Design & Performance Characteristics Of NUSORB® KINA™ Series Adsorbents

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Bulletin 11B29

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1. INTRODUCTION

The NUCON International Inc. (NUCON) NUSORB® family of adsorbents was developed for the treatment and purification of air and gas. The knowledge acquired from over twenty-five years of experience in some of the most critical air and gas treatment applications (e.g. radioactive effluent control in nuclear power plants) combined with laboratory and pilot testing facilities gives NUCON the unique ability to make this technology available to a wide variety of industrial users.

This bulletin describes typical properties, manner of operation and typical test data for NUSORB® KINA™. As is the case for all adsorptive or catalytic applications, the performance of the material depends on actual composition and conditions of the incoming air stream and the contact time between the adsorbent and the treated airflow. NUCON can assist the users in selecting the most cost effective applications of the NUSORB® KINA™ in both once through and in recirculation air treatment systems.

NUCON uses extensive process controls and final product quality assurance to assure that the batches of special adsorbents produced are of uniform quality. NUCON's laboratory and pilot facilities are dedicated to the evaluation, characterization and testing of adsorbents. In this way, critical process operating and performance parameters can be evaluated and tailored for a particular application. Even ultra trace contaminant removal can be evaluated by taking advantage of NUCON's radio analytical techniques.

1.1 PRODUCT DESCRIPTION

The KINA™ grade of the NUSORB® family of specialty adsorbents was specifically developed for the control of inorganic and organic vapors in the presence of oxygen for the most critical applications, such as space related assembly technology, computer chip manufacturing and the protection of electronic equipment in control rooms from corrosion or other deleterious contamination. The NUSORB® KINA™ is also suitable for BIOGAS purification when undesirable inorganic compounds are present.

A technical data sheet for KINA-3™ is included in section 11. It includes a combination of specified and typical properties for the grade.

Pressure drop curves for KINA-3™ & KINA-4™ are included in section 11.

1.2 SPECIFIC APPLICATIONS OF NUSORB® KINA™

The NUSORB® KINA™ adsorbent/catalyst material is suitable for the control of combined inorganic/organic contaminants from oxygen-containing streams in the following applications:

CONTROL ROOM INTAKE FILTERS

CONTROL ROOM RECIRCULATION FILTERS

Central Computer Facility Intake Filters

ELECTRONIC CHIP MANUFACTURING PLANT INTAKE FILTERS

SATELLITE ASSEMBLY FACILITY INTAKE FILTERS

SATELLITE ASSEMBLY FACILITY RECIRCULATION FILTERS

BIOGAS RECOVERY FACILITIES

PURIFICATION OF EXHAUST STREAMS FROM MANAUFACTUREING FACILITIES

CLEAN ROOM INTAKE FILTRATION

MUSEUM INTAKE FILTERS

LIBRARY INTAKE FILTERS

VISCOSE MANUFACTURING PLANT EXHAUST STREAM TREATMENT

HYDROCARBON PROCESSING (WITH AIR IN BLEED)

CATALYST PROTECTION SYSTEMS (AMMONIA PLANTS)

2.0. HYDROGEN SULFIDE REMOVAL

The NUSORB® KINA™ adsorbent catalyst removes hydrogen sulfide from contaminated air streams by several different processes. While most of the steps result in the conversion of the hydrogen sulfide to elemental sulfur within the pores of the adsorbent, other surface deposited catalysts are capable of either oxidizing the hydrogen sulfide with oxygen from the air or catalyzing cross reactions with other impurities. Process conditions, the substrate activated carbon and a catalyst are chosen to avoid as far a possible those side reactions, which produce sulfuric acid.

Impurities, which cross-react the hydrogen sulfide, are: ammonia, ozone, sulfur dioxide and nitrogen oxide (the latter is only partial). The resulting elemental sulfur is deposited (adsorbed) in the pores of the adsorbent material. The catalyst composition is very carefully selected to promote the oxidation or cross reaction of the hydrogen sulfide only to elemental sulfur and not to sulfur oxides. The chosen catalyst not only reduces unwanted side reactions but also increases the reaction rate for sulfur deposition. The deposited catalyst components do not strip from the adsorbent substrate at operating typical operating temperatures (< 180° C). While all catalytic processes perform better at elevated temperatures, the NUSORB® KINA™ performs well on hydrogen sulfide removal at temperatures as low as – 30° C inlet gas temperature.

The NUSORB® KINA™ is capable of removing hydrogen sulfide from both high concentration and low concentration hydrogen sulfide containing streams. (Inlet concentrations from 100 vppm to a few ppb). The presence of oxygen or other oxidizing gas is required for high hydrogen sulfide removal efficiency. (For non-oxygen or oxidizer containing gas stream purification NUCON FC™ or FN™ grades are available). However, in some non-oxygen containing streams the NUSORB® KINA™ has been successfully applied with small amounts of air bled into the treated gas stream. The NUSORB® KINA™ also requires the presence of some water in the entering air stream (greater than 30% but less than 90% RH) for optimum performance.

Since the sulfur formed during the reaction with H_2S is deposited in the pores of the carbon, the ultimate capacity for hydrogen sulfide of the NUSORB® KINA™ depends on the pore volume of the adsorbent and on the presence of other adsorbed impurities. Capacities as high as 30 wt. % sulfur loading can be reached from high hydrogen sulfide concentration at long residence times. The micro and macro porosity of the NUSORB® KINA™ is in the range of 1 ml/g. Due to the high surface area and high pore volume of the NUSORB® KINA™ the tolerance for typical organic vapor impurity presence is very high. However, in most ambient air purification systems for the prevention of contamination in clean rooms or control rooms, the life of the NUSORB® KINA™ will be determined by the deposition (adsorption) of large molecular weight organic compounds rather than the exhaustion of hydrogen sulfide removal capacity.

When the potential exists for high organic contaminant inlet concentrations, it is advantageous to use a "guard bed" of activated carbon (NUSORB® GC 60-3) to increase the life of the NUSORB® KINA™.

The NUSORB® KINA™ is suitable for hydrogen sulfide protection both in recirculation and in inlet or exhaust air streams depending on the source of the hydrogen sulfide. In some cases the most optimum process is recirculation together with inlet air purification. NUCON can supply information for the optimum design of such systems.

Operating data for removal of hydrogen sulfide from an air stream at low concentration (1 ppmv) is shown in Figure 1 (Section 12).

Operating data for removal of H_2S from an air stream containing 1ppmv each of SO_2, H_2S, NO_2, and Cl_2 is shown in Figure 1 (Section 11). The total loading of H_2S from this 1.0 ppmv mixed input stream for KINA-3™ is shown below:

% Breakthrough	Loading, g/Kg KINA™
3	23.7
5	25.2
10	>27.4

At concentrations above 10,000 ppmv, the capacity is 230g H_2S/ Kg KINA™.

3.0 SULFUR DIOXIDE REMOVAL

The removal of sulfur dioxide by NUSORB® KINA™ occurs in several different manners. The first method is neutralization of the adsorbed sulfur dioxide by the alkali material deposited on the surface. The second method is the catalyzed oxidation of the sulfur dioxide to sulfur trioxide on the catalyst surface. The adsorbed SO_2 reacts with adsorbed oxygen to produce sulfur trioxide, which in turn reacts with adsorbed water to produce sulfuric acid that is neutralized by the deposited alkaline materials. If in the same incoming air stream hydrogen sulfide is also present, the NUSORB® KINA™ also catalyzes the cross reaction of the hydrogen sulfide and the sulfur dioxide to elemental sulfur and water. (Two molecules of hydrogen sulfide react with one molecule of sulfur dioxide.)

