F I N A L R E P O R T

THE DEVELOPMENT OF A SINGLE CHANNEL BELT CONVEYOR SYSTEM FOR THE INDIANAPOLIS AIR ROUTE TRAFFIC CONTROL CENTER

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November 1959

TDR-416

NATIONAL AVIATION
FACILITIES EXPERIMENTAL CENTER
Atlantic City, New Jersey

FEDERAL AVIATION AGENCY
National Aviation Facilities Experimental Center
Atlantic City, New Jersey

November 4, 1959

RD-441:AWG

Director
Bureau of Research and Development
Federal Aviation Agency
Washington 25, D. C.

Subject: Final Report on Technical Development Center Task Assignment No. 59-730, Titled "The Development of a Single Channel Belt Conveyor System for the Indianapolis Air Route Traffic Control Center"

Dear Sir:

The Director of the Technical Development Center assigned the Navigation Aids Evaluation Division the task of developing a single channel belt conveyor for the Indianapolis, Indiana, Air Route Traffic Control (ARTC) Center. To accomplish this task the facilities of the Technical Development Center and Indianapolis ARTC Center were utilized.

All development work was performed at the Technical Development Center, Indianapolis, Indiana.

The Final Technical Development Center Report, titled "The Development of a Single Channel Belt Conveyor System for the Indianapolis Air Route Traffic Control Center," is herewith enclosed.

Sincerely,

Wm S Cowart Jr

William S. Cowart, Jr.
Director

Enclosure - 1

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Director (5 Copies)
Development Division (5 Copies)
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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

ABSTRACT

The development and installation of the single-channel belt conveyors were made specifically for providing means of transporting strip holders containing flight data from the computer room to an appropriate control position in the Indianapolis Air Route Traffic Control Center operations room.

It is believed that other systems, such as the wide channelized belt, have possibilities and deserve consideration where there is sufficient space and the arrangement permits such an installation.

PURPOSE

The purpose of this task was to develop a usable, single-channel belt conveyor suitable for transporting strip holders containing flight data from the computer room to the appropriate control positions in the Indianapolis Air Route Traffic Control Center operations room.

SUMMARY

This report describes the testing, design, installation, and operation of the single-channel belt conveyors in the Indianapolis Air Route Traffic Control Center. These conveyors are used for transporting strip holders containing flight data from the computer room to appropriate control positions in the Center operations room. The conveyor channels are fabricated of stainless steel, except for belts and accessories, and are chain-driven at belt speeds of approximately 166 linear feet per minute.

INTRODUCTION

The Indianapolis Air Route Traffic Control (ARTC) Center was equipped with the IBM 650/RAMAC computer on July 3, 1958. Prior to the installation of the computer, all flight data and strips were processed manually. Manual preparation of strips required per flight is four, requiring between 2 to 4 minutes. The time will vary according to the complexity of the flight and the number of interruptions that may occur.

The introduction of the computer has relieved the controller from a large part of the clerical-type work so that he may devote his entire attention to his primary function of traffic control. The computer not only has relieved the controller workload, but has increased the capacity of the system by processing the flight data and printing the necessary strips more rapidly. As many as 50 strips a minute can be printed by the IBM 407 printer.

DISCUSSION

a. Environment: With any new in-service improvement, certain problems usually are introduced. In this case, the size and complexity of the computer system required that it be located in quarters separate from the control room. Although these quarters physically were adjacent to the control room, the problem of delivering the computer-prepared flight data strips to the appropriate control position was increased.

Prior to the installation of the conveyors, a number of people were assigned to the computer section to serve as runners or delivery boys. This system, although reliable, required at least three persons per shift. Even the most efficient runner required considerable time to pick up strips in the computer room and deliver them to the appropriate control position and return to repeat the cycle. While several flight plans may be delivered by one runner at a time, the average delivery time required per flight plan was 1 minute since the nearest position was located approximately 25 feet away. The physical layout of the Indianapolis ARTC Center and associated computer room requires that a runner traverse a one-way distance of nearly 90 feet to deliver a strip to the sector farthest from the computer room.

The Indianapolis Center quarters are located in a portion of a semipermanent-type single-story building. That portion which the center occupies is approximately 44 feet wide and 50 feet long, with ceilings 9 feet high.

