PWM SOLENOID EXPANSION VALVE WITH INTERCHANGEABLE ORIFICE

APPLICATION

Solenoid expansion valve Castel type 2028 regulates the refrigerant flow into the evaporator by modulating the opening time phase of the plug and so permitting a wide range of power.
This valve must be used with a coil type HM4 (see table 2), controlled by an electronic regulator device (not supplied by Castel).
This valve is most frequently used in refrigeration systems, in particular refrigerated cabinets in the supermarket, which use the following refrigerant fluids: R22, R134a, R404A, R407C ; R410A, R507 proper to the Group II (as defined in Article 9, Section 2.2 of Directive 97/23/EC and referred to in Directive 67/548/EEC).

OPERATION

Valve type 2028 is a lamination device that receives liquid from the condenser and injects it into the evaporator, operating the necessary pressure drop across the expansion orifice.
It's an ON/OFF valve that must be regulated with the **Pulse Width Modulation** (PWM) method and it can be actuated by a very simple electronic controller. In according to the PWM method, the evaporator refrigerant capacity QT, required in a fi xed period "T", is delivered by the valve in a time interval "t", shorter than "T". During the period "t" the valve opens and permits maximum flow (ON phase); in the remaining period "T-t" the valve closes with no flow (OFF phase).
For an effective PWM regulation, the valve must be sized in such a way that in the hardest conditions of the system, the orifice of the valve is big enough to deliver the refrigerant requested; in these extreme conditions the valve will last opened for the entire period "T".
The use of an electronic regulator allows a more accurate metering of the refrigerant reaching a greater efficiency (and then a sensible decrement of the machinery management costs) and a faster response to the variations of the evaporation load.

CONSTRUCTION

Valve is supplied complete with its orifice; there are nine different orifices corresponding to seven different evaporator capacities that increase passing from orifice 01 to orifice 09. The last two numbers in the code identify what size of orifice has been mounted on the valve into the factory; for example the code 2028/3S02 identifies a valve with 3/8" solder connections, size 02 orifice. The orifices are interchangeable and can be mounted even if the valve is soldered on the system; in this case use the corresponding spare parts kit, in according to table 3.

The main parts of the valves are made with the following materials:

- Hot forged brass EN 12420 – CW 617N for body and the housing pipe of the mobile plug
- Copper tube EN 12735-1 – Cu-DHP for solder connections
- Austenitic stainless steel EN 10088-3 – 1.4301 for the filter
- Ferritic stainless steel EN 10088-3 – 1.4105 for mobile and fixed plugs
- Austenitic stainless steel EN 10088-3 – 1.4305 for orifices
- Chloroprene rubber (CR) for outlet seal gaskets
- P.T.F.E. for seat gaskets

COILS AND CONNECTORS

Coils type HM4 must be mounted on these valves. Table 2 presents the most important characteristics of coils and corresponding connectors. For further technical characteristics about HM4 coils and their connectors see to the "Solenoid valve" handbook.

SELECTION

To correctly select a solenoid expansion valve on a refrigerating system, the following design conditions must be available:

- Type of refrigerant
- Evaporator capacity, Q_e

- Temperatura/pressione d'evaporazione; T_e / p_e
- Lowest possible condensing temperature/pressure, T_c / p_c
- Liquid refrigerant temperature, T_l
- Pressure drop in the liquid line, distributor and evaporator, Δp

The following procedure helps to select the correct valve for the system.

