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SPECIFICATION FOR AN
MRBR 9.4 TESLA/310MM/AS
CRYO-COOLED MAGNET SYSTEM

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1. DESCRIPTION OF THE SYSTEM

The MRBR 9.4/310 system is a complete superconducting magnet system intended primarily for Research Studies on the biological applications of NMR imaging (MRI) and NMR spectroscopy (MRS).

The system essentially consists of a highly homogeneous superconducting 9.4 Tesla magnet housed in a horizontal room temperature bore (310mm), low-loss helium cryostat. The magnet can be operated with a pulse-tube type cryocooler to give nominally zero helium loss or as a conventional two cryogen system that can later be upgraded to zero boil-off with the addition of a cryocooler system.

Field shimming is accomplished using superconducting shim coils. The ultimate homogeneity specifications require room shim coils.

The system is complemented with cryomonitors for helium and nitrogen. An emergency quench heater control unit is also provided.

2. THE SUPERCONDUCTING MAGNET

i. General Description

The magnet is wound from multi-filamentary NbTi conductor with a high percentage of copper to superconductor. The windings are placed on a precision-machined aluminium alloy former and then fully vacuum impregnated for robustness and long-term reliability.

The field homogeneity is defined over a 14cm diameter spherical volume. Inevitably winding tolerances and small amounts of environmental influence will distort the central field. Corrections for these distortions are made in the first instance by superconducting shim coils located on a former surrounding the main coil.

The magnet coils are fully protected from accidental damage due to a quench by a passive resistor network located within the helium reservoir.

In the event of the need to activate an emergency discharge of the magnet a quench heater circuit is incorporated within the windings.

The magnet is designed to conservative levels of stress and mechanical stability to ensure reliable and stable operation. In addition the use of high quality superconducting wire ensure that a highly stable magnet system is achieved.

ii. Specifications

Magnet Type	:	Multi-coil superconducting
Central Field	:	9.4 Tesla (¹ H 400MHz)

Field stability measured a minimum of 72 hours after energisation	:	Less than 0.05 ppm/hour drift (Ultimate field stability expected less than 0.01ppm/hr)
Operating current	:	200 Amps (nominal)
Field homogeneity values		
Superconducting only shimmed	:	Less than 20ppm over 14cm dsv ¹
Fully shimmed using Magnex standard set of RT shim coils	:	Less than 5ppm over 14cm dsv ¹ 0.1ppm HHLW over 10cm dsv ²
Typical time to energise magnet to full field	:	24 hours
Estimate of helium consumption during ramping to full field	:	400 litres
Fringe Field ³ (position of 5 gauss contour) - (see figure 1)		
Axially from magnet centre line	:	4.9 metres
Radially from magnet centre line	:	2.7 metres
Screening factor	:	Greater than 10

¹ Defined as the peak to peak variations of points plotted over a seven plane plot on the surface of the stated spherical volume.

² HHLW measurement.

³ **Safety Note:** In the event of a quench it is possible for the magnetic field to momentarily bloom beyond this limit. For further details please consult the Magnex site planning guide for this magnet.

iii. Superconducting Shim Coils

These coils are positioned on a non-conducting former surrounding the main coil in the helium reservoir. Each coil set is fitted with a superconducting switch for persistent mode operation.

