JOURNAL OF THE MINE VENTILATION SOCIETY OF SOUTH AFRICA

Published monthly by the Mine Ventilation Society of South Africa.

Secretaries — ASSOCIATED SCIENTIFIC AND TECHNICAL SOCIETIES OF SOUTH AFRICA, KELVIN HOUSE, 75 MARSHALL STREET, JOHANNESBURG. TELEPHONE 33-5248 P.O. BOX 9426

Contributions are welcome from members and non-members.

The attention of authors is drawn to the Guide to Authors, conventional signs and abbreviations which appear in the Journal from time to time.

The opinions expressed by contributors do not necessarily represent the official views of the Society.

VOLUME 16 NO. 1 JANUARY 1963, PRICE 50 CENTS (5/-)

VENTILATION AND DUST CONTROL IN AN UNDERGROUND CRUSHING-CONVEYING SYSTEM

By G. Phimister*

Synopsis

A system of underground crushing and conveying is described. The method used to ventilate the system, the measures taken to effect dust control and the filtration arrangements are presented.

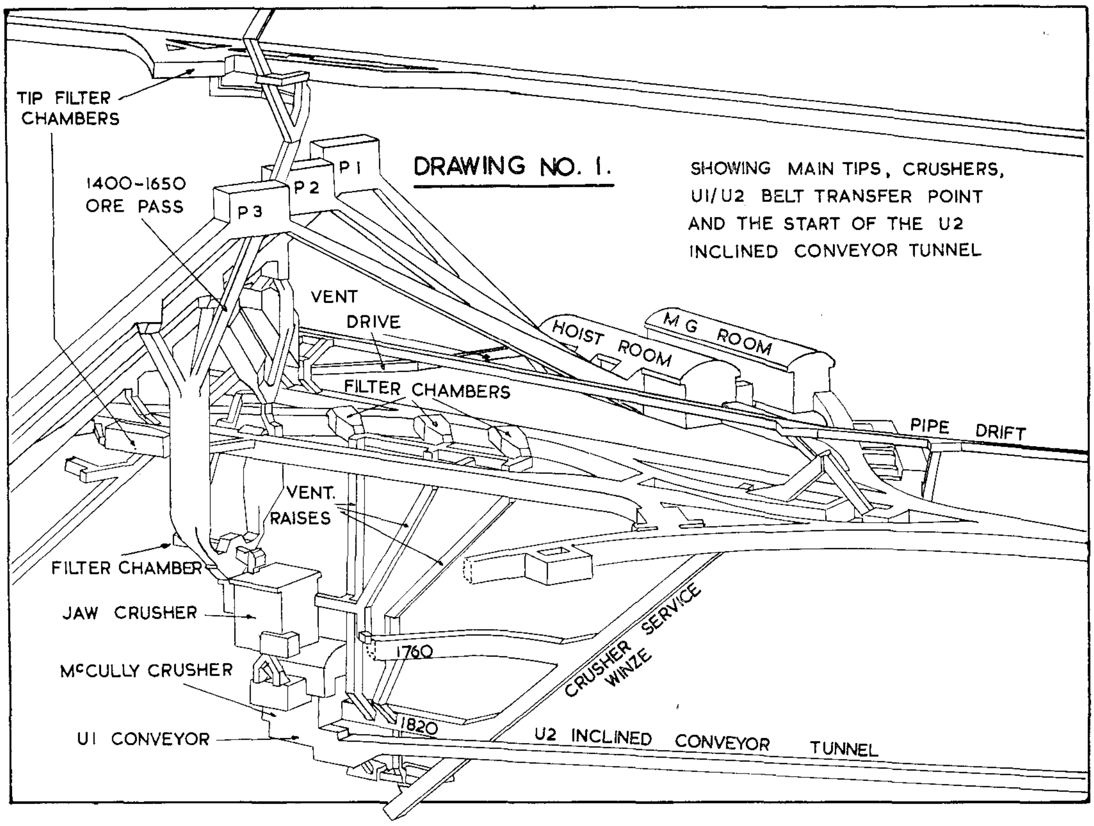
Filtration versus the " direct return " of the dust-laden air is discussed.

Introduction

Underground at Mufulira there is established an ore-crushing and conveying system of a rated capacity of 1,000 plus tons per hour, handling at present an output in the region of 450,000 tons per month. In the system there is a primary jaw crusher and two secondary gyratory crushers connected by a series of conveyor-belts to an 8,800 ton storage pocket feeding Selkirk and Boise Shafts together with direct tipping facilities to these hoisting shafts.

*Ventilation Engineer, Mufulira Copper Mines Ltd.