The length of the room is oriented east and west. On the north side of these quarters, in a separate room, is the computer. The equipment layout in the Center consists of two rows of A-3 flight progress boards. The rows of boards also are oriented east and west. The south row of flight progress boards is positioned 4 feet from the south wall. There is approximately 24 feet between the rows, leaving 10 feet between the rear side of the north row and the partition separating the Center quarters from the computer room. There also is a short row of boards, consisting of two sectors, aligned along the east wall of the center. The location from the high-altitude sector is between the north and south rows of flight progress boards. It covers approximately 48 square feet, being 12 feet long and 4 feet wide. Located at the west end of this room is the supervisor's position.

Due to the limitations imposed by this layout and the limited space below the low ceilings, a single-channel system was the only choice which was believed to be feasible. Other methods which received serious consideration were a pneumatic tube, an overhead trolley with suspended basket utilizing electronic switching devices for proper sector selection, and wide channelized belts. Each of the systems, including the single channel, was thoroughly investigated with regard to cost, ease of installation, adaptability to the environment, operation, maintenance, and operating noise level.

b. Single-Channel Prototypes and Tests: The first prototype single-channel conveyor was built and installed in the center in the summer of 1958. This conveyor was fabricated from aluminum U-channel. The delivery channel was 2 1/2 inches wide and 1 1/2 inches deep. The belt return channel, 2 1/2 inches wide and 1/2-inch deep, was Heli arc-welded to the underneath side of the delivery channel. The length of this conveyor was 48 feet. It was supported 4 inches below the ceiling by 1/2-inch steel rods. It was believed that by anodizing the aluminum channel of this conveyor, the wearing quality would be increased; however, after one week in operation, the aluminum channel began to wear on the bed surface of the channel creating a soot-like residue which coated the belt, strip holders, and finally reached an accumulation of sufficient quantity to filter down on persons and objects beneath. Since no reasonable method for surface-treating the aluminum was found that would retard the wearing characteristic, it was decided to try a different type of material.

The second conveyor, patterned after the first one, was made of stainless steel. The method used in fabrication was identical, and the channel dimensions were the same except for the length. This conveyor was 32.5 feet in length. There was considerable improvement in the wearing quality of the stainless steel as opposed to the aluminum; however, there were definite indications that a different type of belting was necessary. Sturdier bearing and pulleys were needed to produce a quieter operation. To reduce slippage between the belts and drive pulley, a coating of hard rubber or other suitable material needed to be applied to the face of the drive pulley. In addition, there were indications that a deeper belt return channel was needed, as well as smoother joints between sections of the conveyor to reduce belt wear.

To determine appropriate belt speeds and the amount or degree of incline that could be tolerated and still maintain efficiency and reliability, a number of tests were made using both the aluminum strip holders and the much lighter nylon holders. Since it was believed that the nylon holders would replace the aluminum holders, no tests for the aluminum holder are listed since results obtained with the nylon holders would apply equally well to the metal holders.

By changing sprocket ratios, it was possible to test varying speed ranges from 131 to 555 linear feet per minute (fpm). The higher linear belt speeds presented the greatest problem and consumed most of the test time. Another problem was the resolution of the incline angle in the first section of the conveyor. This first section, 9 feet in length, was joined to the horizontal section via a 24-inch-long noseover section, adjustable from zero to 35°. The length of the first section was standardized at 9 feet because of the necessity of reaching maximum height as rapidly as possible to allow sufficient head clearance for personnel operating the "FLIDAP" positions in the area between the north row of flight progress boards and the partitions separating the computer room from the operations room (see Fig. 1).

To arrive at optimum belt speed and incline angle of this first section, it was necessary to establish a working level for loading the conveyors. The position of the computer equipment and its relationship to the conveyors plus subjective opinions of those persons assigned to operate the equipment established that: (1) the conveyors, in this instance, be loaded from a standing position; and (2) the height of the loading zone should be 54 inches from the floor. This height compares to the chest height measurement for the average man 5 feet 8 inches tall; therefore, the incline angle, the maximum that would be required in this installation, was determined to be 31°.

