GC-TR-87-1628-F

REFERENCE FILTERS FOR ELECTROSTATIC CHARGING TENDENCY MEASUREMENTS OF FUELS

GEO-CENTERS, INC

GC-TR-87-1628-F

REFERENCE FILTERS FOR ELECTROSTATIC CHARGING TENDENCY MEASUREMENTS OF FUELS

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A study has been made to determine whether laboratory filter papers might be suitable as reference filters for the determination of charging tendencies of jet fuels as measured in the EXXON Mini-Static Tester (MST). From the filter papers which were investigated it was concluded that, compared to commerical fuel filters, these filters do not generate enough charge to afford repeatable and reliable measurements.

Some correlation was observed between the polarity of the generated charges and the nature of the filter paper surfaces. However, attempts to repeat these experiments

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after a time period of about six to eight months were unsuccessful because of variations in the data, particularly that of polarity of the charge. It is suggested that the variations may have been due to relative humidity and temperature changes in the laboratory over the time period. Another possible explanation might be that there were changes in fuel composition due to degradation.

A few studies of some ion exchange resin coated filter papers suggest some tentative generalizations regarding these papers.

It was cbserved that the flow rate of fuel through each type of filter was not constant for any given run. Since it was necessary to have accurate flow rate data for each filter in order to be able to calculate charging tendency from the measured streaming current, a method was devised to make this measurement.

Some suggestions are made for modifying the MST method and proposals for future research are presented.

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1.0 INTRODUCTION

Wherever flammable vapors are present in air, there is always the hazard that an unwanted ignition source might ignite the mixture. The most unpredictable and insidious of the many possible ignition sources is a spark discharge resulting from electrostatic charge build up in a flowing fuel. It was pointed out in an earlier report (1) that one of the key measurements in the study of the electrostatic properties of jet aircraft fuels is the measurement of charging tendency (sometimes referred to as "charge density"). Attempts have been made by the Coordinating Research Council (CRC) to establish correlations between unexplained ignitions of fuel fires and the charging tendencies of the fuels which were involved.

The CRC has made surveys of various jet fuels at airports in the United States to determine the ranges of charging tendency and electrical conductivity of these fuels (2). Electrical conductivity, which is related to charging tendency, is also an important electrostatic property. A summary of one such survey is shown in Table I. It should be noted that the electrical conductivity data in the table for Jet A and JP-4 were obtained before conductivity requirements were put into the specifications for these two fuels (4,5). There are no conductivity requirements in the specifications for JP-5. The charging tendency data in Table I were obtained using the EXXON Mini-Static Tester (MST) (6-9) with "Type 10" paper used as the reference filter. There are no specification requirements for charging tendency for any of the jet fuels. It is seen in the table that both the conductivity and charging tendency data cover a wide range. Although for a given additive in a given fuel, charging tendency increases with conductivity, reaching a maximum somewhere above a 100 picosiemens/meter (ps/m), there is no general relationship between conductivity and charging tendency. However, it is known that if the conductivity of a given fuel is relatively high, i.e., above 50 p s/m, the charge will be dissipated almost as quickly as it is generated (8). A fuel is defined as "high charging" if the charge density is greater than 4000 $\mu c/m^3$ (using "Type 10" paper) and the conductivity is less than 50 p S/m (8).

2.0 REFERENCE FILTER FOR MEASURING CHARGING TENDENCY

It was pointed out in the earlier report (1) that the reference filter used in the CRC survey ("Type 10" paper) is now obsolete and is no longer available. For obvious reasons, there is a need to find a replacement reference filter in order to continue using the Mini-Static Tester (MST) method to measure charge density. The primary objective of this research is to study the effect of fuel composition (fuel components, additives, water, etc.) on the electrostatic properties of jet fuels. A restriction in our assigned objective, however, is that the present study is confined to the measurement of charging tendency by means of the MST. With this in mind, because of the unavailability of the "Type 10" paper, a secondary objective was to find another reference filter (preferably more than one) for measuring charging tendency with the MST. A detailed discussion of the desirable properties of a reference filter are included in the earlier report (1).

