

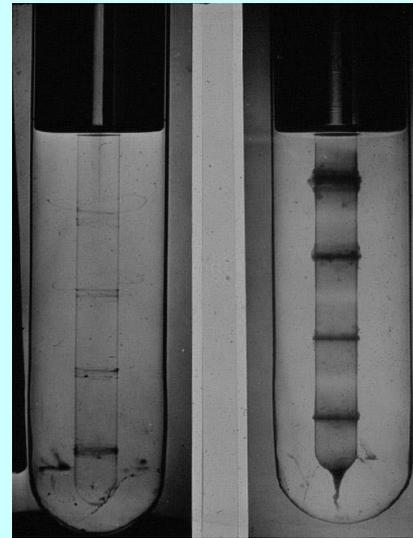
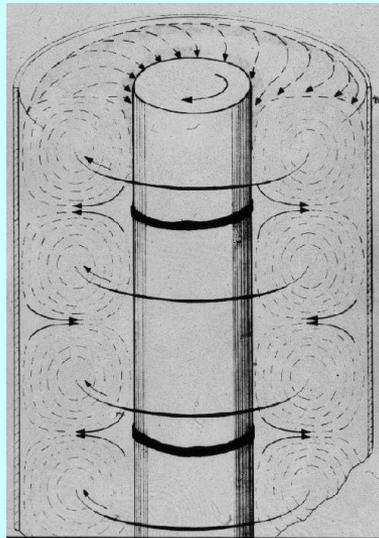
Salcombe Devon 2013

# **High Modulus Polyethylene (HMP)**

**by**  
**Malcolm Mackley**

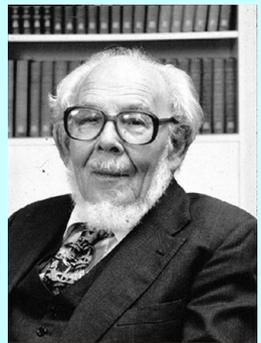
## 1969. Albert Pennings. Groningen

Prof Albert Pennings sends the late Andrew Keller and Sir Charles Frank (University of Bristol) a preprint paper on the way Taylor vortices in Couette flow can induce elongated “shish kebab” crystal fibres of polyethylene from solution.



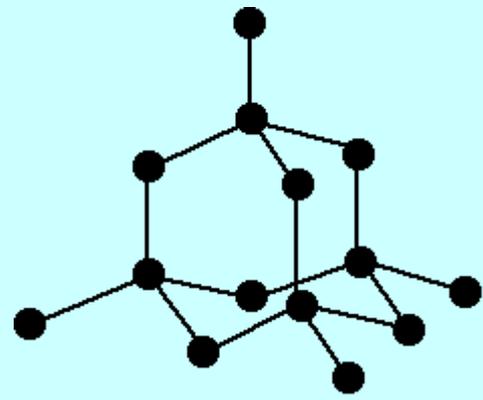
# 1969 Sir Charles Frank. Bristol

Sir Charles Frank, recognised that the unit cell of diamond was similar to Polyethylene (PE) along the *c* chain axis and concluded that PE could have a Young's modulus of order  $E = 210$  GPa if the chains were all aligned. Normally PE has an  $E$  of order 1 GPa

