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NATIONAL HAIL RESEARCH EXPERIMENT - ARMORED AIRCRAFT WORK PLANS - 1976

By: D. J. Musil and J. H. Killinger

Prepared for:

National Center for Atmospheric Research
P. O. Box 3000
Boulder, Colorado 80303

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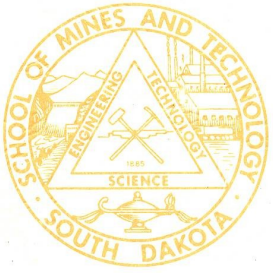

Institute of Atmospheric Sciences

South Dakota School of Mines and Technology

Rapid City, South Dakota 57701

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

The Institute of Atmospheric Sciences (IAS) of the South Dakota School of Mines and Technology will provide an armored T-28 aircraft for participating in the 1976 National Hail Research Experiment (NHRE) under a continuation of Subcontract No. NCAR 182-71. The project is sponsored by the National Science Foundation under the direction of the National Center for Atmospheric Research.

Work to be carried out includes penetration of active hailstorms according to procedures outlined in Section 4. The T-28 will be involved mainly in the Mature Storm Studies as outlined on pages 21 - 26 of "The National Hail Research Experiment Operations Plan 1976." The purpose of the work is to answer certain questions related to the understanding of hailstorms.

Many new instruments were successfully tested on the T-28 during the 1975 NHRE field season. These tests were purposely set up to prepare for the 1976 field season; hence, no major changes are planned for instrumentation in 1976. Equipment to be used in 1976 is outlined in Section 5.

Plans call for a "quick recall" type reduction of data gathered by the T-28, with the products being returned to both Laramie and Grover for use in detection of problems in equipment and preliminary analysis of data. This will involve the replay capability of the Data Acquisition and Display System (DADS), as well as a rapid turnaround for reduction of recorded radar data at Grover.

2. OBJECTIVES

The overall objective of the T-28 research is to use the armored aircraft to obtain data within and in the immediate vicinity of hailstorms. This is consistent with the NHRE objectives to locate and characterize the hailstone growth region in different types of storms. The specific IAS objectives include:

1) Determination of particle size distributions in various stages of thunderstorm/hailstorm development;

2) using the particle size measurements as input for further numerical model development;

3) Determination of ice/water budgets in hailstorms; and

4) Identification of the relative importance of the collision-coalescence and Bergeron processes in the formation of hail embryos.

These objectives strongly interrelate with specific questions being addressed by NHRE in "The National Hail Research Experiment Operations Plan 1976."

3. PERSONNEL

The field operation phase of the project will be carried out by the following individuals:

Name	Function
Dennis J. Musil	Project Meteorologist
Joseph H. Killinger	Pilot
Gary N. Johnson	Engineer
Jon E. Leigh	Aircraft Mechanic
Jerry L. Halvorson	Computer Programmer
Carlton P. Laco	Technician/Graduate Student

The project meteorologist will be located at the field project site at Grover and the computer programmer will remain in Rapid City, while the other individuals will be located in Laramie with the T-28. Wayne R. Sand of the University of Wyoming will be the T-28 pilot on some of the missions, especially early in the season.

The project leader is Dr. Paul L. Smith, Jr., who along with Dr. Arnett S. Dennis and Mr. Dennis J. Musil are co-principal investigators for the studies being carried out in this project.

4. PENETRATION PROCEDURES

4.1 General Comments

The general penetration procedure for 1976 will consist of making repeated penetrations at a single level near a temperature of -15C (approximately 20 kft MSL). It is also planned to occasionally make penetrations at a warmer level between 0 and -5C, to look for evidence of recirculation of particles from above. A few sub-cloud passes through precipitation are also planned to test the response of the various particle sensors.

Safety is of primary importance in any of the penetration procedures designed for the T-28. It is felt that portions of the storm with reflectivity factors greater than 55 dBz at or above the level of penetration should be avoided. This limit has worked satisfactorily in the past and has produced encounters with hail up to 2.5 cm diameter. No major changes in the flight procedures outlined below, except for those necessary to adjust to vagaries of the storm, should be made during a specific mission. It is doubtful that spur of the moment thoughts and decisions produce much valuable data, and they may compromise the safety aspects that are involved.

