A PROCEDURE TO EVALUATE GROUND DISTRIBUTION PATTERNS FOR WATER DROPPING AIRCRAFT

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ABSTRACT

The test procedure for determining the ground distribution pattern of water dropped by the various types of air tankers used throughout Canada is outlined.

The results are those that can be obtained under conditions in the open and are in no way indicative of the patterns obtained when fire bomber aircraft are used under wild fire conditions in the forest.

Thoughts for future developments and refinements are presented.

To supplement the report, a training movie of the test procedure is to be produced.

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ACKNOWLEDGEMENTS

The series of evaluation test drops were carried out during the spring and summer of 1967 by the Forest Fire Research Institute, Department of Forestry and Rural Development, in cooperation with the Flight Research Section, National Aeronautical Establishment of the National Research Council, Ottawa.

Many people have assisted with the many various phases of this project and I would like to convey my thanks to each and every one of them; there being too many to name individually.

The loan of aircraft and pilots by the Ontario Department of Lands and Forests and the Forest Protection Service, Department of Lands and Forests, Quebec, is gratefully acknowledged.

All photographs were taken by the Department of Forestry and Rural Development photographer or the author.

INTRODUCTION

In the past some of the fire control agencies throughout North America have conducted drop tests with a variety of air tankers. Unfortunately different units of spacing have been used to catch the water, with markedly differing results. This difference in units used in the various reports has caused some confusion. The Canadian contour line results are measured in inches whereas the American reports are generally quoted in gallons per 100 square feet. This report is written in an attempt to standardize this type of evaluation technique.

In the TBM Avenger tests carried out by Storey et al, the tank capacity was 440 (340 Imp) gallons. In open field drops the average dimensions of the wetted area was 378 by 90 feet with a 53% recovery of load.

Affleck (1960) in his comparison of the Canso (650 gal.), Otter (160-gal. roll-over tank) and Beaver (90-gal. roll-over tank) came up with the following figures for total wetted area. Canso: 599-900 x 130 feet; Otter: 250-290 x 100 feet; and Beaver 260-280 x 100 feet. Some drops were made into a red pine stand 38 feet average height and average crown density of 65% using the Otter. Wet water gave a pattern 190 x 70 feet whereas plain water was 180 x 50 feet. He reported that plain water had better penetration through the canopy but lacked the penetration of duff and humus achieved by the wet water.

Many of the tests carried out in Ontario have been multiple drops over the same area. Results have shown that the accumulation of water in any one collector can bears no relationship to the number of drops; therefore, some water must splash out of cans.

Drops from the side door opening Martin Mars show two distinct patterns, one for each tank. This may be important during low level drops with the possibility of straddling the fire being bombed. Williams (1962) showed that the benefits gained from dropping from altitudes below 250 feet was not worth the additional risk. The 0.02 inch contour for drops of 6,000 gallons at 120 and 250 feet are very similar, but with higher concentrations in the 120-foot drop pattern occurring in two definite and separate contour patterns within the overall pattern.

Two methods are employed in Canada for transporting water and retardants by aircraft to a forest fire. The first method entails the use of built-in belly tanks as in the TBM Avenger and the PBY Canso. The second method, by far the newest and developed in Canada by Field Aviation Ltd., Toronto, consists of building water tanks into the floats, partially utilizing the buoyancy space of the pontoons. This system does not affect the aerodynamics or handling characteristics of the aircraft. Retractable loading probes and tanks form part of the aircraft, thus no time is lost in preparing the aircraft for water drop use, as was the case with earlier float-mounted tanks. The pilot need only actuate the necessary safety switches when he desires to use the pontoon floats for water carrying.

OBJECT OF TESTS

The object of the tests was to determine the ground distribution patterns produced when various quantities of water were dropped from different types of aircraft used in fire bombing throughout Canada. Water concentration within the pattern was examined together with the relationship to the volume released and the release altitude.

PROCEDURE

PLOT SET-UP

A plot grid was established at Uplands Airport, Ottawa, in an area between the main runway 25 and taxiway E (Echo) at the junction of taxiway D (Delta). This site gave ready access to the National Aeronautical Establishment hangar via taxiway D.

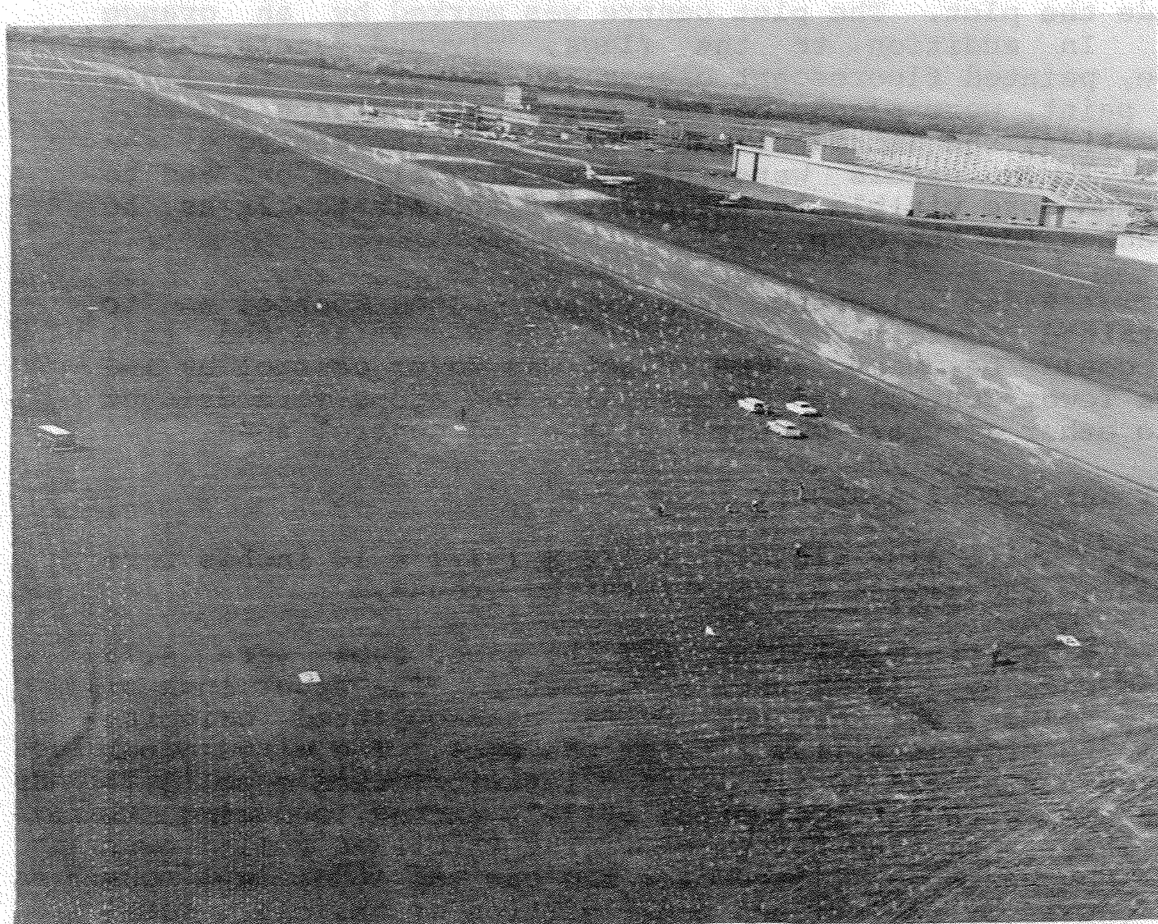

Figure 1. Aerial view of test drop site at Uplands Airport. Note the panel markers and flags.

Overall slope of the ground was downward SW to NE, with a slight crossfall and with considerable rolling unevenness across the width and length of the plot. Initial grid layout was 480 feet long by 172.5 feet wide covering an area of 81,840 square feet. Later, a further increase of the grid dimensions was made to give approximate gross overall dimensions of 570 by 202 feet with actual coverage area of 113,737.5 square feet.

On the grid area picket can holders were placed at intervals of 15 feet by 7.5 feet to form the rectangular grid.

The pickets in the grid were allocated coordinate letters and numbers, letters A-Z across the plot width and numerals 0-38 along the plot length. This enabled the position of any cup to be determined within the plot.

The centre line of the plot was marked by 3 flags. Two white flags were placed at either end about 10 feet outside the plot. The plot centre was marked by an orange flag. In addition to the flags, plywood panels 4 feet square, painted fluorescent orange and numbered 1 to 5 in black paint, were placed at each corner to indicate the plot extremities, the 5th panel being placed at the centre of the plot. These panels were elevated slightly on one end to make them more visible to the pilot of the air tanker as he approached for the drop.

Radio clearance from Ottawa Ground Control had to be obtained before movement between the hangar and the test plot could be made. The pilot was under control by the Ottawa Tower Control and occasionally the drops were delayed due to other aircraft movement within the control zone.

PICKET CAN-HOLDER ASSEMBLY

White pine pickets, 1-1/2 x 1-1/2 x 18 inches were pointed to facilitate driving into the ground.

The tin can holders for the paper cups were 4.75 inches deep by 3.25 inches in diameter. The upper inch of the cup holder was crimped by a hand-operated crimping machine to provide a firm fit for the cups. The waxed paper cups were standard 10 fluid ounce interior waxed cups, 3.75 inches deep with a top diameter of 3.3 inches reducing to 2.25 inches at the bottom end. The thickened rolled-over rim of the waxed cup fitted over the can top edge and was held snugly by the crimped upper portion of the can. Total number of cups was 935.

Figure 2. Ground view of the test site.

Total receptive area of cup surface was 219.4688 square feet, giving an area receptive ratio of 113,737.5:219.4688, i.e., a 0.193% coverage of the grid area by the cups.

This shows considerable similarity with the per cent coverage of 0.19% obtained for the Martin Mars tests (Williams, 1962). Prior to the first drop each day the stake station number was marked on each wax cup before being fitted into the appropriate cup holder.

To facilitate removal of the waxed cups after each test drop, the bottom of the tin cans were removed prior to assembly of the picket components. These tin cans were fastened to the stake by 2 flat-head nails and then securely bound with locking wire twisted around the can and stake as a precaution against breakaway from the stake.

A jig assembly arrangement was used to maintain correct positioning of the can during assembly. Details of the jig assembly are indicated in the Appendix, together with dimension sketches of other pieces of apparatus used and discussed later in the text.

HELICOPTER FOR HEIGHT CONTROL

To ensure a standard height for all the test drops a Bell 47-G helicopter stationed about 150 feet abeam of the centre of the grid plot hovered at a height of 75 feet. This was the standard height selected for the drops. The pilot of the incoming aircraft lined his aircraft up with the centre line of the plot and adjusted his height to correspond to that of the hovering helicopter.

The actual height of the aircraft at the time of water release was measured from the film taken by the theodolite camera mentioned below. Due to the nature of the cross winds experienced during the series of tests the aircraft had to fly a path away from the centre line such that the falling mass of water would land within the plot after deflection by the wind.

Because water droplets adhere to the waxed cup interior, it was not possible to pour the catch into a graduate measure. In this case, weighing gave a more accurate measure of water quantity caught.

After each test drop, any of the waxed cups showing evidence of containing water, in liquid or droplet form, were capped with plastic lids that fitted the cups. Care in putting these caps on is important, otherwise spillage or evaporation can take place. The best method of capping found was to place the lid over the cup at one point and then run the palm of the hand around the cup edge pressing down at the same time. Once capped, the cup was pushed up from the underside away from the firm hold of the crimped edge of the can, so that it could easily be picked up by the collectors without damaging the closed cup.

Figure 3. Collecting cup after drop from TBM Avenger with Phoschek retardant.

Capped cups were brought from the drop area in 32-cup capacity aluminium carriers. At the central collecting point these cups were transferred into a 320-cup capacity plywood framed box. This box was sectioned into 40 compartments, each holding 8 cups in 2 layers of 4 each.

The filled plywood boxes were transported back to the laboratory where each cup was weighed to determine the quantity of water collected by that cup.

Figure 4. Collecting tray and carrying box.

A standard average weight was determined for the dry cups. This tare weight was set on a direct reading balance so that an empty cup would give a zero reading, thus any cups containing water would give a reading of the water quantity caught. Some of the cups with small traces of water recorded negative values. These were discarded and a zero measure attributed to that cup.

Prior to the next drop, new cups were placed, where necessary, and marked with the appropriate picket coordinate.

MEASUREMENTS TAKEN

At the test site relative humidity and temperature measurements were taken with a hygrothermograph. Calibration checks on this instrument were carried out with a sling psychrometer.

The 'on site' wind was measured by a 3-cup Casella anemometer mounted 6 feet above the ground adjacent to the drop area. The indicated wind noted on the final ground distribution charts is the wind as measured by the Uplands Control Tower from a 30-foot mast mounted in the centre of the airfield. During the first series of Twin Otter test drops, several different types of wind recorders were tried out. These included a Woelfle recorder mounted at eye level and a Gill 3-cup anemometer at 18 inches to record ground surface wind. In the 2nd series of Twin Otter drops, wind conditions were milder and a truer indication of pattern was obtained.

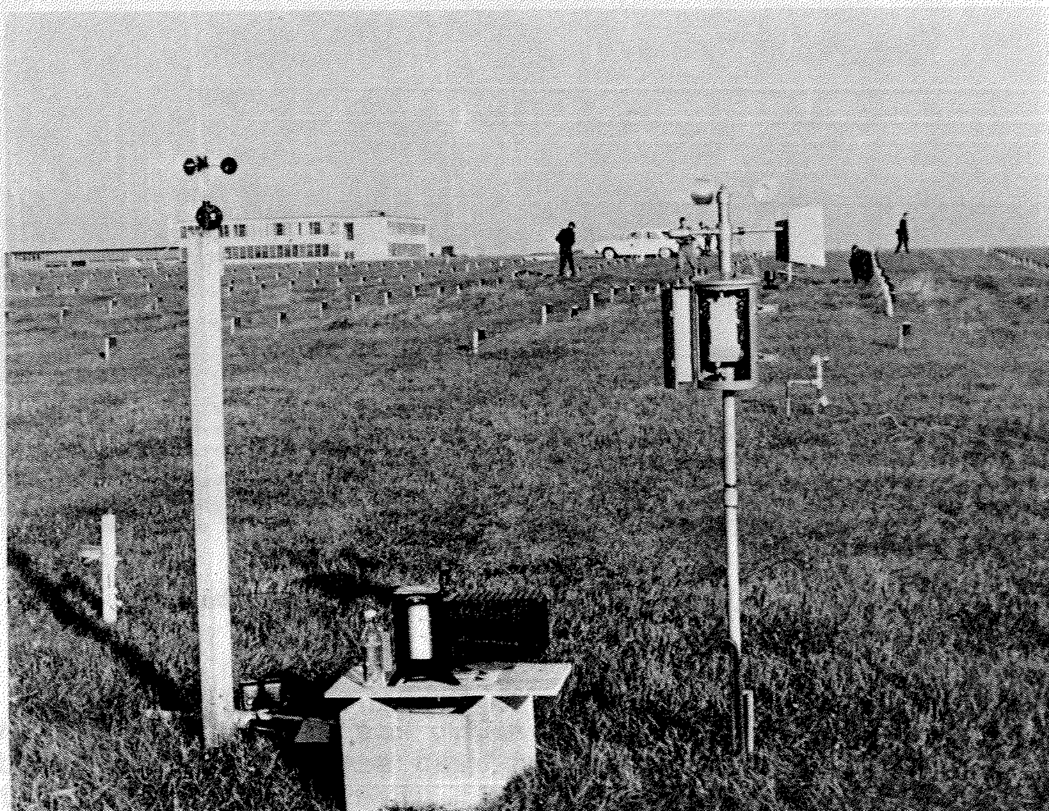

Figure 5. Wind recorders used during Twin Otter tests.

A film record of each drop was made using a high speed theodolite camera situated 1226 feet north from the drop area. This enabled precise measurements of drop height and ground speed to be made. Measurements of altitude were guaranteed to within 2% of true, provided the aircraft was within 30 feet of the centreline of the grid plot, the line to which the instrument was calibrated.

In addition, 2 sets of thermocouples were used to record wet and dry bulb temperatures at 2 points. One point was situated at the centre of the plot grid and the other mounted outside and well upwind from any effect of relative humidity changes induced by the dropped water. The thermocouples were connected to a 12-point recorder that enabled a continuous measurement of relative humidity to be made. The duration of any relative humidity change could also be noted. This, however, was greatly dependent upon surface wind moving the moist air mass away from the drop area. Analysis of this particular data is still continuing.

ADDED WEIGHT

Pieces of grass were found in cups on several occasions. It is doubtful whether they were blown in but more likely to have been carried in by water splashes. Extraneous matter was found only in the cups situated at the main impact point of the water mass, thus the contours in this region indicate water concentrations higher than they should be. The impact area being defined as that area in which the force of impact of the falling water mass has been sufficient to obviously flatten the grass by its force of impact. This impact area will depend greatly on the height at which the load is released, for example, for a drop height of 75 feet the impact area for the Twin Otter is about 60 x 25 feet gross dimensions.

CUPS LOST

Several cups were knocked out of the holders by the falling water mass, due to improper replacement after a previous drop. Early in the tests trouble was experienced with rotor blast from the helicopter blowing out cups that had been insecurely placed in the can assembly.

On several occasions cup/can assemblies were flattened during drops where no load disintegration of the water mass had taken place. No aircraft can be singled out as the chief offender -- it occurred with each aircraft type tested.

LOAD DISINTEGRATION

Bulk water has a low ratio of drag to mass and hence a large terminal velocity which is the opposite for water droplets which have a high drag mass ratio. Water in bulk form, forming the sharp front of the falling water mass only proceeds to a certain distance below the aircraft before it breaks sharply rearward. At this point the bulk water is eroded into droplets which have a low terminal velocity with little horizontal movement. The presence of flattened and squashed cans indicated that load disintegration had not taken place and in fact the water was reaching the ground, at least in places, in bulk form.

Figure 6. Can flattened by dropped water.

Load disintegration was observed to be very distinct in some cases, it again was not restricted to any particular aircraft. The photo of the TBM Avenger shows 'fingering' to a very marked degree; the ground distribution pattern for this particular drop is quite splotchy.

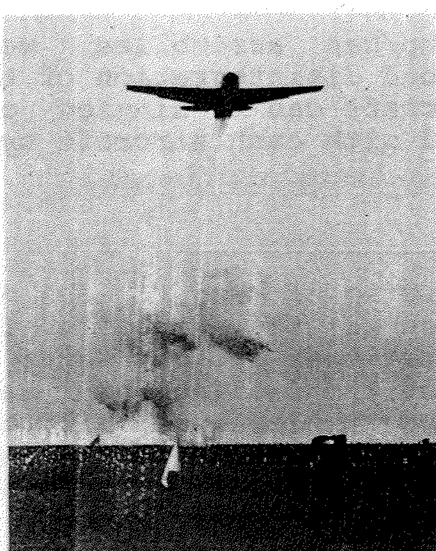

Figure 7. TBM Avenger drop. Note fingering of the water mass.

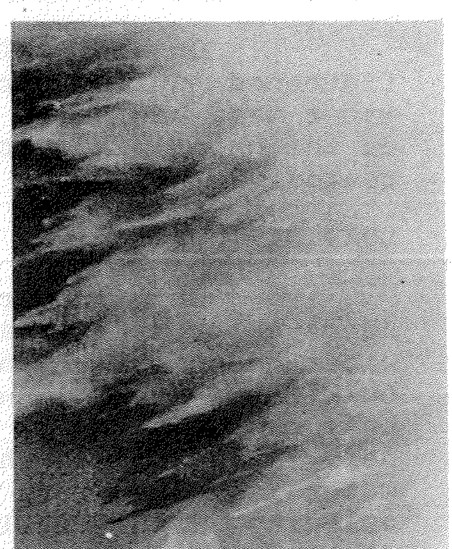

Figure 8. Typical frontal disintegration during Canso drop.

Generally the water reached the ground in a fine disintegrated form, very much like a heavy rain. Photograph No. 9 shows the water moments after impact in the form of a heavy mist rain.

Figure 9.

A wind effect on the resulting ground pattern distribution is obvious. The contours bunch up on the forward edge of the water mass nearest to the wind, the wind holding this front flank whilst the momentum of the remainder of the load pushes up against this wind barrier. This phenomenon is most strikingly shown in the plotted ground distribution patterns for the first series of Twin Otter drops, where all the contours have bunched at the leading edge with the tail end of the load aligned along the direction of the wind. With all the other aircraft types the wind has had the effect of moving the whole downwind side of the drop away from the drop area.

ANALYSIS OF DATA

Ground distribution pattern measurements are indicated in inches of water. The outside contour, i.e. 0.005 inches of water, requires 0.68 grams of water per cup.

A computer was programmed to read across the data, i.e. up and down the longitudinal rows, until it came to a measurement of 0.68 gms. If this occurred somewhere between two of the plot points the computer would estimate where the 0.68 gms. point should be and give an output answer in units of 15 feet, e.g., 4/15 would indicate that the 0.005 contour cut that particular longitudinal row 4 feet from the previously scanned point.

After scanning all rows for 0.68 gms. the computer then worked on the 0.01 inch contour and so on until the whole ground distribution pattern had been completed.

Although the analysis of the data determined the length and outline perimeter of the 0.005 inch contour, this quantity of water would have an insignificant effect on a fire and hence in the summary sheet this contour length and area has been omitted.

From the plotted contours the continuous longitudinal lengths for given concentration contours are measured.

STANDARDS USED FOR MEASURING CONTOUR LENGTHS

All the longitudinal measurements are taken within a 50-foot width. This width was selected as the standard because it is extremely difficult for the pilot to place his load directly where wanted on the burning edge of the fire, so some lateral deviation must be allowed for. Factors which must be taken into account here are wind force, visibility and smoke condition, topography and pilot accuracy. It is thought that 50 feet would be an adequate width to allow for the above factors.

In the case of an elliptical contour the tips of which lie within the 50-foot width, then measure to the extremities of the contour, Case (a).

In the case of broken contours, in which there is lateral overlap within the assigned width, the shortest distance between the adjacent edges of the same concentration contours is not to exceed 10 feet, and the length measured is that for the overall length occupied by the contour sections, Case (b).

In the situation where two contours of the same concentration do not overlap laterally and are in linear alignment, measure as if a complete contour, provided the gap between the individual contours does not exceed 5 feet. If greater than a 5-foot separation, then for all purposes the ground distribution pattern has no length for that particular concentration contour, Case (c).

The following diagram may help illustrate the problem, e.g., consider a single contour within a ground distribution pattern.

Because of the unevenness of the water concentrations, the resulting contour patterns occasionally have 'holes' within them. It is not uncommon to find a contour within the same contour on several of the ground distribution patterns drawn, e.g., Canso test drop No. 4.

To study the water losses that occurred during the test drops, recovery values were plotted against temperature and relative humidity readings taken at the time of each drop. No meaningful results could be obtained from these plots. In a further attempt, the percentage loss for each drop was plotted against the saturated vapour pressure deficit which is a more accurate measure of the relative dryness of the air than relative humidity deficit. Again no correlation could be obtained.

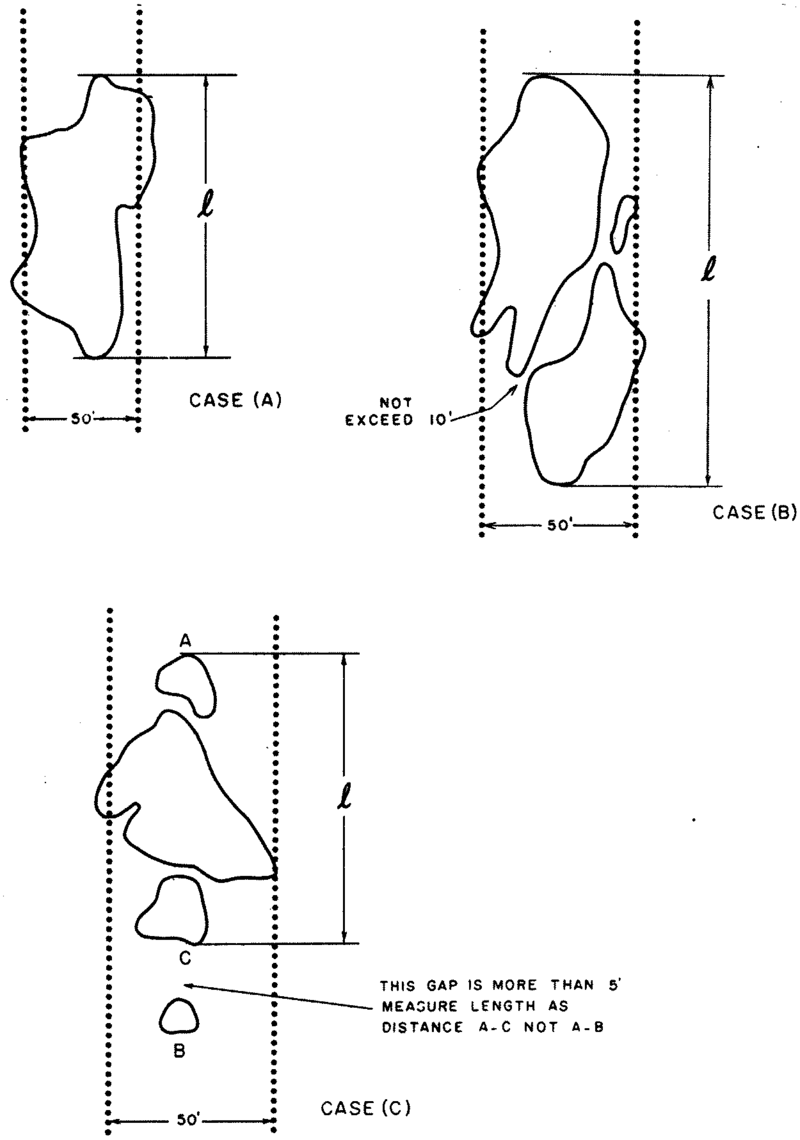

Figure 10

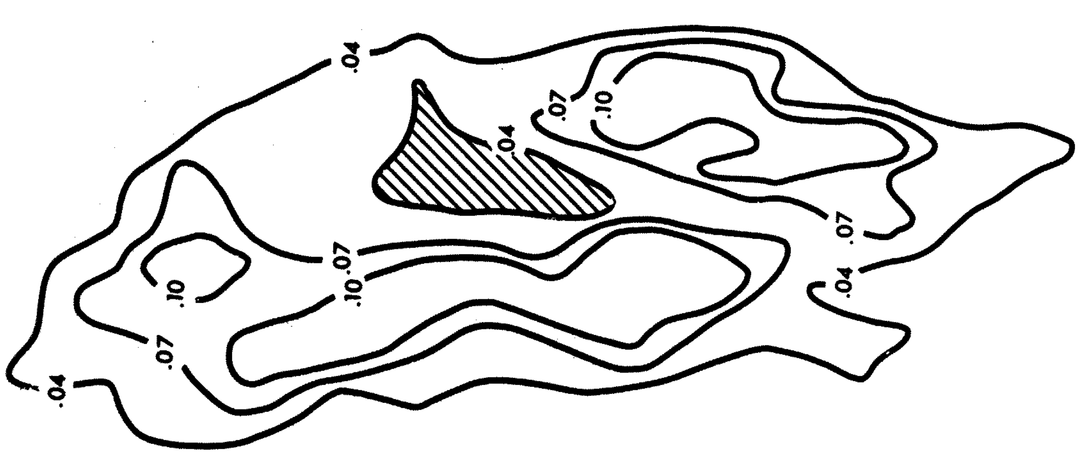

Figure 11

TBM Avenger

The tests for the TBM Avenger were carried out under conditions that were far from ideal.

