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**DESIGN AND OPERATION OF THE INTERCELL CONVEYOR SYSTEM
FOR THE TRANSURANIUM PROCESSING PLANT**

T. L. Trent

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General Engineering Division

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FOR THE TRANSURANIUM PROCESSING PLANT

T. L. Trent

DECEMBER 1967

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee
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CONTENTS

	<u>Page</u>
Abstract	1
1. INTRODUCTION	1
2. SUMMARY	3
3. DESIGN REQUIREMENTS	5
4. DESIGN PROBLEMS	7
5. DESIGN AND FUNCTION OF CONVEYOR COMPONENTS	9
Canister, Carrier, and Tracks	9
Canister Cover	14
Port Closures	15
Drive System	19
Controls	23
Conveyor Housing	29
6. CONCLUSIONS	31

DESIGN AND OPERATION OF THE INTERCELL CONVEYOR SYSTEM FOR THE TRANSURANIUM PROCESSING PLANT

Abstract

An alpha-tight intercell conveying system has been designed, fabricated, and installed in the Transuranium Processing Plant at Oak Ridge National Laboratory. The system was designed to transfer relatively small radioactive items between nine cell cubicles and the transfer area cubicle rapidly and with a minimum of operator skill and attention. This system has been in operation for over a year, and its operational availability has been approximately 99%. The functional requirements, problems, design, and operation of the conveyor system are discussed in this report.

1. INTRODUCTION

The Transuranium Processing Plant constructed at Oak Ridge National Laboratory (ORNL) was designed to prepare target rods for irradiation in the High Flux Isotope Reactor and to process these rods after irradiation for the separation of transuranium elements. Special provisions were necessary for the containment of these high alpha emitters and associated gamma and neutron emitters. The area of primary containment in the Transuranium Processing Plant is a cell bank about 95 ft long that is composed of nine in-line cell cubicles and a transfer area cubicle. A large part of the processing work is carried out within the primary containment of these cell cubicles where no unprotected openings for the transfer of material are permitted.

The need to make routine transfers of supplies, radioactive materials, and relatively small miscellaneous items between the nine cells and the transfer area cubicle without cross contaminating the cells or permitting radioactive contamination of the limited-access operating area led to the design and development of the intercell conveyor system presently installed in the Transuranium Processing Plant.

A partial horizontal section through the cell bank and the operating area in the Transuranium Processing Plant is shown in Fig. 1. Each of the nine cell cubicles is 7 ft wide, 7 ft long, and 8.5 ft high inside, and the transfer area cubicle has inside dimensions of 6 x 6 x 7 ft. The ten cubicles have a common floor elevation, and the intercell conveyor is located under the floor of the cubicles about 1 ft back from their inside front face, as indicated in Fig. 1.

Fig. 1. Partial Horizontal Section Through the Cell Bank in the Transuranium Processing Plant Showing the Location of the Intercell Conveyor.

The initial design requirements for the intercell conveyor system are given in Chapter 3, the problems involved in designing the system to meet these requirements are discussed in Chapter 4, the design and functions of the conveyor subsystems are described in Chapter 5, and the conclusions drawn from the operating experience with the conveyor system are presented in Chapter 6. This information is summarized in Chapter 2.

2. SUMMARY

Relatively small items of material less than 8 in. in diameter and 8 in. long are transferred inside a canister on a chain-driven carrier that operates on rails within the stainless steel housing located under the floor of the cubicles. This location provides shielding for the operating personnel, and it also made it necessary to locate a minimum amount of conveyor equipment inside the housing because of the difficulty involved in its maintenance. The air-tight conveyor housing is connected to each cubicle by a transfer port, which is sealed with a closure inside the cubicle. To effect a transfer, the canister on the carrier must be elevated to a precise location at each transfer port to allow it to be sealed and locked to the port closure where the double-cover technique is used to remotely remove the canister cover. A controlling system is required to effect this precise positioning of the canister, and a remote indicating system is required to determine the location of the carrier and the canister at any time.

A small portable position-selector control box can be plugged into one of several receptacles conveniently located in the operating area. The operator selects the cubicle at which a transfer of material is to be made by rotating the knob on the control box to the desired cubicle number. The control system sets the conveyor in motion to bring the carrier with its sealed canister to the selected transfer station regardless of the carrier's location at the start of the operation. However, the operator can determine the location of the carrier at any time by observing the pointers on the large position indicator panel that is visible from any of the operating positions within the operating area. One pointer indicates the longitudinal location of the carrier within the housing and the other indicates the vertical position of the canister on the carrier. If a transfer is being made, the indicator will show that the canister is elevated and in contact with the port closure at the cubicle indicated by the other pointer. While traveling from one station to another, the position of the canister is shown as being down, and the other pointer follows the progress of the carrier to the selected station.

