Energy delivered to magnet during current rise:	
Stored energy	39 MJ
Copper loss	1.92 MJ
Eddy current loss	0.07 MJ
Energy delivered during flat-top	1.04 MJ
Energy required during current decay:	
Stored energy	39 MJ
Copper loss	2.03 MJ
Eddy current loss	0.08 MJ
Iron loss (hysteresis)	0.12 MJ
Nett energy loss/pulse	5.26 MJ
Overall average losses	2.22 MW

SECTION 2

COMPUTATION AND THEORETICAL WORK

Computing programs, developed by the Theoretical Physics Group, have been used for the design of the injector and for studying the dynamics of Nimrod, the extracted proton beam and secondary beams. Since most of the work has been fully recorded in reports, only an outline list of these and the computer programs available is given here. Copies of the programs can be obtained from the originators.

2.1 Linac Injector

(a) A.E.R.E./R/3012: 'Calculation of drift-tube dimensions in the linac injector for the 7 GeV Harwell proton synchrotron' by R. Taylor (Sept 1959).

A Mercury Autocode program which computed drift tube dimensions.

(b) A.E.R.E./R/3013: 'Acceptance of axially and radially oscillating particles for the Nimrod injector' by R. Taylor (Oct. 1959).

Several Autocode programs which use the field data from the previous report.

(c) A.E.R.E./R/3096: 'Effect of rotational misalignment for the Nimrod injector' by R. Taylor (Oct. 1959).

A Mercury Autocode program.

(NOTE. Some of the above programs exist in adapted form for tanks 2 and 3, and the redesign of tank 1 of the 50 MeV Proton Linear Accelerator at the Rutherford High Energy Laboratory).

2.2 Linacs; General Theory

The following are more general in application but are included for completeness.

(a) NIRL/M/37: 'Finite-difference computation of parameters of electromagnetic resonant cavities relevant to proton linear accelerators' by R. Taylor and P. Kitching (July 1962).

This report contains a detailed description of a Fortran program for computing dimensions, shunt impedance and field patterns for Alvarez-type cavities, and has been used extensively in accelerating structure studies (e.g. see P.L.A. Progress Report, 1962; NIRL/R/24, p.13).

An Autocode prograr has beer written for the simpler case with sharp corners and no axial hole in the drift tubes. An analytical solution of this was used to test the finite-difference program (See 'Calculation of resonant frequencies of re-entrant cylindrical electromagnetic cavities', J. Nucl. Energy, Part C, 3 (1961), p.129; R.Taylor).

(b) A Fortran program also exists for the calculation of dimensions in an iris-loaded cylindrical waveguide (see 'Calculation of dispersion

of iris-loaded cylindrical electromagnetic waveguides', J. Nuc. Energy, Part C, 4 (1962), p.418; R. Taylor).

2.3 Nimrod Dynamics

A Fortran program is available for studying particle dynamics in Nimrod. The input can be either in the form of directly measured fields or in some simpler form. Straight sections with or without fringe fields are included. The program has been used for studying closed orbits, betatron oscillations and Q-values, and also for extraction studies of the primary protons and secondary particles.

NIRL/R/46: 'Computer program for particle tracking in Nimrod' by D. Whiteside (1963).

NIRL/R/47: 'Trajectories from a Nimrod octant' by D. Whiteside (not yet published).

2.4 Extracted Proton Beam

Early descriptions of the design of the extracted proton beam are contained in:

(a) 'An achromatic modification of the Piccioni extraction system' by R. G. T. Bennett and J. W. Burren (1960). This was originally issued as an internal laboratory note but most of the information, except for some numerical calculations, was published in the Journal of Nuclear Energy (Part C, 3 (1961), p.14; R. G. T. Bennett and J. W. Burren) under the title 'An achromatic system of extraction for proton synchrotons'.

(b) AERE/M/521: 'The extraction system for Nimrod, Part 1: the Piccioni target and the extraction magnet' by J. W. Burren (November 1959).

(c) NIRL/R/12: 'Design studies for the Nimrod external proton beam' by J. W. Gardner, N. M. King and D. Whiteside (1962).

Detailed design, using more accurate input data, has been carried out recently using the Fortran program described above.

2.5 Irradiation Studies

Orbit calucations were made to estimate the probable distribution of high energy irradiation of the upper and lower walls of the vacuum vessel.

AERE T/M 173: 'High energy irradiation of the vacuum envelope of the 7 GeV Harwell synchrotron' by J. W. Burren and D. Morgan (November 1958).

2.6 Beam Design

Two general purpose programs are available for the design of particle beams. TRAMP (Tracking and matching program) can be used for systems of

quadrupoles, bending magnets and crossed field separators. For a description of the Mercury Autocode version of the program see NIRL/M/21 by J. Gardner and D. Whiteside (1961). The Fortran version by the same authors is described in NIRL/M/44 (1963).

The second program is called OPUS (Optimisation program for unstable secondaries); NIRL/Note (1962) by J.W. Gardner and D. Whiteside.

The principles of separated beam design are contained in the following reports:-

NIRL/R/2: 'Basic concepts in design of electrostatic separators' by N. M. King (1961).

NIRL/R/10: 'Finite separation in electrostatic velocity separator design' by N. M. King and R. G. Cox (1961).

NIRL/R/18: 'Theory of two-stage separated beam systems' by J. W. Gardner (1962).