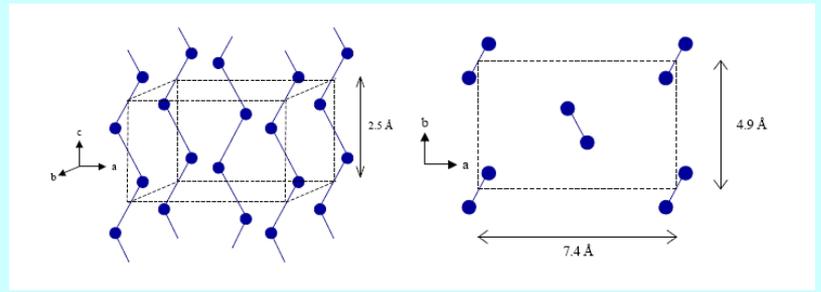


Sir Charles Frank

Diamond



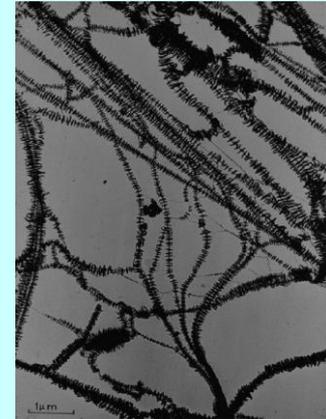
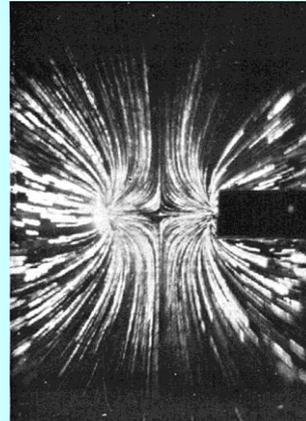
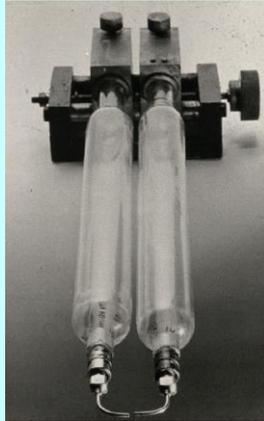
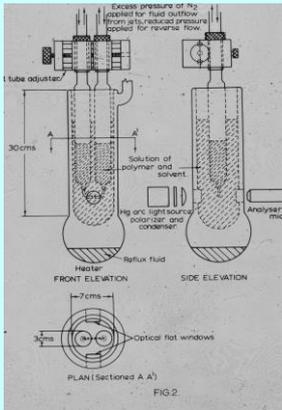
Polyethylene



Frank, F. C. 1970 *Proc. R. Soc. Lond. A* **319**, 127–136.

# 1970-1972 Bristol

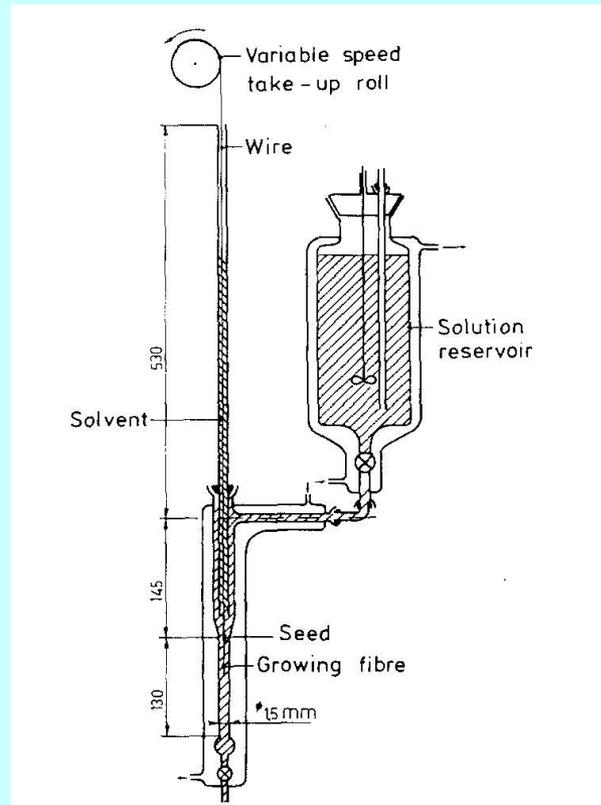
Frank conjectured the extensional flow component of “Pennings” Taylor vortices caused chain stretching and proposed the use of “Opposed jets” to induce sufficiently high extensional strain rates to stretch chains. I, Malcolm Mackley Was the PhD student asked to develop a rig and test the idea.



Localised chain extension was observed from flow birefringence studies and “Shish Kebab” PE crystals formed in an aggregated mass; but with low overall modulus.

