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NUCON Radioiodine Adsorbents

NUCON Bulletin 11B31 – April 2006
(Revised January 2011)

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Background

Radioiodine removal adsorbents used in ESF (and non-ESF) air cleaning components have been of interest to utilities, researchers and commercial suppliers for over 40 years. There has been at least one technical paper (and usually several) about this important protection component presented at each of the twenty-five bi-annual Nuclear Air Cleaning Conferences. Impregnated activated charcoal is the most commonly used adsorbent but other types of materials, such as silver zeolite, have been and continue to be used. However, the bulk of experience is with the activated carbon based products.

As with any technology there have been changes in manufacturing and testing methods over the years. The early KI (potassium iodide) impregnated products have been largely replaced by co-impregnated materials treated with KI and TEDA (triethylenediamine). Some users prefer carbons treated only with TEDA. No matter what the impregnants are, or how the adsorbent is manufactured, the end products must meet industry standards and confirm to US NRC requirements.

The drivers of change have been both technical and commercial. The users want the best performing material possible and the manufacturers seek competitive advantage. In the United States, current adsorbents are impregnated coconutshell based (steam activated) carbons with specific characteristics. This bulletin highlights several NUCON adsorbents.

NUCON Products

We supply three principal products under the brand names:

NUSORB® KITEG-II™; co-impregnated with potassium iodide (KI) and triethylenediamine (TEDA)
NUSORB® TEG™; triethylenediamine
NUSORB® KIG™; iodide salts

The specifications for these grades are shown in attached data sheets 11B4-7/98, 11B5-8/98 and 11B19-1/99. All of these products use activated coconut shell carbon as a base material.

All NUCON radioiodine adsorbents are manufactured and tested to meet:

- US NRC Regulatory Guides 1.52 & 1.140 (all revisions)
- Industry Codes & Standards; ANSI/ASME & ASME N509 (all editions),
- ASME AG-1, and
- ASTM standard test method D3803 (79 & 89) for radioiodine adsorbents.

Product specifications and performance requirements for applications outside the United States are often slightly different. A different particle size than the standard U.S. 8 x 16 mesh is sometimes required. Radioiodine performance testing may be at slightly different velocities, temperatures or relative humidities. In some cases, the requirements dictate that a base material other than activated coconut shell carbon be used. Customized adsorbents have been supplied worldwide to meet a wide variation in specifications.

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Typical Properties vs Specifications

There have been various standards and requirements developed for radioiodine adsorbents used in U.S. nuclear power plants and related applications. A detailed listing of them is contained in Table 1, attached. The references range from RDT M16-1T issued in 1973 to the most recent revision of the ANSI/ASME AG-1 code.

The NUCON in-house product specifications for physical properties such as particle size, ignition temperature and hardness listed in the attached data sheets are based on the most recent of the historical requirements.

If a customer's Technical Specifications reference an older document, the requirements may be different and a customized product is supplied to meet them. NUSORB® products can be supplied to meet the requirements of any of the referenced documents. Typical performance is listed in the attached data sheets. Examples of test results for NUCON radioiodine adsorbents are shown in Table 2.

Performance vs Operating Conditions

The operating conditions for the adsorber can have an impact on the radioiodine removal efficiency of the installed adsorbent. Extensive studies have been performed by NUCON and others to determine the impact of changes in residence time, temperature, relative humidity, particle size and the effect of poisons.

The volume of the adsorber and the airflow through that adsorber are used to calculate a value for empty bed residence time. For example, a flow rate of 333 cfm through a type II tray containing 1.4 ft^3 of carbon gives an empty bed residence time of 0.25 seconds. If the residence time is increased, the radioiodine removal efficiency will be improved. This relationship is shown in Figure 1.

Operating temperature can also affect the radioiodine removal efficiency. The primary mechanisms for removal of methyl iodide are chemisorption and isotope exchange (of ^{131}I with ^{127}I, by the impregnants which are deposited on the activated carbon). Since chemical reactions and isotope exchange proceed more efficiently at higher than room temperatures, the removal efficiency is improved at slightly elevated temperatures. The effect of temperature on efficiency is shown in Figure 2.

Activated carbon is hygroscopic and will adsorb large amounts of water at high relative humidity. Adsorbed water prevents adsorption of radioiodine compounds. The general relationship between relative humidity and methyl iodide penetration is shown in Figure 3. When the airstream relative humidity is above 95%, performance is dramatically reduced. (See Figure 4)

Adsorption efficiency is always improved by using a smaller particle size adsorbent. In Figure 5, it can be seen that the change is dramatic over the range of particle sizes used for radioiodine adsorbents.

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Adsorbent Life

The shelf life of NUCON radioiodine adsorbents has been demonstrated to be 5 years under ANSI/ASME N45.2.2, Level B storage conditions. If the adsorbent is older than 5 years, shelf life extensions can be made if testing of samples shows that the material meets requirements.

Exposure of adsorbents to organic chemicals will reduce performance. NUCON has done extensive studies of the effects of adsorption of common solvents on radioiodine removal efficiency. The attached figure 6 shows this effect. To guard against loss of effectiveness, periodic laboratory testing is required to evaluate the performance of adsorbents installed in air cleaning systems.

The performance of the adsorbent can also be impacted by exposure to “clean” air. Experimental and empirical data have shown that slow oxidation of the impregnants occurs, even at ambient temperatures. Products with high levels of TEDA experience an initial rapid loss of the impregnant when subjected to clean air flow because of the high vapor pressure of TEDA.

NUCON Capabilities

The NUSORB® series of radioiodine adsorbents manufactured by NUCON are used by a great number of clients around the world. A partial listing of them is attached (Bulletin 11B1-1/96).

