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ELECTRICAL HAZARDS IN MECHANISED MINING.

U.S. Survey of Problems.*

By E. J. Gleim and H. B. Brunot.

In the mining of coal the trend is toward more and more mechanisation. This increased use of machinery to replace hand labour is assuming many new forms and presents a constantly changing aspect. Safety engineers must be alert if the many electrical problems resulting from these new installations are to be handled safely. Some of these problems present possible electrical hazards that may be overlooked by the safety engineer unless they are called to his attention by one who has made a special study of the conditions.

The foregoing is especially true of conveyor systems of mining. The terms "conveyor systems" and "conveyor mining" are used to indicate those systems in which various types of conveyors are employed to transport coal away from the working place. In some mines this means complete elimination of track, cars, and locomotives. In others it means that conveyors take the coal from the working place to a convenient loading point, from which transportation is completed by cars and locomotives.

Under some of the modern systems a number of cuts are made in a working place each day with a mining machine where formerly only one cut was made. This suggests the possibility of liberating more gas than formerly in 24 hours in a given working place, with the probability that ventilation must receive greater consideration. Likewise, more coal dust will be thrown into suspension in the same period unless steps are taken to allay it, as by spraying the cutter bits with water while mining machines are in operation. It is essential to apply water and rock dust or take equally effective measures to safeguard against ignitions of dust.

Conveyor Mining Hazards.

The various schemes of mechanical mining that require the presence of several machines and a number of men in the same working place all at one time tend to enhance both the mechanical and electrical hazards. The object of the Circular is to indicate that the presence of two machines in one place may more than double the hazard from failure of insulation and to emphasise that increase in mechanisation must be accompanied by a commensurate increase in precautions to avoid unsafe conditions.

In recent years an increasing number of instances have been reported to the Bureau's engineers of trouble arising when two or more machines were present in the same working place at the same time. Hazards of this general nature are not new, but fortunately in the past have occurred more or less infrequently. These additional electrical hazards may be divided into two groups—open sparking between normally non-current-carrying parts and overheating of conductors that would not occur if the machine were alone.

As an example of the first group may be cited the possible results of a failure of insulation at or near the grounded terminal of a machine supplied from a grounded direct-current system. This may not seriously hamper operation of the machine. In fact, such an occurrence may not even become evident to the machine runner for an indefinite period in the ordinary course of work. Nevertheless, the machine is in a hazardous condition. If, as is so frequently true, the machine frame is not adequately grounded by a separate conductor of ample size any disturbance of the return circuit, such as might result from a broken or loose rail bond or dislodgment or loosening of the rail hook, may cause the frame to be charged to a dangerous potential. Under such circumstances the operator not only may receive a fatal shock, especially if he is also in contact with a conveyor or other fairly well-grounded machine frame, but open sparking between the faulty machine and the conveyor may, if explosive gas is present, lead to a disastrous explosion with the attendant destruction of life and property.

In addition to sparking, contact between a grounded direct current mining machine and a conveyor has been known to start the machine or cause it to continue running even after the controller has been disconnected. This is possible when the controller is connected only in the line that goes to the return.

Any ground in the machine may create such hazards; but some grounds make their presence evident by causing distress in the machines' operation, by odour of burning insulation, or by stopping the machine entirely. These grounds may therefore sometimes prove less hazardous to life and property by making themselves manifest sooner and thus demanding correction.

Sources of Danger.

As an example of conditions that might result in overheating of conductors consider a coal-cutting machine, a conveyor, and a hand drill in the same room, the drill receiving its power through a connection on the mining machine. Failure of the drill insulation could provide a parallel path for the return current from the mining machine through the small drill cable. If the drill is not properly protected by a fuse the cable could be overheated. Again, when the drill frame is grounded to the cutting-machine frame to protect the driller from shock the ground wire from the drill might readily become a parallel path for return current from the cutting motor in case of insulation failure in the latter. Open sparking between the conveyor and drill or cutting-machine frames also is one of the possible sources of danger in such a combination. Moreover, should the rail connection become loose or dislodged it would be possible to burn the drill cable by current through the ground wire. It is for this reason that the Bureau requires the fusing of both sides of such branch circuits to drills and headlights.

Previous to conveyor mining it was customary to operate mining machines with cable-reel trucks, which served a double purpose. In addition to providing a means of transporting the machine from room to room they also carried a switch and fuse, or equivalent, to protect the machine. With the adoption of conveyor mining the truck was no longer required for moving the machine, and as track was not laid in the rooms the truck was too large and unwieldy to be taken into the rooms. Consequently there have been many installations in which the machine operator had no means other than the controller of cutting off the power near at hand. Furthermore, the overload protection, if any, was no nearer than the end of the trailing cable. Thus an unsafe operating condition arose. If a machine should suddenly "jump out" of its place because the bits strike some hard substance while the machine is being sumped in, it might get out of control and knock out posts or catch the operator. Without an independent switch for stopping the machine considerable damage or severe injury to men might result before some one could disconnect the trailing to stop it. In such emergencies, and especially when the coal seam is low, considerable time elapses before a man can travel 300 feet or more to reach the point where he can disconnect the cable.

Another hazard that must not be overlooked is the possibility of flashovers in drum controllers on some of the older-type 500-volt machines. Under certain conditions the arcing that follows the flashover can burn a hole in the controller case, and disconnecting the controller will not stop the flow of current. Here, again, the

* Extracts from U.S. Bureau of Mines Information Circular 7160 on "Mechanised Mining Brings New Electrical Hazards." The authors are electrical engineer and associate electrical engineer respectively at the Pittsburgh Central Experiment Station.

absence of a switch is a serious handicap to prompt action in an emergency.

As mechanisation has advanced the design of mining machinery has become progressively more complicated, until to-day there are single machines with as many as 40 explosion-proof compartments. Corresponding increase in the amount of wiring on these machines now makes adequate protection of the circuits between the explosion-proof enclosures one of the chief problems. Wiring must be so placed and protected by conduit and guards that mechanical injury or deterioration of rubber insulation from contact with oil is minimised. Adequate overload protection for the numerous branch circuits for small motors, headlights, and the control devices must be devised and provided. This problem also is being solved successfully for any given machine as an individual unit.

Inspection of Equipment.

It cannot be emphasised too strongly that efforts to prevent mine explosions of electrical origin should not cease with the mere purchase of permissible equipment. Equipment that has been abused and neglected is no longer trustworthy as a safeguard against electrical ignition of gas or coal dust. The safety valve on a boiler, the safety catches on a mine cage, and the gauzes in a safety-lamp all must receive periodic inspection, cleaning, adjustment, and lubrication if they are to be relied upon to function as intended. The same is true of permissible equipment. If bolts are omitted, if unauthorised changes are made, if holes are burned or broken through walls of explosion-proof housings, and if cables are poorly spliced on such equipment, it can no longer be truly regarded as permissible because any one of these faulty conditions might cause an ignition. This demands well-trained electricians and mechanics who understand the safety features of permissible equipment, as well as for the correct supplies and replacement parts if the equipment is to be maintained properly.

Thorough inspection must include frequent checking of the insulation of machinery by means of suitable instruments such as "meggers" to find incipient faults before the insulation actually fails; repair made promptly upon the basis of conscientious use of a megger is one of the best safeguards against electric shock.

Grounding methods must be studied carefully to guard against disaster from such insulation failures as may occur in spite of the best precautions. Some measure of protection against hazards resulting from the proximity and interconnection of several machines in the same locality is obtained by intelligent use of grounding conductors and fuses (or equivalent overload protection). In many instances such expedients alone are not sufficient to protect fully against the hazards introduced by concentration of electrical circuits and machinery.

Restricting Length of Exposed Cable.

Some attempt has been made to reduce the total amount of cable exposed in rooms. One system employs a main cable whose length when fully extended equals or nearly equals that of the completed room. The end toward the face terminates in one or more junction boxes with receptacles or sockets to take plugs attached to cables for the various machines. This permits restricting the length of the individual machine cables merely to that required for convenience in operation and movement of the several machines. In most cases 50-foot lengths are adequate for the purpose.

When shaker conveyors are used further reduction in amount of cable exposed in a room is obtained by the use of a multiple-circuit junction box. In one such system the junction box was placed at the entrance to the room, and three circuits were served, namely: (1) mining machine, (2) shaker conveyor, and (3) blower. As the conveyor drive and the blower were placed at or near the room entrance, the cables to them were relatively short. This left only the mining machine and conveyor control cable to be carried to the face. The mining-machine cable was taken through a fused box (mounted on the mining machine), in which the cable was tapped for a drill circuit, which was protected by this fused switch. In this system the mining machine and control circuits were carried on insulators fastened to the roof or to posts. By comparison with systems employing mobile loaders it is apparent that the system just described offers a much safer arrangement, as far as cables are concerned.

SAFETY PROVISIONS.

By "TESTER."

Fire-fighting Regulations.

Regulation 1(*a*) of 8th August, 1938, No. 797, requires that "In every mine, other than small mines which are naturally wet throughout and mines of stratified ironstone, there shall be kept, ready for immediate use, at appropriate places in relation to each working face and along main roads, a sufficient supply of suitable dust or sand and of portable fire extinguishers, except in so far as water is provided at these places with equipment to serve the same purpose."

In the foregoing it is required that suitable dust or sand should be provided in addition to portable fire extinguishers, unless water is already provided together with the necessary equipment to enable it to be used effectively in the case of fire. The dust normally used as a diluent of the coal dust that accumulates in roadways might well be provided in bags, or sand contained in similar packages might be provided; indeed, one often finds that both dust and sand are provided together with portable fire extinguishers, even in places where a liberal supply of water is provided either in tanks or in pipes led along the roadways. The important matter is that whatever means may be provided for fire-fighting should be within easy reach of the working places and of any place in a main road at which a fire might occur.

