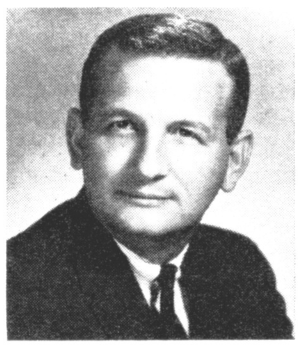
Metrology—reliability and accuracy

It makes good sense to set up routine certification program, full maintenance procedure, periodic review meetings and refresher training schedule.

BY D. D. DANISON, MANAGER OF CUSTOMER ENGINEERING, INDUSTRIAL NUCLEONICS CORP.

This is the fourth of six parts in a series within a series. Earlier installments covered economic opportunities, sampling methods and ways to obtain full benefits.



Mr. Danison joined Industrial Nucleonics in 1954 as a field systems engineer, and became manager of the customer engineering department in 1961. He has been active in all planning and operational phases of systems engineering, installation and maintenance.

Actual results achieved from a process measurement and control system depend on:

System accuracy and reliability. The system must provide accurate information in a form easily and readily utilizable. All functions of the system must be reliable and tuned to provide optimum performance on the process.

A program to measure results. Standards and goals must be established to compare with results actually being achieved. These standards should be periodically modified to meet changing and generally more stringent process requirements. Ideally, the benefits obtained from a process measurement and control system should increase from year to year.

Equipment upgrading. As process innovations are made, it may be necessary to modify the equipment to provide maximum performance under the new conditions. The initial design of the system should be such that modifications, improvements and additions of functions are possible. The system supplier must be capable and willing to provide these modifications if the system is to be kept current.

Operator confidence. The system performance should be good enough that the operators want to rely on it as a tool to help them make better paper, and are encouraged to do so by management.

Fulfilling these requirements demands a team effort by the system supplier and papermaker.

The functional performance of a system depends on its inherent design characteristics, the maintenance considerations incorporated into the design, the quality of installation, the maintenance program applied to it, and the routine checks made to monitor its operation.

System reliability and ease of maintenance are important factors to be considered during the equipment design. Besides the utilization of proven circuits and high quality components, the location of these within the cabinets can definitely affect reliability. The location of components and the logical separation of functions should allow easy replacement when required.

Heat, vibration, and dust are the primary enemies of electronic equipment and must be given proper consideration in establishing the location of the assemblies or cabinets which comprise the total system. Even though the hardware is rugged, proper consideration of the environmental factors will maximize the mean time to failure of individual assemblies and increase the overall life of the complete system.

The accessibility of the equipment should be seriously considered while planning the installation so that maintenance can be safely performed while the machine is running. A complete maintenance program is difficult to carry out if accessibility is a limiting factor.

When the installation is completed, a record log should be established. This log serves as the beginning of a permanent maintenance record which includes the following sections:

(1) all initial calibration, correlation, and control settings; (2) preventive maintenance procedures and records; (3) record of malfunctions; (4) reliability records; (5) parts usage records.

Performance feedback system

The system supplier must have an equipment performance feedback system to detect component failure trends which are used to guide a continuous product improvement program for systems already installed in the field. The input to this feedback system comes from the supplier's field organization which has exposure to a large number of systems. The actual equipment performance information must be detailed sufficiently that monthly and long term performance by system type can be established. It must also permit analysis of functions within a system and components within a function. Without such an information follow-up program, the total system performance can only deteriorate from its initial level. The information from this performance feedback system is used in the following four ways: (1) working with the component vendor to obtain components with higher reliability; (2) establishing the schedule of the preventive maintenance program described later in this article; (3) designing modification kits to continually improve the performance of systems in the field; (4) aiding in new equipment designs.

Fig. 1 shows a typical format which can be used to provide input to a feedback system. This is raw maintenance data showing the major assembly or function in which the failure occurred, the defective component itself, and the nature of the malfunction. A report is submitted each time a failure occurs. This type of information can be handled quite effectively by a computer and reports are generated periodically for analysis.

Fig. 2 illustrates a typical format to summarize failures by equipment function. This provides a readout of total number of failures and percentage failure rate by function classification. This actual rate is compared with the predicted rate to identify functions which are failing more often than expected. The summary includes failure rates for the current month and cumulative figures for the last six months, thus establishing failure trends and defining the type of corrective action necessary.

Fig. 3 illustrates a typical format to show the detailed information about specific failures by component. This information is needed primarily for the functions which have higher than expected failure rates and permit detailed analysis of the component or components which are causing the high failure rate.

Reliability through balanced maintenance

Anticipated results from a process measurement and control system will not be realized unless a balanced maintenance program is established. This should occur at the time of installation and then continue throughout the life of the system.

