

REPORT OF COMMITTEE ON HIGHWAY MAINTENANCE EQUIPMENT ¹By T H DENNIS, *Chairman*

SYNOPSIS

The Committee made a study of the available equipment in use throughout the United States with a view to recommending suitable machinery for performing specific maintenance operations. A study was also made of State highway department practice with respect to equipment rental

The data on equipment use received from 34 States and the 12 districts of the Public Roads Administration were grouped on the basis of similar climatic conditions. The equipment selected for recommendation for specific purposes represents the recommendations of a majority of the reporting agencies

The general trends of use and scope of work of the following items are discussed: discs, distributors, tank car heaters and retorts, asphalt heating kettles, loaders, motor graders, mudjacks, snow removal equipment, rollers, power shovels, spreaders, sweepers, oil storage tanks, water tanks, tractors, trucks

It was found that geographical location had little to do with the general trends of equipment usage

In general the reporting agencies appear satisfied with their present practices in use of equipment and hence no attempt to establish uniform policy is attempted. This is also the case with respect to the possibility of establishing a uniform rental system

The information and recommendations received, together with the opinions of the committee members led to the formulation of some conclusions on items of policy as follows

State highway maintenance should in general be done with State forces and equipment although there is place for some contract work, and rental of seasonal equipment

State owned equipment should be administered by an equipment engineer in charge of a separate department

Rental rates on an hourly basis covering all costs except wages of the operator are favored for all mobile equipment and certain other units

The standardization of highway maintenance equipment has long been advocated by those interested in highway maintenance. The economy of such a move was obvious both to the maintenance organizations and the manufacturers of equipment. Realizing the need for such action, the Highway Research Board in 1940 selected a subcommittee to make a special study of this subject. The study encompassed a review of the various types of equipment available as well as that used in performing highway maintenance work. From the study it was hoped to recommend the most suitable and practical equipment for accomplishing specific

maintenance operations, as well as to enumerate the essential features for that equipment. At the meeting of the Highway Research Board in December 1940, this program was expanded to include a study of the establishment of uniform equipment rental procedure throughout the United States

EQUIPMENT USE

To facilitate the study and permit the placing of each piece of equipment under its proper function, the subject of highway maintenance was divided into eight major categories as follows:

- 1 Maintenance of traveled way.
- 2 Maintenance of shoulders.
- 3 Maintenance of roadsides.
- 4 Maintenance of bridges.

¹This is a condensed version of the complete report with detailed descriptions and illustrations on file at the office of the Highway Research Board

5. Maintenance of miscellaneous structures
6. Snow removal, drift and ice control.
7. Maintenance of trees, shrubbery and plantings
8. Maintenance of safety devices

This outline was submitted to all State highway maintenance departments, the Public Roads Administration, the Asphalt Institute and the Portland Cement Association, a total of sixty-two organizations

AREA COVERED

Response from the various organizations was very good. Reports of equipment used in maintenance work were received from 34 States and from all twelve Public Roads Administration districts. The information submitted was not complete in all cases, but it was representative and reflected a majority practice.

It was expected that the varied climatic conditions encountered throughout the United States would develop special requirements in maintenance and thereby produce special features in the equipment used. Hence the States, as well as the various Public Roads Administration districts, were grouped by areas of similar climatic conditions to permit summarization of the data on that basis.

BASIS OF SELECTION

Upon receipt of data from the various organizations, every piece of equipment used by them was listed in its proper category on tabulation sheets. The equipment as recommended by each of the subcommittee members for each maintenance operation was also entered on the tabulation and their recommendation was considered equal to that of any state or Public Roads Administration district.

Obviously all of the recommendations received did not merit consideration for inclusion in the final tabulation. It was

agreed, therefore, that a choice of approximately ten per cent of the reporting agencies would be required to qualify a unit of maintenance equipment for inclusion in the final recommendation. Under this procedure the recommendation of any five of the reporting agencies was taken as the minimum requirement for the selection of a particular unit.

This method of selection obviously eliminated certain special non-standard or obsolete types of equipment which some organizations found it expedient or necessary to use under their particular local conditions.

The equipment selected for any specific type of work, therefore, represented the majority recommendation of the reporting agencies. In general the recommendations were remarkably consistent, the principal variance being in size or capacity.

