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VERTICAL SAMPLING FLIGHTS IN SUPPORT OF THE
1981 ASCOT COOLING TOWER EXPERIMENTS:
FIELD EFFORT AND DATA

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ABSTRACT

During the month of August 1981, three nights of experimental sampling of tracers released into the cooling tower plume of a geothermal power plant were conducted. In these experiments a tethered balloon was used to lift a payload so as to obtain vertical profiles of the cooling tower plume and the entrained tracers. A description of the equipment used, the field effort and the data acquired are presented here. This effort was sponsored by the Department of Energy.

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ACKNOWLEDGEMENTS

The author would like to express his gratitude and acknowledge the contributions of others who helped make the Sandia National Laboratory effort in the ASCOT experiment successful.

D. S. Ballantine of DOE/OHER provided the funding and moral support for our participation. P. H. Gudiksen of Lawrence Livermore National Laboratory brought about the participation of Sandia in the ASCOT experiment.

Special thanks go to Ken Lamson of LLNL and Gary Miles of ES&S, Inc., for providing logistical support, Ray Lagomarsino of EML/USDOE for the analysis of the tracer samples, L. M. Moore of AnaChem for data reduction and computer programming, and to Kathy Jackson of AnaChem for assistance in production of this report.

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VERTICAL SAMPLING FLIGHTS IN SUPPORT OF THE
1981 ASCOT COOLING TOWER EXPERIMENTS:
FIELD EFFORT AND DATA

I. INTRODUCTION

A. ASCOT Cooling Tower Experiments

The ASCOT Cooling Tower Experiments were the third major field effort of the U. S. Department of Energy sponsored Atmospheric Studies in Complex Terrain (ASCOT) program. These experiments were conducted in the Big Sulfur Creek Valley, which is located in The Geysers geothermal area of Northern California. The objective of the ASCOT Program is to improve the technology needed to perform air quality impact assessment of energy resource development in areas of complex terrain. The program employs theoretical atmospheric physics research, mathematical models, and field experiments to aid in the development of modelling and measurement methodology to provide the air quality assessment in areas of complex terrain.

The ASCOT Cooling Tower Experiments involved a large number of research groups from many different organizations. These groups fielded several instrumented aircraft, injected perfluorocarbon tracers into the cooling tower plume, took ground level samples, did vertical sampling, tracked tetroons, defined plume geometry with lidar and acquired meteorological data.

At the initiative of Dr. D. S. Ballantine, DOE Program Manager for the ASCOT Program, and Dr. P. H. Gudiksen, the Lawrence Livermore National Laboratory ASCOT Field Studies Program Manager, the Environmental Research Group at Sandia National Laboratories

joined the ASCOT effort. Under the sponsorship of the Department of Energy, Sandia has for some years been developing and utilizing balloon-borne monitoring systems as tools for the study of atmospheric pollutants and their impact upon the environment.

B. Objective

The goal of the SNLA participation in the ASCOT Cooling Tower Experiment was to aid in the definition of the vertical distribution of the tracers up to a height of about 500 m above the valley floor. One reason for this need was determined from experiences in past experiments that indicated the tracer concentrations may exhibit an elevated layered structure over valleys. This objective was to be met by taking a time series of grab samples from a tethered balloon as it was allowed to rise through the cooling tower plume downwind from the power plant.

II. HARDWARE

A. Flight Systems

The balloon used for the vertical sampling portion of the Cooling Tower Experiment was a 7.0 m³ helium-filled blimp-shaped tethered balloon supplied by AIR, Inc., as part of their Tethersonde system. This balloon was chosen because of its ability to lift about 4.5 kg to about 2 km altitude above sea level, and for several reasons that will be discussed in a later section. The winch used to control the ascent and descent of the balloon was also supplied by AIR, Inc., as part of their Tethersonde system. The winch was loaded with 1 km of 360 lb. test kevlar tetherline.

The balloon is fabricated from 1.5 mil urethane plastic. It is constructed with an internal stretch cord and an expansion stinger to allow the balloon to maintain its aerodynamic shape and to present a low drag coefficient at any rated altitude and wind load.

B. Payload

1. Assembly

The payload carried by the tethered balloon consisted of two separate packages. The first package was an AIR, Inc., Tethersonde airborne package for measuring meteorological parameters in the vicinity of the balloon. The second package was a grab sampler package designed by Sandia National Laboratories personnel. This package was designed to obtain air samples at various altitudes to be brought back to the laboratory for later analysis. Figure 1 shows the payload assembly suspended from the balloon.

