TECHNICAL PAPER

# Development of a Range of **Fibre Reinforced Compounds** with **Improved Processing** for **Anti-Extrusion Applications**

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This technical study aims to quantify the reinforcing effect of different loadings and combinations of meta-aramid and para-aramid chopped fibres. By addition of these technical fibres we aim to greatly increase low extension modulus in a variety of rubber materials. These fibre reinforced compounds are predominantly used in the oil and gas industry, particularly anti-extrusion seals.

## Background

Aramid fibres are synthetic fibres well known for their **strength to weight ratio and heat resistant properties**. Aramid fibres gain their strength from the aromatic polyamide molecular chain. The chain forms a highly orientated structure which imparts exceptionally high strength to the material. In a rubber compound it is important to achieve good dispersion of fibres and establish a grain direction in order to optimise reinforcement. Additionally fibre aspect ratio and dip treatment will have an effect on reinforcement.

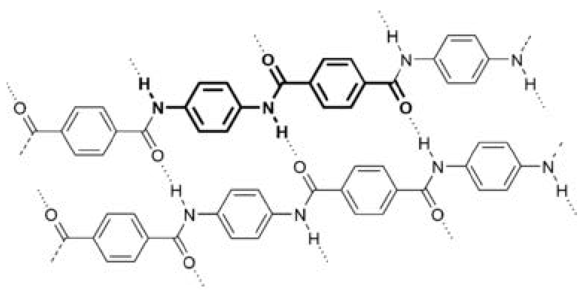


*__Figure 1__ Aramid fibre chemical structure*

## *WHAT TO ASK YOURSELF*

***Are you looking for a compound with improved anti-extrusion processing properties?***

***Do you feel you would benefit from a compound with high modulus values at low elongation?***

***Does your end application require load deflection characteristics at low extensions?***

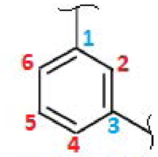
We may have the compound for you, and if we don't currently, we will work alongside you to develop a tailor made compound to suit your application and industry.

## *NOTES*

## Procedure

The test compounds were moulded into sheets for physical testing. We measured various properties including tensile stress, modulus @ 5% and 10% and ultimate elongation; which were tested with and against the grain, using both slow (150 mm/min) and fast (500 mm/min) cross head speeds.

## Results and Discussion



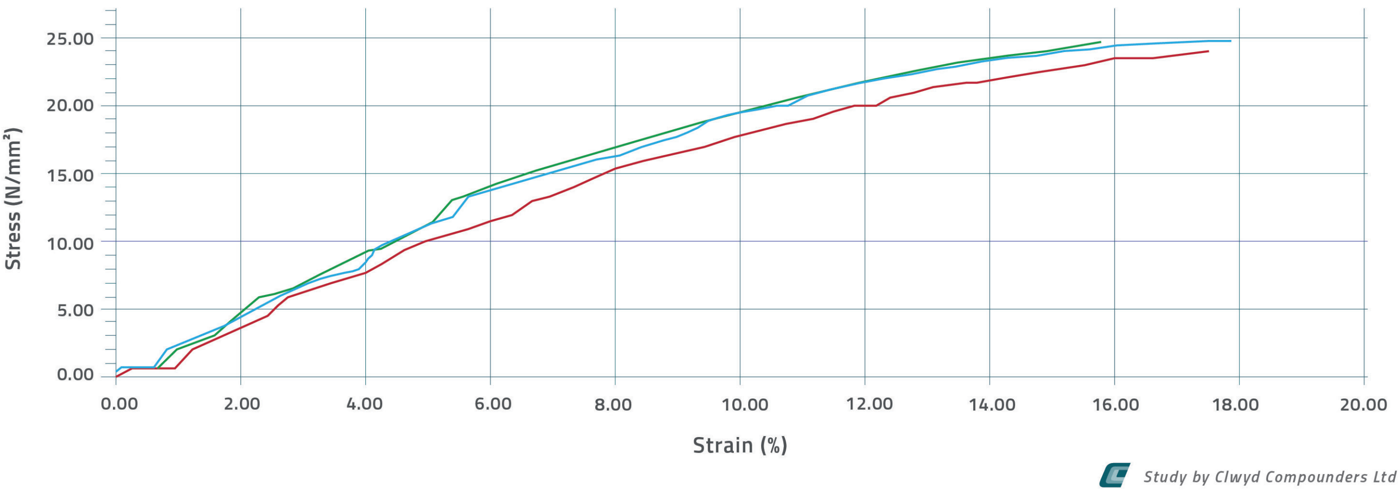
**meta position**

We began our investigation using meta-aramid fibres. This fibre is **very reinforcing**, but not to the same extent as a para-aramid fibre.

