# *Studies of the Effects of Particle Size on the Flow Characteristics of Dry Chemicals*

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The author has studied the effects of particle size on the flow characteristics of several types of dry chemicals in hose lines and fixed pipe systems. The results have permitted him to draw certain conclusions regarding optimum sizes to maximize flow rates and minimize pressure losses.

EXTENSIVE experience with dry chemical fire fighting units has shown that the particle size distribution of the dry chemical affects the dispensing medium performance in the following ways:

- A coarse powder — say, 50 percent through a 325 mesh — will cause excessive surging in hose line applications, will give relatively low flow rates, will require more total gas quantities, and will result in a relatively inefficient unit clean-out capability.
- A fine powder — say, 90 percent through a 325 mesh — will give similar results, but not to the same degree as the coarse powder.

Hence, it appears that there is an optimum particle size distribution for maximum flow rates from a particular configuration, smoothness of flow, minimization of the gas supply quantities and maximization of the unit clean-out efficiency. Experimental confirmations of such effects are not reported in the literature, although each dry chemical manufacturer has probably determined the best particle size distribution for his particular equipment and concept of how to best utilize the equipment.

The purpose of this paper is to present the qualitative results obtained from an experimental program in which the effects of particle size distribution on the flow and pressure loss characteristics of different dry chemical blends and agents in hose lines and fixed pipe systems were evaluated. This program was conducted by University Engineers, Inc. and sponsored by Walter Kidde & Co., Inc.

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## EFFECTS ON DRY CHEMICAL FLOW RATES

At the present time it is customary for a dry chemical equipment manufacturer to warrant his equipment only when used with specified blends or brands of dry chemical agents. It is also the practice of approval agencies, such as Underwriters' Laboratories, Inc., to approve dry chemical units and dry chemical agents as an integrated system. However, the fact still remains that the end user has the capability of purchasing a wide variety of dry chemical blends of any one type as well as different agents for use in his equipment. Thus, the experimental program discussed herein had a two-fold purpose — one, to define the particle size distribution best suited for that particular equipment, and two, to define the performance of that particular equipment with the different blends of agents available on the common market.

Five different blends of sodium bicarbonate dry chemical were discharged through each of several different physical test configurations. In each physical configuration, the operating pressure, nitrogen cylinder start pressure, and nitrogen supply capacity were held constant. Hence, the only variable in each series of tests was the dry chemical particle size distribution. The effects of particle size on the flow rate of sodium bicarbonate agent in a 1-in. inside diameter dry chemical hose is presented in Figure 1. Since the actual magnitude of flow will be different for each possible hose length-nozzle arrangement the data are shown as a percent change in flow rate. As shown, the maximum flow rate occurs at a particle size distribution of about 75 percent through a 325 mesh. The percent through a 325 mesh was selected as a correlating parameter, since the distribution of that portion through a 325 mesh appears to be about the same for the different blends of dry chemicals and the determination of a mean or average particle diameter is a difficult and not very reliable process. As also shown, a change in the particle size distribution from 75 to 50 percent through a 325 mesh will decrease the flow rate in the fixed 1-in. hose configuration by about 30 percent.

Figure 2 presents the effects of particle size on the flow rates through a 1¼-in. inside diameter hose line. In this case the optimum particle size is about 80 percent through a 325 mesh. Decreasing the particle from 80 to 50 percent through a 325 mesh decreases the flow rate by about 35 percent. Similar data for a 2-in. diameter, Schedule 40, fixed pipe system are shown in Figure 3. The data indicate an optimum particle size distribution of about 70 percent through a 325 mesh and a reduction of about 35 percent when the particle size distribution is reduced to 50 percent through a 325 mesh.

A comparison of the data shown in Figures 1, 2, and 3 indicates that the discharge media diameter will have some effect on the flow and pressure loss characteristics of the dry chemical. A measure of this effect is illustrated by the differences in optimum particle size distribution for the different discharge media.

