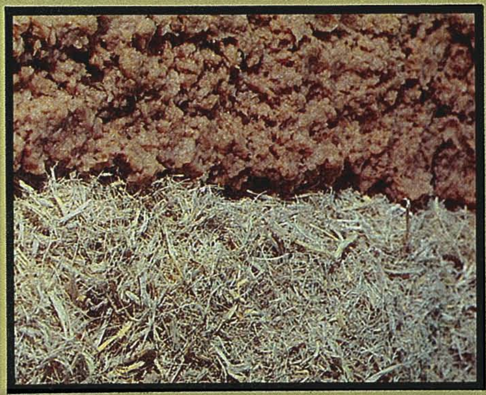
Explosion pulping ideal for recycling paper

'We can make paper pulp from virtually everything known to botany', says Dr Heikki Mamers, talking of the explosion-pulping technique he has developed at the CSIRO Division of Chemical Technology.

Experiments with explosion pulping were done on this rig.

After the explosion, out comes the pulp.



Bagasse before and after explosion pulping.

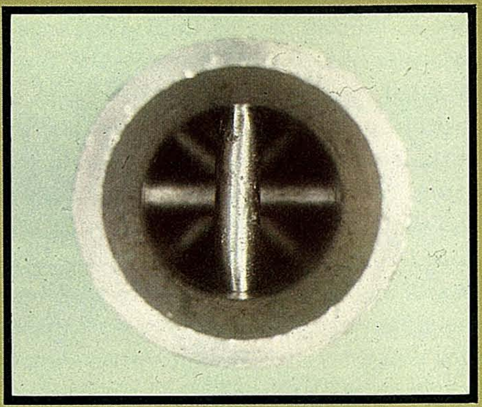
Bagasse, wheat straw, kenaf bark, rice stalks, as well as conventional wood chips — they all yield their fibre content, under the force of an explosive discharge, to provide a pulp suitable for paper-making. The process shatters parenchyma cells, which normally make paper-making from pithy plants a slow process.

More important at this time, thinks Dr Mamers, is the ability of the process to pulp materials unknown to botany: milk cartons, fruit juice cartons, cement bags, and other high-wet-strength materials that often include in their structure plastic, foil, wax, or bitumen layers. These are the materials conventional paper-recycling plants often reject as too hard to reclaim. Yet such rejects contain the Rolls Royce of paper pulps — the long, high-strength fibres that impart resistance to tearing.

Fibres are wrenched apart at a speed approaching that of sound.

According to Dr Mamers, explosion pulping therefore looks like an answer to the paper-recycler's problems. In the process, a batch of the material to be pulped is loaded into a vessel, along with water or a chemical liquor, and placed under high pressure (7 megapascals, or 70 atmospheres). The pressure causes liquid to penetrate rapidly into the fibre structure, leading to a weakening of interfibre bonds (the process is sometimes accelerated by steam heating). In a final *coup de grace*, the weakened material is explosively discharged through a specially designed nozzle into a collecting vessel. Fibres are wrenched apart at a speed approaching that of sound.

In this way, a batch of waste paper can be pulped in only a few minutes, compared with more than an hour for conventional techniques. Another advantage is that 'contraries' — adhesive tape, string, foil, plastics, glass, and other rubbish — survive the process relatively intact, making their subsequent separation fairly easy.



End-on view of the special nozzle used in explosion pulping. The pressurized feed-stock cannot shoot straight through, but must weave its way around a set of bars.

The recycling industry

Some 84% of the world's total paper and cardboard consumption is theoretically available for re-use. The rest is permanently conserved (books), contaminated beyond salvation (food wrapping), or totally destroyed (bank notes). In Australia, we recycle close to one-third of our paper (about half a million tonnes).

The work horse of the Australian waste-paper recycling industry is the open-tub reslusher, a device reminiscent of a large washing machine. There are six of these units spread around the country.

Recycled paper and cardboard are fed into the bowl of the reslusher and sufficient water and chemicals added to give a soup of 3–5% pulp. Constant agitation, and sometimes heating, gradually liberates the fibres from the feed material. This may take an hour or longer.

