

Understanding the Technology 2

Direct-cooling recovery equipment developed for low-boiling-point refrigerants

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To concur with the introduction of the Fluorocarbon Recovery and Destruction Law in Japan in April 2002, Espec has developed direct-cooling recovery equipment to handle low-boiling-point refrigerants. This report introduces the new recovery equipment.

At Espec, working units of this recovery equipment are already in operation at each of our domestic service locations.

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1. Introduction

Since the introduction of the Fluorocarbon Recovery and Destruction Law in Japan in April 2002, it has become obligatory to recover all refrigerants containing CFCs (chlorofluorocarbons) when disposing of these refrigerants. Releasing CFCs into the atmosphere has also become illegal. At Espec, we are a major vendor of a variety of low-temperature equipment that utilizes low-boiling-point refrigerants. Room temperature generally exceeds the critical temperature range of these low-boiling-point refrigerants, and so they are used at extremely high pressure. Since conventional recovery equipment on the market cannot recover this type of refrigerant, we have developed recovery equipment for low-boiling-point refrigerants, and each of our domestic service locations now has this equipment in operation.

2. Properties of low-boiling-point refrigerants

Low-boiling-point refrigerants are used on the low temperature side of cascade refrigerators that generate temperatures below -50

At Espec, we were using the CFCs R13 and R503 since before 1996, but we eliminated all CFCs to protect the ozone layer. However, equipment containing these refrigerants is currently still in operation, and so the refrigerants must be recovered. We are now using R23 and R508A, but, as a rule, low-boiling-point refrigerants have an extremely high global warming potential, contributing strongly to global warming.

Table 1 Properties of low-boiling-point refrigerants

Refrigerant	R13	R23	R503	R508A
Boiling point (°C)	-81.4	-82.0	-88.7	-85.7
Critical temperature (°C)	28.9	25.9	19.6	13.2
Critical pressure (MPa)	3.87	4.82	4.18	4.04
Ozone depleting potential (ODP)	1	0	0.6	0
Global warming potential (GWP)	11700	11700	11700	10175

ODP: with CFC11 as a base value of 1

GWP: with CO₂ as a base value of 1

3. Equipment summary

Photo 1 shows the exterior of the newly developed equipment, and Table 2 presents the main specifications.

The capacity of this unit was designed in accord with the maximum volume (2 kg) of low-boiling-point refrigerant contained in equipment previously marketed by Espec.

Photo 1
Refrigerant recovery unit



Table 2 Main specifications of the
refrigerant recovery unit

Name	Fluorocarbon Recovery Equipment
Model	SRM-000
Refrigerant recovery capability	R13, R23, R503, R508A
Power supply	100 V, 1 , 50/60 Hz
Compressor capacity	400 W x 2
Volume inside recovery cylinder	6.8 L 10.2 L
Recovery rate	80 g/min (excluding cooling time)
Weight	70 kg

4. Recovery method

Because the critical temperature range of low-boiling-point refrigerants is quite low, the low-boiling-point refrigerants cannot be recovered by simply permitting them to cool at room temperature as in general recovery methods, because these refrigerants do not liquefy at room temperature.

Recovery methods for low-boiling-point refrigerants include (1) recovering by cooling to low temperature for liquefied recovery, and (2) recovering by pressurizing with a high pressure pump and recovering as a pressurized gas.

When recovering by cooling, the recovery cylinder is generally cooled and the refrigerant transfers due to the pressure differential. However, with low-boiling-point refrigerants this method would require super-cooling the cylinder to below -80 to recover the refrigerants at atmospheric pressure. The cooling method entails a number of problems, such as cost, portability, and safety issues involving the extremely low temperature of the cylinder, and so in countries other than Japan, pressure type recovery equipment low-boiling-point refrigerants can be found in various places.

In Japan, however, because the pressure inside the compressor exceeds 5 MPa with the pressure method, the High Pressure Gas Safety Law applies. Because of this, problems arise stemming from official requirements that complicate the operation of the equipment.

To avoid falling under this High Pressure Gas Safety Law, this equipment is designed for recovery at less than 5 MPa. The equipment employs a pressurized cooling method so that with the recovery cylinder cooled to -15°C , the refrigerant is pressurized to less than 2 MPa. The system cools the recovery cylinder using a direct cooling method from inside the recovery cylinder by cooling and liquefying the recovered refrigerant and introducing it directly into the recovery cylinder. This eliminates the need for external cooling parts used in external cooling methods.

5. Recovery equipment configuration

Fig.1 shows the configuration of this recovery equipment.

Refrigerant introduced into the recovery refrigerator is liquefied by cooling to about -15°C in the main recovery unit, and then discharged into the recovery cylinder. If the recovery cylinder temperature is high, the refrigerant will evaporate and return to the recovery unit. The recovery cylinder is insulated with thermal insulation material to prevent heat dissipation.

To prevent overcharging, a weight-limiter device monitors the weight of the cylinder and shuts down the operation when standard weight is exceeded.

