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THE ALTERNATING-CURRENT COAL HOIST

BY RAYMOND E. BROWN

ABSTRACT OF PAPER

The paper describes an alternating-current coal hoist recently installed near Pittsburgh in which dynamic braking is employed. The brakes and clutches are operated by compressed air, which permits of a maximum rate of operation and also makes feasible the use of various safety devices.

The electrical equipment of the coal hoist must be capable of continuous operation at the maximum speed and any attempt to insure against motor or brake trouble by providing excess capacity simply results in the motor being operated at that increased capacity. The control in lowering the empty bucket at high speed must be accurate enough so that it can be slowed down quickly without damaging the barges or steamers in landing. With a friction brake the only way to avoid striking too hard in landing is to make a complete stop before reaching the bottom, thereby causing an appreciable loss of time, which is entirely avoided by the use of dynamic braking. In the case of the plant described the control has proved sufficiently accurate and exact so that a complete cycle of the hoist trip due to the overlap of hoisting and racking movements can be made in 40 seconds instead of the estimated time of 50 seconds.

THE COAL hoist, and of course the ore-handling bridge or unloader, is different in several respects from most other machines for hoisting or transferring materials, and also from nearly all other applications of electric or steam power.

One of the points of difference is in the necessity for a very accurate analysis of the cycle of operation, in order to obtain a motor of the proper speed, torque and heating capacity. In the case of a motor handling any material in its progress through the mill, the amount of work it will have to do is, to some extent at least, determined or limited by the apparatus which brings the material to it or takes it away to the next operation. Consequently, by providing some excess over the rated capacity, the motor can be given what we may speak of as a factor of safety against overheating. In the case of the hoist, however, the material in front of it is, we may say, unlimited, as it is usually brought in in quantities sufficient to permit the hoist to operate at its maximum possible speed for a period long

enough to cause any trouble that can arise from overheating of either the electrical or mechanical parts.

The electrical equipment consequently must be capable of continuous operation at the maximum speed which the weight lifted, the motor characteristics and the operators movements will permit. Any attempt by the designer of the hoist to insure against motor or brake trouble by providing an excess in capacity over and above that specified by the purchaser simply results in the machine being operated at that increased capacity as long as any material remains in front of it.

One other point wherein the coal or ore hoist differs from other hoists is in the lowering of heavy unbalanced loads at high speeds and yet under very exact control. The furnace or skip hoist when not counterbalanced approaches this condition, but on account of working between fixed points it can have limit switches to provide for the slow-down and stop. The coal or ore hoist on the other hand has no fixed elevation for the material which it is digging, consequently it is still necessary for the operator to control the lowering of the bucket. The ladle crane lowers its full load, but its speed is very low. The coal or ore hoist must lower an empty bucket weighing from one-half to two-thirds as much as the load hoisted, and must do this at a speed from 300 ft. (91.5 m.) per min., to 500 ft. (151.5 m.) per min. The operator's control over this speed must be accurate enough so that he can quickly slow the bucket down to land it on the frail wooden barges used on our rivers or on the comparatively thin steel plating of the lake steamers.

The statement has been made, and probably is still believed by some, that the friction brake, operated by foot or hand, is the most reliable control for lowering a bucket. With dynamic braking, each notch on the controller gives a uniform lowering speed, and since the load being lowered is always the same, it follows that the speed on any given point is always the same. On the other hand, no uniform pressure or position of a foot brake can fail either to retard the load or permit it to accelerate, because even if the operator does accidentally produce a torque exactly balancing that of the load, the coefficient of friction changes as soon as the brake temperature rises, and consequently the balance is destroyed as soon as it is established. A speed variation of 20 per cent produces a change of 44 per cent in the kinetic energy of the moving masses, and this must be absorbed by the brake. Since the operator can not estimate the speed within 20 per cent and has no means of producing any definite

HOIST CONTROLLER PANEL

[BROWN]

RACK CONTROLLER PANEL

[BROWN]

speed while lowering with a friction brake, it is evident that the only way to avoid striking too hard is to make a complete stop before reaching the bottom. This causes an appreciable loss of time which is entirely avoided when dynamic braking is used. It is unnecessary to dwell at any length on the effect on the machinery and ropes of the shocks caused by sudden applications of the brakes, or on the expense of replacing the brake lining and occasionally the brake wheels.

Reference was made earlier in this paper to the question of heat-absorbing or rather heat-radiating capacity of motors and brakes. Another of the advantages of dynamic braking is that the heat-capacity of motors seems to be capable of more accurate determination, or at any rate, is more accurately determined than is the case with the ordinary friction brake, as it has not been a very rare occurrence for a friction brake to require some changes before it would lower the bucket on a high-speed hoist without overheating.

The purpose of this paper is to describe (to some extent from an operative view-point) a coal hoist recently installed for the Union Railroad near Pittsburgh. This is a duplex tower containing two independent hoists taking coal from river barges and loading it into railroad cars. The coal can be crushed and screened into various sizes or may be loaded direct without any preparation. The entire plant is operated by 220-volt, 25-cycle, three-phase a-c. motors.

The two engines for handling the buckets are located in a room about 28 ft. (8.5 m.) by 42 ft. (12.8 m.) at the top of the tower. Below this are the trolley tracks, which extend out over the river as a fixed boom or cantilever. Below these tracks in the tower is the coal hopper, which is provided with two discharge spouts. The mechanism below this point, like that above the hopper, is in duplicate, so that a description of one side will suffice.

When the coal is to be crushed it is conveyed to the top of the crusher by a pan feeder conveyor driven by a $7\frac{1}{2}$ h.p. motor. The crusher is driven by a belt from a 150-h.p. 480-rev. per min. motor which has an auto-starter with separate transformer, and is protected by a three-pole a-c. contactor-type circuit breaker with push-buttons for resetting overload and for closing the circuit breaker.

The crusher delivers to a set of shaking screens, operated by eccentrics on a shaft driven by a 25-h.p. motor. When it is

not necessary to crush the coal, it is fed by another type of feeder directly from the hopper to the shaking screens.

The auto-starters and circuit breakers for the motors driving the feeders and shaking screens on both halves of the plant are grouped together at a point where the attendant can see the coal passing into the cars, and he can, by pressing a button, stop the flow of coal to either of the cars. As the shaking screens in the two sides of the tower deliver to different tracks, the simultaneous loading of orders for different grades of coal is possible.

The bucket has an average capacity of 4 short tons (3650 kg.) and weighs about 11,000 lb. (5000 kg.). The closing rope passes around sheaves in the top of the bucket and in the vertically moving crosshead which is connected to the spades to give the necessary power for closing them. The ends of this rope pass over sheaves in the trolley, then to sheaves at the ends of the trolley track and to the closing drum in the engine room. The hold rope, which carries the open bucket, passes under a sheave in the top of the bucket and follows the same route as the closing rope, both ends being anchored on the hold drum. The hoist motor is connected to these two drums through two pairs of gears having a total ratio of 10 to 1, which gives the bucket a speed of $7\frac{1}{2}$ feet (2.3 m.) per second. Each drum has an air-operated clutch, and there are two air-operated band brakes, one being on the hold drum and the other on the intermediate shaft or countershaft next to the motor. The operator has a valve for each clutch, and one for the two brakes. The construction of this valve is such that a partial movement of the handle applies the hold brake, and a complete movement applies both.

