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THE MAGNETIC FIELD OF THE BRITISH 1.50 m BUBBLE CHAMBER (B.N.B.C.)

REPORT ON THE MEASUREMENTS

PS/4114/jc

THE MAGNETIC FIELD OF THE B.N.B.C.

Measurements of the properties of the British 1.50 m Bubble Chamber magnet have already been done by W.H. Evans et al. (NIRNS informal report). For the purpose of picture analysis, however, it seemed desirable to produce a numerical listing of the magnetic field inside the chamber volume with as high an accuracy as possible.

The field outside the chamber volume, and inside the magnet yoke, has also been surveyed. The listing will be completed soon.

The magnetic field distribution of the B.N.B.C. magnet was measured when the chamber itself was not yet mounted. At 8 000 and 10 000 amps excitation current we recorded both the absolute field at the centre and the relative deviations from the central value throughout the volume to be occupied by the chamber.

A. Absolute field at the centre

The nuclear magnetic resonance method was used. It indicated that the field at the geometrical centre was

12.269 $\pm$ 0.010 kgauss at 8 000 amps excitation current and
14.787 $\pm$ 0.010 kgauss at 10 000 amps excitation current,

the current being measured by a manganin shunt with number 15 675/62 (Wolff) and a bridge XXX (AIOP).

The main contribution to the errors stated comes from lack of reproducibility after changing current and polarity. (With the field gradient zero at the centre, bad positioning of the probe would have a negligible effect.) We attribute these effects to mechanical deformation and hysteresis.

With zero excitation current we found 4 $\pm$ 2 gauss at the centre of the empty magnet.

B. Relative field inhomogeneity

A Hall plate (Siemens FC 34) was moved on a chariot throughout the volume and an identical one was kept at the geometrical centre of the magnet. Both plates were supplied by almost equal currents with a highly constant ratio, the difference of the Hall voltages, together with the position of the chariot, was written down by a recorder and later evaluated from the paper. The Hall plates having been calibrated against a proton magnetic resonance probe recorded this way the magnetic field component along the camera axis with respect to its central value every 5 cm in space. These measurements were done at 10 000 and 8 000 amps excitation current.

Results

The percentage deviations at both excitation currents were found to be equal for almost all points inside the visible region of the chamber to be inserted.

Therefore, at each point the two percentage field deviations were averaged, punched on cards and listed in an IBM printout. Note that a positive number describes a percentage deviation to be substracted from the central field value.

The card deck as well as the listing of the full 5 x 5 x 5 cm grid (4 000 points) are available in the TC Division.

Fig. 1 - 3 show equifield lines in six different planes in the volume to be occupied by the chamber. One can see that no inhomogeneity above 3 o/o will be of any importance.

Coordinate system

We use a right handed rectangular coordinate system defined by 3 copper marks, A, B, D, on the camera side of the magnet yoke such that DA is the x-direction and the perpendicular to DA through B is the y-direction, (see fig. 4). There are altogether 4 copper marks attached to the yoke, the coordinates of which, together with the ones of the central reference point, are given in the table (in m).

	x	y	z
Reference point	1.800	0.365	0.320
A	3.233	0.365	-1.641
B	1.798	1.303	-1.641
C	1.797	-0.613	-1.638
D	0.437	0.365	-1.641

In order to evaluate photographs, the fiducials on the chamber windows with respect to A, B, C, D must be known.

Measurement errors

The main error contributions come from the positioning of the chariot. They are systematic in character and have therefore not been subjected to a least squares fitting procedure. An estimate of the errors can be obtained from consistency checks in the coordinate system under measuring conditions and from the difference between the two percentage field deviations at 8 000 and 10 000 amps excitation current. The distribution of differences at 4 000 points measured (fig. 5) indicates that 90 o/o of all points had equal relative field deviations within $\pm$ 0.12 o/o, one half of which will go into the error of the average.

The chariot position with respect to the copper marks A, B, C, D is estimated to be correct within 5 mm at any point. With a gradient of 0.2 o/o per cm - which is not exceeded within 95 o/o of the volume of the chamber to be inserted - we arrive at a maximum error contribution of 0.10 o/o.

Measurement errors, summarised

By adding these contributions to the error of the central field we obtain the total error of

$$\Delta H = \pm 0.25 \text{ o/o}$$

at the points measured.

Other errors

The magnet must be taken apart when the chamber is built in. Whereas it is safe to assume the inhomogeneity will not change, the field at the centre depends strongly on the distance of the two coils, and a remeasurement after each magnet splitting cannot be avoided, if the error is to stay low. Also the influence of the stainless steel vacuum tank to be put into position can be checked this way.

When correllating the coordinate system A, B, C, D with the window fiducials the relative positions should be known within 2 mm. If uncertainties of 5 m/m (10 m/m) creep in, the total error will go up to $\Delta H = \pm 0.30$ o/o (0.35 o/o) in a systematic manner in certain regions of the chamber.

When the field at a given point is found by linear interpolation the interpolation error is negligible.