Coil Details:-

Shims provided: : Z1, Z2, Z3, X, Y, ZX, ZY, XY, X2-Y2

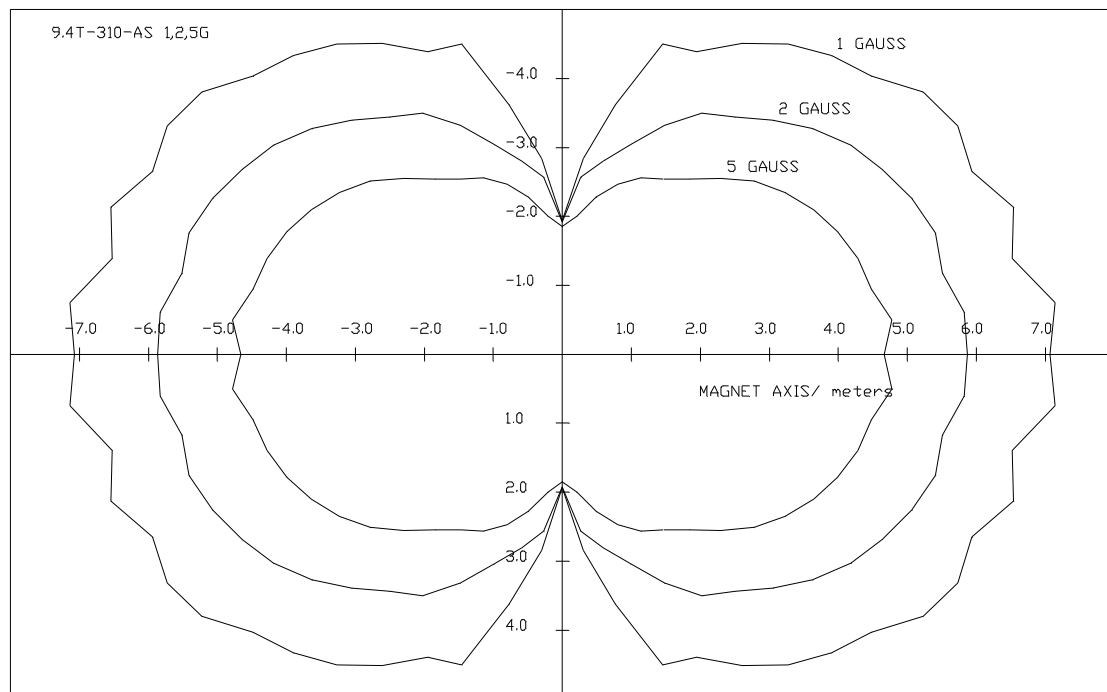
Maximum recommended current : 25 Amps

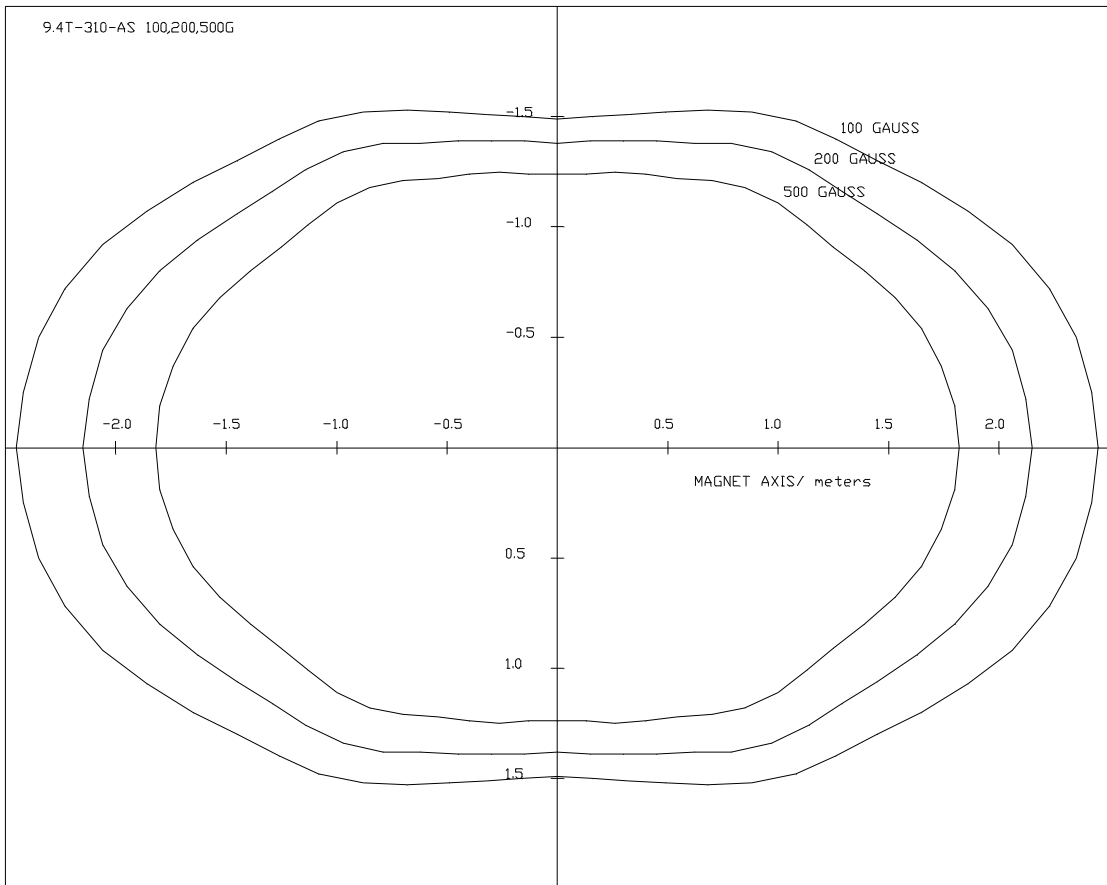
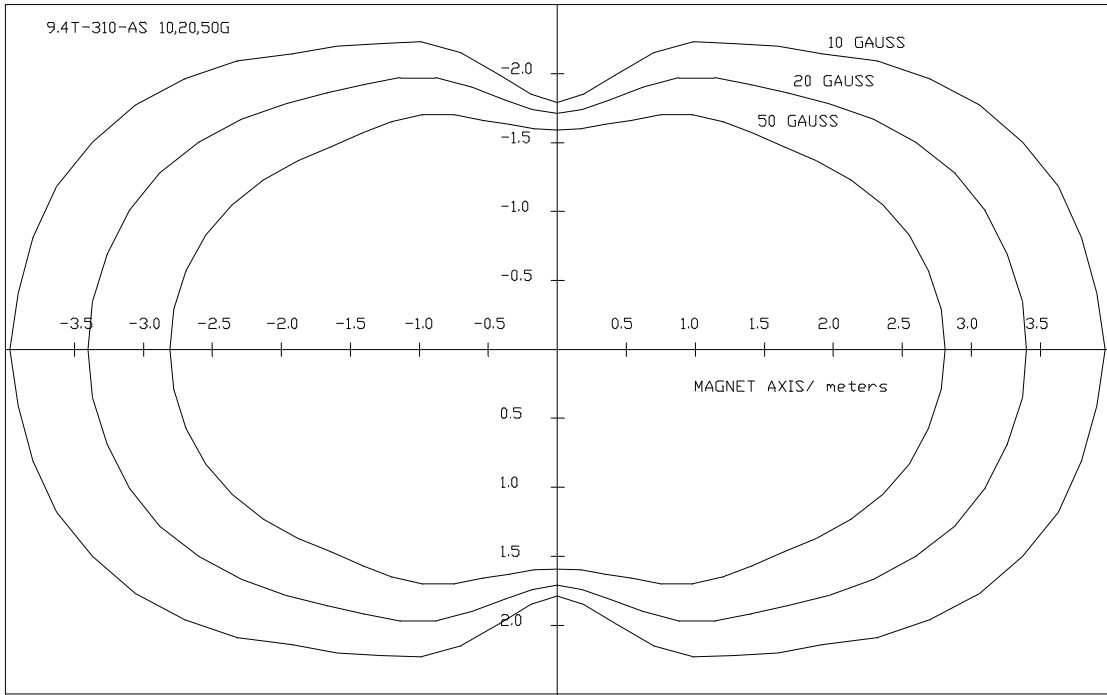
Coupling : All shims are designed to be decoupled from the main coil

