M.V.S. - January, 1955

THE CONSOLIDATION OF FOOTWALL DUST AT VLAKFONTEIN GOLD MINING COMPANY LIMITED

By

B.J.R. BOTHA (Member)

INTRODUCTION

One of the chief obstacles to be overcome when mining at depth, or in strata where the Geothermic gradient is steep, is heat flow from rock to air which, if not curtailed, rapidly produces an atmosphere in which men cannot work.

It has been shown in practice that heat from the above source can be radically reduced if the intake airways are dry. Unfortunately, however, dry intakes, while arresting one problem give rise to another. It was found that when men walked along the dry footwall, and when locos trammed along dry intakes a great deal of dust was disturbed and became airborne, which increased the dust count in the intake air appreciably before it had done any useful work in the development ends or stopes.

The following passages, extracted from one of the publications of the Calcium Chloride Association of Detroit, Michigan, U.S.A., are relevant to this problem. Figures I to IV are taken from the same source.

"One of the prime requisites for the efficient service behaviour of stabilized dusty footwalls is that they possess a certain degree of cohesion. This is supplied by the binder-soil fraction in the presence of sufficient moisture. For it is the films of moisture between the small binder-soil particles and not the particles themselves that furnish the principal bonding forces.

"The bonding value of moisture can readily be demonstrated by adhering two block gauges together with a light lubricant, and it will be found that a direct pull of over 200 pounds per square inch will be required to separate them. The application of plain water to the dusty footwall of dry intakes would merely precipitate heat flow, and this must be avoided.

"Flake calcium chloride, which is the form most suitable for footwall consolidation, is a white, odourless and stable material which possesses both deliquescent and hygroscopic properties.

Deliquescence is the process of dissolving and becoming liquid by attracting and absorbing moisture from the air. Hygroscopicity is the process of readily absorbing and retaining moisture. These properties of calcium chloride are very important and are closely related to the relative

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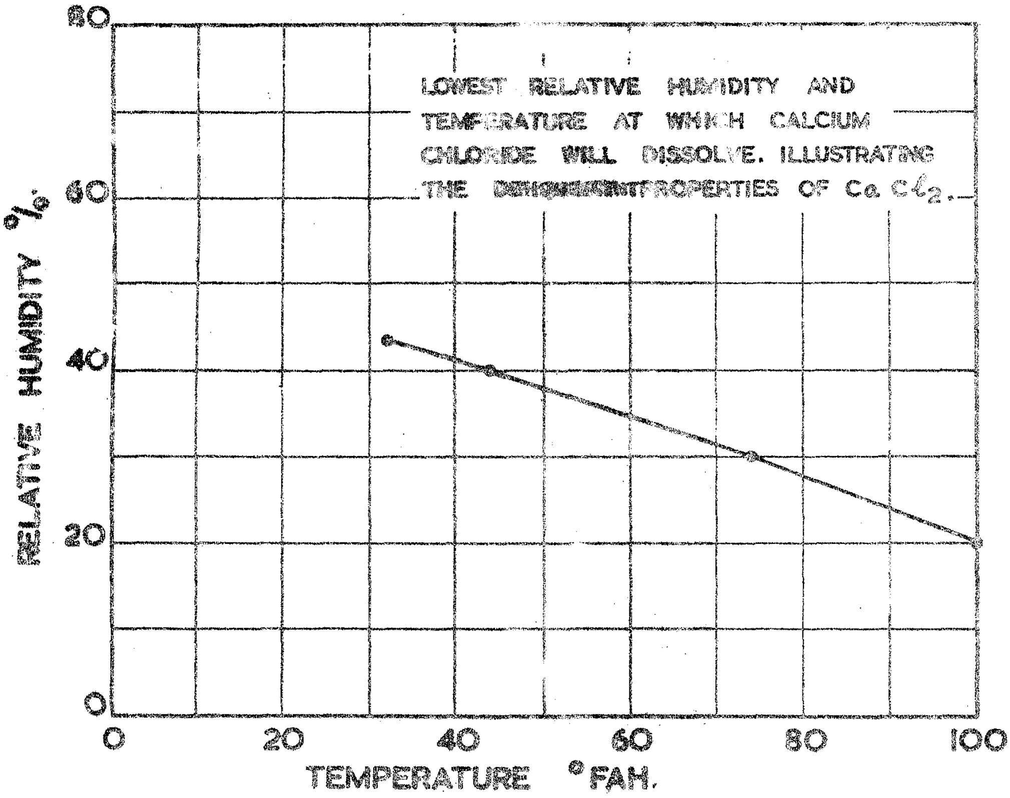
LOWEST RELATIVE HUMIDITY AND
TEMPERATURE AT WHICH CALCIUM
CHLORIDE WILL DISSOLVE. ILLUSTRATING
PROPERTIES OF $CaCl_2$.
RELATIVE HUMIDITY %
0
20
40
60
80
0
20
40
60
80
100
TEMPERATURE °FAH.

FIG. 1.