Extraction for TITLE 3 of GRIND

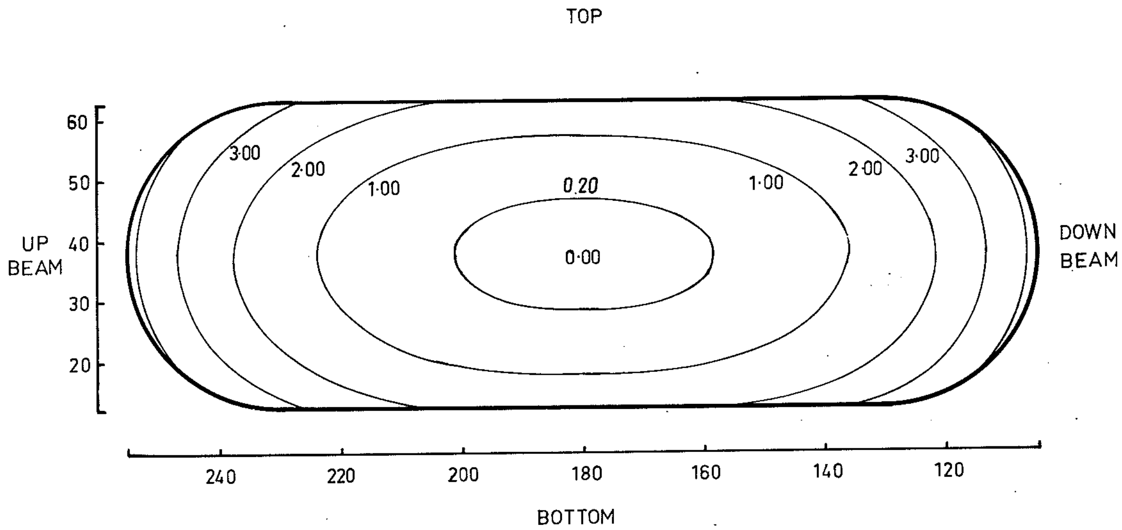
G. Kellner has prepared a TITLE 3 field table by omitting some x - positions, thus reducing the number of table values to 1430. He took care to keep the average extra error from linear interpolation below 1/10 of the ΔH stated above.

Acknowledgements

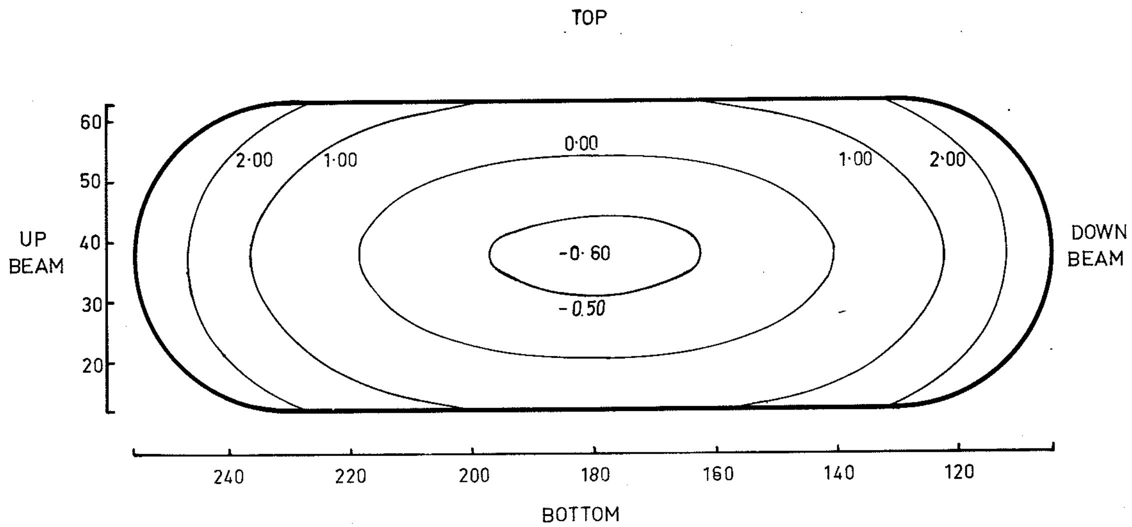
All of the work of running the magnet and of the recording was done by the entire 02-beam group and the bubble chamber group. J. Rushbrooke did the N.M.R. measurements. We are very thankful to G. Petrucci for letting us use his apparatus, as well as to Mrs. S. Miller for carefully listing the recorder readings.