There are three possible approaches to maintenance: (1) repair it when it fails; (2) periodically rebuild the equipment along with corrective repairs; and (3) establish a balanced program of preventive and corrective maintenance. Typical results from these three types of programs are shown in Fig. 4.

NEXT WEEK IN P&P

- **A report on the application of value engineering theories at Mosinee Paper Mills Co.**
- **Rubber roll hardness—another look.**

COMING UP SOON

- **Kraft pulping—a new, important series covering key points in this vital stage in the papermaking process.**

Of these three approaches, the most costly is the "repair it when it fails" concept. The dollars actually spent for maintenance may appear low, but when the lack of results and the drastically shortened equipment life are considered the true costs attributed to this kind of maintenance are the highest of the three. The operators will soon lose confidence in the equipment and it will never be of much value.

Periodic rebuild is second most costly

The periodic rebuild approach is the second most costly. Lack of operator confidence again will be the factor which limits the useful life of the equipment and the results which it produces.

The balanced maintenance program is the only acceptable approach to provide the long term reliability necessary to make the equipment an integral part of the process. The amount of preventive maintenance required depends on the equipment environment, its complexity, and the total planned operating time. Preventive maintenance programs should be tailored to fit the specific situations. Provisions must be made in the program for continually upgrading the equipment on the basis of information from the equipment performance feedback system described earlier.

Preventive maintenance is logically a function of the system supplier. It takes an exceptionally well qualified and trained man to be fully effective in working only occasionally on these complex systems. The supplier can easily provide such men who specialize and devote full time to this task. The training necessary to stay current with the state of the art and turnover of personnel combine to present serious obstacles to any paper company attempting an effective maintenance program on its own. This is not to suggest that the user should have no responsibilities in system maintenance.

Since equipment failures occur at random, it is not reasonable to attempt to design a maintenance program to prevent all failures. Therefore, it is essential that provision be made, either by training the user's instrument people or by arrangements with the supplier, for rapid correction of any malfunctions which may occur. It is usually desirable, because of their relative familiarity with the system, to have minor problems corrected by the user and major ones corrected by the supplier.

Utilizing the services of a resident engineer employed by the systems manufacturer is an excellent arrangement where the amount of equipment involved can justify it. A resident's training is continually upgraded by the supplier with the result that new innovations in equipment and methods are incorporated into the user's system without delay.

A proper stock of replacement components must be available at the installation site for use during both the preventive and corrective portions of the balanced maintenance program.

A maintenance program should be evaluated on the basis of the reliability actually experienced. A monthly report system should be established which spells out the reliability experienced according to the following formula:

$$C = \frac{A - B}{A} \times 100$$

where:

A = actual time machine is producing paper to the reel
B = time system is down when machine is producing paper
C = reliability

A balanced maintenance program utilizing the concepts outlined above will provide system reliability of 99% or more.

The third article in this series (*P&P*, Feb. 12, 1968)

CORRECTIVE MAINTENANCE CARD
FORM BF-318 6-1-65
INDUSTRIAL NUCLEONICS CORP.
COLUMBUS, OHIO

1. AREA	2. CUSTOMER NO.	3. ENGINEER NUMBER	4. DATE	5. EQUIP TYPE	6. EQUIPMENT SERIAL NUMBER	7. RCO	8. ISN	9. ARR	10. CI	11. CPIT HOURS / COND OF SYS	12. COMP REF NO.

13. I.N. PART NUMBER	14. LIFE	15. PROB	16. COMP	17. REASON	18. HOURS

GENERAL INFORMATION

7	8	9	10	11
1 RENTAL	1 INSTALLATION	1 ADJUSTED	1 CUSTOMER CORRECTED	1 COMPLETELY INOPERATIVE
2 CONTRACT, 6 +	2 SCHEDULED	2 REPAIRED	2 I. N. CORRECTED	2 PARTIALLY INOPERATIVE
3 OTHER	3 NON-SCHEDULED	3 REPLACED		3 INTERMITTENT
				4 INACCURATE

FUNCTION

15				
00 GEOMETRY	20 SERVO POSITIONING	40 BUCKING SUPPLY	60 BLIND SERVO	80 ERROR SENSOR
01 BRIDGE	21 OTHER POSITIONING	41 HIGH VOLTAGE	61 AV. RECORDER	81 OUTPUT
02 PRE-AMP	22 LIM. SW. SCANNING	42 28 VOLT	62 X-Y RECORDER	82 ON-TIME
03 STANDARDIZATION	23 U-FRAME	43 B+ OR B-	63 REPEAT RECORDER	83 TRANSPORT LAG
04 OSCILLATOR	24 WIDE-O	44 B + AND B -	64 OTHER RECORDER	84 EXC. ERROR SAFETY
05 TEMPERATURE COMP	25 MINI-O	45 CHAMBER SUPPLY	65 VALVE POSITION IND.	85 SERVO SAFETY
06 MOISTRON COMPUTER	26 MOTOR CONTROL	46 MILLIVOLT SUPPLY	66 DEVIATION METER	86 CONTINUOUS
07 AMPLIFIER	27 MECHANICAL	47	67 PAC	87
08 DELAY STAGE	28 ELECTRICAL	48	68 OTHER COMPUTER	88
09	29 LIFT OFF	49	69	89