'Contraries' are removed in a number of ways. Matchsticks, foam plastics, and other light contraries float to the top and are skimmed off. Heavy ones — metals, glass, and rocks — sink to the bottom and into a special compartment. Materials of substantially neutral buoyancy — such as sheet plastic, ropes, string, and rags — are encouraged to wrap around a length of barbed wire that is gradually withdrawn from the bowl.

This leaves the materials that are particularly difficult to deal with. The list includes adhesive tapes, high-wet-strength papers, waxed cartons, paper laminated with thin layers of plastic, and any material containing bitumen, as either an adhesive or a waterproofing agent.

When being pulped, high-wet-strength papers and laminates don't disperse easily, and they frequently remain as small flakes in the pulp suspension. The flakes must either be filtered out (a difficult process) or subsequently treated to break them down.

Similar problems are posed by adhesive tapes and waxed cartons, with the added complication that gums, waxes, and bitumen also get into the mix, appearing as imperfections in the final paper. As little as 1 kg of bitumen in a 200-tonne batch of recycled paper can render the lot unsuitable for printed packaging.

A final consideration is that reslushers generate large volumes of dilute liquid effluent.

Explosive answer

In this situation, explosion pulping comes into its own. Pilot-plant trials with 'synthetic garbage' have shown that the process quickly loosens the fibres of normal waste paper, but leaves the majority of the unwanted components relatively intact. High pressure rapidly converts paper to a soft mass, but waterproof papers, tapes, and the like retain much of their structural integrity. Not only are adhesive tapes undamaged by the explosion, but the adhesive even remains attached to the tape. Polyethylene bags, cotton rags, and string also remain undamaged; bitumen-impregnated paper is frayed somewhat at the edges, but otherwise intact; polystyrene foam and brittle plastics suffer minimal damage.

According to Dr Mamers, explosion pulping looks like the answer to the paper-recycler's problems.

The process requires little water, and hence effluent problems are minimized.

Dr Mamers suggests that explosion pulping would be ideal for use in garbage-reclamation plants. Here, metal, glass, and other heavy solids would be removed first, leaving a waste-paper stream laden with plastic and other light materials. This stream could then be explosion pulped.

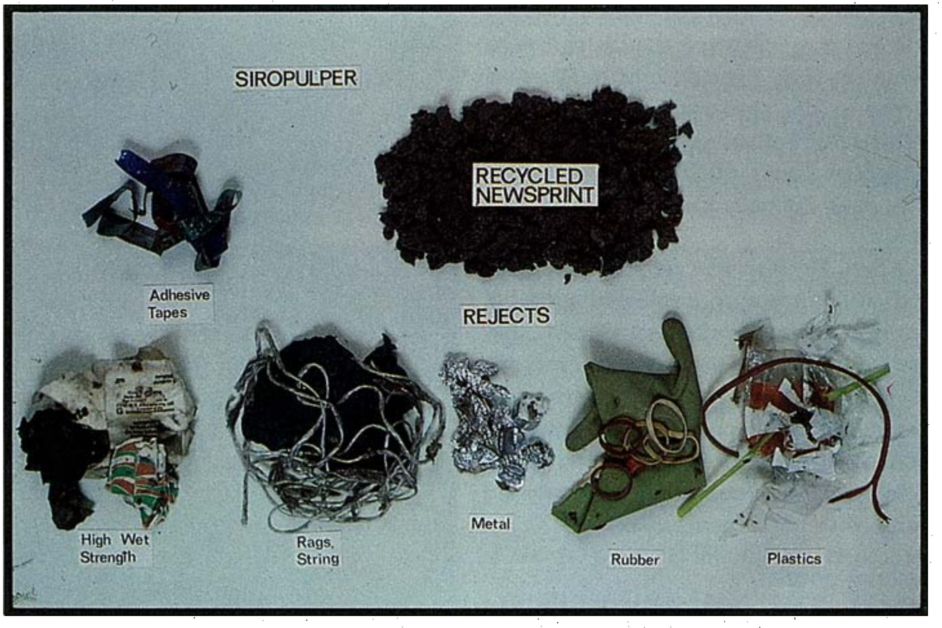
The idea of explosion pulping is not new. For many years Masonite building board has been made using the technique. However, the high temperature required for good pulping (about 280°C) also leads to cooking of the fibres (giving rise to the characteristic dark brown colour). Obviously, such a technique is not suitable for paper-making.

