EVALUATION OF AIRPORT SURFACE DETECTION EQUIPMENT MODEL AN/MPN-7 (XW-1)

PART II OPERATIONAL EVALUATION

By

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Technical Development Report No 176

CIVIL AERONAUTICS ADMINISTRATION
TECHNICAL DEVELOPMENT AND
EVALUATION CENTER
INDIANAPOLIS, INDIANA

November 1952

U S DEPARTMENT OF COMMERCE

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Manuscript received April 1952

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PART II

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SUMMARY

This report is the second of two reports which describe the evaluation tests on experimental airport surface detection equipment (ASDE), designated by the Department of the Air Force as Radar Set AN/MPN-7 (XW-1).

Through the use of controlled taxiing tests during which measurements in range and azimuth were made and through photographs and observation of the radar indicator during periods of good and adverse weather conditions, it was determined that (1) the target resolution of this radar is such that the majority of the surface traffic control functions can be performed safely and accurately, and (2) this radar presents an indication of runway configuration and detail which is adequate for the control of surface traffic under existing weather minimums

This radar was observed and operated during periods of varying kinds of precipitation Falling snow was not observed to affect the radar indication adversely, however, melting snow on the ground caused some deterioration of field detail Some methods of snow plowing resulted in false runway center-line indications Moderate rain showers caused a deterioration of detail both in the airport indication and in target quality

INTRODUCTION

One of the responsibilities of the airport traffic controller is directing aircraft movements within the boundaries of the landing area The taxi clearances that are issued to the various aircraft are formulated by the airport traffic controller with reference to what he sees on the airport and to the aircraft position reports that he receives. The trend to expand and increase the landing area at many of today's airports and the extremely large areas encompassed by many of our newer ones have made the airport traffic controller's job of seeing all of the landing area a very difficult one In addition, authorization has been granted at most airports for the operation of aircraft during weather conditions when the visibility is less than one mile Under these conditions, the controller can no longer rely upon his vision to ascertain the position of landing or taxiing aircraft on a large part of the airport It is also very difficult for the controller to observe the movement of aircraft or the position of parked aircraft on a large landing area during the hours of darkness Airports with heavy traffic present an even greater problem to the traffic controller and to the pilot in the form of numerous hangars, office buildings, vehicular ramp traffic, and congested parking areas In some cases these conditions result in inadequate taxi clearance information, aircraft delays, and damage to aircraft and equipment

At many airports, the approach ends of some of the runways are not discernible from the tower during restricted visibility conditions It is not possible for the controller to determine whether a take-off has commenced or whether the approach end of the instrument runway has been cleared by aircraft and vehicles. In these cases, it is necessary for the controller to wait for position reports before a take-off can be authorized

The communication contacts and delays are excessive whenever the airport traffic controller is unable to view the entire portion of the landing area The controller is not able to offer any assistance to taxiing aircraft or to foresee and prevent any possible ramp traffic conflictions This type of operation becomes hazardous during periods of restricted visibility, because the normal ground reference points are obliterated It is then doubly hard even for the pilot who is familiar with the landing area to determine his position on the airport, and one who is unfamiliar with the landing area may become hopelessly lost. As a result, all aircraft using the landing area are delayed, and, in some instances, an aircraft on the approach has had to take a wave-off at a critical part of the approach because the controller was not able to determine whether or not the landing runway had been cleared by the previous approach or by taxiing aircraft and ramp vehicles

One solution that has been proposed as a means of providing improved information to the control tower during periods of poor visibility is the use of a surveillance radar equipment of high accuracy and resolution

TABLE I

MEASUREMENTS MADE USING AIRCRAFT

Runway	No of Measurements	Average Distance Off Runway Center Line (feet)	Maximum Error (feet)
36	31	7	24
18	21	7	12
27	22	6	20
9	19	5	15
31	15	13	40*
13	9	14	40*
22	5	13	24*
4	4	20	35*

*These large maximum errors were recorded when snow was banked along Runways 31-13 and 22-4 See Fig 7

An ASDE developed originally for this purpose by Gilfillan Brothers, Incorporated, was modified at the Airborne Instruments Laboratory

The results of the technical evaluation of the modified equipment are included in a previous report [1] The evaluation work was conducted at the Civil Aeronautics Administration Technical Development and Evaluation Center under the sponsorship of the Air Navigation Development Board

Two locations were used during the operational test phase of the program the first at the Weir Cook Municipal Airport, Indianapolis, Indiana, and the second at the Wold-Chamberlain Municipal Airport, Minneapolis, Minnesota.

EVALUATION OBJECTIVES

The operational evaluation was conducted with regard to the following objectives in order to determine

1 If the equipment will enable a controller to see all of the landing, taxi, and parking areas

a Which runways, parking areas, and taxi strips are available for use

b Whether this radar will present adequate information to the ground controller to enable him to control surface traffic during adverse weather conditions, snow, high snow embankments adjacent to the runways and taxi strips, and precipitation interference

2 If the target resolution is such that all surface control functions are performed safely and accurately on all portions of the airport.

3. The density of traffic that can be handled by a controller referring to this radar equipment

4. The work load imposed on the controller who is controlling surface traffic with this radar

5. What control procedures are most adaptable for ASDE control functions.

RESULTS OF TESTS AT INDIANAPOLIS

The first portions of the technical evaluation were conducted at Weir Cook Municipal Airport at Indianapolis, Indiana, with the equipment positioned on the west side of the airport approximately 600 feet west of the mid-point of the north-south runway The antenna was mounted on top of the experimental trailer during the first part of the evaluation, and antenna rotational speeds of 30 and 60 revolutions per minute

[1]Blount, Kades, Kay, and McCormick, "Evaluation of Airport Surface Detection Equipment Model AN/MPN-7 (XW-1), Part I, Technical Evaluation," CAA Technical Development Report No 175, June 1952

TABLE II

MEASUREMENTS MADE USING TRUCK

Runway	No of Measurements	Average Distance Off Runway Center Line (feet)	Maximum Error (feet)
36	37	5	13
18	18	4	11
27	46	6	29
9	50	2	10
31	59	7	24
13	47	6	22

(rpm) were used Operationally, it was possible to see only the north-south runway in its entirety and the west end of the east-west runway Aircraft were observed over all portions of the airport

Due to the topography, the east side and center portions of the airport are approximately eight feet higher than the west side Inasmuch as radar transmission and reception depend upon line-of-sight conditions, this elevation resulted in a considerable amount of blanking on the indicator tube of the portions of the field east of the center of the airport. An operational evaluation of the ASDE was not attempted at the time because all the runways and intersections were not visible on the radar indicator tube It was noted that during the first tests with the antenna rotational speed at 30 rpm, moving aircraft images on the indicator tube were widely separated and under some conditions were not easily distinguished When the antenna rotational speed was increased to 60 rpm, these images were closer together and the movement and direction of the images were more easily followed.

In order to proceed on an operational evaluation, it was necessary either to move the equipment to the center portion of the airport or to mount the antenna on a tower To determine the effect of raising the height of the antenna at this first test position, a 30-foot radar tower was obtained on a loan basis from Rome Air Development Center The antenna was placed on the tower adjacent to the ASDE trailer With the antenna in this position, the runway configuration could be ascertained from the west edge to the center of the field The intersections and ramp areas on the east half of the airport were not visible, but aircraft targets were observed over the entire airport

Panel trucks, each equipped with a two-way radio, were used in the tests at the beginning of the operational evaluation This procedure enabled controllers to become familiar with the type of radar information displayed and to develop a technique of control In later operational tests a Piper Pacer equipped with a magnetic compass, a fully instrumented DC-3, and a Boeing 247-D were used All taxi runs for operational testing were conducted on the west half of the airport during the time that the antenna was located on the 30-foot tower Before the completion of the Indianapolis phase of the operational evaluation program, the trailer was moved to the center of the airport and the antenna was placed on top of it With the equipment in this location, several tests were conducted to determine target resolution characteristics of the equipment

During the portion of the evaluation conducted at Indianapolis, measurements were made to determine the accuracy with which a controller is able to provide guidance for an aircraft or vehicle along the center line of the runways and taxi strips A truck and an aircraft were used for these tests The pilot or driver receiving radar guidance estimated the distance off the center line of the runway every 500 feet, using the known dimensions of the concrete sections of the runway as the basis for estimating these distances The results are presented in Tables I and II

The pilot or driver normally adhered to the taxi headings issued by the controller. On occasions, however, the pilot or driver deliberately turned to a heading which took

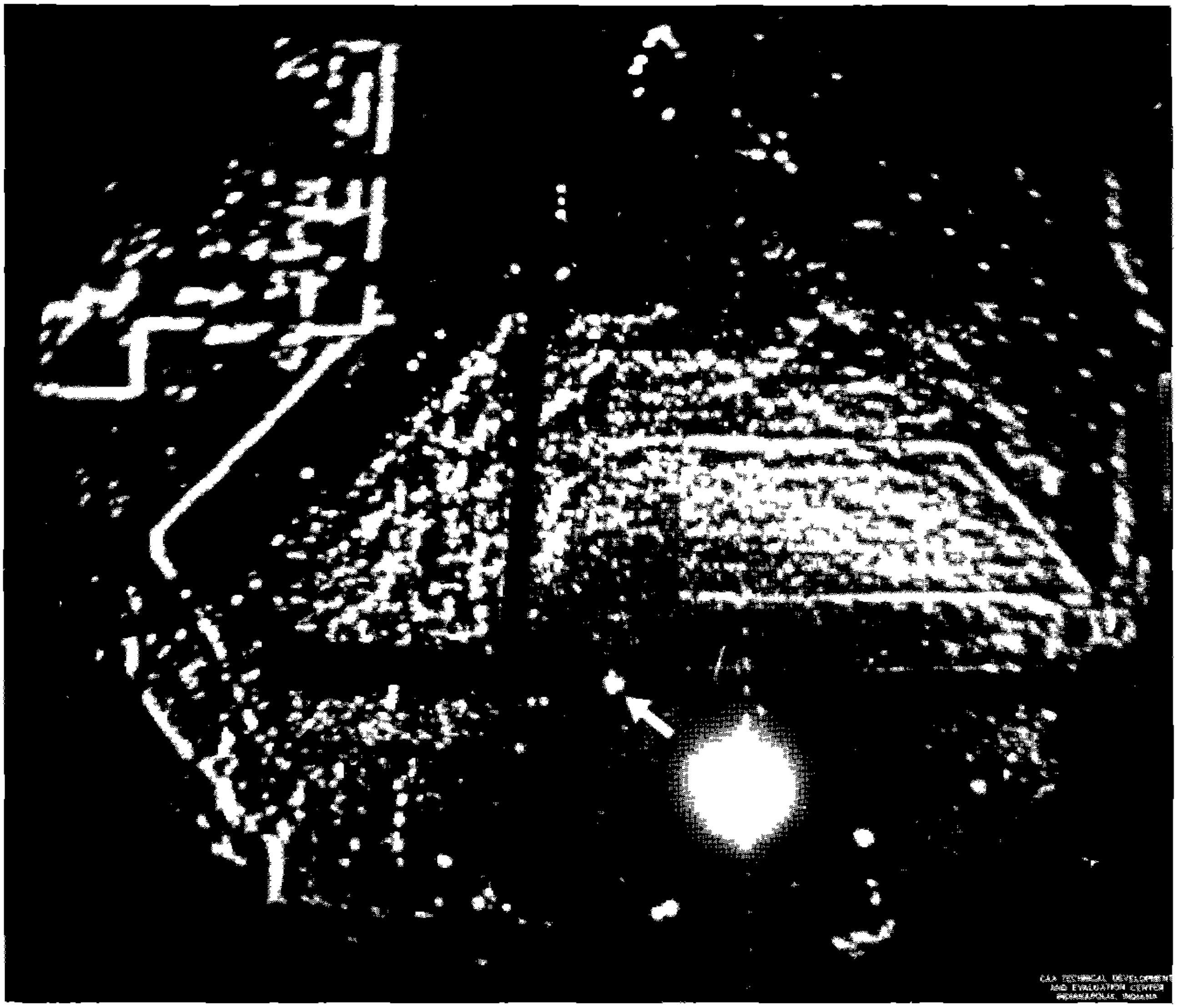

Fig 1 A Photograph of the Radar Indicator Taken During a Brief Heavy Snowfall (Visibility 1/2 Mile)

the vehicle or aircraft off course at a gradual rate in order to determine approximately how far the target would progress on either side of the center line before the controller could determine that fact It was found that the controller could determine that the target was off course after the aircraft or vehicle had moved approximately 12 feet to either side of the center This figure (12 feet) remained the same at all distances from the antenna

Some of these accuracy tests at Indianapolis were conducted during a brief heavy snowfall The visibility at the time was less than one-half mile, and the pilot of the aircraft was unable to taxi his aircraft at a satisfactory rate of speed because of an accumulation of snow on the windshield The aircraft was nevertheless guided without difficulty along the centers of two different runways and onto a taxi strip by instructions from the ASDE operator The falling snow had little effect on the radar presentation Fig. 1 shows the radar indicator during this snowfall