Step 1
Determine the pressure drop across the valve. The pressure drop is calculated by the formula:

$$\Delta p_{tot} = p_c - (p_e + \Delta p)$$

where:
- P_c = condensing pressure
- P_e = evaporating pressure
- Δp = sum of pressure drops in the liquid line, distributor and evaporator

Step 2
Subcooling correction. Use the evaporating capacity Q_e to select the required valve size at a given evaporating temperature. If necessary, correct the evaporator capacity for subcooling. Subcooling liquid refrigerant entering the evaporator increase the evaporator capacity, so that a smaller valve may be required. e subcooling is calculated by the formula:

$$\Delta T_{sub} = T_c - T_l$$

From the subcooling corrector factor table find the appropriate corrector factor F_{sub} corresponding to the ΔT_{sub} calculated and determine the required valve capacity by the formula:

$$Q_{sub} = F_{sub} \times Q_e$$

Step 3
Application correction. To obtain a correct regulation with this valve, is necessary to oversize it so its closing period is between the 25% and the 50% of the total period T of the regulator. The correct choice of this closing period depends on the application that can have peaks of load and on the criterion used by the electronic regulator.
Generally, anyway, this correcting factor F_{ev} is strictly dependent by the evaporation temperature so it be assumed that F_{ev} = 1.25 for T_{ev} >= -15°C and F_{ev} = 1.50 for T_{ev}<= -15°C. These generic instructions must be verified on the real application.

$$Q_{ev} = F_{ev} \times Q_{sub}$$

Step 4
Determine required orifi ce size. Use the pressure drop across the valve, the evaporating temperature and the calculated evaporator capacity Q_e to select the corresponding orifice size from the capacity table corresponding to the chosen refrigerant.

Step 5
Liquid line sizing. Since the 2028 is an ON/OFF valve, during the opening phase of the valve, the flow rate can be too much higher than the mean flow rate. For this reason the designer must size the diameter of the pipes of the liquid line in according to the maximum flow rate across the orifice in the effective conditions of ΔPtot and so avoiding the decrement of the valve capacity due to the pressure drop.

SIZING EXAMPLE

Type of refrigerant:	R404A
Evaporator capacity, Q_e	2,8 [kW]
Evaporating temperature/pressure, T_e	-5 [°C]
Lowest possible condensing temperature/pressure, T_c	35 [°C]
Liquid refrigerant temperature, T_l	20 [°C]
Pressure drop in the liquid line, distributor and evaporator, Δp	2 [bar]

Step 1
Determine the pressure drop across the valve.
- Condensing pressure at + 35 °C - P_c = 16,9 bar
- Evaporating pressure at – 5 °C - P_e = 5,14 bar

$$\Delta p_{tot} = 16,9 - (5,14 + 2) = 9,76 \text{ bar}$$

Step 2
Determine required valve capacity.

$$\Delta T_{sub} = 35 - 20 = 15 \text{ °C}$$

From the subcooling corrector factor table 9, we find the appropriate corrector factor F_{sub} equal to 0,83 for ΔT_{sub} = 15 °C. Required valve capacity is:

$$Q_{sub} = 0,83 \times 2,8 = 2,324 \text{ kW}$$

Step 3
Determine application correction. In according to the above criterion of sizing, F_{ev} = 1,25:

$$Q_{ev} = 1,25 \times 2,324 = 2,91 \text{ kW}$$

Step 4
Determine orifice size. Using the capacity table for R404A on page 17 with:
- pressure drop across the valve = 9,76 bar
- evaporating temperature = - 5 °C
- calculated evaporator capacity = 2,91 kW

select the corresponding orifi ce 04 (N.B. : the expansion valve capacity must be equal or slightly more than the calculated evaporator capacity)

