EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE

CERN - PS DIVISION

PS/ CA/ Note 97-02

REMOTE POSITIONNING SYSTEM BT SMV 20

M. Hourican

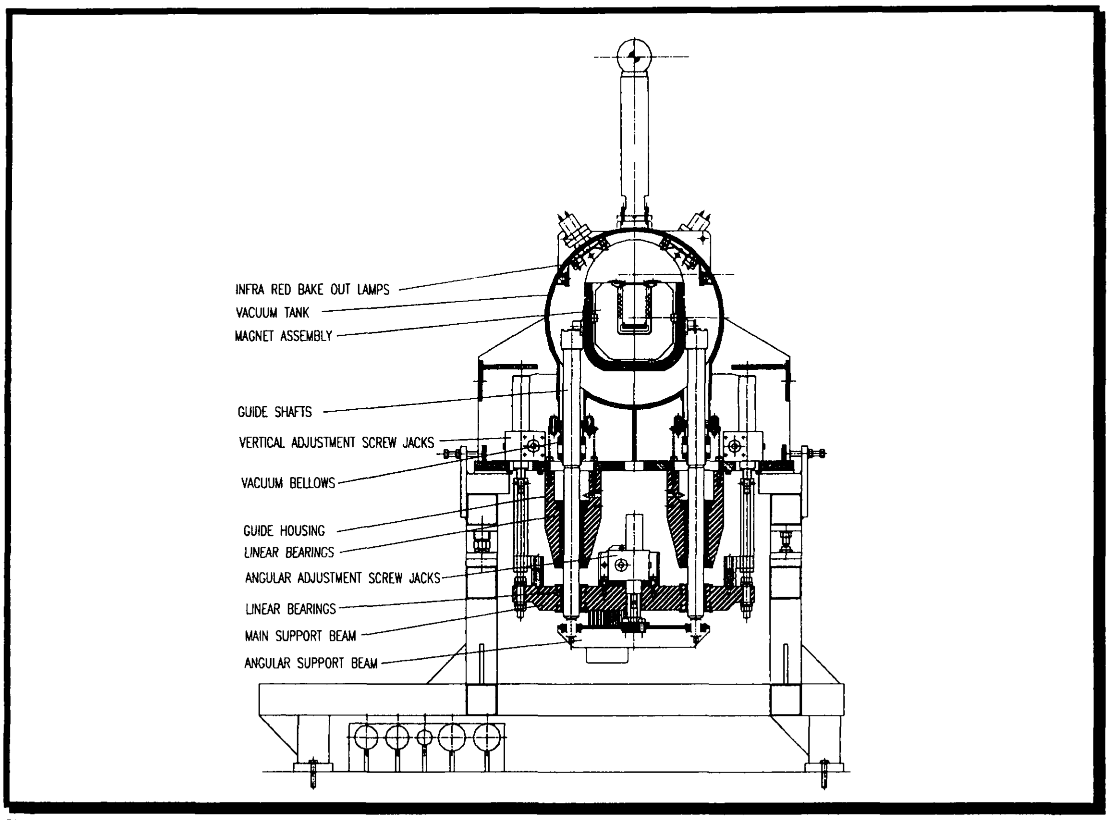
Geneva, Switzerland
17 April 1997

Introduction

The upgrade to 1.4 GeV/c of the PS Booster required the replacement of the vertical recombination septum magnet SMV20 with a new pulsed magnet and tank assembly. The need to remotely position the magnet with respect to the two beams required the design of a new movement system capable of varying the vertical height and the angle of the magnet with respect to the beam.

This note describes the complete mechanical system from the motor characteristics to the basic load bearing structure.