The rope arrangement is such that the trolley or racking movement is independent of the bucket engine. The rack engine consists of a 75-h.p. mill-type motor geared to a drum from which ropes lead to the two ends of the track and thence to the trolley. The drum is provided with an air-operated brake. The motor is controlled by a plain reversing contactor-type controller, with master controller in the operator's cab. This master controller, as well as that for the hoist, has a straight-line bevel-gear drive handle, so that the movements of the handles of the two controllers and the four air valves are all of the same character.

It may be of interest to follow out a cycle of operations, starting at the time when the bucket is ready to begin lowering. The hold brake valve is moved to the release position, and the hoist

controller handle is placed on the point which has been found to give the desired speed. The bucket descends at a uniform speed, and if the coal is deep enough to prevent injury to the boat, the speed is not checked until just before the bucket strikes the coal, when the controller handle is moved to the maximum braking position and the brakes are also applied. When working near the bottom of the boat, the increased dynamic braking is applied earlier, so as to land the bucket without shock. The hold clutch is now released with the left hand while the right moves the controller handle to the proper point for closing. When the bucket is closed the left hand returns the clutch valve handle to its application position, while the right applies full power for hoisting. The left hand is now free to rack the trolley in toward the hopper at the proper time. When the bucket is high enough, the hoist controller is returned to its off position, and as the bucket slows down the hold brake is applied. The bucket by itself would stop its upward motion in about a foot (0.3 m.), but the momentum of armature, gears and drums is sufficient to hoist it several times this amount after the power is shut off.

The bucket is dumped by releasing the hoist clutch, which is applied as soon as the bucket is open. During this time, the left hand is stopping the trolley and racking it out again. If followed out closely this cycle will be found to require only six changes in the position of the operator's hands—that is, six shifts from one handle to another.

All of the handles move in vertical planes toward and away from the operator, and none of them require any appreciable effort.

This system of bucket engine construction permits the use of one motor when the necessary amount of power is available in one unit, and permits the use of two or even more motors if necessary, without any change in the scheme of operation. It allows the full power of hoist motors to be used for the final closing of the bucket where the material being handled is such that this amount of power can be utilized. It also permits the full torque of hoist motors to be used for retarding the speed of the bucket while lowering. In cases where the necessary amount of power can be obtained in one motor, the cost of motor and controller will be considerably less than where the type of engine requires two motors and two controllers. Also, when the hoist is so large that two motors are necessary, the cost of the controller equipment is less if the two motors are handled by one controller than where two separate controllers are needed. Where the two drums are independent, each having

its own motor and controller, lowering requires the manipulation of two handles instead of one, as one motor must pay out the slack closing line while the other acts as a brake.

The use of air for operating brakes and clutches permits the operator to maintain the maximum rate of operation throughout the day, to a much greater extent than can be done where the severe labor of manipulating clutches and brakes by hand or foot is required of him, especially when handling heavy loads. It also makes it feasible to install various safety devices. In this plant the hold brake is automatically applied if the bucket is hoisted too high, also when the overload relay cuts off the power to the motor, and in case of loss of voltage on either the a-c. lines or the d-c. control circuit. Limit switches on the trolley track cut off power to the rack motor and apply the air brake on the drum.

A small motor-generator set is located in each half of the engine room, supplying 220 volts direct current from a six-kw. shunt-wound generator for the coils of the contactors on the hoist and rack controllers. It also excites the fields of the other generator, a nine-kw. 15-volt compound-wound machine, which supplies the low-potential direct current to the stator windings of the hoist motor during dynamic braking. These two generators are direct-connected to a 20-h.p. 710-rev. per min. a-c. motor.

Air is supplied by a two-cylinder compressor driven by an a-c. motor. The compressor governor is arranged to lift the inlet valves in the cylinder heads instead of stopping the motor as is customary in d-c. operation.

The hoist engine is driven by a wound-rotor induction motor with an intermittent rating of 315 h.p. The calculated cycle of operation includes six seconds closing at 150 h.p., three seconds accelerating hoist at 425 h.p., eleven seconds hoisting at 340 h.p., and twelve seconds lowering, at 130 h.p. braking. These values are for power at the motor pinion.

The hoist controller consists of the master switch in the operator's cab, and a panel in the engine room, with the necessary resistance located immediately behind the panel. The panel carries the necessary contactors, interlocks and relays. There are three single-pole contactors to connect the stator windings to the a-c. lines; one contactor to open the stator windings at one point and two contactors to connect the d-c. lines from the 15-volt generator to the stator when this delta switch is open. Each step of resistance with its pair of contactors makes a star connection between the three busbars connected to the slip

rings on the rotor. Resistance is reduced by adding more steps in parallel with the first, and the last step is a short-circuiting contactor. There are five steps in accelerating the hoist, and four points of dynamic brake control. Each of the accelerating switches except the last is provided with an individual accelerating relay. The panel also has no-voltage relays in the a-c. and the 220-volt d-c. circuits, and two overload relays.

On the lowest floor of the tower is located a barge shifter engine, consisting of two drums with clutches and brakes geared to a 30-h.p. motor. This is controlled by a face-plate reversible controller, and the brakes and clutches are hand-operated. Ropes pass along the face of the dock and around sheaves and are attached to the barge which is being unloaded.

The beginning of actual operation of this plant was looked forward to by its builders with considerable interest and possibly some anxiety. The speed was to be 50 per cent higher than had been previously used in any a-c. hoist with dynamic braking, and there had been rumors that the controller designers had encountered some very difficult problems in working out the control. When the first a-c. hoists with dynamic braking were built in 1909, they required a considerable period of adjusting and a number of changes. On account of the higher speed of this hoist, and as this control was being developed by another company, the builders of the hoist were naturally anxious as to the results that might be obtained.

The control equipment had been checked over by a representative of the controller company, and on the day that coal was to be hoisted he and the writer were present to see what would happen. One accelerating relay on the hoist panel required a slight adjustment to smooth out a peak which occurred when the last contactor closed, and a similar adjustment was made on the rack controller. It was not found necessary to make any change in the amount of resistance in any of the various steps and except for the adjustments mentioned, which required only a few minutes' time, the controller is operating exactly as sent from the factory.

As to the accuracy of control over lowering, it may be sufficient to say that the maximum speed is higher than the hoisting speed, and the minimum is low enough to land the bucket on the thin planking of the river barges without perceptible shock. In spite of the wide range in lowering speed, and the small number of steps on the dynamic braking control, the handle may safely be thrown to the maximum braking position while the bucket is

descending at its maximum speed. The use of separate contactors for braking permits their accelerating relays to be adjusted so that torque on the motor will not be brought above the pull-out point.

As a result of the exact and accurate control which the operator has over the bucket movements, this hoist has shown itself to be capable of continued operation on a somewhat shorter cycle than was estimated. This is due to a large overlap of hoisting and racking movements, and a slightly higher lowering speed. While the cycle necessary to make the required capacity was 50 seconds, the hoists can make trips in 40 seconds.

A few words in regard to the first application of dynamic braking to a-c. hoists on a large scale may be of interest. A number of five-ton coal bridges were built by the same company about six years ago for several coal docks in Superior, Wis. The buckets were larger than any previously used for unloading coal from lake boats, and the speeds were higher. The use of friction brakes for lowering the buckets was found to be the cause of considerable expense, not only for replacing the brake lining, but also for replacing the brake wheels, drums and shafts which were occasionally broken as a result of trying to make too quick a stop after attaining an unusually high speed. The castings were made heavier, and the new shafts were of nickel-steel, but even these could not make the operation satisfactory.