W. Blum

B.N.B.C. FIELD INHOMOGENEITY
PERCENTAGE FIELD DEVIATION FROM CENTRAL VALUE



VERTICAL SYMMETRY PLANE CONTAINING BEAM
(CAMERA VIEW)



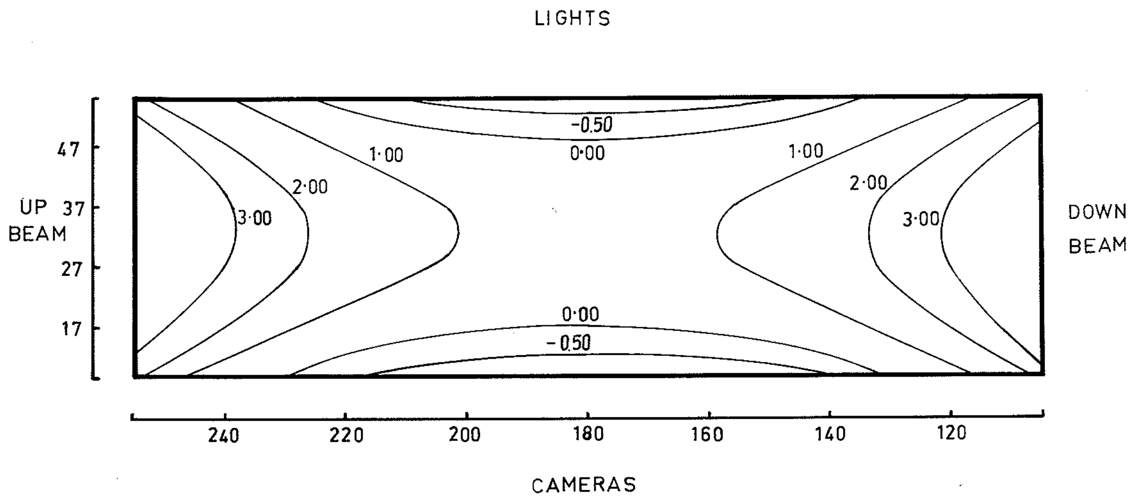
VERTICAL PLANE CONTAINING BEAM 15 cm. TOWARDS LIGHTS FROM CENTRE
(CAMERA VIEW)

