Performance of the Sentry™ Visibility Sensor in Obstructions to Visibility Caused by Blowing Dust & Sand

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Introduction

The Sentry™ Visibility Sensor, Model SVS1, is designed to measure visibility in a variety of atmospheric conditions including fog, haze, rain, drizzle, snow, dust, and smoke. The measurement is based on the principle of forward scatter. It utilizes a high power infrared light at a wavelength of 880 nm. The IR light is beam formed into a collimated cone of light at a nominal angle of 42 degrees to the axis of the receiving optics as shown in Figure 1. Visibility sensors measure extinction coefficient (EXCO) which is a measure of the reduction of transmitted light. EXCO is the sum of the scattering coefficient and the absorption coefficient:

EXCO = Scattering Coefficient & Absorption Coefficient

Since absorption is usually small, the extinction coefficient is approximately equal to the scatter coefficient. Visibility sensors use formulas to convert extinction coefficient into a measurement of visibility.

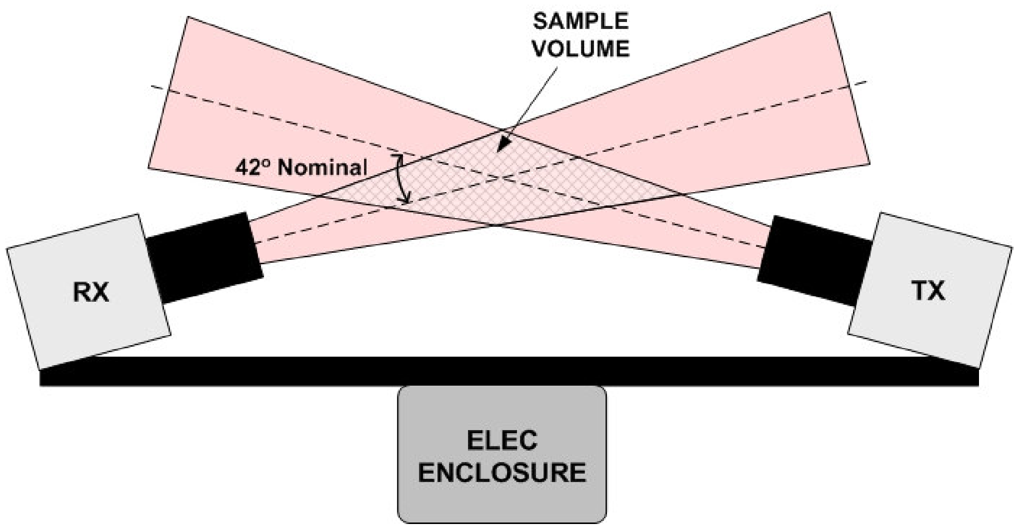


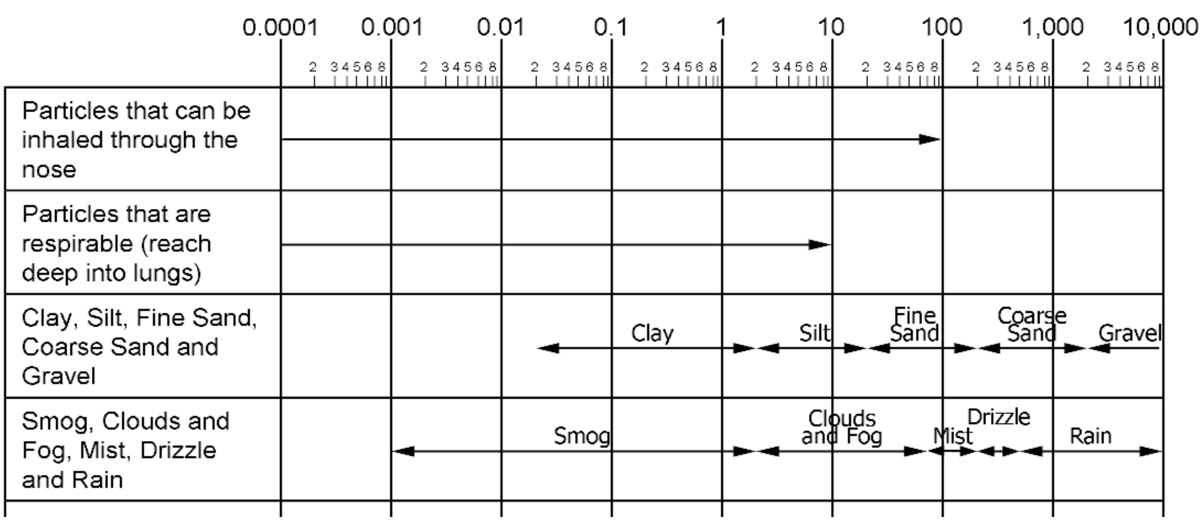
Figure 1 – Forward Scatter Geometry

Background

For the past several decades there have been many investigations into the ability of a forward scatter sensor to accurately measure the extinction coefficient over a range of scatter angles and particle sizes. In 1960 O.D. Barteneva published a paper in the Bulletin Academy of Science USSR Geophys. Sci. 12, 1237–1244. In it, he describes the scattering function at varying visibilities. The data showed that there is a nonlinear relationship between the scattering angle and visibility. His work was corroborated in 1962 by Diran Deirmendjian of the Rand Corporation and suggested that it is not possible to select a single forward scattering angle for which the scattering coefficient will be proportional to a range of visibilities and particle sizes. However, in 1967 the

Soviet researchers Shifrin & Chayanova, showed that a scatter angle in the range of 20-50 degrees would provide a proportional output over the visibility range of <0.15 to 25 miles. They estimated that for this range of scatter angle, the sensor could be expected to provide an accuracy of +/-15%. They attributed this error to the particle size distribution in the sensor sampling volume. Further experimental work by the FAA in the 1990's for the Runway Visual Range (RVR) program recommended a nominal forward scatter angle of 42 degree. The Sentry™ uses the nominal scatter angle of 42 degrees.

