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STATUS REVIEW NOTE

Work Area: 02 Filter Research
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OBJECTIVE:

To develop novel filters and filter technology, aimed at the development of marketable low-tar products, with particular regard to human smoking patterns.

PROGRESS:

The areas of study are as follows:

(1) Selective Filtration:

Filters which selectively remove nitrosamines, nitric oxide or hydrogen cyanide.

(2) Controlled Smoking Filters:

(a) Fundamental aspects of parameters which affect smoke particle capture;

(b) Concepts for producing filters which will modify the puff-by-puff profile;

(c) Concepts for producing filters which will help in the design of cigarettes having reduced deliveries of gas phase constituents, particularly carbon monoxide.

(3) Filter Technology Development:

Investigate microwave drying technology in order to achieve rapid curing of bonding agents in filter manufacture.

(4) Advisory and Support:

(a) Development, with Hercules, of polypropylene tow and filters;

(b) Evaluation of techniques and materials from external sources;

(c) Design and manufacture of special filter samples for GR&DC and Operating Companies.

1. Selective Filtration

(a) Nitrosamines

The main aim of this work is to discover filters which will remove the volatile non-tobacco specific nitrosamines. The tobacco specific nitrosamines are substantially non-volatile and would be expected to reside in the smoke particles - hence it is unlikely that these can be filtered selectively.

So far, a range of different fibrous filter materials has been examined which includes cellulose acetate control), polypropylene, polyamide (nylon) and polyester. None of these materials was as effective as cellulose acetate but some were only slightly less efficient. There was a suggestion from the results that the addition of the hardener to polypropylene filters increased the filtration efficiencies. Work is in hand to explore this further. Additional future work will include a study of the effect of plasticising level (triacetin) and the effect of changing the filter pressure drop on the filtration of volatile nitrosamines and tobacco specific nitrosamines by cellulose acetate filters.

A further aim of this study is to improve the performance of polypropylene for nitrosamine removal as this material is clearly less effective than cellulose acetate. It is unlikely that it will be possible to chemically modify the nature of polypropylene without help from outside sources.

(b) Nitric oxide

After the decision to terminate the ZORBONITE project, contract work with Brunel University has commenced. This is aimed at understanding why activated carbon is unique for the performance of C-nitroso compounds. If this problem can be solved then it might be possible to find other supports for additives to filters which could remove nitric oxide. So far, techniques for studying the form of the C-nitroso compound on carbon surfaces are being developed. It is anticipated that a further year will be required before the project will be completed.

A second approach which is being pursued is the grafting of suitable functional groups onto the fibres. In this respect, Dr. J.T. Guthrie of the University of Leeds has been engaged as a consultant. As yet, it has not been possible to commence work in this area, but very soon work in CRSDC will be progressed using cellulose acetate as the starting material.

(c) Hydrogen cyanide and aldehydes

No work on this has been carried out so far, but the grafting approach will be used to generate filters for these smoke constituents.

2. Controlled Smoking Filters

(a) Fundamental work on smoke particle capture

This work has been in progress for the last year. Initially it was necessary to develop new methods of measuring the filtration efficiencies when smoke is drawn through the filter at different velocities. A modified smoking machine with a very large piston has been obtained from Borgwaldt. The performance of this machine has been reported. A very sensitive spectrophotometric method for measuring very small quantities of smoke particles in filter tips has been developed. Preliminary studies of the particle capture mechanism, using cellulose acetate and paper filters, have indicated that the general smoke velocity/filtration efficiency patterns are similar to those found some years ago using synthetic aerosols, but the relative contributions of the various mechanisms do not agree with those found previously. One interesting result is that

the filtration efficiency for nicotine decreases markedly as the velocity through the filter is increased. A detailed interpretation of the results is premature.

(b) Filters for modification of smoke profiles

The purpose of this work is to devise methods of controlling puff-by-puff delivery profiles of cigarettes without affecting adversely the "Smoking Mechanics". The study has been directed to evaluating basic principles rather than specific commercial designs.

Working on the hypothesis that the high pressure drop in the HEE filter was the result of immobile tar deposited in the constriction of the filter, several filters were examined designed to ease the migration of tar in the filter and hence relieve the pressure drop. Results obtained suggested that the mechanism by which these filters produced level delivery profiles was inescapably linked to increases in pressure drop. This, combined with the variation in puff volumes and puff velocities observed in populations of human smokers, suggests that controlling deliveries by a velocity-dependent mechanism is impracticable. It is therefore necessary to re-think the approach.

Cigarette deliveries are affected by tobacco blend, tobacco column construction, filtration and ventilation. To control delivery profiles, these parameters would need to change during smoking.