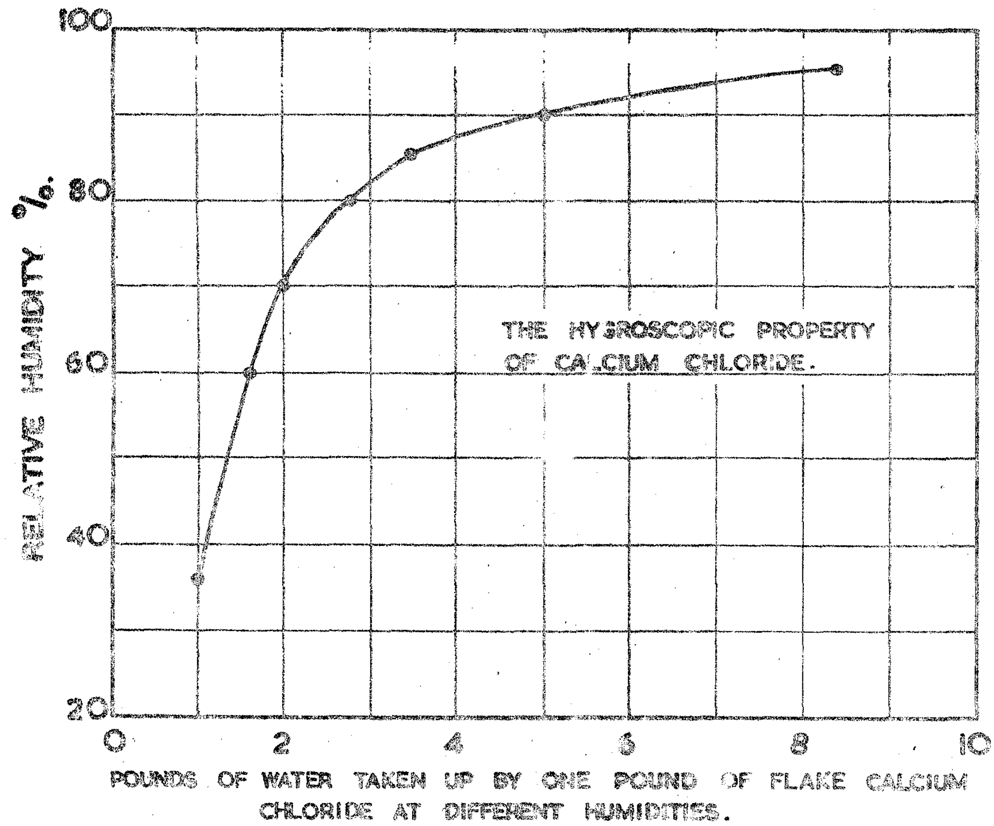
THE HYGROSCOPIC PROPERTY
OF CALCIUM CHLORIDE.
RELATIVE HUMIDITY %
20
40
60
80
100
0
2
4
6
8
10
POUNDS OF WATER TAKEN UP BY ONE POUND OF FLAKE CALCIUM
CHLORIDE AT DIFFERENT HUMIDITIES.

FIG. 2.

humidity and temperature of the air. See Figure I and II for a graphic representation of these properties. From these graphs it is quite obvious that the hygroscopic property of calcium chloride should greatly reduce the evaporation of moisture from the surface of the footwall by replenishing this moisture content during periods of high humidity, i.e. summer time, and during the night. (See Figure III for verification of this relationship).

"The use of calcium chloride, due to its deliquescent and hygroscopic properties, furnishes the important "moisture films" to the loose dirt and dust on the footwall, thus assuring a semi-solid cohesion, which offers the greatest resistance to the shearing action of traffic. The effectiveness and lasting qualities of the calcium chloride "moisture films" are much greater than those of ordinary water "moisture films" because of their lower vapour pressure, which means a much slower evaporation rate, and due to the increased surface tension which produces a tougher membrane than ordinary water."

The following discussion is taken from the Proceedings of the Highway Research Board, U.S.A. Part II page 23, 1932:-

> "Vapour pressure is defined by the physical chemist as 'the tendency shown by a substance to pass from the liquid or solid into the gaseous state'. This phenomena is of great importance in understanding the effect of calcium chloride on the evaporation of water from soil. For similar humidity and temperature the vapour pressure of a calcium chloride solution is always lower than that of water, which means a slower rate of evaporation. Vapour pressure may be considered as being a property of the free energy at the surface of the moisture film that surrounds each particle of the soil. With an increase in the concentration of the calcium chloride solution, the vapour pressure is decreased with a corresponding decrease in moisture loss due to evaporation. It is chiefly the lower vapour pressure of the calcium chloride solution on the surface of the treated soil samples that retards the evaporation of moisture from the soil. This layer of solution on the surface of the soil may be conceived of as an effective semi-permeable blanket through which the moisture from the soil has difficulty in reaching the surface where evaporation takes place".

"A practical verification that the lower vapour pressure of calcium chloride solutions greatly conserves the moisture content in the soil is shown graphically in Figure IV. This conservation of the moisture content in the footwall surface averts the formation of dust, thus keeping the intake air clean and healthy to breathe".

In view of this it was decided that experiments should be conducted with hygroscopic salts in an attempt to supply sufficient moisture in the footwall dust to promote cohesion without affecting the relative humidity of the air.