fig. 1

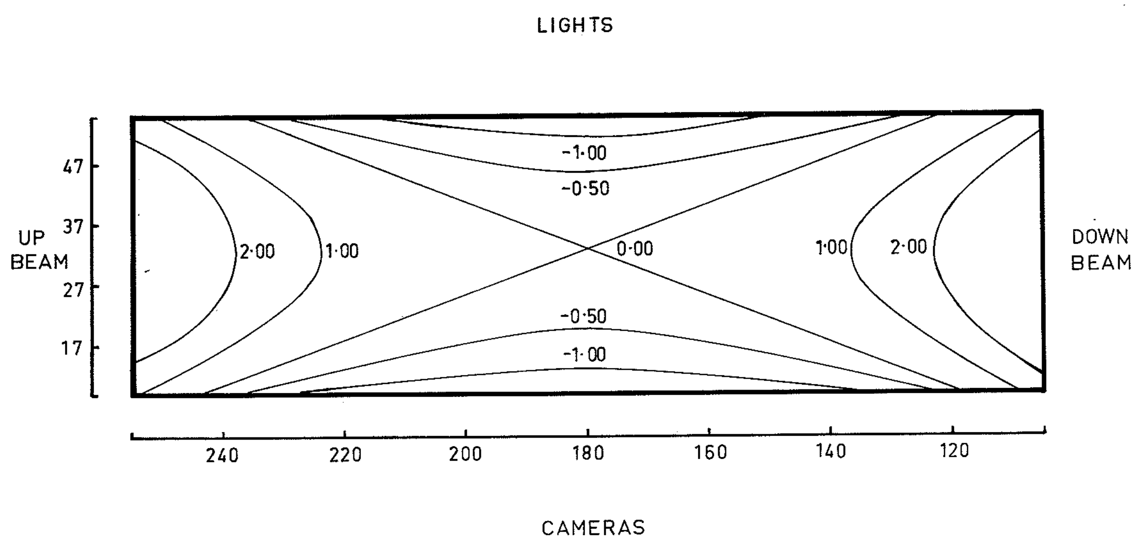
SIS/R/6912

B.N.B.C. FIELD INHOMOGENEITY

PERCENTAGE FIELD DEVIATION FROM CENTRAL VALUE



HORIZONTAL PLANE 20cm. ABOVE CENTRE

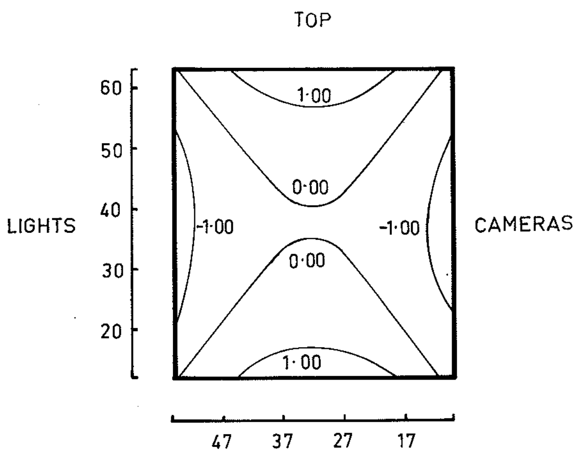


HORIZONTAL SYMMETRY PLANE

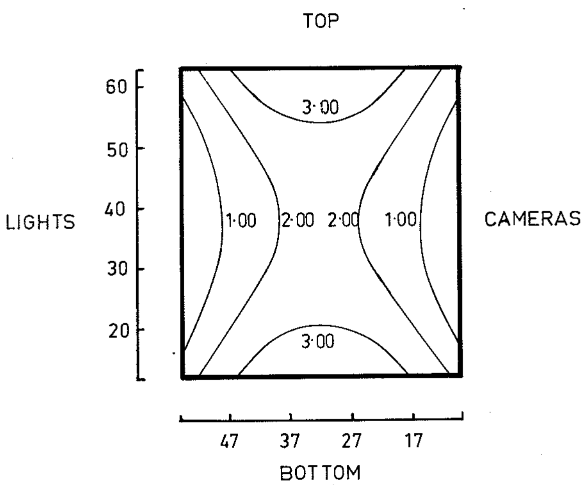
fig. 2

B.N.B.C. FIELD INHOMOGENEITY

PERCENTAGE FIELD DEVIATION FROM CENTRAL VALUE



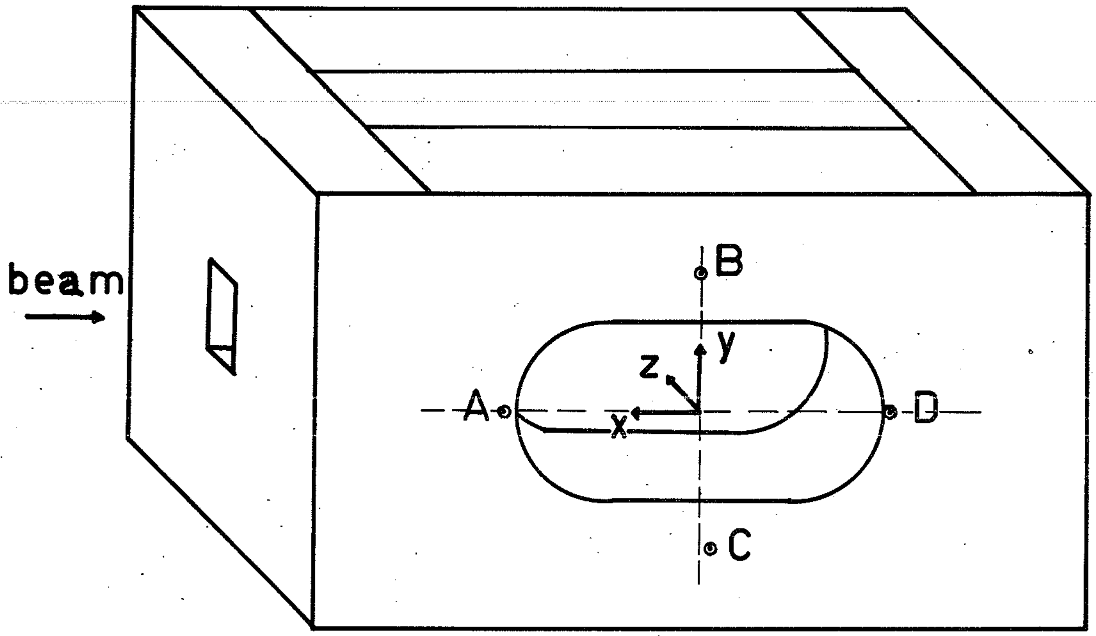
VERTICAL SYMMETRY PLANE
CONTAINING CAMERA AXIS



