In order that ¼" of water may be removed from one acre of land in 24 hours it is necessary to discharge .0105 cubic foot per second. Hence 1.85 ÷ .0105 gives 176 acres, which is approximately the result desired. By this same process, the size of the submains and laterals may be determined.

It is not necessary to figure it all out in this way if we have access to a discharge diagram such as found in Bulletin No. 854, U. S. Department of Agriculture. From this one can at once select the velocity, discharge, slope, and even acres drained by all sizes of tile ranging from 4" to 48" in diameter, with drainage coefficient ranging from ¼ to 1.

I will not go into detail about the elements to be considered otherwise, such as the selection of the tile which will have the proper strength test, the grading and laying of the tile, the protection of the outlets, the refilling of trenches, the layout of the systems, and the construction details. I take it for granted that you are all more or less familiar with these phases.

THE USE OF CALCIUM CHLORIDE AND OIL AS DUST LAYERS ON STONE AND GRAVEL ROADS

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Of all the traveling nuisances of modern roads dust probably is deserving of first place. Besides being uncomfortable and expensive, it offers a source of danger that has taken its toll of human life by outright slaughter caused by obscured driving vision, to say nothing of the more insidious suffering caused by respiratory troubles which can be traced directly to dust. Any toleration of dust is due either to callous indifference on the part of those charged with contributing to the comfort of the traveling public or to lack of funds with which to carry on the ever-increasing fight against this evil. I am glad to say that those with whom it has been my lot to work in this task have a keen appreciation of the dust problem confronting them and are doing all within their power to bring relief. Any program of extensive dust laying costs money, a factor always confronting those acting as trustees of highway funds. Public demand is merciless in many instances and runs counter to good financial judgment. The

financial problem of those responsible for the expenditures is to bring the maximum relief where most demanded by the minimum expenditure. This in many cases has been misconstrued as gross neglect by some not so fortunate as to enjoy dust relief. Others see the impossibility of relieving all dust and are willing to bide their time until traffic intensity warrants diversion of funds from the more permanent types of pavement to the temporary relief offered by dust palliatives.

Dust is merely road metal divided finely enough to be carried by the air. Anything that will bind these particles together, thus causing their united weight to be sufficient to keep them on the road surface, acts as a dust palliative. The most common agent for doing this is rain. All of us have experienced the exhilaration of driving over a smooth gravel or stone road which contained just enough moisture to "lay" the dust and not enough to produce a muddy surface. I submit such a surface as the most pleasant and comfortable driving surface that can be found, whether paved or unpaved. But unfortunately, like so many other desirable conditions, the agencies responsible are short-lived. Much research has been carried on and a great deal of money expended in the effort to duplicate the conditions that go to make up this desirable driving surface supplied by nature's agency of moisture. Any artificially applied palliative offers problems which must be solved if anything like lasting results are attained. What is its first cost, how permanent is the relief it brings, what is its effect on the road surface after the dust season is over, are ever-present questions offered by the now known dust layers. The two agents most universally used at present are calcium chloride and road oil.

Calcium Chloride

This chemical (calcium chloride) is a salt which is present in many different materials ranging as widely as sea water and some minerals. It is a large by-product in the manufacture of sodium carbonate, a very important chemical in the manufacture of glass, soap, sal soda, etc. It is also pumped as a solution direct from the earth. Calcium chloride as we get it for dust-laying purposes contains about 1½% of sodium chloride or common salt. This salt is sometimes objectionable by causing rust and corrosion on vehicle parts. Calcium

chloride as produced for dust laying is white and granular in appearance, and its use as a dust palliative depends on its ability to absorb many times its weight of moisture. When applied to the road surface, it goes into solution by absorbing and retaining atmospheric moisture. This action produces a damp surface which in turn keeps the dust particles bound together, thus preventing their flying in the air. This moisture absorption power of the chemical, however, gradually weakens and other applications must be made if the desired results are to be obtained. Needless to say, heavy rains are very damaging to this material, especially if they occur before the chemical goes into solution.

Our experience shows that frequent light treatments are preferable to fewer heavier ones. I would suggest one pound per square yard for the first treatment, followed by two or three subsequent treatments of one-half pound each, the number of treatments and the elapsed time between them depending on the dryness of the season and the nature of the road metal. Calcium chloride will not work satisfactorily on course or extremely clean road metal, or on any surface that has once been oiled. A little clay, fine sand, or stone dust are necessary ingredients if good results are to be obtained. If applied on an oily surface, it will form globules of moisture which make a dangerous, slippery driving surface. Contrary to the recommendations of calcium chloride advisers we have found that a comfortable dragging coat floated back and forth across the driving surface is preferable. Without this the constantly moist surface compacts so hard that the road drags are unable to prevent the development of a rough surface.

The proper amount of calcium chloride for economical and practical maintenance will not completely lay all the dust. There is a condition between excessive applications producing an absolutely dustless surface, which will be expensive, slippery and hard to maintain, and a moist surface from which only a small amount of dust will fly and which can be maintained much as an untreated surface. In other words, some dust is preferable to a crusted, potted surface.

