

Solenoid Valves and Their Importance in Refrigeration Systems

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Overview

Introduction

Solenoid valves play an important role within refrigeration and air conditioning systems, controlling the flow of refrigerants. Though their base function – turning the refrigerant flow on and off – is quite simple, this function is key to ensuring system performance.

Understanding how solenoid valves work increases the likelihood that contractors will install, remove and reinstall valves correctly, ensuring optimum system performance and protection.

Contents

This paper contains the following topics:

Topic	Page
Basic operation of solenoid valves	1
Solenoid-valve types	2
Mechanical construction	4
Coils	5
Temperature ratings.....	6
Elastomers	8
Solenoid-valve applications	9
Maximum operating-pressure differential	12
Conclusion	12
About Emerson Climate Technologies	13
About the author of this paper	13

Basic operation of solenoid valves

Definitions

A **solenoid** is a simple form of an electromagnet consisting of a coil of insulated copper wire.

A **solenoid valve** is an electromechanical valve frequently used to control the flow of liquid or gas.

Function

Solenoid valves are found in many applications and are commonly used in refrigeration and air conditioning systems. Their function is simply to turn refrigerant flow on and off.

Benefits

Solenoid valves offer fast and safe switching, reliability, long life and compact design.

Operation

A solenoid valve operates in the following way:

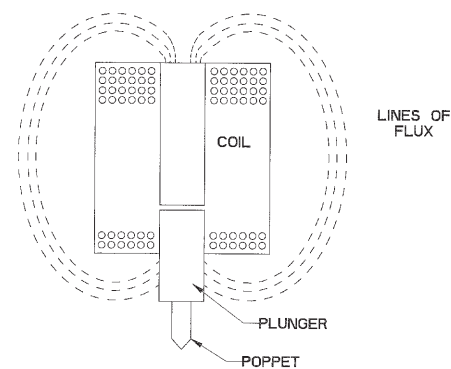
Stage	Description
1	When the solenoid coil is electrically energized, it produces a magnetic field that attracts iron and many of its alloys.
2	An iron armature or plunger (shown in Figure 1) is drawn up into the core of the solenoid.
3	A stem and pin or poppet attached to this plunger opens the valve port.
4	When the solenoid valve is de-energized, the plunger falls, and the poppet closes the valve port.

Note: This magnetic principle constitutes the basis of design for all solenoid valves.

Diagram of solenoid valve

Figure 1 shows the parts of a solenoid valve.

Figure 1



Role in system performance

Because solenoid valves are electrically operated, their on-off function can be controlled automatically by suitable control systems. This function is extremely important, in terms of system performance.

Solenoid-valve types

Introduction

Solenoid valves can generally be divided into two types:

- Direct acting
- Pilot operated

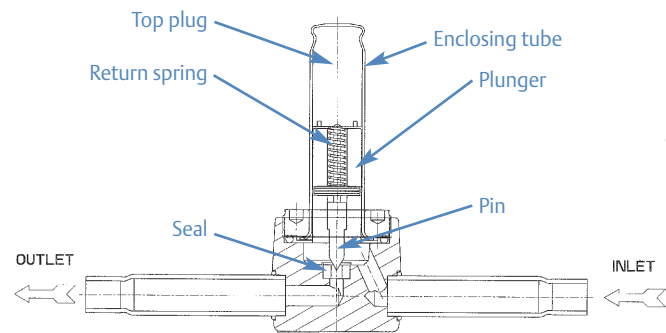
Direct-acting solenoid-valve operation

In a direct-acting solenoid valve, the pull of the coil opens the valve port directly, by lifting the pin off the valve seat.

Diagram of direct-acting solenoid valve

Figure 2 shows the parts of a direct-acting solenoid valve.

Figure 2
Direct Acting



Direct-acting port size limitation

Because a direct-acting solenoid valve depends on the power of the coil for operation, its port size for a given operating-pressure differential is limited by the practical limitations of the coil size.

Direct-acting solenoids are limited to smaller port sizes, below $\frac{1}{4}$ -inch diameter.