Later we shall study the forms of portable fire extinguisher that may be provided, and the means by which water may be taken to convenient points near the working places and used there to quench fires.

1(*b*) requires that "At each place where dust, sand, or water is so kept, means shall be provided for readily conveying the material by hand and for using it for fire-fighting."

It appears to be most desirable that supplies of quenching agents should be provided so near to working places that the transference of them from storage to the points of application should involve as little actual handling as possible. Dust, sand, or water may be conveyed in tubs or other suitable means of conveyance, and dust or sand may be applied by hand, but water may be applied to a fire under the natural pressure arising from the height of the source above the point of application, or it may be applied by turning on the pressure of compressed air to force the water from special tanks through hoses and nozzles to the scene of the fire. When no such source of pressure is available it becomes necessary to use some form of manual pump to project jets of water on the fire.

1(*c*) requires that "At all times when a coal-cutting machine is in operation at any working face in which an ignition of inflammable gas has been, or, having regard to the nature of the strata is liable to be, produced in the cut by its operation, effective means to prevent such ignition shall be provided on the machine; or a supply of suitable dust or sand in a proper container, or a portable fire extinguisher shall either be carried on the machine, or, if that is impracticable owing to the thickness of the seam, shall be kept at suitable intervals along the working face and at the roadhead at the intake end of the working face."

Colliery managers and others have given much thought to the most efficient method of conforming to this paragraph in the regulations, and some of the former have been most energetic in the use of methods likely to prevent the firedamp-air mixture in the undercut from becoming inflammable. But whatever steps may be taken to prevent ignitions from taking place, we must all realise that they may occur, and consequently the means of quenching an inflammation should be readily available in compliance with the statutory regulation.

1(*d*) requires that "Fire extinguishers shall be examined and discharged and refilled as often as may be necessary to ensure that they are kept in good working order."

Fire extinguishers containing water, or a solution of sodium bicarbonate, are liable to deterioration by corrosion of the outer shell. Although there may be no apparent perforation of the shell actual perforation may take place on the release of the propellent contained in the extinguisher, due to the development of a high pressure within it. Although plungers and levers may have been properly lubricated at some time, it is just possible that the attempt to use an extinguisher might be frustrated by the gumming of the lubricant and the sticking of the plunger or lever. Nothing short of periodic discharge, cleaning, and refilling will ensure that extinguishers are in order when the necessity for their use arises.

1(*e*) "Fire extinguishers which are liable, when operated, to give off poisonous or noxious fumes shall not be provided or used underground."

It appears to the writer that the use of the word noxious in this paragraph is singularly unfortunate, particularly since it is not intended that a fire extinguisher in which carbon dioxide (a noxious gas) is the propellent should not be used at underground fires. Indeed, the soda-acid, foam, and carbon dioxide extinguishers are all dependent for their action on the generation of carbon dioxide gas, which is itself an extraordinarily good quencher of fire. However, a carbon tetrachloride extinguisher is quite another matter, because by its use underground there might be formed the carbonyl chloride $COCl_2$, which is more commonly recognised as the very poisonous gas called *phosgene* so much used in gas warfare.

Regulation 2 stipulates that "At every mine at which 100 or more persons are employed underground there shall also be provided and kept ready for use :—

(*a*) a supply of water sufficient for the purpose of fighting underground fires, and (*b*) efficient means of conveying the water and delivering it promptly at adequate pressure and in adequate volume to all parts of the mine in ordinary use for working or travelling where fire is likely to occur.

Except in so far as provision is made so to deliver the water through pipe lines and hose extensions, it shall be delivered from water tanks or barrels by portable manual force pumps and all equipment necessary for this purpose shall be provided and kept ready for use: Provided that the Inspector of the Division "may exempt from any requirement of paragraph (*b*) of this regulation any mine, or part of a mine, in respect of which he is satisfied that it is not reasonably practicable for the owner to comply with the requirement."

Regulation 3: "Once every month all the equipment and material provided for fire-fighting shall be examined by a competent person appointed for that purpose who shall report in writing to the manager of the mine and shall specify in the report anything that he considers to be defective or lacking."

Regulation 4: "The manager of every mine to which No. 2 of these Regulations applies shall adopt and enforce rules for the organisation and conduct of fire-fighting work and of fire drills."

In a later article we shall endeavour to indicate the nature of the problem arising from the liability of an ignition of inflammable gas in connection with coal-cutting, or at a gob-fire, or from other cause, and we shall study the construction and action of several of the popular fire extinguishers and manual force pumps.

ACCIDENTS AT MINES.

The following paragraphs, which are based upon reports of H.M. Inspectors of Mines, draw attention to some of the fatal accidents which occurred at mines under the Coal Mines Act during the month of May, with the object of showing that some at least of them might have been avoided by more foresight and care.

1. Without first making any arrangement to stop the haulages an assistant electrician attempted to tie up a sagging electric cable to its roof plugs in a drift on which two independent main rope haulages are worked. His mutilated body was found in the drift some hours later. Travelling and work in this drift are strictly prohibited while the ropes are in motion, and the accident would certainly not have happened if he had obeyed this instruction.

2. The gear head of a face conveyor was being moved forward by two rippers by means of a sylvester. The trailing cable of a coal-cutter lay near, and the box on the sylvester crushed the cable against the edge of the dint and punctured it. The ripper who was pulling the lever of the sylvester was electrocuted, while the other man received a nasty shock through his hand, which was resting on the gear head.

3. Two shaftsmen were renewing the wood barring of a square shaft and had bared a space 4½ feet deep partly covered by temporary vertical runners at a point where the shaft passed through a coal seam. In order to find a saw which they had mislaid, they descended the shaft standing on a working platform fixed to the top of the cage, and had reached a point about 30 feet below the bare place in the shaft side, when some small pieces of coal fell and hit one of the men, fracturing the base of his skull. Had the exposed side been more carefully examined, the loose coal might have been discovered.

4. A coal filler was filling shot coal in an arcwall heading when a stone fell from the brow between converging slips and killed him. About three quarters of an hour earlier the deputy had fired a shot and had instructed the filler to set a pair of gears under the edge of the canch when he had removed sufficient coal, but he should also have insisted on the setting of temporary stays, which might have prevented the fall.

5. While the superheater of a gas-fired boiler was being dismantled, one end fell on a fitter and killed him instantly. The superheater was secured by rag bolts which should have been grouted into the holes in the base, but the grouting had never been carried out.

6. To enable a pass-bye in a naked light mine to be heightened, the signal and telephone wires were temporarily taken down, cut, and bridged with pieces of shotfiring cable. When a shotfirer was about to fire some shots in the roof, he disconnected the bridging pieces at one end and hung the loose wires in neat coils on a hook near an engine house, from whence he fired the shots. He then coiled up his shotfiring cable and left it with his exploder in the engine house. On the next shift a deputy wanted to fire a side shot. Seeing the coil of wire on the hook, he mistook it for the shotfiring cable and coupled up, whereupon current from the signal wires exploded the shot prematurely, killing a shifter and seriously wounding the deputy. The initial mistake was, when cutting and lengthening the signal and telephone wires to get them out of the way, in using pieces of shotfiring cable which could easily be mistaken for the cable used by the shotfirers.

7. The removal of a corrugated bar alongside a pack on a conveyor face left thirty-five square feet of roof without support, but no temporary supports were set. Nevertheless a packer worked under the unsupported roof casting dirt into the pack. Without warning, a fall of roof occurred at the edge of the waste and killed him instantly. This accident was entirely due to a failure to secure the place in accordance with statutory requirements.

8. A haulier was found fatally injured under a full tram attached to the horse he was driving. The road was fairly level and of good dimensions, and it was pretty certain that either he had been walking in front of the tram and had slipped or else he had been riding on the gun and had fallen off. Riding on the gun is not allowed at this mine.

9. On his way inbye at the commencement of his shift, a fireman was lowering a set of eight empty tubs by haulage rope into a branch road, when seven empty tubs standing higher up ran away and struck him. He was carried fifteen yards by the runaways, and died from his injuries. The second set had not been left securely lockered by the haulage hand on the previous shift, and may have been started away by the haulage rope touching the bottoms of the tubs.

10. While a rider went outbye to bring in a journey of empties, a haulier moved two trams along the haulage road and one of them became derailed. The haulier and a measuring clerk were attempting to re-rail the tram when the rope started, indicating that the rider outbye had signalled the journey away. Although the derailed tram still fouled the road, the two men did not signal to stop the rope, as they could have done, and when the journey of empties arrived it bumped into them and the measuring clerk was crushed and died from his injuries.

Managers and Coal Boards.

The Council of the National Association of Colliery Managers have considered the Government White Paper on coal, and note with satisfaction that pit managers and colliery technicians are to be on the National Coal Board and on Regional Boards. The Association has long felt that the knowledge and experience of its members in the highly specialised problems of coal production could be utilised to a greater national advantage. The Council therefore welcome this opportunity given to pit managers to apply their abilities in the war organisation of the pits.

PRESERVATION OF TIMBER.

In a paper before the Chemical, Metallurgical and Mining Society of South Africa, on "The Preservation of Timber and Fabrics with reference to Utilisation Underground," read by Mr. J. W. Bowen, M.Sc., of the Timber Research Laboratory of the Transvaal Chamber of Mines, it was pointed out that when timber is attacked by wood-destroying fungi several changes occur. (1) There is a gradual loss in weight due to hydrolysis of the carbohydrates, a series of intermediate products being produced until ultimately carbon dioxide and water are formed; (2) there is a corresponding loss in strength; and (3) there is a corresponding depletion of certain chemical constituents of the timber. As far as the mines are concerned these changes are particularly important, because they affect mining practice in a number of ways.