NUCON participated in the interlaboratory test series conducted first by the ASME Committee On Nuclear Air and Gas Treatment and then by the US NRC in 1986 and 1987.Test results obtained by NUCON matched those of the US NRC/Idaho National Engineering Laboratory. The NUCON radioisotope laboratory was one of only two laboratories that produced acceptable test results using ASTM D3803. NUCON is, therefore, recognized by the NRC as providing accurate and dependable test results.

The impact of poisons such as welding fumes or paint solvents can be predicted by performing actual radioiodine efficiency tests on adsorbents with the contaminants of concern used to purposely poison the adsorbent. NUCON has performed studies of this type for many clients as well as for the development of adsorbents. Much of this data has been published in the DOE/HARVARD Nuclear Air Cleaning Conferences. For further information, please request NUCON Document No.287.

Please contact us to discuss radioiodine adsorption applications.

List of Tables & Figures

Radioiodine Test Methods and Specifications

NUCON International, Inc

NUCON Test No.	Test	Temp °C	RH %	Bed Depth inches	Velocity m/min	Pre-Equil hours	Equil hours	Challenge minutes	Elution minutes	Agent	Conc. mg/m3	Efficiency %	Notes
	RDT M16-1T, June 1972												
1	4.5.1	25	70	1	11 to 13	0	16	120	120	I_2	15 to 20	99.9	Qual
2	4.5.2	130	95	1	11 to 13	0	2 (≤ 1°C)	90	90	I_2	15 to 20	99.9	Qual
3	4.5.3	25	70	2	11 to 13	0	16	240	240	CH_3I	1.5 to 2	98.0	Batch
4	4.5.4	130	95	2	11 to 13	0	2 (≤ 1°C)	90	90	CH_3I	1.5 to 2	98.0	Batch
5	4.5.5	25-180	70	1	11 to 13	0	16	120	240	CH3I	1 to 2	99	Batch
	RDT M16-1T, October 1973												
6	4.5.1	25	70	2	12	0	5 (≤ 1°C)	120	120	I_2	15 to 20	99.9	Qual
7	4.5.2	130	95	2	12	0	5 (≤ 1°C)	90	90	I_2	15 to 20	99.5	Qual
8	4.5.3	25	70	2	12	0	5 (≤ 1°C)	120	120	CH_3I	1.5 to 2	98.0	Qual
9	4.5.4	130	95	2	12	0	5 (≤ 1°C)	90	90	CH_3I	1.5 to 2	95.0	Batch
	RDT M16-1T, December 1977 *parameters are from paragraphs primarily, Table 6 secondary*												
10	C.3.1	30	95	2	12.2	0	16	120	120	CH_3I	1.75	99.9	Qual
11	C.3.2	80	95	2	12.2	0	0	60	240	CH_3I	1.75	97.0	Batch
12	C.3.3	130	95	2	12.2	0	2 (≤ 2°C)	90	90	CH_3I	1.75	99.0	Qual
13	C.3.4	30	95	2	12.2	0	16	120	120	I_2	17.5	98.0	Qual
14	C.3.5	30-180	n/a	1	12.2	0	0	10	240	I_2	75	99.9	Batch
	NE 16-1T, October 1981 (ASTM D3803-1979, -86) *used carbon is not equilibrated*												
15	1	30	95	2	12.2	0	0/16	120	240	I_2	17.5	99.9	Qual
16	2	30	95	2	12.2	0	0/16	120	240	CH_3I	1.75	97.0	Qual
17	3	80	95	2	12.2	0	0	60	240	CH_3I	1.75	99.0	Batch
18	4	130	95	2	12.2	0	2	60	240	CH_3I	1.75	98.0	Qual
19	5	30-180	n/a	1	12.2	0	0	10	240	I_2	75	99.5	Batch
	ASTM D3803-1979, -1986 *used carbon is not equilibrated*												
20	A	30	95	2	12.2	0	0/16	120	240	CH_3I	1.75		
21	B	80	95	2	12.2	0	0	60	240	CH_3I	1.75		
22	C	130	95	2	12.2	0	2	60	240	CH_3I	1.75		
23	D	30	95	2	12.2	0	0/16	120	240	I_2	17.5		
24	E	30-180	n/a	1	12.2	0	0	10	240	I_2	75		
	ASTM D3803-1989, -1995												
25		30	95	2	12.2	16	2	60	60	CH_3I	1.75		

ANSI N509-1976 (RDT M16-1T)

26	5a	25	95	2	12.2	0	16 (≤ 1°C)	120	120	CH_3I	1.75	99.0	Qual
27	5b	25-80-25	95	2	12.2	0	16 (≤ 1°C)	120	120	CH_3I	1.75	99.0	Batch
28	5c	130	95	2	12.2	0	2 (≤ 1°C)	120	120	CH_3I	1.75	98.0	Qual
29	5d	25-180	n/a	1	12.2	0	0	10	240	I_2	75	99.9-99.0	Batch

ANSI N509-1980 (ASTM D3803-1979) *used carbon is not equilibrated*

30		30	95	2	12.2	0	0/16	120	240	I_2	17.5	99.9	Qual
31		30-180	n/a	1	12.2	0	0	10	240	I_2	75	99.5	Batch
32		30	95	2	12.2	0	0/16	120	240	CH_3I	1.75	97.0	Batch
33		80	95	2	12.2	0	0	60	240	CH_3I	1.75	99.0	Qual
34		130	95	2	12.2	0	2	60	240	CH_3I	1.75	98.0	Qual

ASME N509-1989 (ASME/ANSI AG-1-1988, Section FF) *used carbon is not equilibrated*