An incessant cross wind made it extremely difficult for the pilot to place the load of water where required. The results we did obtain are attributed to the pilot's skill.

Considerable breakup of the water load is shown in the plotted ground distribution. Rather than nice concentric contours there exist many little islands and pockets which, on the basis of the standard method of measurement outlined previously, result in no measurement being taken for the inner contours. It is realized that this gives rise to anomalies but some form of standard measuring technique had to be adopted.

It must be stressed that this aircraft was tested under adverse conditions and the results do not present the aircraft at its best.

The plot for drop 10 shows several interesting features. Firstly, in spite of the strong headwind there is little or no bunching of the contours and secondly, the fingering nature of the water mass shows up distinctly on the forward contour edge - see Figure 7 of this drop, head view. Several other of the drops show this feature but not to such a marked extent. Percentage recovery has a 15% range.

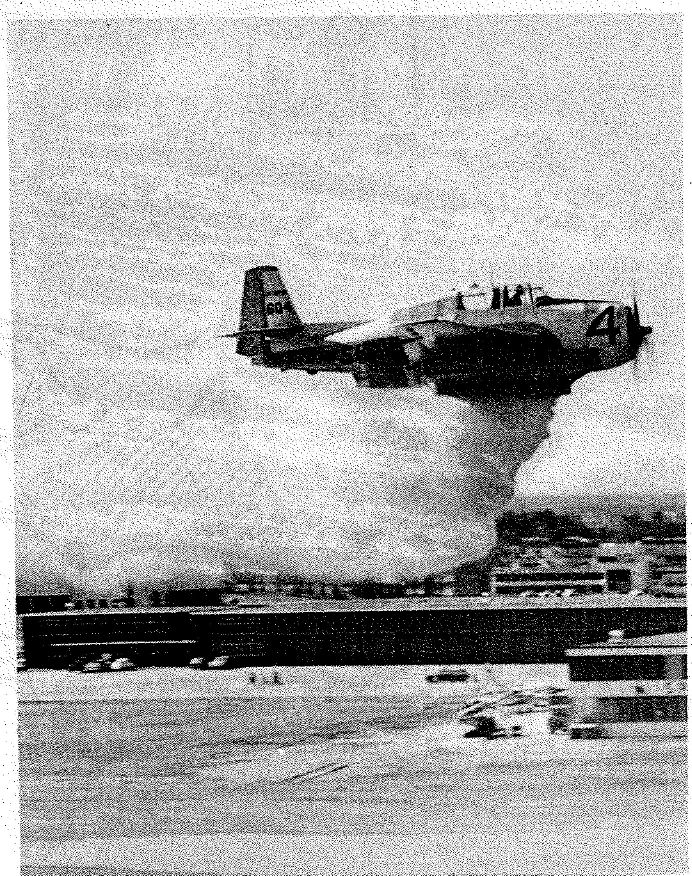

Figure 12.
500 gallon TBM Avenger.

Photo by Flight Research Section, National Research Council.

DHC-2 Turbo-Beaver

The low temperature and high relative humidity conditions under which this set of tests was carried out resulted in very high recovery figures for three of the drops, and increasingly lower recoveries for the remainder. The range of recoveries, 38%, is inexplicable, especially those recovery figures over 100%. The Simpson's rule integration method used for calculation of percentage recoveries may be slightly inaccurate because of the lower number of cups weighed during these drops. It is more likely that the maximum recovery for this aircraft is about 95%.

The inner contours of the distribution patterns show marked breakup into islands. This would suggest great load disintegration of the falling water mass. The fingers reaching the ground first in patches and then the remaining mass of water falling fairly uniformly over the plot thus gives an overall ground distribution pattern containing small pockets of high concentration. Photographs taken at the time of the test drops confirm this degree of load disintegration and a movie film of other drops shows this idea of the mass of water compounding over the 'fingers'.

Figure 13. 140 gallon DHC-2 Turbo-Beaver.

DHC-3 Otter

Similar to the Turbo-Beaver, this aircraft has ground distribution patterns which show considerable breakup into islands at higher concentration levels. This makes measurement of the higher contour lengths almost impossible. Patterns for the Otter are narrower than those of the Turbo-Beaver even though the range of airspeeds is quite comparable.

Figure 14. 230 gallon DHC-3 Otter

PBY Canso

The ground distribution patterns for this aircraft show that the water from the two separate tanks does not coalesce into one large mass by the time it reaches the ground. The fact that the starboard door opens sooner than the port door results in a lopsided contour for the 0.07 inch and higher concentrations. The right-hand mass of the water appears to roll under slightly at the time of initial contact with the ground, thus adding more water to the left side of the pattern.

This initial contact with the ground by the right mass causes it to break up more than when the following left-hand mass hits the ground; thus the left-hand contours will be more complete.

Figure 15. 800 gallon PBY Canso

DHC-6 Twin Otter

This aircraft is the newest addition to the fleet of fire bombing aircraft, making its first appearance this year.

The design of the float tank system incorporates vent flaps on top of the pontoon that open in conjunction with the drop doors. This gives an extremely quick discharge time for the aircraft, with practically no trail out.

The rounded shape of the water mass is illustrated in photograph No. 16.

The first four ground distribution patterns are atypical because of the strong cross wind at the time of testing. The contours of these drops have aligned with the direction of the wind. This differs from the crosswind patterns for the other type of aircraft where the complete downwind side of the pattern has shifted obliquely.

Disregarding the wind effect, the length of the contours are very much smaller than what would be expected for a conventional belly-type tank aircraft. Higher water concentrations are obtained, signifying this lack of load disintegration. The compactness of the water mass and lack of any appreciable trail-out gives the false impression that the drop falls faster than for the other aircraft tested. The actual discharge time from the tanks is quite short, assisted by the vent flaps on the upper surface of the tanks.

Although the contour lengths of the drop patterns for this aircraft are relatively small, an increase in airspeed of the aircraft at time of dropping will help string the load out longer if this is desired.

Figure 16. 400 gallon DHC-6 Twin Otter. Note the vent flaps on the upper side of the pontoons, which open at same time as the drop doors.

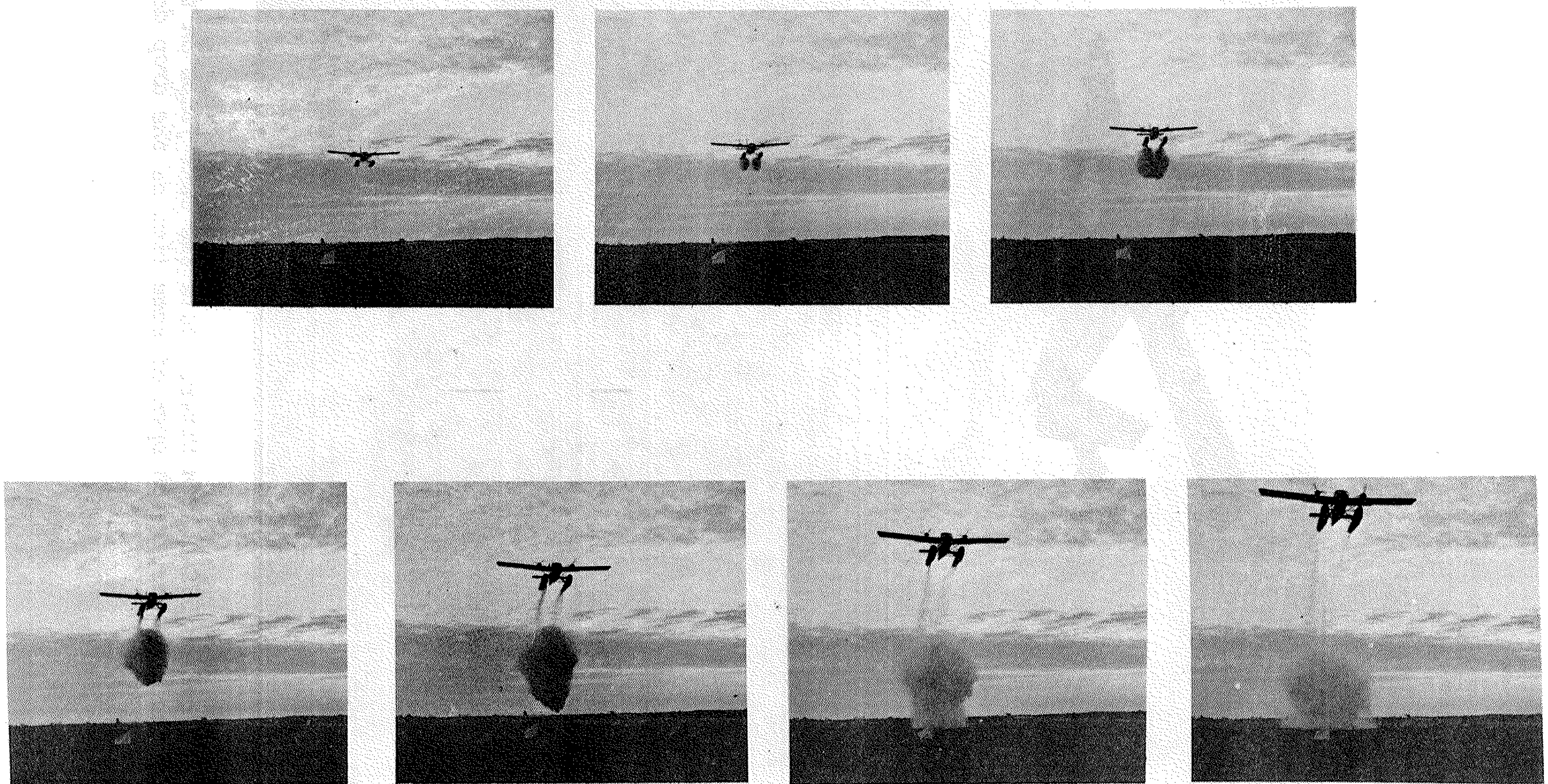

Figure 17. Twin Otter drop, head on view.
Time interval between pictures not constant.

The tables on the following pages summarize the measurements taken from the ground distribution contour patterns in accordance with the standards of measurement adopted.

Aircraft	No. of Drops	Drop No.	Max. Lgth. Contours in feet .01	.02	.04	.07	.10	.15	Highest Conc.
TBM		1	292	232	176	124	47	-	0.18
Avenger		4	319	268	166	72	-	-	0.12
		6	250	212	100+	-	-	-	0.13
		7	339	218	183	28+	-	-	0.11
CF-IMM		8	266	258	188	142	58+	-	0.20
		9	281	208	160	137	68+	-	0.19
		10	348	188	168	40+	22	-	0.16
		11	320	262	164	138	48+	-	0.25
	8	Mean	302	231	163	97	49		
		Std.Dvn.	40.0	29.2	27.3	49.4	17.1		
Phoschek		13	262	234	148	120	110	-	0.22

+Pattern too broken for continuous measurement.

Aircraft	No. of Drops	Drop No.	Max. Lgth. Contours in feet .01	.02	.04	.07	.10	.15	Highest Conc.
DHC-3		5	206	168	82	50	32	-	0.14
Otter		6	206	146	70	53	36	-	0.18
		7	210	167	115	96	55	-	0.24
CF-ODU		8	203	173	115	102	40+	-	0.20
		9	240	189	150	125	22	-	0.17
		11	234	178	144	63	32	-	0.24
		12	211	180	122	68	25	-	0.19
	7	Mean	216	172	114	80	35		
		Std.Dvn.	14.9	13.6	29.5	28.4	10.9		

+Pattern too broken for continuous measurement.

Aircraft	No. of Drops	Drop No.	.01	.02	.04	.07	.10	.15	Highest Conc.
			Max. Lgth. Contours in feet						
DHC-2		1	173	138	55	35	-	-	0.09
Turbo-		2	160	140	68	22+	-	-	0.13
Beaver		3	166	143	65	18+	-	-	0.12
CF-OEJ		4	163	142	66	15	-	-	0.12
normal drop speed									
74 kts	4	Mean	166	141	64	23			
		Std.Dvn.	5.6	2.2	5.8	8.8			
		5	176	112	63	-	-	-	0.09
High		6	176	124	38	-	-	-	0.09
speed		7	153	102	32	-	-	-	0.06
86 kts	3	Mean	168	113	44				
		Std.Dvn.	13.3	11.0	14.0				

+ Pattern too broken for continuous measurement.

Aircraft	No. of Drops	Drop No.	.01	.02	.04	.07	.10	.15	Highest Conc.
			Max. Lgth. Contours in feet						
PBY		1	350	282	218	151	129	100	0.23
Canso		2	320	280	196	139	122	82	0.33
CF-PQL		3	295	262	200	138	110	62	0.28
		4	326	270	208	168	121	+	0.20
		5	308	272	222	149	78	+	0.35
		6	295	232	151	128	109	40	0.24
	6	Mean	316	266	199	146	112	71	
		Std.Dvn.	21.1	18.3	25.6	13.8	18.1	25.8	

+ Pattern too broken for continuous measurement.

Aircraft	No. of Drops	Drop No.	Max. Lgth. Contours in feet .01	.02	.04	.07	.10	.15	Highest Conc.
DHC-6		1	223*	202*	110	85	60	29	0.30
Twin Otter		2	298*	185*	94	64	48	20	0.25
CF-OED		3	285*	193*	161*	48	41	34	0.39
		4	295*	106	84	62	43	36	0.27
		5	258	209	113	68	52	41	0.32
		6	244	199	137	88	68	40	0.19
		8	240	228	150	71	50	33	0.25
	7	Mean	263	189	121	69	52	33	
		Std.Dvn.	29.6	39.0	28.8	13.8	9.5	7.2	
Left tank only		7	213	140	109	76	67	11	0.18

* Measurement doubtful.

Range of Recovery Percentages

Aircraft	No. of Drops	Percentage Recovery Minimum	Mean	Maximum
Avenger	8	79.0	87.1	94.0
Otter	7	78.0	85.0	97.0
Turbo-Beaver (a) Normal speed	4	91.0	101.0	106.0
(b) Fast speed	3	68.0	75.0	80.0
Canso	6	69.0	76.1	92.5
Twin Otter	7	70.5	73.5	84.0

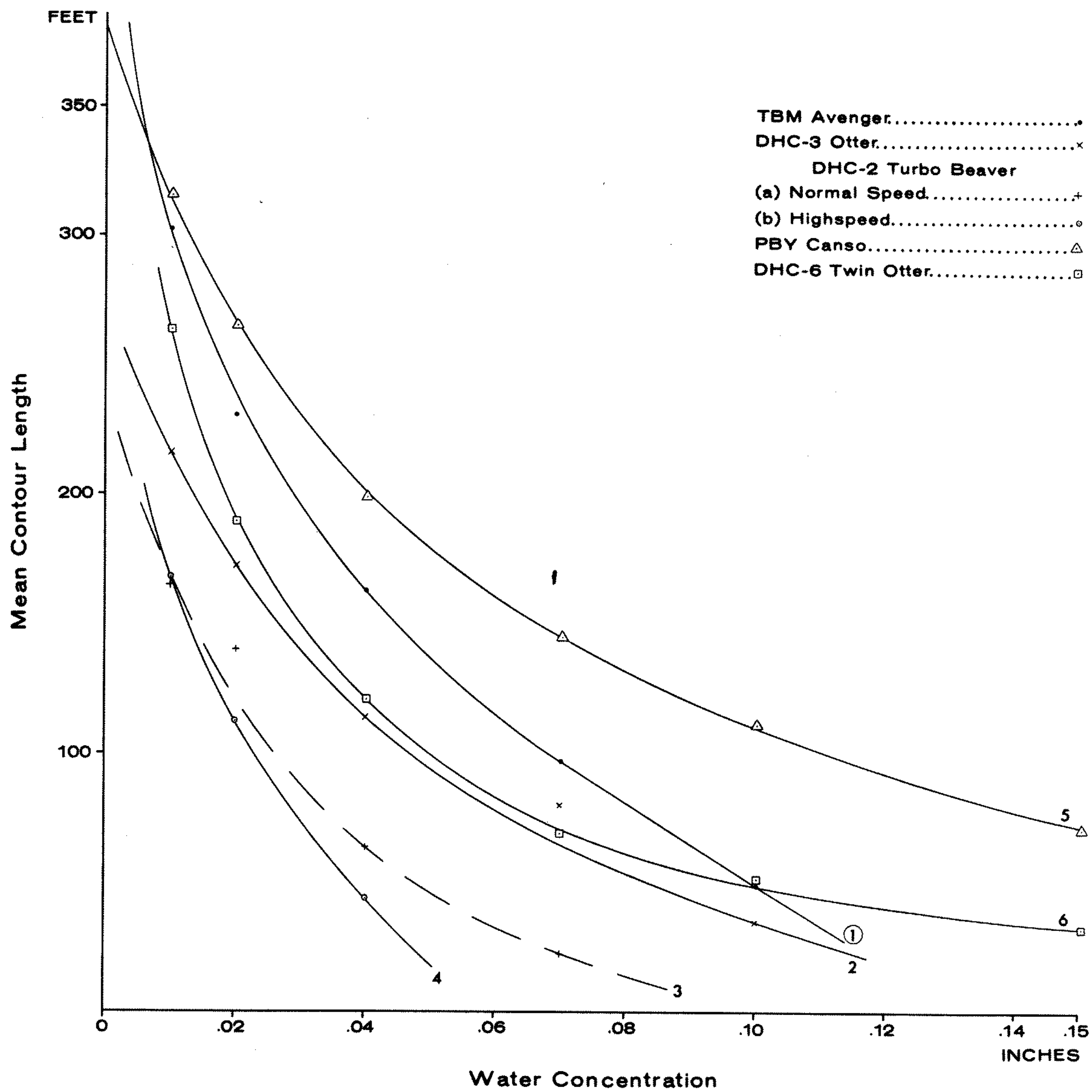

Figure 18. Length of drop patterns for various water concentrations.

REFINEMENTS TO THE SYSTEM

If further tests of this type are to be carried out then it would be desirable to make some improvements to the technique used.

1. If wooden stakes are to be used, larger cleat-headed nails should be used to stop the can from pulling away from the stake.

2. Coordinate numbers on the stakes to be marked with a waterproof and fadeproof marker.

3. Cups numbered with a waterproof type marker. Trouble was experienced with the numbers being smeared from the outside of the cups when handled.

4. Closer spacing of pickets in central area of the grid when testing aircraft which drop their water load in a compact mass.

5. Raise the cups a further 12" above the ground to stop splash-in.

6. Important: Measure accurately the quantity of water held in the tanks of the aircraft. Do not rely on operator's figure.

7. Carry out project in an area other than an airfield if possible -- to avoid problems of radio clearance and complying to traffic procedures.

CONTINUATION OF PROJECT

If possible, it would be in the interests of completeness to extend this project sometime throughout two more phases:

Phase II - Set the grid under a tree canopy in an area that could be described as typical for the region. The new contour lengths obtained could then be described for the known and measurable parameters of that particular stand, e.g., height, crown density, stand density, etc. Values for interception could be determined in relation to crown density and any other desirable factors.

Phase III - Drop onto a steady-state prescribed burn and note length, area extinguished or slowed down, and for how long. Under prescribed fire conditions many of the parameters that can be useful in describing fire behaviour are known or can be readily measured, and therefore equated to the effect of one or more drops from a fire bombing aircraft.

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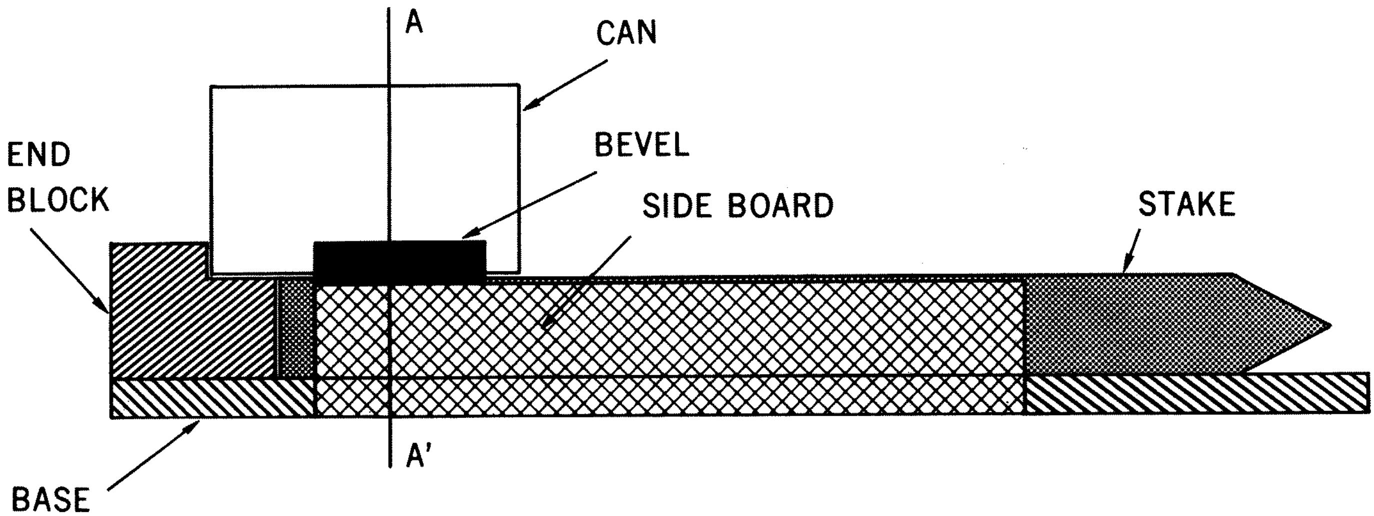
Williams, D.E. 1962. Report on tests of the water-dropping characteristics of the Martin-Mars air tanker. Nanaimo, B.C. Sept. 1960.

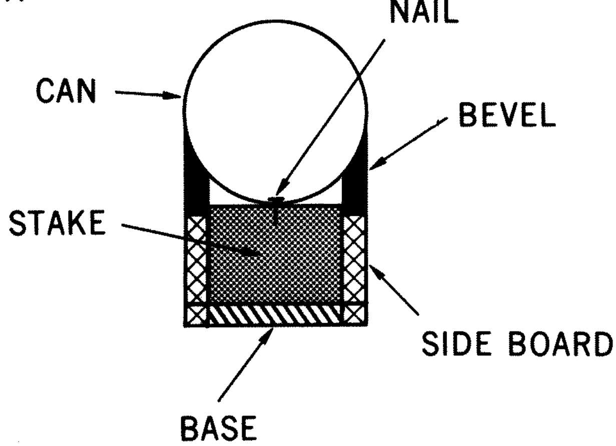
Wood, G.J. and T.C. Cooke. 1957. Report on water dropping Ontario Department of Lands and Forests.