General Description

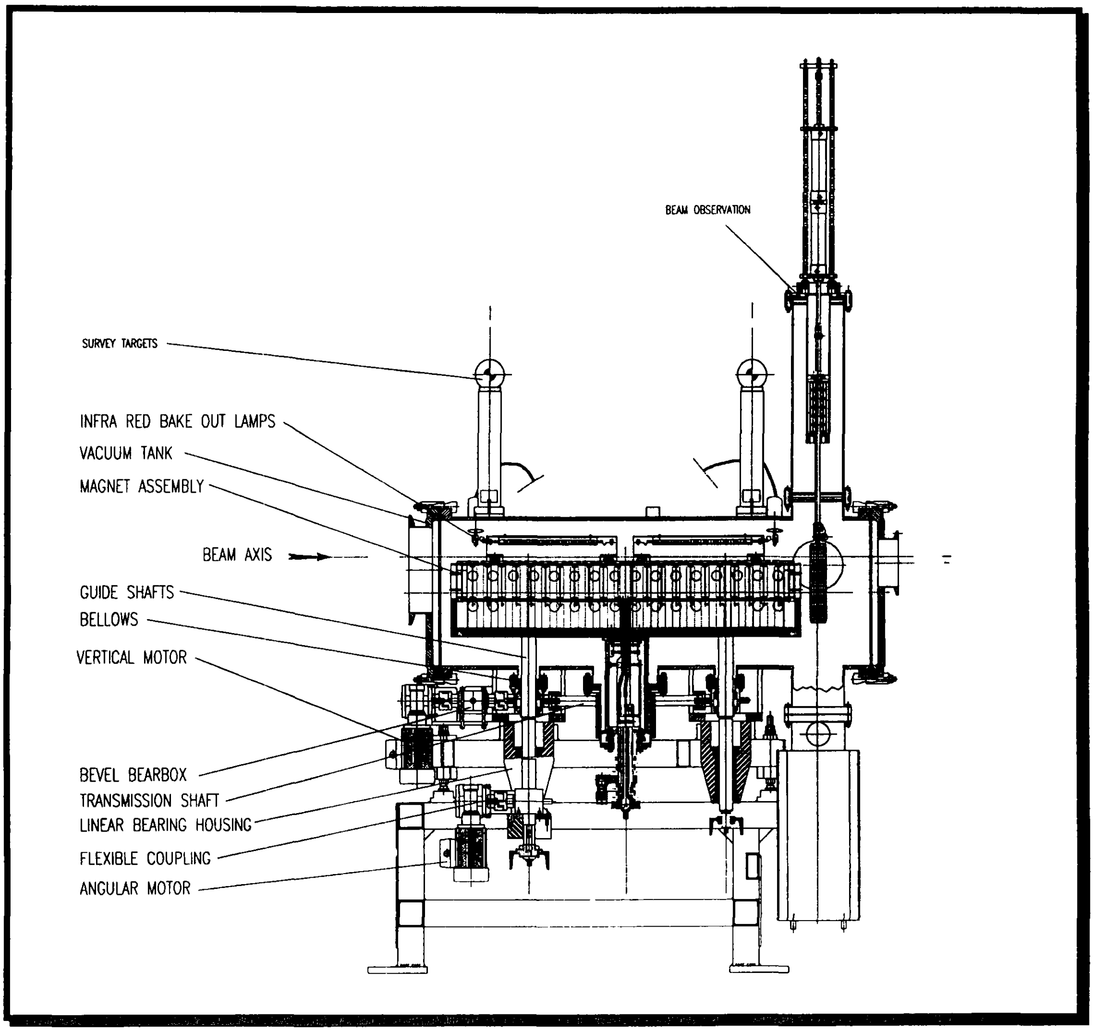


Cross section of SMV20 at upstream end of tank **Fig. 1.**

The drawing above shows a section of the complete magnet tank assembly at the upstream end of the magnet. The vacuum tank (see fig. 1. above) is positioned , aligned and fixed on the main support structure which is itself bolted to the main tunnel floor. Four precision screw jacks are secured to the vacuum tank on machined surfaces and are attached to the main support beam by means of hexagonal rods. The hexagonal rods have threaded ends and are adjusted to ensure the main support beam is horizontal. The main support beam carries the angular adjustment screw jack which itself is attached to a second beam (Angular support beam). The angular support beam carries the magnet assembly by means of solid guide shafts running in linear bearings. Vacuum bellows welded to the guide shafts seal on flanges on the main tank body.

On the downstream end (see fig. 2. below) of the vacuum tank the magnet is supported by similar guide shafts which are then fixed on a support beam linked to two vertical screw jacks. The downstream end is basically a simplified version of the upstream end as there is no angular movement system.

The main vertical drive system consists of one motor connected to a bevel gearbox / screw jack arrangement as shown in fig. 3. The vertical screw jacks are connected by a series of hollow drive shafts mounted with elastic couplings to compensate for any slight misalignments. The angular drive system consists of one motor linked to a screw jack via an elastic coupling.