35	FF-5211	80	95	2	12.2	0	0	60	240	CH_3I	1.75	99.0	Qual
36	FF-5212	30	95	2	12.2	0	0/16	120	240	I_2	17.5	99.9	Qual
37	FF-5213	130	95	2	12.2	0	2	60	240	CH_3I	1.75	98.0	Qual
38	FF-5221	30	95	2	12.2	0	0/16	120	240	CH_3I	1.75	97.0	Batch
39	FF-5222	30-180	n/a	1	12.2	0	0	10	240	I_2	75	99.5	Batch

ANSI N510-1975 (RDT M16-1T-1973)

40	4.5.1	25	70	2	12.2	0	16 (≤ 1°C)	240	240	I_2	17.5	99.9	Qual
41	4.5.2	130	95	2	12.2	0	2 (≤ 1°C)	90	90	I_2	17.5	99.5	Qual
42	4.5.3	25	70	2	12.2	0	16 (≤ 1°C)	240	240	CH_3I	1.75	98.0	Qual
43	4.5.4	130	95	2	12.2	0	2 (≤ 1°C)	90	90	CH_3I	1.75	95.0	Batch

ANSI N510-1980 (ASTM D3803-1979) *used carbon is not equilibrated*

44	A	30	95	2	12.2	0	0/16	120	240	CH_3I	1.75		
45	B	80	95	2	12.2	0	0	60	240	CH_3I	1.75		
46	C	130	95	2	12.2	0	2	60	240	CH_3I	1.75		
47	D	30	95	2	12.2	0	0/16	120	240	I_2	17.5		
48	E	30-180	n/a	1	12.2	0	0	10	240	I_2	75		

ASME N510-1989 (ASTM D3803-1979) *used carbon is not equilibrated*

49		30	95	2	12.2	0	0/16	120	240	CH_3I	1.75		
50		80	95	2	12.2	0	0	60	240	CH_3I	1.75		
51		130	95	2	12.2	0	2	60	240	CH_3I	1.75		
52		30	95	2	12.2	0	0/16	120	240	I_2	17.5		
53		30-180	n/a	1	12.2	0	0	10	240	I_2	75		

ANSI/ASME AG-1-1985, -1988, -1991 (ASTM D3803-1979) *used carbon is not equilibrated*

54	FF-5211	80	95	2	12.2	0	0	60	240	CH_3I	1.75	99.0	Qual
55	FF-5212	30	95	2	12.2	0	0/16	120	240	I_2	17.5	99.9	Qual
56	FF-5213	130	95	2	12.2	0	2	60	240	CH_3I	1.75	98.0	Qual
57	FF-5221	30	95	2	12.2	0	0/16	120	240	CH_3I	1.75	97.0	Batch
58	FF-5222	30-180	n/a	1	12.2	0	0	10	240	I_2	75	99.5	Batch

ANSI/ASME AG-1-1994, -1997 (ASTM D3803-1989) *AG-1 does not provide guidance for parameters as tested IAW D3803-89*

59	FF-5211	80	95	2	12.2	16	2	60	60	CH_3I	1.75	99.0	Qual
60	FF-5212	30	95	2	12.2	16	2	60	60	I_2	17.5	99.9	Qual
61	FF-5213	130	95	2	12.2	16	2	60	60	CH_3I	1.75	98.0	Qual
62	FF-5221	30	95	2	12.2	16	2	60	60	CH_3I	1.75	97.0	Batch
63	FF-5222	30-180	95	2	12.2	16	2	60	60	I_2	75	99.5	Batch

USNRC Regulatory Guide 1.52 Rev. 0-1973 (RDT M16-1T, June 1972)

Table 1 New Carbon

64	5a	130	95	2	12.2	0	2	90	90	I_2	17.5	99.9	Qual
65	5b@95%	130	95	2	12.2	0	2	90	90	CH_3I	1.75	95.0	Batch
66	5b@70%	130	70	2	12.2	0	2	90	90	CH_3I	1.75	99.5	Batch
67	5c	25-180	70	1	12.2	0	0	120	240	I_2	75	99.0	Qual

Table 2 Used Carbon

68	5a	130	95	2	12.2	0	2	90	90	I_2	17.5	99.9	inside
69	5b	130	95	2	12.2	0	2	90	90	CH_3I	1.75	90.0	inside
70	5b	130	70	2	12.2	0	2	90	90	CH_3I	1.75	99.0	outside
71	5b	130	70	4, 6, 8, 15	12.2	0	2	90	90	CH_3I	1.75	99.8	outside

USNRC Regulatory Guide 1.52 Rev. 1-1976 (RDT M16-1T, Oct 1973)

Table 2 New Carbon

72	5a	25	95	2	12.2	0	16 (≤ 1°C)	120	120	CH_3I	1.75	99.0	Qual
73	5b	25-80-25	95	2	12.2	0	16 (≤ 1°C)	120	120	CH_3I	1.75	99.0	Batch
74	5c	130	95	2	12.2	0	2 (≤ 1°C)	120	120	CH_3I	1.75	98.0	Qual
75	5d	25-180	n/a	1	12.2	0	0	10	240	I_2	75	99.9-99.0	Batch

Table 3 Used Carbon

76	5c	130	95	2	12.2	0	2 (≤ 1°C)	120	120	CH_3I	1.75	90.0	inside
77	5b	25-80-25	70	2	12.2	0	16 (≤ 1°C)	120	120	CH_3I	1.75	99.0	outside
78	5b	25-80-25	70	4, +	12.2	0	16 (≤ 1°C)	120	120	CH_3I	1.75	99.8	outside

USNRC Regulatory Guide 1.52 Rev. 2-1978 (ANSI N509-1976)

Section 6a.2 New Carbon

79	5a	25	95	2	12.2	0	16 (≤ 1°C)	120	120	CH_3I	1.75	99.0	Qual
80	5b	25-80-25	95	2	12.2	0	16 (≤ 1°C)	120	120	CH_3I	1.75	99.0	Batch
81	5c	130	95	2	12.2	0	2 (≤ 1°C)	120	120	CH_3I	1.75	98.0	Qual
82	5d	25-180	n/a	1	12.2	0	0	10	240	I_2	75	99.9-99.0	Batch

