

*Laser Cooling Water Guidelines for
Innova[®] Ion Laser Systems*

 **COHERENT[®]**
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TABLE OF CONTENTS

Preface	v
U.S. Export Control Laws Compliance	v
Symbols Used in This Manual and on the Laser System	v
Introduction	1
Function of Cooling Water	1
Advantages of Water Cooling.....	1
Effects of Cooling Water on Laser Performance.....	1
Systems Covered.....	2
Specifications and Recommendations	3
Water Flow Guidelines	3
Water Temperature Specification	5
Temperature Sensors.....	5
Ambient Dew Point	5
Heat Loads	6
Water Quality.....	7
Guidelines	7
Construction Materials for Cooling Systems.....	9
Recommended Pipe Size	9
Types of Water Systems.....	10
Flow-Through Cooling Systems.....	10
Closed-Loop Heat Exchanger.....	11
Closed-Loop Chiller	11
Evaluating an Existing Water System	12
Problems and Solutions.....	15
Selecting the Correct Cooling Water Temperature.....	16
Appendix A: Coherent Cooling Options	19
Coherent LaserPure™ Heat Exchanger	19
The LaserPure 5i.....	20
The LaserPure 20	20
The LaserPure 40	20
The LaserPure 60	20
Coherent Small Frame Heat Exchanger.....	20
Cooling Water Requirement	20
Determining Facility Water Requirements	21
Weights and Dimensions	24
Sabre Heat Exchanger.....	24

Appendix B: Operating Tips26

Appendix C: Bibliography27

LIST OF ILLUSTRATIONS

1. Flow Test Fixture12

2. Plant Water Requirements for Small Frame Heat Exchanger (17 kW heat load)21

3. Plant Water Requirements for Small Frame Heat Exchanger (18 kW heat load)22

4. Plant Water Requirements for Small Frame Heat Exchanger (22 kW heat load)22

LIST OF TABLES

1. Innova Water Flow Specifications4

2. Innova Inlet Temperature5

3. Heat Loads Produced by Innova Lasers6

4. Water Quality Specifications and Recommendations for Innova Laser Systems7

5. Materials Present Inside the Laser Cooling Path9

6. Cooling Water Delivery System Construction Materials9

7. Recommended Minimum Inlet Cooling Water Temperature
for Celsius Temperature Scale17

8. Recommended Minimum Inlet Cooling Water Temperature
for Fahrenheit Temperature Scale18

9. LaserPure Electrical Specifications19

10. Small Frame Heat Exchanger Weights and Dimensions24

11. Heat Exchanger Performance Specifications25

Preface

This document contains user water cooling information and data for the Coherent Innova series of ion lasers.

U.S. Export Control Laws Compliance

It is the policy of Coherent to comply strictly with U.S. export control laws.

Export and re-export of lasers manufactured by Coherent are subject to U.S. Export Administration Regulations, which are administered by the Commerce Department. In addition, shipments of certain components are regulated by the State Department under the International Traffic in Arms Regulations.

The applicable restrictions vary depending on the specific product involved and its destination. In some cases, U.S. law requires that U.S. Government approval be obtained prior to resale, export or re-export of certain articles. When there is uncertainty about the obligations imposed by U.S. law, clarification should be obtained from Coherent or an appropriate U.S. Government agency.

Symbols Used in This Manual and on the Laser System



This symbol is intended to emphasize the presence of important operating instructions.

INTRODUCTION

This booklet provides cooling water specifications, recommendations, and guidelines of interest to all Coherent ion laser owners. A product of Coherent's extensive ion laser research efforts, the information in this booklet will show experienced users how to realize the highest performance and longest service life possible from Coherent's Innova technology. New users will also find this booklet a valuable guide in specifying the most appropriate cooling water system for use with their Innova laser.

Function of Cooling Water

The ion lasers in the Coherent Innova family produce from 5 kW to 55 kW of waste heat as a by-product of the laser action. In order to avoid overheating of critical components, this heat must be efficiently removed from the laser system. This is accomplished through the use of cooling water.

Advantages of Water Cooling

Ion lasers are typically cooled by means of air flow or water flow. Ion laser efficiency of input-to-output power is typically 0.02 – 0.04%. The practical limit to cool ion lasers by direct air flow is 500 mW of multiline power, generating a typical heat dissipation of 2.5 kW.