Pilot-operated solenoid-valve operation

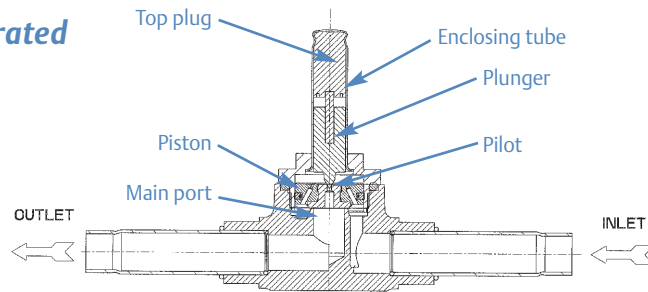
In a pilot-operated solenoid valve, the plunger does not open the main port directly. Instead, the following operation occurs:

Stage	Description
1	The plunger opens a pilot port.
2	Pressure on top of a piston is released through the pilot port, thus creating a pressure imbalance across the piston.
3	With the pressure underneath the piston now greater than the pressure on top, the piston will move in an upward direction, opening the main port.
4	When the plunger drops, it closes the pilot port; thus, the pressure above and below the piston equalizes, and the piston closes the main port.
5	The pressure difference across the valve, acting on the area of the main port, holds the piston in a tightly closed position.

Diagram of pilot-operated solenoid valve

Figure 3 shows the parts of a pilot-operated solenoid valve.

Figure 3
Pilot Operated



Risk of oversized pilot-operated valve

With a pilot-operated valve, there is a minimum operating-pressure differential (minOPD) required for the piston to stay open. If the valve is oversized for the application, then the minOPD may not be achieved, resulting in a valve that will not open or will fail to stay open.

Mechanical construction

Introduction

The basic principles of operation hold true for all refrigerant solenoid valves, although certain mechanical variations in construction can be found.

Common variations

Common examples of mechanical variations include:

- **Short-stroke plungers:** The plunger is rigidly connected to the valve needle or poppet.
 - **Long-stroke/lost-motion plungers:** During opening the plunger imparts a “hammer blow” to the valve stem.
 - **Diaphragm valves:** A diaphragm is used instead of a piston.
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Installation position

Solenoid valves with a spring-loaded plunger or diaphragm may be installed in any position; however, older-style solenoid valves that utilize a plunger dependent on gravity to close must be installed with the plunger in an upright, vertical position.

Normally closed or open solenoids

The most common type of solenoid is the **normally closed** type. When the coil is energized, the valve opens. When power is removed, the valve closes.

In a **normally open** solenoid, the valve closes when power is applied to the coil and opens when the coil is de-energized.

Coils

Description

Coils used in refrigeration applications are usually encapsulated, providing better protection against environmental extremes and longer life. In this coil type, the magnet wire is wound in layers over a nylon bobbin. This assembly is then completely molded or cast over all exposed portions. The most common encapsulants used for coils are epoxy formulations.

Advantages of encapsulation

Advantages of encapsulated coils include:

- Outstanding dimensional stability
- Cleaner appearance
- Moisture resistance
- Abrasion resistance
- Shock resistance
- Electrical strength
- Thermal dissipation

Life expectancy and temperature

The life expectancy of a coil assembly is usually considered to be a function of temperature. If the coil is operated within its design limits, then it will provide many years of acceptable life. As a rule of thumb, for every 10 degrees Celsius operation above the limiting coil temperature, the life expectancy decreases by 50 percent.

Caution: Remove power before disassembly

Any coil that is energized when not assembled to a valve will draw high currents, consequently becoming very hot. Continued operation in this manner will cause the coil to fail in a short period of time; therefore, it is important for the service person to make certain that power is removed from the coil before disassembling the coil from its valve.

Dual-frequency coils

Coils can be wound to operate on dual frequency (50 to 60 Hertz [Hz]). If such a coil is operated on 50 Hz, it will draw more power than when used at 60 Hz. It will also generate more heat than if used at 60 Hz.

Temperature ratings

Introduction

Solenoid coils are classified by their insulating materials with regard to coil-temperature rise. The maximum permissible temperature that can be tolerated is limited by the type of insulation and materials used in the construction of the coil assembly.