When the carrier arrives at the selected station, it stops and the canister is elevated until it comes into contact with the underside of the sealed port closure where the top of the canister cover is sealed circumferentially to the port closure. A switch mounted adjacent to each cell window is used to open and close the port for that cubicle. When the switch is set to "open", the canister cover is unlocked from the canister and locked to the bottom of the port closure and then the port closure opens to allow access to the canister. The canister cover and port closure are sealed to each other to minimize cross contamination between the cubicle and the conveyor housing.

Interlocks prevent operation of the conveyor when a port closure is open. This feature helps maintain the integrity of the cubicle because the canister becomes a part of the cubicle when the port closure is open. By the same token, the interlock system prevents operation of any port closure unless the canister is sealed to the bottom of the selected cubicle. This feature decreases greatly the possibility of contamination from one cubicle entering the conveyor housing and then contaminating another cubicle.

During the first year of operation in the Transuranium Processing Plant, the actual use of the conveyor exceeded the predicted use by a factor of 5 or better. Malfunctions of the conveyor, control circuits, interlock system, and port closures have been minor in nature and corrected with little difficulty. With the plant in operation around the clock seven days a week, the conveyor has been operable approximately 99% of the time.

3. DESIGN REQUIREMENTS

The design criteria for the intercell conveyor system in the Transuranium Processing Plant stipulated that the system would transfer relatively small items of material less than 8 in. in diameter and 8 in. long. These items were to be transferred in a canister on a carrier that would be operated inside an alpha-tight stainless steel housing located under the floor of the cubicles about 1 ft back from their inside front faces. This housing would be connected to each cubicle by a transfer port in the floor pan of the cubicle, and the transfer port was to be sealed by means of a closure located inside the cubicle.

The canister carrier had to be capable of traversing in either direction under the cubicles and of stopping at any of the transfer ports, which are not equally spaced. In addition to the nine cell cubicle transfer ports, there were to be two transfer ports in the transfer area cubicle. One of these two ports would permit the canister to be elevated high enough to be removed and replaced should it become inoperable or too contaminated for use. The other would be operated in the same manner as the ports in the nine cell cubicles. At these ten transfer ports, the canister was to be elevated and sealed against the bottom of the cubicle and the port closure. Removal of the port closure would effect removal of the canister cover, allowing the item to be transferred to be either deposited or removed from the canister.

From the description of what was required of an intercell conveyor system for the Transuranium Processing Plant, three critical design features became apparent. These were that

1. a minimum amount of conveyor equipment should be located inside the conveyor housing because of the difficulty involved in its maintenance and repair,
2. the canister would have to be elevated to a precise location at each transfer port to allow it to be sealed to the port and to allow removal of the cover by means of a port closure mechanism, and
3. with visual monitoring of the conveyor impractical, a remote indicating system would be required.

The reliability of the conveyor is also of utmost importance because the operations within the cell bank would be limited if the conveyor should become inoperative. Therefore, the materials and components used in portions of the conveyor system should have a long service life in the presence of a corrosive atmosphere and a high radiation field of operation.

4. DESIGN PROBLEMS

Early in the conceptual design stage of the Transuranium Processing Plant, the importance of the conveyor system to the successful operation of the processing work to be carried out in the cell bank was acknowledged. After reviewing the design criteria and considering the requirements and desired features inferred from the criteria, it became obvious that commercially available equipment would not satisfy these requirements. Existing special conveyor systems were also reviewed for the possibility of modifying them to suit our purposes, but to no avail. The only resource was to start with a "fresh" idea and develop it to suit the needs of our particular application. High design priority was placed on the conveyor system because the consensus of opinion of project personnel was that redesign or modification of those parts of the system located beneath the cell cubicles would be out of the question.

Therefore, the first problem encountered in the design for the conveyor system involved elimination of as many components as possible from the interior of the conveyor housing, and this effort was directed toward those components that were dynamic or would be affected by radiation or corrosion. Another problem encountered was one of positioning the canister accurately enough to effect transfers at the various transfer ports regardless of the direction of travel required. Development of a means to prevent the canister from being elevated at any point other than a transfer port was imperative. The transfer-port closures inside each cubicle would also have to be designed to remove and replace the sealed cover on the canister when material was to be transferred.

These problems indicated the need for a remote control and indicating system. The controls for the conveyor would have to be designed so that an operator could direct the carrier to a desired cubicle and operate the port closure with a minimum of effort. This requirement might be best met with a simple portable station selector for the conveyor with an interlock system between the conveyor and the transfer-port closures to prevent opening of a port when the canister was not sealed to the port or the removal of a canister from an open port. Since the addition of

viewing windows through the concrete shielding and conveyor housing at numerous points was out of the question, a remote indicating system would be required to continuously show the position of the canister carrier and the elevation of the canister on the carrier.

