Metrology—don't stop at instrument justification

Technical and process results are usually emphasized in the application of basis weight and moisture control systems while the potential effect on corporate financial performance has been neglected. Obtaining full benefits on a continuous basis requires an organized program with clearly stated economic goals.

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Two previous articles in this series outlined potential economic results in a general way and described a systematic method by which process variations can be analyzed and targets optimized.

Few users of basis weight and moisture measurement and control systems consistently get all the results available to them. Managers who could make the necessary decisions to exploit the systems completely are often not aware of the true nature and amount of results available. Their effect on corporate financial performance is often underestimated, thus failing to gain the management attention and support necessary for their complete success.

Results don't just happen spontaneously. They take a great deal of specialized know-how and effort. They need an organized program with definite objectives. Too many "results programs" stop with justification of the instrumentation without seeking the full economic results potential. Setting too narrow objectives is self defeating.

"Results" defined

Process measurement and control systems can generally produce results in two categories: those which reduce costs, and those which increase revenue. Quality improvement might be regarded as a third category—perhaps less tangible than the first two, but important nevertheless.

Getting maximum salable product area from each ton of pulp is the most important controllable economic factor in virtually all paper and board manufacturing. This critical bulk-to-area conversion efficiency depends entirely upon the operating targets for basis weight and moisture. Optimum targets are, in turn, determined by the process uniformity. Consequently, one over-riding goal of all results programs is to improve process uniformity. A successful results program must explore *all* possibilities for improving the bulk-to-area conversion. It must provide management the means for setting and monitoring operating targets with confidence.

Increasing salable production rate is another major area of benefit. This can be accomplished by increasing production efficiency, increasing speed, cutting startup and grade change time, and the like.

Whatever the specific results opportunities in each application—and experience shows that they differ considerably from one to another—a logical program is necessary to overcome the obstacles and to achieve maximum results.

Historical results pattern gives clues to problem areas

In studying the results to date from several hundred installations of basis weight and moisture measurement and control systems, a general pattern is evident. The results achieved seem to be highly dependent upon the amount and type of effort applied initially and the amount of management attention and follow-up after installation.

These conclusions were reached after grouping all activities in the programs studied into four broad categories which could be related to the results produced, Fig. 1. The "typical" application of basis weight and moisture measuring systems passes through four distinct phases of activity to reach full results potential. These phases do not necessarily occur in chronological order, but their general tendency is to do so. Nor has every installation progressed through all phases.

Phase I—measurement and control to existing targets. The mere presence of a measurement and control system on the process can produce certain kinds of results, even with limited effort. For example, automatic control of long term basis weight and moisture variations holds the averages close to target, thereby reducing the amount of off-spec product. The equipment can help make faster startups and grade changes, thus producing more salable product per machine hour.

These results, coupled with the less tangible benefits of more process knowledge and improved quality, are usually more than enough to justify equipment installation. If the

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user started with the narrow objective of "justifying the instrument," he might be satisfied to stop at this point without seeking additional results. Many have done so. *Yet, typically this has produced only about one fifth of the total results available!*

Phase II—process analysis and tuning. Continuous scanning measurement provides a wealth of information about the process. Special analysis methods can help isolate and identify the causes of certain variations in basis weight or moisture, then guide efforts to reduce them. Improving profiles and reducing the short term machine direction variations are of special interest. Unfortunately, many sophisticated process control schemes, even those including computer control, overlook the importance of these variations and concentrate only on the long term machine direction components. Although practical automatic control of the profile or short term machine direction variations is not yet a reality, a conscientious operating crew can "control" them manually if good information is available.

Another important function of Phase II has been to obtain more engineering knowledge about the process factors which might limit or prevent full results achievement. The outcome may recommend changes in machine settings or operating procedures. In extreme cases, major process modifications may be indicated. The more successful programs have included at least some Phase II effort.

Phase III—management/economic decisions. No matter how successfully the two preceding phases have been in the technical sense, their full impact does not show in the financial report without the proper decisions to change targets, increase speed, or change operating practices. Management must make deliberate decisions to translate the technical process/product results into economic results. As much as one half the total results potential depends upon successfully implementing this phase. Some of the natural reluctance to make such decisions in the past can be traced to lack of confidence in the equipment or to the failure to make a thorough engineering analysis of the results potential and the limiting factors.