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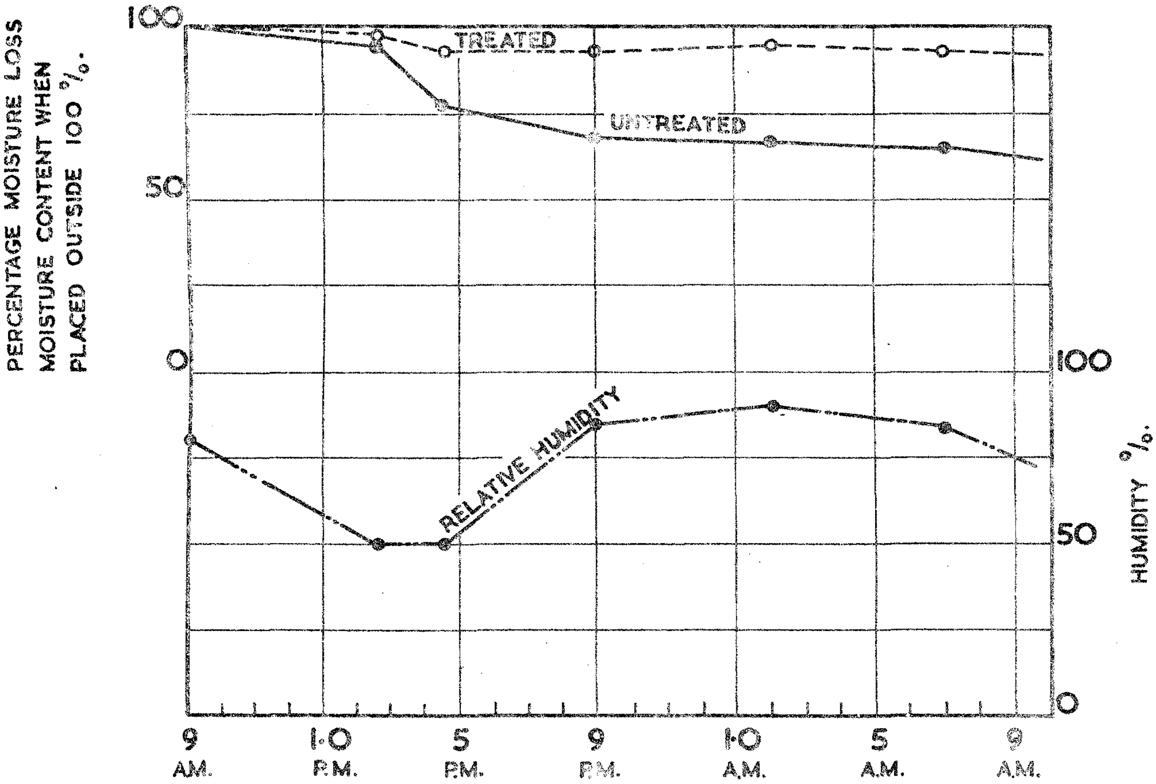
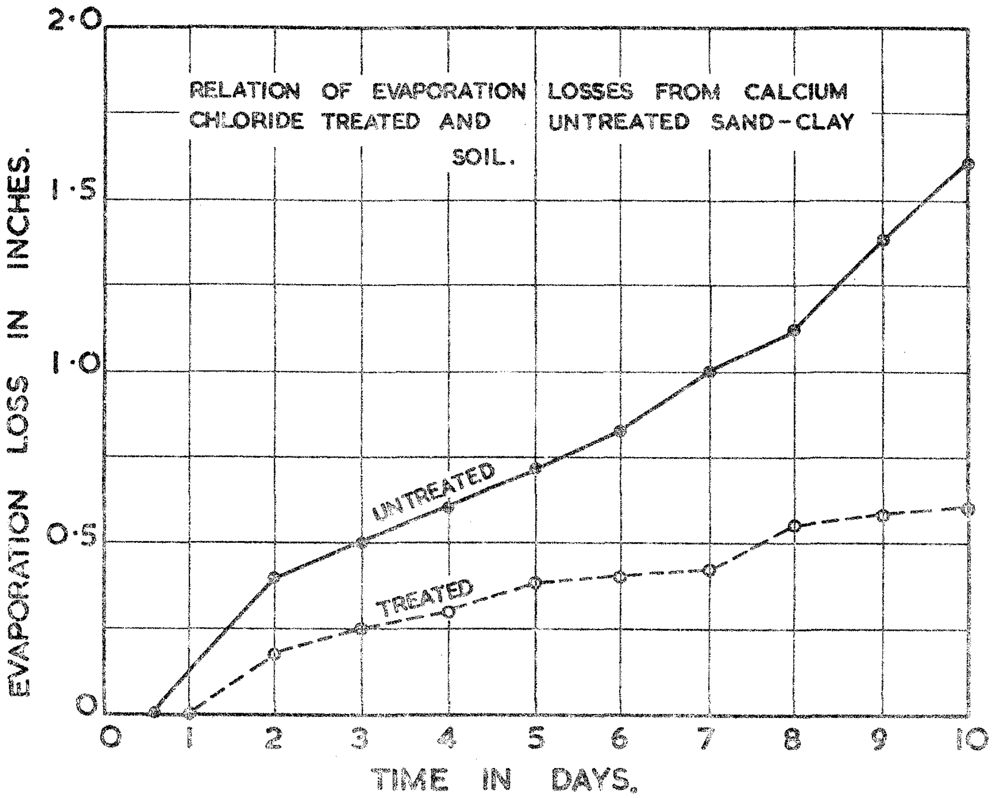


RELATIONSHIP BETWEEN THE RATES OF EVAPORATION OF MOISTURE FROM THE TREATED & UNTREATED SOIL & THE EFFECT OF THE RELATIVE HUMIDITY ON THE HYGROSCOPIC PROPERTY OF THE $CaCl_2$ TREATED SOIL.