APPENDICES

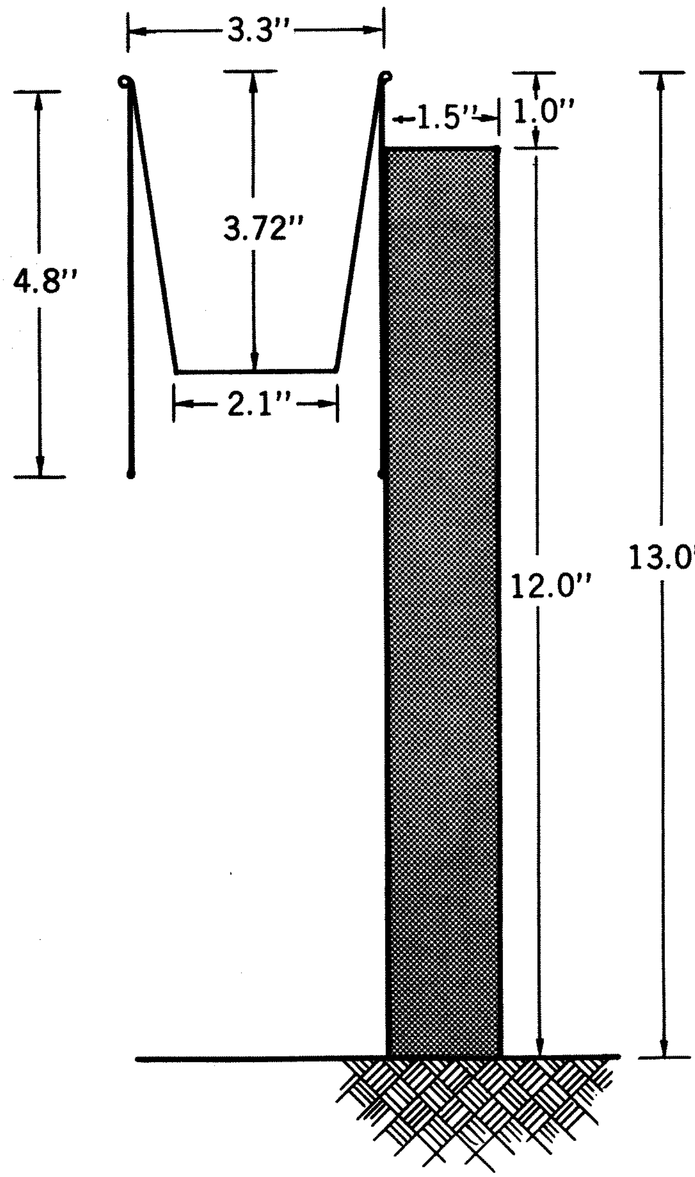
CAN MOUNTING JIG



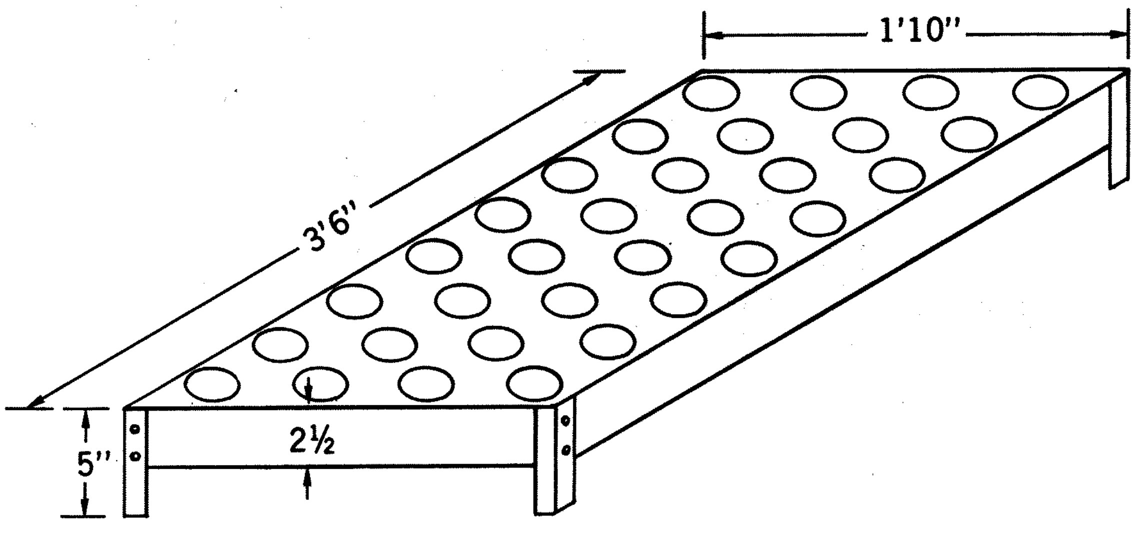
SECTION A A'