Phase IV—results optimization and continuation. Even though initial results may be excellent, they have a way of deteriorating in time if no effort is made to maintain them. After a year or so, the novelty of the equipment wears off. Personnel who spearheaded the initial results program may be transferred or promoted.

A continuing results program must go far beyond the obvious need to maintain the equipment. The most successful users have been those who provided continuing effort and "management information" systems to measure and compare actual results with goals.

Too many projects stop in Phase I

Studying the historical results pattern shows up its weaknesses and helps in designing a program to avoid them. The most significant observation is that too many users stopped their results efforts in Phase I. Evidently even this level of results has been at least satisfactory, for many systems have been acquired on this basis. Yet on the average, five times as much economic return could have been attained by applying a full scale results program!

Today the supplier of these systems has the serious responsibility to provide a complete "results system" rather than "instrumentation."

The user must be willing and prepared to go after the full results potential. He must allow sufficient time for the results program to develop its full effects, not only on the process and product, but on the financial performance as well.

Results operations program—a new approach

The following program is the result of several years of experience in planning and applying basis weight and moisture measure-mean and control systems. It stresses the proper balance of equipment and software and extends from well before installation to years after. An outline flow diagram of the program is shown in Fig. 2. The detailed step-by-step program would be tailored to fit the specific needs of each user, but the following description provides a general understanding of the basic steps.

Techno-economic audit. In one sense this is probably the most important phase of all, for it establishes the technical and economic feasibility of undertaking the project. The audit is a systematic investigation of the economic factors of the paper machine to determine how they would

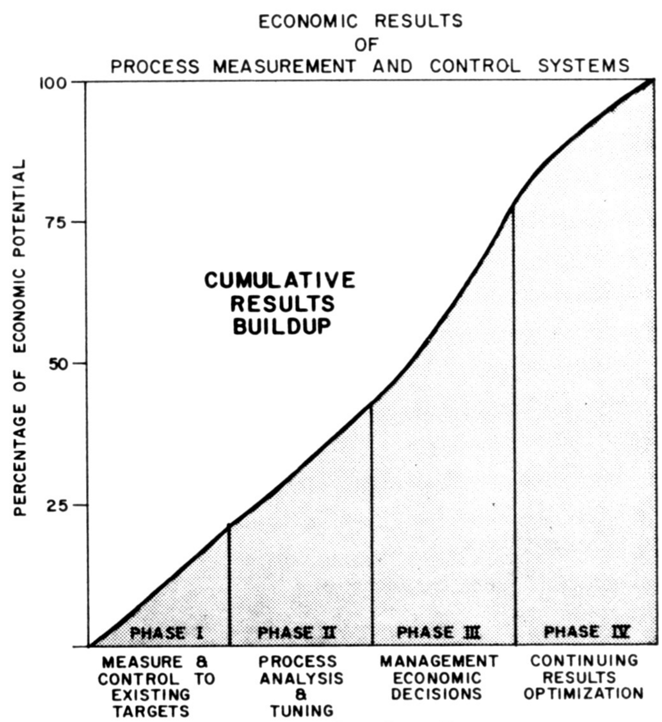

Fig. 1. Historical pattern of results achieved.

react to changes in operating procedures, variable set points or targets, machine limit factors and production rate and other key variables. It characterizes the paper machine as a process/economic "system" and projects the economic potential for measurement and control systems.

The complex inter-relationship of process performance, product characteristics, and economics is developed through the use of modeling techniques. Process and economic models are constructed on the digital computer so that effects of changes in the key variables may be determined easily and quickly. Fig. 3 shows the main steps in an audit. The output of the audit phase is a process/economic model supported by a sound engineering basis for specific program recommendations.

The audit is far more than a collection of data. It necessarily involves all cognizant members of the user's organization, including production, engineering, accounting, quality control, technical services, data processing and management.

Program recommendations. After a thorough audit, it is a simple matter to structure a specific results program. The proper equipment must be specified. The detail steps of the project must be laid out with a proposed schedule.

Results objectives can now be summarized and presented for management review and agreement. This provides the first major checkpoint for comparing expected results against project cost. Clearly, this must at least meet or exceed the user's investment criteria to allow proceeding to the next phase.