Ore from the 1150 ft, 1400 ft and 1650 ft haulage levels and the sub-incline shafts below 1650 ft level is tipped into a main ore-pass system having compressed air operated claw-type finger controls on the 1400 ft level and at the bottom of the passes on the 1720 ft level immediately above the jaw-crusher station. From this point the ore is fed by a pan-feeder over a grizzly to a 72 in by 48 in jaw crusher on the 1760 ft level where the over-size is reduced to minus 12 in. The ore then falls through a forked pass to the gyratory crusher station on 1820 ft level where it is fed by pan-feeders over grizzlies into two 30 in McCully crushers and is further reduced to minus 6 in. The ore leaving the crushers is transported about 2200 ft by belt conveyors (U1 and U2) and tipped by means of a travelling tripper conveyor (U3) into the 8,800 ton storage pocket on the 1720 ft level near to the main hoisting shafts or direct to the shaft loading boxes. Ore is reclaimed from the storage pocket on 1790 ft level through horizontal gates under drawpoints



on to a travelling pan-feeder and reversible conveyor (U4) and is then moved by cross-conveyors (U5 and U6) to either Selkirk or Boise Shafts' loading boxes. See Fig. 1.

The system is in operation daily from 1.00 p.m. until about 7.00 a.m. the following day. The period of time from 7.00 a.m. until 1.00 p.m. is given over to maintenance.

Ventilation

The system falls under the influence of the No. 8 Shaft main exhaust fan. Local exhaust fans positioned at dust-producing points discharge air through filters and, in addition, there is a large volume low pressure centrifugal fan (capacity 110,000 c.f.m. at 1·5 in. w.g.) located at the top of the conveyor ventilation raise on 1650 ft level for the purpose of preventing too great a recirculation of filtered air. The total air volume circulating is 330,000 c.f.m. (see Figs. 1, 2 and 3).

Dust Control

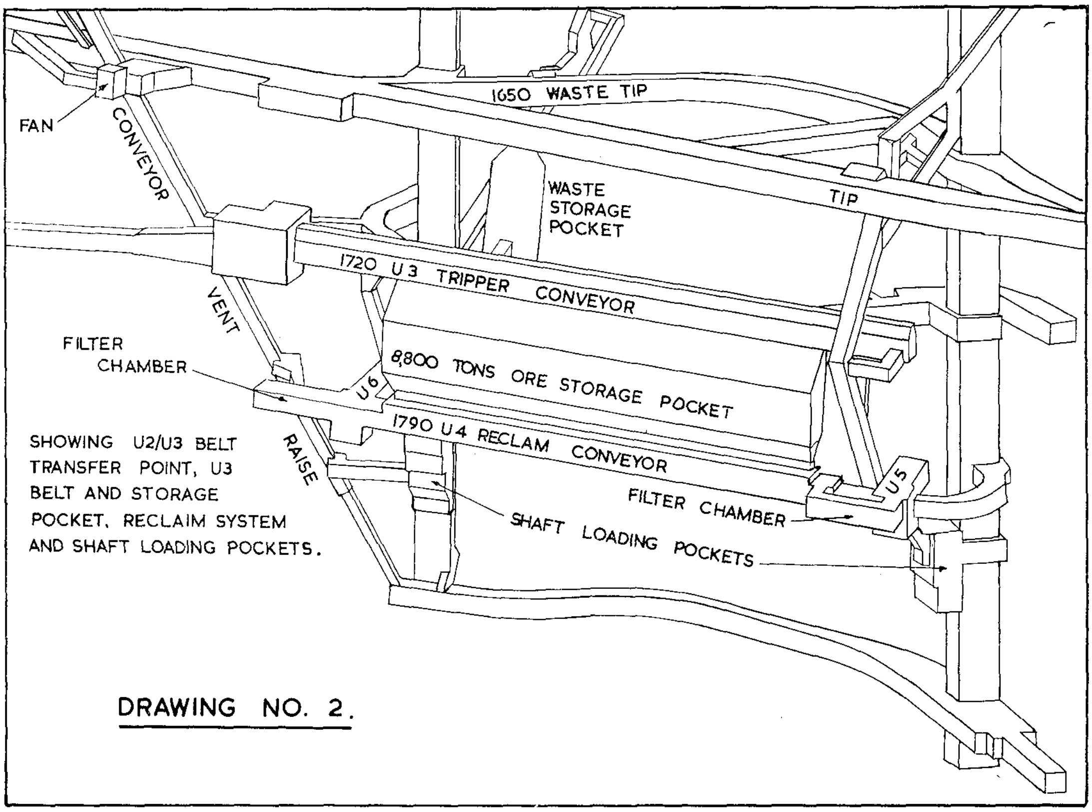
At all main tips, crushers, conveyor-belt transfer points, and shaft loading boxes, systems of dust control are established. Basically these systems embody:—

(a) partial or near total enclosure of the dust-producing processes.
(b) local exhaust systems of ventilation whereby a zone of negative pressure is created and where all air leakage is in-leakage.
(c) filtration and dilution of the vitiated air.