Another problem area encountered in the design for the conveyor system was the remote maintenance of the port closures located inside the cubicles. These units would have to be designed so that they could be serviced with the master-slave manipulators available in all the cells. Maintenance of those components that had to be located within the conveyor housing was also easily recognized as a problem of some magnitude.

5. DESIGN AND FUNCTION OF CONVEYOR COMPONENTS

Because of the problems involved in designing the intercell conveyor system to meet the functional requirements, the decision was made to design and fabricate a mock-up of the system that would incorporate essentially all of the features proposed for the final system. Modifications to the design could then be made during fabrication, assembly, and testing of the mock-up and prior to the final design of the conveyor system that would be installed in the facility.

All of the major components of the conveyor system except the housing and the port closures are illustrated in their relative locations within the plant in Fig. 2. The design and function of the various components of the intercell conveyor can best be described by treating them individually as though they were independent of one another, which obviously is not the case. The major components of the conveyor to be described in some detail are the

1. canister, carrier, and tracks;
2. canister cover;
3. port closures;
4. drive system;
5. controls; and the
6. conveyor housing.

With the exception of the conveyor housing, all of the above components were tested extensively in the mock-up and development facility. The experiences, modifications, redesigns, and additions that occurred during this phase of the development are included in the description of the components.

Canister, Carrier, and Tracks

The prime objective in the design for the conveyor system was to eliminate as many items of equipment as possible from the inside of the conveyor housing. The use of positioning switches or remotely operated

Fig. 2. Major Components of the Intercell Conveyor System for the Transuranium Processing Plant.

mechanical control devices within the housing to position the canister and elevate it was considered highly undesirable. While items located within the housing at each end might be maintained with a slight degree of difficulty, these items could be at a distance from the ends of the housing no greater than 2 or 3 ft.

The initial concept of positioning the canister for transfers at the cubicles was carried through the mock-up, development, and final design stages with virtually no changes. The cylindrical canister is mounted on and locked to a carrier, referred to as a dolly since the early stages of the design work, that rolls on two deep-section tracks and is powered by two separately driven continuous chain loops. The chains are engaged with sprockets attached to bevel gears on the dolly, and these two bevel gears are coupled by a third bevel gear. The third bevel gear is free to rotate around its own axis, and an attached ball nut drives a screw connected to the elevator portion of the dolly. This mechanical arrangement causes the two chains to move at the same rate relative to the dolly but in opposite directions when either chain is driven. The elevator is thus moved up or down, depending upon the relative direction of the motion of the chains, until the top or bottom limit of elevator travel is reached. At either limit of elevator travel, the elevating motion ceases and the dolly will continue to move in the direction of the driving chain unless otherwise restricted. To simplify the explanation of the mechanics of the system, a linkage analogy of the sprocket-gear-screw arrangement is shown in Fig. 3.

Fig. 3. Linkage Analogy of the Sprocket-Gear-Screw Arrangement Indicating the Relative Motions of the Dolly Components.

The relative motions of the components of the dolly are indicated in Fig. 3. The inverted "T" frame represents the dolly, and the two links, A and B, represent the elevator mechanism. Starting at Position 1, if the lower pin on Link A is restrained and the pin attached to Link B is moved to the right, the pivot pin will move along the arc from Position 1 to Position 2. The pivot pin has then moved to the maximum down position and the frame has also moved to the right to Position 2. At this point, if the force to the right on the lower pin in Link B is greater than the restraining force on Link A plus any other system friction, the frame will move to the right and the linkage will remain in the down position.

At Position 3, if the driving force is transferred from Link B to Link A at the lower pin but still in the direction to the right and the restraining force is applied to the lower pin in Link B, the pivot pin will follow the arc from Position 3 to Position 4 and stop when it reaches the top of the slot. The frame will continue to move to the right as long as force is applied in that direction. Similar motions to the left can be obtained by reversing the forces.

If the pivot pin is further restricted by a fixed guide not attached to the inverted "T" frame, as illustrated in Fig. 4, motions of the frame and linkage begin to approach those motions experienced by the dolly and elevator used in the actual conveyor system. Consider the fixed guide as being the track upon which the dolly rolls and the pivot pin as being a roller mounted on the elevating portion of the dolly. Actually, two tracks and two rollers constitute the guidance components for the dolly.

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Fig. 4. Linkage Analogy of the Sprocket-Gear-Screw Arrangement Indicating the Relative Motions of the Dolly Components With a Fixed Positioning Guide.