Program implementation. After a careful audit and results projection, the next step is installation of equipment on the process—not as an end in itself, but as the means of achieving the expected results. This phase includes installation, training, assignment of personnel, calibration of equipment, establishing appropriate reporting procedures, and all the many other details necessary to prepare for the main task of producing results.

This phase, perhaps more than any other, will benefit from the systems engineering "consulting services" avail-

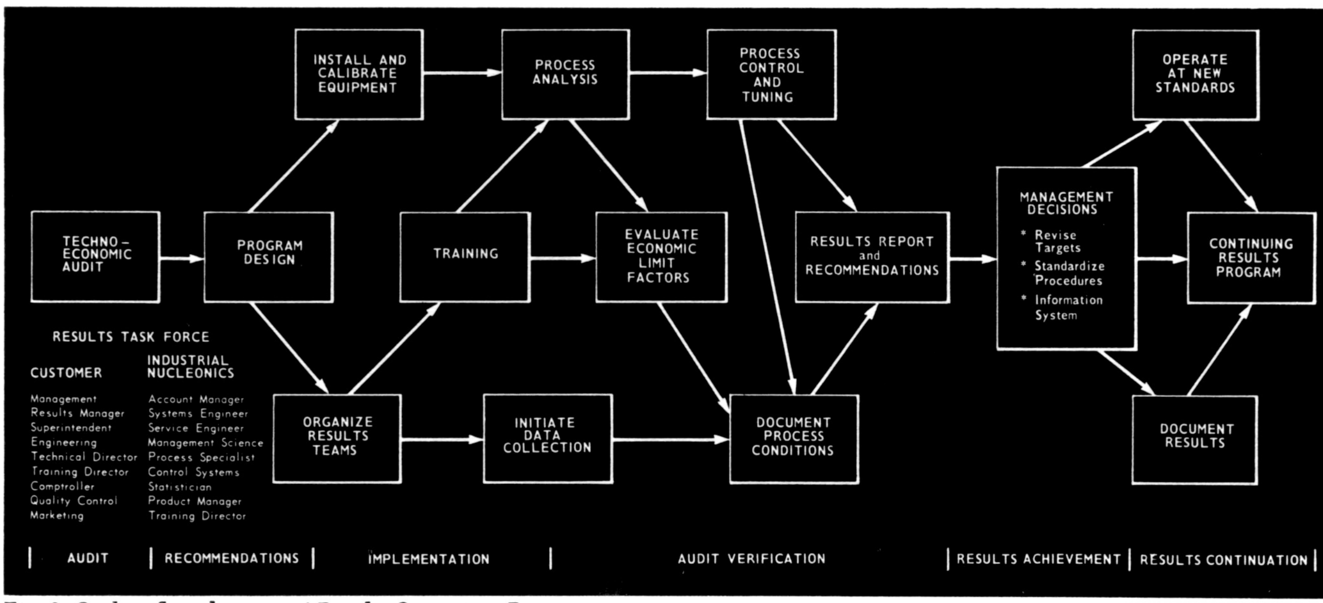

Fig. 2. Outline flow diagram of Results Operations Program.

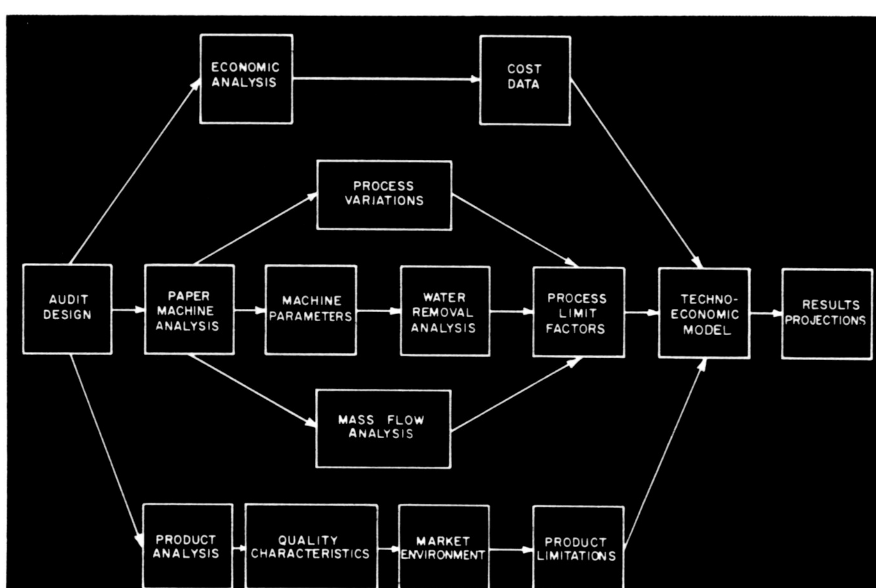

Fig. 3. "Techno-economic" audit determines project feasibility and defines objectives.

