



Handbook of Advance Inventions

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WORLD TECHNOLOGIES

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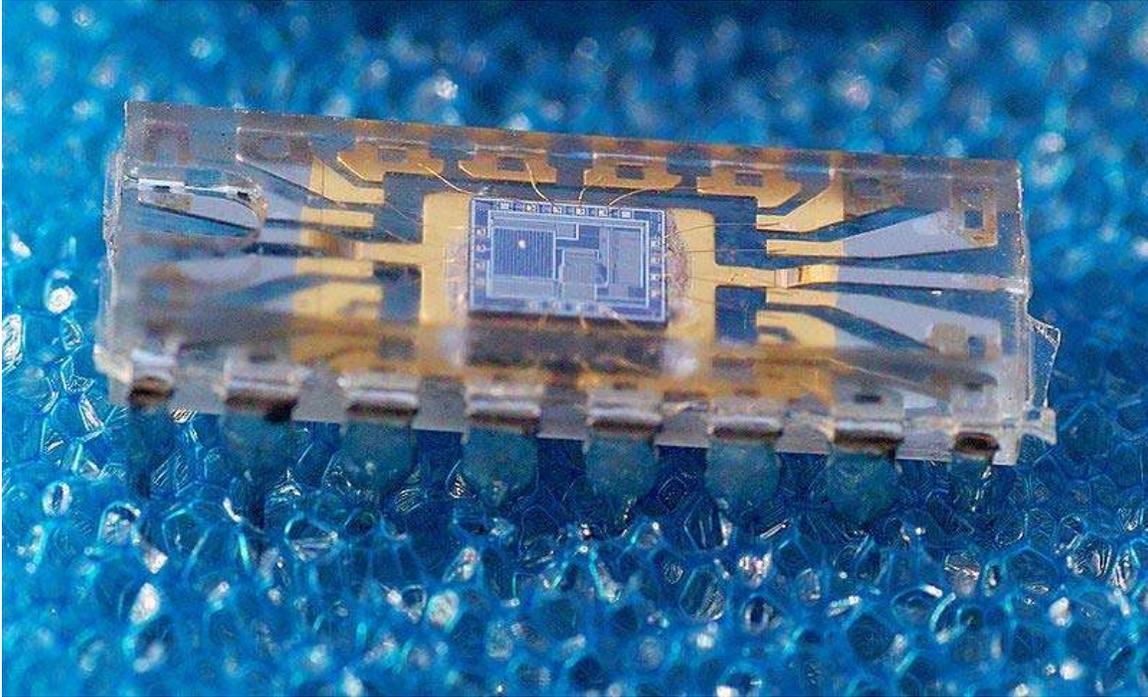
Optical Mouse



A wireless optical mouse

An **optical mouse** uses a light-emitting diode and photodiodes to detect movement relative to the underlying surface, unlike wheeled mice which use a set of one rolling ball and two chopper wheels for motion detection.

Early optical mice



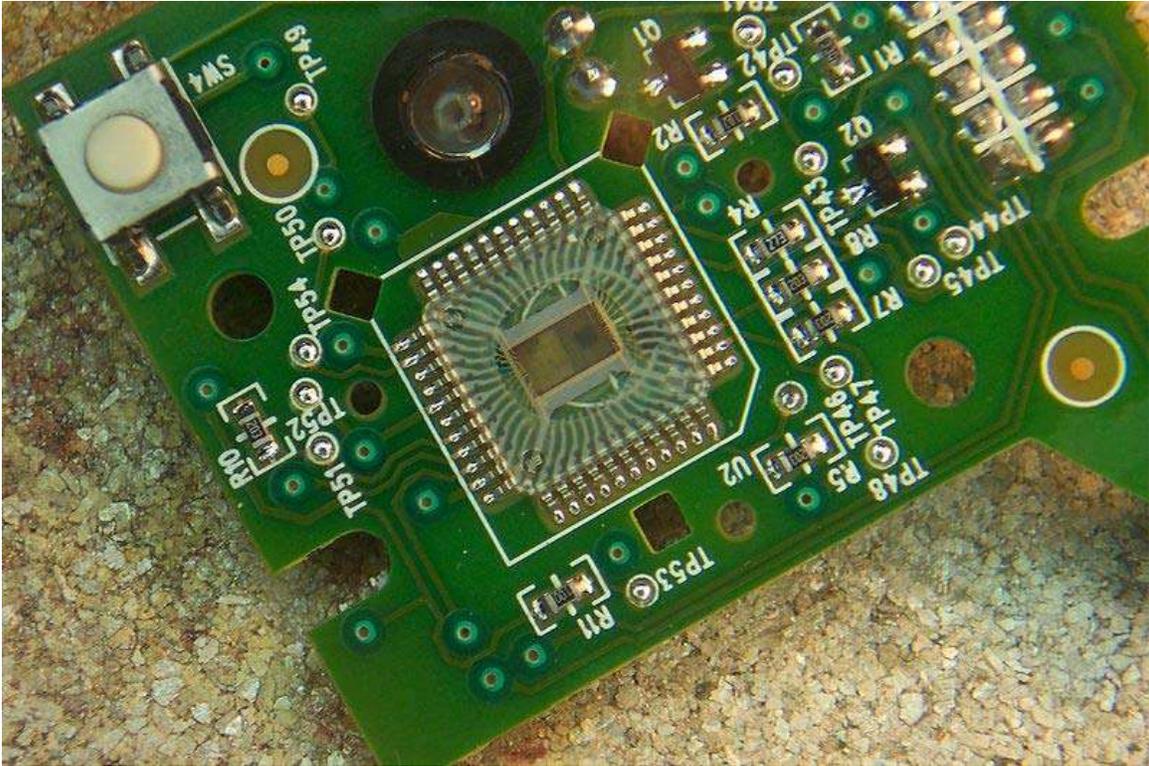
Xerox optical mouse chip

Early optical mice, first demonstrated by two independent inventors in 1980, came in two different varieties: abigail nelson

Some, such as those invented by Steve Kirsch of MIT and Mouse Systems Corporation, used an infrared LED and a four-quadrant infrared sensor to detect grid lines printed with infrared absorbing ink on a special metallic surface. Predictive algorithms in the CPU of the mouse calculated the speed and direction over the grid.

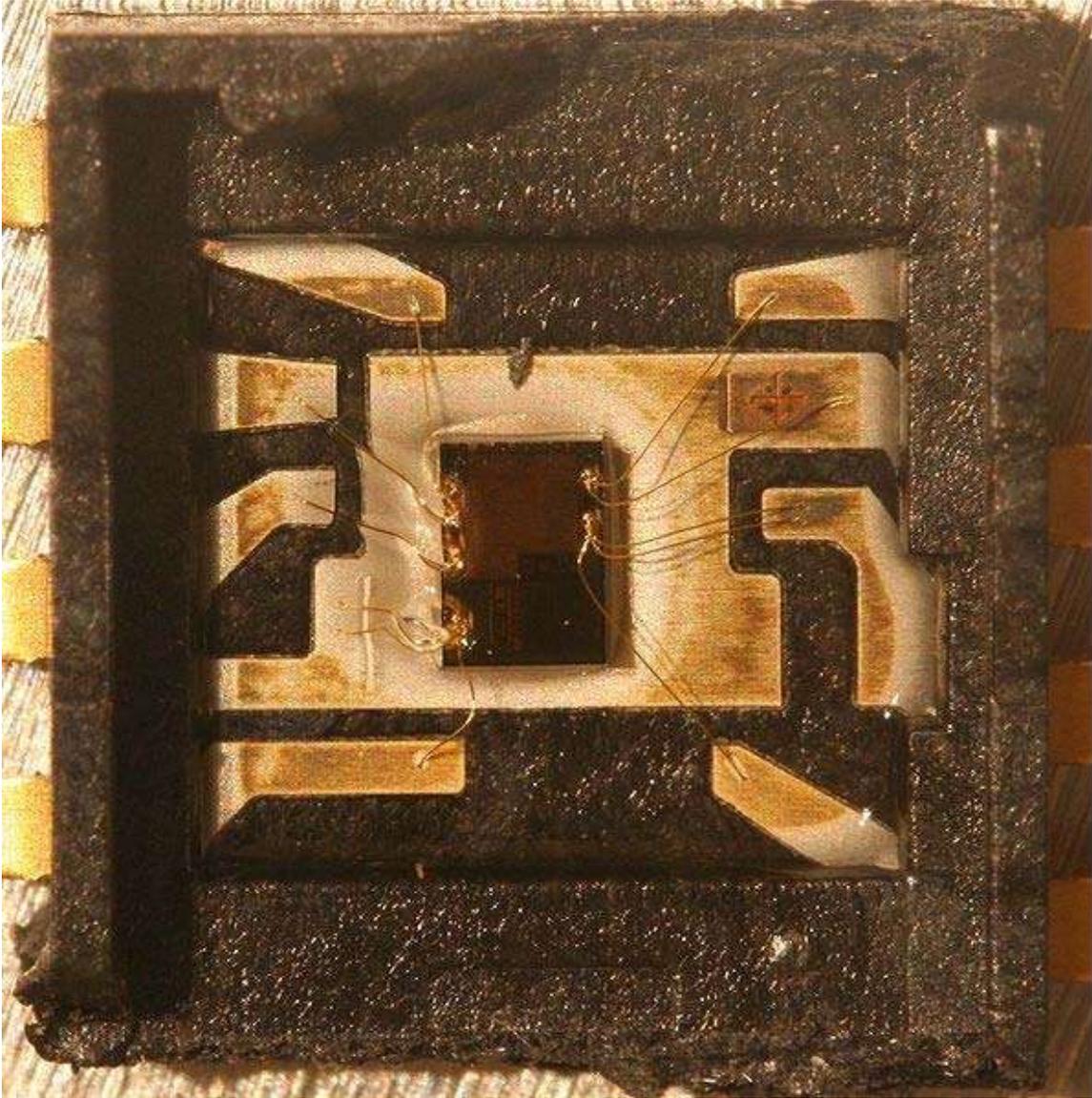
Others, invented by Richard F. Lyon and sold by Xerox, used a 16-pixel visible-light image sensor with integrated motion detection on the same chip and tracked the motion of light dots in a dark field of a printed paper or similar mouse pad.

These two mouse types had very different behaviors, as the Kirsch mouse used an x-y coordinate system embedded in the pad, and would not work correctly when the pad was rotated, while the Lyon mouse used the x-y coordinate system of the mouse body, as mechanical mice do.



The optical sensor from a Microsoft Wireless IntelliMouse Explorer (v. 1.0A)

Modern optical mice



Optical mouse sensor disassembled

Modern surface-independent optical mice work by using an optoelectronic sensor (essentially, a tiny low-resolution video camera) to take successive images of the surface on which the mouse operates. As computing power grew cheaper, it became possible to embed more powerful special-purpose image-processing chips in the mouse itself. This advance enabled the mouse to detect relative motion on a wide variety of surfaces, translating the movement of the mouse into the movement of the cursor and eliminating the need for a special mouse-pad.

The first commercially successful optical computer mouse was the Microsoft IntelliMouse®, introduced in 2001 using technology developed by Hewlett-Packard. It worked on almost any surface, and represented a welcome improvement over mechanical mice, which would pick up dirt, track capriciously, invite rough handling, and need to be taken apart and cleaned. Instead the reliable performance of the IntelliMouse® allowed relaxed grips which also were less likely to cause repetitive strain injury. Other manufacturers soon followed Microsoft's lead using components manufactured by the HP spin-off Agilent Technologies, and over the next several years mechanical mice became obsolete.

The technology underlying the modern optical computer mouse is known as digital image correlation, a technology pioneered by the defense industry for tracking military targets. Optical mice use image sensors to image naturally occurring texture in materials such as wood, cloth, mouse pads and Formica. These surfaces, when lit at a grazing angle by a light emitting diode, cast distinct shadows that resemble a hilly terrain lit at sunset. Images of these surfaces are captured in continuous succession and compared with each other to determine how far the mouse has moved.

To understand how optical mice work, imagine two photographs of the same object except slightly offset from each other. Place both photographs on a light table to make them transparent, and slide one across the other until their images line up. The amount that the edges of one photograph overhang the other represents the offset between the images, and in the case of an optical computer mouse the distance it has moved.

Optical mice capture one thousand successive images or more per second. Depending on how fast the mouse is moving, each image will be offset from the previous one by a fraction of a pixel or as many as several pixels. Optical mice mathematically process these images using cross correlation to calculate how much each successive image is offset from the previous one.

An optical mouse might use an image sensor having an 18 x 18 pixel array of monochromatic pixels. Its sensor would normally share the same ASIC as that used for storing and processing the images. One refinement would be accelerating the correlation process by using information from previous motions, and another refinement would be preventing deadbands when moving slowly by adding interpolation or frame-skipping.

The invention of the modern optical mouse at HP was made more likely by a succession of related projects during the 1990s at its central research laboratory. In 1992 John Ertel, William Holland, Kent Vincent, Rueiming Jamp and Richard Baldwin were awarded US Patent 5,149,980 for measuring paper advance in a printer by correlating images of paper fibers. In 1998 Travis N. Blalock, Richard A. Baumgartner, Thomas Hornak, and Mark T. Smith were awarded US Patent 5,729,008 for tracking motion in a hand-held scanner by correlating images of paper fibers and document features, a technology commercialized in 1998 with the HP 920 Capshare handheld scanner. In 2002 Gary Gordon, Derek Knee, Rajeev Badyal and Jason Hartlove were awarded US Patent 6,433,780 for the modern optical computer mouse using image correlation.

Laser mice



Although nearly invisible to the naked eye, the dot produced by this laser mouse is captured as the color purple.

The laser mouse uses an infrared laser diode instead of a LED to illuminate the surface beneath their sensor. As early as 1998, Sun Microsystems provided a laser mouse with their Sun SPARCstation servers and workstations. However, laser mice did not enter the mainstream market until 2004, when Logitech, in partnership with Agilent Technologies, introduced its *MX 1000* laser mouse. This mouse uses a small infrared laser instead of an LED and has significantly increased the resolution of the image taken by the mouse. The laser enables around 20 times more surface tracking power to the surface features used for navigation compared to conventional optical mice, via interference effects.

Glass laser (or *glaser*) mice have the same capability of a laser mouse but can also be used on top of mirror or transparent glass with few problems.

In August 2009, Logitech introduced mice with two lasers, to track on glass and glossy surfaces better; they dubbed them "dark field" mice.

LED color



The blue LED based V-Mouse VM-101.

The color of the optical mouse's light-emitting diodes can vary, but red is most common, as red diodes are inexpensive and silicon is very sensitive to red light. Other colors are sometimes used, such as the blue LED of the V-Mouse VM-101 illustrated at right.

Power

Manufacturers often engineer their optical mice—especially battery-powered wireless models—to save power when possible. In order to do this, the mouse dims or blinks the laser or LED when in standby mode (each mouse has a different standby time). This function may also increase the laser / LED life. Mice designed specifically for gamers, such as the Logitech G5 or the Razer Copperhead, often lack this feature in an attempt to reduce latency and to improve responsiveness.

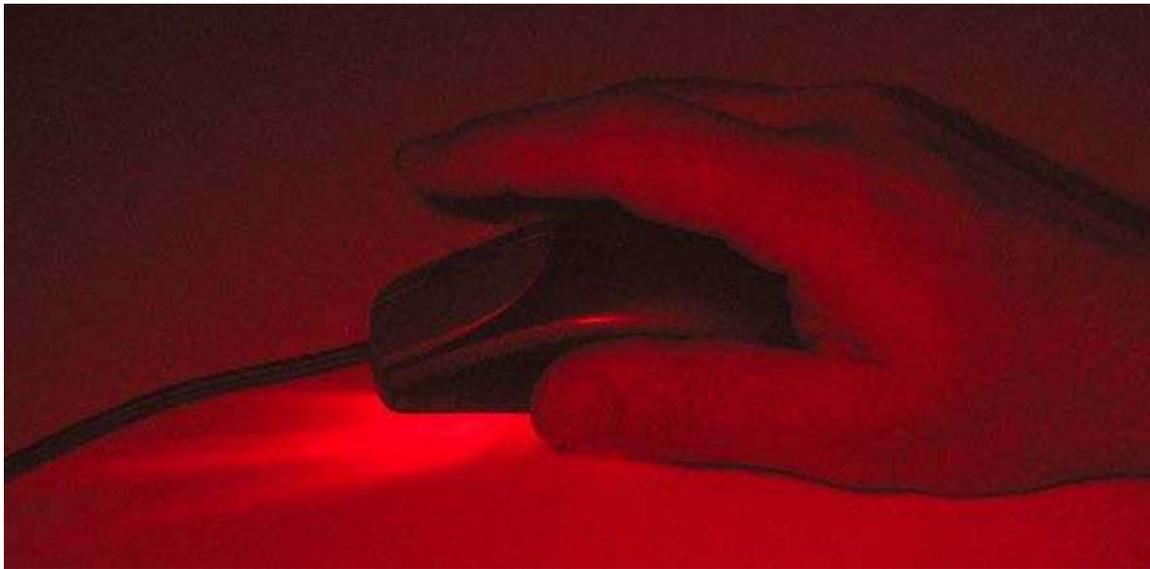
A typical implementation in Logitech mice has four power states, where the sensor is pulsed at different rates per second:

- 1500: full on condition for accurate response while moving, illumination appears bright.
- 100: fallback active condition while not moving, illumination appears dull.
- 10: standby
- 2: sleep state

Some other mice turn the sensor fully off in the sleep state, requiring a button click to wake.

Optical mice utilizing infrared elements (LEDs or lasers) offer substantial increases in battery life. Some Logitech mice, such as the V450 848 nm laser mouse, are capable of functioning on two AA batteries for a full year, due to the low power requirements of the infrared laser.

Optical versus mechanical mice



The Logitech iFeel optical mouse uses a red LED to project light onto the tracking surface.

Unlike mechanical mice, which can become clogged with lint, optical mice have no rolling parts; therefore, they do not require maintenance other than removing debris that might collect under the light emitter. However, they generally cannot track on glossy and transparent surfaces, including some mouse-pads, sometimes causing the cursor to drift unpredictably during operation. Mice with less image-processing power also have problems tracking fast movement, though high-end mice can track at 2 m/s (80 inches per second) and faster.

Some models of laser mice can track on glossy and transparent surfaces, and have a much higher sensitivity than either their mechanical or optical counterparts but are more expensive than their LED based or mechanical counterparts.

As of 2006, mechanical mice have lower average power demands than their optical counterparts. In practice this is only significant when the mouse is either used with a battery-powered computer, such as a notebook model, or is a battery-powered wireless mouse.

Optical models will outperform mechanical mice on uneven, slick, soft, sticky, or loose surfaces, and generally in mobile situations lacking mouse pads. Because optical mice render movement based on an image which the LED (or infrared diode) illuminates, use with multicolored mouse pads may result in unreliable performance; however, laser mice do not suffer these problems and will track on such surfaces. The advent of affordable high-speed, low-resolution cameras and the integrated logic in optical mice provides an ideal laboratory for experimentation on next-generation input-devices. Experimenters can obtain low-cost components simply by taking apart a working mouse and changing the optics or by writing new software.

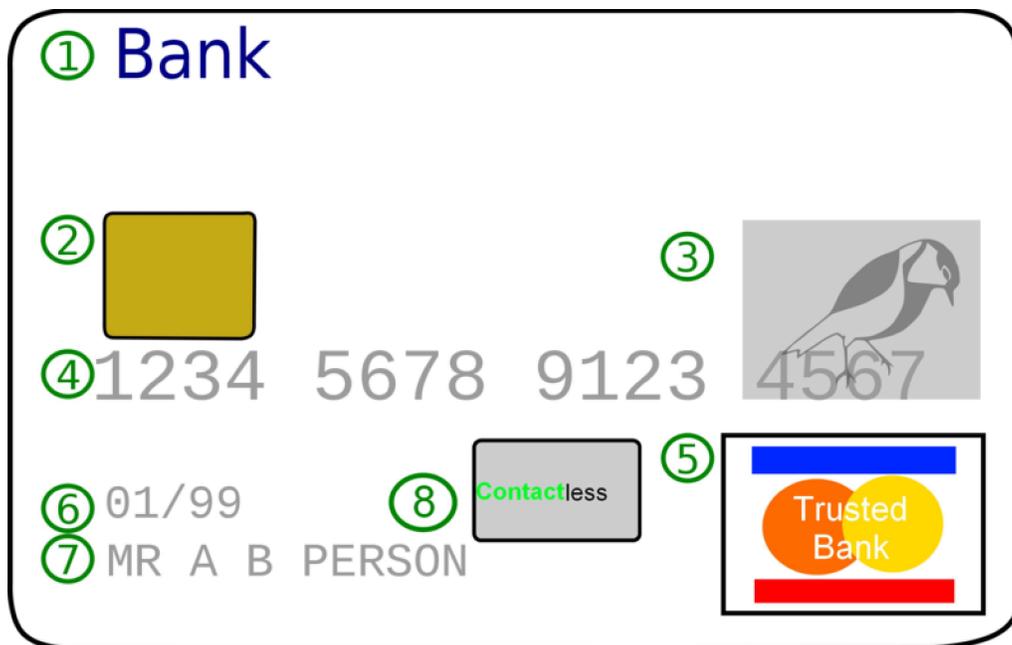
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Chapter- 2

Credit Card

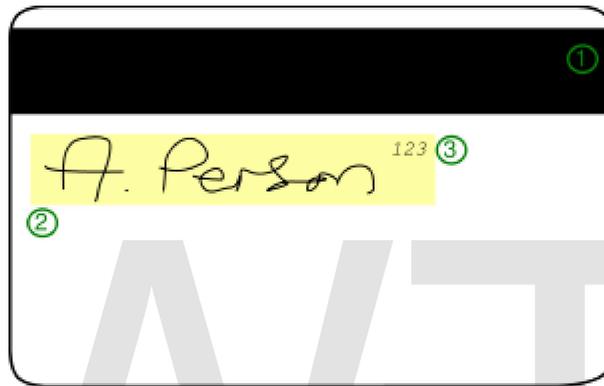


Credit card



An example of the front in a typical credit card:

1. Issuing bank logo
2. EMV chip on "smart cards"
3. Hologram
4. Credit card number
5. Card brand logo
6. Expiration Date
7. Card Holder Name
8. contactless chip



An example of the reverse side of a typical credit card:

1. Magnetic Stripe
2. Signature Strip
3. Card Security Code

A **credit card** is a small plastic card issued to users as a system of payment. It allows its holder to buy goods and services based on the holder's promise to pay for these goods and services. The issuer of the card creates a revolving account and grants a line of credit to the consumer (or the user) from which the user can borrow money for payment to a merchant or as a cash advance to the user.

A credit card is different from a charge card: a charge card requires the balance to be paid in full each month. In contrast, credit cards allow the consumers a continuing balance of debt, subject to interest being charged. A credit card also differs from a cash card, which can be used like currency by the owner of the card. Most credit cards are issued by banks or credit unions, and are the shape and size specified by the ISO/IEC 7810 standard as ID-1. This is defined as 85.60×53.98 mm (3.370×2.125 in) ($3\frac{3}{8} \times 2\frac{1}{8}$ in) in size.

History

The concept of using a card for purchases was described in 1887 by Edward Bellamy in his utopian novel *Looking Backward*. Bellamy used the term *credit card* eleven times in this novel.

The modern credit card was the successor of a variety of merchant credit schemes. It was first used in the 1920s, in the United States, specifically to sell fuel to a growing number of automobile owners. In 1938 several companies started to accept each other's cards. Western Union had begun issuing charge cards to its frequent customers in 1921. Some charge cards were printed on paper card stock, but were easily counterfeited.

The Charg-a-Plate was an early predecessor to the credit card and used in the U.S. from the 1930s to the late 1950s. It was a 2½" × 1¼" rectangle of sheet metal, similar to a military dog tag, and embossed with the customer's name, city and state. It held a small paper card for a signature. In recording a purchase, the plate was laid into a recess in the imprinter, with a paper "charge slip" positioned on top of it. The record of the transaction included an impression of the embossed information, made by the imprinter pressing an inked ribbon against the charge slip. Charg-a-Plate was a trademark of Farrington Manufacturing Co. Charg-a-Plates were issued by large-scale merchants to their regular customers, much like department store credit cards of today. In some cases, the plates were kept in the issuing store rather than held by customers. When an authorized user made a purchase, a clerk retrieved the plate from the store's files and then processed the purchase. Charg-a-Plates speeded back-office bookkeeping that was done manually in paper ledgers in each store, before computers.

The concept of customers paying different merchants using the same card was implemented in 1950 by Ralph Schneider and Frank McNamara, founders of Diners Club, to consolidate multiple cards. The Diners Club, which was created partially through a merger with Dine and Sign, produced the first "general purpose" charge card, and required the entire bill to be paid with each statement. That was followed by Carte Blanche and in 1958 by American Express which created a worldwide credit card network (although these were initially charge cards that acquired credit card features after BankAmericard demonstrated the feasibility of the concept).

However, until 1958, no one had been able to create a working *revolving credit* financial instrument issued by a third-party bank that was generally accepted by a large number of merchants (as opposed to merchant-issued revolving cards accepted by only a few merchants). A dozen experiments by small American banks had been attempted (and had failed). In September 1958, Bank of America launched the *BankAmericard* in Fresno, California. BankAmericard became the first successful recognizably modern credit card (although it underwent a troubled gestation during which its creator resigned), and with its overseas affiliates, eventually evolved into the Visa system. In 1966, the ancestor of MasterCard was born when a group of California banks established Master Charge to compete with BankAmericard; it received a significant boost when Citibank merged its proprietary Everything Card (launched in 1967) into Master Charge in 1969.

Early credit cards in the U.S., of which BankAmericard was the most prominent example, were mass produced and mass mailed to bank customers who were thought to be good credit risks; that is, they were unsolicited. These mass mailings were known as "drops" in banking terminology, and were outlawed in 1970 due to the financial chaos that they caused, but not before 100 million credit cards had been dropped into the U.S. population. After 1970, only credit card applications could be sent unsolicited in mass mailings.

The fractured nature of the U.S. banking system under the Glass-Steagall Act meant that credit cards became an effective way for those who were traveling around the country to move their credit to places where they could not directly use their banking facilities. In 1966 Barclaycard in the UK launched the first credit card outside of the U.S.

There are now countless variations on the basic concept of revolving credit for individuals (as issued by banks and honored by a network of financial institutions), including organization-branded credit cards, corporate-user credit cards, store cards and so on.

Although credit cards reached very high adoption levels in the US, Canada and the UK in the mid twentieth century, many cultures were more cash-oriented, or developed alternative forms of cash-less payments, such as Carte bleue or the Eurocard (Germany, France, Switzerland, and others). In these places, adoption of credit cards was initially much slower. It took until the 1990s to reach anything like the percentage market-penetration levels achieved in the US, Canada, or UK. In some countries, acceptance still remains poor as the use of a credit card system depends on the banking system being perceived as reliable. Japan remains a very cash oriented society, with credit card adoption being limited to only the largest of merchants, although an alternative system based on RFIDs inside cellphones has seen some acceptance. Because of strict regulations regarding banking system overdrafts, some countries, France in particular, were much faster to develop and adopt chip-based credit cards which are now seen as major anti-fraud credit devices. Debit cards and online banking are used more widely than credit cards in some countries.

