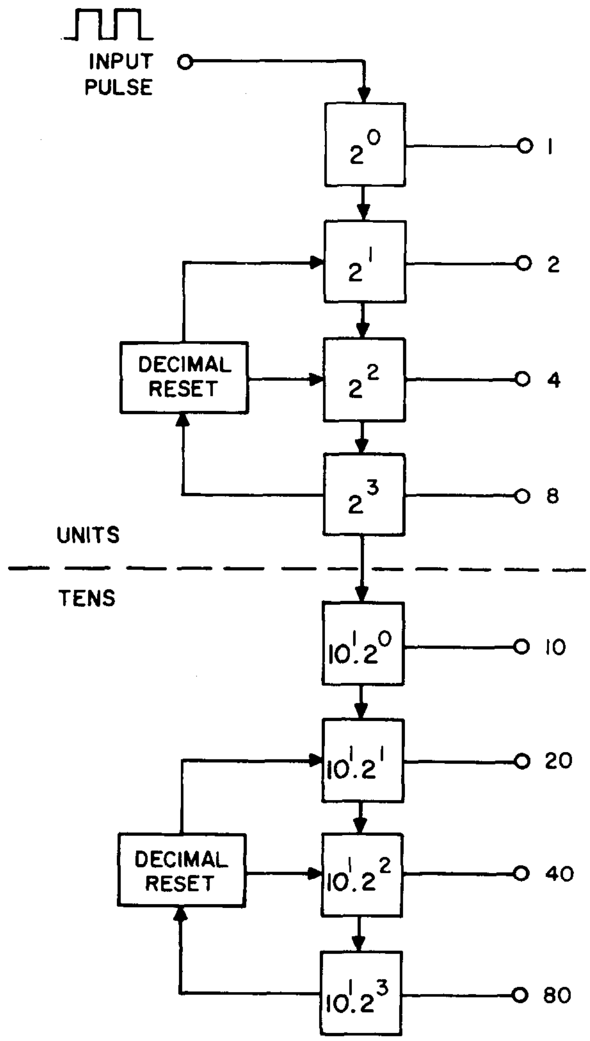
DECIMAL COUNTER
(MAXIMUM 100 COUNT)
FIG 2-1

functions must be represented by a different symbol if at either end of the transmission there is to be a guarantee of only a truthful or a reliable action or display of quantity. We can perform this transmission of symbolizm by utilizing any of the several number schemes. The most familiar scheme to all of us, I am sure, is a scheme utilizing the base ten or our decimal system. Second, would be the system of base twelve, or our dozen, foot, yard measurement. Third would be our binary system which is a simple yes/no, on/off, or true/false type of numbering system. There are many other number systems or base systems used in telemetry such as the ternary system of base three, the octal system of base eight, and the biquinary system which is a combination system of base two plus base five. The utilization of any numbering system instead of another has a justification based on economics, availability of particular equipment the speed requirements of the system, and many other criteria. A simple comparison can be made between the decimal system, straight binary system, and the binary coded decimal system. Figure 2-1 is a simple decimal counter which counts to a maximum of 100 or from 0 to 99. If we were to utilize this counter at some field position and connect the output to some remote visual display 500 ft away, we would require 20 wires plus a common in a cable to this remote point for a total of 10,500 ft of wire. Figure 2-2 is a binary counter which has a maximum capability of 128 counts. This unit counting at one field location, with the data being sent a distance of 500 ft distance to another field location, requires 8 wires plus a common or



BINARY COUNTER
(MAXIMUM 128 COUNT)

FIG 2-2

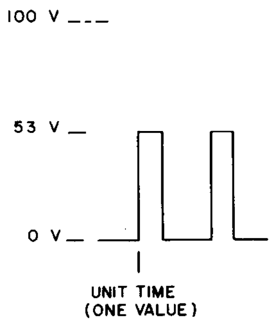


BINARY CODED DECIMAL COUNTER
(MAXIMUM 100 COUNTS)

FIG 2-3

approximately 4,500 ft of wire. It is easy to see that the straight binary method will give you the maximum count (128) with the least amount of wire (4,000 ft). We can note that the binary coded decimal counter uses formation in the familiar decimal form. The decimal output of Figure 2-1 is the most obvious but requires more than twice the amount of wire to send the same amount of information. Why then would we select one scheme over another? In short, we select the decimal system because it is the easiest for visual interpretation; we select binary coded decimal because it saves wire or cost, while giving us the decimal information. Overall, it would be the least expensive of the systems.