Table 2 Used Carbon

83	5c	130	95	2	12.2	0	2 (≤ 1°C)	120	120	CH_3I	1.75	90.0	inside
84	5b	25-80-25	70	2	12.2	0	16 (≤ 1°C)	120	120	CH_3I	1.75	99.0	outside
85	5b	25-80-25	70	4, +	12.2	0	16 (≤ 1°C)	120	120	CH_3I	1.75	99.8	outside

USNRC Regulatory Guide 1.52 Rev. 3-2001

New Carbon Section 4.11 (ASME AG-1-1997 ***AG-1 does not provide guidance for parameters as tested IAW D3803-89*****)**

86	FF-5211	80	95	2	12.2	16	2	60	60	CH_3I	1.75	99.0	Qual
87	FF-5212	30	95	2	12.2	16	2	60	60	I_2	17.5	99.9	Qual
88	FF-5213	130	95	2	12.2	16	2	60	60	CH_3I	1.75	98.0	Qual
89	FF-5221	30	95	2	12.2	16	2	60	60	CH_3I	1.75	97.0	Batch
90	FF-5222	30-180	95	2	12.2	16	2	60	60	I_2	75	99.5	Batch

Used Carbon Table 1 (D3803-1989) *RG 1.52 Rev. 3 does not provide guidance for Elemental Iodine test parameters*

91		30	95	2	12.2	16	2	60	60	I_2	1.75	97.5	
92		30	95	2	12.2	16	2	60	60	CH_3I	1.75	97.5	
93		30	95	4, +	12.2	16	2	60	60	I_2	1.75	99.5	
94		30	95	4, +	12.2	16	2	60	60	CH_3I	1.75	99.5	

USNRC Regulatory Guide 1.140 Rev. 1-1979 (RDT M16-1T, Oct 1973)

Table 1 New Carbon

95	5a	25	95	2	12.2	0	16 (≤ 1°C)	120	120	I_2	17.5	99.5	
96	5b	25	95	2	12.2	0	16 (≤ 1°C)	120	120	CH_3I	1.75	95.0	

Table 2 used Carbon

97	5b	25	95	2	12.2	0	16 (≤ 1°C)	120	120	CH_3I	1.75	90.0	inside
98	5b	25	70	2	12.2	0	16 (≤ 1°C)	120	120	CH_3I	1.75	90.0	outside
99	5b	25	70	4	12.2	0	16 (≤ 1°C)	120	120	CH_3I	1.75	90.0	outside
100	5b	25	70	6, +	12.2	0	16 (≤ 1°C)	120	120	CH_3I	1.75	99.0	outside

DIN 25 414 (Camfil Luftfilter)

101		30	95	100mm	30	2	16	60	60	CH_3I	1.75	$k>8s^{-1}$	

DNR 8200/26/91, 17 December 1990

102		22	80	100mm	21	0	16	60	60	CH_3I	1.75		

Ontario Hydro Specification M-661M-84, Amendment No. 1-July 1984 (ASTM D3803 latest rev.)

103		25	95	50.0mm	12	2	16	60	60	CH_3I	1.75	99.0	
104		25	95	50.0mm	12	2	16	60	60	I_2	17.5	100.0	

Camfil France

105		25	90	50mm	15	2	16	60	60	CH_3I	1.75		

Table 2 Typical Radioiodine Test Results				
Grade	Particle Size, U.S. Mesh	Lot /Batch	Methyl Iodide Removal Efficiency, (%)	Test Method
KITEG® II	8x16	55/160	99.71	ASTM D3803-89
KITEG® II	8x16	55/175	99.74	ASTM D3803-89
KITEG® II	8x16	55/180	99.8	ASTM D3803-89
TEG®	8x16	48/42	99.93	ASTM D3803-89
TEG®	8x16	48/41	99.89	ASTM D3803-89
KIG®	8x16	51/26	99.87	ASTM D3803-89
KITEG® G	10x14	55/181	K=14.4 s-1	DIN
KITEG® F	6x12	55/169	DF=163	French

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Figure 1: NUCON Data
Effect of Temperature on % $CH_3^{131}I$ Penetration