3.0 LABORATORY FILTER PAPERS

Because laboratory filter papers are presumed to be relatively uniform, and are widely available, some might show promise as candidates for reference filters. It was decided to investigate a selection of laboratory filter papers which were on hand. The filter papers which were tried and some of their properties (as furnished by the manufacturers) are shown in Tables II and III. The information for the Whatman filters (Table II) show grade, type, surface, weight, thickness, ash, and filtration speed. The Reeve Angel ion exchange resin coated papers (Table III) show types and natures of the ion exchange resins. The Reeve Angel papers were studied in order to determine if the ion exchange resins might remove ions and hence influence static charge build up. For comparison purposes, two commercial aircraft fuel filters were also included in this study. These were pleated papers from water separator elements, and included the obsolete "Type 10" paper:

(a) Fram CS-58-10 ("Type 10") paper, Fram Corporation, Industrial Division, Tulsa, OK. (A high charging paper which is now obsolete).

(b) Velcon I-4208-C, Velcon Filters, San Jose, CA.

4.0 EXPERIMENTAL

Measurement of Charging Tendency

The apparatus and method used for the Mini-Static Test have been previously described (6-9): the apparatus is shown in Figure 1. In this test, the streaming current (I_S) is measured as a 50-ml sample of fuel is passed at a known flow rate (f) through an electrically isolated filter holder containing a 1.27 cm (0.5-in.) diameter circular filter disc. Filter discs were cut out using a stainless steel cork borer machine. The discs are held in the MST by means of a Millipore (Swinny) filter holder. Streaming current divided by flow rate gives the charge density (ρ):

$$\rho = I_S/f \qquad \text{(Eq. 1)}$$

Usually I_S is expressed in pA, f in cm^3/sec, and ρ in $\mu C/m^3$.

The streaming current (I_S) was measured by means of a Keithley 610C Solid State Electrometer the output of which was measured by a strip chart recording potentiometer (recorder). The recorder was calibrated so that its reading (Volts) was related to the current measured by electrometer.

Measurement of Flow Rate Through the MST

As is shown in Equation 1, for each filter it is necessary to know the flow rate (f) in order to be able to calculate charge density (ρ). Using a single fuel, the flow rate was found to vary from filter to filter depending on its porosity. Therefore, the flow rate of a JP-5 fuel sample (NRL No. S84-10) was determined separately for each filter. This was done by inserting 50-ml of the fuel into the MST syringe and collecting the discharged fluid in a graduated cylinder, recording the time (t) (by means of a stop watch) as successive volumes of fuel were collected.

It was found that flow rate for any given fuel was not constant but varied with time. Plots of flow rate data are shown in Figure 2. In the figure, filtrate volume (v) is plotted against time for three representative filters. Also shown is the plot of the MST syringe drive (air). It is seen that the MST syringe drive plot is linear (constant slope). The other three curves, however, (Fram CS-58-10, Reeve Angel WA-2, and Whatman No. 40) initially show gradually increasing flow rates which are then followed by a linear portion (constant flow rate) and finally gradually decreasing flow rates. This type of curve, as demonstrated by these three filters, was the case for all the sixteen filters investigated. Because of the varying flow rate in the beginning and the end portions of these curves, it was decided to use the middle (linear) sections of the curves to determine a constant flow rate (f). Table IV shows the linear portion (both volume and time) of each of the sixteen filters and the calculated values of f for these filters. The f values (slopes) were estimated by linear regression for each filter:

$$v = ft + b \qquad \text{(Eq. 2)}$$

where b is the "y-intercept" of the linear portion of the filtrate volume (v) vs time (t) curve.

In Fig. 2 it can be seen that the syringe drive took 27 seconds to complete its cycle. For some filters (Whatman No. 40, for example) the linear region occurred after the MST drive had stopped. This can also be seen in the third column of Table IV. For each filter, therefore, charge densities were obtained by measuring the streaming current during the linear region of flow.

An explanation of the variation of flow rate (slope) with time as fuel is forced through the filter can be seen by reference to Fig. 1. The system consists of two similar syringes, the upper one containing air which forces the liquid in the lower syringe to flow out through the filter. It would be expected that the syringe drive initially compresses the air in the upper syringe until the pressure build up is sufficient to force the liquid through the filter. After the syringe has stopped, and after much of the liquid has been forced out, the air in the lower syringe slowly decompresses causing a gradual reduction of pressure and hence rate of liquid flow for the residual liquid. It would seem likely that a better system would perform the operation with a single syringe.