FIG. 3.



THE SELECTION OF A SUITABLE HYGROSCOPIC SALT AND RELEVANT THEORY

Practical tests at Vlakfontein G.M. Co. Ltd., have shown that calcium chloride is the best desiccant, readily available at a reasonable cost, to mix with the footwall deposit in order to abstract moisture from the air passing over it and so keep the deposit moist and consequently dust free. The floor dust should contain about 10% of moisture if it is to be consolidated satisfactorily and remain consolidated.

It should be mentioned in passing that of other desiccants available, magnesium chloride is also suitable since it absorbs water vapour over about as wide a range of atmospheric humidity as calcium chloride. However, the resultant surface is slippery and wood in particular is so affected, and could constitute a danger to safety, e.g. slippery sleepers. Its cost is also greater.

As for sodium chloride, it has a very limited use, since in cannot be used if the relative humidity is below 75% because the salt itself then becomes dry and powdery and the surface cracks up. Calcium chloride acts in quite a different way from sodium chloride as a hygroscopic salt; calcium chloride strives to take water from the atmosphere and to dilute itself until equilibrium is reached at a solution of about 35%.

TREATMENT

A preliminary examination of the footwall is necessary with particular reference to the wettability of the surface dust. If the dust has not been or cannot be uniformly wetted by water alone down to a depth of AT LEAST one inch, the use of a wetting agent is indicated. Two wetting agents were tried out at Vlakfontein, viz., Lissapol N. (Imperial Chemical Industries) and Teepol (Shell Chemicals). Both were found to be equally effective for this particular purpose.

Having assessed the wettability, the next step is to clear the footwall to be treated of everything except dust, and to level off the surface. In certain instances it may even be necessary (and indeed advantageous) to import sand and dirt to spread over stretches where there is only solid footwall. All stones greater than one to one and a half inches in diamater should be raked up and removed.

The next step is to place the drums of flake calcium chloride at the correct spacing, which is worked out as follows:-

(a) determine minimum relative humidity of the air passing over the footwall to be treated, because the amount of calcium chloride which would be necessary is dependent on the humidity of the atmosphere and can be calculated from a knowledge of the vapour pressures of solutions of calcium chloride. Once the relative humidity is known, refer to Figure V and read off how much calcium chloride is required.

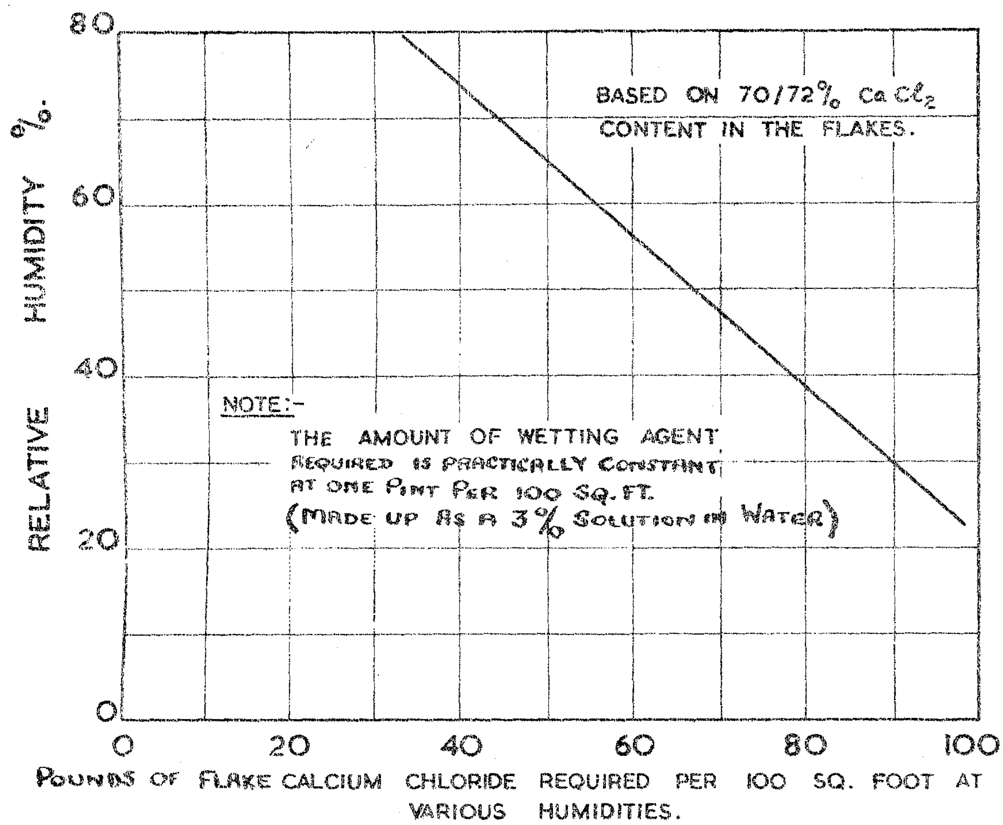

RELATIVE HUMIDITY %.
80
60
40
20
0
BASED ON 70/72% Ca Cl_2
CONTENT IN THE FLAKES.
NOTE:-
THE AMOUNT OF WETTING AGENT
REQUIRED IS PRACTICALLY CONSTANT
AT ONE PINT PER 100 SQ. FT.
(MADE UP AS A 3% SOLUTION IN WATER)
0
20
40
60
80
100
POUNDS OF FLAKE CALCIUM CHLORIDE REQUIRED PER 100 SQ. FOOT AT VARIOUS HUMIDITIES.