Regenerative braking was tried, but the speed resulting from this was high, and very careful manipulation of the controller was necessary. Lowering with the motor on the first point in the hoisting direction was naturally found to be extravagant in the use of current and hard on the motors.

It was finally decided to place small motor-generator sets on the bridges, to apply low-voltage direct current to the stator windings and to change the controllers so as to provide for this system of braking. After this new apparatus was installed and adjusted, the results were such an improvement in the control over bucket and trolley that brake trouble became a thing of the past and the output of these bridges reached a point considerably higher than had been expected.

Reports have recently been received from one of the companies operating these bridges that, after making careful comparison between the records of their a-c. plants and the later ones built on d-c. docks, in figuring on new installations they would consider an a-c. plant to be equally as desirable as one operating on direct current.

DISCUSSION ON "ALTERNATING-CURRENT CONTROLLERS FOR STEEL MILLS" (SIMON) AND "THE ALTERNATING-CURRENT COAL HOIST" (BROWN), PITTSBURGH, PA., APRIL 16, 1915.

Raymond E. Brown: One of the papers presented made mention of the desirability of having motors of a sufficient size to operate part of the time at reduced load, to keep the commutator in good shape. The desirability of low temperature limits for rheostats was also discussed.

When the mill is buying electrical apparatus, it should be a comparatively simple matter to have recommendations like these carried out, but it is different with a manufacturer of cranes and hoists. He is making machines that contain various amounts of electrical apparatus, is obliged to sell against strong competition, and frequently finds, after including in his proposal a number of refinements that help to make economical operation and low cost of upkeep, that the various bids are merely reduced by the purchaser to a pound price basis and compared from that view-point alone.

You cannot expect a manufacturer to include in his product, whatever it may be, many refinements whose value is not yet well recognized by purchasers, unless they effect a saving in the balance of the machine or serve to increase its output.

In the discussion on screw-downs and roll-table drives, it was brought out that in some cases a considerable saving in power could be effected by using two small motors in place of one large one. This hoist, where the load will coast upward about eight feet after power is shut off, may at first glance appear to be another place where the same thing would be true, but it is not.

If the operator shuts off power at the proper time, the kinetic energy of the rotating parts, as well as that of the ascending load, may be completely utilized in hoisting the load, and the brake should be applied only in time to prevent the load from starting downward.

The heavy flywheel effect of the large rotor is also utilized in starting to hoist the bucket. The motor during the final closing of the bucket reaches a speed high enough so that, as it is slowed down by starting the bucket upward, it delivers some of its surplus energy and reduces the peak load occurring at the beginning of the hoist, which is ordinarily the maximum.

Where power is purchased, the rate is often determined by the peak load, and consequently there appears to be an economic advantage in the use of a single large motor for the hoist where there is sufficient head room to give the necessary leeway for coasting to a stop, even though many other parts of the mill are better off with motors having as small a flywheel effect as possible.

M. A. Whiting: Mr. Simon compared the solenoid-operated oil switches and air-break switches (or air-break contactors as

they are sometimes known). His comparison is entirely favorable to the solenoid-operated oil switch. Now, in cases where an oil switch is satisfactory, a hand-operated oil switch has many advantages over either a solenoid-operated oil switch or an air-break contactor. In cases where solenoid operation is required in any case, the question is one between the design and cost of solenoid-operated oil switches and air-break contactors. There are certain cases where the air-break contactors are far more reliable and are preferred by the trade. Those cases are mine hoists and similar classes of work in which the number of operations per day is very large. In this case the carbonization of the oil is entirely eliminated by the air-break contactors, and the contacts are open to inspection at any time, so that wear can be more easily kept track of. Furthermore the wear on the tips of air-break contactors is in many cases less than the wear on the tips of corresponding oil-immersed devices to do the same work. This last statement is at variance with commonly accepted ideas, but tests have been made which tend to show that there is considerable difference in wear of contacts in favor of the air-operated contactors, surprising as that may seem. I am not prepared to state that that would be universally true, but at least there is some tendency in that direction.

The air-operated contactors as we use them are not to provide the ultimate rupturing capacity for a short circuit on the power system, but rather as control devices for making frequent starts and reversals. The ideal arrangement for such frequent operating control equipments is air-break contactors for forward and a reverse, with a normal design of oil switch for ultimate protection in case of the comparatively infrequent excessive overloads or short circuits.

As to the extent to which air-break contactors have been used, I can say that we have sent out over one hundred equipments, meaning over 200 contactors of the air-break type. One such pair of contactors is in use in a rolling mill equipment on the South Side in Pittsburgh, and a number are in use in this immediate vicinity, at Greensburg, Montour, and elsewhere.

A direct comparison of the air-break contactors and solenoid-operated oil switches for frequent reversing service is afforded by the experience on the Rand in South Africa. Complete American equipments of hoisting motors and control have been shipped within the last half-dozen years. In addition to this, since the time when such equipments have been shipped to South Africa and put in operation, a large number of orders have been received for nothing more than a pair of 2200-volt air-break contactors to be used to replace solenoid-operated switches of various foreign makes, principally German, I believe, to be used with existing secondary controls and existing hoist motors. Some minor modifications have developed for use at 3300 volts, and a number of such equipments are in use in America.

The use of such air-break contactors is more general in mine

hoisting work than in rolling mill work, because, of course, the large 2200-volt induction motors in rolling mill work under ordinary conditions are not started and stopped with anything like the frequency of the average mine hoist motor. Nevertheless, there have been a few instances, even in rolling mill work, where these air-break contactors have been applied advantageously.

J. H. Albrecht: I would like to take exception to the statement Mr. Simon made concerning the accelerating relay as used in the secondary or induction motors. The relay he shows in his panel in Fig. 7 is the ordinary drop-out U type magnet, and we found it to be almost absolutely independent of frequency; that is, we can get definite and reliable current settings on the relay, independent of the frequency. We can go down as low as his cycle and a half, even, without having the operation of the relay affected and it does not chatter.

When you get down to the business of relay acceleration, I believe the single-phase relay is the simplest proposition, if you can get the relay to work satisfactorily. That type of relay on the secondary necessitates a lap of auxiliary contactors or butterflies on your secondary contact to provide the necessary safety and interlock, and that means a complexity of control wiring. If you go to the individual three-phase relay in the secondary circuit it means a complication of the strap wiring and the individual single-phase relay is the simplest, as far as connection, and I believe as far as operation is concerned.

Mr. Whiting is very correct in his statement of the superiority of the air-break switch over the oil switch, and I would like to emphasize the point he made about the necessity of putting an oil breaker back of your panel of sufficient ultimate breaking capacity to take care of any short circuit or any very great overloads. We have recently finished some very successful tests on air-break switches. We found that our switch which will carry 312 amperes will break 600 amperes, and we have succeeded in breaking 600 amperes at 5000 volts, 30 per cent power factor. You will realize that is a heavy inductive load, and the switch has successfully handled that with a slight wear on the contacts.

I believe Mr. Simon stated he got 50,000 operations on some oil breakers without any excessive deposit of carbon. I would like to know whether the figure is not exceptionally high for apparatus of that class. Taking the case of mine hoists, where the device is operated quite frequently, we get very great smoking of the oil at perhaps three or four day's operation, and smoking of the oil of course means carbonization and in some cases trouble in a short time. I would like the operating men who have had experience with these switches to give me an idea what is the average run of the oil in these switches.