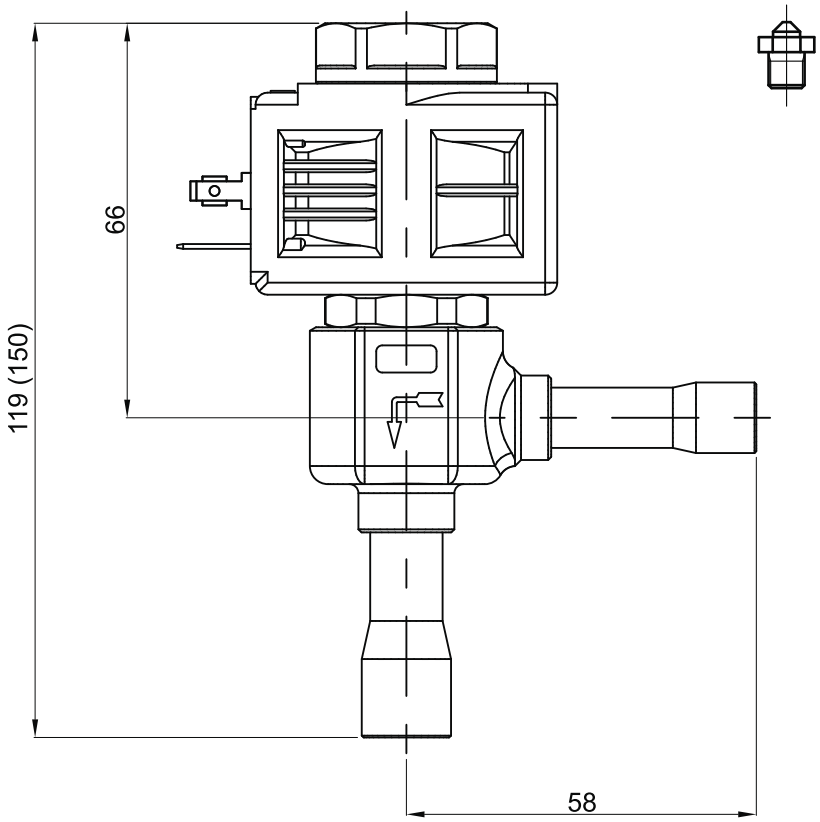

TABLE 1: General Caracteristics of PWM Expansion Valves															
Catalogue number	ODS Connections				Orifice Size [mm]	Kv Factor [m³/h]	Opening Pressure Differential [bar]			Operating principles	Mini-mum Working Time [s]	TS [°C]		PS [bar]	Risk Category accord-ing to PED
	[in]		[mm]				MinOPD	MOPD							
	IN	OUT	IN	OUT				AC	DC			min.	max.		
2028/3S01	3/8"	1/2"	-	-	0,5	0,010	0	18	18	PWM (Pulse Width Modulating)	1	-40	100	45	Art. 3.3
2028/M10S01	-	-	10	12											
2028/3S02	3/8"	1/2"	-	-	0,7	0,017									
2028/M10S02	-	-	10	12											
2028/3S03	3/8"	1/2"	-	-	0,8	0,023									
2028/M10S03	-	-	10	12											
2028/3S04	3/8"	1/2"	-	-	1,1	0,043									
2028/M10S04	-	-	10	12											
2028/3S05	3/8"	1/2"	-	-	1,3	0,065									
2028/M10S05	-	-	10	12											
2028/3S06	3/8"	1/2"	-	-	1,7	0,113									
2028/M10S06	-	-	10	12											
2028/4S07	1/2"	5/8"	-	-	2,3	0,200			14						
2028/M12S07	-	-	12	16											
2028/4S08	1/2"	5/8"	-	-	2,5	0,230									
2028/M12S08	-	-	12	16											
2028/4S09	1/2"	5/8"	-	-	2,7	0,250			10						
2028/M12S09	-	-	12	16											

TABLE 2: General Characteristics of coils

Coil Type	Catalogue Number	Voltage [V]	Voltage tolerance [%]	Frequecy [Hz]	Consumption at 20 °C [mA]				Connections	
					Start		Working		Protection Degree IP65	Protection Degree IP65/IP68
					50 [Hz]	D.C.	50 [Hz]	D.C.		
HM4	9160/RA2	24 A.C.	+6 / -10	50	1490	-	700	-	9150/R02	9155/R01
	9160/RA4	110 A.C.			330		156			
	9160/RA6	220/230 A.C.			162		76			
	9160/RD1	12 D.C.	+10 / -5	-	-	1350	-	1350		
	9160/RD2	24 D.C.				650		650		