The benefit of this is **increased processability** of the compound even at high loadings of the fibre.
It became apparent that a balance of fibre content to polymer content must be struck in order to have a compound that is both processable and has the optimum physical properties. The strength gained from a high fibre loading must be balanced with the drop in elongation to break to produce a suitable compound for the application that can be processed relatively well.

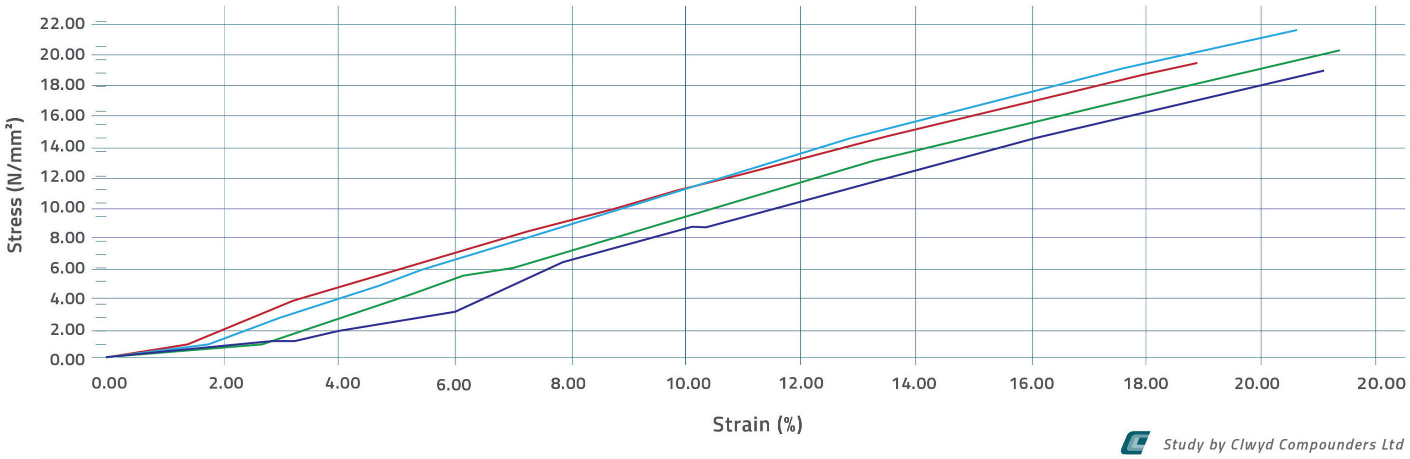
We attempted a high level of the meta-aramid fibre incorporated into a non-black filled FEPM compound and a black filled FKM type 1 compound.

As shown in the tensile plots below low extension modulus is very high for these compounds; the part will **resist deflection at high pressures**. Elongation to break is very low, as expected, and this must be taken into consideration for each application. The part is not designed to extend much, and so a low ultimate elongation is appropriate.



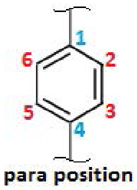

| Test No | Stress @ Peak (N/mm²) | Stress @ 5000 % (N/mm²) | Stress @ 10000 % (N/mm²) | Strain @ Break (%) |
|---|---|---|---|---|
| 1 | 25.023 | 11.185 | 19.440 | 17.868 |
| 2 | 23.909 | 9.858 | 17.824 | 17.585 |
| 3 | 24.701 | 11.347 | 19.570 | 15.848 |
| Median | 24.701 | 11.185 | 19.440 | 17.585 |

