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NEAR SOURCE TRACERS AT HANFORD

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NEAR SOURCE TRACERS AT HANFORD

Today I'd like to review some of the atmospheric tracer work carried out at Hanford. Although we have used particulate tracers in the investigation of the resuspension and translocation of particulates, and although we have on occasion pursued tracers by aircraft beyond a distance of 30 km, I'd like to restrict my discussion today to point source field experiments in which fixed "ground-level" and tower sampling were pursued at distances close to the source. Inasmuch as the last field tracer technique developed at Hanford (a krypton-85 technique) offered more novel data than our earlier techniques, I'll dwell on it a bit more intensely.

First, however, I would like to review very briefly our tracer field experience at Hanford. The first atmospheric tracer used was a visible oil fog. The disadvantage with this approach was that efforts to develop a quantitative assay technique for concentration (based on fluorescent properties of the oil fog) failed. The primary tracer observation technique used was photography. The advantage of a visible technique is that it offers an excellent tool to get the "feel" and the scale of diffusion and transport processes--a feel that is difficult to appreciate with non-visible tracers. Figure 1, for instance graphically portrays the wind speed and (more dramatically) direction shear accompanying this early morning ground-level release into a stable atmosphere.

The second tracer used in atmospheric diffusion studies at Hanford was a fluorescent particulate (FP). A variety of sampling devices were used with FP--including tacky paper, cascade impactors, silicone-coated paper

and metal cylinders, Rotorods and membrane filters. Perhaps our biggest coup was in the development of a device to assay FP on membrane filters. This device, shown in Figure 2, was instrumental in facilitating assay of the tens of thousands of filters deployed during the Green Glow¹ and other Hanford field experiments. This Rankin counter², named for the engineer who developed the device, is based on a scintillation counting technique in which a fixed alpha emitter excites a variable scintillator (the FP) to fluorescence, and the resulting scintillations are monitored by a multiplying phototube. This assay device replaced the tedious and time consuming man, microscope and ultra-violet light source assay approach.

Other particulate tracers used at Hanford in point source studies have been fluorescein (uranine) and rhodamine B fluorescent dyes. The fact that the Rankin assay approach for FP is a nondestructive process permitted collection of fluorescein (or rhodamine) and FP on a common filter and subsequent non-interfering analysis. Dual tracer release field experiments were possible.

The prime difficulty with particulate tracers is that they deposit. An inert gas tracer is a much better baseline tracer. I personally feel that our particulate tracers have given a great deal of valid information with respect to horizontal dispersion. However, absolute concentration and vertical dispersion measurements are addressed less satisfactorily.

Nonisokinetic sampling is another problem associated with particulate tracers. Although much of the Hanford sampling data were corrected for nonisokinetic flow on the basis of a wind tunnel study³, I feel certain that these corrections are only improvements in the field sampled data, and not perfect representations of atmospheric concentration. I recall

a remark at another workshop 10 or 12 years ago that "... there are as many answers as there are particulate sampling methods." I suspect this is a valid assessment with particles larger than $1\text{ }\mu\text{m}$ in diameter. (Our predominant FP tracer, U.S. Radium Corp. FP 2210, has a mass median diameter of about $5\text{ }\mu\text{m}$ and a specific gravity of about 4).

As I stated in my introduction, I'd like to dwell a bit more heavily on our Hanford inert gas krypton-85 field technique⁴. This technique is considerably more sophisticated than the visible and particulate tracer techniques I've been describing. The krypton technique develops histories of concentration at up to 128 field locations; the particulate techniques generate only bulk time integrated samples. The krypton dispersal technique permits release of either a plume or a true puff; the particulate techniques permit continuous releases, but only approximations of puffs through short continuous releases.

Figure 3 shows the krypton apparatus for generation of a true puff. There's little doubt that the presentation to the ambient atmosphere is near-instantaneous. The lead brick at the top of the guillotine drops on a quartz vial containing the krypton.

Release of a continuous source (plume) is rather more conventional. The radioactive krypton (mixed with a non-radioactive argon carrier) is released from a compressed gas cylinder.