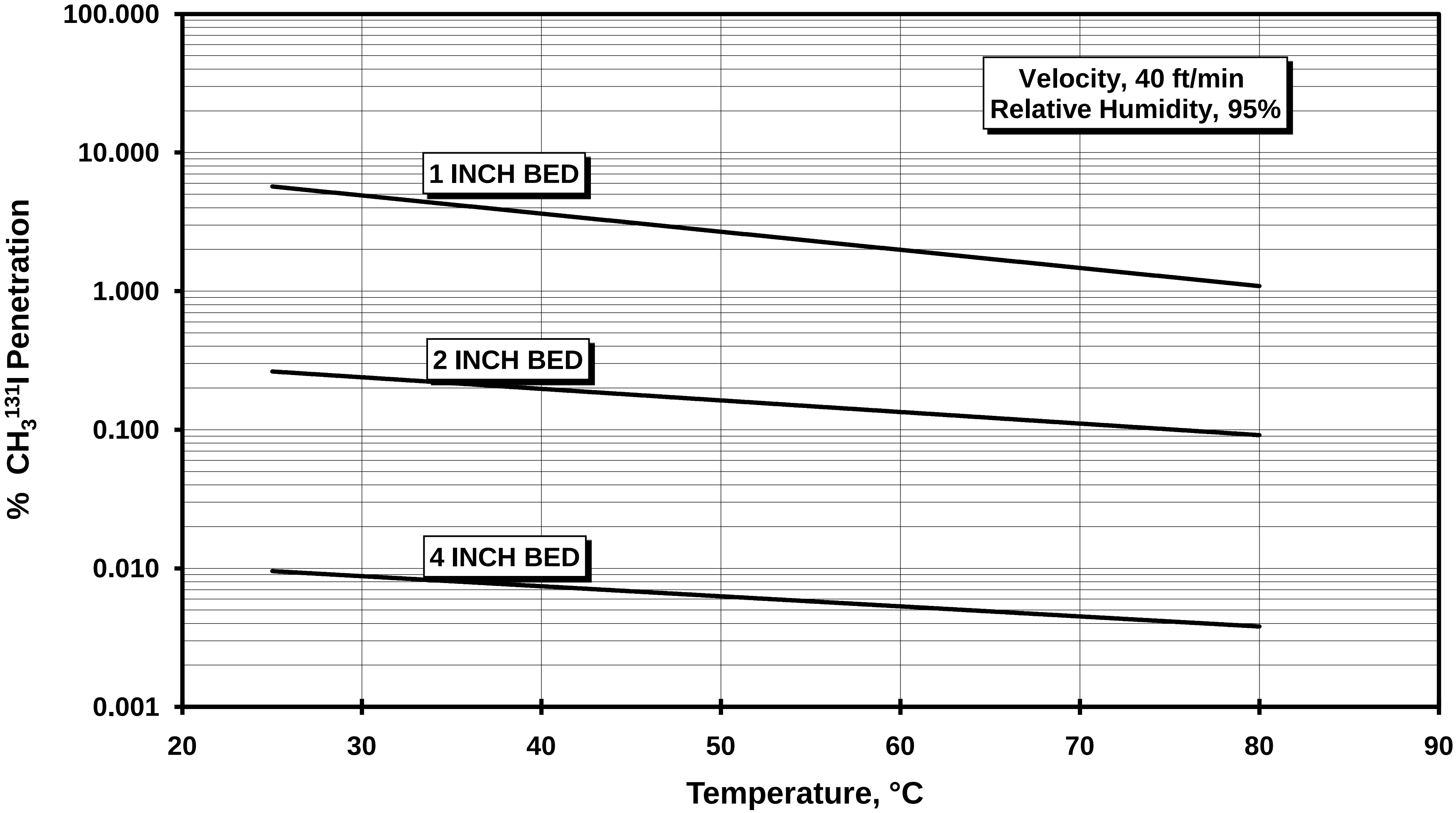
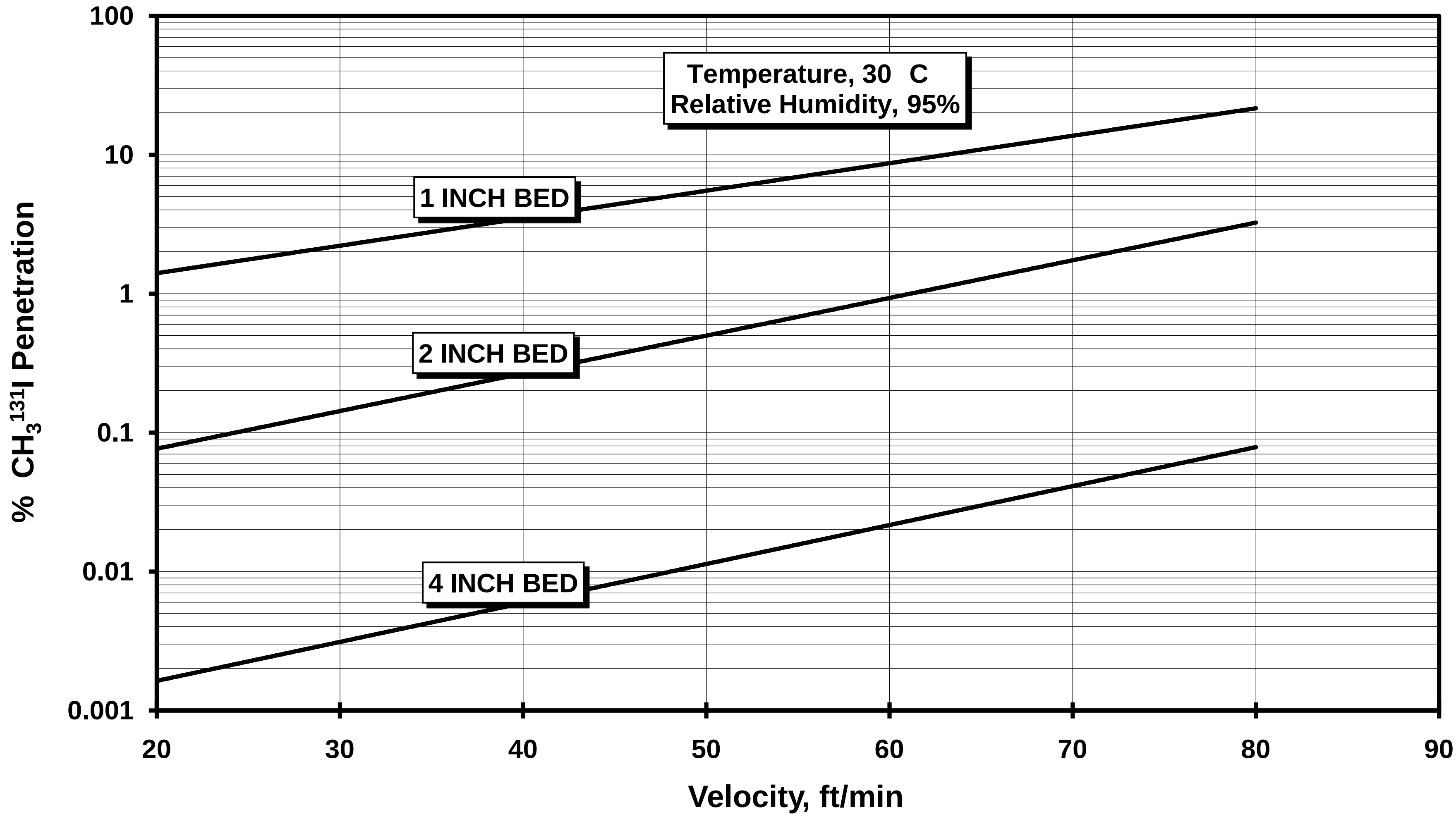