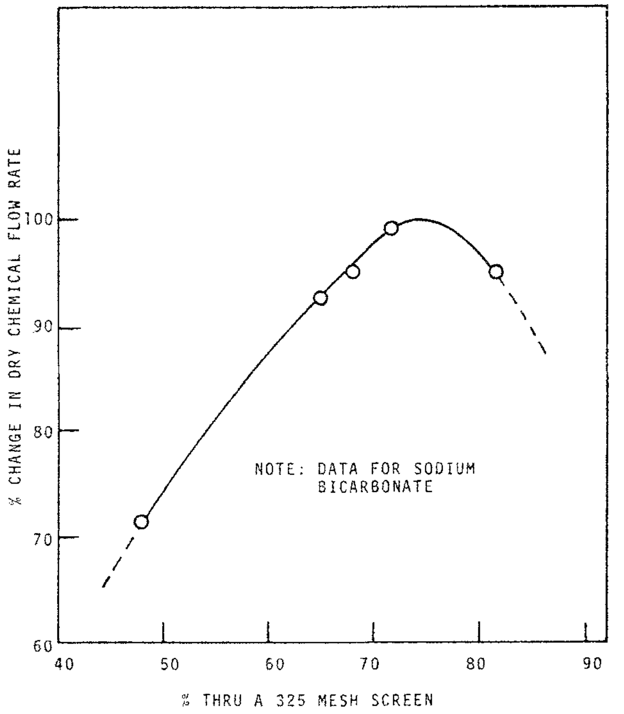


*Figure 1. Effects of particle size on the flow rates through 1-in. diameter hoses.*

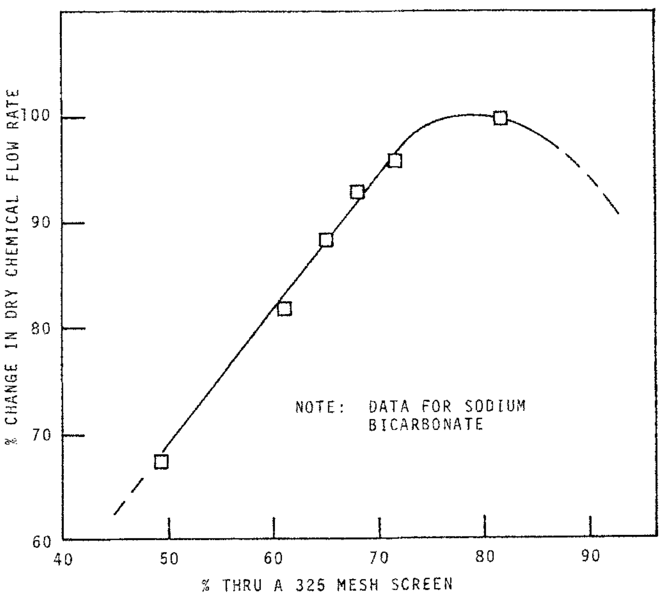


*Figure 2. Effects of particle size on the flow rates through 1¼-in. diameter hoses.*

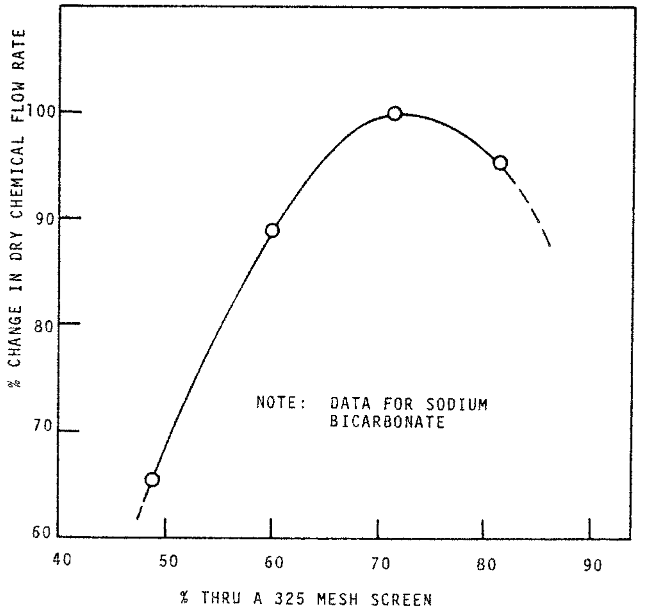


*Figure 3. Effects of particle size on the flow rates through a 2-in. diameter fixed pipe system.*

Based on the evidence that the particle size distribution will greatly affect the flow characteristics of a given hose configuration, it was decided to obtain a general effect that could be applied to any configuration. The best approach appeared to be to establish effects of particle size on the flow rate through the hose line discharge nozzle as a function of nozzle inlet pressure. These data are shown in Figure 4. As expected, the dry chemical blend of 75 percent through a 325 mesh produces the maximum flow rates at any given inlet nozzle pressure. As also expected, particle size distributions above 75 percent give reductions in flow rate but not to the same extent as particle size distributions below 75 percent through a 325 mesh.