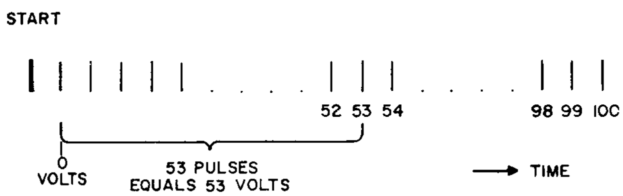
If we are to transmit using any of these schemes for great distances -- 1 mi, 2 mi, 100 mi, or more -- then we must consider some way of transmitting over a simple two wire system. This could be done with the decimal 100 system (Figure 2-4a), by representing the value to be transmitted with any one of a hundred different levels of voltage. The basic problem with this scheme is the inability to transmit these discrete



PROPORTIONAL VOLTAGE PULSE,
DECIMAL (100) SYSTEM

FIG 2-4a

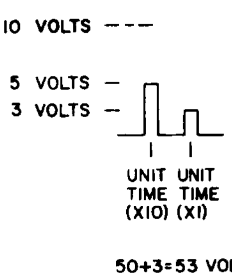
levels with great accuracies, since the transmission system introduces noise or bias which confuses the value. A second method (Figure 2-4b) for sending any one of the hundred decimal numbers would be to send



PULSE COUNT, DECIMAL (100) SYSTEM

FIG 2-4b

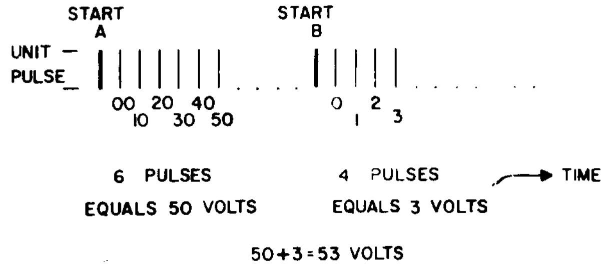
a unit voltage pulse for start, and after that point, to count a hundred units of time-or the number of units representing the voltage of interest. Obviously, we would have used up a hundred units of time to guarantee the maximum value. If we had very many values to send it would require much of our transmission time. Another method to achieve this same end on a decimal basis is shown in (Figure 2-5a) the Decimal Tens/Unit system. Here a voltage from 0 to 9 volts would be sent during the first unit of time representing tens, and a voltage from 0 to 9 volts would be sent in a second



PROPORTIONAL VOLTAGE

DECIMAL (100) TENS/UNITS SYSTEM

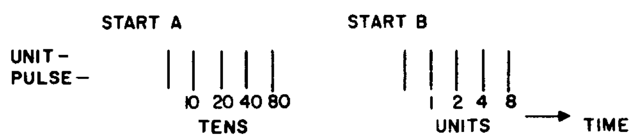
FIG 2-5a



PULSE COUNT DECIMAL (100)
TENS/UNITS SYSTEM
FIG 2-5b

unit of time representing units. At the receiving end the tens and units would be combined to form any value from 0 volts to 99 volts for a total of 100 increments. An equivalent scheme would be to use a unit voltage pulse on a time pulse basis. A start "A" pulse would be sent; then would be sent a number of pulses (up to 10) representing the tens voltage, followed by a start "B" pulse and the number of pulses (up to 10) necessary to represent the units voltage. At the receiving end, the tens and units would be combined into a representation of the voltage anywhere from zero to 99 volts. The voltage level method is still a problem with the fluctuation caused by line noise. The time base problem has been improved by reducing to 1/5 the time required of the straight decimal 100 system. From this point on we will not include the voltage level scheme, since noise does interfere with the recognition of the discrete levels necessary for accurate reception at the remote point.

The binary coded decimal, Tens/Units system shown in Figure 2-6, illustrates how a unit voltage pulse level is utilized to represent the presence or



BINARY CODED DECIMAL (100)
TENS UNITS SYSTEM
FIG 2-6

absence of one of the values of 10, 20, 40, 80 for tens or 1, 2, 4, 8 for units. The operation would be to send a start pulse followed by a pulse in a position of the value to be included. No pulse indicates unit values to be excluded. Shown in Figure 2-7 is a table of the pulse train code that would be sent to represent any particular value. In this table, a zero represents absence of a pulse, and a plus represents presence of a pulse. The sum of these pulse values then represents the total value. An example of a code being transmitted for the total value of 53, is also shown on Figure 2-7. Here, in a total of 10 units time we have, first, a start "A" pulse, the second unit of time representing a ten value, the third unit of time representing a zero value, the fourth unit of time representing a 40 value. The fifth unit of time has no pulse, thus the value is zero; the sixth unit of time is the start "B" pulse; the seventh unit of time represents the value of one; the eight unit of time represents a two value; the ninth and tenth units of time represent the value of zero. If we sum up all these values, we have in the tens group

	10	20	40	80
00	O	O	O	O
10	+	O	O	O
20	O	+	O	O
30	+	+	O	O
40	O	O	+	O
50	+	O	+	O
60	O	+	+	O
70	+	+	+	O
80	O	O	O	+
90	+	O	O	+

TENS

	1	2	4	8
0	O	O	O	O
1	+	O	O	O
2	O	+	O	O
3	+	+	O	O
4	O	O	+	O
5	+	O	+	O
6	O	+	+	O
7	+	+	+	O
8	O	O	O	+
9	+	O	O	+

UNITS

EXAMPLE

50+O+O 3++OO 50+3=53

START A START B

BCD TENS/UNITS SYSTEM
TABLE & EXAMPLE
FIG 2-7

values 10 and 40 representing a total of 50, and in the units group the values 1 and 2 for a total of three. The sum of all values is then 53.