With the first section of the conveyor inclined at 31°, and a belt speed of 131 linear fpm, the nylon holders adhered to the belt with sufficient friction. As the belt speeds were increased in increments, using speeds of 147, 276, 396, and 555 fpm with the incline angle remaining the same, slippage began occurring with a few of the holders at a belt speed of 276 fpm. Speeds above 276 fpm were too great for the holders to adhere to the belt. In order to obtain usable higher speeds, the angle of incline was decreased by raising the height of the loading end of the conveyor from 54 inches to 59 inches. This new angle of 25° permitted a belt speed of 396 fpm before objectionable slippage occurred. A decrease in incline angle to 22° which resulted in a loading height of 64 inches, also was tested. The holders adhered to the belt at this setting up to an estimated belt speed of 450 fpm. Above 450 fpm, the slippage was too great, although some holders did stick long enough to reach the horizontal section, in which case they reached the full speed of the belt. However, when holders adhered to the belt at this speed, they were delivered to the receiving bin with such force that controllers received a rather severe bump on the hands if they were in the process of removing holders from the receiving bin. Some holders passed completely through the bin onto the floor.

These tests result in a selection of a belt speed of 396 fpm and incline angle of 25°. It was believed that this could be done satisfactorily considering the fact that a "Ruff-Top" belt was to be used and that a 59-inch working level would not be objectionable.

c. <u>Final Design</u>: On September 3, 1958, Contract No. C13ca-680, was issued for the construction of eight single-channel conveyors. On January 7, 1959, the original contract was amended for five additional conveyors, making a total of 13 single-channel conveyors for the Indianapolis ARTC Center. Eight of the conveyors were delivered, installed, and placed in operation in January 1959. The remaining five conveyors were delivered and became operational in April 1959. Two minor problems developed after the first eight conveyors became operational:

1. Four of the longest conveyors, in excess of 50 feet, did not have motors of sufficient power for continuous operation. This was corrected by replacing the 1/3-horsepower ratio motor with one of 1/2-horsepower.

2. The designed linear belt speed of 396 fpm was found to be too fast. The speed, plus the "Ruff-Top" belt, was removing the strip from the holder. To overcome this problem, the belt speed was reduced to approximately 166 fpm by changing sprocket ratios.

Neither of these two problems had occurred during the test of the prototype models.

d. Motors: The motors for the conveyors, both prototype and production models, are Boston Ratiomotors, Model M113-10EU, 1/3-horsepower, 220/440 VAC, three-phase. The motor input speed is 1750 rpm, and the output speed is 175 rpm. The output torque is 100 inch-pounds and the output horsepower is .28.

From test results, it was determined that the 1/3-horsepower ratiomotors would not operate continuously driving a belt conveyor in excess of 40 feet in length. On belts in excess of 40 feet in length, the load on the motor was 3/4-ampere. Any temperature rise in the motor tripped the protection circuit, shutting down the motor. To overcome this, larger motors of 1/2-horsepower were substituted on the four conveyors that were in excess of 40 feet. The larger motors are Boston Ratiomotors, Model M113-FU, 1/2-horsepower, 220/400 VAC, three-phase. The input and output speeds were identical to the 1/3-horsepower motor. The output torque was increased to 180 inch-pounds and the output horsepower to .50.

e. Sprocket and Chains: To obtain a belt speed of 396 fpm, a Boston sprocket, Type KSS20, having 20 teeth and a pitch diameter of 3.20 inches, was placed on the output shaft of the motor speed reducer. A Boston sprocket, Type KSS14, having 14 teeth and a pitch diameter of 2.25 inches, was connected to the bearing shaft of the drive pulley. The driven pulley is a Boston PCB-6 cast iron pulley having a 6-inch-diameter, 1.5-inch width, spoke style. A 3/32-inch layer of hard rubber was vulcanized to the outer face of the pulley. The connecting chain was a Boston roller chain, No. 48, of 1/2-pitch single. The roller diameter is .306 inch, width 1/2-inch, pin bearing area .032 inch, weighing .2 pound per foot, with an ultimate strength of 1,700 pounds. Approximately 56 inches of chain was required per conveyor.

f. Delivery Tubes and Receiving Bins: The method used to carry the strip holders from the discharge end of the conveyor to the appropriate position in the A-3 flight progress board was achieved quite simply. An adapter was used which permitted the attachment of a 4-inch OD "Flexflyte" flexible tube to the end of the conveyor (see Fig. 2), thence through the top of the flight progress board to a receiving bin in the 102A key panel position of the A-3 board. The 4-inch flexible tubing is of triple-ply construction. The inner surface consist of two layers of spirally wound Neoprene, each layer being .015-inch thick. Reinforcing the two-ply Neoprene is a galvanized steel wire which is applied spirally. The outer layer is made of Neoprene coated fiberglas. There is a Neoprene coated fiberglas cord applied to the outer surface in the same manner as the reinforcing wire. This cord tends to prevent bulging or separation of layers when the tube is flexed to its maximum.

