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論　　文

Pulse Energization in the Tuft Corona Regime of Negative Corona

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Fabric filtration with integral particle charging and collection in a combined electric and flow field is sensitive to maldistribution of current among bags energized by one power source, especially when operating in the tuft corona regime below glow corona onset. Pulse energization superimposed on the direct current (DC) applied to the bags tends to equalize the currents. Equalization of the currents also takes place when misalignment is present. However, the misalignment could cause sparking to occur at lower applied voltages. Pulse energization in the tuft corona regime could also be useful in electrostatic precipitators (ESPs) if mild misalignment is present.

1. Introduction

Fabric filtration with integral particle charging and collection in a combined electric and flow field is a new technology in which the application of electrostatics to a baghouse causes a non-uniform deposition of the particle or dust layer; conventional filtration causes the deposition of a uniform dust layer. The non-uniform dust layer allows operation of the baghouse with a lowered pressure drop.[1,2]

It has been observed at the EPA owned pilot baghouse at Southwestern Public Service Company's Harrington Station in Amarillo, Texas, that it has been difficult to achieve equal current distribution among the five electrified bags. It was not known whether the problem was due to back corona, misalignment, or some other problem.[3] It has been reported that pulse energization was useful in providing more uniform current distribution, which might help mitigate the unequal current distribution.[4-6] Unfortunately, the literature did not provide much in the way of information of pulse-energization on wire-pipe ESP geometry which most closely resembles the fabric filtration bag with the central corona wire.

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2. Experimental Apparatus

To simulate several fabric filtration bags with integral particle charging and collection an ambient temperature, experimental apparatus was set up as in Fig. 1. Instead of fabric, the tubes were aluminum, so that dimensions and spacings could be set and maintained. The corona electrodes were stainless steel; no special precautions were taken to clean or prepare them. An oval metal termination was placed at the end of each corona wire to minimize end effects that might cause erroneous currents to register on the meter. A PVC plastic bar anchored each corona wire termination at the bottom to prevent swinging, especially when sparking would occur. The support stand for Tube 3 corona wire was slotted to allow sideways adjustment to simulate misalignment.

The apparatus was energized with DC from an adjustable power supply. A pulsed power supply was used to superimpose a pulse upon the DC. The pulse width was 100 μs, and the repetition rate was 100 pulses/s. The pulse amplitude was adjustable from 0 to 50 kV. The DC power supply was current-limited by the apparatus at 36 kV.

Each tube was grounded through a 1000 ohm resistor across which a digital voltmeter was connected. On the meter, 1 mV was equivalent to 1 μA of corona current. Each resistor had a metal oxide varistor in parallel with it to prevent meter damage when sparking occurred.

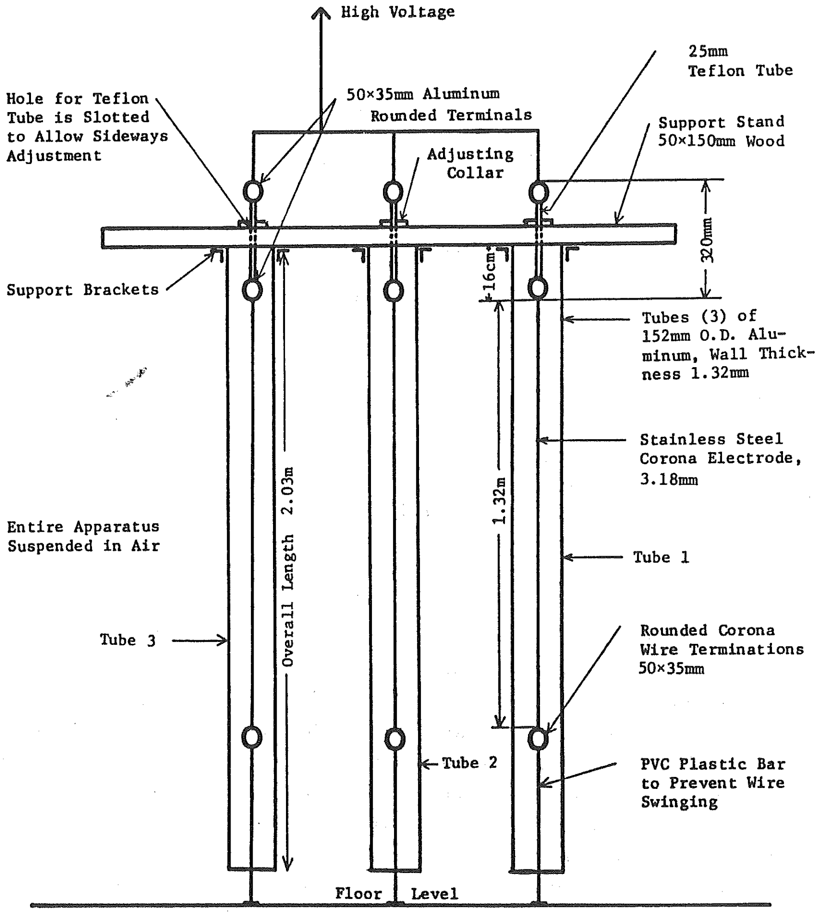

Fig. 1 Wire-pipe test apparatus for effects of pulse energization.