Figure 4 shows several of the Geiger-Muller tube sensors in the field. Most were mounted on fence posts at an elevation 1.5 m above ground level. Several can also be seen mounted on the poles in the background. Each sensor receives high voltage from a central control trailer by means of a coaxial cable. The same cable relays the radiation

induced pulses back to the central location. Counts from all field sensors are simultaneously accumulated over a selected time increment. A sampling increment of 5 or 10 seconds was generally employed.

Figure 5 depicts one of the field arrays used with the krypton system. Each dot represents a sampler. Hence both vertical and ground-level (1.5 m) sampling were carried out on arcs 200 and 800 m from the release point. Only ground-level sampling was attempted at the 1600 m arc.

Figure 6 depicts the history of concentration along an arc 200 m from a ground-level puff release. The left portion of the figure shows isopleths of concentration as functions of azimuth and time. Each row of numbers depicts 5 sec mean concentrations at G-M sensors 1.5 m above ground level. At the right are concentrations measured on a tower on the 200 m arc. The tower sensors generate a history of concentration in the vertical at an azimuth of 114° with respect to the source.

Figure 7 shows the history of concentration at an elevation of 1.5 m during a plume passage. (Not a puff). Whereas the previous slide showed history of concentration based on 5-sec time increments, here we have 40-sec increments of concentration. At the left is a history at 200 m from the ground-level source. At the right is the same plume at 800 m. The "real" and meander components of the mean plume can easily be derived from these data.

The Hanford krypton-85 inert gas system offers the advantages of an inert gas tracer, permits release of either puffs or plumes, and presents histories of concentration as opposed to only time-integrated

concentrations. However, the approach used has the disadvantages of being useable at only short distances, is a relatively expensive system to deploy and maintain, and is restricted as to locations where it may be used due to the radioactive nature of the tracer.

In the remaining few minutes, I'd like to present some "odds and ends" resulting primarily from data generated by the krypton-85 field system. The results presented are novel since they result from the simultaneous continuous recording of concentration at a large (64 or 128) number of field locations.

Let's refer once more to Figure 7. Although in fact 40-second time increments were used during this experiment, a number of other continuous plume release experiments were conducted with 10-second sampling increments. Let's assume the time increment for each row of data on this figure is 10 sec. Let's further assume we have a crop-dusting pilot willing to fly crosswind through this plume at an elevation of 1.5 m, and that he has a magic sampler capable of continuous recording of krypton concentration. It is then not unreasonable to assume that each 10-sec increment of data on Figure 7 represents the profile that would have been seen by the pilot during one traverse. We can then construct the mean crosswind profile the pilot would have deduced on the basis of a series of traverses. And since the true mean profile is known (by integrating over all time increments), we can compare the pilot's estimates with the true profile. Figures 8 and 9 illustrate the effect of an increasing number of traverses. The data in Figures 8 and 9 result from analysis of ground-level crosswind distributions of concentration 800 m from a 26 m elevation release during stable atmospheric conditions.

On Figure 10 we see ground-level crosswind integrated exposure (as determined from 10-sec sampling increments) versus time. These data are from the same 26-m release described at the end of the preceding paragraph. This graph illustrates the variation in short period mean concentration that can be experienced even under stable atmospheric conditions. Figure 11 develops (by methods similar to the pilot argument in the prior paragraph--but using all possible traverses) standard error for crosswind integrated exposure and for real plume maximum concentration as a function of number of traverses. It appears that for this stable-atmosphere experiment, the added dividends in accuracy accruing from repeat traverses decreases after six or seven traverses. Also, on the basis of this one experiment, there appear to be minimal differences in the standard errors for the computed parameters at downwind distances of 800 and 1600 meters.

Although I'll present no tabular or graphical data on the subject here, the time history of concentration shown on Figure 10 suggest the possibility of peak-to-mean concentration relationships. Peak-to-mean concentration ratios can be developed for crosswind integrated values, real plume centerline values and apparent (or mean) plume centerline values.

