A Preventive Maintenance Program for Highway Maintenance Equipment

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The preventive maintenance program for equipment used in the maintenance of California Division of Highways roads is analyzed and reported. The program used has been in effect for 10 yr, and a careful analysis has been made of the many factors affecting such a program. Cost records show a remarkable savings in repairs which naturally reflect in more efficient operating time for the maintenance forces.

•THE FUNCTIONS of the Equipment Department of the California Division of Highways include preparing equipment specifications; accepting delivery and providing for eventual replacement of equipment; repairing and maintaining more than 7,800 pieces of maintenance equipment; repairing more than 2,300 sedans used mainly by supervisory personnel; preparing and administering a rental system to pay for equipment purchase, replacement, maintenance, and repair; designing and developing new equipment not available from commercial sources; providing technical training and research; and developing and fostering the preventive maintenance program to reduce operating cost of equipment. This paper presents a brief discussion of the preventive maintenance program in the California Division of Highways for all equipment other than sedans.

PREVENTIVE MAINTENANCE

As used in this paper, preventive maintenance includes those operations, practices, and activities necessary to decrease the rate of deterioration of a machine. In the Division of Highways the preventive maintenance program includes a planned program for lubrication, servicing, inspecting, adjusting, tightening, and cleaning equipment. It also includes training personnel in operating and servicing practices which tend to prevent premature wear and breakdown and reduce repair costs to that minimum level concomitant with normal wearing out of parts.

It is the policy of the Division to assign to the operator of a particular piece of equipment a large part of the responsibility for preventive maintenance work during the period when he is using the unit. He is responsible for lubricating the machine at regularly scheduled intervals, making inspections and minor adjustments, and tightening and cleaning it. Major adjustments or any repairs are made by a traveling mechanic working in the area or at an Equipment Department shop.

The policy of frequently changing operators and depending on the individual equipment operator to do the preventive maintenance work on the particular piece of equipment to which he happens to be assigned at the time when such work is due, is both an advantage and a disadvantage. The advantage accrues to the Maintenance Department. It provides necessary flexibility in assignment of duty in terms of the need for highway repair and maintenance. Highway maintenance men can be quickly shifted from one type of work to another as storms or other conditions dictate. Personnel problems and travel expenses are avoided, which would result if a certain highway maintenance man was assigned more or less permanently to a particular machine and sent with the unit wherever it was needed.

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It is not present practice to provide lubrication specialists with appropriate truck-mounted servicing equipment to do the preventive maintenance work, as is common with construction contractors. Highway maintenance equipment is so scattered and subject to unanticipated moves that planning a fixed servicing schedule by such specialists is difficult. Many items must be lubricated and serviced each day before start of shift. With widely distributed equipment, these items can only be taken care of by the operator then using the equipment.

The disadvantage of frequently changing operators for a particular piece of equipment accrues to the detriment of equipment maintenance. No one is specifically responsible for the continued preventive maintenance work on a particular machine. The attitude of the highway maintenance superintendent toward the need and importance of taking care of equipment is reflected by his foremen and their crews and largely determines the amount and quality of preventive maintenance work done on the equipment.

Each highway maintenance man will perform preventive maintenance work on many different types and models of equipment during his service with the Division of Highways. One man cannot remember the many details associated with these machines. Therefore, lubrication manuals and charts must be provided for guidance.

ACTIVITIES INCLUDED IN THE PREVENTIVE MAINTENANCE PROGRAM

Major activities involved in the preventive maintenance program include:

1. In-service training of equipment operators on preventive maintenance with particular emphasis on lubrication;
2. Preparation and distribution of lubrication manuals, lubrication charts, and dash-mounted servicing record stickers, and
3. In-service training of equipment operators on mechanical features of equipment operation.

Training in Lubrication

In-service training on preventive maintenance includes a 2-day training course with particular emphasis on lubrication. It is given to all operators and other personnel directly involved with operating and maintaining highway maintenance equipment. Instruction is given in a special classroom trailer towed to the shops and to various maintenance stations throughout the State.

The course is revised and presented approximately every 5 yr. This seems sufficient to train new employees, to introduce new features of equipment and its maintenance, to bring the operating force up to date, and perhaps most important, to motivate the operating agency to fuller participation in this important money-saving work.