FIG. 5.

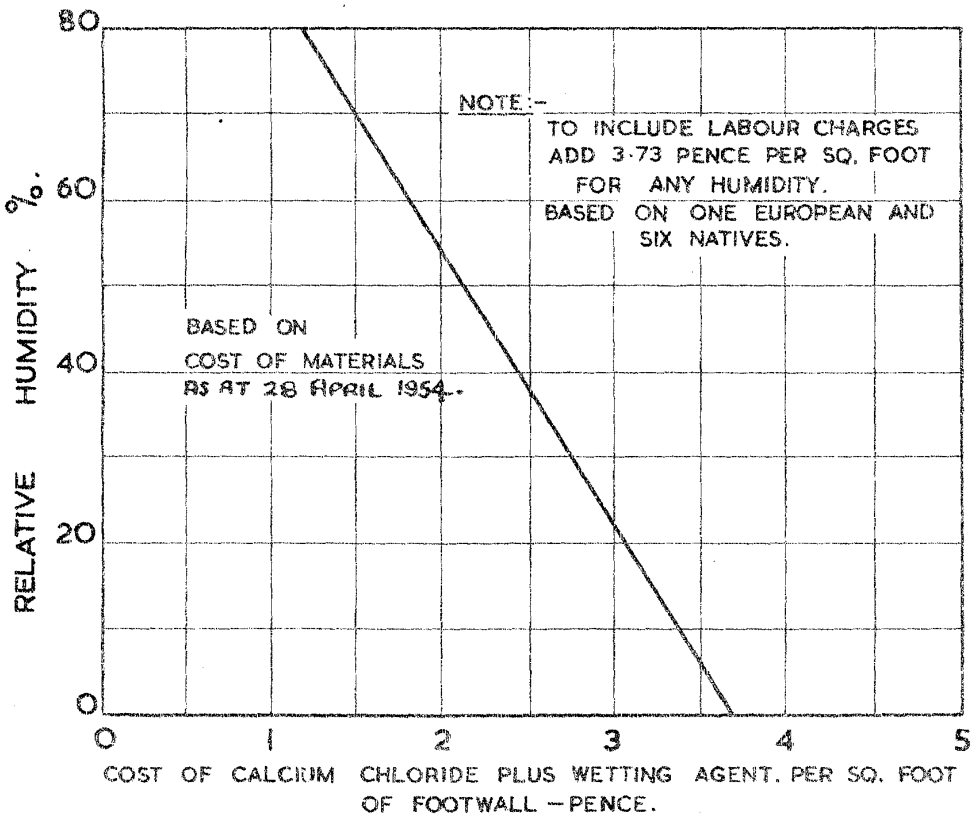

RELATIVE HUMIDITY %.
80
60
40
20
0
NOTE:-
TO INCLUDE LABOUR CHARGES
ADD 3·73 PENCE PER SQ. FOOT
FOR ANY HUMIDITY.
BASED ON ONE EUROPEAN AND
SIX NATIVES.
BASED ON
COST OF MATERIALS
AS AT 28 APRIL 1954.
0
1
2
3
4
5
COST OF CALCIUM CHLORIDE PLUS WETTING AGENT. PER SQ. FOOT OF FOOTWALL - PENCE.

FIG. 6.

b) determine the weight of calcium chloride per drum. By simple division the number of square feet per drum can be determined, e.g. RH = 20%, then from Figure V it is seen that 100.8 lbs. of flake calcium chloride per 100 sq. feet is required. Then if the weight of calcium chloride per drum is 336 lbs. (this is usual) 100 x 336/100.8, or 333 sq. feet can be treated per drum. Furthermore, if the strip of footwall to be treated is 3 feet wide it follows that 111 feet of footwall per drum can be treated, and "drum sections" of 111 feet can be marked off on the side wall, and a drum placed in the centre of each section.

From practical experience it has been found that seven drums can be spread per shift using one European supervisor (essential) and six Natives, at a relative humidity of 20%. When the humidity is higher, less drums can be laid per shift because a greater area of footwall has to be wetted and it is this operation that takes most of the time.

The wetting of the footwall can now be commenced, and again assuming a RH of 20% the wetting should be done over the seven "drum sections" plus ten feet on either side.

A 3% solution of wetting agent is first applied, using an ordinary garden watering can with a rose spray at the rate of four gallons per 100 sq. feet. In practice it has been found best to use a two-gallon can which is convenient to carry. To make a 3% solution in a two-gallon can, half a point of wetting agent is required. This is followed by four to six gallons of pure water per 100 sq. feet, and in certain cases of high evaporation losses, a larger volume of water may be required. In cases where the footwall dust is very dry, as it is at Vlakfontein, it will be found that even with the addition of a wetting agent, it still takes a long time to wet the dust to the required depth of one inch. If this condition is encountered, it will be found that the wetting can be greatly accelerated by brushing the water and wetting agent solution into the footwall, using bass brooms and rakes.

At this stage it should be mentioned that on no account should the calcium chloride be spread until the whole surface to be treated, on any one shift, is wet to a depth of <u>at least</u> one inch.