There are 17 dust-producing points in the system and a total air volume amounting to 290,000 c.f.m. is exhausted by 17 auxiliary fans drawing approximately 400 horse power.

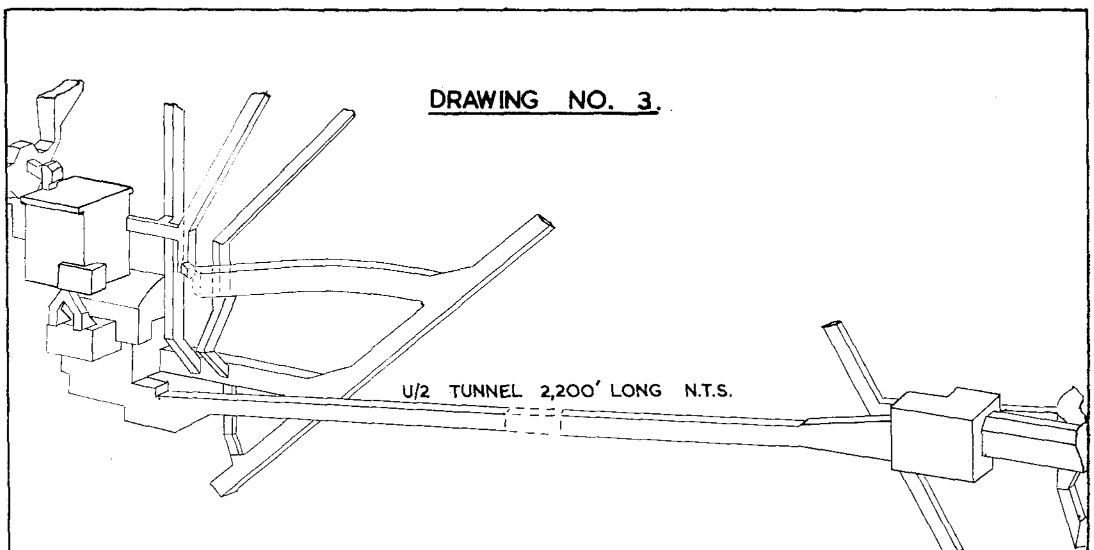
Crushers

To ventilate the jaw crusher on 1720 ft level and the two McCully crushers on



SHOWING U2/U3 BELT TRANSFER POINT, U3 BELT AND STORAGE POCKET, RECLAIM SYSTEM AND SHAFT LOADING POCKETS.

DRAWING NO. 2.



DRAWING NO. 3.

SHOWING MCCULLY CRUSHER DISCHARGE POINT TO UI/U2 BELT, U2 TUNNEL AND U2/U3 BELT TRANSFER POINT.

1820 ft level, three 49 in. dia. centrifugal-type fans, each having a rated capacity of 30,000 c.f.m. at 10·0 in. w.g., are employed. The crushers are almost totally enclosed and the dusty air from each crusher is exhausted and ducted to individual return air raises which are linked to a common collecting trunk on 1650 ft level. From this trunk three large chambers are excavated, each housing a filter unit and a fan. A sytem of doors in the collecting trunk is arranged so that in the event of breakdown of one of the three fans, the remaining two can ventilate the crushers. In the extreme case of two fans breaking down simultaneously, the doors can be adjusted in such a manner that one fan may ventilate, under emergency conditions, all three crushers. Normally all of the fans operate and 90,000 c.f.m. of air is returned and filtered (see Figs. 1, 2 and 3).

U1/U2, U2/U3 Conveyor Belt Transfer Points

Ventilation and dust control is by fish-tail exhaust ducts placed close to the actual transfer point. At each place 6,000 c.f.m. is exhausted by a 19-in. dia. axial flow fan and the dusty air is filtered.

1720 ft Level Ore Storage Pocket

The storage pocket is almost totally enclosed. The ducting which has subsidiary take-off points fitted with butterfly valves, runs the 200-ft length of the pocket and is located above the inspection walkway. From this duct subsidiary leads are carried down and under the walkway at intervals of 25 ft to a position just below the top of the pocket and below the tripper conveyor discharge. When the tripper is in operation, the butterfly valve in the subsidiary lead nearest to the selected tipping position is opened and the dust created by the falling ore is exhausted and filtered. The fan used here is a 38-in. dia. two stage unit having a rated capacity of 20,000 c.f.m. at 5·0 in. w.g.