Figure 12 displays field measurements made following a puff release in very light wind conditions. The field grid used during this release was a marriage between a grid deployed for other purposes and a grid intended specifically for the light wind case. Each dot on Figure 12 represents a ground-level Geiger-Muller sensor. The array of sensors permitted a definition of the extent of above background krypton con-

centrations at specific post-release times. Perhaps the most interesting contour is that observed at 14 minutes after puff release. Note that the puff was detected at a distance greater than 1 km from the release point at that time, but was also still detected at the source. The measured winds (with vectors shown at the bottom of the figure) were not sufficient to permit transport to a distance of 1 km in 14 minutes. Yet even in this thermally stable atmospheric situation (see temperatures at lower right in figure) a portion of the ground-release puff was transported with a speed greater than that observed at 50 feet above the surface.

Figure 13 is the final figure in my "odds and ends" from the field krypton data. In this figure, crosswind integrated concentrations observed on arcs at 200 m and 800 m are graphed as a function of time after release. Data from two ground-level puff releases are presented. The data at the left were generated following puff P7, a puff released in winds of about 5 m sec^{-1} during unstable atmospheric conditions. At the right, the data represent concentrations following a release into a stable atmosphere with winds of 3 m sec^{-1} . These data afford the opportunity to investigate the magnitude of σ_x , a parameter of interest in describing puff diffusion, but a parameter for which there are few field measurements. If it is assumed that the effective transport speed (U_e) of the puff is the speed with which the mean of the graphed distribution passed a sampling arc, the abscissa of Figure 13 can be converted to units of distance, i.e., $x = U_e \bar{t}$ (where $\bar{t}$ is a temporal mean as indicated on Figure 13). The standard deviation of a distribution is then σ_x .

Another interesting observation from Figure 13 is that in both puffs, the leading edge of the puff was detected at 800 m while the tail of the puff was still observed at 200 m. This situation occurred following all experimental ground-level puff releases regardless of wind speed or atmospheric stability. It is pertinent to note that vegetation at Hanford is primarily sagebrush and desert grasses. The canopy, although not dense, reaches an elevation of about 1.5 to 2 m. The surface roughness, z_0 , is estimated as 3 cm.

I'd like to close by acknowledging that the work described was sponsored by the US Department of Energy and its antecedent agencies.

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Figure 1. Wind direction and speed shear affecting ground-level release.

Figure 2. Assembled Rankin counter (right) and disassembled Rankin counter (left) with several field filter assemblies in place for assessment.

FIG. 3 Guillotine employed in puff generation.

Figure 4. Geiger-Muller tube sensors mounted at 1.5-m elevation and on taller poles.

Figure 5. Field array of 128 sensors used with krypton-85 tracer system.

Time
Increment
Pacific
Standard Time

DIRECTION FROM SOURCE (All data from elevation of 1.5 meters)