The design of the credit card itself has become a major selling point in recent years. The value of the card to the issuer is often related to the customer's usage of the card, or to the customer's financial worth. This has led to the rise of Co-Brand and Affinity cards - where the card design is related to the "affinity" (a university or professional society, for example) leading to higher card usage. In most cases a percentage of the value of the card is returned to the affinity group.

Collectible credit cards

A growing field of numismatics (study of money), or more specifically exonumia (study of money-like objects), credit card collectors seek to collect various embodiments of credit from the now familiar plastic cards to older paper merchant cards, and even metal

tokens that were accepted as merchant credit cards. Early credit cards were made of celluloid plastic, then metal and fiber, then paper, and are now mostly plastic.

How credit cards work

Credit cards are issued by a credit card issuer, such as a bank or credit union, after an account has been approved by the credit provider, after which cardholders can use it to make purchases at merchants accepting that card. Merchants often advertise which cards they accept by displaying acceptance marks – generally derived from logos – or may communicate this orally, as in "Credit cards are fine" (implicitly meaning "major brands"), "We take (brands X, Y, and Z)", or "We don't take credit cards".

When a purchase is made, the credit card user agrees to pay the card issuer. The cardholder indicates consent to pay by signing a receipt with a record of the card details and indicating the amount to be paid or by entering a personal identification number (PIN). Also, many merchants now accept verbal authorizations via telephone and electronic authorization using the Internet, known as a card not present transaction (CNP).

Electronic verification systems allow merchants to verify in a few seconds that the card is valid and the credit card customer has sufficient credit to cover the purchase, allowing the verification to happen at time of purchase. The verification is performed using a credit card payment terminal or point-of-sale (POS) system with a communications link to the merchant's acquiring bank. Data from the card is obtained from a magnetic stripe or chip on the card; the latter system is called Chip and PIN in the United Kingdom and Ireland, and is implemented as an EMV card.

For card not present transactions where the card is not shown (e.g., e-commerce, mail order, and telephone sales), merchants additionally verify that the customer is in physical possession of the card and is the authorized user by asking for additional information such as the security code printed on the back of the card, date of expiry, and billing address.

Each month, the credit card user is sent a statement indicating the purchases undertaken with the card, any outstanding fees, and the total amount owed. After receiving the statement, the cardholder may dispute any charges that he or she thinks are incorrect. Otherwise, the cardholder must pay a defined minimum proportion of the bill by a due date, or may choose to pay a higher amount up to the entire amount owed. The credit issuer charges interest on the amount owed if the balance is not paid in full (typically at a much higher rate than most other forms of debt). In addition, if the credit card user fails to make at least the minimum payment by the due date, the issuer may impose a "late fee" and/or other penalties on the user. To help mitigate this, some financial institutions can arrange for automatic payments to be deducted from the user's bank accounts, thus avoiding such penalties altogether as long as the cardholder has sufficient funds.

Advertising, solicitation, application and approval

Credit card advertising regulations include the Schumer box disclosure requirements. A large fraction of junk mail consists of credit card offers created from lists provided by the major credit reporting agencies. In the United States, the three major US credit bureaus (Equifax, TransUnion and Experian) allow consumers to opt out from related credit card solicitation offers via its Opt Out Pre Screen program.

Interest charges

Credit card issuers usually waive interest charges if the balance is paid in full each month, but typically will charge full interest on the entire outstanding balance from the date of each purchase if the total balance is not paid.

For example, if a user had a \$1,000 transaction and repaid it in full within this grace period, there would be no interest charged. If, however, even \$1.00 of the total amount remained unpaid, interest would be charged on the \$1,000 from the date of purchase until the payment is received. The precise manner in which interest is charged is usually detailed in a cardholder agreement which may be summarized on the back of the monthly statement. The general calculation formula most financial institutions use to determine the amount of interest to be charged is $APR/100 \times ADB/365 \times \text{number of days revolved}$. Take the Annual percentage rate (APR) and divide by 100 then multiply to the amount of the average daily balance (ADB) divided by 365 and then take this total and multiply by the total number of days the amount revolved before payment was made on the account. Financial institutions refer to interest charged back to the original time of the transaction and up to the time a payment was made, if not in full, as RRFC or residual retail finance charge. Thus after an amount has revolved and a payment has been made, the user of the card will still receive interest charges on their statement after paying the next statement in full (in fact the statement may only have a charge for interest that collected up until the date the full balance was paid, i.e. when the balance stopped revolving).

The credit card may simply serve as a form of revolving credit, or it may become a complicated financial instrument with multiple balance segments each at a different interest rate, possibly with a single umbrella credit limit, or with separate credit limits applicable to the various balance segments. Usually this compartmentalization is the result of special incentive offers from the issuing bank, to encourage balance transfers from cards of other issuers. In the event that several interest rates apply to various balance segments, payment allocation is generally at the discretion of the issuing bank, and payments will therefore usually be allocated towards the lowest rate balances until paid in full before any money is paid towards higher rate balances. Interest rates can vary considerably from card to card, and the interest rate on a particular card may jump dramatically if the card user is late with a payment on that card *or any other credit instrument*, or even if the issuing bank decides to raise its revenue.

Benefits to customers

The main benefit to each customer is convenience. Compared to debit cards and cheques, a credit card allows small short-term loans to be quickly made to a customer who need not calculate a balance remaining before every transaction, provided the total charges do not exceed the maximum credit line for the card. Credit cards also provide more fraud protection than debit cards. In the UK for example, the bank is jointly liable with the merchant for purchases of defective products over £100.

Many credit cards offer rewards and benefits packages, such as offering enhanced product warranties at no cost, free loss/damage coverage on new purchases, and points which may be redeemed for cash, products, or airline tickets. Additionally, carrying a credit card may be a convenience to some customers as it eliminates the need to carry any cash for most purposes.

Detriments to customers

High interest and bankruptcy

Low introductory credit card rates are limited to a fixed term, usually between 6 and 12 months, after which a higher rate is charged. As all credit cards charge fees and interest, some customers become so indebted to their credit card provider that they are driven to bankruptcy. Some credit cards often levy a rate of 20 to 30 percent after a payment is missed; in other cases a fixed charge is levied without change to the interest rate. In some cases universal default may apply: the high default rate is applied to a card in good standing by missing a payment on an unrelated account from the same provider. This can lead to a snowball effect in which the consumer is drowned by unexpectedly high interest rates. Further, most card holder agreements enable the issuer to arbitrarily raise the interest rate for any reason they see fit. As of December 2009, First Premier Bank is reportedly offering a credit card with a 79.9% interest rate.

Inflated pricing for all consumers

Merchants that accept credit cards must pay interchange fees and discount fees on all credit-card transactions. In some cases merchants are barred by their credit agreements from passing these fees directly to credit card customers, or from setting a minimum transaction amount (no longer prohibited in the United States). The result is that merchants may charge all customers (including those who do not use credit cards) higher prices to cover the fees on credit card transactions. In the United States in 2008 credit card companies collected a total of \$48 billion in interchange fees, or an average of \$427 per family, with an average fee rate of about 2% per transaction.

Grace period

A credit card's grace period is the time the customer has to pay the balance before interest is assessed on the outstanding balance. Grace periods may vary, but usually range from

20 to 50 days depending on the type of credit card and the issuing bank. Some policies allow for reinstatement after certain conditions are met.

Usually, if a customer is late paying the balance, finance charges will be calculated and the grace period does not apply. Finance charges incurred depend on the grace period and balance; with most credit cards there is no grace period if there is any outstanding balance from the previous billing cycle or statement (i.e. interest is applied on both the previous balance and new transactions). However, there are some credit cards that will only apply finance charge on the previous or old balance, excluding new transactions.

Benefits to merchants



An example of street markets accepting credit cards. Most simply display the acceptance marks (stylized logos, shown in the upper-left corner of the sign) of all the cards they accept.

For merchants, a credit card transaction is often more secure than other forms of payment, such as cheques, because the issuing bank commits to pay the merchant the moment the transaction is authorized, regardless of whether the consumer defaults on the credit card payment (except for legitimate disputes, which are discussed below, and can result in charges back to the merchant). In most cases, cards are even more secure than cash, because they discourage theft by the merchant's employees and reduce the amount of cash on the premises.

Prior to credit cards, each merchant had to evaluate each customer's credit history before extending credit. That task is now performed by the banks which assume the credit risk. Credit cards can also aid in securing a sale, especially if the customer does not have enough cash on his or her person or checking account. Extra turnover is generated by the fact that the customer can purchase goods and/or services immediately and is less inhibited by the amount of cash in his or her pocket and the immediate state of his or her bank balance. Much of merchants' marketing is based on this immediacy.

For each purchase, the bank charges the merchant a commission (discount fee) for this service and there may be a certain delay before the agreed payment is received by the merchant. The commission is often a percentage of the transaction amount, plus a fixed fee (interchange rate). In addition, a merchant may be penalized or have their ability to receive payment using that credit card restricted if there are too many cancellations or reversals of charges as a result of disputes. Some small merchants require credit purchases to have a minimum amount to compensate for the transaction costs.

In some countries, for example the Nordic countries, banks guarantee payment on stolen cards only if an ID card is checked and the ID card number/civic registration number is written down on the receipt together with the signature. In these countries merchants therefore usually ask for ID. Non-Nordic citizens, who are unlikely to possess a Nordic ID card or driving license, will instead have to show their passport, and the passport number will be written down on the receipt, sometimes together with other information. Some shops use the card's PIN for identification, and in that case showing an ID card is not necessary.

Costs to merchants

Merchants are charged several fees for the privilege of accepting credit cards. The merchant is usually charged a commission of around 1 to 3 per-cent of the value of each transaction paid for by credit card. The merchant may also pay a variable charge, called an interchange rate, for each transaction. In some instances of very low-value transactions, use of credit cards will significantly reduce the profit margin or cause the merchant to lose money on the transaction. Merchants must accept these transactions as part of their costs to retain the right to accept credit card transactions. Merchants with very low average transaction prices or very high average transaction prices are more averse to accepting credit cards. In some cases merchants may charge users a "credit card supplement", either a fixed amount or a percentage, for payment by credit card. This practice is prohibited by the credit card contracts in the United States, although the contracts allow the merchants to give discounts for cash payment.

In certain countries, merchants are required to pay the acquiring banks a monthly terminal rental fee if the terminals are provided by the acquiring banks. Merchants can apply to the acquiring banks for waivers of the fees, which the banks usually agree to for merchants with a high volume of sales, but not for smaller ones.

Parties involved

- **Cardholder:** The holder of the card used to make a purchase; the consumer.
- **Card-issuing bank:** The financial institution or other organization that issued the credit card to the cardholder. This bank bills the consumer for repayment and bears the risk that the card is used fraudulently. American Express and Discover were previously the only card-issuing banks for their respective brands, but as of 2007, this is no longer the case. Cards issued by banks to cardholders in a different country are known as offshore credit cards.
- **Merchant:** The individual or business accepting credit card payments for products or services sold to the cardholder.
- **Acquiring bank:** The financial institution accepting payment for the products or services on behalf of the merchant.
- **Independent sales organization:** Resellers (to merchants) of the services of the acquiring bank.
- **Merchant account:** This could refer to the acquiring bank or the independent sales organization, but in general is the organization that the merchant deals with.
- **Credit Card association:** An association of card-issuing banks such as Visa, MasterCard, Discover, American Express, etc. that set transaction terms for merchants, card-issuing banks, and acquiring banks.
- **Transaction network:** The system that implements the mechanics of the electronic transactions. May be operated by an independent company, and one company may operate multiple networks.
- **Affinity partner:** Some institutions lend their names to an issuer to attract customers that have a strong relationship with that institution, and get paid a fee or a percentage of the balance for each card issued using their name. Examples of typical affinity partners are sports teams, universities, charities, professional organizations, and major retailers.

The flow of information and money between these parties — always through the card associations — is known as the interchange, and it consists of a few steps.

Transaction steps

- **Authorization:** The cardholder pays for the purchase and the merchant submits the transaction to the acquirer (acquiring bank). The acquirer verifies the credit card number, the transaction type and the amount with the issuer (Card-issuing bank) and reserves that amount of the cardholder's credit limit for the merchant. An authorization will generate an approval code, which the merchant stores with the transaction.
- **Batching:** Authorized transactions are stored in "batches", which are sent to the acquirer. Batches are typically submitted once per day at the end of the business day. If a transaction is not submitted in the batch, the authorization will stay valid for a period determined by the issuer, after which the held amount will be returned back to the cardholder's available credit. Some transactions may be

submitted in the batch without prior authorizations; these are either transactions falling under the merchant's floor limit or ones where the authorization was unsuccessful but the merchant still attempts to force the transaction through. (Such may be the case when the cardholder is not present but owes the merchant additional money, such as extending a hotel stay or car rental.)

- **Clearing and Settlement:** The acquirer sends the batch transactions through the credit card association, which debits the issuers for payment and credits the acquirer. Essentially, the issuer pays the acquirer for the transaction.
- **Funding:** Once the acquirer has been paid, the acquirer pays the merchant. The merchant receives the amount totaling the funds in the batch minus either the "discount rate," "mid-qualified rate", or "non-qualified rate" which are tiers of fees the merchant pays the acquirer for processing the transactions.
- **Chargebacks:** A chargeback is an event in which money in a merchant account is held due to a dispute relating to the transaction. Chargebacks are typically initiated by the cardholder. In the event of a chargeback, the issuer returns the transaction to the acquirer for resolution. The acquirer then forwards the chargeback to the merchant, who must either accept the chargeback or contest it. A merchant is responsible for the chargeback only if she has violated the card acceptance procedures as per the merchant agreement with card acquirers.

Secured credit cards

A secured credit card is a type of credit card secured by a deposit account owned by the cardholder. Typically, the cardholder must deposit between 100% and 200% of the total amount of credit desired. Thus if the cardholder puts down \$1000, they will be given credit in the range of \$500–\$1000. In some cases, credit card issuers will offer incentives even on their secured card portfolios. In these cases, the deposit required may be significantly less than the required credit limit, and can be as low as 10% of the desired credit limit. This deposit is held in a special savings account. Credit card issuers offer this because they have noticed that delinquencies were notably reduced when the customer perceives something to lose if the balance is not repaid.

The cardholder of a secured credit card is still expected to make regular payments, as with a regular credit card, but should they default on a payment, the card issuer has the option of recovering the cost of the purchases paid to the merchants out of the deposit. The advantage of the secured card for an individual with negative or no credit history is that most companies report regularly to the major credit bureaus. This allows for building of positive credit history.

Although the deposit is in the hands of the credit card issuer as security in the event of default by the consumer, the deposit will not be debited simply for missing one or two payments. Usually the deposit is only used as an offset when the account is closed, either at the request of the customer or due to severe delinquency (150 to 180 days). This means

that an account which is less than 150 days delinquent will continue to accrue interest and fees, and could result in a balance which is much higher than the actual credit limit on the card. In these cases the total debt may far exceed the original deposit and the cardholder not only forfeits their deposit but is left with an additional debt.

Most of these conditions are usually described in a cardholder agreement which the cardholder signs when their account is opened.

Secured credit cards are an option to allow a person with a poor credit history or no credit history to have a credit card which might not otherwise be available. They are often offered as a means of rebuilding one's credit. Fees and service charges for secured credit cards often exceed those charged for ordinary non-secured credit cards, however, for people in certain situations, (for example, after charging off on other credit cards, or people with a long history of delinquency on various forms of debt), secured cards can often be less expensive in total cost than unsecured credit cards, even including the security deposit.

Sometimes a credit card will be secured by the equity in the borrower's home.

Prepaid "credit" cards

A **prepaid credit card** is not a true credit card, since no credit is offered by the card issuer: the card-holder spends money which has been "stored" via a prior deposit by the card-holder or someone else, such as a parent or employer. However, it carries a credit-card brand (such as Visa, MasterCard, American Express, Discover, or JCB) and can be used in similar ways just as though it were a regular credit card. Unlike debit cards, prepaid credit cards generally do not require a PIN. An exception are prepaid credit cards with an EMV chip. These cards do require a PIN if the payment is processed via Chip and PIN technology.

After purchasing the card, the cardholder loads the account with any amount of money, up to the predetermined card limit and then uses the card to make purchases the same way as a typical credit card. Prepaid cards can be issued to minors (above 13) since there is no credit line involved. The main advantage over secured credit cards is that you are not required to come up with \$500 or more to open an account. With prepaid credit cards purchasers not charged any interest but are often charged a purchasing fee plus monthly fees after an arbitrary time period. Many other fees also usually apply to a prepaid card.

Prepaid credit cards are sometimes marketed to teenagers for shopping online without having their parents complete the transaction.

Because of the many fees that apply to obtaining and using credit-card-branded prepaid cards, the Financial Consumer Agency of Canada describes them as "an expensive way to spend your own money". The agency publishes a booklet entitled *Pre-paid Cards* which explains the advantages and disadvantages of this type of prepaid card.

Features

As well as convenient, accessible credit, credit cards offer consumers an easy way to track expenses, which is necessary for both monitoring personal expenditures and the tracking of work-related expenses for taxation and reimbursement purposes. Credit cards are accepted worldwide, and are available with a large variety of credit limits, repayment arrangement, and other perks (such as rewards schemes in which points earned by purchasing goods with the card can be redeemed for further goods and services or credit card cashback).

Some countries, such as the United States, the United Kingdom, and France, limit the amount for which a consumer can be held liable due to fraudulent transactions as a result of a consumer's credit card being lost or stolen.

Security problems and solutions

Credit card security relies on the physical security of the plastic card as well as the privacy of the credit card number. Therefore, whenever a person other than the card owner has access to the card or its number, security is potentially compromised. Once, merchants would often accept credit card numbers without additional verification for mail order purchases. It's now common practice to only ship to confirmed addresses as a security measure to minimise fraudulent purchases. Some merchants will accept a credit card number for in-store purchases, whereupon access to the number allows easy fraud, but many require the card itself to be present, and require a signature. A lost or stolen card can be cancelled, and if this is done quickly, will greatly limit the fraud that can take place in this way. For internet purchases, there is sometimes the same level of security as for mail order (number only) hence requiring only that the fraudster take care about collecting the goods, but often there are additional measures. European banks can require a cardholder's security PIN be entered for in-person purchases with the card.

The PCI DSS is the security standard issued by The PCI SSC (Payment Card Industry Security Standards Council). This data security standard is used by acquiring banks to impose cardholder data security measures upon their merchants.



A smart card, combining credit card and debit card properties. The 3 by 5 mm security chip embedded in the card is shown enlarged in the inset. The contact pads on the card enable electronic access to the chip.

The low security of the credit card system presents countless opportunities for fraud. This opportunity has created a huge black market in stolen credit card numbers, which are generally used quickly before the cards are reported stolen.

The goal of the credit card companies is not to eliminate fraud, but to "reduce it to manageable levels". This implies that high-cost low-return fraud prevention measures will not be used if their cost exceeds the potential gains from fraud reduction - as would be expected from organisations whose goal is profit maximisation.

Internet fraud may be by claiming a chargeback which is not justified ("friendly fraud"), or carried out by the use of credit card information which can be stolen in many ways, the simplest being copying information from retailers, either online or offline. Despite efforts to improve security for remote purchases using credit cards, security breaches are usually the result of poor practice by merchants. For example, a website that safely uses SSL to encrypt card data from a client may then email the data, unencrypted, from the webserver to the merchant; or the merchant may store unencrypted details in a way that allows them to be accessed over the Internet or by a rogue employee; unencrypted card details are always a security risk. Even encryption data may be cracked.

Controlled Payment Numbers which are used by various banks such as Citibank (Virtual Account Numbers), Discover (Secure Online Account Numbers, Bank of America (Shop Safe), 5 banks using eCarte Bleue and CMB's Virtualis in France, and Swedbank of Sweden's eKort product are another option for protecting against credit card fraud. These are generally one-time use numbers that front one's actual account (debit/credit) number,

and are generated as one shops on-line. They can be valid for a relatively short time, for the actual amount of the purchase, or for a price limit set by the user. Their use can be limited to one merchant. If the number given to the merchant is compromised, it will be rejected if an attempt is made to use it again.

A similar system of controls can be used on physical cards. For example if a consumer has a Chip and PIN (EMV) enabled card the card can be limited so that it be used only at point of sale locations (i.e. restricted from being used on-line) and only in a given territory (i.e. only for use in Canada). This technology provides the option for banks to support many other controls too that can be turned on and off and varied by the credit card owner in real time as circumstances change (i.e., they can change temporal, numerical, geographical and many other parameters on their primary and subsidiary cards). Apart from the obvious benefits of such controls: from a security perspective this means that a customer can have a Chip and PIN card secured for the real world, and limited for use in the home country. In this eventuality a thief stealing the details will be prevented from using these overseas in non chip and pin (EMV) countries. Similarly the real card can be restricted from use on-line so that stolen details will be declined if this tried. Then when card users shop online they can use virtual account numbers. In both circumstances an alert system can be built in notifying a user that a fraudulent attempt has been made which breaches their parameters, and can provide data on this in real time. This is the optimal method of security for credit cards, as it provides very high levels of security, control and awareness in the real and virtual world. Furthermore it requires no changes for merchants at all and is attractive to users, merchants and banks, as it not only detects fraud but prevents it.

Additionally, there are security features present on the physical card itself in order to prevent counterfeiting. For example, most modern credit cards have a watermark that will fluoresce under ultraviolet light. A Visa card has a letter V superimposed over the regular Visa logo and a Mastercard has the letters MC across the front of the card. Older Visa cards have a bald eagle or dove across the front. In the aforementioned cases, the security features are only visible under ultraviolet light and are invisible in normal light. Similar security features are present in paper currency and certain ID cards in the United States, as well.

The Federal Bureau of Investigation and U.S. Postal Inspection Service are responsible for prosecuting criminals who engage in credit card fraud in the United States, but they do not have the resources to pursue all criminals. In general, federal officials only prosecute cases exceeding US\$5,000. Three improvements to card security have been introduced to the more common credit card networks but none has proven to help reduce credit card fraud so far. First, the on-line verification system used by merchants is being enhanced to require a 4 digit Personal Identification Number (PIN) known only to the card holder. Second, the cards themselves are being replaced with similar-looking tamper-resistant smart cards which are intended to make forgery more difficult. The majority of smart card (IC card) based credit cards comply with the EMV (Europay MasterCard Visa) standard. Third, an additional 3 or 4 digit Card Security Code (CSC) is now present on the back of most cards, for use in card not present transactions.

Stakeholders at all levels in electronic payment have recognized the need to develop consistent global standards for security that account for and integrate both current and emerging security technologies. They have begun to address these needs through organizations such as PCI DSS and the Secure POS Vendor Alliance.

Code 10

Code 10 calls are made when merchants are suspicious about accepting a credit card. The phrase "Code 10 authorization" is used to avoid alerting the customer to the fact that the merchant is suspicious of their card.

The operator then asks the merchant a series of YES or NO questions to find out whether the merchant is suspicious of the card or the cardholder. The merchant may be asked to retain the card if it is safe to do so.

Credit history

The way credit card owners pay off their balances has a tremendous effect on their credit history. Two of the most important factors reported to a credit bureau are the timeliness of the debt payments and the amount of debt to credit limit. Lenders want to see payments made as agreed, usually on a monthly basis, and a credit balance of around one-third the credit limit. The credit information stays on the credit report generally for 7 years. However, there are a few jurisdictions and situations where the timeframe might differ.

Profits and losses

In recent times, credit card portfolios have been very profitable for banks, largely due to the booming economy of the late nineties. However, in the case of credit cards, such high returns go hand in hand with risk, since the business is essentially one of making unsecured (uncollateralized) loans, and thus dependent on borrowers not to default in large numbers.

Costs

Credit card issuers (banks) have several types of costs:

Interest expenses

Banks generally borrow the money they then lend to their customers. As they receive very low-interest loans from other firms, they may borrow as much as their customers require, while lending their capital to other borrowers at higher rates. If the card issuer charges 15% on money lent to users, and it costs 5% to borrow the money to lend, and the balance sits with the cardholder for a year, the issuer earns 10% on the loan. This 10% difference is the "net interest spread" and the 5% is the "interest expense".

Operating costs

This is the cost of running the credit card portfolio, including everything from paying the executives who run the company to printing the plastics, to mailing the statements, to running the computers that keep track of every cardholder's balance, to taking the many phone calls which cardholders place to their issuer, to protecting the customers from fraud rings. Depending on the issuer, marketing programs are also a significant portion of expenses.

Charge offs

When a consumer becomes severely delinquent on a debt (often at the point of six months without payment), the creditor may declare the debt to be a charge-off. It will then be listed as such on the debtor's credit bureau reports (Equifax, for instance, lists "R9" in the "status" column to denote a charge-off.) The item will include relevant dates, and the amount of the bad debt.

A charge-off is considered to be "written off as uncollectable." To banks, bad debts and even fraud are simply part of the cost of doing business.

However, the debt is still legally valid, and the creditor can attempt to collect the full amount for the time periods permitted under state law, which is usually 3 to 7 years. This includes contacts from internal collections staff, or more likely, an outside collection agency. If the amount is large (generally over \$1500–\$2000), there is the possibility of a lawsuit or arbitration.

In the United States, as the charge off number climbs or becomes erratic, officials from the Federal Reserve take a close look at the finances of the bank and may impose various operating strictures on the bank, and in the most extreme cases, may close the bank entirely.

Rewards

Many credit card customers receive rewards, such as frequent flyer points, gift certificates, or cash back as an incentive to use the card. Rewards are generally tied to purchasing an item or service on the card, which may or may not include balance transfers, cash advances, or other special uses. Depending on the type of card, rewards will generally cost the issuer between 0.25% and 2.0% of the spread. Networks such as Visa or MasterCard have increased their fees to allow issuers to fund their rewards system. Some issuers discourage redemption by forcing the cardholder to call customer service for rewards. On their servicing website, redeeming awards is usually a feature that is very well hidden by the issuers. Others encourage redemption for lower cost merchandise; instead of an airline ticket, which is very expensive to an issuer, the cardholder may be encouraged to redeem for a gift certificate instead. With a fractured and competitive environment, rewards points cut dramatically into an issuer's bottom line, and rewards points and related incentives must be carefully managed to ensure a

profitable portfolio. Unlike unused gift cards, in whose case the breakage in certain US states goes to the state's treasury, unredeemed credit card points are retained by the issuer.