Having established that the footwall is sufficiently wet (it must be tested with a pick every ten feet or so) the spreading of the calcium chloride can be commenced, and this is done in two stages. On the first day (never a Saturday) 75% of the contents of the drum are spread over the "drum sections" and the remaining 25% the following day, preferential treatment being given to any patches which appear drier than the rest. The following procedure should be adopted on the first day:- Open the drum and turn it over on its side, then take a spade full of flakes and spread a little at either end of the "drum section" to mark the area to be treated with that particular drum. This expedient is very necessary since the Natives used are mainly convalescents

/who ....

who not only are not trained in this job but also may only be on the job for one shift. New labour may well have to be trained the following day. It was proved in practice that if the marking of the sections was not done in this way the Natives simply pass the mark on the sidewall and continue spreading into the adjoining section; consequently the density of calcium chloride per sq. foot will not be as calculated and poorly consolidated patches will result.

After the section has been marked as described, 75% of the calcium chloride in the drum is spread as evenly as possible over the section. For this operation it is best to use empty 4 gallon oil tins with the tops cut off, and simple wire handles fitted. Note also that the tins should not be filled more than half-full with flakes, otherwise they become unwieldy and uneven spreading results. When this has been done, a bass broom should be used to even out the flakes, making the layer as uniform as possible. The drum should then be stood upright, and covered with the lid as well as possible. Where the humidity exceeds 30% it is advisable to cover the flakes in the drum with an old piece of dry sack to check deliquescence, and then to replace the lid.

The remaining sections are then treated as detailed above, and on the second day the balance of the contents of the drums are apread as previously described. This operation takes very little time and the wetting of the next stretch is soon under way.

The time that the calcium chloride takes to deliquesce depends on the humidity of the ambient air and varies from 6 - 48 hours before the calcium chloride disappears into the floor.

The aim should be to obtain a uniform surface just plastic enough to take easily and retain the imprint of an unworn heel or hobnails. The appearance of an ideal surface can be gauged from Plate I. When this photograph was taken the person whose feet appear in the photograph was running at full speed and it will be noticed that there is a complete absence of dust. A surface such as this can tolerate quite an appreciable amount of subsequent deposition of dust which it absorbs.

When the surface has not been treated correctly, e.g. if it was not wetted sufficiently, or if too little calcium chloride was applied, then a surface such as shown in Plate II is obtained. It required a very hard stamp of the foot to produce the heel print shown and it will be noticed that the surface is loose and granular with complete lack of cohesion. A job breakdown is given in Annexure "A".

MAINTENANCE

Once the footwall has been properly consolidated, deterioration is mainly dependent on the amount of new dust being deposited on the treated surface, and if the amount is at all substantial deterioration will be rapid, since the necessary proportion of calcium chloride will no longer be

/maintained .....

maintained in the uppermost dust layers, and the surface will disintegrate as shown in Plate II.

It is thus obvious that the deposition of fresh dust must be avoided, and this can best be accomplished by suppressing it at its source. Since it is mainly intake airways that are affected, on the Witwatersrand gold mines at any rate, there are three main sources of new dust:-

(a) Shaft loading boxes plus, in some cases, transfer ore passes.

(b) Main tips in the vicinity of the downcast shaft.

(c) Dust blowing off full cars on their way to the station tips. (Today this is mainly high speed loco tramming).

Of the above sources of new dust (a) and (b) can be entirely eliminated by the judicious use of filters, while (c) can be reduced to a minimum by the use of "car wetters".

At Vlakfontein it was found that a great deal of dust was caused by the latter source. It will be appreciated that with the very low RH prevailing at this mine (annual average 28%) the rock in the cars dries out very quickly, especially when they stand at the marshalling points waiting for spans to be made up. In view of this "car wetters" were constructed at strategic points. There are now several of these in use at present, and they are of two types, viz:

(i) Manually operated wetter. See Plate III. This type is used for loco spans. As soon as the loco is past the sprays the driver turns these on and hauls the span through the wetter which is turned off again by another Native detailed, amongst other things, to do this job.

(ii) Automatically operated wetter. See Plate IV. This type is used in endless rope haulages, and is automatically turned on and off by the car as it passes through.

Three main benefits were derived from these wetters:-

1. Deposition of new dust was largely eliminated.
2. The filters at the tipplers did not choke up so quickly.
3. Creation of dust as the cars bumped into one another before entering the tippler and again after leaving was virtually eliminated.
   The RH is hardly affected by the sprays since they only operate for a short time. A rubber flap on one side of the wetter checks the escape of most of the dust created as the cars are wetted.

However, in spite of the above precautions, corrective treatment does become necessary after a period (which is