We have shown, therefore, that we may represent any value by utilizing only two variables. These are time as one variable through pulse position, and the presence or absence of a pulse amplitude at a particular time as another. Let us suppose that we wanted to save time and send the units and tens simultaneously. How could this be accomplished? One way would be to send them by the same scheme that was just described, but transmitted over separate wires or separate channels. This could mean 3 wires instead of 2. But what about transmission over a radio link? Two separate tone channels or oscillators could be used to represent units and tens and, additional channels could be added to represent 100's and 1000's. This scheme could be used, but it is somewhat impractical. If more speed is required, what we really mean to do is to send more data in a given amount of time. It would be more advantageous, from a circuit standpoint, to send many values related to a given parameter over the same channel and different parameters over different channels. We arrive at a point of applying the multiplex method. Multiplexing is a generic term to be applied when we use time separation, frequency separation, phase separation, and amplitude separation to represent different parameters, different messages or, different values. It actually reduces to a data/bandwidth/speed of transmission problem in which we can make a trade off between the amount of data and the speed with which we transmit to the bandwidth requirements. You might say, "Why not have unlimited bandwidth?" Then we would send all the data we want at whatever speed we require? Let us look, however, at the difference in price on a 100 mi length of line utilizing a 15 cycle bandwidth, a 30 cycle bandwidth, and a 300 to 3,000 cycle bandwidth. The 15 cycle bandwidth would require approximately $75 a month and permit the transmission of 50 wpm. The 30 cycle per second bandwidth would run approximately $150 a month for the 100 mi and permit 100 wpm transmission. So renting the higher grade line to transmit more data really means that the dollars per word are exactly equal. Moving up to a voice grade line which is approximately a 300 to 3000 cycles per sec bandwidth and costs approximately $3 per mile per month would represent a $300 per month charge for 100 mi of transmission. At this point we could connect a telephone at each line and have a man orally transmit the data, and a man at the other end to orally transmit the controls. When we try to multiplex, a voice plus binary code transmission, the cost per mile per mile per month goes up according to the number of functions we try to perform over the same line. Without going into great detail the dollars per word stay approximately the same. Quite frankly, the real savings would be to reduce what we have to say. Often, what we have to say is not economically justifiable.

SUMMARY

Telemetry as a means for Control and Data Transmission is a reliable and proven tool.

Improvement of operations should be preceded by the use of "Operations Research" techniques as a guide. Man and machine tasks must be identified as well as the criticality and timeliness of the tasks.

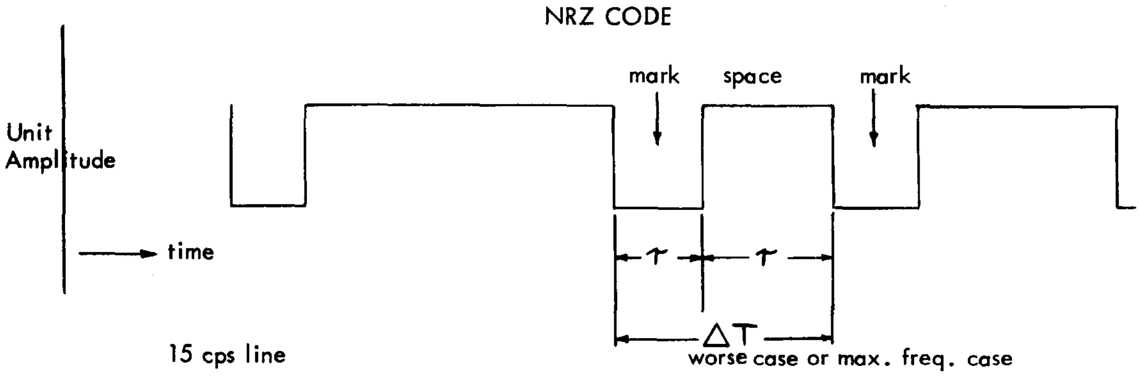
Binary or other base digital telemetry techniques should be used where distance between sites justifies the communications link; where sampling is permissable and reliability required.

Data and status requirements should be reduced to the minimum feasible level so as to reduce requirements on communications bandwidth and the continuing costs.

Most important is to take a long range look and plan your local controls today for automation or supervisory control tomorrow.

APPENDIX

Definition of word length



15 cps line

min period = 1/15 = 66.6 milliseconds = ΔT

$\Delta T = 2\tau$

$\tau = 33.3$ ms/bit

Definitions:

1 bit = 33 ms

1 character = 6 bits

1 word = 6 characters

1 word length = (6) (6) (33) X 10^{-3} X 1/60 minutes

OR the transmission rate = 1/word length = 50 words/minute

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