The initial work included controlling tip ventilation as a means of regulating the delivery profile. Normally, ventilation is a function of hole size, number of holes and the balance of draw resistance pre- and post-ventil zone. To circumvent the predominantly linear pressure drop versus flowrate relationship of fixed hole size ventilation, filters have been examined with flaps to provide variable hole size and high efficiency pre-ventil filter sections to increase pre-ventil draw resistance during smoking. The results from some of these designs are encouraging.

Various factors which can change during smoking and hence regulate puff-by-puff deliveries have been examined. The important parameters are length, cross-sectional area, structure, pressure drop, filament denier, tow denier, packing fraction, total surface area and specific surface area.

An initial prototype being examined causes the smoke path through the filter to change and hence alters the effective length of the filter during smoking. The design depends upon the use of small-circumference filters wrapped in porous plugwraps and surrounded by an annular channel down which the smoke passes before entering the filter. Alternative pathways controlled by the changing relative pressure drops as the cigarette is smoked essentially change the effective length of the filter. The design can also incorporate several different filter sections in a composite filter.

Small-circumference filters have been obtained for evaluation of the variable path length filter, both as single filters and as composite filters.

(c) High pressure drop/low efficiency filters

About two to three years ago, GR&DC was asked by BAT (Hamburg) to investigate the possibilities of producing filters which had a

pressure drop of 50-100 mm WG and an efficiency of 20% or less. The filters must be capable of being ventilated. The purpose was to provide draw resistance for highly ventilated cigarettes for reducing carbon monoxide deliveries. Other companies (B&W, Schweitzer and the Celanese Corporation, USA) had realised the attractive potential of this idea.

Two somewhat different approaches were adopted to meet this objective. Attention was given to the possibility of using large-diameter fibres. The main difficulty was obtaining such fibres. Brion supplied 14 and 32 dpf polypropylene, which was difficult to process into filters and the resulting products had filter efficiencies which were too high.

Filters were then prepared using very large nylon filament. It was found that the specification could be met but the filament denier required was well outside the normal range of filter tows and the filter tips were much too heavy.

Meanwhile, attention was directed towards a filter having a small-bore tube sealed into it to provide a smoke passage. A tube about 0.8 - 1.0 mm diameter gave the desired performance and met the specification. Patent coverage has been applied for. Samples have been sent to BAT (Hamburg) and comments are awaited. At present, filters of this type can only be made in the laboratory by hand. If there is a requirement to produce these in quantity, consideration can be given to sealing the tube into cellulose acetate filters by spin moulding. Alternatively, it should be possible to produce filters in which the tube is embedded in closed cell foam, preferably cellulose acetate, or polypropylene.

It is not intended to carry out further work on this type of filter until there are definite indications that these filters are of commercial interest.

Spin moulding of filters was the second approach adopted and the code given to this type of filter was CSF/1. The CSF/1 filter has an orifice restriction to the smoke flow and this restriction is created by the spin moulding operation. Relatively high pressure drop is generated by the orifice and low filtration efficiency is achieved by using high denier per filament tow. For good formation of the orifice it is necessary to use a thermoplastic plugwrap.

Simple tests showed that the CSF/1 filter could significantly reduce the carbon monoxide to tar ratio for low delivery products ($\sim$5mg) whilst retaining good draw resistance. At that stage it was decided to explore the technical and commercial viability of the CSF/1 filter concept at the 5mg delivery level. The objectives were to evaluate the filter manufacturing process (spin moulding) and the assembly of cigarettes, to examine machine smoking performance (including variability in delivery) and to carry out a subjective evaluation. Encouraging results have been obtained for each of these objectives. Recent effort aimed at comparing the subjective qualities of the CSF/1 product with a LOCO product (a "conventional" design stretched to the limit for producing a low carbon monoxide to tar ratio) and a control (conventional) product showed that, with a small group of confirmed low tar consumers:

- CSF/1 and control compared favourably;

- CSF/1 has a subjective advantage over the LOCO product.

All of the products under comparison were designed to give 5mg of tar (FTC/IF); both the CSF/1 and the LOCO products gave a carbon monoxide to tar ratio of 0.5 : 1, whereas the conventional control product gave a ratio of 0.9 : 1.

Currently, work is under way to confirm these initial findings by carrying out a much wider subjective assessment of the three products through conducting a pilot scale consumer test.

To support the work on the CSF/1 filter and to provide opportunities for creating novel filters or products, effort has been directed towards the further development of thermoplastic plugwraps and the spin moulding technology.