At power levels greater than 500 mW of multiline power, the most efficient means of cooling is the use of water. This is due to the high heat dissipation (>2.5 kW) which would be radiated into the laboratory or operating environment of the laser. Water is an effective and reliable means of cooling high- powered ion laser systems.

Effects of Cooling Water on Laser Performance

In addition to the beneficial effect of removing heat from the laser, cooling water can also have certain adverse effects. These can be avoided, in many cases at little or no cost, by adhering to the specifications and recommendations in this booklet.

Some water related problems may be immediately apparent, such as when excessive water pressure creates vibrations in the laser head. Other effects are more subtle and may be manifested only over the course of thousands of operating hours, such as when hard water

causes deposits to build up on the surface of the plasma tube. Such long-term effects can lead to premature and costly failure of the tube or other vital system components.

Coherent's Innova program has dramatically extended the lifetime of ion laser plasma tubes. Slow processes associated with cooling water, heretofore relatively unexplored, have emerged as a significant cause of tube failure. The water quality guidelines in this document, which set new standards for the laser industry, are presented to our customers as part of Coherent's continuing commitment to improving the reliability and performance of ion lasers.

Systems Covered

This booklet presents specifications and recommendations for the Coherent Enterprise™ series, PureLight™ series, SkyLight™ series, Innova 70/70C, Innova 90/90C, Innova 90C FreD™, Innova 300/300C series, Innova 300C FreD™ and MotoFreD™, Innova 322C, Innova 400 (including Innova 100 and 200) and Innova Sabre™ series ion lasers.

SPECIFICATIONS AND RECOMMENDATIONS

The cooling water for Innova laser systems must meet certain basic specifications, which vary according to the system model number. These specifications, which pertain to both the flow and the quality of the water, are given in tabular form in this chapter. Operating a laser with cooling water that does not conform to these specifications may invalidate the system warranty and is likely to shorten tube life.

This chapter also gives recommendations that may improve system performance and reliability.

Water Flow Guidelines

The following guidelines should be used in conjunction with the system specific flow information provided in Table 1.

1. Keep the flow rate as constant as possible.

The rate at which heat is conducted from the laser depends on flow rate. Changes in the flow rate cause temperature changes in the laser head, which may result in problems such as:

- Drift in the laser output power
- Frequency drift in single-frequency operation
- Drift in the output beam direction (beam pointing)

Long term flow rate stability can be measured using electronic pressure gauges attached to a chart recorder, or by manually recording the data over the time the laser will be in use. This should be done only in critical situations where there is a suspected problem with flow rate stability.

2. Do not allow the flow rate to exceed the maximum specified value. Excessively fast flow creates vibrations in the laser head. This can cause problems such as:

- Amplitude noise on the output laser beam;
- Poor frequency stability in single-frequency operation (frequency jitter);
- Rapid changes in the beam direction (beam pointing jitter).

Table 1. Innova Water Flow Specifications

LASER SYSTEM	MAXIMUM STATIC PRESSURE ¹	FLOW RATE MIN MAX	PRESSURE DELTA RANGE ⁶	C_v ⁷	EQUIVALENT ORIFICE DIAMETER ⁸
	KPa ² (psig ³)	lpm ⁴ (gpm ⁵)	KPa (psig)		mm (in)
Sabre, Sabre R, Sabre Krypton Sabre SkyLight, Sabre Pure-Light Sabre MotoFreD	620 (90)	22.7 – 30.3 (6.0 – 8.0)	345 – 605 (50 – 88)	0.86	5.7 (0.225)
Innova 100, 200, 400,	620 (90)	22.7 – 30.3 (6.0 – 8.0)	345 – 605 (50 – 88)	0.86	5.7 (0.225)
Innova 70C, Innova 90C, Innova 90C FreD, Innova 310C, Innova 32XC, Innova 300C, Innova 300C FreD/MotoFred	415 (60)	8.5 – 11.6 (2.2 – 3.0)	150 – 275 (22 – 40)	0.47	4.2 (0.165)
Innova 70, Innova 90 Innova 300, 310, 32X	415 (60)	8.5 – 11.6 (2.2 – 3.0)	150 – 275 (22 – 40)	0.47	4.2 (0.165)
PureLight, PureLight Star SkyLight, SkyLight Star	415 (60)	8.5 – 11.6 (2.2 – 3.0)	150 – 275 (22 – 40)	0.47	4.2 (0.165)
Enterprise II	415 (60)	8.0 – 11.6 (2.0 – 3.0)	135 – 400 (20 – 60)	0.40	3.8 (0.150)