The vertical slots in the fixed guide or tracks are located only at those positions where vertical motion of the elevating mechanism is desired. In the case of the actual conveyor, the slots are located only at transfer port positions. With the same force applications as in the preceding example, the path of the pivot pin is altered by the fixed guide as shown in Fig. 4. The same actions are followed by the dolly and elevator except that the arcs followed by the pin become straight-line diagonals for the rollers because of the constant ratio of the gear and screw arrangement. As shown in Fig. 4, when the elevator is in the full down position, from Position 2 to Position 3, there is some clearance between the rollers and tracks because the rollers are not the controlling factor required to maintain this condition.

The design for the conveyor tracks and guide prevents elevation of the canister except when the dolly is located at a transfer port position. This eliminates the possibility of damaging the canister cover by scraping it against the top of the conveyor housing. Nominally, the vertical slots in the guide are 10 mils wider than the diameter of the rollers, which results in accurate positioning of the canister in the elevated position.

Each conveyor chain is a continuous loop that is individually driven, as shown in Fig. 2. One drive chain will lower the elevator when driven in one direction and elevate it when driven in the opposite direction. The second drive chain does just the opposite. Traversing in one direction by driving the chain that lowers the elevator when going in that direction to the full down position permits the dolly to be moved to any position along the length of the tracks without entering any of the slots. The other chain driven in the opposite direction will drive the dolly in the opposite direction with the same result. When traversing in either direction, if the driving force is changed to the opposite chain but in the same direction, the elevating mechanism on the dolly will rise until the rollers contact the bottom of the tracks. The dolly will continue to travel until the first slot is reached and then the rollers enter the slot, the dolly stops, and the elevator resumes its rise until the top of the canister comes into contact with the bottom of the port closure.

This concept of the functioning of the carrier or dolly is the heart of the intercell conveyor, and all other components were developed to enable the dolly to perform these functions. The first tests made in the mock-up verified that the dolly and elevator would perform in the manner described above. Hand cranks were first used to drive the two chains, and the dolly could be positioned at any of the three stations existing in the mock-up. Replacement of the hand cranks with motors to drive the chains provided smoother, faster, and easier operation of the equipment. Some modifications were made in the final design for the dolly and tracks to be used in the Transuranium Processing Plant, but these were rather minor.

Canister Cover

Although the design for the canister remained relatively unchanged during the developmental stages, the design for the canister cover underwent a series of modifications brought about primarily by the changes in the design for the port closure with which it is closely associated.

The canister cover must be locked and sealed to the canister when the canister is being transported between cubicles, but the cover must be unlocked from the canister and locked and sealed to the port closure during a transfer operation. The cover is attached to the canister with locking bars that extend radially and are pivoted from a disk assembly located in the center of the cover. The cover is sealed to the canister with a neoprene seal around the periphery of the cover. The seal has a U-shaped cross section, with the opening in the U-shaped section toward the center of the cover so that the seal can be stretched over the edge of the cover without having to be retained by mechanical means. This arrangement provides the seal between the cover and the canister and also the seal between the cover and the port closures.

Locking bars are located on both the outside and inside faces of the canister cover. The ones on the inside face lock the cover to the canister by extending into a wedge groove in the canister when the center disk is

rotated. The locking bars are pivoted over-center when the cover is locked to the canister, which insures that the cover will remain locked until the disk is rotated in the opposite direction. A similar set of locking bars located on the outside surface of the canister cover lock the cover to the port closure. They are arranged in a manner similar to that of the bars on the inside surface of the cover, but they retract when the other bars extend and vice versa.

Port Closures

The design for the port closures went through a series of changes during the developmental period that were related to methods of sealing the port and of removing the canister cover. The first design was for a purely mechanical closure that was to be operated by using the master-slave manipulators located in each cell cubicle. This closure is shown in Fig. 5.

Fig. 5. Manipulator-Operated Port Closure in Conveyor Mock-Up.

In the design shown in Fig. 5, a mechanism integral with the port closure is used to unlock the cover from the canister and lock it to the port closure. When the canister is elevated and in contact with the port closure, lugs in the closure mechanism engage with slots in the disk assembly in the center of the cover to which the locking bars are attached. Rotation of the disk by the closure mechanism retracts the locking bars on the inside surface of the canister cover and extends those on the outside surface of the cover, unlocking the cover from the canister and locking and sealing it to the port closure.

At about the same time that fabrication of the first unit was completed, it was decided that the manipulators in the cubicles would be relieved of all routine operations. Opening and closing of the transfer port closures was considered routine. As an alternate, the design for pneumatically operated port closures with mechanical interlocks was developed, and a prototype of this design is shown in Fig. 6. Extensive testing of this prototype showed that it performed satisfactorily, but the mechanical interlock system had to be located underneath the closed port.

Fig. 6. Pneumatically Operated Port Closure With Mechanical Interlocks.

Repairing a failed interlock in this location would be extremely difficult. At this time, it was also decided that the mechanisms for the interlock system were too complex.