Typical shim strength over 14cm diameter.

Shim	Strength (ppm/amp of main field)	% Impurity over Stated Spherical Volume
Z1	19.6	Less than 1%
Z2	5.0	Less than 1%
Z3	0.45	Less than 1%
X(Y)	5.23	Less than 1%
ZX(ZY)	0.40	Less than 1%
XY(X2-Y2)	0.22	Less than 1%

Figure 1. Fringe Field





3. THE CRYOSTAT

i. General Description

The cryostat is of conventional design, consisting of a central all-welded stainless-steel helium vessel which is surrounded by an aluminium gas-cooled radiation shield and liquid nitrogen reservoir. The complete assembly is contained in a stainless-steel outer vacuum vessel with a vertical service turret located centrally on top of the cryostat. The turret provides access to the helium reservoir for the demountable magnet leads and helium transfer siphon. The outer vessel has end-flange closures constructed from aluminium which are sealed to the main body and bore-tube by compressed rubber 'O' ring seals. The room-temperature bore-tube is constructed from stainless steel.

The cryostat is supplied with a support stand that consists of load-spreading plates which have provision for fixing to the floor of the installation room. The helium reservoir contains in total approximately 2500 litres of liquid helium of which approximately 750 litres volume is above the upper level of the superconducting shim coils. It is recommended that the system is operated with the superconducting shim coils only partially non-immersed in liquid helium. Details of refill intervals are given below.

Cryogen level monitors are incorporated into both the liquid helium and liquid nitrogen vessels and the associated electronics provide liquid level display and low level alarms. A back-up liquid helium level probe is included for use in the event of failure of the primary probe. The probes will monitor helium continuously from empty to full conditions.

ii. Specifications

The cryostat is generally as shown in drawing no. CHZ331218. Full specifications for the system areas follows:-

Dimensions:

Length of cryostat	:	1900+/-5mm
Height with support frame	:	2901mm
Room temperature clear bore (without shims and gradients)	:	310mm
Room temperature bore-tube material	:	Stainless steel
Centre of field to base of stand	:	1205mm
Cryostat end-flange to centre of field	:	950mm

Outside diameter	:	2380mm
Minimum ceiling height for helium siphon	:	3569mm
Weight of cryostat (excluding cryogenics and gradients)	:	12,000kg (approximately)
Weight of cryostat (including cryogenics but excluding gradients)	:	12,550kg (approximately)

Liquid helium cryogen details:-

Volume for initial installation (includes cooling the magnet from 77K to 4.2K, volume required to completely fill helium reservoir and to top-up helium reservoir after magnet energisation)	:	7000 litres
Maximum volume of reservoir	:	2500 litres
Hold-time during normal operation (static magnetic field, leads withdrawn)	:	Nominally zero boil off Annual service recommended nominal 300 litre refill during annual service
Hold-time without coldhead fitted (static magnetic field, leads withdrawn Magnex baffles set fitted)	:	Greater than 110 days Refill volume 750 litres

Liquid nitrogen cryogen details:-

Volume for initial installation (includes pre-cool of magnet to 77K and volume required to completely fill LN ₂ reservoir)	:	7000 litres
Volume of reservoir	:	400 litres
Refill volume	:	400 litres
Hold-time without coldhead fitted (static magnetic field, leads withdrawn Magnex baffles set fitted)	:	Greater than 14 days