## EFFECTS ON DRY CHEMICAL PRESSURE LOSSES

It is a well-accepted phenomenon that a two phase-mixture of solid particles suspended in a gas stream exhibits a much greater pressure loss than that which can be calculated for the transport gas alone or for a homogeneous fluid of like mixture density. The effect is partially due to the very turbulent action of the small diameter solids suspended in the gas stream. Generally, pressure loss correlations have been based on the fact that the total pressure loss for the mixture is a summation of the gas losses, calculated by assuming that only gas is flowing in the empty duct, and the pressure losses due to the moving solids. However, at high loading ratios, such as 25 pounds of solids to one pound of gas, the contribution of the gas pressure losses to the total pressure losses is quite small, only one to two percent. Hence, in dry chemical flow calculations, it is

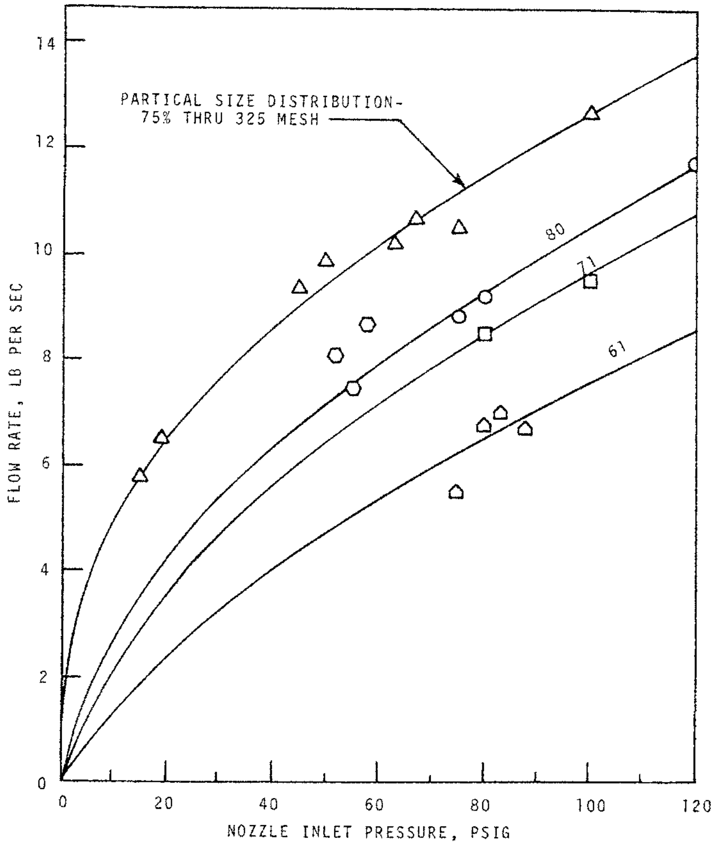


*Figure 4. Effect of particle size on the flow rates of a typical hose configuration.*

customary to neglect the gas pressure losses, since they are well within the range of experimental error.

Generally in fluid flow analyses, it is customary to calculate a dimensionless friction factor from the experimental data and correlate this factor with Reynolds Number. However, due to the difficulties in determining the viscosity of a solid-gas mixture, many researchers in the field of pneumatic transport of small diameter solids have utilized only the solids velocity for correlating purposes in lieu of the Reynolds Number. Use of the solids velocity as the sole correlating parameter assumes that the flow characteristics are dependent only on the gross properties of the dry chemical and is, therefore, independent of the individual particle velocities and sizes. However, since there is always an interacting relationship between fluid flow and fluid pressure loss, it is reasonable to assume that the demonstrated effects of particle size on dry chemical flow will have a corresponding effect on dry chemical pressure losses. Figure 5 illustrates these effects. As shown, at a constant mass flow rate in a 1-in. diameter hose line configuration, the particle size distribution of the dry chemical has a marked effect on the fixed length hose line pressure losses. The minimum pressure losses, at constant flow rate, occur with the blend of 75 percent through a 325 mesh screen. Decreasing the distribution to 50 percent through a 325 mesh, and holding the mass flow rate constant, increases the pressure losses by about 275 percent.

The result of ignoring these effects of particle size on dry chemical pressure losses is illustrated by the generalized pressure loss correlations in Figure 6. The upper correlation was determined by calculating the friction factor from the experimental data and plotting this factor as a function of the solids velocity. As shown, the test data can best be presented by a straight line relationship determined by a linear regression analysis of the data. However, as shown, the data spread is about a factor of three (similar data in the literature have a spread of about 10). Examination of the data also show that the data to the left and below the line were obtained with blends of less than 70 percent through a 325 mesh, while points above the line were obtained with blends of 70 percent or greater. It should also be emphasized that such linear regression analyses should *never* be extrapolated outside the range of actual experimental data.