Along with changes in construction features, an electric-pneumatic method of interlocking was applied to the second design for the port closure, and the prototype of this design is shown in Fig. 7. The prototype was tested in the mock-up, and this design was used for those remotely operated units installed in the Transuranium Processing Plant.

Fig. 7. Pneumatically Operated Port Closure With Electric-Pneumatic Method of Interlocking Used in Transuranium Processing Plant.

One of the two port closures located in the transfer area cubicle was to be used for removing and replacing the canister when necessary. This was expected to be an infrequent operation so the port closure was designed for manipulator operation. Four toggle clamps spaced 90° apart are used to secure a gasketed cover plate to the port opening. These toggle clamps mounted around the periphery of the opening also serve to center the cover properly prior to clamping and sealing.

The ten remotely operated port closures are individually controlled with two-position switches conveniently located adjacent to their appropriate viewing windows in the operating area. Each port closure is pneumatically operated by means of an air-cylinder controlled lock and an air-cylinder controlled hinge on the closure. Solenoid-operated air valves direct air to the proper cylinder at the open or close sequence of operation. When "open" is selected for a port, air pressure is routed to the lock cylinder, which retracts. This action unlocks the canister cover from the canister and locks the cover to the bottom of the port closure. At the end of the retracting stroke of the lock cylinder, a lug on the shaft actuates a transfer valve that directs air to the cylinder attached to the hinged cover. The closure rotates approximately 110° in the vertical plane about a horizontal axis in the front-to-rear direction of the cubicle.

When "close" is selected, air is directed to the other side of the piston in the cylinder that operates the closure. At the end of the closing stroke, a lug on this shaft actuates another transfer valve that routes air to the lock cylinder. As the lock cylinder operates in the return stroke, the canister cover is released from the port closure and simultaneously locked to the canister. The hinged port closure is connected to a toggle clamp mechanism that locks when the port is closed. Therefore, air pressure on the cylinder is not required to keep the closure closed or securely clamped, nor will the upward force exerted by the canister open the closure when the conveyor stalls.

Each port closure is equipped with a third air transfer valve that is a part of an interlock system which prevents operation of the conveyor when a port is open. When the port closure is locked, a lug on the locking mechanism opens a valve that admits air to a remotely located pressure switch. When the lock cylinder first starts through the unlock cycle of port operation, the valve opens, exhausting its pressure, and this opens the electrical switch. All ten of the pressure switches at the ten ports are electrically connected in series and are part of the traverse circuit of the conveyor. Therefore, if any port closure is unlocked, the conveyor cannot be operated by the control system.

As was previously stated, a port closure cannot be opened unless the conveyor is at that position and the elevating mechanism is in the full up position. If a port closure is selected to open while the conveyor is enroute to that station, the conveyor will continue on its way and the port will remain closed. When the conveyor stops at the selected station and the elevator has risen to the full up position, the port closure will then unlock and open with the canister cover attached to it. If another station is selected at this time, the conveyor will not start until the port is closed and locked and the cover is attached to the canister.

Of all the components that make up the conveyor system, the port closures are subjected to the most severe operating conditions. As well as being located in a field of high radiation and in a corrosive atmosphere, the port closures are located on the floor of the cells where they are subjected to accidental contacts with manipulated or dropped objects. For these reasons, methods of maintaining them were given a great deal of consideration. To eliminate the necessity of removing an entire port closure assembly for maintenance, the port was designed so that subassemblies of the unit could be removed, and the weight of each subassembly was kept within the lifting capabilities of the manipulators within the cells.

Drive System

After determining an appropriate design basis for the canister, port closures, and the carrier or dolly, the next logical step in the development of the intercell conveyor was to determine an adequate type of propulsion for the system. The three major requirements to be met by the prime movers were that

1. they must be reversible,
2. they must be operable in a stalled condition for an indefinite period, and
3. they must have a wide range of speed control.

The reason for the first requirement is quite evident. The second

requirement was based on the concept that the canister would be sealed to the bottom of the port closure during a transfer of material and the sealing force would be supplied through the drive system by the prime movers. The length of time required to effect transfers of material could vary considerably, and a distinct possibility existed that an operator might forget about the equipment and leave the prime movers on after removing something from the canister. The third requirement was established primarily for the mock-up so a suitable traverse speed could be selected. It was intended to have two speeds: one for traversing and a second for elevating the canister.

