Injector

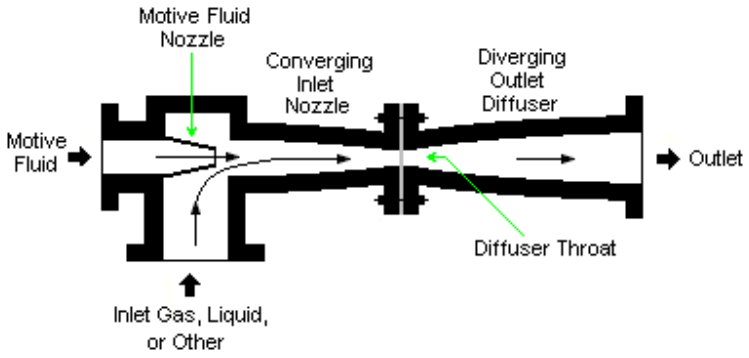


Diagram of a typical modern ejector.

An **injector**, **ejector**, **steam ejector**, **steam injector**, **eductor-jet pump** or **thermocompressor** is a pump-like device that uses the Venturi effect of a converging-diverging nozzle to convert the pressure energy of a motive fluid to velocity energy which creates a low pressure zone that draws in and entrains a suction fluid. After passing through the throat of the injector, the mixed fluid expands and the velocity is reduced which results in recompressing the mixed fluids by converting velocity energy back into pressure energy. The motive fluid may be a liquid, steam or any other gas. The entrained suction fluid may be a gas, a liquid, a slurry, or a dust-laden gas stream.[1] [2]

The adjacent diagram depicts a typical modern ejector. It consists of a motive fluid inlet nozzle and a converging-diverging outlet nozzle. Water, air, steam, or any other fluid at high pressure provides the motive force at the inlet.

An injector is a more complex device containing at least three cones. That used for delivering water to a steam locomotive boiler takes advantage of the release of the energy contained within the latent heat of evaporation to increase the pressure to above that within the boiler.

The Venturi effect, a particular case of Bernoulli's principle, applies to the operation of this device. Fluid under high pressure is converted into a high-velocity jet at the throat of the convergent-divergent nozzle which creates a low pressure at that point. The low pressure draws the suction fluid into the convergent-divergent nozzle where it mixes with the motive fluid.

In essence, the pressure energy of the inlet motive fluid is converted to kinetic energy in the form of velocity head at the throat of the convergent-divergent nozzle. As the mixed fluid then expands in the divergent diffuser, the kinetic energy is converted back to pressure energy at the diffuser outlet in accordance with Bernoulli's principle.

Depending on the specific application, an injector is commonly also called an *Eductor-jet pump, a water eductor*, a *vacuum ejector*, a *steam-jet ejector*, or an *aspirator*.

Key design parameters

The compression ratio of the injector, P_2/P_1, is defined as ratio of the injectors's outlet pressure P_2 to the inlet pressure of the suction fluid P_1.
The entrainment ratio of the injector, W_s/W_v, is defined as the amount of motive fluid W_s (in kg/hr) required to entrain and compress a given amount W_v (in kg/hr) of suction fluid..
The compression ratio and the entrainment ratio are key parameters in designing an injector or ejector.

History

The injector was invented by a Frenchman, Henri Giffard in 1858[3] and patented in the United Kingdom by Messrs Sharp Stewart & Co. of Glasgow. Motive force was provided at the inlet by a suitable high-pressure fluid.

Feedwater injectors

The injector was originally used in the boilers of steam locomotives for injecting or pumping the boiler feedwater into the boiler. The injector consisted of a body containing a series of three or more nozzles, "cones" or "tubes". The motive steam passed through a nozzle that reduced its pressure below atmospheric and increased the steam velocity. Fresh water was entrained by the steam jet, and both steam and water entered a convergent "combining cone" which mixed them thoroughly so that the water condensed the steam. The condensate mixture then entered a divergent "delivery cone" which slowed down the jet, and thus built up the pressure to above that of the boiler. An overflow was required for excess steam or water to discharge, especially during starting. There was at least one check valve between the exit of the injector and the boiler to prevent back flow, and usually a valve to prevent air being sucked in at the overflow.

After some initial skepticism resulting from the unfamiliar and superficially paradoxical mode of operation, the injector was widely adopted as an alternative to mechanical pumps in steam-driven locomotives. The injectors were simple and reliable, and they were thermally efficient.