Temperature limitations of insulation classes

There are three classes of insulation commonly used for refrigeration coils. These are referred to as Class F, H and N. The temperature limitations of these classes are set by various standards associations (UL, CSA, etc.) and are as follows:

Table 1

Class	Maximum temperature rise	
	°F	°C
F	171	95
H	207	115
N	243	135

Safety warning: Hot coils

Regardless of which class insulation is used, the surface of the coil can become too hot to be safely touched by hand, even though the temperature is within the design limits of the insulation system. For this reason, solenoid coils should be located to avoid accidental human contact.

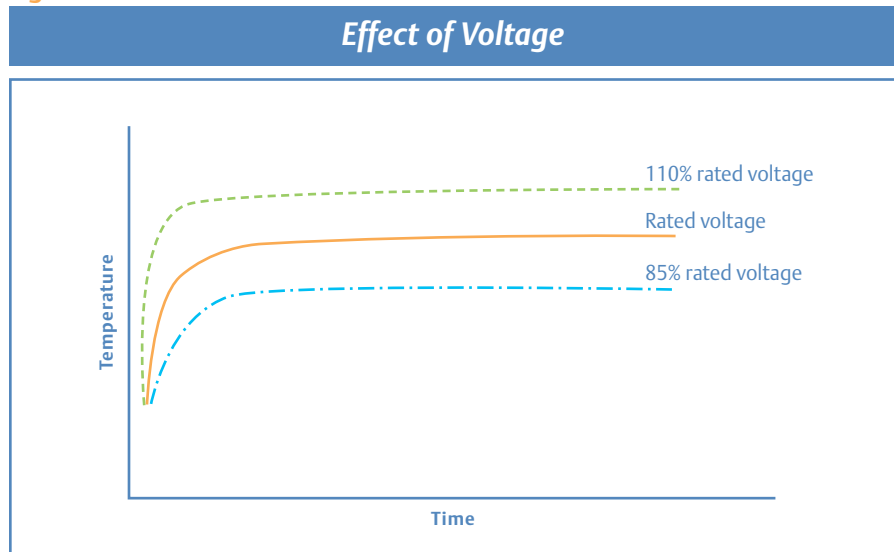
Other temperature factors

Other factors that affect solenoid-coil temperature include voltage, ambient fluid temperature and frequency. These are depicted in the following diagrams.

Effect of voltage

Figure 4 shows the effect of voltage on solenoid-coil temperature.

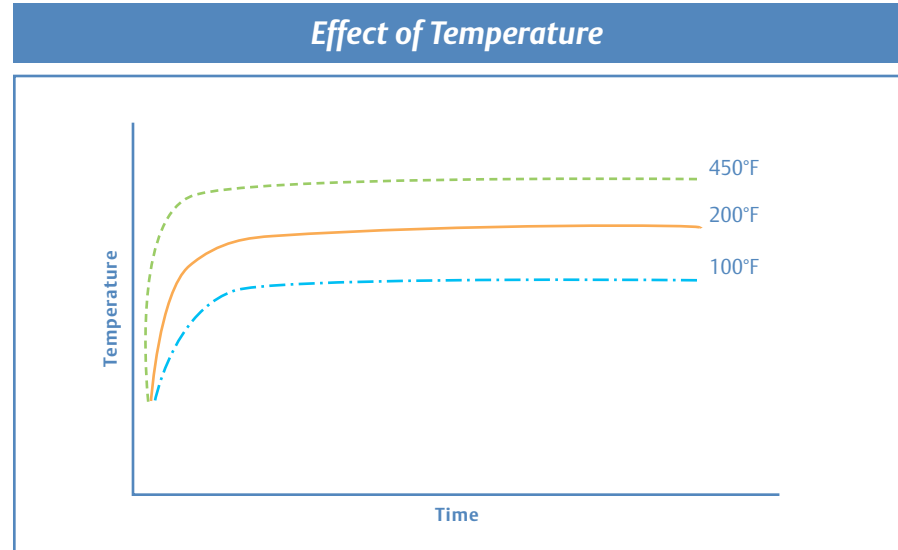
Figure 4



Effect of temperature

Figure 5 shows the effect of temperature on solenoid-coil temperature.