Figure 2: NUCON Data
Effect of Velocity on $CH_3{}^{131}I$ Penetration



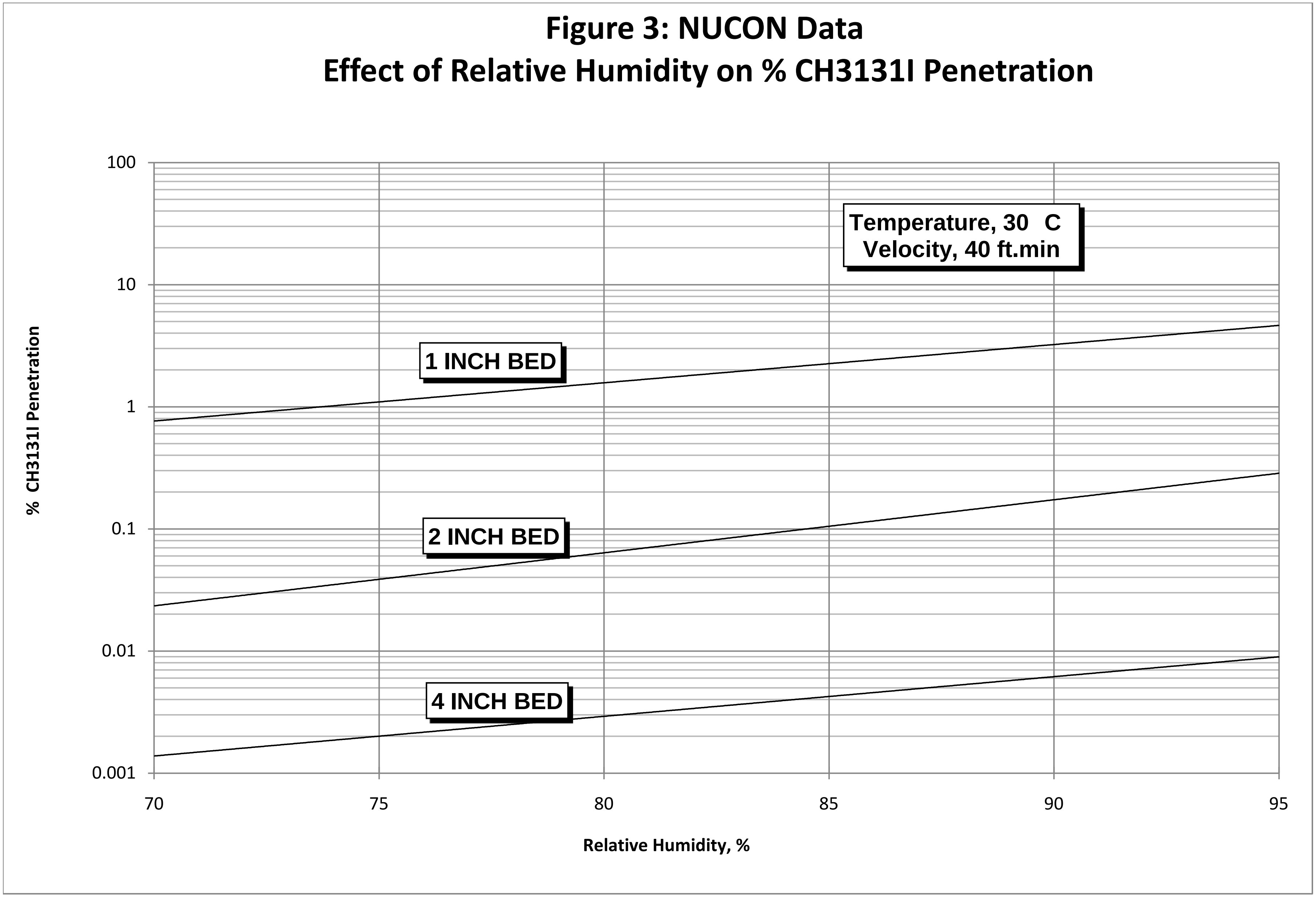


Figure 3: NUCON Data
Effect of Relative Humidity on % CH3131I Penetration
100
10
1
0.1
0.01
0.001
70
75
80
85
90
95
% CH3131I Penetration
Relative Humidity, %
Temperature, 30 C
Velocity, 40 ft.min
1 INCH BED
2 INCH BED
4 INCH BED

Figure 4: Effect of Relative Humidity on CH3131I Penetration (Data from Idaho National Engineering Laboratory)