Jet Fuel Sample

In order to compare the charging tendencies of the various filters being investigated, all measurements were made using the same fuel. This fuel was a JP-5 jet turbine fuel (NRL No. S84-10). The fuel was obtained from fuel storage tanks at the Patuxent River Naval Air Station and met the requirements of its military specification (4). It was stored in an epoxy lined can. Fuel was sampled as needed by means of a syphon system. The fuel was replaced with air which passed through a drying tube containing Drierite. The electrical conductivity of this fuel was measured by the ASTM method (5) and was found to be 1.46 pS/m. This value was later found to change somewhat with time and this will be discussed later in this report (Table X).

Recorder Strip Chart Traces

Both the electrometer and recorder were set at "center zero" because the sign of any given generated charge was not predictable in advance. There was a wide combination of choices for the range and attenuation settings of both the electrometer and the recorder, and also the chart speed of the recorder. In order to to be able to compare results, and to maintain maximum precision, the choice of settings among the various runs were standardized.

Recorder traces (streaming current vs time) varied considerably among the various types of filter papers which were investigated. Some runs gave steep sharp spikes, some gave multiple spikes, whereas others built up slowly with very broad maxima. Perhaps the ideal way to interpret these data would be to measure the area under the curves. However, from the point of view of flammability hazard, the maximum charge build up should be more significant. For this reason, maximum streaming current values were used for the estimation of charge density data which will be reported here. Averaged data of several runs were used.

5.0 RESULTS

The flow rate, streaming current, and charging tendency data for the eight Whatman filter papers are shown in Table V. The information supplied by its manufacturer for each Whatman filter is shown in Table II. Both data were examined and attempts to find correlations were made. An obvious correlation was observed between the flow rate (f) data in Table V with that of the water filtration speed (the reciprocal) in Table II. The only significant charging tendency correlation was that the polarites of the first four filters ("grained" surface) were all negative, whereas, that of the last four ("smooth" surface) were all positive. The nature of the Whatman filter paper surfaces, and whether they contained some kind of special filler or sizing is not known, and for that reason no explanation is offered at this time for the polarity differences. Unfortunately, attempts to repeat this work at a later time (over a half year) were not successful.

The precision for the Whatman filter paper runs was relatively poor. The standard deviation of the mean for all of the Whatman runs was about ±24%, ranging from ±9% for Whatman 50 to ±42% for Whatman 541.

Electrostatics data for the four Reeve Angel papers are shown in Table VI. The charging tendency data are all positive. The papers are listed in order of decreasing charging tendency. Some generalizations are possible from the limited data. The "acid" type papers have higher charging tendencies than that of the "base" type and, within these two types, the "strong" types show higher charging tendencies than the "weak". The precision of the Reeve Angel paper runs was much better than that of the Whatman papers. The standard deviation of the mean (overall) was ±8.5% varying from ±4% (WA-2) to ±19% (WB-2).

The charging tendency data for the two commercial aircraft fuel filters are shown in Table VII. Both values are negative. The exceptionally high charging tendency of the Fram CS-58-10 ("Type 10") paper stands out here. The precision of the data for the two commercial papers was rather good, particularly when compared to that of the Whatman papers. The standard deviation of the mean was ±6% and ±5% for the Type 10 and the Velcon papers respectively.

Variations of Charging Tendency Results With Time

Because of the interesting polarity differences exhibited by the Whatman filter papers (Table V), it was decided to repeat and extend that work. This was done about six to eight months later. The results in the measurements with Whatman 40 were quite unexpected. Differences in the charging tendency polarities were observed using the same type of filter paper. This was hard to understand, and the experiment was then varied in two ways. First of all, it was thought that perhaps the "head-tail" orientation of the paper discs might be a factor in polarity. If this were the case, it was decided to use double filter paper discs to see whether the head or tail orientation would make any difference in polarity. Perhaps, it was speculated that a head-tail:tail-head double configuration might cancel out the charge, or perhaps on the other hand, a head-tail:head-tail configuration might increase the charge if the surface phenomenon were additive. An additional filter (Whatman #541) was added to the orientation study.