When the plant was first commissioned it was found that even 20,000 c.f.m. exhausted close to the tipping position was insufficient air to effect dust control and to prevent upsurge and contamination of the main body of the ventilating air in this area. It was necessary to improve closure over the mouth of the pocket and to limit the size of the aperture through which tipping was taking place, thereby confining the influence of the fan more closely to ore discharge point.

The problem was solved by laying a 3 ft wide belt the entire length of the pocket mouth and lacing this belt over rollers on the tripper discharge. The belt does not move, but lifts at the tripper discharge, as it travels. This effectively limits the discharge aperture to about 10 sq. ft. and bearing in mind other smaller openings into the pocket, this limitation ensures a strong downcast flow at an air velocity of the order of 900 f.p.m.

Reclaim System 1790 ft Level
Reclaim Conveyor (U4)

Ducting having subsidiary take-off points somewhat similar to those at U3 position on 1720 ft level is installed on 1790 ft level. A 6 in section of metal piping is attached to the travelling pan-feeder and when ore is reclaimed this ducting " lines-up " opposite a subsidiary take-off point. A 24 in. dia. axial flow fan is used to exhaust 10,000 c.f.m. at 5·0 in. w.g. It should be noted that there is a 3 in gap between the take-off point in the main ducting and the short length of piping attached to the tripper. This is arranged deliberately to ensure a wider zone of negative pressure around the reclaim drawpoint and to prevent dust escaping to atmosphere.

Cross-Conveyors (U5 and U6)

On this level the belt transfer points from the reversible reclaim conveyor (U4) to the conveyors leading to the hoisting shafts have fish-tail exhaust hoods, and here again 24 in. dia. axial flow fans (capacity each fan 10,000 c.f.m. at 5·0 in. w.g.) are installed at both belt transfer positions. The dusty air is filtered through individual units.

Main Tips

At the main ore tips feeding the system, 38 in. dia. axial flow fans (capacity 20,000 c.f.m. at 5·0 in. w.g.) are installed and a downcast velocity into each tip in the region of 200 f.p.m. is maintained. Dusty air is again filtered.

Shaft-loading Boxes

At all shaft-loading boxes exhaust fans are employed and a strong downcast into the top of the measuring flasks is ensured. In each case the dusty air is ducted and filtered. At the Selkirk Shaft box dusty air is conveyed through 170 ft of ducting to a filter and the fan installed here is a 30 in. dia. axial flow unit having a rated capacity of 20,000 c.f.m. at 9·7 in. w.g. At the Boise Shaft box the filter is installed near the box and a 24 in fan (capacity 10,000 c.f.m. at 5·0 in. w.g.) is adequate. In Peterson No. 1 Sub-incline Shaft the fans and filters are located close to the 2050 ft and 2550 ft levels loading boxes and at these places 38 in. dia. fans are installed handling 20,000 c.f.m. each.

Water Sprays

Water atomizers are placed at the U1 transfer belt, at the discharge chutes from the McCully crushers and again at a point midway along the main U2 belt. The addition of water to the ore stream is discouraged to prevent the formation of mud and spillage. The sprays are used only when the ore in transit is very dry and this condition seldom arises.

Filtration

Air filtration is accomplished by flannel bags and there are 17 filtration units in operation in the Crusher-Conveyor System; the size of each unit being determined by the air volume handled. Only best quality flannel is used and great care is taken to ensure correct utilization. For reasons of filtration efficiency, filtration speeds (air velocity) do not exceed 26 f.p.m. and the average velocity attained is 20 f.p.m. The bags used are 18 in in dia by 20 ft long and the life of a bag is about 20 months when used as follows:—

on a crusher filter ..	7 months
on an orepass filter ..	6 months
on a waste-pass filter..	7 months
Total	20 months

The bag life utilization is distributed in this manner on a basis of dust loading and filtration efficiency. Discarded bags are burnt or buried under rock in the surface waste dump.

Filtration by means of flannel bags was preferred for this application after full consideration of the relative merits of mechanical and electrostatic filters.

All the filtration units attached to the Crusher-Conveyor System are of the horizontal type and are not self-cleaning (see Fig. 4). Bag changing and cleaning is done manually and care is taken to prevent contamination of the main intake air stream. Dusty bags are removed by a special crew wearing respirators and, at the filter chamber discharge, a well constructed virtually airtight door is shut during this process. Bags are placed in dust-tight cannisters and are removed to a main return airway for cleaning. (See Fig. 5 showing bag cleaning arrangements.)