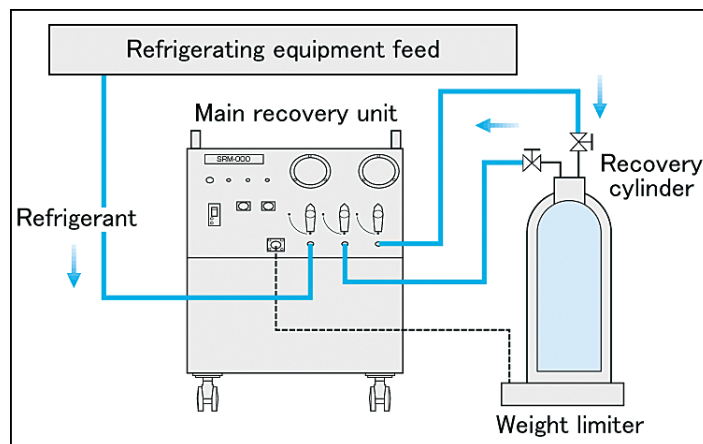


Fig.1 Equipment configuration

5-1 Configuration of the main recovery unit

Fig.2 shows a diagram of the circuits in the main recovery unit.

The refrigerant coming from the refrigerating equipment feed (REF) is passed through a pressure-reducing valve where the pressure is lowered, and then the refrigerant is pressurized upon entering the compressor (CM1) on the recovery side. The refrigerant is then liquefied by a cooling refrigerator (CM2) using a cascade condenser (C.C.) and is collected in the recovery cylinder. The configuration is set up to allow refrigerant that evaporates inside the recovery cylinder to return to the recovery unit.

If the recovery cylinder is not cooled sufficiently, it will undergo a gradual increase in pressure during recovery. Reaching specified pressure causes an intake solenoid valve (SV1) to close, and only the cooling operation continues for the recovery cylinder until the pressure drops below the specified pressure.

The completion of recovery is determined by the intake pressure (P1), and the device shuts off.

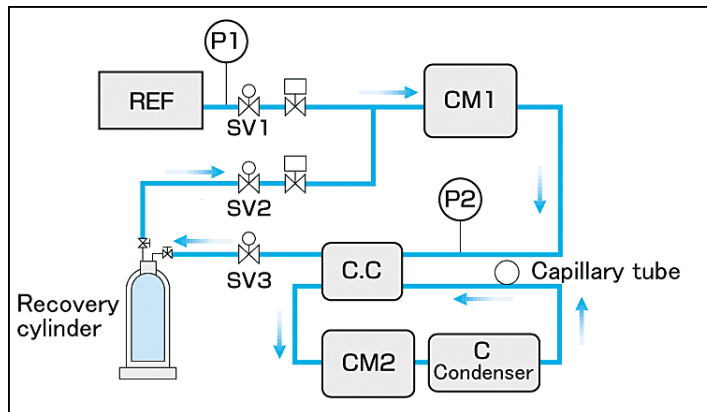


Fig.2 Circuit diagram of the main recovery unit

5-2 Recovery cylinder

After recovery has been completed, the temperature of the recovery cylinder rises, increasing the pressure, and so special seamless cylinders are used that are capable of withstanding 24.5 MPa. These cylinders are equipped with two valves, one for the liquid inlet and one for the gas return port.

Table 3 Recovery cylinder specifications

Materials	Manganese steel
Pressure rating	24.5 MPa
Operating temperature range	-30 to 40
Internal volume	6.8 L; 10.2 L

5-3 Preventing overcharging

Overcharging is prevented by monitoring the weight limit of the recovery cylinder. Table 4 shows the 90 percent level of the maximum recovery weight of a special purpose cylinder at 40 and 15 MPa pressure. When operating, the standard weight limit is set to the lightest refrigerant, R23.

Table 4 Maximum allowable recovery weights for various refrigerants

Refrigerant	R13	R23	R503	R508A
Allowable recovery weight (for 6.8 L cylinder)	3.6kg	2.4kg	3.1kg	5.6kg

6. Operating performance

A recovery experiment was performed using cylinder 1, the same type as a 10.2 liter recovery cylinder, and charging the cylinder with 2 kg of R23. Fig.3 shows the experiment conditions, and Fig.4 shows the results.

Performance measurements were performed in accord with performance standards¹⁾ published by the Refrigerant Recovery Promotion and Technical Center (RRC), but since this is a low-boiling-point refrigerant, the pre-charged weight of the recovery unit and the recovery cylinder were set according to pressure standards rather than weight standards.

In other words, pressure was set at 1.5 MPa for the recovery unit and cylinder 2 on the recovery side, and the R23 was pre-charged. Also, since cylinder 1 sustains high pressure, it was bled off to 0.8 MPa using a pressure-reducing valve.

