Case Study: Marotta Scientific Controls, Inc. provides an oxygen system relief valve solution for NASA's Stennis Space Center.

Overview: Stennis Space Center had encountered serious problems with relief valves on its oxygen system. Valve oscillation was a major concern due to associated heat of compression of the oxygen and risk of fire.

Stennis published a Small Business Innovative Research (SBIR) topic, soliciting proposals from qualified small businesses that could provide a solution. Marotta Scientific Controls, Inc. successfully submitted a proposal for Phase I, during which a detailed study of the problem was performed, and a proposed solution proposed for Phase II prototype hardware.

Marotta used its extensive knowledge of valve design and fluid-system dynamics to develop a relief valve that would have the following characteristics:

- No oscillation throughout the open-reseat cycle
- Provide excellent, repeatable control, with a tight "open/reseat" band
- Offer a tight band between open and reseat

Marotta analyzed relief valve designs on the market and determined the cause of instability (chatter) was their use of downstream pressure sensing in controlling the valve. Pressure immediately downstream of the valve seat is unstable, translating into unstable opening and closing of the valves. By moving the pressure sensing area upstream of the valve seat, Marotta was able to produce a valve that had smooth, consistent operating characteristics.

This valve is to be ASME qualified in the near future, offering the advantages of upstream control in a compact package to the industrial community at large.

The following article was published in the March 1999 issue of NASA Tech Briefs. Peter A. Tartaglia, Brian L. Magnone, Larry Rayhon, and Richard Molesworth of Marotta Scientific Controls, Inc. were awarded a patent for their work in developing this relief valve.

Marotta has successfully applied the seat design used in this relief valve to high-pressure air regulators that are considerably more tolerant of contamination than a typical soft seat design.

This article is from the March 1999 issue of NASA Tech Briefs, and can be accessed by the following URL:

http://www.nasatech.com/Briefs/Mar99/SSC00073.html

Stable, Soft-Opening/Soft-Closing Pressure-Relief Valves

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The risk of ignition in systems containing oxygen is reduced.

Stennis Space Center, Mississippi

Improved pressure-relief valves have been developed for systems that contain gases and liquids in a variety of pneumatic, hydraulic, and cryogenic applications. These valves could prove especially beneficial in both cryogenic and noncryogenic systems that contain oxygen. The improved valves are designed to suppress instabilities that shorten operational lifetimes and create hazards in the operation of older pressure-relief valves.

A typical older pressure-relief valve exhibits instability that can result in oscillation ("chatter"), which degrades the valve beyond the normal anticipated wear of parts. Oscillation can result in hard impact; in the presence of oxygen, hard impact can lead to ignition, with resultant catastrophic failure of the valve and possibly of the entire system. A valve of the present improved type is stable over its entire operational range from fully closed to fully open. It does not oscillate or generate hard impacts; instead, it opens and closes softly.

The key to stable, soft-opening/soft-closing operation is a concept of upstream control. A conventional "pop"-type pressure-relief valve is characterized as operating under downstream control: Once the valve has opened, the flow is controlled mainly by an effective cross-sectional area downstream of the valve seat. In a valve of the improved type, the flow-limiting cross section remains upstream of the valve seat at all times, and so the valve is said to operate under upstream control.