T-28 flights will be initiated whenever suitable storms are in the area. The suitability of a storm will be determined essentially by its location and intensity. It is not advisable to launch the T-28 on the basis of a forecast of storm development because of the short loiter time of the T-28. The storms to be penetrated by the T-28 will almost always be in a mature state and past experience has shown that most storms within the operational limits of the M-33 radar will be moving into or through the area rather than developing within it.

Whenever suitable storms are available, the T-28 crew at Laramie will be notified by radio. Several radio calls on any given day will be necessary to keep the crew abreast of the meteorological situation. The weather updates and the alert for flight will be made by the T-28 project meteorologist at Grover in coordination with the NHRE operations director.

Since many more aircraft are involved in the 1976 season, more coordination will necessarily be required in order to accomplish the mission. Flight plans must be clarified prior to launch of the T-28 because once penetrations begin, little can be done to change things. In this regard and because of safety considerations, the T-28 requirements and those of the Wyoming Queenaire must take priority, especially if simultaneous penetrations are being attempted. Since the decision

to make simultaneous penetrations rests with personnel at the Grover headquarters, there should be especially close coordination between the operations director and the meteorologists working with the two penetration aircraft.

Advance decisions must be made on which DADS radar displays will be requested and on which channels they will appear during an operation. We are especially concerned with keeping the number of different displays used to a minimum to reduce the turnaround time on the DADS system and so minimize the lag time of the displays to be used for operational direction of the T-28. Tests should be run prior to June, during the checkout phase of the project.

Three types of penetration procedures are planned, those related to: 1) quasi-steady-state storms, 2) multicell storms; and 3) line storms. The majority of storms in northeast Colorado will be of the multicell type, although some of these may take on a steady-state appearance for periods of time. Furthermore, line storms may contain cells which are multicellular and steady state in nature. Consequently, the real time identification of storm type is very difficult is most cases. Hence, the decision as to which penetration procedure is ultimately used in any particular situation will require close coordination between the operations director and the T-28 project meteorologist, so that the procedure can be agreed upon in advance of the penetrations.

4.2 Steady-State Storm Procedures

The plan calls for a penetration heading from an oblique angle starting from the southern quadrant of the storm (avoiding reflectivity factors greater than 55 dBz) followed by a right turn through the weak echo (WER) and the embryo curtain (EC) regions of the storm (Fig. 1). An initial point (IP) will be identified along with a penetration heading. The right turn instruction will be given from Grover, radio communications permitting, at some predetermined point. As a backup measure, in the event radio communications have been lost, the turn will be made automatically at some pre-selected time (2 - 6 minutes) following cloud entry.

For this type of storm, the possible loss of accuracy due to poor radio communications in the regions where the turns are to be performed is not considered serious because penetrations at various points in the weak echo region and embryo curtain are desirable. Also, the degradation of updraft measurements in regions where the turns are being made is regarded as acceptable because of the great interest in the particulate makeup of the embryo curtain region.