The course is given to approximately 2, 450 employees of the Division of Highways. Instructors are associate equipment engineers with broad backgrounds in highway equipment repair and maintenance and with special training in teaching practical preventive maintenance procedures. They appreciate the value of safety practices and emphasize this very important phase of training in all contacts with trainees.

This course was initiated in June 1953 and continued for a 3-yr period. The need for such training, and the interest and widespread enthusiasm with which it was received, are shown by the impressive decrease in average annual repair cost of $107 per inventory unit (not including sedans). This amounted to a saving of more than $1, 236, 000 during the period.

Further decrease in average unit repair costs was achieved by persistent effort in providing reference aids to the operators to perform more and better preventive maintenance work and increasing the skill of operators in handling equipment with minimum damage or abuse.

No claim is made that the preventive maintenance program is the sole cause for the impressive savings. However, the major savings in average annual unit repair costs took place concurrently with operation of this program. Other factors also contributed to the savings. The contribution of the individual factors is impossible

to evaluate precisely; they work together to produce the desired result. Some of the other contributing factors and other items concerning economics will be discussed later in this paper.

Manuals and Charts

Lubrication manuals and charts are provided by the Equipment Department for each major make and model of equipment, giving detailed information on the points to be lubricated and serviced, the kind of lubricants to be used and, in many cases, the specific procedure for application.

The items are grouped in progressively increasing periods of service. A simple code symbol is used to identify the items to be serviced at any one particular interval, based on hours of use or on mileage, whichever is appropriate to the particular machine. The servicing periods are chosen to coordinate conveniently with the standard 8-hr workday and 40-hr workweek used by the Division of Highways. A printed shape for each symbol rather than a color code is used to avoid the effects of color blindness, to allow a larger number of symbols, and to reduce cost of reproduction. Another simple code refers to the particular lubricant to be used in terms of the product name and number, as shown on the State specifications for lubricants and incorporated in the currently effective contract for lubricants.

Special operating notes and instructions are included to cover major mechanical features of equipment operation. Particular attention is given to safe operation and to procedures to avoid lugging, overspeeding of engines and other forms of abuse. Emphasis is placed on obtaining high production, yet keeping repair to a minimum and prolonging the useful life of equipment.

Lubrication manuals must spell out simply the information needed and must be easily and quickly understood. The average highway maintenance man is primarily concerned with getting his work done on the highway. The competent maintenance man appreciates his equipment, but is seldom interested in reading through a detailed, voluminous operator's manual to find those items needed to do the preventive maintenance work.

Each year a new contract is issued on a low-bid basis to an oil company to furnish various lubricants for State use. The varied brand names and numbers used by different oil companies for equivalent oils and greases are very confusing. To eliminate the confusion and at the same time assure adequate quality, lubricants are purchased in accordance with carefully prepared State specifications and receive permanent names and numbers assigned by the State by type.

Particular lubricants are selected to assure high-quality lubricants and to keep to a minimum the number maintained on inventory at the 274 maintenance stations and 20 equipment shops and subshops widely distributed throughout California. The latter is done to avoid unnecessary expense in providing storage and dispensing facilities and to decrease chance that the wrong lubricant might be applied. Wherever possible, multipurpose oils and grease are used.

The lubrication chart shows a line sketch of the machine with arrows leading to the lubrication and service points. Symbols show the period of service and coordinate with the symbols used in the manual and on servicing-record dash stickers. Items are coded to assure the use of the correct lubricant.

A copy of the lubrication chart is mounted in durable plastic and attached to the machine in a convenient and protected location. This is of particular value when the piece of equipment is serviced in the field. A complete set of all lubrication charts is also maintained at all highway maintenance stations and shops. The applicable chart is easily removed from the folio, used at the grease rack, and then returned.

Servicing-record dash stickers are placed in the cab where the operator can record the hours of use and the date when various items are serviced. The hourmeter reading, if available, is used as a basis for servicing; otherwise, hours of use are estimated. For equipment serviced on a mileage basis, a dash sticker is used which is coded in terms of mileage and date of last service. To supplement the record on the dash sticker, a permanent record of major periodic servicing is maintained in the equipment report book for each vehicle.