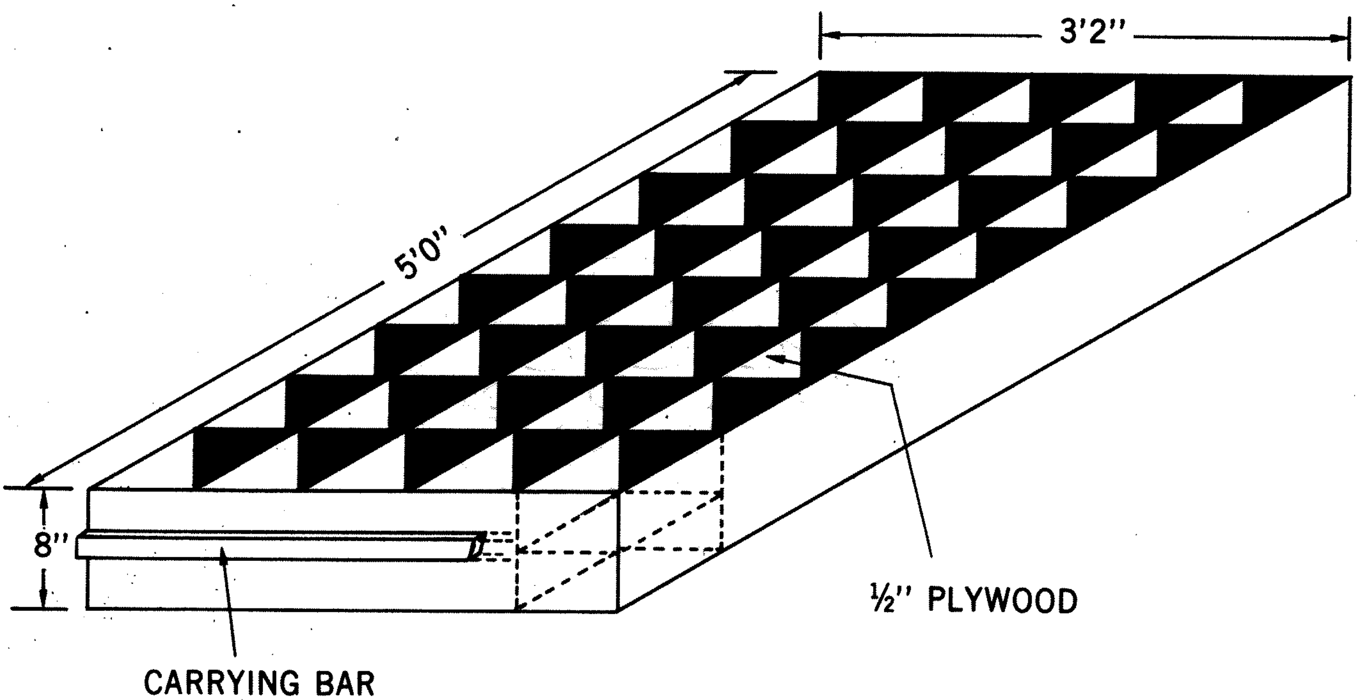
SECTION VIEW
CUP/CAN/STAKE ASSEMBLY



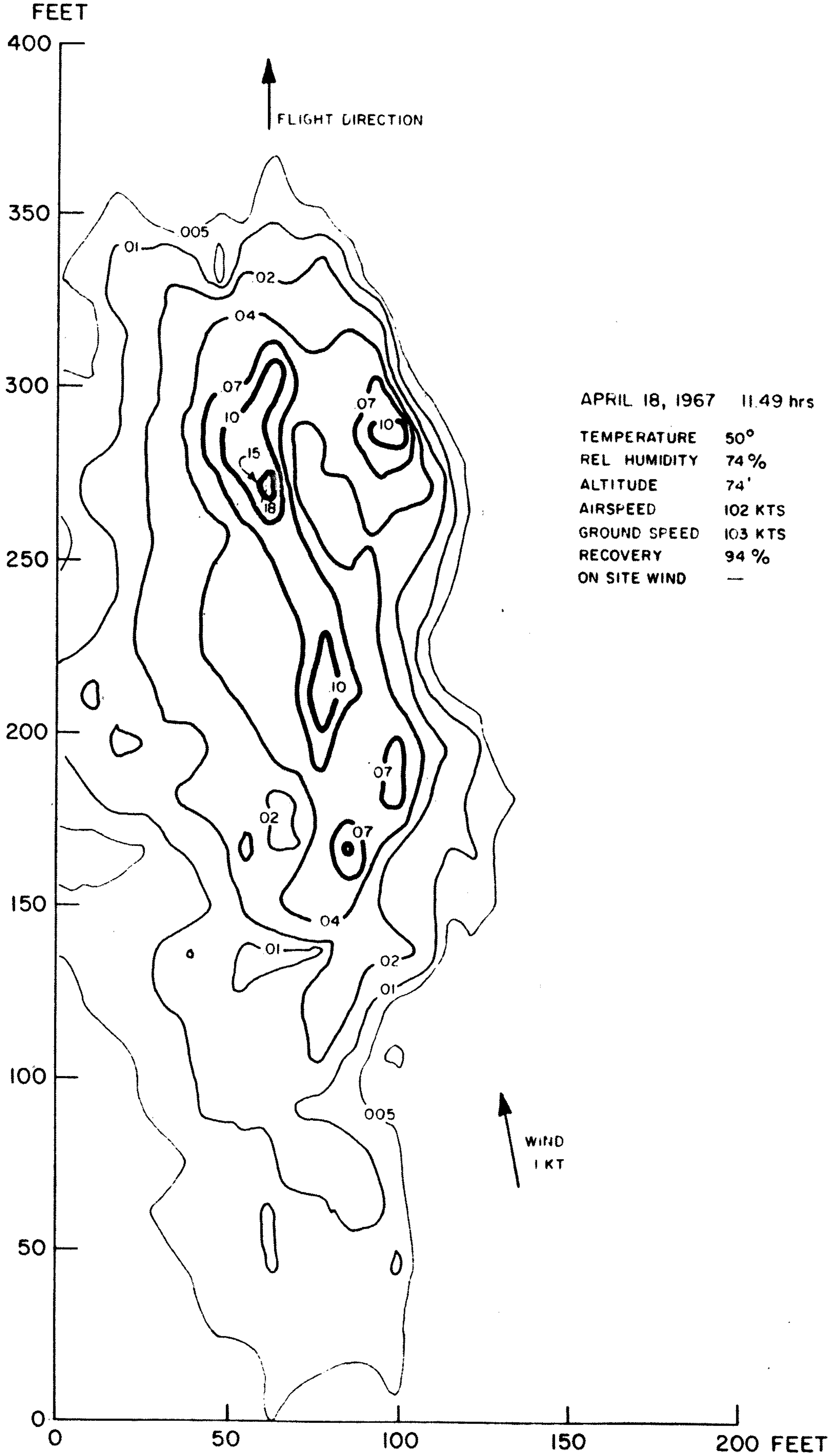
32 CUP
ALUMINIUM COLLECTING TRAY



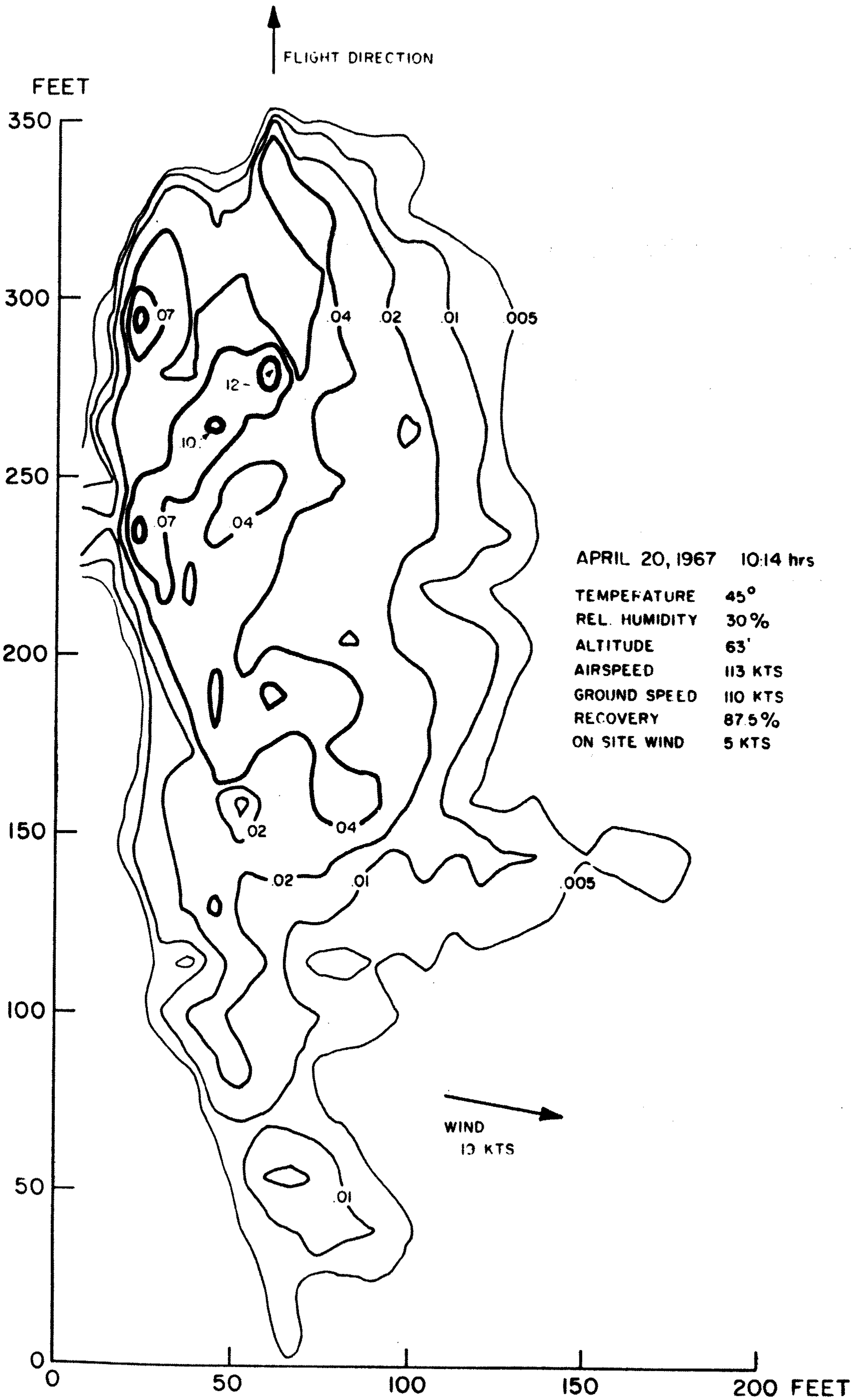
320 CUP
PLYWOOD CARRYING BOX



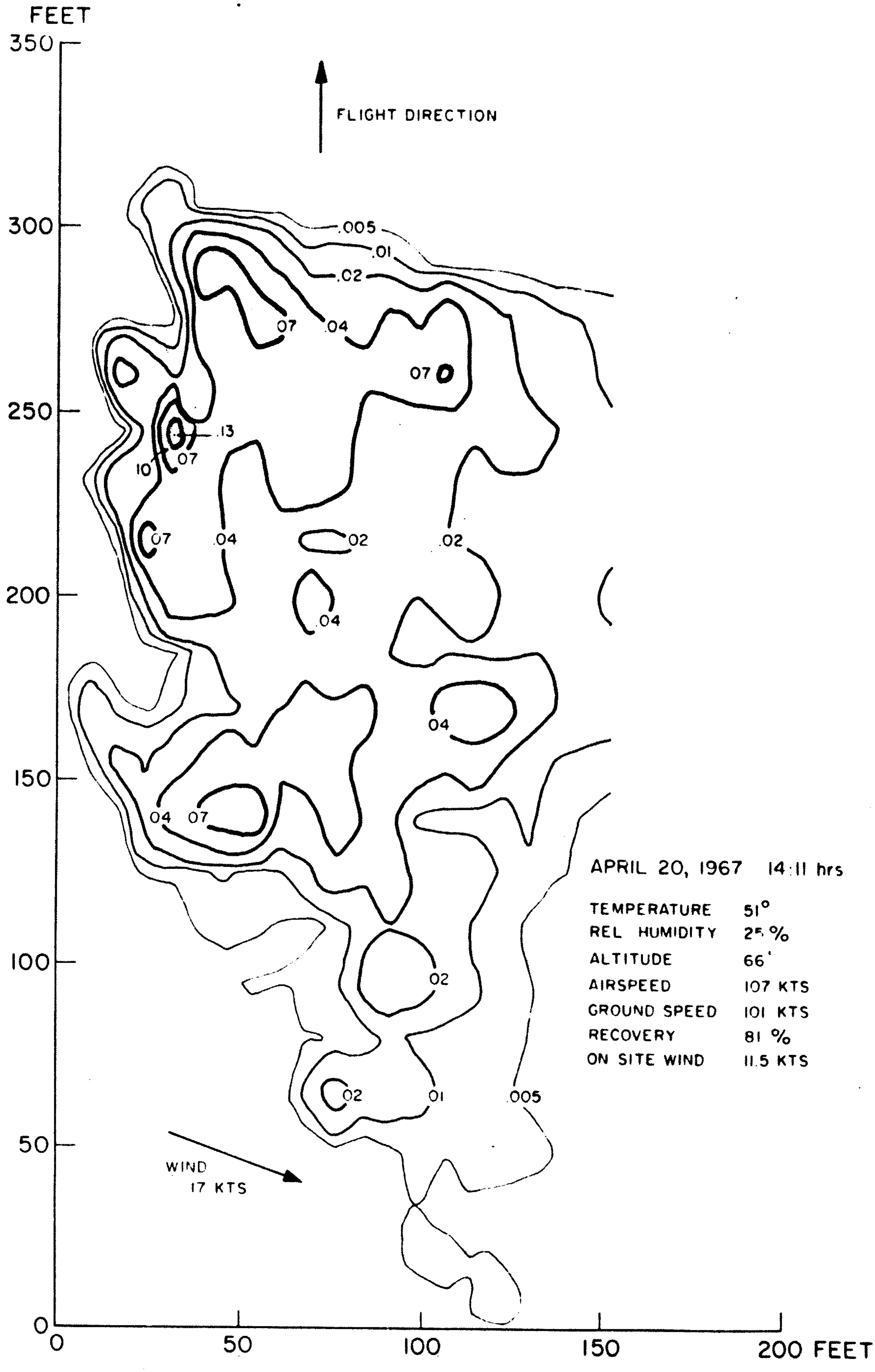
AVENGER, DROP No. 1



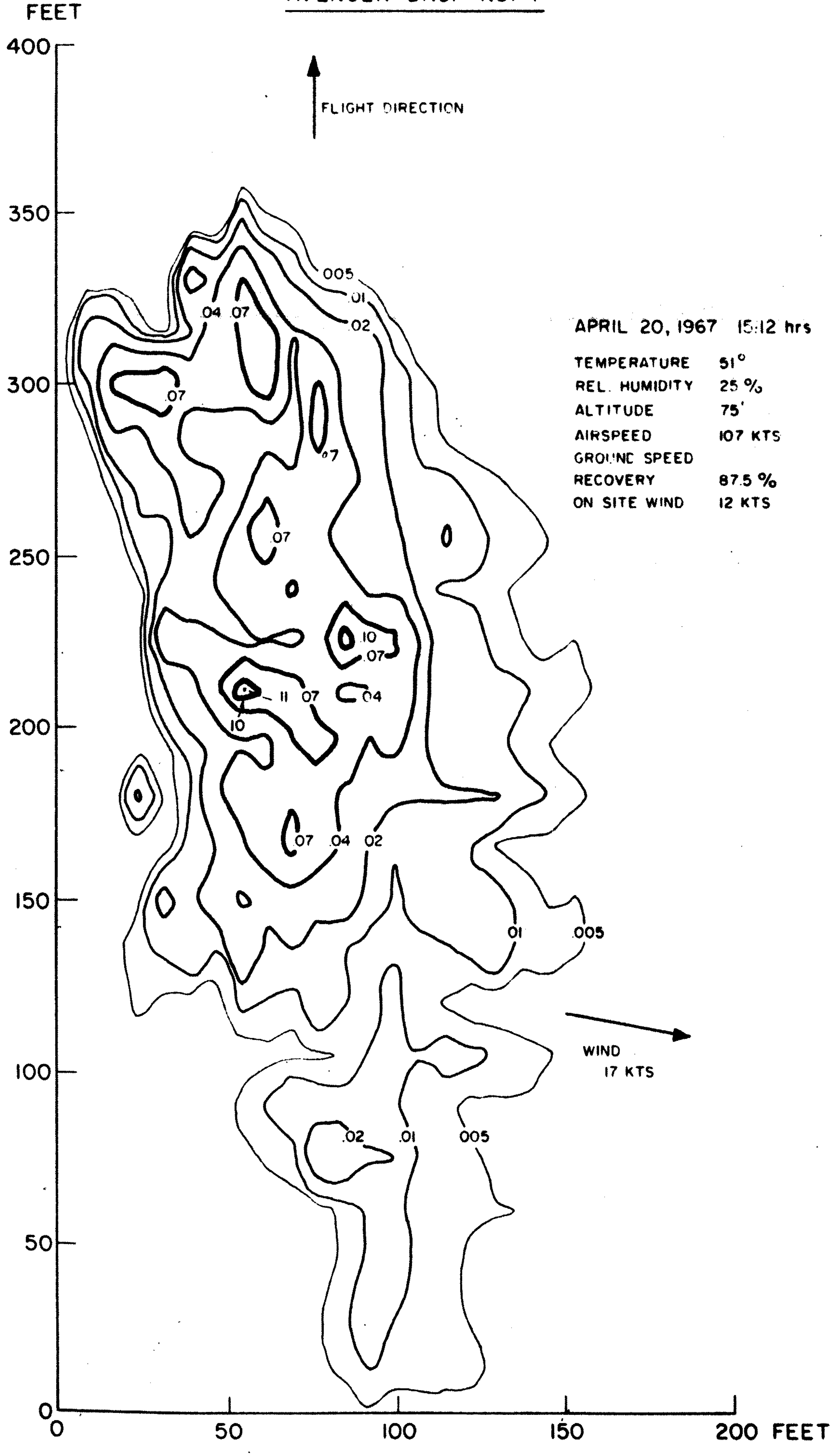
AVENGER DROP NO. 4



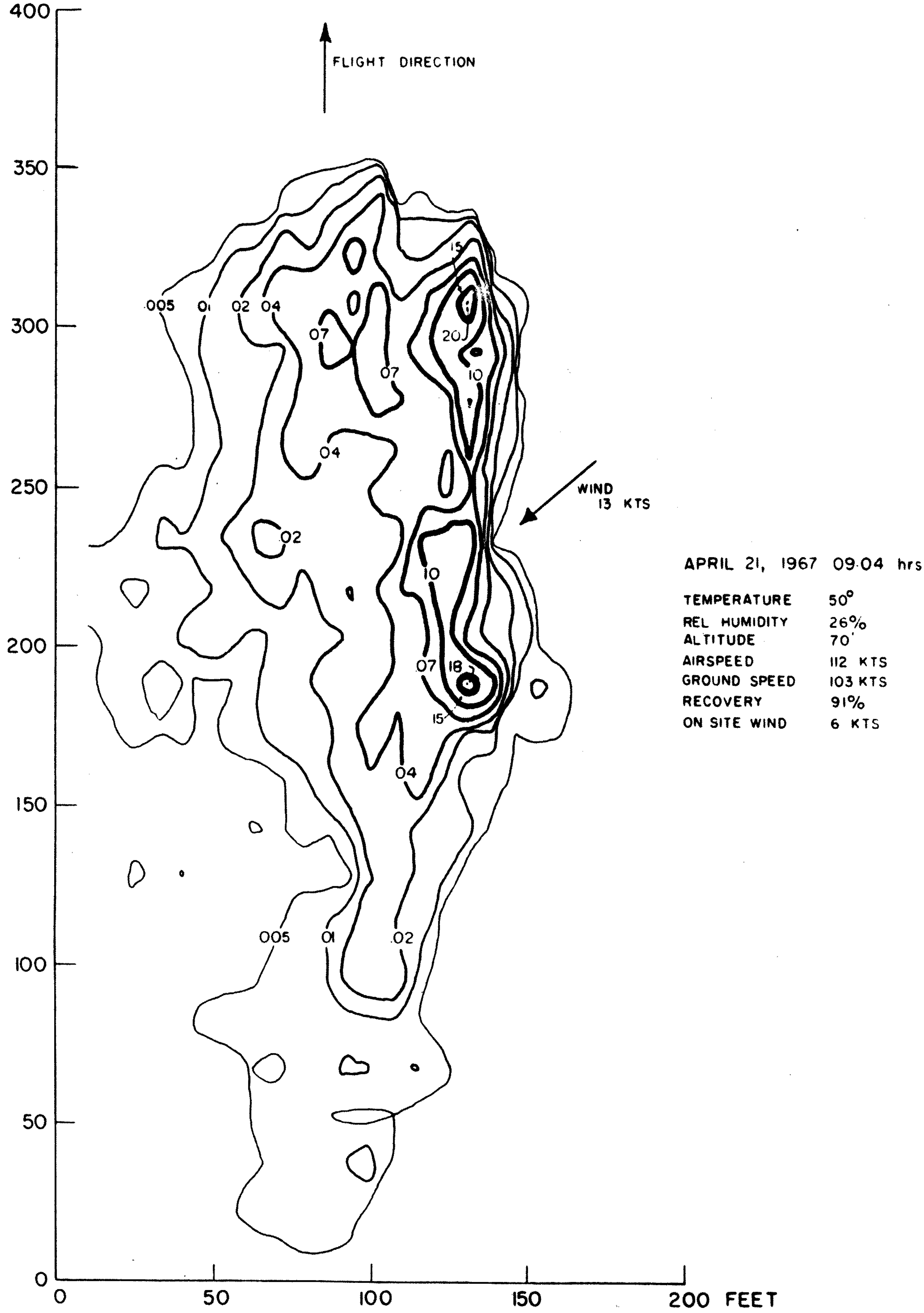
AVENGER DROP NO. 6



AVENGER DROP NO. 7



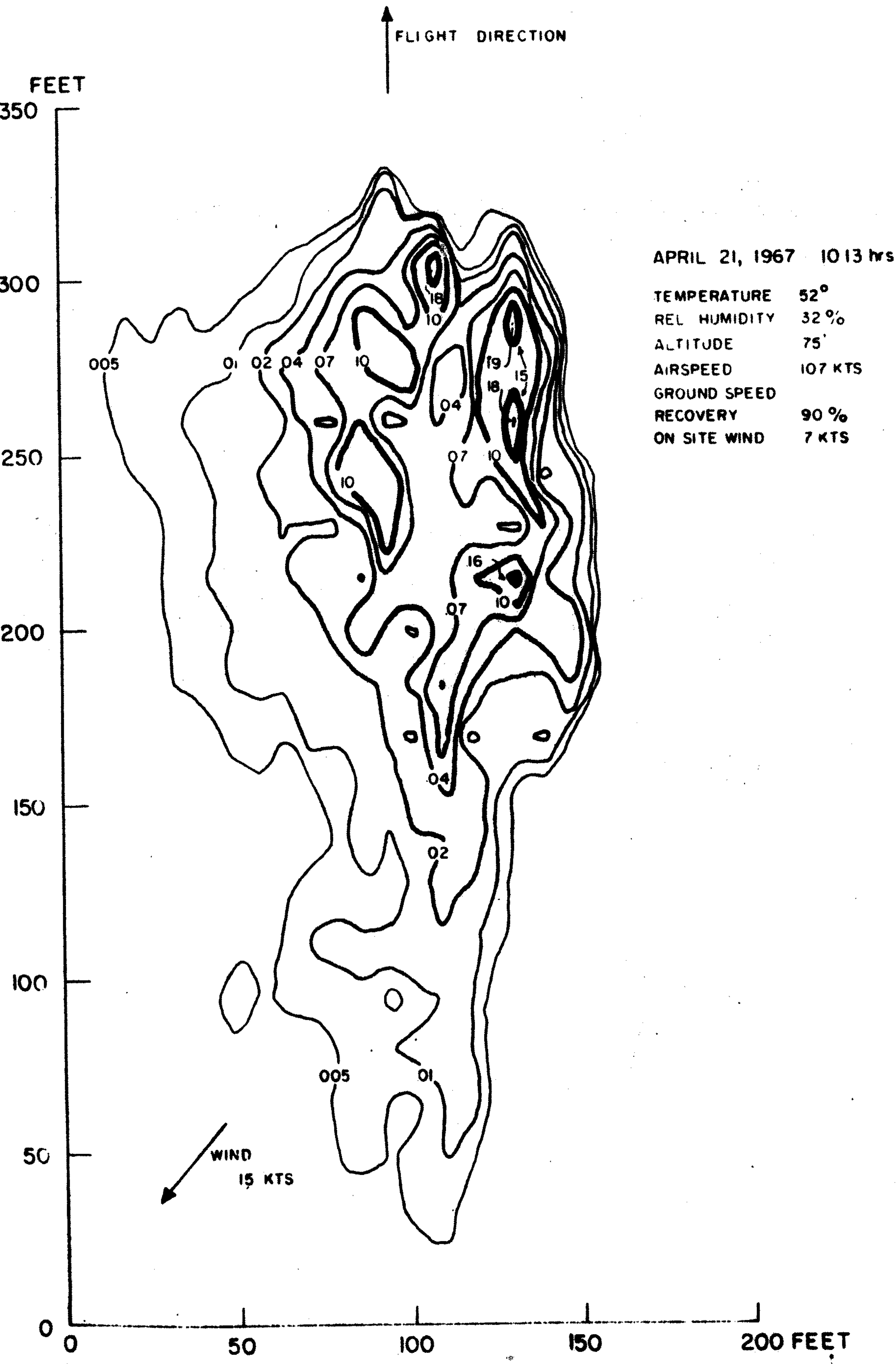
AVENGER DROP NO. 8



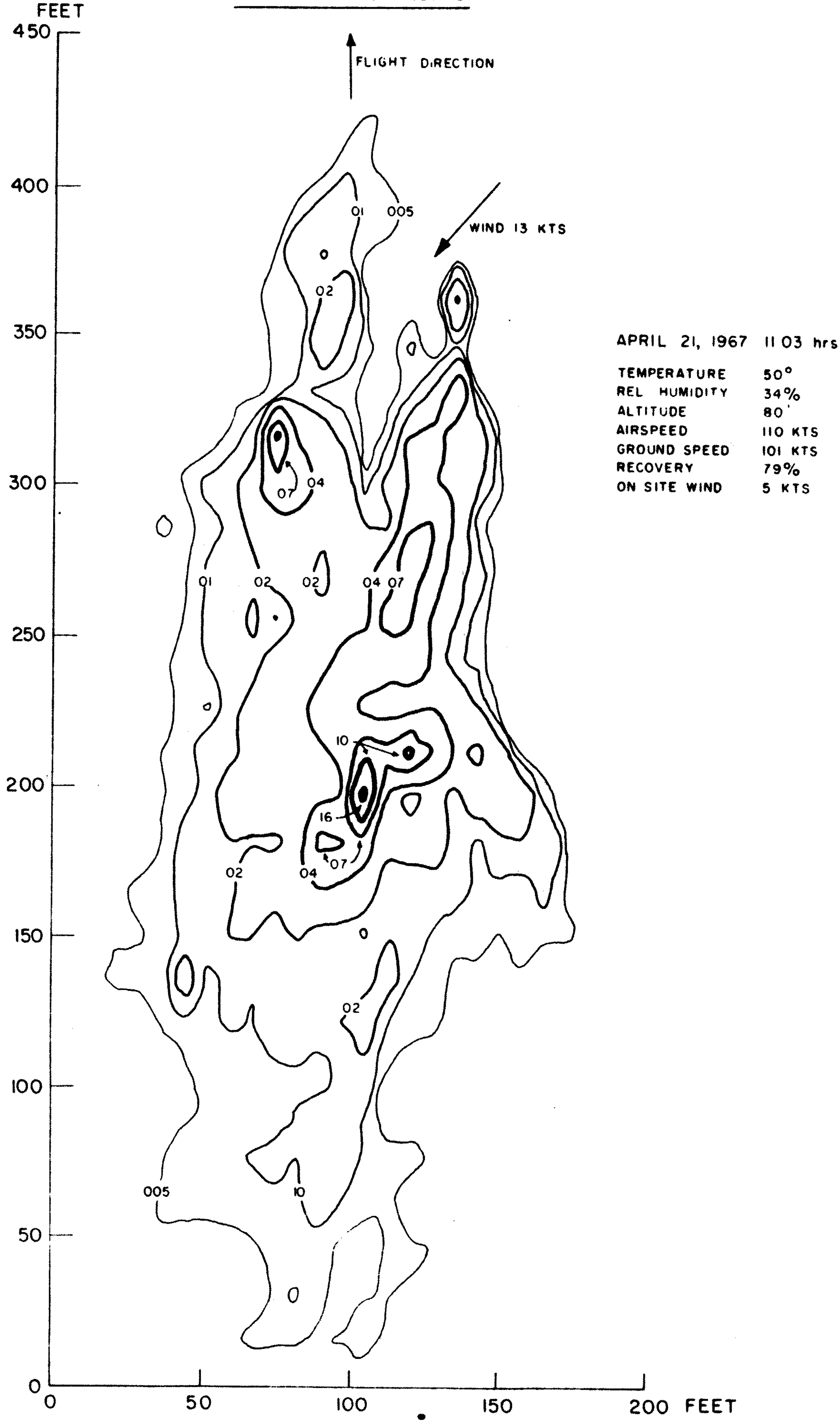
APRIL 21, 1967 09.04 hrs

TEMPERATURE	50°
REL HUMIDITY	26%
ALTITUDE	70'
AIRSPEED	112 KTS
GROUND SPEED	103 KTS
RECOVERY	91%
ON SITE WIND	6 KTS

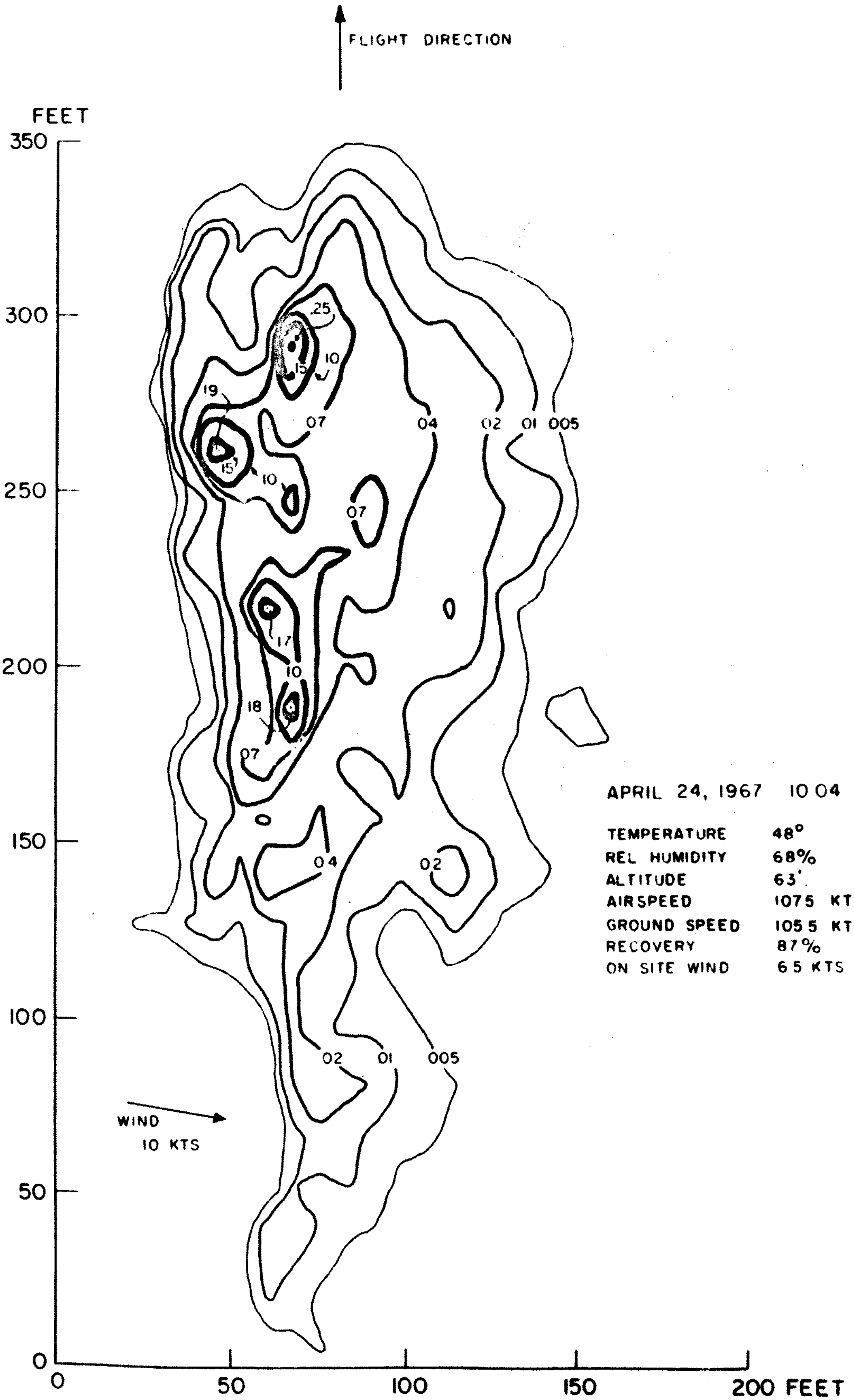
AVENGER DROP NO. 9



AVENGER DROP NO. 10



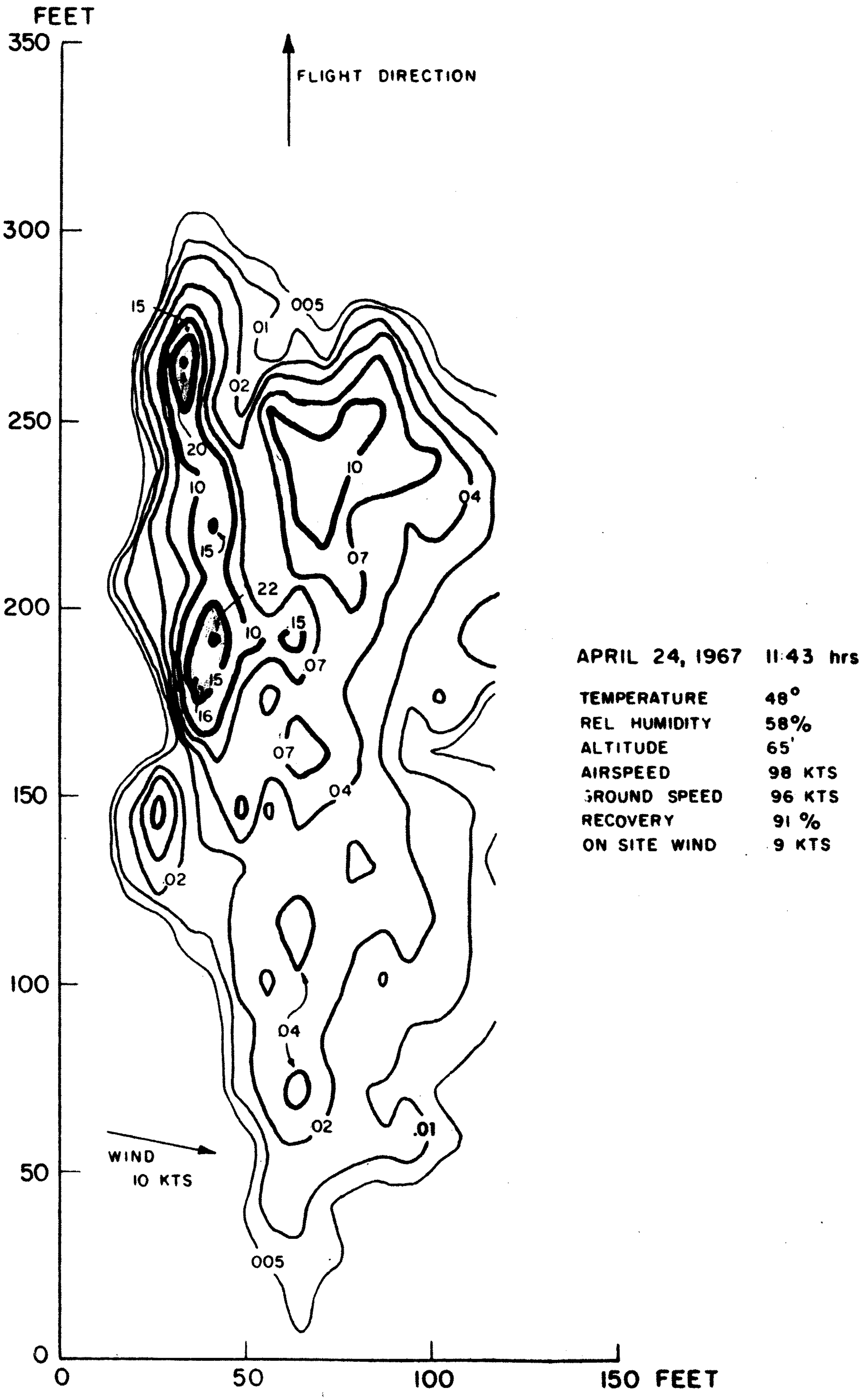
AVENGER DROP NO. 11

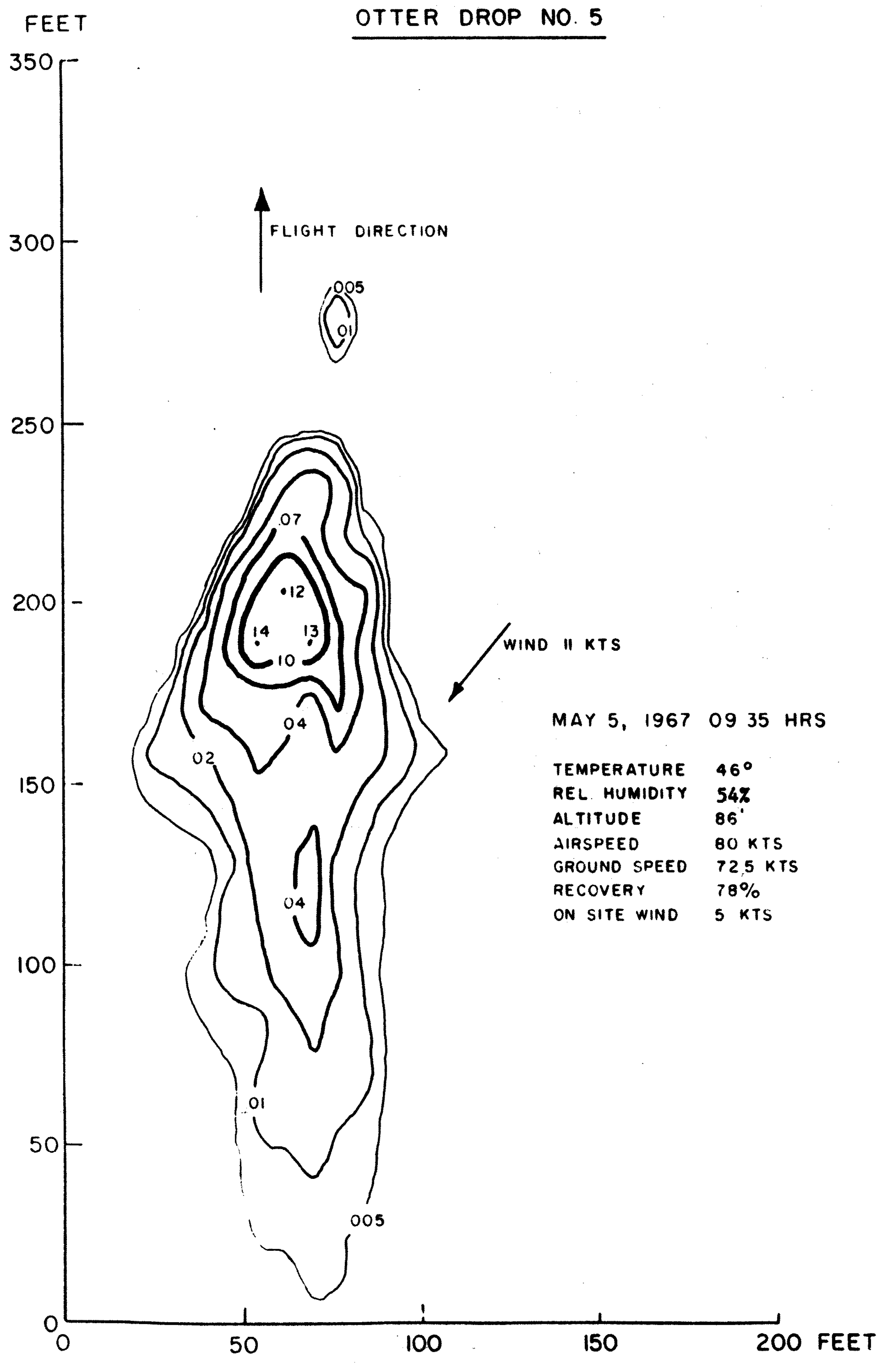


APRIL 24, 1967 10 04 hrs

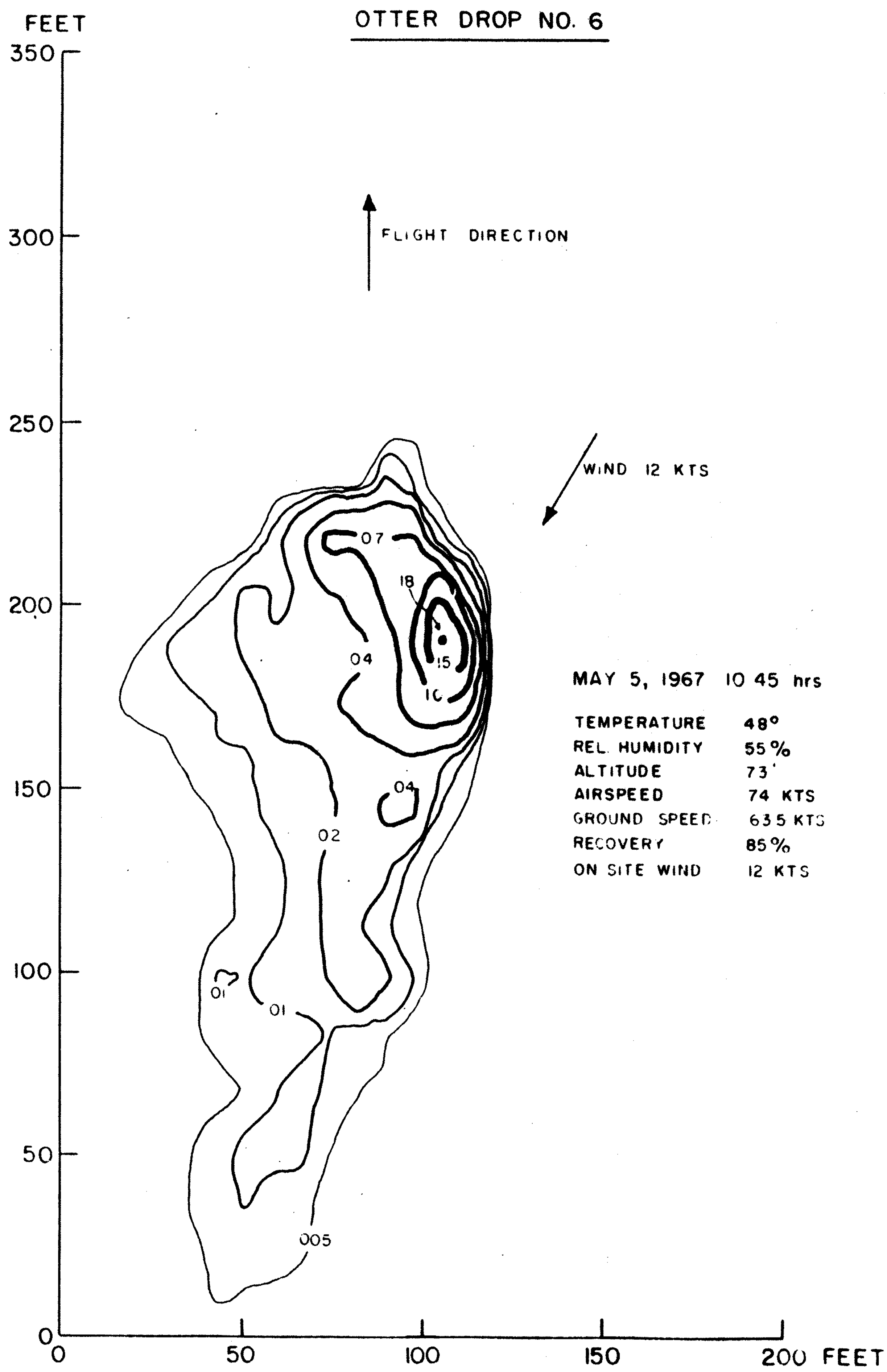
TEMPERATURE	48°
REL HUMIDITY	68%
ALTITUDE	63'.
AIRSPEED	1075 KTS
GROUND SPEED	105 5 KTS
RECOVERY	87%
ON SITE WIND	6 5 KTS