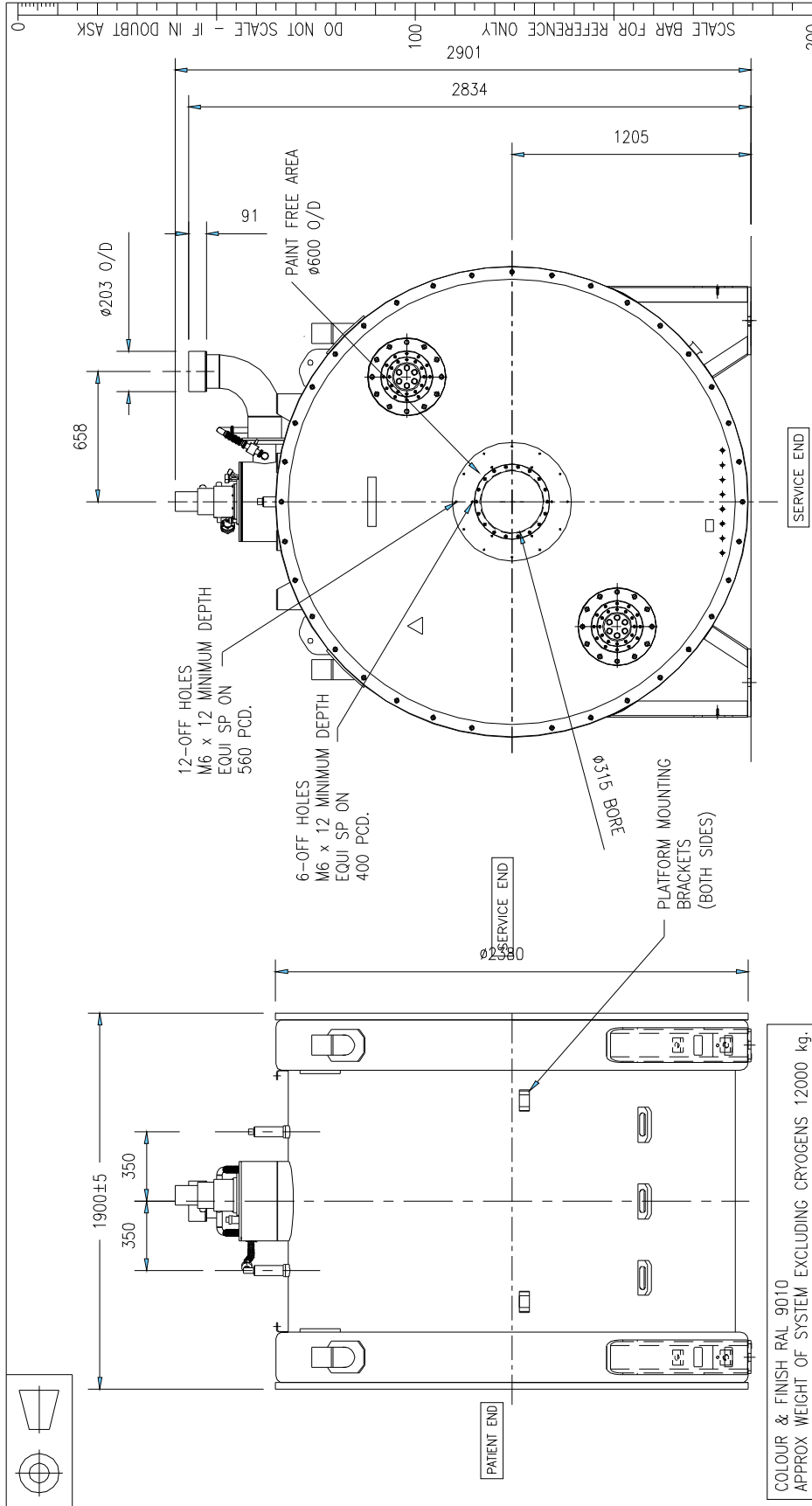
Cryocooler details:-

Type	:	4.2K two stage pulse tube
Compressor		

Cooling : Water-cooled (air-cooled TBD)
Input Power (50/60 Hz) : approx. 8.5/11.0 kW steady state
Electrical requirements : 3 phase, 50Hz/60Hz, high voltage