The results of this polarity vs orientation study are shown in Tables VIII and IX. Several observations were made. First of all, head-tail orientation did not appear to be a factor in the polarity of the charging tendency. Secondly, almost 80% of the Whatman 40 polarities were negative, but when double filter sheets were used (16 runs), it was almost the converse. For the Whatman #541 (single discs, 40 runs), the polarities were almost 70% negative. The 16 double sheets were all negative.

Table IX is an attempt to examine the variability of results (absolute values, overlooking polarity) for the Whatman 40 and 541 filter papers, and also a Type 10 paper over a six to eight month period. The data in Table IX show considerable variation in the charging tendencies (ignoring polarity) over the time period studied. The overall average deviation of 68% is much higher than that previously found for the earlier data, and is very difficult to explain without questioning whether there might have been some change in the fuel sample over the time period of this study.

<u>Electrical Conductivity of JP-5 Sample No. S84-10</u>

To see whether some obvious change in the fuel had occurred, the variation in electrical conductivity of the fuel over the time period involved was examined and is shown in Table X. The initial and final measurements were made at room temperature, 23°C. The second measurement, made under warmer laboratory conditions, was at 27°C. The second value (2.57 pS/m) is a bit high, even if attempting to correct for its somewhat higher temperature (27°). The electrical conductivity of the fuel would be expected to increase with temperature, (10) but even allowing for this, the 2.57 figure is somewhat high. The change in electrical conductivity from the initial measurement of 1.46 to the final one of 1.83, although showing some change, is not excessive.

6.0 DISCUSSION AND RECOMMENDATIONS

The charging tendencies of laboratory filter papers as determined by the EXXON MST method with a JP-5 fuel were relatively low compared to that of commercial fuel filters. So far, no laboratory filters which have been investigated stand out as a candidate of choice to be a reference filter for this work. The two commercial filter papers investigated for this study gave higher charging tendency values, especially the "Type 10" paper. Unfortunately, as has been discussed previously, the goal of this particular study was to find an available laboratory filter paper for this purpose. Aircraft fuel filters, which are not designed with this purpose in mind, may not be uniform between samples, may be withdrawn from the market just because they are high charging or for other reasons. This data, therefore, leave the search for a reference filter unresolved.

Perhaps it would be possible to confer with filter paper manufacturers (laboratory and commercial types) to see whether they might have some suggestions and either have a suitable paper available, or would be willing to manufacture one for this purpose. Because of the very limited use for such a filter paper, however, it would obviously be best to try to find an existing filter for charge density studies.

The problems of variability of results with time, and polarity changes, raise many questions. What caused the variations? Were these the result of compositional changes in the <u>fuel</u> with time? Were they due to problems with the filters? Or were they problems which involved both the fuel and the filter? Were they due to changes in laboratory humidity and temperature?

Even if the study were limited to a single fuel (of constant composition) and a single type of filter, there are environmental considerations which might influence results. These include relative humidity and temperature, both of which were found to vary widely over the period in which these experiments were made. No attempt was made in performing these experiments to prevent moisture adsorption on the filters or the fuel samples while they were being handled. The filters were handled very carefully at all times to keep them from being contaminated with foreign material, but it was not possible to prevent the filters from picking up moisture from the atmosphere.

Another possible cause of problems might be the question of fuel stability and whether the fuel sample composition changed significantly with time. For this reason, it is suggested that the study be made with model fuels whose composition could be controlled and monitored from time to time. Control of the laboratory humidity and temperature are also important. Unfortunately, during the time period of this investigation, because of the building renovation taking place, the atmosphere in the laboratory was poorly controlled if at all.

7.0 SOME SUGGESTIONS FOR FUTURE WORK

Elimination of the Double Syringe System:

It was pointed out earlier in this report that there is variation of flow rate during a given passage of fluid through the MST system. For this reason, it is necessary to determine the flow rates during linear flow for all fuel-filter combinations. This is due to the double syringe system where the air in the upper syringe (Fig. 1) compresses and pushes the fuel through the filter. This problem would be eliminated if a single syringe (containing the fuel sample) were connected to the MST drive.

Integration of Recorder Strip Chart Traces:

For some MST runs there were problems interpreting the current-time traces because of multiple "spikes" in the trace. For most runs, maximum values were used. It is suggested that the output of the recorder be connected to an integrator so that the area under the curves could be measured. This might result in more meaningful data.

