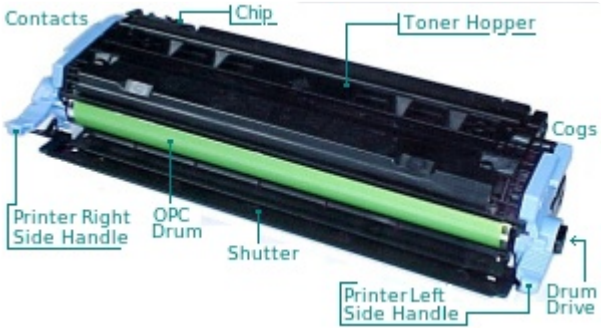
Color Laserjet 2600 Series Cartridge Dismantling and Recycling



The HP Color LaserJet 2600 series include the Color LaserJet 1600, 2600N, 2605 and the CM1015 and CM1017 multifunction print, scan and copy machines. They are all based on the Canon LBP-5000 engine, but the printer is much less common with a Canon badge. These printers proved very popular and are still widely in use, although HP have something of a campaign to replace them with "business quality" inkjets like the OfficeJet Pro 8600.

The primary design intention with these printers seems to have been low manufacturing cost. The printers were around the same cost as a professional inkjet printer to buy but could claim the reliability and running cost of a laser printer. Reliability was generally good at first, but as they age the cheap build of these printers tells a bit. Faults are almost invariably repairable, but more difficult than would be true for a more expensive machine. Repair is therefore for the talented amateur, or someone dedicated to getting the best from cheap hardware.

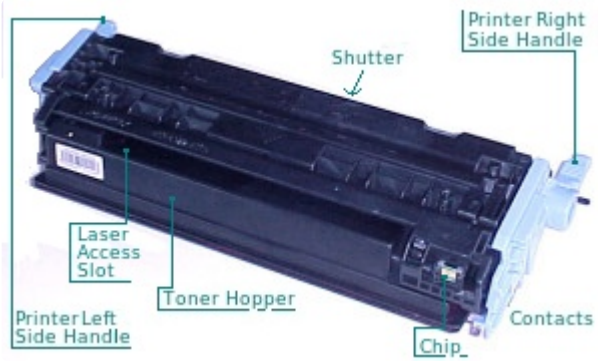
These printers can be seen as the smallest members of a wider family including the Color LaserJet 3600, 4600 and 5500 which are all around the same age and work using similar principles. The change in specification that most people would notice with these bigger printers was that they were faster. More importantly:

- Bigger cartridges are more cost effective. The CLJ 2600 costs about 2.65p per page to run, 2.5p for manufacturers original toner and about 0.15p for the belt and fuser when the machine wears them out. Comparative costs for printers the same age are CLJ 3600 2.2p, CLJ 4600 1.9p and CLJ 9500 about 1.6p per page.
- The bigger machines are intended for long life and easy maintenance. The fuser and transfer belt on the CLJ 3600 and bigger printers both plug in for instance - whilst those on the CLJ 2600 require the printer covers to be removed and work with a screwdriver.

Printer manufacturers would very much like you to pay for their original toner of course. It is widely reckoned that their profit on original toners is something like 80%. However only about a third of the

cartridges sold are refills, remanufactured and compatibles; the original manufacturers do have two thirds of the market. Quite simply, refills have a reputation for being more trouble so people just put up with the costs of original cartridges.

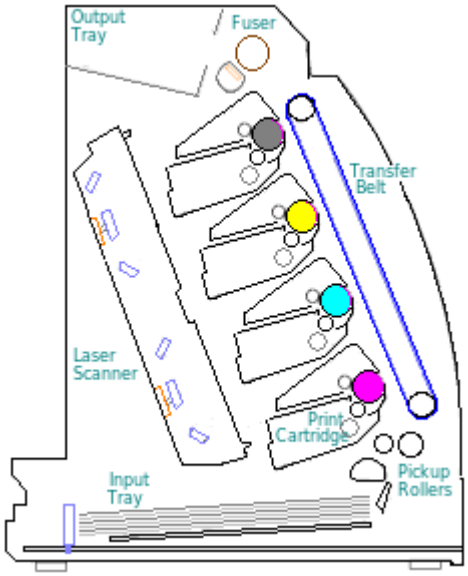
What we try to do here is to look closely at the ways a typical colour cartridge is made, how it might be refilled and what is likely to go wrong.



The Cartridge Idea

All printers in the CLJ 2600 series take the same cartridges, the Q6000A black, Q6001A cyan, Q6002A yellow and Q6003A magenta. The black cartridge carries a charge sufficient for 2500 pages. Colour cartridges carry a charge of toner sufficient for 2000 pages of print. Physically the cartridges are very similar (they might not be identical, Uninet sell a different developer roller for black).

Cartridges are typical of the HP/Canon all-in-one style with a toner-charge, developer and photo-conductor drum in a single unit. The idea of a cartridge is to make fault-finding and consumable buying fairly easy for the user. Wrapping up most of the print functions in a cartridge means most problems will be cleared by just changing this one thing. In principle a separate toner, developer and drum might be cheaper to use, but using cartridges means fewer things to buy and identify faults in.



This outline of disassembly and functioning of the Color LaserJet 2600 cartridge gives some idea of what the innards of the device look like and how they work.

Information Sources

Information here is our own, discovered by looking at the cartridge and the printer. We have referred to other material found on the web, notably "Future Graphics HP2600/2605/1600/ CM1015/1017 Technical Instructions (HP2600Tech)", "Uninet Imaging HP LASERJET 2600 Â® Cartridge Remanufacturing Instructions" which also contains part of the HP Service Manual and "Oasis HP Color LaserJet 2600 Remanufacturing Instructions ". They seem to be freely available in PDF form.

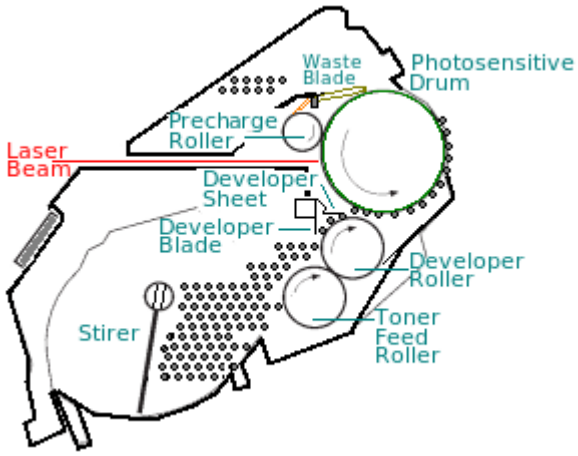
The manufacturers (Canon and HP) do not make much technical information on the workings of cartridges available. There is some in the Service Manuals, which give some details of the voltage patterns applied as the machine operates but not much on what is actually inside a cartridge. Technicians are intended to understand the general principles but not to open cartridges up.

Opening a cartridge is not generally thought worthwhile. There is not intended to be anything inside that can be fixed. There is a high probability of making a mess of clothes and carpets, so be familiar with what will be needed to clean things up (toner rated vacuum cleaner, disposable tissue, soap and cold water). If you put a cartridge you have attempted to refill or repair unsuccessfully into a printer it could make a serious mess. A missing transfer voltage could result in heavy print onto the transfer belt and overload the fuser foil - be prepared to replace them or clean them up.

However cartridges have become expensive items so this exploration of what they contain and why they might fail might prove useful.

HP CLJ 2600 cartridge are not easy to work on for refilling or remanufacture. Uninet remark on this "This is one of the first cartridges where HP/Canon really seems to have gone out of their way to make a toner cartridge very difficult to remanufacture ".

The cartridge might deliberately be difficult to refill or remanufacture, but equally that might just be a side effect of a manufacturing process that needs to produce great numbers of cartridges at low cost. The manufacturers intended that they would be rewarded for the attractively low sales price of the printer by profits from cartridges.



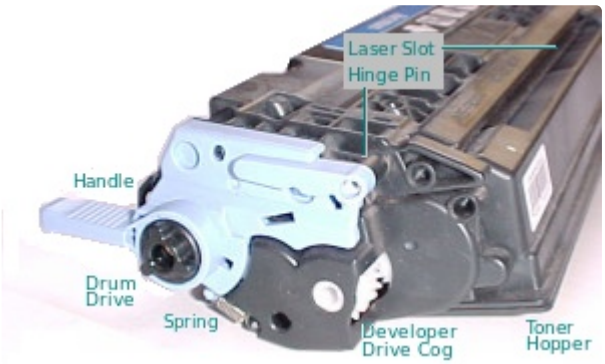
Cartridge Dismantling

Cartridges are not normally dismantled. In the words so often printed in User Guides there are "No User Serviceable Parts Inside". It depends on the user of course, but is more true of a cartridge than most things, there is nothing which a user would normally repair and a toner spill might create your very own Rothko painting. On the other hand there is very little that cannot be repaired or replaced - although that might be a job better left to professional recyclers.

About a third of the cartridge market is served by refill or remanufacture. To refill a laser printer cartridge it generally is necessary to open it up. People can go on courses to learn the techniques and franchise a refill business. Refill shops are the normal audience for the Uninet, Future Graphics and Oasis guides.

There are also a few kits available for home refilling. These generally suggest drilling a couple of holes in the cartridge, one in the top to let waste toner out and one in the back to put clean toner in. You can see roughly how this would work from the picture, we'll look at the job in more detail later.

At a casual glance the cartridge is a black plastic brick with lots of details in the plastic mouldings hinting at some complexity inside. About 70 components are used in one of these cartridges. The pattern on the exterior is partly dictated by mounting points and screw holes inside and is partly just to give the polystyrene case a degree of mechanical stability.

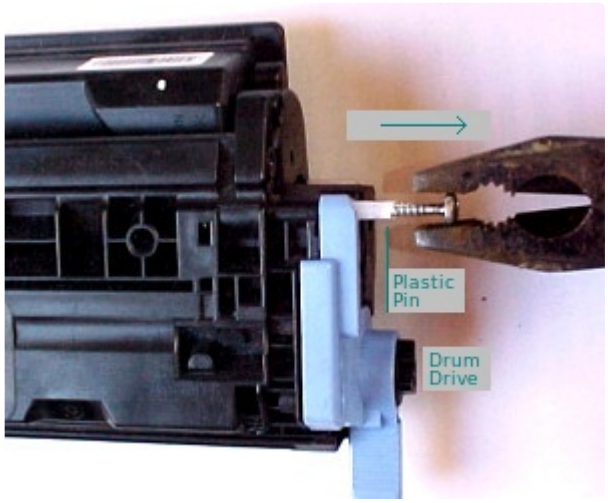


The blue handles not only help insert the cartridge into the machine, they support the OPC drum. The main problem is that they are firmly glued to the black body of the cartridge. To get the OPC out either excessive force has to be applied to the cartridge or the OPC bearings have to be cut with a hacksaw - not an elegant procedure.

