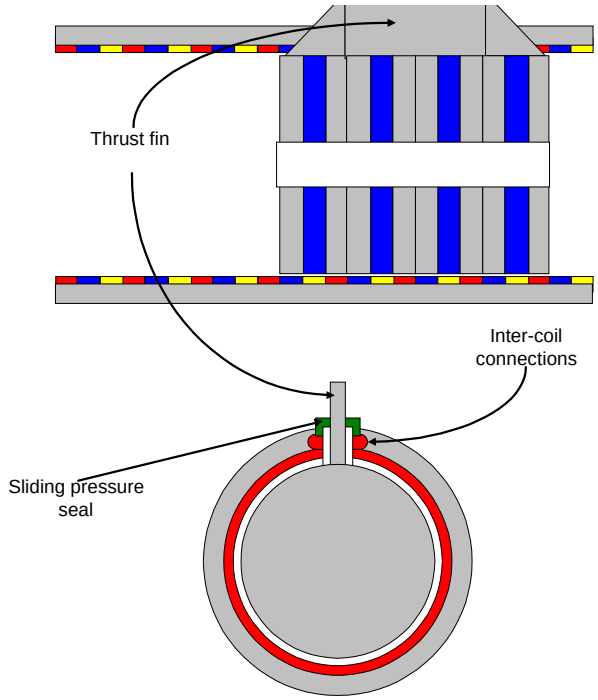
The slotted electromagnetic ram



Many of the problems presented to us are best solved by the use of a machine in which the piston or armature moves within a hollow tube that forms the stator of the machine. Generally the piston carries an array of magnets and the tube is lined with coils, but the reverse arrangement is sometimes useful. The stator coils are connected in blocks and in long machines only the two blocks next to the piston are switched in at any time, saving power.

The piston carries a fin that protrudes through a slot that runs the length of the stator tube, so that there is no need for a long piston rod. (There are many pneumatic rams of a similar design in long-term use. The technique of sealing the slot so that the ram may be fully protected from an adverse environment, or so that it may contain fluid under pressure, is already well developed.)

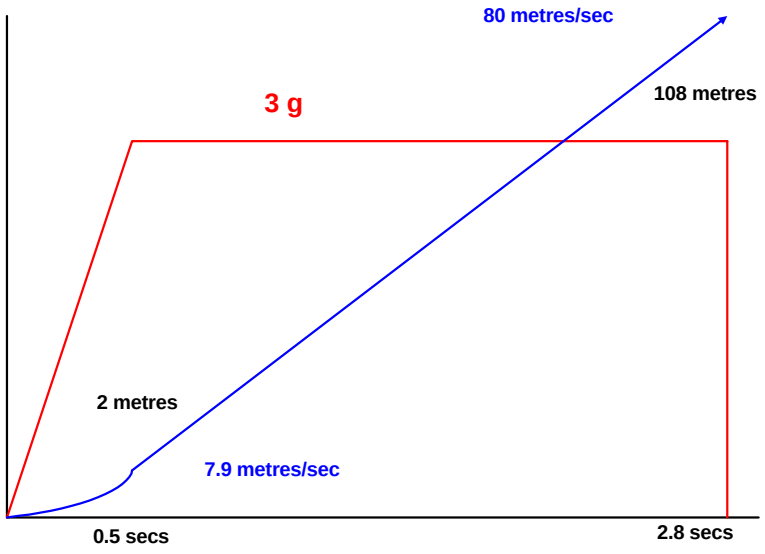
The principal advantages of the slotted electromagnetic ram technology are: -

- Very long travel machines can be designed. There is no known upper limit and rams more than a kilometre in length have been proposed for spacecraft launches.
- The force is transmitted a short distance from the piston to the fin. There are no problems associated with piston rod guidance or buckling.
- The piston length may be considerable without detracting from its function. This allows small diameter rams to be designed to produce large electromagnetic forces
- The piston runs on its own bearings, pressing against the internal surface of the ram. No other close-tolerance bearings are necessary.
- The piston may be designed to be flexible, so that it follows any curvature of the stator tube in three dimensions – and any axial rotation.
- The stator tube cross section may be ovoid, so as to hold the line of the fin to the centre line of the slot.
- The technology of sealing the ram is well established, allowing the piston to be a dual-action device if necessary.