Electric, air, and hydraulic motors and manual operation were considered as means of providing propulsion for the system. Air motors were selected for use as the prime movers because commercially available models without modification are reversible, operable in a stalled condition for indefinite periods, and have a wide range of speed control. Hand cranks were included for preliminary testing of the mock-up, and they were retained in the final design for the conveyor system installed in the plant for use during possible power failures or other emergencies. With the figure of 50 fpm having been selected as a reasonable traversing speed, two 0.9-hp axial-piston-type air motors were chosen, one for each drive. The performance chart for the selected motors indicated that the desired traversing speed of 50 fpm could be obtained with an air pressure considerably less than the 90 psi that would be available. Preliminary calculations showed that a load or chain pull of 48 lb would produce the 50 fpm speed. With the motors chosen, this traversing speed can be varied from zero to well in excess of the 50 fpm.

The mock-up of the intercell conveyor shortly after its completion and while still in the fabrication shop is shown in Fig. 8. The air motors are located adjacent to the hand wheels but they are hidden by the mounting bracket in the photograph. The motors are engaged with the chains that are connected to the handwheels. The mechanical clutches adjacent to the large drive sprockets were discarded later and replaced with electrical clutches. Although the conveyor would function properly

Fig. 8. Mock-Up of Intercell Conveyor Shortly After Its Fabrication.

with one motor driving and the other being driven through the chain system, the unnecessary drag created by the unpowered motor is eliminated by uncoupling it when it is not in use.

To remove the loading on the elevating mechanism of the dolly while traversing from one port to another, the two input drives are coupled by means of a series of stop disks. Each input shaft has a disk rigidly attached to it, and there are several free-wheeling disks sandwiched between the two fixed ones. Each disk has a lug that contacts the lug on an adjacent disk at some position in the relative rotation of the two drives. With the dolly removed from the drive system, either drive is rotated in its traverse direction until all of the lugs are in contact, which locks the disks together. This couples both chains to one drive motor for traversing in either direction. The dolly is then put back into the drive system but with the elevator just above the full down

position. Relative chain motions in the opposite direction that produce the elevating motion cause the stop disks to rotate in the opposite direction, but they do not reach the locked condition until after the elevator has reached its upper limit.

Since the length of the conveyor mock-up was considerably shorter than that required for the conveyor in the Transuranium Processing Plant, friction disks were added to the return idlers at the end of the conveyor opposite the drives. These were spring loaded and adjustable so that the frictional resistance load of the actual length of chain to be used could be simulated. Based on calculations derived from the manufacturer's performance data for the air motors, a two-to-one ratio between the motors and the conveyor chain drives was used. Test runs made with the mock-up revealed that the arbitrary figure of 50 fpm for the traverse speed was too low, and the system operated just as well at higher speeds. A supply air pressure of 50 psi produced a traversing speed of 160 fpm in the mock-up and a speed of 180 fpm in the actual installation. The drive system for the conveyor that was actually installed in the Transuranium Processing Plant is illustrated in Fig. 9. This photograph was taken during the acceptance tests at the fabricator's plant. The air motors can be seen on the right side of the large metal box, which represents the shielding plug between the conveyor and the drives.

Fig. 9. Drive System for the Intercell Conveyor in the Transuranium Processing Plant.

Controls

The controls underwent more changes during the development stages of the intercell conveyor system than any of the other subsystems. Those changes were not brought about by improper operation but by the desire to eliminate the need for a great deal of skill and attention to operate the conveyor. The initial concept was to have an electrical control box with selections to control various solenoid-operated air valves that in turn would direct the air supply to the proper motor and run it in the

desired direction. The operator would select the direction of travel, up, down, or stop, at the proper time by observing a remote indicator that was to have been integrated with the controls in the planned control box. During this stage of the developmental work, it was planned that the port closures would be operated by using the manipulators located in each cell. When the decision was made to have the port closures self-powered, the concept of the control box was modified to include operation of the port closures as well as operation of the conveyor. The controls for the conveyor were simplified somewhat, but proper operation of the conveyor still required monitoring of the position indicator.

The original concept of the position indicator transmitter was for a device that would give a remote indication of the approximate position of the dolly and elevator. However, the decision was made to devise a control system that would relieve the operator of the need to constantly monitor the conveyor position indicator. The key to this desired "automatic" operation was provided as a result of the discovery of an unexpected feature in the drive system soon after the conveyor mock-up was put into operation. When the conveyor is traversing, the driving chain is taut in front of the dolly and any slack in the chain is behind the dolly. The reverse is true of the other chain; the slack is in front of the dolly and the tautness is behind it. Thus, when the direction of travel is reversed, there is no slack to be taken up and the position indicator tracks the conveyor with a high degree of accuracy. By adding a number of cams and switches, the position indicator transmitter could therefore be made to automatically control the operation of the conveyor.

The controlling portion of the system was developed and tested extensively in the mock-up and then used in the Transuranium Processing Plant. A schematic diagram of the controller installed in the plant is shown in Fig. 10. For clarity, the reducers and other gearing have been left out of the diagram. The two inputs, A and B, are coupled to the conveyor drive system through miniature chains and sprockets. When the conveyor is traversing, the output shaft from Differential A rotates because both inputs are rotating in the same direction at the same speed and the end gears of Differential A are rotating in the same direction.

