HANDBOOK

EXPANSION VALVES

Ed. 2017

Castel®
Italian technology

CHAPTER 6
SOLENOID EXPANSION VALVES
FOR REFRIGERATION PLANTS THAT USE HC REFRIGERANTS

APPLICATIONS
The solenoid expansion valves illustrated in this chapter have been developed by Castel for all those refrigeration applications that use the following HC refrigeration fluids: R290, R600, or R600a, belonging to Group 1, defined in Article 13, Chapter 1, Point (a) of Directive 2014/68/EU, with reference to EC Regulation No. 1272/2008.

The solenoid valves in series 2028N must be employed only in refrigeration systems located in areas not classified as at risk of explosion, according to the definition in Annex I of Directive 1999/92/EC.

The solenoid expansion valves in series 2028EX comply with the European standard EN 13463-1:2009 and, therefore, comply with the ESR of Directive 2014/34/EU – ATEX. This equipment is suitable for use on refrigeration systems located in areas classified as "Zone 2" risk of explosion, according to the definition in Annex I of Directive 1999/92/EC.

CAUTION!: The solenoid expansion valves in this chapter cannot be used with mineral oils or alkylbenzenes.

OPERATION
Please refer to Chapter 3, second paragraph, for the description of the operation of the valves in series 2028N and 2028EX, as it is identical to that of valves in series 2028.

CONSTRUCTION
The valves in series 2028N and 2028EX are supplied complete with orifice. Nine different orifices with nine different maximum capacities that range from orifice 01 to orifice 09 can be assembled. The last two numbers in the part number identify the type of orifice that has been mounted on the valve at the factory. For example, part number 2028N/3S02 identifies a 3/8" valve with solder connections and size 02 orifice. The orifices are interchangeable and can be mounted even after the valve is soldered on the system. If you wish to change orifice, purchase the corresponding spare parts kit, according to the part number indicated in Table 33.

Valves in series 2028N are sold exclusively in the model without coil (suffix S).
The valves in series 2028EX are sold only in the version with coil series 9100EX (A6 suffix with coil, 9100EX-220/230 VAC, ATEX certified).

The main parts of the valves in series 2028N and 22028EX are made from the same materials as the valves in series 2028, with the exception of:
- Hydrogenated nitrile butadiene rubber (HNBR) for outlet seal gaskets

SELECTION
Please refer to Chapter 3, paragraph 4, for the description of the operation of the valves in series 2028N and 2028EX, as it is identical to that of valves in series 2028.

DIMENSIONING EXAMPLE
- Type of refrigerant: R290
- Evaporator capacity, Q_e: 2.8 kW
- Evaporating temperature, T_e: 0°C
- Minimum condensing temperature, 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 = 12.2 bar
- Evaporating pressure at 0 °C - P_e = 4.7 bar

$$\Delta p_{tot} = 12{,}2 - (4{,}7 + 2) = 5{,}5 \cdot bar$$

Step 2 - Determine required valve capacity

$$\Delta T_{sub} = 35 - 20 = 15 \cdot °K$$

From the subcooling correction factor Table 34B, we find the

appropriate correction factor, F_{sub}, equal to 1.12 for ΔT_{sub} = 15 °K. The required valve capacity is

$$Q_{sub} = 2{,}8 / 1{,}12 = 2{,}5 \cdot kW$$

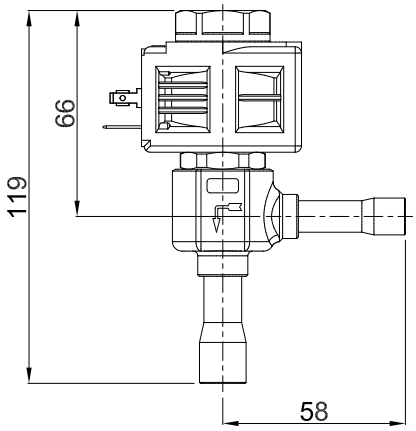
Step 3 - Capacity correction based on the application
According to the above sizing criterion, a correction of + 25% is applied to the calculated capacity:

$$Q_{ev} = 1{,}25 \cdot 2{,}5 = 3{,}1 \cdot kW$$

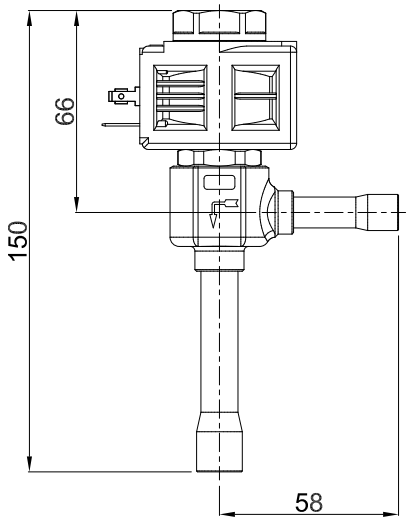
Step 4 - Determine required orifice size.
Using the capacity Table 34A for R290 refrigerant, enter the data:

- Pressure drop across the valve = 5.5 bar
- Evaporating temperature = 0 °C
- Calculated evaporator capacity = 3.1 kW

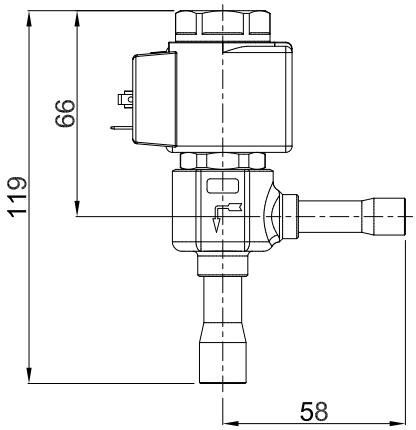
Select the corresponding orifice, 04 (Note: the expansion valve capacity must be equal to or slightly greater than the calculated evaporator capacity)



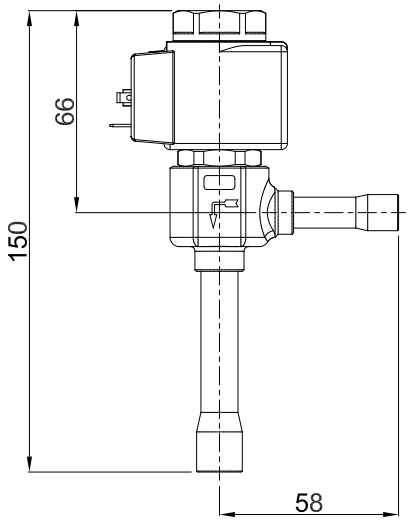
2028N/3
2028N/M10



2028N/4
2028N/M12



2028EX/3
2028EX/M10



2028EX/4
2028EX/M12

TABLE 32: General caracteristics of PWM expansion valves, suitable for HC (R290, R600, R600a)

Catalogue number		Orifice Type	ODS Connections				Kv Factor [m³/h]	Opening Pressure Differential [bar]				Operating principles	Minimum Working Time [s]	PS [bar]	TS [°C]		TA[°C]		Risk Category according to PED Recast
			[in]		[mm]			MinOPD	MOPD										
ATEX No compliance	ATEX Compliance for use in EX Zone 2		IN	OUT	IN	OUT			9100EX 9110EX (AC)	9160 (AC)	9160 (DC)				min.	max.	min.	max.	
2028N/3S01	2028EX/3A601	01	3/8"	1/2"	-	-	0,010	0	37	37	37	PWM (Pulse Width Modulating)	1	45	-40	+100	-20	+50	Art.4.3
2028N/M10S01	2028EX/M10A601		-	-	10	12													
2028N/3S02	2028EX/3A602	02	3/8"	1/2"	-	-	0,017												
2028N/M10S02	2028EX/M10A602		-	-	10	12													
2028N/3S03	2028EX/3A603	03	3/8"	1/2"	-	-	0,023												
2028N/M10S03	2028EX/M10A603		-	-	10	12													
2028N/3S04	2028EX/3A604	04	3/8"	1/2"	-	-	0,043												
2028N/M10S04	2028EX/M10A604		-	-	10	12													
2028N/3S05	2028EX/3A605	05	3/8"	1/2"	-	-	0,065												
2028N/M10S05	2028EX/M10A605		-	-	10	12													
2028N/3S06	2028EX/3A606	06	3/8"	1/2"	-	-	0,113		27	27	18								
2028N/M10S06	2028EX/M10A606		-	-	10	12													
2028N/4S07	2028EX/4A607	07	1/2"	5/8"	-	-	0,200		15	18	14								
2028N/M12S07	2028EX/M12A607		-	-	12	16													
2028N/4S08	2028EX/4S08	08	1/2"	5/8"	-	-	0,230		12										
2028N/M12S08	2028EX/M12S08		-	-	12	16													
2028N/4S09	2028EX/4S09	09	1/2"	5/8"	-	-	0,250		10		22								
2028N/M12S09	2028EX/M12S09		-	-	12	16													