R. H. McLain: "Jamming" relays are mentioned, and since

Mr. Simon does not discuss jamming relays very fully I think it would be well to add one point concerning them. I have heard of operators who consider that the jamming relay prevents strains on the apparatus which was being driven. I think it would be well to point out that these strains are prevented only in a certain measure. The jamming relay operates only after the strain has taken place and not before, so it really does not prevent the strain, it only prevents the continuation of the strain. Furthermore, after the jamming relay operates there is a flywheel effect in the armature that will carry the hoisting ropes, etc., for a slight distance further, and nothing will prevent this except the give in the apparatus, such as stretching of the ropes or slipping of something somewhere. I think it is well to advise the use of some kind of a slipping friction clutch between the motors and the driven parts where absolute protection is needed. There are certainly valuable features in connection with the jamming relays, because they will prevent a continuation of the strain, and still enable the bucket to hold on to its load. If a friction clutch is used, after the friction clutch slips a small amount, the jamming relay will prevent it slipping further, and thereby relieve the friction clutch of any wear. Consequently the friction clutch will remain in better adjustment and be better prepared to take care of the operation the next time.

In regard to current-limiting relays of the individual type for each accelerating contactor, I notice that the claim is made that with these relays an individual adjustment can be made to suit the conditions desired for accelerating as the various contactors are closed. The relay shown in the paper would operate as follows: After the first contactor closes, and we are depending on the current-limit relay to prevent the succeeding contactor from closing, this relay must pick up and open and control the circuit before the second contactor closes. In other words, it must beat the second contactor out, it must work faster.

The current relays shown seemed to be set at successively lower values, that is, the first relay might drop out at 105 amperes, the next 103, the next 102, and so on each seemed to set at lower values. Is it necessary with this kind of relay, in order to accomplish the result, that when the first overload is thrown on it will raise all of the relays and thereby eliminate the chance of having a contactor beat out a relay in the succeeding operations? If that is true, it seems to me that the claim that individual adjustments can be made to suit the conditions of operation is wrong, and that the adjustments really have to be made to suit the conditions of the relays; that is, adjusting each one at a successively lower value.

Another point Mr. Simon mentioned, and brought out more fully in the paper, is the use of d-c. operated contactors on a-c. motors. It seems to me that this introduces another link

in the chain of things that might happen to prevent the operation of the coal hoist. He has a low-voltage generator to excite the a-c. hoist motor and a high-voltage generator to excite the field of this low-voltage generator, and also to supply d.c. for operating the contactors. If anything should happen to this high-voltage d-c. generator, it would put everything out of commission. There would be no power with which to operate the contactors, and certainly no power with which to operate the dynamic brake. Now, if alternating current were used for the contactors they could continue to operate the hoist by means of mechanical brakes for lowering for a short time, or at reduced output. In that way, there is an additional link in the chain.

Another advantage of a-c. operating contactors is that no complications at all are required to give no-voltage protection. For instance, if the a-c. power fails and the d-c. power does not fail, and then the a-c. power returns, it is necessary that all the contactors should have dropped out and come back in sequence. In order to do this with a-c. contactors no extra complications are necessary, but with direct current, some extra relays are required.

Another point is the question of using accelerating rheostats connected in parallel rather than in series for hoist work. The parallel method has the advantage of making it possible to use divided circuits and small currents, and therefore the contactors can be small and of low cost, but it has this disadvantage, that one leg of the rheostat, if called on in an emergency to carry the motor at reduced speed for a considerable time, does not have the benefit of the capacity in the other legs to help it out; whereas if you had the rheostats in series and cut the successive blocks by the contactors, all the capacity of the rheostat, all the weight of the iron would be in service when running at reduced speed, and this is certainly an advantage in regard to rheostats.

Another disadvantage is that it takes a pretty good mathematician to adjust rheostats connected in parallel if anything goes wrong, whereas when they are connected in series it is only a case of sliding a tap and experimenting with each tap as you slide it.

I certainly think that Mr. Brown's coal bridge has marked quite an advance in a-c. coal hoists as to the speed attained, and that it is quite remarkable to see how coal bridge builders can calculate capacity that they are going to unload, with all the variable factors that they encounter. The manufacturer of electrical coal hoists has a hard job to predict all of the variable factors which he encounters, the varying shapes of the boat, and the uncertain quantity of the human element, and he is doing pretty well if he will guarantee some capacity near to what is actually required. The temptation of these men who want to design reliable apparatus is to guarantee away above the capacity, so they will be sure to take account of all

these factors, and it indicates a great deal of skill when they don't have to guarantee away above the requirements in order to make sure of meeting all of them.

W. C. Kennedy: The discussion of Mr. Simon's paper by the last two speakers brings up a point which is of great interest to the manufacturer. I refer in particular to the statement made that air-break high-tension switches are not circuit breaker devices, but that they should be installed in connection with hand operated circuit breakers to take care of emergency conditions.

That question is not one which pertains to a difference between high-tension oil switches and high-tension air-break switches, but rather is a difference between a magnetically operated switching device and a hand-operated or circuit closing switch. It is impossible to make a magnetically operated switch, either direct or alternating current, that will be a good circuit breaker to take care of emergency conditions and at the same time be a magnetic switch of good design. This is true because, in a switch movement operated by a magnet or other electrical means, there is a certain amount of inertia in the moving parts and also it is not possible to operate this switch with as large an air gap as one that is closed by hand. For this reason a hand-operated circuit breaker should always be installed with either d-c. or a-c. equipments to take care of emergency short-circuiting conditions.

Another fact brought out in the paper was the operation of the individual series relay system. Probably there may have been a misunderstanding in regard to the arrangement of the control circuits which is not entirely clear at first inspection. During the ordinary operation of the equipment it is not necessary that the three-phase series-wound relays first open the control circuit to their respective switches and then close it again when the current in the rotor circuit has dropped to a value dependent upon the setting of the relay. Such an arrangement would be absolutely impractical. What actually happens is that the contacts on the magnetic switches have a certain lead and the series relay actually lifts a very short distance before the control circuit which it controls is energized. The only function, therefore, that the relay is to perform is that of dropping at the proper time, dependent upon its setting and in dropping it closes the circuit to the next succeeding accelerating switch.

The accelerating current curve of the 1000-h.p. motor shows distinctly that the dropping points of the various individual relays are different for the different switches. This is an advantage which this system shares in common with the present d-c. methods of acceleration, in that it is possible to vary the accelerating current during the period of acceleration and thereby adapt it to different load conditions. In fact with this system of three-phase accelerating relays, it is possible to obtain exactly the same accelerating characteristics as is at present obtained with direct current by the use of series, magnetic

lockout switches or shunt-wound switches controlled by series relays.

In regard to the parallel connection of resistance, it is purely a case of resistance design. Sometimes it is very advantageous to use parallel connections, at other times it is just as advantageous to use series connections. For example, on motors of very large capacities, it is absolutely necessary to parallel groups of resistance. The main point to be gained by the parallel connection of resistance steps is that, as more accelerating steps are cut into circuit, the amount of available resistance material from which heat can be radiated is increased, whereas just the opposite is true where the resistance is connected in series.