Though falling snow did not affect the radar picture operationally, it was found that as several inches of snow covered the ground most of the detail of the runway and taxi strip was obliterated on the radar indicator The radar return from the Bartow runway lights on Runway 4 at Indianapolis remained

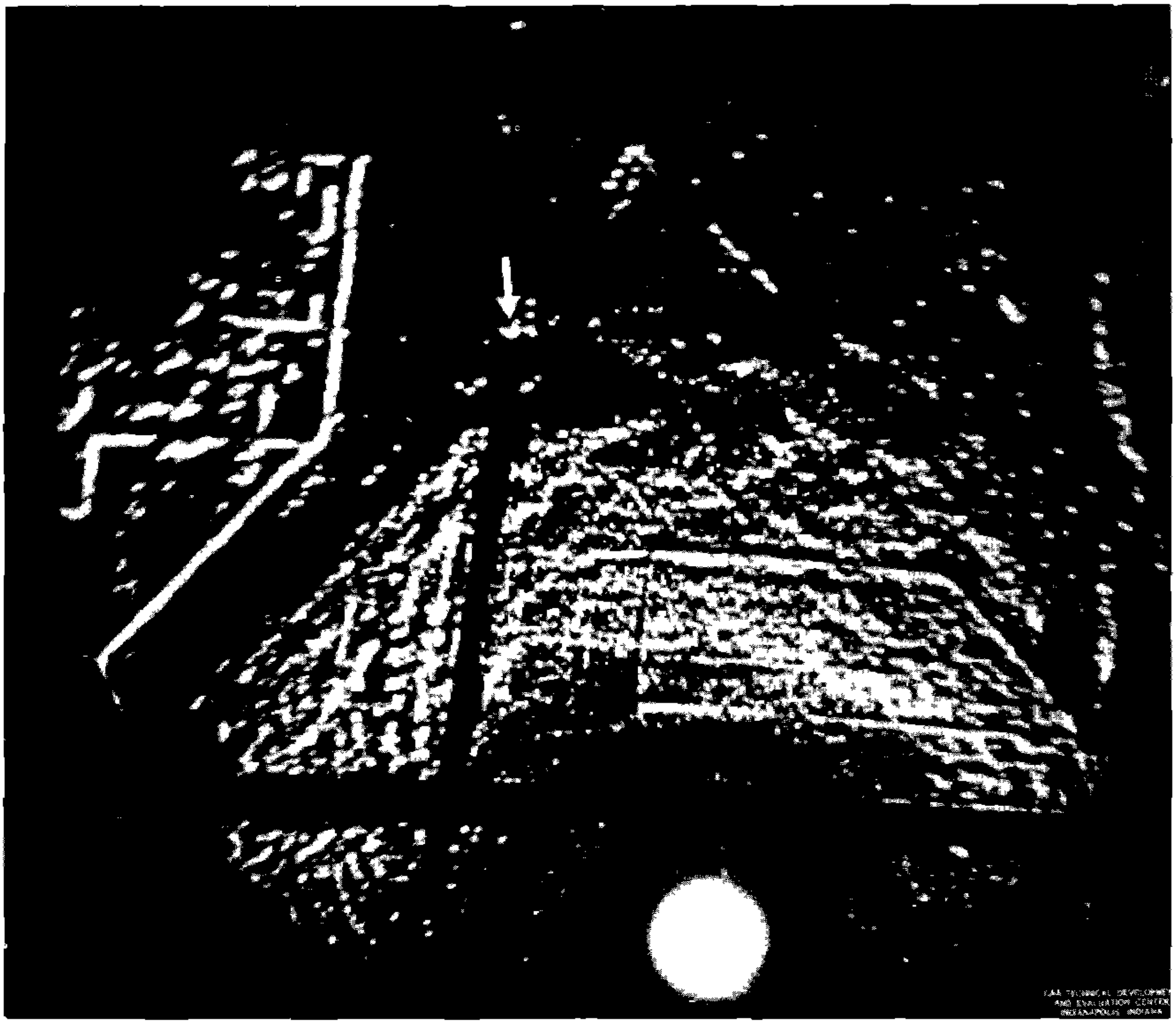

Fig 2 A Photograph of the Radar Indicator Taken During a Light Rain Shower

visible in all precipitation conditions observed and during times that the ground was covered by several inches of snow The Bartow runway lights on Runway 4 were approximately two feet above ground level. Flush type runway lighting was installed on all of the other runways The radar return from aircraft and vehicles was observed during all snow conditions Figs 2, 3, and 4 show the effect of rain showers of different intensities on the radar presentation. During very heavy rainfall none of the areas observed by radar, with the exception of Runway 4, were displayed in sufficient detail for control purposes

It is significant to note that the largest control errors, with regard to the controller's ability to keep a target in the center of a runway, were recorded at a time when there were snowbanks from one to four feet high along the edges of the runways. During this time, the controller consistently kept the aircraft being guided on the side of the runway nearest the antenna It is believed that the radar received the return signals from the sides of the snowbanks nearest the antenna giving the controller a false indication of runway width, as illustrated in Fig. 5 In most places the banks were higher than the runway lights, thereby eliminating the lights as an aid in outlining the runway This condition existed only on runways which ran perpendicular to the antenna

The above condition was not encountered during the work in Minneapolis even though there was considerably more snow It is

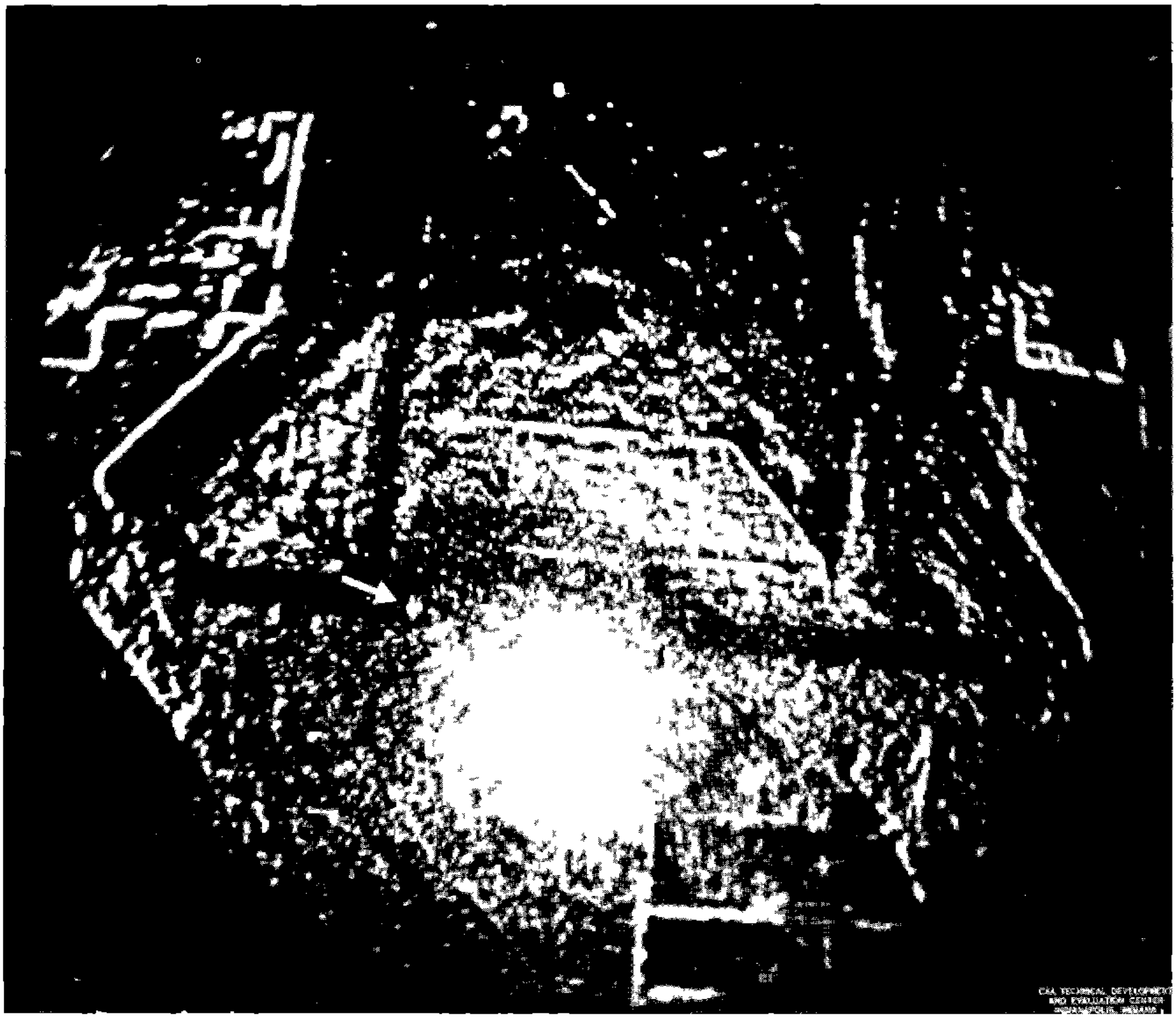

Fig 3 A Photograph of the Radar Indicator Taken During a Moderate Rain Shower

believed that there are two reasons for this (1) all runways at Minneapolis are equipped with runway lights which are approximately 24 inches above ground level, and (2) the method of snow removal is different from that at Indianapolis At Minneapolis the runways are first plowed starting at the center, and the snow is banked on both sides of the runways Immediately after the runways are plowed the snow blowers blow the snow many feet back from the runway edges, thus leaving the tops of the runway lights exposed Following this procedure, the snow is removed from around the runway lights for a distance of approximately 10 feet, leaving the lights entirely exposed and separated from the snowbanks Fig 6 shows the Minneapolis Airport when there were approximately 15 inches of snow on the ground and after the runways had been cleared.

After observing the radar presentation under many conditions, it was decided that it would not be practical to attempt to provide information to pilots to aid them in taxiing into, out of, or near congested areas, particularly parking areas which contain several aircraft It would also not be practical for the controller to furnish information for guiding the pilot along narrow taxi strips This is illustrated in Fig 7, which shows an

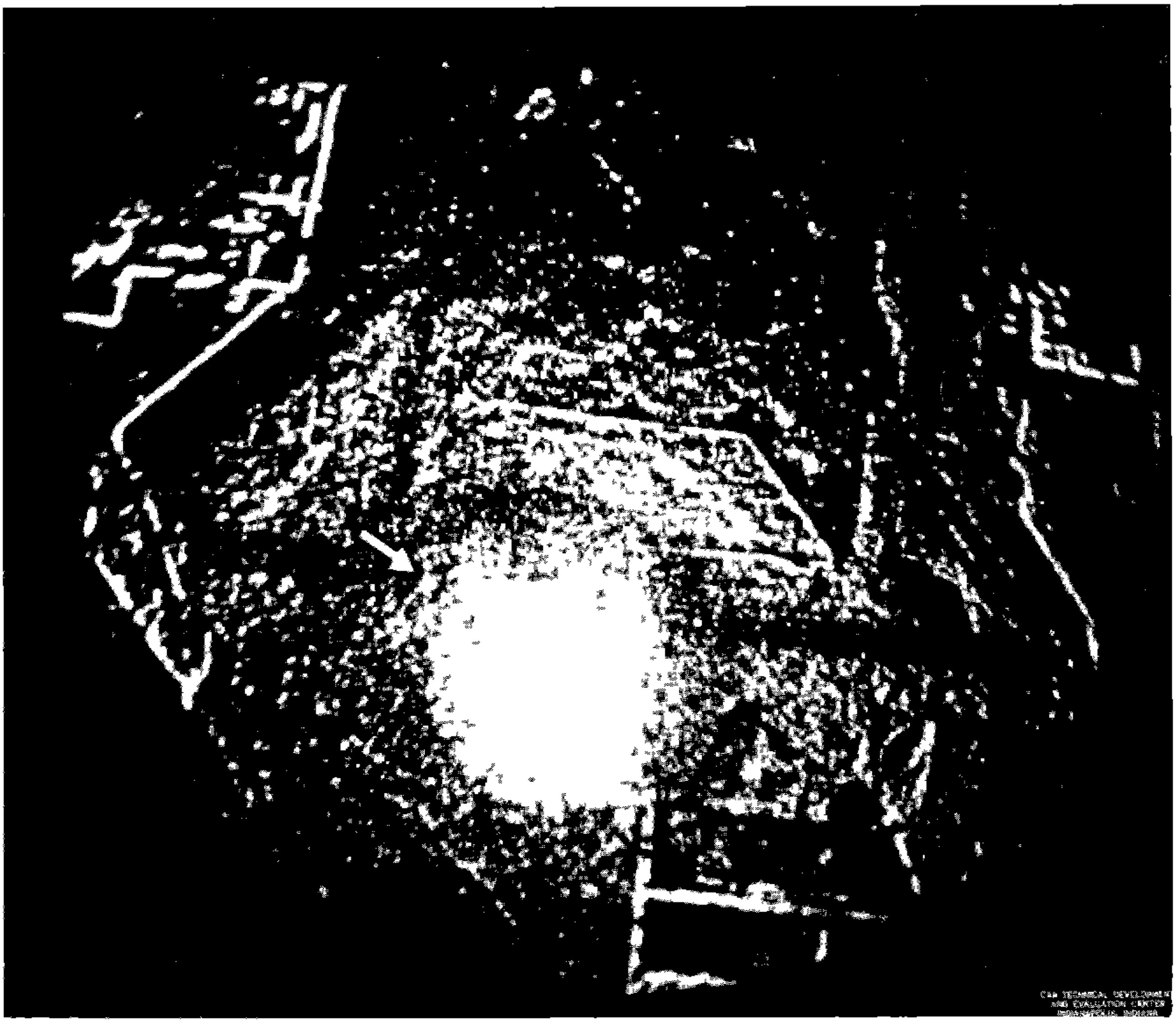

Fig 4 A Photograph of the Radar Indicator Taken During a Brief Heavy Rain Shower

aircraft taxiing near congested ramp areas Fig 8 shows that a Boeing Stratocruiser target appears as wide as a taxi strip 75 feet wide Fig 9A shows the apparent position of aircraft parked in several different parking areas at the Indianapolis airport For comparison, Fig 9B shows the actual position of the same parked aircraft on a drawing of the Indianapolis airport These figures indicate that it is not practical for the ground controller to use this model of the ASDE to aid the pilot in moving about a congested parking area or in determining if space is available in a parking area