Using an Alternative Commercial Filter as a Reference Filter:

If it is decided to select a different commercial filter to replace the "Type 10" paper as a reference filter, it has been shown (1) that the Fram CC-15-1 coalescer (paper or fiber) appears to be a good candidate.

Special Use Filters:

Special filters such as Millipore, Nucleopore, and the like might be investigated for possible use as reference filters.

Fundamental Studies:

The approach of this study was quite empirical and does not really attempt to answer fundamental questions:

What causes the charge build-up as fuel flows through a given filter? What are the constituents and/or additives in the fuel which contribute to charge generation? How do these constituents and/or additives determine the polarity of the charge? How do polar impurities and their combinations play a part in charging? How important is water in the fuel as a participant in charging? Why is a given filter a high charger and another a low charger? Do the physical and electrostatic properties of the fuel play a role? How does electrical conductivity influence charge build up? What are the importance of viscosity, density, dielectric constant, and mobility?

As charge begins to build up, there is an immediate tendency for the charge to "relax". The net charge, therefore, at any given time will depend on the equilibrium between these two opposing phenomena. Charge relaxation has been shown by Goodfellow and Graydon (11) and others to be a diffusion controlled process. It is shown by Bustin et al (12) to be a function of electrical conductivity and ionic mobility as well as other factors. Since both charging tendency and conductivity are both functions of the mobility of the fuel, and since mobility is a function of viscosity, it might therefore be useful to measure viscosity as an additional piece of data for these studies. The additional parameter (viscosity) and perhaps also dielectric constant, may help establish relationships among the electrostatic properties.

The question of what causes polarity differences also remains to be solved. Goodfellow and Graydon (11) observed polarity differences depending on the chemical nature of the polar additives which were used, but they were not able to predict polarity theoretically. Additive studies should be made to ascertain the influence of the chemical structure of additives on the magnitude and polarity of charge density. One of the most important additives which should be studied is that of water.

An extensive literature review of these subjects is given by Leonard (13).