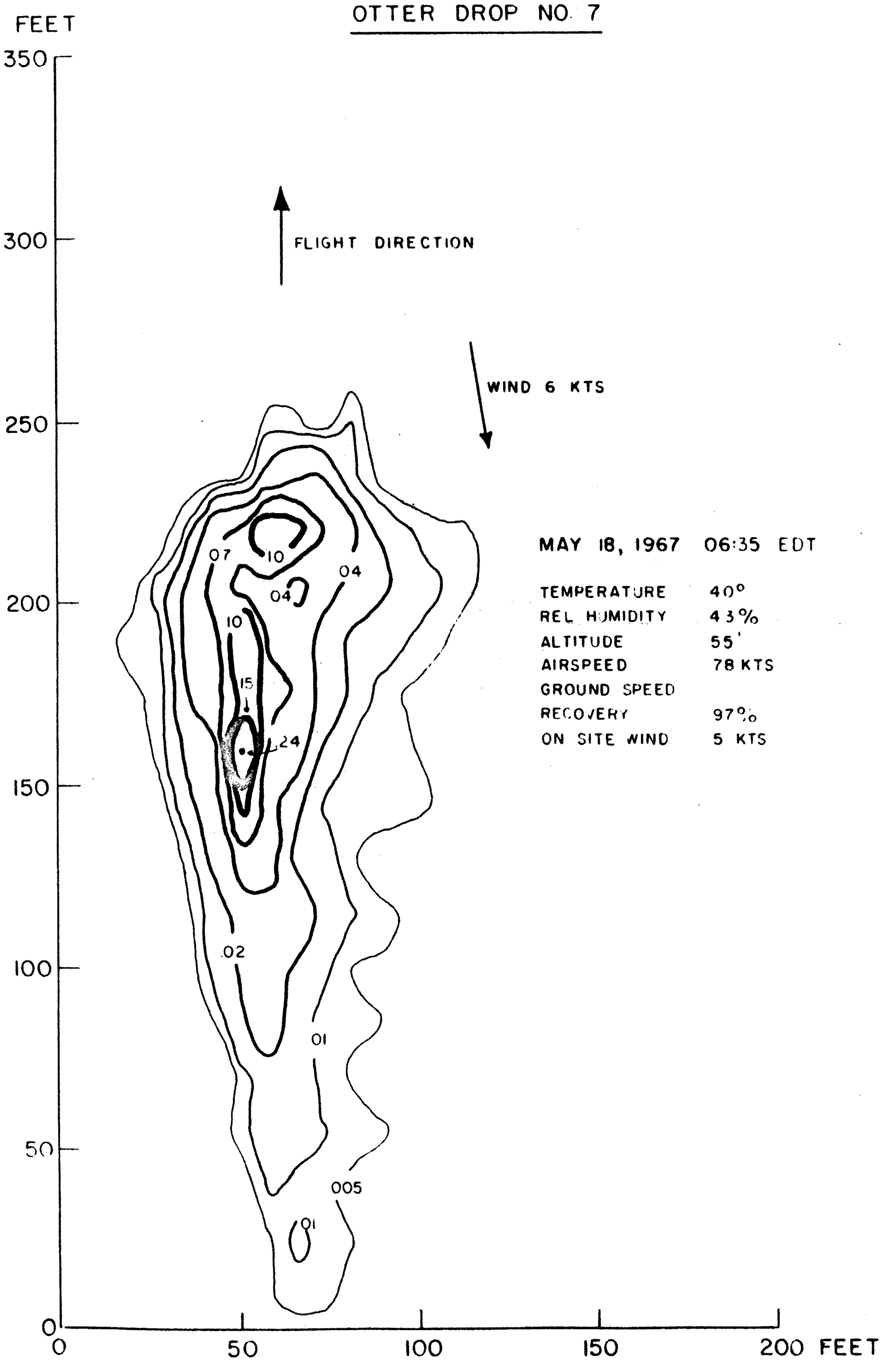
AVENGER, PHOS-CHEK DROP NO. 13





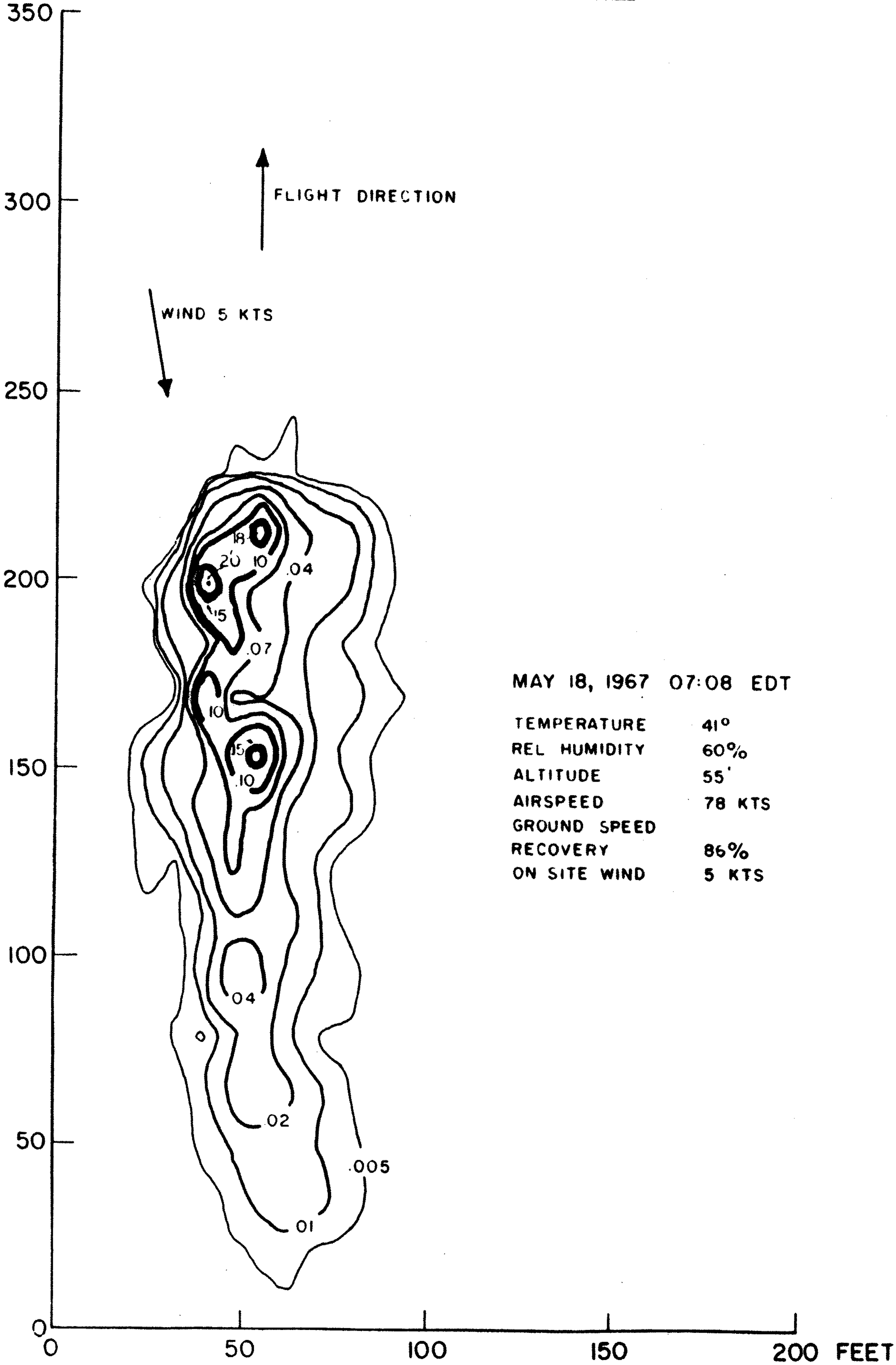
OTTER DROP NO. 5
FEET
350
300
250
200
150
100
50
0
0
50
100
150
200 FEET
FLIGHT DIRECTION
005
01
07
12
14
13
10
04
02
04
01
005
WIND 11 KTS
MAY 5, 1967 09 35 HRS
TEMPERATURE 46°
REL. HUMIDITY 54%
ALTITUDE 86'
AIRSPEED 80 KTS
GROUND SPEED 72.5 KTS
RECOVERY 78%
ON SITE WIND 5 KTS

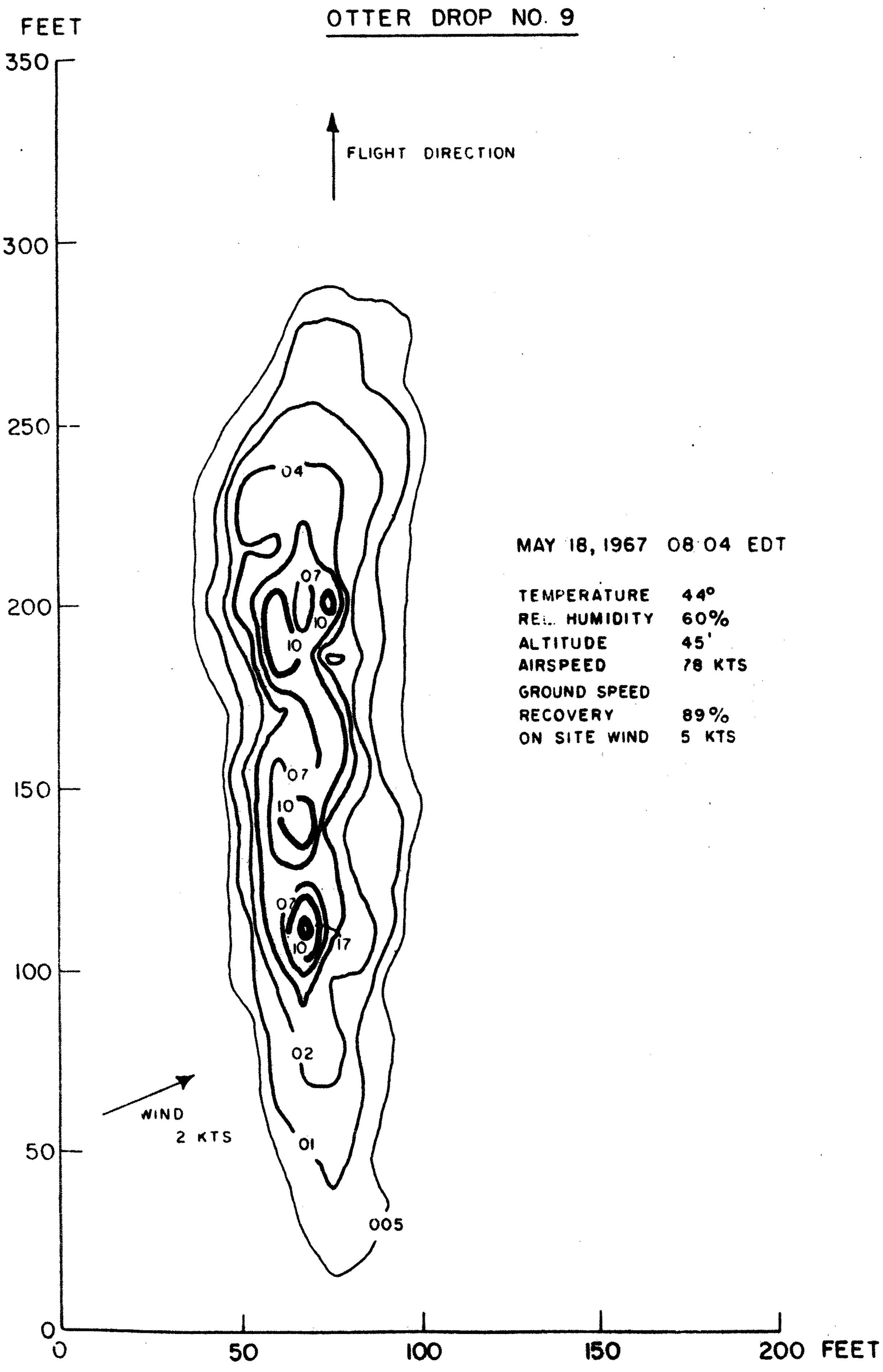

OTTER DROP NO. 6
FLIGHT DIRECTION
WIND 12 KTS
MAY 5, 1967 10 45 hrs
TEMPERATURE 48°
REL. HUMIDITY 55%
ALTITUDE 73'
AIRSPEED 74 KTS
GROUND SPEED 63.5 KTS
RECOVERY 85%
ON SITE WIND 12 KTS
07
18
04
15
10
04
02
01
01
005
350
300
250
200
150
100
50
0
0
50
100
150
200



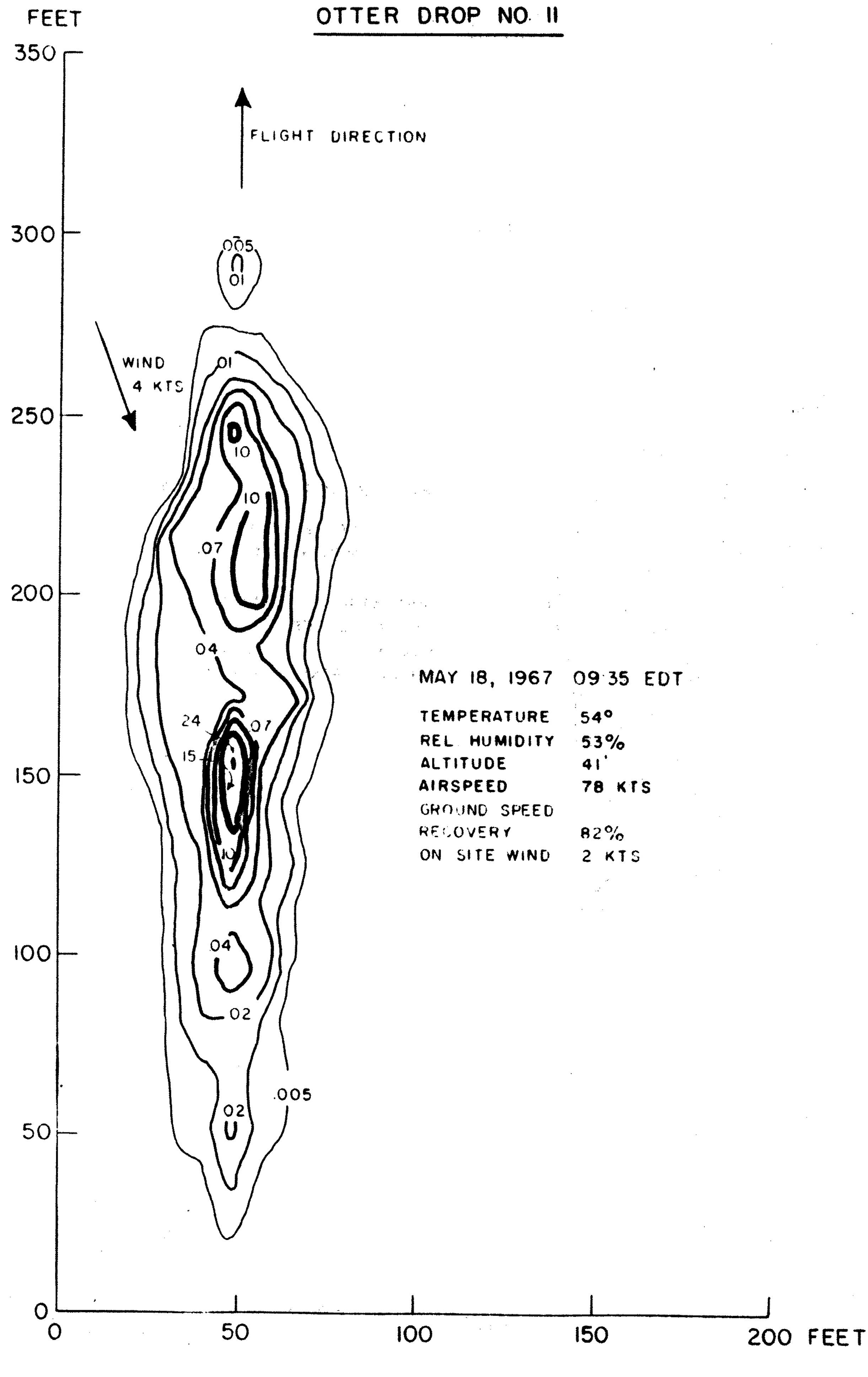
OTTER DROP NO. 7
FEET
350
300
250
200
150
100
50
0
0
50
100
150
200 FEET
FLIGHT DIRECTION
WIND 6 KTS
MAY 18, 1967 06:35 EDT
TEMPERATURE 40°
REL. HUMIDITY 43%
ALTITUDE 55'
AIRSPEED 78 KTS
GROUND SPEED
RECOVERY 97%
ON SITE WIND 5 KTS
07
10
04
04
10
15
.24
.02
01
005
01

OTTER DROP NO. 8




OTTER DROP NO. 9
FEET
350
300
250
200
150
100
50
0
FLIGHT DIRECTION
04
07
10
10
07
10
07
10
17
02
01
005
WIND
2 KTS
MAY 18, 1967 08 04 EDT
TEMPERATURE 44°
REL. HUMIDITY 60%
ALTITUDE 45'
AIRSPEED 78 KTS
GROUND SPEED
RECOVERY 89%
ON SITE WIND 5 KTS
0
50
100
150
200 FEET