TABLE 33: Orifices - Rated capacities in kW

Catalogue number	Orifice Type	Orifice Size [mm]	Refrigerant		
			R290	R600	R600a
9150N/R63	01	0,5	1,10	0,60	0,70
9150N/R64	02	0,7	2,20	1,30	1,50
9150N/R65	03	0,8	2,70	1,50	1,70
9150N/R66	04	1,1	4,20	2,30	2,60
9150N/R67	05	1,3	7,40	4,10	4,60
9150N/R68	06	1,7	10,10	6,40	7,30
9150N/R69	07	2,3	16,10	10,30	11,10
9150N/R78	08	2,5	19,40	13,20	13,40
9150N/R79	09	2,7	21,60	14,70	14,90

Rated capacities are based on:
- Evaporating temperature T_{evap} = + 5 °C
- Condensing temperature T_{cond} = + 32 °C
- Refrigerant liquid temperature ahead of valve T_{liq} = + 28 °C

TABLE 34A: Refrigerant R290 - Capacities in kW

Evaporating Temperature 10 °C									
Orifice Type	Pressure drop across valve [bar]								
	2	4	6	8	10	12	14	16	18
01	0,85	0,98	1,08	1,16	1,21	1,25	1,25	1,24	1,19
02	1,75	2,05	2,26	2,38	2,41	2,34	2,18	1,92	1,57
03	1,99	2,43	2,74	2,92	2,99	2,92	2,74	2,43	1,99
04	3,12	3,80	4,29	4,58	4,67	4,58	4,29	3,80	3,13
05	5,50	6,68	7,51	8,01	8,17	8,00	7,49	6,64	5,46
06	7,47	9,07	10,21	10,90	11,12	10,89	10,20	9,06	7,45
07	12,00	14,55	16,36	17,44	17,80	17,42	16,30	14,46	11,89
08	14,31	17,43	19,66	21,00	21,45	21,02	19,70	17,49	14,40
09	15,91	19,38	21,87	23,37	23,88	23,40	21,93	19,47	16,03

Evaporating Temperature 0 °C									
Orifice Type	Pressure drop across valve [bar]								
	2	4	6	8	10	12	14	16	18
01	0,88	1,00	1,10	1,18	1,23	1,26	1,27	1,26	1,22
02	1,88	2,11	2,28	2,38	2,42	2,39	2,30	2,14	1,91
03	2,15	2,50	2,76	2,93	3,01	3,00	2,91	2,73	2,45
04	3,37	3,91	4,32	4,59	4,72	4,71	4,56	4,27	3,85
05	5,94	6,87	7,57	8,03	8,24	8,22	7,95	7,44	6,69
06	8,06	9,34	10,29	10,91	11,21	11,18	10,82	10,14	9,13
07	12,94	14,98	16,49	17,47	17,94	17,88	17,30	16,20	14,57
08	15,44	17,94	19,81	21,03	21,63	21,58	20,90	19,59	17,64
09	17,16	19,95	22,04	23,41	24,08	24,03	23,28	21,82	19,65