On the other hand, for purposes of speed control, such as, for example, on a large motor where a slip regulating resistance is used, it is more advantageous to connect the resistance steps in series. Individual groups may be connected in parallel, but the resistance itself is in principle a series connection. If it is desired to run with 10 per cent slip on a motor with full load current, then the slip regulating resistance must dissipate approximately 10 per cent of the full load capacity of the motor; whereas, if 5 per cent slip is desired, then the resistance must dissipate only 5 per cent of the energy. It will readily be seen that in the second case only one-half as much resistance material is required as in the first case, therefore a series connection of resistance is more advantageous.

With a-c. work there is another point to be gained with a series connection of resistance. The series arrangement is very much easier to adjust than parallel connection, especially where resistance in three phases of the rotor must be considered. This is so apparent in some classes of work, especially hoisting service, that the hoist manufacturers almost invariably specify that the accelerating switches must be made of the proper capacity for a series connection of resistance. This necessarily increases the cost of the equipment, but adds to the simplicity of adjustment.

C. D. Knight: I desire to add a few words with reference to the oil- and air-break contactor situation. There is no doubt each of them has a very decided field, but where frequent operation is required the air-break type is the only one which can be successfully used.

I know of one installation consisting of a 2300-volt, 1000-h.p. motor, which had two reversing contactors in oil, the duty cycle being so heavy that the oil was continually becoming carbonized, which necessitated its replacement so frequently as to require one barrel of oil a week. These contactors were replaced with those of the air-break type, and apart from the occasional replacement of contactor tips, the maintenance charges have been practically nil.

I also have a record of a test made on a contactor immersed

in oil, which was operated at 5000 volts, opening 50 amperes. At the end of three thousand operations, the oil, which was in a perfect state at the beginning of the test, presented a very thick, muddy appearance, and was unfit for further use. Where the duty cycle amounts in a mine to twelve or fifteen hundred operations a day, it can readily be seen that the above test represents about a two-day run for the contactors.

I wish also to make a few remarks with reference to the question of standardization. Mr. Pauly gave some figures, representing the various combinations which could be obtained with motors. In the case of the alternating current, his estimate ran up to from 7500 to 8000, due to the different voltages, frequencies and phases. In the case of magnetic control contactors those containing the same magnetic circuits, blow-out coils and contacts can be used for applications of a given current value. A different operating coil, however, must be designed for each voltage and frequency, which naturally runs into a great number of combinations.

We are all very optimistic regarding the future use of alternating current in steel mills, and I believe if we could standardize on three-phase, 25 cycles—I will say nothing at present about the voltage—we could simplify matters considerably.

W. F. Detwiler: I would like to hear from the manufacturers whether they have developed an automatic relay for protecting a two-phase or three-phase motor from operating on single-phase. Is there anything in that line that we can depend upon?

J. H. Albrecht: We have had several requests for a device of that kind, and while there are certain schemes,—one notably, a German scheme, involving four or five different relays,—we have yet to find a satisfactory solution for that proposition. I do not believe there is a satisfactory solution right now to prevent a motor from running single-phase; at least, I have never seen it, and I do not believe there is any in operation.

In regard to Mr. Kennedy's statement about using switches for circuit breakers, we do not advise using them for circuit breakers, of course. I have made interesting tests recently on d-c. contactors, and I have oscillograms showing a d-c. contactor opening a short circuit on a 500-volt power line, showing a peak of 60,000 amperes, at which point the oscillogram went off the scale. Out of respect to our power superintendent we cut the current in the next operation to 45,000 amperes, and then we reached the process at 30,000 amperes, and the contact was still partially there. That is an exceptional case, but shows what a d-c. contactor will do when it has to do it. On alternating current it would be a different proposition.

C. D. Knight: I wish to state that there will soon be a relay on the market to prevent motors running single-phase.

W. O. Oschmann: There is a certain field in which the solenoid-operated switch is preferable to the air-break contactor. Take cases where you have only twenty or thirty operations in a

day's time and still expect some time to have reversing service on the motor, by the use of the air-break contactor you find it necessary to complicate your control circuit to the extent of providing some method of preventing the reversing contactor from coming in before the arc is interrupted on the contactor going out. We had a case where the arc held to such an extent that the incoming contactor closed before the arc was interrupted on the outgoing contactor, thereby producing a short circuit which not only burned the contactor, but also stopped all the synchronous apparatus on the system. The ordinary electrical interlock does not prevent the above trouble.

We eliminated the short circuit troubles by placing a small transformer across the motor circuit; the secondary of this transformer operates a small contactor which controls the circuit of the incoming contactor. It is evident that solenoid-operated oil switches would have avoided this complication.

I notice in Mr. Simon's paper that he uses a triple-pole contactor of the air-break type. We have found that these triple-pole contactors invariably break the arc on two poles only. Practically at no time will there be an arc on the three poles, therefore it seems a needless complication to use the additional pole, unless it is to take care of the voltage on the motor when the contactor is out, and this should be taken care of by an oil switch.

Regarding the question of primary relays versus secondary relays, I agree with Mr. Albrecht that a single-phase secondary relay is in a great many cases better than the three-phase relay. I note the statement made by Mr. Simon relating to the use of current transformers for large secondary relays. It does not seem as if this would be as good as the use of a single-phase relay in the secondary, at least two series transformers would be required and with the very low frequencies very large, bulky series transformers would be needed.

Graham Bright: I would like to make a few remarks regarding the interlock on air-break switches. I have had some experience in operating a hoist in which reversal was very quick, and, as has been mentioned, the arc sometimes holds long enough, where we have mechanical interlocking, to allow the other reverse switch to come in before the current is actually broken. That has occurred in a hoist where plugging was used to stop the hoist, and about once in every two thousand operations this short-circuiting took place. Of course, the voltage on the line dropped, which immediately robbed the motor of its torque, and only by the agility of the operator jumping on his foot brake was the cage prevented from causing a serious wreck. That was naturally trying on the nerves of the operator. I believe one method of prevention is to put an electrical interlock on reverse switches, which does not permit of the reverse switch starting in until the current is broken.

By electrical interlock I mean the true electrical interlock which depends solely on the current dying down to zero before

the reverse switch can come in and not the so-called electrical interlock which depends upon the movement of fingers over plates making or breaking contact.

Mr. Brown made a statement I would like to take issue with, in regard to the weights and the inertia of the armature. He seemed to think it did not make much difference whether the armature was large with a great deal of inertia or small with little inertia. Heavy armature with high inertia will mean a slow rate of acceleration and retardation with a corresponding decrease in schedule speed. Light armatures with small radii of gyration will permit of quick acceleration and quick retardation, which in turn increases the schedule speed when the maximum speed is fixed. There is no question but that the rotating parts of the motor should have as low inertia as possible to keep down peak loads, and to keep the schedule as high as possible.

He mentioned a geared limiting switch used for stopping a hoist in case the operator went to sleep. Sometimes in hoists we have plenty of room above the dumping position so that in case the power is not thrown off at the proper time, the geared limiting switch, if placed in the circuit, will take care of the stop nicely. On the other hand, there are a number of installations which have been equipped without this point in view, in which the head sheaves are only a short distance above the dumping position. If we arrive at the dumping position at full speed there is not room to stop. If you apply the brakes you are too close to the head sheaves to stop and a geared limit switch under those circumstances is useless. You must produce some kind of a slow-down, and that has been accomplished in some coal hoists by a fly ball governor arrangement which works out very nicely. A geared limit switch is therefore in many cases of no value unless a positive slow-down is also provided.

C. D. Knight: I want to say, as far as I know, that electrical interlocks usually are used between these high-voltage air-break contactors—that is, in those I am acquainted with.

