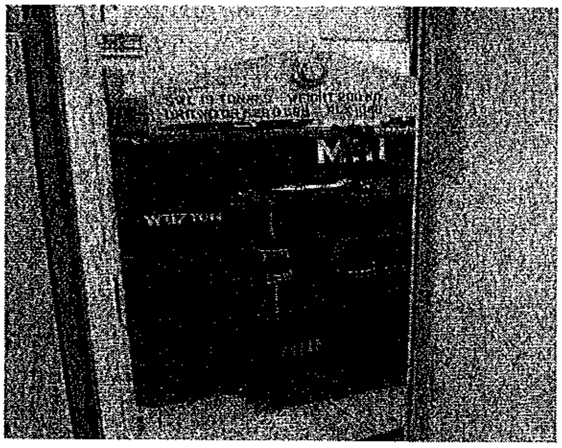
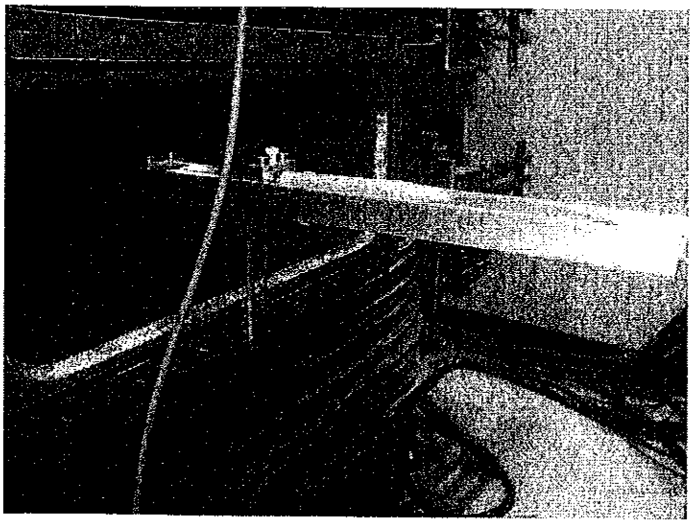
Main Dipole D1 Measurements, *K. Tilley*

The M1 dipole, proposed to be used for the first bending dipole in the MICE beamline, was transferred to the ISIS magnet/power supply test area in R6. It was connected up to a 200kW power supply, and fed with demin water cooling.



To measure the magnetic field, a Hirst GM05 handheld Gaussmeter was used, together with the standard transverse Hall probe (PT4500).

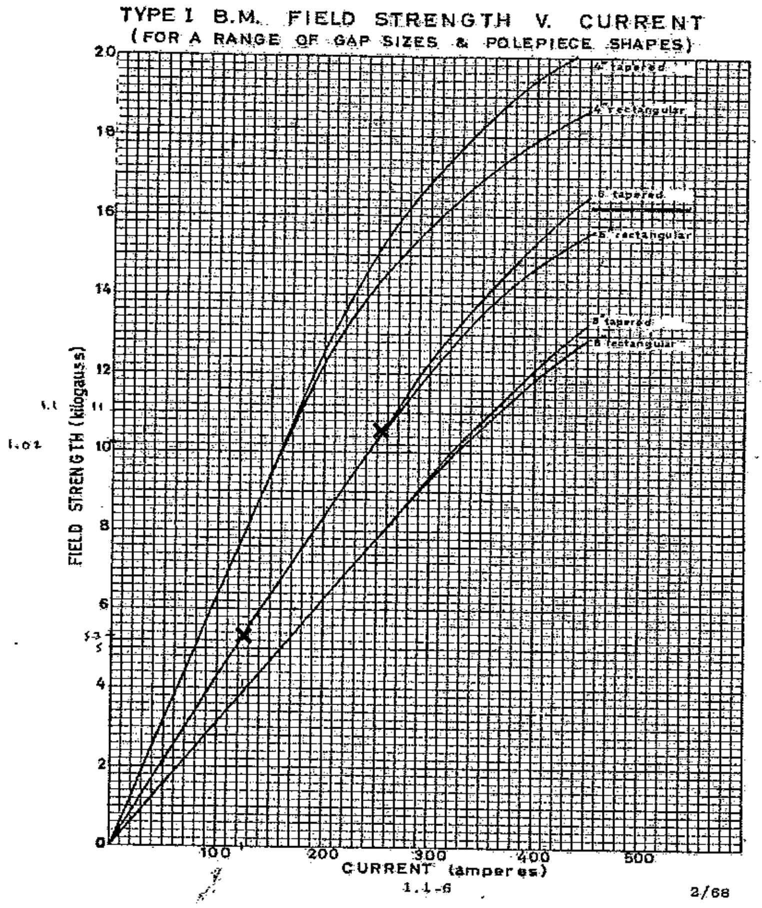
A number of items were acquired or manufactured to support the Hall probe in position. The vacuum chamber from the old HEP beamline was purposefully left in the magnet to allow use of its fixture points. A 2 metre long rail was then connected to the vacuum chamber, and the Hall probe was mounted in a small carousel, which both held the sensor upright, and which could slide along the rail to an arbitrary position.