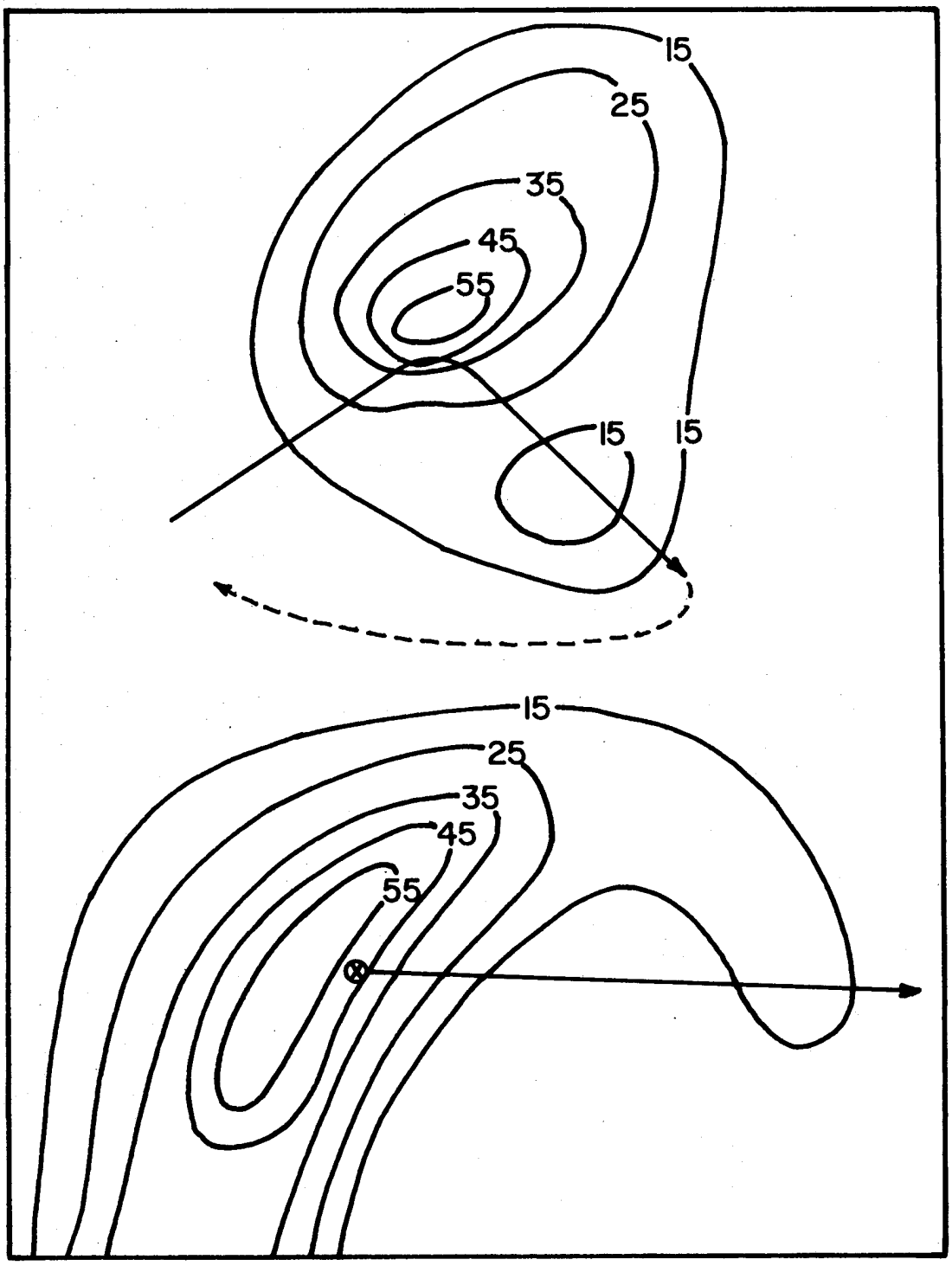

Fig. 1. Schematic of radar PPI (upper) and vertical section (lower) showing location of T-28 penetration track on each. Vertical section is drawn along the track of the T-28 (and an extension) after the turn has been made. The drawings are not to scale and isolines are labeled in dBz.

4.3 Multicell Storm Procedures

An IP and penetration heading will be given for the penetrations to be carried out along the line of new cell formation through cells in various stages of development (Fig. 2). This will be similar to penetration procedures which were used in 1972 and 1973, but much better accuracy is now possible because of the availability of the DADS system. In the event that reflectivity factors are too high (>55 dBz) along the desired flight path, the penetration track may have to be moved several kilometers toward the leading edge of the storm.