able from an experienced supplier. He knows that for a successful program beyond this phase, certain things are required:

1. The machine personnel must develop confidence in the accuracy and reliability of the equipment. They must be fully informed about the program objectives and understand their responsibility, for their faith and support provide the solid foundation for results.

2. Quality control must be prepared to provide know-how and effort to check and document dynamic accuracy of the equipment. They must also arrange for periodic accuracy validation to assure continuing confidence in the system. They also can provide invaluable guidance in the design of experiments to assure maximum efficiency in data collection and analysis.

3. The technical or instrument department should develop sufficient familiarity with equipment to recognize symptoms of malfunction and provide routine maintenance of the system.

4. Management must understand the broad program objectives and demonstrate confidence in achieving results. It must provide capable leadership and motivation. Also, by maintaining close contact with the program all along, management will be better prepared and more confident to make economic decisions.

5. The user must appoint a capable "project manager" to oversee the program and provide continuity, coordination, and communications among the many people and departments involved and with the supplier's systems engineers. This man must command the respect of everyone involved and be able to "get things done." Ideally, he should have broad general management knowledge ranging from the process to quality control to accounting and data processing.

6. Effective and appropriate training must be provided; the training program should be set up through the mill training director to assure effective follow-up training as machine crews and other personnel change. The user should demand and get considerable help from the supplier in his training effort.

During this phase the systems engineer helps the user team firm up specific projects and tests to be made during the phases to follow. Data collection and analysis procedures are spelled out and put in operation to document the process and economic conditions before results achievement is started. If the user already has a management information system or standard cost system in operation, so much the better. In all probability, it will include the capability to show the program results directly; or it can be modified to do so with very little effort.

Audit verification. Now the machine crew and process engineers show their ingenuity and skill, for the main objective of this phase is to improve process uniformity and efficiency and thus verify the assumptions and results predictions made in the audit phase, the heart of the entire program. If it is carried out in a superior manner, management decisions and results documentation will follow almost as a matter of course.

The principle steps in this phase are:

1. Documentation of process variations, throughput, speeds, costs, material yield and all other significant measures of performance *before* making improvements. This establishes the reference level for comparison with the final results.

2. Process improvement by closing "control loops." In closing loops, many users think only in terms of automatic feedback control of basis weight or moisture. In fact, this controls only the long term component of machine direction variation, not usually the largest contributor to total sheet variation. Cross machine and short machine direction variations must also be reduced to gain worth-

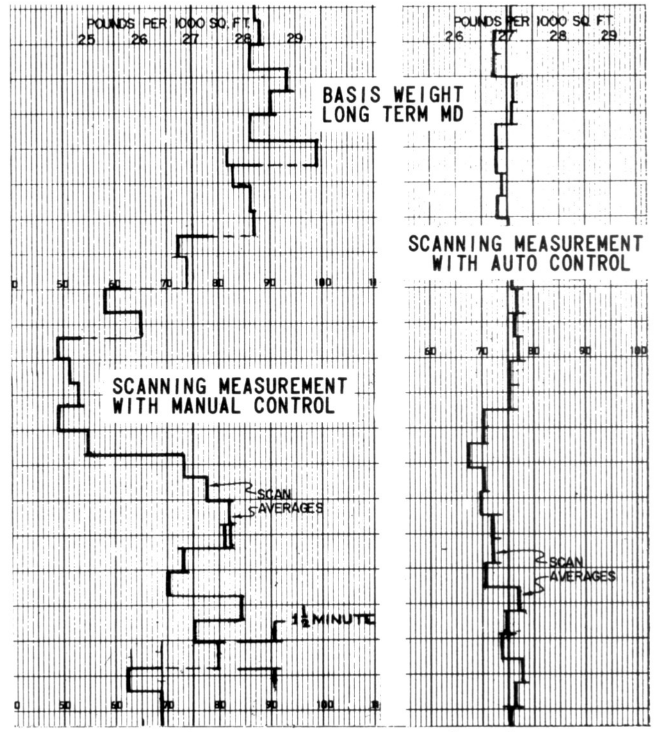

Fig. 4. Auto control reduces long term machine direction variations.