Regarding the preservation of timber Mr. Bowen said: —

In order to preserve timber against fungal and insect attack, a preservative is applied which is poisonous or repellent to these organisms. Preservatives can be divided into three groups: (1) Oil preservatives, *e.g.*, creosote, coal tar and creosote derivatives; (2) Water-soluble preservatives, *e.g.*, zinc chloride, copper sulphate, sodium fluoride and various arsenical preservatives; (3) Oil-soluble preservatives, *e.g.*, copper naphthenate, copper oleate and copper stearate and barium salts of the same acids.

The perfect preservative has yet to be discovered. It should be cheap, safe, odourless, stainless and permanent.

All types of preservatives mentioned have both advantages and disadvantages when used for the preservation of mining timber. Generally, all oil-soluble and oil preservatives can be excluded on account of cost. It must be realised that the effective life required from timber underground to a great extent governs the cost and the efficacy of treatment that can be given. Untreated timber, under conditions conducive to decay, *i.e.*, temperatures of 80°F. and relative humidities of 95 per cent., becomes so rotten that it loses its effectiveness as support after a period of a year. By comparison, in stopes where large quantities of timber are used, rarely is a life of more than four years required from timber, consequently a cheap, relatively effective preservative is all that is wanted to give this extra life. In drives, haulages and permanent ways where considerably longer life is required, it is essential that a more effective treatment, entailing greater absorption of preservative, be given. The treatment of shaft sets is a somewhat different problem. Here an extremely long life is required from this timber and it is profitable to use a relatively costly preservative to ensure that the required life is obtained. Unfortunately excellent preservatives, *e.g.*, creosote, have some disadvantages such as an unpleasant smell, being dirty to handle and inflammable. Whether or not these disadvantages outweigh the increase in life obtained is a moot point.

In addition a number of water-soluble preservatives cannot be considered on account of some individual disadvantages. The arsenicals are excellent preservatives, but are unsafe for natives to handle and would present a grave problem in a case of fire underground. Copper salts are also excluded as treatment is carried out in iron cylinders and precipitation of the copper results.

The present preservative used by the mining industry is a mixture of zinc sulphate from the reduction works and triolith—one of the Wolman salts—composed of sodium fluoride, potassium dichromate and dinitrophenol. Although no cases of dermatitis have been recorded, it is advisable to take precautions and see the persons handling this salt wash and avoid unnecessary contact as the dinitrophenol is extremely poisonous.

In the method of treating timber, investigations carried out have revealed that a number of factors play an important part in the penetration and absorption of preservative into timber. Briefly these factors are as follows:—

(1) Up to air pressures of 110 lb. per square inch absorption of preservative increases correspondingly with the pressure.

(2) Most of the preservative is absorbed within the first five minutes. Continued treatment, however, increases the quantity of preservative absorbed. On being subjected to pressure for twenty minutes, timber absorbs 82 per cent. of the preservative which it would absorb if subjected to the same pressure for one hour.

(3) The temperature of the treatment solution in the case of relatively easily impregnated woods has little effect on increased absorption.

(4) Dry timber absorbs more preservative than green timber. On the sap drying out from green timber the pores become filled with air which is readily replaceable with preservative.

(5) Drawing a vacuum prior to the application of pressure brings about a considerable increase in absorption of preservative. Generally, drawing a vacuum prior to the application of pressure, treating air-dried wood only and applying maximum air pressure available for a reasonable time, are conducive to better absorption and penetration of preservative.

WASTE OF FUEL ORDER.

The Minister of Fuel and Power has made an Order, entitled "The Waste of Fuel Order, 1942." It came into force on the 29th June. The object of the Order is to prohibit the waste and the uneconomical use and consumption of coal, gas, electricity, paraffin and liquid fuel.

The Order, which may be regarded as a prelude to the "Save fuel publicity campaign," has been made because of many complaints about waste in public places. It does not apply to fuel used by mechanical vehicles. It prohibits the use of fuel for purposes such as advertisements, lighting shop windows and show cases. The term "advertisement" includes the display of any article in the course of any business.

Business people may be required to instruct members of their staff to maintain efficient use of fuel and prevent waste, and persons authorised by the Minister are given the right to enter and inspect premises and to inspect and test fuel fittings and appliances.

Major Gwilym Lloyd George, Minister of Fuel and Power, in his radio appeal for fuel economy on 28th June, referred to oil and coal as the two principal sources of our power and fuel supplies. Oil is almost entirely imported, and he directed his remarks principally to the coal problem and the need to increase production or lessen consumption—or combine the two courses. Following the statement that "everyone in this country wants the miner to have a square deal" the Major said "The commanding position which this little island has enjoyed in the world for so long is largely founded on coal, and our ability to retain that position in the face of the present attack again depends on coal. Coal is one of our great national assets and from now on it will be the property of the nation. . . Remember this always—not a glimmer of light can we see, not a glow of warmth can we feel, without coal being consumed. Every rifle, every machine gun, every gun, every aeroplane, every tank—and all their amunition—mean more coal from our mines."

It is because of the greatly increased consumption by the essential industries that the domestic consumer is being asked to economise. Factory operators must exercise the same economies at work as they do at home. Boiler house and furnacemen must use their skill to get the last ounce out of each ton of fuel and managers will have to make themselves responsible for seeing that their plants are worked at highest efficiency. Whilst firms engaged on essential Government work get priority for their fuel, this does not entitle them to waste it.

"I believe," said the Minister of Fuel and Power, "that if the economies that can be made are made, we shall be able to ensure that every house in the country and every essential undertaking gets the necessary fuel next winter. . . Many people believe that a voluntary scheme of restriction could not succeed. I believe that, provided we all put our backs into it, this one will."

Miners' Welfare Education Scheme.

In connection with the Miners' Welfare National Mining Education Scheme (Part-time Day Advanced Mining Scholarships) the Advisory Committee includes *England:* Messrs. T. Bryson, A.R.T.C., M.I.Min.E., G. Foster, M.I.Min.E., R. L. Hay, M.Ed., B.Sc., A.M.I.Min.E., F. Oxley, F.G.S.; *Wales:* Mr. R. James, A.R.C.S., D.I.C., A.M.I.Mech.E.; *Scotland:* Mr. R. McAdam, Ph.D., M.I.Min.E. The committee will hold office for three years, and amongst other things will be concerned with the preparation of syllabuses, conduct of the examinations, and the qualifications of candidates.

B.T.U. VALUES OF COAL.

The discussion of "The Various B.T.U. Values of a Coal" is undertaken by Messrs. J. F. Barkley and L. R. Burdick, of the U.S. Bureau of Mines Fuel Economy Service, in Information Circular 7193. Appended are extracts.

The inherent heating value or the amount of heat that will be produced when a coal is completely burned is measured in British thermal units per pound of coal. This standard heat unit is the quantity of heat required to raise the temperature of 1 pound of water 1°F. at about 60°F. The amount of inherent heat is determined by burning a small quantity of the coal in a heat meter or calorimeter, which gives results in British thermal units. The value so determined is the total heat developed by complete burning, with all the products of combustion cooled down to the temperature of the calorimeter. The calorimeter is kept at about room temperature. This total heat is sometimes called the "high" or gross heat value, because it includes the latent heat given up by the water vapour in the products of combustion when the vapour condenses to water in the calorimeter. The heat as measured is reported as the heat of combustion at constant volume, since the burning is carried out in a tightly closed calorimeter chamber whose volume does not change.

The chemical elements in coal that produce essentially all the heat are carbon, hydrogen, and sulphur. Therefore, the B.T.U. value of a coal as shown by the calorimeter may be approximated by computation from Dulong's formula :

$$\text{B.T.U. per lb.} = 14544\,\text{C.} + 62028\left\{\text{H} - \frac{\text{O}}{8}\right\} + 4050\,\text{S},$$

where C, H, O, and S represent the quantities (fractions of a pound) of carbon, hydrogen, oxygen, and sulphur in 1 pound of coal. One pound of each element is considered to produce the quantity of heat expressed by the number preceding it in the formula. It is assumed that all oxygen in the coal is combined with hydrogen in the ratio of 8 : 1 to form water (H_2O) ; hence, only the remaining uncombined hydrogen is available for producing heat. For anthracite, semianthracite, and bituminous coals the computed B.T.U. values are usually within 1½ per cent. of the values determined by the calorimeter. For sub-bituminous and lignitic coals the computed values often deviate as much as 5 per cent. Causes for these differences include: (1) The heating values given by the numbers in the formula may not be quite correct for the conditions; (2) all the oxygen may not be combined with hydrogen, as part may be combined with other substances, such as carbon ; (3) the percentage of oxygen in coal is determined by subtracting the sum of all the other substances found by analysis from 100 per cent., thus throwing all errors into the percentage of oxygen ; and (4) the production of heat from coal is not as simple as the formula indicates, since various heat reactions occur with other substances in the coal, such as the burning of the iron in the ash. The usefulness of the Dulong formula is quite limited. It is much simpler and cheaper to make a calorimeter test than to analyse for the various chemicel elements in the coal. Formulæ have been proposed at various times for the calculation of the heating value from the "proximate" analysis of the coal. The proximate analysis gives the moisture, volatile matter, fixed carbon, and ash. Such formulæ are apt to give unreliable results.

There are various ways of consideraing the B.T.U. value of coal. It is ordinarily expressed as the B.T.U. per pound: (1) "As received" or "as sampled"; (2) "moisture free" or "dry"; (3) "moisture- and ash-free"; (4) "H" value; (5) dry, "mineral matter free"; (6) moist, "mineral matter free." For any one coal sample, all these values are related by values of the chemical analysis of the coal. If the moisture, ash, and sulphur contents are known, any one of these values may be calculated from any other.