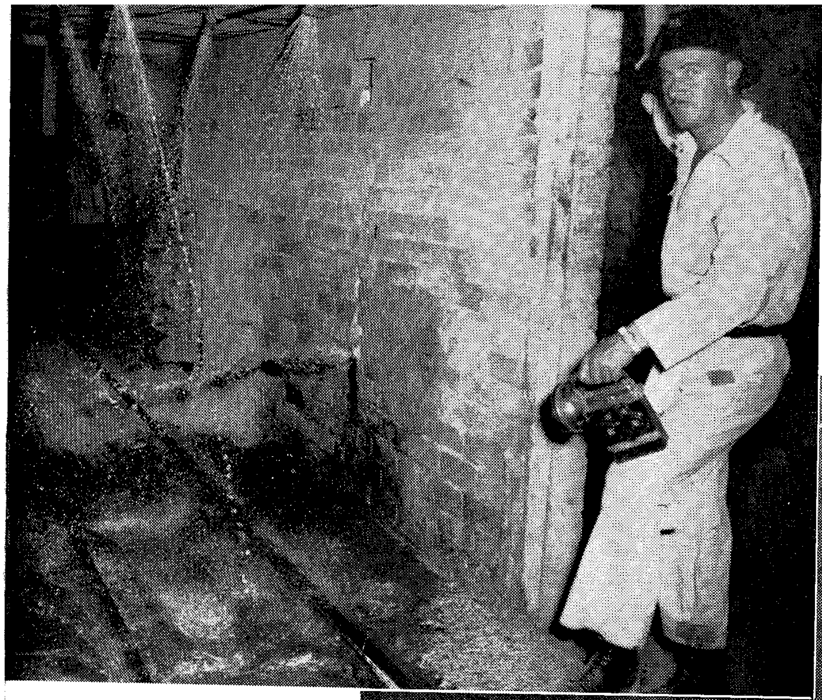
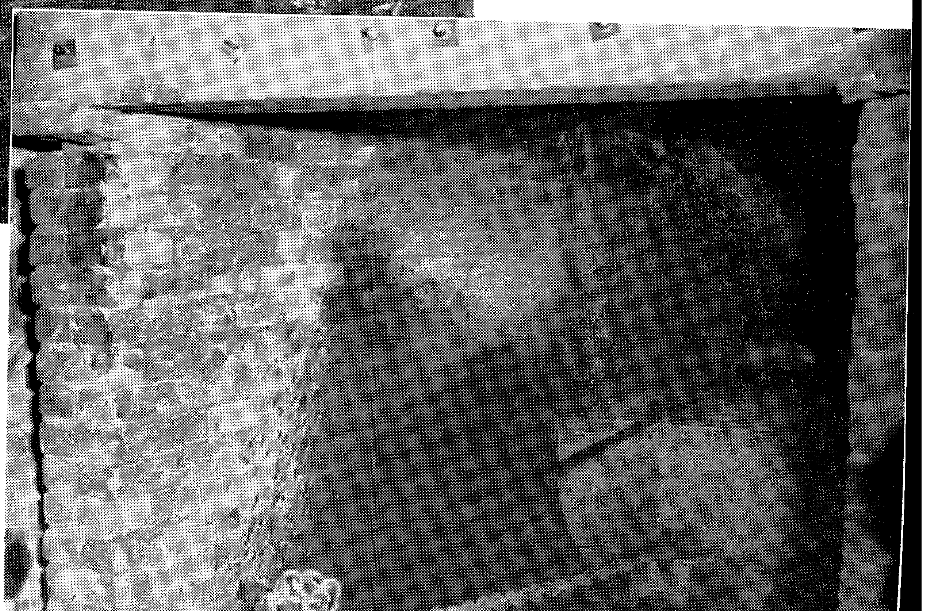


PLATE III ←

PLATE II →

← PLATE I

PLATE IV →



dependent on circumstances). At Vlakfontein there is a stretch 750 feet long by 4½ feet wide that was laid in February, 1950, and to date no remedial treatment has been found necessary, the surface being still perfectly plastic and dust free, i.e. free of loose dust that could become airborne.

When remedial treatment is deemed necessary the operation is simple. "Drum sections" are marked out as before, but with four times the spacing used for the initial treatment. The solution of wetting agent is applied as before, except that a quarter of the original volume is required.

To date over 12,000 feet of footwall has been treated at Vlakfontein, and so far no remedial treatment has been required. In the great majority of cases the treatment has proved successful.

GENERAL

1. Precautions

A few precautions are necessary when using calcium chloride.

(a) Calcium chloride dust can cause smarting of the eyes, though with reasonable care this can be avoided.

(b) Calcium chloride-damped clothing has no ill effects on the skin, provided prolonged contact with the skin is avoided. A daily rinse, first with pure water, then with soap, will suffice.

(c) Calcium chloride tends to shrink leather boots; consequently gum boots should be worn.
To date there is no evidence that calcium chloride has accelerated the corrosion of metal underground, e.g. tracks and haulage ropes.

2. Snags

When attempting to consolidate inclined portions, considerable difficulty will be experienced in wetting the surface because the water and wetting agent run off so easily. In such cases the water has to be applied in small amounts and vigorous brushing with bass brooms must be done simultaneously. In most cases it will be found that two days are necessary for the wetting.

In an attempt to improve on the above technique, an experiment was conducted using calcium chloride Lissapol NX Flake manufactured by Imperial Chemical Industries (South Africa) Limited - as was all the other calcium chloride used at Vlakfontein - and it proved quite satisfactory. This compound has the wetting agent ready mixed with the flakes which can be spread on the footwall without pre-wetting. After the flakes have been spread and evened off, a careful sprinkling of water is all that is required. The cost is, however, appreciably higher than calcium chloride flakes.

/Thus .....

Thus far only one strip of 100 x 3 feet on an 8^{o} incline has been treated with this compound on Vlakfontein, and it has proved most successful.

A word of warning should also be given regarding the treatment of loco haulages, because when the flakes are spread they make the tracks very slippery and render the locos' brakes practically useless. The loco driver should, therefore, be warned to brake early, otherwise a serious accident may result. Fortunately this condition only lasts a few hours. If the loco has a sand box, use should be made of it.