It is not immediately evident from the outside but the cartridge is in two halves.

There is an upper assembly holding the Organic PhotoConductor Drum (OPC) with the blue plastic handles

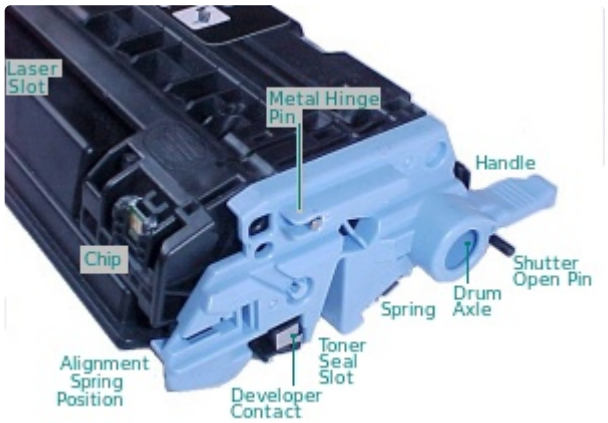
There is a lower assembly which holds the toner hopper and the developer. The toner compartment lid (the base of the cartridge) is glued in place.



The two assemblies are locked together by a pair of hinge pins towards the top rear of the blue plastic handles. Two springs on the front underside pull the top and bottom halves together. The developer roller has a plastic bushing on each end. The springs pull the developer roller up against the OPC drum so that developer to drum spacing is precisely determined by the bushings.

- A steel pin on the right of the cartridge also serves as the electrical connection for the precharge roller
- A plastic pin on the left is just a hinge pin.

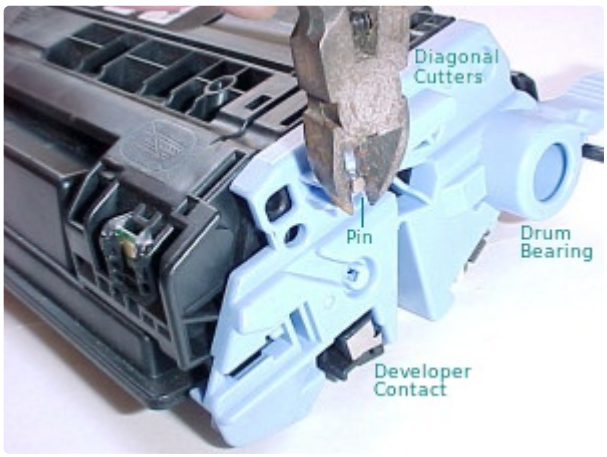
Note that I'm using "left" to mean the printer's left - not yours. Its the side of the cartridge with the shorter blue plastic endpiece and the gear assembly. Right is the side of the cartridge with the larger blue assembly and the visible metal contacts. When the cartridge is in the printer the right hand side of the machine contains the high voltage electronics and the left side has the motors and gear chain.



Neither pin is easy to remove

The metal pin may pull out if it's tip is gripped with diagonal cutters. However it is usually level with the plastic surrounds so the cutter blade will need to damage the plastic. Future Graphics, Oasis and Uninet suggest drilling a 2mm or so hole in the guide next to the pin so that the cutters can get a better grip. Since the pin serves as an electrical contact it should be damaged as little as possible. Rotating the pin a

bit as it is withdrawn may help because on the inside it is gripped by a metal plate. The plate will need to make good contact when the pin is reinserted, or the pre-charge and scraper blade voltage will be down.

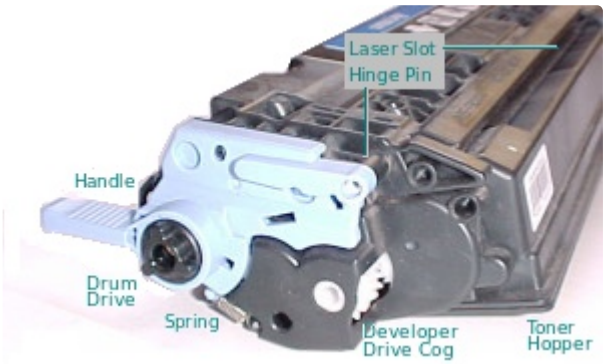


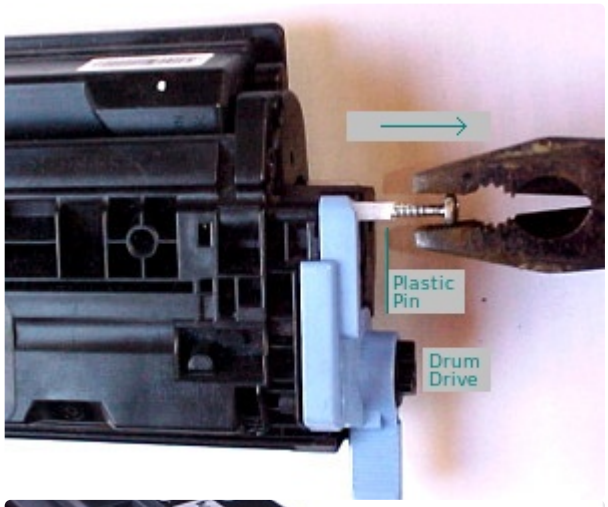
The plastic pin can be removed by using either a small boring tool or a woodscrew with a diameter of about 2mm. Put the screw into the hole and turn 3 or 4 times so that it has a good grip then use pliers to pull both the screw and plastic pin out.

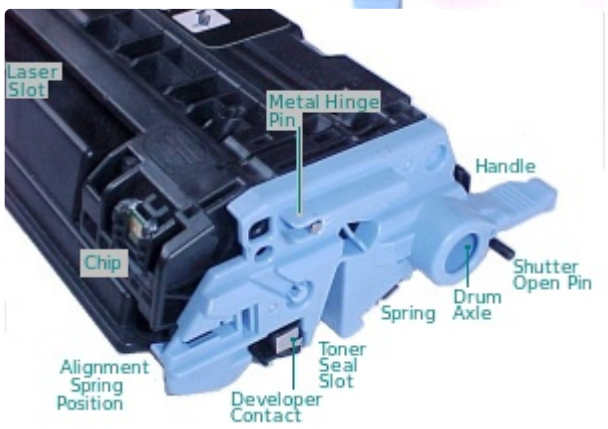
Remove the drum shutter door from the front. It is held by four hinge-pivot points and a little force will release them. Note the position of the shutter spring and don't let it escape.

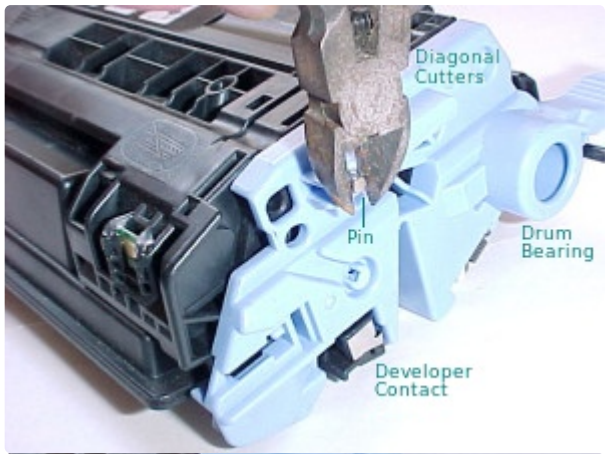
The cartridge is now held together by the springs on its underside. The springs are both the same length and 7 turns but they are different. The spring for the right side of the cartridge is black or marked with a black stripe and is stronger. The spring mounting points are not very fragile but if they are broken (or the spring gets away) the cartridge will be useless.

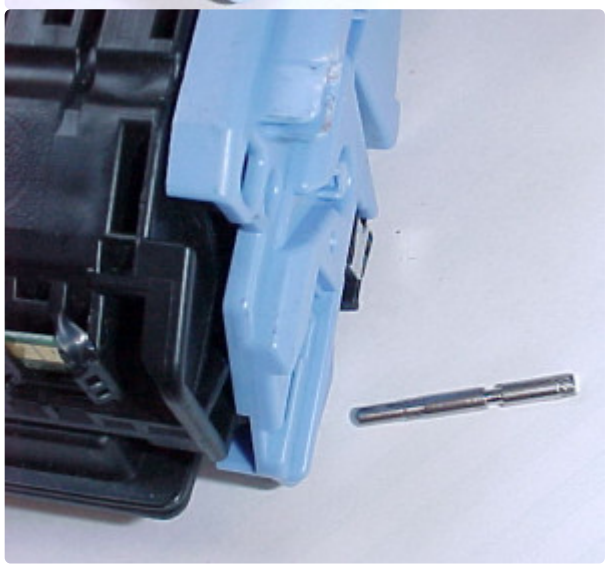
With springs and shutters removed the cartridge top and bottom half will now lift apart. The top half contains the OPC drum, PCR roller, drum scraper blade and waste tank. If the OPC is to be re-used it should be kept in a dark place, as exposure to light ages it badly. An aged OPC will give faint prints with a colour cast in the background - on a mono printer it is grey but with a colour printer the cast will be the colour of the bad cartridge.