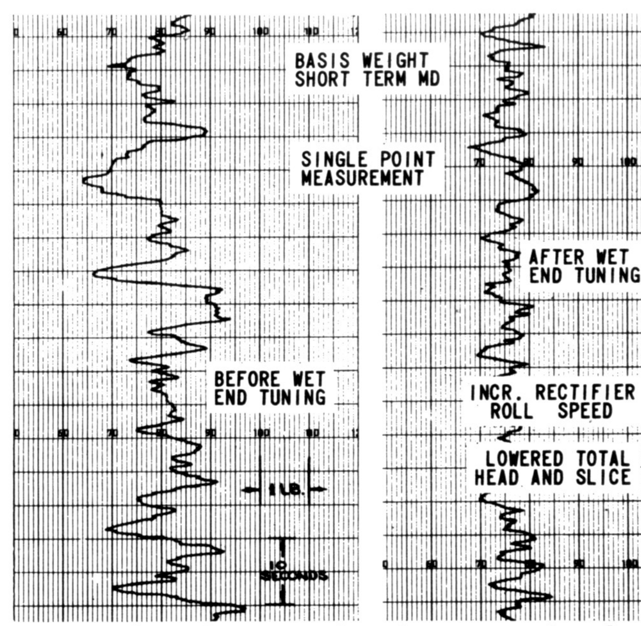

Fig. 5. Machine adjustments reduce short term machine direction variations.

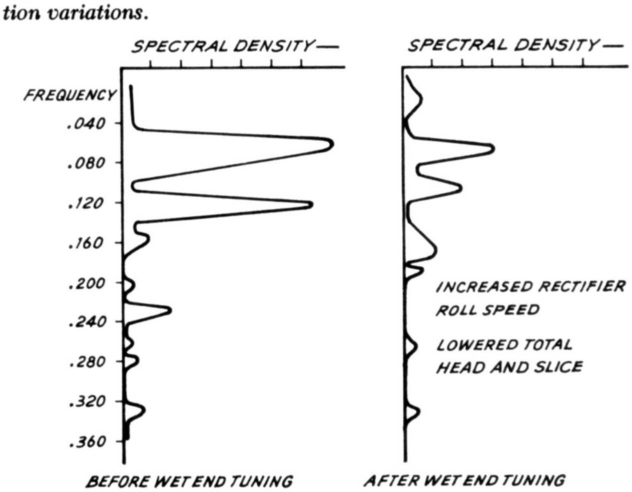

Fig. 6. Frequency analysis identifies prominent variations.

while improvements in total variation. As was shown in the preceding article, total sheet variation is the root mean square of all the components: $\sigma_T = \sqrt{\sigma_{LTMD}^2 + \sigma_{STMD}^2 + \sigma_{CD}^2 + \sigma^2_{Sampling}}$. Reducing any one of these without improving the others may have very little effect on the total.

"Control loops" to improve profile and short term machine direction variations can be closed by operating personnel using the information available from a scanning measurement to adjust the slice and tune the machine. Sophisticated techniques for this have been devised.

Figs. 4 through 7 show examples of some of these techniques and the results they can produce.

These examples are drawn from an actual case study to illustrate the principle of reducing all components of sheet variation. Fig. 4 depicts the effect of automatic feedback control of the stock valve on long term basis weight variation (V_{LTMD}). Each scan average represents approximately $1^1/_2$ minutes of production. The reader may refer to the previous article for an explanation of compatible control based on these averages.

Fig. 5 shows a reduction in the short term machine direction variation (V_{STMD}) by adjustments at the wet end. Briefly, the procedure is to measure basis weight or moisture along the machine direction. A high speed recorder is used to permit analysis of the measurement signal for characteristic patterns which can be related to specific causes in the machine. Fig. 6 shows the corresponding frequency analysis, which here has prominent peaks at approximately .07 to .12 cycles per second.