Fraud

In relative numbers the values lost in bank card fraud are minor, calculated in 2006 at 7 cents per 100 dollars worth of transactions (7 basis points). In 2004, in the UK, the cost of fraud was over £500 million. When a card is stolen, or an unauthorized duplicate made, most card issuers will refund some or all of the charges that the customer has received for things they did not buy. These refunds will, in some cases, be at the expense of the merchant, especially in mail order cases where the merchant cannot claim sight of the card. In several countries, merchants will lose the money if no ID card was asked for, therefore merchants usually require ID card in these countries. Credit card companies generally guarantee the merchant will be paid on legitimate transactions regardless of whether the consumer pays their credit card bill. Most banking services have their own credit card services that handle fraud cases and monitor for any possible attempt at fraud. Employees that are specialized in doing fraud monitoring and investigation are often placed in Risk Management, Fraud and Authorization, or Cards and Unsecured Business. Fraud monitoring emphasizes minimizing fraud losses while making an attempt to track down those responsible and contain the situation. Credit card fraud is a major white collar crime that has been around for many decades, even with the advent of the chip based card (EMV) that was put into practice in some countries to prevent cases such as these. Even with the implementation of such measures, credit card fraud continues to be a problem.

Promotion

Promotional purchase is any purchase on which separate terms and conditions are set on each individual transaction unlike a standard purchase where the terms are set on the cardholder's account record and their pricing strategy. All promotional purchases that post to a particular account will be carrying its own balance called as Promotional Balance.

Revenues

Offsetting costs are the following revenues:

Interchange fee

In addition to fees paid by the card holder, merchants must also pay interchange fees to the card-issuing bank and the card association. For a typical credit card issuer, interchange fee revenues may represent about a quarter of total revenues.

These fees are typically from 1 to 6 percent of each sale, but will vary not only from merchant to merchant (large merchants can negotiate lower rates), but also from card to card, with business cards and rewards cards generally costing the merchants more to

process. The interchange fee that applies to a particular transaction is also affected by many other variables including: the type of merchant, the merchant's total card sales volume, the merchant's average transaction amount, whether the cards were physically present, how the information required for the transaction was received, the specific type of card, when the transaction was settled, and the authorized and settled transaction amounts. In some cases, merchants add a surcharge to the credit cards to cover the interchange fee, encouraging their customers to instead use cash, debit cards, or even cheques.

Interest on outstanding balances

Interest charges vary widely from card issuer to card issuer. Often, there are "teaser" rates in effect for initial periods of time (as low as zero percent for, say, six months), whereas regular rates can be as high as 40 percent. In the U.S. there is no federal limit on the interest or late fees credit card issuers can charge; the interest rates are set by the states, with some states such as South Dakota, having no ceiling on interest rates and fees, inviting some banks to establish their credit card operations there. Other states, for example Delaware, have very weak usury laws. The teaser rate no longer applies if the customer doesn't pay their bills on time, and is replaced by a penalty interest rate (for example, 23.99%) that applies retroactively.

Fees charged to customers

The major fees are for:

- Late payments or overdue payments
- Charges that result in exceeding the credit limit on the card (whether done deliberately or by mistake), called overlimit fees
- Returned cheque fees or payment processing fees (e.g. phone payment fee)
- Cash advances and convenience cheques (often 3% of the amount)
- Transactions in a foreign currency (as much as 3% of the amount). A few financial institutions do not charge a fee for this.
- Membership fees (annual or monthly), sometimes a percentage of the credit limit.
- Exchange rate loading fees (sometimes these might not be reported on the customer's statement, even when applied). The variation of exchange rates applied by different credit cards can be very substantial, as much as 10% according to a Lonely Planet report in 2009.

Over limit charges

Consumers who keep their account in good order by always staying within their credit limit, and always making at least the minimum monthly payment will see interest as the biggest expense from their card provider. Those who are not so careful and regularly surpass their credit limit or are late in making payments are exposed to multiple charges that were typically as high as £25 - £35 until a ruling from the Office of Fair Trading that

they would presume charges over £12 to be unfair which led the majority of card providers to reduce their fees to exactly that level.

US

The Credit CARD Protection Act of 2009, initiated during the term of President G W Bush, and signed into law by President Obama, requires that consumers "opt-in" to over-limit charges. Some card issuers have therefore commenced solicitations requesting customers to opt in to overlimit fees, presenting this as a benefit as it may avoid the possibility of a future transaction being declined. Other issuers have simply discontinued the practice of charging overlimit fees. Whether a customer opts in to the overlimit fee or not, banks will in practice have discretion as to whether they choose to authorize transactions above the credit limit or not. Of course, any approved over limit transactions will only result in an overlimit fee for those customers who have opted in to the fee. This legislation took effect on February 22, 2010.

UK

The higher level of fees originally charged were claimed to be designed to recoup the costs of the card operator's overall business and to ensure that the credit card business as a whole generated a profit, rather than simply recovering the cost to the provider of the limit breach which has been estimated as typically between £3-£4. Profiting from a customer's mistakes is arguably not permitted under UK common law, if the charges constitute penalties for breach of contract, or under the Unfair Terms In Consumer Regulations 1999.

Subsequent rulings in respect of personal current accounts suggest that the argument that these charges are penalties for breach of contract is weak, and given the OFT's ruling it seems unlikely that any further test case will take place.

Whilst the law remains in the balance, many consumers have made claims against their credit cards providers for the charges that they have incurred, plus interest that they would have earned had the money not been deducted from their account. It is likely that claims for amounts charged in excess of £12 will succeed, but claims for charges at the OFT's £12 threshold level are more contentious.

Neutral consumer resources

Canada

The Government of Canada maintains a database of the fees, features, interest rates and reward programs of nearly 200 credit cards available in Canada. This database is updated on a quarterly basis with information supplied by the credit card issuing companies. Information in the database is published every quarter on the website of the Financial Consumer Agency of Canada (FCAC).

Information in the database is published in two formats. It is available in PDF comparison tables that break down the information according to type of credit card, allowing the reader to compare the features of, for example, all the student credit cards in the database.

The database also feeds into an interactive tool on the FCAC website. The interactive tool uses several interview-type questions to build a profile of the user's credit card usage habits and needs, eliminating unsuitable choices based on the profile, so that the user is presented with a small number of credit cards and the ability to carry out detailed comparisons of features, reward programs, interest rates, etc.

Controversy

Credit card debt has increased steadily. Since the late 1990s, lawmakers, consumer advocacy groups, college officials and other higher education affiliates have become increasingly concerned about the rising use of credit cards among college students. The major credit card companies have been accused of targeting a younger audience, in particular college students, many of whom are already in debt with college tuition fees and college loans and who typically are less experienced at managing their own finances. Credit card debt may also negatively affect their grades as they are likely to work more both part and full time positions.

Another controversial area is the universal default feature of many North American credit card contracts. When a cardholder is late paying a particular credit card issuer, that card's interest rate can be raised, often considerably. With universal default, a customer's *other* credit cards, for which the customer may be current on payments, may *also* have their rates and/or credit limit changed. The universal default feature allows creditors to periodically check cardholders' credit portfolios to view trade, allowing these other institutions to decrease the credit limit and/or increase rates on cardholders who may be late with another credit card issuer. Being late on one credit card will potentially affect all the cardholder's credit cards. Citibank voluntarily stopped this practice in March 2007 and Chase stopped the practice in November 2007. The fact that credit card companies can change the interest rate on debts that were incurred when a different rate of interest was in place is similar to adjustable rate mortgages where interest rates on current debt may rise. However, in both cases this is agreed to in advance, and is a trade off that allows a lower initial rate as well as the possibility of an even lower rate (mortgages, if interest rates fall) or perpetually keeping a below-market rate (credit cards, if the user makes their debt payments on time). It should be noted that the Universal Default practice was actually *encouraged* by Federal Regulators, particularly those at the Office of the Comptroller of the Currency (OCC) as a means of managing the changing risk profiles of cardholders.

Another controversial area is the trailing interest issue. Trailing interest is the practice of charging interest on the entire bill no matter what percentage of it is paid. U.S Senator Carl Levin raised the issue of millions of Americans affected by hidden fees, compounding interest and cryptic terms. Their woes were heard in a Senate Permanent

Subcommittee on Investigations hearing which was chaired by Senator Levin, who said that he intends to keep the spotlight on credit card companies and that legislative action may be necessary to purge the industry. In 2009, the C.A.R.D. Act was signed into law, enacting protections for many of the issues Levin had raised.

In the United States, some have called for Congress to enact additional regulations on the industry; to expand the disclosure box clearly disclosing rate hikes, use plain language, incorporate balance payoff disclosures, and also to outlaw universal default. At a congress hearing around March 1, 2007, Citibank announced it would no longer practice this, effective immediately. Opponents of such regulation argue that customers must become more proactive and self-responsible in evaluating and negotiating terms with credit providers. Some of the nation's influential top credit card issuers, who are among the top fifty corporate contributors to political campaigns, successfully opposed it.

Hidden costs

In the United Kingdom, merchants won the right through The Credit Cards (Price Discrimination) Order 1990 to charge customers different prices according to the payment method. As of 2007, the United Kingdom was one of the world's most credit-card-intensive countries, with 2.4 credit cards per consumer, according to the UK Payments Administration Ltd.

In the United States, until 1984 federal law prohibited surcharges on card transactions. Although the federal Truth in Lending Act provisions that prohibited surcharges expired that year, a number of states have since enacted laws that continue to outlaw the practice; California, Colorado, Connecticut, Florida, Kansas, Massachusetts, Maine, New York, Oklahoma, and Texas have laws against surcharges. As of 2006, the United States probably had one of the world's if not the top ratio of credit cards per capita, with 984 million bank-issued Visa and MasterCard credit card and debit card accounts alone for an adult population of roughly 220 million people. The credit card per US capita ratio was nearly 4:1 as of 2003 and as high as 5:1 as of 2006.

Credit card numbering

The numbers found on credit cards have a certain amount of internal structure, and share a common numbering scheme.

The card number's *prefix*, called the Bank Identification Number, is the sequence of digits at the beginning of the number that determine the bank to which a credit card number belongs. This is the first six digits for MasterCard and Visa cards. The next nine digits are the individual account number, and the final digit is a validity check code.

In addition to the main credit card number, credit cards also carry issue and expiration dates (given to the nearest month), as well as extra codes such as issue numbers and security codes. Not all credit cards have the same sets of extra codes nor do they use the same number of digits.

Credit cards in ATMs

Many credit cards can also be used in an ATM to withdraw money against the credit limit extended to the card, but many card issuers charge interest on cash advances before they do so on purchases. The interest on cash advances is commonly charged from the date the withdrawal is made, rather than the monthly billing date. Many card issuers levy a commission for cash withdrawals, even if the ATM belongs to the same bank as the card issuer. Merchants do not offer cashback on credit card transactions because they would pay a percentage commission of the additional cash amount to their bank or merchant services provider, thereby making it uneconomical.

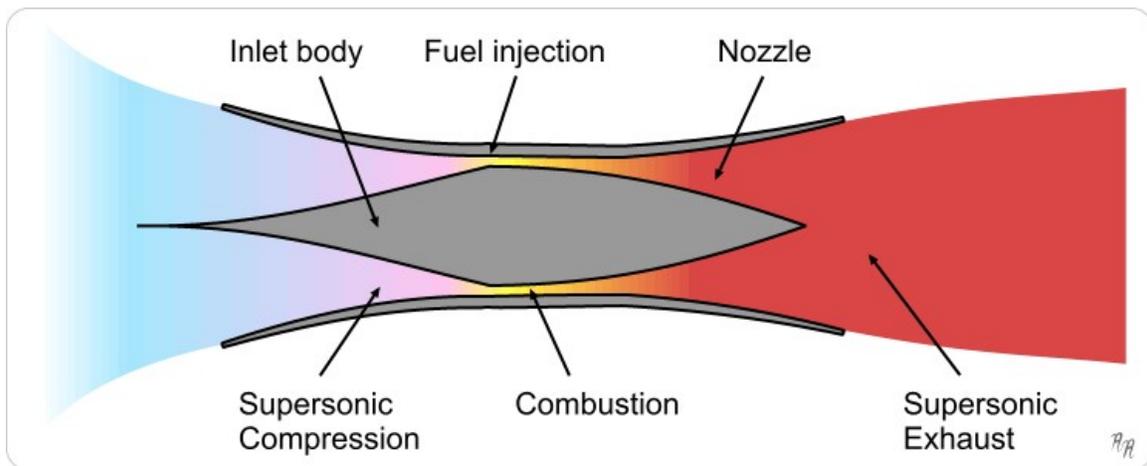
Many credit card companies will also, when applying payments to a card, do so at the end of a billing cycle, and apply those payments to everything before cash advances. For this reason, many consumers have large cash balances, which have no grace period and incur interest at a rate that is (usually) higher than the purchase rate, and will carry those balance for years, even if they pay off their statement balance each month.

Credit cards as funding for entrepreneurs

Credit cards are a risky way for entrepreneurs to acquire capital for their start ups when more conventional financing is unavailable. It's widely reported that Len Bosack and Sandy Lerner used personal credit cards to start Cisco Systems. It is rumoured that Larry Page and Sergey Brin's start up of Google was financed by credit cards to buy the necessary computers and office equipment, more specifically "a terabyte of hard disks". Similarly, filmmaker Robert Townsend financed part of *Hollywood Shuffle* using credit cards. Director Kevin Smith funded *Clerks* in part by maxing out several credit cards. Actor Richard Hatch also financed his production of *Battlestar Galactica: The Second Coming* partly through his credit cards. Famed hedge fund manager Bruce Kovner began his career (and, later on, his firm Caxton Associates) in financial markets by borrowing from his credit card. UK entrepreneur James Caan (as seen on *Dragon's Den*) financed his first business using several credit cards.

Chapter- 3

Scramjet



On 30 July 2002, the University of Queensland's HyShot team (and international partners) conducted the first ever successful test flight of a scramjet. This test was conducted at the rocket range in outback South Australia called Woomera.

A **scramjet** (*supersonic combustion ramjet*) is a variant of a ramjet airbreathing combustion jet engine in which the combustion process takes place in supersonic airflow. As in ramjets, a scramjet relies on high vehicle speed to forcefully compress and decelerate the incoming air before combustion (hence *ramjet*), but whereas a ramjet decelerates the air to subsonic velocities before combustion, airflow in a scramjet is supersonic throughout the entire engine. This allows the scramjet to efficiently operate at extremely high speeds: theoretical projections place the top speed of a scramjet between Mach 12 and Mach 24, which is near orbital velocity. The fastest air-breathing plane is a SCRAM jet design, the NASA X-43a which reached Mach 9.8. For comparison, the second fastest manned airbreathing aircraft, the SR-71 Blackbird, has a cruising speed of Mach 3.2.

The scramjet is composed of three basic components: a converging inlet, where incoming air is compressed and decelerated; a combustor, where gaseous fuel is burned with atmospheric oxygen to produce heat; and a diverging nozzle, where the heated air is accelerated to produce thrust. Unlike a typical jet engine, such as a turbojet or turbofan engine, a scramjet does not use rotating, fan-like components to compress the air; rather,

the achievable speed of the aircraft moving through the atmosphere causes the air to compress within the nozzle. As such, no moving parts are needed in a scramjet, which greatly simplifies both the design and operation of the engine. In comparison, typical turbojet engines require inlet fans, multiple stages of rotating compressor fans, and multiple rotating turbine stages, all of which add weight, complexity, and a greater number of failure points to the engine. It is this simplicity that allows scramjets to operate at such high velocities, as the conditions encountered in hypersonic flight severely hamper the operation of conventional turbomachinery.

Due to the nature of their design, scramjet operation is limited to near-hypersonic velocities. As they lack mechanical compressors, scramjets require the high kinetic energy of a hypersonic flow to compress the incoming air to operational conditions. Thus, a scramjet-powered vehicle must be accelerated to the required velocity by some other means of propulsion, such as turbojet, railgun, or rocket engines. In the flight of the experimental scramjet-powered Boeing X-51A, the test craft was lifted to flight altitude by a turbofan powered B-52 before being released and accelerated by a detachable rocket to near Mach 4.5.

While scramjets are conceptually simple, actual implementation is limited by extreme technical challenges. Hypersonic flight within the atmosphere generates immense drag, and temperatures found on the aircraft and within the engine can be nearly six-times greater than that of the surrounding air. Maintaining combustion in the supersonic flow presents additional challenges, as the fuel must be injected, mixed, ignited, and burned within milliseconds. While scramjet technology has been under development since the 1950s, only very recently have scramjets successfully achieved powered flight.

History

During and after World War II, tremendous amounts of time and effort were put into researching high-speed jet- and rocket-powered aircraft. The Bell X-1 attained supersonic flight in 1947 and, by the early 1960s, rapid progress towards faster aircraft suggested that operational aircraft would be flying at "hypersonic" speeds within a few years. Except for specialized rocket research vehicles like the North American X-15 and other rocket-powered spacecraft, aircraft top speeds have remained level, generally in the range of Mach 1 to Mach 3.

In the 1950s and 1960s a variety of experimental scramjets engines were built and ground tested in US and the UK. In 1964, Dr. Frederick S. Billig and Dr. Gordon L. Dugger submitted a patent application for a supersonic combustion ramjet based on Billig's Ph.D. thesis. This patent was issued in 1981 following the removal of an order of secrecy.

In 1981 tests were made in Australia under the guidance of Professor Ray Stalker in the T3 ground test facility at ANU.

The main goal of civilian air transport has been reducing operating cost, rather than increasing flight speeds. Because supersonic flight using conventional jet engines

requires significant amounts of fuel, airlines have favored subsonic jumbo jets rather than supersonic transports. The production supersonic airliners, Concorde and the Tupolev Tu-144, operated with little profit for the French and Russian airlines, but British Airways flew Concorde at a 60% profit margin over its commercial life (though this does not include government-subsidized initial costs). Military combat aircraft design has focused on maneuverability, more recently combined with stealth.

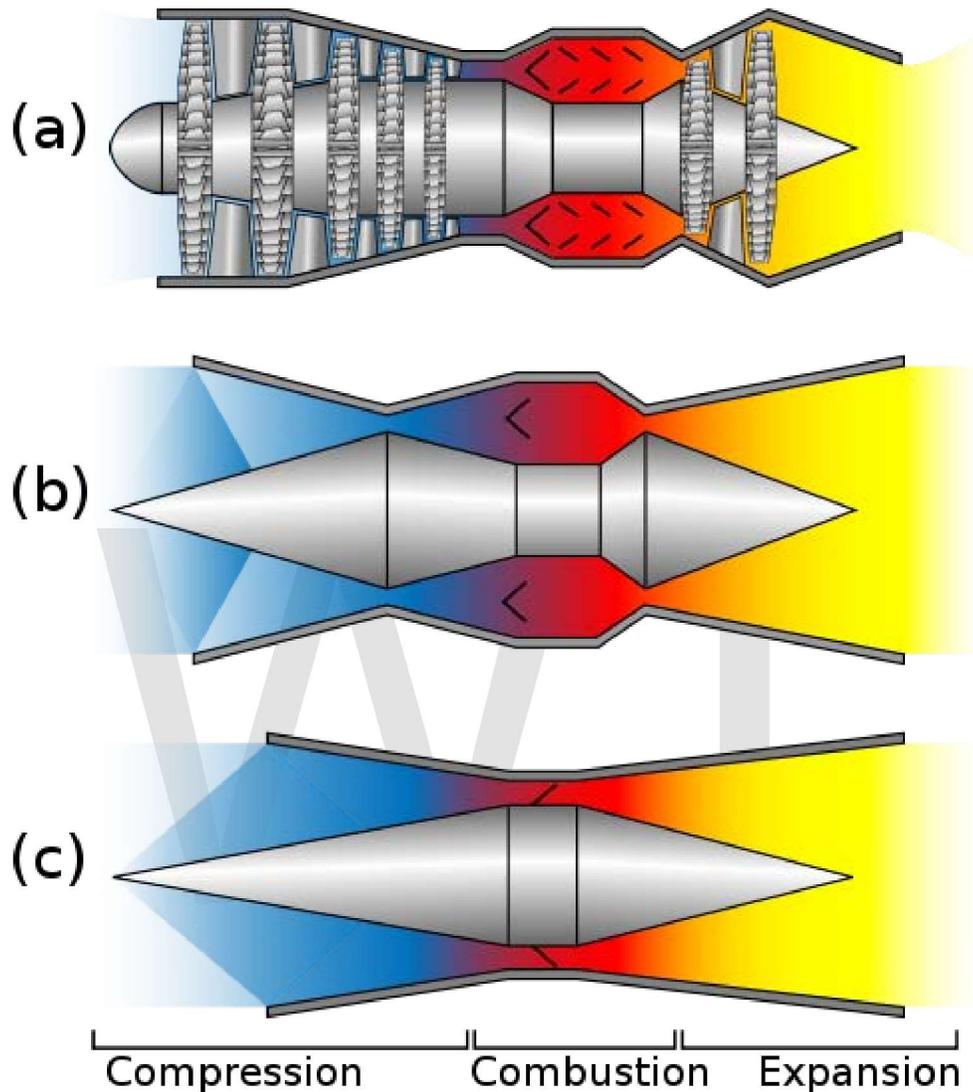
Hypersonic flight concepts haven't gone away, however, and low-level investigations have continued over the past few decades. Presently, the US military and NASA have formulated a "National Hypersonics Strategy" to investigate a range of options for hypersonic flight.

Different U.S. organizations have accepted hypersonic flight as a common goal. The U.S. Army desires hypersonic missiles that can attack mobile missile launchers quickly. NASA believes hypersonics could help develop economical, reusable launch vehicles. The Air Force is interested in a range of hypersonic systems, from air-launched cruise missiles to orbital spaceplanes, that the service believes could bring about a true "aerospace force."

The problem is complicated by the release of previously classified material and by partial publication, where claims are made, but specific parts of an experiment are kept secret. Additionally experimental difficulties in verifying that supersonic combustion actually occurred, or that actual net thrust was produced mean that at least four consortia have legitimate claims to "firsts", with several nations and institutions involved in each consortium. On June 15, 2007, the US Defense Advanced Research Project Agency (DARPA) and the Australian Defence Science and Technology Organization (DSTO), announced a successful scramjet flight at Mach 10 using rocket engines to boost the test vehicle to hypersonic speeds, at the Woomera Rocket Range in Central Australia.

No scramjet powered vehicle has yet been produced outside an experimental program.

Design principles



The compression, combustion, and expansion regions of: (a) turbojet, (b) ramjet, and (c) scramjet engines.

Scramjet engines are a type of jet engine, and rely on the combustion of fuel and an oxidizer to produce thrust. Similar to conventional jet engines, scramjet-powered aircraft carry the fuel on board, and obtain the oxidizer by the ingestion of atmospheric oxygen (as compared to rockets, which carry both fuel and an oxidizing agent). This requirement limits scramjets to suborbital atmospheric flight, where the oxygen content of the air is sufficient to maintain combustion.

Basic principles

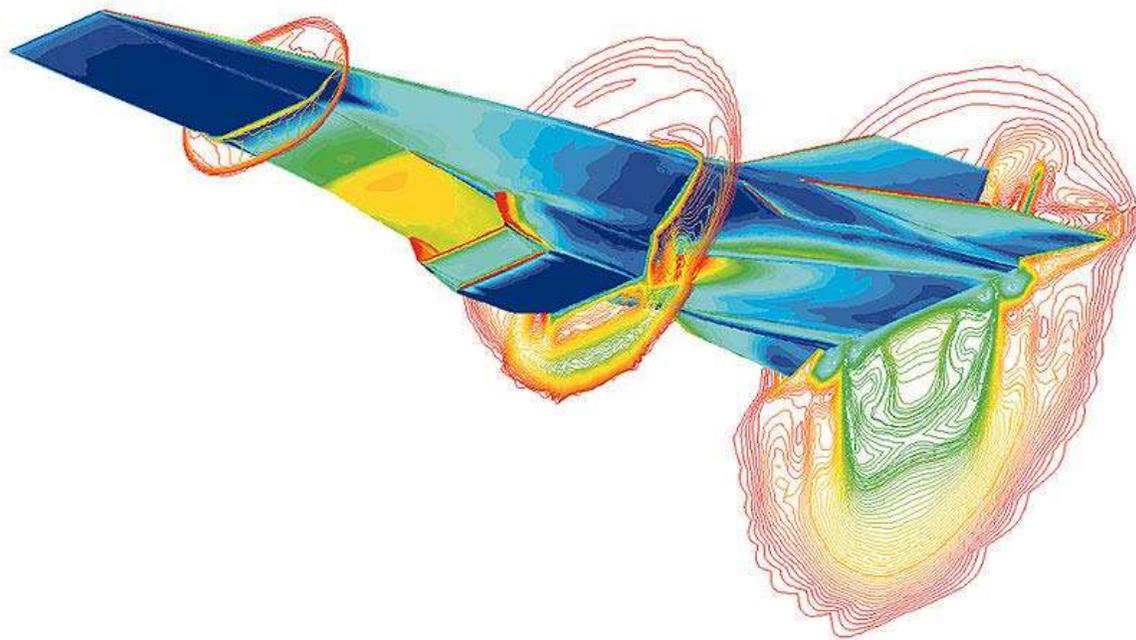
Scramjets are designed to operate in the hypersonic flight regime, beyond the reach of turbojet engines, and, along with ramjets, fill the gap between the high efficiency of turbojets and the high speed of rocket engines. Turbomachinery-based engines, while highly efficient at subsonic speeds, become increasingly inefficient at transonic speeds, as the compressor fans found in turbojet engines require subsonic speeds to operate. While the flow from transonic to low supersonic speeds can be decelerated to these conditions, doing so at supersonic speeds results in a tremendous increase in temperature and a loss in the total enthalpy of the flow. Around Mach 3–4, turbomachinery is no longer useful, and ram-style compression becomes the preferred method.

Ramjets utilize high-speed characteristics of air to literally 'ram' air through an inlet nozzle into the combustor. At transonic and supersonic flight speeds, the air upstream of the nozzle is not able to move out of the way quickly enough, and is compressed within the nozzle before being diffused into the combustor. Combustion in a ramjet takes place at subsonic velocities, similar to turbojets, but the combustion products are then accelerated through a convergent-divergent nozzle to supersonic speeds. As they have no mechanical means of compression, ramjets cannot start from a standstill, and generally do not achieve sufficient compression until supersonic flight. The lack of intricate turbomachinery allows ramjets to deal with the temperature rise associated with decelerating a supersonic flow to subsonic speeds, but this only goes so far: at near-hypersonic velocities, the temperature rise and inefficiencies discourage decelerating the flow to the magnitude found in ramjet engines.

Scramjet engines operate on the same principles as ramjets do, but do not decelerate the flow to subsonic velocities. Rather, a scramjet combustor is supersonic: the inlet decelerates the flow to a lower Mach number for combustion, after which it is accelerated to an even higher Mach number through the nozzle. By limiting the amount of deceleration, temperatures within the engine are kept at a tolerable level, from both a material and combustive standpoint. Even so, current scramjet technology requires the use of high-energy fuels and active cooling schemes to maintain sustained operation, often using hydrogen and regenerative cooling techniques.

Theory

All scramjet engines have fuel injectors, a combustion chamber, a thrust nozzle and an intake, which compresses the incoming air. Sometimes engines also include a region which acts as a flame holder, although the high stagnation temperatures mean that an area of focused waves may be used, rather than a discrete engine part as seen in turbine engines. Other engines use pyrophoric fuel additives, such as silane, to avoid such issues. An isolator between the inlet and combustion chamber is often included to improve the homogeneity of the flow in the combustor and to extend the operating range of the engine.