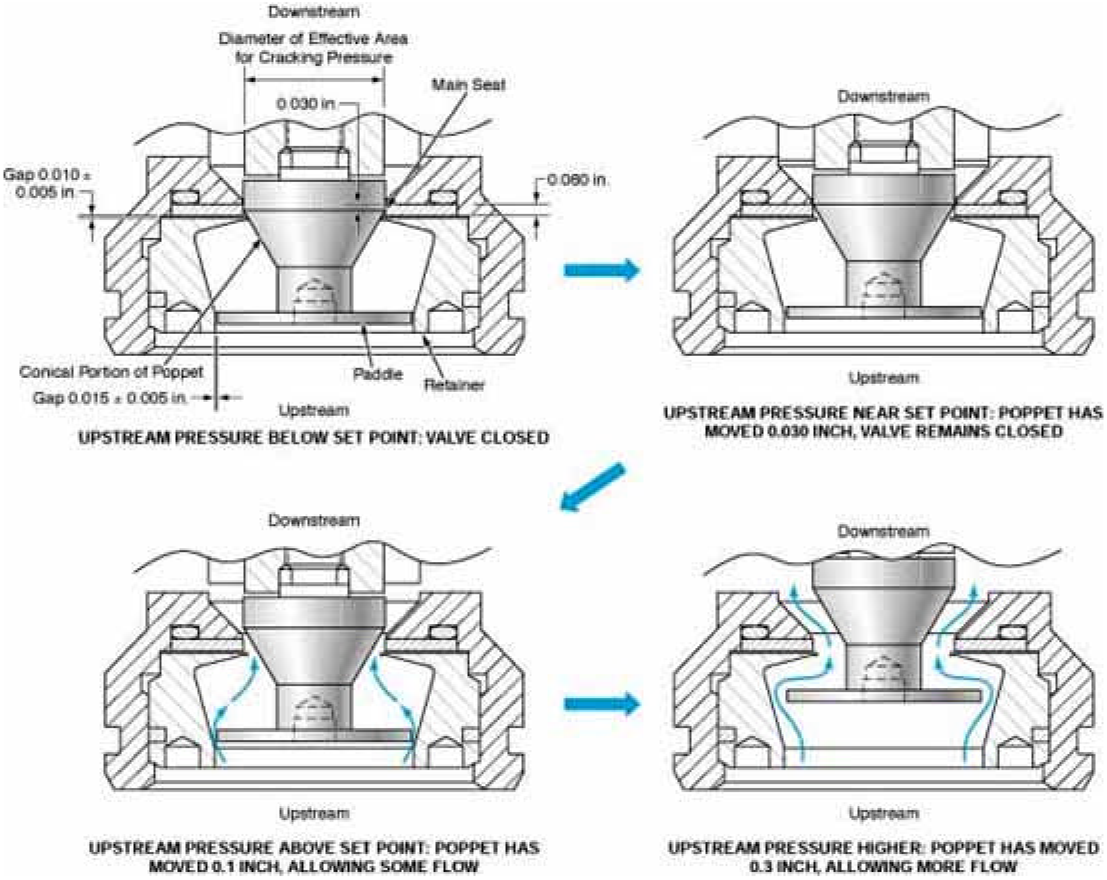
The figure illustrates the basic design and principle of operation of a valve of the improved type. As in a conventional relief valve, excessive upstream pressure opens the valve by lifting of a poppet from a seat in a valve body; however, the similarity with a conventional pressure-relief valve ends here. The poppet in the improved valve includes a conical portion and a paddle (essentially a disk) upstream of the conical portion. When the valve is closed and the upstream pressure is below the set point, the conical portion of the poppet engages about half the thickness of a main valve seat, forming a tight seal. In this condition, the paddle engages the wall of a cylindrical passage upstream of the main valve seat.

When the upstream pressure rises to approximately the set point, the poppet moves downstream a little, but the valve is not yet open; the conical portion of the poppet remains partly engaged with the main valve seat, while the paddle remains in the cylindrical passage in the retainer. As the pressure rises above the set point, the conical portion of the poppet moves out of the main valve seat and the paddle moves out of the cylindrical passage in the retainer. To ensure upstream control, the area of the annular opening between the main seat and the conical poppet surface must be made larger than the area of the annular opening between the paddle and the retainer; for this purpose, the angle of the conical inner valve-body surface immediately downstream of the main valve seat must be made greater than the angle of the conical inner valve-body surface immediately downstream of the cylindrical passage in the retainer.

The advantages of upstream control are:

- There are no adjustments other than the set point;
- There is a smooth transition from the fully closed to the fully open valve condition because there is minimal variation in density of fluid over a wide range of flow, and
- The upstream-control concept is amenable to mathematical modeling because the basic valve geometry (except for specific dimensions) is fixed. A user-friendly computer program based on a mathematical model of the valve dynamics can be used to design and select valves of this type for specific applications.

The improved valves offer several advantages over older pressure-relief valves, in addition to those mentioned above. Noise and wear are reduced through elimination of chatter. The risk of fire and explosion is reduced through elimination of hard impact, and the risk of uncontrolled venting of hazardous fluids is correspondingly reduced. Increased stability yields better performance, with wider operating ranges and better control. The basic valve design can be implemented in cartridge versions, so that it becomes unnecessary to remove entire valves from plumbing systems for overhaul or repair. The foregoing advantages translate to the additional advantage of lower life-cycle costs.



UPSTREAM PRESSURE BELOW SET POINT: VALVE CLOSED

UPSTREAM PRESSURE NEAR SET POINT: POPPET HAS MOVED 0.030 INCH, VALVE REMAINS CLOSED

UPSTREAM PRESSURE ABOVE SET POINT: POPPET HAS MOVED 0.1 INCH, ALLOWING SOME FLOW

UPSTREAM PRESSURE HIGHER: POPPET HAS MOVED 0.3 INCH, ALLOWING MORE FLOW

This **Valve Operates Under Upstream Control** in the sense that the flow-constricting cross section is the annulus between the paddle and retainer, upstream from the annulus between the poppet cone and the main valve seat. The few dimensions shown here are typical only; the dimensions for a specific application are chosen, with the help of a mathematical model of valve dynamics, to obtain stable operation.

This work was done by Peter A. Tartaglia, Brian L. Magnone, Larry Rayhon, and Richard Molesworth of Marotta Scientific Corp. for **Stennis Space Center.**

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to SSC-00073, volume and number of this NASA Tech Briefs *issue, and the page number.*