***Figure 2*** *FEPM with high level meta-aramid fibre tested with grain at 150 mm/min*



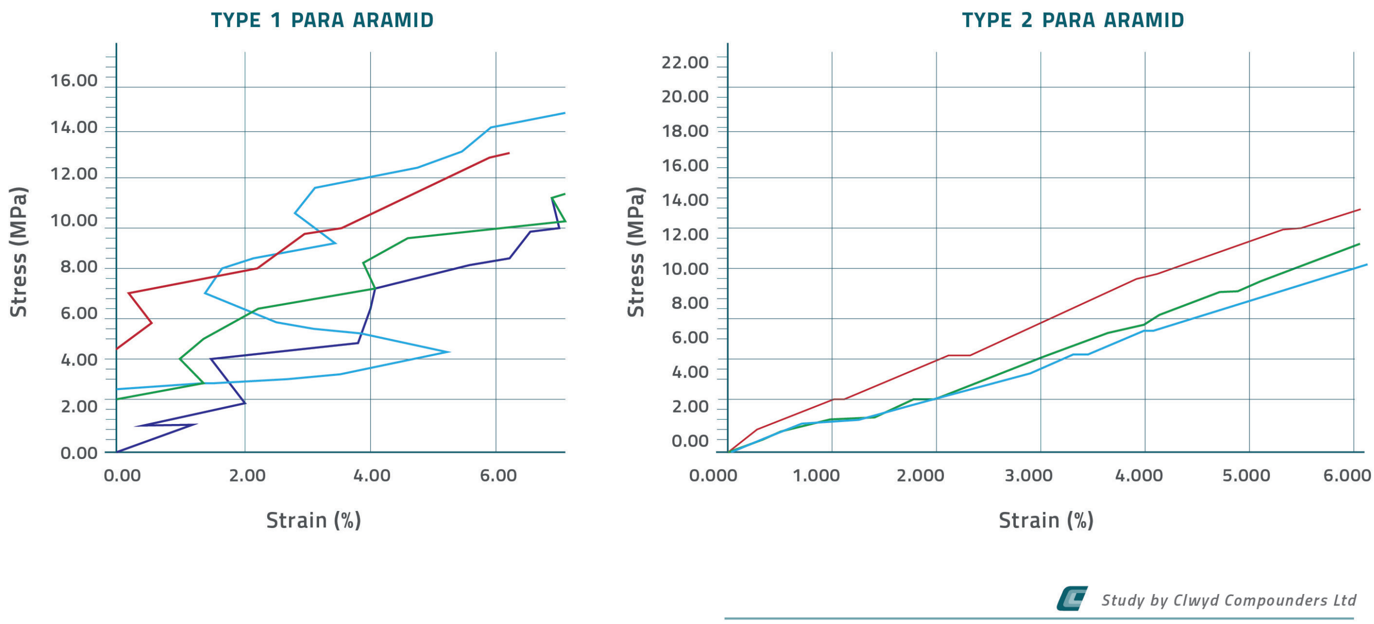

| Test No | Stress @ Peak ($N/mm^2$) | Stress @ 10000 % ($N/mm^2$) | Stress @ 20000 % ($N/mm^2$) | Strain @ Break (%) |
|---|---|---|---|---|
| 1 | 21.776 | 11.401 | 21.204 | 20.648 |
| 2 | 19.598 | 11.299 | | 18.927 |
| 3 | 20.271 | 9.378 | 19.074 | 21.451 |
| 4 | 19.054 | 8.447 | 18.178 | 21.054 |
| Median | 19.934 | 10.339 | 19.074 | 20.851 |

***Figure 3*** *FKM with high level meta-aramid fibre tested with grain at 500 mm/min*




Having established an optimum level of meta-aramid fibre in our compounds we began adding small amounts of para-aramid fibre to **increase the anti-extrusion properties** further.