The lower correlation of the same test data considers the effect of particle size and discharge media diameter in addition to the solids velocity as correlating parameters. Since both the particle diameter and duct diameter would appear in the mixture Reynolds Number, both parameters

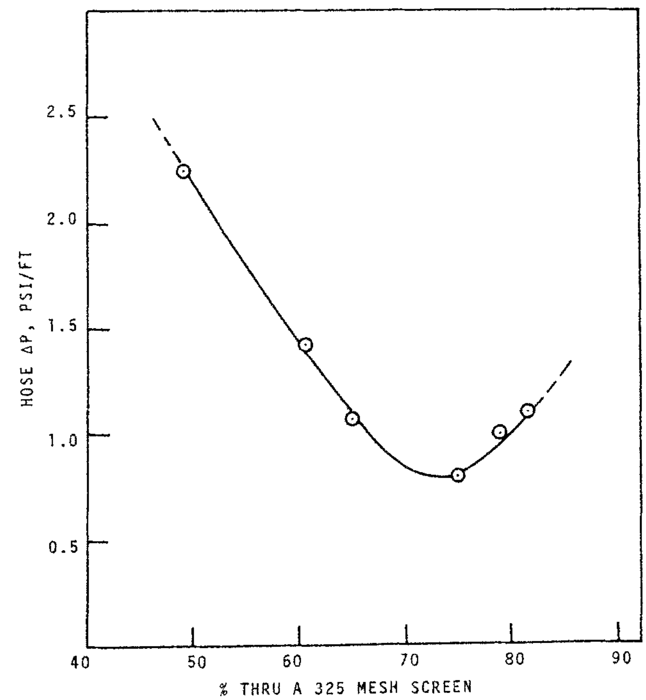


*Figure 5. Effects of particle size on the pressure losses in a 1-in. diameter hose with a constant mass flow rate.*

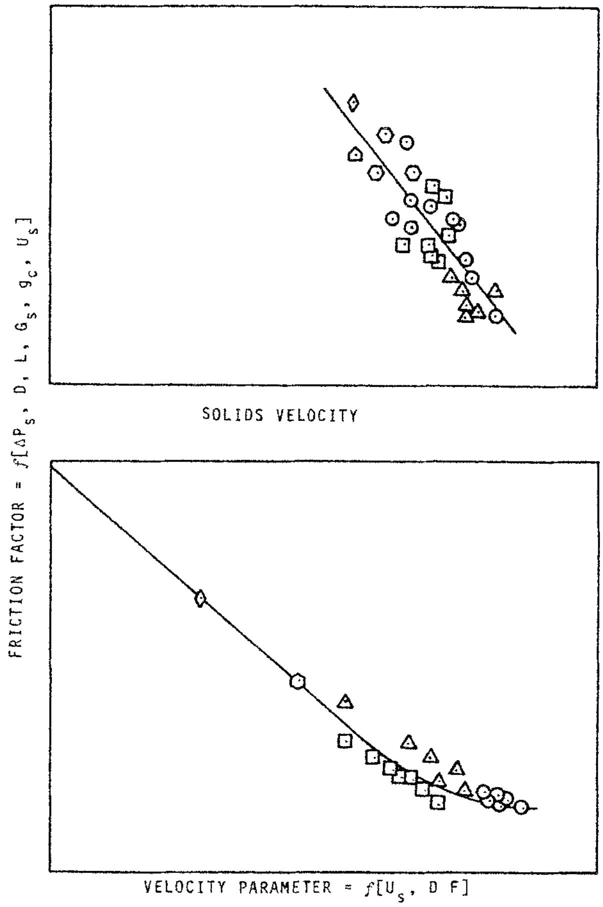


*Figure 6. Generalized pressure loss correlation.*

should be used with the solids velocity rather than the friction factor. As shown, a much improved correlation results. The correlation line also appears quite similar to the standard friction factor versus Reynolds Number correlations for pure single phase fluids, i.e., at low velocities the correlation is linear and at high velocities it approaches a limiting value. Extrapolation of the upper correlation to higher velocities would give a constantly decreasing value for the friction factor and could lead to gross errors at high dry chemical flow rates. It is also interesting to note that the points above the line at the higher values were obtained with rough wall standard line pipe. The points below the line were obtained from tests on smooth wall hose lines. Thus, one can visualize a correlation that is linear at low velocities for all types of ducting but has unique lines at the higher velocities for each wall roughness condition, just like the conventional correlation for water flow in smooth and rough wall pipes. This apparent effect of wall surface roughness factor should be investigated in more detail.

Another factor that needs to be evaluated is the effect of particle size on the nitrogen gas requirements. From these investigations we observed that particle size does have some effect on the gas velocity required to avoid surging, i.e., the larger particles require a higher velocity. Hence, there should be some effect on the gas flow rates required to expell a given dry chemical flow rate. We hope to evaluate these effects during future research work in the area of dry chemical flow and pressure losses.