The availability of profile presentation from scanning measurement enables adjustments to be made to level the profile. Effects of the adjustments can be checked within a few minutes. Fig. 7 shows a sequence of slice adjustments to level basis weight profile.

The overall impact reducing all the components of variation makes it clear that failure to improve all of the components would have a big effect on the final result.

3. Improving productive capacity. In nearly all cases there is an opportunity to increase the salable production rate. This can be achieved by taking less time to start up or to change grade or weight, for example. Tear outs, rejects, and off spec production can be reduced. These factors and others can combine to make a gain in productivity.

Over the long term, a far more important objective is to increase speed. Speed may have been limited by uniformity problems; if so, these limits may now be removed because of the improved uniformity. For example, wet streaks limit the speed of many machines. With continuous measurement and control, moisture profiles and averages can be improved, offering two important results. Increasing average moisture replaces costly fiber, and incidentally gives many

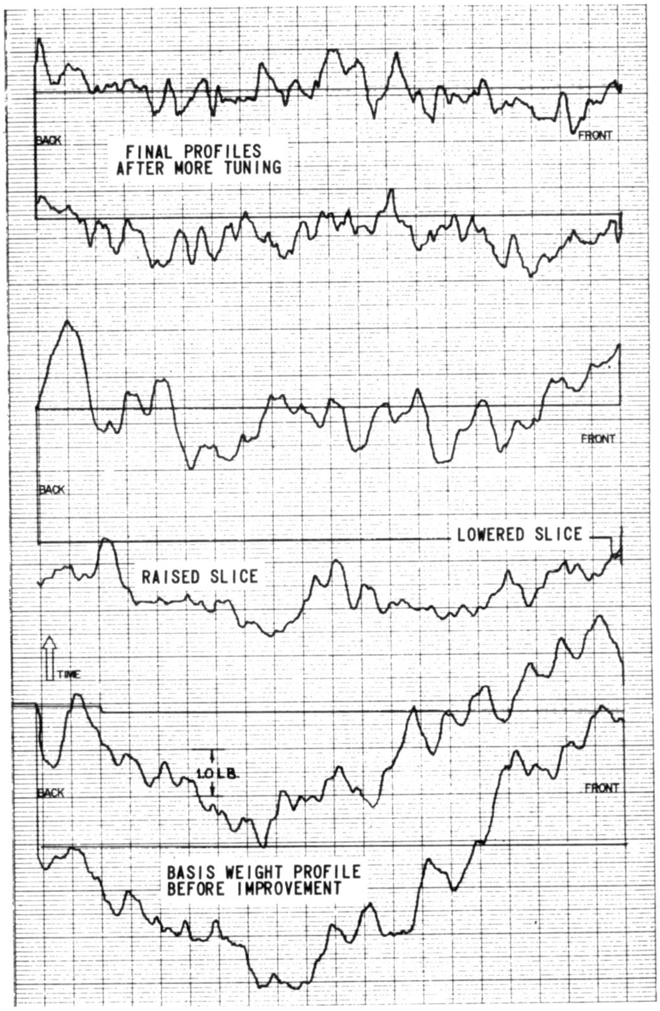

Fig. 7. Slice adjustments level profile.

end users exactly what they want—more water uniformly distributed in the sheet. Also, machine speed increases of two per cent to 15 per cent, depending upon the particular machine and degree of over-drying, can result from an increase of only one per cent in average moisture.

4. Evaluate limit factors. Limitations may be in the machine, the personnel, material supply, converting capacity, or even the market.

5. Evaluation report. The final output of the verification phase is a report covering all phases of the program and presenting specific recommendations to management. These may cover a wide range, including: (a) target revisions, (b) operating procedures and standards, (c) process modifications, (d) reporting and data processing, (e) continuing results program. This report should indicate the expected process conditions and economic performance after all the individual improvements have been put into effect at the same time.

Results achievement and continuation. To this point the technical and process projections made in the audit should have been examined and verified. Many of the opportunities for process improvement have been experimentally checked and recommendations presented to management. Management must now implement the recommendations and establish them as standard procedures to produce an economic return.

A successful results operations program never ends, for if it can produce worthwhile results initially, it must surely be worth a modest continuing effort to maintain the results. Continued training of all personnel, including management, is required. A management information system to continually monitor performance is essential. □

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