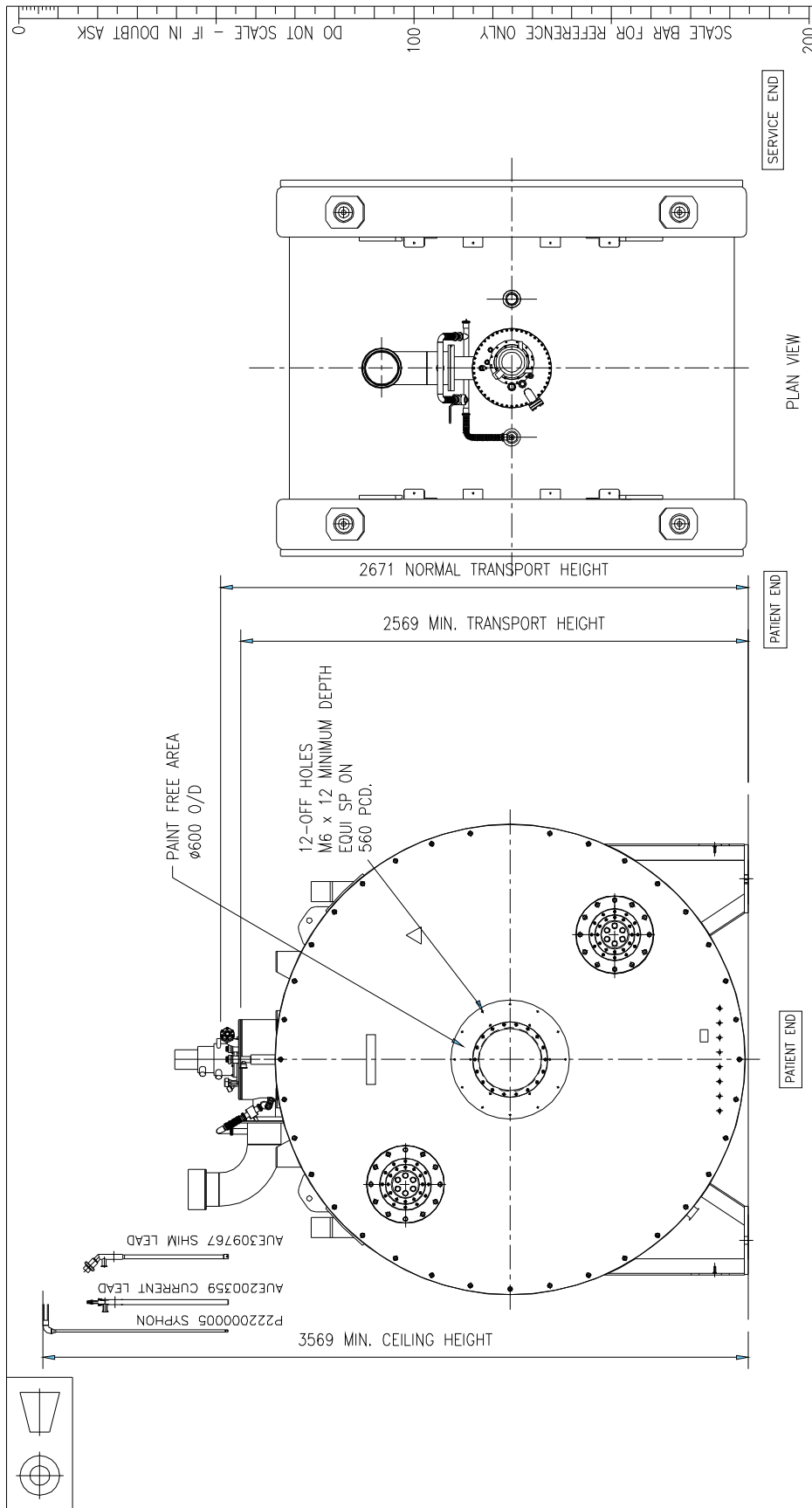
Recommended Service Interval

Magnet : 1 year
Compressor : 2 years (20,000 hrs)
Coldhead : 2 years (20,000 hrs) target