DEFECTIVE COMPONENT

16				
01 AMPLIFIER	08 CLUTCH	15 LAMP	22 RECTIFIER, BRIDGE	29 SWITCH
02 BATTERY	09 COUNTER	16 METER	23 RELAY	30 TIMER
03 BEARING	10 CYLINDER	17 MICROPOSITIONER	24 RESISTOR	31 TRANSFORMER
04 CABLE	11 DIODE	18 MOTOR	25 SHAFT	32 TRANSISTOR
05 CAPACITOR	12 FUSE	19 POT, ONE TURN	26 SLIDEWIRE	33 TUBE
06 CHAIN	13 GEIGER TUBE	20 POT, MULTITURN	27 SOLENOID	34 WINDOW
07 CHAMBER	14 HEATER	21 PROBE	28 SPROCKET	35 WIRE

NATURE OF MALFUNCTION

17				
01 ADJ., INCREASE	07 IMPROPER INSTALLATION	13 NOISY	19 SOURCE DECAY	25
02 ADJ., DECREASE	08 INTERMITTENT	14 NON-LINEAR	20 TEMP. SENSITIVE	26
03 ADJ., BALANCE	09 LEAKING	15 OPEN	21 UNSTABLE	27
04 DAMAGED	10 LOOSE CONNECTION	16 OVER-HEATED	22 VIBRATION	28
05 DIRTY	11 MECHANICAL BIND	17 RECALIBRATION	23 WIRING ERROR	29
06 GRID CURRENT	12 MISSING	18 SHORTED	24 WORN OUT	30

CD CD | 1. | 2. | 3. | 4. | 5. | 6. | 7 | 8 | 9 | 10 | 11. | 12. | 13. | 14 | 15 | 16 | 17 | 18.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

676336 BSC

(Top) Fig. 1. This format illustrates the raw maintenance data input into the performance feedback system.

EQUIPMENT FAILURE SUMMARY — ONE MONTH AND SIX MONTHS ENDING ______

FUNCTION		ONE MONTH				SIX MONTHS			
CODE	DESCRIPTION	SYSTEM DESCRIPTION A	B	C	D	SYSTEM DESCRIPTION A	B	C	D
1500	GEOMETRY	- NUMBER OF FAILURES -							
		- NUMBER OF FUNCTIONS IN USE -							
		- PERCENT OF FAILURES -							
1501	BRIDGE	2	8	7	5	9	39	46	22
		240	600	612	600	222	540	546	520
		0.8	1.3	1.1	0.8	4.1	7.2	8.4	4.2
1502	PREAMPLIFIER								
1503	STANDARDIZATION								
1504	OSCILLATOR								

Fig. 2. The failure summary compares the actual failures with the number of functions in use for each major function classification. The result is per cent failure rates.

FAILURES BY COMPONENT — SIX MONTHS ENDING ______

SYSTEM DESCRIPTION B

FUNCTION CODE	FUNCTION DESCRIPTION	COMPONENT CODE	COMPONENT DESCRIPTION	CAUSE CODE	CAUSE DESCRIPTION	NO. OF FAILURES
1501	BRIDGE	1601	AMPLIFIER	1718	SHORTED	2
				TOTAL		2*
		1604	CABLE	1708	INTERMITTENT	1
				1710	LOOSE CONNECTION	3
				TOTAL		4*
		1611	DIODE	1715	OPEN	5
				1718	SHORTED	4
				TOTAL		9*
		1620	M-TURN POT	1708	INTERMITTENT	2
				1713	NOISY	1
				1714	NON LINEAR	2
				1715	OPEN	4
				TOTAL		9*
		1624	RESISTOR	1715	OPEN	2
				TOTAL		2*
		1626	SLIDEWIRE	1713	NOISY	2
				1715	OPEN	1
				TOTAL		3*
		1631	TRANSFORMER	1715	OPEN	1
				1718	SHORTED	1
				TOTAL		2*
		1632	TRANSISTOR	1715	OPEN	4
				1718	SHORTED	3
				1720	TEMPERATURE SENSITIVE	1
				TOTAL		8*
1501	BRIDGE	TOTAL				39*

Fig. 3. Detailed information by component is needed for any function which has a higher than predicted failure rate.

defined the "results operations or people efforts" required for initial results. The program established initially must be continued throughout the life of the installation to insure continuing and improved results. The flow chart in Fig. 5 shows how accuracy certification and system reliability reports can be combined with the results reports to provide a continuing management information system.