When a calcium chloride treated road comes out of the dusty season into the wet winter season, new problems arise. After a slight thaw, the surface becomes very slippery; and if the weather continues fair long enough, the slush so created becomes dry and hardens almost to concrete density. If main-

tenance is lax at this time, a rough surface results until rains relieve the situation. However, I believe the metal retained on the road surface by being held in place during the summer season, metal which was formerly lost as flying dust, will well account for itself during the annual spring thaw and "break-up." It will take a period of years economically to determine the value of this phase of calcium chloride as a dust palliative.

The cost of a two pound per square yard treatment is about $300.00 per mile applied. If a treatment follows one of the previous year, probably it can be reduced in amount, since a slight amount of the chemical will carry over the winter. But with the constantly increasing traffic we are encountering, which necessitates the addition of so much fresh metal, in turn calling for more palliative, the first year cost will likely be an average. Calcium chloride as a dust layer has much merit but, like all other methods, is also subject to some criticism. The wisdom of its continued use will have to be determined over a period of time. It certainly is not a panacea for all dust ills, but if properly used in the right location, it has much to commend it.

Road Oil

Of the two methods of dust laying that of road oil is the more positive. Its power to make one dust particle adhere to another does not depend on anything so changeable as the varying moisture content of the atmosphere. Its successful use, however, is subject to finer adjustments of conditions, and when this is true of any procedure the chances for complete success are that much more remote. The kind of material, the grade of oil, the method and amount of application, and the proper maintenance methods following application are all problems.

Our first aim was an oil-coated dragging course which could be handled much as that of untreated road metal. Clean road metal was applied to the road at the rate of about 300 cu. yds. per mile. This was ridged along one side of the road with a blade grader. The oil was applied to the bare surface at the rate of ½ gallon per square yard. As soon as possible, the ridged metal was spread evenly over the surface and traffic was allowed on it at once. In the first work of this

kind, an asphaltic oil of 40 to 50 viscosity was used with an asphalt content of about 70%. Soon after this was applied, our troubles began. The large asphalt content in the oil began to form a mat and severe "pot-holing" resulted. No dragging equipment would break up the crust formed in some places. The next remedy was to apply metal to drag into the previously formed "pot-holes." By the addition of more metal, a very objectionable oily dust was formed. This in turn called for more oil and so the vicious cycle went on. The patrolman would "peddle" oil into the holes while dragging, but because of the hard crust surrounding the "pot-holes," the impact of passing wheels dropping into the holes from the edge of the hardened crust would throw out the patching material.

On one ten-mile stretch of road, we got on 910 cu. yds. of metal per mile and finally had to scarify the crusted surface before a decent riding surface resulted. The crust was so hard that a pressure of 175 pounds had to be used on the scarifier teeth and the teeth had to be sharpened every day. This experience determined two things: either a mat forming oil should be used and a mat maintained, or a low viscosity, low asphaltic content oil used, and a dragged surface maintained. The latter plan was finally used, even with a non-asphaltic oil, and with gratifying results. I am of the opinion that the non-asphaltic oil will not be as beneficial as the heavier oil when taken as a water-shedding agency for the road surface.

Contrary to our forecasts an oiled road does not seem to be as solid in some places after a thaw as an untreated one. If the subgrade is non-porous and the drainage poor, the oil prevents capillarity from below and thus prevents the escape of subgrade moisture by capillarity and evaporation, the agencies capable of best drying the road. On a surface underlaid by a subgrade of this kind, the oily slush dries slowly and by just that much is inferior in rapid drying qualities to an untreated surface. Whether the oil will prevent objectionable quantities of water from getting into the road is a matter of conjecture until the usual spring break-up comes. It is my opinion that no appreciable benefits in the early spring will be derived from oil until a road has two or more annual treatments. In this opinion, I seem to be somewhat alone, but here again it will take some time to verify or re-

pudiate opinion. After increased traffic has warranted the expenditure for oil treatment for two or three seasons, it seems economical to apply some kind of paved surface. I do not see how good road economics can justify successive annual dust treatments on any road for a very long period in lieu of more permanent relief.

Road oil has been costing about 6 cents per gallon applied. The first application consisting of ½ gallon per sq. yd. and a second of ¼ gallon makes a total of ¾ gallons. At 18 feet wide, a mile contains 10,560 sq. yds., which at ¾ gallons would take 7,920 gallons per mile. At 6 cents per gallon, the oil applied would be $475.00 per mile. Our contract price has been a little under 6 cents but after supervision and manipulation cost has been added, the $475.00 per mile is a close approximation for the first year's treatment.

Conclusions

Our experience offers little choice between stone and gravel for the metal to be treated. Either must be clean and free from dust if good results are obtained. If stone is used, I would recommend a size of 1¼" to ¾"; if gravel, it should be screened or washed and about 1" to ½". Too much stress cannot be placed on the proper size of aggregate. If properly graded aggregate is not available, oiling had better be abandoned; for if it is too fine a non-uniform mat will form which will seriously "pot-hole" under traffic, and if too coarse, the large pebbles will fly from the tires of passing vehicles and be a source of serious danger. Also the coarse metal will roll under the tires, thus causing skidding, which makes driving unsafe and uncomfortable.

In conclusion, do not be misled into believing that dust palliatives will reduce your maintenance problems—they will only intensify them. Your reward will have to come from some other source. The benefits will be realized in safer, more comfortable driving conditions which reflect from the traveling public an assurance to those making the expenditure that they have acted wisely.