J. H. Albrecht: The point Mr. Bright referred to was the opening of the electrical interlock with the relay. We have an electrical interlock all right, to be held up by a series coil, and the series coil is in series with the line contactor relay and will drop out on occasion, but until the arc is extinguished and the current has died to zero in the working of the motor, this relay will hold up and not permit the other switch to be energized.

Clark S. Lankton: There has been considerable discussion concerning accelerating relays in the secondary control. My experience has all been with the single-pole relay. There is one thing I have noticed. At the start, when the motor is at low speed, the frequency will be high enough to get very good working conditions in the relay. When the motor approaches full speed, the acceleration is much greater, so that the last switches close very rapidly as compared with the switches on the low speed. It occurred to me that the reason we have good

operation with a single-pole relay is because it is not of much use when the motor is nearly up to speed. While the three-pole relay is theoretically good, the single-pole relay serves the purpose because of that fact.

Speaking of the use of either the contactor or the circuit breaker, of course if you use contactors you will need the circuit breaker. If you can combine the two you save that much in first cost, but there may be added complication to your system. Where it is possible to use a circuit breaker, I have found it good practise to do so. The service I have in mind is not particularly severe, so that the carbonization of the oil is not the limiting feature at all.

W. T. Snyder: There is one point I want to mention about the open face controllers and starting contactors. As we know, they are now in disrepute in the steel mills on account of a certain amount of danger even on the low-voltage starters, not so much from shock, as from flashes and burns. The manufacturers have recognized this and have started to provide covers for them.

I noticed in one of the switches shown by Mr. Simon there is no method of providing for lowering the oil tanks. That becomes quite a problem on the large size switches, containing several gallons of oil, located back in the switch cell—it is hard to get a couple of men around them to lift them down. It is a job to lower them, either to replenish the oil or to make adjustments to the contact. On our high-tension oil switches which have the oil tanks hanging underneath, we put a drain cock on the bottom. We first drain all the oil into a vessel and then it is easy to remove the tank.

Mr. Simon says: "The resistance has to be designed with a considerably heavier capacity, and in some cases requires even continuous carrying capacity on all points." It is not clear to me whether or not he means full load carrying capacity, but if that is his meaning, his ideas conform to my own along that line.

In regard to the coal hoist referred to in Mr. Brown's paper, I was wondering why he had two small generators to supply exciting current to his contactors and the fields of the other small generator, why one was not enough. I imagine it is because he would have a factor of safety of two.

E. S. Zuck: I think I can answer the question Mr. Snyder raised about the two generators. The characteristics of the a-c. hoist motor were such that it required about 18 volts to furnish the necessary excitation current. The other machine, the 220-volt machine, was for operating the solenoid magnet. It is out of the question to operate the solenoid magnet from a machine having 18 volts.

Mr. Brown makes a statement that in the case of a hoist the material to be handled is unlimited. This may be the case in a great many instances, but if I remember correctly

the motor manufacturers were advised in this case that the capacity of the tower was limited by the crushing machinery and the capacity of the hopper. I believe after one hour's operation, starting with the empty hopper, the hopper would have been filled, even with the crushing machinery in operation, so that would have limited the capacity of the hoist.

The question of dynamic brake control for towers of this kind is one which has been successfully worked out in several cases and this is a notable one. I worked out the dynamic braking problem, and using d-c. motors the problem is somewhat simpler. The characteristics of the d-c. motor are pretty well known and for different motors are more or less the same. When you come to a-c. motors the characteristics are not likely to be the same at all. Each case requires careful consideration by itself.

In this present case in the scheme of control used, the exciting current is not varied, there is a constant excitation on the motor used, and the control is obtained by varying the resistance. In this case I would like to call attention to the fact that the motor manufacturers gave values for the amount of magnetic resistance to be used in the rotor circuit, and so far as I know those were not changed by the control manufacturers.

Another point which may be brought out is that there is always a certain amount of resistance left in the rotor circuit, and that the rotor circuit cannot be short-circuited when lowering under dynamic control. There is a definite limit beyond which you cannot go without running risk of losing control and dropping the bucket.

W. T. Snyder: The gentleman did not get my question correctly. Mr. Brown said: "A small motor-generator set is located in each half of the engine room, supplying 220 volts d-c. from a 6-kw. shunt-wound generator for the coils of the contactors on the hoist and rack controllers." I take it from that that he has two of the generators, one on each half of the hoist, and I was wondering, if that is the case, why he had two of them.

E. S. Zuck: One generator is a 220-volt machine, while the other is an 18-volt machine. The 18-volt machine supplies excitation for the a-c. hoisting motor, while the 220-volt machine supplies the current to operate the contactor.

Raymond E. Brown: There are two motor-generator sets, one on each side of the plant. In the motor-generator set are a motor and two generators. This seems like a useless duplication of material, but in the design of this hoist the idea carried out throughout was to have two completely independent units, either of which could operate all of the devices. This idea was carried out from the point where the wires entered the building. We separated everything on the first floor into two circuits, everything being separated from that point up. This was done to make an economical plant for operation on half

capacity, as well as to prevent the breakdown in any one piece of apparatus being able to shut down the entire plant.

G. E. Stoltz: Mr. Lankton brought out the point of the relative action of the relay at different frequencies. There might be something else besides the frequency in the secondary that affected its action. In starting up a rolling mill, the bearings are sometimes tight and the relays are probably adjusted to take care of a rather heavy starting condition. As the mill is brought up to speed the bearings gain their lubrication, so that the mill accelerates much more rapidly as it approaches full speed. This mill may have been at practically full speed before the last contactors had time to come in.

There has been considerable discussion of oil breakers, particularly those shown on the lantern slide by Mr. Simon, which are used on rolling mill drive. I believe he explained that this breaker was used on a 1000-h.p. rolling mill. We are coming to that in the application of hoists. Of course, the circuit breaker and contactor both have their own line of application. The mechanical construction of the oil breaker is not adapted for frequent closing. In rolling mills where the starting and stopping only takes place a few times a day, naturally the oil-breaker can withstand such service. But if it is necessary to run the mill back and forth, it is severe on the breaker, and it is necessary to put in an air breaker to take care of that condition.

W. O. Lum: Mr. Simon showed the position of the oil breakers as one for forward, another for reversing, and still a third for applying the direct current for braking. He also brought up the fact that this installation was made practically five years ago, and naturally cannot be fairly compared to present practise. Since that time it has been practically adopted as standard to plug the motor; in other words, reverse it, in order to bring it to rest, instead of applying d-c. voltage. Direct-current voltage for braking has worked out very successfully on the hoist that Mr. Brown has described, but other cases of application require study, as there are certain stresses set up by the direct current which we were not fully aware of in rolling mill practise.

Mr. McLain brought out a point in reference to added complication by using d-c. operated 220-volt switches on the hoist Mr. Brown described. I doubt very much if the addition of the 220-volts, and this other unit that generates the power, will cause failure or shut down any more frequently than if those switches were operated from the alternating current which is supplied to the motor. Direct-current operated switches are better developed and have been in the field a greater number of years than a-c. operated switches, so that we can depend on them to a greater extent.

As to the application of the bridge or coal unloader, there is no doubt but what that will give fewer interruptions with the d-c. than with the a-c. operated switches. I have in mind

one case where an attempt was made to install a full automatic a-c. hoist. I do not think its success has been nearly so great as it would have been if the switches had been operated by direct current.