Notes on some of the potential applications

1. Aircraft catapults

At the request of the US Navy – and with the informal interest of the UK MOD – two designs were proposed, the first using one ram and the other using three rams. These were based on a ram topology that we call the slotted ram, for which we have lodged a new series of patent applications. The design calculations show that it should be possible to achieve an efficiency of 94% at launch, with peak power demand of 80 Megawatts and a total ram weight of about 50 tons. This is a great improvement on the steam catapult, whose efficiency is 6%, and the smooth action greatly increases the operating life of the aircraft.



The design proposal also includes dry braking and energy recovery for the piston and a motored and automatic return of the shuttle to the hook-up position. The catapult can be designed to rise up a ski-ramp at the end of a level launch run.

We have given some time to studying the method of storing and delivering the high peak power demand of the catapult and we have located means of doing this. The energy storage machine is also useful in recovering the energy of landing aircraft, recycling the electrical energy of the complete ship's system, reducing the energy usage and thus reducing the ship's thermal signature.

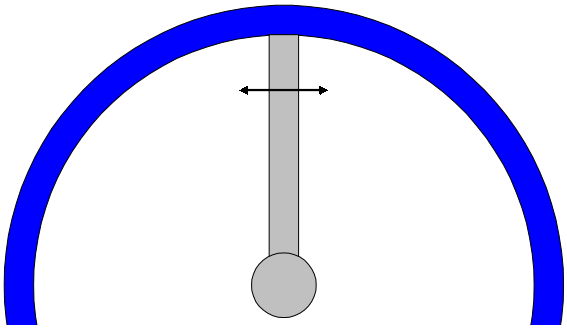
We have also worked on the problem of the catapult bearings and we can propose designs that levitate the piston clear of the walls and hold it central in the tube by two different technologies working independently.

2. High speed mast elevation actuators

We believe that it would also be possible to make the mast dynamic so that e.g. it would maintain a fixed height above the water surface. We have devised means for operating the rams at depth, outside the pressure hull of a submarine craft.

3. Ship's steering gear

We have examined the steering gear of a large US carrier and we have also looked at the drive mechanism for a UK destroyer. It is possible to wrap the slotted ram topology into an arc – in fact a complete circle – to form a very high torque motor in the form of a torus. Calculations based on such machines show that it would be possible to produce peak torques of several hundred tonne metres at a high efficiency, with only one moving part.



The slotted ram may be curved into an arc to produce torque via a connecting arm. Either or both chambers may be pressurised to balance deadload forces on the piston

Such machines would be very dynamic and controllable. It is possible that the rudder could be used as a roll-stabiliser. We have proposed means by which the rudder could be locked and by which it could be inched manually under emergency conditions.

It seems to us that similar designs might be produced for the control of power jet nozzles or deflectors.

4. Moveable high points

The high point mechanisms shown to us have been based on the use of a geared rotary motor with a chain drive for the point anchor. The disadvantage of these machines is their unreliability – the chains corrode and collect grunge that is extremely difficult to remove.

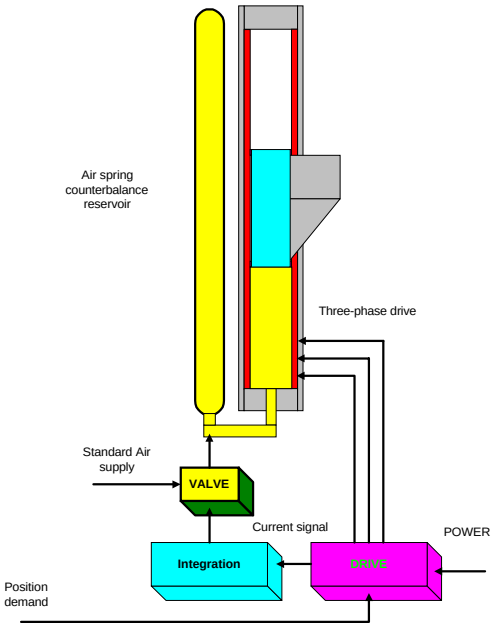
Again, we have proposed the use of the slotted ram topology, since there is only one moving part in the simple drive mechanism and the integral sealing strip should eliminate the reliability problems of the chain-driven machines.