Typically, when purifying incoming contaminated air all of these reactions can take place. When the incoming air also contains ozone the adsorbent collects the ozone and assists in the direct oxidation of sulfur dioxide to sulfur trioxide, which is then again converted to sulfuric acid. (And as discussed above it is then neutralized on the adsorbent surface).

The alkalinity on the NUSORB® KINA™ is important for several different reasons. First, the lowest vapor pressure deposit is formed when elemental sulfur or sulfate salts are formed on the NUSORB® KINA™ surface, thus the alkalinity of the catalyst material is important for maintaining the low outlet concentrations from the adsorber stage of the air purification unit.

Secondly, the alkalinity of the NUSORB® KINA™ also prevents the deposited sulfur from oxidizing into sulfur dioxide, which could otherwise bleed from the adsorbent, if no humidity or hydrogen sulfide were present.

NUSORB® KINA™ has been successfully used in diverse air purification applications both for environmental control and air pollution control systems. The retention of co-adsorbed organic compounds slows the reaction rate and the total sulfur dioxide removal capacity of any adsorbent material.

The level of organic adsorption that can be tolerated is dependent not only on the incoming air composition but also on the properties of the adsorbent substrate material. The substrate for

NUSORB® KINA™ has been carefully selected to result in long service life in the presence of organic compounds and it has both a very high surface area and a large pore volume (> 1.0 ml/g).

However, if elevated organic compound concentration is present in the inlet stream, it can be advantageous to place a "guard" bed of activated carbon (NUSORB® GC60-3) upstream of the NUSORB® KINA™ bed to result in longer inorganic gas removal life for the NUSORB® KINA™ carbon.

While all catalytic reactions are more efficient at higher temperatures, it is important to maintain reactant product vapor pressure as low as possible, thus the preferred operating range of the NUSORB® KINA™ for sulfur dioxide removal is below 50° C.

The presence of water is beneficial for several of the sulfur dioxide removal mechanisms and it is preferable to keep the relative humidity above 30 % RH. The operation above 90 % RH should be avoided because the pore structure of the NUSORB® KINA™ will fill up with water and the removal efficiency, by mechanisms other than oxidation to sulfur trioxide (sulfuric acid),will be lowered.

Operating data for removal of SO_2 from an air stream containing 1ppmv each of SO_2, H_2S, NO_2, and Cl_2 is shown in Figure 2 (Section 11).

The total loading of SO_2 from this 1.0 ppmv mixed input stream for KINA-3™ is shown:

% Breakthrough	Loading, g/kg KINA™
3	26.3
5	34.4
10	47.1

4.0 REMOVAL OF NO_x

NO_2 is adsorbed on the NUSORB® KINA™ surface and in the presence of adsorbed water the following chemical reaction step takes place:

$$3NO_2 + H_2O = 2HNO_3 + NO$$

The generated nitric acid is neutralized by the deposited alkalinity on the adsorbent surface and thus converted to a low vapor pressure salt.

The process results in a 66 % removal efficiency as NO_x because one out of three molecules can penetrate the adsorbent as NO. For this manner of NO_x control the presence of alkalinity on the surface is very important otherwise the generated nitric acid can attack (oxidize) the carbon and release additional NO_x.

In the presence of ammonia, the NUSORB® KINA™ also catalyzes a cross reaction between nitrogen dioxide and ammonia to nitrogen and water which further reduces the NO_x in the air stream.

Because the presence of water is important for the control of nitrogen oxides, the inlet air relative humidity should be in the 30% to 90% range. Since elevated temperature is beneficial in most chemical reactions, the recommended operating temperature should be in the –20° C to + 80° C range.

When high NO_x concentrations are present and/or carbon monoxide control is also necessary, such as in engine exhausts streams, other special grades need to be used. Contact NUCON International Inc. for special catalyst materials.

The co-adsorption of large amounts of organic material on the NUSORB® KINA™ surface is deleterious for the removal of nitrogen oxides. In those cases, NUCON recommends a guard bed of activated carbon such as NUSORB® GC60-3.

Operating data for removal of NO_2 from an air stream containing 1ppmv each of SO_2, H_2S, NO_2, and Cl_2 is shown in Figure 2 (Section 11). Data showing the conversion of NO_2 to NO is given in Figure 5.

5.0 CHLORINE REMOVAL

NUSORB® KINA™ removes chlorine by surface physical adsorption and by chemisorption due to the presence of surface oxides on the adsorbent. The alkalinity of the adsorbent surface partially converts the adsorbed chlorine to chloride and chlorate compounds. Since the vapor pressure of the chloride and chlorate salts is much lower than that of the unreacted chlorine, the retention capacity also becomes higher at elevated alkalinity levels.

When hydrogen sulfide is also present with chlorine, the NUSORB® KINA™ catalyzes a cross reaction with chlorine to form elemental sulfur and hydrochloric acid. The alkali present on the surface then neutralizes this acid to low vapor pressure alkali chloride. The simultaneous presence of chlorine and sulfur dioxide results in the formation of sulfuryl chloride. This reacts with adsorbed water to form hydrochloric acid and sulfuric acid, which in turn are neutralized by the alkali.

While the physical adsorption (and within limits the chemisorption) of the chlorine on the NUSORB® KINA™ surface is not humidity dependent, the formation and neutralization of the formed acids needs the presence of adsorbed water. Thus, the preferred humidity for the NUSORB® KINA™ for mixed inlet inorganic vapor component removal is above 30 % RH. To avoid filling the microporosity of the adsorbent with water, NUSORB® KINA™ should not be operated above 90% RH.

High organic compound concentrations in the inlet stream will retard the chlorine conversion capability of the NUSORB® KINA™. In such cases, a "guard bed" of activated carbon (NUSORB® GC60-3) should be used upstream of the NUSORB® KINA™ bed to increase the life of the adsorbent for inorganic gas removal.

A data sheet describing this product is included in section 11. The recommended operating temperature range of the NUSORB® KINA™ for chlorine removal is -40° C to +50° C range. If the application requires operation outside these ranges NUCON International should be consulted.

Special safety note: The NUSORB® KINA™ should not be used for fluorine removal above 1 vppm inlet fluorine concentration. Fluorine can violently react with the NUSORB® KINA™ carbon substrate.

Operating data for removal of Cl_2 from an air stream containing 1ppmv each of SO_2, H_2S, NO_2, and Cl_2 is shown in Figure 4 (Section 11). The total loading of Chlorine from a 1.0 ppmv mixed input stream for KINA-3™ is shown below:

% Breakthrough	Loading, g/kg KINA™
3	29.2
5	30.2
10	3.10

6.0 ACID GAS REMOVAL

NUSORB® KINA™ removes acid gases such as hydrogen chloride and sulfur trioxide by physical adsorption followed by neutralization of the adsorbed acid on the surface of the adsorbent. The resulting low vapor pressure salts are retained in the pores of the adsorbent.

The capacity of the NUSORB® KINA™ for these acid gases is dependent on the alkalinity of the adsorbent and the efficiency of the adsorbent is dependent on the contact time between the inlet air stream and the adsorbent bed.

The neutralization of the surface adsorbed acids is improved by the presence of adsorbed moisture, thus the NUSORB® KINA™ should be operated between 30% and 90% inlet air RH.