This type of tubing and method of installation permits considerable latitude in locating the receiving bins with respect to the fixed end of the conveyor. Distances up to 3 feet either side of the conveyor may be obtained without changing the tube length. Greater distance may be achieved by installing a longer tube. The receiving bins were designed to fit into the 102A key panel space at the assistant controller's position. The width of the face place of the bin is 8 inches by 9 1/4 inches. In addition to a receiving area, this provides space for a 3-inch OD discharge chute for the disposal of used holders that are to be returned to the computer room via runners. The receiving portion of the bin is 5 inches wide, 6 inches high and 10 inches in depth. The bin is attached to the A-3 frame in the same manner as the 102A key panels and A/G equipment.

g. Belting: Belting used on the aluminum prototype conveyor was a laminate consisting of seven layers of fabric bound together with a rubber or synthetic-type material. The transporting surface of this belt had a texture comparable to a very fine sandpaper. This roughness was sufficient to give adequate friction between the belt and the drive pulley. The test belt was 7/32-inch thick, 2 inches wide, and of sufficient length to transport strip holders a distance of approximately 55 feet.

To splice this belt requires some skill on the part of a mechanic or technician. It was necessary to separate the layers on each of the two ends, using caution to avoid damage to the fabric. With the layers separated, the next step is to trim each layer in the manner of steps, the thread of each step being 3/4-inch. Each end of the belt must be trimmed in the same manner except that one end must be measured and cut precisely to insure a perfect joint. After preparing the belt as described, a coating of contact cement is applied to each layer of each end of the belt. The ends are joined and clamped, allowing the clamps to remain until the cement has thoroughly dried.

This splicing method proved to be satisfactory, although the seven-layer belt itself proved to be unsatisfactory because:

1. The smooth surface of this belt was not considered adequate for transporting the nylon holders at a desirable incline angle. At angles of 22° or greater, a slippage of the holders was objectionable. To achieve an angle of less than 22°, it would have been necessary to raise the loading end above 59 inches.

2. The thickness of the seven-ply belt was considered to be excessive for the workload demanded.

3. The short radius on the pulleys created stresses on the splice which in time tended to loosen it, necessitating frequent repairs. There was no decernible damage in evidence to the belt other than the splice due to the short radius over the pulleys.

The "Ruff-Top" belt used on the production units is three-ply, having a Neoprene-impregnated cord under surface and a solid white latex rubber top layer. The top surface has a pebble-like texture with irregular projections extending above the surface approximately 1/16 inch. The three-ply is 5/32-inch thick and 1 3/8 inches wide. This belt is very flexible and adaptable to operation over radii as small as 2 inches. The rough surface of this belt permitted greater belt speeds and incline angle up to 31°. Splicing of this belt was accomplished with a 5/16-inch double-O alligator clip, which is easily installed on the belt. To apply the clip, it was necessary to remove the top Neoprene layer from the belt about 3/16-inch from the ends, leaving the Neoprene-impregnated cord exposed. The clips are clamped to the exposed ends and joined by means of an appropriate length of steel wire. This resultant splice resembles a small piano hinge. It must be noted that this belt was susceptible to initial stretching, which required a new splice after a run-in period.

CONCLUSIONS

The production model conveyors have been in service approximately one month. During this period, the one breakdown occurred when an improperly applied metal splice pulled out, resulting in belt separation.

The "Ruff-Top" three-ply belt has proven to be adequate for transporting the strip holders at an incline angle of 31° and a belt speed of 166 linear feet per minute.

The stainless channel has shown no appreciable wear. Its operation does not cause dirt to fall onto working surfaces or persons below.

The smooth machined joints have reduced belt wear to a minimum.

The 1/3-horsepower motors are adequate for conveyors 40 feet in length or under. The 1/2-horsepower motor is adequate on lengths to 50 feet or more.

The sturdier bearing and pulley have resulted in a quieter running assembly. Facing the drive pulley with a vulcanized rubber coating has practically eliminated belt slippage.