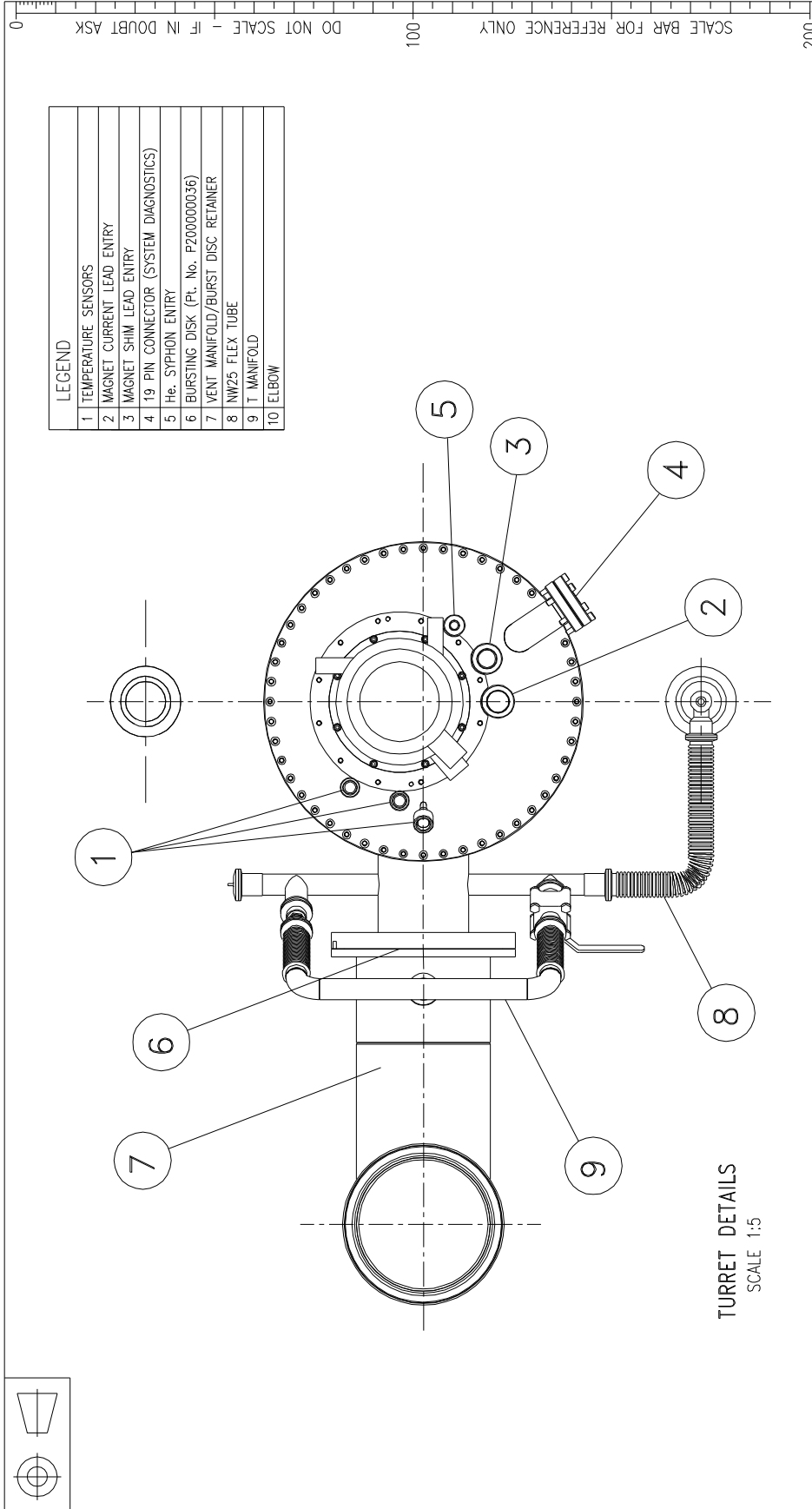


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 APPROX WEIGHT OF SYSTEM EXCLUDING CRYOGENS 12000 kg.