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Figure 1

EXXON MINI-STATIC TESTER

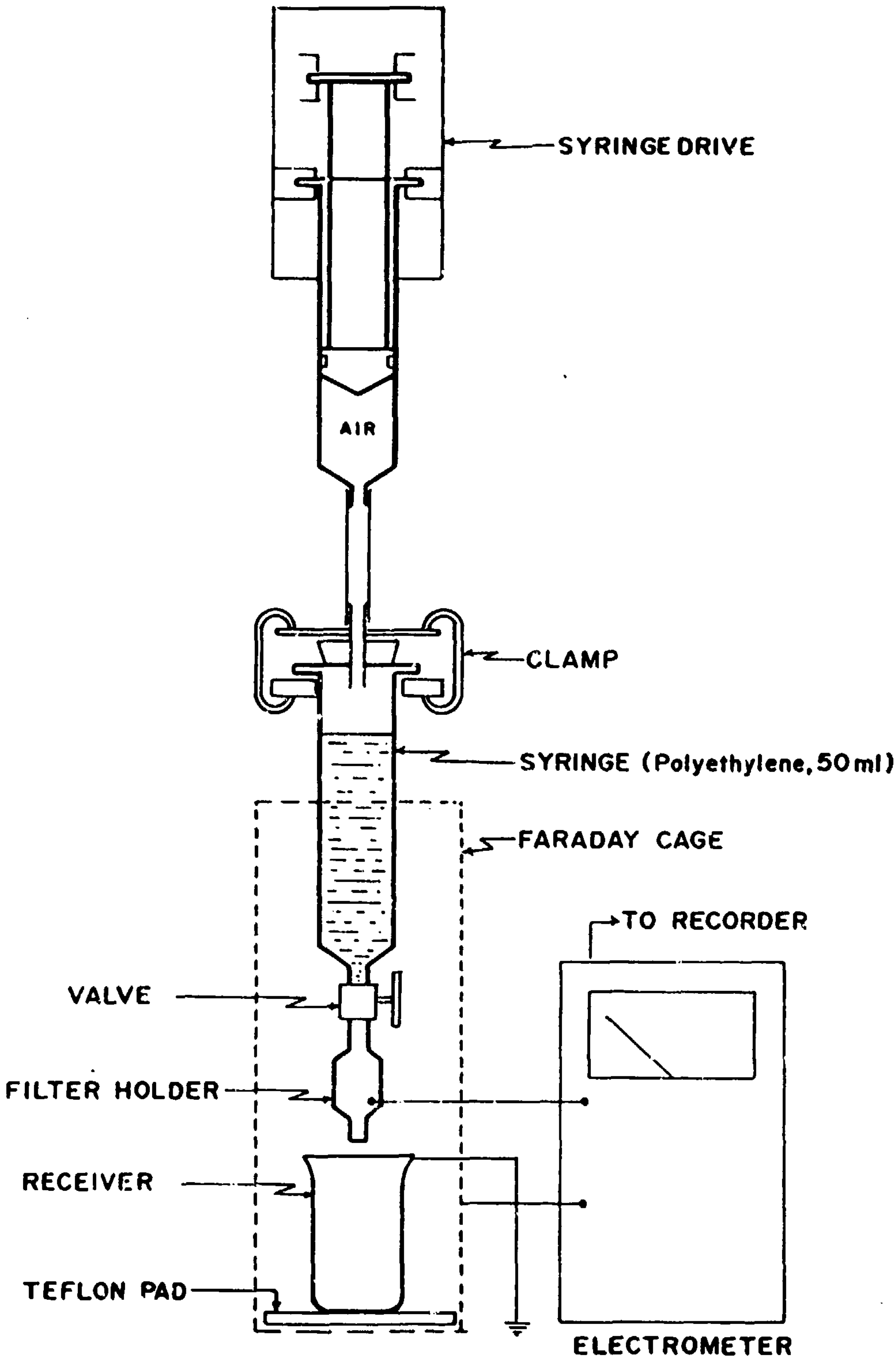

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Figure 2

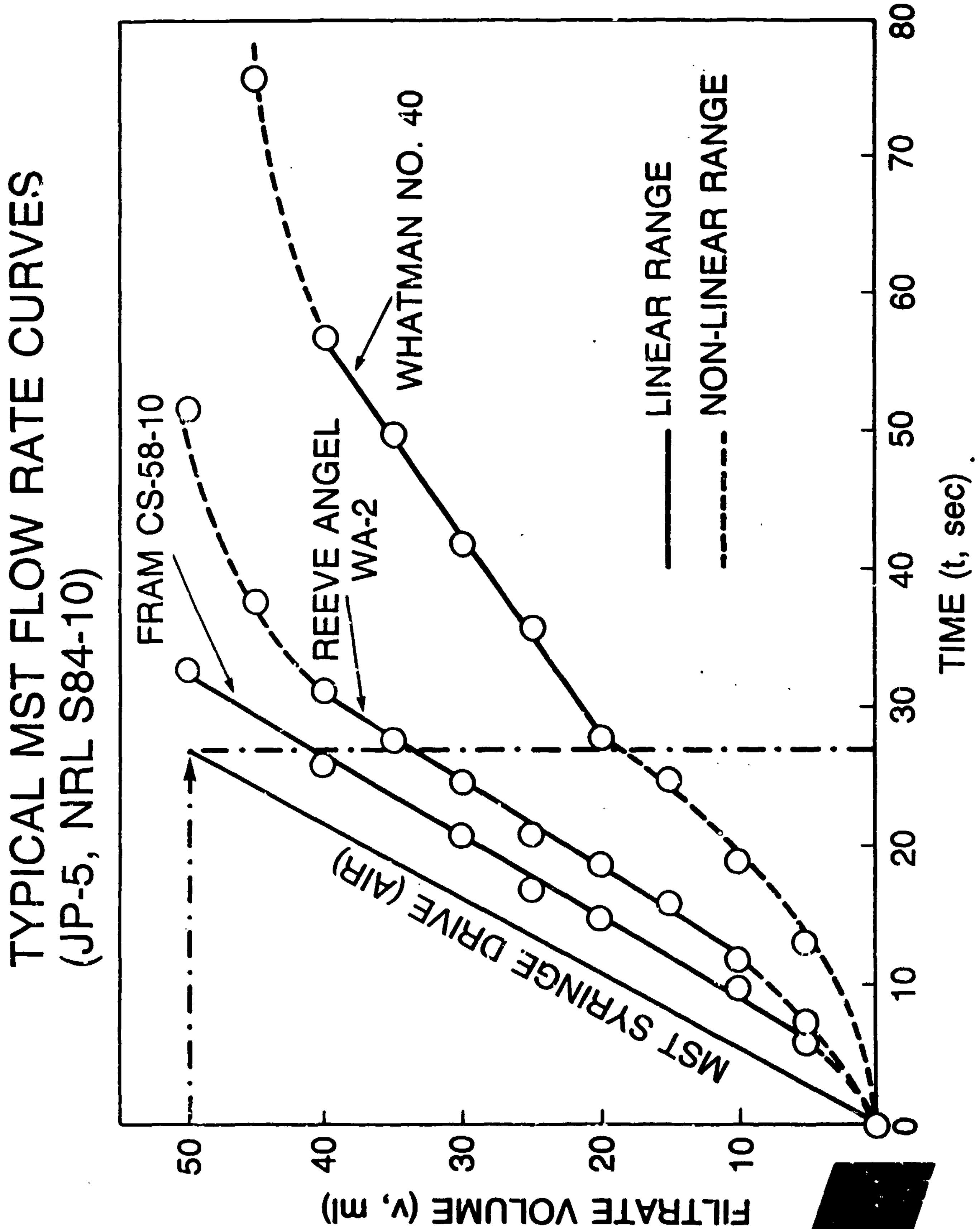

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Table I - Electrostatic Property Ranges of Jet Aircraft Fuels

Fuel	Electrostatic Data (2) Minimum	Maximum	Mean
ELECTRICAL CONDUCTIVITY (pS/M)*			
Jet A (ASTM Spec.) (3)**	50	450	-
Range	0.09	40.5	1.6
JP-4 (MIL. Spec.) (4)	200	600	-
Range	2.42	34.2	6.0
JP-5 Range***	0.8	14.9	2.3
CHARGING TENDENCY ($\mu C/m^3$)****			
Jet A Range	34	5940	670
JP-4 Range	550	4900	1150
JP-5 Range	1600	3900	2380

* - Conductivity determined by ASTM D 4308-83 (5)

** - Limits apply only when an electrical conductivity additive is used. Additives allowed but not required.

*** - There are no conductivity requirements in the military specification for JP-5 (4); the conductivity requirements for Jet A and JP-4 were established after the survey was made (2)

**** - Charging Tendency determined by EXXON Mini-Static Tester (6 - 9) using Fram CS-58-10 ("Type 10") paper

TABLE II - Selected Properties of Whatman Filter Papers*