Tests were conducted to determine if the resolution of the equipment is adequate for the control of opposite-direction traffic on runways It was determined that if the targets were small and compact, such as trucks or F-51 type aircraft, and if the runway is at least 100 feet wide, it might be possible to issue control instructions However, when larger aircraft were observed to be approaching each other from opposite directions, it was not possible to determine if there would be sufficient room for them to pass on the runways used during these tests The runways at Indianapolis are 104 feet wide with the exception of Runway 36, which is 150 feet wide Fig 10 reproduces the PPI display of two trucks approaching and passing each other while traveling in opposite

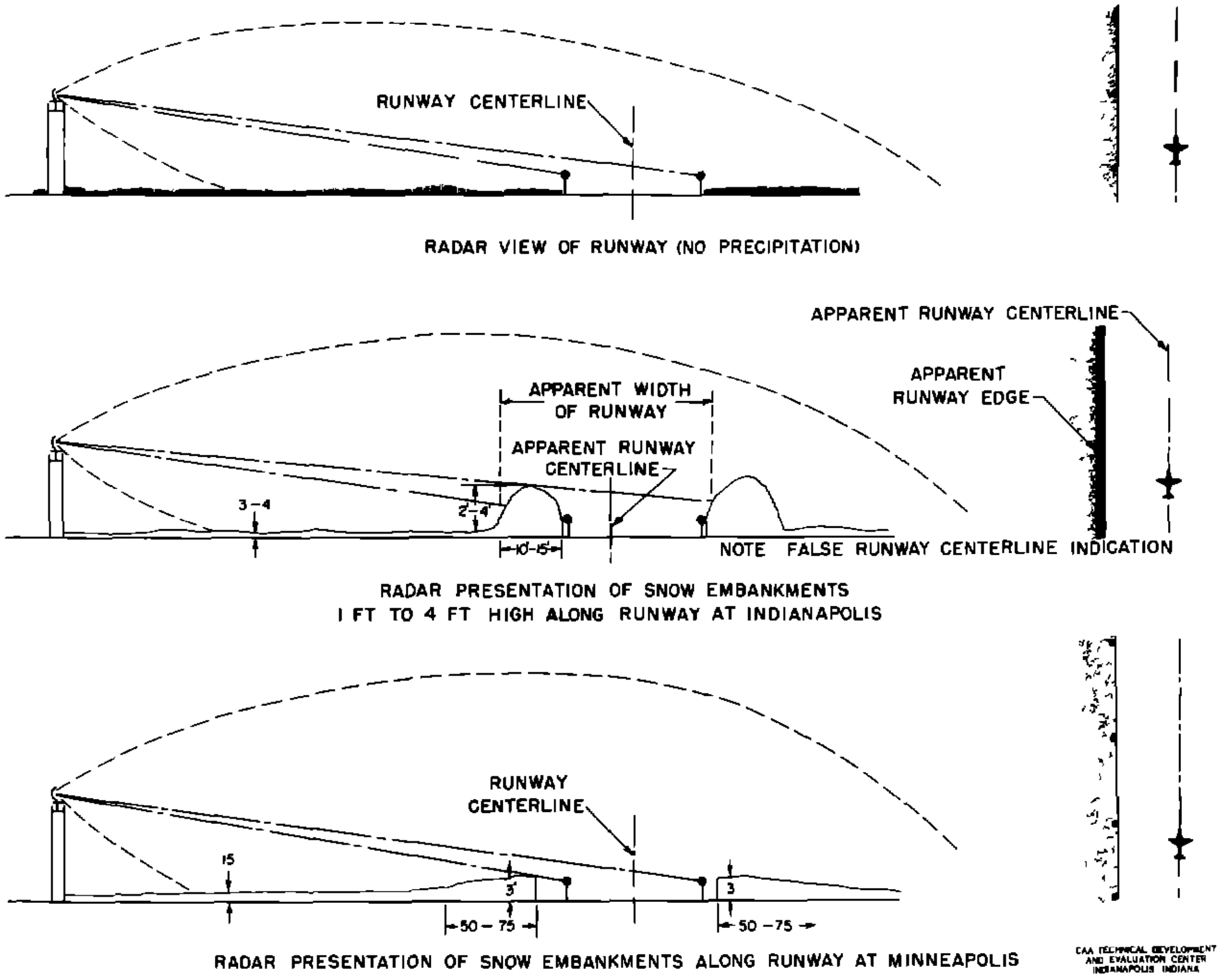

Fig 5

directions at distances of 500 and 2,000 feet from the antenna Fig. 11 shows a display during which two DC-3 type aircraft approach and pass each other on Runway 31 approximately 1,000 feet from the antenna, Fig 12 shows trucks in trail on Runway 4, and Fig 13 shows two DC-3 type aircraft in trail on Runway 31 The radar indication of seven aircraft of various types parked on a taxi strip in run-up position approximately 4,000 feet from the antenna is reproduced in Fig 14 These aircraft were parked 20 to 40 feet apart The photographs indicate the resolution qualities of this radar from the operational point of view

From the results of the operational tests, it appears that the use of the ASDE for ground control purposes does not require a change in the current rules and regulations governing the control of surface traffic. Standard radar phraseologies with respect to compass headings were found most adaptable when providing guidance for an aircraft or vehicle on a runway or wide taxi strip.

RESULTS OF TESTS AT MINNEAPOLIS

The ASDE was moved to the Wold-Chamberlain International Airport at Minneapolis during the last week in January 1952, where the second phase of the operational evaluation began early in February. The equipment was centrally located at the airport, and the antenna was again placed on top of the 30-foot tower The ASDE was integrated in the traffic control system, and the radar was evaluated with various kinds of aircraft in various weather conditions, including moderate snowfall, low visibility

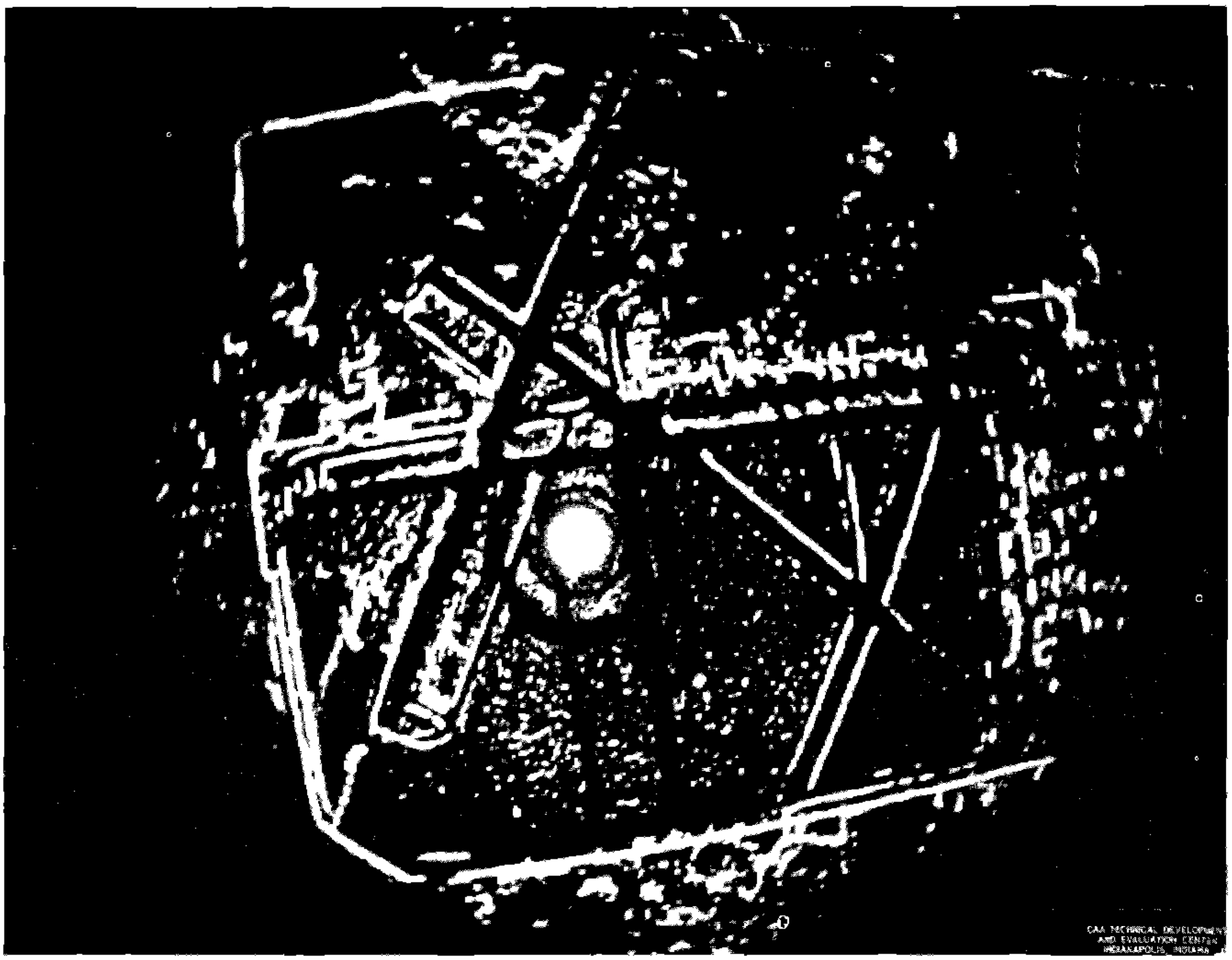

Fig. 6 A Photograph of the Radar Indicator at the Minneapolis Airport When There Were 15 Inches of Snow on the Ground and After the Runway Had Been Cleared

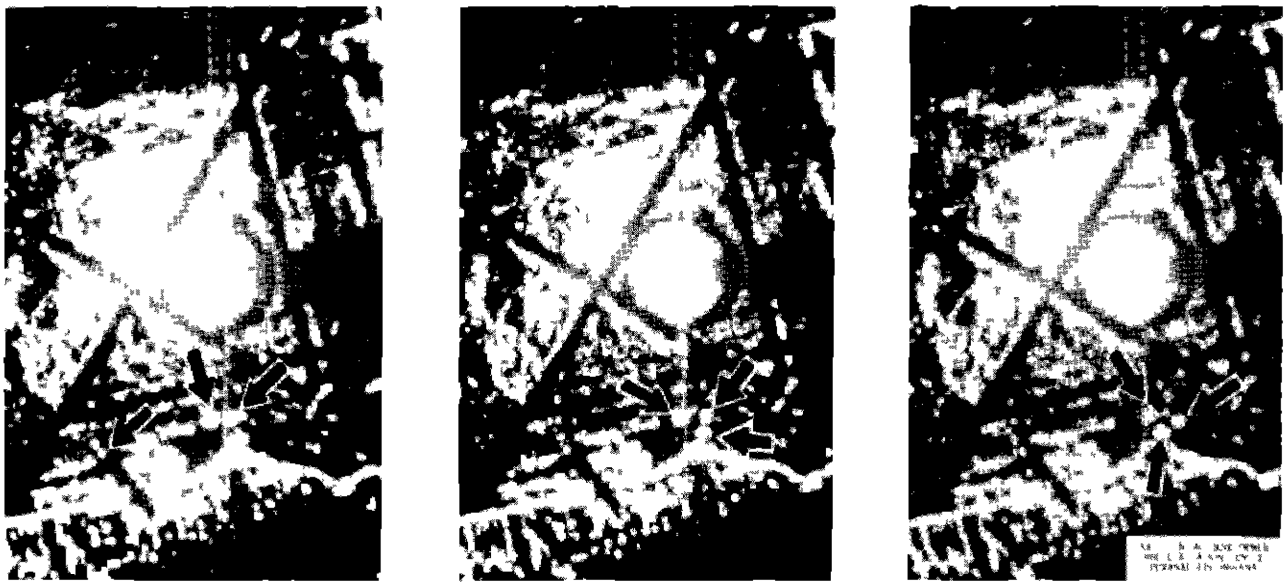

Fig. 7 Photographs of the Radar Indicator Showing Aircraft Taxiing Near Congested Ramp Areas at the Indianapolis Airport