USE AND ADAPTABILITY

Study of the principal equipment types reported indicates the following general trend as to use and also the scope of work for which the unit is particularly suited.

Discs

The light disc harrow and scarifier is used to some extent in certain areas in the construction and maintenance of intermediate oil type surfaces. This limited use is due either to a preponderance of high type surface or the employment of mixing plants. The scarifier attachment on motor graders and tow graders is responsible for the declining use of the separate scarifier unit. The motor grader disc attachment is adaptable for removing irregularities on bituminous type surfaces.

Distributors

Truck mounted oil distributors of 800- to 1200-gal capacity are best suited for general maintenance oiling operations. The capacity is sufficient for a day's work.

with a small crew and if a greater quantity of oil is required, the truck is powered to tow a tank trailer of equal capacity. On smaller jobs the 300- to 600-gal. capacity trailer mounted distributors are preferred. These latter units are easily towed by a one and one-half to two ton truck.

The distributors described are also suitable, when equipped with special spray bars, for applying diesel oil or other liquid agents to roadside vegetation.

Since oiling operations are seasonal, the distributor unit (especially the truck mounted type) should be designed for easy removal from the truck chassis.

Tank Car Heaters and Retorts

The two car capacity two-wheel trailer mounted steam heater is preferred for heating the lower viscosity liquid asphalts where deliveries are taken from tank cars or storage. In localities where severe winter prevails, the heater may also be used for thawing out culverts or frost boils.

The retort heater, four wheel trailer mount type, is used for heating the heavier grades of liquid asphalts and paving asphalts required in armor coat, seal coat and retread surfaces. The unit, however, was not recommended by the Atlantic or New England group of States, where apparently heating requirements are handled by either stationary plants or field kettles.

Asphalt Heating Kettles

The asphalt heating kettles from 165- to 300-gal. capacity mounted on two-wheel trailers are the size most widely used on all types of surfaces other than untreated earth or gravel. They have sufficient capacity for normal daily maintenance requirements and can be readily towed by light trucks.

The 300- to 500-gal. capacity, two-wheel trailer type kettle, is not a popular

choice and its use (mainly by certain Central States) is confined to bituminous plant mixed surfacing. It is noted that in States where these units are used, there is no recommendation for oil distributors.

Loaders

The belt type loader mounted on two pneumatic tires is generally favored. Two other types of belt loaders are worthy of special mention—one is attached to a motor grader, the other is a self-propelled pneumatic-tired unit with force feed. Second choice is the bucket type loader. The pneumatic-tire mounting is preferred over the track-laying type for the latter unit.

The tractor mount front-end bucket loader has its supporters for loading stockpiles and slide removal work. It is available for mounting on both the wheel and track-laying type tractors.

Motor Graders

Recommendations received for the different size motor graders covered, in general, two classes, namely the 35- to 55-hp. with 10- to 12-ft. blade and the 60 plus hp. with 12- to 14-ft. blade. There is apparently no definite explanation of this classification other than the distinction indicated by the length of blade. The 14-ft blade, incidentally, is not standard and is probably made up by special extensions.

The motor grader is recommended above all other blading units for normal requirements. It is also adaptable to snow and ice removal operations within its capacity. For this particular work the 45 to 65 plus hp. unit is the most popular and is operated either with the blade or a "V" type snow plow attached to the front end. For ice removal a saw tooth blade is recommended.

Mudjack

The mudjack is used in all but the Mountain States where there is a com-

paratively small amount of concrete pavement. On badly warped slabs the mudjack has proved effective for corrective work. Practice varies—in some instances, premixed asphaltic material is used for leveling rather than attempting to restore the slabs to their original positions, and in others, the premix is laid as a temporary measure pending final restoration to grade with the mudjack at which time the patch is removed.

Snow Removal Equipment

The type of equipment required for snow removal varies with local conditions. The field includes straight blade and "V" type push plows and rotary plows.

The push plow will handle 12 to 24 in. of new snow at truck speeds of 12 m.p.h. The reversible type push plow lacks the capacity of the one-way push plow and is efficient in fresh snow depths of less than 15 in.

The "V" type plows can be operated in approximately four feet of fresh snow at truck speeds of 3 to 6 m.p.h. Equipped with wing blades, they are capable of maintaining sections where the maximum seasonal snowfall does not exceed 9 ft. The rotary type plows are essential for opening, widening and clean-up operations where heavy and continuing snowfall makes disposal necessary.