C. D. Knight: I do not mean to state that alternating current is as flexible as direct current for all applications, but I do say that a-c. contactors as manufactured today are just as reliable as d-c. contactors.

W. O. Oschmann: Last year at the Detroit Convention a description of a six-speed concatenated a-c. motor was presented. This control has seven triple-pole low-voltage contactors, one double-pole low-voltage contactor, two triple-pole high-voltage contactors and two single-pole low-voltage contactors. The oil switch equipment consists of one triple-pole circuit breaker, six hand-operated triple-pole single-throw oil switches and one double-pole single-throw oil switch. It is quite a complicated control. It has been in operation about two years, and in that time has developed very little trouble the most serious interruption being due to a broken control wire, which delayed the mill a short time. This outfit is not handled by an electrical man. The engineer operating a Corliss engine in the immediate vicinity also starts and stops the electrically-driven mill; he also manipulates the oil switches to secure the various speeds desired at the mill rolls. In the time that this plant has been in operation it has clearly shown that if the interlocks and control equipment are taken care of in a manner similar to d-c. apparatus, the results will be equally as reliable. The contactors and interlocks are examined each week, cleaned, and kept in good repair, the whole equipment is cleaned by compressed air each week, and the results obtained on this mill indicate that the reliability of a-c. control equipment is as good as the d-c. equipment, even if the a-c. equipment is more complicated.

G. E. Stoltz: I ask if the control on a rolling mill is not probably started more than once an hour; in other words, is not the operation of the switches about five per cent what it would be in the case of hoisting operations carried on continuously?

W. O. Oschmann: The operation of a mill depends greatly on whether there is trouble at the rolls. There have been cases where this mill has started and stopped repeatedly for several hours, also it has been maintained at a very low rate of speed for an hour at a time. In ordinary operation the mill may start and stop four or five times a day. At other times it may have four or five starts and stops in two or three minutes time. It is a rolling mill proposition.

G. E. Stoltz: There is hardly any comparison with a hoist.

W. O. Oschmann: It cannot be compared with a hoist.

J. D. Wright: There are many tables and other auxiliaries at the Gary mill which are operated by a-c. control, where no

trouble has developed due to the use of alternating current rather than direct current.

Mr. Oschmann made the remark that in opening a three-phase circuit, with a three-pole contactor, arcing was observed on only two of the poles. I think that is probably due to some improper adjustment, and there is no question in my mind that a three-pole contactor would be better for opening a three-phase circuit than a double-pole.

W. O. Oschmann: In reply to Mr. Wright, I would say that the arc is not on the same two poles each time, it may be on any two of the three poles. It seems to depend on what part of the cycle the switch starts out.

J. D. Wright: Is it possible the current is passing through zero on one of these poles?

W. O. Oschmann: Possibly that is the reason.

C. D. Gilpin: I have been much interested in Mr. Brown's description of the a-c. unloading tower, as I had considerable experience some years ago with some a-c. dynamic braking coal handling bridges. On these bridges the controllers and motor-generators very much resembled those described by Mr. Brown, except that no separate contactors were provided for dynamic braking and consequently the control when lowering was not particularly accurate. These bridges were provided with 220-volt, 25-cycle mill motors and it was our endeavor to make the equipment as near the equivalent of a d-c. outfit as was possible. We found, for instance, that owing to the poor characteristics of the a-c. motor for trolley service it was necessary to increase the size of the trolley motors considerably over what would be required for direct current. The cost was considerably greater than that for a d-c. equipment of equal capacity, and we estimated roughly that it would have cost but a very few thousand dollars more to install a synchronous converter station. As great nicety of control, however, was not necessary, the a-c. system was probably preferable in this case.

The question of cost in plants of this nature is one over which there is sometimes considerable confusion. For instance, a number of d-c. machines equipped with expensive mill motors and provided with a substation are often compared as to cost with a-c. machines which are operated by the ordinary open type of wound-rotor induction motor, which is hardly fair to the d-c. system. In a plant such as Mr. Brown describes, however, where the peak loads are very high and a substation would have to be quite large in comparison with the mean current used, alternating current is undoubtedly a very attractive proposition.

While agreeing with Mr. Brown that the single hoist motor with clutches is cheaper than the type of hoist in which each of two independent drums is operated by a separate motor and controller, yet it would hardly seem possible that operation by means of clutches can be faster and less complicated than where independent motors are used. In the former system there are

two master controllers and four air valves to be handled, while with the latter scheme, in which solenoid brakes are mounted on the motor shafts, there are three master controllers and one air valve to be manipulated, making two less pieces of apparatus. Moreover, with the independent drum arrangement each mechanism is reduced to its simplest elements, *i. e.*, a drum, the necessary gear reduction, a motor and a solenoid brake. The wear on the latter is quite slight if the dynamic braking is effective. The independent drum drive, however, is certainly more expensive in first cost, and therefore in certain cases it is undoubtedly better engineering to install the clutch system.

Arthur Simon: Mr. Whiting compares the oil-break switch with the air-break switch, and says that the air-break switch is more reliable. I think that Mr. Whiting has compared his newest air-break switch with the oil-break switch which he discarded, because as I pointed out in my paper, there is one oil-break switch operating on a rolling mill which operated 50,000 times with the oil just as clear, apparently, at the end as it was when it was put in. I also know of a large installation that has an oil-break switch which has been in service for several years, and the oil in one instance was not renewed for one and a half years. Of course, it is necessary once in a while to replenish the oil.

As far as inspection is concerned, I do not believe that any operator would stick his nose into the air-break switch while it is operating. In such case you have to open your circuit-breaker, and you may just as well lower the oil tank and look at the contacts. There is no doubt that the contacts of the air-break switch must have more metal than the contact of the oil-break switch, and as that is copper, it is more expensive and the weight of material is greater. If the oil switch, on the other hand, is properly constructed there is practically no spilling of the oil, so that the replacing of the oil is a small item, provided the switch is constructed so that the carbon deposits settling on the bottom are not stirred up every time the switch operates.

Mr. Albrecht spoke of the relative value of the three-phase and single-phase relays in the secondary circuit, if I understood his remarks right. I pointed out in the paper, or tried to point out, that the three-phase relay, because it gives a constant pull for a constant effective current, is independent of the frequency. On the other hand, it is not possible to get a constant pull on the single-phase relay, because it is not possible to get phase displacement of 90 degrees between the flux interlinked with the main coil and shading coil. Therefore, there is a pumping action when the frequency in the secondary is low.

One of the speakers mentioned a particular installation where the acceleration was very rapid towards the end, when the motor was at high speed. I believe that is due to this cause—if relays of the single-phase type were employed this could not be avoided by any adjustment, because an adjustment which is correct for high frequency is not correct for low frequency.

Mr. McLain said the jamming relay did not prevent strain on the operating parts. He modified that and said it would prevent the strain only in a degree. If that degree is sufficient, the jamming relay does all it is intended for. If you use several jamming relays, you can prevent any serious strain on the parts. There are certain installations where the jamming relay performs another purpose, take the electric shovel and other similar installations like that. It is possible for the shovel to strike solid rock while the motor is running at full speed. Then the motor would be stalled with the resistance short-circuited and the torque which developed at that point would probably not be in excess of the normally rated torque of the motor. If we have a slip clutch only and no jamming relays, the clutch will slip while the motor is slowing down, and will hold on again as the motor reaches lower speed and the torque is decreased again. The jamming relay prevents the motor from going beyond the breaking-down point. That is an important application of the jamming relay, and as far as I know, the jamming relay is the only device that will do that. We have slip clutches on that installation, also.