2. Realtime Measurements

The Tethersonde airborne package carried sensors for measuring wind speed, wind direction, temperature, wet bulb depression and differential atmospheric pressure. Signals from these sensors were time multiplexed and then transmitted via telemetry transmitter to a ground station. The ground station received the telemetry signal, processed it, recorded it on magnetic tape and also displayed it on an LED display. The realtime data were used by the experimenter for control of the experiment. The recorded data were used for later evaluation of the experiment after return to the laboratory where the data could be used for subsequent calculations and plotting.

Figure 1. Balloon and payload assembly showing Tethersonde package near rear of balloon, and grab sampler package near front of balloon.

3. Grab Sampler

The grab sampler package carried an array of six 50 cc syringes used to obtain samples of the air in the vicinity of the balloon. Each syringe was preceded by a solenoid valve and a capillary tube. The valves were controlled by an onboard solid state timer/sequencer. The capillaries were used to control the flow of air into the syringes so that a time integrated air sample could be obtained. The package carried a battery pack and a strobe light to mark the location of the balloon for any aircraft in the area. Figures 2 and 3 show the package. The gas samples obtained with the syringes were analyzed for tracer concentration by Ray Lagomarsino of EML.

C. Auxiliary Equipment

The Cooling Tower Experiments were designed to study the drainage flow below Unit 14 in the Big Sulfur Creek Valley. These drainage flows generally become well established near midnight, thus all of these experiments took place at night.

To support the vertical sampling experiment at night required some lighting. This was provided by two quartz-iodide flood lamps. These were powered by two gasoline engine driven portable A.C. power generators. These generators also provided power for the Tethersonde ground station and balloon winch.

Some miscellaneous hardware and rigging were needed because of the nature of the sampling location. These will be described further in the section dealing with the sampling site.

Figure 2. Grab Sampler (front view) showing 50 cc syringes loaded into grab sampler package.

Figure 3. Grab Sampler (back view) showing valves, capillaries, battery and strobe light on grab sampler package.

III. TEST SITE

A. Location

The site chosen for the vertical sampling experiment was about 300 m northwest of Units 1 and 2 on the north side of Big Sulfur Creek. The UTM coordinates of the site are: UTM North: 4294.5, UTM East: 516.7, based on California coordinate system, zone 2 (latitude N38°47'55", longitude W122°48'34"). This site is about 2.6 km down the valley from Unit 14, the source under study. Figure 4 shows the site for the vertical sampling and the cooling towers for Units 1 and 2.

B. Physical Characteristics of Site

For several kilometers below Unit 14 the Big Sulfur Creek Valley is very narrow at the bottom and the valley walls are very steep. In addition, the valley bottom and lower walls are in most places covered with thick brush and small trees. Sites that are suitable for flying balloons are limited. The site described above was selected, but it was not ideal from several standpoints. The experimental plan required sampling from as near the valley bottom as possible. Access to the valley bottom at this location was limited to a point close to Units 1 and 2 several hundred meters down the creek bed. The creek bed was strewn with rocks and steam fumeroles which made the transport of equipment difficult and potentially dangerous, especially at night. A road with access to a well pad was located about 50 m above the valley bottom, near the site.

A scheme was devised for rigging the balloon tether whereby the bulk of the equipment could be located on a ledge below the

Figure 4. Tether site showing vertical sampling site and units 1 and 2 cooling towers.

well pad. The balloon could be filled on the well pad and the operation of the vertical sampling could be done from the ledge. Figure 5 shows schematically the site and tether rigging.

C. Equipment Location

As stated above, the bulk of the equipment was located on a small ledge above the tether site and below the well pad (Figure 6). One of the wood packing crates used for shipping the equipment was placed on the valley floor at the tether site. It was filled with rocks, located nearby, and thus served as the tether fairlead anchor. A plate, to which the fairlead pulley was mounted, was affixed to the fairlead anchor. A line was run through the fairlead pulley and both ends terminated on the ledge above where the equipment was located. This line was used to pull the tether line through the fairlead pulley each time an experiment was to be set up. By using this line there was no need for anyone to have to climb down to the valley bottom prior to and after each experiment.