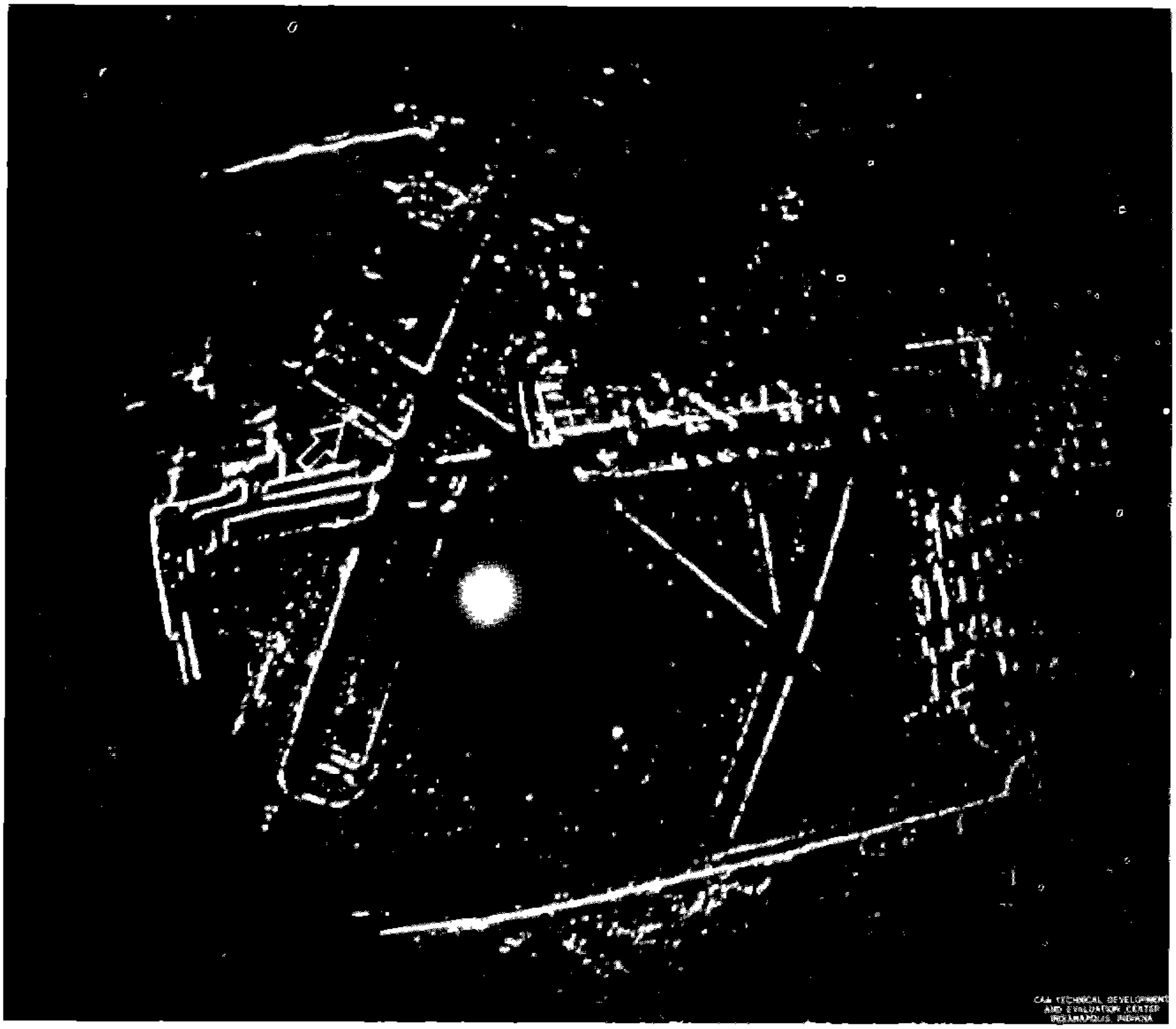

Fig 8 A Photograph of the Radar Indicator Showing How the Target Return of a Boeing Stratocruiser Completely Fills a 75-Foot Taxi Strip at the Minneapolis Airport

and ceilings, and high snow embankments near the runways With the exception of those conditions noted in a later portion of this report all of the runways, taxi strips, and parking areas were shown on the radar indicator at the Minneapolis airport Aircraft were observed and guided during periods of moderate snowfall, and precipitation interference was not observed For much of the time during the snowfall the visibility, as reported by the U S Weather Bureau, was variable from one-quarter to three-quarters of a mile Comparative photographs, Figs 15 and 16, taken while the snow was falling and when the weather was clear show that there is little change in the radar indication

Snow-removal procedures at the Minneapolis airport are well organized Snowplows push the snow out to the edge of the runways, and from that point the snow blowers blow it back several feet into the field area Small hand-operated snow blowers are used to clear the snow from the runway lights The resultant radar indication is a sharp outline of the runways, with the runway light targets visible along them False runway center-line indications, such as those received at the Indianapolis airport, were not observed at Minneapolis

The radar was observed during periods when the snow-removal equipment was in operation During this time the removal

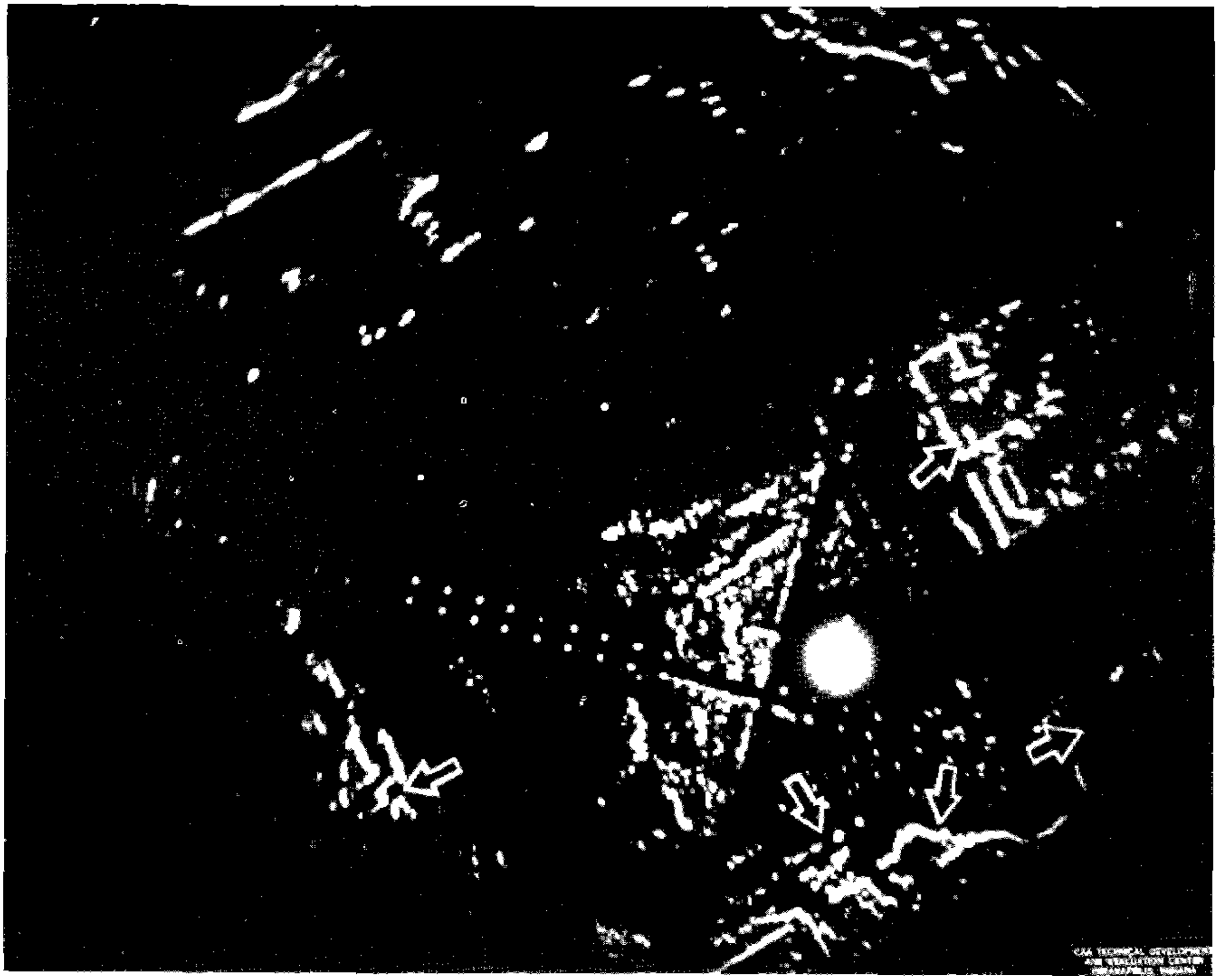

Fig. 9A A Photograph of the Radar Indicator Showing Aircraft Parked in Several Different Parking Areas at the Indianapolis Airport

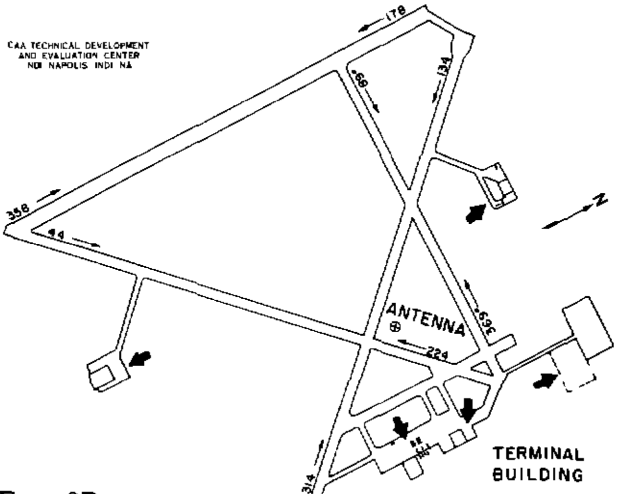

Fig. 9B
Position of Parked Aircraft Plotted on the Airport Map to Compare With Fig 9A

equipment, vehicular traffic, and some aircraft were observed in the vicinity of snow embankments of heights varying from 18 inches to 12 feet The targets from these vehicles and aircraft were not obliterated at any time in the vicinity of the highest snow embankments, and, though the vehicle targets became very small, it was possible to follow the progress of the target at all times Fig 17A shows the radar indication of a Bonanza airplane and other small aircraft passing behind 12-foot snow embankments near the south end of the main parking ramp, and Fig 17B shows a small panel truck passing the same point on the ramp

Aircraft and ground vehicles were observed and controlled on the two taxiways adjacent to the ASDE site The target returns did not bloom or change shape while airplanes were operating in proximity to the