		10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5	22.5	23.5	24.5	25.5	26.5	27.5	28.5	29.5	30.5	31.5	32.5	33.5	34.5	35.5	36.5	37.5	38.5	39.5	40.5	41.5	42.5	43.5	44.5	45.5	46.5	47.5	48.5	49.5	50.5	51.5	52.5	53.5	54.5	55.5	56.5	57.5	58.5	59.5	60.5	61.5	62.5	63.5	64.5	65.5	66.5	67.5	68.5	69.5	70.5	71.5	72.5	73.5	74.5	75.5	76.5	77.5	78.5	79.5	80.5	81.5	82.5	83.5	84.5	85.5	86.5	87.5	88.5	89.5	90.5	91.5	92.5	93.5	94.5	95.5	96.5	97.5	98.5	99.5	100.5	101.5	102.5	103.5	104.5	105.5	106.5	107.5	108.5	109.5	110.5	111.5	112.5	113.5	114.5	115.5	116.5	117.5	118.5	119.5	120.5	121.5	122.5	123.5	124.5	125.5	126.5	127.5	128.5	129.5	130.5	131.5	132.5	133.5	134.5	135.5	136.5	137.5	138.5	139.5	140.5	141.5	142.5	143.5	144.5	145.5	146.5	147.5	148.5	149.5	150.5	151.5	152.5	153.5	154.5	155.5	156.5	157.5	158.5	159.5	160.5	161.5	162.5	163.5	164.5	165.5	166.5	167.5	168.5	169.5	170.5	171.5	172.5	173.5	174.5	175.5	176.5	177.5	178.5	179.5	180.5	181.5	182.5	183.5	184.5	185.5	186.5	187.5	188.5	189.5	190.5	191.5	192.5	193.5	194.5	195.5	196.5	197.5	198.5	199.5	200.5	201.5	202.5	203.5	204.5	205.5	206.5	207.5	208.5	209.5	210.5	211.5	212.5	213.5	214.5	215.5	216.5	217.5	218.5	219.5	220.5	221.5	222.5	223.5	224.5	225.5	226.5	227.5	228.5	229.5	230.5	231.5	232.5	233.5	234.5	235.5	236.5	237.5	238.5	239.5	240.5	241.5	242.5	243.5	244.5	245.5	246.5	247.5	248.5	249.5	250.5	251.5	252.5	253.5	254.5	255.5	256.5	257.5	258.5	259.5	260.5	261.5	262.5	263.5	264.5	265.5	266.5	267.5	268.5	269.5	270.5	271.5	272.5	273.5	274.5	275.5	276.5	277.5	278.5	279.5	280.5	281.5	282.5	283.5	284.5	285.5	286.5	287.5	288.5	289.5	290.5	291.5	292.5	293.5	294.5	295.5	296.5	297.5	298.5	299.5	300.5	301.5	302.5	303.5	304.5	305.5	306.5	307.5	308.5	309.5	310.5	311.5	312.5	313.5	314.5	315.5	316.5	317.5	318.5	319.5	320.5	321.5	322.5	323.5	324.5	325.5	326.5	327.5	328.5	329.5	330.5	331.5	332.5	333.5	334.5	335.5	336.5	337.5	338.5	339.5	340.5	341.5	342.5	343.5	344.5	345.5	346.5	347.5	348.5	349.5	350.5	351.5	352.5	353.5	354.5	355.5	356.5	357.5	358.5	359.5	360.5	361.5	362.5	363.5	364.5	365.5	366.5	367.5	368.5	369.5	370.5	371.5	372.5	373.5	374.5	375.5	376.5	377.5	378.5	379.5	380.5	381.5	382.5	383.5	384.5	385.5	386.5	387.5	388.5	389.5	390.5	391.5	392.5	393.5	394.5	395.5	396.5	397.5	398.5	399.5	400.5	401.5	402.5	403.5	404.5	405.5	406.5	407.5	408.5	409.5	410.5	411.5	412.5	413.5	414.5	415.5	416.5	417.5	418.5	419.5	420.5	421.5	422.5	423.5	424.5	425.5	426.5	427.5	428.5	429.5	430.5	431.5	432.5	433.5	434.5	435.5	436.5	437.5	438.5	439.5	440.5	441.5	442.5	443.5	444.5	445.5	446.5	447.5	448.5	449.5	450.5	451.5	452.5	453.5	454.5	455.5	456.5	457.5	458.5	459.5	460.5	461.5	462.5	463.5	464.5	465.5	466.5	467.5	468.5	469.5	470.5	471.5	472.5	473.5	474.5	475.5	476.5	477.5	478.5	479.5	480.5	481.5	482.5	483.5	484.5	485.5	486.5	487.5	488.5	489.5	