The principle aim of the experiment was to confirm that the magnet was delivering the correct fields, as this magnet was intended to steer the beam out of the ISIS synchrotron hall. A set of central field measurements were taken in order to check this. The effective length was also measured.
Further measurements included a short exploration of hysteresis. Also sextupole components in the fringe fields. The later experiments weren't quite as successful.

Field measurements versus current.

The Hall probe was positioned into the centre of the magnet, and the currents were set at 125Amps, and 250Amps (maximum output from supply). The field values were found to be 0.534Tesla and 1.053Tesla respectively. Errors on the field measurements are +/-1.5% and on the current ~ +/-2Amps. Correspondence with tabulated data is shown below:-



The measurements agreed very well with the tabulated data.

Effective length

The effective lengths were measured at both 125Amps and 250Amps. This was done by making a number of 5cm markings along the lead of the Hall probe, together with measurements of the geometry, and pulling scanning the probe through the field.

The Hall probe lead was not long enough to allow a scan of the whole 2metre long field in one attempt, and partly because of this, the effective length was reconstructed from the centre outwards in one direction.

Data from the I=125Amps, 0.534Tesla case is shown below:-

z from ctr/pole (cm)	Field (T)
-10.28	0.534
-5.28	0.534
-0.28	0.534
4.72	0.534
9.72	0.534
14.72	0.534
19.72	0.534
24.72	0.534
29.72	0.533
34.72	0.532
39.72	0.523
44.72	0.473
49.72	0.328
54.72	0.219
59.72	0.1383
64.72	0.081
69.72	0.0448
74.72	0.0247
79.72	0.01391
84.72	0.00869
89.72	0.0046