RECOMMENDATIONS

The single-channel belt conveyor system is recommended for use where the environment is similar to that of Indianapolis.

It is believed other systems such as the wide channelized belt have possibilities and deserve consideration where there is sufficient space and the arrangement permits such an installation.

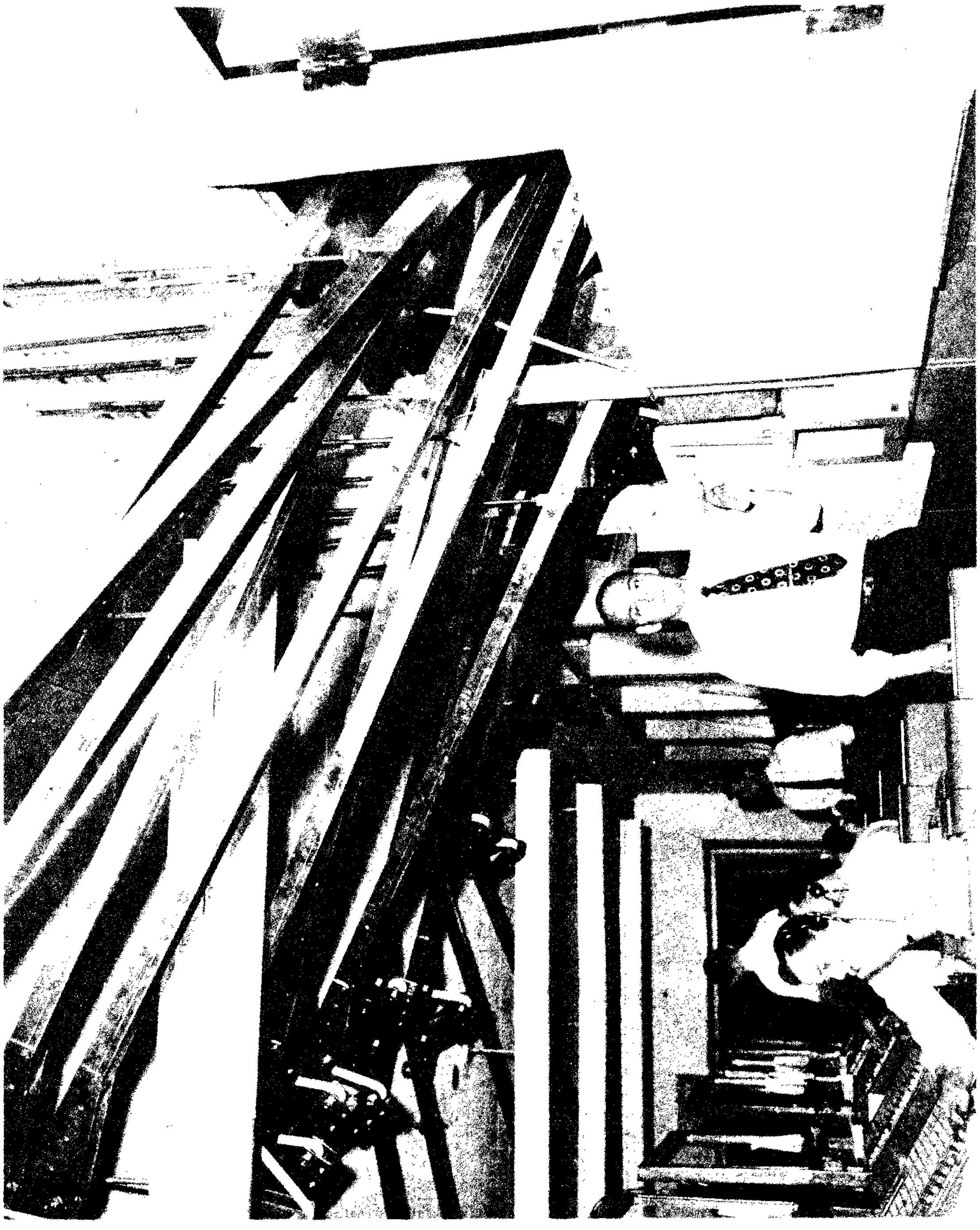
BIBLIOGRAPHY

1. Contract No. C13ca-680 - Construction of 13 Single-Channel Belt Conveyors for the Indianapolis Air Route Traffic Control Center.