An alternative procedure will be to pick a cell expected to merge with the main cloud mass and penetrate it in a direction perpendicular to the line of cell formation. This will allow the T-28 to follow the life cycle of a particular cell without getting into reflectivities which are too high. The decision whether to penetrate a single cell or a line of several cells in various stages of their life cycle will depend to a large degree on an on-the-spot assessment of whether cells are merging or growing on their own, the strength of the radar echoes, and the type of equipment being carried on the T-28 that day. For the latter, it seems that lengthwise penetrations would be more suitable when the IAS hail sensor is being carried because this would likely lead to higher reflectivities (and larger particles); while crosswise penetrations would be more suitable when the Cannon camera is aboard because this device can provide information on the phase of particles. Consideration can be given to reverse the roles of the above equipment later in the field season. Evidence suggests the importance of following the evolution of the hydrometeors closely around the time of first echo development.

4.4 Line Storm Procedures

The plan is to penetrate along and in front of the line of cells, while avoiding reflectivity factors greater than 55 dBz (Fig. 3). This will enable penetrations of several cells in various stages of development. A disadvantage of this type of penetration is that they are generally very long and in the inflow region, leading to large accumulations of ice on the aircraft. This reduces the number of penetrations that can be made on a given mission.

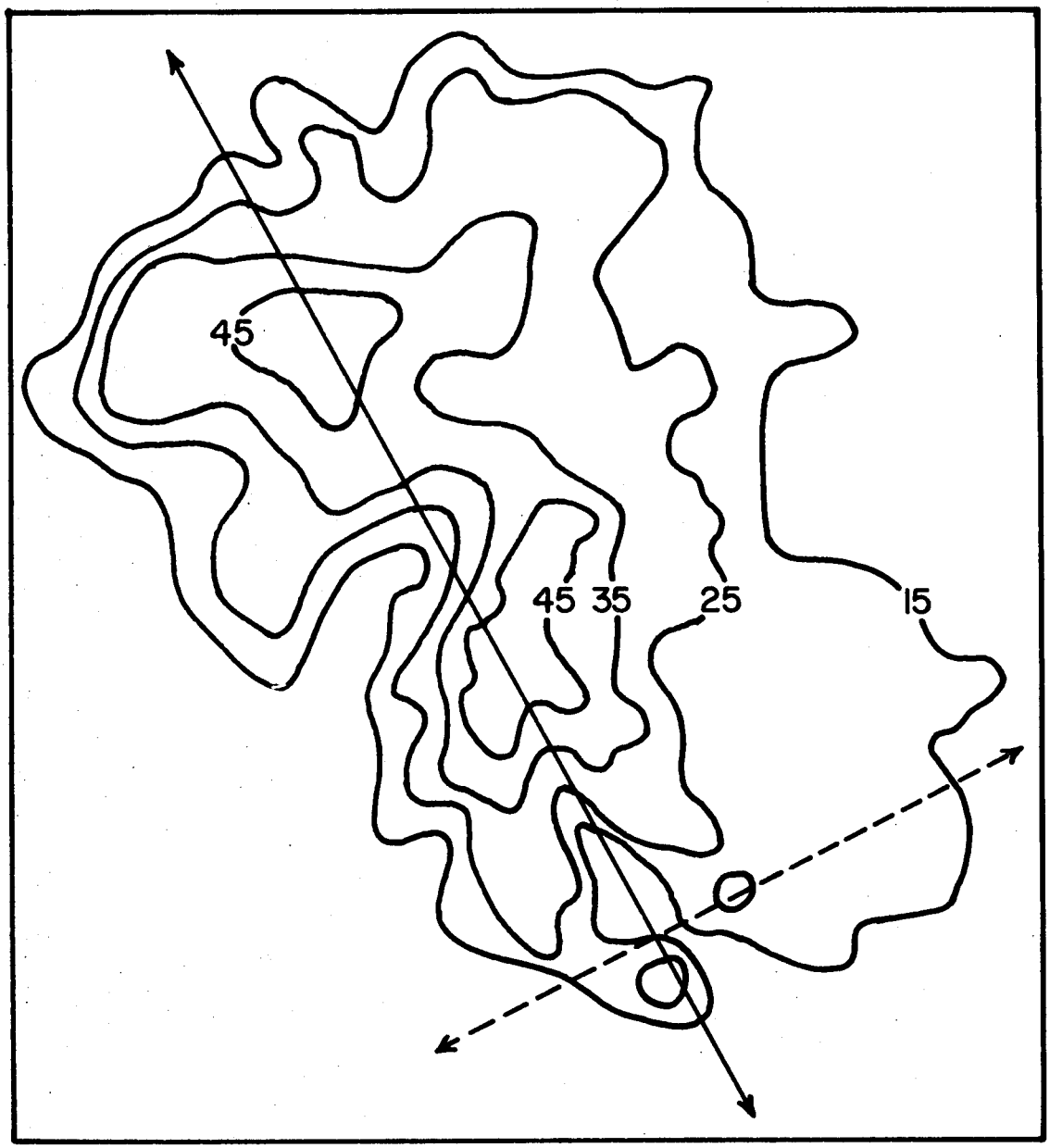

Fig. 2. Schematic showing penetration track of T-28 in multicell storm. Solid track is along line of formation of new cells, while dashed track denotes alternate plan across the line of formation of new cells concentrating on the evolution of a single cell in the system. Isolines are labeled in dBz.