VERTICAL PLANE CONTAINING CAMERA-AXIS
60cm. DOWN BEAM FROM CENTRE

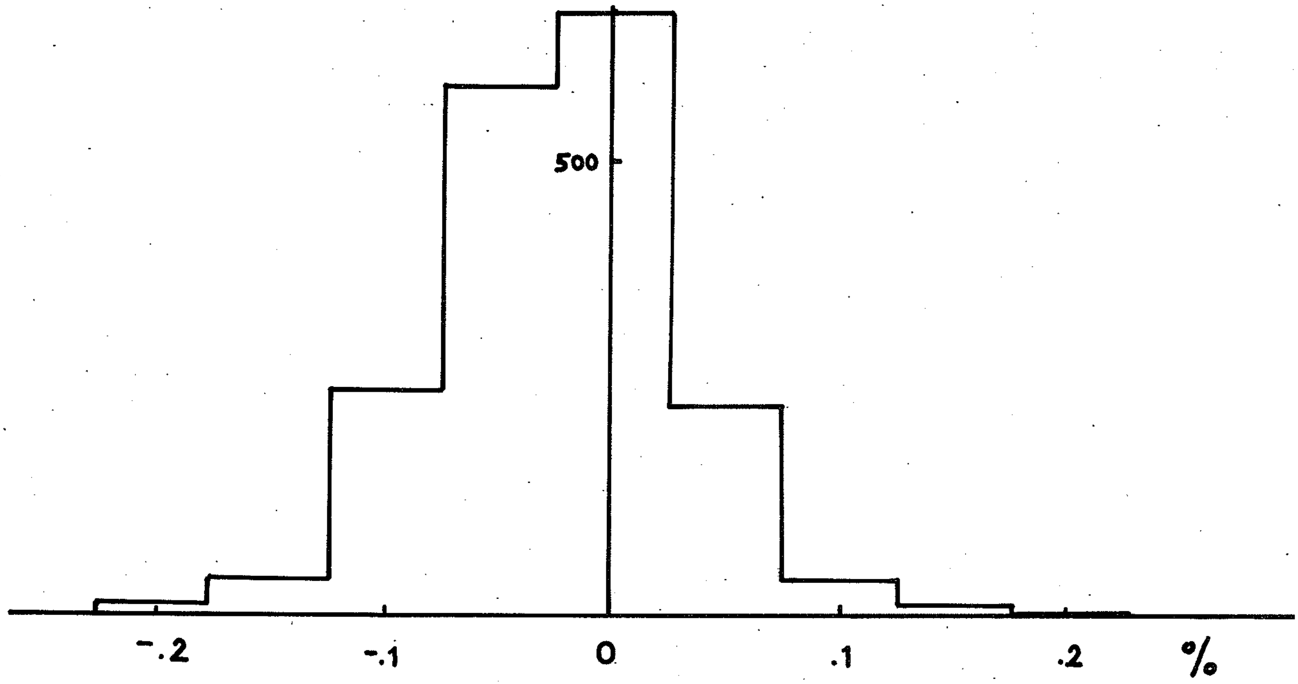
fig. 3

SIS/R/6914



COORDINATE SYSTEM

fig. 4



DISTRIBUTION OF DIFFERENCES
BETWEEN TWO RUNS

fig. 5

MAGNETIC FIELD TABLE FOR 1.50 M BRITISH HYDROGEN BUBBLE CHAMBER

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TITLE3          1.50 M    B.N.B.C.      HYDROGEN   BUBBLE   CHAMBER