Computational fluid dynamics (CFD) image of the NASA X-43A with scramjet attached to the underside at Mach 7

A scramjet is reminiscent of a ramjet. In a typical ramjet, the supersonic inflow of the engine is decelerated at the inlet to subsonic speeds and then reaccelerated through a nozzle to supersonic speeds to produce thrust. This deceleration, which is produced by a normal shock, creates a total pressure loss which limits the upper operating point of a ramjet engine.

For a scramjet, the kinetic energy of the freestream air entering the scramjet engine is large comparable to the energy released by the reaction of the oxygen content of the air with a fuel (say hydrogen). Thus the heat released from combustion at Mach 25 is around 10% of the total enthalpy of the working fluid. Depending on the fuel, the kinetic energy of the air and the potential combustion heat release will be equal at around Mach 8. Thus the design of a scramjet engine is as much about minimizing drag as maximizing thrust.

This high speed makes the control of the flow within the combustion chamber more difficult. Since the flow is supersonic, no upstream influence propagates within the freestream of the combustion chamber. Thus throttling of the entrance to the thrust nozzle is not a usable control technique. In effect, a block of gas entering the combustion chamber must mix with fuel and have sufficient time for initiation and reaction, all the while traveling supersonically through the combustion chamber, before the burned gas is expanded through the thrust nozzle. This places stringent requirements on the pressure and temperature of the flow, and requires that the fuel injection and mixing be extremely efficient. Usable dynamic pressures lie in the range 20 to 200 kPa (0.2-2 bar), where

$$q = \frac{1}{2}\rho v^2$$

where

q is the dynamic pressure of the gas
 ρ (rho) is the density of the gas
 v is the velocity of the gas

To keep the combustion rate of the fuel constant, the pressure and temperature in the engine must also be constant. This is problematic because the airflow control systems that would facilitate this are not physically possible in a scramjet launch vehicle due to the large speed and altitude range involved, meaning that it must travel at an altitude specific to its speed. Because air density reduces at higher altitudes, a scramjet must climb at a specific rate as it accelerates to maintain a constant air pressure at the intake. This optimal climb/descent profile is called a "constant dynamic pressure path". It is thought that scramjets might be operable up to an altitude of 75 km.

Fuel injection and management is also potentially complex. One possibility would be that the fuel be pressurized to 100 bar by a turbo pump, heated by the fuselage, sent through the turbine and accelerated to higher speeds than the air by a nozzle. The air and fuel stream are crossed in a comb like structure, which generates a large interface. Turbulence due to the higher speed of the fuel leads to additional mixing. Complex fuels like kerosene need a long engine to complete combustion.

The minimum Mach number at which a scramjet can operate is limited by the fact that the compressed flow must be hot enough to burn the fuel, and have pressure high enough that the reaction be finished before the air moves out the back of the engine. Additionally, in order to be called a scramjet, the compressed flow must still be supersonic after combustion. Here two limits must be observed: Firstly, since when a supersonic flow is compressed it slows down, the level of compression must be low enough (or the initial speed high enough) not to slow the gas below Mach 1. If the gas within a scramjet goes below Mach 1 the engine will "choke", transitioning to subsonic flow in the combustion chamber. This effect is well known amongst experimenters on scramjets since the waves caused by choking are easily observable. Additionally, the sudden increase in pressure and temperature in the engine can lead to an acceleration of the combustion, leading to the combustion chamber exploding.

Secondly, the heating of the gas by combustion causes the speed of sound in the gas to increase (and the Mach number to decrease) even though the gas is still travelling at the same speed. Forcing the speed of air flow in the combustion chamber under Mach 1 in this way is called "thermal choking". It is clear that a pure scramjet can operate at Mach numbers of 6-8, but in the lower limit, it depends on the definition of a scramjet. Certainly there are designs where a ramjet transforms into a scramjet over the Mach 3-6 range (Dual-mode scramjets). In this range however, the engine is still receiving significant thrust from subsonic combustion of "ramjet" type.

The high cost of flight testing and the unavailability of ground facilities have hindered scramjet development. A large amount of the experimental work on scramjets has been undertaken in cryogenic facilities, direct-connect tests, or burners, each of which simulates one aspect of the engine operation. Further, vitiated facilities, storage heated facilities, arc facilities and the various types of shock tunnels each have limitations which have prevented perfect simulation of scramjet operation. The HyShot flight test showed the relevance of the 1:1 simulation of conditions in the T4 and HEG shock tunnels, despite having cold models and a short test time. The NASA-CIAM tests provided similar verification for CIAM's C-16 V/K facility and the Hyper-X project is expected to provide similar verification for the Langley AHSTF, CHSTF and 8 ft (2.4 m) HTT.

Computational fluid dynamics has only recently reached a position to make reasonable computations in solving scramjet operation problems. Boundary layer modeling, turbulent mixing, two-phase flow, flow separation, and real-gas aerothermodynamics continue to be problems on the cutting edge of CFD. Additionally, the modeling of kinetic-limited combustion with very fast-reacting species such as hydrogen makes severe demands on computing resources. Reaction schemes are numerically stiff requiring reduced reaction schemes.

Much of scramjet experimentation remains classified. Several groups including the US Navy with the SCRAM engine between 1968–1974, and the Hyper-X program with the X-43A have claimed successful demonstrations of scramjet technology. Since these results have not been published openly, they remain unverified and a final design method of scramjet engines still does not exist.

The final application of a scramjet engine is likely to be in conjunction with engines which can operate outside the scramjet's operating range. Dual-mode scramjets combine subsonic combustion with supersonic combustion for operation at lower speeds, and rocket-based combined cycle (RBCC) engines supplement a traditional rocket's propulsion with a scramjet, allowing for additional oxidizer to be added to the scramjet flow. RBCCs offer a possibility to extend a scramjet's operating range to higher speeds or lower intake dynamic pressures than would otherwise be possible.

Advantages and disadvantages of scramjets

Advantages

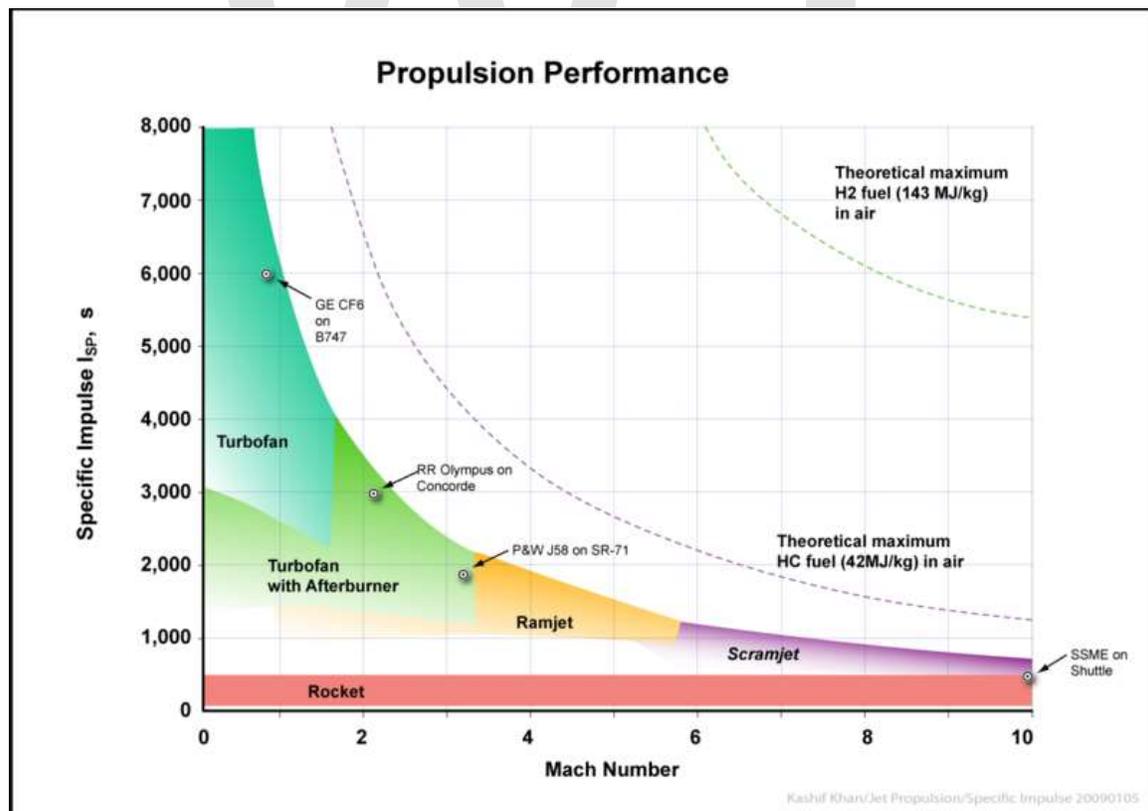
1. Does not have to carry oxygen
2. No rotating parts makes it easier to manufacture
3. Has a higher specific impulse (change in momentum per unit of propellant) than a conventional engine; could provide between 1000 and 4000 seconds, while a rocket only provides 600 seconds or less
4. Higher speed could mean cheaper access to outer space in the future

Special cooling and materials

Unlike a rocket that quickly passes mostly vertically through the atmosphere or a turbojet or ramjet that flies at much lower speeds, a hypersonic airbreathing vehicle optimally flies a "depressed trajectory", staying within the atmosphere at hypersonic speeds. Because scramjets have only mediocre thrust-to-weight ratios, acceleration would be limited. Therefore time in the atmosphere at hypersonic speed would be considerable, possibly 15–30 minutes. Similar to a reentering space vehicle, heat insulation would be a formidable task. The time in the atmosphere would be greater than that for a typical space capsule, but less than that of the space shuttle.

New materials offer good insulation at high temperature, but they often sacrifice themselves in the process. Therefore studies often plan on "active cooling", where coolant circulating throughout the vehicle skin prevents it from disintegrating. Often the coolant is the fuel itself, in much the same way that modern rockets use their own fuel and oxidizer as coolant for their engines. All cooling systems add weight and complexity to a launch system. The cooling of scramjets in this way may result in greater efficiency, as heat is added to the fuel prior to entry into the engine, but result in increased complexity and weight which ultimately could outweigh any performance gains.

Engine weight and efficiency



The specific impulse of various engines

The performance of a launch system is complex and depends greatly on its weight. Normally craft are designed to maximise range (R), orbital radius (R) or payload mass fraction (Γ) for a given engine and fuel. This results in tradeoffs between the efficiency of the engine (takeoff fuel weight) and the complexity of the engine (takeoff dry weight), which can be expressed by the following:

$$\Pi_e + \Pi_f + \frac{1}{\Gamma} = 1$$

Where :

- $\Pi_e = \frac{m_{\text{empty}}}{m_{\text{initial}}}$ is the empty mass fraction, and represents the weight of the superstructure, tankage and engine.
- $\Pi_f = \frac{m_{\text{fuel}}}{m_{\text{initial}}}$ is the fuel mass fraction, and represents the weight of fuel, oxidiser and any other materials which are consumed during the launch.
- $\Gamma = \frac{m_{\text{initial}}}{m_{\text{payload}}}$ is initial mass ratio, and is the inverse of the payload mass fraction. This represents how much payload the vehicle can deliver to a destination.

A scramjet increases the mass of the engine Π_e over a rocket, and decreases the mass of the fuel Π_f . It can be difficult to decide whether this will result in an increased Γ (which would be an increased payload delivered to a destination for a constant vehicle takeoff weight). The logic behind efforts driving a scramjet is (for example) that the reduction in fuel decreases the total mass by 30%, while the increased engine weight adds 10% to the vehicle total mass. Unfortunately the uncertainty in the calculation of any mass or efficiency changes in a vehicle is so great that slightly different assumptions for engine efficiency or mass can provide equally good arguments for or against scramjet powered vehicles.

Additionally, the drag of the new configuration must be considered. The drag of the total configuration can be considered as the sum of the vehicle drag (D) and the engine installation drag (D_e). The installation drag traditionally results from the pylons and the coupled flow due to the engine jet, and is a function of the throttle setting. Thus it is often written as:

$D_e = \varphi_e F$ Where:

- φ_e is the loss coefficient
- F is the thrust of the engine

For an engine strongly integrated into the aerodynamic body, it may be more convenient to think of (D_e) as the difference in drag from a known base configuration.

The overall engine efficiency can be represented as a value between 0 and 1 (η_0), in terms of the specific impulse of the engine:

$$\eta_0 = \frac{g_0 V_0}{h_{PR}} \cdot I_{sp} = \frac{\text{Thrust Power}}{\text{Chemical energy rate}}$$

Where:

- g_0 is the acceleration due to gravity at ground level
- V_0 is the vehicle speed
- I_{sp} is the specific impulse
- h_{PR} is fuel heat of reaction

Specific impulse is often used as the unit of efficiency for rockets, since in the case of the rocket, there is a direct relation between specific impulse, specific fuel consumption and exhaust velocity. This direct relation is not generally present for airbreathing engines, and so specific impulse is less used in the literature. Note that for an airbreathing engine, both η_0 and I_{sp} are a function of velocity.

The specific impulse of a rocket engine is independent of velocity, and common values are between 200 and 600 seconds (450s for the space shuttle main engines). The specific impulse of a scramjet varies with velocity, reducing at higher speeds, starting at about 1200s, although values in the literature vary.

For the simple case of a single stage vehicle, the fuel mass fraction can be expressed as:

$$\Pi_f = 1 - \exp \left[- \frac{\left(\frac{V_{initial}^2}{2} - \frac{V_i^2}{2} \right) + \int g dr}{\eta_0 h_{PR} \left(1 - \frac{D+D_e}{F} \right)} \right]$$

Where this can be expressed for single stage transfer to orbit as:

$$\Pi_f = 1 - \exp \left[- \frac{g_0 r_0 \left(1 - \frac{1}{2} \frac{r_0}{r} \right)}{\eta_0 h_{PR} \left(1 - \frac{D+D_e}{F} \right)} \right]$$

or for level atmospheric flight from air launch (missile flight):

$$\Pi_f = 1 - \exp \left[- \frac{g_0 R}{\eta_0 h_{PR} \left(1 - \phi_e \right) \frac{C_L}{C_D}} \right]$$

Where R is the range, and the calculation can be expressed in the form of the Breguet range formula:

$$\Pi_f = 1 - e^{-BR}$$
$$B = \frac{g_0}{\eta_0 h_{PR} (1 - \phi_e) \frac{C_L}{C_D}}$$

Where:

- C_L is the lift coefficient
- C_D is the drag coefficient

This extremely simple formulation, used for the purposes of discussion assumes:

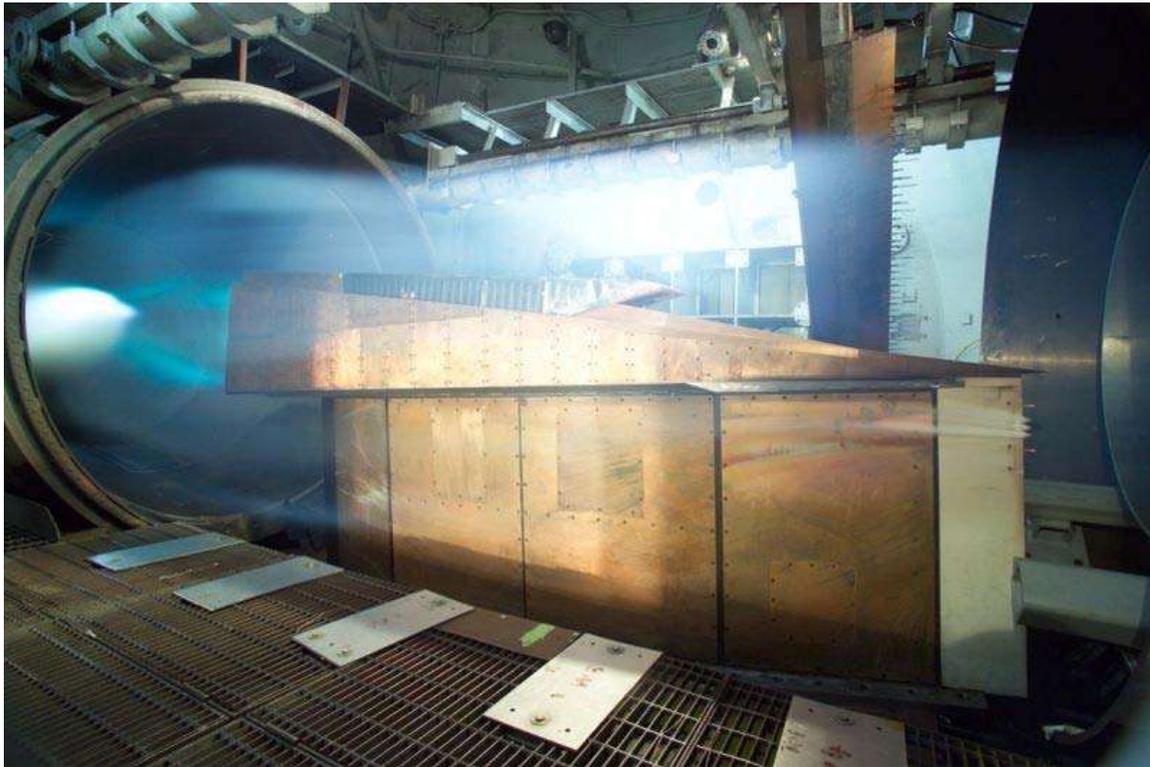
- Single stage vehicle
- No aerodynamic lift for the transatmospheric lifter

However they are true generally for all engines.

Additional propulsion requirements

A scramjet cannot produce efficient thrust unless boosted to high speed, around Mach 5, although depending on the design it could act as a ramjet at low speeds. A horizontal take-off aircraft would need conventional turbofan or rocket engines to take off, sufficiently large to move a heavy craft. Also needed would be fuel for those engines, plus all engine-associated mounting structure and control systems. Turbofan engines are heavy and cannot easily exceed about Mach 2-3, so another propulsion method would be needed to reach scramjet operating speed. That could be ramjets or rockets. Those would also need their own separate fuel supply, structure, and systems. Many proposals instead call for a first stage of droppable solid rocket boosters, which greatly simplifies the design.

Testing difficulties



Test of Pratt & Whitney Rocketdyne SJY61 scramjet engine for the Boeing X-51

Unlike jet or rocket propulsion systems facilities which can be tested on the ground, testing scramjet designs use extremely expensive hypersonic test chambers or expensive launch vehicles, both of which lead to high instrumentation costs. Tests using launched test vehicles very typically end with destruction of the test item and instrumentation.

Advantages and disadvantages for orbital vehicles

Propellant

An advantage of a hypersonic airbreathing (typically scramjet) vehicle like the X-30 is avoiding or at least reducing the need for carrying oxidizer. For example the space shuttle external tank holds 616,432 kg of liquid oxygen (LOX) and 103,000 kg of liquid hydrogen (LH₂) while having an empty weight of 30,000 kg. The orbiter gross weight is 109,000 kg with a maximum payload of about 25,000 kg and to get the assembly off the launch pad the shuttle uses two very powerful solid rocket boosters with a weight of 590,000 kg each. If the oxygen could be eliminated, the vehicle could be lighter at liftoff and maybe carry more payload. That would be an advantage, but the central motivation in pursuing hypersonic airbreathing vehicles would be to reduce cost.

On the other hand, scramjets spend more time in the atmosphere and require more hydrogen fuel to deal with aerodynamic drag. Whereas liquid oxygen is quite a dense fluid, liquid hydrogen has much lower density and takes up much more volume. This means that the vehicle using this fuel becomes much bigger and gives even more drag.

Thrust-to-weight ratio

A rocket has the advantage that its engines have *very* high thrust-weight ratios (~100:1), while the tank to hold the liquid oxygen approaches a tankage ratio of ~100:1 also. Thus a rocket can achieve a very high mass fraction (Takeoff rocket mass:unfuelled rocket mass+fuel+oxidiser+structure+engines+payload), which improves performance. By way of contrast the projected thrust/weight ratio of scramjet engines of about 2 mean a very much larger percentage of the takeoff mass is engine (ignoring that this fraction increases anyway by a factor of about four due to the lack of onboard oxidiser). In addition the vehicle's lower thrust does not necessarily avoid the need for the expensive, bulky, and failure prone high performance turbopumps found in conventional liquid-fuelled rocket engines, since most scramjet designs seem to be incapable of orbital speeds in airbreathing mode, and hence extra rocket engines are needed.

The Need for Additional Engine(s) to Reach Orbit

Scramjets might be able to accelerate from approximately Mach 5-7 to around somewhere between half of orbital velocity and orbital velocity (X-30 research suggested that Mach 17 might be the limit compared to an orbital speed of Mach 25, and other studies put the upper speed limit for a pure scramjet engine between Mach 10 and 25, depending on the assumptions made). Generally, another propulsion system (very typically rocket is proposed) is expected to be needed for the final acceleration into orbit. Since the delta-V is moderate and the payload fraction of scramjets high, lower performance rockets such as solids, hypergolics, or simple liquid fueled boosters might be acceptable. Opponents of scramjet research claim that most of the theoretical advantages for scramjets only accrue if a single stage to orbit (SSTO) vehicle can be successfully produced. Proponents of scramjet research claim that this is a straw man argument, and that SSTO vehicles are exactly as difficult to produce and bring the same benefits to rocket-powered and scramjet-powered launch vehicles.

Reentry

The scramjet's heat-resistant underside potentially doubles as its reentry system if a single-stage-to-orbit vehicle using non-ablative, non-active cooling is visualised. If an ablative shielding is used on the engine it will probably not be usable after ascent to orbit. If active cooling is used the loss of all fuel during the burn to orbit will also mean the loss of all cooling for the thermal protection system.

Costs

Reducing the amount of fuel and oxidizer does not necessarily improve costs as rocket propellants are comparatively very cheap. Indeed, the unit cost of the vehicle can be expected to end up far higher, since aerospace hardware cost is about two orders of magnitude higher than liquid oxygen, fuel and tankage, and scramjet hardware seems to be much heavier than rockets for any given payload. Still, if scramjets enable reusable vehicles, this could theoretically be a cost benefit. Whether equipment subject to the extreme conditions of a scramjet can be reused sufficiently many times is unclear; all flown scramjet tests only survive for short periods and have never been designed to survive a flight to date.

The eventual cost of such a vehicle is the subject of intense debate since even the best estimates disagree whether a scramjet vehicle would be advantageous. It is likely that a scramjet vehicle would need to lift more load than a rocket of equal takeoff weight in order to be equally as cost efficient (if the scramjet is a non-reusable vehicle).

Applications

Seeing its potential, organizations around the world are researching scramjet technology. Scramjets will likely propel missiles first, since that application requires only cruise operation instead of net thrust production. Much of the money for the current research comes from governmental defense research contracts.

Space launch vehicles may or may not benefit from having a scramjet stage. A scramjet stage of a launch vehicle theoretically provides a specific impulse of 1000 to 4000 s whereas a rocket provides less than 450 s while in the atmosphere, potentially permitting much cheaper access to space. A scramjet's specific impulse decreases rapidly with speed, however, and the vehicle would suffer from a relatively low lift to drag ratio.

One issue is that scramjet engines are predicted to have exceptionally poor thrust to weight ratio- around 2. This compares very unfavorably with the 50-100 of a typical rocket engine. This is compensated for in scramjets partly because the weight of the vehicle would be carried by aerodynamic lift rather than pure rocket power (giving reduced 'gravity losses'), but scramjets would take much longer to get to orbit due to lower thrust which greatly offsets the advantage. The takeoff weight of a scramjet vehicle is significantly reduced over that of a rocket, due to the lack of onboard oxidiser, but increased by the structural requirements of the larger and heavier engines.

Whether this vehicle would be reusable or not is still a subject of debate and research.

An aircraft using this type of jet engine could dramatically reduce the time it takes to travel from one place to another, potentially putting any place on Earth within a 90 minute flight. However, there are questions about whether such a vehicle could carry enough fuel to make useful length trips, and there are issues with sonic booms.

There are also questions as to how realistic such a proposal is that revolve around costs (capital and maintenance) of technology that is yet to be developed.

Recent progress



Artist's conception of the NASA X-43 with scramjet attached to the underside

In recent years, significant progress has been made in the development of hypersonic technology, particularly in the field of scramjet engines.

US efforts are probably the best funded, and the Hyper-X group has claimed the first flight of a thrust-producing scramjet with full aerodynamic maneuvering surfaces. However, the first group to demonstrate a scramjet working in an atmospheric test was a project by a joint British and Australian team from UK defense company QinetiQ and the University of Queensland. The HyShot project demonstrated scramjet combustion on July 30, 2002. The scramjet engine worked effectively and demonstrated supersonic combustion in action. However, the engine was not designed to provide thrust to propel a craft. It was designed more or less as a technology demonstrator.

On Friday, June 15, 2007, the US Defense Advanced Research Project Agency (DARPA), in cooperation with the Australian Defence Science and Technology Organization (DSTO), announced a successful scramjet flight at Mach 10 using rocket engines to boost the test vehicle to hypersonic speeds.

On May 22, 2009, Woomera hosted the first successful test flight of a hypersonic aircraft in HIFire. The launch was one of 10 planned test flights. The series of up to 10 planned hypersonic flight experiments are part of a joint research program between the Defence Science and Technology Organisation and the US Air Force, designated as the Hypersonic International Flight Research Experimentation (HIFiRE). HIFiRE is investigating hypersonics technology (the study of flight exceeding five times the speed of sound) and its application to advanced scramjet-powered space launch vehicles — the objective is to support the new Boeing X-51 scramjet demonstrator while also building a strong base of flight test data for quick-reaction space launch development and hypersonic "quick-strike" weapons.

On 22 and 23 March 2010, Australian and American defence scientists successfully tested a (HIFiRE) hypersonic rocket. It reached an atmospheric velocity of "more than 5,000 kilometres per hour" after taking off from the Woomera Test Range in outback South Australia.

On May 27, 2010, NASA and the United States Air Force successfully flew the X-51A Waverider for approximately 200 seconds at Mach 5, setting a new world record hypersonic airspeed. The Waverider flew autonomously before losing acceleration for an unknown reason and destroying itself as planned. The test was declared a success. The X-51A was carried aboard a B-52, accelerated to Mach 4.5 via a solid rocket booster, and then ignited the Pratt & Whitney Rocketdyne scramjet engine to reach Mach 5 at 70,000 feet.

On 16 November 2010, Australian scientists have successfully demonstrated that the high-speed flow in a naturally non-burning scramjet engine can be ignited using a pulsed laser source.

Chapter- 4

Refrigerator



A typical refrigerator with its door open

A **refrigerator** (commonly called a "fridge") is a cooling apparatus. The common household appliance comprises a thermally insulated compartment and a heat pump—chemical or mechanical means—to transfer heat from it to the external environment (i.e., the room in which it is located), cooling the contents to a temperature below ambient. Cooling is a popular food storage technique in developed countries and works by decreasing the reproduction rate of bacteria. The device is thus used to reduce the rate of spoilage of foodstuffs.