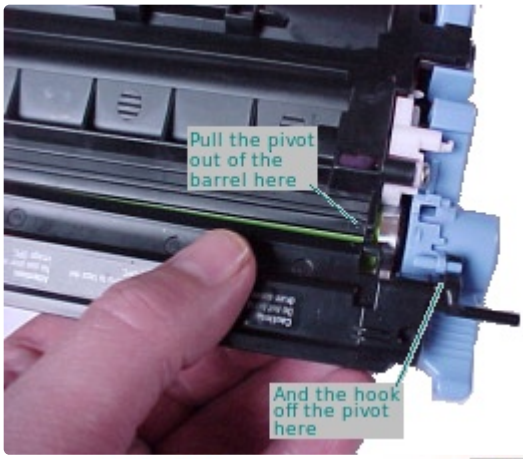


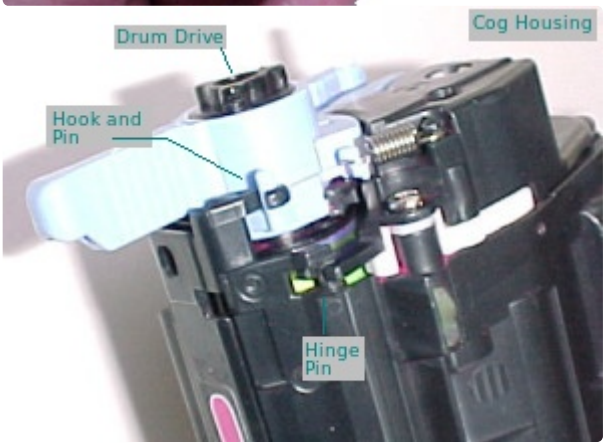

Plastic Pin
Drum Drive


Laser Slot
Metal Hinge Pin
Handle
Chip
Shutter Open Pin
Drum Axle
Spring
Toner Seal Slot
Alignment Spring Position
Developer Contact

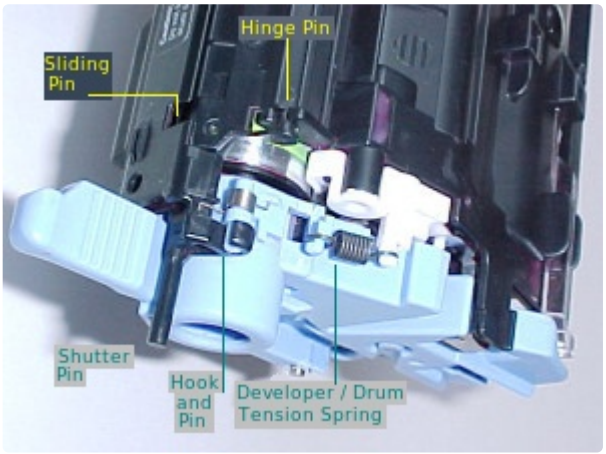

Diagonal Cutters
Pin
Drum Bearing
Developer Contact

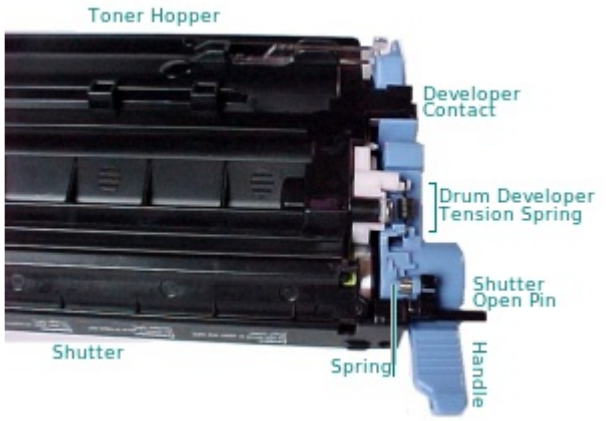


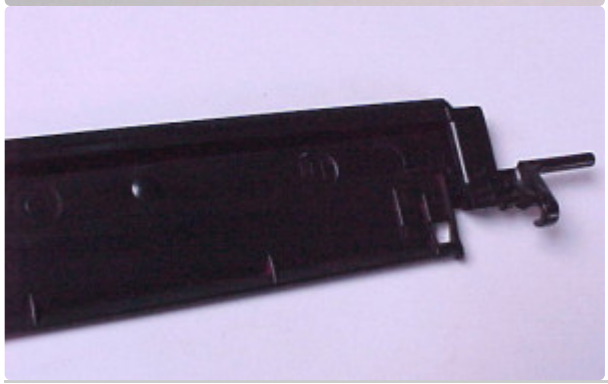

Pull the pivot out of the barrel here
And the hook off the pivot here

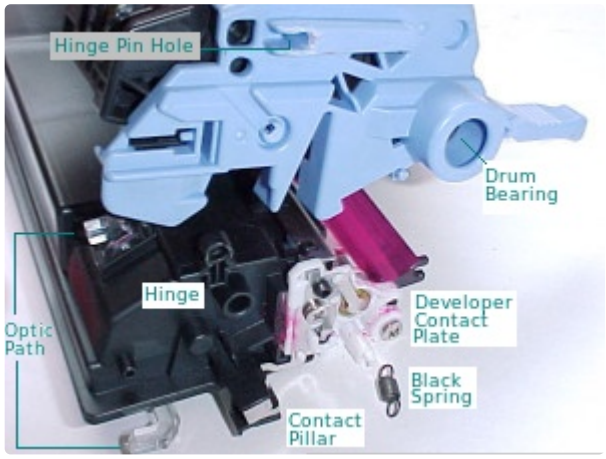

Drum Drive
Cog Housing
Hook and Pin
Hinge Pin


Toner Hopper
Cog Housing
Drum Developer Tension Spring
Drum Drive
Shutter


Hinge Pin
Sliding Pin
Shutter Pin
Hook and Pin
Developer / Drum Tension Spring



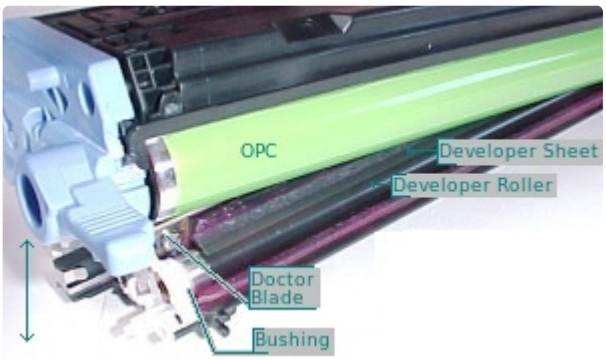




Principles of Operation

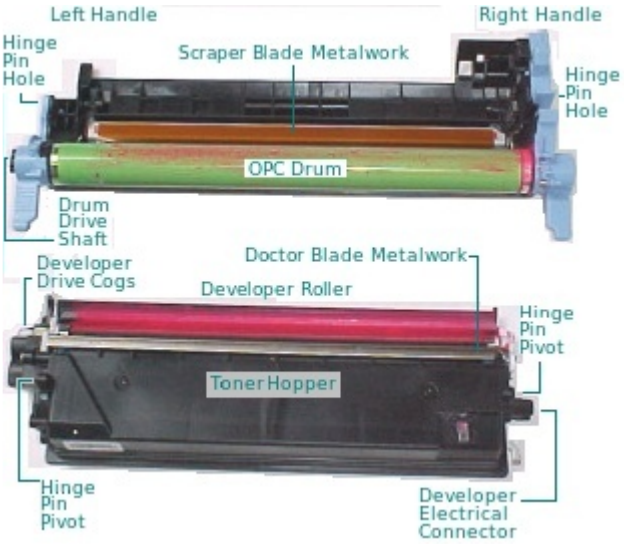
The bulk of the bottom half of the cartridge is made up of the toner hopper. The roller in the front (normally covered in toner) is the developer. The developer roller itself should have a thin but continual cover of toner. The surrounds should not really be quite as messy as some photos here suggest - (but I wouldn't have dismantled the cartridge if it had been working well).

The purpose of the developer is to supply a thin but consistent layer of electrically charged toner in close proximity to the heart of the laser print mechanism which is the photoconductor or "OPC".



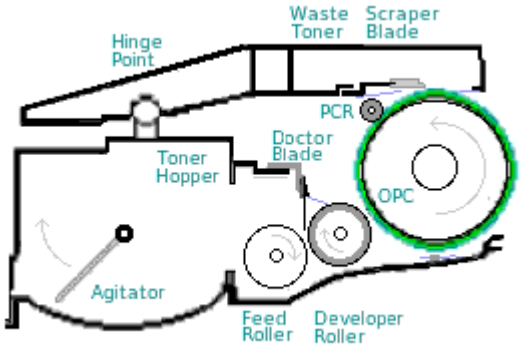
OPC Drum

The OPC (Organic PhotoConductor) is the big green roller in the upper half of the cartridge. Photoconductors conduct electricity in the light, but not in the dark. If a static electric charge is placed on a surface coated in photoconductor in the dark it persists. If the surface is illuminated at a point the local charge drains away. The result is a "latent image" in static electricity. Electric charges that are different create a force of attraction on whatever carries them. Electric charges that are the same repel one another. If a surface has a pattern of charges and is dusted with charged powder then the powder is attracted and sticks where charges are different but is pushed away where it is the same. The pattern is made visible or "developed" where powder sticks.



Photoconductor and developer are both implemented as rollers in most printers. Photoconductors were traditionally made big enough to be referred to as a "drum". The photoconductor used in most modern cartridges is rather small. The small size of drums is partly:

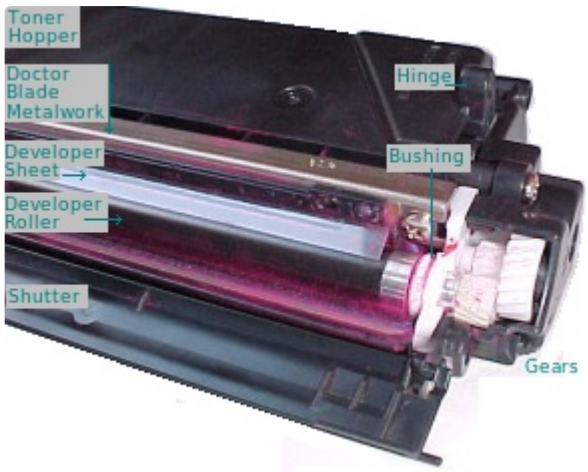
- they aren't intended to have a long life so a small one will suffice
- small drums give better paper separation - paper attracted to the drum surface can't so easily bend and disappear into the cartridge.
- larger drums would mean bigger cartridges and a larger printer.



The image to be transferred to the page is created on the photoconductive drum. The drum rotates under the close control of a motor. It takes almost four rotations of the drum (circumference 75.4mm) to complete an A4 page (length 297 mm).

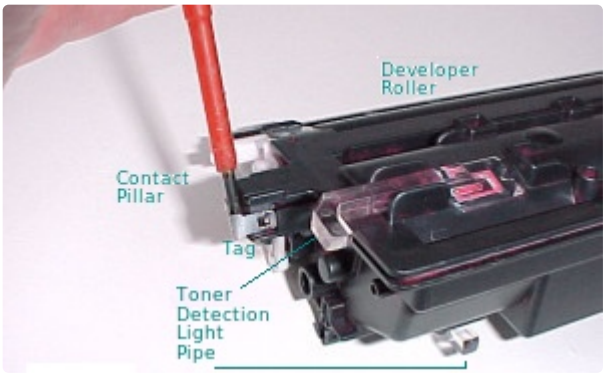
Laser

First the drum surface is given a negative electric charge in the dark by the precharge roller (often called PCR). The PCR is a rubber roller with a conductive coat pushed hard against the OPC surface. The drum turns and is then scanned by a thin laser beam. The photo-conductive layer on the drum allows the electric charge to run away where the laser strikes. After the OPC drum has been exposed to laser-light it carries a "latent pattern" in static electricity, parts that were never exposed by the laser carry a charge several hundred volts negative greater than parts where light struck.