490.5	491.5	492.5	493.5	494.5	495.5	496.5	497.5	498.5	499.5	500.5	501.5	502.5	503.5	504.5	505.5	506.5	507.5	508.5	509.5	510.5	511.5	512.5	513.5	514.5	515.5	516.5	517.5	518.5	519.5	520.5	521.5	522.5	523.5	524.5	525.5	526.5	527.5	528.5	529.5	530.5	531.5	532.5	533.5	534.5	535.5	536.5	537.5	538.5	539.5	540.5	541.5	542.5	543.5	544.5	545.5	546.5	547.5	548.5	549.5	550.5	551.5	552.5	553.5	554.5	555.5	556.5	557.5	558.5	559.5	560.5	561.5	562.5	563.5	564.5	565.5	566.5	567.5	568.5	569.5	570.5	571.5	572.5	573.5	574.5	575.5	576.5	577.5	578.5	579.5	580.5	581.5	582.5	583.5	584.5	585.5	586.5	587.5	588.5	589.5	590.5	591.5	592.5	593.5	594.5	595.5	596.5	597.5	598.5	599.5	600.5	601.5	602.5	603.5	604.5	605.5	606.5	607.5	608.5	609.5	610.5	611.5	612.5	613.5	614.5	615.5	616.5	617.5	618.5	619.5	620.5	621.5	622.5	623.5	624.5	625.5	626.5	627.5	628.5	629.5	630.5	631.5	632.5	633.5	634.5	635.5	636.5	637.5	638.5	639.5	640.5	641.5	642.5	643.5	644.5	645.5	646.5	647.5	648.5	649.5	650.5	651.5	652.5	653.5	654.5	655.5	656.5	657.5	658.5	659.5	660.5	661.5	662.5	663.5	664.5	665.5	666.5	667.5	668.5	669.5	670.5	671.5	672.5	673.5	674.5	675.5	676.5	677.5	678.5	679.5	680.5	681.5	682.5	683.5	684.5	685.5	686.5	687.5	688.5	689.5	690.5	691.5	692.5	693.5	694.5	695.5	696.5	697.5	698.5	699.5	700.5	701.5	702.5	703.5	704.5	705.5	706.5	707.5	708.5	709.5	710.5	711.5	712.5	713.5	714.5	715.5	716.5	717.5	718.5	719.5	720.5	721.5	722.5	723.5	724.5	725.5	726.5	727.5	728.5	729.5	730.5	731.5	732.5	733.5	734.5	735.5	736.5	737.5	738.5	739.5	740.5	741.5	742.5	743.5	744.5	745.5	746.5	747.5	748.5	749.5	750.5	751.5	752.5	753.5	754.5	755.5	756.5	757.5	758.5	759.5	760.5	761.5	762.5	763.5	764.5	765.5	766.5	767.5	768.5	769.5	770.5	771.5	772.5	773.5	774.5	775.5	776.5	777.5	778.5	779.5	780.5	781.5	782.5	783.5	784.5	785.5	786.5	787.5	788.5	789.5	790.5	791.5	792.5	793.5	794.5	795.5	796.5	797.5	798.5	799.5	800.5	801.5	802.5	803.5	804.5	805.5	806.5	807.5	808.5	809.5	810.5	811.5	812.5	813.5	814.5	815.5	816.5	817.5	818.5	819.5	820.5	821.5	822.5	823.5	824.5	825.5	826.5	827.5	828.5	829.5	830.5	831.5	832.5	833.5	834.5	835.5	836.5	837.5	838.5	839.5	840.5	841.5	842.5	843.5	844.5	845.5	846.5	847.5	848.5	849.5	850.5	851.5	852.5	853.5	854.5	855.5	856.5	857.5	858.5	859.5	860.5	861.5	862.5	863.5	864.5	865.5	866.5	867.5	868.5	869.5	870.5	871.5	872.5	873.5	874.5	875.5	876.5	877.5	878.5	879.5	880.5	881.5	882.5	883.5	884.5	885.5	886.5	887.5	888.5	889.5	890.5	891.5	892.5	893.5	894.5	895.5	896.5	897.5	898.5	899.5	900.5	901.5	902.5	903.5	904.5	905.5	906.5	907.5	908.5	909.5	910.5	911.5	912.5	913.5	914.5	915.5	916.5	917.5	918.5	919.5	920.5	921.5	922.5	923.5	924.5	925.5	926.5	927.5	928.5	929.5	930.5	931.5	932.5	933.5	934.5	935.5	936.5	937.5	938.5	939.5	940.5	941.5	942.5	943.5	944.5	945.5	946.5	947.5	948.5	949.5	950.5	951.5	952.5	953.5	954.5	955.5	