I think Mr. McLain has misunderstood the connections of the three-phase relay. That relay, as Mr. Kennedy has pointed out, does not need to beat the switch which it controls. That the current peaks on the 1000-h.p. motor which I show are decreasing is merely accidental. As a matter of fact, the last peak, as I remember is the second highest of the whole cycle. The advantage of the individual series relay is, as I pointed out, the adjustment of the various relays for different torques. In most cases we adjust them for increased torque, increasing torque with the motor speed on centrifugal pumps, and also on excavating machinery. This particular instance was exceptional. Furthermore, the relays are not energized when the primary circuit of the motor is closed. They are energized in succession as the different clappers are cut out and the resistance decreases. That is clearly shown in diagram Fig. 13.

Mr. McLain also criticised the use of d-c. contactors on coal bridges where d-c. is used for dynamic breaking, on the ground that it would add to the number of links which might stop the equipment. The most important thing on the hoist is to prevent the load from overhauling the motor, in other words, to prevent the bucket from dropping. That is the reason why we put in direct current for dynamic breaking. We would rather have the equipment stop with our d-c. supply, than to have it go on and hoist and give us no indication that we cannot lower our load with safety. So that the use of d-c. contactors in that particular instance, I believe, is an additional safety rather than a weakness in the method of control.

Mr. Knight has mentioned that a phase failure relay will be put on the market soon. There is one on the market already, which prevents not only failure of phase, both during running and

during the standing still of the motor, but also protects against phase reversal.

Mr. Knight further says that the oil-type switch is a good one where infrequent operation is encountered. I have given some data referring to frequent operation of oil switches.

Mr. Knight also mentioned something about standardization. That brings me to a subject which I have had in mind for many years, but I always ran against a stone wall. That is at least the approximate standardization of secondary currents and voltages. The operating men here know that when they ask for a control equipment for an a-c. motor they always have to specify the secondary current limitations. If our motor friends could get together and standardize secondary voltages within certain limits—we have to allow some leeway to the designer—matters would be helped a good deal, I believe. I have made an attempt in that direction on various occasions, as long ago as ten years, but nothing ever came out of it. Perhaps I was wrong in my ideas.

Mr. Oschmann spoke of the expensive current transformer in the secondary circuit. As a matter of fact, while it is possible to use a transformer in a secondary circuit, we have not yet encountered any case where we had to actually use it. It was always possible to get a series relay directly into the secondary circuit, and this is much more desirable, because a relay on ordinary accelerating service always forms neutral form of the resistance, and therefore has, when it is in circuit, practically no voltage to ground. As regards the bulkiness of the transformers, they would mostly run at low frequency, and the iron induction can be high.

President Lincoln also mentioned the use of single-phase secondary relays in contrast with three-phase relays. I have answered that point. It is significant that in some installations where single-phase series relays were used for all of the accelerating points, it was found necessary to use three-phase relays for the last step, which supports the point I make in regard to the frequency affecting the sensitiveness.

Mr. Snyder mentioned some means for lowering the tank used for the oil switches. I believe that most of the oil switches of medium and large capacity today are equipped with such lowering gear, at least they ought to be.

When I spoke of the capacity of resistance in the particular case, which Mr. Snyder mentioned, I contrasted the reversible automatic speed regulator with the non-reversing starter. The resistance has to be figured the same way, taking into consideration the duty cycle, as it is done on direct current.

Mr. Stoltz also spoke about the oil breaker not being adapted for frequent closing. I have answered that point.

With regard to the plugging of the motor for quick stopping, there is always the danger that the operator throws his control handle over to full speed, reverse, and then leaves the

equipment alone, expecting it to stop the motor. We have the same trouble as before, so in some cases dynamic braking by d.c. may be desirable. I have noticed lately that it has been specified by the mill, so that while the particular installation I described is several years old, there seem to be some operating men who still believe in that method of motor stopping.

The necessity of using a three-pole switch for opening a three-phase motor circuit or reversing it has been mentioned. It seems to me there is no more reason for using a triple-pole switch for opening a three-phase motor than there is for using a double-pole contactor for opening the circuit of a d.c. motor. We often use a contactor only on one side of the line in the case of direct-current, and we get the same factor of safety if we use a double-pole contactor on a three-phase or three-wire circuit in alternating-current.

Raymond E. Brown: When Mr. McLain introduced the question of the advisability of using series or parallel grouping of the resistance, that is, in adding additional steps in parallel or by cutting out the steps in series, I thought possibly we would find out the reason for the use of these two methods in different cases. In buying equipment for about fifty coal and ore handling bridges in the last ten years, our firm has been interested in trying to find out why the resistance varies so much in different cases. We are very much interested in the weight of the equipment, as in designing a trolley bridge the weight of the electrical equipment on the trolley is an important factor in getting at the weight of the bridge and its cost. Each pound of additional weight in the trolley means three pounds of additional weight in providing the span.

We have so far been unable to find any real uniformity in the weight of resistance in consecutive jobs of about the same size and voltage. Manufacturers seem to vary this a great deal, and one time will offer a control with resistances grouped in series, and another time in parallel, with a wide variation in the weights.

Referring to the question brought up this morning about the material for the bridge, I hoped to hear some one speak of the new material which was recently called to our attention in the shape of an alloy which is rolled or drawn into the girders. According to the claims of the manufacturer, it will do away with most of the disadvantages of cast iron. It is lighter, and the material for the entire drum could be one continuous piece, no joints between the separate bridges, merely doubling on itself and bending around the mounting rope. Outside of the circular and one visit of their representative we know nothing about that, and there may be other reasons why it is not being considered.

It is usual for steel mills to say they will use resistances with a rise of temperature of 100 degrees or 200 degrees, or any

other amount you choose; but the poor manufacturer who is designing the machinery to be sold on a competitive basis has to deal with the purchasing agent, who very frequently tabulates his bid on the basis of total weight and total price, and apparently decides them on the basis of price per pound. Under these circumstances it is hard for the crane or bridge manufacturer to introduce many refinements which would be undoubtedly of great advantage to the operator if they were installed. Many times we find after the machine has been in operation for some time that these refinements are put in by the users of the machinery, whereas we were unable to obtain any recognition of their value when the machine was first supplied.

With reference to the criticisms about my statement as to the advisability of a large motor for hoisting, the statement made by Mr. Bright would be correct on a hoist where the lift was low, and the time of hoisting was small in comparison with the time for closing. In the particular hoist described, the height of hoist is 90 ft., and as we were able to design it with a large leeway at the top, the operator was able to let the load coast to a stop in the majority of cases.

With reference to the question of limiting switches, and the advisability of using the geared limiting switch, it seems to me that the desirability of the geared limiting switch as against one operated by the load itself depends, to some extent, on the organization of the mill. In the particular hoist I described, it is cared for by one department which operates and repairs it. In other mills the crane is operated by one department and repaired by another. I think in the case of a bridge or hoist it is entirely possible that one department will replace the ropes, while the geared limiting switch, being an electrical device, is outside of their jurisdiction, and consequently is not changed. We know of cases where a new rope was put on a bridge, the geared limiting switch not changed. The new operator coming on the next shift knows nothing of the change having been made, and proceeds to hoist the bucket into the drum. In the case where the repairing is done by one department, and the operating done by another department, the geared limiting switch does not appear to be desirable, but the style of limiting switch operated by the dump or skip should be used.