A refrigerator maintains a temperature a few degrees above the freezing point of water. Optimum temperature range for perishable food storage is 3 to 5 °C (37 to 41 °F). A similar device which maintains a temperature below the freezing point of water is called a "**freezer**".

The refrigerator is a relatively modern invention among kitchen appliances. It replaced the icebox, which had been a common household appliance for almost a century and a half prior. For this reason, a refrigerator is sometimes referred to as an "**icebox**".

Freezer

Freezer units are used in households and in industry and commerce. Most freezers operate around 0 °F (−18 °C). Domestic freezers can be included as a separate compartment in a refrigerator, or can be a separate appliance. Domestic freezers are generally upright units resembling refrigerators, or chests resembling upright units laid on their side. Many upright modern freezers come with an ice dispenser built into their door.

Commercial and domestic refrigerators

Commercial fridge and freezer units, which go by many other names, were in use for almost 40 years prior to the common home models. They used toxic gas systems, which occasionally leaked, making them unsafe for home use. Practical household refrigerators were introduced in 1915 and gained wider acceptance in the United States in the 1930s as prices fell and non-toxic, non-flammable synthetic refrigerants such as Freon or R-12 were introduced. It is notable that while 60% of households in the US owned a refrigerator by the 1930s, it was not until 40 years later, in the 1970s, that the refrigerator achieved a similar level of penetration in the United Kingdom.

Styles of refrigerators

Most households use the freezer on top and refrigerator on bottom style, which has been the basic style since the 1940s.

- Traditional style 1940s-present freezer top/refrigerator bottom (although most of the earlier models, some of the cheaper later models and still some mini-fridges use the 'freezer chest,' or what is known as the 'freezer in the fridge').
- Side by side style – introduced by Amana in 1949 but not popular until 1965–present; left side is freezer and the right is refrigerator.
- Top refrigerator/bottom freezer style – mid-1950s – present.



Frigidaire Imperial "Frost Proof", top refrigerator/bottom freezer with brushed chrome door finish made by General Electric Canada in 1963

- French door style – late 1990s-present. Two French doors for refrigerator and bottom freezer.

In the early-1950s, most refrigerators were white, but from the mid-1950s through present day, designers and manufacturers put color into refrigerators. In the late-1950s/early-1960s, colors like turquoise and pink were popular, brushed chrome plating (similar to stainless finish) was available on some models from different brands. In the 1970s, common colors were Harvest Gold, Avocado Green and almond. In the 1980s, black colors were viewed as luxurious. In the late 1990s, stainless steel became stylish, and in 2009, one manufacturer introduced multi-color designs.

Many refrigerators can be blended into the cabinetry of the kitchen with panels that can slide over the doors for a built-in look.

Most home refrigerators weigh between 200 pounds (91 kg) and 450 pounds (200 kg), with some models weighing up to 875 pounds (397 kg).

History



An Oldman's refrigerator, more like an icebox with its refrigerating mechanisms on top



An older style refrigerator, running empty with its door open. Note the freezer compartment at the top inside the cabinet

Before the invention of the refrigerator, icehouses were used to provide cool storage for most of the year. Placed near freshwater lakes or packed with snow and ice during the winter, they were once very common. Natural means are still used to cool foods today. On mountainsides, runoff from melting snow is a convenient way to cool drinks, and during the winter one can keep milk fresh much longer just by keeping it outdoors.

In the 11th century, the Persian physicist and chemist Ibn Sina (Avicenna) invented the refrigerated coil, which condenses aromatic vapours. This was a breakthrough in distillation technology and he made use of it in his steam distillation process, which requires refrigerated tubing, to produce essential oils.

The first known artificial refrigeration was demonstrated by William Cullen at the University of Glasgow in 1748. Between 1805, when Oliver Evans designed the first refrigeration machine that used vapour instead of liquid, and 1902 when Willis Haviland Carrier demonstrated the first air conditioner, scores of inventors contributed many small advances in cooling machinery. In-home refrigeration became a reality in 1834 with the invention of the cooling compression system by the American inventor Jacob Perkins. In 1850 or 1851, Dr. John Gorrie demonstrated an ice maker.

In 1857, Australian James Harrison developed the world first practical ice making machine and refrigeration system, and it was used in the brewing and meat packing industries of Geelong, Victoria. Ferdinand Carré of France developed a somewhat more complex system in 1859. Unlike earlier compression-compression machines, which used air as a coolant, Carré's equipment contained rapidly expanding ammonia. The absorption refrigerator was invented by Baltzar von Platen and Carl Munters from Sweden in 1922, while they were still students at the Royal Institute of Technology in Stockholm. It became a worldwide success and was commercialized by Electrolux. Other pioneers included Charles Tellier, David Boyle, and Raoul Pictet. Carl von Linde was the first to patent and make a practical and compact refrigerator.

These home units usually required the installation of the mechanical parts, motor and compressor, in the basement or an adjacent room while the cold box was located in the kitchen. There was a 1922 model that consisted of a **wooden cold** box, water-cooled compressor, an ice cube tray and a 9-cubic-foot (0.25 m³) compartment, and cost \$714. (A 1922 Model-T Ford cost about \$450.) In 1923 Frigidaire introduced the first self-contained unit. About this same time porcelain-covered metal cabinets began to appear. Ice cube trays were introduced more and more during the 1920s; up to this time freezing was not an auxiliary function of the modern refrigerator.

The first refrigerator to see widespread use was the General Electric "Monitor-Top" refrigerator introduced in 1927, so-called because of its resemblance to the gun turret on the ironclad warship USS *Monitor* of the 1860s. The compressor assembly, which emitted a great deal of heat, was placed above the cabinet, and surrounded with a decorative ring. Over a million units were produced. As the refrigerating medium, these refrigerators used either sulfur dioxide, which is corrosive to the eyes and may cause loss of vision, painful skin burns and lesions, or methyl formate, which is highly flammable, harmful to the eyes, and toxic if inhaled or ingested. Many of these units are still functional today. These cooling systems cannot legally be recharged with the hazardous original refrigerants if they leak or break down.

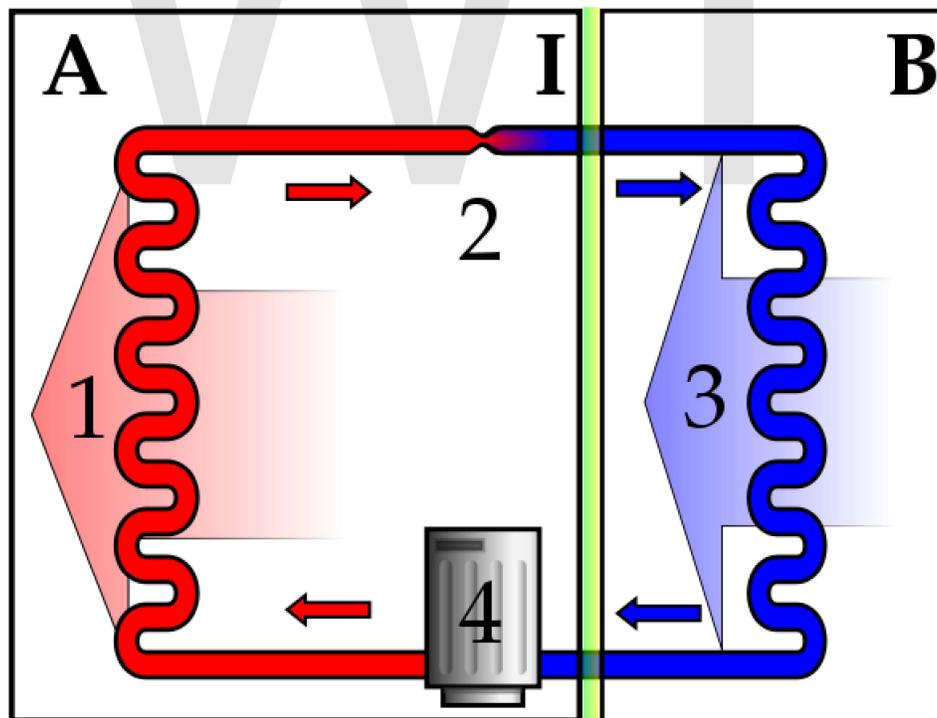
The introduction of Freon in the 1920s expanded the refrigerator market during the 1930s and provided a safer, low-toxicity alternative to previously used refrigerants. Separate freezers became common during the 1940s, the popular term at the time for the unit was a "deep freeze". These devices, or "appliances", did not go into mass production for use in the home until after World War II. The 1950s and 1960s saw technical advances like automatic defrosting and automatic ice making. More efficient refrigerators were developed in the 1970s and 1980s, even though environmental issues led to the banning

of very effective (Freon) refrigerants. Early refrigerator models (from 1916) had a cold compartment for ice cube trays. From the late 1920s fresh vegetables were successfully processed through freezing by the Postum Company (the forerunner of General Foods), which had acquired the technology when it bought the rights to Clarence Birdseye's successful fresh freezing methods.

The first successful application of frozen foods occurred when General Foods heiress Marjorie Merriweather Post (then wife of Joseph E. Davies, United States Ambassador to the Soviet Union) deployed commercial-grade freezers in Spaso House, the US Embassy in Moscow, in advance of the Davies' arrival. Post, fearful of the USSR's food processing safety standards, fully stocked the freezers with products from General Foods' Birdseye unit. The frozen food stores allowed the Davies to entertain lavishly and serve fresh frozen foods that would otherwise be out of season. Upon returning from Moscow, Post (who resumed her maiden name after divorcing Davies) directed General Foods to market frozen product to upscale restaurants.

Home freezers as separate compartments (larger than necessary just for ice cubes), or as separate units, were introduced in the United States in 1940. Frozen foods, previously a luxury item, began to be commonplace.

General technical explanation



Vapor Compression Cycle – A: hot compartment (kitchen), B: cold compartment (refrigerator box), I: insulation, 1: Condenser, 2: Expansion valve, 3: Evaporator unit, 4: Compressor



An Embraco compressor and fan-assisted condenser coil

A vapor compression cycle is used in most household refrigerators, refrigerator-freezers and freezers. In this cycle, a circulating refrigerant such as R134a enters a compressor as low-pressure vapor at or slightly above the temperature of the refrigerator interior. The vapor is compressed and exits the compressor as high-pressure superheated vapor. The superheated vapor travels under pressure through coils or tubes comprising "the condenser", which are passively cooled by exposure to air in the room. The condenser cools the vapor, which liquefies. As the refrigerant leaves the condenser, it is still under pressure but is now only slightly above room temperature. This liquid refrigerant is forced through a metering or throttling device, also known as an expansion valve (essentially a constriction) to an area of much lower pressure. The sudden decrease in pressure results in explosive-like flash evaporation of a portion (typically about half) of the liquid. The latent heat absorbed by this flash evaporation is drawn mostly from adjacent still-liquid refrigerant, a phenomenon known as "auto-refrigeration". This cold and partially vaporized refrigerant continues through the coils or tubes of the evaporator unit. A fan blows air from the refrigerator or freezer compartment ("box air") across these coils or tubes and the refrigerant completely vaporizes, drawing further latent heat from the box air. This cooled air is returned to the refrigerator or freezer compartment, and so keeps the box air cold. Note that the cool air in the refrigerator or freezer is still warmer than the refrigerant in the evaporator. Refrigerant leaves the evaporator, now fully vaporized and slightly heated, and returns to the compressor inlet to continue the cycle.

An absorption refrigerator works differently from a compressor refrigerator, using a source of heat, such as combustion of liquefied petroleum gas, solar thermal energy or an electric heating element. These heat sources are much quieter than the compressor motor in a typical refrigerator. A fan or pump might be the only mechanical moving parts; reliance on convection is considered impractical.

The Peltier effect uses electricity to pump heat directly; this type of refrigerator is sometimes used for camping, or where noise is not acceptable. They can be totally silent (if they don't include a fan for air circulation) but are less energy-efficient than other methods.

Other uses of an absorption refrigerator (or "chiller") include large systems used in office buildings or complexes such as hospitals and universities. These large systems are used to chill a brine solution that is circulated through the building.

Many modern refrigerator/freezers have the freezer on top and the fridge on the bottom. Many ask the question "How does the fridge stay cold if the motor doesn't start when I turn the fridge knob?" This question is answered easily. Most fridge/freezers, with the exception of manual defrost models and/or cheaper models utilize what appears to be two thermostats. Only the freezer compartment is properly temperature controlled. When the freezer gets too warm, the thermostat starts the refrigeration process and a fan also starts. The air is circulated around the freezer. During this time, the fridge is also getting colder. The fridge temperature control knob is doing nothing to 'control' the temperature. This knob is only controlling the amount of air that actually flows into the fridge via a damper system. This means that the fridge may become too warm. However, because only enough air is partitioned off to the fridge compartment, the freezer usually re-acquires the set temperature quickly, unless the door is opened. When a door is opened, either in the fridge or the freezer, the fan stops straight away to prevent excessive frost build up on the freezer's evaporator coil (because this coil is technically cooling two areas). When the freezer reaches temperature, the unit cycles off, no matter what temperature the fridge is at. Some people recommend setting the fridge to max and the freezer to a point where your fridge food won't freeze.

There are also many complaints about fridge/freezers being kept in garages. One very common complaint is that the freezer is defrosted, but the fridge is not. This occurs when the temperature becomes cool enough to cool the inside of the fridge. Because the fridge thinks the temperature is ok, it won't start unless warm beverages etc. are added. When this happens, the freezer thaws. It is therefore recommended to keep this type of fridge/freezer in a place where it won't get this cold. If the fridge compartment is the sole temperature controller, then, due to the design, the unit is likely to run for a longer amount of time, which will in turn keep the freezer very cold.

Modern, computerized refrigerators do not use the damper system. The computers manage fan speed for both compartments (although air is still pumped from the freezer).

Other alternatives to the vapor-compression cycle but not in current use include thermionic, vortex tube, air cycle, magnetic cooling, Stirling cycle, Malone refrigeration, acoustic cooling, pulse tube and water cycle systems.

Features



The inside of a home refrigerator containing a large variety of everyday food items.

Newer refrigerators may include:

- Automatic defrosting;
- A power failure warning, alerting the user by flashing a temperature display. The maximum temperature reached during the power failure may be displayed, along with information on whether the frozen food has defrosted or may contain harmful bacteria;

- Chilled water and ice available from an in-door station, so that the door need not be opened;

Water and Ice Dispensing became available in the 1970s. Also some refrigerators have icemakers built-in so the user doesn't have to use ice trays. Some refrigerators have water chillers and water filtration systems.

- Cabinet rollers that allow the refrigerator to be easily rolled around for easier cleaning;
- Adjustable shelves and trays which can be repositioned to suit the user;
- A Status Indicator to notify the user when it is time to change the water filter;
- An in-door ice caddy, which relocates the ice-maker storage to the freezer door and saves approximately 60 litres (2 cu ft) of usable freezer space. It is also removable, and helps to prevent ice-maker clogging;
- A cooling zone in the refrigerator door shelves. Air from the freezer section is diverted to the refrigerator door, to cool milk or juice stored in the door shelf.

Early freezer units accumulated ice crystals around the freezing units. This was a result of humidity introduced into the units when the doors to the freezer were opened condensing on the cold parts, then freezing. This frost buildup required periodic thawing ("defrosting") of the units to maintain their efficiency. Manual Defrost (referred to as Cyclic) units are still available. Advances in automatic defrosting eliminating the thawing task were introduced in the 1950s, but are not universal, due to energy performance and cost. These units utilized a counter, that only defrosted the freezer compartment (Freezer Chest) when a specific number of door openings had been made. The units were just a small timer combined with an electrical heater wire which heated the freezer's walls for a short amount of time to remove all traces of frost/frosting. Also, early units featured freezer compartments located within the larger refrigerator, and accessed by opening the refrigerator door, and then the smaller internal freezer door; units featuring an entirely separate freezer compartment were introduced in the early 1960s, becoming the industry standard by the middle of that decade. These older freezer compartments were the main cooling body of the refrigerator, and only maintained a temperature of around -6°C , which is suitable for keeping food for a week.

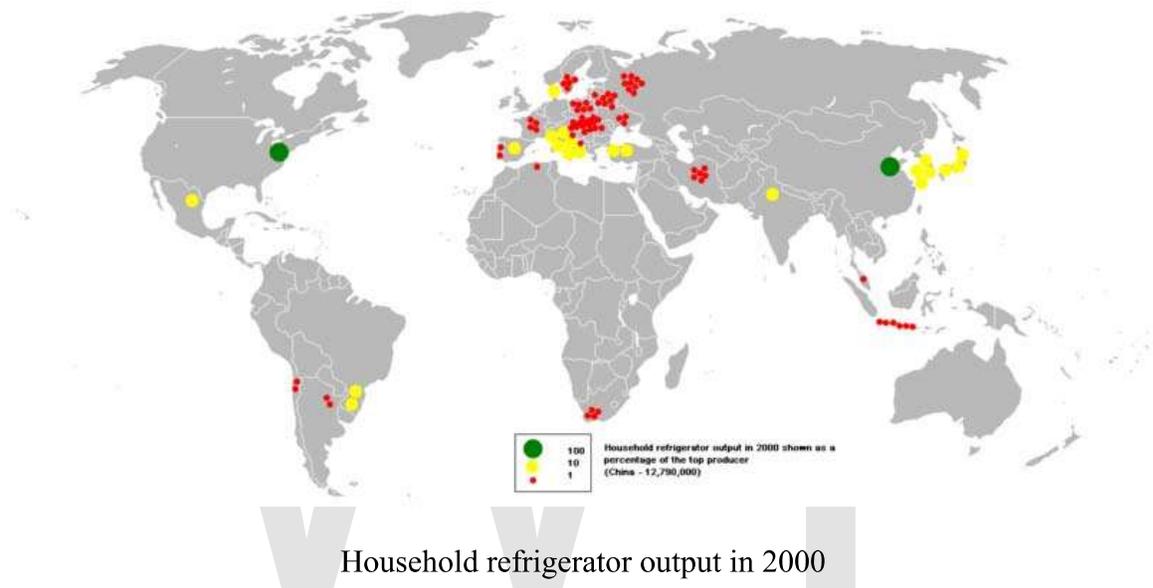
Later advances included automatic ice units and self compartmentalized freezing units.

An increasingly important environmental concern is the disposal of old refrigerators – initially because of the freon coolant damaging the ozone layer, but as the older generation of refrigerators disappears it is the destruction of CFC-bearing insulation which causes concern. Modern refrigerators usually use a refrigerant called HFC-134a (1,1,1,2-Tetrafluoroethane), which does not deplete the ozone layer, instead of freon. A R-134a is now becoming very uncommon in Europe. Instead, newer refrigerants are being used instead. The main refrigerant now used is R-600a, or Isobutane. This refrigerant is naturally occurring and therefore has a smaller effect on the atmosphere, if released. There have been some reports of refrigerators exploding, if the refrigerant leaks

and comes into contact with a spark inside the cabinet (due to a loose wire, mechanical thermostat or bad build quality from China)

Disposal of discarded refrigerators is regulated, often mandating the removal of doors; children playing hide-and-seek have been asphyxiated while hiding inside discarded refrigerators, particularly older models with latching doors. More modern units use a magnetic door gasket which holds the door sealed but can be pushed open from the inside. This gasket was invented by Herman C. Ells Sr.

Types of domestic refrigerators



Domestic refrigerators and freezers for food storage are made in a range of sizes. Among the smallest is a 4 L Peltier fridge advertised as being able to hold 6 cans of beer. A large domestic fridge stands as tall as a person and may be about 1 m wide with a capacity of 600 L. Some models for small households fit under kitchen work surfaces, usually about 86 cm high. Fridges may be combined with freezers, either stacked with fridge or freezer above, below, or side by side. A fridge without a frozen food storage compartment may have a small section just to make ice cubes. Freezers may have drawers to store food in, or they may have no divisions (chest freezers).

Fridges and freezers may be free-standing, or built into a kitchen.

- Compressor refrigerators are by far the most common type; they make a noticeable noise.
- Absorption refrigerators or thermo-electric Peltier units are used where quiet running is required; Peltier coolers are used in the smallest refrigerators as they have no bulky mechanism.
- Compressor and Peltier refrigerators are powered by electricity; absorption units can be designed to be powered by any heat source. A noticeable difference

between the two types is the absence of refrigerant with the Peltier coolers (these use a different method of cooling). But Peltier coolers use more electricity because they are thermodynamically inefficient.

- Oil, gas (natural gas or propane) and dual power gas/electricity units are also available (typically found in RV's).
- Solar refrigerators and Thermal mass refrigerators are designed to reduce electrical consumption. Solar refrigerators have the added advantage that they do not use refrigerants that are harmful to the environment or flammable. Typical solar designs are absorption refrigerators that use ammonia as the working gas, and employ large mirrors to concentrate sufficient sunlight to reach the temperature required to free gaseous ammonia from the solvent. Most thermal mass refrigerators are designed to use electricity intermittently. As these units are heavily insulated, cooling load is limited primarily to heat introduced by new items to be refrigerated, and ambient air transfer when the unit is open. Very little power is therefore required if opened infrequently. Refrigeration units for commercial and industrial applications can be made in various size, shape or style to fit customer needs.

Other specialised cooling mechanisms may be used for cooling, but have not been applied to domestic refrigerators.

- Magnetic refrigerators are refrigerators that work on the magnetocaloric effect. The cooling effect is triggered by placing a metal alloy in a magnetic field.
- Acoustic refrigerators are refrigerators that use resonant linear reciprocating motors/alternators to generate a sound which is then converted to heat and cold using compressed helium gas. The heat is discarded and the cold is routed to the refrigerator.

Energy efficiency

In the past, refrigerators consumed more energy than any other home appliance, but in the last twenty years progress has been made to design, manufacture, and encourage the sale of refrigerators with improved energy efficiency. In the early 1990s a competition was held among the major manufacturers to encourage energy efficiency. Current models that are Energy Star qualified use 50 percent less energy than the average models made in 1974. The most energy-efficient unit made in the US is designed to run on 120 or 110 volts, and consumes about half a kilowatt-hour per day. But even ordinary units are quite efficient; some smaller units use less than 0.5 kilowatt-hour per day.

Larger units, especially those with large freezers and icemakers, may use as much as 4 kW·h per day. The small, mini-fridge (or bar fridge), is an example of bad design. Because these fridges are so small and lacking in large amounts of capacity, when the door is opened a large amount of the cool air escapes, leaving a large amount of warm, moist air for the unit to cool down. This means, if the unit is cycled off when the door is opened, it is likely the unit will start almost as soon as the door is shut.

Among the different styles of refrigerators, top-freezer models are more efficient than bottom-freezer models of the same capacity, which are in turn more efficient than side-freezer models. Models with through-the-door ice units are less efficient than those without. Dr. Tom Chalko in Australia has developed an external thermostat to convert any chest freezer into a chest fridge using only about 0.1kWh per day—the amount of energy used by a 100 watt light bulb in one hour. A similar device is manufactured by Johnson Controls. Scientists at Oxford University have reconstructed a refrigerator invented in 1930 by Leó Szilárd and Albert Einstein in their efforts to replace current technologies with energy efficient green technology. The Einstein refrigerator operates without electricity and uses no moving parts or greenhouse gases.

It is interesting to note that many refrigerators made in the 1930s and 1940s were far more efficient than most that were made later. This is partly attributable to the addition of new features, such as auto-defrost, that reduced efficiency. Another reason as to why post World War 2 refrigerators was because style was more important than efficiency, this was especially true in the 1970s, when side by side models with ice dispensers and water chillers became popular. However, the reduction in efficiency also comes partly from cost cutting (less insulation). Only now are refrigerators getting back to the energy efficiency of 1930s models, with the introduction of new energy requirements.

The efficiency of older refrigerators can be improved by defrosting (if the unit is manual defrost) and cleaning them regularly, replacing old and worn door seals with new ones, adjusting the thermostat to be appropriate to the actual contents (a fridge doesn't need to be colder than 4°C if it is storing drinks and non-perishable items only) and also replacing insulation, where applicable. Some sites recommend that you clean the condenser coils every month or so on units that have coils on the rear. It has been proved that this does very little for improving efficiency, however, the unit should be able to 'breathe' with adequate spaces around the front, back, sides and above the unit. If the refrigerator uses a fan to keep the condenser cool, then this must be cleaned, at the very least, yearly.

Frost Free refrigerators and/or freezers utilize electric fans to cool the appropriate compartment. This could be referred to as a 'Fan Forced' refrigerator, whereas manual defrost units rely on colder air lying at the bottom, versus the warm air at the top to achieve adequate cooling. The air is drawn in through an inlet duct and passed through the evaporator where it is cooled, the air is then circulated through-out the cabinet via a series of ducts and vents. Because the air passing the evaporator is supposedly warm and moist, frost begins to form on the evaporator (especially on a freezer's evaporator). In cheaper and/or older models, a defrost cycle was controlled via a mechanical timer. This timer was set to shut off the compressor and fan and energize a heating element located at the base of the evaporator for up to 30 minutes. This melted any frost or ice build up and allowed the refrigerator to work normally once more. It is believed that frost free units have a lower tolerance for frost, due to their air-conditioner like evaporator coils. Therefore, if a door is left open accidentally (especially the freezer), the defrost system may not remove all frost, in this case, the freezer (or fridge) must be defrosted.

If the defrosting system melts all the ice before the timed defrosting period ends, then a small device (called a Defrost Terminator) acts like a thermostat and shuts off the heating element to prevent too large a temperature fluctuation, it also prevents hot blasts of air when the system starts again, should it finish defrosting early. When the 30 minutes or so defrost is completed, the compressor and fan are allowed to cycle back on if necessary.

Single frost free fridge units that are frost free generally don't shut off their fans whilst defrosting. This allows consumers to leave food in the main fridge compartment uncovered, and also helps keep any vegetables some-what moist. This method also helps reduce energy consumption, because a fridge is above freeze point, the warmer than freezing air can be passed through the evaporator to aid the defrosting cycle. The less time the electric heater element is left on, the lower the energy consumption.

Regarding total life-cycle costs, many government's offer incentives to encourage recycling of old refrigerators. One example is the Phoenix fridge program launched in Australia. This government incentive picked up old refrigerators, paying their owners for 'donating' the fridge. The fridge was then refurbished, with new door seals, a thorough cleaning and the removal of items, such as the cover that is strapped to the back of many older units. The resulting fridges, now over 10% more efficient, were then distributed to low income families.

Impact on lifestyle

The refrigerator allows the modern family to keep food fresh for much longer than before. This, along with the modern supermarket, allows most families, without a sizable garden in which to grow vegetables and raise animals, a vastly more varied diet and improved health resulting from improved nutrition. Dairy products, meats, fish, poultry and vegetables can be kept refrigerated in the same space within the kitchen (although raw meat should be kept separate from other foodstuffs for reasons of hygiene).