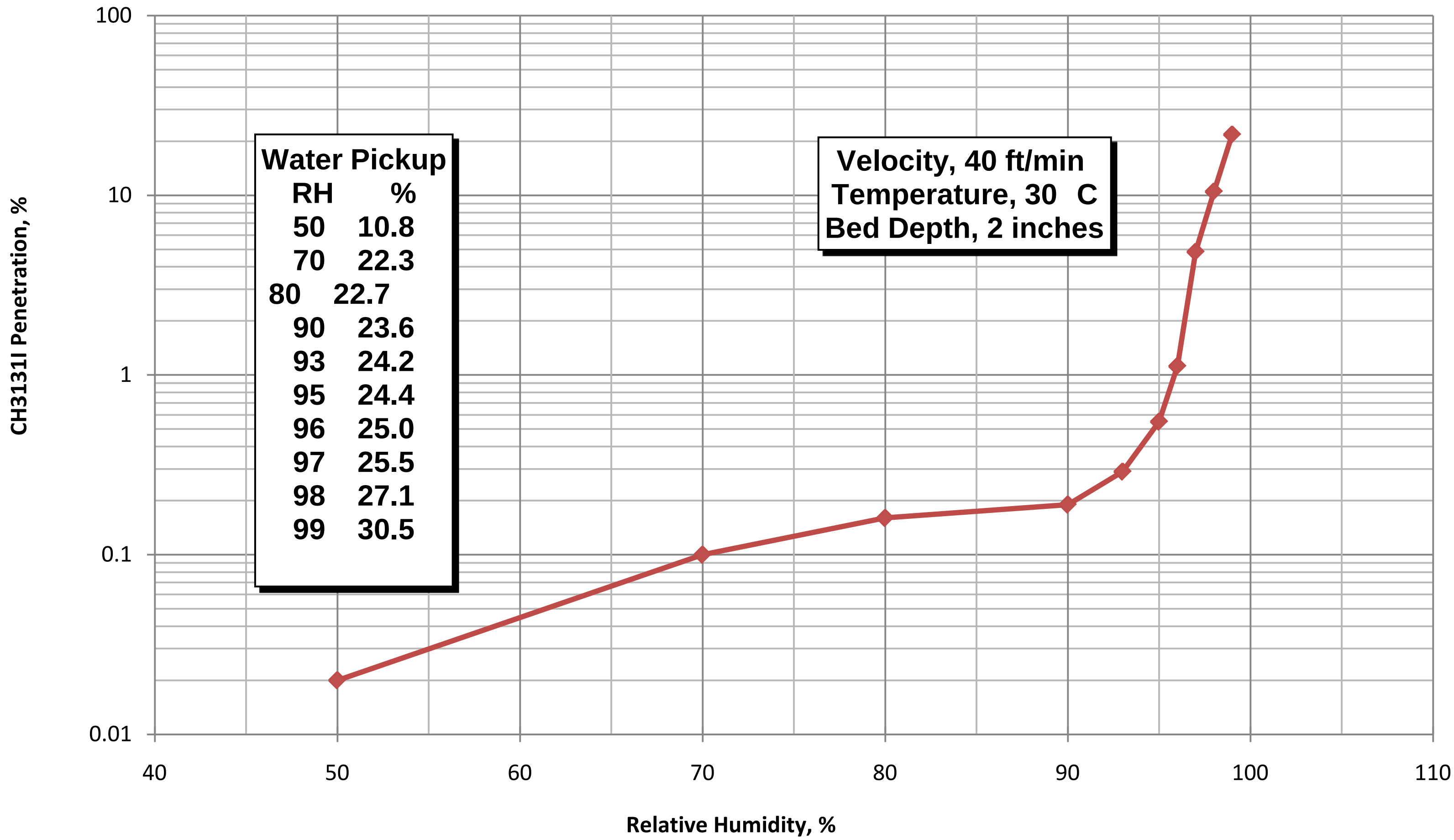
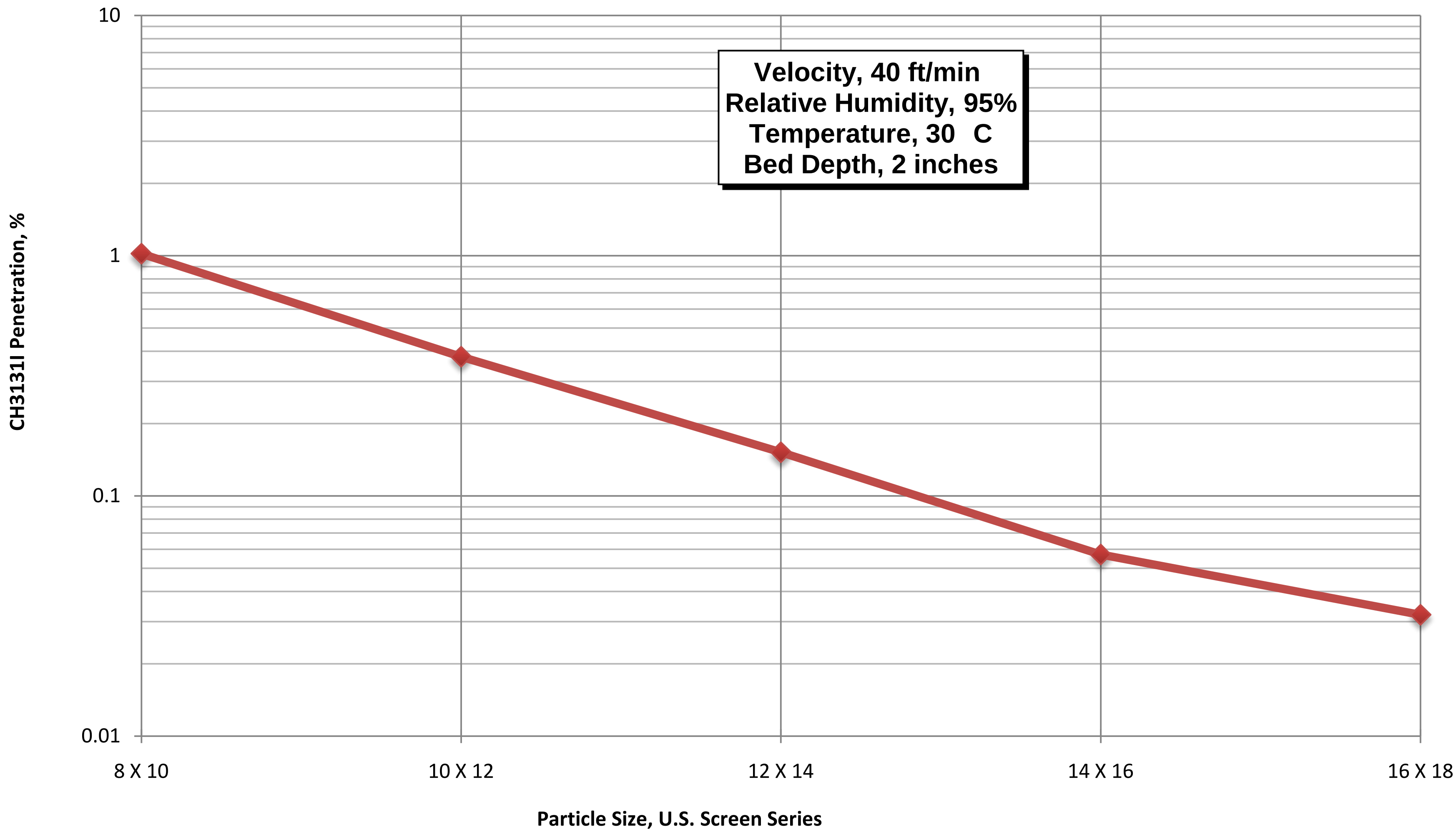