3. Experimental Results

For DC the voltage/current characteristics for the test apparatus are presented in Fig. 2.

For wire-pipe cylindrical geometry the relationship for corona onset is given by

$$V_0=f(30ad+q\sqrt{ad})\ \ln\left(\frac{c}{a}\right) \qquad (1)$$

in which f is the surface roughness factor, a is the corona wire radius, d is the relative gas density, and c is the cylinder radius.[7] If the surface roughness factor is set equal to 1,[8] the computed voltage is 32,000 V.

The corona onset voltage for Tube 3 is quite close to the calculated value. The onset voltage for the corona wires in the other two tubes is considerably lower. Once above the corona onset and into the glow discharge region, the individual currents merge.

In the glow corona discharge region the voltage-current characteristics agreed quite well with the relation for cylindrical geometry[9]

$$V=V_0+aE_c\left[\left(1+\frac{c^3J}{\varepsilon_0\mu a^2E_c^{\,2}}\right)^{0.5}-1 -\ln\left\{\frac{1+\left(1+\dfrac{c^3J}{\varepsilon_0\mu a^2E_c^{\,2}}\right)^{0.5}}{2}\right\}\right] \qquad (2)$$

in which E_c is the corona initiation field at the wire, J is the current density, ε_0 is the permittivity of free space, and μ is the ion mobility.

The currents seen for Tubes 1 and 2, at voltages less than the glow corona onset voltage, are in the regime that has been characterized as tuft corona.[10,11]

As seen in Fig. 2 the current density in the tuft corona regime can be significant. The VI curves illustrate very well the reason for uneven

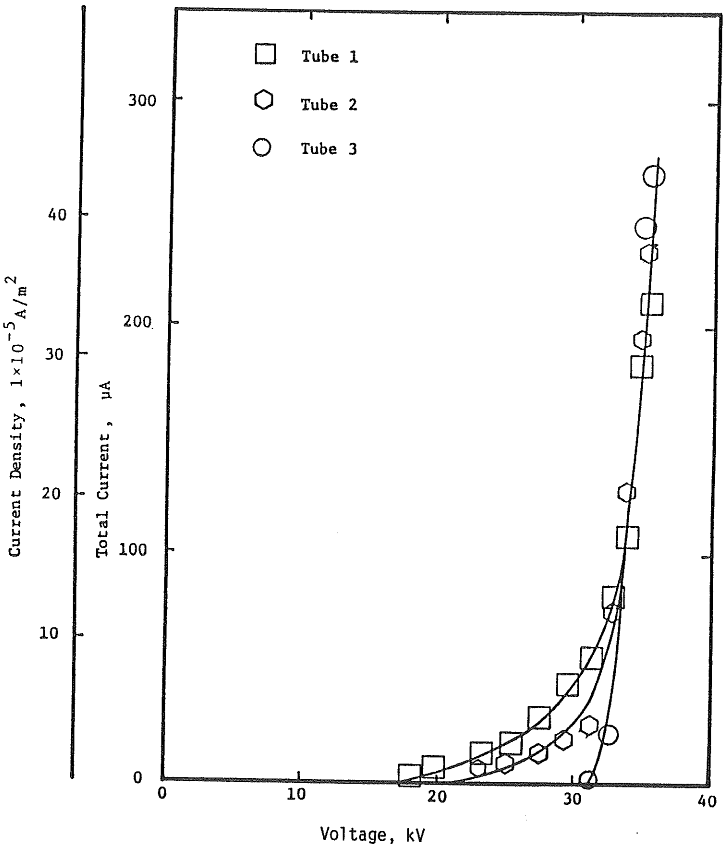

Fig. 2 Voltage/current relationship for apparatus of Fig. 1.

distribution of currents that occurred among the several bags.

The results of the application of pulse energization to the DC bias is shown in Table 1. With just DC applied, the results were similar to those shown in Fig. 2. With the DC bias set below that of glow corona onset, the superimposing of the pulses upon the DC tended to equalize the currents.

To evaluate the effects of misalignment, the corona wire was first offset 12.7 mm and then 25.4 mm. The results are seen in Tables 2 and 3, respectively.