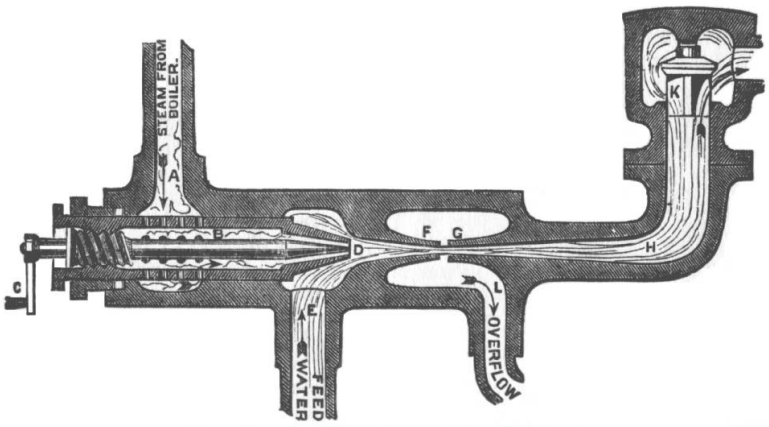
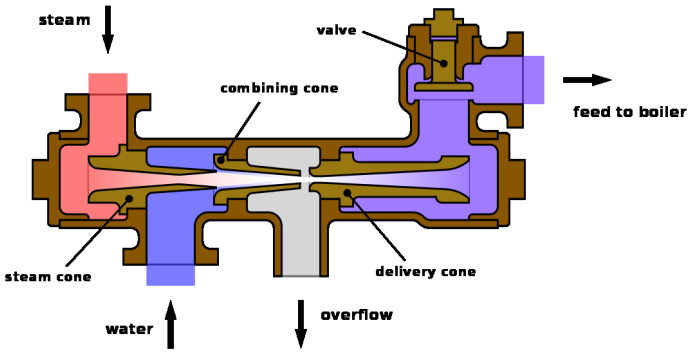


FIG. 6.— *Section of Giffard's Injector.*

A- Steam from boiler, B- Needle valve, C- Needle valve handle, D- Steam and water combine, E- Water feed, F- Combining cone, G- Delivery nozzle and cone, H- delivery chamber and pipe, K- Check valve



A more modern drawing of the injector used in steam locomotives.

Steam injector of a steam locomotive boiler.

Efficiency was further improved by the development of a multi-stage injector which was powered not by live steam from the boiler but by exhaust steam from the cylinders, thereby making use of the residual energy in the exhaust steam which would otherwise have gone to waste.

Vacuum ejectors

An additional use for the injector technology was in vacuum ejectors in continuous train braking systems, which were made compulsory in the UK by the Regulation of Railways Act 1889. A vacuum ejector uses steam pressure to draw air out of the vacuum pipe and reservoirs of continuous train brake. Steam locomotives, with a ready source of steam, found ejector technology ideal with its rugged simplicity and lack of moving parts. Vacuum brakes have been superseded by air brakes in modern trains, which use pumps, as diesel and electric locomotives no longer have a suitable working fluid for vacuum ejectors.

Modern uses

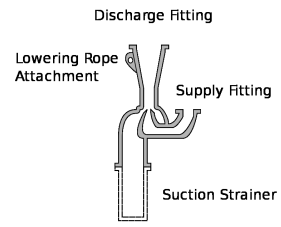
The use of injectors (or ejectors) in various industrial applications has become quite common due to their relative simplicity and adaptability. For example:

- To inject chemicals into the boiler drums of small, stationary, low pressure boilers. In large, high-pressure modern boilers, usage of injectors for chemical dosing is not possible due to their limited outlet pressures.
- In thermal power stations, they are used for the removal of the boiler bottom ash, the removal of fly ash from the hoppers of the electrostatic precipitators used to remove that ash from the boiler flue gas, and for creating a vacuum pressure in steam turbine exhaust condensers.
- Jet pumps have been used in boiling water nuclear reactors to circulate the coolant fluid.[4]
- For use in producing a vacuum pressure in steam jet cooling systems.
- For the bulk handling of grains or other granular or powdered materials.
- The construction industry uses them for pumping turbid water and slurries.
- Some aircraft (mostly earlier designs) use an ejector attached to the fuselage to provide vacuum for gyroscopic instruments such as an attitude indicator.

Similar devices called aspirators based on the same operating principle are used in laboratories to create a partial vacuum and for medical use in suction of mucus or bodily fluids.

Well Pumps

Jet pumps are commonly used to extract water from water wells. A powered pump, often a centrifugal pump, is installed at ground level. Its discharge is split, with the greater part of the flow leaving the system, while a portion of the flow is returned to the jet pump installed below ground in the well. This recirculated part of the pumped fluid is used to power the jet. At the jet pump, the high-energy, low-mass returned flow drives more fluid from the well, becoming a low-energy, high-mass flow which is then piped to the inlet of the main pump.