The operating temperature of the NUSORB® KINA™ for acid vapor removal should be below 50° C.

7.0 OZONE REMOVAL

Ozone is removed by the NUSORB® KINA™ by chemical reaction between the carbon substrate and the ozone. The product of this chemical reaction is carbon dioxide. The carbon life for this reaction is very long and nearly 100% efficient. The inlet ozone concentration should be kept below 10 vppm to prevent the potential build up of solid carbon/oxygen complexes on the adsorbent surface and generation of excessive heat from the exothermic reaction. In some cases when adsorbed organic compounds are also present, a partial "regeneration" step can also occur, due to the oxidation of the organic compounds by the incoming ozone.

When inlet ozone concentrations are above 100 vppm, the NUSORB® KINA™ should not be used.

The operating temperature should be kept between –20° C and + 80° C and the inlet relative humidity between 30% and 90% for optimum performance.

The incoming ozone will also cross react with any simultaneously present hydrogen sulfide and will result in elemental sulfur deposition on the surface of the NUSORB® KINA™. Incoming sulfur dioxide can also be oxidized by ozone and be converted to sulfuric acid, which is again neutralized into a nonvolatile sulfate salt on the adsorbent surface. (For methods to control high concentrations of ozone, contact NUCON).

8.0 AMMONIA REMOVAL

The NUSORB® KINA™ has only limited adsorption capacity for the removal of ammonia when present alone (in the range of 10 mg/ml adsorbent).

However, the NUSORB® KINA™ catalyzes the cross reaction between ammonia and most acid type inorganic gases, (nitric oxides, hydrogen sulfide, sulfur dioxide, chlorine, etc.). The cross-reaction results in the formation of less volatile salts on the adsorbent surface.

In some cases the ammonia acts as an additional catalyst for the conversion of inorganic compounds into strongly adsorbed forms, for example, the conversion of hydrogen sulfide to elemental sulfur.

When ammonia is present alone, other adsorbents produced by NUCON International are available. NUCON AMMOSORB™ is recommended when relatively high concentrations of ammonia need to be removed from an air or other gas stream.

For the catalytic and adsorptive process of ammonia removal -20° C to 80° C is the optimum temperature range. A relative humidity of 30% to 90% is preferred for ammonia control using NUSORB® KINA™

9.0 VOLATILE ORGANIC COMPOUND REMOVAL

Since the amount of impregnant contained in NUSORB® KINA™ adsorbent is relatively small, there is essentially no reduction in adsorption of organic vapors. The amount of a compound adsorbed by activated carbon is impacted by the physical properties of the activated carbon and the adsorption conditions (temperature, pressure, concentration). Figures 6, 7 & 8 (Section 12) are adsorption isotherms showing the capacity of NUSORB® KINA™ adsorbents for a common paraffin, aromatic and chlorinated hydrocarbons.
Activated carbon is very effective in removing low concentrations of odorous compounds. In typical ambient air applications, the concentration of VOC's will be extremely low and the amount adsorbed on the carbon will not interfere with the performance of the impregnants for gaseous contamination control.

The NUSORB® KINA™ adsorbent material consists of a specially impregnated activated carbon substrate specifically selected for high surface area and for high pore volume.

The retention of organic compounds on activated carbon is typically affected by the molecular weight and vapor pressure of the organic compounds. While low molecular weight compounds such as methane are not well removed under ambient temperature and pressure conditions, compounds which can deposit on critical electronic surfaces are very strongly adsorbed on the NUSORB® KINA™ adsorbent surface.

In many cases, applications involving critical control of atmospheres for electronic equipment require removal of both inorganic ant organic vapors at high removal efficiencies. In these saturations, it is often beneficial to use NUSORB® GC60-3 for organic vapor removal to extend the life of the NUSORB® KINA™. When the organic compounds are present at low concentrations, or when the

inorganic compounds are present at very high concentrations, such as paper mill control rooms, there is no additional benefit from the use of an unimpregnated carbon guard bed.

The physical adsorption based organic compound removal is better at lower temperatures and at relative humidities below 70%.

If the major reason for the contamination control application is the presence of organic compounds at high concentrations, contact NUCON International Inc. for special adsorbents and systems for organic compound control.

10.0 INSTALLATIONS

Plant A: The NUSORB® KINA™ material protects a solvent recovery system from hydrogen sulfide and sulfur dioxide intrusion from viscose manufacturing plant, in the presence of carbon disulfide vapor. The plant is successfully operating with the protection system.

- Continuous operation
- Inlet hydrogen sulfide conc.: 2 vppm
- Inlet sulfur dioxide conc.: periodic to 200 vppm
- Typical residence time: 2 seconds

Plant B The NUSORB® KINA™ material protects chip manufacturing plant intake air from environmental impurities. Same adsorbent bed installed and successfully operating for over 3 years.

- Continuous operation
- GC60 guard bed installed
- Typical residence time: 1.3 seconds
- There are multiple installation of this type

Plant C: The NUSORB® KINA™ protects the intake air and recirculation air of a space satellite assembly facility by removing typical inorganic and organic contaminants of a metropolitan area. The installation protects the satellite components from deposition/corrosion and from potential fogging of components from out gassing in vacuum.

- Typical residence time of intake: 0.25 sec
- Typical residence time of recirculation: 0.15 sec
- Continuous operation.

Plant D: The NUSORB® KINA™ protects the control room of a paper mill by filtering both intake air and partial recirculation.

- Typical residence time of intake: 1.0 sec
- Typical residence time of recirculation: 0.5 sec
- There are multiple installations of this type.

Installations using NUSORB® KINA™ adsorbents to purify the air in many control room, library, and electronics facility operations are all performing well.

11.0 APPLICATIONS DATA

11.1 APPLICATIONS

The NUSORB® KINA™ can be used to treat both incoming ambient air and recirculated air with internally generated contamination. The KINA™ substrate is a high surface area, very high pore volume activated carbon, specially treated with catalyst material and alkalized for additional process control. The KINA™ is most commonly used in 3 mm diameter pelleted form (KINA-3™). However for other applications it is also produced in 4 mm and 1.5 mm pellet diameters. Figure 9 (Section 12) shows the pressure drop for the 3 & 4 mm product.

While other NUSORB® grades are available for cases when no oxygen is present in the treated gas stream, the NUSORB® KINA™ grade also works very well in hydrocarbon purification when small amounts of oxygen (a ratio of 3:1 to hydrogen sulfide) are bled into the gas stream.

11.2 LONG TERM ADSORPTION OF H_2S, SO_2, NO_2 and Cl_2

Figures 1-4 show effluent concentrations as a function of time for removal of several inorganic gases, each at 1 ppmv inlet concentration. The tests were performed at 40% relative humidity, and a residence time of 0.5 seconds. The adsorbent was NUSORB® KINA-3™ and KINA-8/16™. The tests were monitored for 1800 hours.

11.3 ROUND ROBIN H_2S TESTING OF KINA-3™

Five laboratories tested NUSORB® KINA-3™ as part of a round robin to verify a proposed ASTM H_2S capacity test. The test is performed by passing air containing 1% H_2S through a nine inch long column of adsorbent until the outlet concentration reaches 50 ppmv. The average capacity for H_2S of the KINA-3™ was 23 weight %.

11.4 VOC ADSORPTION DATA

Adsorption isotherms for compounds representing typical paraffin, aromatic, and chlorinated hydrocarbons are shown in Figures 6, 7 & 8.