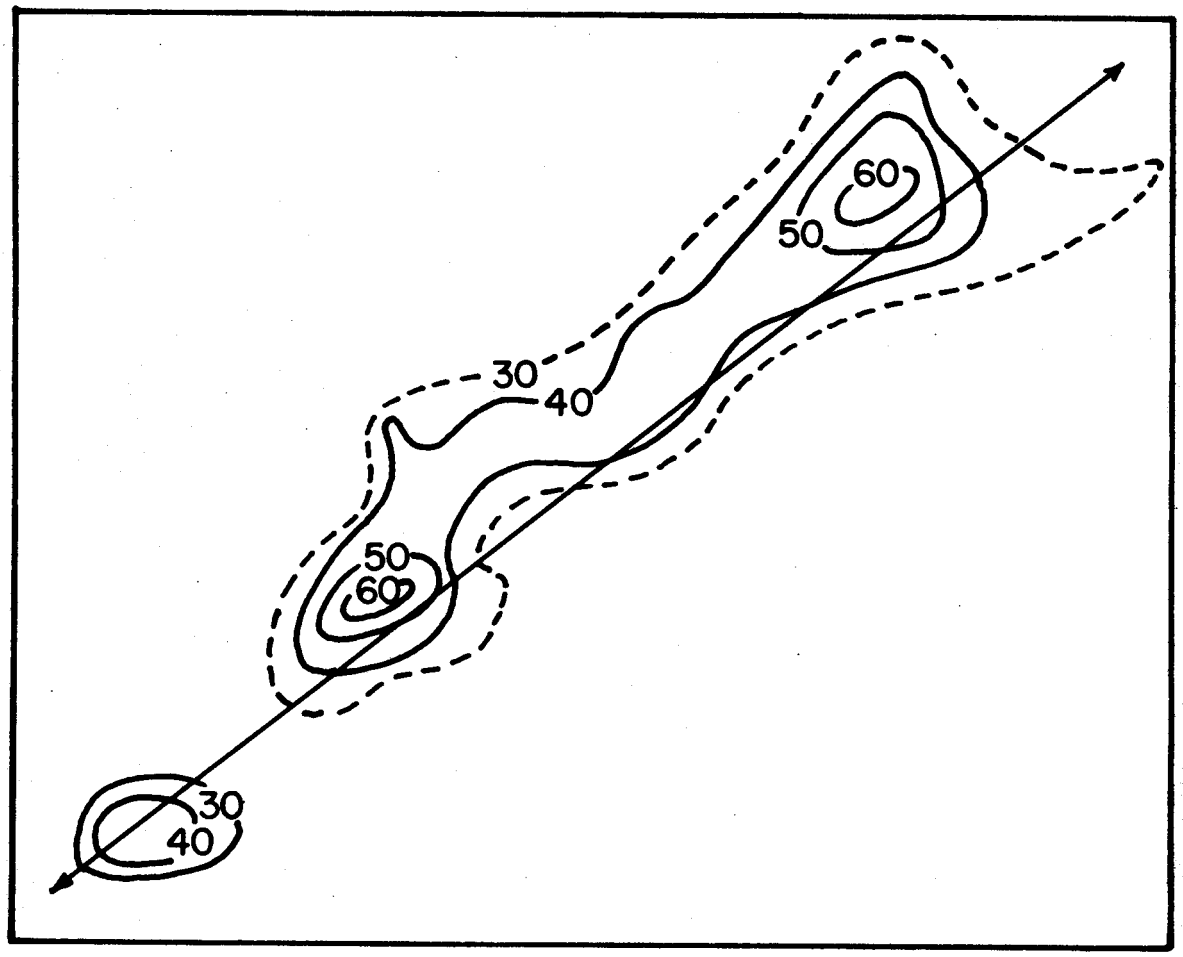

Fig. 3. Schematic showing penetration track of T-28 in a line storm. Isolines are labeled in dBz.

5. AIRCRAFT INSTRUMENTATION

The data system on the T-28 includes sensors to measure meteorological and aircraft variables which are recorded on magnetic tape. The instruments that will be flown on the T-28 during the 1976 field season and data to be recorded are given in Table 1. The primary data recording system consists of a Precision Instruments incremental recorder coupled with a multiplexer and digital conversion package by Monitor Labs. A separate recorder is necessary to record data from the Knollenberg devices, as well as for the duplicate recording of certain variables from the primary recording system. Data from the foil impactor and Cannon camera are separate from, but coordinated in time with, the tape recorded data. Audio tapes from the onboard voice recorder and possibly backup data tapes from the telemetry ground station at Grover will also be available.

TABLE 1

List of Variables Recorded and Scientific Equipment to be Used on the T-28 in 1976

Recorder Data Channel	Variable	Equipment Used
--	Time	Primary data system internal master clock
0	Pressure Altitude*	Rosemount Model 1301-A-4-B temperature controlled absolute pressure transducer; output amplified by 5 for rate-of-climb calculations
1	Indicated Airspeed	Rosemount Model 1301-D-1-B temperature controlled differential pressure transducer