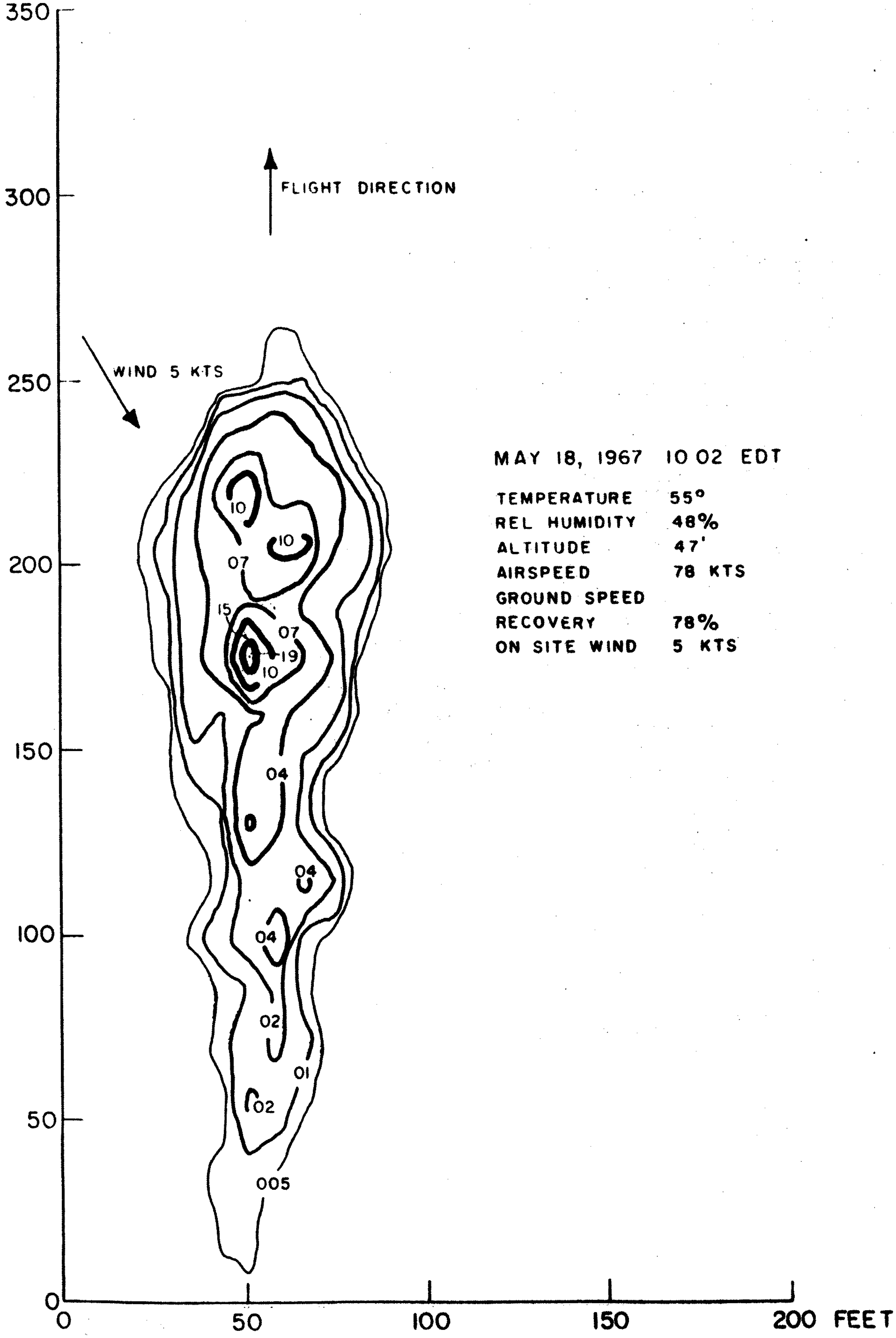
OTTER DROP NO. 11



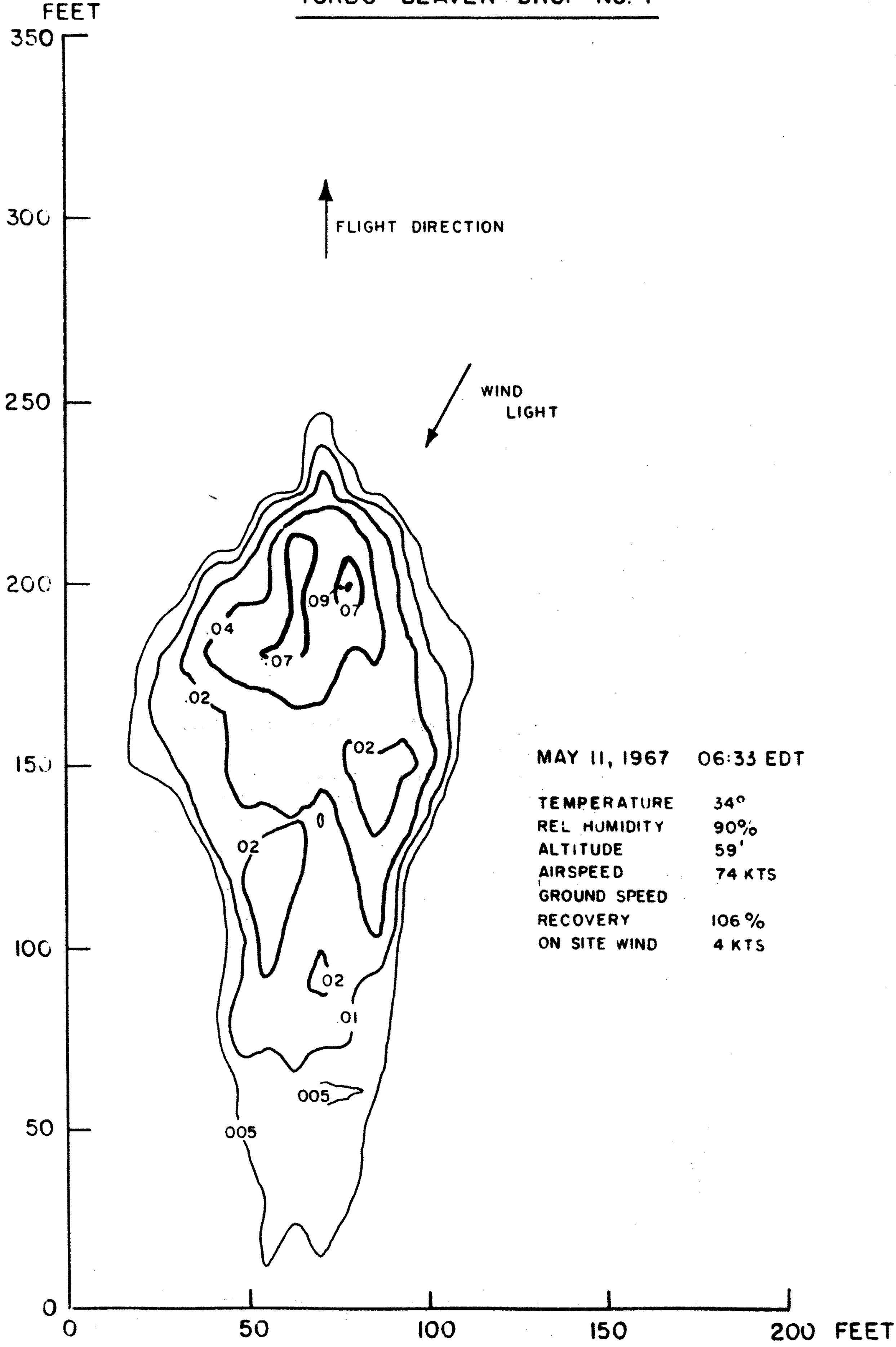
MAY 18, 1967 09:35 EDT

TEMPERATURE	54°
REL. HUMIDITY	53%
ALTITUDE	41'
AIRSPEED	78 KTS
GROUND SPEED	
RECOVERY	82%
ON SITE WIND	2 KTS

OTTER DROP NO. 12

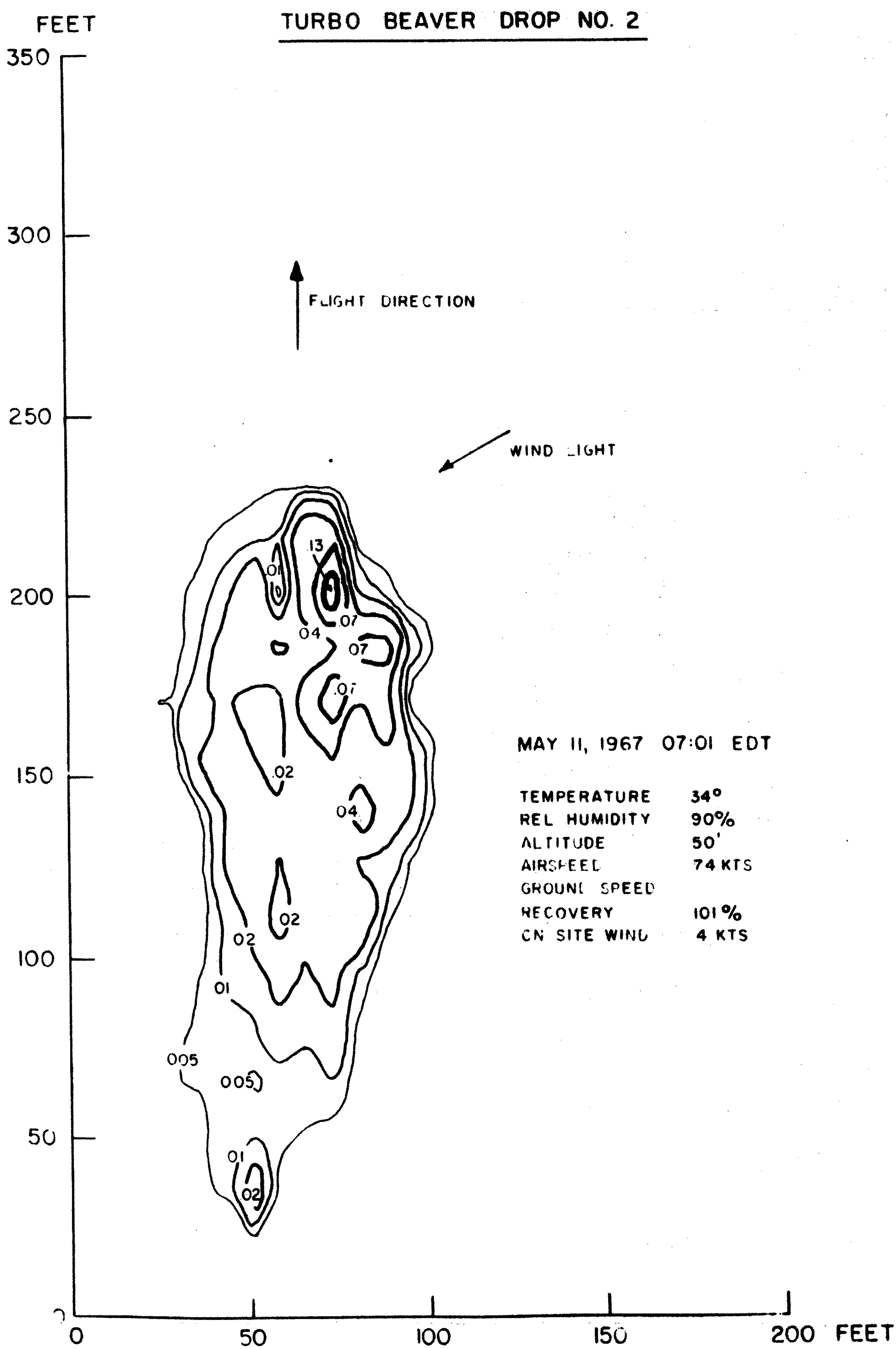


TURBO BEAVER DROP NO. 1

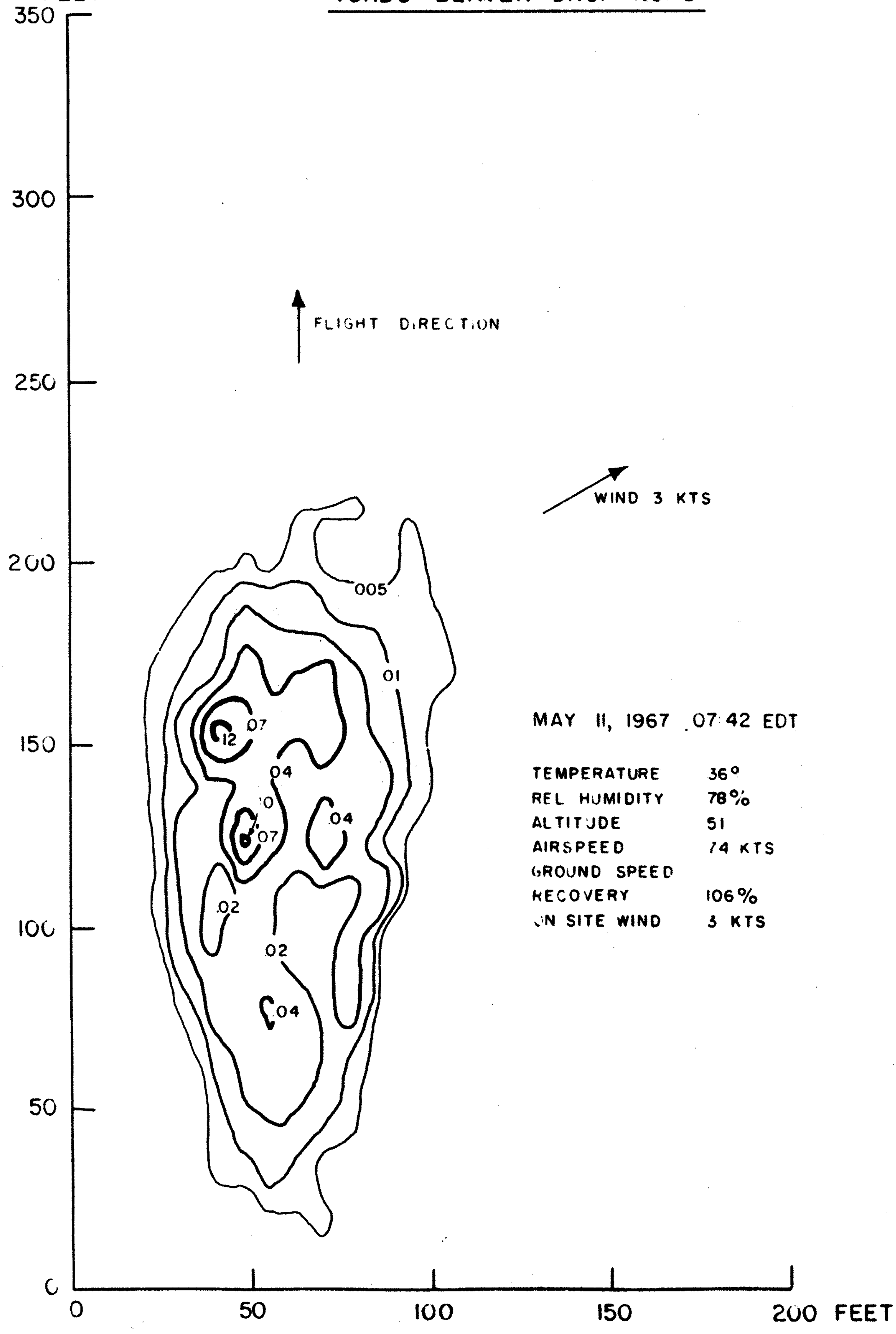


MAY 11, 1967 06:33 EDT

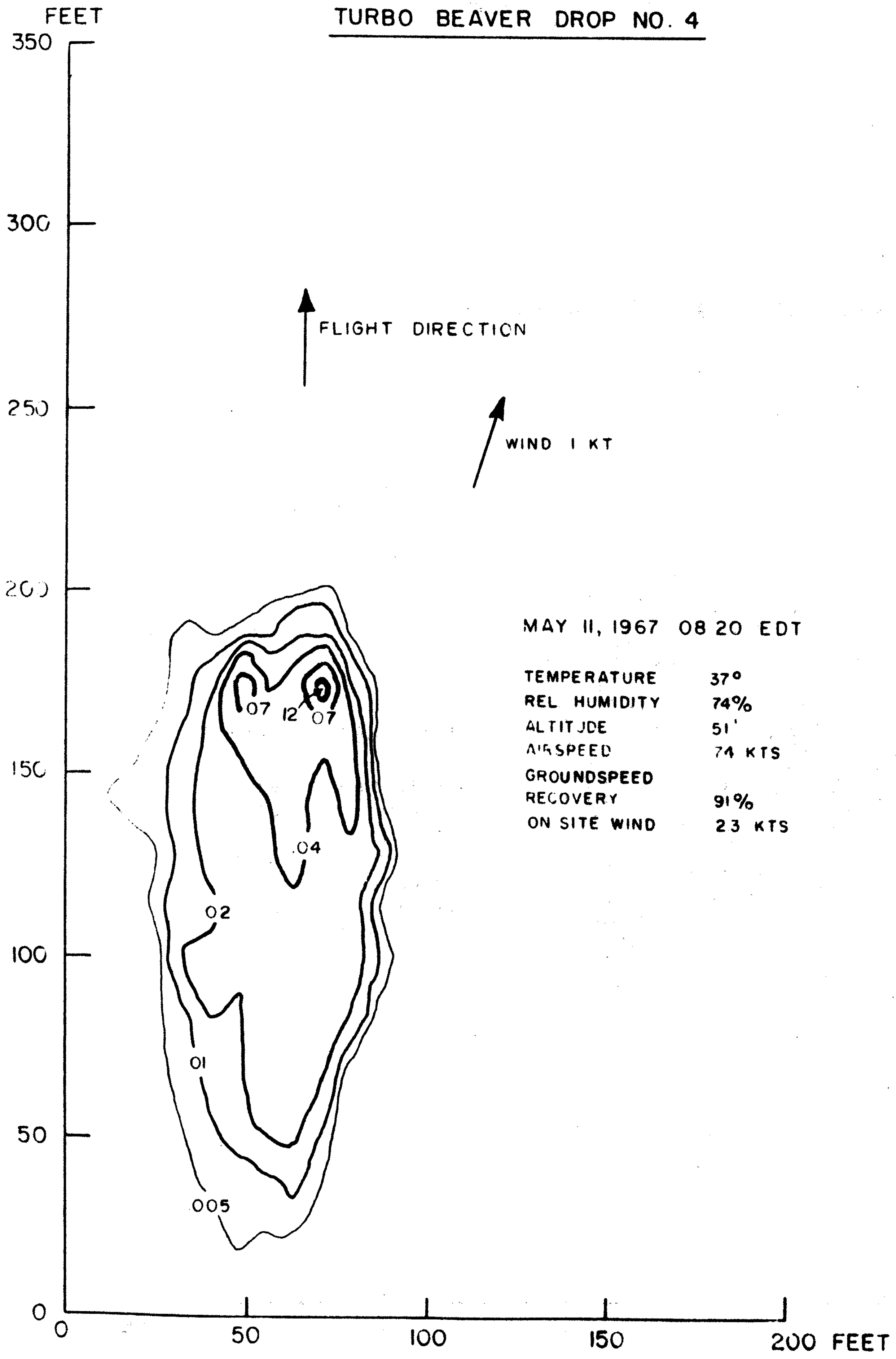
TEMPERATURE	34°
REL HUMIDITY	90%
ALTITUDE	59'
AIRSPEED	74 KTS
GROUND SPEED	
RECOVERY	106 %
ON SITE WIND	4 KTS


TURBO BEAVER DROP NO. 2
FEET
350
300
250
200
150
100
50
0
50
100
150
200 FEET
FLIGHT DIRECTION
WIND LIGHT
13
01
04
07
07
07
02
04
02
02
01
005
005
01
02
MAY 11, 1967 07:01 EDT
TEMPERATURE 34°
REL HUMIDITY 90%
ALTITUDE 50'
AIRSPEED 74 KTS
GROUND SPEED
RECOVERY 101%
ON SITE WIND 4 KTS

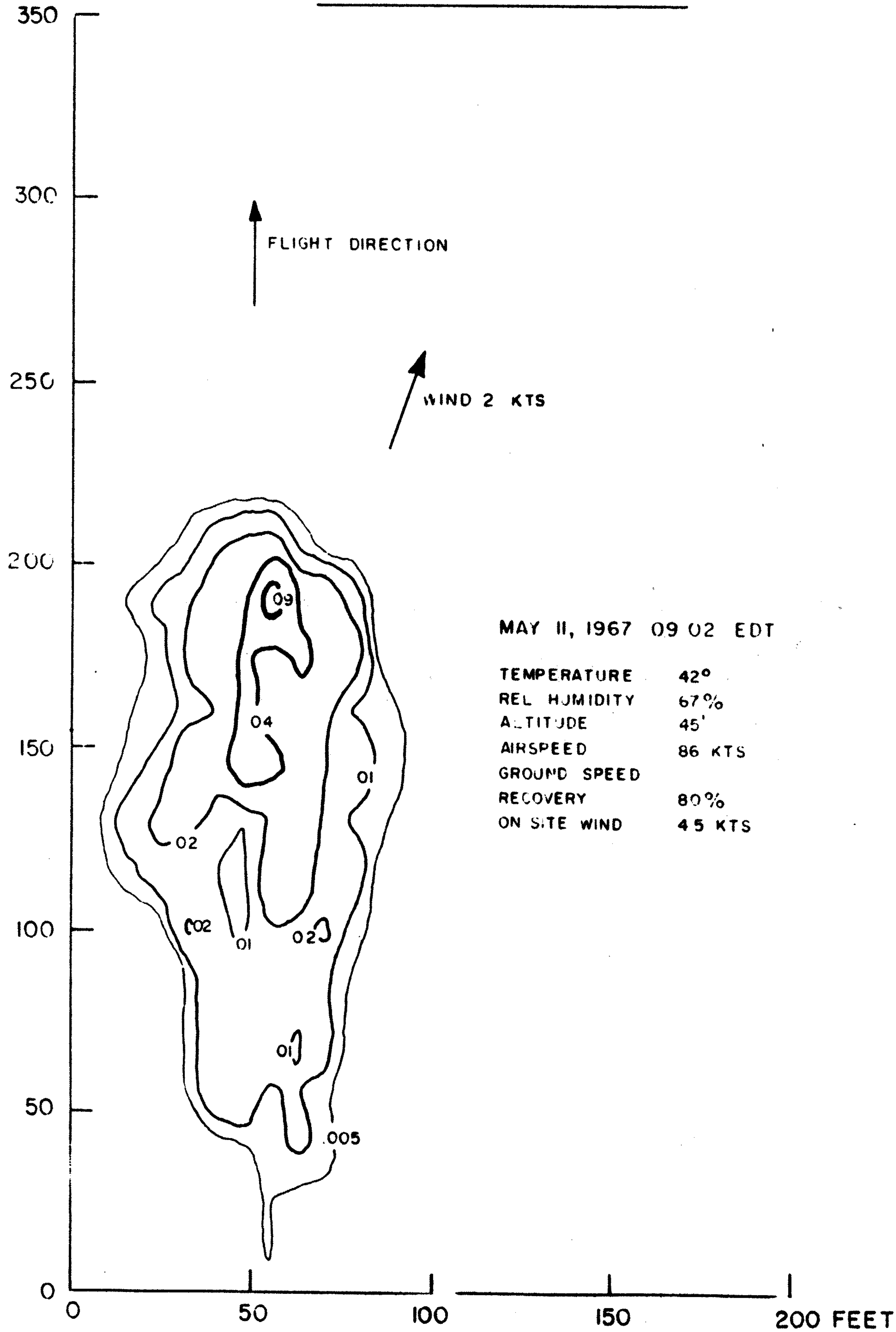
TURBO BEAVER DROP NO. 3



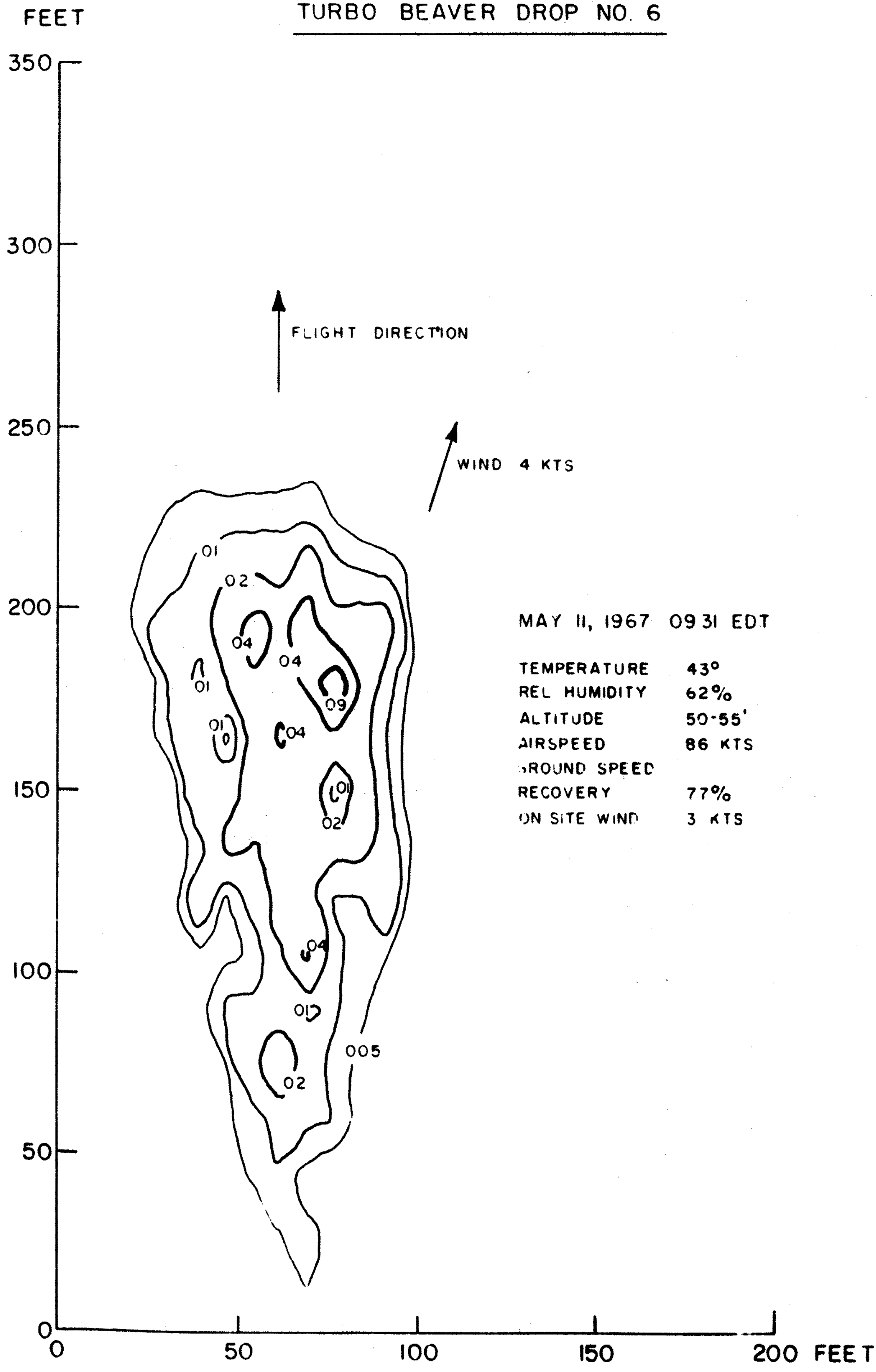
TURBO BEAVER DROP NO. 4

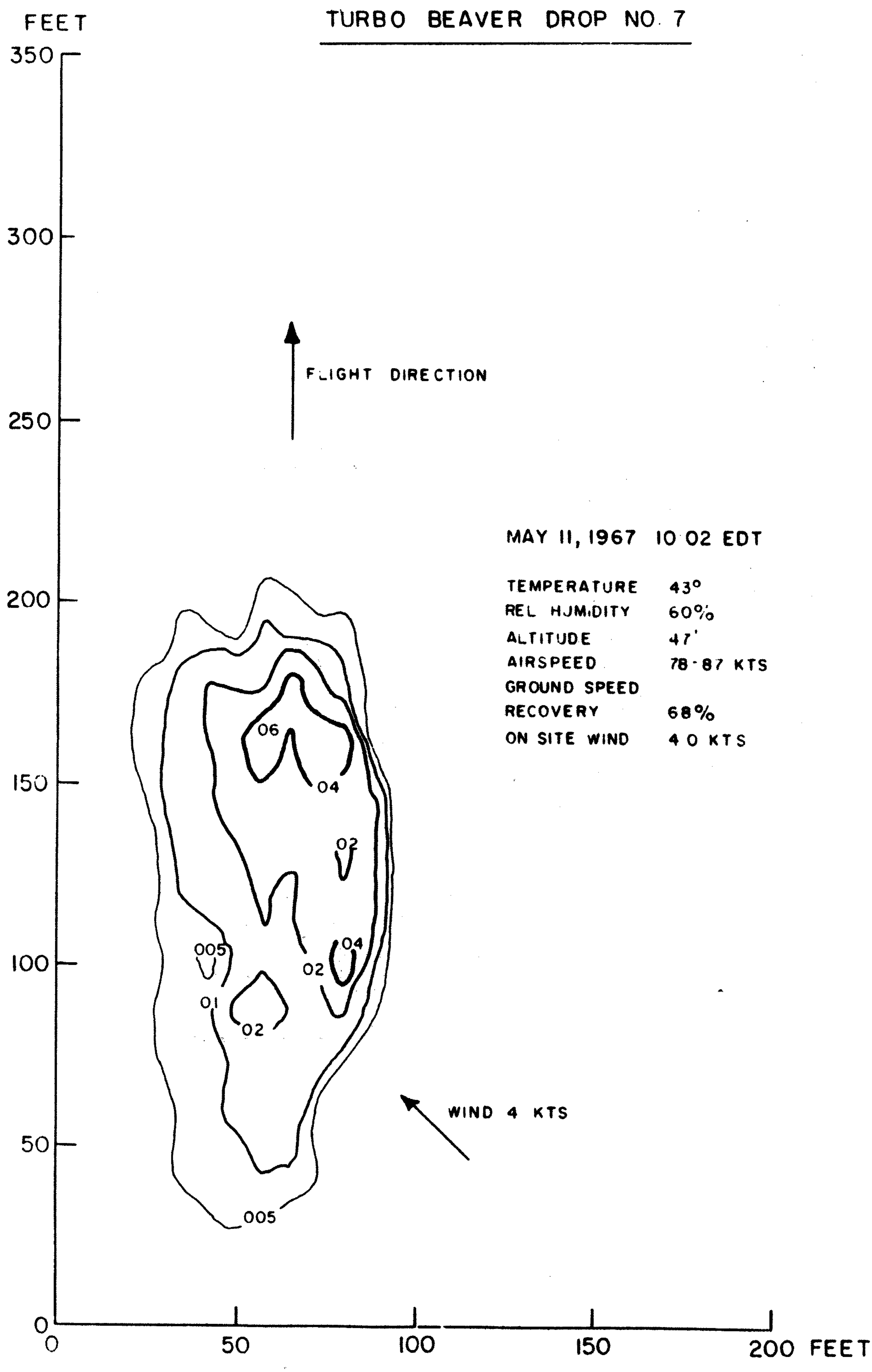


TURBO BEAVER DROP NO. 5

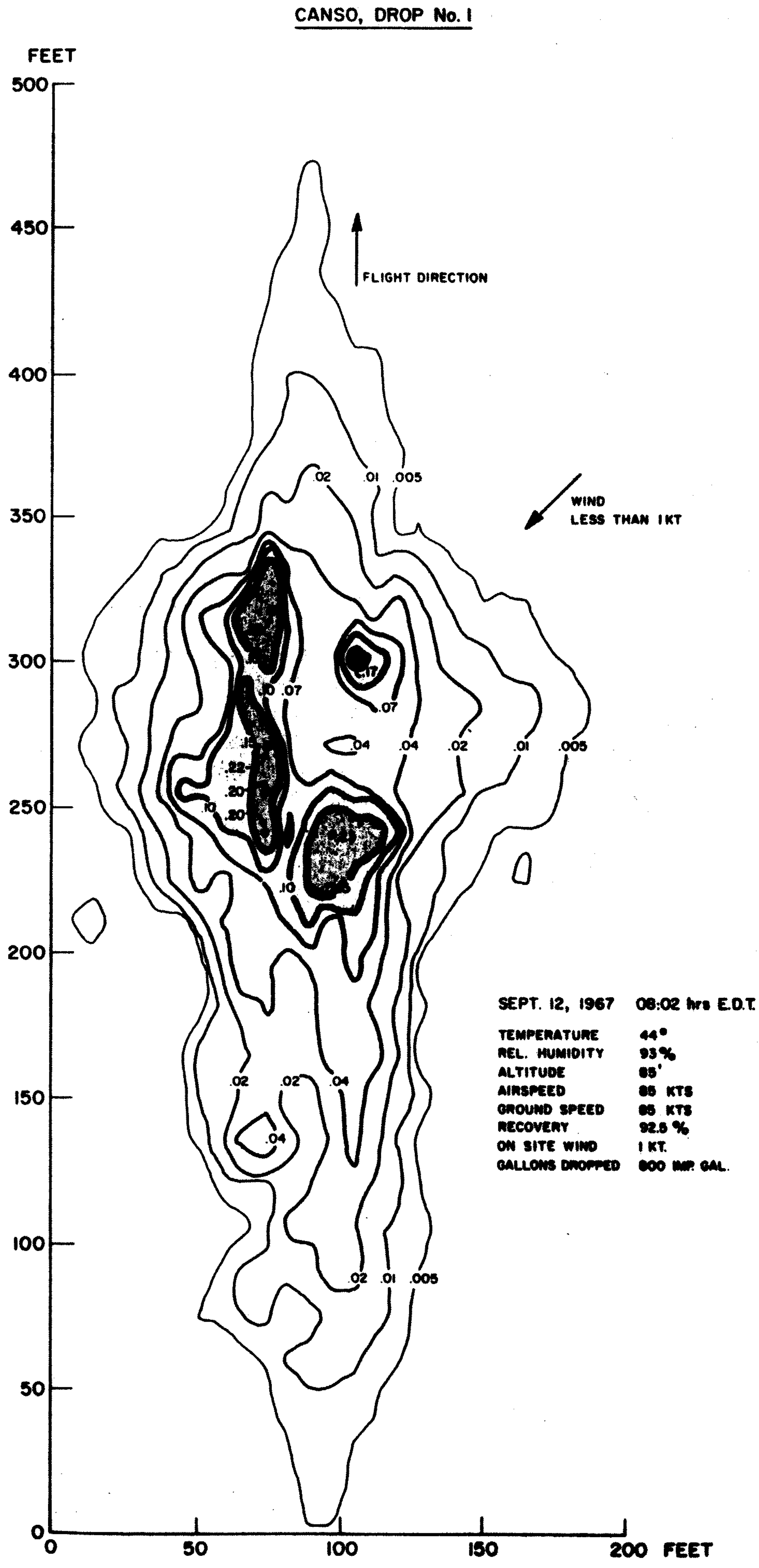


TURBO BEAVER DROP NO. 6



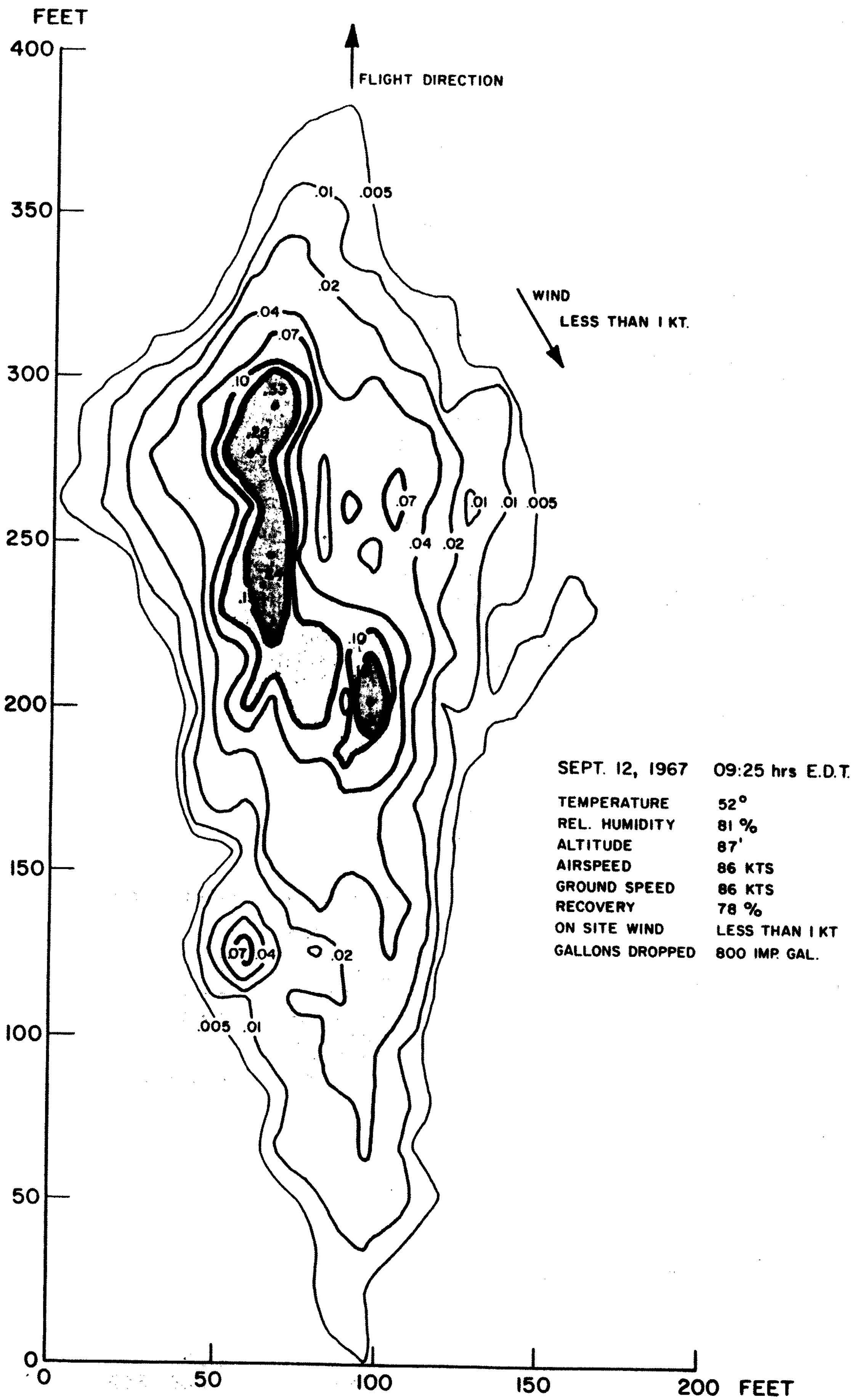


TURBO BEAVER DROP NO. 7
FEET
350
300
250
200
150
100
50
0
0
50
100
150
200 FEET
FLIGHT DIRECTION
MAY 11, 1967 10 02 EDT
TEMPERATURE 43°
REL HUMIDITY 60%
ALTITUDE 47'
AIRSPEED 78-87 KTS
GROUND SPEED
RECOVERY 68%
ON SITE WIND 4 0 KTS
06
04
02
005
04
02
01
02
WIND 4 KTS
005