Evaporating Temperature -10 °C									
Orifice Type	Pressure drop across valve [bar]								
	2	4	6	8	10	12	14	16	18
01	0,91	1,02	1,11	1,18	1,23	1,25	1,26	1,25	1,21
02	2,02	2,19	2,30	2,38	2,40	2,39	2,33	2,23	2,08
03	2,33	2,59	2,78	2,92	2,99	3,00	2,95	2,84	2,67
04	3,65	4,05	4,36	4,56	4,67	4,69	4,60	4,42	4,15
05	6,43	7,12	7,64	7,99	8,17	8,19	8,04	7,73	7,24
06	8,73	9,66	10,37	10,86	11,11	11,14	10,93	10,50	9,84
07	14,02	15,50	16,63	17,38	17,78	17,81	17,48	16,79	15,73
08	16,73	18,57	19,97	20,93	21,44	21,50	21,13	20,31	19,04
09	18,60	20,66	22,22	23,29	23,86	23,94	23,53	22,61	21,21

Evaporating Temperature -20 °C									
Orifice Type	Pressure drop across valve [bar]								
	2	4	6	8	10	12	14	16	18
01	0,93	1,03	1,11	1,17	1,22	1,24	1,25	1,23	1,20
02	2,12	2,23	2,31	2,36	2,37	2,35	2,30	2,21	2,09
03	2,45	2,65	2,79	2,89	2,94	2,94	2,90	2,80	2,66
04	3,84	4,14	4,37	4,53	4,61	4,61	4,54	4,39	4,16
05	6,75	7,28	7,67	7,93	8,07	8,07	7,94	7,68	7,29
06	9,17	9,88	10,42	10,78	10,96	10,96	10,78	10,43	9,90
07	14,73	15,86	16,70	17,27	17,55	17,55	17,26	16,69	15,84
08	17,59	19,00	20,07	20,79	21,16	21,18	20,86	20,19	19,18
09	19,55	21,13	22,32	23,13	23,55	23,58	23,22	22,47	21,34

Evaporating Temperature -30 °C									
Orifice Type	Pressure drop across valve [bar]								
	2	4	6	8	10	12	14	16	18
01	0,94	1,03	1,11	1,16	1,20	1,22	1,23	1,21	1,18
02	2,17	2,25	2,31	2,33	2,33	2,30	2,25	2,16	2,05
03	2,52	2,68	2,79	2,86	2,90	2,89	2,84	2,76	2,63
04	3,95	4,19	4,36	4,47	4,52	4,51	4,43	4,29	4,08
05	6,96	7,36	7,65	7,84	7,92	7,89	7,75	7,51	7,15
06	9,44	9,99	10,39	10,65	10,76	10,71	10,52	10,19	9,70
07	15,16	16,03	16,66	17,06	17,22	17,14	16,83	16,29	15,51
08	18,12	19,21	20,02	20,53	20,76	20,70	20,35	19,71	18,78
09	20,14	21,37	22,27	22,85	23,11	23,05	22,66	21,95	20,92

TABLE: 34B - Correction factor for subcooling Δtsub ≠ 4°K

Δtsub [°K]	4	10	15	20	25	30	35	40	45
Fsub	1,00	1,06	1,12	1,18	1,24	1,30	1,35	1,40	1,45

When subcooling ahead of the expansion valve is other than 4 °K , adjust the evaporatore capacity by dividing by the appropriate correction factor found in Table 34B

TABLE 35A: Refrigerant R600 - Capacities in kW

Evaporating Temperature 12 °C									
Orifice Type	Pressure drop across valve [bar]								
	0,5	1	2	4	6	8	10	12	16
01	0,60	0,62	0,65	0,69	0,72	0,73	0,71		
02	0,99	1,17	1,37	1,62	1,78	1,91	2,01		
03	1,05	1,28	1,57	1,92	2,15	2,34	2,50		
04	1,65	2,01	2,46	3,00	3,37	3,66	3,91		
05	2,93	3,56	4,33	5,27	5,91	6,41	6,83		
06	4,58	5,58	6,79	8,27	9,28	10,07	10,73		
07	7,39	8,98	10,92	13,27	14,87	16,12	17,17		
08	9,41	11,48	14,02	17,12	19,24	20,91	22,29		
09	10,44	12,75	15,58	19,04	21,41	23,27	24,82		