The refrigerator lets people eat more salads, fresh fruits and vegetables, without having to own a garden or an orchard. Exotic foodstuffs from far-off countries that have been imported by means of refrigeration can be enjoyed in the home because of domestic refrigeration.

While allowing more healthy foods to be stored for longer times, more refrigerators and freezers are stocked with processed, quick-cook foods that are less healthy. Studies connecting the correlation between frozen (microwaved) foods and obesity have proven that access to easy meals has lead to a general decline in overall health.

Freezers allow households to buy food in bulk: it can be eaten at leisure, and bulk purchase saves money. Ice cream, a popular commodity of the 20th century, could previously only be obtained by traveling long distances to where the product was made fresh, and had to be eaten on the spot. Now it is a common food item. Ice on demand not only adds to the enjoyment of cold drinks, but is useful for first-aid, and for cold packs that can be kept frozen for picnics or in case of emergency.

Temperature zones and ratings



Commercial for electric refrigerators in Pittsburgh, Pennsylvania, 1926

Some refrigerators are now divided into four zones to store different types of food:

- $-18\text{ }^{\circ}\text{C}$ ($-0\text{ }^{\circ}\text{F}$) (freezer)
- $0\text{ }^{\circ}\text{C}$ ($32\text{ }^{\circ}\text{F}$) (meats)
- $5\text{ }^{\circ}\text{C}$ ($41\text{ }^{\circ}\text{F}$) (refrigerator)
- $10\text{ }^{\circ}\text{C}$ ($50\text{ }^{\circ}\text{F}$) (vegetables)

The capacity of a refrigerator is measured in either litres or cubic feet. Typically the volume of a combined fridge-freezer is split to 100 litres (3.53 cubic feet) for the freezer and 140 litres (4.94 cubic feet) for the refrigerator, although these values are highly variable.

Temperature settings for refrigerator and freezer compartments are often given arbitrary numbers by manufacturers (for example, 1 through 9, warmest to coldest), but generally 3 to $5\text{ }^{\circ}\text{C}$ (37 to $41\text{ }^{\circ}\text{F}$) is ideal for the refrigerator compartment and $-18\text{ }^{\circ}\text{C}$ ($-0\text{ }^{\circ}\text{F}$) for the freezer. Some refrigerators are required to be within certain external temperature parameters to run properly. This can be an issue when placing units in an unfinished area such as a garage.

European freezers, and refrigerators with a freezer compartment, have a four star rating system to grade freezers.

- * : min temperature = $-6\text{ }^{\circ}\text{C}$ ($21.2\text{ }^{\circ}\text{F}$). Maximum storage time for frozen food is 1 week
- ** : min temperature = $-12\text{ }^{\circ}\text{C}$ ($10.4\text{ }^{\circ}\text{F}$). Maximum storage time for frozen food is 1 month
- *** : min temperature = $-18\text{ }^{\circ}\text{C}$ ($-0\text{ }^{\circ}\text{F}$). Maximum storage time for frozen food is 3 months

- **(***)** : min temperature = $-18\text{ }^{\circ}\text{C}$ ($-0\text{ }^{\circ}\text{F}$). Maximum storage time for frozen food is up to 12 months

Although both the three and four star ratings specify the same minimum temperature of $-18\text{ }^{\circ}\text{C}$, only a four star freezer is intended to be used for freezing fresh food. Three (or fewer) stars are used for frozen food compartments which are only suitable for storing frozen food; introducing fresh food into such a compartment is likely to result in unacceptable temperature rises. Most European refrigerators include a moist cold fridge section (which does require (automatic) defrosting at irregular intervals) and a (rarely frost free) freezer section.

Non-food use

Refrigerators have many other uses. Examples include: storing samples awaiting analysis in a laboratory, storing film stock, and storing corpses in a morgue.

Recycling

Old refrigerators have been adapted to create low cost passive solar water heating systems. Also, many refrigerators have been refurbished for low-income families in eastern Australia via the Phoenix fridge program

Chapter- 5

Harrier Jump Jet

Harrier Jump Jet



A Harrier GR7A of 800 Naval Air Sqn, Royal Navy

Role	V/STOL strike aircraft
Manufacturer	Hawker Siddeley British Aerospace/McDonnell Douglas Boeing/BAE Systems
Introduced	1969
Status	Active
Primary users	United States Marine Corps Royal Air Force Royal Navy Spanish Navy
Developed from	Hawker P.1127/Kestrel FGA.1
Variants	Hawker Siddeley Harrier BAE Sea Harrier AV-8B Harrier II BAE Harrier II

The **Harrier**, informally referred to as the **Jump Jet**, is a family of British-designed military jet aircraft capable of Vertical/short takeoff and landing (V/STOL) via thrust

vectoring. The Harrier family is the only truly successful design of this type from the many that arose in the 1960s.

There are four main versions of the Harrier family: Hawker Siddeley Harrier, British Aerospace Sea Harrier, Boeing/BAE Systems AV-8B Harrier II, and BAE Systems/Boeing Harrier II. The Hawker Siddeley Harrier is the first generation version and is also known as the AV-8A Harrier. The Sea Harrier is a naval strike/air defence fighter. The AV-8B and BAE Harrier II are the US and British variants respectively of the second generation Harrier aircraft.

Development

Background

Following an approach by the Bristol Engine Company in 1957 that they were planning a directed thrust engine, Hawker Aircraft came up with a design for an aeroplane that could meet the NATO specification for a "Light Tactical Support Fighter". There was no financial support for the development from HM Treasury, but aid was found through the Mutual Weapon Development Project (MWDP) of NATO.

The P.1127 was ordered as a prototype and flew in 1960. NATO developed a specification (NBMR-3) for a VTOL aircraft, but one that was expected to have the performance of an aircraft like the F-4 Phantom. Hawker drafted a supersonic version of the P.1127, the P.1150, and also the Hawker P.1154 which would meet NBMR-3. The latter was a winner of the NATO competition and development continued until cancelled at the point of prototype construction in 1965.

Work on the P.1127 continued with 9 evaluation aircraft, the Hawker Siddeley Kestrel, ordered. These started flying in 1964 and were assessed by the "Tri-partite Evaluation Squadron" which consisted of British, US and German pilots. With the cancellation of the P.1154, the RAF ordered a modified P.1127/Kestrel as the Harrier GR.1 in 1966.

Harrier development summary

The *Hawker Siddeley Harrier GR.1/GR.3* and the *AV-8A Harrier* were the first generation of the Harrier series, the first operational close-support and reconnaissance attack aircraft with Vertical/Short Takeoff and Landing (V/STOL) capabilities. These were developed directly from the Hawker P.1127 prototype and the Kestrel evaluation aircraft.

The Harrier was extensively redeveloped by McDonnell Douglas and British Aerospace, leading to the AV-8B Harrier II and Harrier GR5/GR7/GR9, respectively. Both were built by companies that are now parts of Boeing and BAE Systems.

The *British Aerospace Sea Harrier* is a naval V/STOL jet fighter, reconnaissance and attack aircraft, a development of the Hawker Siddeley Harrier. The first version entered

service with the Royal Navy's Fleet Air Arm in April 1980 as the **Sea Harrier FRS.1**, and was informally known as the *Shar*. The upgraded **Sea Harrier FA2** entered service in 1993. It was withdrawn from Royal Navy service in March 2006. The **Sea Harrier FRS Mk.51** is in active service with the Indian Navy, which operates the jet from its aircraft carrier INS *Viraat*.

The *Boeing/BAE Systems AV-8B Harrier II* is a family of second-generation V/STOL jet multi-role aircraft of the late 20th century. Developed from the earlier Hawker Siddeley Harrier, it is primarily used for light attack or multi-role tasks, typically operated from small aircraft carriers. Versions are used by several NATO countries, including Spain, Italy, and the United States. The **BAE Systems/Boeing Harrier II** is a modified version of the AV-8B Harrier II. The Harrier II is used by the Royal Air Force (RAF) and, since 2006, the Royal Navy. Both are primarily used for light attack or multi-role tasks, and are often operated from small aircraft carriers.

Between 1969 and 2003, 824 Harrier variants were delivered. While manufacture of new Harriers concluded in 1997, the last remanufactured aircraft (Harrier II Plus configuration) was delivered in December 2003 which ended the Harrier production line.

Replacement

As of late 2010, the F-35B STOVL variant of the F-35 Lightning II (formerly the Joint Strike Fighter) is intended to replace the AV-8B Harrier II in service with the US Marine Corps and the Italian Navy from 2014 onwards. The RAF and Royal Navy are scheduled to introduce the CATOBAR F-35C variant around 2020, after retiring their Harriers in 2011. In December 2010 the RAF's Harrier IIs made their last operational flights.

Variants

Pre-Harrier prototype and evaluation aircraft



The Hawker P.1127, predecessor of the Harrier



An RAF Harrier GR3 on display at Bletchley Park, England

- Hawker P.1127 (1960)
- Hawker Siddeley Kestrel FGA.1 (1964)

RAF Harriers

- Single-seater combat aircraft
 - Harrier GR.1 (1966)
 - Harrier GR.1/1A (1969)
 - Harrier GR.3/3A
- Two-seater training aircraft
 - Harrier T.2/2A (1970)
 - Harrier T.4/4A
 - Harrier T.4N
 - Harrier T.8 (1994)
 - Harrier Mk.52 (two-seat company demonstrator)
 - Harrier T.Mk 60

AV-8A Harrier (US, Spain, Thailand)

- AV-8A Harrier/Harrier Mk.50 (USMC version, 1970)
- TAV-8A Harrier/Harrier Mk.54
- AV-8C Harrier
- AV-8S Matador/Harrier Mk.53 (for Spain, later Thailand)
- AV-8S Matador/Harrier Mk.55 (second batch of AV-8S for Spain, later Thailand)
- TAV-8S Matador/Harrier T.54 (for Spain, later Thailand)

British Aerospace Sea Harrier



Royal Navy Sea Harrier FA2s of 801 Naval Air Squadron on the deck of HMS *Illustrious* in the Persian Gulf



US Marine Corps AV-8B Harrier

McDonnell Douglas/Boeing-BAe/BAE Systems AV-8B Harrier II

- AV-8B Harrier II (1983)
- EAV-8B Matador II (for Spain)
- AV-8B Harrier II Night Attack (1987)
- AV-8B Harrier II Plus (1992) (USMC, Spain, Italy)

BAe/BAE Systems-McDonnell Douglas/Boeing Harrier II



RAF Harrier GR9 arrives at RIAT 2008

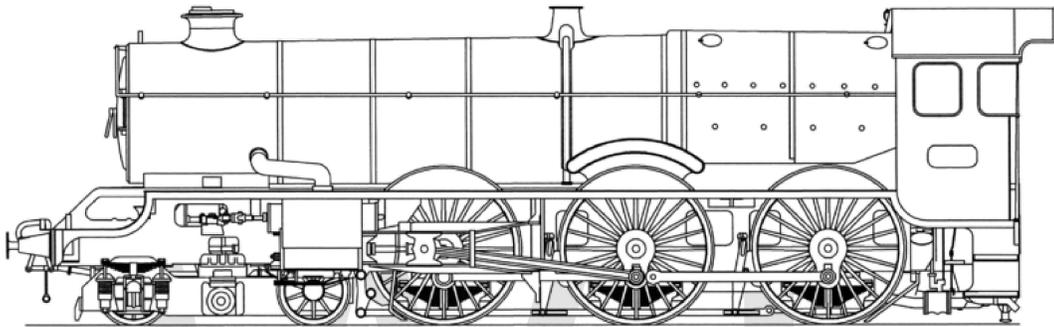
- Harrier GR5/5A (1985)
- Harrier GR7/7A (1992)
- Harrier GR9/9A (2002)
- Harrier T10
- Harrier T12

Specifications

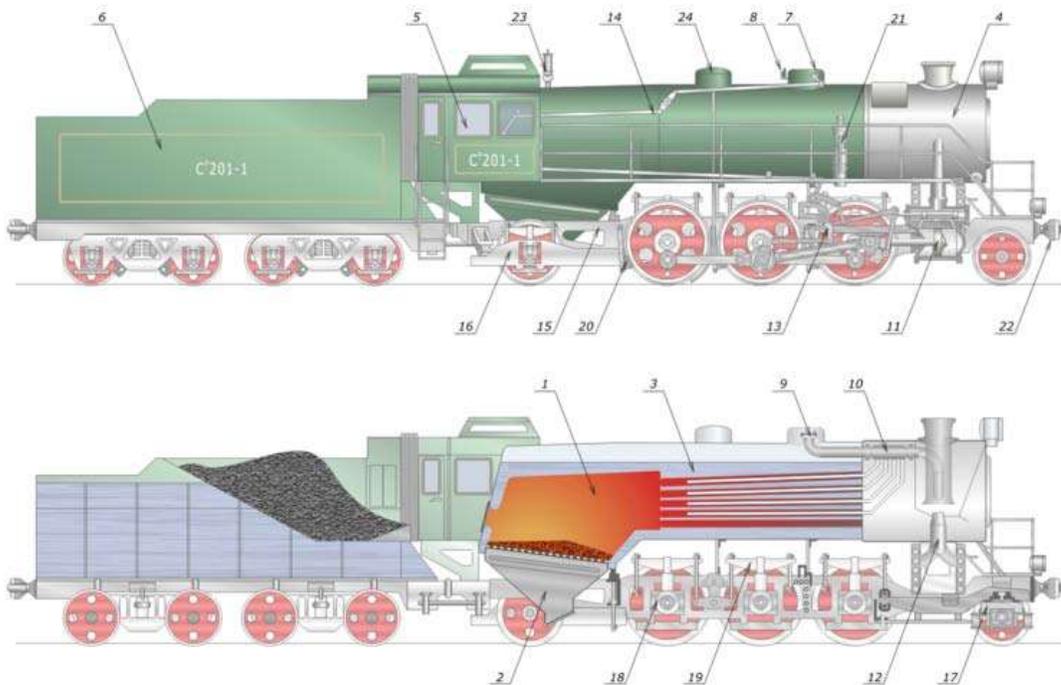
	Kestrel FGA.1	Harrier GR3/AV-8A	Sea Harrier FA2	Harrier GR9	AV-8B+ Harrier
Crew		One (Two for trainer versions)			
Length	42 ft 6 in (13.0 m)	47 ft 2 in (14.4 m)	46 ft 6 in (14.2 m)	46 ft 4 in (14.1 m)	47 ft 8 in (14.5 m)
Wingspan	22 ft 11 in (6.99 m)	25 ft 3 in (7.70 m)	25 ft 3 in (7.70 m)	30 ft 4 in (9.25 m)	30 ft 4 in (9.25 m)
Height	10 ft 9 in (3.28 m)	11 ft 4 in (3.45 m)	12 ft 4 in (3.76 m)	11 ft 8 in (3.56 m)	11 ft 8 in (3.56 m)
Empty Weight	10,000 lb (4,540 kg)	12,200 lb (5,530 kg)	14,052 lb (6,370 kg)	12,500 lb (5,670 kg)?	13,968 lb (6,340 kg)
Maximum take-off weight (short takeoff)	17,000 lb (7,710 kg)	26,000 lb (11,800 kg)	26,200 lb (11,900 kg)	31,000 lb (14,100 kg)	31,000 lb (14,100 kg)
Max speed	545 mph (877 km/h)	731 mph (1,180 km/h)	735 mph (1,180 km/h)	662 mph (1,070 km/h)	662 mph (1,070 km/h)
Combat radius		200 nmi (370 km)		300 nmi (556 km)	300 nmi (556 km)
Engine	Pegasus 6	Pegasus 11 Mk 101	Pegasus 11 Mk 106	Pegasus 11 Mk 107	Pegasus 11 Mk 105
Thrust	15,000 lbf (66.7 kN)	21,800 lbf (97.0 kN)	21,800 lbf (97.0 kN)	24,750 lbf (110 kN)	23,500 lbf (105 kN)
Radar	None	None	Blue Vixen	None	AN/APG-65

Chapter- 6

Steam Locomotive



Drawing of a Great Western Railway *King* class locomotive

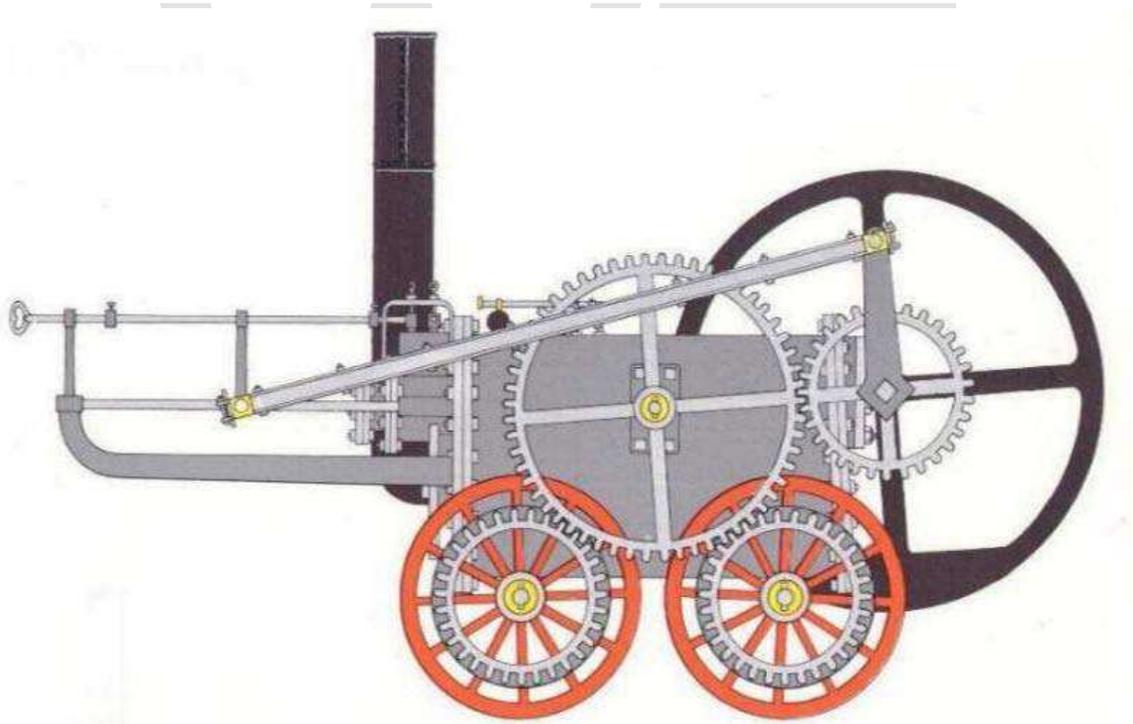


The main components of a steam locomotive

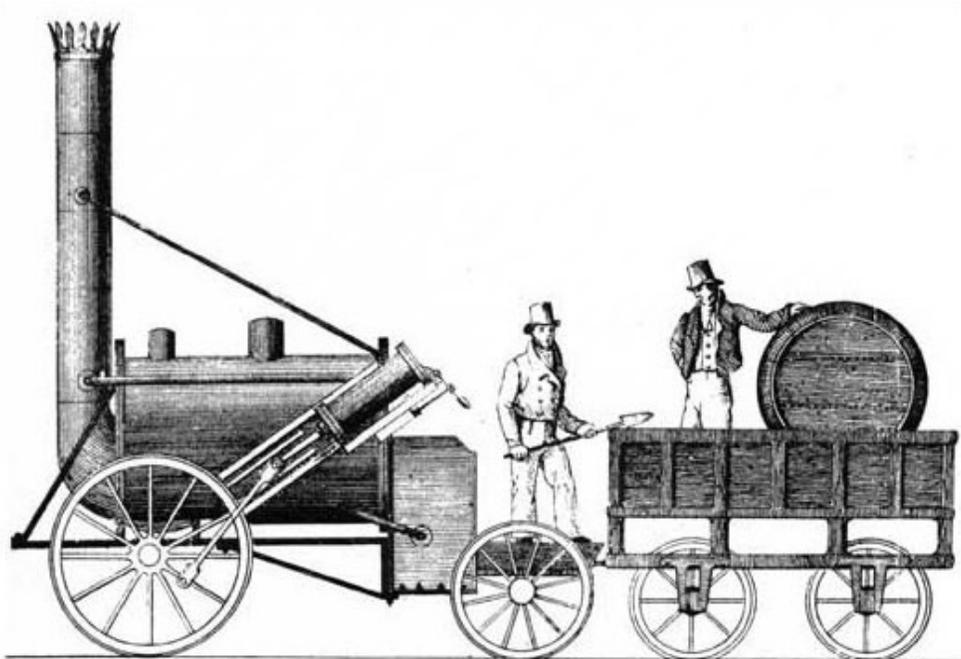
A **steam locomotive** is a locomotive that produces its power through a steam engine. The term *locomotive* refers to any self-propelled vehicle. This may also include a *road locomotive* such as a traction engine or steam car, however when the term is used on its own, it commonly refers to a railway locomotive. Its purpose is to haul a train for freight wagons or passenger coaches along a railway track. The locomotive is usually fueled by coal, wood or oil. This fuel is burned to produce steam in a boiler, which drives the steam engine. Both fuel and water supplies are carried with the locomotive, either on the locomotive itself or in wagons pulled behind.

Beginning in Britain, steam locomotives dominated railway transportation from the start of the 19th century, until the middle of the 20th century. They were gradually improved and developed in their over 150 years of use. Starting in about 1930, other types of engines were developed, and steam locomotives were gradually superseded by diesel and electric locomotives.

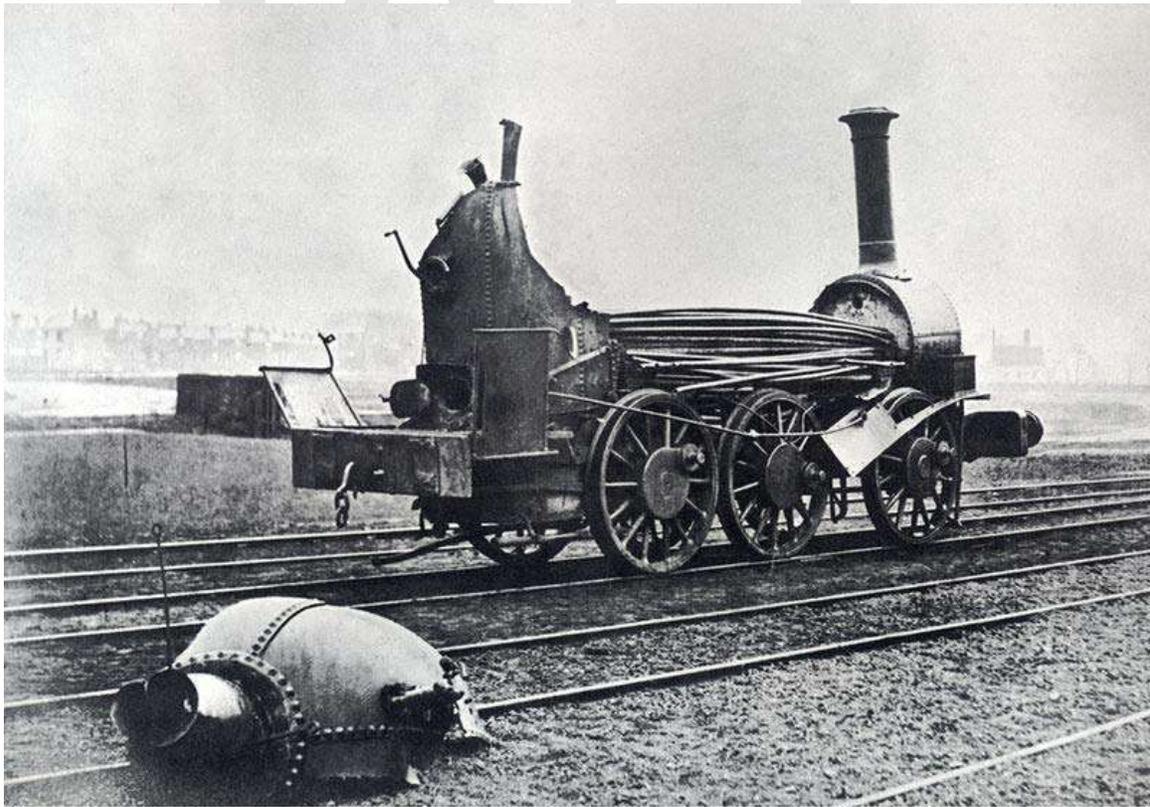
Origins



Trevithick's locomotive, 1804 the first successful steam locomotive



Stephenson's *Rocket* 1829, the winner of the Rainhill Trials



Aftermath of a boiler explosion on a railway locomotive circa 1850.

The earliest railways employed horses to draw carts along railed tracks.

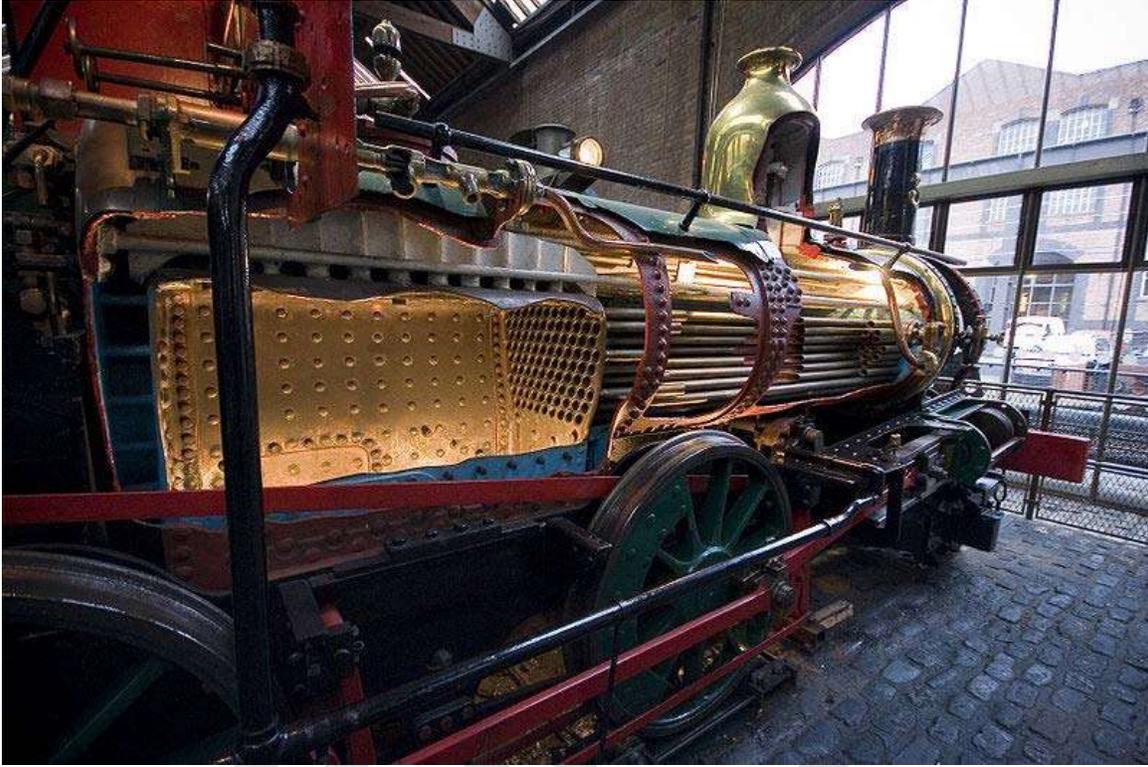
As the development of steam engines progressed through the 18th century, various attempts were made to apply them to road and railway use. In 1784, William Murdoch, a Scottish inventor, built a prototype steam road locomotive. An early working model of a steam rail locomotive was designed and constructed by steamboat pioneer John Fitch in the United States probably during the 1780s or 1790s. His steam locomotive used interior bladed wheels guided by rails or tracks. The model still exists at the Ohio Historical Society Museum in Columbus.