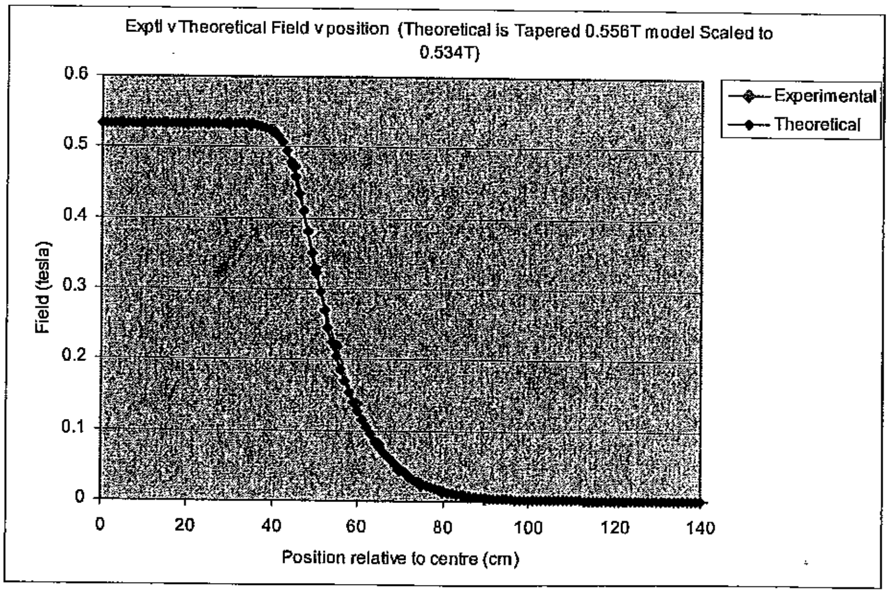
So at B0 at centre is 0.534 T

Half Leff = :=(2.36*0.534+SUM()*5)*/0.534 54.73828

So Leff = 109.4766

Care was taken in both the limits of the integral and its evaluation as seen above. Errors in the field measurements are again ~+/-1.5% and the error in the position is estimated at +/- 0.2cm max. The effective length is estimated to be 109.5cm+/-2cm.

The raw data and the extracted value were compared to the Opera3d model of the magnet. The closest excitation and field value available was 0.556Tesla, which was scaled down to 0.534Tesla to allow comparison below:-



The theoretical effective length at this excitation is 1.091 metres, compared to the measured value of 1.095m +/- 2cm. Quite remarkable correspondence between the field map values and measured points are also seen.

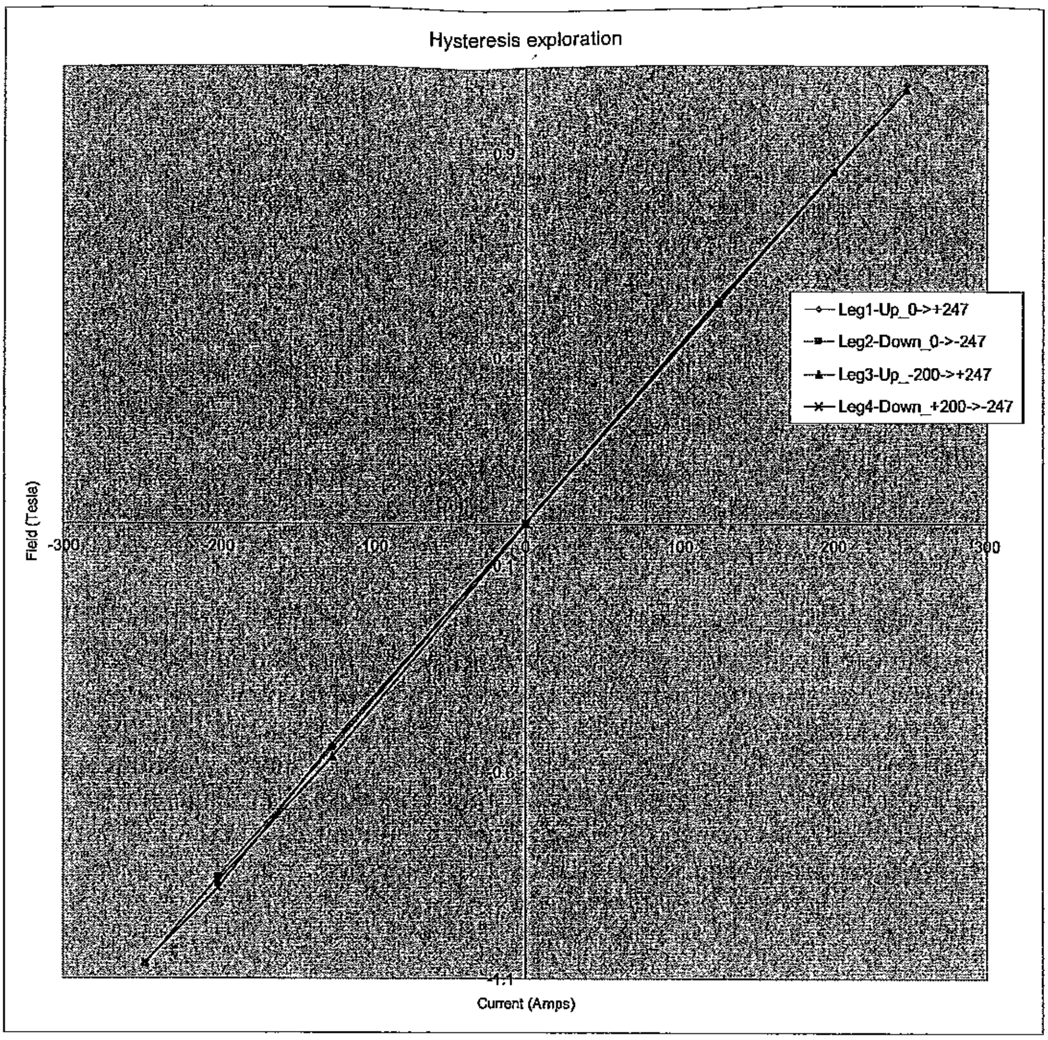
At I=250Amps, 1.055Tesla, the theoretical effective length is 1.088metres, compared to a measured value of 1.103metres +/-2cm.