Grade	Type	Surface	Weight (g/m^2)	Thickness (mm)	Ash (%)	Initial Water Filtration Speed (Secs/100 ml)
40	Ashless, Quantitative	Grained	95	0.21	0.010	75
41	" "	"	85	0.22	0.010	12
42	" "	"	100	0.20	0.010	240
44	" "	"	80	0.18	0.010	175
541	Ashless, Hardened	Smooth	78	0.16	0.008	12
50	Low Ash, Hardened	"	97	0.12	0.025	250
54	" "	"	90	0.19	0.025	10
1	Qualitative	"	87	0.18	0.06	40

* - Based on information supplied by the manufacturer (Whatman, Inc., Clifton, N. J., 07014, Publication 900-LPG-A) and the supplier (American Scientific Products, McGaw Park, Il. 60085, 1987-88 General Catalog).

TABLE III - Selected Properties of Reeve Angel Amberlite

For Exchange Resin Coated Papers*

Grade	Exchanger	Amberlite Resin	Type	Form
SA-2	Cation	IR-120	Strong Acid	Na^+
WA-2	"	IRC-50	Weak Acid	H^+
SB-2	Anion	IRA-400	Strong Base	Cl^-
WB-2	Anion	IR-4B	Weak Base	OH^-

* Based on information supplied on container by manufacturer, Reeve Angel, Clifton, NJ