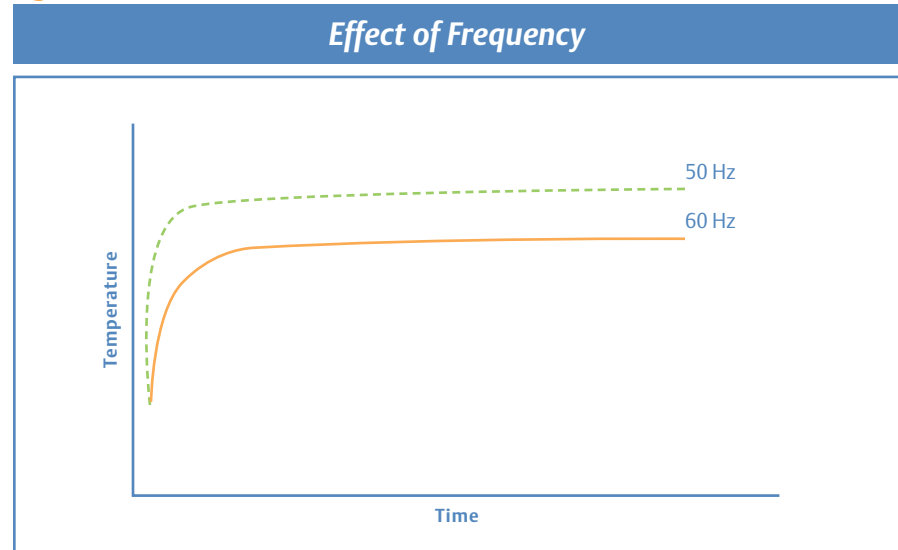
Figure 5



Effect of frequency

Figure 6 shows the effect of frequency on solenoid-coil temperature.

Figure 6



Elastomers

Definition

An elastomer, by American Society for Testing and Materials (ASTM) standards, is defined as “a substance that can be stretched at room temperature to at least twice its original length and, after having been stretched and the stress removed, returns with force to approximately its original length in a short period of time.”

Use with solenoid valves

Elastomers are used in solenoid valves for many different functions, including:

- O-rings
- Gaskets
- Piston rings
- Diaphragms
- Seats

Refrigeration applications

Elastomers used for refrigeration applications include neoprene and polytetrafluoroethylene (PTFE). A glass-filled PTFE (Rulon®) is also used in many instances in which a harder material is required.

Solenoid-valve applications

Introduction

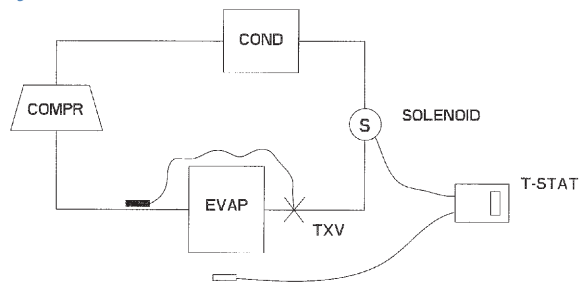
Solenoid valves are used for controlling refrigerants in liquid or suction lines or in hot-gas lines. Some common applications for solenoid valves are:

- Pump-down cycle
- Temperature control of separate units in a multiple system
- Suction applications
- Compressor unloading
- Hot-gas bypass
- Hot-gas defrost

Pump-down cycle

In the pump-down cycle application, the solenoid valve is installed in the main liquid line and wired so that it closes whenever the thermostat is satisfied. A low-pressure control valve allows the refrigerant in the evaporator to be “pumped down” (see Figure 7).

Figure 7
Pump-Down Cycle

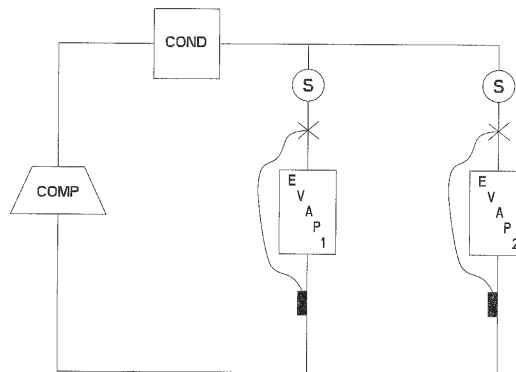


Note: This type of cycle is ideal in systems with large charges, because it prevents the possibility of the compressor starting with a large amount of liquid in the evaporator.

Temperature control of separate units in a multiple system

Figure 8 illustrates how the temperature of a single unit in a multiple system can be controlled by a thermostat operating a solenoid valve in the liquid line to that unit.