The same crew replace " clean " bags, (i.e. a set " cleaned " the previous day) and the same procedure is adopted in that the handling and fitting of the bags is done with the chamber discharge door closed.

After the bags on a unit have been laid out and the suspension has been checked, the fan is restarted and allowed to recirculate air for about ten minutes in order to gather any dust shaken off on starting. The dust door is then opened and the unit left to operate. It should be noted that dusty bags are never fully cleaned. Bags having a certain amount of dust on them bring about better filtration at the start of a " run " and this observation is substantiated by a study of filtration discharge sampling results which show that the longer the " run " and the dustier the bags the better the filtration efficiency as shown by konimeter counts.

Pre-filters

The crushers are prolific dust producers and it was found, when the system was first commissioned, that during a crushing run the pressure loss through the flannel bags increased rapidly with a consequent decrease in air volume handled; thus lessening the important aspect of negative pressure in and around the bowls. The fans used here, as already mentioned, are heavy-duty centrifugal type each having a rated capacity of 30,000 c.f.m. at 10·0 in. w.g. and it was noted that as much as 7 lb weight of dust per bag or 140 lb per unit was collected after an 11 hour run. The bags assumed an irregular elongated shape. To overcome this difficulty and to lengthen the duration of a " run " coconut-matting screens were fitted in front of each fan at the top of each return air raise (see Figs. 1, 2 and 3). This expedient raised the initial fan pressure on restarting, but the increase in pressure loss over an 18 hour run was markedly slowed down and the bags were no longer distorted. The coconut-matting is not close-knit and, although each screen was dust-caked at the time of cleaning, it did not cause a rapid rise in pressure nor an excessively high final result. It was thought that this was due to the screens trapping dust in the upper micron range, but this assumption was shown to be incorrect following a size grading analysis of dust from a pre-filter and from the immediately following flannel bags.

On the pre-filter, 36·56 per cent. of particles were less than 0·8 micron, as against 37·2 per cent. on the flannel bag in the one case and 50·8 per cent. as against 44·8 per cent. in the other; and 11·6 per cent. of particles were larger than 3 micron on the pre-filter as against 9·4 per cent. on the flannel bag in the one case and 6·0 per cent. as against 6·3 per cent. in the other case.

The size distribution of the dust on the matting and in the bags was surprisingly similar and the high percentage of the finer fraction dust caught on the matting can only be explained by the " caking " effect apparent at the time of cleaning. The coconut-matting is effective as a pre-filter despite the high filtering speed which is of the order of 900 f.p.m. Screens last about three months, but replacement costs are low.

Dust Sampling and Inspection

The system is inspected and dust sampled weekly using the konimeter technique. Satisfactory conditions have been maintained since the system was commissioned in 1955 and dust counts throughout seldom exceed 150 p.p.c.c. Good house-keeping is a feature of this plant and officials and operators are thoroughly conversant with all aspects of ventilation and dust control. Table No. I shows the location, size and type of each fan, the air volume handled, the size of each filtration unit and typical dust concentrations.

OBSERVATIONS

Filtration versus " Direct Return "

This question was fully considered in the planning stage. Filtration by any medium, although generally cheaper initially than a " direct return " system, is often costly to maintain. In this instance there was no choice really in deciding in favour of filtration, because at this time the total mine air volume upcast was substantially less than is at present the case, i.e. 920,000 c.f.m. as against 2,080,000 c.f.m. Commitments in the mine were such that air from open stopes, scrapers and grizzlies (where secondary blasting was in progress) was the only air returned immediately to main return airways. Development sections were all ventilated in series with infusions of fresh air and it was out of the question to consider the direct return of air from any place where filtration could reasonably be used. It was appreciated that the maintenance costs of filtration would be fairly high and it was recognized that at the crushers particularly, filtration would limit the duration of a crushing run. Nevertheless it was impossible then to return directly even 90,000 c.f.m. (the air volume required to ventilate the crushers) or roughly 10 per cent. of the total air volume upcast.

In the near future the upcast equivalent for the mine will increase further to 2,500,000 c.f.m. The situation, with regard to filtration, has been reviewed and it has been decided now to return directly, through an airway yet to be developed, the air from the crushers only, especially as the tonnage of ore passed through the system has increased progressively from 220,000 tons to 450,000 tons per month.