APPENDIX

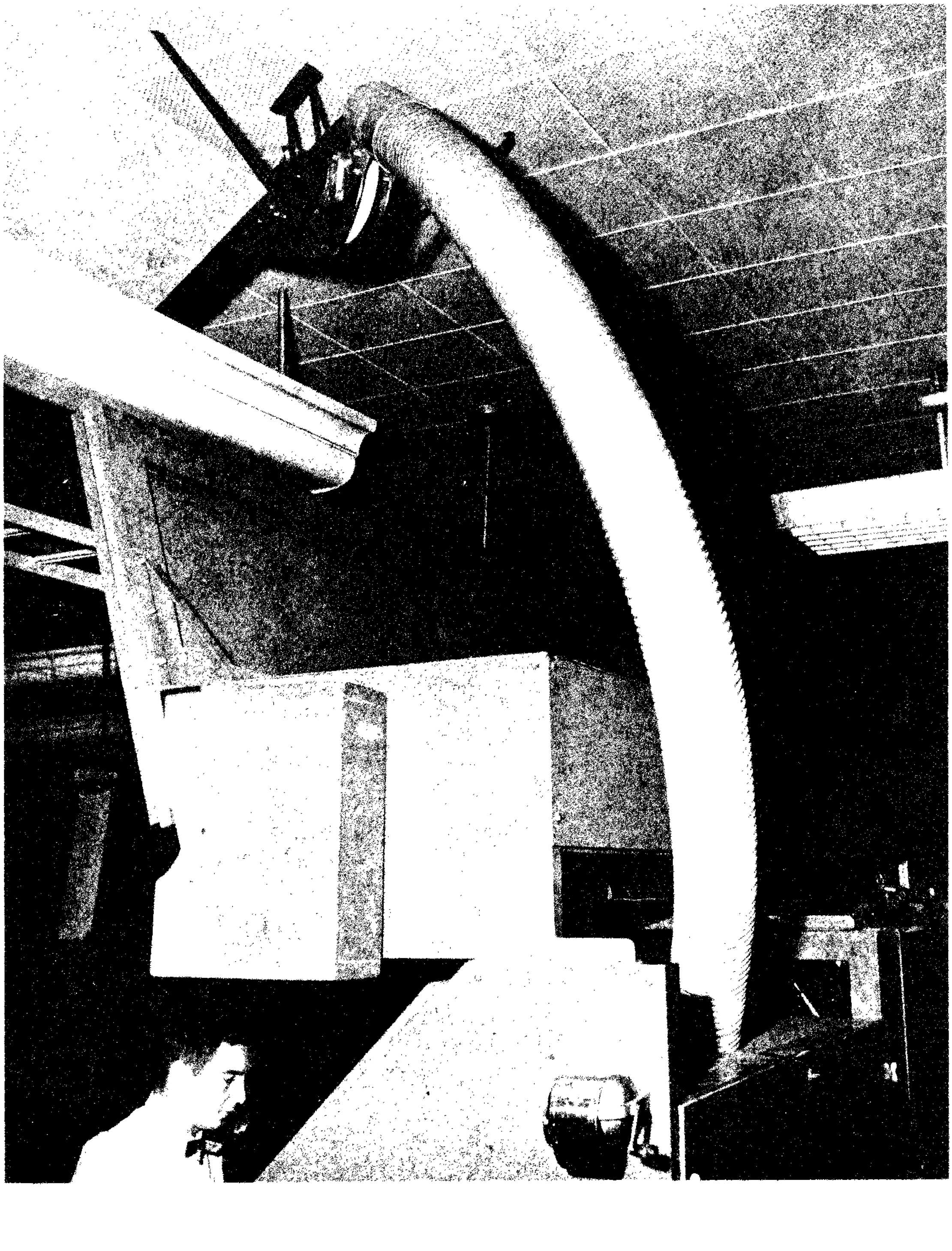
INSTALLATION PHOTOGRAPHS

FIGURES 1 AND 2



NINE FOOT INCLINE SECTION
SINGLE CHANNEL CONVEYOR
ARTC ROOM

FIG. I



BELT CONVEYOR–DISCHARGE END
AND TUBE ENTERING A-3
FLIGHT PROGRESS BOARD

Task No. 59–730

FIG. 2