 13 10 11
   110    115    125    135    150    165    180    195    210    225    235    245
   250
    15     20     25     30     35     40     45     50     55     60
     7     12     17     22     27     32     37     42     47     52     57
0.9850 0.9914 0.9987 1.0029 1.0073 1.0097 1.0092 1.0091 1.0077
1.0045 0.9995 0.9943 0.9887
0.9910 0.9955 1.0025 1.0065 1.0105 1.0127 1.0124 1.0123 1.0111
1.0080 1.0038 0.9984 0.9946
0.9944 0.9987 1.0052 1.0090 1.0128 1.0149 1.0145 1.0145 1.0134
1.0105 1.0064 1.0013 0.9975
0.9963 1.0006 1.0068 1.0106 1.0142 1.0163 1.0158 1.0159 1.0148
1.0120 1.0081 1.0030 0.9995
0.9973 1.0014 1.0077 1.0113 1.0149 1.0170 1.0165 1.0166 1.0154
1.0127 1.0089 1.0038 1.0002
0.9973 1.0014 1.0077 1.0113 1.0149 1.0171 1.0165 1.0166 1.0154
1.0127 1.0090 1.0038 1.0002
0.9962 1.0004 1.0067 1.0104 1.0141 1.0161 1.0157 1.0159 1.0149
1.0118 1.0080 1.0028 0.9992
0.9940 0.9982 1.0048 1.0087 1.0123 1.0144 1.0142 1.0143 1.0129
1.0099 1.0060 1.0007 0.9969
0.9904 0.9949 1.0017 1.0059 1.0098 1.0121 1.0118 1.0118 1.0103
1.0072 1.0030 0.9974 0.9934
0.9850 0.9904 0.9976 1.0020 1.0063 1.0086 1.0083 1.0084 1.0068
1.0033 0.9990 0.9929 0.9879
0.9724 0.9795 0.9882 0.9937 0.9993 1.0018 1.0019 1.0014 0.9995
0.9950 0.9892 0.9818 0.9754
0.9790 0.9845 0.9928 0.9980 1.0032 1.0058 1.0057 1.0053 1.0034
0.9992 0.9937 0.9867 0.9818
0.9826 0.9880 0.9961 1.0011 1.0060 1.0085 1.0084 1.0081 1.0063
1.0022 0.9969 0.9902 0.9853
0.9848 0.9902 0.9982 1.0029 1.0077 1.0102 1.0101 1.0098 1.0080
1.0041 0.9990 0.9923 0.9876
0.9861 0.9914 0.9991 1.0038 1.0086 1.0109 1.0109 1.0107 1.0089
1.0050 1.0000 0.9933 0.9886
0.9861 0.9914 0.9990 1.0038 1.0086 1.0109 1.0109 1.0107 1.0088
1.0049 0.9999 0.9933 0.9886
0.9848 0.9900 0.9979 1.0028 1.0075 1.0100 1.0099 1.0098 1.0078
1.0038 0.9988 0.9920 0.9873
0.9822 0.9875 0.9955 1.0006 1.0055 1.0080 1.0078 1.0078 1.0058
1.0015 0.9965 0.9895 0.9847
0.9780 0.9835 0.9919 0.9972 1.0023 1.0050 1.0050 1.0049 1.0027
0.9982 0.9929 0.9857 0.9805
0.9718 0.9782 0.9870 0.9927 0.9982 1.0008 1.0009 1.0008 0.9984
0.9936 0.9880 0.9804 0.9741
0.9630 0.9700 0.9798 0.9862 0.9923 0.9956 0.9958 0.9952 0.9927
0.9871 0.9803 0.9719 0.9660
0.9691 0.9755 0.9850 0.9911 0.9971 1.0000 1.0002 0.9997 0.9972
0.9919 0.9855 0.9773 0.9716
0.9733 0.9795 0.9886 0.9946 1.0003 1.0031 1.0034 1.0029 1.0004
```

0.9954	0.9892	0.9811	0.9756					
0.9759	0.9820	0.9910	0.9967	1.0022	1.0052	1.0053	1.0049	1.0025
0.9975	0.9915	0.9834	0.9781					
0.9771	0.9832	0.9920	0.9977	1.0033	1.0060	1.0062	1.0058	1.0035
0.9985	0.9926	0.9848	0.9792					
0.9771	0.9832	0.9920	0.9977	1.0032	1.0060	1.0063	1.0058	1.0034
0.9985	0.9926	0.9847	0.9792					
0.9758	0.9818	0.9908	0.9965	1.0020	1.0049	1.0052	1.0049	1.0022
0.9972	0.9913	0.9834	0.9778					
0.9728	0.9789	0.9881	0.9941	0.9998	1.0026	1.0029	1.0027	1.0000
0.9947	0.9887	0.9805	0.9748					
0.9682	0.9746	0.9842	0.9902	0.9963	0.9993	0.9996	0.9992	0.9963
0.9908	0.9846	0.9761	0.9702					
0.9622	0.9686	0.9786	0.9853	0.9914	0.9946	0.9948	0.9945	0.9915
0.9857	0.9792	0.9703	0.9639					
0.9559	0.9633	0.9737	0.9806	0.9873	0.9910	0.9914	0.9905	0.9875
0.9812	0.9739	0.9644	0.9587					
0.9620	0.9690	0.9791	0.9859	0.9925	0.9959	0.9961	0.9955	0.9925
0.9864	0.9794	0.9702	0.9639					
0.9664	0.9733	0.9831	0.9897	0.9961	0.9992	0.9996	0.9989	0.9961
0.9902	0.9834	0.9744	0.9681					
0.9693	0.9761	0.9856	0.9921	0.9983	1.0013	1.0017	1.0013	0.9984
0.9926	0.9855	0.9771	0.9709					
0.9706	0.9774	0.9868	0.9932	0.9994	1.0023	1.0026	1.0022	0.9995
0.9937	0.9871	0.9783	0.9723					
0.9706	0.9774	0.9869	0.9932	0.9993	1.0023	1.0027	1.0023	0.9994
0.9938	0.9871	0.9783	0.9723					