The economics of the project warrant the development of an airway 630 ft in length costing an estimated £4,800 and it has been calculated that this expenditure will be offset within two years due to lower power costs, elimination of flannel bags and the very much lower labour and maintenance costs. Under the revised layout, auxiliary fans will continue to be required for individual crusher ventilation in order to overcome ducting losses, and for this purpose it is intended to modify the existing fans to give a reduced volume at lower pressure; that is, to change the fan characteristic in each case from 30,000 c.f.m at 10·0 in. w.g. to 20,000 c.f.m. at 4·5 in. w.g.

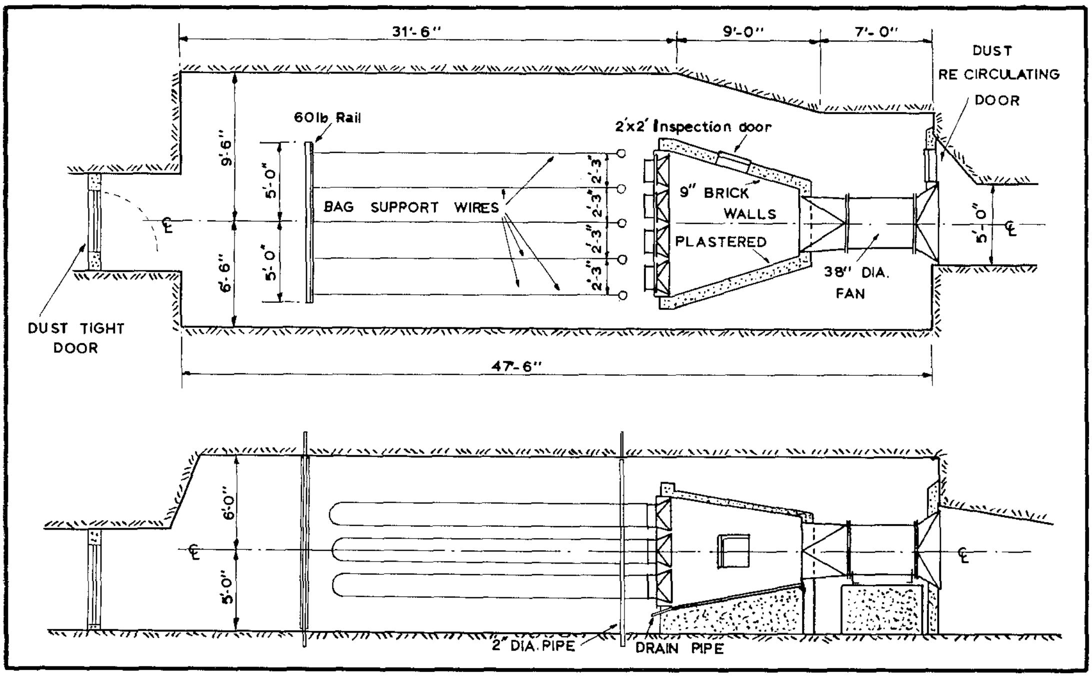

31'-6"
9'-0"
7'-0"
DUST
RE CIRCULATING
DOOR
60lb Rail
2'x2' Inspection door
9'-6"
5'-0"
BAG SUPPORT WIRES
2'-3"
9" BRICK
WALLS
PLASTERED
38" DIA.
FAN
5'-0"
6'-6"
DUST TIGHT
DOOR
47'-6"
6'-0"
5'-0"
2" DIA. PIPE
DRAIN PIPE

Fig. 4.