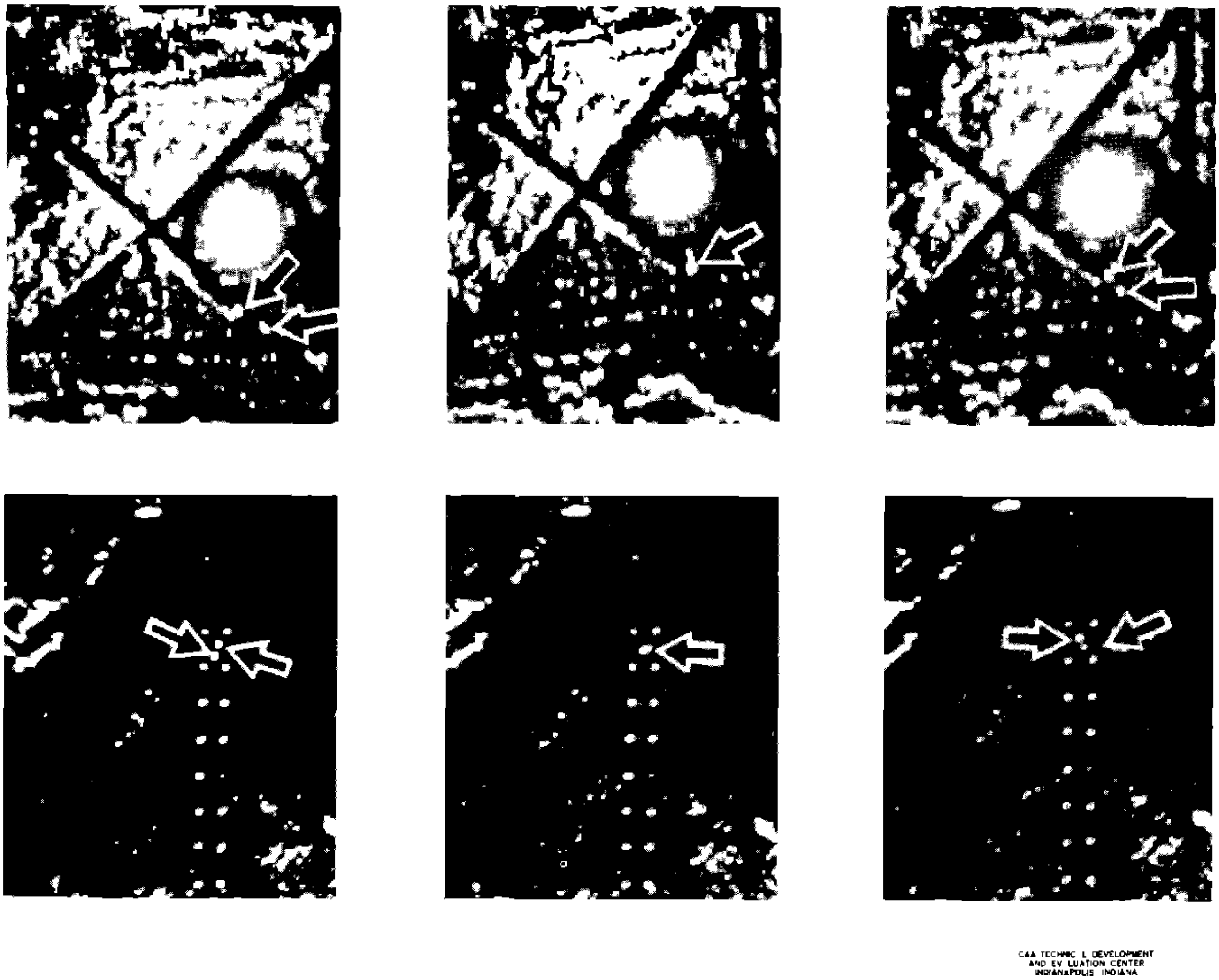

Fig. 10 Photographs of the Radar Indicator Showing Panel Trucks Approaching and Passing Each Other at Distances of 500 and 2000 Feet From the Antenna at the Indianapolis Airport

radar site Aircraft and vehicles operating in normal range from each other were resolved into two distinct targets at both minimum and maximum ranges from the antenna Fig 18 shows a DC-3 and an F-51 airplane proceeding east past the radar site and then north on the east taxi strip to take-off position at Runway 22

It is significant to note that a deterioration of airport detail was evident whenever the temperature at the surface of the snow was high enough to permit melting Concurrent with a dropping of the temperature and the freezing of surface snow and runway slush, an improvement was noted in the radar indication of airport detail The radar return from aircraft, vehicles, runway lights, and buildings was not affected during this time Fig 19 shows the radar indicator during the morning hours before the surface snow had begun to melt, during the day while the snow was melting, and during the late afternoon and evening when the snow and slush were freezing

It is the opinion of the traffic control personnel who observed and worked with this radar equipment that the density of traffic that could be handled by a controller referring solely to the ASDE for information would depend largely upon the kind of weather that was prevalent and the aircraft cockpit instrumentation Whenever the visibility is less than one-quarter mile and it is necessary for the controller to supply full radar guidance, it is believed that three aircraft with full cockpit instrumentation are the maximum number that can be safely controlled If it is necessary to issue full

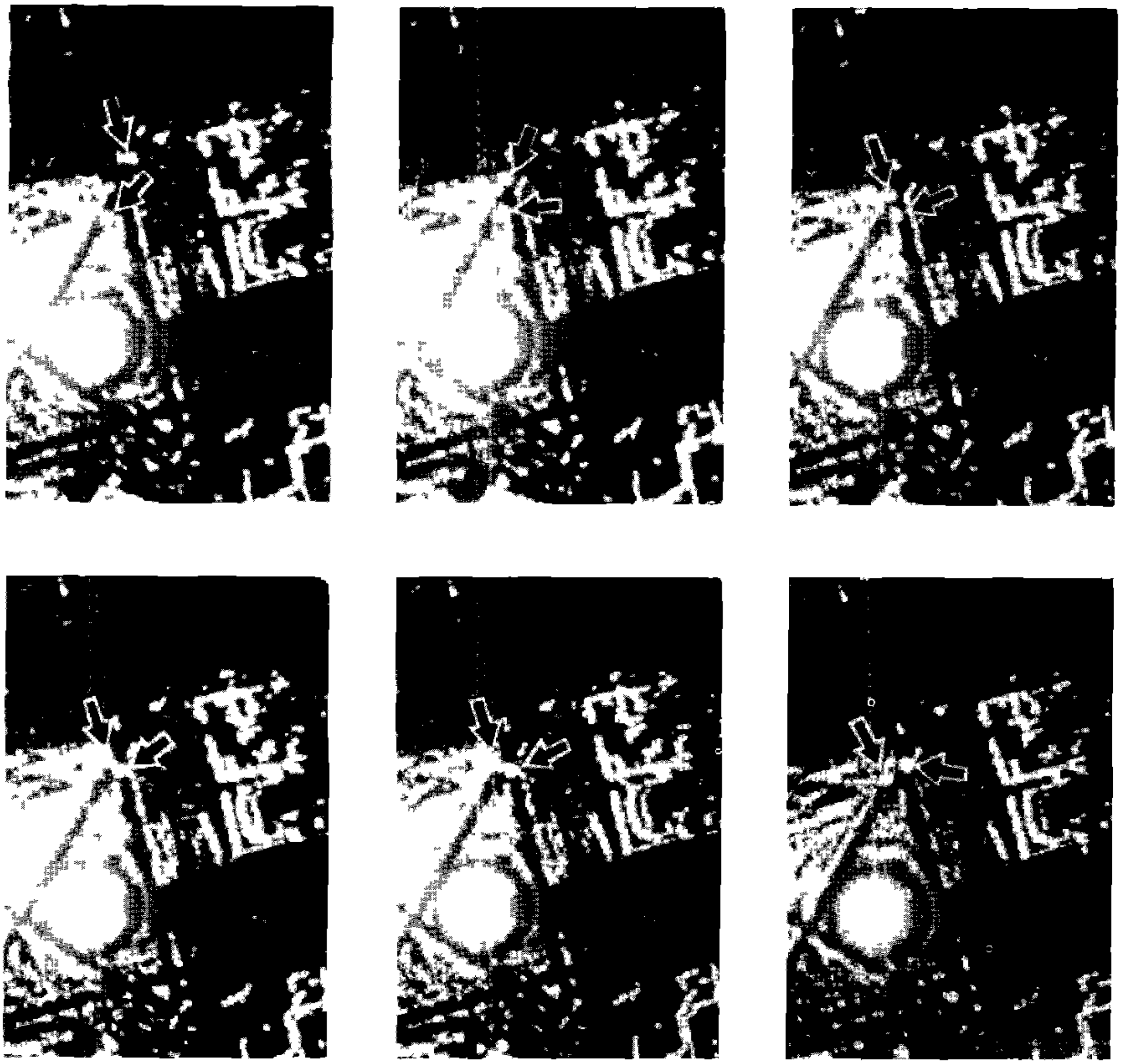

Fig 11 Photographs of the Radar Indicator Showing Aircraft Approaching and Passing Each Other on a Runway Approximately 1000 Feet From the Antenna at the Indianapolis Airport

guidance instructions to aircraft equipped only with magnetic compasses, it appears that two are the maximum number that can be controlled safely Additional attention and concentration are necessary in controlling aircraft equipped with magnetic compasses to assure proper headings and center-of-runway placement

CONCLUSIONS

The following conclusions regarding the operational use of the ASDE were reached as a result of this evaluation

1 Provided that the airport surface information is displayed on the ASDE indicator in sufficient detail, then the controller can

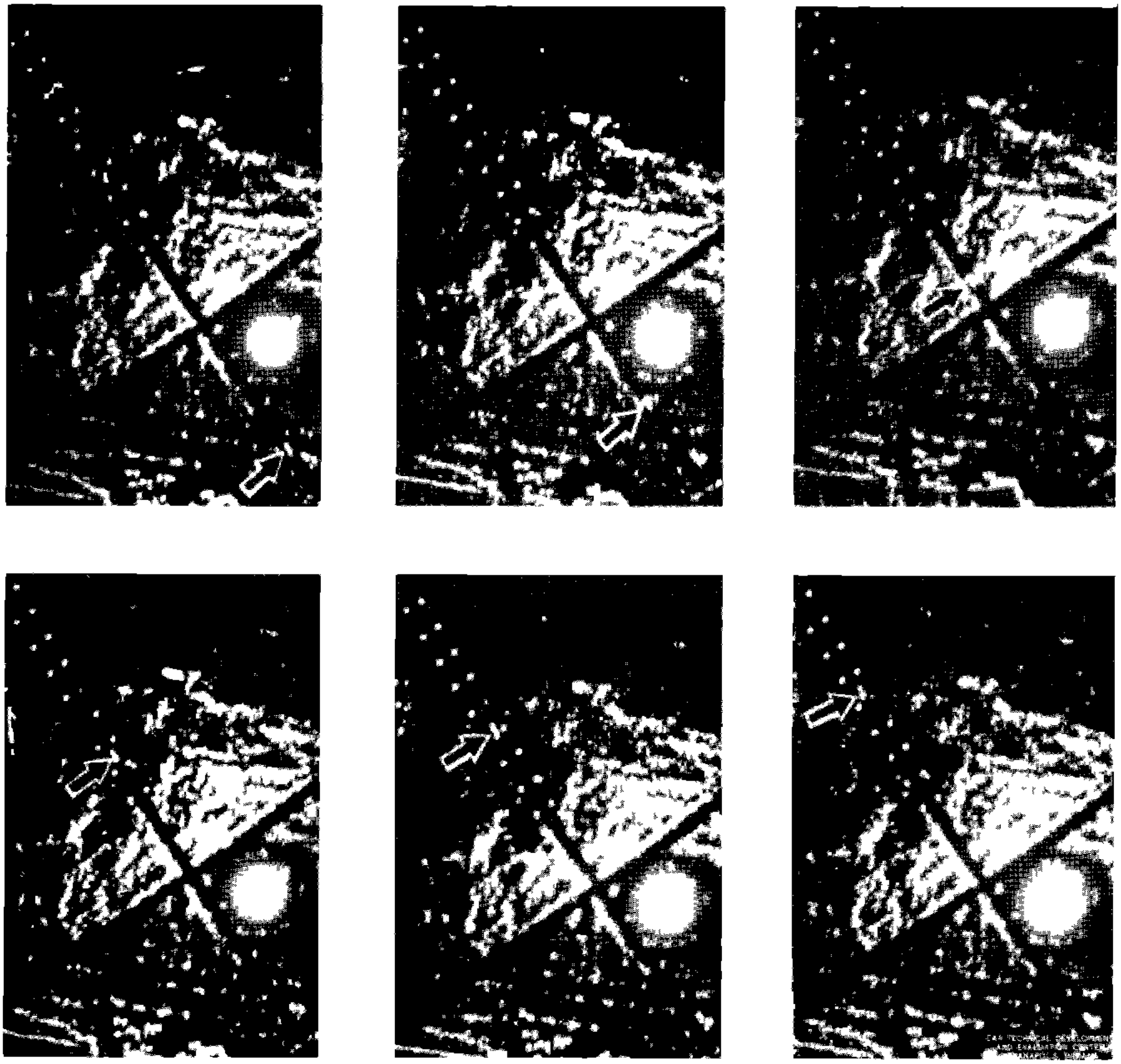

Fig. 12 Photographs of the Radar Indicator Showing Trucks in Trail 20 Feet Apart on a Runway at the Indianapolis Airport

adequately control the surface traffic on an airport

a By providing sufficient information to pilots or drivers to guide them along a desired course on runways and wide taxi strips

b By providing the pilot or driver with information to aid him in turning accurately to taxi strips, runways, or ramp areas

c By providing safe separation between converging aircraft or vehicles operating on the airport

d By viewing portions of the airport that are not now discernible from the tower cab because of obstructions or low visibility

2 The resolution of the ASDE is not adequate for the control of aircraft on the terminal ramp or in congested parking areas