It should be noted that the effective length is a function of excitation (field) and changes as the magnet enters saturation (it becomes shorter). The quoted value of 1.038metres is for a standard aperture (6" as per here) and excitation (1.55Tesla) (and pole geometry). This field value wasn't reachable in the current experiment, but the model gives 1.053 for this case, suggesting it may be slightly overestimating the real values.

Hysteresis & Standardisation

An attempt was made to look for the presence of hysteresis in the limited range 0 to +/-250Amps. This was the maximum available from the power supply and indeed lower than the desired operational saturation values at ~ +/-450Amps.

To search for hysteresis effects, the magnet was run through 1¾ cycles and the field values plotted on top of each other during up & down directions. The results are shown below:-



In summary, a trend was seen which was consistent with hysteresis:-

- down-direction values were higher than up-direction values at 0Amps
- most down-direction values were higher than up-direction values at finite Amps

However, there was also uncertainty in some of the data.
Some up/down field differences were ~ 0.01-0.02Tesla, although the differences at 0Amps were consistently less than ~0.002Tesla. Two readings were also found which didn't fit in with the expected pattern.
The uncertainties here are attributed to instability in the final current settings from the 200kW power supply, and perhaps lack of stability in temperature at each reading. Because of this it wasn't felt possible to assign a hysteresis up/down field difference with confidence.

Data from a standardisation experiment isn't reported due the spurious readings, however a possible practical approach was sourced in the literature.[1], although there maybe others.

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[1] The Physical Way of Standardising Magnets, Franz-Josef Decker, SLAC-PUB-5483 May 1991