Rollers

The pneumatic-tired roller is recommended for compaction of oiled gravel, road mix, plant mix and retread surfaces. It is also used to a lesser extent on other types of surfacing. The 5- to 10-ton three-wheel rollers are generally accepted as the "all-around" unit, apparently meeting any and all rolling requirements. The third selection is the 2-ton to 5-ton power-driven portable roller closely followed by the 2-ton to 5-ton portable tow type. Due to their portability these latter two units

are particularly suited to scattered patch work. The 5- to 10-ton tandem ranks fifth in preference, the 5-ton unit being generally used more on routine maintenance work.

Shovels

The one-half cubic yard shovel is definitely the preference of all reporting agencies. The crawler type with trailer is more popular than the truck mounted type. The crawler type possesses a tractive advantage which evidently outweighs the lack of portability. Some agencies are still operating units of three-eighths cubic yard capacity, but there is little economic justification for such practice.

Spreaders, Sand, Chip or Stone

The two-wheel roll feed hopper type spreader, 10 or 12 ft. long, is highly favored, particularly for the maintenance and construction of thin oil top, retread and non-skid type surfaces.

Second in choice is the tail gate gravity spreader generally used where it is desirable to operate the vehicle in reverse to apply material in advance of the wheels.

The revolving disc type spreader, while not rated as highly as the other two for spreading aggregate, is definitely the more popular unit for sanding operations on snow and ice removal. It is also suitable for spreading chlorides.

Sweepers

The front-end tractor mounted rotary broom is the most extensively employed type of sweeper reported. The reason for this evidently is the compactness of the unit which permits turning within a short radius, thus minimizing interference with traffic. The attachment is easily removed, freeing the tractor for other operations. The greatest use of this unit is in connection with seal coat application.

The four-wheel trailer mounted power-

driven broom is a close second choice for all sweeping requirements.

The four-wheel trailer mounted traction driven broom is apparently less popular than the power-driven types

Tanks, Oil Storage

Oil supply tanks covered a wide range of capacities. General practice indicates little preference as to type of mount for the group between 800- and 1200-gal capacity. There is a definite trend toward truck mounting of tanks ranging from 1200- to 2000-gal. capacity.

The 10,000 to 14,000-gal. capacity oil storage tanks are not generally used, due perhaps to the ease of securing material deliveries as needed. Present transportation difficulties will no doubt encourage a return to the early practice of road oil and asphalt storage.

Tanks, Water

The 700- to 1000-gal. capacity truck mounted tanks with sprinklers are not extensively used, but are preferred to the trailer mounted tank of the same capacity. The truck mounted unit of approximately 1000-gal. capacity is the most popular size for tree watering.

Tractors, Tow Graders

The reporting agencies generally favor the 25- to 50-hp track-laying type tractor towing an 8- to 12-ft blade grader for the maintenance of earth, gravel and crushed rock surfaces. The unit is also adaptable to maintenance of oiled surfaces as well as shoulder and roadside blading. The size and capacity of the unit are governed by local conditions. A tractor of approximately 40 hp. with 10-ft blade grader meets the demands of routine maintenance. Tractors up to 70 hp with 12- to 14-ft blades were accorded second choice for maintenance of earth roads, possibly due to their adaptability to construction

work when not required as maintenance units.

Wheel type tractors of 25 to 50 hp. towing an 8- to 12-ft. blade grader have also proved satisfactory for traveled way maintenance on both treated and untreated surfaces. This particular combination is more adaptable to light work where tractive conditions are favorable. The wheel type tractor is particularly suited to the operation of various attachments such as the front-end loader, hoists, tractor driven rotary sweeper and mowers.

The track-laying type tractors of 40 to 95 hp. are very popular. The larger sizes equipped with angle or bulldozer are most efficient in slide removal and grading work, especially where traction is poor. They also perform exceptionally well in combination with loading attachments. The 40-hp unit is the most widely used on highway maintenance work.

Trucks

The $\frac{1}{2}$ - to $\frac{3}{4}$ -ton express body, while very popular for shoulder, roadside, and traveled way maintenance in the Pacific States, is not so extensively used in the remaining areas where the $1\frac{1}{2}$ - to 2-ton capacity dump truck apparently meets general demands.