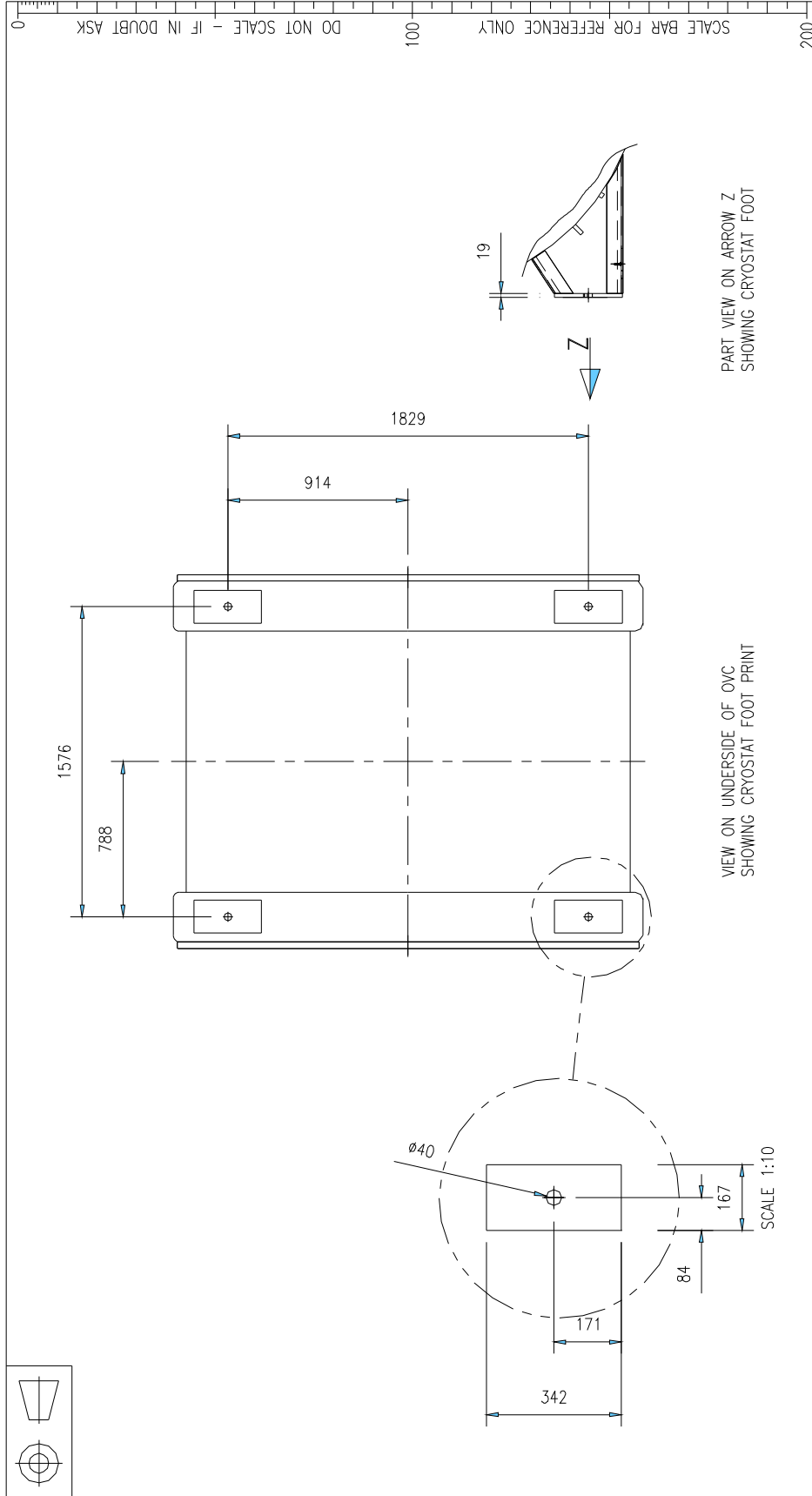
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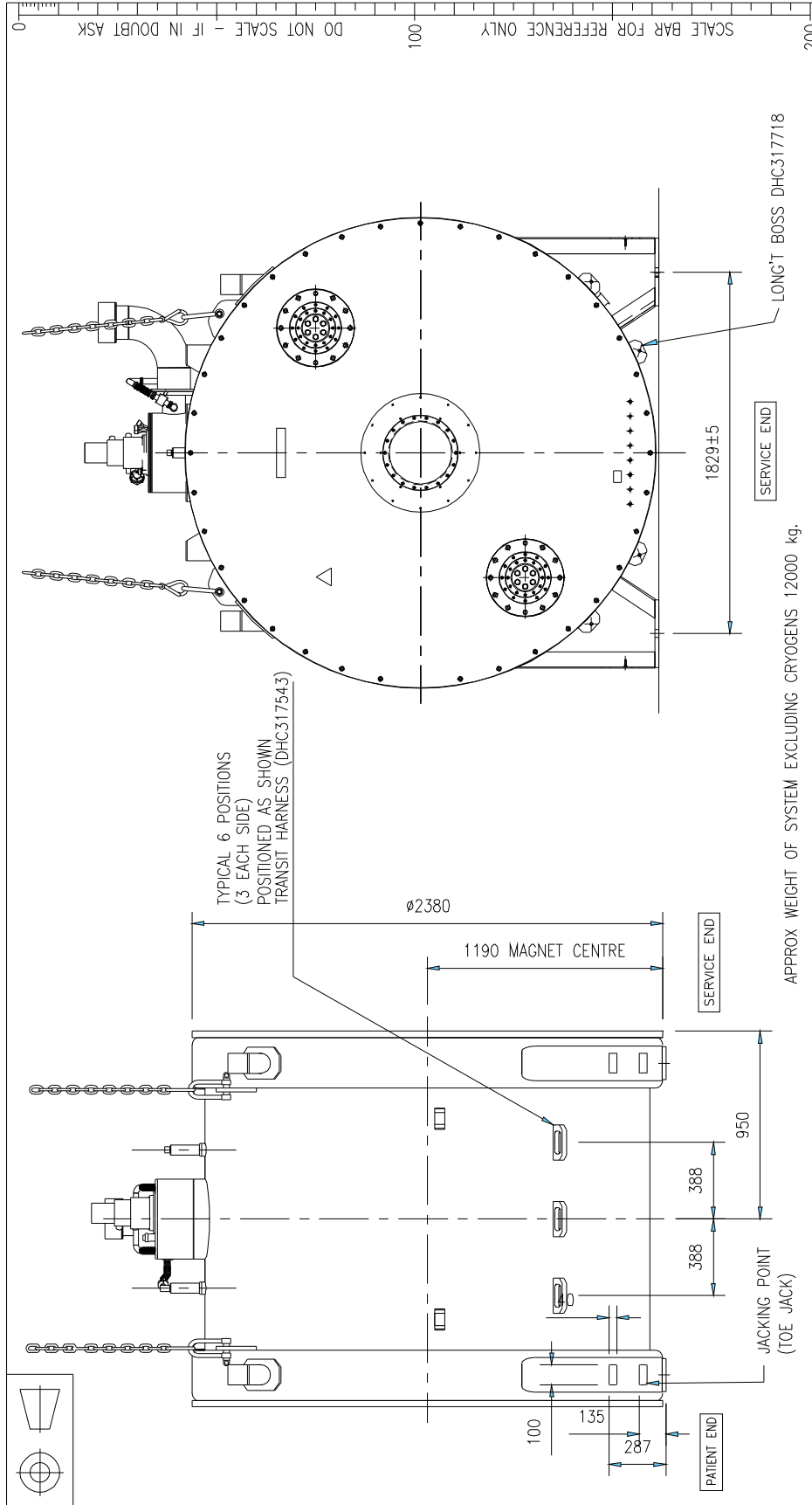
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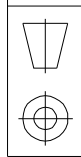
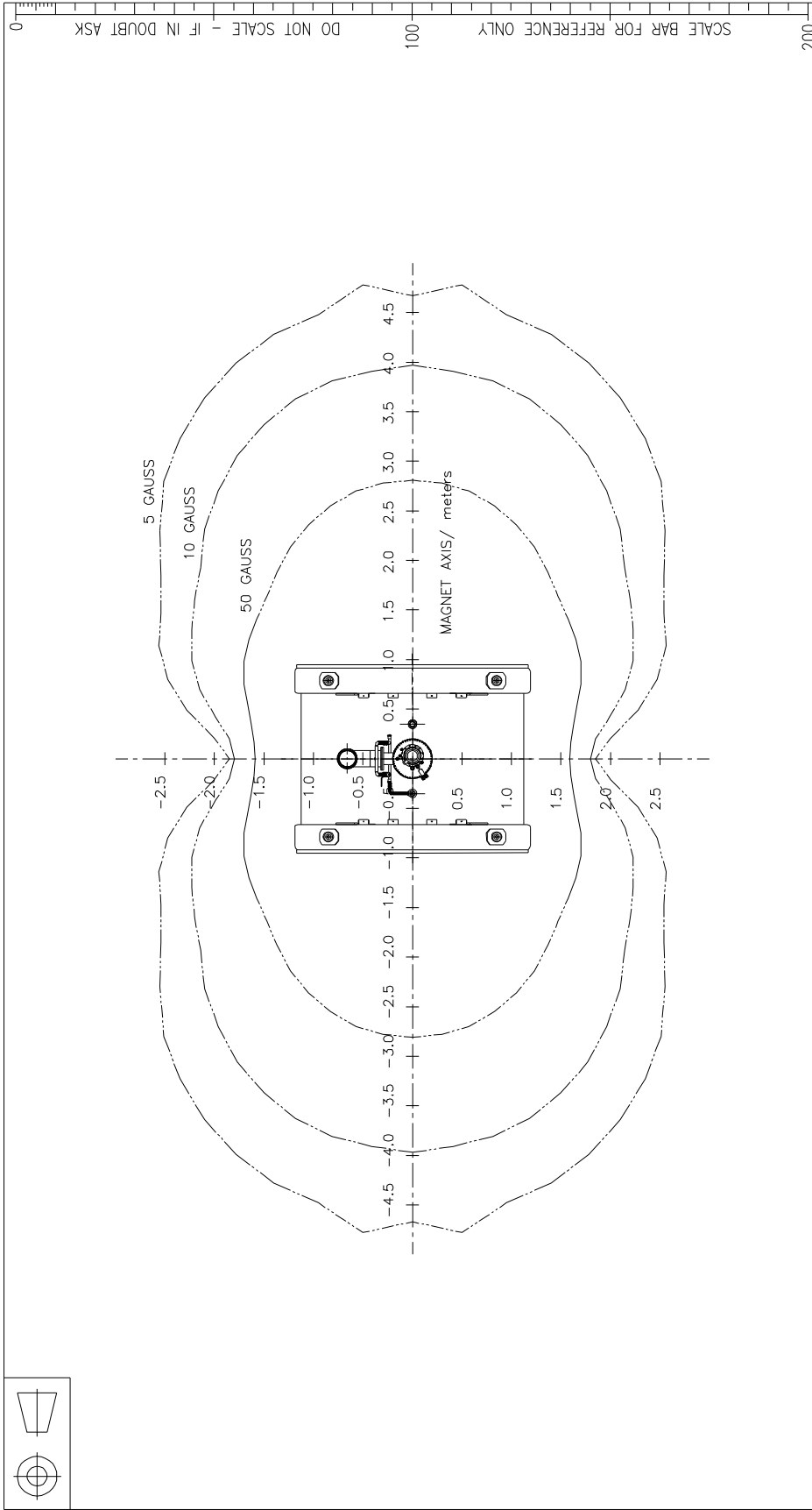
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4. SCOPE OF SUPPLY