956.5	957.5	958.5	959.5	960.5	961.5	962.5	963.5	964.5	965.5	966.5	967.5	968.5	969.5	970.5	971.5	972.5	973.5	974.5	975.5	976.5	977.5	978.5	979.5	980.5	981.5	982.5	983.5	984.5	985.5	986.5	987.5	988.5	989.5	990.5	991.5	992.5	993.5	994.5	995.5	996.5	997.5	998.5	999.5	1000.5	1001.5	1002.5	1003.5	1004.5	1005.5	1006.5	1007.5	1008.5	1009.5	1010.5	1011.5	1012.5	1013.5	1014.5	1015.5	1016.5	1017.5	1018.5	1019.5	1020.5	1021.5	1022.5	1023.5	1024.5	1025.5	1026.5	1027.5	1028.5	1029.5	1030.5	1031.5	1032.5	1033.5	1034.5	1035.5	1036.5	1037.5	1038.5	1039.5	1040.5	1041.5	1042.5	1043.5	1044.5	1045.5	1046.5	1047.5	1048.5	1049.5	1050.5	1051.5	1052.5	1053.5	1054.5	1055.5	1056.5	1057.5	1058.5	1059.5	1060.5	1061.5	1062.5	1063.5	1064.5	1065.5	1066.5	1067.5	1068.5	1069.5	1070.5	1071.5	1072.5	1073.5	1074.5	1075.5	1076.5	1077.5	1078.5	1079.5	1080.5	1081.5	1082.5	1083.5	1084.5	1085.5	1086.5	1087.5	1088.5	1089.5	1090.5	1091.5	1092.5	1093.5	1094.5	1095.5	1096.5	1097.5	1098.5	1099.5	1100.5	1101.5	1102.5	1103.5	1104.5	1105.5	1106.5	1107.5	1108.5	1109.5	1110.5	1111.5	1112.5	1113.5	1114.5	1115.5	1116.5	1117.5	1118.5	1119.5	1120.5	1121.5	1122.5	1123.5	1124.5	1125.5	1126.5	1127.5	1128.5	1129.5	1130.5	1131.5	1132.5	1133.5	1134.5	1135.5	1136.5	1137.5	1138.5	1139.5	1140.5	1141.5	1142.5	1143.5	1144.5	1145.5	1146.5	1147.5	1148.5	1149.5	1150.5	1151.5	1152.5	1153.5	1154.5	1155.5	1156.5	1157.5	1158.5	1159.5	1160.5	1161.5	1162.5	1163.5	1164.5	1165.5	1166.5	1167.5	1168.5	1169.5	1170.5	1171.5	1172.5	1173.5	1174.5	1175.5	1176.5	1177.5	1178.5	1179.5	1180.5	1181.5	1182.5	1183.5	1184.5	1185.5	1186.5	1187.5	1188.5	1189.5	1190.5	1191.5	1192.5	1193.5	1194.5	1195.5	1196.5	1197.5	1198.5	1199.5	1200.5	1201.5	1202.5	1203.5	1204.5	1205.5	1206.5	1207.5	1208.5	1209.5	1210.5	1211.5	1212.5	1213.5	1214.5	1215.5	1216.5	1217.5	1218.5	1219.5	1220.
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Neg 740787-4

FIGURE 8. Observed Crosswind Distributions of Exposure and Similar Distributions Based on "Instantaneous" Crosswind Traverses, Test V-6, 800-m

Neg 740787-3

FIGURE 9. Observed Crosswind Distributions and Similar Distributions Based on "Instantaneous" Crosswind Traverses, Test V-6, 800-m

Neg 740787-1

FIGURE 10. Crosswind Integrated Exposure as a Function of Time, Test V-6, 800-m Arc

Neg 740787-2

FIGURE 11. Standard Error in Measurement as a Function of the Number of Traverses Through the Continuous Plume, Test V-6, 800 and 1600-m

Neg 715022-1

FIGURE 12. Areal Extent of Detectable ⁸⁵Kr Concentration at 1.5 m Elevation During Field Test P9, 30 July 1971. Puff release at 0451 PST.

FIG. 13. Crosswind summed concentration vs elapsed time since puff release. Multiplication of elapsed time by an appropriate transport speed converts the time scale to a length scale extending radially from the source.