All figures include the two 7.6 m (25 feet) lengths of 16 mm (5/8 inch) I.D. hose supplied with each laser. The figures do not include a 60 micron water filter. A new filter produces a 5 KPa (0.75 psig) pressure delta at 22.7 lpm (6 gpm) or a 2 KPa (0.30 psig) pressure delta at 8.3 lpm (2.2 gpm).

¹The static pressure is the inlet pressure measured under conditions of zero flow.

²KPa = kilo pascals

³psig = pounds per square inch (gauge)

⁴lpm = liters per minute

⁵gpm = U.S. gallons per minute

⁶Pressure delta is the inlet pressure minus the drain pressure.

⁷The dimensionless quantity C_v is widely used to provide a simple description of the hydraulic properties of a complex apparatus. The C_v is the average calculated value based on the measured flow rate and pressure deltas. Its value can be related to the size of an “equivalent orifice” that mimics the flow characteristics of the entire laser system.

⁸The orifice should be 2 mm (0.08 inches) or less in thickness.

3. Do not allow the flow rate to fall below the minimum specified value. All Coherent ion lasers have flow sensors inside the power supply. When a sensor detects a condition of low water flow, it shuts off the laser to protect the system from damage. Although this has proven a reliable safeguard against rare instances of water flow failure, it is inadvisable to subject the laser to such conditions on a regular basis. Coherent does not warranty any laser system against damage from inadequate water flow.
4. Do not exceed the maximum static pressure. High pressure causes stress to hoses and seals, which may eventually develop leaks.
5. For best performance, operate the laser near the low end of the specified flow rate range and the specified pressure range. This will minimize any effects due to vibrations or excessive pressure.

Water Temperature Specification

The temperature of the cooling water is specified at the point where the water enters the laser system. All Innova lasers have the same specification, presented in Table 2.

Table 2. Innova Inlet Temperature

RANGE	10° – 35°C (50° – 95°F), always above ambient dew point. See “Selecting the Correct Cooling Water Temperature” on page 16.
STABILITY	±1°C (1.8°F) during operation Laser system stability (power and frequency) can be directly correlated to water temperature fluctuations in the environment

Temperature Sensors

The Innova series lasers incorporate thermal sensors that shut the laser off when the water temperature is too high or prevent the laser from running when the water temperature is too cold.

Ambient Dew Point

The ambient dew point is not a constant value but varies with the time of day, the season of the year, and the operation of any heating and cooling equipment that controls the laser environment. Tap water temperatures are also subject to seasonal variations. Insure

that the cooling water temperature remains above the dew point **at all times!** To determine this value, See “Selecting the Correct Cooling Water Temperature” on page 16.



It is very important that the laser cooling water temperature never fall below the ambient dew point. Should this occur, condensation may form on electrical components of the power supply and laser head, possibly resulting in high voltage shorts and electrical failure. The damage will not be covered under the terms of the system warranty.

Heat Loads

The maximum heat load produced by each Innova laser system is listed in Table 3. If you are using a closed-loop cooling system, be certain that it has sufficient capacity to handle the heat load as listed for your system in Table 3.

Table 3. Heat Loads Produced by Innova Lasers

LASER SYSTEM	HEAT LOAD
ALL Sabre	55 kW
Innova 100, 200, 400	55 kW
Innova 310C/32xC (except I322C)	24 kW
Innova 70/70C, 90/90C/90C FreD, 300/300C, 300C FreD/MotoFreD, 322C	20 kW
PureLight, PureLight Star, SkyLight, SkyLight Star	13 kW
Enterprise II	4.5 kW

Water Quality

Water quality specifications and recommendations are listed in Table 4 for all Innova lasers.