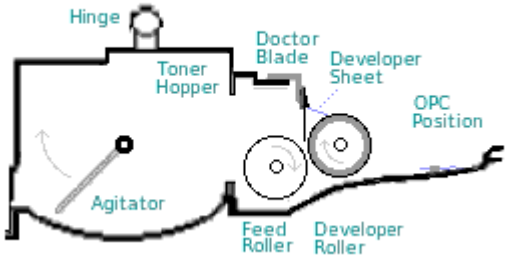


Developer

That latent image is "developed" by toner powder supplied by the developer. Toner is a fine powder with grains about 5 microns across. Toner can be electrically charged, much as a plastic comb becomes charged when pulled through hair. The toner used is styrene acrylate in this case, with about 10% of a proprietary colourant and 10% wax to help the fusing process. The cartridge carries about 80 grams of toner, which is considered enough for about 2000 pages at 5% page cover (and so only about 100 pages if you cover them solidly).



Where the OPC and developer rollers meet, toner from the developer will transfer if the contrasting charges are sufficiently attractive. The gap between them is determined by the developer roller bushings and looks to be of the order 1mm. Drum and developer rollers are both about 250mm wide in this printer, allowing the printer to deal with pages a bit wider than ISO-A4. Alignment and gap between developer roller and drum must be got just right despite using a plastic cartridge in a lightly built printer. This is achieved by spring-loading the two halves of the cartridge so that the developer is pulled upwards towards the OPC. The developer bushings run on the ends of the OPC drum, giving just the right separation. The layer of toner delivered by the developer must be just right as well, hence the amount available is controlled by a doctor-blade mounted on a fairly substantial piece of angled steel.



Note on equivalent terminology - there are references to a number of different blades within this toner cartridge. The following list gives the alternative names which are often used.

- Doctor blade - Developer blade
- Recovery blade
- Stirrer blade - Agitator bar/blade
- Wiper blade - Scraper or Waste blade

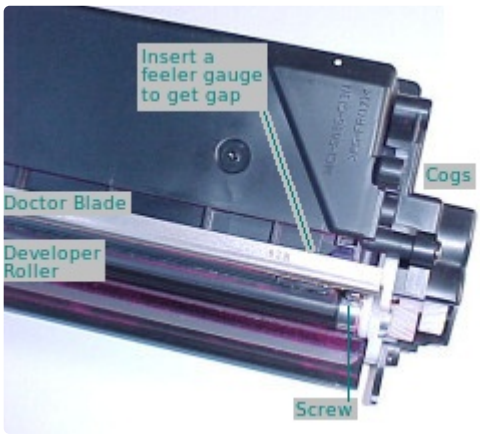
Developer Details

The toner hopper and developer subsystem forms the lower half of the cartridge. The bulk of it is the toner hopper. At the front is the developer roller, positioned behind the OPC drum.

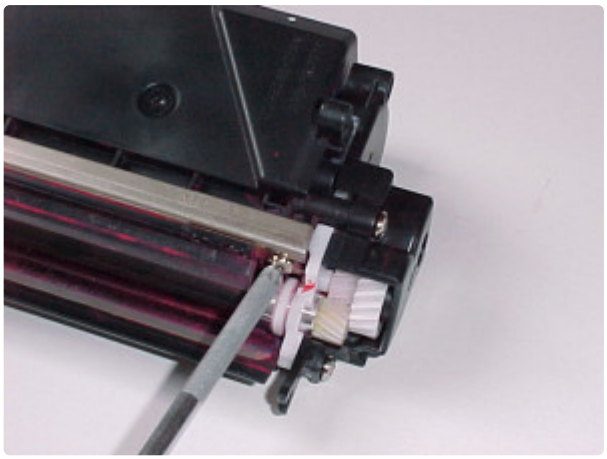
Doctor Blade

Toner cover on the roller and the maximum cover on the page is controlled by the doctor blade. The doctor blade is under the steel angle to the rear of the developer roller secured by a screw at either end. Future Graphics suggest taking the blade out before the developer roller. Uninet say to measure the doctor-blade height with a feeler gauge (gapping tool, separation tool) first, but then take the contact and gear end plates off before unscrewing the doctor blade itself. Either way both the developer roller and the

blade are delicate and suspended so as to release a very thin layer of toner, so they shouldn't be roughly handled or even come unnecessarily into contact with one another. It's probably best to have the end-plates holding the roller until the doctor blade is out (but its arguable).



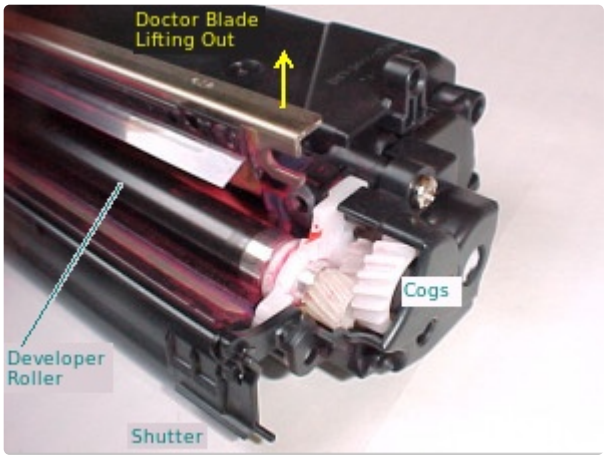
Measuring the separation between the blade metalwork and toner hopper before removing the blade seems a good idea, then there is certainty that it has gone back in the right place. The doctor blade metalwork is secured by screws but there is also a dab of something like silicone sealant at either end and a foam seal behind it. Although it's probably sensible to measure the gap between metal and plastic with a feeler gauge before disassembly and on reassembly there doesn't seem to be any way to adjust the gap reliably - perhaps they have a shim in the factory, or the plastic moulding is just made to micron precision.



The doctor blade probably does need cleaning. The blade looks simple enough, it's metal with a brass/copper colour. Some sources say it is coated steel, but magnets do not stick. The blade is springy, and seems harder than copper. Blade thickness is about 0.12mm. The edge is precise and should look smooth but has not visibly been sharpened, possibly it was cut by spark erosion?

At the gap the blade is under constant pressure from the flow of toner going past it. It may be eroded by this. The blade is electrically at the same voltage as the developer but most sources suggest that part of it's purpose is to help electrically charge the toner grains as well as to limit the flow.

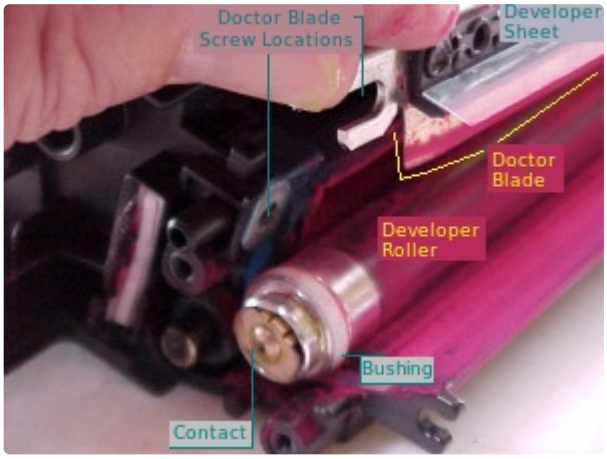
Uninet say "CAUTION: The working edge is made of coated steel that can be easily damaged by solvents or applying excessive pressure". However Future Graphics recommend using water to remove any stubborn toner build-up on the blade. Presumably isopropyl (a computer workshop favourite cleaner) might wreck the blade coating.



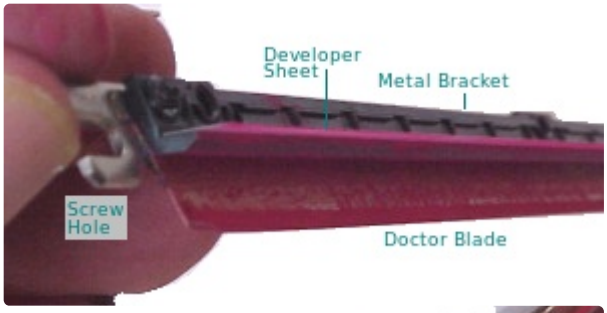
Toner is under pressure as it passes the blade so it is naturally inclined to stick. A polymer coating on the blade reduces the probability of this being a problem during the normal service life of a cartridge. Toners with a low melting point or softer consistency are more likely to stick to the blade. If the doctor blade is damaged it won't work properly, probably leaving light bands and voids in the print where the toner flow is choked. A refilled cartridge may print several thousand pages before this problem sets in.

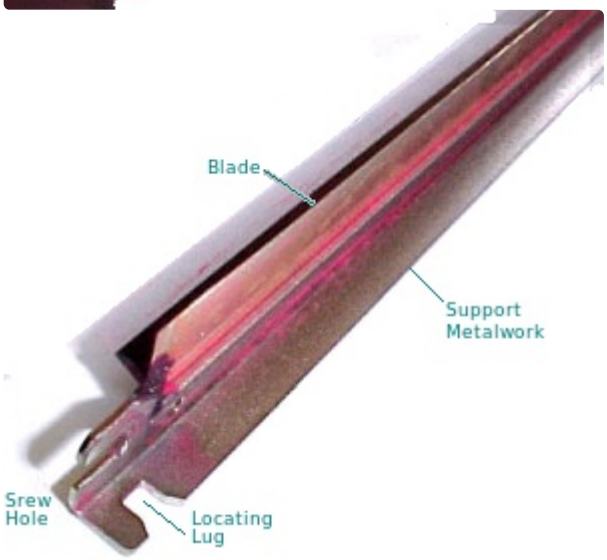
Lightly touching the blade with a meter probe on the tip didn't detect any coating - the tip seemed conductive - but then the cartridge was a used one taken out of a printer precisely because it didn't work well. The blade curves away from the developer rollers at the end. The blade was stamped 070617-22:36-14-B on one side and matrix-printed C172-893B-02-3F7E000346N0611 on the other. Clearly Canon/HP production are carefully tracking these critical parts

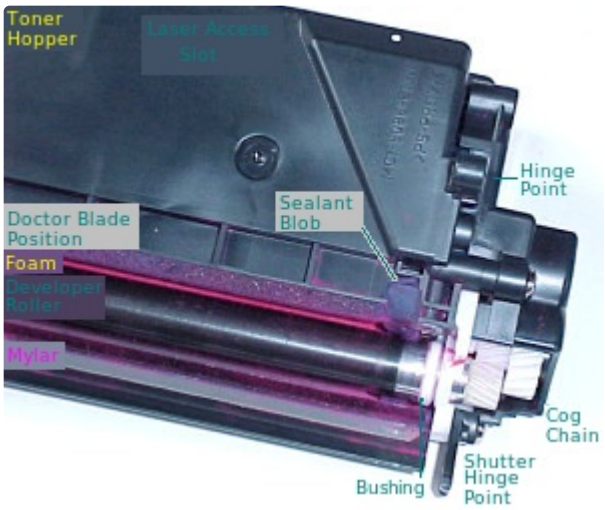
In practice I found that the doctor blade had a persistent mark along its surface where it seemed to have rubbed against the developer roller or possibly the flow of toner going around with the roller. Visual inspection of the tip suggested it wasn't perfect, so to re-use the cartridge a new blade might be wise.