The $1\frac{1}{2}$ - to 2-ton capacity dump truck is the most widely used truck on highway maintenance. The unit is consistently favored on all types of maintenance, other than bridges, even for hauling material. It is likewise used in towing light blade graders, drags, road maintainers, mowing machines, propelling the light duty straight blade snow plow, sanding icy pavements and all related work.

The $1\frac{1}{2}$ - to 2-ton capacity flat bed is widely used in the maintenance of safety devices, since special racks or compartments can be readily constructed.

In certain localities a limited number of 3- to 6-ton dump trucks have been found desirable either because such units

are required for snow removal operations, or because they cannot be rented readily from outside sources as needed for slide removal, grading and large scale hauling. Apparently their necessity and advantages for specific operations outweigh their lack of adaptability to routine maintenance. On snow removal work the four-wheel drive truck, 2- to 5-ton capacity, with dump body is greatly favored over the two-wheel drive of similar capacities. They are also suitable for towing grading units and the transportation of maintenance materials. Where snow removal is of no consequence the two wheel drive trucks will meet all requirements.

GEOGRAPHICAL EFFECT

Contrary to general expectations, geographical locations exhibit little influence on the general trends of equipment usage. The few instances where this occurred and the particular units affected are enumerated herewith.

The light $\frac{1}{2}$ - to $\frac{3}{4}$ -ton capacity express body truck is used as a patrol unit in the Pacific and Mountain group of States. This particular unit was not recommended elsewhere. The $1\frac{1}{2}$ - to 2-ton capacity dump truck is favored by the remaining reporting agencies.

The portable two-blade maintainer is most commonly used on maintenance of untreated crushed rock or gravel surfacing. Its use is confined mainly to the Central States having a considerable mileage of untreated rock or gravel surfacing.

Small portable bituminous mixers are favored in all but the Pacific and Mountain States. This might indicate that in the latter two areas patch material is either blade mixed or purchased from commercial sources.

Discs and harrows were recommended by the Pacific Group of states for use

in oil treatment work. This equipment is apparently not used in other areas.

Large dump trucks are recommended only by the Pacific and Mountain States. The $1\frac{1}{2}$ - to 2-ton capacity dump truck is more popular in all other areas. The use of heavy trucks may be due, in part, to the necessity of utilizing the heavy trucks when not required for snow removal work.

For loading operations the Pacific and Mountain States prefer the power shovel rather than the mechanical loaders used in the other localities.

EQUIPMENTAL RENTAL

Forty-one states responded to the questionnaire on equipment rental. The majority opinion of the reporting agencies generally reflected the subcommittee's opinion. The replies, however, definitely argued against the possibility of any general acceptance of a uniform rental system. A summary of the replies to each of the items included in the questionnaire and the subcommittee's recommendations follow.

Item 1.

- (A) Is the present method of handling equipment satisfactory?
- (B) Are any changes contemplated in the present system?

The majority of States reporting considered present methods of handling equipment satisfactory and none contemplated changing present methods. It would thus appear that promotion of a uniform rental system will be difficult.

Item 2. Does the state highway department perform all maintenance work on state highways, or is all or a portion let to contract to other political subdivisions or private contractors?

The information obtained indicates that some portion of all maintenance on state

highways is carried out by day labor forces in 42 states, while 14 states report that certain phases of maintenance work are let to contract. General practice, therefore, dictates that maintenance of highways should be performed by day labor forces and that special work be let to contract wherever such work is beyond the capacity of these forces and the items of special work can be readily defined

Item 3 Does the state own all equipment used on maintenance work or is a portion of the equipment rented from outside parties?

Equipment used on state highway maintenance is, in general, state-owned. It is common practice, however, to rent privately owned equipment such as power shovels, oil distributors, heavy trucks, etc., for seasonal or emergency work. The purchase of state-owned equipment is usually confined to units required continuously or to special types not readily available on a rental basis. Such a policy is of mutual benefit both to the state and the private equipment owner since it avoids the necessity of a heavy capital investment by the State, and provides work for privately owned equipment which might otherwise be idle.

The recommendations received indicate that all equipment required for normal maintenance operations should be owned by the supervising authority and that outside equipment be rented for special or emergency use.

Item 4. What is the average annual expenditure for rental of state-owned equipment, and for equipment rented from outside parties?