The first full scale working railway steam locomotive was built by Richard Trevithick in the United Kingdom and, on 21 February 1804, the world's first railway journey took place as Trevithick's unnamed steam locomotive hauled a train along the tramway of the Penydarren ironworks, near Merthyr Tydfil in south Wales. Accompanied with Andrew Vivian, it ran with mixed success. Then followed the successful twin cylinder locomotive *Salamanca* by Matthew Murray for the edge railed rack and pinion Middleton Railway in 1812. In 1825 George Stephenson built the *Locomotion* for the Stockton and Darlington Railway, north east England, which was the first public steam railway in the world. In 1829, he built *The Rocket* which was entered in and won the Rainhill Trials. This success led to Stephenson establishing his company as the pre-eminent builder of steam locomotives used on railways in the United Kingdom, United States and much of Europe. The Liverpool and Manchester Railway opened a year later making exclusive use of steam power for both passenger and freight trains.

The United States started developing steam locomotives in 1829 with the Baltimore and Ohio Railroad's *Tom Thumb*. This was the first locomotive to run in America, although it was intended as a demonstration of the potential of steam traction, rather than as a revenue-earning locomotive. The first successful steam railway in the US was the South Carolina Railroad whose inaugural train ran on 25 December 1830 hauled by the *Best Friend of Charleston*. Many of the earliest locomotives for American railroads were imported from Great Britain, including the *Stourbridge Lion* and the *John Bull*, but a domestic locomotive manufacturing industry was quickly established, with locomotives like the *DeWitt Clinton* being built in the 1830s.

The first railway service in Continental Europe (or for that matter, outside the United Kingdom and the United States) was opened on 5 May 1835 in Belgium, between Mechelen and Brussels. The name of the locomotive used was *The Elephant*.

Basic form



A steam locomotive with the boiler and firebox exposed

Boiler

The typical steam locomotive employs a steel fire-tube boiler that contains pressurized water and steam. A firebox is normally located in the rear of the boiler (chimney in front). The firebox has a water filled steel chamber surrounding the top and sides of the flame in the firebox. If wood or coal is used to make the fire in the firebox it is built on a set of grates where ashes may be separated from the burning fuel. These ashes must periodically be removed from the engine. If wood or coal are the fuel used in the firebox there is a door at the rear of the firebox that is opened to add more fuel. If oil is used there nearly always is a door for adjusting the air flow, maintenance or for cleaning the oil jets. To extract even more heat, the smoke and hot air from the combustibles in the firebox travel horizontally through a bundle of parallel tubes submerged in the water in the boiler from the front of the firebox to the front of the boiler. The heat extracted in the firebox and tubes in the boiler converts the water to pressurized steam in the boiler. To minimize heat loss from the boiler it is normally surrounded with layers of insulation. The water and steam in the boiler are kept pressurized to raise the boiling temperature of the water and generate high pressure steam. The amount of pressure in the boiler is monitored by the engineer or fireman by a gauge mounted in the cab. Excess steam pressure can be released manually or may blow a safety valve. Too much pressure may cause the boiler to burst potentially killing the crew as well as disabling the engine.

At the front of the boiler is the smokebox, where steam is ejected into the chimney (US: "smoke stack") drawing the smoke and hot air through the fire tubes in the boiler and out the top of the chimney. The combustion in a typical steam engine is not very complete leading to a prodigious amount of smoke and often sparks being produced. This made these engines very dirty to live around as well as being an acute hazard while passing through a forest, tunnel or snow shed.

The steam generated in the boiler is used to drive the locomotive and also for other purposes (whistles, brakes, pumps, air flow, etc.). This constant use of steam requires the boiler to have water continually pumped (usually automatically) into it. The source of this water is an unpressurized tank, which is periodically topped up at water stops. The water level is normally monitored with a transparent tube or gauge. If the boiler runs out of water the fire may melt a hole in it, possibly causing an explosion. In a wreck or accident the boiler may burst, potentially hurting or killing the crew. Scale may build up in boiler to prevent good heat transfer, and corrosion eventually makes the boiler unsafe and it has to be rebuilt or replaced. Start up on a large engine may take an hour or more of preliminary heating of the water in the boiler before it is ready to go. These are several of the serious disadvantages of steam engines, which have led to their eventual replacement by safer and cleaner engines requiring less maintenance.

The boiler is typically placed horizontally. For locomotives designed to work on steep slopes, it may be placed vertically or mounted at an angle instead.

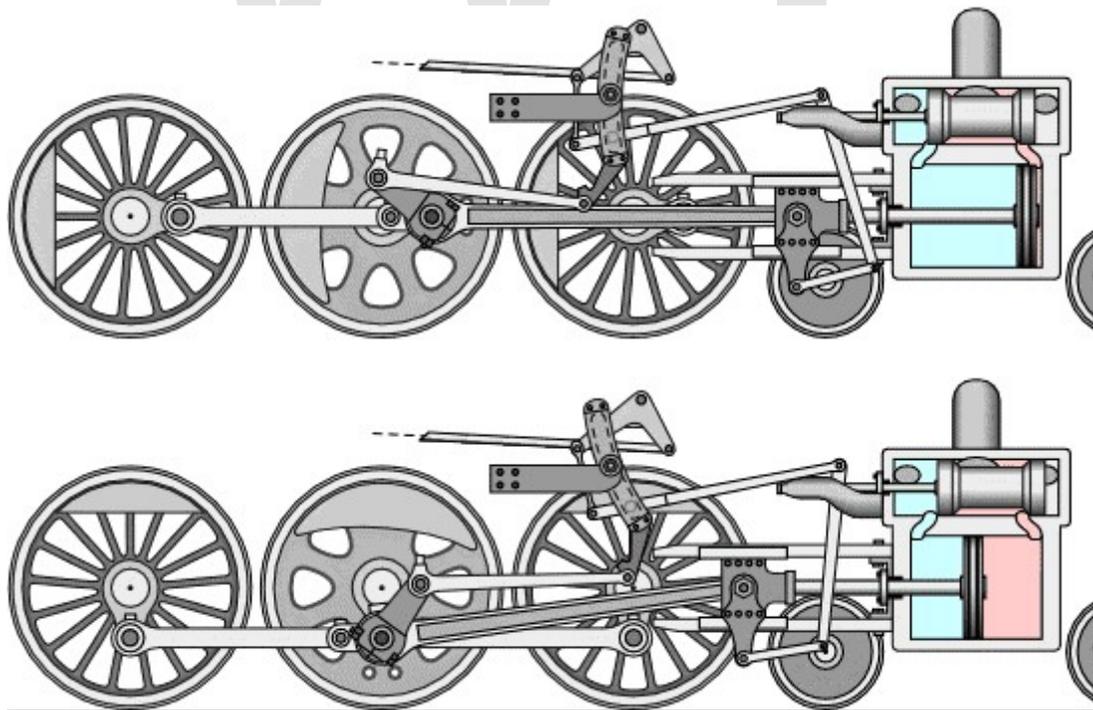
Steam circuit

The steam generated in the boiler fills the steam space above the water in the partially-filled boiler. Its maximum working pressure is limited by spring-loaded safety valves. It is then collected either in a perforated tube fitted above the water level or from a dome that often houses the regulator valve, or throttle, the purpose of which is to control the amount of steam leaving the boiler. The steam then either travels directly along and down a steam pipe to the engine unit or may first pass into the wet header of a superheater, the role of the latter being to improve thermal efficiency and eliminate water droplets suspended in the "saturated steam", the state in which it leaves the boiler. On leaving the superheater, the steam exits the dry header of the superheater and passing down a steam pipe entering the steam chests adjacent to the cylinders of a reciprocating engine. Inside each steam chest is a sliding valve that distributes the steam via ports that connect the steam chest to the ends of the cylinder space. The role of the valves is twofold: admission of each fresh dose of steam and exhaust of the used steam once it has done its work.

The cylinders are double acting, with steam admitted to each side of the piston in turn. In a two-cylinder locomotive, one cylinder is located on each side of the locomotive. The cranks are set 90° out of phase. During a full rotation of the driving wheel, steam provides four power strokes; each cylinder receives two injections of steam per revolution. The first stroke is to the front of the piston and the second stroke to the rear of the piston; hence two working strokes. Consequently two deliveries of steam onto each piston face in two cylinders generates a full revolution of the driving wheel. Each piston

is connected to the driving axle on each side by a connecting rod, the driving wheels are connected together by coupling rods to transmit power from the main driver to the other wheels. Note that at the two "dead centres", when the connecting rod is on the same axis as the crankpin on the driving wheel, the connecting rod applies no torque to the wheel. Therefore, if both cranksets could be at "dead centre" at the same time, and the wheels should happen to stop in this position, the locomotive could not be started moving. Therefore the crankpins are attached to the wheels at a 90° angle to each other, so only one side can be at dead centre at a time.

Each piston transmits power directly through a connecting rod (US: main rod) and a crankpin (US: wristpin) on the driving wheel (US main driver) or to a crank on a driving axle. The movement of the valves in the steam chest is controlled through a set of rods and linkages called the valve gear, actuated from the driving axle or else from the crankpin; the valve gear includes devices that allow reversing the engine, adjusting valve travel and the timing of the admission and exhaust events. The cut-off point determines the moment when the valve blocks a steam port, "cutting off" admission steam and thus determining the proportion of the stroke during which steam is admitted into the cylinder; for example a 50% cut-off admits steam for half the stroke of the piston. The remainder of the stroke is driven by the expansive force of the steam. Careful use of cut-off provides economical use of steam and, in turn, reduces fuel and water consumption. The reversing lever (US: Johnson bar), or screw-reverser, (if so equipped) that controls the cut-off therefore performs a similar function to a gearshift in an automobile - maximum cut-off, providing maximum tractive effort at the expense of efficiency, is used to pull away from a standing start, whilst a cut-off as low as 10% is used when cruising, providing reduced tractive effort with lower fuel/water consumption.



Walschaerts valve gear in a steam locomotive. In this, the red colour represents live steam entering the cylinder, blue represents expanded (spent) steam being exhausted from the cylinder. Note that the cylinder receives two steam injections during each full rotation; the same occurs in the cylinder on the other side of the engine.

Exhaust steam is directed upwards to the atmosphere through the chimney, by way of a nozzle called a blastpipe that gives rise to the familiar "chuffing" sound of the steam locomotive. The blastpipe is placed at a strategic point inside the smokebox that is at the same time traversed by the combustion gases drawn through the boiler and grate by the action of the steam blast. The combining of the two streams, steam and exhaust gases, is crucial to the efficiency of any steam locomotive and the internal profiles of the chimney, (or more strictly speaking, the *ejector*) require careful design and adjustment. This has been the object of intensive studies by a number of engineers (and almost totally ignored by others with sometimes catastrophic effect). The fact that the draught depends on the exhaust pressure means that power delivery and power generation are automatically self-adjusting and among other things, a balance has to be struck between obtaining sufficient draught for combustion whilst giving the exhaust gases and particles sufficient time to be consumed. In the past, fierce draught could lift the fire off the grate, or cause the ejection of unburnt particles of fuel, dirt and pollution for which steam locomotives had an unenviable reputation in the past. Moreover, the pumping action of the exhaust has the counter effect of exerting *back pressure* on the side of the piston receiving steam, thus slightly reducing cylinder power. Designing the exhaust ejector has become a specific science in which Chapelon, Giesl and Porta were successive masters, and was largely responsible for spectacular improvements in thermal efficiency and a significant reduction in maintenance time and pollution. A similar system was used by some early gasoline/kerosene tractor manufacturers (Advance-Rumely/Hart-Parr) – the exhaust gas volume vented through a cooling tower meant that the steam exhaust helped draw more air past the radiator.



Steam locomotive 909, still in operation, Wakefield, Quebec, Canada

Chassis



The Jacobite Steam Train in September 2003.

The chassis or locomotive frame is the principal structure onto which the boiler is mounted and which incorporates the various elements of the running gear. The boiler is rigidly mounted on a "*saddle*" beneath the smokebox and front of the boiler barrel, but the firebox at the rear is allowed to slide forward and back, to allow for expansion when hot.

European locomotives usually use "*plate frames*", where two vertical flat plates form the main chassis, with a variety of spacers and a buffer beam at each end to keep them apart. When inside cylinders are mounted between the frames, these are a single large casting that forms a major support to the frames. The axleboxes slide up and down to give some sprung suspension, against thickened webs attached to the frame, called "*hornblocks*".

For many years, in American practice, the boiler was the main structural element, with built-up bar frames, "smokebox saddle/cylinder" structure and "*drag beam*" integrated therein; but from the late 1920s with the introduction of "superpower", the "cast-steel locomotive bed" became the norm, incorporating frames, spring hangers, motion brackets, smokebox saddle and cylinder blocks incorporated into a single complex, sturdy

but heavy casting. André Chapelon developed a similar structure but of welded construction with around 30% saving in weight for the still-born 2-10-4 locomotives the construction of which was begun then abandoned in 1946.

Running gear

This includes the brake gear, wheel sets, axleboxes, springing and the "motion" that includes connecting rods and valve gear. The transmission of the power from the pistons to the rails and the behaviour of the locomotive as a vehicle, able to negotiate curves, points and irregularities in the track is of paramount importance. Because reciprocating power has to be directly applied to the rail from 0 rpm upwards, this poses unique problems of "adhesion" of the driving wheels to the smooth rail surface. Adhesive weight is the portion of the locomotive's weight bearing on the driving wheels. This is made more effective if a pair of driving wheels is able to make the most of its "axle load" i.e. its individual share of the adhesive weight. Locomotives with "compensating levers" connecting the ends of plate springs have often been deemed a complication but locomotives fitted with them have usually been less prone to loss of traction due to wheel-slip.

Locomotives with total adhesion, *i.e.* where all the wheels are coupled together, generally lack stability at speed. This makes desirable the inclusion of unpowered carrying wheels mounted on two-wheeled trucks or four-wheeled bogies centred by springs that help to guide the locomotive through curves. These usually take the weight of the cylinders in front or of the firebox at the rear end when the width of this exceeds that of the mainframes. For multiple coupled wheels on a rigid chassis a variety of systems for controlled side-play exist.

Railroads typically wanted a locomotive with as few axles as possible. This would reduce the cost of maintenance. The number of axles required was dictated by the maximum axle loading of the railroad in question. A builder would typically add axles until the maximum weight on any one axle was acceptable to the railroad's maximum axle loading. A locomotive with a wheel arrangement of two lead axles, two drive axles, & one trailing axle was in actuality a high speed machine. Two lead axles were necessary to have good tracking at high speeds. Two drive axles had a lower reciprocating mass than three, four, five, or six coupled axles. They were thus able to turn very high speeds due to the lower reciprocating mass. A trailing axle was able to support a huge firebox. Hence most locomotives with the wheel arrangement of 4-4-2 (American Type Atlantic) were "free steamers" able to maintain steam pressure regardless of throttle setting.

Fuel and water



Water gauge. Here the water in the boiler is at the "top nut", the maximum working level.

Generally, the largest locomotives are permanently coupled to a tender that carries the water and fuel. Alternatively, locomotives working shorter distances carry the fuel in a bunker, and the water in tanks mounted on the engine, the latter placed either alongside the boiler or on top of it; these are called tank engines.

The fuel used depended on what was economically available to the railway at the time. In the UK and parts of Europe, plentiful supplies of coal made this the obvious choice from the earliest days of the steam engine. Until 1870, the majority of locomotives in the USA burnt wood but, as the Eastern forests were cleared, coal gradually became more important. Thereafter, coal became and remained the dominant fuel worldwide until the end of general use of steam locomotives. Bagasse, a waste by-product of the refining process, was burned in sugar cane farming operations. In the USA, the ready availability of oil made it a popular steam locomotive fuel after 1900 for the southwestern railroads, particularly the Southern Pacific. In Victoria, Australia after World War II, many steam

locomotives were converted to heavy oil firing. German, Russian, Australian and British railways experimented using coal dust to fire locomotives.

A number of tourist lines and heritage locomotives in Switzerland, Argentina and Australia have been using light diesel-type oil.

Water was supplied at stopping places and locomotive depots from a dedicated water tower connected to water cranes or gantries. In the UK, the USA and France, water troughs (US track pans) were provided on some main lines to allow locomotives to replenish their water supply without stopping. This was achieved by using a 'water scoop' fitted under the tender or the rear water tank in the case of a large tank engine; the fireman remotely lowered the scoop into the trough, the speed of the engine forced the water up into the tank, and the scoop was raised again once it was full.



"Water is an essential element in the operation of a steam locomotive"
Here a locomotive is "taking-on water" – having its tanks refilled using a water crane.

Water is an essential element in the operation of a steam locomotive; because as Swengel argued:

it has the highest specific heat of any common substance; that is more thermal energy is stored by heating water to a given temperature than would be stored by heating an equal

mass of steel or copper to the same temperature. In addition, the property of vapourising (forming steam) stores additional energy without increasing the temperature...water is a very satisfactory medium for converting thermal energy of fuel into mechanical energy

Swengel went on to note that "at low temperature and relatively low boiler outputs" good water and regular boiler washout was an acceptable practise, even though such maintenance was high. As steam pressures increased, however, a problem of "foaming" or "priming" developed in the boiler, wherein dissolved solids in the water formed "tough-skinned bubbles" inside the boiler, which in turn were carried into the steam pipes and could blow off the cylinder heads. To overcome the problem, hot mineral concentrated water was deliberately wasted (blowing down) from the boiler from time to time. Higher steam pressures required more blowing down of water out of the boiler. Oxygen generated by boiling water attacks the boiler and with increased steam pressures the rate of rust (iron oxide) generated inside the boiler increases. One way to help overcome the problem was water treatment. Swengel suggested that the problems around water contributed to the interest in electrification of railways.

In the 1970s, L.D. Porta developed a sophisticated heavy duty chemical water treatment that not only keeps the inside of the boiler clean and prevents corrosion, but modifies the foam in such a way as to form a compact "blanket" on the water surface that filters the steam as it is produced, keeping it pure and preventing carry-over into the cylinders of water and suspended abrasive matter.

Crew

A steam locomotive is normally controlled from the backhead of the firebox and the crew is usually protected from weather by a cab. A crew of at least two people is normally required to operate a steam locomotive. One, the driver, is responsible for controlling the locomotive's starting, stopping and speed and the fireman is responsible for the fuel for the fire, steam pressure and water levels in the boiler and storage tank(s). Due to the historical loss of operational infrastructure and staffing, preserved steam locomotives operating on the mainline will often have a support crew travelling with the train.

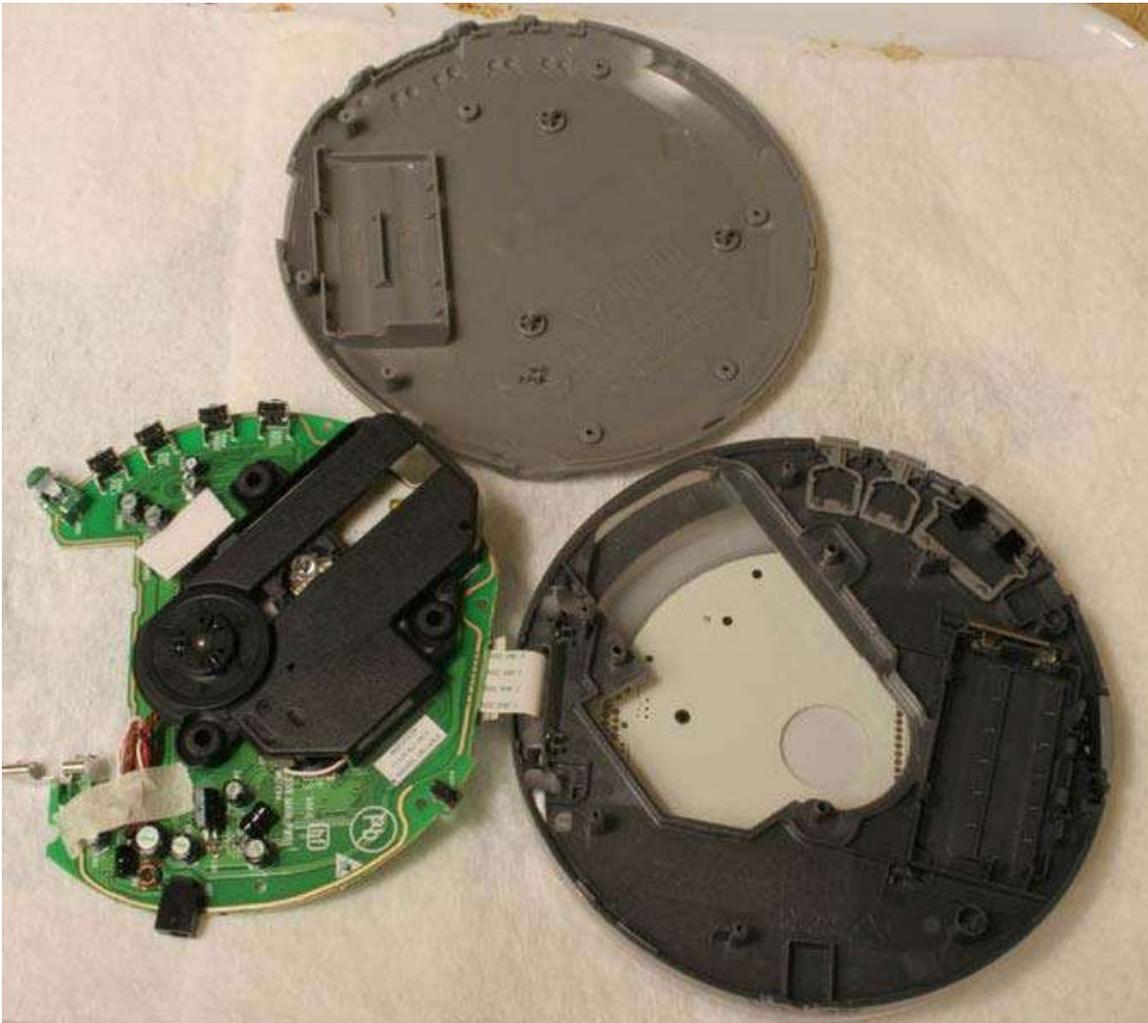
Chapter- 7

Portable CD Player and Camcorder

Portable CD player



An early portable player, a Sony Discman model D121



A Philips portable CD player disassembled



One of the latest portable CD players available, with MP3 and ATRAC capabilities

A **portable CD player** is a portable audio player used to play Compact Discs.

History

Portable Compact Disc players were first introduced in the 1980s. Electronic skip protection, a simple system to reduce disruption of audio from mechanical disturbance of players, was introduced in 1993.

Features

The basic features to a portable CD player are:

- Play/Pause
- Stop
- Rewind
- Fast forward
- Hold (some models)
- Liquid crystal display
- Headphones

Some CD-audio players can read CD-R/CD-RW discs and play other formats such as MP3-encoded audio.

The 8 cm CD provides a smaller alternative to the normal 12 cm CD (although with a lower capacity) and miniature players exist that exclusively play this format.

Future

While as of 2010 CDs remain a popular audio medium, portable CD players have seen competition from other forms of portable audio storage. MiniDisc players, flash memory players and audio devices with their own internal storage such as smart phones and the iPod, offer listeners alternatives to portable CD players. However, the ability to read MP3 CDs has allowed CD players to continue to compete against these alternatives, although standard CDs are bulkier.

Camcorder



Canon HD camcorder

A **camcorder** (*video camera recorder*) is an electronic device that combines a digital camera and a digital video recorder into one unit. Equipment manufacturers do not seem to have strict guidelines for the term usage. Marketing materials may present a video recording device as a *camcorder*, but the delivery package would identify content as *video camera recorder*.

In order to differentiate a camcorder from other devices that are capable of recording video, like mobile phones and digital compact cameras, a camcorder is generally identified as a portable, self-contained device having video capture and recording as its primary function.

The earliest camcorders employed analog recording onto videotape. Tape-based camcorders use removable media in the form of video cassettes. Nowadays, digital

recording has become the norm, with tape being gradually replaced with other storage media such as internal flash memory, hard drive and SD card. As of January 2011, none of the new consumer-class camcorders announced at the 2011 International Consumer Electronics Show record on tape.

Camcorders that do not use magnetic tape are often called tapeless camcorders, while camcorders that permit using more than one type of medium, like built-in hard disk drive and memory card, are sometimes called *hybrid camcorders*.

History



An arrangement of a separate portable recorder like a Betamax unit shown here and a video camera is still considered a camcorder by some sources.



A shoulder-mount RCA camcorder

Video cameras originally designed for television broadcast were large and heavy, mounted on special pedestals, and wired to remote recorders located in separate rooms.

As technology advanced, out-of-studio video recording was made possible by means of compact video cameras and portable video recorders. The recording unit could be detached from the camera and carried to a shooting location. While the camera itself could be quite compact, the fact that a separate recorder had to be carried along made on-location shooting a two-man job. Specialized video cassette recorders were introduced by both JVC (VHS) and Sony (U-matic and Betamax) to be used for mobile work. The advent of the portable recorders helped to eliminate the phrase "film at eleven"—rather than wait for the lengthy process of film developing, recorded video could be shown during the 6 o'clock news.

In 1982 Sony released the Betacam system. A part of this system was a single camera-recorder unit, which eliminated the cable between camera and recorder and dramatically improved the freedom of a cameraman. Betacam quickly became the standard for both news-gathering and in-studio video editing.

In 1983 Sony released the first consumer camcorder—the Betamovie BMC-100P. It used a Betamax cassette and could not be held with one hand, so it was typically resting on a shoulder. In the same year JVC released the first camcorder based on VHS-C format. In 1985 Sony came up with its own compact video cassette format—Video8. Both formats had their benefits and drawbacks, and neither won the format war.

In 1985, Panasonic, RCA, and Hitachi began producing camcorders that recorded to full-sized VHS cassette and offered up to 3 hours of record time. These shoulder mount camcorders found a niche with videophiles, industrial videographers, and college TV studios. Super VHS full-sized camcorders were released in 1987 which exceeded broadcast quality and provided an inexpensive way to collect news segments or videographies.

In 1986 Sony introduced the first digital video format, D1. Video was recorded in uncompressed form and required enormous bandwidth for its time. In 1992 Ampex used D1 form-factor to create DCT, the first digital video format that utilized data compression. The compression utilized discrete cosine transform algorithm, which is used in most modern commercial digital video formats.