i. Superconducting Magnet System Components

1 off 9.4T 310 mm actively shielded MRBR magnet system with integral s/c shims and housed in a low loss cryostat.

ii. Standard Ancillary Parts

Conventional (two cryogen) configuration

1 off	Set of neck baffles	AHC329478
1 off	Helium level monitor	E5011
1 off	Helium monitor cable	C0090003
1 off	Nitrogen Monitor	E5031
1 off	Emergency discharge unit	E7007
1 off	Set of service cables (8.5m)	A/R
1 off	Flexible siphon (2.0m)	P222000005
1 off	Nitrogen fill tube	AHU327799
1 off	Spares kit	AKZ509324
1 off	Demountable main current lead	AUE221963
1 off	Demountable shim lead	AUE200289
2 off	Remote quench buttons (1 to EDU, 1 to filter panel)	A/R
1 off	System manual	MHI1330

Refrigerated (zero boil off) configuration

1 off	Pulse-tube 4.2K coldhead	TBA
1 off	Cryocooler compressor with cables	TBD
1 off	Set of compressor gas lines	TBD
1 off	Helium pressure controller	TBD
1 off	Helium level monitor	E5011
1 off	Helium monitor cable	C0090003
1 off	Emergency discharge unit	E7007
1 off	Set of service cables (8.5m)	A/R
1 off	Flexible siphon (2.0m)	P222000005
1 off	Spares kit	AKZ509324
2 off	Remote quench buttons (1 to EDU, 1 to filter panel)	A/R
1 off	System manual	MHI1330

iii. Optional Components

Split service tools for low ceiling height	
Side mounting service access platform	NC1445AV01