Corona onset voltage using DC for Tube 3 was only slightly affected for the 12.7 mm offset which represented moderate misalignment. However, once corona onset occurred, the effects of the misalignment became very apparent as a higher current in Tube 3. The superimposing of pulse energization upon the DC bias, at voltages below glow corona onset, again caused the currents to equalize.

For the 25.4 mm offset representing severe misalignment, the application of DC caused sparking at voltages below that of glow corona onset. The current equalizing ability of the pulse energization was not as good as it was with the moderate offset. However, with the application of pulse energization upon the DC bias, which was set below the glow corona onset voltage, it was possible to get some corona currents for all of the corona discharge wires. For the test condition in which the DC bias was 35 kV, the decreasing current of Tube 3, with increasing pulse voltage, is attributable to the current limited DC power supply.

4. Conclusions

Pulse energization has been shown to equalize currents in that portion of the VI regime that is known as the tuft corona region--voltage< corona onset, if DC only was being used. It was further shown that electrodes, which had no current below glow corona onset with DC, would

Table 1 Application of pulse energization to wire-pipe test apparatus.

DC bias (kV)	Pulse voltage (kV)	Current (μA)		
		Tube 1	Tube 2	Tube 3
15	0	0	0	0
	10	1	0	0
	20	2	0	0
	30	36	36	32
	40	79	75	77
	50	111	112	116
20	0	8	0	0
	10	9	1	0
	20	18	9	8
	30	60	57	58
	40	100	95	98
	50	130	131	132
25	0	20	11	0
	10	21	12	0
	20	54	47	43
	30	93	84	84
	40	129	122	122
	50	154	150	151
30	0	34	39	0
	10	52	52	22
	20	86	79	63
	30	120	112	102
	40	156	150	142
	50	Sparked	Sparked	Sparked
35	0	186	176	157
	10	193	185	162
	20	202	199	169
	30	216	221	177
	40	238	245	193

have current if pulse energization was superimposed upon the DC.

These findings relative to pulse energization have some significant implications. For a given geometry and current, increased electric field strength can be gained by use of a larger diameter corona wire.[12] If the larger diameter corona wire shifts the operating point so that it is in the tuft corona regime for that size wire, pulse energization will allow each of the wires (bags) operated by one power supply to have corona current.

Table 2 Application of pulse energization with 12.7 mm offset in Tube 3.

DC bias (kV)	Pulse voltage (kV)	Current (μA)		
		Tube 1	Tube 2	Tube 3
16	—	0	0	0
18	—	4	0	0
20	—	8	0	0
22	—	12	2	0
24	—	17	7	0
26	—	22	13	0
28	—	27	23	0
30	—	33	38	1
32	—	40	54	4
34	—	85	87	155
35.6	—	244	237	417
15	0	0	0	0
	10	0	0	0
	20	1	0	0
	30	26	24	27
	40	66	66	72
	50	104	105	114
20	0	7	0	0
	10	8	0	0
	20	17	8	13
	30	57	50	55
	40	90	86	93
	50	127	126	135
25	0	18	9	0
	10	19	10	0
	20	53	43	43
	30	87	78	82
	40	122	115	123
	50	156	152	161
30	0	34	39	0
	10	51	51	26
	20	85	79	67
	30	119	111	108
	40	156	149	151
	50	Sparked	Sparked	Sparked
35	0	170	173	333
	10	181	185	320
	20	195	200	313
	30	220	226	298
	40	Sparked	Sparked	Sparked

Table 3 Application of pulse energization with 25.4 mm offset in Tube 3.

DC bias (kV)	Pulse voltage (kV)	Current (μA)		
		Tube 1	Tube 2	Tube 3
16	—	0	0	0
18	—	4	0	0
20	—	7	0	0
22	—	11	2	0
24	—	17	7	0
26	—	21	11	0
28	—	27	22	0
30	—	Sparked	Sparked	Sparked
15	0	0	0	0
	10	0	0	0
	20	2	0	0
	30	30	27	40
	40	Sparked	Sparked	Sparked
20	0	1	0	0
	10	8	0	0
	20	16	6	21
	30	Sparked	Sparked	Sparked
25	0	18	9	0
	10	19	9	6
	20	49	39	51

Equalization of current, when misalignment is present, by pulse energization could also be useful for an electrified baghouse. The cylindrical geometry of a fabric filtration bag is established by the pressure drop of the gas inflating a bag that is hoped had been correctly cut, sewn, installed, and tensioned. It is quite likely that there would be some degree of misalignment.

Pulse energization in the tuft corona regime for conventional ESPs might also help overcome the effects of minor misalignment which contributes to performance degradation of ESPs. Also, the low current density under which ESPs are forced to operate when working with high resistivity fly ash, especially with larger diameter round corona wires, may place the electrical operating point into the tuft corona regime; pulse energization might provide a more uniform current distribution for the ESPs.

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