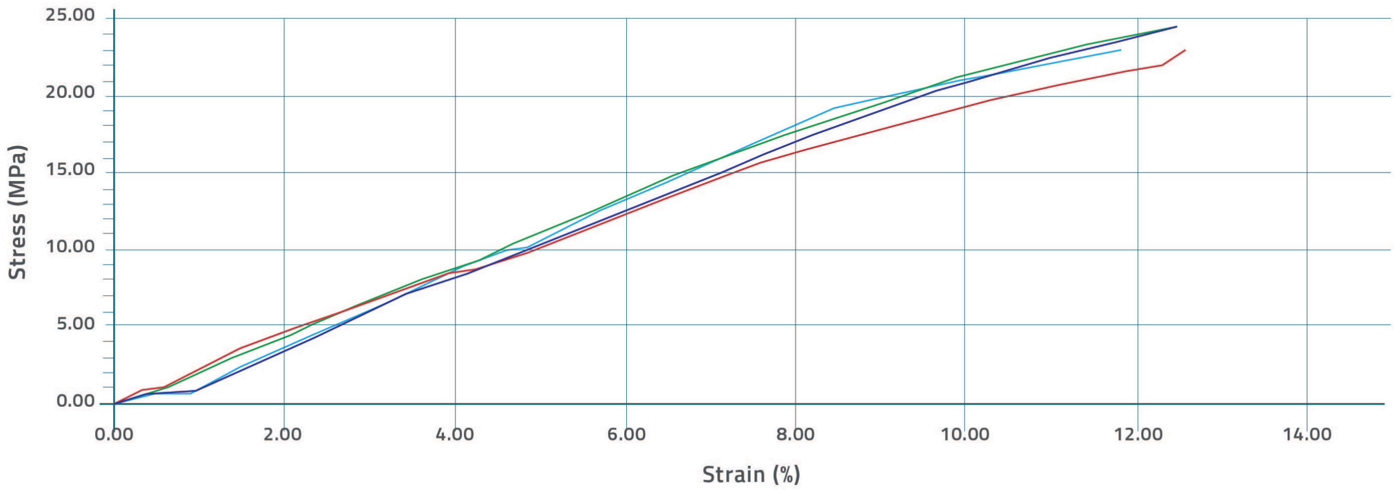
The blend of two fibres allows a **large increase in strength** without dramatically affecting the compound processability. We tried both low and medium loadings of two different types of para-aramid with a high loading of meta-aramid.




| Stress @ Peak ($N/mm^2$) | Stress @ 5000 % ($N/mm^2$) | Strain @ Break (%) |
|---|---|---|
| 18.679 | 8.554 | 10.651 |
| 15.964 | 11.348 | 7.375 |
| 21.594 | 9.579 | 11.644 |
| 21.033 | 9.189 | 10.870 |
| 19.056 | 9.384 | 10.760 |

***Figure 4*** *Comparison of two different para-aramids in an FKM compound measured with grain at 150mm/min*

There is a clear difference in the para-aramid fibres tested. Type 1 fibres do not interact well with the polymer matrix and so act as weak points in the structure. This leads to lower strength and elongation to break. The tensile plot is more erratic as the fibre-matrix interface is broken due to insufficient reinforcement. A low level of fibre Type 2 was chosen as this gave a **good balance of strength and elongation with good processability**.