By the explosion of firedamp in the Five Quarter Seam of Murton Colliery 13 men were killed and several others injured. It was in the same seam, although in another district, in which an explosion occurred in December, 1937, when four lives were lost.

MECHANISATION AND EXPLOSION HAZARDS.

The following notes are extracted from the U.S. Bureau of Mines Information Circular 7181 on "Status of Safety in Mining." The author is Mr. D. Harrington, chief of the Bureau's Health and Safety Branch.

The mechanisation of coal mines unquestionably introduces additional explosion and other hazards, although it affords numerous opportunities to decrease many types of hazards that accompany more primitive mining practices and methods. In addition to the mechanical hazards involved in mechanised mines, there is almost invariably a considerable concentration of workers readily susceptible to injury from any untoward occurrence; moreover, the more rapid extraction of coal as a result of mechanical loading liberates greater quantities of gas and dust in a given period than does hand loading, and the gas is liberated in the presence of an increased number of sources of ignition, chiefly in connection with electrically operated equipment. Consequently, better ventilation must be provided and greater vigilance maintained in the detection of gas and elimination or neutralisation of dust. Many explosions result directly or indirectly from carelessness or infractions of rules by employees and many from unsafe methods, installations, or practices (or all three) for which the management is responsible; therefore, the prevention of explosions is the responsibility not only of the management but also of the workers.

During the winter the cold air entering mines absorbs moisture and dries the coal dust, making it more capable of being raised into the air, more readily ignited, and more violently explosive upon ignition; and during these months particular precautions should be taken to prevent accumulations of explosive gas or dust and the initiation of an explosion. This applies even more emphatically to modern mechanised mines than to those still using the most primitive hand-loading methods.

Pulverised rock dust, such as that from limestone, should be applied in bituminous and lignitic coal mines to walls, roof, and floor of mine passages to prevent propagation or extension of an explosion. When an ignition of gas or of pure coal dust or a combination of both occurs, this pulverised rock dust and the coal dust present on adjacent surfaces (floor, roof, and walls) are raised into the air. The rock dust prevents the coal dust from igniting, which localises the flame and prevents the explosion from spreading, or "propagating" as it is termed. Experiments and experience have shown that an explosion will not propagate or extend any considerable distance from its origin in a mine that has been well-rock-dusted.

The partial rock-dusting of mines gives little or no real protection; in fact, it fosters a false sense of security, and in many instances the result is even worse than if no rock-dusting were done. To provide adequate assurance against widespread explosion disasters in coal mines all accessible open areas should be thoroughly rock-dusted, including haulage entries, aircourses, rooms, crosscuts, short or long faces, and pillar regions; and the rock-dusting should be repeated from time to time so as to hold the incombustible content of the rib, roof, and floor dusts at all times to over 65 per cent.

Safety Consciousness.

Dealing with some of the outstanding phases of the "human element" in a contribution to the CANADIAN MINING JOURNAL, Mr. W. B. Paton expresses the view that "When a man sincerely believes that his daily conduct in the mine will guarantee his safe return to the surface, when he has pity rather than contempt for the fool, when he advises rather than derides the beginner in his mistakes, when his eyes and his ears and his very soul have a more mutual understanding than dear friends, when he gives doubt the benefit, when he has satisfied himself that preordination is a silly myth, and when procrastination, like Satan, is behind him, that man is standing on the very threshold of *safety consciousness :* that man has mastered the 'human element' complex."

Coal royalties have existed since 1563, when a legal ruling was given that property owners' rights entitled them to payment for the mining of all minerals except gold and silver below ground.

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The Science and Art of Mining

WIGAN, SATURDAY, JULY 11, 1942.

[ESTABLISHED 1890.]

SILICOSIS-CAUSATION FACTORS.

A paper by Mr. J. de V. Lambrechts on "A Critical Review of Dust Sampling Methods Employed in Witwatersrand Gold Mines," has been under discussion by the Chemical, Metallurgical and Mining Society of South Africa. In his contribution Professor C. W. Biccard Jeppe said:—

In general, we have still very much to learn about silicosis-causation; investigation so far has not disclosed, with any real assurance, the influence on silicosis-causation of such factors as:—

(1) The solubility of silica dust particles.

(2) The size of silica particles.

(3) The freshness of silica particles. It is known that silica particles when freshly formed are far more soluble than when they have been exposed to air or water, even for short periods. When fresh also they possess other special physical and chemical properties which may conceivably play a part in silicosis-causation. It has been argued that old dust is much less dangerous than new dust; if this is the case it is an argument against the importance of dust from atomised mine water. It is known, however, that old silica dust still causes silicosis.

(4) The type of silica. There is a large number of forms in which silica may occur. Gardner has carried out investigations indicating that these various forms of silica differ very greatly in their harmfulness. It is of interest to note that he concludes that the most dangerous form of silica as regards silicosis-causation is its occurrence as a dispersed gel, which indeed is very possibly the form it takes after atomisation of water containing silica.

(5) Chemical reactions, whereby dissolved silica is re-deposited as a solid.

(6) The possible effect on the initiation of lipoid formation of other ingredients of rock dusts. Complete analyses of typical Witwatersrand conglomerates, quartzites and shales, and of the dusts formed from them, have still to be made. It has been suggested that the various ingredients should be investigated as to their influence on silicosis-causation, both individually and in combinations.

(7) The importance or otherwise of sudden concentrations of dust entering the lungs. It is conceivable that whilst the lungs can cope, with reasonable success, with normal dust concentrations, they may not be able to deal effectively with sudden clouds of dust, such as must accompany many mining operations. Size frequency may be an important factor in this connection.

MINING CALCULATIONS.

By "M.E."

Locomotive Traction.

The theory of locomotive traction is essentially simple and involves a knowledge of the principles of friction and the inclined plane. When sets of tubs are hauled along underground roadways by a locomotive the number of tubs per set, or alternatively, the maximum gradient upon which sets of tubs may be hauled, depends on the weight of the locomotive and the frictional resistance between the wheels and the rails. It is essential that the load to be hauled by a locomotive should not be so great as to cause the wheels to skid on the rails, thus bringing the tubs to a standstill.

Sliding Friction.

When a body of weight W is placed on a horizontal plane, and allowed to remain at rest, the reaction N of the plane is equal to the weight and normal to the plane. When, however, a force P is applied to the body in a direction parallel to the plane to cause the body to move, the ratio of P to W when the movement begins is called the coefficient of friction from rest, and the ratio P to W when the body is kept moving at uniform speed is a number, representing the coefficient of friction, which is generally smaller than the first. For that reason, tables of coefficient of friction give two values of the coefficient of sliding friction, one from rest, the other in motion, and values are also given for dry and wet, or lubricated, surfaces in contact.

Referring to FIGURE 1, it is seen that, when P equals F and motion of the body is just about to take place, the point O is in equilibrium under the action of the forces P, W, and R, the reaction. Taking these forces in clockwise order, and constructing the triangle of forces, we can evaluate R and the angle θ, which latter is generally called the angle of friction. $P \div W = \tan \theta$.

Example 1.—A loaded tub having a total weight of 15 cwts. was placed on a level track with all wheels spragged. The force required to cause it to move was 269 lb. Calculate the coefficient and the angle of friction.

Answer.—Coefficient of friction $= 269 \div 15 \times 112 = 0{\cdot}16$.
Angle of friction $= \tan^{-1} 269 \div 15 \times 112 = \tan^{-1} 0{\cdot}16 = 9°05'$.

Journal Friction.

The frictional resistance of axle bearings depends mainly on the form of the bearing and the efficiency of the lubrication of the surfaces in contact. In FIGURE 2 the load on the axle is seen to be represented by W, and the force F tending to prevent the axle from turning about the centre O of the axle is seen to act at a distance r from O. If the surfaces in contact in the bearing are lubricated the movement of one relative to the other will be brought about by a smaller tractive force applied to the drawbar of the tub of which the bearing forms a part than would be the case if the bearing surfaces were dry. In any case, the coefficient of journal friction would be expressed by $f = F \div W$. It is clear that the greater the radius of the axle the greater would be the effort required to turn the axle in the bearing, however it might be lubricated, and for that reason the diameter of the axles of tubs is kept at a minimum consistent with strength. Again, the more effective the lubrication the less will be the effort required to turn the axle in the bearing, and when roller, or ball, bearings are used the effort is least. The coefficient f may vary from about 0·01 to 0·005 for lubricated journals, the smaller value relating to ball or roller bearings.

Rolling Friction.

All surfaces are more or less rough, and the irregularities in surfaces in contact tend to prevent relative movement of the surfaces. Apart from the elasticity of bodies in contact, the effect of roughness of the surfaces in contact is just the same as if an impediment were placed in front of a wheel rolling along a tub track. In FIGURE 3 it is supposed that a wheel is caused to roll from left to right by a force P applied at the centre of the axle, and that a small obstacle B is opposed to the rolling of the wheel. Equating the moments about B we have $P \times AB = Wf$, we find that $P = Wf \div r$, when the obstacle is very small and lies close to O. On well-laid railways $f = 0{\cdot}002$, and the same might be said of well-laid tub tracks, provided it was possible to keep them free from such obstacles as that indicated at B.

Frictional Resistance to Traction.

From these considerations it becomes apparent that the movement of tubs along underground railways is hindered to some extent by sliding, journal, and rolling friction according to the design of the axle bearing, the ratio of diameter of journals to diameter of wheels, and the obstacles that find their way on to the rails. With plain axle bearings we may assume that the frictional resistance to traction is about 0·01 to 0·015, and with ball or roller bearings the coefficient is 0·007 or thereabout. In the case of locomotive haulage it now becomes apparent that the available drawbar pull on no load is obtained by multiplying the weight of the locomotive by the coefficient of sliding friction, and that the resistance to traction may vary from 0·01 W to 0·007 W.