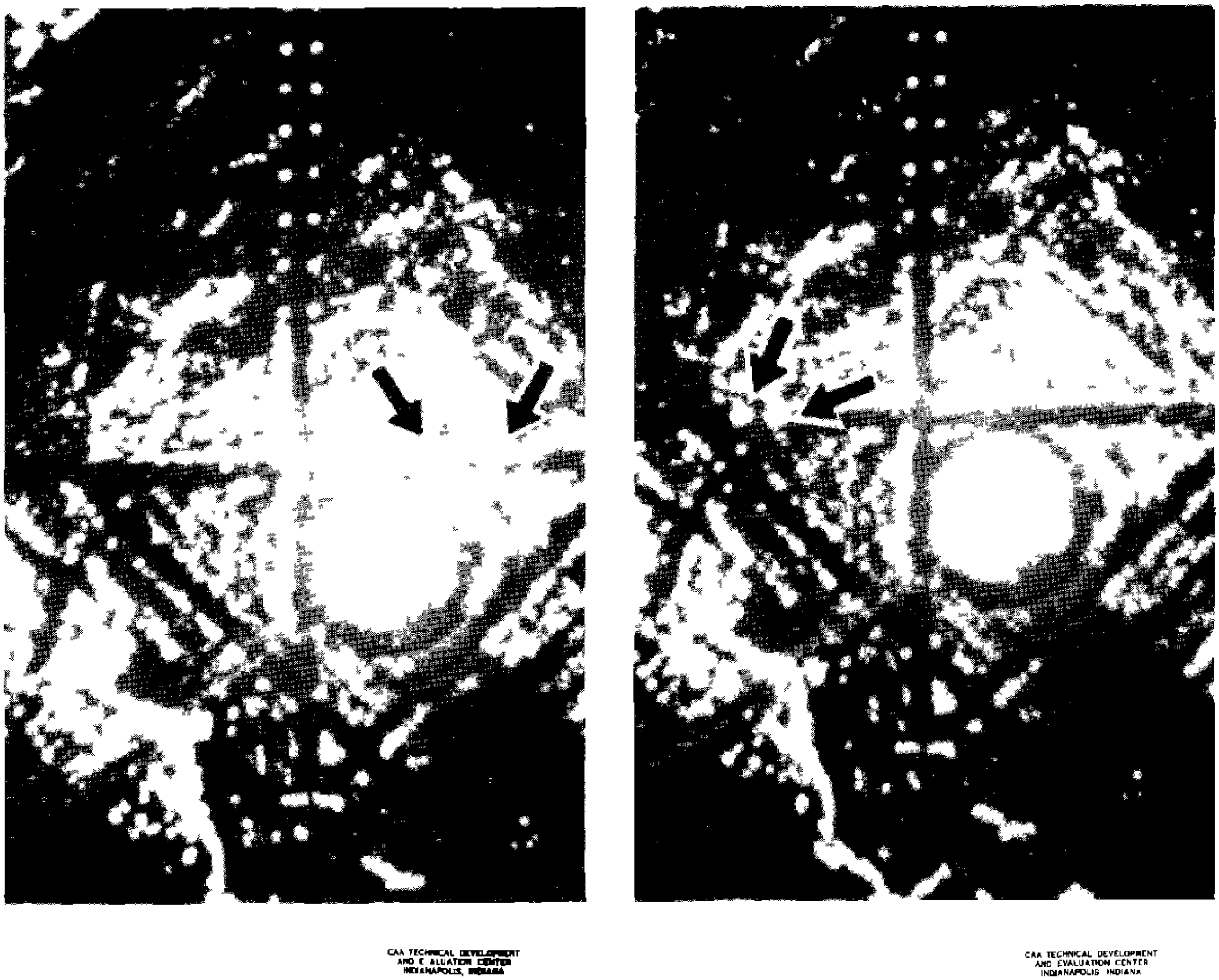

Fig. 13 Photographs of the Radar Indicator Showing Aircraft in Trail on a Runway at the Indianapolis Airport

3 The integration of surface radar in the traffic control system is not expected to lessen the work load imposed upon the ground controller It is believed, however, that surface radar will enable the ground controller to control the surface traffic more efficiently and safely In effect, surface radar presents a good picture of the airport to the controller during the hours of darkness and during most weather conditions

4 A deterioration of airport detail is noted during moderate rain showers and also whenever the temperature at the surface permits the melting of snow The use of the equipment as a ground control aid was satisfactory under all the test conditions encountered

5 A map overlay is not practicable for use with this model of the ASDE because of the associated servosystem error which causes picture shifting and because it is often desirable to use off-centering and expansion of portions of the airport

6 Snow-removal procedures are believed to be a factor affecting the indications received by the ASDE

7 Elevated runway lights aid materially in outlining the runways during all kinds of weather conditions

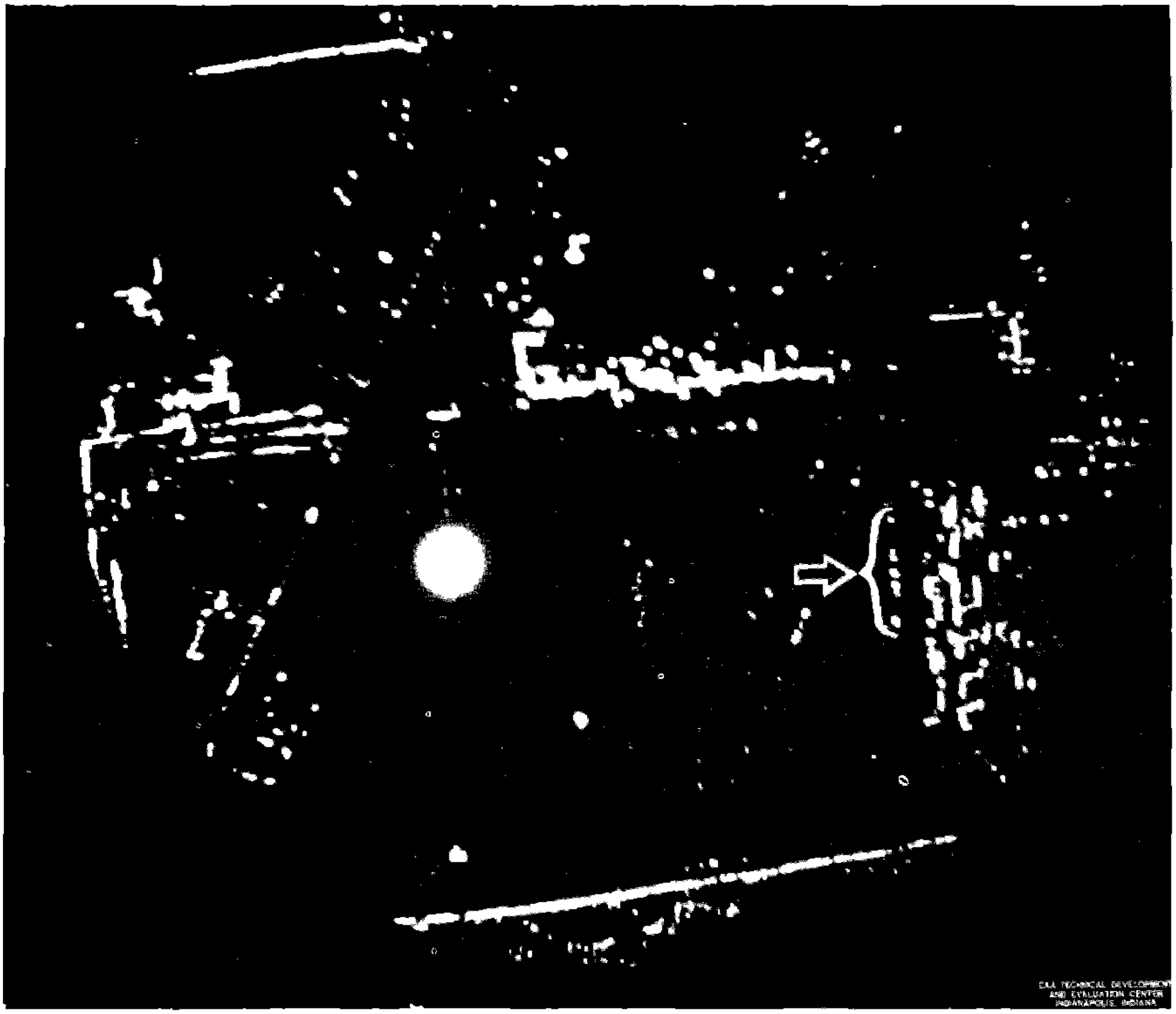

Fig. 14 A Photograph of the Radar Indicator Showing Seven Aircraft Parked in Run-up Position Approximately 4000 Feet From the Antenna at the Minneapolis Airport

RECOMMENDATIONS

In the event that other radars are to be developed for the purpose of all-weather ground control, the following recommendations are made for the improvement of the display from an operational standpoint

1 The radar should be capable of presenting the whole airport in detail under all weather conditions

2 The radar display should be presented on a larger indicator than those now used It is believed that the concentration necessary in observing and tracking targets would be lessened In addition, the larger picture would provide a surface on which the controller might write important information of a temporary nature, such as

a The identification of several aircraft spotted about the airport awaiting take-off clearance

b A reminder that certain portions of the airport are closed to traffic

c An area of the field which has been assigned for special use for a specified length of time

3 Consideration should be given to the use of a daylight type cathode-ray tube for the presentation It is probable that the ground controller would use this equipment

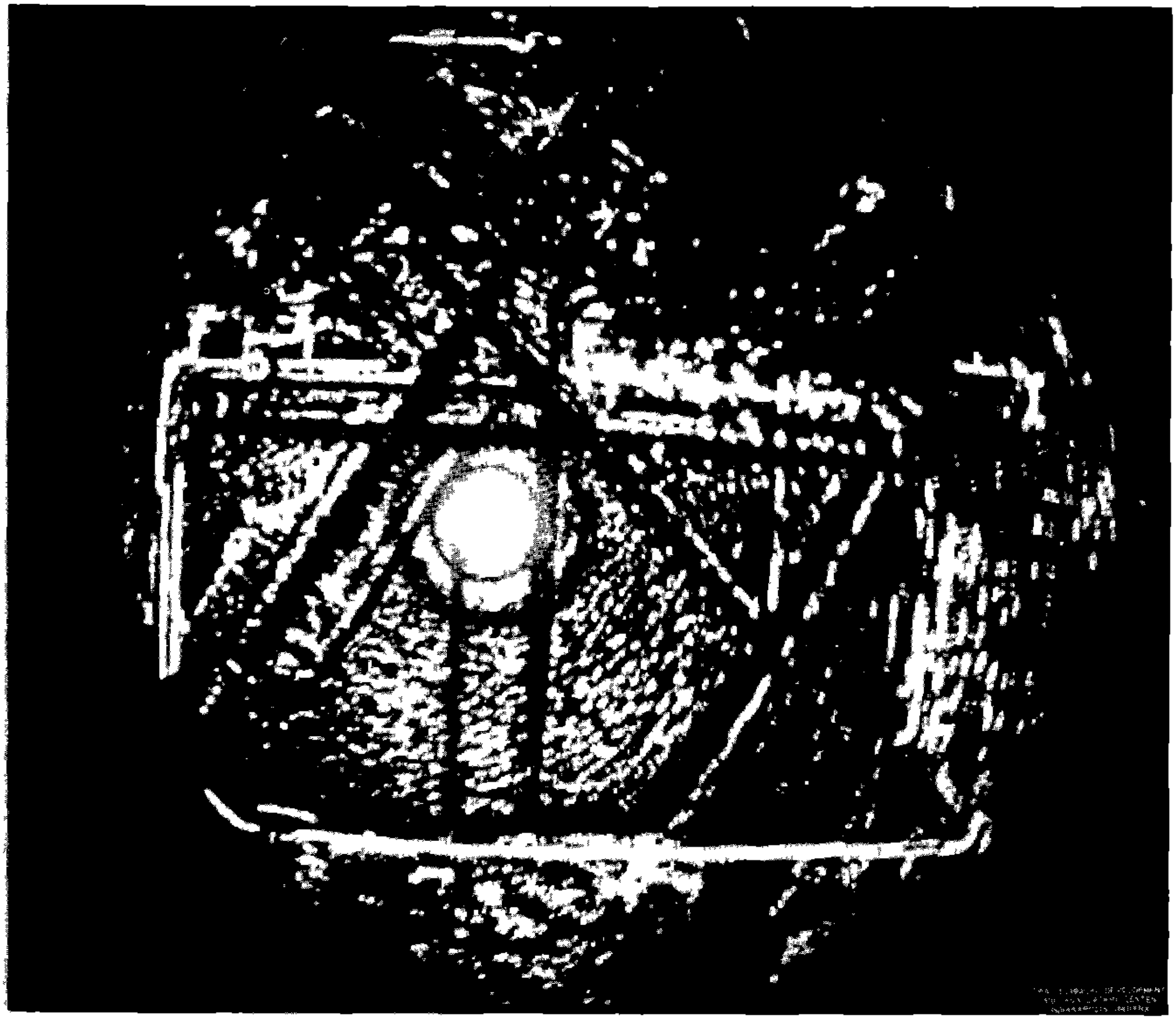

Fig 15 A Photograph of the Radar Indicator at the Minneapolis Airport During Moderate Snowfall

in the tower cab and not under a hood Some airports have surface areas that cannot be seen *from the tower cab by a controller* It is possible for him to see such areas by using radar The controllers would be using this equipment in all weather conditions, day or night