0.9691	0.9758	0.9854	0.9919	0.9982	1.0011	1.0015	1.0011	0.9981
0.9923	0.9856	0.9767	0.9706					
0.9660	0.9727	0.9826	0.9892	0.9956	0.9989	0.9992	0.9987	0.9955
0.9896	0.9828	0.9737	0.9673					
0.9611	0.9681	0.9783	0.9853	0.9917	0.9950	0.9955	0.9949	0.9917
0.9854	0.9784	0.9689	0.9627					
0.9548	0.9619	0.9724	0.9795	0.9865	0.9898	0.9902	0.9898	0.9864
0.9799	0.9727	0.9628	0.9568					
0.9517	0.9590	0.9698	0.9774	0.9842	0.9879	0.9885	0.9876	0.9844
0.9775	0.9696	0.9597	0.9532					
0.9576	0.9652	0.9756	0.9828	0.9894	0.9931	0.9935	0.9927	0.9895
0.9830	0.9754	0.9657	0.9591					
0.9623	0.9694	0.9794	0.9868	0.9933	0.9968	0.9972	0.9965	0.9933
0.9869	0.9795	0.9701	0.9636					
0.9652	0.9723	0.9823	0.9893	0.9957	0.9990	0.9995	0.9987	0.9957
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0.9666	0.9737	0.9836	0.9904	0.9969	1.0000	1.0005	0.9999	0.9969
0.9906	0.9834	0.9742	0.9678					
0.9666	0.9737	0.9836	0.9904	0.9969	1.0000	1.0005	0.9999	0.9968
0.9906	0.9834	0.9742	0.9677					
0.9651	0.9720	0.9822	0.9890	0.9955	0.9989	0.9994	0.9987	0.9955
0.9892	0.9820	0.9726	0.9660					
0.9617	0.9690	0.9791	0.9862	0.9929	0.9962	0.9968	0.9961	0.9928
0.9862	0.9791	0.9695	0.9628					
0.9566	0.9642	0.9748	0.9819	0.9887	0.9923	0.9929	0.9922	0.9887
0.9820	0.9746	0.9645	0.9580					
0.9502	0.9578	0.9686	0.9762	0.9834	0.9870	0.9876	0.9868	0.9833
0.9762	0.9684	0.9581	0.9508					
0.9498	0.9577	0.9684	0.9761	0.9832	0.9869	0.9875	0.9867	0.9831
0.9761	0.9680	0.9579	0.9509					
0.9562	0.9639	0.9744	0.9818	0.9884	0.9921	0.9927	0.9919	0.9884
0.9816	0.9740	0.9639	0.9571					
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0.9857	0.9782	0.9684	0.9615					
0.9640	0.9711	0.9812	0.9882	0.9947	0.9982	0.9988	0.9979	0.9947
0.9882	0.9808	0.9712	0.9645					
0.9653	0.9725	0.9825	0.9894	0.9960	0.9992	1.0000	0.9991	0.9959
0.9894	0.9820	0.9725	0.9658					
0.9653	0.9725	0.9825	0.9894	0.9959	0.9992	0.9997	0.9991	0.9958

0.9894	0.9820	0.9726	0.9658					
0.9637	0.9709	0.9811	0.9881	0.9946	0.9980	0.9985	0.9979	0.9944
0.9879	0.9806	0.9708	0.9642					
0.9603	0.9677	0.9780	0.9853	0.9919	0.9954	0.9959	0.9952	0.9916
0.9849	0.9775	0.9677	0.9609					
0.9554	0.9629	0.9734	0.9809	0.9877	0.9913	0.9919	0.9912	0.9875
0.9806	0.9728	0.9628	0.9557					
0.9489	0.9564	0.9671	0.9751	0.9822	0.9859	0.9864	0.9859	0.8820
0.9748	0.9666	0.9563	0.9488					
0.9519	0.9591	0.9698	0.9772	0.9840	0.9876	0.9884	0.9873	0.9840
0.9770	0.9692	0.9589	0.9519					
0.9579	0.9653	0.9755	0.9827	0.9892	0.9928	0.9934	0.9925	0.9891
0.9826	0.9750	0.9650	0.9581					
0.9625	0.9698	0.9796	0.9867	0.9930	0.9965	0.9970	0.9962	0.9929
0.9866	0.9791	0.9692	0.9626					
0.9655	0.9725	0.9823	0.9892	0.9955	0.9987	0.9994	0.9985	0.9953
0.9890	0.9817	0.9722	0.9655					
0.9669	0.9739	0.9837	0.9904	0.9966	0.9999	1.0003	0.9996	0.9965
0.9902	0.9830	0.9734	0.9668					
0.9668	0.9739	0.9837	0.9904	0.9966	0.9998	1.0004	0.9996	0.9965
0.9901	0.9830	0.9734	0.9668					
0.9652	0.9722	0.9821	0.9890	0.9952	0.9986	0.9993	0.9985	0.9951
0.9887	0.9815	0.9718	0.9651					
0.9621	0.9692	0.9792	0.9862	0.9926	0.9961	0.9967	0.9958	0.9923
0.9859	0.9784	0.9687	0.9619					
0.9570	0.9643	0.9747	0.9820	0.9885	0.9921	0.9928	0.9919	0.9883
0.9815	0.9740	0.9637	0.9568					
0.9506	0.9579	0.9685	0.9761	0.9831	0.9868	0.9875	0.9866	0.9828
0.9756	0.9678	0.9572	0.9499					
0.9568	0.9635	0.9734	0.9805	0.9867	0.9902	0.9910	0.9897	0.9867
0.9801	0.9728	0.9629	0.9568					
0.9631	0.9694	0.9790	0.9858	0.9918	0.9952	0.9958	0.9949	0.9917
0.9855	0.9784	0.9686	0.9622					
0.9675	0.9736	0.9830	0.9896	0.9954	0.9987	1.0003	0.9983	0.9957
0.9892	0.9823	0.9729	0.9666					