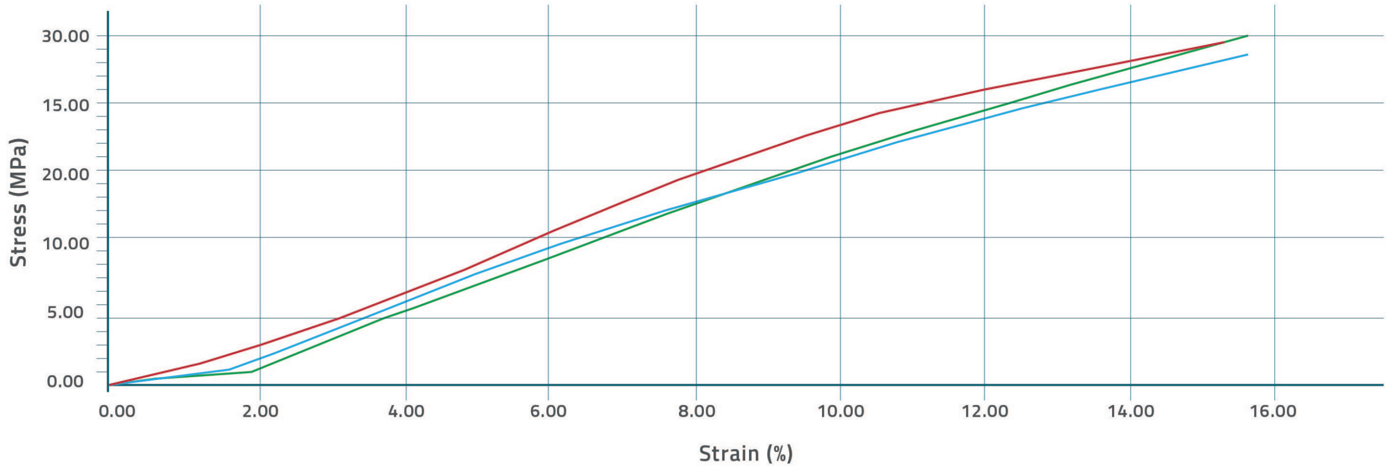

*Study by Clwyd Compounders Ltd*

| Test No | Stress @ Peak (N/mm$^2$) | Stress @ 5.000 % (N/mm$^2$) | Stress @ 10.000 % (N/mm$^2$) | Strain @ Break (%) |
|---|---|---|---|---|
| 1 | 23.028 | 11.085 | 20.907 | 11.833 |
| 2 | 23.142 | 12.041 | 19.770 | 12.590 |
| 3 | 23.364 | 12.032 | 21.353 | 11.440 |
| 4 | 24.551 | 10.709 | 20.850 | 12.482 |
| Median | 23.253 | 11.559 | 20.878 | 12.158 |

***Figure 5** FKM with high loading of meta-aramid and low loading of para-aramid tested with grain at 150 mm/min*

This FKM compound has **high modulus** values and a similar elongation to the previous FEPM compound. The combination of the two fibres imparts a high strength to the compound when tested in grain.

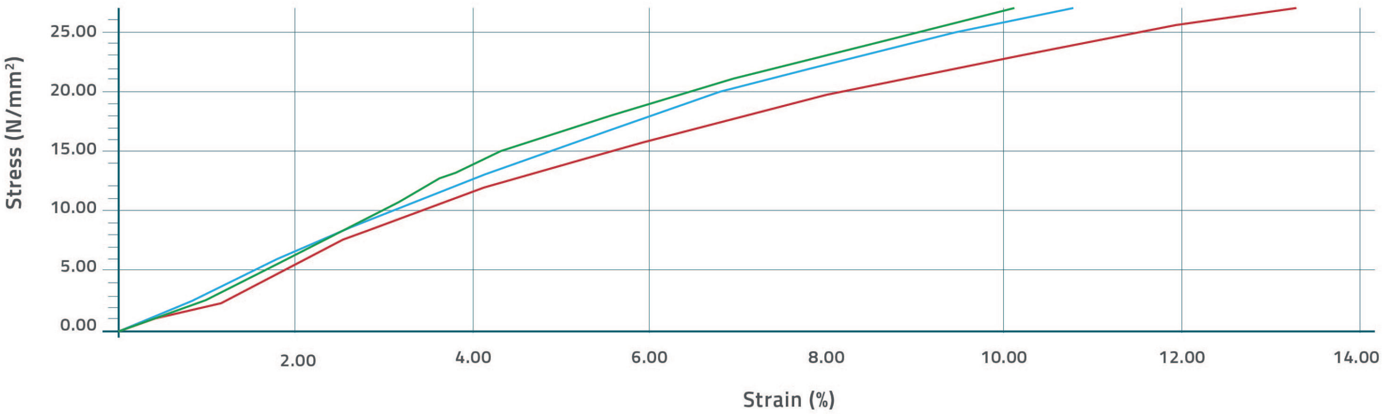
Current anti-extrusion seals are often made by using a high amount of black filler to give a high strength, high hardness compound. As such many engineers are familiar with these stiff seals, and trust their effectiveness. Compounds were therefore stiffened by the addition of a small amount of highly reinforcing black filler, in order to feel like current **anti-extrusion seals**.




Study by Clwyd Compounders Ltd

| Test No | Stress @ Peak (N/mm²) | Stress @ 10.000 % (N/mm²) | Strain @ Break (%) |
|---|---|---|---|
| 1 | 28.431 | 19.425 | 15.635 |
| 2 | 29.604 | 22.307 | 15.350 |
| 3 | 30.235 | 19.827 | 15.725 |
| Median | 29.604 | 19.827 | 15.635 |

***Figure 6** Reinforcing black filled FEPM with established fibre package tested with grain at 500 mm/min*




Study by Clwyd Compounders Ltd

| Test No | Stress @ Peak (N/mm²) | Stress @ 10.000 % (N/mm²) | Strain @ Break (%) |
|---|---|---|---|
| 1 | 29.873 | 25.890 | 12.914 |
| 2 | 28.630 | 22.853 | 14.645 |
| 3 | 31.963 | 26.833 | 13.056 |
| Median | 29.873 | 25.890 | 13.056 |

***Figure 7** Reinforcing black filled FKM with established fibre package tested with grain at 500 mm/min*

By using a careful blend of technical fibres we can **dramatically improve the strength and low extension modulus whilst maintaining low fibre content**. This has benefits in compound processability indicated by maintaining a workable compound viscosity.