In-Service Training in Equipment Operation

Abuse of highway equipment is rarely deliberate and so can be reduced measurably by increasing mechanical knowledge and operating skill. Training in this area is being given under a program called MEFEO (Mechanical Features of Equipment Operation). This training is limited to the operation of equipment from the mechanical point of view and does not include training in the techniques of getting a highway maintenance job done, such as in forming a windrow or blading a berm. Such training is handled by the Maintenance Department

MEFEO training is given at the time a new model or a unique piece of major equipment is first put into operation. A schedule is prepared in cooperation with the appropriate equipment superintendent and the highway maintenance superintendent. Highway maintenance men who will likely operate the units are assembled in small groups at a suitable place, usually a maintenance station. Instruction is given by an associate equipment engineer familiar with the particular model and qualified to give authentic information and instruction. Each operator is usually given an opportunity to maneuver and manipulate the unit under simulated working conditions.

This method of obtaining the needed instruction has proved to be more satisfactory than that occasionally provided by a factory representative. For one thing, the shortcomings and limitations are presented, as well as the peculiar advantages. The representatives of the manufacturer, for obvious reasons, are certainly not inclined to admit or emphasize shortcomings that could be used adversely by competitors but that must be included in training for proper preventive maintenance.

The MEFEO training provides uniformly high-quality instruction coordinated with shop practices and the needs of the Maintenance Department. This activity has helped to decrease repair costs and downtime on equipment. It has proved to be particularly productive in preparing the many highway maintenance men hired for only the short snow-removal season. These men are expected to use mechanical equipment during the three working shifts per day in the heavy snow period. Many have little knowledge of such equipment, and in past years have caused much downtime and increased repairs. Now the men are given at time of hiring short, intensive training on the proper operation and use of, and preventive maintenance work on, snow-removal equipment.

Training to be effective must be a continuing activity. Having given the in-service course on lubrication and preventive maintenance to the operating forces, it would be nice to be able to check off the need and go on to new activities. However, the training must be repeated, with necessary revision. Persistent effort is needed to get unit repair costs down and to keep them down. Unit repair cost seems to be related to the interval between course presentation. Unit repair costs seem to rise about 3 yr after termination of the course. A decrease in average annual unit repair cost of $1.00 amounts to a saving of nearly $8,000. It is, therefore, economical to carry on with such training activity.

SAVINGS IN UNIT REPAIR COSTS

The following computations of savings are based on each respective year's inventory and average annual unit repair cost compared with the average annual unit repair cost for all items on inventory (excluding sedans) for FY 1952. This was the fiscal year immediately before the introduction in August 1953 of the initial phase of the preventive maintenance program. It is believed that the consequent values of savings shown are conservative because costs of labor, repair parts, and replacement component have consistently increased since that year, and computed savings have not been adjusted to include the effect of inflation.

Eleven months after the introduction of the in-service course on lubrication and preventive maintenance, the average annual unit repair cost decreased $55 for FY 1953, with a further decrease of $107 during the following year. With consideration for the units on inventory each year, this represents a saving of more than $266,000 during the first year and an additional saving of over $508,000 during the second year. The average annual repair cost per unit, starting with FY 1952 and including FY 1962, is shown in Figure 1.

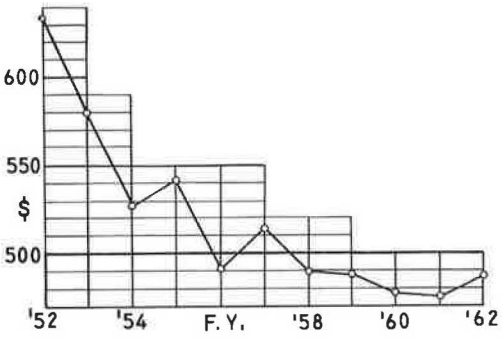

Figure 1. Average unit repair cost, all equipment except sedans.

There was an increase in unit repair cost for FY 1955. This is attributed to the unusual repairs required because of the effects of the "big flood" during the winter of that year. Many pieces of equipment were inundated and required major work to get them back into operation. In spite of an increase of approximately 2 percent, the total saving for the year was more than $461,000.

Favorable effects of the lubrication course were supplemented by introduction of lubrication manuals and lubrication charts in July 1954, the second phase of the program. These, together with the fine cooperation of the equipment superintendents, shop personnel, and especially of the Highway Maintenance Department, assisted in reducing unit repair costs $143 at the end of FY 1956. This represents a saving of more than $782,000 during the year—or a gross saving of greater than $2,018,000 during the four fiscal years following the inception of the program.