4 At least four off-center switches should be provided on the front of the radar console The circuits associated with each switch should be adjusted for a preset expansion to cover a particular area of the airport *It would then be possible for the* controller to change from a picture of the entire field to an expanded picture of a particular area of activity without the necessity of adjusting the X and Y controls and the sweep speed control Fig 20 illustrates this function

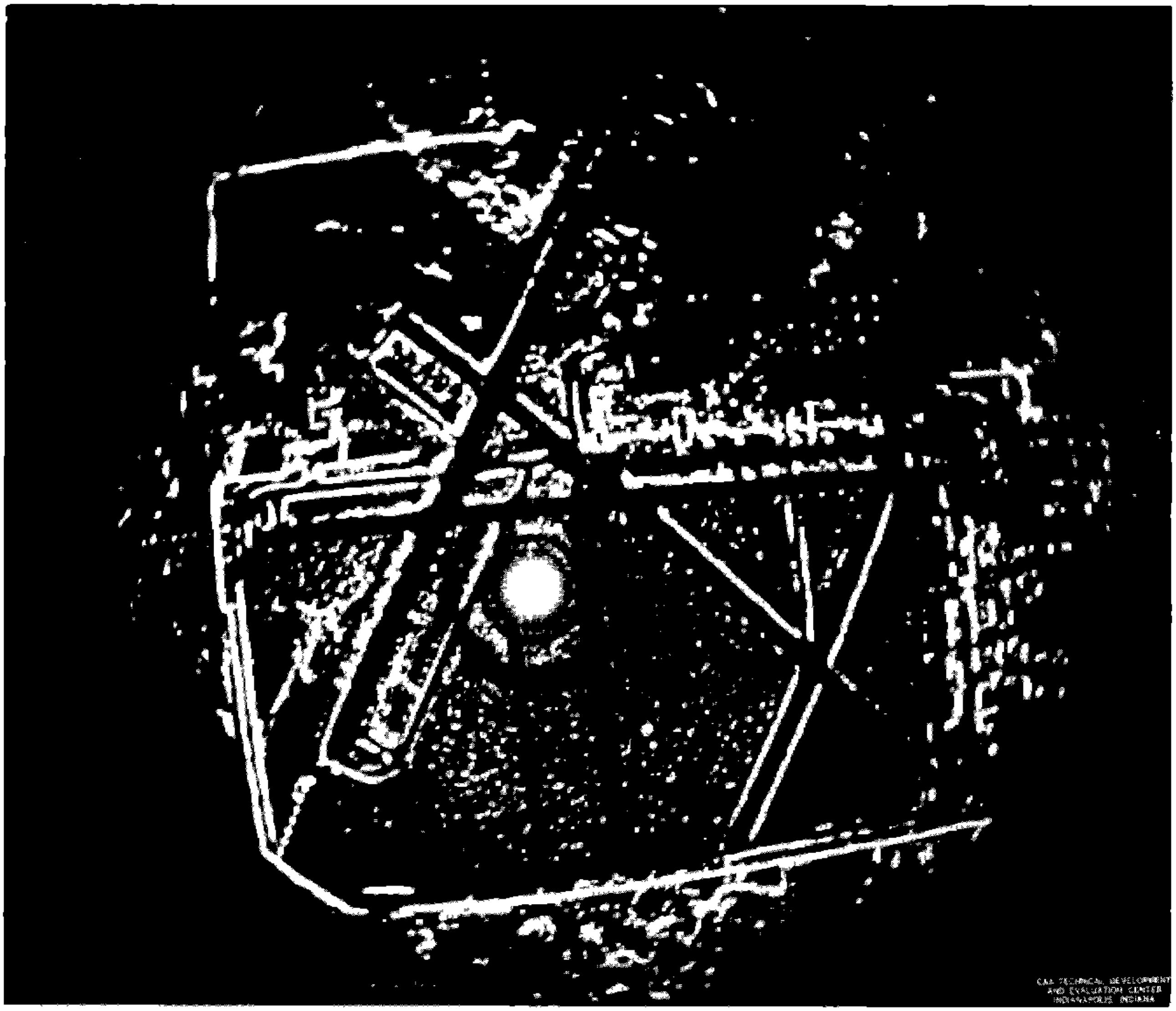

Fig 16 A Photograph of the Radar Indicator at the Minneapolis Airport on a Clear Cold Day

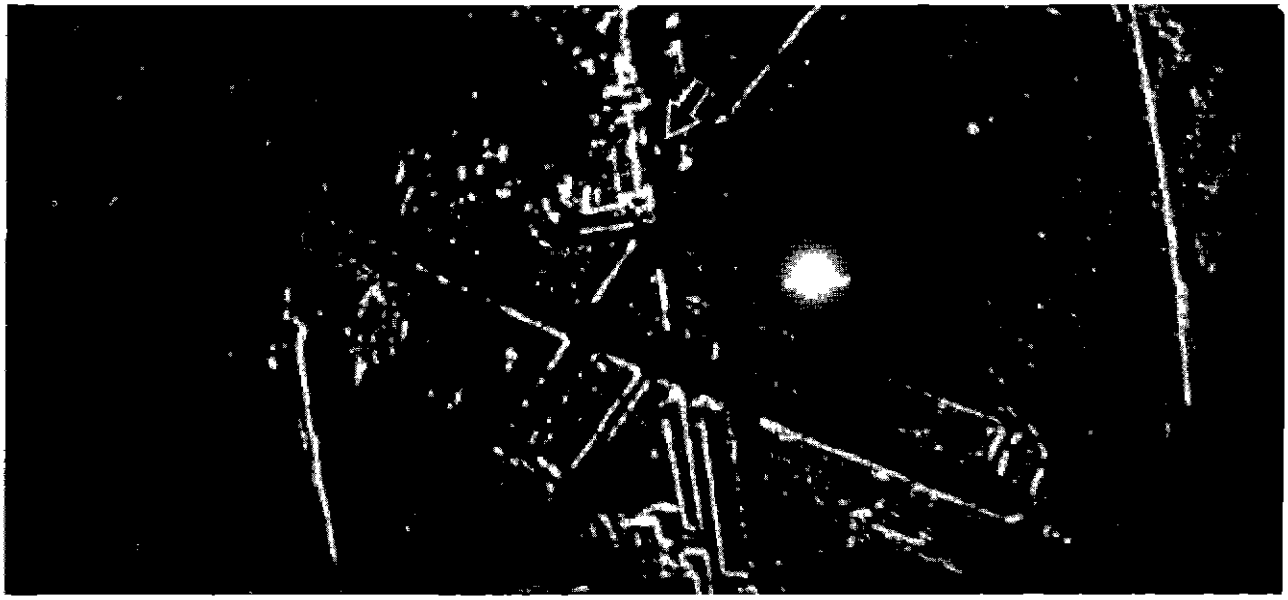

Fig. 17A A Photograph of the Radar Indicator Showing Small Aircraft Passing Behind a Snow Embankment 12 Feet High at the Minneapolis Airport

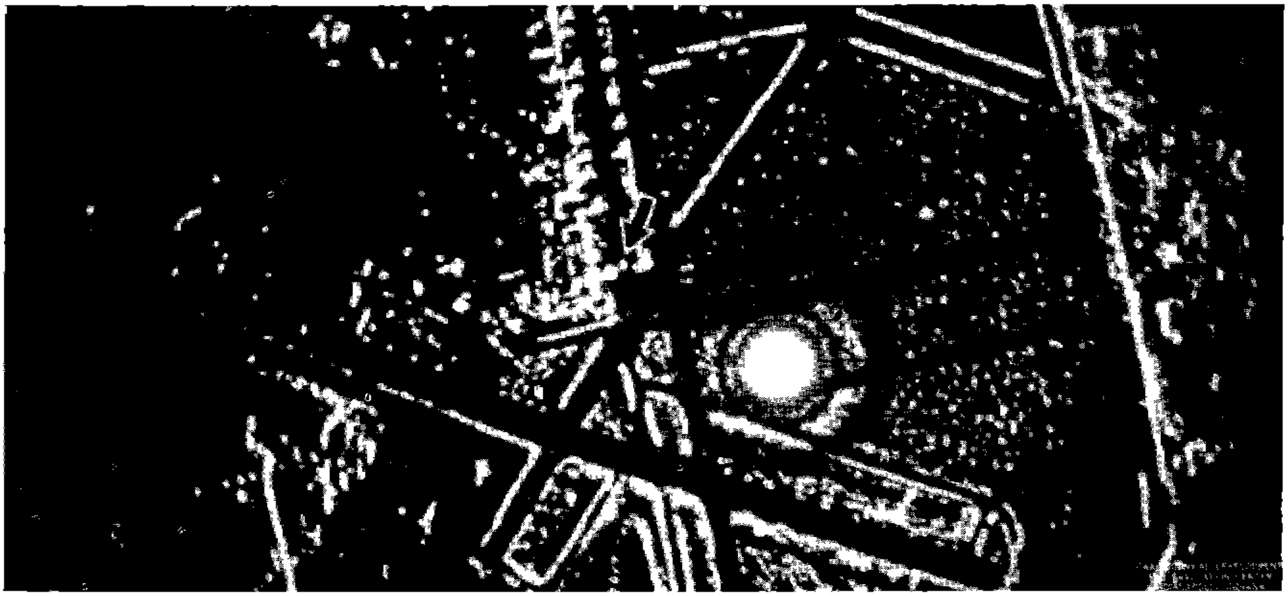

Fig. 17B A Photograph of the Radar Indicator Showing a Truck at the Same Point as the Aircraft in Fig 17A

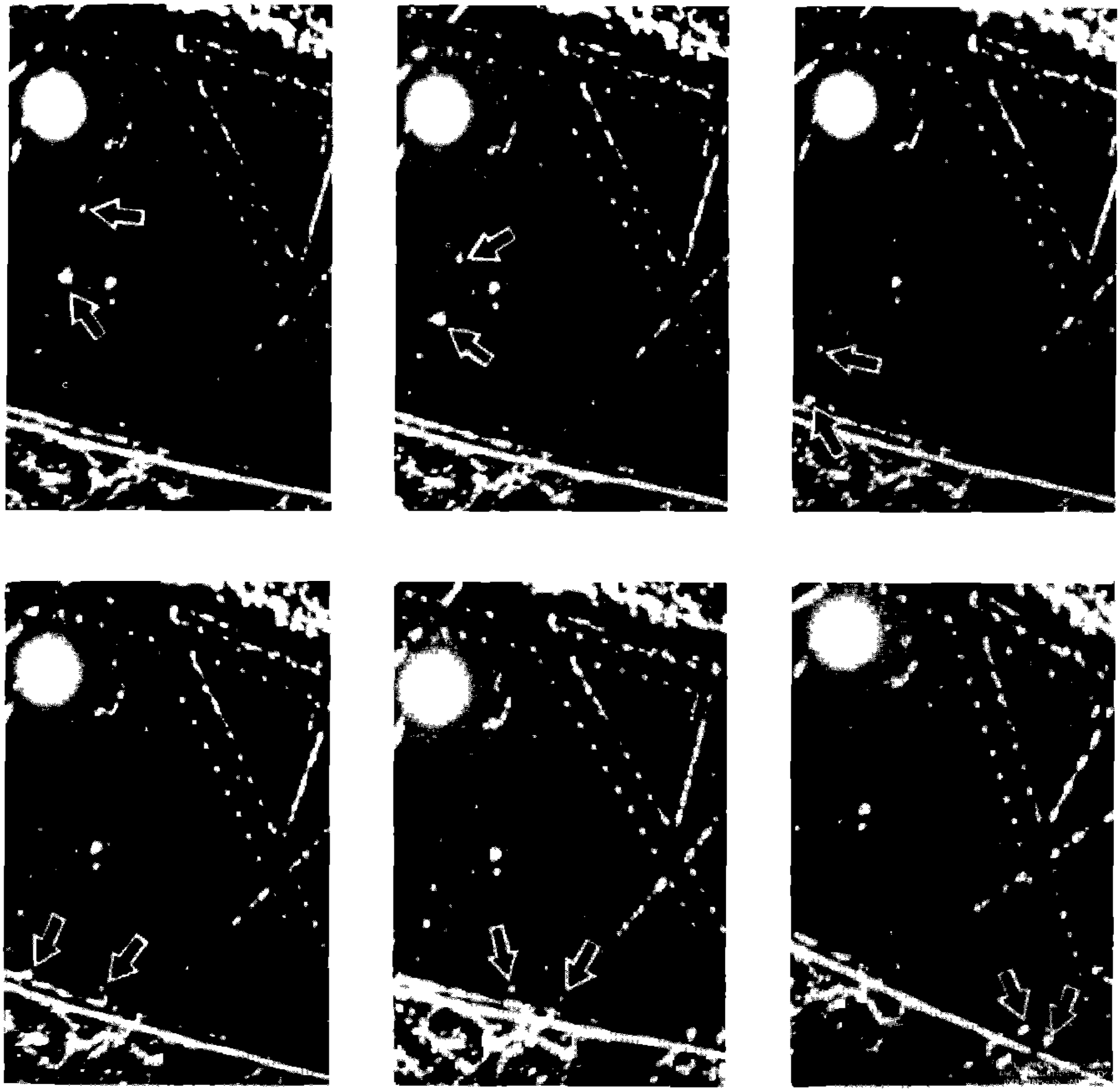

Fig. 18 Photographs of the Radar Indicator Showing an F-51 and a DC-3 Taxiing East and North at the Minneapolis Airport

