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DISCUSSION

Comments on "Acoustic Agglomeration of Power Plant Fly Ash for Environmental and Hot Gas Clean-up" (Paper No. 87-WA/NCA-10)

J. A. Gallego-Juárez² and G. Rodríguez-Corral². This paper deals with acoustic agglomeration of power plant fly ash. It presents a brief history of the topic and some analytical and experimental results in order to show the viability of the method.

In our opinion this is an interesting paper which shows the current renewed interest in the acoustic agglomeration process. Nevertheless, there is an important point about which we would like to express our disagreement. This is in relation with the sound source.

The author declares the importance of the source for the efficiency of the process. In this light Professor Reethof says: "Before deciding on the siren as a very promising sound source, we investigated several other potential high acoustic sound pressure sources Sirens have been shown to be the only sound source which promises to provide the high overall efficiencies of 50 to 60 percent required for economically viable acoustic agglomerators in power plant applications."

We disagree with this statement and in order to support our point of view, we can provide several basic arguments shared by many other authors. First of all, it is surprising that despite the supposed potentialities of the sirens and the many attempts to develop efficient powerful devices, few industrial plants have employed these sonic generators for an extended period of time. In fact, and as it was clearly exposed by P. Greguss in a review article [28], the rotary sirens pose many important practical problems as, for example, the spacing between the stator and rotor which must be small in order to be effective. In practice, it is very difficult to maintain this spacing "since the large stresses produced by the high rotational speeds, the excessive loads on the bearing and temperature variations may all increase the separation and reduce efficiency or, on the contrary, may reduce it and cause scoring" [28]. Other disadvantages are that they are unable to radiate high power at frequencies above 10-20 kHz, their maintenance is costly and their electric energy consumption is much higher than that of conventional electrostatic filters used for aerosol precipitation. Therefore, we can conclude that the sirens don't seem to be the adequate sonic generators for industrial acoustic agglomeration.

Due to the lack of good air-borne sound and ultrasound sources, we have been working during the last 15 years in developing a new type of high-efficiency generator for high-power applications [29-32]. This generator is based on a new piezoelectric transducer, designed to obtain good impedance matching with the propagation medium, high amplitudes of vibration and high directivity. It consists essentially of a piezoelectric element of transduction, in a sandwich configuration, a solid horn, which acts as a vibration amplifier, and a radiator consisting of a stepped circular plate of extensive area which oscillates flexurally with several nodal circles. The transducer is driven by an electronic unit consisting of a power amplifier and a new system for dynamic control of resonance.

Different prototypes of this new type of airborne generator have been constructed and the good performance obtained can be summarized as follows:

electroacoustic efficiency	75 percent
directivity (3dB beamwidth)	2 percent
power capacity	400 W (with a radiator of 480 mm in diameter)
frequency range experimented:	10-50 kHz
maximum intensity levels reached:	175 dB

Because of this excellent performance we have worked towards applying our transducer to the aggregation of aerosol particles in the micron range. The results, published in several papers [33-36], have clearly shown the efficiency of our generator for the precipitation of aerosols. At present, we are working at increasing the scale of our generators for the industrial treatment of large volumes of gaseous media.

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Authors' Closure

The authors are grateful for the comments by Drs. Gallego-Juárez and Rodríguez-Corral. The commentators are very critical of the reliability potential of sirens. We point to the fact that rotating axial flow sirens are simple high speed rotating machines similar in design to the millions of turbochargers in automobiles and trucks and the thousands of jet engines. A simple constant strength rotor is held in close axial location by two preloaded angular contact ball bearings. The bearings easily carry the low thrust load which is the result of careful pressure balancing of the rotor. A commercial face-type seal or labyrinth seal meets the requirements of operating at pressures above atmospheric. The axial rotor-stator clearances for the high acoustic power applications that are required in typical power plants such as 5000 to 50,000 acoustic watts can be in excess of 0.010" without affecting siren output through leakage. Thus their concern about scoring and rotor distortions are not valid. The many sirens we have designed and built have been essentially trouble-free. We are dealing with a highly developed technology.