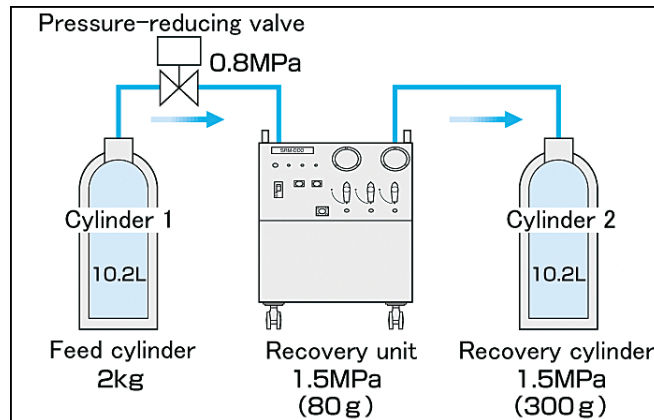


Fig.3 Experiment conditions

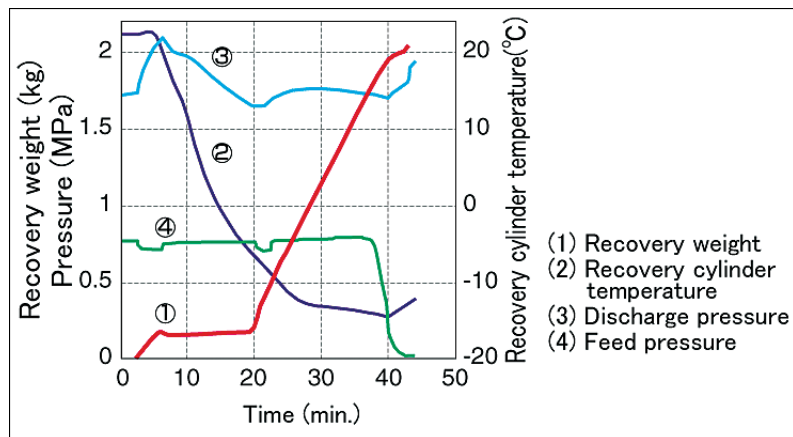


Fig.4 Recovery experiment results

Immediately after recovery had begun, the temperature of the recovery cylinder was high, and a sharp surge in pressure was seen in the cylinder. However, at about 2.1 MPa, the intake solenoid valve (SV1) closed and the unit operated in cooling mode. During cooling mode operation, no refrigerant was recovered, and the refrigerant in the recovery cylinder was circulated, performing only cooling of the cylinder. At approximately 15 minutes, the cooling of the recovery cylinder was completed, and the recovery operation started up again. The temperature of the recovery cylinder did not rise again.

The rate of recovery during the operation was approximately 90 g/min.

As the recovery operation progressed and the residual pressure in the feed cylinder (cylinder 1) dropped, the operation entered the three minute completion mode. During the completion mode, the solenoid valve on the return side (SV2) closed, and recovery progressed until the feed pressure dropped below atmospheric pressure. In the experiment, pressure dropped to 0.02 MPa. This pressure falls within the requirements of the Fluorocarbon Recovery and Destruction Law to recover well below atmospheric pressure. However, in actual practice, recovered refrigerant would likely contaminate the refrigerating system by dissolving into the oil, and this would reduce the recovery rate somewhat.

We have devised a means of reducing the refrigerant volume remaining in the recovery unit by stopping the cooling compressor (CM2) in the final minute of the completion mode, and raising the pressure in the cascade condenser (C.C.) on the recovery unit to transfer as much refrigerant as possible from inside the recovery unit to the recovery cylinder.

The time required to recover 2 kg of R23 was approximately 45 minutes.

Table 5 shows a summary of the experiment results.

Table 5 Summary of test results

Item	Feed cylinder	Recovery unit	Recovery cylinder
Initial charged refrigerant weight	2003 g	76 g	679 g
Final refrigerant weight	6 g	48 g	2704 g
Difference	-1997 g	-28 g	+2025 g
Recovery rate	90 g/min. (excluding recovery cylinder cooling time)		
Recovery percentage	99 wt%		

7. Topics for consideration

There is a down side to this equipment having a recovery capacity of less than 5 MPa. With these characteristics, recovery is not possible when recovered refrigerant is already in the recovery cylinder and the cylinder pressure is above 2.5 MPa, and so the unit demonstrates poor efficiency when repeatedly recovering small volumes.

We are currently deploying 6.4 liter recovery cylinders, but in consideration of operating conditions, we are considering modifying the volume of the recovery cylinders.

At 70 kg, the weight of these devices currently requires the use of a hand lift truck for loading on and off vehicles, and so we would like to make the devices more compact and lightweight.

8. Summary

Based on the Fluorocarbon Recovery and Destruction Law, Espec service branches in Japan have already completed registration to add four new types of low-boiling-point refrigerants to the conventional refrigerants for which we are registered as recovery business locations. We are now using this new equipment for both service and disposal in our recovery operations.

This report has presented the configuration and performance of the newly developed low-boiling-point refrigerant recovery equipment. It is our sincere hope that these CFC recovery units will contribute to the preservation of the global environment.

[Bibliography]

- 1) "Refrigerant recovery device performance standard RRC7002," The Refrigerant Recovery Promotion and Technical Center, 1999.
- 2) "Fluorocarbon refrigerant recovery device safety standard RRC7001," The Refrigerant Recovery Promotion and Technical Center, 1998.