RAL

DESIGN & DISCOVERY

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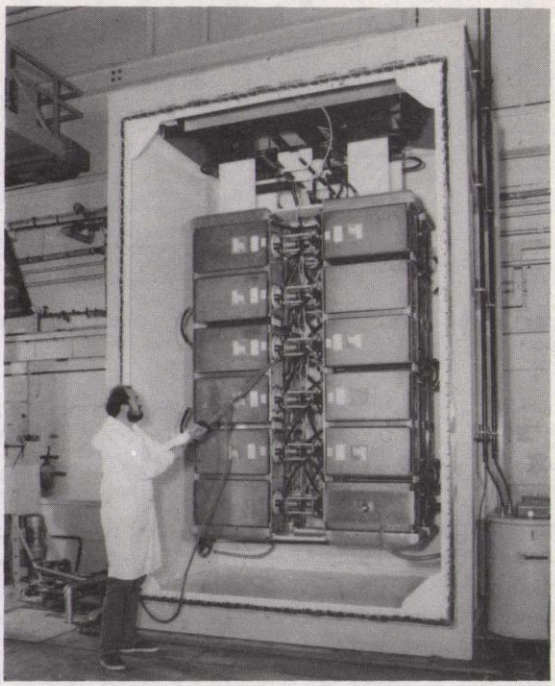
RUTHERFORD APPLETON LABORATORY

SCIENCE AND ENGINEERING RESEARCH COUNCIL

THE PULSED POWER DEVELOPMENT LABORATORY

"Pulsed power" is the name given to the science of generating very short, very high power electrical pulses. These have a number of uses in research physics, in particular as sources of power for particle accelerators, plasma physics experiments and pulsed lasers. The Pulsed Power Development Laboratory is run by the Central Laser Facility to develop electrical drivers for the next generation of very large lasers. The working pulsed power system which drives the Sprite laser can be seen in the neighbouring building, R2.



The photo shows a high voltage generator using energy storage capacitors linked by spark-gaps and liquid resistors.

WHAT DO WE MEAN BY PULSED POWER ?

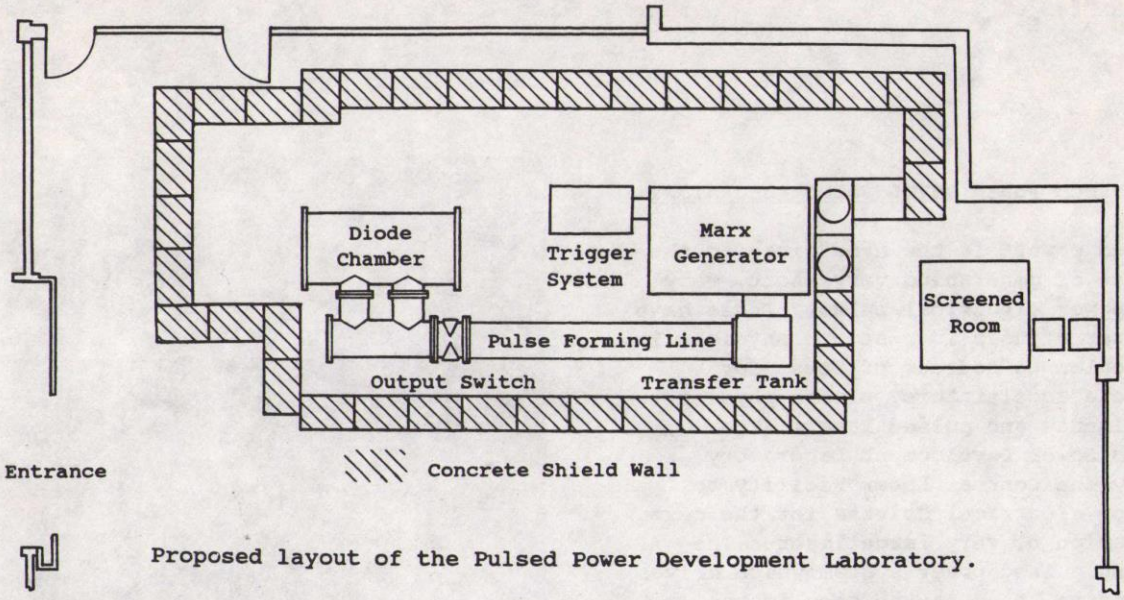
Physicists define power as the rate at which energy (measured in joules) is delivered. Power is measured in watts, where one watt is equal to one joule of energy per second. Familiar items such as a light bulb (say one hundred watts) an electric fire bar (a thousand watts) and a car engine (up to one hundred thousand watts) represent typical everyday power levels. A power station such as Didcot might generate two thousand million watts.

Pulsed systems, which deliver modest amounts of energy in short periods of time, can generate high peak powers for the short duration of the pulse. A typical example is a camera flash bulb which uses perhaps five joules of energy in five millionths of a second. During the flash it is working at a power of one joule per millionth of a second i.e. one million watts ! The flashgun takes its energy very slowly (i.e. at very low power) from a small battery and stores it temporarily in an electrical component called a capacitor. This behaves in many ways like a battery itself. It can't store as much energy as a battery but the energy it does store can be released very quickly, giving a large power increase. This practice of charging an energy store very slowly and discharging it very quickly is precisely what is done by pulsed power systems.

The other common function of pulsed power machines is to increase the available voltage from a few hundred thousand volts, which is the limit of d.c. power supplies, to several million volts, which components can only withstand for very short pulses. These extremely high voltages are needed to drive the final devices.

THE MACHINES IN BUILDING R7

We are presently assembling and testing a system which is half of that required to drive a large laser. The laser action itself takes place in a mixture of gases when this is bombarded by a pulsed beam of high energy electrons. The layout of the electron beam generator in building R7 is shown below.



Proposed layout of the Pulsed Power Development Laboratory.

THE MARX GENERATOR

The capacitors which store the electrical energy form a circuit called a Marx Generator, after its inventor Erwin Marx. Once they are fully charged, which takes about two minutes, a set of 12 spark-gap switches is fired connecting all 24 capacitors together. Each one can be charged to one hundred thousand volts so the peak output voltage can be up to 2.4 million volts. If the capacitors were mounted in air the air itself would spark over and the machine would fail. To prevent this they are hung in a steel tank, normally filled with 12 tons of transformer oil.

The energy stored on the fully-charged capacitor bank is 160 thousand joules, which shows how large a volume is needed to hold electrical energy, compared, say, with the chemical energy stored in food. The same amount of energy is released by digesting a single Cream Cracker although, of course, the release is much slower !

THE PULSE-FORMING LINES AND THE OUTPUT SWITCHES

Once the Marx Generator switches have fired, the stored energy is transferred onto the Pulse-Forming Lines (or PFLs) via an intermediate oil tank called the Transfer Tank. This process takes less than two millionths of a second, so the Generator's output power is one hundred million times the input power used to charge it. Each PFL is made from two coaxial metal cylinders, with the space in between filled by a ton of deionised water. Their job is to speed up the electrical pulse a further 6 times and to turn it on and off more quickly than could the Marx alone. Each PFL drives an electron beam diode via a laser-triggered spark-gap "output switch".

THE ELECTRON BEAM DIODES

The final part of the generator will be the electron beam diodes, which are still being designed. They will operate inside a large vacuum chamber, separated from the laser gas by a very thin titanium foil through which the electrons will pass. In doing so they generate an intense x-ray pulse, needing a thick concrete shield.