11.5 PRESSURE DROP DATA

Figure 9 shows the pressure drop for 3 & 4 mm KINA™.

12.0 REFERENCES

12.1 Enbom, S., Hagsröm, K. and Railio J., "Sähkötilojen ilmastointi Kemiallisten suodattimien mittuasraportti", INVENT-teknologiaohjelma, Raportti 39, Maaliskuu 1994

Figure 1: Hydrogen Sulfide Removal, NUSORB KINA

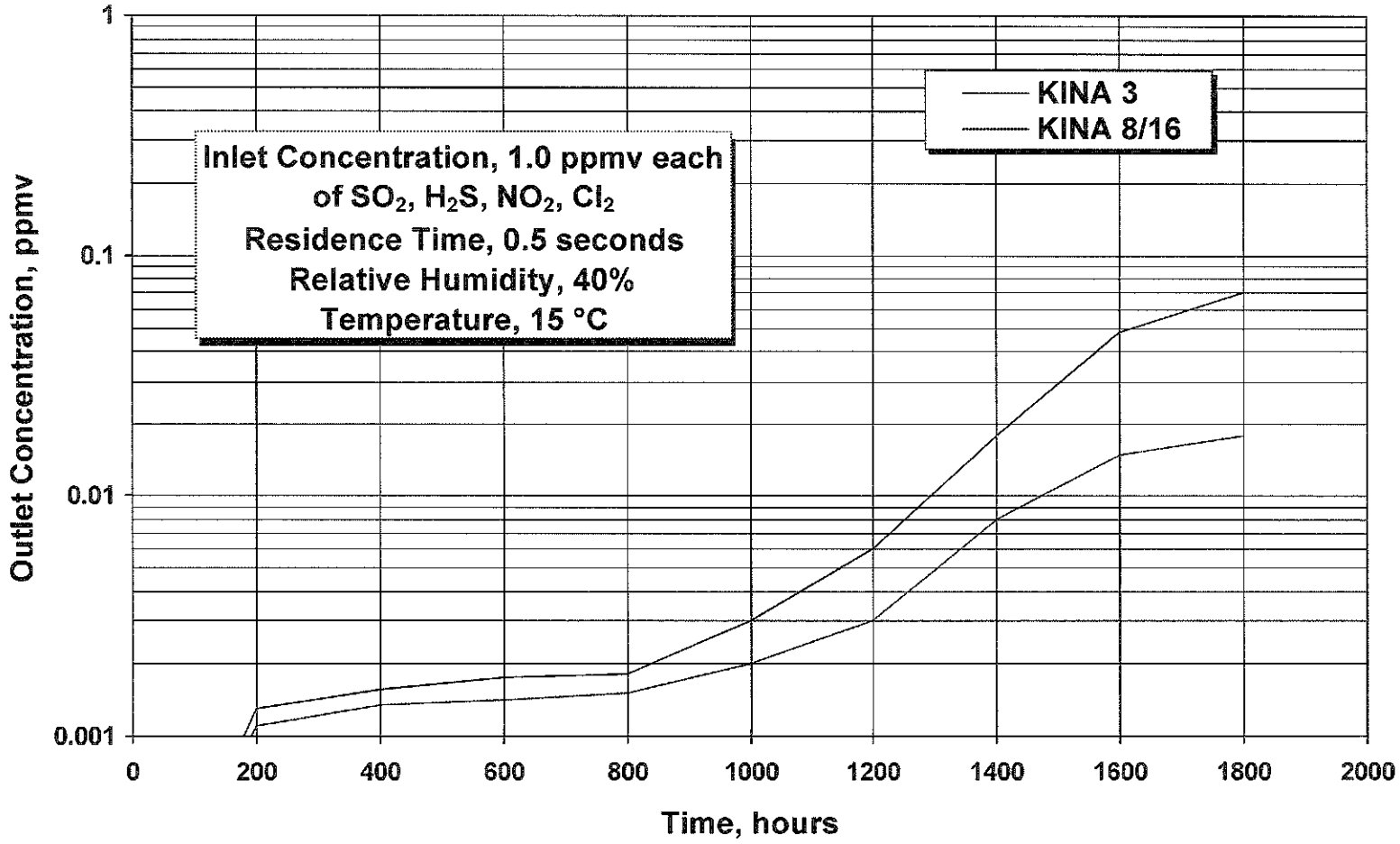


Figure 2: Sulphur Dioxide Removal, NUSORB KINA

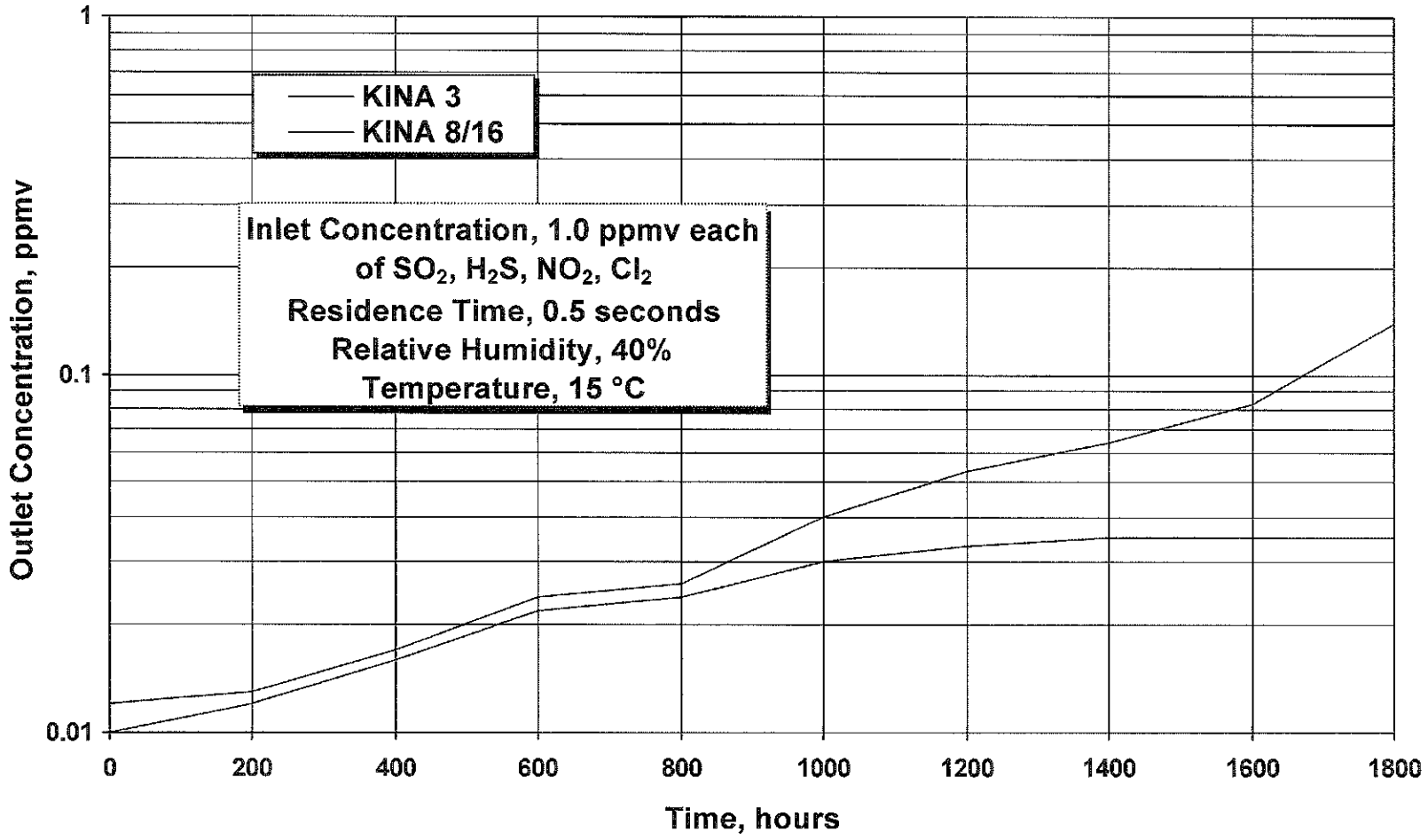


Figure 3: Nitrogen Dioxide Removal, NUSORB KINA