Fig. 10. Schematic Diagram of the Controller for the Intercell Conveyor in the Transuranium Processing Plant.

On the other hand, the end gears of Differential B are rotating at the same speed but in opposite directions that cancel each other, and the output shaft of Differential B remains stationary.

These output shafts are connected to synchro transmitters that relay information to receivers mounted on the remote position indicator panel. Pointers are attached to the receiver shafts to visually indicate the positions of the dolly and elevator. When the dolly is stationary and the elevator is moving either up or down, the conveyor drive chains are moving in opposite directions at the same speed. This produces a rotation to the elevate transmitter input shaft while the transverse transmitter input shaft is stationary. The input shaft on the traverse synchro transmitter rotates approximately 310° from one end of the conveyor run to the other, and the input shaft of the elevate synchro transmitter rotates 180° for the limit of the elevator motion.

Other components added to this mechanism made it a controller and interlock device as well as a position indicator. A synchro transmitter mounted on the portable control box is electrically connected to the control synchro receiver. The knob on the control box can be rotated through 310° with detents located through this rotation to match the linear locations of the transfer ports in the cubicles. The control function of the system can best be described by following a typical operation required to move the conveyor from an up position at one cubicle to the up position at another cubicle.

With the conveyor at a cubicle transfer port, the correct location of the dolly and the position of the elevator are displayed by the remote indicators. The cams and switches on shaft Z shown in Fig. 10 are in phase with the dolly location. When a different transfer station is selected at the portable control box, an equal angular rotation of the control synchro receiver results. The feedback inputs A and B are mechanically coupled directly to the conveyor drive, and they have the entire gearing system in the controller locked with the exception of the end gear on Differential C, which is coupled to Cam Shaft Z. Since the control synchro receiver is coupled to the spider shaft of Differential C,

any rotation of the spider shaft will produce a rotation of Shaft Z. The cams on this shaft actuate switches that control the operation of the conveyor; left, right, up, or down.

If the station selected is to the right of the station at which the conveyor is located at the time the new position is selected, one cam on Shaft Z actuates a switch to traverse and another to go right. These switches actuate appropriate solenoid air valves that direct air to the motor that will run the conveyor in the desired direction. The conveyor drive chains must move in opposite directions to lower the elevator mechanism from the slots in the guides at the transfer port. While the elevator is being lowered, the feedback shafts move in opposite directions and the elevate shaft rotates while the traverse shaft remains stationary. When the rollers on the elevating mechanism reach the bottom of the slots in the guides, the dolly is free to traverse in the desired direction.

After the elevator reaches the full down position, the output rotation of Differential B ceases because both conveyor drives move in the same direction for traversing. Traversing rotates the output of Differential A that in turn rotates the meshed end gear of Differential C. With the spider gear of this differential being held stationary by the control synchro, the end gear driving Shaft Z will rotate. This rotates the cams until the switch controlling the traverse and up mode of operation is actuated. The distance the conveyor has to travel in order to actuate this switch is dependent upon the angular displacement of the control at the start of the operation. Since the linear travel of the conveyor is proportional to the angular offset of the control, Shaft Z and its cams always return to the same position when the position of the conveyor and the control setting are in agreement.

The lobe on the up-down cam attached to Shaft Z is adjusted so that the switch is actuated, the elevator on the dolly rises, and the rollers on the elevating mechanism contact the bottom of the tracks at a distance of 1 ft away from the slots of the selected station. When the rollers on the elevating mechanism reach the slots, the traversing action of the dolly

ceases and the canister is elevated until it contacts the transfer port and the system stalls.

There are three cams on the elevate output shaft and two on the traverse output shaft that are related to operation of the conveyor. The three cams on the elevate output shaft control switches that operate solenoid air valves. High-pressure air is supplied to the drive motors and is adjusted by pressure regulators to control the traversing speed of the dolly. With the elevator in the full down position and the dolly traversing, the angular position of the elevate output shaft is always the same. When the elevator is signaled to rise just prior to reaching the selected station, the slight rise of the elevator required to make contact between the rollers and the bottom of the tracks rotates the shaft a few degrees, and one of the cams actuates a switch to reroute the supply air through another pressure regulator set at a lower pressure. This reduces the speed of the conveyor prior to stopping and the subsequent actuation of the elevator. After the slots at the desired transfer station are reached and the elevator is free to rise, the other two switches on the elevate output shaft are actuated. One energizes a valve that admits air at a still lower pressure into the system, while the other supplies air to the drive motor, which has not been in operation during the later phase of traversing. Air is also supplied to the other drive motor that will drive the chain in the opposite direction to elevate the canister. Both motors are therefore used to elevate once the rollers on the elevating mechanism have entered the slots at the transfer station. Both are also used to lower the canister but their direction of drive is reversed. The two cams and related switches on the traverse output shaft are the left and right traverse limit switches. These are safety switches that would stop the conveyor if it should overrun either of the two end stations. Mechanical stops are also attached to the tracks as a backup.