The highly porous thermoplastic plugwrap produced for us by Schweitzer has been developed to a point of commercial readiness. In parallel a zero-permeability plugwrap has been developed with Wiggins-Teape. Work is continuing on producing further materials to cover the permeability range in between these. The machine technology centres on a pre-production machine which will now produce CSF type filters (a relatively complicated spin moulding design) at 750 rods per minute in a single operation. Since the Wiggins Teape plugwrap allows the elimination of sealant from this filter, speeds up to 1,000 r.p.m. should be realised soon.

The flexibility and scope of the process is being explored by the creation of a series of novel moulded product ideas which can be produced as a result of having mouldable plugwrap and mouldable tipping papers. These designs are being carefully screened by a variety of techniques, including subjective assessment. It is not intended to go beyond the feasibility stage for these products.

3. Filter Technology Development

Microwave Drying

Following the closure of the Lucas Aerospace Microwave group, attempts were made to establish working relationships with both Philips and Thompson to permit joint development of systems which would meet our objectives. Contractural negotiations were not a success and were brought to an end. Currently, discussions are being held with Raytheon and Westinghouse.

4. Advisory and Support

(a) Polypropylene tow

Discussions on the continuation of the working relationship between GR&DC, Souza Cruz and Hercules have taken place throughout the period but have not resulted in a clear definition of GR&DC's role. Emphasis has remained on the development of a 4.5Y/35000 tow for Souza Cruz which is being test marketed. The development of 2.2Y/28000 tow has not progressed as intended because of these uncertainties, resulting in a

moratorium on joint work with Hercules, so the direction of GR&DC work has been altered towards more fundamental issues and alternative methods of processing fibres. Major studies have included T/WP and selective filtration, subjective assessment of polypropylene filter and hardener properties, initial work on an alternative hardener, measurement of on-machine tension forces generated in tow, and tensile testing. A contract has been placed with Shirley Institute for the development of the scientific understanding of filter hardness. This model is intended to identify whether polypropylene fibres are likely to exhibit different mechanical characteristics to cellulose acetate fibres, because of differences in modulus, surface friction coefficient, etc. Gear crimping may have some value for crimping polypropylene tows and initial studies have been undertaken.

(b) Cellulose Acetate Tow Development:

Several types of experimental cellulose acetate tow are being examined including tows with mixed sized fibres, different crimp forms or large dpf. Main interest lies in obtaining better yield and hardness in rods through enhanced blooming and better crimp forms. This is especially true for lower dpf tows (<2pdf). The quality of crimp and the matching of the crimp and fibre characteristics to the machine capability have been of particular interest.

(c) Sample Filter Manufacture:

A wide range and large number of filter samples have been produced for GR&DC laboratories, product development work and Operating Companies to support research and product projects. This activity continues to provide a base of current filter making capability and know-how from which new ideas can be evolved.

FUTURE WORK:

The current work on the filtration of nitrosamines will be extended to include a study of changing the plasticiser level in cellulose acetate filters. It is also intended to explore the effect of changing the level of hardener in polypropylene filters. In addition, the effects of changing the filter pressure drop will be studied.

Future work on the filtration of nitric oxide and hydrogen cyanide will include a feasibility study of grafting suitable functional groups onto cellulose acetate and, in due course, advantage will be taken of any finding as a result of the work at Brunel University.

The fundamental work on smoke particle capture will be extended to a study of different filter types, including those with different fibre sizes, the overall aim being to discover the important factors which influence the particle capture mechanisms. In the future, it will be necessary to combine this work with particle size measurements as the puff velocity could cause a change in particle size which can change the particle capture mechanism.

Work on filters for the modification of smoke profiles will concentrate for the time being on filter designs in which the effective length of the filter is increased during smoking. Obviously, alternative designs based on this theme will be examined.

The spin moulding technique, together with the associated thermoplastic plugwraps, are likely to figure strongly in the design of novel filters or products, for modifying puff profiles, reducing CO deliveries or imparting other subjectively beneficial characteristics to low delivery cigarettes. Thus most emphasis will be on fully exploiting the potential of the process and extending the range of permeabilities for the plugwraps. Support for CSF/1 filters will continue.

The exploitation of polypropylene tow remains a major goal. It is anticipated that a research programme will be formulated with Hercules to cover areas of knowledge essential to the satisfactory world-wide use of polypropylene tow but which will not be dealt with by the Souza Cruz/Hercules Joint Venture. Areas proposed include selective filtration, hardener and thermal bonding. Some work on alternative texturing may be pursued.

New process techniques or filter materials will be examined for their potential value in filter operations as they become available.