The discussers claim that the electric energy consumption for sirens is much higher than that of electrostatic filters without providing any basis in fact. The power required to rotate a freely spinning rotor is determined by the bearing resistance, the seal resistance, the viscous drag of the rotor in its clearance space and the power to accelerate a small fraction of the flow. Our experience with many sirens indicates that the rotational power varies between 8 to 15 percent of the acoustic power at typical operating conditions. Thus, our 4000 acoustic watt siren uses from 400 to 600 electrical watts with a motor designed for the application.

The discussers claim that operation above 10-20 KHz is needed for effective acoustic agglomeration. The optimum frequency is determined by the particle size distribution, the particle density, the gas density, and viscosity. For most of the applications, we have encountered, dealing with coal-fired power plant applications, as well as petrochemical and chemical industries, the particle mean sizes range from 5 to 20 μm , densities in the range of 1.5 to 2.3 g/cc and gases dominated by air properties. The optimum frequencies range from 500-4000 Hz. Only for the submicron size dominated

aerosols are ultrasonic frequencies effective as the larger particles are not at all entrained in the ultrasonic acoustic fields.

To demonstrate this contention we have used the discussers conditions as the input parameters to our highly developed, fundamentals based simulation of the acoustic agglomeration processes (Tiway, 1984, Tiway, 1986, Reethof, 1987, Pla, 1987). The conditions were as follows: $\mu_g = 0.33 \mu\text{m}$, $\sigma_g = 1.65$, loading = 7 g/m³, $f = 20.4 \text{ KHz}$, residence time = 5 seconds, acoustic level = 163 dB, carbon black density = 1490 kg/m³, reflection coefficient 0.85 and the acoustic agglomerator dimensions given. The agreement with the discussers' result is remarkable. The predicted growth to mean size of 18 is very close. Even closer is the mean diameter ratio of 57 for the 2.41 w/cm² intensity. The results of our simulation are given in the attached figure. Of interest also is the particle number ratio of final to initial which is 1.95×10^{-6} . We note that a certain amount of gravitational settling should be expected since the mass ratio (final to initial) is predicted to be 0.769.

We also draw attention to the fact that the absorption of acoustic energy by particularly molecular relaxational phenomena become very high, in fact prohibitive, at high frequencies and typical temperatures of acoustic agglomerators. The primary gases that contribute to absorption are water vapor, CO and CO₂. Thus for an acoustic agglomerator in a hot gas clean-up system of a coal burning power plant, operating at 1600°F and atmospheric pressure the 10, 20 and 30 KHz acoustic energy absorptions are 11.63, 23.5 and 37.6 dB/m whereas at a 1500 Hz the absorption is only 0.075 dB/m. At a temperature of 700°F the values for absorption are somewhat lower.

The discussers are to be congratulated on their success with piezoelectric sound sources and their creative solutions to the efficient acoustic power coupling problem. In studying their very interesting papers were observed that the transducer systems using the stepped circular plate principle are highly directional raising the question whether a large acoustic agglomerator could be successfully filled with sound. We also note with interest that the axial reduction in sound pressure level in their 1986 Journal of Sound and Vibration article [(110 (3), 413-427)] of about 13 dB over on meter may well be the result of gas absorption.

In summary, we have learned that siren sound sources are mechanically very simple thus reliable devices with designs based on extensive experience with high speed rotating machinery. Sirens are capable of delivering the very high acoustic powers required in large industrial and power plant installations. They are very efficient acoustic sound sources. The frequency of 20.4 KHz typical of their experience is close to the optimum of their very small particles with submicron mean sizes. Such high frequencies are not as effective for the more commonly encountered micron sized particles in many potential applications of acoustics where frequencies in the sonic range are needed.