One cam and switch on the elevate output shaft and ten on the traverse output shaft are directly related to controlling the port closure interlock system. Each of the ten cams operating switches on the traverse shaft are adjusted to make contact as the conveyor approaches a transfer

port, and there is never more than one switch energized at any time that the conveyor is in the immediate vicinity of a port. The cam on the elevate output shaft energizes its switch when the elevator is in the full up position. This switch feeds the other ten switches so that only the port closures contacted by the canister on the dolly can be operated at that time. This also means that none of the ports can be operated while the dolly is traversing or while the canister is being elevated.

Conveyor Housing

The basic functions of the conveyor housing are to provide an alpha-tight enclosure for the conveyor with appropriate junctions at each transfer port and to support the tracks upon which the dolly is mounted. The size of the housing was determined from the mock-up of the dolly, canister, and tracks and the length of the cell block in the Transuranium Processing Plant. The final dimensions of the housing are 12 in. wide, 20 in. high, and approximately 95 ft long. The housing was fabricated of 1/4-in.-thick stainless steel with gasketed cover plates at each end. The drive mechanism is located at one end and the chain adjustments at the other end.

It was necessary to have the housing completed and ready for installation fairly early in the construction phase of the plant because it had to be in place before the concrete bank was finished and before the cubicles in the cell bank were assembled. Thus, the housing became a permanent part of the cell bank. Water and drain lines are conveniently located to flush out the housing. An off-gas line is attached to pull air into the housing when an end cover plate is removed for adjustment or maintenance of the drive or for removal and replacement of the dolly.

When the conveyor housing was being designed, it was recognized that there would be problems in aligning the cubicle floor pans with the transfer port openings in the housing. Therefore, the openings in the housing were made oblong and adapter plates were provided. These adapter plates were placed between the openings in the housing and the

floor pans and adjusted so that the center of the openings could be matched with the center lines of the concrete cells.

Although installed at a much later date, the dolly tracks and chain guides became almost an integral part of the housing because they can be removed only with the utmost difficulty now that the plant is operational. Except for those items, all of the other components in the system are dynamic in nature and therefore are more subject to malfunction. These latter components were designed for accessibility.

6. CONCLUSIONS

All the basic requirements of the design criteria for the intercell conveyor have been met, and many features were added during the conceptual and mock-up stages of development to enhance the operation, maintenance, and reliability of the system. In spite of the original concern about the physical location of the conveyor in the cell block presenting maintenance problems, the first year of operation has proved that the conveyor is reliable. Based on service requirements of 24 hours per day and 7 days a week, the operational availability of the system has been estimated to be 99%. Curtailment of operations has been caused mainly by malfunction of the port closures rather than the conveyor itself.

The location of the port closures within the cubicles makes them vulnerable to damage through contact with items being manipulated. Air line disconnects have been separated inadvertantly, and when this happens, the interlock system automatically makes the conveyor inoperative. The couplings are difficult to see because of their location, and time has been consumed by tracing down the cause of stoppage.

Three sequence valves located on the port closure are used to direct the air pressure to the proper end of the operating air cylinders and to the interlock system. Substitute valves were supplied for the type called for in the design, and although they were considered to be acceptable substitutes, some did not perform properly after having been in use for a short period of time. These substitute valves are suspected of being responsible for most of the conveyor's down time, and they should be replaced with those specified if the present method of port closure operation and interlocking is to be retained.

Too much emphasis may have been placed on the need for an interlocking system during the conceptual stages of the design for the intercell conveyor, and it is possible that the elimination of the interlocks might have more advantages than disadvantages. However, if the interlock system is removed, the burden of preventing cross contamination of atmospheres between the cubicles and the conveyor will fall upon the operators of the conveyor.

Maintenance of the components of the conveyor within the housing has been less of a problem than expected. The dolly has been removed several times with little difficulty, and in one instance a section of the chain drive connected to the dolly was replaced. Since most of the components of the control system are readily accessible in the conveyor maintenance area, the problems related to maintenance and adjustment have been minor.

No attempt was made to present technical data or the calculations performed for the intercell conveyor because they were unique to this particular application. However, the concept of the system in its entirety or any portion of it might be suitable for other applications, and the positioning concept could be applied to many remotely operated pieces of equipment as well as to conveyors or transfer systems.

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