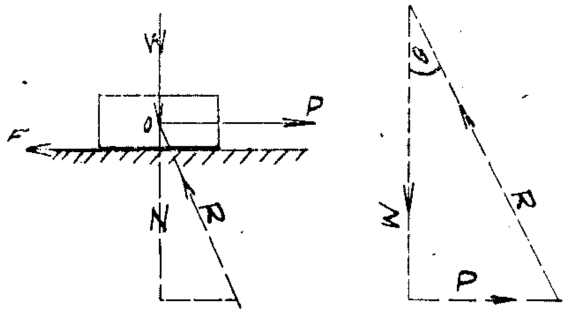


Figure 1.

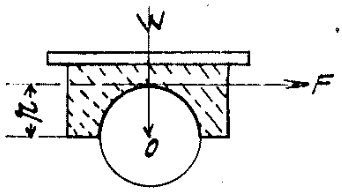


Figure 2.

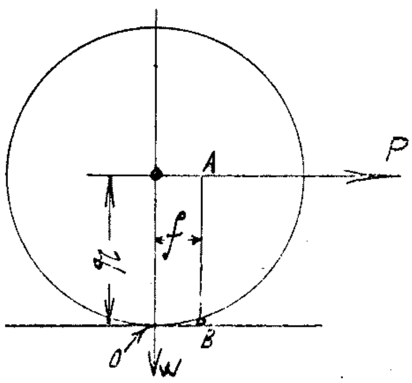


Figure 3.

Example 2.—A locomotive designed for use in mines weighs 6 tons. Calculate the tractive force it is capable of exerting on a level track, assuming the coefficient of sliding friction to be 0·15 and the coefficient of resistance to traction to be 0·007.

Answer.—Tractive force $= 6 \times 2240 \times 0{\cdot}15 = 2{,}016$ lb.
Force to overcome frictional resistance $= 6 \times 2240 \times 0{\cdot}007 = 94{\cdot}1$ lb. Available drawbar pull $= 2016{\cdot}0 - 94{\cdot}0 = 1922$ lb.

Example 3.—An underground locomotive capable of exerting a drawbar pull of 1,922 lb. on a level track is to be used to haul sets of tubs each having a total weight of 5 tons when loaded. Calculate the number of tubs that can be hauled at one time by the locomotive, assuming that the coefficient of resistance to traction is 30 lb. per ton of load.

Answer.—Let N be the number of tubs to be handled per journey, then $P = NW \times 30 = 30 \times 5N$, hence $N = 1922 \div 150 = 12{\cdot}8$. Obviously, the greatest number of tubs per set would be 12, and if the tubs had a capacity of 3·5 tons, the total load of coal per set would be $3{\cdot}5 \times 12 = 42$ tons.

Example 4.—A locomotive with a drawbar pull of 1922 lb. is to haul tubs weighing 5 tons along a track dipping at 1 in 200. How many tubs may be hauled per set if the resistance to traction is 0·015 ?

Answer.—$P = -Wi + Wf$

$$1922 = -(5 \times 2240 \times \tfrac{1}{200})N + (5 \times 2240)\,0{\cdot}015N.$$

$$\therefore\ 1922 = -11{\cdot}2N + 168{\cdot}0N = 156{\cdot}8N.$$

$$\therefore\ N = 1922 \div 156{\cdot}8 = 12{\cdot}2.$$

Here the gravitational force acts downhill and is negative in consequence.

PRIZE COMPETITION AWARDS FOR VOLUME 52.

As an educational medium the Prize Competition has a purpose to serve, and that is to supply an addition to the training received by students at the mining schools and colleges. At the present time in particular, young men resident in remote districts and faced with restricted travelling facilities should find in it a helpful medium in the pursuit of knowledge. It affords at home practice in the reasoned and methodical preparation of answers to questions of more than passing importance to them as members of the mining community. Such work involves a certain amount of research under conditions most favourable to quiet study, the results of which will be reflected in the field of labour where instructions have to be given and the job of work in hand explained in language that the workmen can understand.

Conscientious study of the questions set will help to make readers who actively engage in the Prize Competition better and safer workmen. This idea in "safety first" cannot be too strongly emphasised in these days of mechanised mining. Students who wish to improve themselves and to "step up" to positions of trust and authority as their elders have done will have little difficulty in appreciating the significance of this safety pointer.

The conditions and regulations governing the Competition are quite simple, and for the benefit of younger competitors we again commend the following hints, which may be worth noting by all candidates for examination purposes :

1. Read the question very carefully and ascertain what exactly is required.

2. Keep strictly to the points of the question and build up the answer in sequence without unnecessary padding. Remember that a long rambling answer often increases the liability to omit important points.

3. In sketching or drawing (*a*) use only good Indian ink and use a separate piece of unruled paper ; (*b*) Make the lines on drawings bold, as also any lettering or dimensions used in connection with them ; (*c*) Do not make the drawings too large, or on the contrary too small, otherwise publication may be rendered impossible.

4. In answering mathematical questions, bear in mind that setting out in logical sequence is a necessity, and if a formula is used the "key" to its symbols should be given.

5. Assume any data which after consideration you decide are missing from a question and which you consider are essential to the correct answering of the question, first mentioning what you are about to assume.

The winners in the three classes in Volume 42 were :

Firemen.—First place in this stage has been secured by Mr. T. Turner Robson, of Coxhoe, who may continue to compete in the Second Class or First Class at his own discretion, the Firemen section being no longer open to him.

Second Class.—Mr. R. Dawson of Crook has secured the first place in this stage, and he must now confine his attention to questions in the First Class stage, the lower sections of the Competition being closed to him by virtue of his present success.

First Class.—In the final reckoning the award in this stage goes to Mr. Geo. Corless of Bamfurlong, who in view of this success will no longer be eligible as a competitor in any of the three stages. We hope in due course to receive from Mr. Corless particulars of his career and photograph for publication in this journal.

Turn to page 8, read the simple conditions, and send in your answers to the questions in *either* the Firemen, Second Class, or First Class.

SHOCK BUMP AT BARNBOROUGH PIT.

Giving evidence at the inquest on the four men killed in the disaster at Barnborough Main Colliery in April, Mr. Godfrey C. Payne, manager of the colliery, expressed the view that the occurrence was due to a shock bump in the district, covering approximately 15 acres. It was the liberation of a large amount of pent-up energy which suddenly reacted in the roof and gave the district a sort of smack. That tremendous force, transmitted through the coal pillars, would cause the floor to heave up.

Mr. Payne said the Parkgate seam, which was affected, was 4 feet 6 inches to 5 feet 6 inches thick, and above it was overlying rock 30 yards thick. The floor was mostly of fireclay up to a foot thick, and hard rock beneath. They had had more trouble with floor lifting in the last six months than previously. The increase in floor heave was due to the increase of weight above. He said that in course of the work 870 yards of blocked roadway had to be cleared, and it was done by men passing shovelfuls back from one to another, to a space through which a man could only crawl, and in a temperature of 85 degrees. Over 400 men took part in the work.

Dr. Arthur Winstanley, H.M. Inspector of Mines, said he was convinced that the cause of the disaster was a shock bump, and not a pressure bump. We had had no previous experience of such a bump in mining in this country, though shock bumps were known in Canada and America. An earth tremor was the effect of the bump and not the cause.

The Coroner (Mr. W. H. Carlile) accepted this theory, and recording a verdict of "Accidental death" he paid tribute to the gallant work of all who helped in the rescue of the imprisoned men, specially mentioning the two boys, Cruise and Thompson, who, he said, probably helped their older comrades to maintain their courage. The Coroner said he did not attach any blame to the method of working previously carried on, but if the inquiry led to a review of methods of mining so as to prevent accidents it would have served a useful purpose.

THE WHITEHAVEN EXPLOSION.

Two Unusual Features.

In his report to the Mines Department on the explosion at the William Pit, Whitehaven Collieries, Cumberland, on 3rd June, 1941, when 12 men lost their lives and 11 were injured, Mr. F. H. Wynne, Chief Inspector of Mines, states that two of the features of the disaster were unusual.

One was that the explosion was not associated with the normal operations of coal production. It occurred in a large sealed-off area which had been abandoned since 1928, and no suspicion arose of the possibility of an explosion here. In the second place, there was little doubt that the explosion was one of inflammable gas produced by the application of water to a considerable mass of glowing coal. Water had been used for some time with other measures of control which had been in progress for several years.

This finding, says the report, is "bound to create some misgiving as to the possibility of a similar danger arising when water is used for ordinary fire-fighting operations below ground. The accumulated experiences of more than a generation in fighting underground fires with water suggests that the risk of a dangerous water-gas explosion is unusual and even remote.

"Such an explosion cannot occur unelss there are concurrently (*a*) a large mass of red-hot carbonaceous or coaly material, (*b*) a supply of water which on conversion to steam remains for an appreciable time in close contact with the hot carbon, (*c*) partial confinement to a space in which mixture of the water-gas with air takes place, and (*d*) contact with the explosive mixture of water-gas and air with some igniting medium. These essentials are not likely to occur except when a fire is deep seated in a mass of coal.

"While it may perhaps be dangerous to dogmatise, the opinion is here definitely expressed that in the case of deep-seated spontaneous fires treatment by water can only be promiscuous and it may also be hazardous. In any event, water cannot be relied upon as a curative unless it is applied in such quantity as to cause complete immersion. The William Pit explosion is a striking example of this thesis."

PRIZE COMPETITION.

With Notes by S.G.

Regulations for Volume LIII.