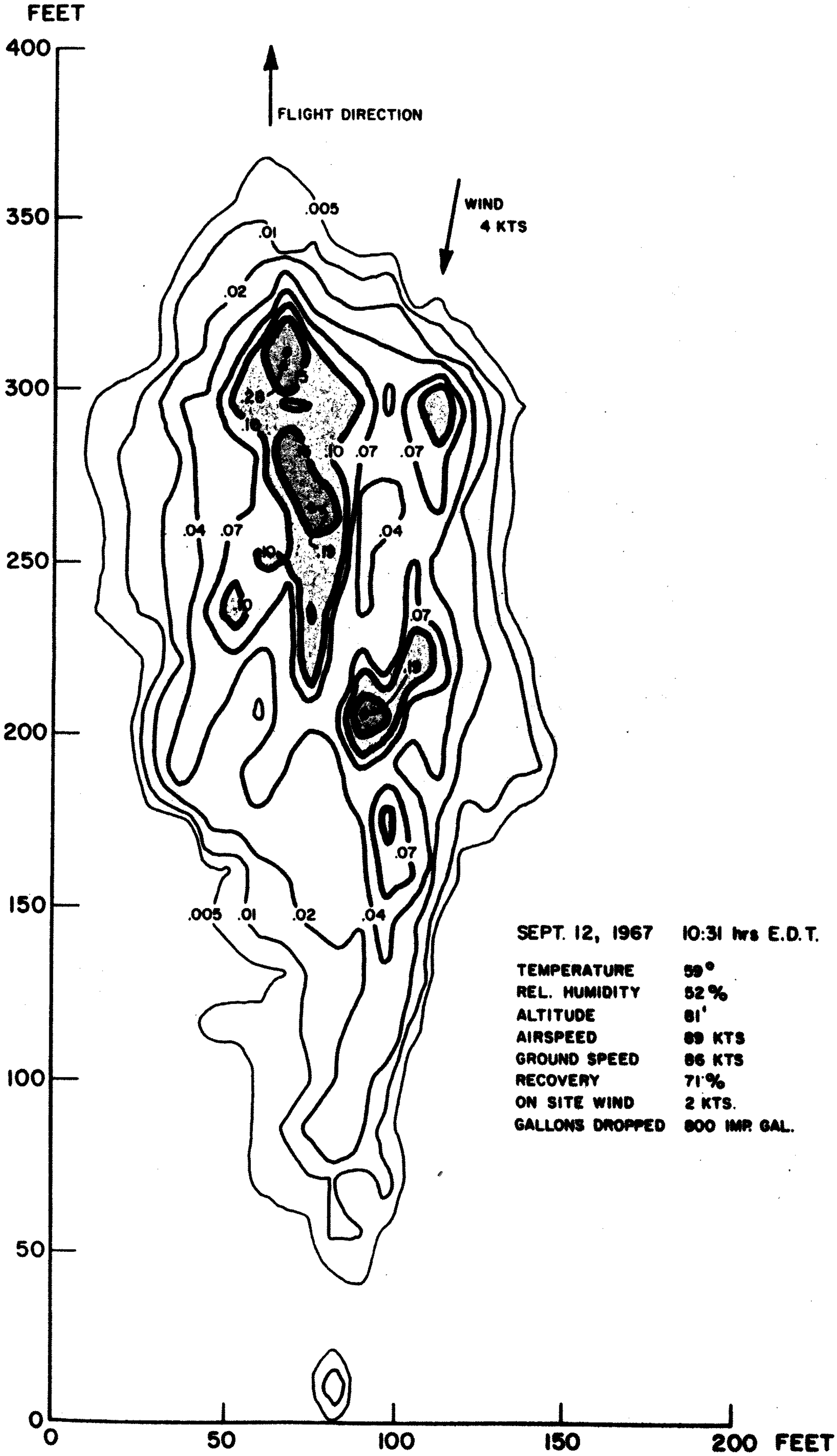


CANSO, DROP No. I
FEET
500
450
400
350
300
250
200
150
100
50
0
0
50
100
150
200 FEET
FLIGHT DIRECTION
WIND
LESS THAN I KT
.02
.01
.005
.07
.04
.10
.15
.22
.20
.17
SEPT. 12, 1967 08:02 hrs E.D.T.
TEMPERATURE 44°
REL. HUMIDITY 93 %
ALTITUDE 85'
AIRSPEED 85 KTS
GROUND SPEED 85 KTS
RECOVERY 92.5 %
ON SITE WIND I KT.
GALLONS DROPPED 800 IMP. GAL.

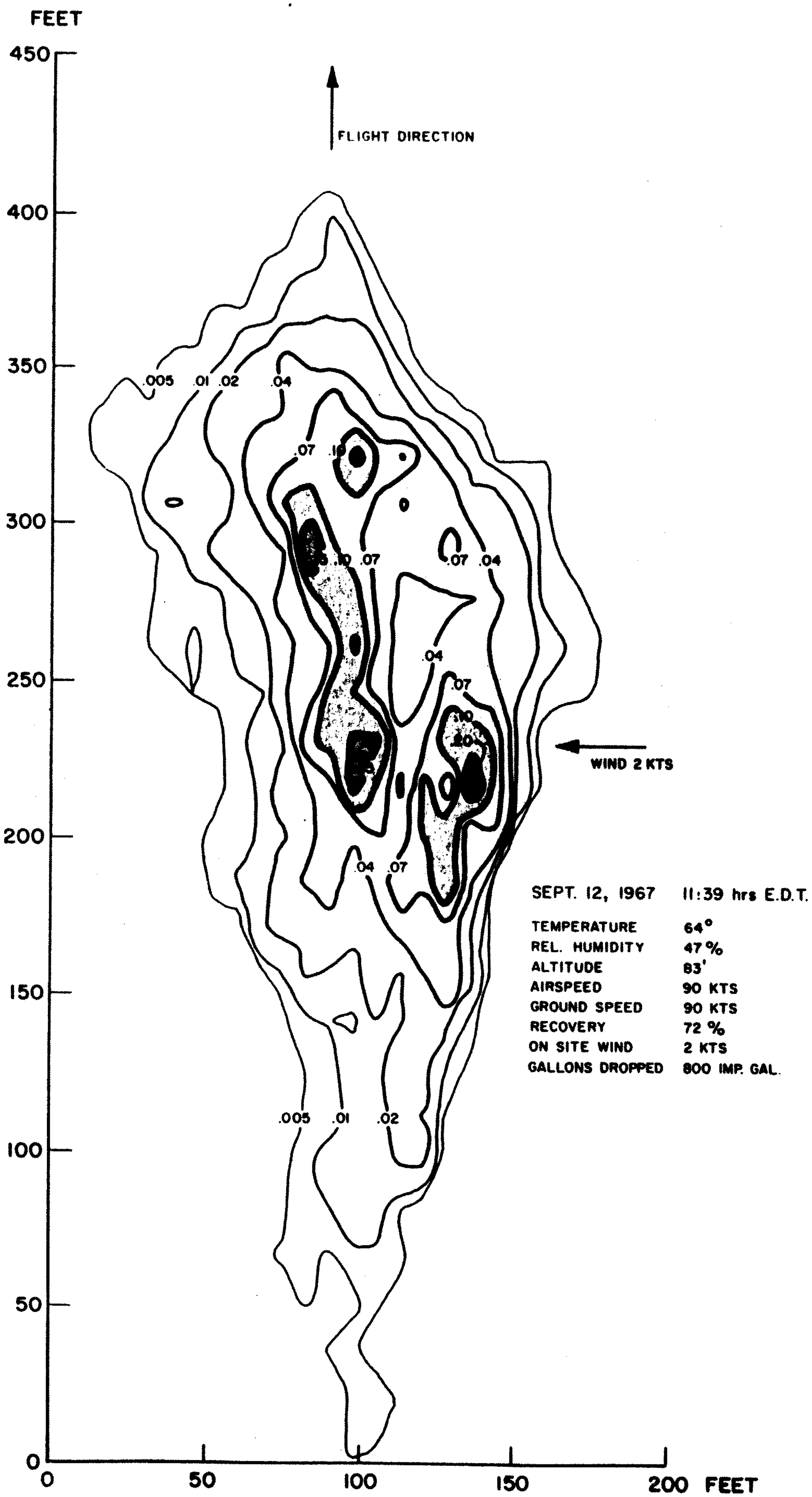
CANSO, DROP No. 2



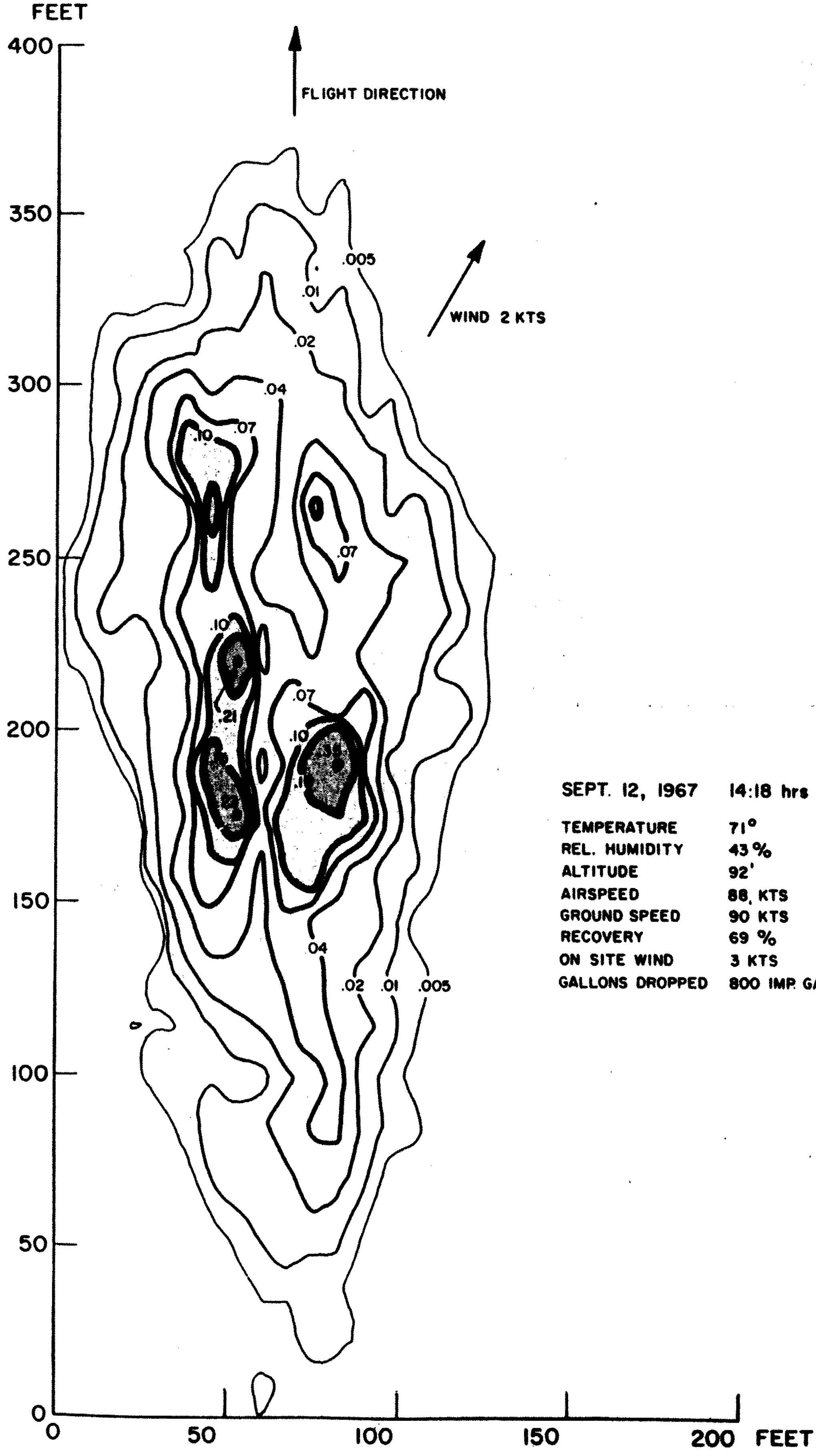
CANSO, DROP No. 3



CANSO, DROP No. 4

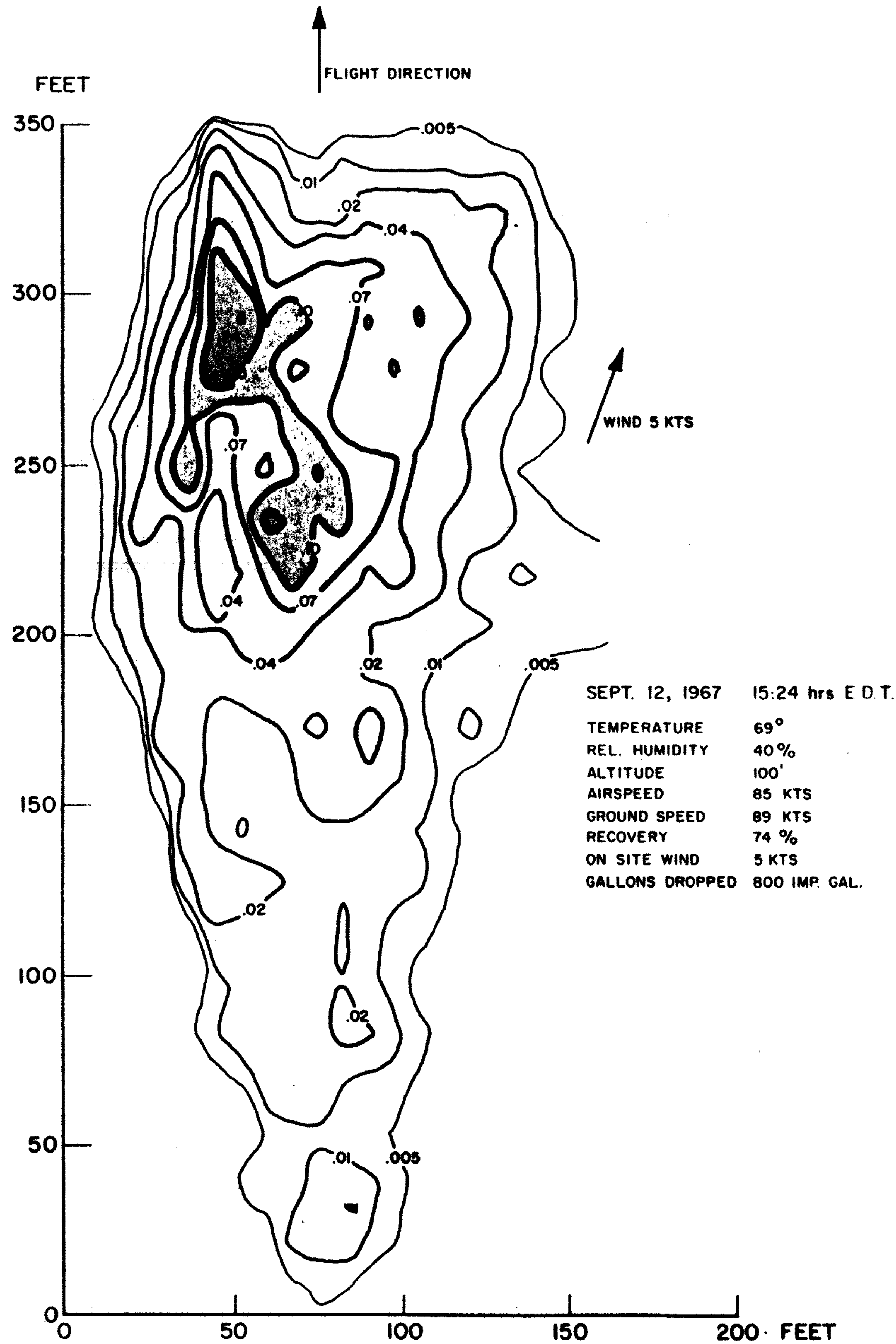


CANSO, DROP No. 5

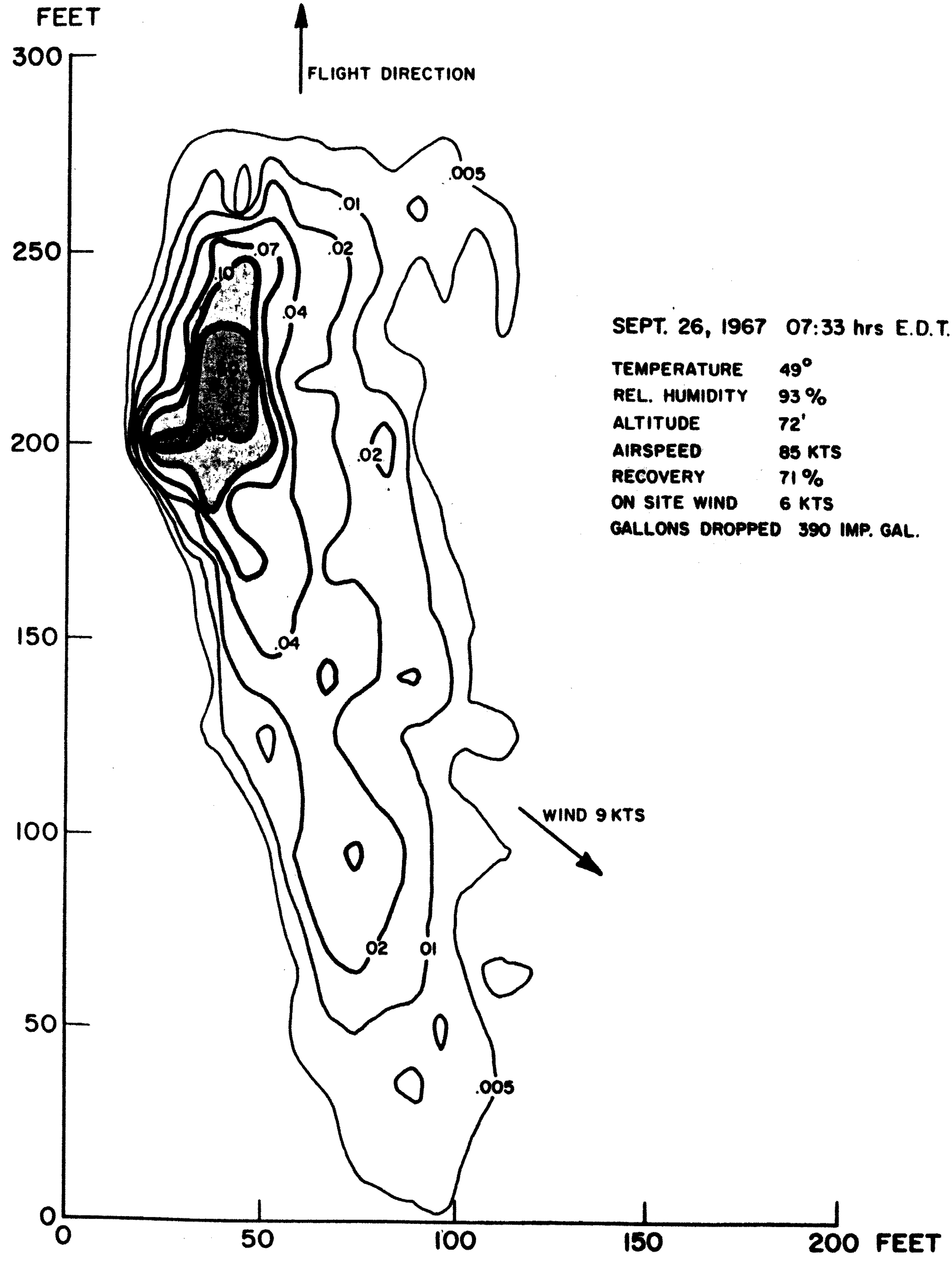


SEPT. 12, 1967	14:18 hrs E.D.T.
TEMPERATURE	71°
REL. HUMIDITY	43 %
ALTITUDE	92'
AIRSPEED	88 KTS
GROUND SPEED	90 KTS
RECOVERY	69 %
ON SITE WIND	3 KTS
GALLONS DROPPED	800 IMP. GAL.