0.9702	0.9763	0.9855	0.9921	0.9978	1.0008	1.0019	1.0006	0.9976
0.9916	0.9848	0.9755	0.9694					
0.9716	0.9777	0.9867	0.9932	0.9989	1.0019	1.0025	1.0016	0.9987
0.9928	0.9859	0.9768	0.9707					
0.9716	0.9777	0.9867	0.9932	0.9989	1.0019	1.0025	1.0016	0.9986
0.9928	0.9859	0.9868	0.9706					
0.9701	0.9761	0.9854	0.9919	0.9977	1.0007	1.0013	1.0005	0.9975
0.9913	0.9846	0.9752	0.9691					
0.9670	0.9730	0.9825	0.9892	0.9951	0.9983	0.9989	0.9981	0.9949
0.9886	0.9818	0.9722	0.9658					
0.9622	0.9684	0.9782	0.9851	0.9911	0.9945	0.9952	0.9943	0.9910
0.9844	0.9775	0.9662	0.9611					
0.9559	0.9622	0.9723	0.9795	0.9859	0.9895	0.9904	0.9891	0.9857
0.9788	0.9715	0.9612	0.9547					
0.9637	0.9706	0.9795	0.9861	0.9915	0.9944	0.9953	0.9943	0.9913
0.9855	0.9785	0.9694	0.9630					
0.9698	0.9761	0.9846	0.9909	0.9961	0.9990	0.9997	0.9989	0.9960
0.9904	0.9836	0.9750	0.9690					
0.9740	0.9800	0.9884	0.9945	0.9995	1.0021	1.0028	1.0020	0.9993
0.9938	0.9873	0.9786	0.9731					
0.9766	0.9825	0.9906	0.9966	1.0016	1.0042	1.0049	1.0041	1.0014
0.9961	0.9896	0.9812	0.9757					
0.9779	0.9837	0.9918	0.9977	1.0026	1.0052	1.0057	1.0051	1.0024
0.9972	0.9908	0.9825	0.9769					
0.9779	0.9837	0.9918	0.9977	1.0026	1.0052	1.0058	1.0051	1.0024
0.9971	0.9908	0.9825	0.9769					
0.9766	0.9823	0.9906	0.9966	1.0015	1.0041	1.0048	1.0040	1.0013
0.9959	0.9895	0.9810	0.9754					
0.9735	0.9796	0.9881	0.9942	0.9993	1.0019	1.0026	1.0018	0.9989
0.9934	0.9868	0.9781	0.9723					
0.9691	0.9752	0.9841	0.9903	0.9957	0.9985	0.9992	0.9983	0.9953

0.9894	0.9807	0.9737	0.9679					
0.9632	0.9695	0.9784	0.9853	0.9909	0.9937	0.9945	0.9936	0.9905
0.9842	0.9771	0.9666	0.9609					
0.9730	0.9803	0.9878	0.9934	0.9979	1.0003	1.0009	1.0002	0.9979
0.9926	0.9868	0.9789	0.9722					
0.9797	0.9851	0.9925	0.9977	1.0019	1.0044	1.0048	1.0043	1.0020
0.9972	0.9915	0.9837	0.9784					
0.9834	0.9886	0.9958	1.0008	1.0049	1.0072	1.0076	1.0070	1.0048
1.0002	0.9947	0.9873	0.9881					
0.9859	0.9910	0.9978	1.0026	1.0067	1.0089	1.0093	1.0088	1.0067
1.0022	0.9967	0.9896	0.9845					
0.9870	0.9920	0.9989	1.0035	1.0077	1.0098	1.0102	1.0097	1.0076
1.0030	0.9979	0.9906	0.9856					
0.9870	0.9920	0.9989	1.0035	1.0077	1.0098	1.0102	1.0098	1.0076
1.0030	0.9979	0.9905	0.9856					
0.9859	0.9909	0.9979	1.0026	1.0068	1.0089	1.0094	1.0088	1.0065
1.0019	0.9967	0.9892	0.9842					
0.9831	0.9883	0.9955	1.0004	1.0047	1.0070	1.0074	1.0069	1.0045
0.9998	0.9942	0.9866	0.9816					
0.9792	0.9844	0.9919	0.9973	1.0016	1.0044	1.0045	1.0038	1.0013
0.9964	0.9905	0.9828	0.9774					
0.9730	0.9793	0.9870	0.9927	0.9974	0.9999	1.0004	0.9997	0.9972
0.9916	0.9856	0.9774	0.9710					
0.9861	0.9920	0.9982	1.0025	1.0057	1.0077	1.0082	1.0077	1.0059
1.0018	0.9971	0.9905	0.9856					
0.9922	0.9964	1.0020	1.0061	1.0093	1.0110	1.0114	1.0109	1.0093
1.0056	1.0010	0.9949	0.9903					
0.9954	0.9994	1.0048	1.0088	1.0117	1.0133	1.0136	1.0133	1.0117
1.0081	1.0038	0.9980	0.9936					
0.9975	1.0011	1.0065	1.0103	1.0133	1.0148	1.0150	1.0147	1.0132
1.0098	1.0055	0.9999	0.9955					
0.9984	1.0021	1.0075	1.0110	1.0141	1.0155	1.0157	1.0154	1.0139
1.0105	1.0063	1.0006	0.9965					
0.9984	1.0020	1.0075	1.0110	1.0141	1.0156	1.0157	1.0154	1.0139
1.0104	1.0063	1.0006	0.9965					
0.9974	1.0011	1.0066	1.0103	1.0132	1.0149	1.0150	1.0146	1.0131
1.0096	1.0054	0.9995	0.9954					
0.9951	0.9991	1.0047	1.0086	1.0116	1.0133	1.0135	1.0131	1.0114
1.0078	1.0034	0.9975	0.9931					
0.9916	0.9959	1.0016	1.0059	1.0091	1.0109	1.0111	1.0106	1.0088
1.0049	1.0002	0.9937	0.9895					
0.9857	0.9914	0.9976	1.0019	1.0055	1.0074	1.0077	1.0072	1.0051
1.0008	0.9960	0.9893	0.9849					

MAGNETIC FIELD GIVEN BY TABLE VALUE X CENTRAL VALUE