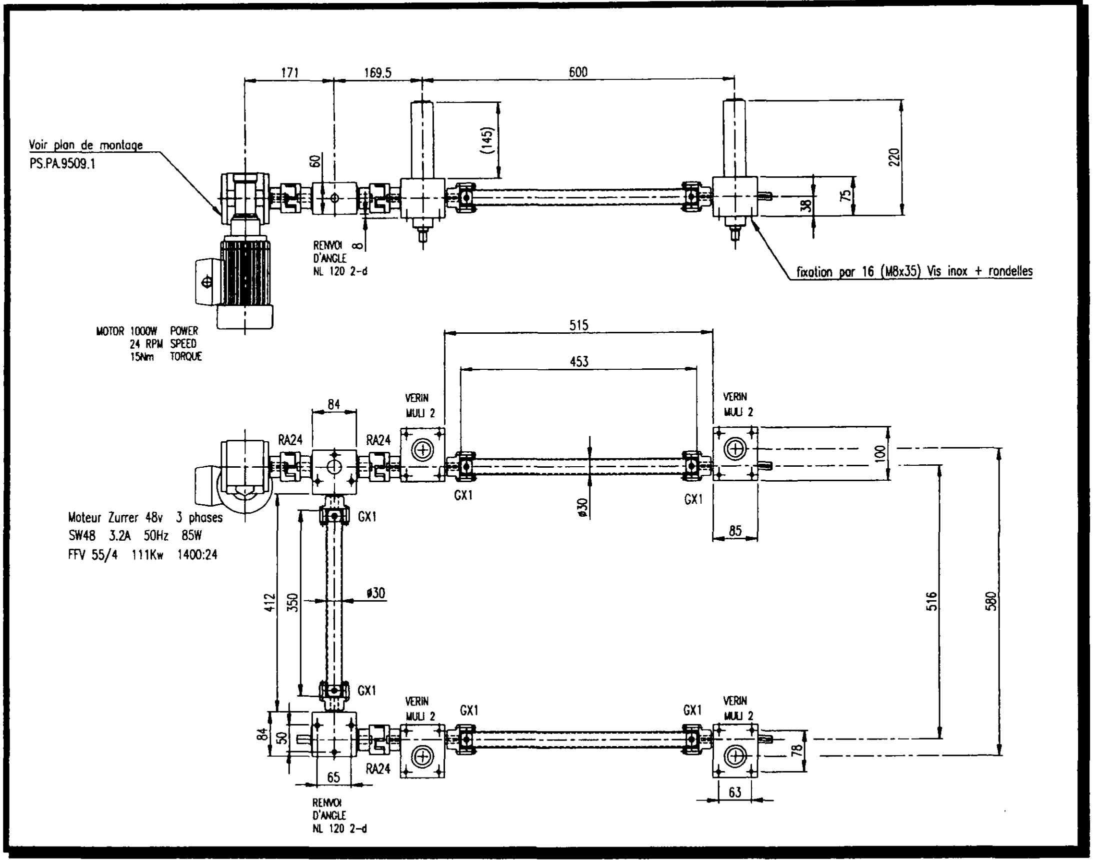
Section along beam direction SMV20 **Fig. 2.**

Drive Train Load Analysis

The positioning system must operate under two different loading conditions, the first being when the tank is at atmospheric pressure and the second is when the tank is under vacuum such that the actual load on the drive train is reduced by a significant factor due to the vacuum force tending to raise the magnet. The system was thus designed to operate efficiently under atmospheric conditions.
The following section outlines the system characteristics and load conditions.

Total mass of "mobile" magnet assembly = 480 kg	
Load on each guide shaft	120 kg = 1200 N
Motor Characteristics:	Torque 15 Nm
	Reduction ratio 1400:24 = 58.33:1
	Motor output speed 24 R.P.M
Bevel Gearbox Ratio	1:1
Screw Jack	Type MULI-2
	Max. Load 10 kN
	Ratio 1 rev = 1mm advance of screw

Fig. 3. Below shows the layout of the vertical displacement system.