The chief disadvantage of the electromagnetic ram for lifting loads is that it is a force generator, so that a sustained force requires a sustained power input that does not, by definition, do any real work. If the ram operates in the stalled condition, all the energy is wasted as heat in the coils of the machine.

So for industrial applications it would be normal for the deadload to be carried by air pressure beneath the piston, the air pressure being automatically controlled by a well-proven technique. The internal air pressure also helps to block troublesome ingress of water and other materials. (It should be noted that the use of air as a gas spring does not mean that a ship's pneumatic line has to be used for the high point. The air is not consumed and is merely "topped up" as required, perhaps by a very small pump that may be part of the high point fitting.

In the alternative we can propose an additional mechanism that locks the position of the ram at any point along its travel, preventing wasted energy.

5. Ordnance elevators



We have proposed that the existing systems of chain-driven and hydraulic mechanisms might be replaced by a number of slotted rams running in the elevator shafts and supporting the loaded platforms. Such machines would be swift, silent and very precise, with the minimum number of moving parts.

In this application it may be an advantage to use the ability of the slotted ram to move in three dimensions simultaneously and to rotate the fin around the axis along its path. This should allow the elevator to travel without interruption along “dog-leg” paths and through interlocked blast doors, greatly reducing the time from magazine to hangar deck or missile platform.

6. Ordnance elevator door operators

It was our original proposal that the doors might be supported from beneath by rams using a more conventional topology, but it is now clear that the slotted ram offers a simpler and more compact design. In this arrangement the rams are located on either side of the door, in the elevator shaft.

The deadload of the armoured door is designed to be carried by a gas spring counterbalance. The spring pressure is created by a small air pump attached to

the ram, controlled automatically by the ram controller so as to minimise energy use.

It will also be clear that the technology makes it possible to operate the doors by an emergency battery system (driving the small air pumps to raise or lower the spring pressure) and that fallback emergency manual control is also facilitated by the counterbalancing system.

7. Stabilised platforms

These mechanisms rely on an earlier topology of the electromagnetic actuator that is generally referred-to as the double-cup configuration. In this design the thrust is conveyed by a hollow tube that also functions as a gas reservoir. Early enquiries for this technology were for radar scanners and missile launch platforms, for which the basic principles were developed. This was later extended to vehicle suspension systems and a protected by a separate series of patent applications.

The technology represents a quantum leap in performance over any previous type of suspension system or stabilised platform. Its principal advantages are:-

- Simple in design, using easily-serviced components
- Low energy consumption – can be passive and recycling
- Self-adaptive to changing loads and motion envelopes
- Wide bandwidth provides millisecond response
- Well-controlled fail-soft behaviour
- Easily scaleable for different loads and dynamic response requirements

It became clear that a small platform might be developed to stabilise a heavy machine gun on the rail of a fast boat. The gun is designed to be fired by a marine, who has to compensate for the vigorous motion of the high-speed attack craft. It is clear that a very much higher hit rate would be achieved by fitting a TV sight to the **stabilised** gun – aimed by the same simple stabilising platform – and giving the marine gunner a videogame crosswire sight and a shock-absorbing seat!

The concept has been extended to a means by which the passenger capsule of a high speed craft may be isolated from the shocks of the journey in the same way that a land vehicle suspension isolates the passengers from major surface roughness. In particular, the fitness-to-fight of marine personnel would be greatly improved by the use of a self-adapting electromagnetic suspension. We also believe that the sea performance of the craft itself would be enhanced, because decoupling the passenger load would reduce the "unsprung mass" of the vehicle and allow it to move faster for the same degree of maneuverability.

There are, of course, many other military uses for the stabilised platform in land craft or amphibious vehicles, although some of these will require some advances in the design of the electromagnetic rams.

The non-military applications of the slotted electromagnetic ram will be covered in a document to be published shortly.