TABLE IV - Fuel Flow Rate Data - All Filters Using Anti-Static Tester*

Filter	LINEAR RANGE: v = ft + b Volume (v,ml) Range	Time (t,sec) Range	Flow Rate* (f = dv/dt; ml/sec)	Intercept* (b)
WHATMAN				
40	20-40	28-57	0.692	0.46
41	5-40	9-38	1.22	-6.4
42	15-30	35-87	0.29	5.32
44	0-10	58-123	0.081	0.10
541	10-40	11-30	1.60	-8.44
50	5-25	23-70	0.418	-3.04
54	10-40	11-30	1.59	-9.00
1	5-30	13-41	0.906	-7.10
40 (2x)	10-30	26-66	0.497	-1.59
541 (2x)	10-35	15-36	1.23	-8.58
REEVE ANGEL				
SA-2	10-40	11-28	1.75	-9.54
WA-2	10-40	12-31	1.58	-9.32
SE-2	10-45	10-30	1.77	-7.67
WB-2	10-45	11-33	1.62	-8.73
FRAM CS-58-10	5-50	6-33	1.69	-5.06
VELCON I4208C	15-50	11-31	1.75	-3.82

* - Flow rate data using JP-5 (NRL #S84-10); MST power plunger (50 ml Air) = 27 sec, f (Air) = 1.85 ml/sec.

TABLE V - Electrostatic Charging Tendency Data

For Whatman Filter Papers*

Grade	Surface	FLOW RATE f, ml/sec	STREAMING CURRENT I_s, pA	CHARGING TENDENCY** ρ, $\mu C/m^3$
40	Grained	0.692	-134	-194
41	"	1.22	-120	- 98
42	"	0.29	- 28.1	- 97
44	"	0.081	- 16.2	-200
541	Smooth	1.60	+136	+ 85
50	"	0.418	+ 26	+ 61
54	"	1.59	+195	+123
1	"	0.91	+220	+242

* Fuel: JP-5 jet fuel, NRL No. S84-10.
Conductivity (ASTM D 4308-83) = 1.46 pS/m (5)

** $\rho = I_s/f$

TABLE VI - Electrostatic Charging Tendency Data

For Reeve Angel Papers*

Grade	Type	FLOW RATE f, ml/sec	STREAMING CURRENT I_s, pA	CHARGING TENDENCY** ρ, $\mu C/m^3$
SA-2	Strong Acid	1.752	+293	+168
WA-2	Weak Acid	1.58	+137	+ 87
SB-2	Strong Base	1.77	+117	+ 66
WB-2	Weak Base	1.62	+ 57	+ 35

* - Fuel: JP-5 jet fuel, NRL No. S84-10, Conductivity (ASTM D 4308-83) = 1.46 pS/m (5)

** - $\rho = I_s/f$

TABLE VII - Electrostatic Charging Tendency Data For Two Commercial Aircraft Fuel Filters*

Manufacturer	Type	FLOW RATE f, ml/sec	STREAMING CURRENT I_s, pA	CHARGING TENDENCY** ρ, μC/m³
Fram	CS-58-10cid	1.69	-9960	-5890
Velcon	I-4208C	1.75	-358	- 205

* Fuel: JP-5 jet fuel, NRL No. S84-10, Conductivity (ASTM D 4308-83) = 1.46 pS/m (5)
** $\rho = I_s/f$

Table VIII - Variations in Charging Tendency Polarity Over a Six to Eight Month Period*

Whatman Paper*		Number of Runs			Percent	
Type	Sheets	Positive	Negative	Total	Positive	Negative
40	Single	41	49	63	22.2%	77.8%
40	Double	12	4	16	75.0	25.0
541	Single	13	27	40	32.5	67.5
541	Double	0	16	16	0	100.0

* Fuel: JP-5, S84-10.
** No apparent differences were noted resulting from variations in "Head-Tail" orientation of filters.

Table IX - Variation in Absolute Value of Charging Tendency

Over a Six to Eight Month Period*

Filter Paper	Sheets	Number of Runs	Charging Tendency Min.	Max.	Mean	Standard Deviation	%Dev.
Whatman #40	Single	63	34	433	155	100	65%
Whatman #40	Double	16	28	392	130	115	89
Whatman 541	Single	40	4	131	47	36	78
Whatman 541	Double	16	37	163	67	43	64
Fram CS-58-10 ("Type 10")	Single	27	1480	6490	4430	1830	44
						Aver.	68%

* Fuel: JP-5, S810.

Table X - Variation of Electrical Conductivity of JP-5 Jet Fuel Sample S84-10 Over a Fifteen Month Time Period

Date	Temperature (°C)	Conductivity*(pS/m)
2/12/86	23	1.46
3/25/87	27	2.57
5/21/87	23	1.83

* - ASTM D 4308-83 (5)