Evaporating Temperature 4 °C									
Orifice Type	Pressure drop across valve [bar]								
	0,5	1	2	4	6	8	10	12	16
01	0,61	0,62	0,64	0,68	0,70	0,71	0,70		
02	1,04	1,19	1,35	1,55	1,67	1,77	1,84		
03	1,10	1,31	1,55	1,83	2,02	2,17	2,29		
04	1,73	2,05	2,42	2,87	3,17	3,39	3,58		
05	3,07	3,62	4,27	5,04	5,55	5,94	6,27		
06	4,80	5,67	6,70	7,91	8,71	9,33	9,85		
07	7,75	9,13	10,76	12,68	13,96	14,95	15,76		
08	9,86	11,67	13,82	16,36	18,06	19,38	20,46		
09	10,94	12,96	15,36	18,20	20,10	21,56	22,78		

Evaporating Temperature 0 °C									
Orifice Type	Pressure drop across valve [bar]								
	0,5	1	2	4	6	8	10	12	16
01	0,61	0,62	0,64	0,67	0,69	0,70	0,69		
02	1,06	1,20	1,35	1,52	1,63	1,71	1,78		
03	1,13	1,32	1,54	1,80	1,97	2,10	2,21		
04	1,77	2,06	2,41	2,82	3,08	3,29	3,46		
05	3,14	3,65	4,25	4,95	5,40	5,76	6,04		
06	4,91	5,72	6,66	7,76	8,48	9,04	9,49		
07	7,92	9,21	10,71	12,45	13,60	14,48	15,19		
08	10,08	11,77	13,75	16,07	17,59	18,77	19,73		
09	11,19	13,08	15,28	17,87	19,57	20,88	21,96		

Evaporating Temperature -8 °C									
Orifice Type	Pressure drop across valve [bar]								
	0,5	1	2	4	6	8	10	12	16
01	0,61	0,62	0,64	0,66	0,67	0,67	0,66		
02	1,10	1,21	1,33	1,47	1,55	1,61	1,66		
03	1,17	1,33	1,52	1,74	1,87	1,98	2,07		
04	1,84	2,09	2,38	2,72	2,93	3,10	3,23		
05	3,26	3,70	4,20	4,77	5,14	5,42	5,65		
06	5,11	5,80	6,58	7,47	8,05	8,48	8,84		
07	8,22	9,33	10,59	12,02	12,95	13,65	14,22		
08	10,47	11,93	13,59	15,49	16,72	17,65	18,40		
09	11,61	13,25	15,12	17,25	18,63	19,68	20,54		

Evaporating Temperature -20 °C									
Orifice Type	Pressure drop across valve [bar]								
	0,5	1	2	4	6	8	10	12	16
01	0,60	0,61	0,62	0,63	0,64	0,63	0,62		
02	1,14	1,22	1,30	1,39	1,44	1,48	1,51		
03	1,21	1,34	1,49	1,65	1,75	1,82	1,88		
04	1,91	2,11	2,33	2,58	2,73	2,85	2,94		
05	3,38	3,73	4,11	4,53	4,79	4,99	5,15		
06	5,30	5,84	6,44	7,10	7,52	7,83	8,08		
07	8,54	9,40	10,35	11,40	12,05	12,55	12,94		
08	10,87	12,02	13,29	14,71	15,60	16,27	16,80		
09	12,06	13,35	14,77	16,35	17,35	18,10	18,70		

TABLE: 35B - Correction factor for subcooling Δtsub ≠ 4°K

Δtsub [°K]	4	10	15	20	25	30	35	40	45
Fsub	1,00	1,06	1,09	1,14	1,19	1,23	1,28	1,38	1,43

When subcooling ahead of the expansion valve is other than 4 °K , adjust the evaporatore capacity by dividing by the appropriate correction factor found in Table 35B

TABLE 36A: Refrigerant R600a - Capacities in kW

Evaporating Temperature 12 °C									
Orifice Type	Pressure drop across valve [bar]								
	0,5	1	2	4	6	8	10	12	16
01	0,61	0,64	0,68	0,72	0,75	0,76	0,78		
02	1,04	1,22	1,42	1,66	1,82	1,94	2,03		
03	1,11	1,34	1,62	1,96	2,20	2,38	2,53		
04	1,74	2,10	2,54	3,08	3,44	3,72	3,96		
05	3,08	3,72	4,48	5,40	6,03	6,51	6,92		
06	4,84	5,85	7,05	8,51	9,50	10,27	10,91		
07	7,41	8,92	10,75	12,95	14,44	15,60	16,56		
08	8,75	10,59	12,82	15,51	17,35	18,78	19,97		
09	9,71	11,76	14,24	17,25	19,30	20,90	22,23		