Lower compound viscosity allows for easier grain orientation when forming the part to give **high anisotropic strength**.

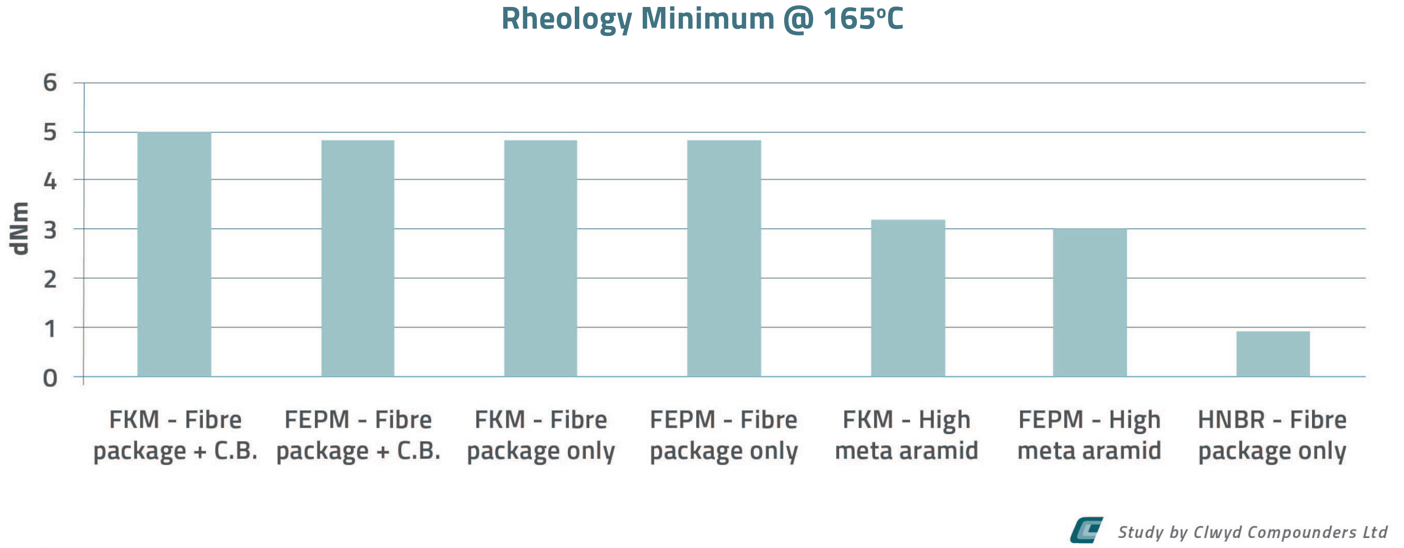



***Figure 8*** *Compound rheology minimum (ML) of a number of samples containing aramid fibres*

## Conclusion

This project shows that by utilising a combination of meta-aramid and para-aramid fibre we can achieve a compound with **high resistance to extrusion**; indicated by high modulus values at low elongation. Fibre loaded compounds remain difficult to process but by reducing compound viscosity **improved reinforcement**, from fibre orientation in the matrix, is achievable.

Clwyd Compounders can develop a range of bespoke fibre enhanced compounds for many processes and applications. These compounds target applications requiring particular load deflection characteristics at low extensions. By incorporating these aramid fibres into high quality synthetic elastomers we can produce highly chemically resistant and temperature resistant compounds for very demanding high pressure applications. These types of elastomeric compounds will be in greater demand in the future as the oil and gas industry attempts to drill deeper wells in more extreme environments.

## GET IN TOUCH WITH OUR TECHNICAL TEAM TO DISCUSS YOUR REQUIREMENTS FURTHER

For further information on polymer types and grades used in this paper please visit our website **www.clwydcompounders.com** or call to speak to a member of our technical team +44 (0) 1978 810551.