TABLE 3: Orifices - Rated capacities in kW

Catalogue number	Orifice Type	Orifice Size [mm]	Refrigerant				
			R22	R134a	R404A R507	R407C	R410A
9150/R63	01	0,5	1,0	0,9	0,8	1,1	1,3
9150/R64	02	0,7	1,9	1,7	1,6	2,0	2,4
9150/R65	03	0,8	2,5	2,0	1,9	2,4	3,0
9150/R66	04	1,1	3,9	3,2	2,9	3,8	4,8
9150/R67	05	1,3	6,7	5,6	5,1	6,7	8,4
9150/R68	06	1,7	9,2	7,7	7,0	9,1	11,4
9150/R69	07	2,3	14,7	12,2	11,3	15,3	18,2
9150/R78	08	2,5	17,4	14,7	13,5	17,7	21,6
9150/R79	09	2,7	19,3	16,3	15,0	19,6	24,1

Rated capacities are based on:
- Evaporating temperature Tevap = + 5 °C
- Condensing temperature Tcond = + 32 °C
- Refrigerant liquid temperature ahead of valve Tliq = + 28 °C

TABLE 4: Refrigerant R22 - Capacities in kW									
Orifice Type	Pressure drop across valve [bar]								
	2	4	6	8	10	12	14	16	18
01	0,7	0,9	1,0	1,1	1,1	1,1	1,2	1,2	1,2
02	1,3	1,7	1,9	2,1	2,2	2,2	2,3	2,3	2,3
03	1,7	2,2	2,5	2,7	2,8	2,9	2,9	3,0	3,0
04	2,7	3,5	3,9	4,2	4,4	4,5	4,6	4,7	4,7
05	4,7	6,0	6,7	7,3	7,6	7,8	7,9	8,1	8,1
06	6,4	8,3	9,2	9,9	10,4	10,6	10,8	11,0	11,0
07	10,3	13,2	14,7	15,8	16,6	17,0	17,3	17,6 (1)	17,6 (2)
08	12,2	15,7	17,4	18,8	19,7	20,2	20,5	20,9 (1)	20,9 (2)
09	13,5	17,4	19,3	20,8	21,8	22,4 (1)	22,8 (2)	23,2 (2)	23,2 (2)

TABLE 5: Refrigerante R134a - Potenzialità in kW									
Orifice Type	Pressure drop across valve [bar]								
	2	4	6	8	10	12	14	16	18
01	0,6	0,8	0,9	0,9	1,0	1,0	1,0	1,0	0,9
02	1,2	1,5	1,7	1,8	1,8	1,9	1,9	1,8	1,8
03	1,4	1,8	2,0	2,1	2,2	2,2	2,2	2,2	2,1
04	2,3	2,9	3,2	3,5	3,6	3,6	3,6	3,6	3,5
05	3,9	5,0	5,6	6,0	6,1	6,2	6,2	6,1	6,0
06	5,4	6,9	7,7	8,2	8,4	8,5	8,5	8,4	8,2
07	8,5	10,9	12,2	13,0	13,4	13,5	13,5	13,4 (1)	13,0 (2)
08	10,3	13,2	14,7	15,7	16,2	16,3	16,3	16,2 (1)	15,7 (2)
09	11,4	14,7	16,3	17,4	17,9	18,1 (1)	18,1 (2)	17,9 (2)	17,4 (2)

(1) : differential pressure non available with coils 9160/RD2
(2) : differential pressure non available with coils 9160/RD1 and 9160/RD2