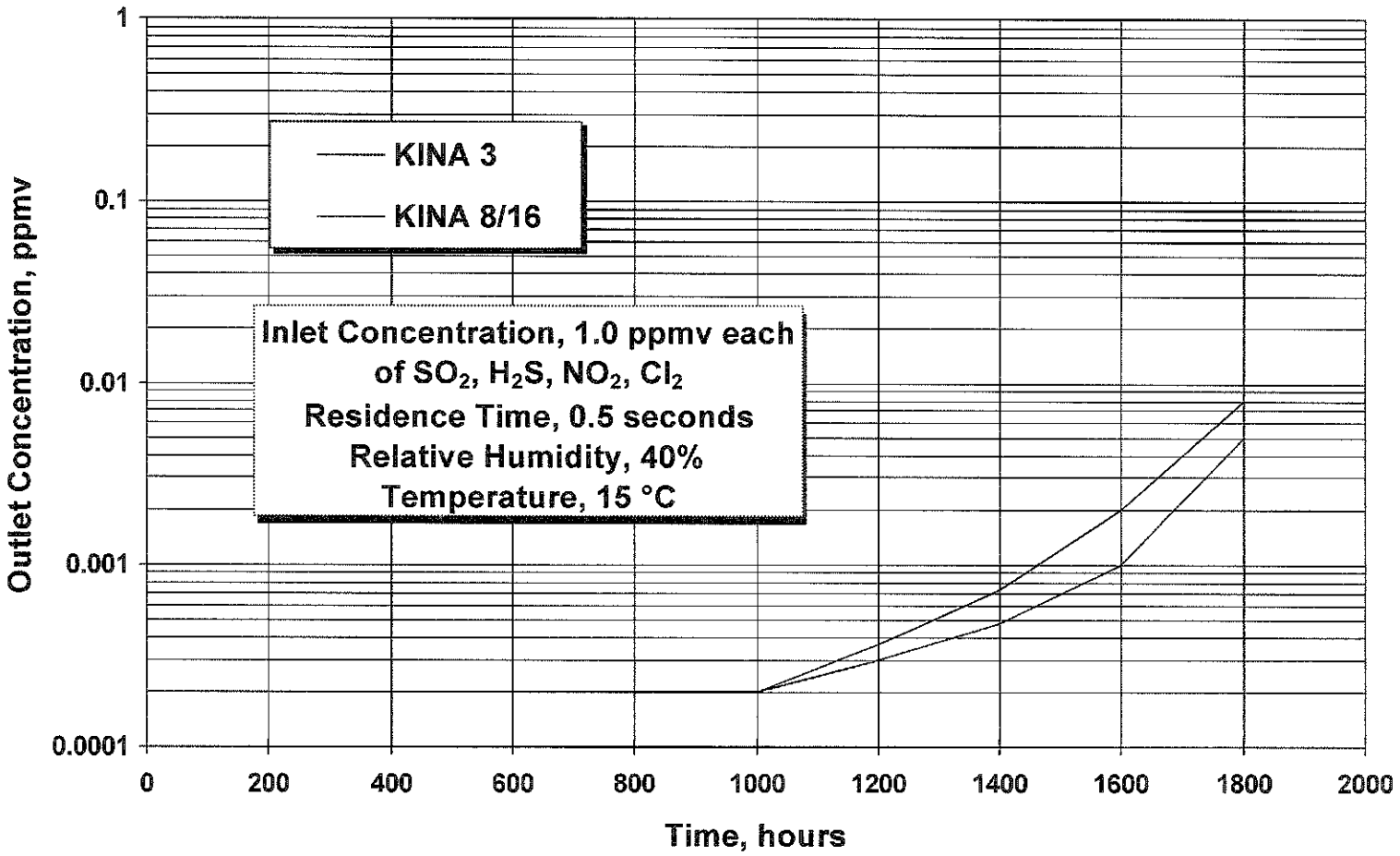


Figure 4: Chlorine Removal, NUSORB KINA

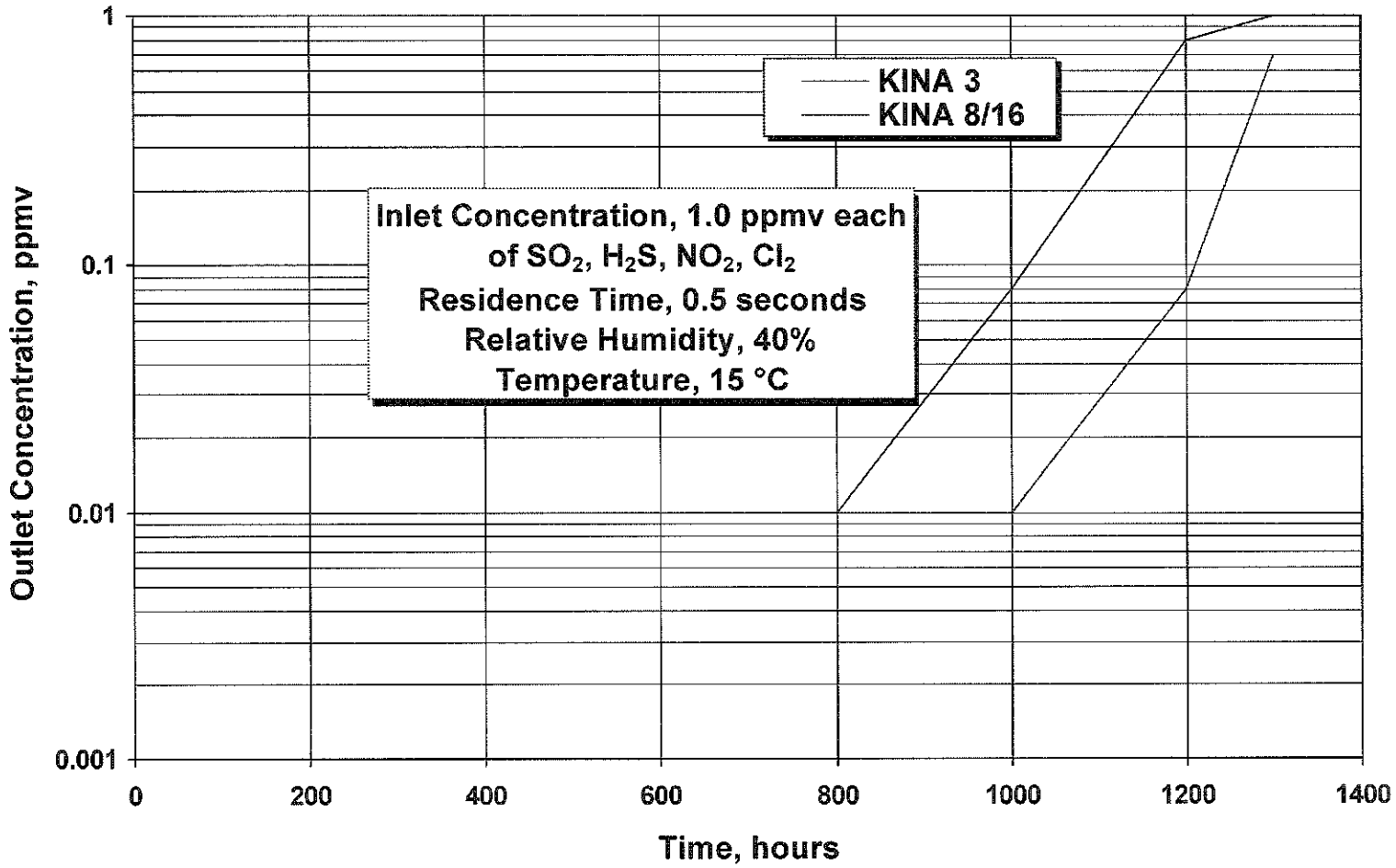


Figure 5: NO_2 Conversion to NO, NUSORB KINA 3

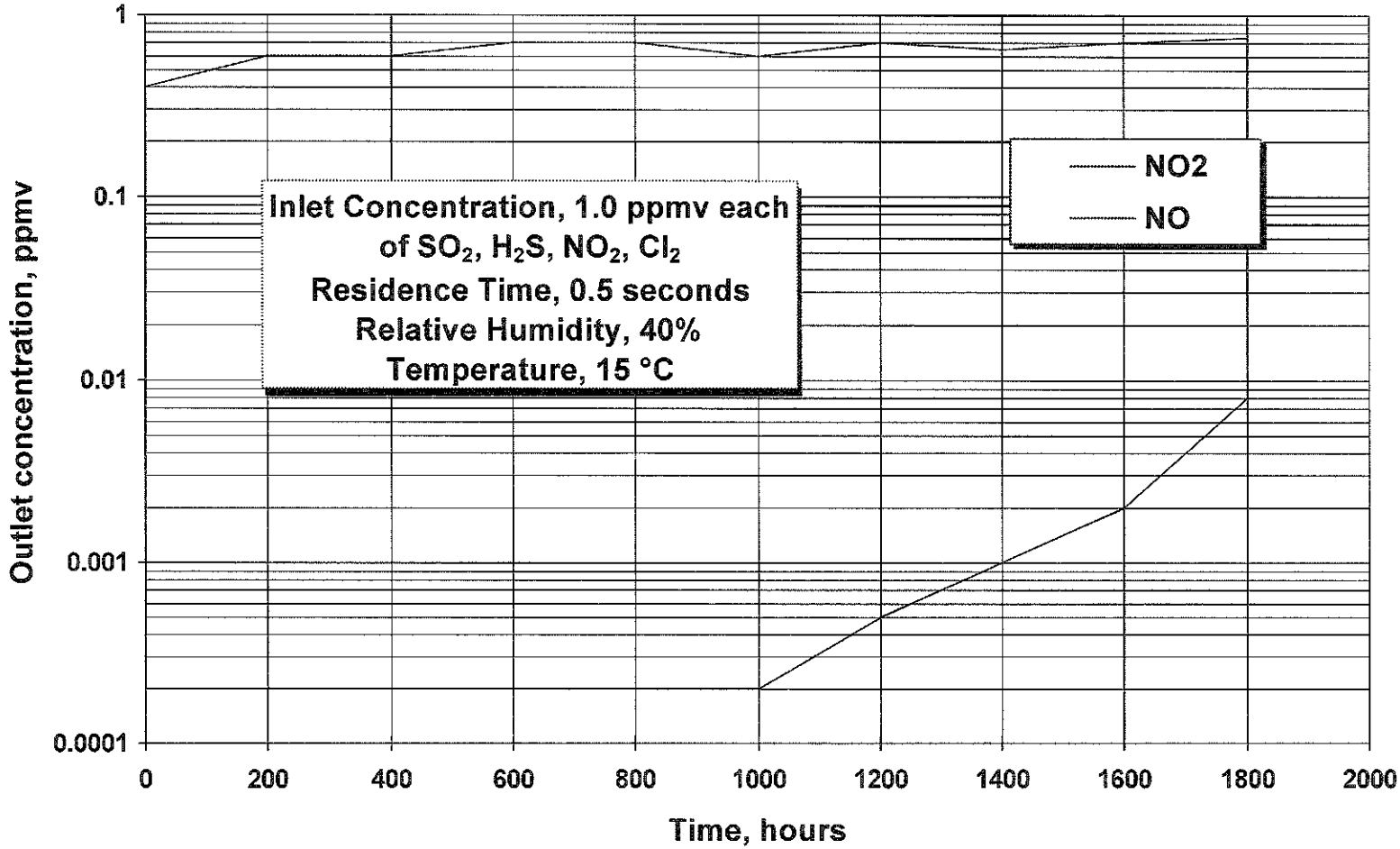


Figure 6: Adsorption of 111 Trichloroethane on NUSORB KINA

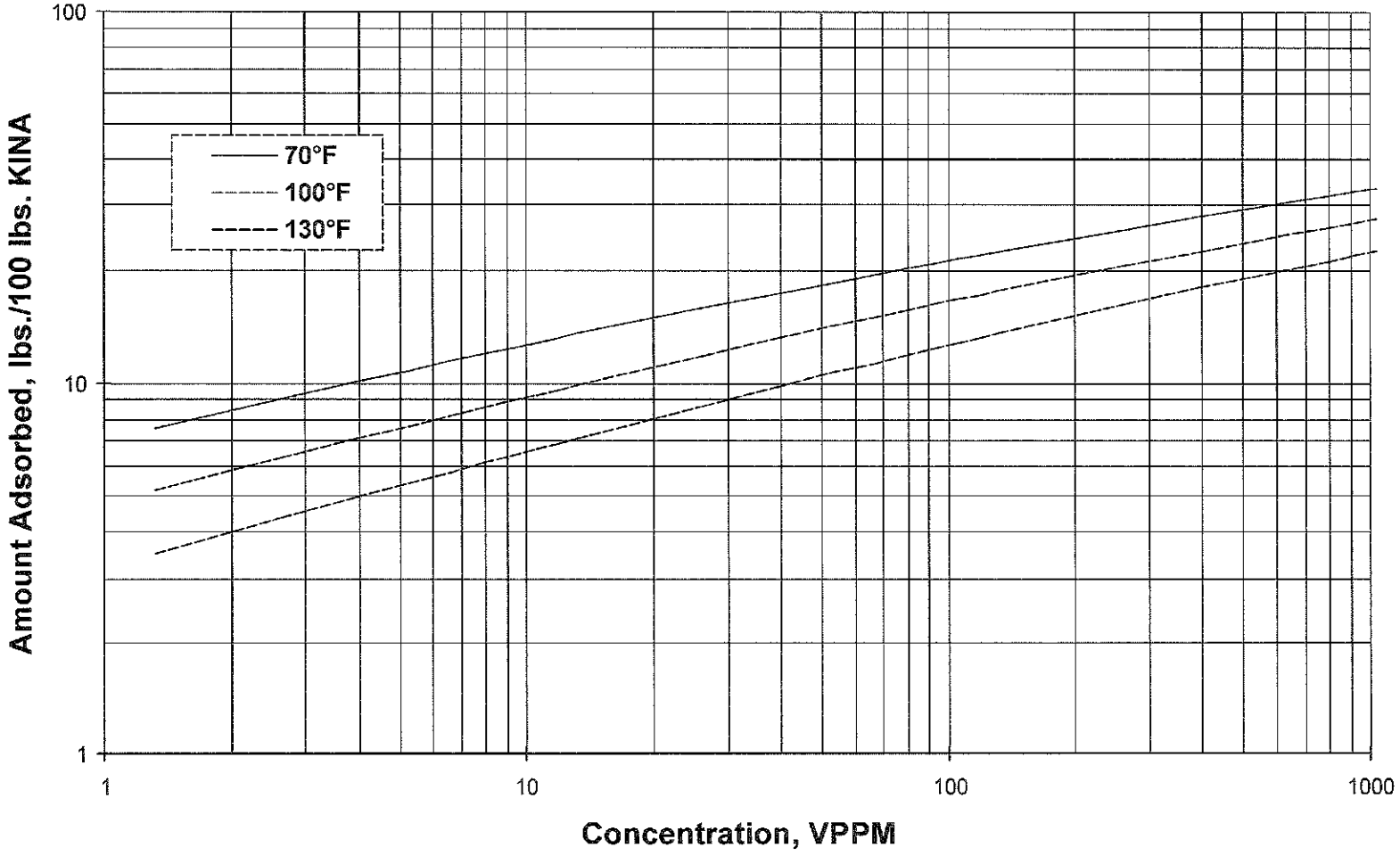


Figure 7: Adsorption of Heptane on NUSORB KINA

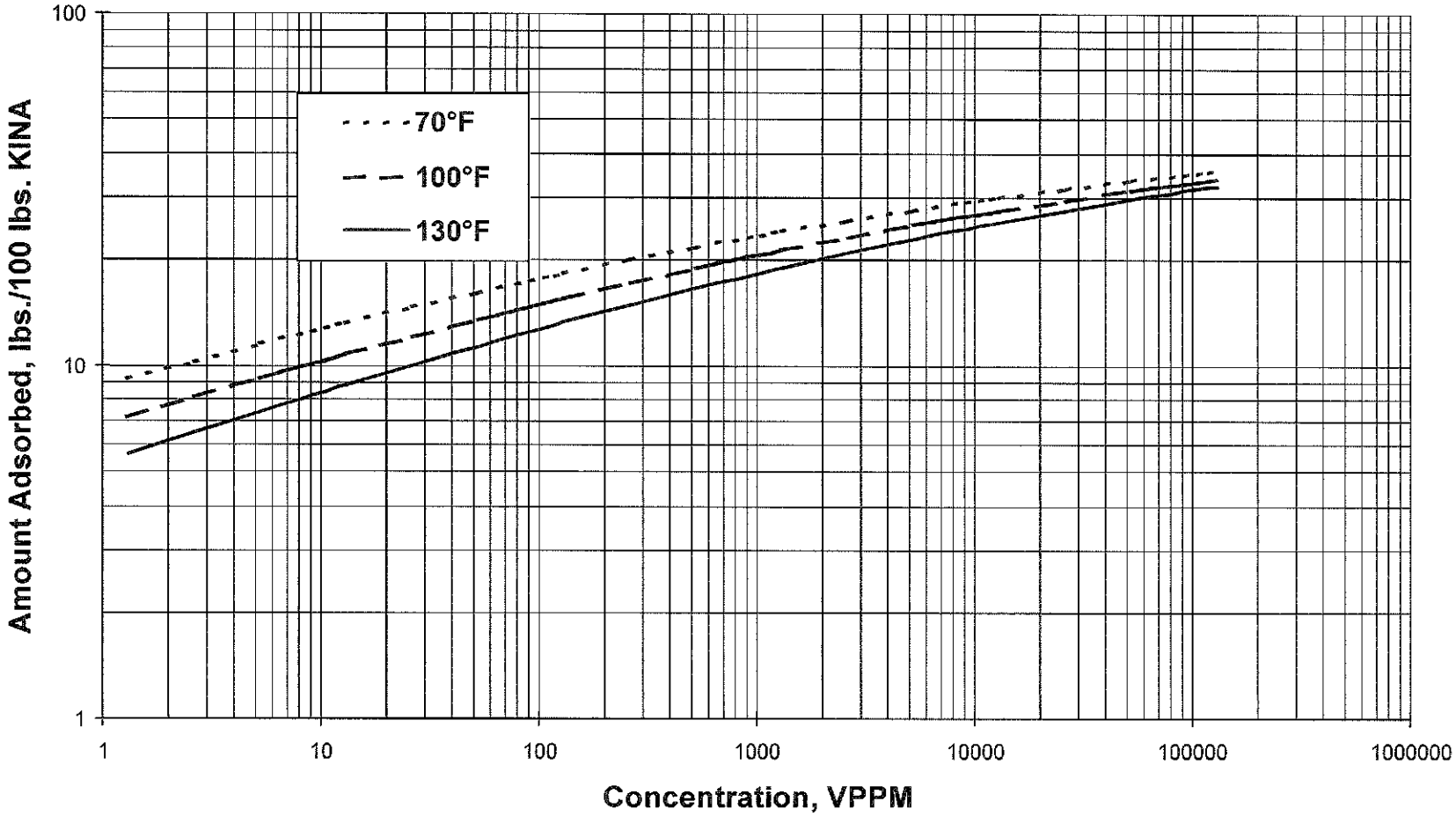


Figure 8: Adsorption of Toluene on NUSORB KINA

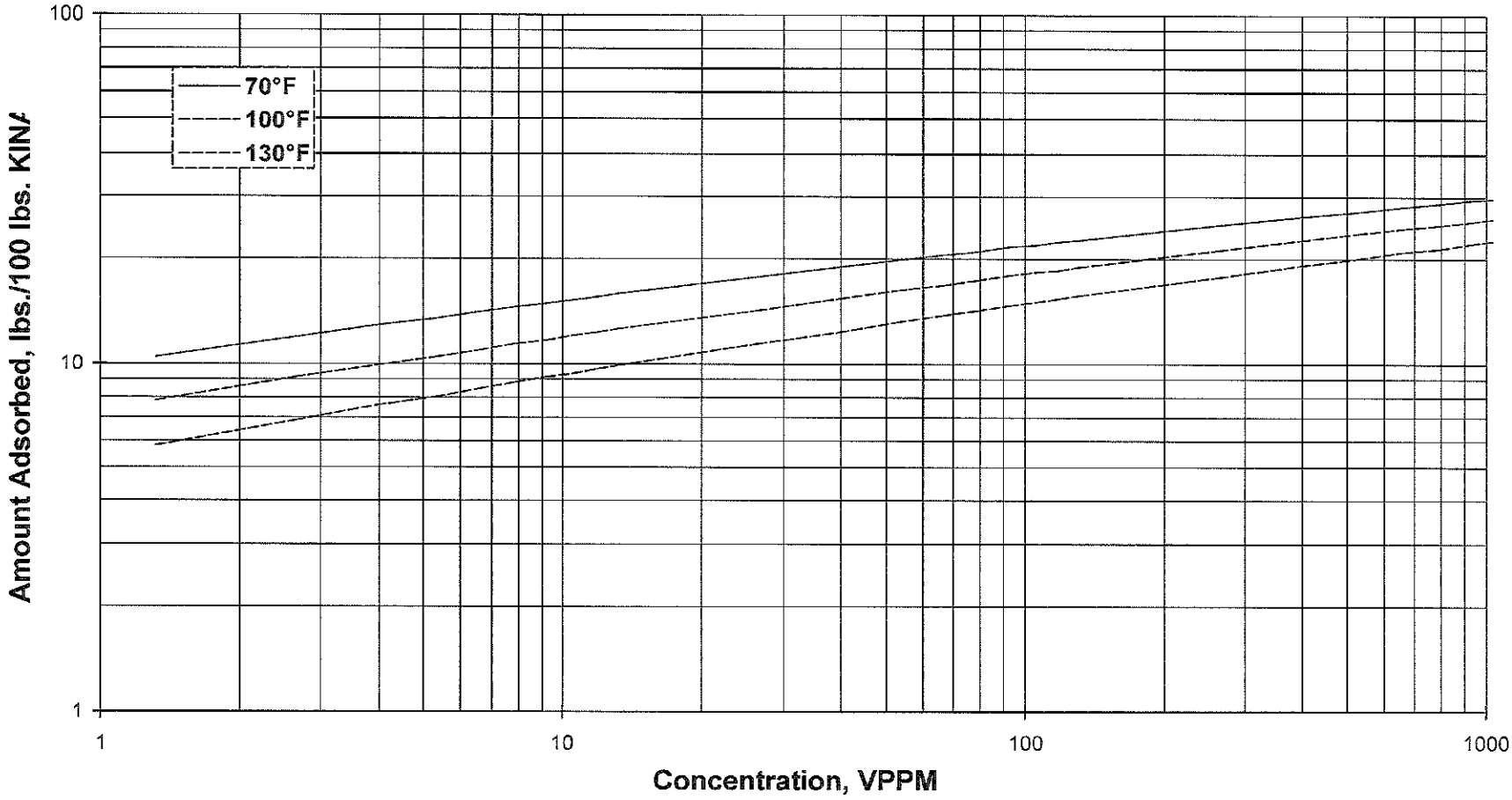