The forward scatter sensor is designed to respond to all atmospheric phenomena that reduce visibility to the human eye. These are known as obstructions to visibility. These phenomena can be divided into 2 major groups; hydrometeors and lithometeors. Hydrometeors are characterized as liquid or solid water particles. These include rain, drizzle, fog, and snow. Lithometeors are mostly solid, dry particles. Examples are haze, smoke, dust, and sand. As seen in Figure 3, the size of these particles can range from as small as 0.001 μm for smog to 10,000 μm for large rain drops. The figure also shows that, dust storms, composed of small particles of clay and silt, typically have particles in the range of <0.10 to 20 μm and fine sand typically has particles in the range of 20 to 200 μm. V.R. Squires (1967) states that in practice, only those particles with diameters <100 μm can be carried and transported into the atmosphere by the wind.



Source: [www.niehs.nih.gov/health/docs/**particles**-size.pdf](www.niehs.nih.gov/health/docs/particles-size.pdf)

Figure 3 - Particle Diameter Distribution Graph (μm)

From Figure 3 we can see that a typical dust/sand storm contains particles in the range of <0.10 to 100 μm. This range of clay, silt, and small sand particles typically found in dust/sand storms overlap the range of particle sizes that the Sentry™ is designed to measure.

Conclusions

The extensive theoretical work and experimentation over the past 50 years have established a firm foundation for the use of forward scatter sensors. Many thousands are in use around the country for such customers as the Federal Aviation Administration, National Weather Service, US Air Force, & US Navy as well as DOT's in most states for road weather information systems (RWIS). The EnviroTech Sentry™ has been in production for 7 years with almost 800 units installed around the world. Applications for the Sentry™ include road weather systems, road tunnels, coastal & maritime monitoring, offshore oil platforms, fog detection networks, and dust warning systems. Of special interest are 3 projects:

1) Tennessee DOT I-75 Fog Detection Project Upgrade
2) California DOT Route 99 Fog Pilot Project
3) Arizona DOT I-10 Severe Dust Storm Warning Project – see Figure 4

The Sentry™ performance is field proven in a wide range of climatic conditions from the deserts of the Middle East to the Arctic Ice Shelf. Obstructions to visibility from windblown dust and sand fall well into the detection capabilities of the Sentry™.

Figure 4 – Sentry™ Visibility Sensor in AZDOT Dust Warning System