2	Instantaneous Acceleration	Humphrey Model SA09-D-0101-1 vertically stabilized accelerometer
3	Pressure Altitude*	Rosemount Model 1301-A-4-B temperature controlled absolute pressure transducer
4	Pressure Altitude	Ball Model EX-210-B absolute pressure transducer
5	Temperature*	Rosemount Model 102AU2AP total temperature probe
6	Temperature	NCAR reverse flow probe
7	Rate-of-climb	Ball Model 101A variometer
8	Manifold Pressure	Giannini Model 45218YE pressure transducer
9	Heading	IAS designed device to enable recording of aircraft heading from gyrocompass
10	VOR Bearing	MetroData Systems, Inc., M-8 used to record from Narco MK-12 VOR receiver

TABLE 1 (Continued)

Recorder Data Channel	Variable	Equipment Used
11	DME Distance	MetroData Systems, Inc., M-8 used to record from a Narco UDI-2ARD DME unit
12	DME Distance	MetroData Systems, Inc., M-8 used to record from a Narco UDI-4 DME unit
13	Liquid Water Concentration	Johnson-Williams liquid water concentration probe
14	Icing Rate	Rosemount Model 871 BG icing rate probe
15	True Airspeed	NCAR designed true airspeed computer
16	Angle of Attack*	Servomechanisms, Inc. Type TR541 relative wind transducer
17	Aircraft Pitch Angle	Humphrey Model SA09-0101-1
18	Aircraft Roll Angle	Humphrey Model SA09-0101-1
19	Blank	
20	+5VDC	Reference voltage (optional)
21	Blank	
22	Positive Peak Acceleration	Humphrey Model SA09-D-0101-1 vertically stabilized accelerometer
23	Negative Peak Acceleration	Same as Channel 22
24*	Blank	
25*	Pressure Altitude*	Same as Channel 0
26*	Indicated Airspeed	Same as Channel 1