The Competition is open to all who have not secured first place in Honours or First Class in earlier volumes. No entrance fee. Intending Competitors may start now, with the questions set below. It is not necessary to wait until the end of a volume is announced. Not more than two questions may be attempted, and answers to questions in more than one stage in the same issue cannot be recognised. The selected answers will be published and the successful competitor for each question will receive a Prize of 2s. 6d.

Each question and answer must be written on separate sheets of paper, bearing the full name and address of the sender; the top left-hand corner of the envelope to be endorsed "Competition."

All accompanying sketches must be in good Indian ink, no colouring or wash, and on white, unruled paper, separate from the manuscript. Lettering on sketches should be bold and clear.

Marks will be awarded. THE SELECTED PUBLISHED ANSWER will possess a value of 15 marks, whilst to the remaining answers for competition will be given a value in marks according to merit. The names of Competitors who are awarded marks are appended to each answer. Our decisions are final, and we cannot enter into correspondence regarding them.

Answers not accepted for publication will be returned, subject to stamped addressed envelope being enclosed for the purpose.

The Competitor in each stage who has the largest number of published answers during the volume will be held to be the winner in that stage. Each winner will be entitled to and receive the Publishers' Book Prizes, value not less than One Guinea. The photo of the successful First Class Competitor will be published; he will be awarded the Editor's Special Prize, and he cannot take part in the Competition of later volumes.

Prize Competition answers and other MSS. may be sent under Printed Rates enclosed in a wrapper or other open cover, but must not be accompanied by anything in the nature of a letter, unless sent at Letter Rate.

All answers to the set of questions given below must be addressed: The Editor, THE SCIENCE AND ART OF MINING, Rowbottom Square, Wigan, and be received not later than

MONDAY, JULY 27, 1942.

READ THIS: IMPORTANT REGULATION.

Original answers are specially desired. No contributions whatever to these columns will be published unless (1) the Competitor states at the foot of the answer that it is his own original composition; or (2) quotes in the course of the answer the source (with name of author) from which any portion thereof —text or sketches—has been quoted. If Competitors have been helped by more than one authority the full title of each work—whether it is a book or in the form of lessons by Correspondence Class—with the name of the Author, should be given, also, if possible, the chapter and page of the volume. Competitors sending in as their original composition matter extracted from text-books, etc., will upon such breach of this regulation coming to our notice, be debarred from all future competitions.

Questions for Mining and Engineering Students.

The selected answers to the following questions will appear in No. 4, Vol. LIII. Sketches essential only when asked for. Competitors are asked to write to the point, and not make too much use of text-books. In the selection of answers for publication, other things being equal, preference will be given to answers not exceeding 600-700 words.

FIREMEN.

Q. 1.—*Ventilation.—Describe clearly how the quantity of air passing along an airway may be increased.*

Q. 2.—*Roof Breaks.—How can breaks in roof strata contribute to an explosion of firedamp? Make a sketch plan and section to illustrate your answer.*

SECOND CLASS OR UNDER-MANAGERS.

Q. 3.—*Deterioration of Ropes.—Describe clearly the chief causes of deterioration and failures of wire ropes used for haulage and winding.*

Q. 4.—*Opening Out Workings.—Describe how you would set out and ventilate the working faces while forming the shaft pillar in a coal seam 4 feet 6 inches thick; the beds have a gradient of 1 in 20, and the shafts are 80 yards apart along the line of strike.*

FIRST CLASS OR COLLIERY MANAGERS.

Q. 5.—*Steam Engines.—Describe briefly how you would determine (a) the indicated horse-power of a steam driven engine of the ordinary double-acting type; (b) the brake horse-power of the engine; (c) the mechanical efficiency of the engine.*

Q. 6.—*Shaft Fittings.—A circular shaft is to be equipped for coal winding. Give a sketch plan of the position of the cages, having four tubs in a deck, and the positions of the rope guides. State how you would support the guides in the headgear, and how you would steady them in the sump. If the tubs are made to hold 10 cwt. of coal, what would be the approximate diameter of the winding shaft required for safe working?*

Best Answers Received to Questions in No. 24, Vol. LII.

FIREMEN.

Instruments.

Q. 1.—*What instruments for indicating the conditions of the atmosphere are required by the Mines Act to be provided at collieries? Where are such instruments to be placed, and what are the requirements of the Act as to recording the readings?*

A.—Several instruments are required to be provided to enable various officials of the mine to ascertain the conditions of the atmosphere underground generally. In practice these instruments measure the temperature and pressure of the air entering the mine, and whether it is dry or not; one instrument measuring the quantity of air being produced, together with another provided with the ventilating fan to measure the difference in pressure between the downcast and the upcast shafts.

The following data give the instruments required to be provided by the Act, when they should be read and the bookings of the readings.

A. A barometer and thermometer shall be placed in some conspicuous position near the entrance to the mine and a hygrometer shall be placed below ground in a conspicuous place near the shaft or outlet both in the main intake and the main return airways.

The above instruments shall be read by such persons as may be prescribed by the General Regulations and the readings obtained entered into a book to be kept at the mine for that purpose at prescribed intervals.

The General Regulations made to comply with the foregoing statement are:

(1) Every person who is in any way responsible for the ventilation underground and who is required to make a daily report in a book kept at the mine for the purpose, shall immediately before going into the mine and after coming out of the mine read the barometer provided.

The above regulation shall not apply to mines of stratified ironstone in the Cleveland district or to any other district if the Secretary of State is satisfied that similar conditions prevail.

(2) Each hygrometer placed below ground shall be read by a responsible official of the mine once every week-day if in the main intake airway, and once every week if in the main return airway.

The above regulation shall only apply to mines in which coal is worked.

B. The Coal Mines Act also requires that the quantity of air passing along the main intake airway, and in every split and at any such points as may be determined by the regulations of the mine shall, at least once in each month, be measured and entered into a book to be kept at the mine for that purpose.

There is one regulation made to amend, and which should be used in conjunction with, the aforegoing section of the Act. This states that the quantity of air required for ventilating purposes must be measured:

(1) In the main intake airway of every seam as near as practicable to the downcast shaft;

(2) In every split as near as practicable to a point where the split commences;

(3) In each ventilating district at or as near as possible to a point one hundred yards back from the first working place where the air enters.

The foregoing section of the Act and Regulations as to the measurement of the quantity of air passing into the various parts of the mine is usually carried out with the aid of an instrument called the anemometer. This instrument measures the velocity of the air flowing through the various roadways. Hence if the velocity of the air passing into the district per minute is found, and this is multiplied by the cross-sectional area in square feet of the roadway at the point where the velocity in feet was measured, then we shall have the quantity of air in cubic feet that is passing in that roadway.

C. The General Regulations also require a water-gauge to be provided with the ventilating fan. These regulations state:

(1) Every fan driven by mechanical power shall be provided with a water-gauge and either an automatic indicator registering the number of revolutions of the fan or an automatic indicator registering the water-gauge.

(2) The person in charge of the ventilating appliance shall from time to time observe the ventilating pressure as indicated by the water-gauge, and where an automatic indicator registering the water-gauge is not provided he shall, at the end of every two hours, enter into a book to be kept for the purpose the number of revolutions of the fan together with the ventilating pressure as shown by the water-gauge.

GENERAL: It can easily be seen that, once the aforegoing readings and statements have been collected at some one point, the state of the ventilation, together with the quantity of inflammable gas that may be expected, can be easily ascertained, together with many other important points which it is very desirable to know.

Original.

T. T. Allbrighton, 105, Whitehouse Road, Dordon, Tamworth, Staffs.

[*Note.—The answers were good and the required instruments were correctly given. In addition to the barometer, thermometer and hygrometer, several students mentioned the ordinary and self-recording water-gauge, and the anemometer. These are certainly necessary and their inclusion increases the value of the answer.—S.G.*]

Joseph O. Aktinson, H. Renshaw (*15 marks each*).

W. H. Allsopp, Wm. A. Craig, A. Dennis, C. J. A. Hoyle, Alex. McD. Paterson, John E. Turner (*14 marks each*).

Air Necessary.

Q. 2.—*What minimum quantity of air in cubic feet per minute is considered necessary for a man, a lamp, and a horse respectively? If the quantity of firedamp produced in a given mine is 1,000 cubic feet per minute, what is the minimum quantity of air necessary to comply with the requirements of the Coal Mines Act?*

A.—When estimating the minimum quantity of air required for any mine the principal factor to be considered is, in most cases, the quantity of firedamp given off from the strata. Different collieries and even districts in the same mine vary greatly in this respect, and it is obvious that a quantity of air adequate for one mine may be totally inadequate for another. To estimate the required quantities of air recourse may be made to two or three rules which must at all times be used with the greatest discretion and with full appreciation of their limitations.

The following rule is based on the number of persons employed below ground at one time in the principal shift:

In mines where gas is unknown allow 150 cubic feet per minute per person.

In moderately gassy mines allow 250 cubic feet per minute per person.

In very gassy mines allow 300 to 500 cubic feet per minute per person.

For each pony allow 600 cubic feet per minute.

For each lamp allow 15 cubic feet per minute.

It is obvious that the rule quoted only gives an estimate for the minimum quantities. In mines where firedamp is produced the larger figure should always be used. The only safe guide to find whether any mine is adequately ventilated is by constant measuring of the quantity of air flowing in the main roads, splits, and particularly in the working faces.

Calculation of Air Necessary.—Section 29 (Par. 3) of the C.M.A. states: An intake airway shall not be deemed to be normally kept free from inflammable gas, if the average percentage of inflammable gas found in six samples of air taken by an inspector in the air-current in that airway at intervals of not less than a fortnight exceeds ¼ per cent.

If the firedamp is reduced to 0·25 per cent. then the air will form the remaining 99·75 per cent. of the atmosphere, which

means there are $\frac{99 \cdot 75}{0 \cdot 25} = 399$ times more air than firedamp.