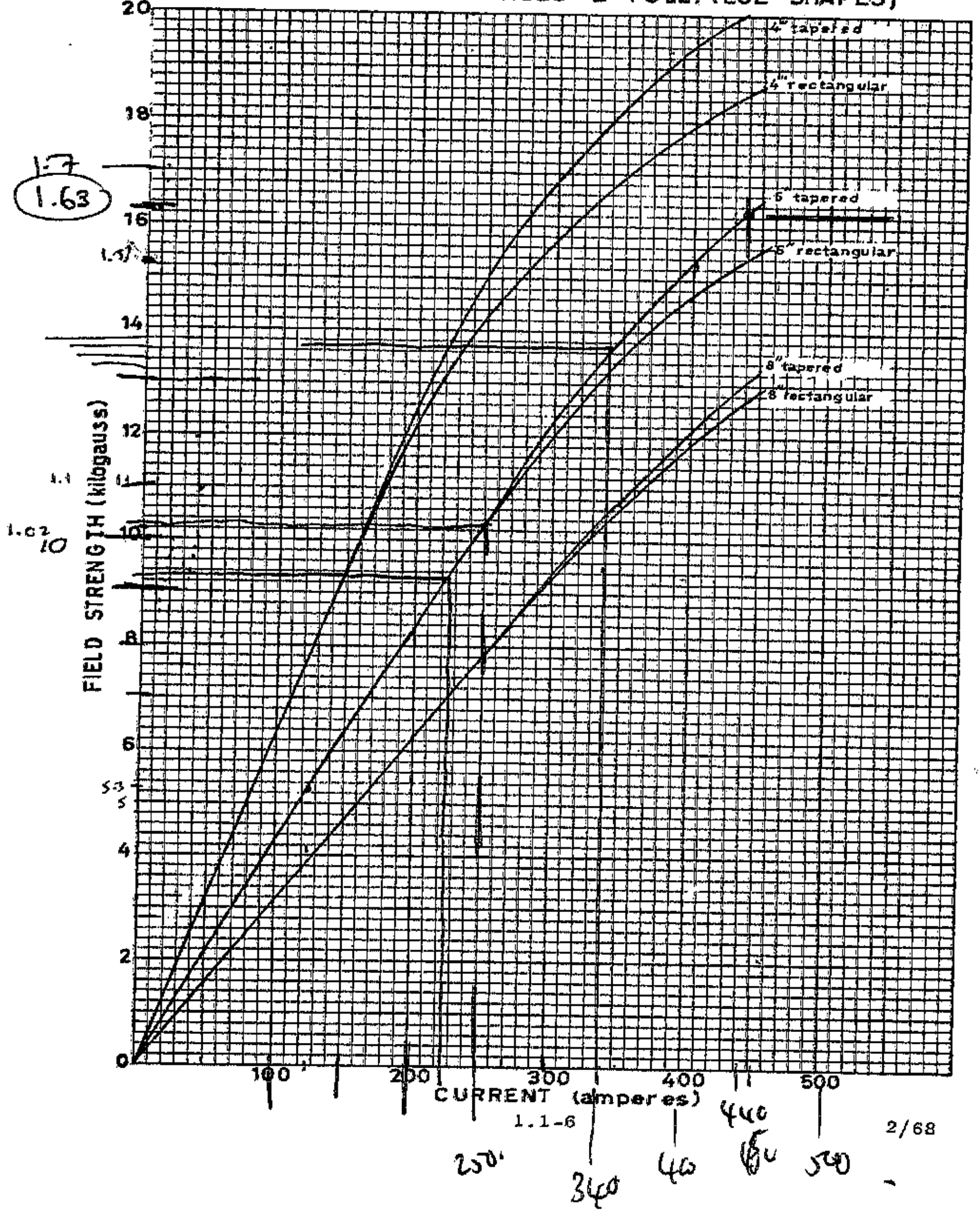
It is recommended that a search for hysteresis effects is attempted when the full current is available to the magnet. A careful experiment with this supply should help determine the magnitude of any effects, and if it is large enough to warrant deriving a standardisation procedure or not. (One criteria is to what accuracy MICE can measure p_z and p_tot). It would be of interest also due to current concept to use B2 as a steerer.

Sextupole Component

An attempt to measure this was made by scanning the field across the aperture horizontally, at fixed z-value.

This was not very successful for at least two reasons.
One was due to the limited x-range allowed from the presence of the vacuum chamber. It was also important to have good reproducibility in the z-position of the probe when different x-positions were sampled, since the field was dropping off quite sharply in the fringe fields. Together with the inherent accuracy of positioning of ~ 0.2cm relative to the rail & the movement of the rail between readings, it was difficult to reproduce the z-position accurately enough for different x-values. Large variations were seen in the results and were attributed to this problem.