3. Reduction in Dust Content of Intake Air

The use of calcium chloride has certainly eliminated the dust hazard along the dry intake airways and will no doubt play a big part in the control of silicosis in the future.

Tests were carried out along a stretch 2,000 feet long before and after consolidation with calcium chloride, and no effect on the RH was noticed.

In order to get actual figures regarding its effects on dust control, the Transvaal Chamber of Mines was asked to conduct a series of tests using a thermal precipitator, and this was duly done on 20th August, 1950, as follows:-

The test was conducted along a horizontal drive, 250 yards of which had been consolidated, and 250 yards not. Thermal precipitators were set up simultaneously at the beginning and end of each section and eight Natives were made to walk fast to and fro along the two sections for half an hour, and the following results were obtained:-

(a) T.P. count (after ignition) at beginning of treated section .... 70 p.p.c.c

(b) T.P. count (after ignition) at end of treated section .... 90 p.p.c.c

INCREASE .... 20 p.p.c.c

(c) T.P. count (after ignition) at beginning of untreated section .... 75 p.p.c.c

(d) T.P. count (after ignition) at end of untreated section ....170 p.p.c.c

INCREASE 95 p.p.c.c

(e) A further test was made of a fast moving loco span of fulls passing over the treated and untreated sections and over the untreated section the dust count rose to 210 p.p.c.c., while over the treated portion the concentration was well below 100 p.p.c.c. (The span had been through the wetter beforehand).

/The ....

The size distribution of the dust was as follows:

	(a)	(b)	(c)	(d)	(e)
Less than $\frac{1}{2}$ micron	66%	48%	44%	53%	55%
$\frac{1}{2}$ - 2 micron	26%	23%	29%	29%	36%
Greater than 2 micron	8%	29%	27%	18%	9%

Further information regarding the test strips is as follows:-

Volume of air flowing	=	58,000 c.f.m.
Velocity of air flowing	=	600 ft/min.
Wet Bulb temperature	=	68°F.
Dry Bulb temperature	=	90°F.
Relative humidity	=	31%

From the above Table it can be seen that the percentage of harmful dust is high and that the treatment was fully justified.

As can be seen from Figure VI the cost of the treatment is low; for conditions prevailing at Vlakfontein the average cost is $6\frac{1}{4}$ pence per square foot. The cost of concrete walkways is more than double this figure. Concrete is also not nearly as effective as regards dust control, since dust settles on it and has to be continually watered down and swept.

In conclusion, I wish to express my thanks to Mr. A.J. Cundill, the Manager of Vlakfontein G.M. Co. Ltd., for permission to present this paper.

A N N E X U R E "A"

JOB BREAKDOWN SHEET

DISTRIBUTION

1. Manager
2. Assistant Manager
3. Underground Manager
4. Production Engineer
5. Training Officer
6. All Mine Overseers
7. Ventilation Officer

PART Consolidation of Footwall Dust

OPERATION Application of wetting agent and calcium chloride ($Cacl_2$)

LABOUR One European (essential)
Six Natives plus one boss-boy.

STEPS IN THE JOB	KEY POINTS
PRELIMINARY EXAMINATION	1. Check wettability 2. Check condition of surface 3. Determine lowest RH (ventilation Dept)
TOOLS	1. Three rakes 2. Three picks 3. Three shovels 4. Three bass brooms 5. Three 2-gallon cans with rose sprays 6. Three empty oil tins with handles 7. One half-pint measure 8. One ventilation pipe cutter 9. One 100 ft. tape
PREPARE SURFACE	1. Remove all stones larger than 1-1½" diameter 2. Level off ground 3. Import sand and dirt where necessary 4. Determine average width of surface to be treated
CALCULATE QUANTITIES	1. Read off amount of $Cacl_2$ required from Figure V. 2. Divide this figure into weight of drum 3. Multiply this figure by 100 4. Divide this figure by average width of surface to be treated 5. Result will be the length of surface that can be treated with one drum 6. Mark off drum sections 7. Place drum in centre of each section

STEPS IN THE JOB	KEY POINTS
WET THE GROUND	1. Mark off area to be treated in one shift plus 10 ft. 2. Mix wetting agent ½ pint to 2 gallons water 3. Apply solution 4 galls/100 sq. ft. 4. Follow up with plain water 4-6 galls./100 sq. ft. 5. Brush liquid into F.wall with bass brooms 6. Whole surface must be wetted to a depth of at least one inch 7. Test with a pick
APPLY CALCIUM CHLORIDE FLAKES (First Day)	1. Open drum and spread a little $Cacl_2$ at extremities of drum section 2. Spread 75% of contents of drum evenly using empty oil tins 3. Do not fill tins more than half 4. Use broom to make layer uniform 5. Cover up remainder of $Cacl_2$ in drum - sacking
APPLY CALCIUM CHLORIDE FLAKES (Second Day)	1. Spread remainder of flakes 2. Give preferential treatment to dry patches
EXAMINE TREATED SURFACE	1. Allow interval of one month 2. Surface should be plastic 3. Retain print of unworn heel 4. Re-wet and apply additional $Cacl_2$ to dry patches(25% of original loading)
REMEDIAL TREATMENT	1. Necessary when F.wall is crumbly and dry 2. Re-wet and apply flakes as for initial treatment, but use only 25% of original amounts