Doctor blades in older developers are suspended above the roller, although the gap may be so fine it is scarcely visible. In this case the blade seems to be tangential to the roller. It isn't easy to examine but with the feed-roller out there was no visible gap at all, although toner fed to one side of the roller did emerge as a bloom on the other side.


Developer
Sheet
Metal Bracket
Screw
Hole
Doctor Blade

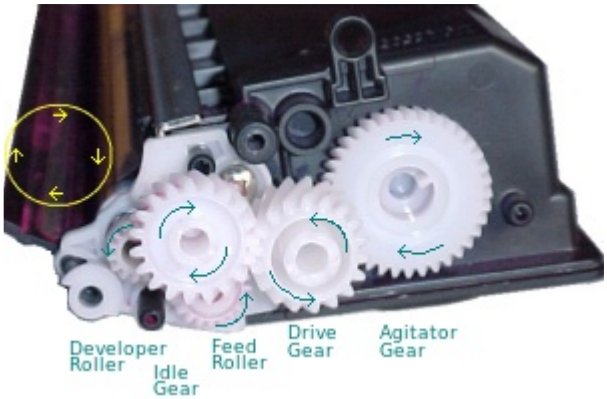

Blade
Support
Metalwork
Srew
Hole
Locating
Lug



Developer Roller

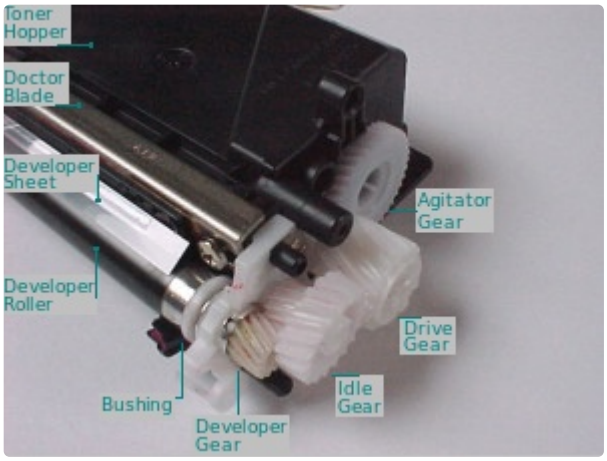
Both Future Graphics and Uninet recommend removing and cleaning the developer roller, which means taking the contact endcap off. The tin-plate metal contact has to be levered away from the plastic support pillar without too much damage. The roller contacts are then cleaned and re-lubricated with a small amount of conductive grease.

Gear Assembly



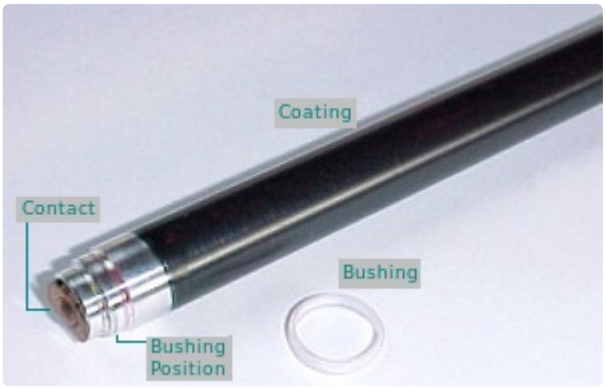
The gear assembly unscrews from the other side. Note where the gears go - they will fall off, but only fit one way. It is possible to remove the developer roller without taking the gear end cap off, but the gears probably need cleaning anyway.

The contact end plate and gear end plate come off and the developer roller is lifted out. The bushings will probably fall off, they look rather unimpressive, a couple of little plastic rings. The developer bushings are actually critical, they set the gap between the developer and the OPC drum, Both roller and bushings should be thoroughly cleaned.



Developer rollers were at one time usually uncoated aluminium on the outside, in HP, Canon, Kyocera and many other cases with a with a magnet inside. The developer magnet attracted either iron filings in the developer hopper or a magnetic component in the toner itself. Magnetic toners may not work so well with colour. Incorporating a substantial magnetic component in the toner decreases the colour density (and may change the colour) so more toner is needed for a given colour quality. Simple tests suggest there is no magnetic component in the CLJ 2600 toner

The developer roller is coated in something to improve it's ability to impart charge to the toner powder. Coatings are typically an elastomer such as a phenol applied in solution and containing a conductive material such as carbon black or graphite (See US Patent 5,942,287 and 5,997,772). The conductive coating reduces toner layer sorting by size and improves image density.



Uninet say "DEVELOPER ROLLER SLEEVE COATING SOLUTION RECOMMENDED This universal coating solution extends the life of the sleeve by applying a coating of Teflon and sealants to the transfer layer. The coating fills in surface scratches and provides much needed lubrication to the sleeve to prevent wear that can lead to failure."

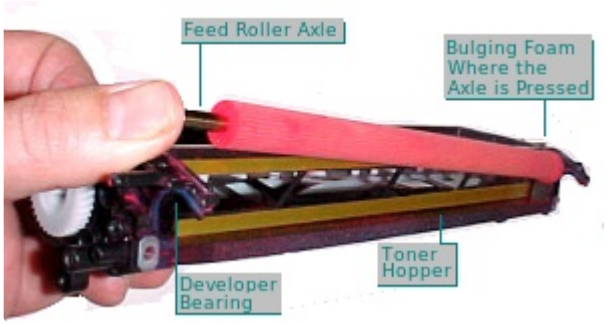
The coating on this roller is black, seems to be conductive and is soft - rubbing with a finger-nail marks it. It does seem to be graphite. A used roller has a satin finish with marks running round the roller, through to bare metal in places. This might be friction with the doctor blade and toner. A worn roller needs either to be replaced or recoated as otherwise print density, contrast and colour gamut will be reduced.

The developer roller is hollow aluminium and at the contact end it has an insert to give electrical continuity with the contact end plate. To ensure continuity the plate and roller need to be cleaned and a small dab

of fresh conductive grease applied.

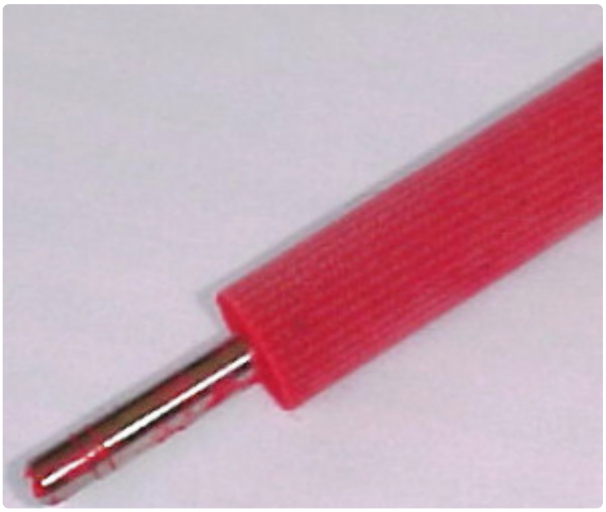
By taking the feed roller out (which you are not supposed to do) I tried to examine any gap between the developer roller and doctor blade but wasn't able to come to any firm conclusions. With the printer at rest there isn't any visible gap. However when I tested electrical continuity (by separating the blade and roller contacts with a bit of cardboard) there was none - so there seems to be a gap, a coating, or both.

The feed and developer rollers and the doctor blade nearly meet, the feed roller is separated by a gap of a couple of millimeters or so.



Toner Feed Roller

The developer and feed roller both rotate in the same direction. However the gearing is such that although both rollers are about the same diameter and rubbing against one another the feed roller only rotates about half as fast. This is a bit of a puzzle as it might seem that the feed roller would work faster to ensure the developer roller is well stocked with toner, relying on the doctor blade to create the thin layer needed for printing. Friction between them presumably helps create the static field that adheres toner to the developer roller and then to the OPC drum.



The toner feed roller (sometimes called toner adder roller) is made of soft spongy open-pore foam and has parallel ridges at intervals of about a millimeter. In the factory it seems to be put in place by gluing a little bearing to the main body of the developer. The Uninet instructions explicitly say it shouldn't be removed. The foam sleeve seems to be glued to the shaft, but not all the way along. Pressing it one way so the shaft pops out of its bearing then the other does allow it to come out. The roller drips toner, even when its been cleaned it goes on dripping toner out of it's pores. It probably is conductive in some measure but the resistance is greater than 20 megaohms. The foam presumably is conductive because there is a contact plate putting the shaft at the same voltage as the developer and doctor blade.

At this point Uninet and Future Graphics both recommend thoroughly cleaning the toner hopper with a vacuum cleaner and compressed air. Most of any remaining toner can be shifted with a soft brush and sealed in a plastic bag. Regardless of how harmless the Material Safety Data Sheets say toner is, a filter rated for fine-grained colour toner and a fume-cupboard of some sort are recommended -there will be residual toner in the hopper and blasting it with compressed air will clean it quite well but will make a mess.

Residual toner should not be left in the hopper when a cartridge is refilled. A replacement toner may not work well with the original CLJ 2600 toner - they may both work, but not work properly when mixed.

Agitator

Something has to push toner from the back of the toner hopper towards the feed roller and developer. The job is done here by a stirrer or agitator blade.

The agitator or stirrer blade is an axle driven by the same cog chain as the developer roller. The axle has a slot running down the middle and a strip of something like mylar is inserted into it. It rotates, however the compartment isn't circular, so periodically it jumps and presumably flicks toner off the bottom of the cartridge to the top of the feed-roller.