The S type pump is useful for removing water from a well or container.

Shallow well pumps are those in which the jet assembly is attached directly to the main pump and are limited to a depth of approximately 5-8m to prevent cavitation.

Deep well pumps are those in which the jet is located at the bottom of the well. The maximum depth for deep well pumps is determined by the inside diameter of and the velocity through the jet. The major advantage of jet pumps for deep well installations is the ability to situate all mechanical parts (e.g. electric/petrol motor, rotating impellers) at the ground surface for easy maintenance. The advent of the electrical submersible pump has partly replaced the need for jet type well pumps, except for driven point wells or surface water intakes.

Multi-stage steam ejectors

In practice, for suction pressure below 100 mbar absolute, more than one ejector is used, usually with condensers between the ejector stages. Condensing of motive steam greatly improves ejector set efficiency; both barometric and shell-and-tube surface condensers are used.

Construction materials

Injectors or ejectors are made of carbon and stainless steel, titanium, PTFE, carbon and other materials.

References

[1] Perry, R.H. and Green, D.W. (Editors) (2007). *Perry's Chemical Engineers' Handbook* (8th Edition ed.). McGraw Hill. ISBN 0-07-142294-3.

[2] Power, Robert B. (1993). *Steam Jet Ejectors For The Process Industries* (First Edition ed.). McGraw-Hill. ISBN 0-07-050618-3.

[3] Strickland L. Kneass (1894). *Practice and Theory of the Injector*. John Wiley & Sons (Reprinted by Kessinger Publications, 2007). ISBN 0-548-47587-3.

[4] "Steam-assisted jet pump" (http://www.freepatentsonline.com/4847043.html). General Electric. . Retrieved 17 March 2011. "United States Patent 4847043 ... recirculation of a coolant in a nuclear reactor"

Additional reading

- J.B. Snell (1973). *Mechanical Engineering: Railways*. Arrow Books. ISBN 0-09-908170-9.
- J.T. Hodgson and C.S. Lake (1954). *Locomotive Management* (Tenth Edition ed.). Tothill Press.

External links

- Use of Eductor for Lifting Water (http://www.muleshoe-eng.com/sitebuildercontent/sitebuilderfiles/Eductor.pdf)

Article Sources and Contributors

Injector *Source*: http://en.wikipedia.org/w/index.php?oldid=419244316 *Contributors*: 7severn7, 84user, Andy Dingley, Anthony Appleyard, Atlant, Bergsten, Bermicourt, CZmarlin, Claush66, DA3N, DePiep, Die Oubaas, Dore chakravarty, E Wing, Ellehammer1904, France3470, GS3, Gertdam, Globbet, H Padleckas, HarryHenryGebel, Hellbus, Hrm3319, Incompetence, Interiot, Inwind, JohJak2, Kelly Martin, Ketiltrout, Kkmurray, KnowledgeOfSelf, LilHelpa, LouisCYUL, Lvranek, Magioladitis, Mbeychok, Miwanya, Nilsrk, Per Honor et Gloria, Peridon, PhilKnight, Pol098, Postrach, RJFJR, Rpresser, Rsajan1, Sabergum, Sean Whitton, SimonP, Sobhuev, Stahlkocher1, User A1, Varano, Velella, Wikiborg, Zhangzhe0101, 32 anonymous edits

Image Sources, Licenses and Contributors

Image:Ejector or Injector.png *Source*: http://en.wikipedia.org/w/index.php?title=File:Ejector_or_Injector.png *License*: GNU Free Documentation License *Contributors*: Original uploader was Mbeychok at en.wikipedia

Image:Injector Giffard-02.jpg *Source*: http://en.wikipedia.org/w/index.php?title=File:Injector_Giffard-02.jpg *License*: Public Domain *Contributors*: Robert Routledge

Image:Boiler Feed Injector Diagram.svg *Source*: http://en.wikipedia.org/w/index.php?title=File:Boiler_Feed_Injector_Diagram.svg *License*: Creative Commons Attribution-Sharealike 3.0 *Contributors*: User:Globbet

Image:Injektor Dampfstrahlpumpe.jpg *Source*: http://en.wikipedia.org/w/index.php?title=File:Injektor_Dampfstrahlpumpe.jpg *License*: GNU Free Documentation License *Contributors*: Andy Dingley, Kneiphof, Stahlkocher, Sv1xv

File:S Eductor pump.svg *Source*: http://en.wikipedia.org/w/index.php?title=File:S_Eductor_pump.svg *License*: unknown *Contributors*: User:Egmason

License