Another wood packing crate was employed at the ledge to mount a transition sheave so that the tether line could come up out of the winch guide, over the sheave and then down the hill to the fairlead pulley (Figure 5). Another line was attached to a carabiner. The tether line was passed through this carabiner and then attached to the balloon. By a combination of inhaul/outhaul on the tether line and the line attached to the carabiner, the balloon and payload could be serviced at the ledge or well pad without having to climb down to the valley floor. Figure 7

Figure 5. Schematic of Experiment Site.

Figure 6. Equipment site showing equipment located on ledge above tether site and below well pad.

Figure 7. Balloon shown tethered at sampling site prior to an experiment.

shows the balloon, as seen from the ledge above, tethered at the sampling site prior to one of the experiments.

IV. EXPERIMENTS

A. Experimental Plan

Three nights of experiments were planned during the month of August, 1981. These experiments were predicated on obtaining meteorological conditions that were conducive to drainage flows in the Big Sulfur Creek Valley on three nights during the month of August.

The ASCOT experimental plan called for the release of two perfluorocarbon tracers, the perfluoromonomethylcyclohexane tracer to be injected into the cooling tower of Unit 14 while the perfluorodimethylcyclohexane tracer would be released simultaneously on the surface near the power plant. The tracer releases would occur over a one-hour period after it was determined that the drainage flow had been established.

The Sandia vertical sampling experiment was to begin 30 minutes after the start of the tracer release. The balloon was controlled so as to rise to 500 m above the valley bottom in one hour as uniformly as possible. Syringe samples were taken during ascent only at 10-minute intervals, thus obtaining integrated air samples over six altitude bands of approximately 83 m each. Three such flights were made each night at two-hour intervals. Thus a total of 18 syringe samples were taken for each experiment over a five-hour period.

The original plan had called for taking three samples as the balloon rose and three samples as the balloon was retrieved. But because of the inability to retrieve the balloon at a rate that would correspond to the ascension rate, the above described procedure was used. The slowness of balloon retrieval was due in part to the limited power available to the winch and in part to the additional friction introduced by the rigging that was needed as a result of the site terrain.

B. Experiment One

The first experiment was conducted on the night of August 15, 1981. Release of the tracers was begun at 2100 PST. The first vertical sampling run was started at 2130. Six syringe samples were taken at 10-minute intervals. The second vertical sampling run was started at 2334 and again obtained six syringe samples at 10-minute intervals. The third and final vertical sampling run of the evening was started at 0132 with six syringe samples taken at 10-minute intervals. On this run at about 0150 the balloon encountered strong winds which caused it to move down the canyon instead of climbing up as it would normally. It was not until about 0208 that the balloon could be maneuvered out of this wind situation and back to the desired altitude to continue routine sampling.

Tethersonde data were taken continuously during each of the three runs. In shipping equipment back to Albuquerque at the conclusion of the ASCOT Cooling Tower Experiments, the data tape for Experiment One, Run One, was damaged and the data contained on it were lost.

C. Experiment Two

The second experiment was conducted on the night of August 16, 1981. The release of tracers was begun at 2200 PST and the first vertical sampling run started at 2230. The second sampling run started at 0025 and the third sampling run started at 0210. Each of the three runs followed the same plan as executed in Experiment One.

D. Experiment Three

The third experiment was conducted on the night of August 21, 1981. The tracer releases were started at 2200 PST. The first vertical sampling run was started at 2228, the second at 0026 and the third at 0200. As occurred on Experiment One the balloon encountered strong winds which caused the balloon to move down the valley instead of vertically as planned. This occurred about 0210 and it was not until about 0218 that the balloon was maneuvered back to a position to continue the planned vertical sampling.

V. RESULTS

A. Experiment One

As was mentioned earlier, the data tape for Run One containing Tethersonde data was damaged during shipment and all the Tethersonde data for Run One were lost.

Table I contains the tracer concentration data for the three runs of Experiment One. The altitudes listed for Run One are the best estimate of the altitudes at which the syringe samples were taken. These altitudes were deduced from data manually logged

from the Tethersonde ground station display during the experiment. The altitudes for all other runs were derived from the data recorded on the Tethersonde data tapes.

The times listed in the tables are the times at which the syringe samples were taken. These times were obtained by manually logging the time at which a lamp on the payload was visually observed to actuate. The lamp on the payload is wired so as to actuate when a new syringe sample is initiated.