Dr Mamers' advance was to devise an explosion-pulping apparatus that required significantly lower temperature. Indeed, for a number of feed-stocks, including recycled paper, it is better to use no heating at all.

One way of viewing the process is to see it as one using an explosion to sort materials: masses of paper fibres are blown to bits; the rest escape relatively unscathed. A practical operating strategy at a recycling depot may thus be to pulp everything without heating after only a short high-pressure treatment. This would readily pulp normal papers, leaving 'difficult' papers to be easily separated. Later, these materials (such as high-wet-strength papers, waxed cartons, photographic papers, foil-laminated board, and plastic-coated items) could be pulped after a more prolonged treatment.

Heating is avoided because elevated temperatures cause contraries such as bitumen and waxes to disperse during the explosive release.

However, if well-sorted feed-stock is available, heat is a decided advantage for most materials — it allows the use of shorter soak times and lower pressures. Using pressures below 3·5 MPa means that air can be used to pressurize the vessel (at higher pressures, air becomes a bit dangerous because the high concentration of oxygen could lead to an unwanted chemical explosion). Otherwise nitrogen or low-oxygen flue gas needs to be employed.



This shows how the various components fared when waste paper, loaded with rubbish, was explosion-pulped.

Actually, if clean milk cartons or other laminates are to be processed, pressure treatment and cooking are enough to let the layer containing paper fibre free itself from the rest. No chemical treatment or explosion pulping is necessary, and in fact the latter is not desirable since it would needlessly fragment the unwanted layers. As it is, treated plastic laminates appear as long strings, so most of them can be

Instead of burning it, we can make paper from wheat stubble.

readily removed with barbed wire fitted in an agitated tank. In experiments conducted by Dr Mamers, the plastic content of recycled milk carton pulp was less than 0·2% after a preliminary screening. About 90% of the fibre was recovered.

As well as recycled paper, explosion pulping is especially suited to the processing of bagasse, wheat straw, and other fast-growing crops such as kenaf. Normally these materials are difficult to pulp because they contain a high proportion of pith (parenchyma cells). Bagasse (sugarcane after crushing) can contain 25–30% pith and in wheat straw the figure can be as high as 68%. Upon pulping by standard methods, the thin-walled parenchyma cells readily collapse and inhibit the free escape of water during paper-making. The poor drainage slows down production.

When Dr Mamers subjected bagasse and wheat straw to explosion pulping, however, the new method produced a distinct difference. Through a microscope he could see that the parenchyma cells had not just collapsed, but disintegrated into small fragments. These pieces, he found, could be screened out to yield pulps with much better drainage.

Special nozzle

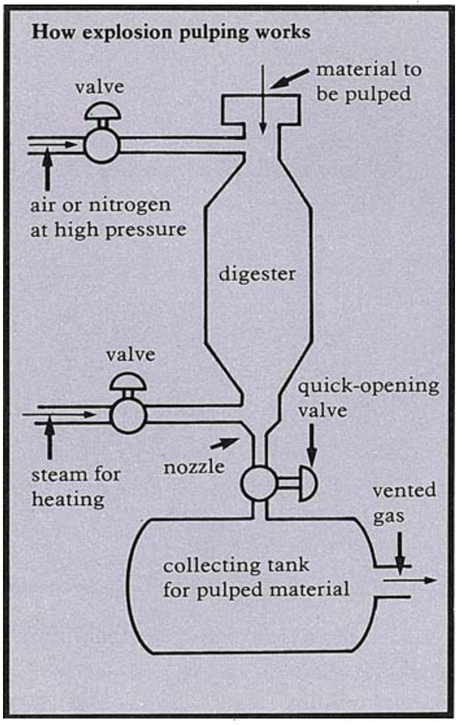
The key to Dr Mamers' success in making explosion pulping operate efficiently at low temperatures was to use a discharge nozzle of novel design. This nozzle very effectively turns the energy stored as gas pressure into work done in tearing the wood fibres apart. At the beginning of the research program he used a straight, open nozzle and found the pulping efficiency of wood chips to be only about 17%. Constricted nozzles were tried — as other workers in the field had suggested — but no more than 20% of the mass of fibre bundles ended up as single fibres. Furthermore, problems with blocking became very pronounced.