Figure 5: NUCON Data
Effect of Particle Size on % $CH_3{}^{131}I$ Penetration



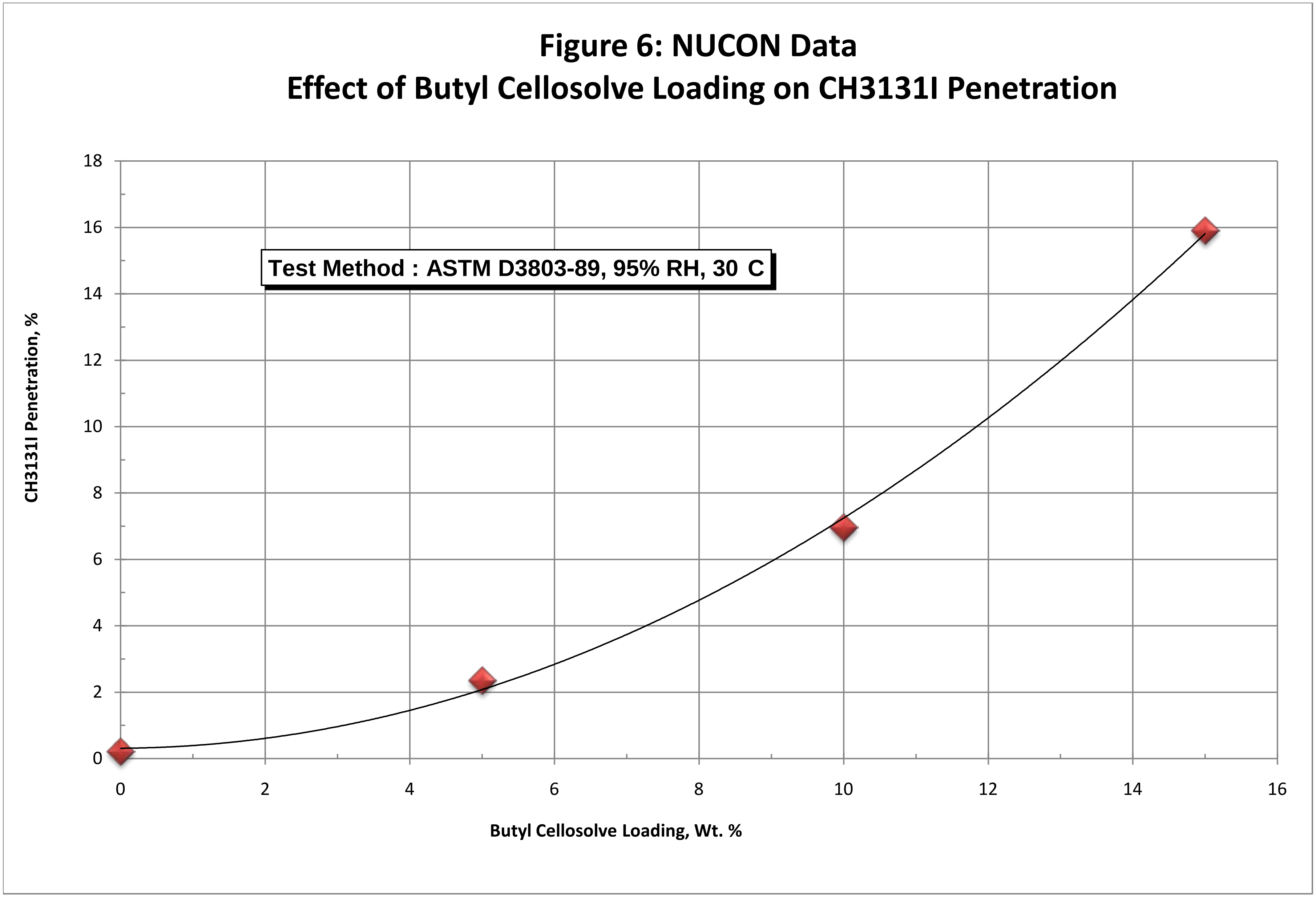


Figure 6: NUCON Data
Effect of Butyl Cellosolve Loading on CH3131I Penetration
Test Method : ASTM D3803-89, 95% RH, 30 C
CH3131I Penetration, %
Butyl Cellosolve Loading, Wt. %
0
2
4
6
8
10
12
14
16
18