1. Repetition Rate and Load Limit

To avoid overheating due to friction in the screw jack assembly the configuration must satisfy the following criteria,

F_{eff} x V_h <= F_h x $V_{h\,max}$ x f_t where

F_{eff} = 1.2 kN Load on each screw jack
V_h = 24 mm min^{-1} screw advance
F_h = 10 kN (Manufacturers max. load value)
V_h = 1500 mm min^{-1} (Manufacturer max. limit)
f_t = 0.6 (Manufacturer thermal coefficient)

In the case of SMV20 the resulting analysis provides a satisfactory solution,

$$1.2 \text{ kN x } 24 \text{ mm min}^{-1} < 10 \text{ kN x } 1500 \text{ mm min}^{-1} \text{ x } 0.6$$

2. Torque exerted on Screw Jack by flange

$$M = F_{eff} \text{ x } f$$

where M = torque exerted on the jack by the method of fixing
F_{eff} = Axial load on screw
f_m = Friction and geometric coefficient

$$M = 1200 \text{ x } 1.6 = 1.92 \text{ kNm}$$

3. Required Torque per screw jack for efficient operation

$Ms = (F_{eff} / (2 \times \eta)) \times (P / i) + Mo$

where Ms = Torque required Nm
F_{eff} = Axial Load kN
η = Screw efficiency (%)
P/i = ratio of screw advance per revolution of shaft
Mo = Starting Torque (No Load) Nm

$Ms = (1.2 / (2 \times 0.3)) \times (1/1) + 0.06$

$Ms = 2.12$ Nm

4. Required Motor torque

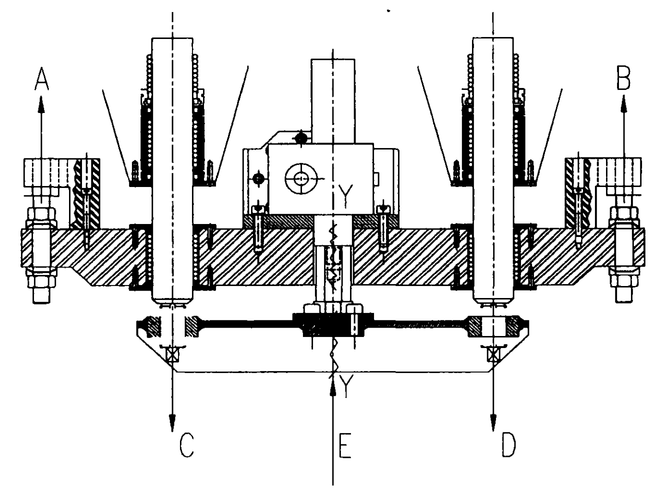
$M_{motot} = (Ms_{shg1} \times 1/\eta_{V1}) + Ms_{shg2} + (Ms_{shg3} \times (1/f_{V2}) \times (1 / f_k))$

$+ (Ms_{shg4} \times (1/\eta_{V3}) \times (1 /\eta_{v2}) \times (1 / f_k^2)$

where Ms_{shg} = Torque required at screw jack (2.12Nm)
η_V = Efficiency of transmission shaft (0.95)
f_k = Efficiency of Bevel gearbox (0.9)

Total Torque required at Motor = 10 Nm
The max. torque available from the motor is 15 Nm allowing 50% reserve.

5. Stress Values in main structural members



Main support beam (1) $W = bd^2/6 = 130 \times 60^2 / 6 = 7800$ mm^3
Lower beam (2) $W = 60.7 \times 10^3$ mm^3
Load at A,B,C & D = 120 kg
Minimum Diameter Screw jack shaft = 12 mm

- Tensile stress in screw jack shaft = 240 kg $/ \pi \times 6^2 = 2.1$ kg mm^{-2}

- Bending stress $\sigma_{y\text{-}y}$ in main beam = $M / W_{main\ beam} = (290 \times 120 \times 6) / 130 \times 60^2$ kg mm^{-2}

  $= 0.446$ kg mm^{-2}

- Bending stress $\sigma_{y\text{-}y}$ in lower beam = $M/W_{\text{lower beam}}$ =120 x 160 kg mm / 60.7 x 10^3 mm^{-3}

  =0.32 kg mm^{-2}

Conclusions

The positioning system has been designed with a redundancy of 50% to allow for any increase in friction coefficients with time and also to allow for operation at higher temperatures such as immediately after a bake-out cycle.

The incorporation of backlash elimination is not necessary as the drive train remains constantly under tension.

All precision bearings and guides have been incorporated outside the vacuum tank thus allowing for regular lubrication if necessary.

Most of the individual components of the main drive system are standard items (as used on other septum magnet installations) and thus a lesser number of reserve parts are required.