Fig 19 The Following Eight Illustrations are Photographs of the Indicator Showing Deterioration and Improvement of Picture Quality

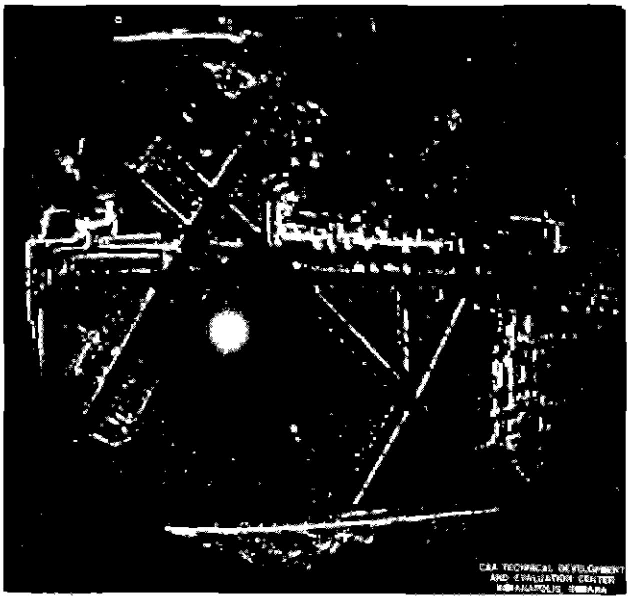

Fig 19A 10 30 A M

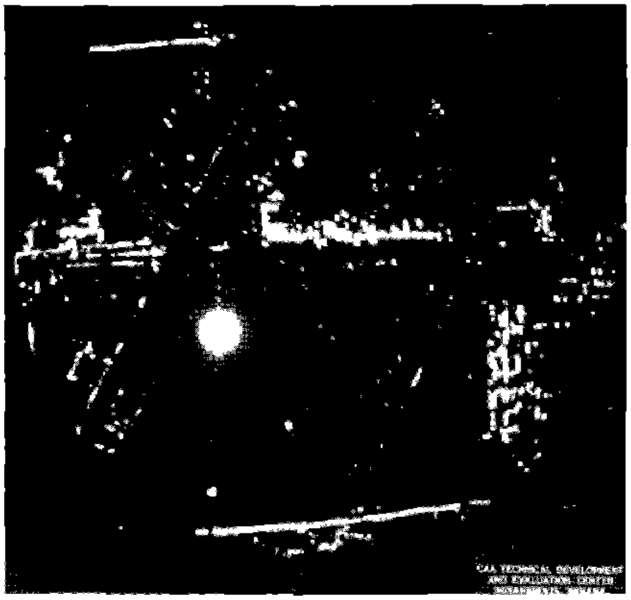

Fig 19B 2 00 P M

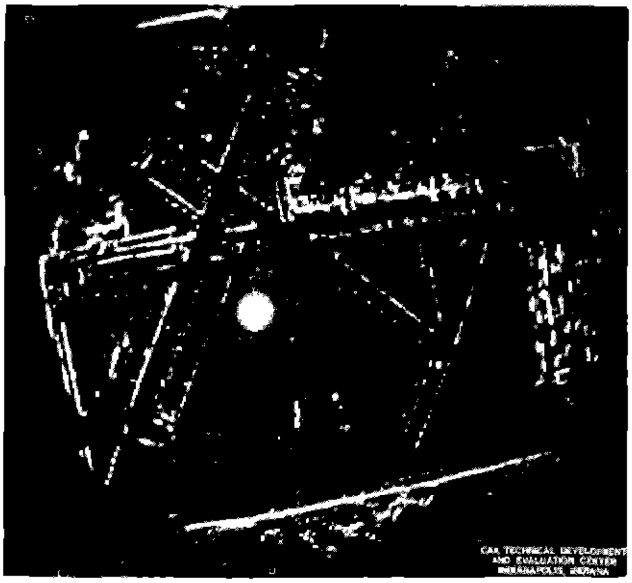

Fig 19C 4 30 P M

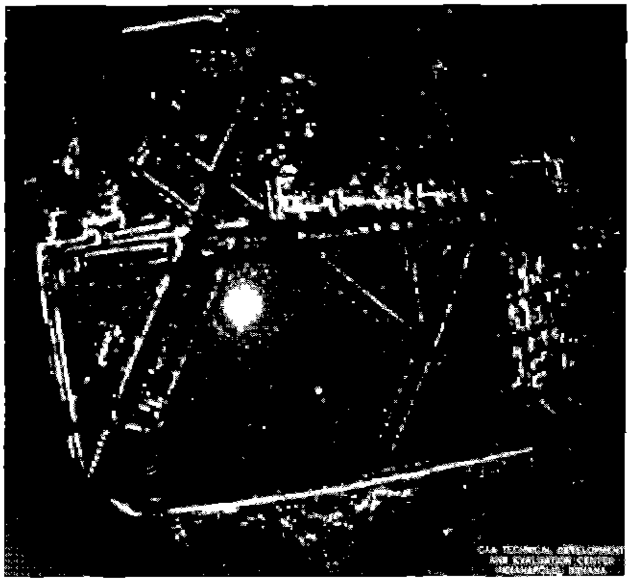

Fig 19D 5 00 P M

Fig 19 (Continued)

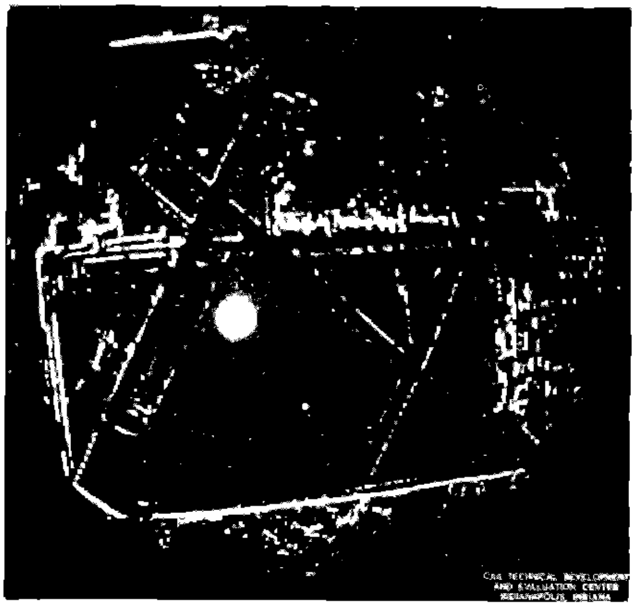

Fig 19E 5 30 P M

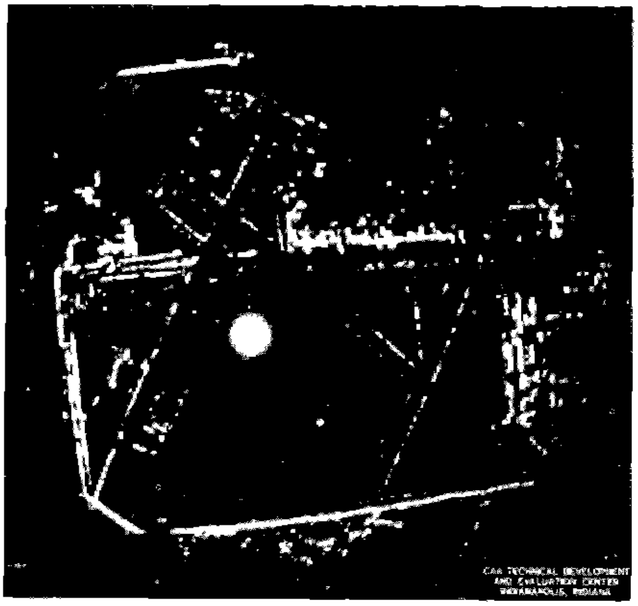

Fig 19F 6 00 P M

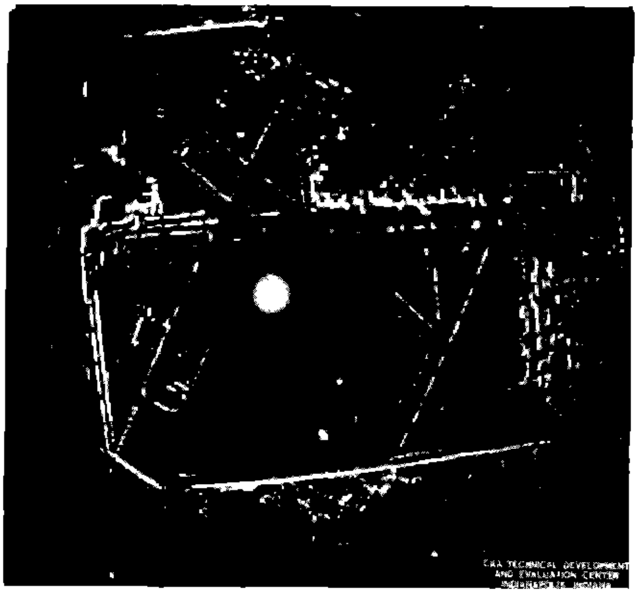

Fig 19G 6 30 P M

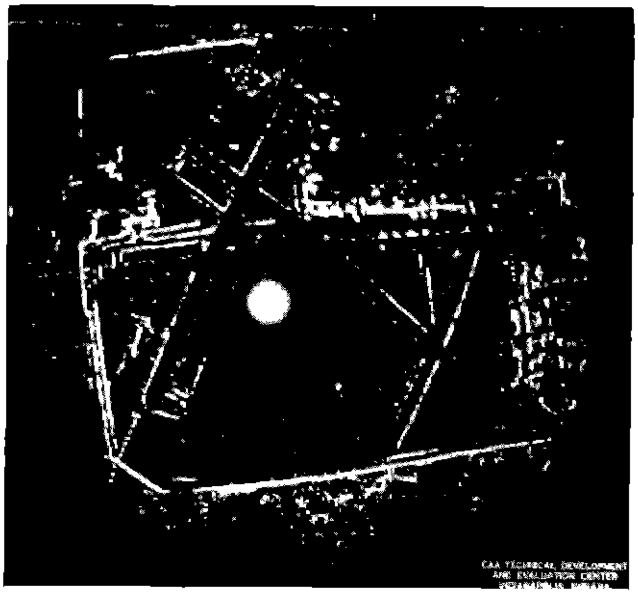

Fig 19H 7 00 P M

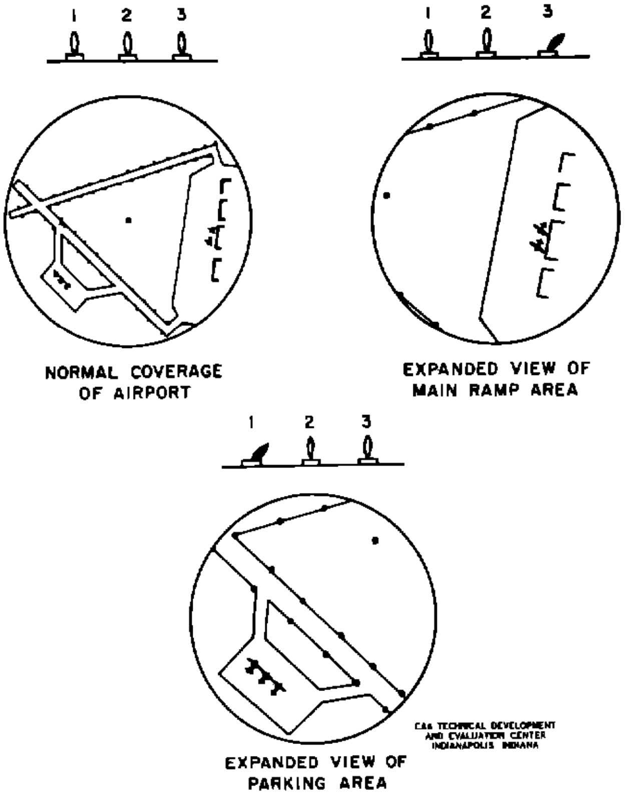

Fig 20 Application of Preset Off-Centering Positions

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