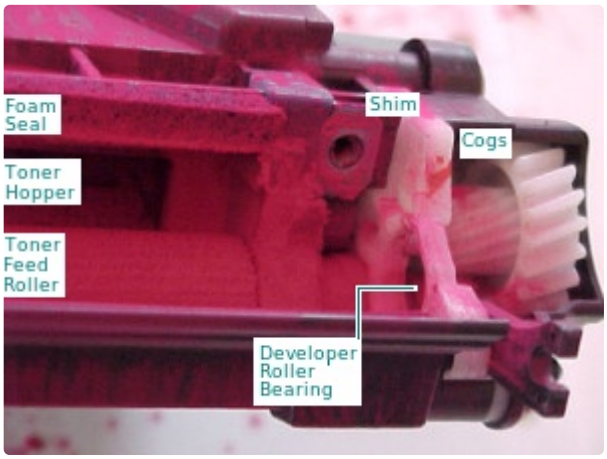
Neither Future Graphics or Uninet recommend doing anything with the agitator; it can't normally be removed because it isn't possible to get at it. The agitator is in the toner hopper and the cover is glued to the body of the cartridge.

As it happens, the toner hopper cover here cracked open quite easily with a knife inserted along the seal. The cover was neatly glued all the way round, but the glue line was less than a millimeter wide so it hadn't a great deal of strength. The cover is secured at the front by the screws that hold the contact and gear end plates.

The agitator drive cog is held into the shaft by a post with latch. The cartridge dismantled here had cyan toner in the crannies so this hadn't been done before. Remanufacturing instructions don't recommend getting into the hopper, and re-sealing it in production-line conditions would be a nuisance.

With cleaned parts the developer part of the cartridge can be reassembled.

Future Graphics have devised several jigs and tools for the assembly process.

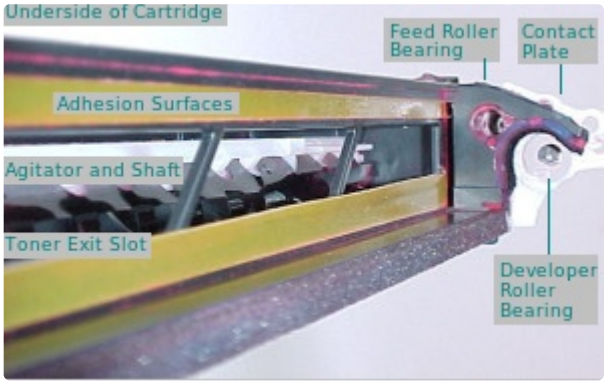


Toner Seal Tape

HP and Canon ship cartridges with the toner hopper sealed. This tape is the strip with an orange handle removed when the cartridge is installed. The tape pretty much guarantees that the cartridge arrives looking clean, and influences the user's judgement of it's quality.

The seal tape keeps toner in the hopper (and the atmosphere out) until the tape is pulled out of the side of the cartridge. The tape is tough and the adhesive holding it has the consistency of sellotape so it comes away relatively easily.

The toner hopper is the space behind the developer and feed roller. The agitator flings toner forward at it until the cartridge is largely empty.



A significant problem for refilling and remanufacturing is to get the toner seal tape in place. The toner seal goes between the toner hopper and the rollers but there is only a couple of millimeters clearance between the exit slot of the hopper and the feed roller, and those surfaces are contaminated with toner which prevents tape sticking.

Re-manufacturers need to put the seal in place so that it does stick firmly over the hopper exit slot preventing leaks. On the other hand the tape should release when the user pulls it. The effort shouldn't disrupt anything else. The original manufacturer can put the seal onto a clean plastic hopper before the lid

goes on and the rollers are put in place. Remanufacturers can't do this. Uninet and Future Graphics both make folded-back strips with an adhesive backing to do the job. Future Graphics have a jig and tool to help insertion.

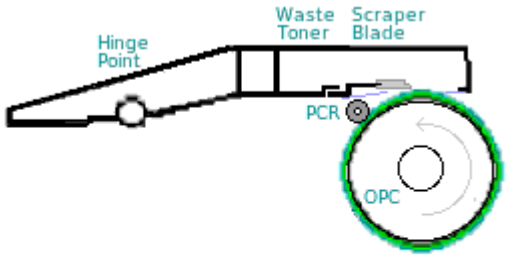
The seal is not compulsory. A seal is necessary if the cartridge is to be shipped by courier; otherwise it will almost certainly leak. If the cartridge is for local use or being delivered to site where it will be used quickly a seal probably isn't necessary. Once the cartridge is in use there is no seal there and the cartridge just depends on foam and mylar strips to prevent toner leaking out. Toner is only likely to leak on any scale if an unsealed cartridge is treated roughly. In a warehouse of a couriers truck rough treatment will happen, so either the seal is needed or the customer tolerates a cartridge that could have poor cosmetic presentation.

The seal tape comes out from the cartridge on it's left hand (contact) side. The hole has a soft plastic plug in it so that the tape can be pulled out but toner cannot leak sideways in any great quantity. Remanufacturers generally remove this plug, clean it and re-use it.

Uninet and Future Graphics both suggest refilling the cartridge through a hole drilled after the sealing tape is installed. This is a rather horrible idea because whether the hole is made using a soldering iron or with a drill bit it is likely to do a bit of damage and leave some residue in the toner hopper. If a hole is needed I would suggest making it before the toner hopper is cleaned and the tape is installed, so the debris is cleaned out.

A hole may not be needed. Toner can be loaded into the hopper whilst the developer roller and doctor blade are out. The problem with this is that some toner will inevitably drift onto the surfaces where the sealing tape is to go and it will be difficult to clean off - although a soft brush will take most of it away. Making a hole is intellectually ugly but may be the most reliable way to re-fill a cartridge in production-line conditions.

A significant problem in re-manufacturing a cartridge is to get good cosmetic presentation despite the difficulties - and to do that recyclers are even willing to drill a hole where there should not be one.



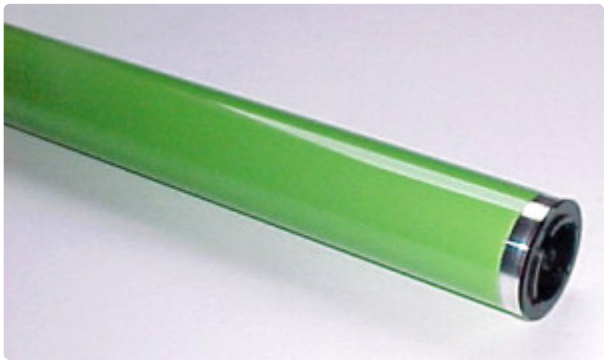
OPC Drum

The upper part of the cartridge contains the OPC drum, precharge roller and waste mechanism.

There are a variety of materials which change conductivity on exposure to light. Amorphous selenium was once a favourite, used in Xerox copiers. Silicon can be used although for best response it needs warming to about 70 centigrade. Zinc oxide, zinc sulphide and Cadmium sulphide also exhibit photoconductive qualities. OPC was developed in the 1960s by IBM as a way to bypass Xerox patents on the

photocopying process. Older materials are carbazoles. Modern materials seem to be phthalocyanine and hydrazone in a polycarbonate matrix.

OPC colours therefore vary from the bright green shown here to blue and even red tints. Most CLJ 2600 cartridges seem to have a green or green-blue OPC material. It is quite common to find cartridges with different OPC colours in the same machine where original and remanufactured cartridges have been mixed. (If you aim for photographic reproduction mixing cartridges may be a bad idea - but that is because of variations in toner shade)



The organic photo conductor (OPC) drum is two or three layers of thin plastic spray painted or coated using a doctor blade onto an aluminium cylinder. The top layer is a largely transparent holder of electrical charge and the layer beneath is photoconductor, it conducts electricity in bright light. The drum material is thin, probably less than 30 microns thickness. OPC can be fragile and doesn't last forever. The urethane waste scraper blade is specifically intended to erode the surface slightly, removing several microns of material over 10,000 pages of print. However drums similar to those in this printer can last 10,000 to 25,000 pages so in principle the OPC could outlive 5 or more charges of toner. The material does age however, so for the colour photographs this printer might produce it will need replacing more often.

Drum Replacement

Replacing the drum is a particular difficulty with this cartridge design. The problem is that the drum support bearings are part of the blue plastic handles irreversibly glued to the chassis of the cartridge.

For simple refilling the drum may not need changing - they are highly likely to outlast any one toner charge and possibly several. Problems will show slowly. An exhausted OPC drum won't give adequate contrast so there will be some background flecking on the page and / or it will be difficult to get strong colours.

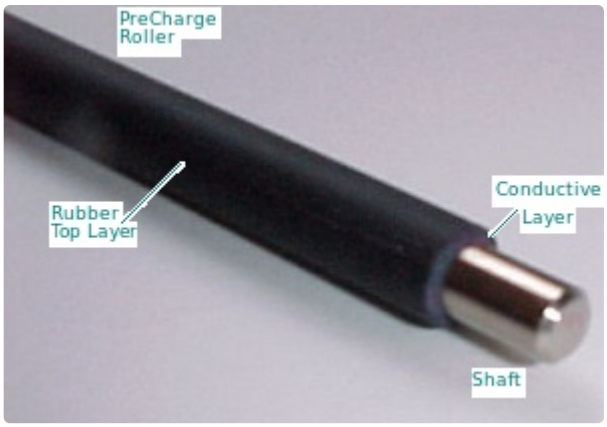
Measuring the quality of an OPC shouldn't be terribly difficult. The simplest and most reliable way might be a printer with a test cartridge where the OPC can easily be changed. A test page could then be assessed with a colorimeter. An alternative might a dark box with a charge roller and an electroscope. (Or a jig positioning a test roller next to a developer and printing black, white and striped page).It is probably a matter of what the recyclers policy is as to whether the drum is always, sometimes or rarely replaced.

To replace the drum it must first be got out of the support bearings. Uninet suggest taking a hacksaw to the drum plastic shaft on the gear side, sawing half way through, and then turning it 90 degrees and sawing again until the shaft breaks. The drum can then be removed. Future Graphics sell a jig which seems to compress the hubs into drums until they break. For remanufacturing purposes the existing drums in cartridges are likely to be waste metal as they ought to be replaced.

It is possible to recoat used drums - or even aluminium tube. SeeRotby.Com. There are some Chinese firms advertising via Alibaba as well.

Replacement drums come with a rather different bearing with a flange in the drum and a cap that inserts into the bearing and then the pair screw together. However that is getting a couple of steps ahead.