Periodic accuracy verification is essential

Confidence by user personnel in the reliability and accuracy of a continuous measurement and control system is a must. Results from these systems depend mainly upon improving product uniformity. This, in turn, requires precise, reliable measurement which provides maximum information about the operation of the process.

Standards of accuracy are established in the initial calibration. However, no matter how carefully this is done, changes in the process or environment can cause errors. These can be detected or avoided by conducting routinely an accuracy certification program.

Most basis weight gauges in use today contain automatic self-standardization systems to compensate for changes in the air gap, such as the accumulation of dust or other foreign material. In addition, there are several routine ways to check basis weight gauge accuracy. One of these is the daily use of standard samples such as Mylar to verify measurement stability. This can be supplemented by pre-established circuit voltage checks. The better systems contain a built-in test system which can accurately and quickly check the critical voltages. Laboratory sample checks can also provide an independent test. Another method gaining wide acceptance is to compare calculated reel averages with the gauge averages once or twice each shift.

Most modern moisture gauges contain some degree of self-checking circuits and are inherently very stable. However, they usually present even more stringent gauge/process interface requirements than do basis weight gauges. For maximum confidence in gauge accuracy, a dynamic moisture sample should be taken at least once every shift. This can be a relatively simple procedure with automatic on-line sample cutters now available.

The supplier's systems and service engineers can provide guidance as to the best procedures for each user's needs. Whatever the methods used to verify accuracy, it is essential to post the results where the operating personnel can see them. Nothing destroys confidence quicker than vague doubts about accuracy which go unresolved. It is easy to maintain high confidence by the preventive approach of routine certification.

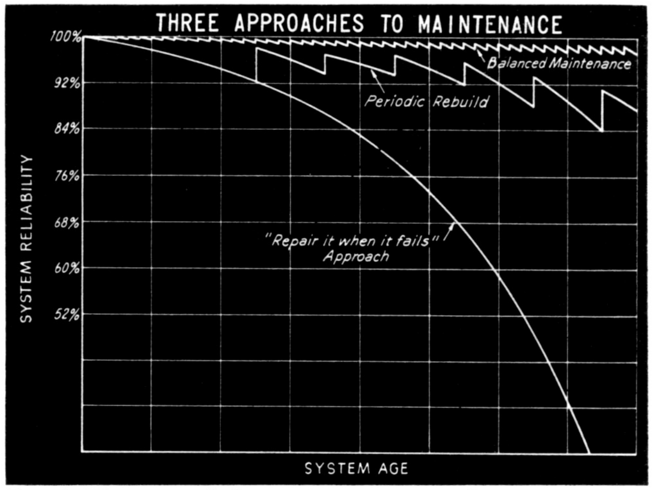


Fig. 4. The proper balance of preventive and corrective maintenance is the only approach which will provide acceptable equipment reliability.

Experience shows that the single most effective step to assure continuing results is the establishment of regularly scheduled refresher training and results review sessions. These should involve management as well as operating personnel. These sessions perform the very necessary function of reviewing correct procedures for operating and maintaining the equipment. Perhaps of even greater importance, they provide an ideal means of introducing new techniques for producing results.

Semi-annual results reviews with the supplier's consulting systems engineer should include a frank appraisal of progress and problem areas. One desirable objective of these sessions is to set new performance goals. Another is to refocus attention of all user personnel on getting results. The continuing results program should insure not only that the original results are maintained, but that they increase as time goes on. □

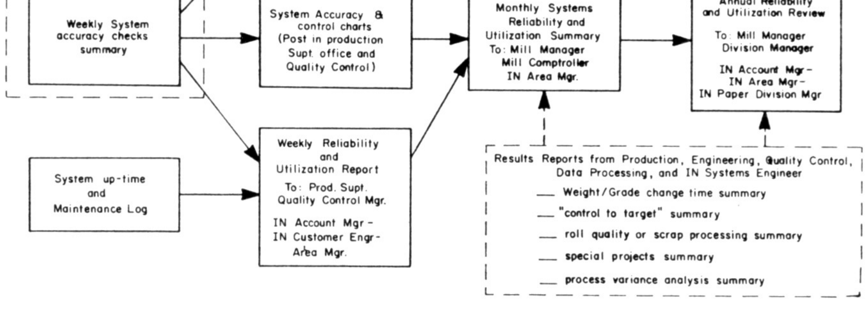


Fig. 5. A continuing reliability and utilization program insures continuing results.