Figure 8
Multiple Systems



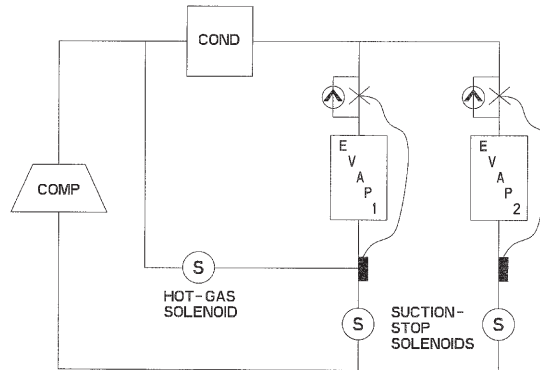
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Solenoid-valve applications (continued)

Suction applications

In a suction application, the solenoid valve provides complete isolation for temperature control and defrosting, or operates as a suction bypass on installations with two or more evaporators in a series fed by one expansion valve (see Figure 9).

Figure 9
Suction-Stop Solenoid Valves



Note: When used in suction applications, a valve with a low pressure drop should be used (less than two pounds-per-square-inch differential [psid]). Piston-type pilot valves often have a minOPD that exceeds this. For this reason, diaphragm valves are recommended for suction service.

Compressor unloading

Solenoid valves can be used to “unload” compressors in a variety of ways. The most common method works as follows:

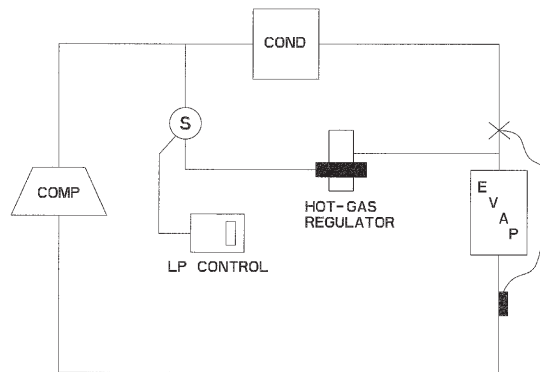
Stage	Description
1	A solenoid is employed to divert discharge pressure to a piston that, when activated, “blocks” the suction valve in an open position.
2	With the valve blocked open, no compression takes place in that cylinder.
3	This lack of compression results in a drop in capacity.

Hot-gas bypass

The compressor capacity can be reduced by bypassing the hot discharge gas through a solenoid directly to the suction line. A desuperheating valve must be used in this type of system, to prevent the compressor from overheating and tripping its internal protector.

As shown in Figure 10, an alternate approach is to feed the discharge gas to the inlet of the evaporator. As the evaporator warms up, the thermostatic expansion valve (TXV) will respond by allowing more flow, thereby acting as a desuperheating valve. This approach is preferred, as it maintains good velocity through the evaporator and prevents oil logging.

Figure 10
Hot-Gas-Bypass Capacity Control

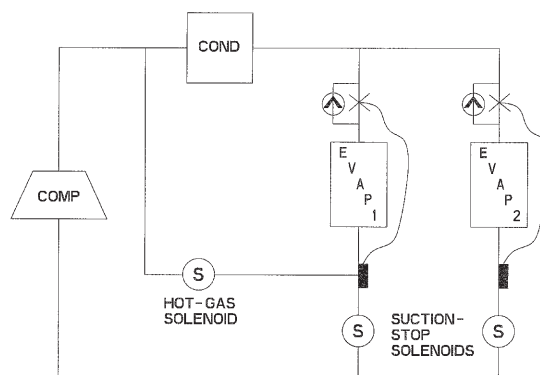


Hot-gas defrost

When defrost is required, the solenoid in the hot-gas-bypass system opens. This allows discharge gas to go to the evaporator, thereby defrosting the coil (see Figure 11).

A suction-stop solenoid is also needed in this system, to isolate the discharge from going right back to the compressor.

Figure 11
Hot-Gas Defrost



Maximum operating-pressure differential

Introduction

Solenoid valves are rated in terms of maximum operating-pressure differential (MOPD) against which the valves will open.