TABLE 6: Refrigerant R404A/R507 - Capacities in kW									
Orifice Type	Pressure drop across valve [bar]								
	2	4	6	8	10	12	14	16	18
01	0,6	0,7	0,8	0,8	0,8	0,8	0,8	0,8	0,8
02	1,1	1,4	1,6	1,7	1,7	1,7	1,7	1,6	1,5
03	1,3	1,7	1,9	2,0	2,1	2,1	2,0	2,0	1,9
04	2,1	2,7	2,9	3,1	3,2	3,2	3,2	3,1	2,9
05	3,7	4,7	5,1	5,5	5,6	5,6	5,5	5,4	5,1
06	5,0	6,4	7,0	7,4	7,6	7,6	7,5	7,4	6,9
07	8,0	10,2	11,3	11,9	12,2	12,2	12,0	11,8 (1)	11,1 (2)
08	9,6	12,3	13,5	14,3	14,6	14,6	14,4	14,2 (1)	13,4 (2)
09	10,7	13,7	15,0	15,9	16,2	16,2 (1)	16,0 (2)	15,8 (2)	14,9 (2)

TABLE 7: Refrigerant R407C - Capacities in kW									
Orifice Type	Pressure drop across valve [bar]								
	2	4	6	8	10	12	14	16	18
01	0,8	1,0	1,1	1,2	1,2	1,3	1,3	1,3	1,3
02	1,4	1,8	2,0	2,2	2,3	2,4	2,4	2,4	2,4
03	1,7	2,1	2,4	2,6	2,7	2,8	2,8	2,9	2,9
04	2,7	3,4	3,8	4,1	4,3	4,4	4,5	4,6	4,6
05	4,7	6,0	6,7	7,3	7,6	7,8	7,9	8,1	8,1
06	6,4	8,2	9,1	9,8	10,3	10,5	10,7	10,9	10,9
07	10,7	13,8	15,3	16,5	17,3	17,7	18,1	18,4 (1)	18,4 (2)
08	12,4	15,9	17,7	19,1	20,0	20,5	20,9	21,2 (1)	21,2 (2)
09	13,7	17,6	19,6	21,2	22,1	22,7 (1)	23,1 (2)	23,5 (2)	23,5 (2)

(1) : differential pressure non available with coils 9160/RD2
(2) : differential pressure non available with coils 9160/RD1 and 9160/RD2

TABLE 8: Refrigerant R410A - Capacities in kW									
Orifice Type	Pressure drop across valve [bar]								
	2	4	6	8	10	12	14	16	18
01	0,9	1,1	1,3	1,4	1,5	1,5	1,6	1,6	1,6
02	1,6	2,1	2,4	2,6	2,8	2,9	2,9	3,0	3,0
03	2,0	2,7	3,0	3,3	3,5	3,6	3,7	3,8	3,8
04	3,2	4,3	4,8	5,3	5,6	5,8	5,9	6,1	6,1
05	5,6	7,4	8,4	9,2	9,7	10,0	10,2	10,5	10,6
06	7,7	10,1	11,4	12,5	13,1	13,6	13,9	14,3	14,4
07	12,2	16,0	18,2	19,8	20,9	21,6	22,2	22,7 (1)	22,9 (2)
08	14,5	19,0	21,6	23,5	24,8	25,7	26,4	27,0 (1)	27,2 (2)
09	16,1	21,2	24,1	26,3	27,7	28,7 (1)	29,4 (2)	30,1 (2)	30,4 (2)

(1) : differential pressure non available with coils 9160/RD2
(2) : differential pressure non available with coils 9160/RD1 and 9160/RD2

TABLE 9: Correction factor for subcooling Δt_{sub} tsub > 4°C										
Refrigerants	4K	10K	15K	20K	25K	30K	35K	40K	45K	50K
R22	1	0,94	0,9	0,87	0,83	0,8	0,77	0,74	0,72	0,69
R134a	1	0,93	0,88	0,84	0,8	0,76	0,73	0,7	0,68	0,65
R404A/R507	1	0,91	0,83	0,78	0,73	0,68	0,65	0,61	0,59	0,56
R407C	1	0,93	0,88	0,83	0,79	0,75	0,72	0,69	0,66	0,64
R410A	1	0,95	0,9	0,85	0,81	0,77	0,73	0,7	0,67	0,64

When subcooling ahead of the expansion valve is other than 4 °C , adjust the evaporatore capacity by dividing by the appropriate correction factor found in Table 9.

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