$\therefore$ Amount of air required $= 399 \times 1000$
$= 399000$, cubic feet per minute.

Assisted by U.M.S.

A. RAMSAY, 4, Weardale Terrace, Annfield Plain, Co. Durham,

[*Note.—The majority of the answers were good and suitable values were given by most students. A few competitors did not realise that the quantity of air will depend upon several factors, each of which requires special consideration. The solutions to the latter part of the question produced two answers, based on the regulations, " An intake airway shall not be deemed to be kept normally free from inflammable gas if the average percentage of inflammable gas found in six samples of air taken by an Inspector in the air-current of that airway at intervals of not less than a fortnight exceeds 0·25 per cent " ; and again " the percentage of inflammable gas in the return airway used for the haulage of coal must not exceed 0·5 per cent." Several students omitted to mention " a return airway used for haulage of coal."—S.G.*]

A. Dennis, Cynon Evans, W. S. Richardson (*15 marks each*).
Joseph O. Atkinson, T. T. Allbrighton, Wm. A. Craig, C. J. A. Hoyle, Alex. McD. Paterson (*14 marks each*).
J. E. Turner (*13 marks*).

SECOND CLASS OR UNDER-MANAGERS.

Winding Ropes.

Q. 3.—*What are the various kinds of ropes used for winding, and the merits of each ? For haulage ropes which require splicing, do you prefer four or six strands, and why ?*

A.—Wire ropes used in connection with shaft winding should be of good flexibility for safe bending over drums and pulleys, high tensile strength for safety against excessive live loads, and sufficient hardness to resist abrasion to be of great durability to resist rust and corrosion.

Materials for winding ropes may be tabulated as follows :—

Improved patent steel ..	80 to 90	tons per square inch ultimate strength.
Mild plough steel	95 to 100	"
Best plough steel	100 to 110	"
Special improved plough steel	110 to 120	"
Special high tension steel ..	120 to 140	"

Winding ropes are chiefly manufactured round in shape, and are classified as under :

Langs Lay.—The ropes have uniform twist ; the wires of the strands are twisted in the same direction as the strands in the rope, thus a larger wearing surface for each of the wires.

Ordinary Lay.—The strands receive a right-handed twist, while the wires of the strand get a left-handed twist, thus a small surface of each wire is exposed to wear.

Flattened Strand ropes are very flexible, have a smooth surface exposed to wearing action and are greatly used in winding shafts.

Locked Coil Ropes.—These are specially constructed with interlocking wires and resemble a round bar when completed. These ropes have a non-rotative action, and are mostly used for winding in sinking pits and for cage guide ropes in shaft.

Galvanised Wire Ropes.—The core consists of galvanised wire and the whole rope is made with galvanised wires ; they may be used in wet shafts, especially where the water has corrosive properties.

Haulage ropes may consist of *Ordinary Lay* or *Langs Lay* type and consist of 4 to 6 strands or upwards.

For splicing and good wearing I prefer the rope of the 6 strand and with 6 wires and centre wire in each strand (total of 42 wires).

The 6 strand has better flexibility and wear, and is more able to give good and reliable service if one of the strands is hogged. Also, it is easy to splice with the 6 strand rope, and the strands give strength to the rope, thus making a good substantial rope. Owing to the larger wearing surface there is less danger of broken wires ; also the flexibility gives good wear, and the rope is easily adjustable around curves, wheels and haulage drums.

Assisted by class lessons.

PERCY WATSON, 16, Bloomfield Terrace, Pelton Fell, Co. Durham.

[*Note.—The answers were only fair and not sufficient in number. Students should know that " flat ropes " are rarely found. Most students prefer the 6 strand rope, and good reasons for their choice were given.—G.S.*]

T. Turner Robson (*14 marks*).
Cliff Daniels (*12 marks*).

Material.

Q. 4.—*What is meant by the terms : Tensile strength, torsional strength, elongation, reduction of area, elastic limit, as applied to the testing of materials ? How is the knowledge of such properties of metals useful in connection with the plant and machinery of a colliery ?*

A.—The various tests to which metals are subjected in order to ascertain their qualities and ability to withstand shocks, long life and other effects, are known to be effective and give valuable information to those wise enough to take advantage of such information. These qualities are aptly described by the terms used to indicate the certain quality to which they refer, and are briefly described in the following summary :

(*a*) *Tensile Strength.*—The word " tensile " indicates pulling force ; obviously then, the tensile strength of a metal is the resistance put forth by the metal to pulling forces which tend to warp or bend the metal, thus causing weakness and destroying uniformity if allowed to take place. In a metal plate the tensile strength is the point at which the force applied is halted, but which has a weakening effect when exceeded. In a steel wire rope the tensile strength is referred to as tons per square inch of the rope, at which the rope will resist the pulling force but which will fracture the rope when exceeded. Thus in all metals the tensile strength is the force applied by the metal to counteract the pulling force exerted upon it, in so far as it succeeds in resisting " tension."

(*b*) *Torsional Strength.*—The word " torsion " indicates twisting or turning force. The torsional strength of a metal is the point to which the metal can be subjected to such a twisting force and retain its uniformity and original strength. Any force exceeding that point weakens the metal and destroys its uniformity if allowed to take place. Thus the torsional strength of any metal is the force applied by the metal in resistance to the twisting force that may be exerted upon it, in so far as it succeeds in resisting " torsion."

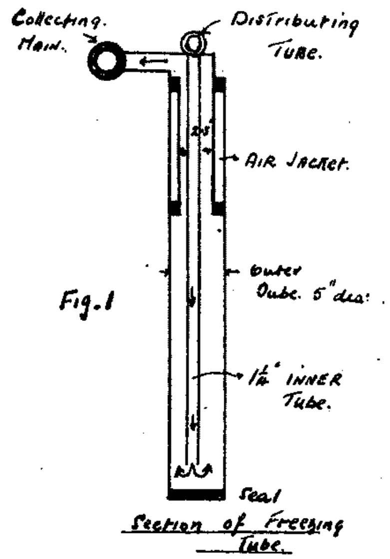
(*c*) *Elongation.*—This means, as the word " elongation " implies, lengthening, due to forces applied along the length of the metal; *e.g.*, steel wire ropes are subject to elongation over a period of time. The extent of the elongation is determined by the quality of the steel, the period of time the rope is used, and the load the rope operates upon.

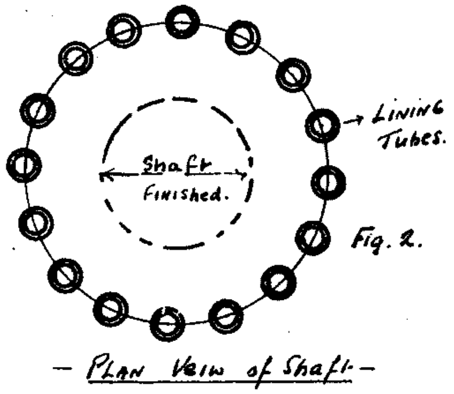
(*d*) *Reduction of Area.*—This means the amount of reduction in area that metal, plates, bars, ropes, etc., may be subjected to due to the exertion of any of the forces, tensile, torsional or elongation. Bulging of a metal plate due to tensile or torsional force will cause a reduction of the original area of the plate as elongation in a metal, bar or steel rope will cause a reduction of area (sectional).

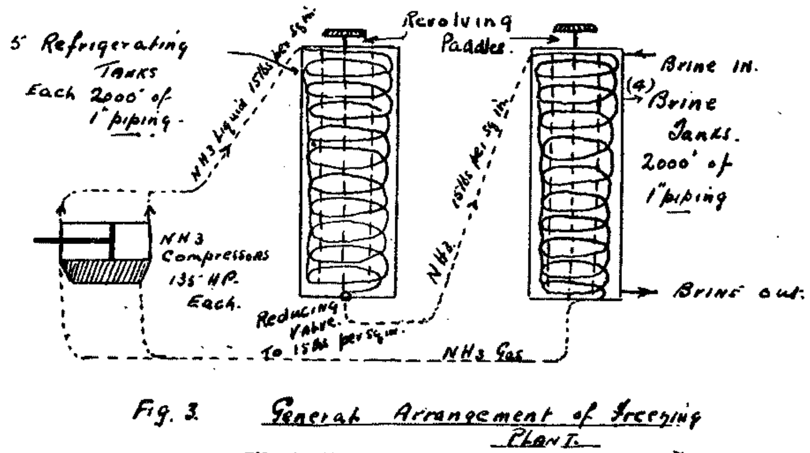
(*e*) *Elastic Limit.*—This term indicates the property of matter by virtue of which it tends to return, or spring back, to its original shape and dimensions when the applied forces are removed. The term indicates the point at which the stress changes from elasticity to permanent extension, *i.e.*, permanent set, and material loaded beyond the elastic limit is said to be overstrained. The modulus of elasticity can be calculated by applying the following simple formula $\frac{\text{Stress}}{\text{Strain}}$ = Modulus of elasticity (described as tons per square inch or lb. per square inch, depending on how the stress is measured).

Such loads as are applied above that at which the elastic limit of ductile materials, such as steel or iron, is capable of resisting, causes a point to be reached known as the " yield point," and in the case of a steel or iron bar or rope causes a reduction in cross-sectional area and a reduction in the factor of safety, if allowed to continue.

The knowledge of such properties of metals is useful in connection with the plant and machinery of a colliery as it gives information as to the working efficiency of the various instalments of the plant in use. From the knowledge given an accurate estimate of the safety of the plant can be derived, *e.g.*, safe loads for winding and haulage ropes, their safety factors and the effect that stress and strain, elongation and elastic limit has upon them ; the safe amount of steam pressure for boiler plates, rivets, angle plates, stays, etc., in the boilers ; the effects of torsional, tensile and shearing stresses upon winding and haulage engines ; also







Illustrating Question 5.

the behaviour of safety chains, etc., under certain loads can all be arranged to a safe degree. In general, such knowledge as is given by the above terms, if taken advantage of, will greatly ensure the efficiency of the plant and machinery in use by applying just the forces with which they are capable of dealing and not overstraining them by loads beyond their strength and limits. Thus saving in costs and life may well be achieved.