TYPE I B.M. FIELD STRENGTH V. CURRENT
(FOR A RANGE OF GAP SIZES & POLEPIECE SHAPES)



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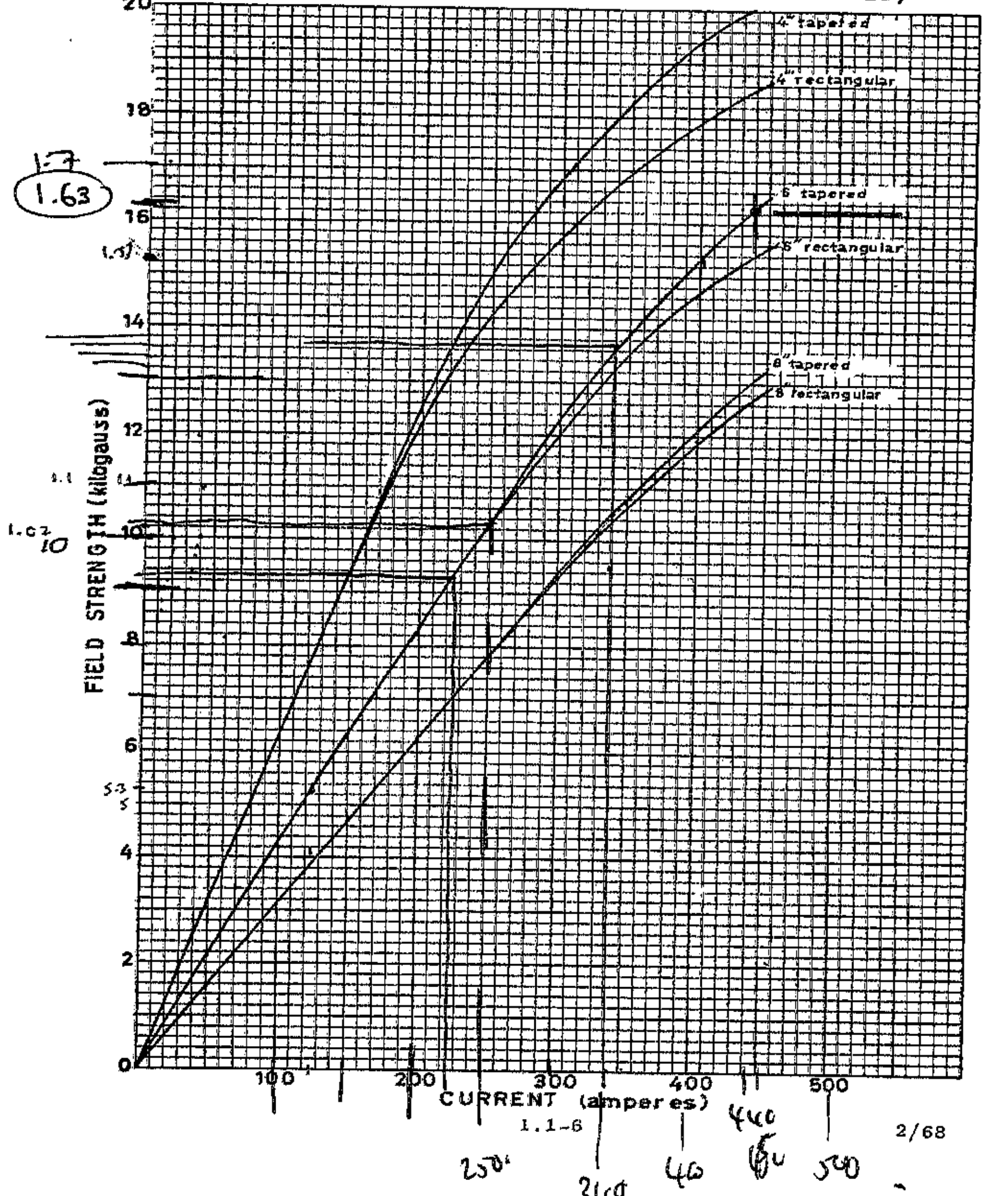
TYPE I B.M. FIELD STRENGTH V. CURRENT
(FOR A RANGE OF GAP SIZES & POLEPIECE SHAPES)



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