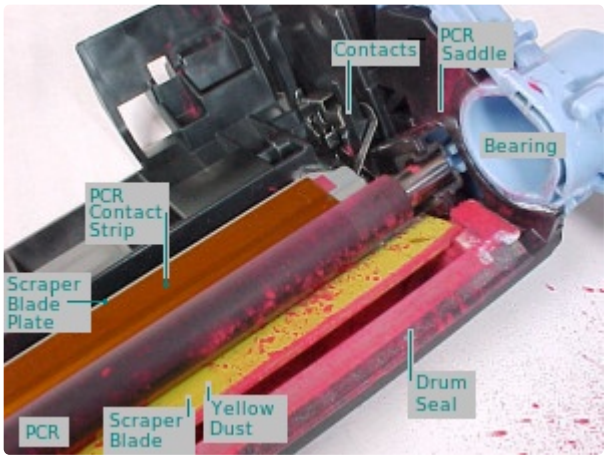
Drums in laser printers are usually fairly similar to this, they typically turn about 3 times in producing one A4 page. The diameter in this case is 24mm



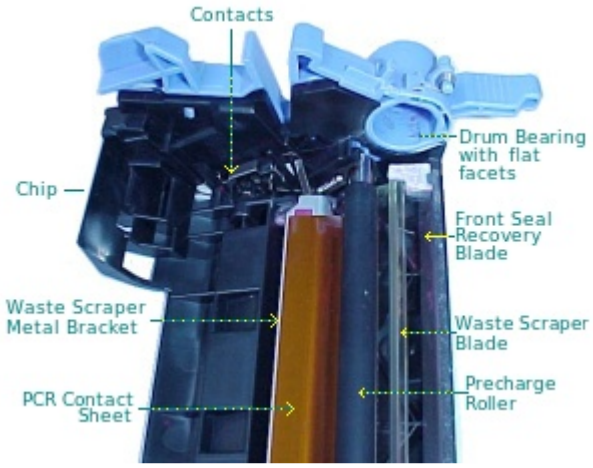
Precharge Roller

The OPC drum starts out with a electrical charge which it gets from the precharge roller or PCR. The drum is then discharged by the laser. For the process to work well the drum should carry a strong charge without the OPC material breaking down. In older photocopiers and laser printers OPC Drum charging was done with corona wires; the wire was charged to several thousand volts which created a voltage on the nearby surface of the drum. Corona wires used very high voltages and a certain amount of power, air breaks down creating ozone. Using a conductive roller for charge transfer substantially reduces the space needed not only for the charge transfer device, but the support circuits and ozone filter.

Roller charging was developed by Canon in the late 1980s. The support circuitry puts an AC waveform on the roller to discharge the drum after use, then it uses DC, or superimposes alternating current and direct current to create the initial charge on the OPC. The voltage is lower, something of the order 1000 volts, and ozone production is about 1,000th of the level with corona wires. Canon say the idea was first used in the LBP-LX engine.



The PCR roller may look dull, but it is a piece of precision engineering. With the drum out the PreCharge Roller (PCR)can be removed and cleaned. Its a heavy roller of black rubbery material, again with no measurable resistance to it's surface. At the edges and with a probe that penetrates the surface there is a resistance of about 20 megaohms, There is a conductive layer within- most sources say it's a surface coat but that isn't what measurement suggested. The roller should not be handled if it is to be reused, lift it with pliers rather than fingers. Clean it by rubbing with a lint-free cloth. If there are stubborn marks Uninet suggest water and mild soap as a cleaner. Residues will need to be thoroughly washed away possibly with distilled water. The PCR roller probably needs cleaning because it is spring-loaded against the OPC and picks up some material from it's surface.



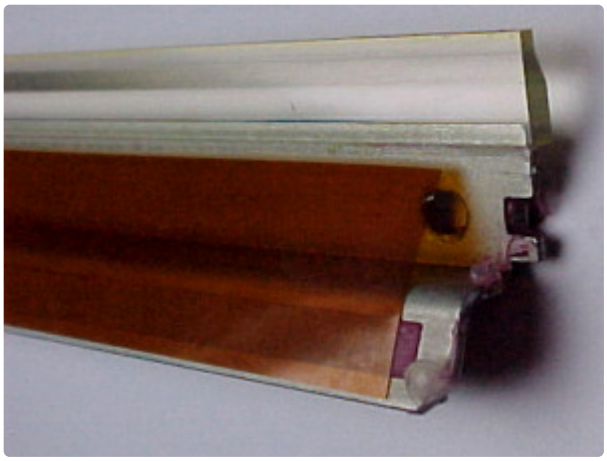
The precharge roller and waste scraper blade are held at one electrical potential through a tin-plate contact strip running on the right side of the cartridge from the metal hinge pin. A common defect is that the metalwork gets damaged when the hinge pin is removed so there is intermittent or no electrical conductivity. Probably for manufacturing purposes there is a hole in the top of the cartridge with a bit of the inner tin-plate showing and this should have good continuity to the hinge-pin on a properly re-made cartridge.

The PCR metal shaft sits in a pair of plastic saddle bearings. The contact end is black and made of conductive plastic. Some sources suggest a drop of conductive grease to ensure a good contact.

The toner agitator, rubbing between grains of toner, toner feed roller and precharge roller contact strip all create voltages and these will modify the overall precharge voltage.

In use the printer places an AC signal on the precharge roller to clear any residual image from the OPC drum in one rotation. Then when the page image is built a constant high voltage negative is supplied to charge the OPC surface.

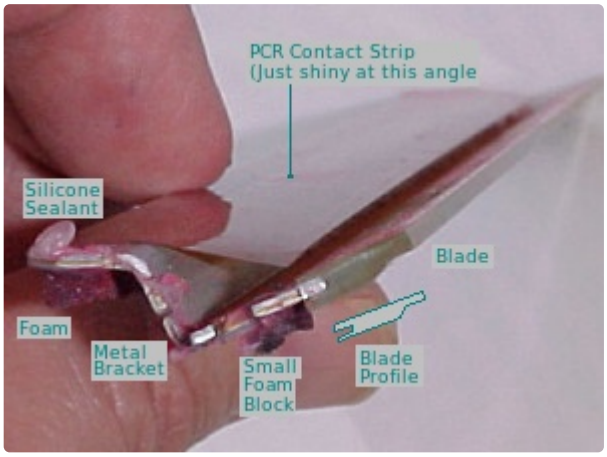
Precharge roller diameter is 8.28mm



Scraper Blade

With the PCR out the drum cleaning wiper blade metalwork can be unscrewed and lifted out. The PCR contact strip is the orange-brown plastic film on top and it partly covers the screws so it needs to be eased out of the way without damaging it. The orange-brown strip is stuck to the metal with a red double-sided sticky tape. Once again there is no measurable resistance with the tools to hand.

The wiper blade metalwork is held to the waste compartment by two screws and an adhesive strip. There are also dabs of soft grey sealant in the corners and along a slot behind. The waste compartment almost certainly needs to be emptied before a cartridge can be re-used. This is likely to be particularly true of magenta toners, because this is used to clean material printed on the transfer belt at calibration. The metalwork needs to be levered up without damaging the adhesive if possible. When it is removed it opens up the waste compartment. The waste compartment needs to be emptied, probably with a vacuum cleaner rated for toner work.



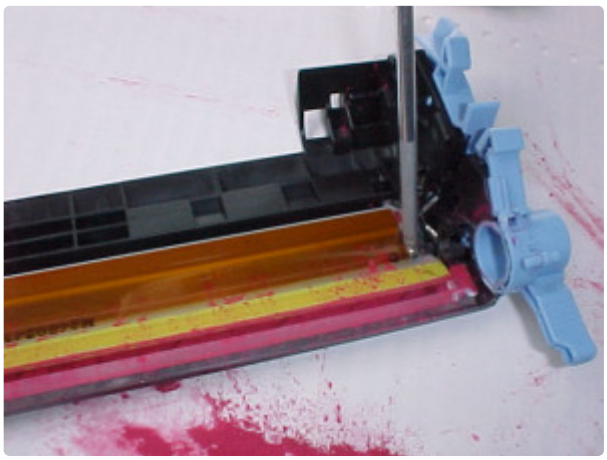
The wiper blade needs to be cleaned and so does the PCR contact strip. Future Graphics say to use compressed air but Uninet says to use a vacuum so as to leave the adhesive sticky and useful.

Once again its a matter of policy whether a new blade is used. A clean wiper blade might be treated with drum powder before it is replaced. Future Graphics seem to have special powder for this (DRUMPOWDERCPT - probably Kynar powder). Oasis suggest a bit of yellow toner on blade and drum to act as a lubricant.

Looking at the wiper blade it may be something of a surprise that it works, but this general technique is used in many cartridges. The blade material is a clear hard elastic in consistency. Some sources suggest

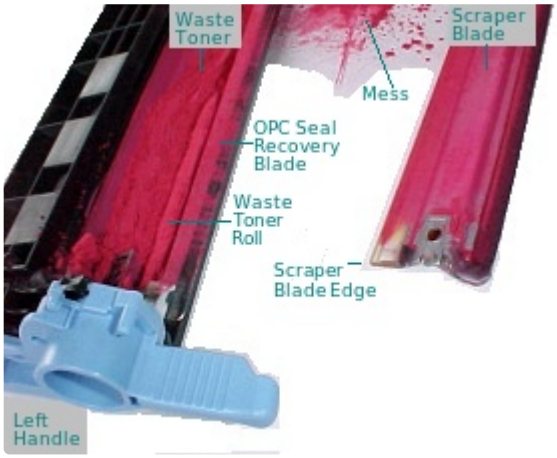
it is silicone, others say urethane, perhaps it is polyurethane . The blade stretches across the working width of the drum, it is fractionally wider than the space between the developer bushings. Flexibility is important as well as consistency, the blade depth in 9mm. The blade presents a sharp square edge to the drum in it's direction of travel. Turning the drum against this in the correct direction requires some force.

The wiper blade does not rely on adhesive to hold it to the metalwork. The steel blade protrudes about 3mm into the material of the blade holding it firmly in place.



An elastic scraper blade's exact mode of operation depends on it's material, angle to the drum, shape and pressure. In this case the angle is about 20 degrees, and there is a little pressure as a new drum is put in place. The blade seems to be acting largely as a residual toner removal blade but similar materials can be used only to remove the degraded layer of the OPC and harmful deposits of electric discharge, to remove paper powder as well or to remove these materials and toner - see US Patent 5701559 (Ootaka, 1997)

Scraper blade operation seems to be a matter of stick and slip. As the drum rotates the blade sticks to it somewhat, elastic tension builds and the blade jumps forward, cleaning most of the debris in its path. It does not normally clean all the toner, some toner grains, particularly the spherical ones, roll under the blade, separating it slightly from the drum and effectively lubricating the action. Lubricating the blade edge with yellow toner stops this happening - and a fraction of yellow scarcely shows when the machine comes to print.