Obviously, a way of creating a highly turbulent flow during the discharge, without too much hindrance to the flow, was wanted. Dr Mamers tried putting a small bar across the nozzle; this time close to 30% pulping efficiency was obtained. He then tried a spiral staircase of bars (35%), various flutings on the inside surface of the nozzle (not much difference), and finally a random orientation of cross bars — success! About 85% of the woodchip mass finished up as individual fibres.

Dr Mamers surmises that the bars serve to catch each wood chip so that it folds over a bar like lint on a drain-hole plate. Other material passing over the chip progressively pulls fibres off.

Blocking doesn't seem to be a large problem, and in practice a number of nozzles side-by-side would be used.

A further advantage of explosion pulping is that the forces generated during the explosive discharge combine with the chemical effects of a cooking process to release ink particles from recycled paper. As a result of this combination, the process uses less chemicals than most other de-inking methods.



Material is fed into the digester (and sometimes heated with steam) before being placed under high pressure for a few minutes. It is then explosively released through a special nozzle.

The gain is not great when dealing with newsprint, but is significant when dealing with very adhesive inks, such as those on frozen-food packs. Here, chemically bonded, or ultraviolet-cured, inks are used to increase durability; they also make recycling the pack more difficult. A conventional reslusher could work for hours trying to separate fibres from the pack, whereas explosion pulping can do so in minutes with greater than 99% fibre release.

Utilizing crop wastes

The sugar industry has become very interested in the prospect of turning excess bagasse into paper pulp. Sugar mills use some of their bagasse for firing boilers, but they have much more on hand than they need.

The idea then is that bagasse could be turned into pulp, dried and pelletized, and stockpiled for shipment. Prices for pulp are quite stable compared with that of sugar, which fluctuates a lot.

The approach that makes the whole scheme feasible is that each mill could produce pulp on site, because a single explosion-pulping vessel is small but has a large processing capacity. A 5-m^3 digester could handle all the bagasse from a small mill (100 tonnes of bagasse a day). The smallness of the unit means lower capital cost and better ability to pump heat quickly into it. Larger mills would simply have multiples of the same unit. The only chemical the mill would need would be caustic soda for cooking the pulp, and explosion pulping needs only half the quantity normally used.

Feasibility studies done so far by Dr Mamers look favourable on both practical and economic grounds.

Another promising avenue for explosion pulping is wheat straw. At the present moment, of all the millions of tonnes of wheat straw left in our paddocks after each season, only a minute fraction is turned into paper. APM Ltd have a plant at Broadford, Vic., that processes a small quantity of straw into pulp.

Dr Mamers envisages a number of small explosion-pulping plants in the wheat belt that could be profitably run, despite their operation being only seasonal.

To balance his optimism regarding these enterprises with bagasse and wheat straw, Dr Mamers is much more sanguine about the possibilities of exploiting kenaf wood and rice straw — they produced paper of poor quality. He is also very reserved about the likelihood of getting explosion pulping taken up by our conventional wood-chip pulping concerns. Theoretically, the process has a lot to offer, but nobody in the present state of affairs is ready to invest in a novel plant to expand this type of operation.

The future for explosion pulping, according to Dr Mamers, lies in the recycling of all sorts of waste paper and perhaps in processing annual crops like bagasse and straw.

More about the topic

The Siropulper — a new concept in wastepaper recovery. H. Mamers. *Appita*, 1978, 32, 124–8.

Explosion pulping of annual and fast-growing plants. H. Mamers, D. Menz, and J. P. Yuritta. *Proceedings of the 33rd Appita General Conference, Hobart, 1979*, 1979.