Example

With the solenoid valve closed against an inlet pressure of 250 pounds-per-square-inch gauge (psig) and outlet pressure of 50 psig, the pressure differential is 250 minus 50, or 200 pounds per square inch (psi).

Rating for proper operation

The MOPD rating of the valve must be equal to or greater than 200 psi, if the valve is to open properly.

Factors affecting rating

The temperature of the coil windings and the actual applied voltage are prime factors affecting the MOPD rating. The MOPD is reduced as the coil temperature increases or the applied voltage is lowered.

The MOPD ratings listed in solenoid manufacturers' catalogs are determined by operating the valve with 85 percent of rated coil voltage applied to the coil after the solenoid coil has attained its maximum temperature under full rated voltage.

Conclusion

Solenoid valves in refrigeration systems

Although the solenoid valve's primary function within refrigeration systems – turning refrigerant flow on and off – seems simple enough, this function can be quite complex and is essential in terms of ensuring correct installation, service and benefits.

Ensuring correct installation and service

Knowing how the solenoid valve works increases the likelihood that contractors will install the valves correctly and in a way that ensures optimum system performance.

This information will also aid service technicians who may have to remove the valves to service the system, allowing them to correctly do so and then protect the system by correctly reinstalling the valves.

Ensuring refrigeration-system benefits

The solenoid valve is a vital component in any refrigeration system. Knowing how it works helps to ensure system benefits, such as energy efficiency, leak prevention and overall system protection.

About Emerson Climate Technologies

HVACR solutions leader

Emerson Climate Technologies is the world's leading provider of heating, ventilation, air conditioning and refrigeration solutions for residential, industrial and commercial applications. Best-in-class technology is combined with proven engineering, design, distribution, educational and monitoring services to provide customized, integrated climate-control solutions for customers worldwide. Emerson Climate Technologies is committed to working with contractors and manufacturers to provide global solutions to improve human comfort, safeguard food and protect the environment.

Emerson Climate Technologies – Flow Controls division

Emerson Climate Technologies – Flow Controls division is the leading provider of precision mechanical and electromechanical controls for air conditioning and refrigeration systems. The group designs innovative refrigerant flow products, moisture indicators, filter driers and oil controls for the HVACR industry that make contractors' jobs easier, saving them time and money.

Emerson® solenoid valves

The Emerson® solenoid-valve offering plays an important role in the performance of air conditioning and refrigeration systems. As part of Emerson's commitment to the industry, each valve undergoes stringent Emerson testing to ensure fail-safe operation. And, with the lowest external leak rates in the industry, Emerson solenoid valves ensure precise refrigerant flow, preventing system failures and aiding in environmental protection.

More information

For more information, visit Emersonflowcontrols.com.

About the author of this paper

Al Maier

Al Maier is vice president of application engineering for Emerson Climate Technologies – Flow Controls division, with more than 30 years of refrigeration systems and components design experience. He held several positions at Emerson Climate Technologies, Inc. (formerly Copeland Corporation), including director of application engineering, general manager and engineering manager of the condensing unit division. Al has an associate's degree in electronics technology from the Academy of Aeronautics and a bachelor of science degree in engineering from Long Island University. He is a member of ASHRAE (American Society of Heating, Refrigerating & Air Conditioning Engineers) and chairman of the engineering committee of ARI's (Air-Conditioning and Refrigeration Institute) valves and accessories section.

About Emerson

Emerson (NYSE: EMR), based in St. Louis, is a global leader in bringing technology and engineering together to provide innovative solutions to customers through its network power, process management, industrial automation, climate technologies, and appliance and tools businesses. Sales in fiscal 2006 were \$20.1 billion. For more information, visit **GoToEmerson.com**.

About Emerson Climate Technologies

Emerson Climate Technologies, a business of Emerson, is the world's leading provider of heating, ventilation, air conditioning and refrigeration solutions for residential, industrial and commercial applications. The group combines best-in-class technology with proven engineering, design, distribution, educational and monitoring services to provide customized, integrated climate-control solutions for customers worldwide. Emerson Climate Technologies' innovative solutions, which include industry-leading brands such as Copeland Scroll and White-Rodgers, improve human comfort, safeguard food and protect the environment. For more information, visit **EmersonClimate.com**.

About Emerson Climate Technologies – Flow Controls division

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