If the blade is not lubricated "chatter" results, the blade distorts too much, jumps, and the backlash damages the drum. A fractional damage then becomes a site for the action to repeat, resulting in horizontal marks in the print and scratches on the drum at regular intervals.

If the blade sticks to the drum during shipment due to lack of lubrication then there is likely to be a permanent horizontal mark. Perhaps worse still the blade may be forced round and "flip" out of position. With these cartridge the drum will then probably jam altogether, or since the motor is quite powerful it may rotate but make violent vibration and noise.

The scraper blade idea looks a bit ephemeral and unlikely. It might be thought a sharp piece of elastic material would wear badly, however it doesn't seem to. New blades can be quite expensive items. Nevertheless the idea has been in use for many years, in most printers.

The wiper blade working edge is precise and sharp; it must remain so, a nick or warp in the edge will let toner from one cycle of the drum pass through to the next and create ghost prints down the page. A defect in the wiper blade tends to show as vertical streaks with greyish edges.

Scraper blade chatter will tend to mark the drum at intervals around its circumference and the page will have a pattern like tire marks.

Scraper blade sticking will tend to make one rather solid horizontal line across the drum, causing sharp horizontal marks on prints at 75.4mm intervals.

Wiper blades often seem to yellow with age and when they are old they are not effective and need replacing.

The electrical connection to the wiper blade metalwork is something of a puzzle. A bit of tinplate sticks out in its direction and seems intended to make a good connection. If it rests on top (which some pictures show) then we rely on spring tension to overcome any oxidation and make the contact. If it goes underneath then there is a bit of mechanical force making it bite as well. Examining the soft sealant suggests it normally should be underneath. Why a blade made from a very good insulator needs an electrical connection is mysterious - the answer seems to be that it doesn't but that any metalwork in the cartridge does or it would spoil the electrostatic environment of the PCR.

With the drum surface largely clean and ready to re-use the cartridge is ready for another cycle. There is some toner left on the drum surface - otherwise the blade would stick more. However there is comparatively little and it is evenly spread so it should not contribute a perceptible background on a printed page.

Reassembly

When all the parts are clean and checked for damage the cartridge can be reassembled by reversing the order in which it came apart. Avoid touching the surface of rollers and blades as finger-marks change the electrostatic character of things. The problem of marking things is reduced by wearing thin latex gloves. If you have concerns about toner exposure wear gloves and possibly a facemask to minimise it.

Obviously if you are handling cartridges on any scale, like professional refilling and remanufacturing, then you need work positions with controlled air circulation. Powerful air extractors and filters or centrifuges to take particles potentially finer than 1 micron out of the air are needed. With every movement of toner some billows out into the air. The quickest way to clean components is an air pressure hose, and that will make enormous clouds of toner.

One of the main problems in re-making the cartridge is getting a toner seal back in place without disturbing the feed roller. This can easily be done in the factory where a new charge of toner is delivered before the base is glued on. It's much less easy if the

Obviously someone reassembling the cartridge is going to give it a full charge with 80 grams of the appropriate toner. (HP do not sell lose toner, so there is a choice of Imex, Faroudja and so forth).

In writing this I have drawn primarily on my own examination of the printer, scrap cartridges and some experience of printer technology as well as on the service manuals and professional recycling documents. The service manuals give the polarities of the charges and some sort of voltage curves. The documentary sources are moderately informative and sometimes accidentally give something important away.

These cartridges deliver 80 grams of toner, together with 560 grams of other material - about half the weight is the polystyrene shell and there is nearly 250 grams of metalwork. I didn't carefully separate all the plastics from the metalwork to weigh the parts because that would be difficult to do, the rubber will not easily come away from the PCR nor will the OPC coat strip from the drum without mechanical abrasion, solvents or heat.

Together with packaging the total weight of a cartridge delivered is about 1kg, it may be a bit more if the delivery has an outer pack. Package dimensions are 410 x 109 x 92 mm.

-
As usual with computers (technology and science generally) looking at the works of a cartridge raises a lot more questions.

-

Cartridge Prices

Original manufacturers cartridges for the CLJ 2600 series cost about Â£50 new.

The printer manufacturers make a great deal of money from cartridges but distributors and retailers generally do not make much; we estimate that average markup on the web is 10% with a few of the well known names aiming to make 20%. Printers and cartridges are "overdistributed" because manufacturers don't want to lose any opportunity to sell one and get that cartridge revenue.

Retailers make more money selling refilled and remanufactured cartridges, to some extent they have to because these products really are more trouble - an issue we'll come to. A fairly common trick is to promote manufacturers original cartridges at low prices but then have no stock and sell remanufactures instead.

Could a cartridge be repaired?

Almost everything in a cartridge can be repaired and replaced. The OPC, developer and precharge roller can be recoated with little more complicated than a lathe and a spray-gun although the chemicals involved suggest a bit more care.

Failure on delivery is rare but isn't completely unknown. (Zero defects policies aren't always effective). You won't just get distributors to send a new one immediately unless you pay for it, they will want the other back first and credit you when it proves faulty.

Cartridges are intended to be disposable, try it and if it doesn't work just get another. If cartridges were Â£10 each people might accept that the odd one would have defects.

If you don't want that inconvenience things to look for are:Defects in the printer: dirty or damaged spring contacts marks on the OPC drum, damage to the contacts, missing springs and damaged gears. It shouldn't happen but experience is that even brand new factory sealed toners do, occasionally, have faults.

Remanufactured toners cost upwards from a third of the new price - clustering at about 30% cheaper. Remanufacturing is more difficult because old cartridges are taken to bits and they have had the stress of use, then collection and dismantling. Even if all the critical internal components are new the plastics have been stressed. Remanufacturing also has lower volumes and higher costs than the original factories so they aren't equipped to be quite so reliable. there are faults such as fading of the OPC roller, overflowing the waste chamber or clogging the doctor blade that will happen when the cartridge is half way through it's life. Would this sort of thing be covered by warranty? If the remanufacture was done by a local shop they might well fix the problem, but if it involves the cost of courier fees that's more doubtful.

If you have a lot of printers to look after and a few cartridges fail then looking at the causes seems reasonable. If you clean up the developer, doctor blade and OPC, empty the waste chamber and check continuity of the contacts then a cartridge should work.

You may not get the first cartridge you look at working again - and certainly don't try looking at cartridge innards where toner spills can't be tolerated. Cartridges are quite an interesting mechanism.

Why Remanufacture

Few things are remanufactured at present; printers generally aren't, why remake cartridges when they are intended to be disposable?

Toner for laser printers has never been a very cheap item, but at one time copiers were refilled from a big bottle for about Â£10. These days little cartridges cost Â£50 each. The print market is largely drive by profits on cartridges, particularly at the home and small-office end.

Canon and HP more or less invented and developed the cartridge market. Canon needed a way to make personal copiers feasible, otherwise they would need periodic attention by someone with engineering knowledge. Making a cartridge holding most of the works that wear out achieved this.

In the early 1990s a laser printers was an expensive item - most were between Â£1000 and Â£2000 and the cartridges were Â£60- Â£100. The fall in computer costs generally and the effect of a mass market reduced prices for printers. By the 2005 - 2009 period when the CLJ 2600 series were new products they were selling for between Â£400 and Â£180 - depending on the feature set and when and where they were bought. (Printers tend to be half-price when the model is discontinued).

Cartridges did not fall in price, except perhaps that they got much smaller. If anything the price per page has risen.

It is sometimes estimated that low cost printers sell for about two thirds of their actual manufacturing cost, whilst the profit margin on cartridges is 60% to 80%. There are half a dozen large printer manufacturers and competition on the price of new printers is intense. Buyers are sensitive to the price of printers, but seem oblivious of the price of cartridges to put in them. Once the printer is in place, though, they need the cartridges. Manufacturers don't actually give the printers away (although it has been tried) but they do manufacture them largely in order to sell cartridges.

Cartridges are moderately complicated. The example dismantled here has about 70 parts, most of them polystyrene mouldings. The most expensive part is sometimes said to be the waste scraper blade

Other companies can't just make cartridges.

The brand owner has some protection in copyright law for their specific design and labelling. Copyright has been challenged at times, notably in the motor trade.

Manufacturers also aim for protection using patents. The public are sympathetic to the idea of patents and the promise of new inventions. For instance in January 2012 Canon announced court action against Clover Technologies and DataProducts for infringement of it's US patent 5,903,803. Canon also raised the issue with USITC presumably to get import of offending parts banned.

Most of the original patents on copiers expired long ago and those on laser printers are expiring. Patents from the 1990s which are now relied on are for minor tweaks rather than breakthroughs in the print process, so they might be sidestepped, prove invalid due to prior art or many of the most useful will simply expire. If the printer brands push patents too far they could attract political attention as Xerox did in the 1970s when they forced to sign a consent decree, licensing their patents to others.

At the moment the issue of printing costs mostly plays out in fairly obscure court cases.

Simple Refill

The simplest refill is just to put more toner into the hopper. Little more is needed than to drill a hole in the hopper, which could be in the base or rear. It is almost certainly necessary to empty the waste chamber as well, particularly that of the magenta toner. This too can be done by drilling a hole in the top. The holes can then be covered up with electricians black tape.

Probably for cosmetic reasons, refillers seem to separate the toner hopper and the OPC and make any holes out of sight.

A simple refill will probably work twice and perhaps three times according to various sources on the Web. They generally reckon that the problem is decay of the OPC, but that might not be the case. Contamination of the precharge roller (PCR) or decay of the developer roller coating could also be an issue.

Mixing original and replacement toner is likely to be a bad idea. The electrostatic performance of either formulation on its own may work, but a mixture of both might not.

A simple refill has the advantage that very little of a cartridges original structure is disturbed. But things that are getting contaminated or worn are not replaced.

Remanufacture

Remanufacture strips a cartridge down and replaces parts. Replacing all the parts is likely to be an expensive exercise dependent on lines of supply and scale economies.

The main problem with this cartridge design is the OPC drum which is held by the handles and glued in. The glue (or ultrasonic weld) on the cartridge handles does not fail easily under tension or pressure. To get an intact cartridge shell remanufacturers cut the old OPC out by taking a hacksaw to the plastic shaft, and then completely replace it.

Without cutting the OPC out the PCR, waste scraper and recovery blade can't be replaced.

The developer roller can be re-coated or replaced.

Which components remanufacturers choose to replace is a matter of their choice. If they have good scale econonmies they may be able to replace everything economically. What is done is not usually explicitly stated by remanufacturers.