The Tethersonde data for Runs Two and Three are presented in Figures 8 and 9. The concentration data for Runs Two and Three are plotted vs. some selected meteorological parameters and are presented in Figures 10 and 11. It should be noted that on Run Three Tethersonde data only go up to about 375 m AGL. While running the experiments it was observed from the Tethersonde ground station display that the signal from the airborne package became very intermittent above about 350 m. Sampling continued on up to about 470 m in every case, but because of the intermittent signals the ground station microprocessor would not synchronize on the signal nor record the data on tape. The battery in the airborne package was well charged for all experiments and at the proper voltage for the experiment duration. The loss of RF signal was probably due to some sort of terrain related RF signal path disturbances. Similar signal problems were experienced with the voice communications radio links at the test site throughout the period of the experiments.

During Run Three at about 0142 the balloon was carried down canyon by the winds instead of traveling vertically upward as

planned. This was at the beginning of syringe sample 14 and this condition was not overcome until about 0157 which would be near the end of the sampling period for syringe 15. At this time the balloon was maneuvered back to its proper sampling position and samples 16 through 18 were taken at planned altitudes. It can be seen in Figures 9 and 11 that there were also periods of signal dropout during the time that the balloon was blown down canyon. Again, it was probably due to path disturbances and antenna orientation. The airborne package transmitter is only 5 mw at 403 MHz, so only minor variations in signal strength at the receiver can be tolerated.

B. Experiment Two

The second experiment was conducted in the same manner as the first. Figures 12, 13 and 14 show the Tethersonde data for the three runs. Again, note that Tethersonde data quit at about 350-370 m but tracer samples were taken on up to about 470 m. Figures 15, 16 and 17 show the tracer concentration data. It should be noted that in a couple of instances the plot of tracer concentration is only a horizontal line. This only means that the concentration was out of range for the scale used for the plot. Actual values can be found in the tables.

C. Experiment Three

The third experiment followed the same plan as the previous two. As happened on the first experiment, the wind carried the balloon down canyon during a part of two runs. At about 0044 during the second sampling period of Run Two this occurred and

then again on Run Three beginning about 0208 and lasting through the first two sampling periods of Run Three. Figures 18, 19 and 20 show the Tethersonde data for the third experiment. The tracer concentration data are shown in Figures 21, 22 and 23. As can be seen in Figures 19 and 22, there were again some missing data caused by signal loss. The concentration data in Figure 22 shown between 50 and 250 m should be interpreted as being the concentration generally around the 75-100 m altitude range for the entire sampling period, as the balloon was not rising uniformly during this period. Also in Figure 23 the concentration data shown between 0 and 140 m is better interpreted as being the concentration found between about 25-75 m during the first two sampling periods, as again the balloon was not rising uniformly.

D. Conclusion

No attempt will be made here to interpret the meaning of the data presented in this report. Interpretation should await the receipt of the information from the many other experimenters. It can be said, however, that the feasibility of taking air samples with a small balloon system in very difficult terrain has been successfully demonstrated while obtaining data useful to the ASCOT program. A small versatile sampling package was developed and used and now provides the means for obtaining vertical profile information with a modest investment in equipment.

Table I

TRACER CONCENTRATIONS FOR EXPERIMENT ONE

ASCOT 1981
Test No. 1 8/15/81

Run #	Time (PST)	Altitude AGL (m)	Tracer Conc. (Pil/1)	
			*PMCH	*PDCH
1	2130-2140	.5 - 80.0	1.6	19.0
1	2140-2150	80.0 - 160.0	2.0	2.5
1	2150-2200	160.0 - 240.0	3.7	5.2
1	2200-2210	240.0 - 320.0	0.61	15.7
1	2210-2220	320.0 - 400.0	2.7	10.7
1	2220-2230	400.0 - 480.0	2.9	2.8
2	2334-2344	.7 - 94.8	0.74	3.4
2	2344-2354	94.8 - 161.0	0.95	2.1
2	2354-0004	161.0 - 240.9	1.5	2.7
2	0004-0014	240.9 - 322.2	1.7	3.6
2	0014-0024	322.2 - 390.1	0.85	2.2
2	0024-0034	390.1 - 465.8	1.7	2.6
3	0132-0142	.5 - 62.4	1.1	1.7
3	0142-0148	62.4 - 238.0	1.5	2.1
3	0148-0158	238.0 - 248.0	2.1	1.8
3	0158-0208	248.0 - 312.9	1.8	1.7
3	0208-0218	312.9 - 374.5	1.1	1.7
3	0218-0228	374.5 - 470.0	ND*	ND

*PMCH = perfluoromonomethylcyclohexane (C_7F_{14})