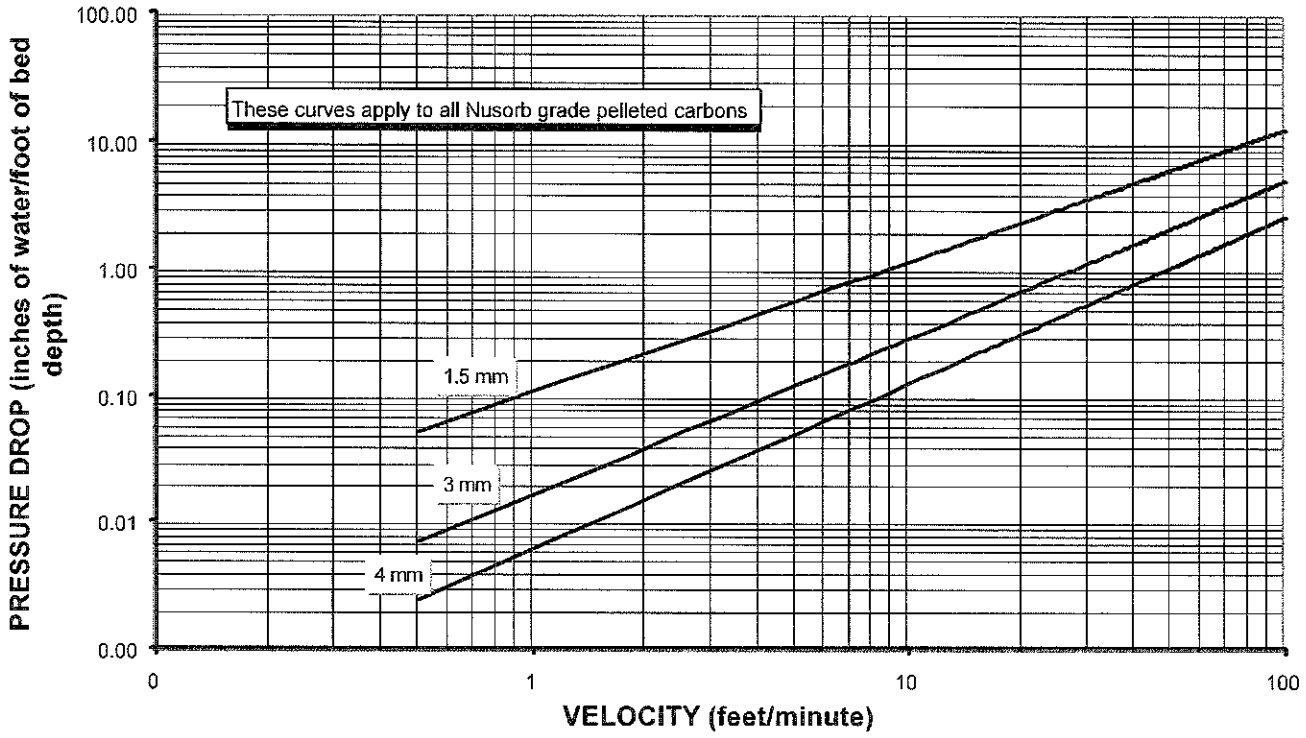


Figure 9: Pressure Drop Curve for All NUSORB Grades of 1.5 mm, 3mm and 4 mm Diameter Pelleted Coal Based Carbons



NUSORB® KINA™-3 TECHNICAL DATA SHEET

TYPICAL APPLICATIONS:	Acid gas purification
RAW MATERIAL:	Coal
ACTIVATION METHOD:	High Temperature Steam
PARTICLE TYPE:	Pellet
IMPREGNANT	Proprietary

PHYSICAL PROPERTIES:	Test Method	Values	
Apparent Density,	ASTM D2854	0.50 g/ml	Typical
Hardness	ASTM D3802	98	Typical
Ash	ASTM D2866	10 wt %	Typical
Moisture Content, as packaged	ASTM D2867	15 %	Typical
Particle Size		3 mm	Diameter
Carbon Tetrachloride Activity	ASTM D3467	60 %	Minimum

Additional ASTM or custom testing available on request

PACKAGING: Square fiber drums (150 pounds) or "tote bags"(1,000 pounds)

For additional information contact:

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NUSORB® KINA™-4 TECHNICAL DATA SHEET

TYPICAL APPLICATIONS:	Acid Gas Purification
RAW MATERIAL:	Coal
ACTIVATION METHOD:	High Temperature Steam
PARTICLE TYPE:	Pellet
IMPREGNANT	Proprietary

PHYSICAL PROPERTIES:	Test Method	Values	
Apparent Density	ASTM D2854	0.55 g/ml	Typical
Hardness	ASTM D3802	97	Typical
Ash	ASTM D2866	10 wt %	Typical
Moistuer Content, as packaged	ASTM D2867	15 %	Maximum
Particle size (pellet)		4 mm	Diameter
Carbon Tetrachloride Activity	ASTM D3467	60 %	Minimum

Additional ASTM or custom testing available on request

PACKAGING: Square fiber drums (150 pounds) or "tote bags"(1,000 pounds)

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