Mainly original; slightly assisted by class notes.

T. Turner Robson, 43, Park Avenue, Coxhoe, Co. Durham.

[*Note.—Perusal of the above answer will be of value to students. More competitors should have dealt with the question, the subject being of importance to mining men.—S.G.*]

Cliff Daniels (*14 marks*).
Percy Watson (*13 marks*).

FIRST CLASS OR COLLIERY MANAGERS.

Freezing Method of Sinking.

Q. 5.—*Describe clearly the freezing process of sinking. What are the conditions suitable for its application, and what are its disadvantages?*

A.—The freezing process of sinking has as its object the conversion of the beds to be sunk through, by the circulation of a freezing mixture of brine, into solid impervious strata. The procedure is as follows:

(1) The boring of the holes to receive the freezing tubes.

(2) The freezing of the strata, or making and maintaining of the ice wall.

(3) Sinking within the ice wall, and inserting the necessary tubbing.

(4) Thawing the ice wall and extracting the freezing tubes.

A number of boreholes are put down from the surface, all around the circumference of the shaft to the rock head at the base of the ground to be frozen. Each borebole is lined with tubes for the circulation of the brine, being connected together at the top and to the freezing plant. The freezing tubes comprise an outer tube inserted to the whole depth of borehole, with the bottom end closed; a central tube, open at the bottom, placed within the outer tube and reaching to within 3 feet of the bottom of the outer tube (see Figure 1). The freezing mixture is pumped down the central tube and rises up the outside tube, and thus through the circulatory system back to the refrigerator.

The freezing plant consists of ammonia compressors. The ammonia at a pressure of 150 lb. per square inch is circulated through spiral pipes in cooling condensers, and liquefied by the circulation of cooling water. The liquid ammonia passes to four refrigerating tanks containing brine, and circulated through spiral tubing in each tank, reducing the temperature of the brine to — 17° Centigrade (1·4° Fah.), and is then conveyed to the compressors again. The brine which consists of chloride of magnesia, is forced by a pump through the circulating tube in the boreholes and back to the brine tanks.

The freezing brine absorbs the heat in the strata and its circulation goes on until an ice wall is formed all around the shaft, of sufficient thickness to keep back the water feeders and to resist all external pressure, and this ice wall is maintained until the shaft is secured.

Temperatures of the ascending and descending brine are taken regularly, and from these it is known when the ice wall around the shaft is complete.

Sinking is done in the ordinary manner, with great care in shot-firing so as not to fracture the ice wall or damage the freezing tubes. Cast-iron tubbing is put in and backed with concrete, the crib beds being formed at suitable places.

On completion of the tubbing the frozen ground is quickly thawed by cutting off the liquid ammonia and circulating heated brine through the bore-hole tubes. The object of thawing the frozen ground is to allow the withdrawal of the circulating tubes, and to enable the pressure of water to come on gradually to the tubbing. After the frozen zone is thawed the freezing tubes are withdrawn and the boreholes filled with concrete.

FIGURE 2 is a plan view of shaft and FIGURE 3 shows the general arrangement of freezing plant.

Sinking by freezing is applicable to running sand containing water, or broken fissured strata, with water in large volume. It has its disadvantages owing to the limit of depth at which freezing is applicable. This is due to the fact that ice itself is rather a plastic than a truly rigid substance. Therefore, whatever the thickness of the ice wall may be, it cannot stand excessive pressures. A mixture of clay, sand and water, when frozen solid will doubtless have a larger resistive power than pure frozen water. Still, it is clear that even such a frozen mass can only have a comparatively small crushing stress. The second circumstance which limits the depth at which the freezing system can be successfully applied is the fact that the temperature of the strata increases with depth and obviously, the greater the natural temperature of the strata, the more difficult will it be to freeze them.

Assisted by Southern's Mining Lessons and sketches from Colliery Manager's Guide.

THOMAS MOORFIELD, 29, First Avenue, Rainhill, near Liverpool.

[*Note.—Though limited in number the answers received to this question on the freezing process of sinking were quite good. This method of sinking is seldom used, but in certain cases the conditions may be suitable for the system. Students should have a knowledge of the subject.—S.G.*]

A. Haigh (*15 marks*).

Shaft Pumps.

Q. 6.—*Briefly describe the pumping plant that you would use in a sinking shaft 20 feet in diameter to deal with a feeder of 1,000 gallons per minute. The shaft is at present 300 yards deep, and the pumping will be needed down to 500 yards.*

A.—At the 300-yard level I should make a lodgment in the side of the shaft and install a permanent electrically driven turbine pump. This would consist of six stages; the rotary portions of the pump and the chamber liners are made of zincless bronze to resist the abrasive action of gritty water. The pump and motor connected by flexible coupling would be bolted down to a concrete bed. The motor would be 300 H.P. induction motor controlled by a star-delta starter and isolation switch. The main shaft cable would be a 3-core double wire armoured type bitumen insulated, assuming that the shaft is wet. This cable is led from the surface sub-station.

Each stage of the pump is provided with a priming tap; the delivery is a 7-inch diameter pipe and the suction 8 inches. The delivery is provided with gate valve, bye-pass valve and retaining valve, and pressure gauge, whilst the suction is provided with footvalve, strainer and suction gauge. A cable drum is also installed in this inset, and the cable from the inset controls is led to this drum and each phase connected to the appropriate terminal in the slip ring box, which is explosion proof. By this means the sinking pump which operates below this level can be raised or lowered at will without disconnecting the cables.

The sinking pump is also of the electrically driven turbine type, consisting of six stages, although all the stages are not in use until the sinking is at the required depth. Thus at 1,150 feet the sinking pump would have two stages in operation, at 1,150-1,250 feet three stages, from 1,250-1,450 feet five stages, and below this depth all six stages. The drive would be by 3-phase, 50 cycles, 1,450 R.P.M. induction motor controlled by the same type of switchgear as the inset pump.

The sinking pump is of the vertical type, supported in a channel section frame. Inspection of pump parts is made by means of a ladder. The whole is suspended vertically in the shaft by a steel rope in double purchase, one end of this rope being capped and secured in the headgear; the rope then passes down the shaft and round a pulley fitted to the pump motor and frame, and up the shaft over a second pulley in the headgear, thence to a capstan engine.

The cable and rising main are supported by clamps fitting loosely the supporting cable. The impellers and chamber of this pump are also made of zincless bronze. The extremity of the suction range is fitted with footvalve and strainer, the delivery main with gate valve, bye-pass valve and retaining valve, also with pressure gauge. This pump would be fitted with a 500 H.P. motor, so that in the event of breakdown to inset pump it could be connected to the delivery of the inset pump, and pump water to the surface.

This type of pump possesses distinct advantages over other types, namely :—

(1) Will pump gritty or sandy water, although this leads to frequent renewals of impellers, which for the above pump are 13 inches diameter and ¼-inch wide.

(2) They may be applied to varying heads by the addition of an impeller in place of a dummy.

(3) They occupy less room for a given capacity than other types.

(4) Valves are extremely simple and a minimum, only two being required.

(5) No steam is required in the shaft.

(6) Readily lowered and raised.

(7) They will work submerged if necessary.

(8) They are more efficient and economical in power consumption than any other type.

Original.

Wm. Smith, 18, Greenslate Road, Billinge Hr. End, nr. Wigan.

[*Note.—This was a general question and students were not required to give calculation details. A lodgment at 300 yards, with a fixed pump, was required, the remaining 200 yards being unwatered by a suspended sinking pump pumping into the lodgment at the 300-yard level. The construction of the pump must be considered in view of the gritty water.—S.G.*]

A. Haigh (*15 marks*).
Joseph Ford (*14 marks*).

COMRIE CANTEEN AND BATHS OPENED.

The opening of the canteen and baths on 27th June completes the surface equipment at Comrie Colliery, West Fife, belonging to the Fife Coal Company, Ltd. The guests had an opportunity for seeing what amounts to a revolution in colliery practice, displaying the finest layout in the country. The ceremony of opening was performed by Mr. Tom Smith, Parliamentary Secretary, Ministry of Fuel and Power.

At Comrie coal is raised from a depth of 427 yards by a skip winder, with 10½ tons capacity skips, and the general equipment is designed to produce and prepare for the market upwards of 4,000 tons of coal per day. The surface buildings are flat-roofed, symmetrically grouped, and designed in collaboration with the Miners' Welfare Commission. The coal-washing plant is capable of cleaning the whole output, and middlings are crushed and rewashed. Altogether the new colliery represents the utmost refinement in mining, and incorporates the latest European and American improvements.

Referring to the new Ministry Mr. Smith said they had now a Minister of Cabinet rank, and they intended to do their very utmost to help the industry reach maximum production, and to resolve some of those problems which had hampered that object in the past. He had been amazed at the reservoir of ability he had found amongst mineworkers, but, speaking of the Miners' Welfare Scholarship Scheme, he was disappointed to find that only a small percentage of applicants for scholarships wanted anything to do with mining. That position would have to be altered.

Mr. C. A. Carlow, the chairman and managing director of the Fife Coal Company, Ltd., alluded to the fact that another colliery had been completely planned, and the company were ready to start as soon as war conditions permit. A third and probably still larger project might, he said, be described as "on the drawing-board." He was also interested in the Lothians, where two, and probably three, new collieries would be required to develop fully the coal measures in that area.

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