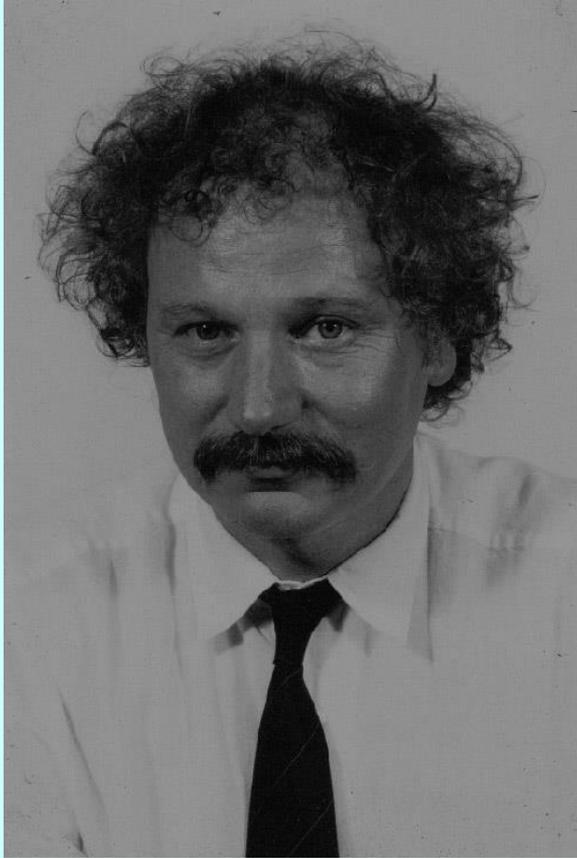
# Pennings 1975

Zwijnenburg and Pennings invent a process for producing continuous lengths of high Modulus polyethylene (HMP) with a modulus greater than 100GPa.



Zwijnenburg, A Pennings, A J Colloid and Polymer Science 1975

1980. Two Dutch scientist. Paul Smith, who had worked with Pennings at Groningen and Piet Lemstra, who had worked with Andrew Keller at Bristol, combined their talents at DSM Holland and invented a batch gel spinning process