The average annual expenditure for rental of equipment owned by the 26 States reporting was \$1,383,270 per State. An additional amount equal to 21 per cent of this average was likewise expended for the rental of privately owned equipment. This latter figure serves to emphasize the dependence now placed on that source.

Item 5. Is state-owned equipment handled by a separate department, by the maintenance department or by the districts?

It was found from the replies that support for each method of equipment administration is about equally divided. Some of the advantages as well as the disadvantages of each method are enumerated:

Under an equipment engineer with special training there should be greater assurance of the performance of mechanical features, the enforcement of necessary working restrictions and insistence on timely upkeep and repairs. On the other hand, this centralization of authority unless accompanied by a knowledge of maintenance problems and operations might well handicap a maintenance organization.

Administration under a district would of course permit the selection of equipment best suited to its particular conditions and insure its coordinated use. However, under such administration there is always the likelihood of over-equipping or concentrating on specialized equipment. Furthermore, the exigencies and demands of particular work might well overrule practical considerations of upkeep and repair.

Many of the disadvantages of the district method apply equally well to administration by a maintenance engineer. His major concern naturally is the performance of work, generally with a contractor's viewpoint regarding the use of the equipment but without the latter's opportunity of writing off the investment at the conclusion of the job. Then too, the purchase of equipment, its repair and upkeep is a specialized job for which the maintenance engineer is seldom trained. He is, however, conversant with the demands of his work and therefore better versed in setting up the control features of the equipment required.

Because of the equal popularity of the

three methods of administration, the views of the committee members were taken as the deciding factor. Of the five committee members who expressed a preference, three favored a separate department and two considered that the administration of equipment matters should be under the maintenance department.

Item 6. Is state-owned equipment handled on a rental basis? State-owned equipment is handled on a rental basis in 75 per cent of the states reporting on this question.

Two desirable objectives are reached through use of a rental system. First, it permits creation of a reserve fund from which to finance the cost of repair and replacement of maintenance equipment. Second, the cost of equipment is distributed currently against the work on an equitable and reasonably accurate basis. In addition there is a decided advantage in having a basis of comparison as to cost of operation of equipment in the several districts which normally make up a state highway organization. The information is desirable also if a comparison is to be made between the cost to the State of owning and operating equipment as against the cost of renting privately owned and operated equipment. There would be a further benefit from an administrative point of view, if the policies and rental rates in the various states were calculated on a basis which would permit comparisons.

Item 7. What method is used for figuring depreciation?

Replies to this question indicate that it is the general practice to establish depreciation rates on a straight line basis with due consideration given to first-cost and trade-in values. Only one state reported a varying rate from year to year for units in a given group. One state reported original purchase from special appropriation and one state reported that entire cost is depreciated in the year of purchase.

It is possible that legal requirements in some States make it mandatory to secure special appropriations for purchase of equipment. However it should be noted that the true cost of work cannot be ascertained if the cost of equipment is not distributed in some manner.

Allowance for depreciation is based on the service life of the equipment and the salvage value at the time of retirement. The service life of each unit in a group of similar equipment units is dependent on (1) the number of hours of operation and the severity of work performed within the given period, (2) indeterminate items such as the skill of operators or care in servicing and (3) the policy followed by different states as to repairs and/or replacements. The question of time of replacement has a special significance. It is the policy in some cases to replace units before extensive overhaul is necessary. Obsolescence as well as changes in traffic requirements or improvement of the road system may effect changes in equipment needs and thus limit the period of usefulness of certain units. All these factors must be considered in establishing depreciation rates. There are also varying emergency conditions. For example, the life of highway maintenance equipment now in service will no doubt be prolonged through more intensive overhauls and replacement of worn parts as a result of the war emergency.

Item 8. List the items included in the rental rates for state-owned equipment (operating costs, operating supplies, repair, upkeep, depreciation, overhead, profit, etc.)

The majority of states reported that rental rates include depreciation, cost of repairs, upkeep and all operating costs except wages of the operator. There is practically universal agreement that the wages of the operator should be excluded from equipment rental rates.

In arriving at the cost of repair and upkeep, the following overhead items

should be taken into account in addition to depreciation and gradual obsolescence

1. Major repair, overhaul and upkeep
2. Storage, insurance, incidentals and equipment overhead.
3. Cost of plant including land, shop buildings and power machine tools
4. Cost of operating (fuel and lubricants) and servicing costs.