An increase in average annual unit repair cost of $23.42 for FY 1957 showed that changes in personnel and other factors influencing the effectiveness of the program were such as to justify another intensive training effort. The second presentation of the lubrication and preventive maintenance in-service course was started in April 1958. It contributed to a reduction of $24.56 in unit repair cost for FY 1958, representing a saving of more than $874,000.

MEFEO training, the third phase of the preventive maintenance program, was initiated in November 1959, and this contributed to a further reduction in average unit repair costs of $2.96 for FY 1959 and $9.65 for FY 1960. This accounts for a saving of more than $913,000 and $1,054,000 for the FY's 1959 and 1960, respectively. A further reduction in unit repair cost of $1.39 and a corresponding saving of more than $1,135,000 occurred in FY 1961.

An increase in average unit repair cost of $11.25 over the previous year took place during FY 1962. This still represents a saving of more than $1,143,000 for the year. The increase in average unit repair cost may again reflect that the major "benefit span" of the previous in-service course has been reached.

The total savings attained since adopting a strong preventive maintenance program amounts to the impressive sum of $7,822,083. This represents savings in direct repair costs only. No evaluation has been made of the savings due to decreased downtime, increased average selling price of equipment because of improved preventive maintenance, and other advantages associated with good operating condition of equipment.

The general increase in cost of labor, replacement components and repair parts leads to increased cost of repairs. The wages of the shop men have increased 49.4 percent between FY 1952 and 1962 (Fig. 2). Increase in cost of repair parts has been approximately 35 percent and of replacement components, 21 percent, during the 10-yr period.

In spite of the relatively large increase in cost of these factors, the average annual repair cost per inventory unit (not including sedans) has shown a percent reduction on a yearly basis (Fig. 2), reaching 24.93 percent in FY 1961.

When it is realized that a 1 percent decrease in unit repair cost reflects a saving of approximately $38,000 per year, the dollar value of cost-reducing activities becomes significant.

ADDITIONAL FACTORS AFFECTING REPAIR COSTS

As previously mentioned, there are many factors which affect repair costs on highway maintenance equipment in addition to preventive maintenance.

One of the nine most generally used methods for reducing excessive operating costs of equipment (1) is the minimizing of abuse of equipment by a system of discipline and merit awards. In California this can only be accomplished in a general way. The policy of frequently changing operators makes it impractical to associate an abuse with any particular person, except in flagrant cases. It also negates selection for merit awards, except in over-all improvement. The promotion of self-discipline by appealing to the sense of responsibility and providing adequate training in the mechanical features of equipment operation through MEFEO training is the strongest approach to the problem of abuse.

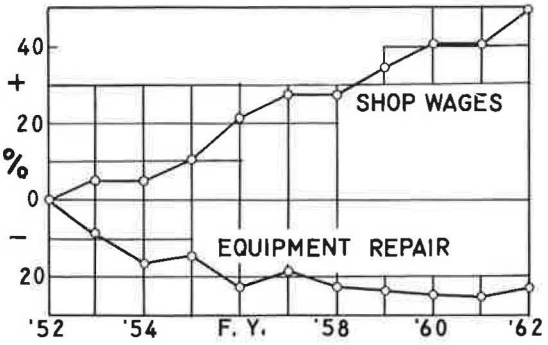

Figure 2. Change in unit costs.

There are many additional factors affecting repair costs which, in some degree, share with the preventive maintenance program in producing the impressive savings in average annual unit repair costs previously discussed. They include:

1. Improved quality of lubricants: During the 10-yr period included in this discussion, a series of State specifications were prepared which assure high-quality lubricating oil, hydraulic oil, multipurpose grease, diesel fuel, etc., for use in highway maintenance equipment. Engines are now free of sludge and there is evidence that the rate of deterioration of equipment is less ;
2. Improved shop buildings and grounds, better shop tools and repair equipment;
3. Increased knowledge and improvement in skills by the repair mechanic forces: This has been helped by in-service training courses on automotive electricity, automatic transmissions, and alternators, given at the various equipment shops and subshops. Other in-service training obtained at the Institute of Transportation and Traffic Engineering conducted by the University of California, at technical training centers, equipment service schools, and at night school courses have been of positive value;
4. Modernization and improvement in procedures and methods of handling repair parts in the stores section at shops: Mechanics spend appreciably less time waiting to obtain parts and, hence, there is less labor charged to repairs;
5. Improvements in operation of equipment by the Maintenance Department beyond the results of MEFEO training: Specific instructions from maintenance superintendents to avoid using certain equipment beyond its economic limitations have been helpful. A tendency to emphasize increase in production, even at the expense of excessive repair, has in some cases resulted in a negative effect on unit repair cost savings;
6. Improvements in equipment design and construction: There is a more general use of improvements such as torque converters in loaders and graders, better air cleaners, improved oil filters, and alternators. However, the necessary practice of purchasing equipment largely on a low-bid basis sometimes leads to equipment with high maintenance cost. Also, it should be noted that no particular improvements in equipment were made before FY 1957, yet the major reductions in annual unit repair costs took place before that year. Hence, it is difficult to establish the degree of positive influence of this factor;
7. Improvement in specifications to obtain equipment more compatible with the job required;
8. Decreased travel time for mechanics by locating resident and traveling mechanics nearer to the equipment on which they work;
9. Change in policy to eliminate regular routine periodic major overhaul given certain equipment, especially rotary snow plows: Since 1958 such equipment has been given a major overhaul only when there is definite indication that it is needed. A calculated risk is involved, but experience indicates that, in general, there has been no appreciable increase in breakdowns;

10. Decrease in the workweek: During the period studied, the introduction of the officially recognized coffee break took place, which theoretically reduces the workweek more than 2 hr. This amounts to an increase in labor cost of 5.2 percent and, hence, should increase unit repair cost. Actually, it probably has resulted in a decrease in labor costs; and

11. Change in general character of the highway maintenance fleet: Eleven years ago, the fleet consisted of about one-half construction equipment, such as graders, loaders, and tractors. Now it is made up of only about one-third construction equipment, the remainder being trucks and other equipment serviced on a mileage basis. There is little data to justify considering this change either positive or negative in its influence on average unit repair costs.

It should be remarked that the average annual unit repair cost for sedans has increased rather steadily to more than 84 percent relative to 1952 costs and reflected the effects of inflation during the 10-yr period covered in this study. The major difference between the sedan fleet and other inventory equipment, as far as maintenance is concerned, is the fact that the sedan fleet, in general, was given preventive maintenance work at commercial service stations and the other equipment was subject to the preventive maintenance program operated by the Division of Highways.

SUMMARY

An organized and continually fostered preventive maintenance program for highway maintenance equipment has proved to be a profitable activity for the California Division of Highways. The three primary phases of the preventive maintenance program are as follows:

Phase I. An in-service training course in preventive maintenance with particular emphasis on lubrication, repeated approximately each 5 yr for all personnel involved with equipment operation or repair;

Phase II. Preparation and distribution of lubrication manuals and charts for all major units of equipment; and

Phase III. Field-training classes on the mechanical features of equipment operation (MEFEO) to improve skill and knowledge of the operators and reduce repair costs from unintentional abuse.

Less than a year after the initiation of Phase I, the average annual repair cost per inventory unit of heavy equipment reduced nearly 9 percent, representing a saving of more than $266,000. Phase II was added and at the end of the second fiscal year, the annual unit repair cost reduced nearly 17 percent, representing a saving of more than $774,000 during the two fiscal years. With the introduction of Phase III, the entire program was in operation. At the end of FY 1961, the annual unit repair cost had reduced 25 percent compared to unit cost in 1952. The total saving in repair costs since the program was introduced amounts to $7,822,083, in spite of a 49 percent increase in hourly labor costs and a 35 percent increase in cost of repair parts.

It is not claimed that the preventive maintenance program is the sole cause of the impressive savings reported. However, most of the other favorable factors, such as improved repair facilities, tools and equipment, also applied to the unit repair cost for sedans which steadily increased during the 10-yr period studied in the paper. Preventive maintenance on sedans is largely accomplished by contract at private service stations and is not performed by operating personnel. This fact would seem to justify the statement that the preventive maintenance program has been an important contributing factor in saving for other highway uses more than seven million dollars since 1953.

ACKNOWLEDGMENTS

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Acknowledgment is also made to the staffs of the Equipment and Maintenance Departments for their cooperation in the program.

REFERENCE

1. "Manual of Uniform Highway Accounting Procedures." Amer. Assn. of State Highway Off., p. 149 (1958).