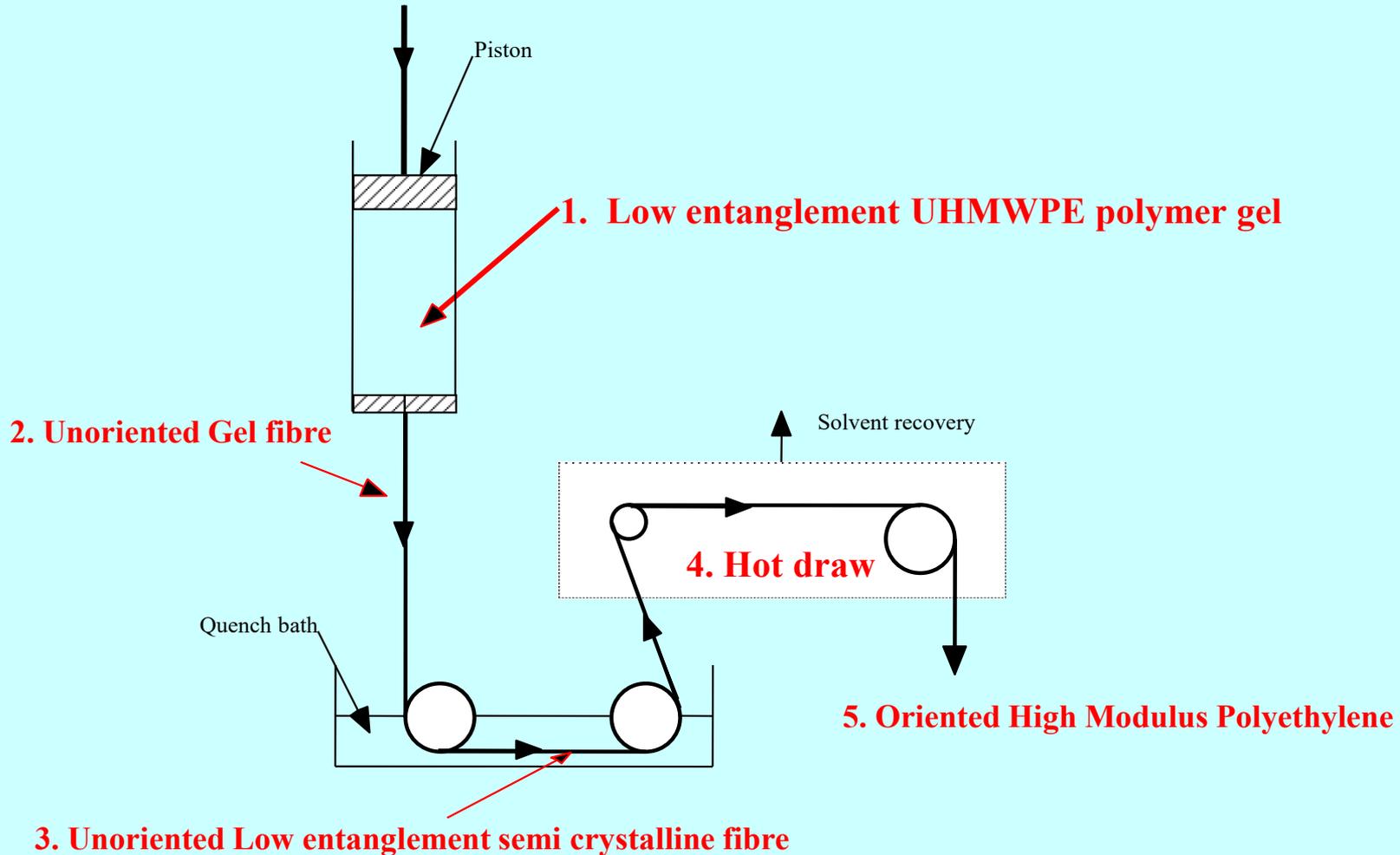


Paul Smith

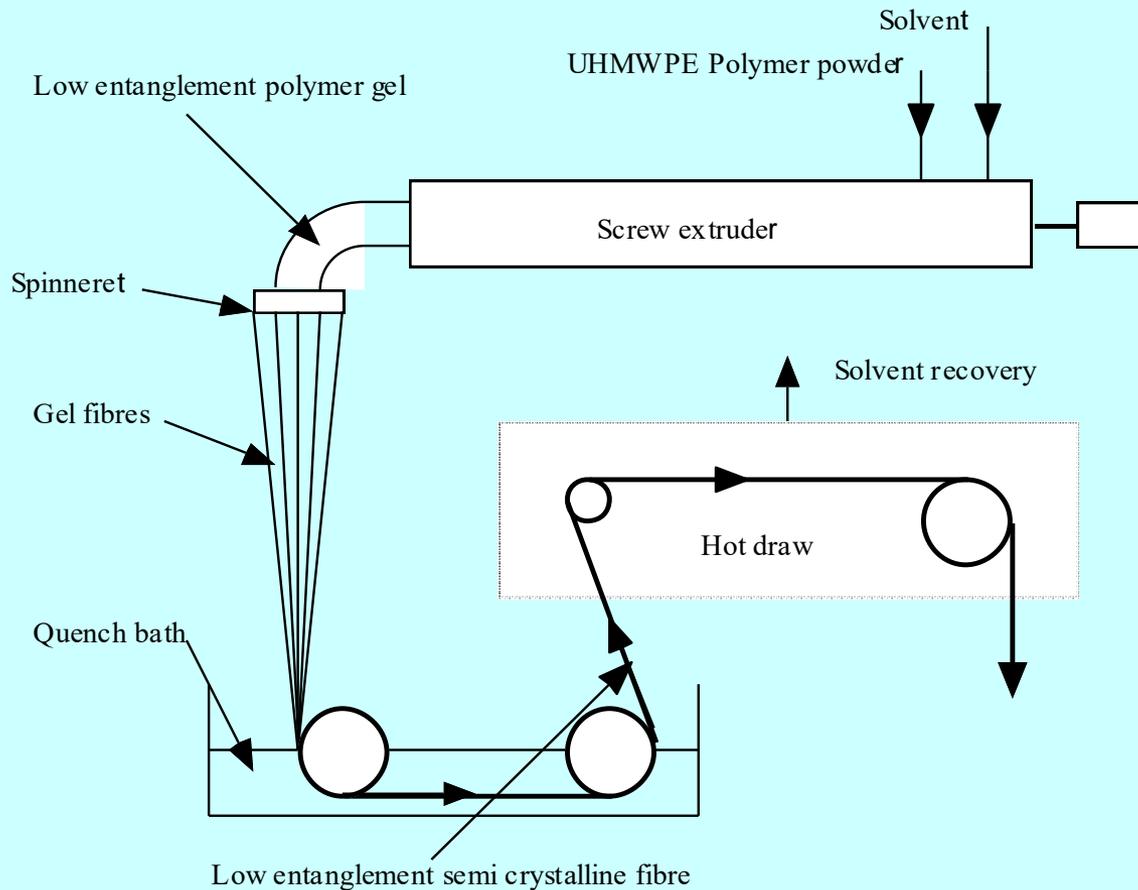


Piet Lemstra

# Ultra High Molecular Weight (UHMWPE) batch gel processing



Subsequently, DSM developed the continuous processing of UHMWPE Dyneema fibre. This used for the first time, solution processing of PE with a screw extruder and this element of the work was pioneered by Han Meijer.



Schematic diagram of continuous High Modulus Polyethylene (HMP) process

# Dyneema® , the world's strongest fiber™

2000. Malcolm Mackley sailing his National Twelve dinghy “Big Issue” at Whitstable. Some of the running rigging was made from Dyneema



## Note added in 2021

- HMP Dyneema has now become global and a massive asset for DSM. The early days were very tentative with fishing lines being the first market. Now Dyneema fibres can be found throughout the Yachting community, body armour and many other applications.
- A relatively new technology Endomax has been developed to manufacture HMP tapes.