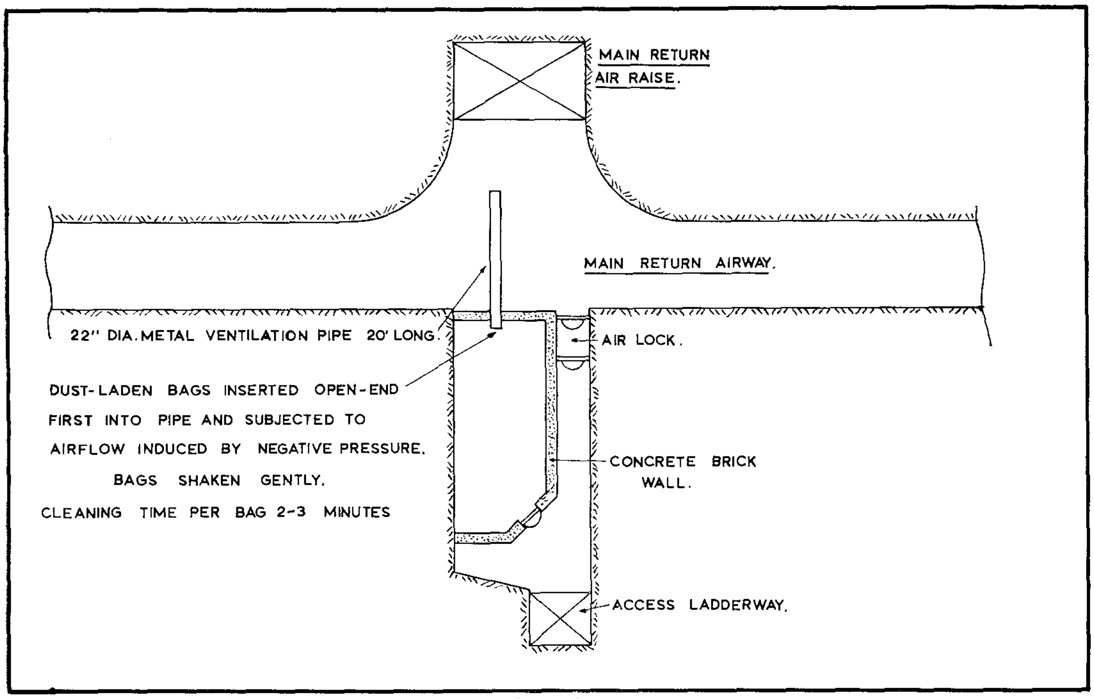

MAIN RETURN
AIR RAISE.
MAIN RETURN AIRWAY.
22" DIA. METAL VENTILATION PIPE 20' LONG.
AIR LOCK.
DUST-LADEN BAGS INSERTED OPEN-END
FIRST INTO PIPE AND SUBJECTED TO
AIRFLOW INDUCED BY NEGATIVE PRESSURE.
BAGS SHAKEN GENTLY.
CLEANING TIME PER BAG 2-3 MINUTES
CONCRETE BRICK
WALL.
ACCESS LADDERWAY.

Fig. 5.

TABLE I

Location	Size and type of fan	Air volume c.f.m.	No. of bags on filtration unit	Typical dust-sampling results		Fresh air volume for dilution c.f.m.
				At working-place p.p.c.c.	At filter discharge after dilution p.p.c.c.	
1150′ level main tip	38 in. dia. axial flow	20,000	12			400,000
1400′ level main tip	38 in. dia. axial flow	20,000	12	130	100	320,000
1650′ level main tip	38 in. dia. axial flow	20,000	12			175,000
1760′ level fingers	19 in. dia. axial flow	6,000	3	150	100	50,000
Jaw crusher	49 in. dia. centrifugal	30,000	20			
McCully (South) Crusher	49 in. dia. centrifugal	30,000	20	140	90	350,000
McCully (North) Crusher	49 in. dia. centriugal	30,000	20			
U1/U2 belt transfer point	15 in. dia. axial flow	4,500	3	150	100	10,000
U2/U3 belt transfer point	19 in. dia. axial flow	6,500	3			50,000
U3 tripper conveyor	38 in. dia. axial flow	20,000	12	120	90	70,000
U4 reclaim conveyor	24 in. dia. axial flow	10,000	6	120	90	
U4/U5 belt transfer point	24 in. dia. axial flow	10,000	6	130	90	30,000
U4/U6 belt transfer point	24 in. dia. axial flow	10,000	6			
1850′ Level Selkirk Shaft loading box ..	30 in. dia. axial flow	20,000	12	90	60	60,000
1850′ Level Boise Shaft loading box ..	24 in. dia. axial flow	10,000	6	130	100	25,000
2050′ Level Peterson No. 1 loading box ..	38 in. dia. axial flow	20,000	12	120	90	50,000
2555′ Level Peterson No. 1 loading box ..	38 in. dia. axial flow	20,000	12	120	90	30,000

Location and Capacity of Filtration Units.

TABLE II

	Filtration	Direct return
Duration of a crushing " run " ..	Limited to about 18 hours, provided pre-filters are used	No limitation
Type of fans required	High-pressure, high-volume fans, capable of operating at increasing load due to dust build-up. Horsepower of the order of 80 h.p.	High (constant) volume fans. Horsepower of the order of 25 h.p.
Excavations in the *vicinity* of the shaft	Three chambers each having dimensions as follows: 52′ × 16′ × 11′	375′ of airway; dimensions 7′ × 7′
Cleaning station for dusty bags ..	Required	Not required
Possible contamination of intake air stream	Can occur when a bag bursts or becomes detached from the manifold; and if care is not exercised when removing dusty bags for cleaning	Cannot occur
Cleaning and maintenance crew	One European and 6 Africans daily for about 4 hours. Artisan routine inspection	Artisan routine inspection only

The air volume initially decided upon for crusher ventilation and dust control was 30,000 c.f.m. per crusher. It has since been ascertained that this figure is on the high side and that 20,000 c.f.m. is adequate. There was no yard-stick at the time the plant was commissioned by which to assess air requirements. Underground crushing on the scale envisaged was very much a pioneering effort having due regard to the high standard of dust control then applicable. Furthermore, it was difficult at the drawing-board stage to determine the extent of closure around the crusher bowls without detriment to operating technique.