*PDCH = perfluorodimethylcyclohexane (C_8F_{16})

*ND = not detectable

TETHERSONDE (SNLA)

DATE: 081581 2331 TO 0039 PST
UTM NORTH 4294.5 EAST 516.7

Figure 8. Tethersonde Data, Experiment One, Run Two

TETHERSONDE (SNLA)

DATE: 081681 0129 TO 0220 PST
UTM NORTH 4294.5 EAST 516.7

Figure 9. Tethersonde Data, Experiment One, Run Three

TETHERSONDE (SNLA)
ASCOT-CALIFORNIA

DATE: 081581 2331 TO 0039 PST
UTM NORTH 4294.5 EAST 516.7

Figure 10. Tracer Data, Experiment One, Run Two

TETHERSONDE(SNLA)
ASCOT-CALIFORNIA

DATE: 081681 0129 TO 0220 PST
UTM NORTH 4294.5 EAST 516.7

Figure 11. Tracer Data, Experiment One, Run Three

Table II

TRACER CONCENTRATIONS FOR EXPERIMENT TWO

ASCOT 1981
Test No. 2 8/16/81

Run #	Time (PST)	Altitude AGL (m)	Tracer Conc. (Pil/l)	
			*PMCH	*PDCH
1	2230-2239	.5 - 72.8	9.9	52.0
1	2239-2249	72.8 - 148.7	10.3	1.9
1	2249-2258	148.7 - 220.1	7.9	2.9
1	2258-2307	220.1 - 277.2	9.8	2.6
1	2307-2317	277.2 - 363.0	5.1	6.9
1	2317-2327	363.0 - 470.0	7.7	2.9
2	0025-0035	.5 - 36.4	9.8	6.0
2	0035-0045	36.4 - 114.0	4.1	3.3
2	0045-0055	114.0 - 178.8	10.4	8.3
2	0055-0105	178.8 - 265.9	9.7	8.2
2	0105-0114	265.9 - 348.4	8.6	4.9
2	0114-0124	348.4 - 465.0	7.75	10.0
3	0209-0219	.5 - 68.0	10.0	3.9
3	0219-0229	68.0 - 161.3	10.0	2.6
3	0229-0239	161.3 - 210.4	34.3	4.7
3	0239-0249	210.4 - 273.4	9.4	9.5
3	0249-0259	273.4 - 353.0	6.2	2.4
3	0259-0309	353.0 - 465.0	ND*	10.0

*PMCH = perfluoromonomethylcyclohexane (C_7F_{14})

*PDCH = perfluorodimethylcyclohexane (C_8F_{16})

*ND = not detectable

TETHERSONDE (SNLA)

DATE: 081681 2212 TO 2319 PST
UTM NORTH 4294.5 EAST 516.7

Figure 12. Tethersonde Data, Experiment Two, Run One

TETHERSONDE (SNLA)

DATE: 081781 0017 TO 0118 PST
UTM NORTH 4294.5 EAST 516.7

Figure 13. Tethersonde Data, Experiment Two, Run Two

TETHERSONDE (SNLA)