If comparisons are to be made with rental rates charged for outside or privately owned equipment, the following items should be given consideration.

1. Interest on investment or profit.
2. Insurance and surety bond premium.
3. Taxes.
4. Wages of operators.

It may be assumed that in states where the costs of fuel and lubricants and other operating items are not included as part of the rental rates, such charges are distributed directly to the cost of the work. On that assumption there is very substantial agreement among the 33 States as to the items which should be included.

The inclusion of charges for fuel and lubricants as part of the rental rates presents little difficulty. There is no question but that the inclusion of these items in the rental rate would permit more accurate distribution of the cost of work than is the case when fuel, oil and other lubricants are delivered in bulk and distribution of the cost thereof is made to road sections on a mileage or some other fixed basis. This is not the case with the labor engaged in servicing and operating the equipment. Maintenance crews are generally organized and trained to perform the routine as well as special work within their sections. Obviously each section is not fully equipped for all such operations since much of it is either intermittent or seasonal. As a result equipment is transferred from place to

place as the need arises. Equipment rented on an operated basis under such conditions would necessitate a uniform rate which might conflict with the classification and pay scale of the particular crew. Likewise the permanent assignment of the operator to the equipment might not always be either economical to the maintenance organization or fair to the equipment operator.

The majority opinion favors a rental system which includes depreciation, repairs and upkeep, plant and storage, and all operating costs except wages of operator. From a cost accounting viewpoint, such a system permits a day by day cost distribution on the basis of actual use of equipment. It simplifies the daily accumulation of expenditures so that the men in charge can readily ascertain the status of their job funds at any time.

A study of data furnished by the States shows the variety of methods followed in calculating rates and a wide range in the rates for similar units of equipment.

There is also wide variance in the basis on which rates were established. For instance, rates were reported as being on an hourly, daily, weekly, monthly, mileage and seasonal basis. One State reported a seasonal rate for its snow plows and a second State reported a weekly rate for two water pumps. A number of States use either a per mile or monthly basis for automobiles and a monthly rate for graders and similar equipment.

By grouping like equipment and neglecting incidental differences it was ascertained that the following basis for rates prevailed among the 33 states reporting.

Basis of applying rates	Percentage of units reported
Hourly	59.1
Daily	15.9
Weekly	0.1
Monthly	20.3
Mileage	4.4
Seasonal	0.2
	100.0

The 59.1 per cent that favored rental on an hourly basis was broken down to indicate the preference as to method of computing rates:

- 79.9 per cent favored an hourly rental to cover all operating costs except operator.
- 12.6 per cent favored an hourly rental to cover depreciation, repairs and upkeep
- 4.8 per cent favored an hourly rental to cover all operating costs exclusive of depreciation and operator
- 2.7 per cent favored an hourly rental to cover all operating costs including operator.

These percentages are representative only of the total units reported in the hourly rate group.

SUMMARY

A summary of the information and recommendations secured from the different States and views of the committee members lead to the following conclusions in regard to the subjects covered.

In view of the many methods of handling equipment as reported by the different States, it is evident that considerable difficulty would be encountered in attempting to establish a uniform policy. The reporting agencies appear satisfied with their present setup and no changes from the adopted policies are contemplated.

Maintenance of State highways should be performed with state personnel and equipment. Work of considerable conse-

quence where the quantities involved are readily determinable and other conditions are favorable may frequently be let to contract.

The State should own all equipment that is extensively used or special units that are particularly designed for highway maintenance. Seasonal equipment should be rented from privately owned sources during the required period.

Administration of state-owned equipment should be handled by a separate department under an equipment engineer who is directly subordinate to the chief engineer or commissioner.

All mobile equipment and certain other units of a predetermined minimum value should be placed on a rental basis. Rental rates should be established from actual records of the costs and experience as to usable life for the particular type of equipment involved.

Depreciation is generally calculated by the "Straight Line" method based on the estimated trade-in value of the equipment, and applied throughout the entire service life of the unit.

Rental rates established for each class of equipment should be sufficient to cover all costs except operator. The most generally favored method of assessment is on an hourly basis.

COMMITTEE ON MAINTENANCE EQUIPMENT

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