TABLE 1 (Continued)

Recorder Data Channel	Variable	Equipment Used
27*	Instantaneous Acceleration	Same as Channel 2
28-29*	Blank	
30*	Positive Peak Acceleration	Same as Channel 22
31*	Negative Peak Acceleration	Same as Channel 23
3 BCD digits	Event Codes (9)	IAS designed digital event codes
3 BCD digits	Frame Count	Frame counter for Cannon particle camera
--	Hydrometeors	Williamson Aircraft Company continuous hydrometeor sampler (foil impactor; 0.25 mm - 20 mm dia.)
--	Precipitation	NCAR designed precipitation sampler to gather samples for laboratory analysis
--	Voice Recorder	SONY audio tape recorder (2-channel) 1) Pilot's comments 2) Hail impact sounds
--	Hydrometeors*	Two Knollenberg optical array spectrometer probes 1) OAP-2D (25-800 μm dia.) 2) ASP-100 (2- 30 μm dia.)
--	Hydrometeors*	Cannon particle camera
--	Visual Cloud	Super 8-mm movie camera with automatic exposure and remote control

*Denotes new or modified equipment.

6. DATA REDUCTION

Data reduction will operate in two stages: 1) a "quick recall" system, whereby reduced data from a particular T-28 mission will be returned to Laramie and Grover in less than 24 hours; and 2) a more standard reduction following the field season where reduced data will be placed in a form amenable to detailed analysis.

For the quick recall method, tapes from the primary recording system on the T-28 will be hand carried to Cheyenne and placed on a bus to Rapid City by personnel traveling to Boulder with the Knollenberg data tapes following a penetration mission. Following receipt of the tapes in Rapid City by IAS personnel and subsequent reduction on the School of Mines computer, the reduced data will be transmitted to personnel at Laramie and Grover using a Xerox telecopier system. The IAS is providing the telecopier in Laramie, and NHRE has a telecopier for use at Grover. The reduced data will be in a form similar to that shown in Fig. 4.

A secondary quick recall method, which will be tested during the summer of 1976, will be to transmit 22 channels of data (essentially the same data as recorded on the T-28 primary recording system) by telemetry from the T-28 to a ground station at Grover and thence to Rapid City via phone lines while a T-28 operation is in progress. If this is successful, reduced data will be returned to Laramie and Grover via telecopier shortly after the completion of a mission. The telemetry ground station located at Grover will provide real time readout of rate of climb and altitude measured by the T-28 on the T-28 console in the operations room.

Data reduction following the field season will result in plots of variables or combinations of variables with respect to time for each penetration for days to be selected from the 1976 season. These plots can be used for detailed analysis of data for assigned test cases and will be the same form as shown in Fig. 4, except that much more flexibility in presentation and programming is possible.

Analysis of the data will follow the past procedures. Analysis tasks currently underway have been summarized in the T-28 final report for the year ending 29 February 1976 (IAS Report 76-1) and will not be repeated here. The 1976 data will be added to the data base for those tasks. New tasks may also be identified after review of the 1976 data.