In 1995 Sony, JVC, Panasonic and other video camera manufacturers launched DV. Its variant using a smaller MiniDV cassette quickly became a de-facto standard for home and semi-professional video production, for independent filmmaking and for citizen journalism.

In 2000 Panasonic launched DVCPRO HD, expanding DV codec to support high definition. The format was intended for use in professional camcorders and used full-size DVCPRO cassettes. In 2003 Sony, JVC, Canon and Sharp introduced HDV, the first truly affordable high definition video format, which used inexpensive MiniDV cassettes.

In 2003 Sony pioneered XDCAM, the first tapeless video format, which uses Professional Disc as recording media. Panasonic followed next year, offering P2 solid state memory cards as recording medium for DVCPRO HD video.

In 2006 Panasonic and Sony introduced AVCHD as an inexpensive consumer-grade tapeless high definition video format. Presently AVCHD camcorders are manufactured by Sony, Panasonic, Canon, JVC and Hitachi.

In 2007 Sony introduced XDCAM EX, which offers similar recording modes to XDCAM HD, but records on SxS memory cards.

With proliferation of file-based digital formats the relationship between recording media and recording format became weaker than ever: the same video can be recorded onto different media. With tapeless formats, recording media has become a storage device for digital files, signifying convergence of video and computer industries.



JVC KY D29 Digital-S pro camcorder.

Overview

Camcorders contain 3 major components: **lens**, **imager**, and **recorder**. The lens gathers and focuses light on the imager. The imager (usually a CCD or CMOS sensor on modern camcorders; earlier examples often used vidicon tubes) converts incident light into an electrical signal. Finally, the recorder converts the electric signal into video and encodes it into a storable form. More commonly, the optics and imager are referred to as the *camera* section.

Lens

The **lens** is the first component in the light path. The camcorder's optics generally have one or more of the following adjustments:

- *aperture* or *iris* to regulate the exposure and to control depth of field;
- *zoom* to control the focal length and angle of view;
- *shutter speed* to regulate the exposure and to maintain desired motion portrayal;

- *gain* to amplify signal strength in low-light conditions;
- *neutral density filter* to regulate the exposure.

In consumer units, the above adjustments are often automatically controlled by the camcorder's electronics, but can be adjusted manually if desired. Professional units offer direct user control of all major optical functions.

Imager

The **imager** converts light into electric signal. The camera lens projects an image onto the imager surface, exposing the photosensitive array to light. The light exposure is converted into electrical charge. At the end of the timed exposure, the imager converts the accumulated charge into a continuous analog voltage at the imager's output terminals. After scan-out is complete, the photosites are reset to start the exposure-process for the next video frame.

Recorder

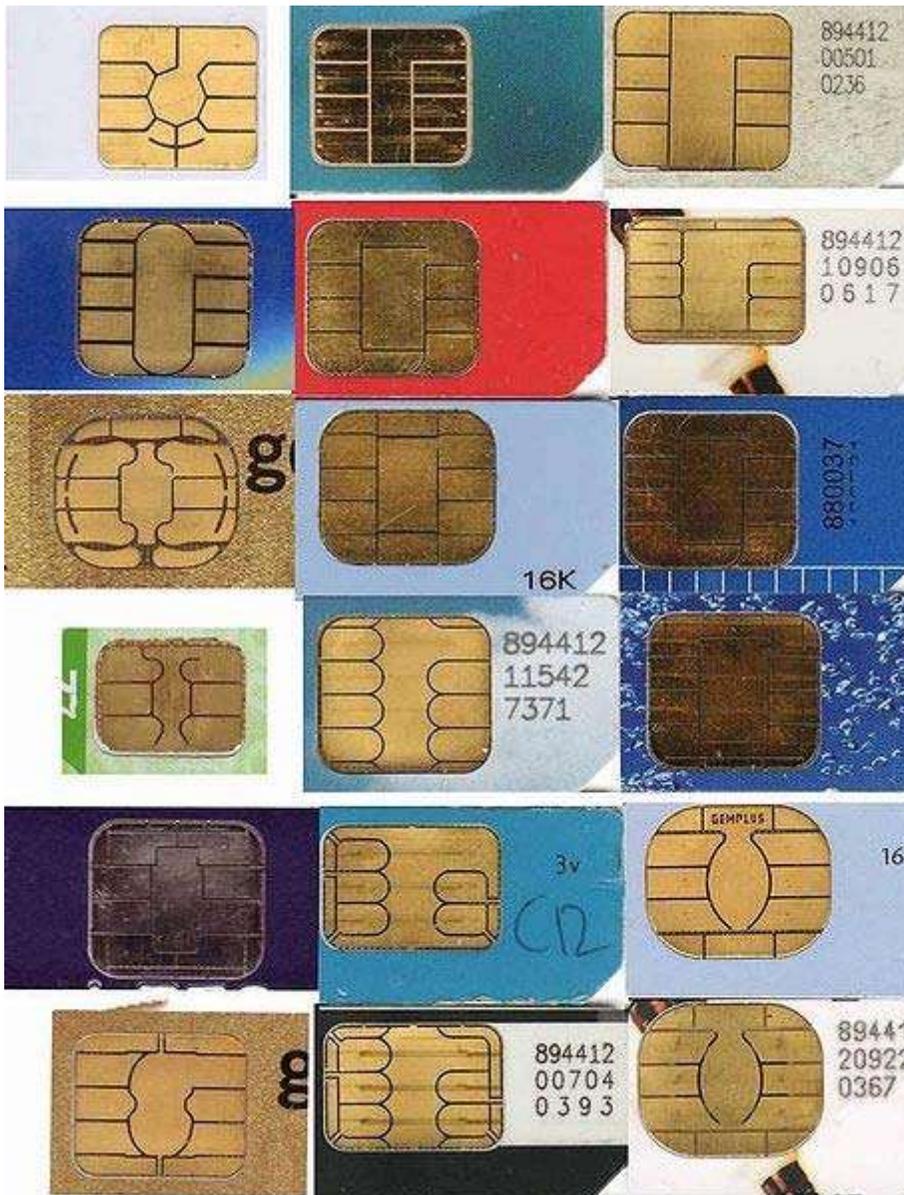
The **recorder** is responsible for writing the video-signal onto a recording medium (such as magnetic videotape.) The record function involves many signal-processing steps, and historically, the recording-process introduced some distortion and noise into the stored video, such that playback of the stored-signal may not retain the same characteristics/detail as the live video feed.

All but the most primitive camcorders imaginable also need to have a recorder-controlling section which allows the user to control the camcorder, switch the recorder into playback mode for reviewing the recorded footage and an image control section which controls exposure, focus and white-balance.

The image recorded need not be limited to what appeared in the viewfinder. For documentation of events, such as used by police, the field of view overlays such things as the time and date of the recording along the top and bottom of the image. Such things as the police car or constable to which the recorder has been allotted may also appear; also the speed of the car at the time of recording. Compass direction at time of recording and geographical coordinates may also be possible. These are not kept to world-standard fields; "month/day/year" may be seen, as well as "day/month/year", besides the ISO standard "year-month-day".

Chapter- 8

Smart Card



Many different pad layouts can be found on a contact Smart card

A **smart card**, **chip card**, or **integrated circuit card (ICC)**, is any pocket-sized card with embedded integrated circuits. There are two broad categories of ICCs. Memory cards contain only non-volatile memory storage components, and perhaps dedicated security logic. Microprocessor cards contain volatile memory and microprocessor components. The card is made of plastic, generally polyvinyl chloride, but sometimes acrylonitrile butadiene styrene or polycarbonate . Smart cards may also provide strong security authentication for single sign-on within large organizations.

Overview



Smart card used for health insurance in France

A smart card may have the following generic characteristics:

- Dimensions similar to those of a credit card. ID-1 of the ISO/IEC 7810 standard defines cards as nominally 85.60 by 53.98 millimetres (3.370×2.125 in). Another popular size is ID-000 which is nominally 25 by 15 millimetres (0.984×0.591 in) (commonly used in SIM cards). Both are 0.76 millimetres (0.030 in) thick.
- Contains a tamper-resistant security system (for example a secure cryptoprocessor and a secure file system) and provides security services (e.g., protects in-memory information).
- Managed by an administration system which securely interchanges information and configuration settings with the card, controlling card blacklisting and application-data updates.

- Communicates with external services via card-reading devices, such as ticket readers, ATMs, etc.

Benefits

Smart cards can provide identification, authentication, data storage and application processing.

The benefits of smart cards are directly related to the volume of information and applications that are programmed for use on a card. A single contact/contactless smart card can be programmed with multiple banking credentials, medical entitlement, driver's license/public transport entitlement, loyalty programs and club memberships to name just a few. Multi-factor and proximity authentication can and has been embedded into smart cards to increase the security of all services on the card. For example, a smart card can be programmed to only allow a contactless transaction if it is also within range of another device like a uniquely paired mobile phone. This can significantly increase the security of the smart card.

Governments gain a significant enhancement to the provision of publicly funded services through the increased security offered by smart cards. These savings are passed onto society through a reduction in the necessary funding or enhanced public services.

Individuals gain increased security and convenience when using smart cards designed for interoperability between services. For example, consumers only need to replace one card if their wallet is lost or stolen. Additionally, the data storage available on a card could contain medical information that is critical in an emergency should the card holder allow access to this.

History



A smart card, combining credit card and debit card properties. The 3 by 5 mm security chip embedded in the card is shown enlarged in the inset. The contact pads on the card enables electronic access to the chip.

In 1968 German rocket scientist Helmut Gröttrup and his colleague Jürgen Dethloff invented the automated chip card, receiving a patent only in 1982, while working for German company Giesecke & Devrient. The first mass use of the cards was as a *Télécarte* for payment in French pay phones, starting in 1983.

French inventor Roland Moreno patented the memory card concept in 1974. In 1977, Michel Ugon from Honeywell Bull invented the first microprocessor smart card. In 1978, Bull patented the SPOM (Self Programmable One-chip Microcomputer) that defines the necessary architecture to program the chip. Three years later, Motorola used this patent in its "CP8". At that time, Bull had 1,200 patents related to smart cards. In 2001, Bull sold its CP8 division together with its patents to Schlumberger, who subsequently combined its own internal smart card department and CP8 to create Axalto. In 2006, Axalto and Gemplus, at the time the world's no. 2 and no. 1 smart card manufacturers, merged and became Gemalto.

The second use integrated microchips into all French *Carte Bleue* debit cards in 1992. Customers inserted the card into the merchant's POS terminal, then typed the PIN, before the transaction was accepted. Only very limited transactions (such as paying small highway tolls) are processed without a PIN.

Smart-card-based "electronic purse" systems store funds on the card so that readers do not need network connectivity and entered service throughout Europe in the mid-1990s,

most notably in Germany (Geldkarte), Austria (Quick), Belgium (Proton), France (Mon€o), the Netherlands (Chipknip and Chipper), Switzerland ("Cash"), Norway ("Mondex"), Sweden ("Cash", decommissioned in 2004), Finland ("Avant"), UK ("Mondex"), Denmark ("Danmønt") and Portugal ("Porta-moedas Multibanco").

The major boom in smart card use came in the 1990s, with the introduction of smart-card-based SIMs used in GSM mobile phone equipment in Europe. With the ubiquity of mobile phones in Europe, smart cards have become very common.

The international payment brands MasterCard, Visa, and Europay agreed in 1993 to work together to develop the specifications for smart cards as either a debit or a credit card. The first version of the EMV system was released in 1994. In 1998 a stable release of the specifications became available. EMVco, the company responsible for the long-term maintenance of the system, upgraded the specification in 2000 and in 2004. EMVco's purpose is to assure the various financial institutions and retailers that the specifications retain backward compatibility with the 1998 version.

With the exception of countries such as the United States EMV-compliant cards and equipment are widespread. Typically, a country's national payment association, in coordination with MasterCard International, Visa International, American Express and JCB, jointly plan and implement EMV systems.

Contactless smart cards that do not require physical contact between card and reader are becoming increasingly popular for payment and ticketing applications such as mass transit and highway tolls. Visa and MasterCard have agreed to an easy-to-implement version that was deployed in 2004–2006 in the USA. Most contactless fare collection implementations are custom and incompatible, though the MIFARE Standard card from Philips has a considerable market share in the US and Europe.

Smart cards are also being introduced in personal identification and entitlement schemes at regional, national, and international levels. Citizen cards, drivers' licenses, and patient card schemes are appearing. In Malaysia, the compulsory national ID scheme MyKad includes eight different applications and has 18 million users. Contactless smart cards are part of ICAO biometric passports to enhance security for international travel.

Contact smart card

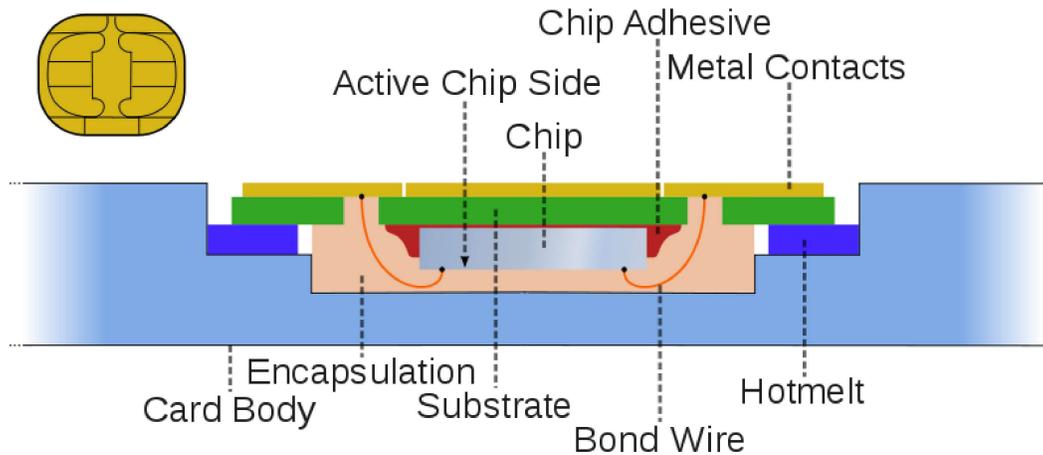


Illustration of smart card structure and packaging

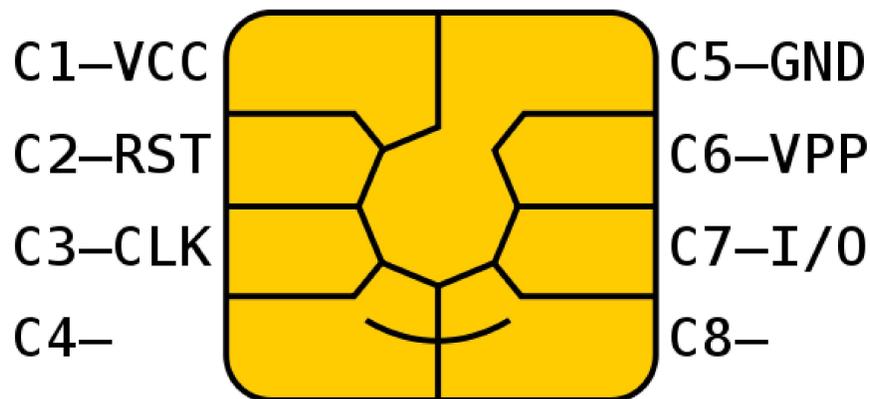
Contact smart cards have a contact area of approximately 1 square centimetre (0.16 sq in), comprising several gold-plated contact pads. These pads provide electrical connectivity when inserted into a reader.

The ISO/IEC 7810 and ISO/IEC 7816 series of standards define:

- physical shape and characteristics
- electrical connector positions and shapes
- electrical characteristics
- communications protocols, including commands sent to and responses from the card
- basic functionality

Cards do not contain batteries; power is supplied by the card reader.

Signals



A smart card pinout

VCC	Power supply.
RST	Reset signal, used to reset the card's communications.
CLK	Provides the card with a clock signal, from which data communications timing is derived.
GND	Ground (reference voltage).
VPP	Programming voltage input - originally an input for a higher voltage to program persistent memory (e.g., EEPROM), but now deprecated.
I/O	Serial input and output (half-duplex).
C4, C8	The two remaining contacts are AUX1 and AUX2 respectively, and used for USB interfaces and other uses.

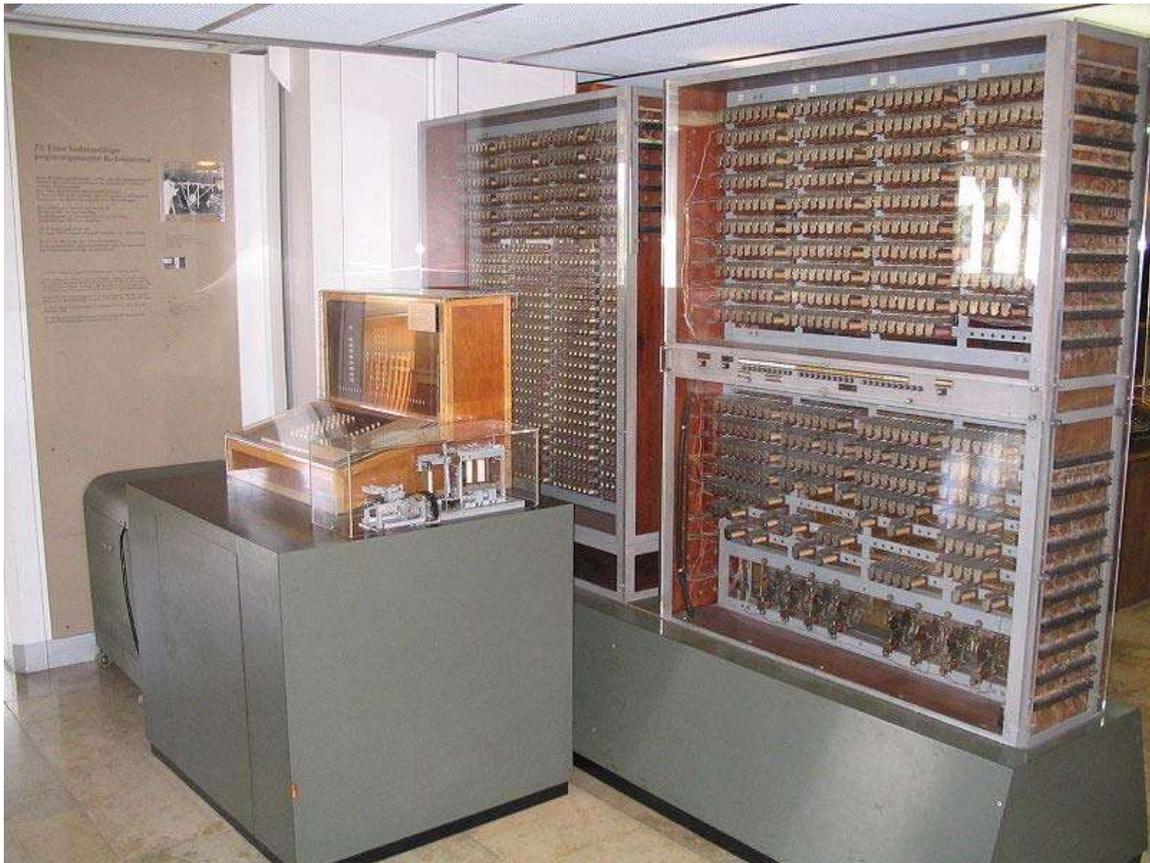
Reader

Contact smart card readers are used as a communications medium between the smart card and a host (e.g., a computer, a point of sale terminal) or a mobile telephone.

Because the chips in financial cards are the same as those used in Subscriber Identity Modules (SIMs) in mobile phones, programmed differently and embedded in a different piece of PVC, chip manufacturers are building to the more demanding GSM/3G standards. So, for example, although the EMV standard allows a chip card to draw 50 mA from its terminal, cards are normally well below the telephone industry's 6 mA limit. This allows smaller and cheaper financial card terminals.

Chapter- 9

Z3 (computer)



Zuse Z3 replica on display at Deutsches Museum in Munich

The **Z3** was an electromechanical computer designed by Konrad Zuse. It was the world's first working programmable, fully automatic computing machine. It was Turing-complete, and by modern standards the Z3 was one of the first machines that could be considered a complete computing machine, although it lacked the conditional branch operation. The Z3 was built with 2,000 relays, implementing a 22 bit word length that operated at a clock frequency of about 5–10 Hz. Program code and data were stored on punched film.

The Z3 was completed in Berlin in 1941. The German Aircraft Research Institute used it to perform statistical analyses of wing flutter.

The original Z3 was destroyed in 1943 during an Allied bombardment of Berlin. A fully functioning replica was built in the 1960s by Zuse's company, Zuse KG, and is on permanent display in the Deutsches Museum.

Zuse asked the German government for funding to replace the relays with fully electronic switches, but funding was denied during World War II as "not war-important".

Design and development

Zuse designed the Z1 in 1935 to 1936 and built it from 1936 to 1938. The Z1 was wholly mechanical and only worked for a few minutes at a time at most. Helmut Schreyer advised Zuse to use a different technology. As a doctoral student at the Berlin Institute of Technology in 1937 he worked on the implementation of Boolean operations and (in today's terminology) flip-flops on the basis of vacuum tubes (valves). In 1938 Schreyer demonstrated a circuit on this basis to a small audience and explained his vision of an electronic computing machine – but since the largest operational electronic devices contained many fewer tubes this was considered practically unfeasible.

So Zuse decided to implement the next design based on relays. The realization of the Z2 was helped financially by Dr. Kurt Pennke, who manufactured small calculating machines. The Z2 was completed in 1939 and presented to an audience of the *Deutsche Versuchsanstalt für Luftfahrt* ("German Laboratory for Aviation") in 1940 in Berlin-Adlershof. Zuse was lucky – this presentation was one of the few instances where the Z2 actually worked and could convince the DVL to partly finance the next design.

Improving on the basic Z2 machine, he built the Z3 in 1941, which was a highly secret project of the German government. Dr. Jenissen, member of the Reich Air Ministry acted as a government supervisor for orders of the ministry to Zuse's company *ZUSE Apparatebau*.

The Z3 was completed in 1941 and was faster and far more reliable than the Z1 and Z2. The Z3 floating point was improved over that of the Z1 in that it implemented exception handling. The exceptional values plus infinity, minus infinity and undefined could be generated and passed through operations. The Z3 stored its program on an *external* tape, thus for reprogramming no rewiring was necessary to change programs.

On 12 May 1941 the Z3 was presented to an audience of scientists including the professors Alfred Teichmann and C. Schmieden of the *Deutsche Versuchsanstalt für Luftfahrt* ("German Laboratory for Aviation"), in Berlin.

Zuse moved onto the Z4 design; this was built as the war ended.

Relation to other work

The success of Zuse's Z3 is often attributed to its use of the simple binary system. This was invented roughly three centuries earlier by Gottfried Leibniz; Boole later used it to develop his Boolean algebra. In 1937, Claude Shannon of MIT introduced the idea of mapping Boolean algebra onto electronic relays in a seminal work on digital circuit design.

The United Kingdom's 10 codebreaking Colossus computers (1943) were the first electronic digital computers, other than the one-off Atanasoff–Berry Computer (1942). They used thermionic valves (vacuum tubes) and binary representation of numbers. Programming was by means of re-plugging patch panels and setting switches. This development was kept secret for many decades which led to claims of "firsts" in computing that later turned out to be incorrect.

The ENIAC was completed after the war. It used thermionic valves (vacuum tubes) to implement switches, and decimal representation for numbers. Until 1948 programming was, as for Colossus, by patch leads and switches.

The Manchester Baby of 1948 and the EDSAC of 1949 were the world's first computers with *internally* stored programs. They implemented a concept frequently (but erroneously) attributed to a 1945 paper of John von Neumann and colleagues. Von Neumann's own papers give proper credit to Alan Turing, and the concept had actually been mentioned earlier by Konrad Zuse himself, in a 1936 patent application (which was rejected).

Defining characteristics of some early digital computers of the 1940s (In the history of computing hardware)

Name	First operational	Numeral system	Computing mechanism	Programming	Turing complete
Zuse Z3 (Germany)	May 1941	Binary floating point	Electro-mechanical	Program-controlled by punched 35 mm film stock (but no conditional branch)	Yes (1998)
Atanasoff–Berry Computer (US)	1942	Binary	Electronic	Not programmable—single purpose	No
Colossus Mark 1 (UK)	February 1944	Binary	Electronic	Program-controlled by patch cables and switches	No
Harvard Mark I – IBM ASCC (US)	May 1944	Decimal	Electro-mechanical	Program-controlled by 24-channel punched paper tape (but no conditional branch)	No

Colossus Mark 2 (UK)	June 1944	Binary	Electronic	Program-controlled by patch cables and switches	No
Zuse Z4 (Germany)	March 1945	Binary floating point	Electro-mechanical	Program-controlled by punched 35 mm film stock	Yes
ENIAC (US)	July 1946	Decimal	Electronic	Program-controlled by patch cables and switches	Yes
Manchester Small-Scale Experimental Machine (Baby) (UK)	June 1948	Binary	Electronic	Stored-program in Williams cathode ray tube memory	Yes
Modified ENIAC (US)	September 1948	Decimal	Electronic	Read-only stored programming mechanism using the Function Tables as program ROM	Yes
EDSAC (UK)	May 1949	Binary	Electronic	Stored-program in mercury delay line memory	Yes
Manchester Mark 1 (UK)	October 1949	Binary	Electronic	Stored-program in Williams cathode ray tube memory and magnetic drum memory	Yes
CSIRAC (Australia)	November 1949	Binary	Electronic	Stored-program in mercury delay line memory	Yes

Relation to the concept of a universal Turing machine

It was possible to construct loops on the Z3, but there was no conditional branch instruction. Nevertheless, the Z3 was Turing-complete – how to implement a universal Turing machine on the Z3 was shown in 1998 by Raúl Rojas. He proposes that the tape program would have to be long enough to execute every possible path through both sides of every branch. It would compute all possible answers, but the unneeded results would be canceled out (a kind of speculative execution). Rojas concludes, "We can therefore say that, from an abstract theoretical perspective, the computing model of the Z3 is equivalent to the computing model of today's computers. From a practical perspective, and in the way the Z3 was really programmed, it was not equivalent to modern computers."

From a pragmatic point of view, however, the Z3 provided a quite *practical* instruction set for the typical engineering applications of the 1940s – Zuse was a civil engineer who only started to build his computers to facilitate his work in his main profession.

Specifications

- Average calculation Speed: Addition 0.8 seconds Multiplication 3 seconds
- Arithmetic Unit: Binary floating point, 22 bit, add, subtract, multiply, divide, square root
- Data memory: 64 words with a length of 22 bits
- Program memory: Punched celluloid tape
- Input: Decimal floating point numbers
- Output: Decimal floating point numbers
- Input and Output was facilitated by a terminal, that had a special keyboard and a row of lamps to show results
- Elements: Around 2,000 relays (1,400 for the memory)
- Frequency: 5.3 Hertz
- Power Consumption: Around 4000 watts
- Weight: Around 1,000 kilograms (2,200 lb)