Evaporating Temperature 4 °C									
Orifice Type	Pressure drop across valve [bar]								
	0,5	1	2	4	6	8	10	12	16
01	0,60	0,64	0,68	0,73	0,75	0,77	0,79		
02	1,12	1,27	1,43	1,61	1,72	1,81	1,88		
03	1,19	1,39	1,63	1,90	2,08	2,22	2,34		
04	1,87	2,18	2,55	2,98	3,26	3,48	3,66		
05	3,32	3,86	4,50	5,23	5,72	6,09	6,39		
06	5,22	6,08	7,08	8,24	9,01	9,60	10,08		
07	7,98	9,28	10,79	12,54	13,69	14,58	15,30		
08	9,43	11,01	12,86	15,02	16,45	17,55	18,45		
09	10,46	12,23	14,29	16,71	18,31	19,53	20,54		

Evaporating Temperature 0 °C									
Orifice Type	Pressure drop across valve [bar]								
	0,5	1	2	4	6	8	10	12	16
01	0,60	0,64	0,68	0,72	0,75	0,77	0,78		
02	1,16	1,29	1,43	1,59	1,68	1,76	1,82		
03	1,23	1,42	1,63	1,88	2,04	2,16	2,26		
04	1,93	2,22	2,56	2,94	3,19	3,38	3,54		
05	3,43	3,93	4,51	5,16	5,59	5,92	6,18		
06	5,40	6,19	7,10	8,14	8,82	9,33	9,75		
07	8,25	9,45	10,81	12,38	13,40	14,17	14,80		
08	9,75	11,21	12,90	14,83	16,10	17,06	17,85		
09	10,82	12,45	14,33	16,50	17,91	18,99	19,87		

Evaporating Temperature -8 °C									
Orifice Type	Pressure drop across valve [bar]								
	0,5	1	2	4	6	8	10	12	16
01	0,61	0,64	0,68	0,72	0,74	0,75	0,77		
02	1,24	1,33	1,44	1,55	1,62	1,67	1,71		
03	1,31	1,47	1,64	1,83	1,96	2,05	2,13		
04	2,06	2,30	2,57	2,87	3,07	3,21	3,33		
05	3,65	4,07	4,53	5,05	5,37	5,62	5,82		
06	5,74	6,40	7,13	7,95	8,47	8,86	9,17		
07	8,78	9,77	10,87	12,09	12,87	13,46	13,93		
08	10,37	11,60	12,96	14,49	15,47	16,20	16,79		
09	11,51	12,88	14,41	16,12	17,21	18,03	18,69		

Evaporating Temperature -20 °C									
Orifice Type	Pressure drop across valve [bar]								
	0,5	1	2	4	6	8	10	12	16
01	0,62	0,65	0,67	0,69	0,71	0,72	0,73		
02	1,31	1,38	1,47	1,56	1,61	1,65	1,68		
03	1,42	1,52	1,64	1,77	1,85	1,90	1,95		
04	2,22	2,39	2,57	2,77	2,89	2,98	3,05		
05	3,94	4,23	4,53	4,86	5,07	5,22	5,34		
06	6,19	6,65	7,14	7,66	7,99	8,23	8,42		
07	9,47	10,15	10,88	11,66	12,14	12,49	12,78		
08	11,19	12,05	12,97	13,97	14,59	15,04	15,40		
09	12,42	13,38	14,42	15,53	16,23	16,74	17,14		

TABLE: 36B - Correction factor for subcooling Δtsub ≠ 4°K

Δtsub [°K]	4	10	15	20	25	30	35	40	45
Fsub	1,00	1,06	1,11	1,16	1,21	1,26	1,31	1,40	1,45

When subcooling ahead of the expansion valve is other than 4 °K , adjust the evaporatore capacity by dividing by the appropriate correction factor found in Table 36B

www.castel.it

ed. 001-VE-ENG

Castel Srl - Via Provinciale 2-4 - 20060 Pessano con Bornago - MI