DATE: 081781 0203 TO 0300 PST
UTM NORTH 4294.5 EAST 516.7

Figure 14. Tethersonde Data, Experiment Two, Run Three

TETHERSONDE (SNLA)
ASCOT-CALIFORNIA

DATE: 081681 2212 TO 2319 PST
UTM NORTH 4294.5 EAST 516.7

Figure 15. Tracer Data, Experiment Two, Run One

TETHERSONDE (SNLA)
ASCOT-CALIFORNIA

DATE: 081781 0017 TO 0118 PST
UTM NORTH 4294.5 EAST 516.7

Figure 16. Tracer Data, Experiment Two, Run Two

TETHERSONDE (SNLA)
ASCOT-CALIFORNIA

DATE: 081781 0203 TO 0300 PST
UTM NORTH 4294.5 EAST 516.7

Figure 17. Tracer Data, Experiment Two, Run Three

Table III

TRACER CONCENTRATIONS FOR EXPERIMENT THREE

ASCOT 1981
Test No. 3 8/21/81

Run #	Time (PST)	Altitude AGL (m)	Tracer Conc. (Pil/l)	
			*PMCH	*PDCH
1	2225-2235	.5 - 82.3	0.36	31.1
1	2235-2245	82.3 - 155.0	1.25	9.05
1	2245-2255	155.0 - 224.3	0.30	11.6
1	2255-2305	224.3 - 300.0	4.72	36.2
1	2305-2314	300.0 - 365.0	0.20	16.8
1	2314-2324	365.0 - 465.0	0.17	9.14
2	0024-0034	.5 - 48.1	0.98	9.75
2	0034-0044	48.1 - 255.1	0.82	11.0
2	0044-0054	255.1 - 330.1	0.34	11.4
2	0054-0104	330.1 - 375.0	0.96	7.25
2	0104-0113	375.0 - 421.0	0.30	3.64
2	0113-0123	421.0 - 470.0	0.74	5.94
3	0158-0208	.5 - 62.3	0.02	0.35
3	0208-0218	62.3 - 144.4	0.01	0.57
3	0218-0228	144.4 - 209.9	0.17	10.8
3	0228-0238	209.9 - 283.5	0.29	4.69
3	0238-0248	283.5 - 370.0	0.29	5.87
3	0248-0258	370.0 - 465.0	0.46	11.5
Background 2002			0.08	0.72
Background 2055			0.03	0.08

*PMCH = perfluoromonomethylcyclohexane (C_7F_{14})

*PDCH = perfluorodimethylcyclohexane (C_8F_{16})

TETHERSONDE(SNLA)
ASCOT-CALIFORNIA

DATE: 081781 0203 TO 0300 PST
UTM NORTH 4294.5 EAST 516.7

Figure 17. Tracer Data, Experiment Two, Run Three

Table III

TRACER CONCENTRATIONS FOR EXPERIMENT THREE

ASCOT 1981
Test No. 3 8/21/81

Run #	Time (PST)	Altitude AGL (m)	Tracer Conc. (Pil/l)	
			*PMCH	*PDCH
1	2225-2235	.5 - 82.3	0.36	31.1
1	2235-2245	82.3 - 155.0	1.25	9.05
1	2245-2255	155.0 - 224.3	0.30	11.6
1	2255-2305	224.3 - 300.0	4.72	36.2
1	2305-2314	300.0 - 365.0	0.20	16.8
1	2314-2324	365.0 - 465.0	0.17	9.14
2	0024-0034	.5 - 48.1	0.98	9.75
2	0034-0044	48.1 - 255.1	0.82	11.0
2	0044-0054	255.1 - 330.1	0.34	11.4
2	0054-0104	330.1 - 375.0	0.96	7.25
2	0104-0113	375.0 - 421.0	0.30	3.64
2	0113-0123	421.0 - 470.0	0.74	5.94
3	0158-0208	.5 - 62.3	0.02	0.35
3	0208-0218	62.3 - 144.4	0.01	0.57
3	0218-0228	144.4 - 209.9	0.17	10.8
3	0228-0238	209.9 - 283.5	0.29	4.69
3	0238-0248	283.5 - 370.0	0.29	5.87
3	0248-0258	370.0 - 465.0	0.46	11.5
Background 2002			0.08	0.72
Background 2055			0.03	0.08

*PMCH = perfluoromonomethylcyclohexane (C_7F_{14})

*PDCH = perfluorodimethylcyclohexane (C_8F_{16})

TETHERSONDE (SNLA)

DATE: 082181 2223 TO 2315 PST
UTM NORTH 4294.5 EAST 516.7

Figure 18. Tethersonde Data, Experiment Three, Run One

TETHERSONDE (SNLA)

DATE: 082281 0017 TO 0055 PST
UTM NORTH 4294.5 EAST 516.7

Figure 19. Tethersonde Data, Experiment Three, Run Two

TETHERSONDE (SNLA)

DATE: 082281 0154 TO 0247 PST
 UTM NORTH 4294.5 EAST 516.7

Figure 20. Tethersonde Data, Experiment Three, Run Three

TETHERSONDE (SNLA)
ASCOT-CALIFORNIA

DATE: 082181 2223 TO 2315 PST
UTM NORTH 4294.5 EAST 516.7

Figure 21. Tracer Data, Experiment Three, Run One

TETHERSONDE (SNLA)
ASCOT-CALIFORNIA

DATE: 082281 0017 TO 0055 PST
UTM NORTH 4294.5 EAST 516.7

Figure 22. Tracer Data, Experiment Three, Run Two

TETHERSONDE (SNLA)
ASCOT-CALIFORNIA

DATE: 082281 0154 TO 0247 PST
UTM NORTH 4294.5 EAST 516.7

Figure 23. Tracer Data, Experiment Three, Run Three

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