NEW PROJECTS

(a) No. 14 Shaft Gyratory Crusher Station 1950 ft Level

This station will be in operation during 1962 and the crushers, together with the attendant main tip and shaft loading box, fall in a different ventilation district to the system already described. It is intended to return directly all of the air from these points; an air volume totalling 60,000 c.f.m. distributed as follows:—

From the crushers ..	20,000 c.f.m.
From the main tip ..	20,000 c.f.m.
From the loading box ..	20,000 c.f.m.
Total	60,000 c.f.m.

NOTE: Two gyratory crushers will be installed but one only will be in use at any time.

It was calculated that the initial cost of the " direct return " system in this instance would be offset within three years because maintenance costs would be comparatively low. Other factors favouring the " direct return " method are given in Table II.

(b) Peterson No. 1 Sub-incline Shaft Gyratory Crusher Station 2370 ft Level

At this station also, plans are made to return directly the air from the crushers, but to the extent of only 20,000 c.f.m.

Conclusions

In the light of experience gained, it is considered advisable to arrange a " direct return " system of ventilation for any prolific dust-producing equipment underground. It is further recommended when filtration methods are used that pre-filters be employed, if the dust loading is high and this recommendation applies to mechanical and electrostatic filters as well as to filtration by flannel. Finally it is desirable to avoid too great a recirculation of filtered air and to install a fan to " sweeten " a section relying on filtered air for ventilation.

Acknowledgment

(1) Thanks are due to the Management, Mufulira Copper Mines Limited, for permission to publish these notes.

(2) The size grading analysis of dust from filters was carried out in the Dust Research Laboratory of the Northern Rhodesia Government Mines Department and an appreciation of this service is recorded.

CONTRIBUTION

By D. G. Beadle

Crushing is always a prolific source of dust unless adequate steps are taken to control it. When crushing is carried out on surface there is usually a considerable amount of " natural ventilation " through the buildings to help dilute any dust which might escape through the dust suppression devices fitted to the crushing plant. Because of this, it is sometimes found that such suppression devices are not as highly effective or maintained as well as they should be. But when crushing is undertaken underground—as it is sometimes highly desirable to do in order to improve skip loading factors, which is necessary to enable high tonnages to be hoisted rapidly from depth, then adequate dust control around the crushers and ancillary equipment, such as conveyors, is essential, since the quantity of air available for external dilution is usually far less than in the case of surface plants. Any dust which escapes may have a serious health hazard or may prove to be harmful to nearby machinery, etc.

During a visit in July to the Northern Rhodesia Copper Belt I had the priviledge of being shown, by Mr. Phimister, the dust control system at the underground crushers at Mufulira Mine, which he has described so clearly in his paper. In my opinion it is an outstanding example of how dust should be controlled under these conditions. The various enclosures around different parts of the plant and the system of draw-off points had obviously been planned not only to perform their functions efficiently, but also so that they did not interfere with access to the plant for its normal operation or for maintenance purposes. It is my experience that if the dust suppression devices do interfere with the work of the plant operators or maintenance staff, the devices will very soon be dispensed with! Obviously the design of these devices should be agreed on with the operators before they are installed, and I feel sure this must have been the case at Mufulira.

I found some of the flannel bag filter units in use were impressive, consisting of approximately twenty horizontal bags in parallel, each 20 ft long by 18 in. dia., and handling around 20,000 c.f.m. They apparently prefer this design to the multiple-vertical bag design. Inspection and maintenance of the various underground filtration plants is the full-time duty of a gang consisting of one timberman and more than a dozen assistants. This system is obviously far more effective than the rather casual intermittent checking of filter plants as one duty out of many for all members of the Ventilation Department that exists on some South African gold mines.

I am particularly glad to have had the opportunity of seeing the Mufulira installation, and would like to take this opportunity of paying tribute to the Management and Ventilation Department of the mine, and particularly to Mr. Phimister for the very important progress they have made in dust control generally in their mine. During my visit to Northern Rhodesia this was only one of many interesting and important developments in dust control and research which I saw and it is a pity that distance prevents many more South African ventilation officials from visiting the Copperbelt, where we could all learn a great deal from our colleagues in the North.