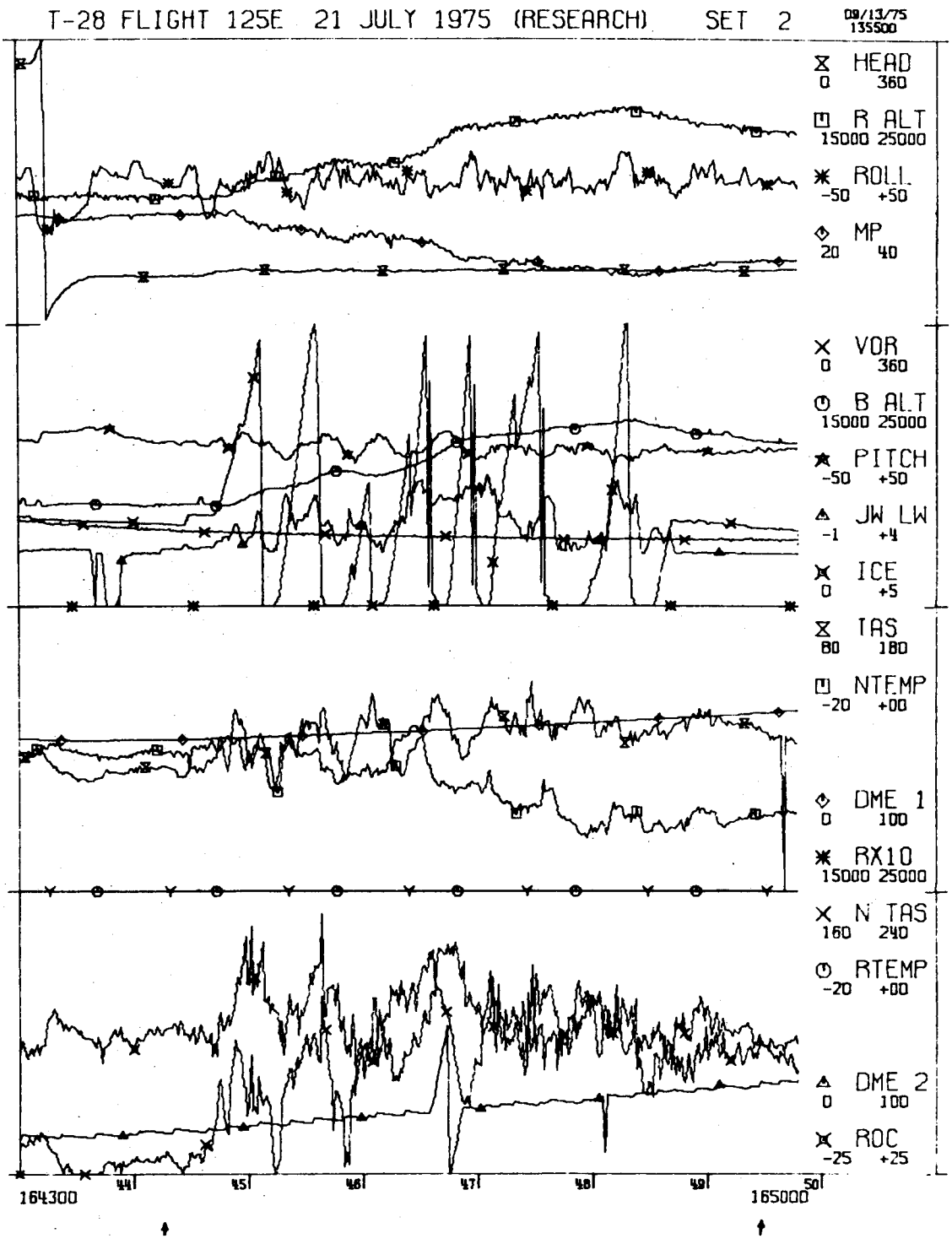

Fig. 4. Quick recall data as transmitted from Rapid City to Cheyenne over a telecopier. Data are from Penetration 4 on 21 July 1975.

7. BRIEFINGS

IAS personnel will participate in the daily NHRE briefings to be held at Grover. The project meteorologist will be available for preparation and presentation of information at these briefings. This includes weather information and debriefing-type information, as well as information pertaining to the status of the T-28 and its equipment.

IAS personnel also plan to have informal debriefing sessions using the T-28 quick recall data and any other data that are available from operations, such as radar data, etc. Because of the distances involved much of the information available will have to be discussed over radio between Grover and Laramie. Many of the same items will be discussed at the briefings mentioned in the previous paragraph. It is possible that an end result will be a nearly complete ranking of the days on which missions occurred by the end of the field season, thus leading to an early data reduction schedule for case study analysis.