CANSO, DROP No. 6



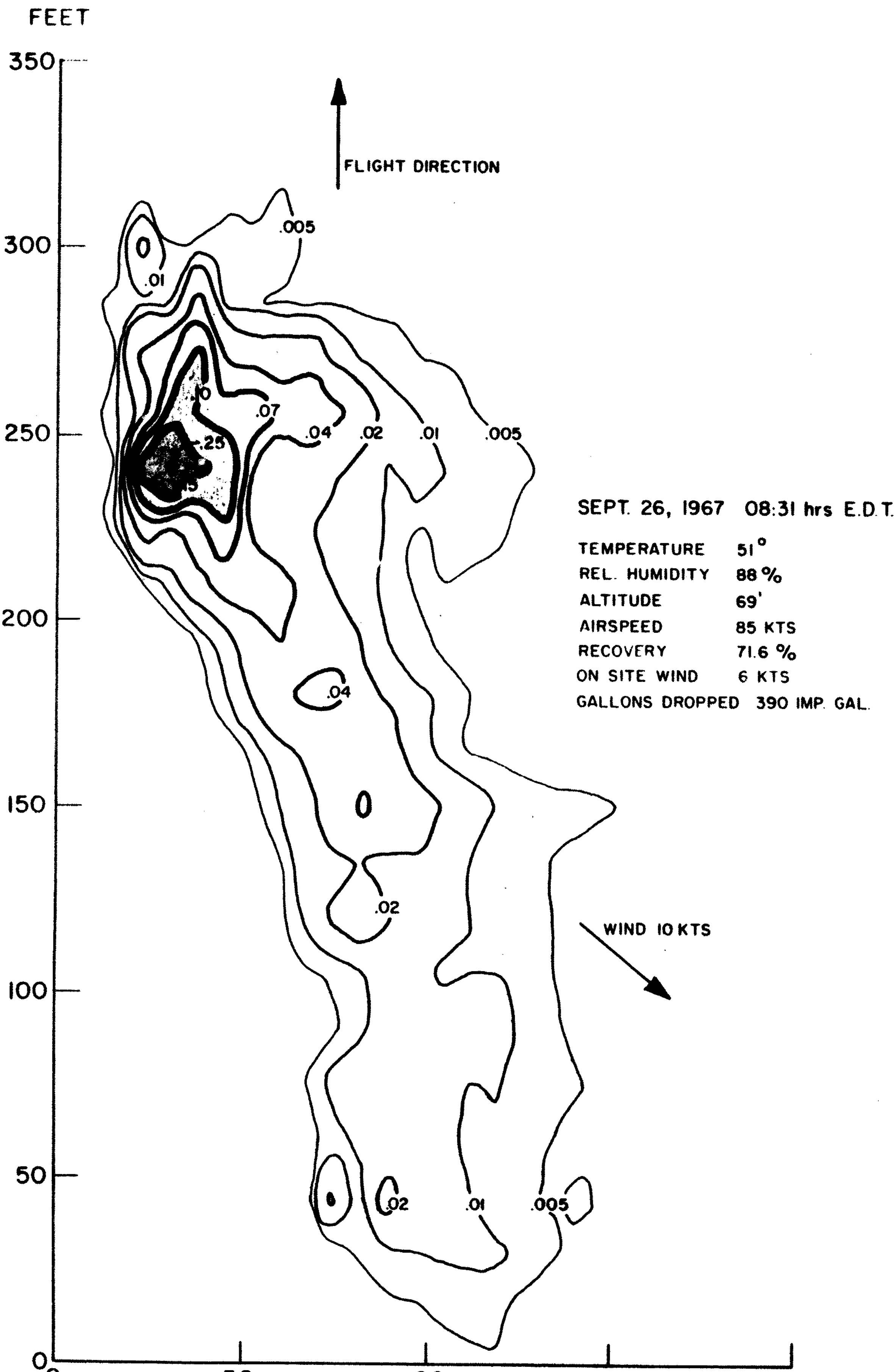
TWIN OTTER, DROP No. 1



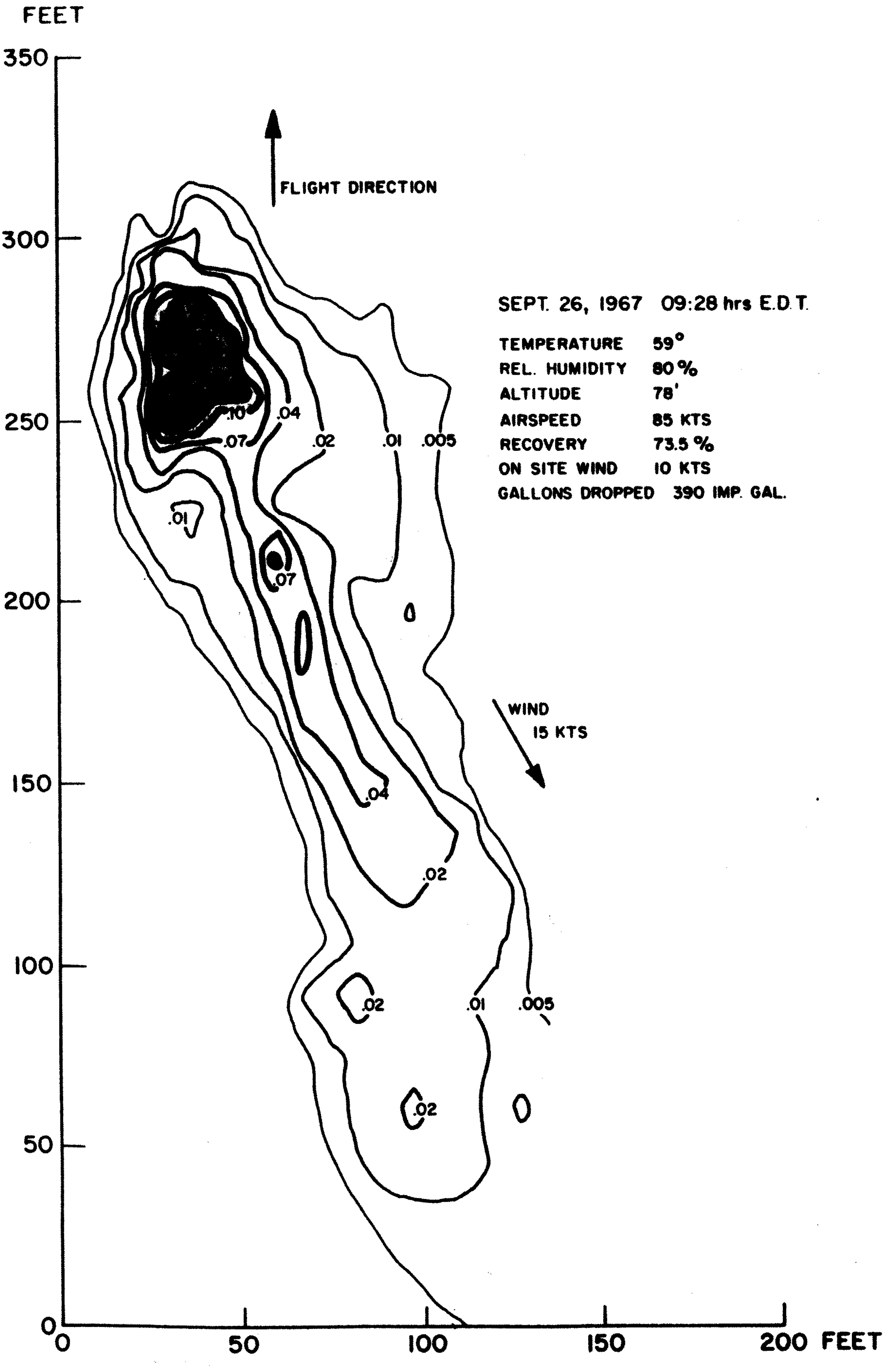
SEPT. 26, 1967 07:33 hrs E.D.T.

TEMPERATURE	49°
REL. HUMIDITY	93 %
ALTITUDE	72'
AIRSPEED	85 KTS
RECOVERY	71 %
ON SITE WIND	6 KTS
GALLONS DROPPED	390 IMP. GAL.

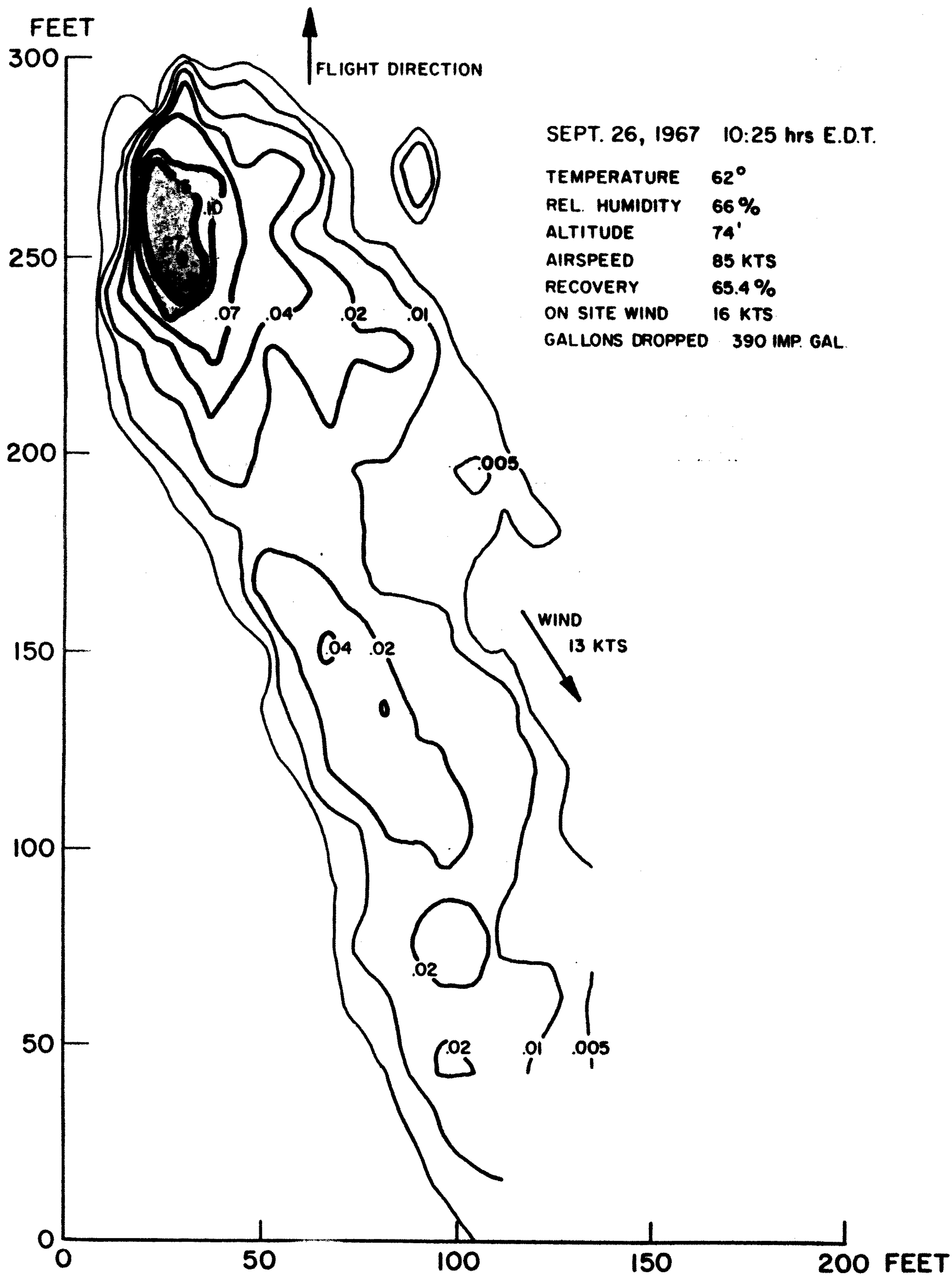
TWIN OTTER, DROP No. 2



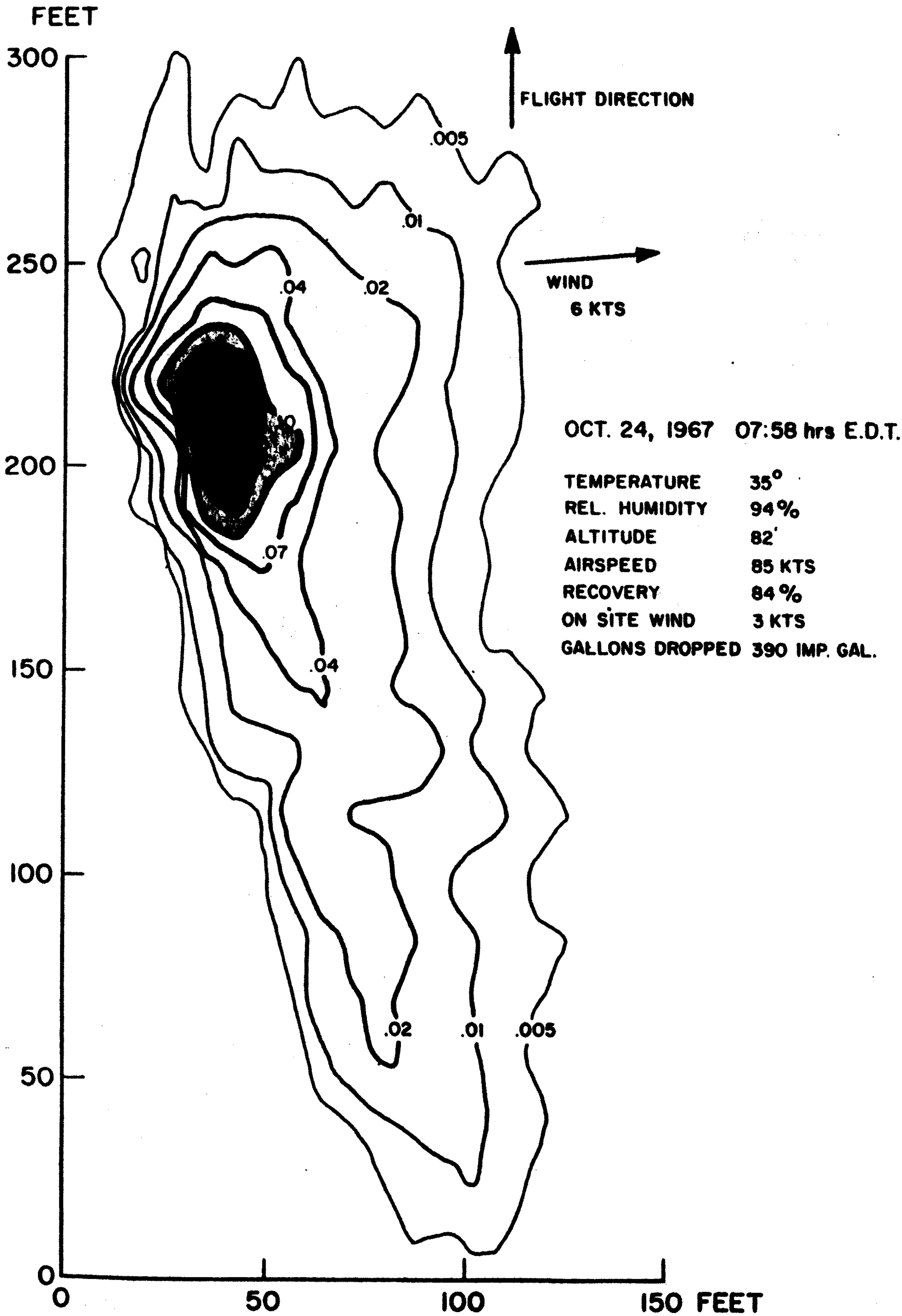
TWIN OTTER, DROP No. 3



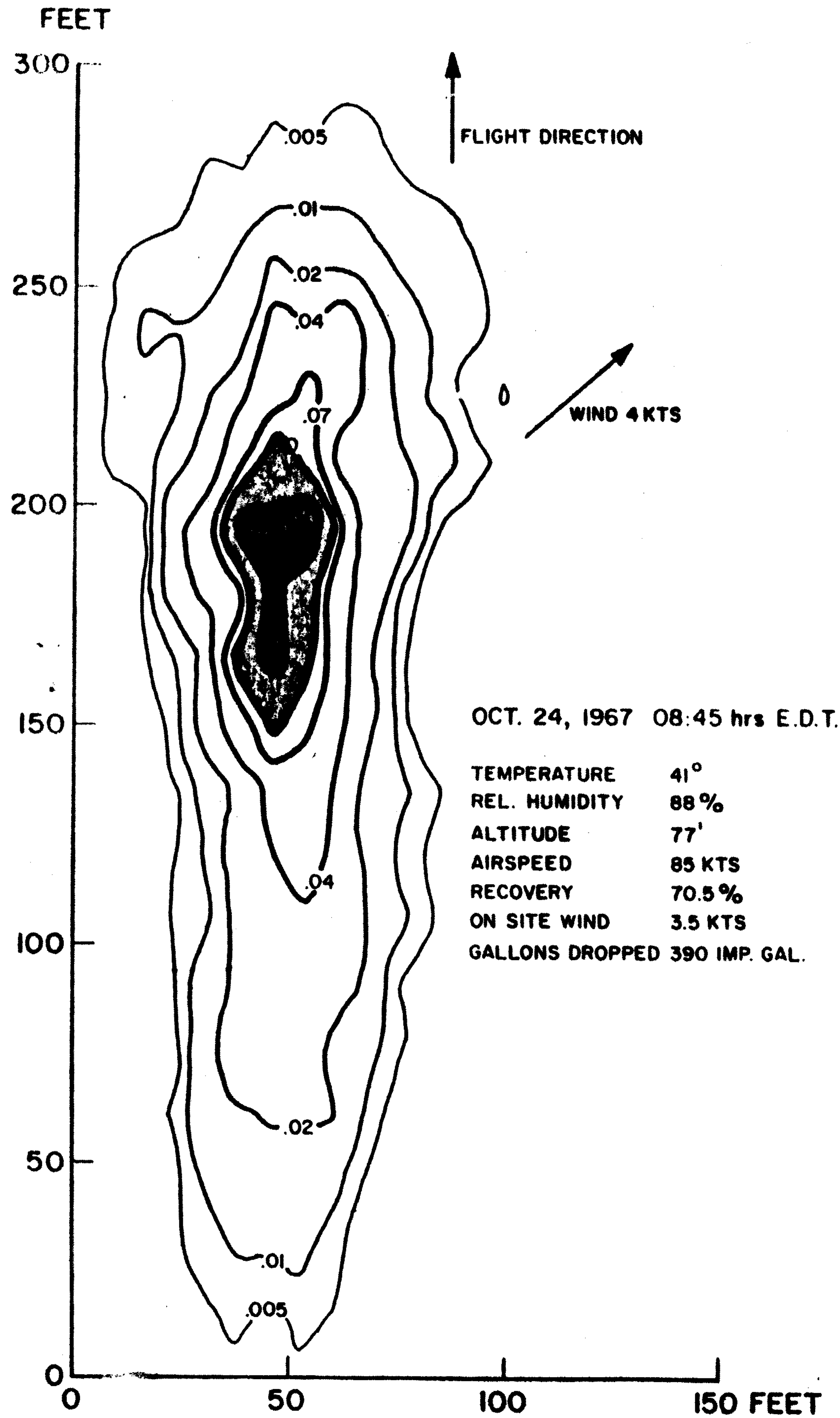
TWIN OTTER, DROP No. 4



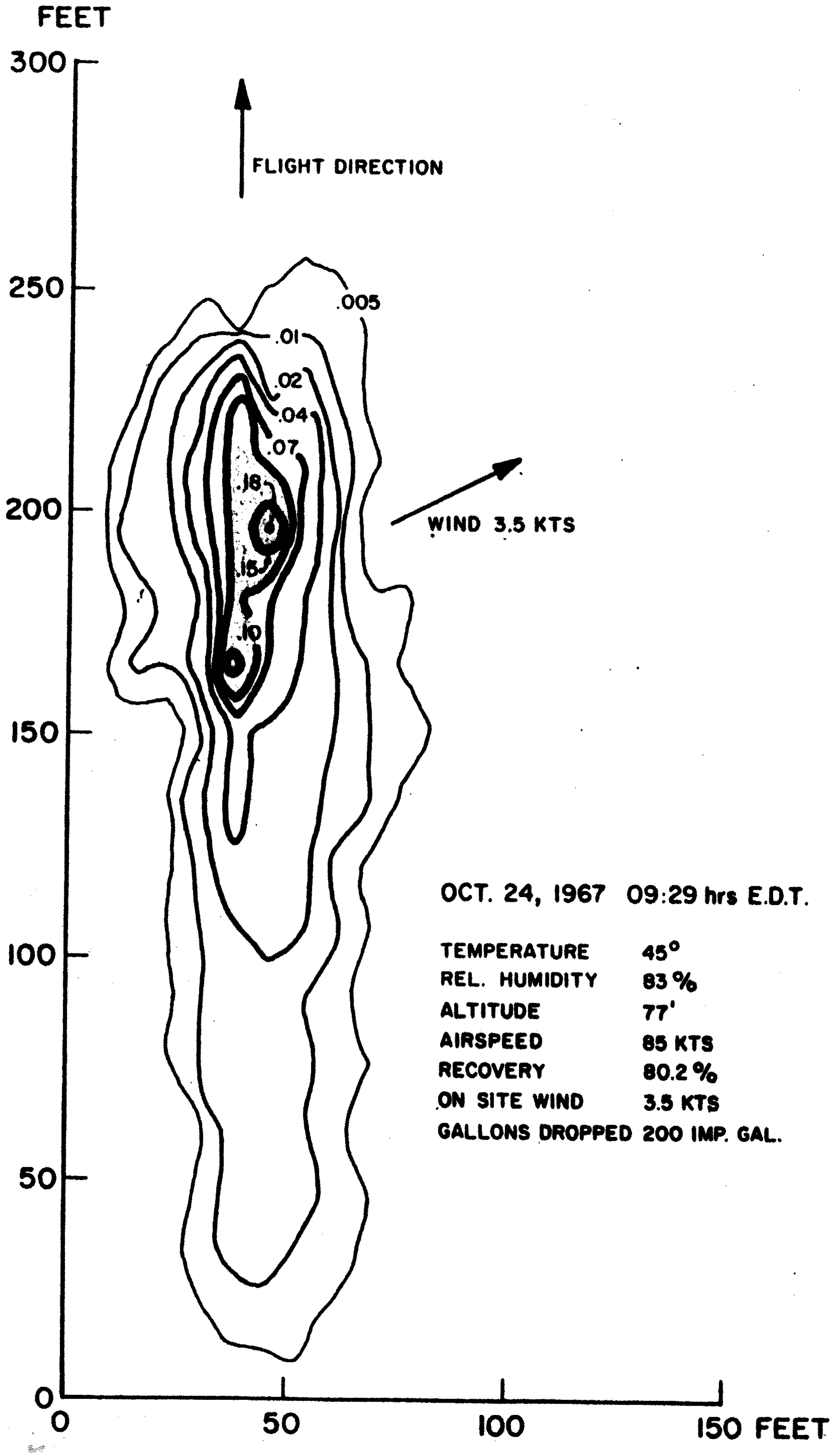
TWIN OTTER, DROP No. 5



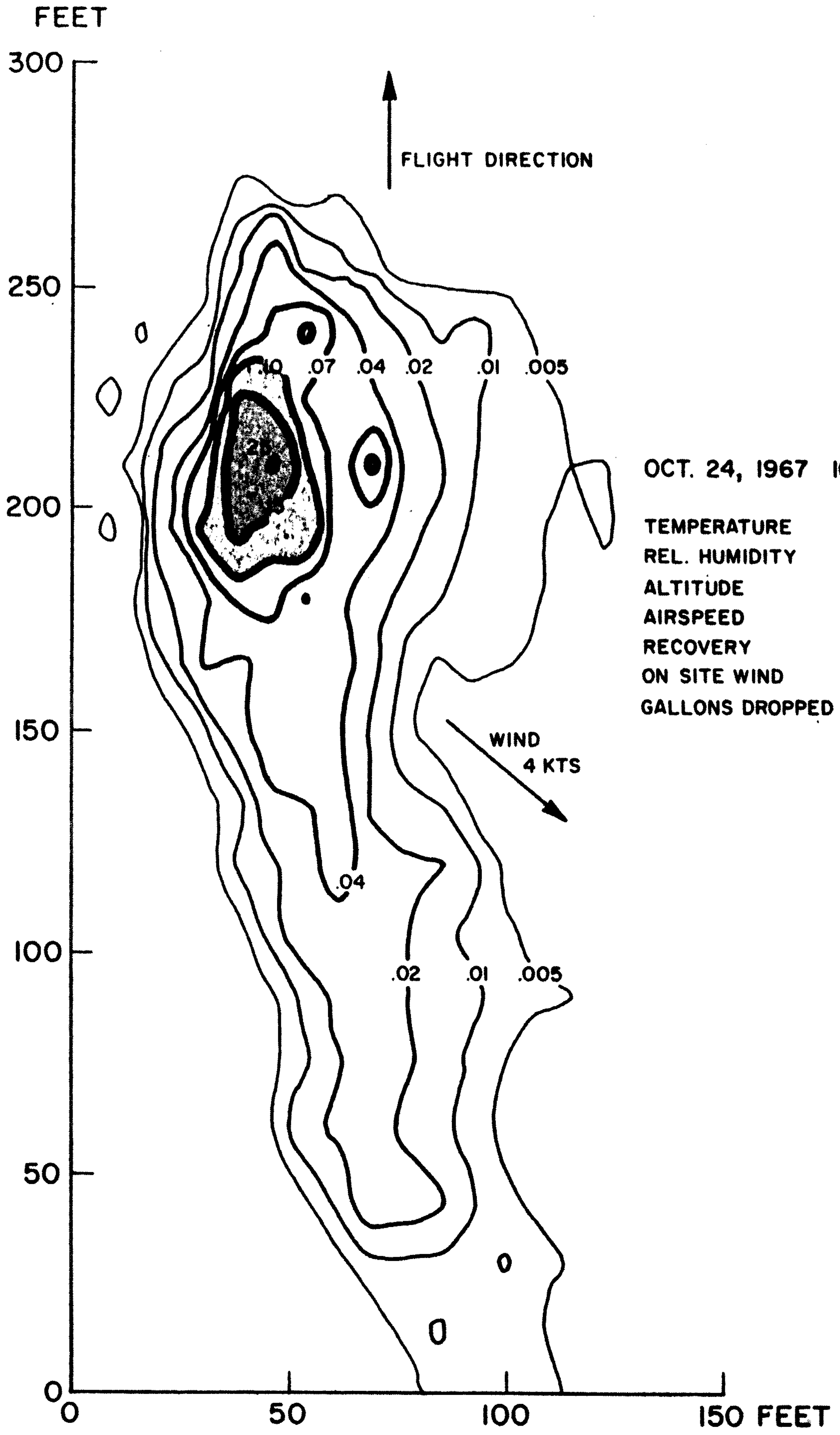
TWIN OTTER, DROP No. 6



TWIN OTTER, DROP No. 7 (LEFT FLOAT TANK ONLY)



TWIN OTTER, DROP No. 8



OCT. 24, 1967 10:12 hrs E.D.T.

TEMPERATURE	53°
REL. HUMIDITY	71 %
ALTITUDE	84'
AIRSPEED	85 KTS
RECOVERY	72 %
ON SITE WIND	3.5 KTS
GALLONS DROPPED	400 IMP. GAL.