Table 4. Water Quality Specifications and Recommendations for Innova Laser Systems

PARAMETER	SPECIFICATION	RECOMMENDATION
Resistivity ¹	50 kΩ - cm to 2 MΩ - cm	> 100 kΩ - cm
Hardness	< 100 ppm ²	< 10 ppm
Particulate diameter	< 200 μm	< 60 μm
pH	6 – 8	— —
Additives	NONE	— —

¹ The unit of resistivity is Ω-cm, here given as kΩ-cm = 10³ Ω-cm or MΩ-cm = 10⁶ Ω-cm.
² ppm = parts per million of calcium.
 Coherent recommends the use of U.V. light treatment to control the bacterial growth in closed-loop water systems.

Guidelines

The following guidelines supplement the information in Table 4.

1. Do not use water with less than the specified minimum resistivity (50 kΩ-cm) or greater than the specified hardness (100 ppm).

Water that is low in resistivity contains a relatively high concentration of dissolved salts. Hard water has a high mineral content. Either condition can result in the formation of deposits on the envelope of the plasma tube, gradually resulting in an insulating layer of scale between the tube and the cooling water. This can lead to poor cooling and possible tube failure due to cracking of the tube ceramic envelope.

2. Do not use water with greater than the specified maximum resistivity.



Water that is high in resistivity (>2 MΩ-cm) will slowly dissolve metal components in the cooling path. Dissolved metals, as with dissolved salts and minerals, can result in these materials depositing on the envelope of the plasma tube, and thereby lead to possible tube failure.

3. If you intend to use tap water to cool the laser, and are unsure of its quality, have it checked by a local water quality lab.

Tap water generally has a resistivity between 5 k Ω -cm and 20 k Ω -cm. In most locations, tap water meets Coherent's hardness and resistivity specifications and therefore constitutes a satisfactory coolant. However, since tap water quality varies with location (and possibly also with the season of the year) it is advisable to verify its suitability.

4. To minimize the likelihood of premature tube failure due to poor water quality, use cooling water with resistivity greater than 100 k Ω -cm, but less than 2 M Ω -cm.

Coherent recommends the use of water that exceeds all minimum quality specifications. As a protection against premature tube failure, use a water system that maintains the resistivity above 100 k Ω -cm at all times. Use of a resistivity indicator is recommended to monitor the water quality.

5. Always use a water filter on the inlet to the laser to remove particulates.

Particulates are undissolved material such as sand and rust. They can deposit on the tube, foul the flow meter, and form sediment in the cooling path. A filter is an inexpensive way to eliminate them.

Water filters are rated according to the largest particle size that can pass through them.

6. Use water that is neither too acidic (pH <6) nor too basic (pH >8). If you are unsure of the pH of your water, have it measured.

Water falling outside the specified pH range is corrosive. The pH level of the water can be measured using pH paper, a pH meter, or by a water quality lab.

7. Check your water for organic contamination.

Organic contamination is rarely a problem, except with water systems that use cooling ponds or evaporative heat exchangers. If you are unsure of the organic content of your water, have it checked by a water quality lab.

8. Regularly inspect the cooling water for signs of discoloration or cloudiness.

9. Do not use additives or biocides of any kind in the water that flows to the laser head.

Use of additives in the water of the cooling system of a Coherent laser will void the system warranty. If bacterial growth is present in your water system, Coherent recommends the use of U.V. light sources to prevent bacterial growth. Use of biocides/additives may chemically react with other materials in the laser system, thereby causing premature failure of the laser system.

Construction Materials for Cooling Systems

The laser cooling path contains the materials listed in Table 5.

Table 5. Materials Present Inside the Laser Cooling Path

Alumina ceramic (plasma tube envelope) Brass Copper Stainless steel Soft solder (an alloy of lead and tin) Viton Neoprene (inlet and outlet water hoses) Celcon (water flow sensor)
--

Recommended and prohibited materials for the use in the construction of a cooling water delivery system are listed in Table 6.

Table 6. Cooling Water Delivery System Construction Materials

RECOMMENDED MATERIALS
Stainless steel, Brass, Plastic (Polycarbonate, Polyethylene, Nylon), Copper
PROHIBITED MATERIALS
Iron, Aluminum, Steel

Recommended Pipe Size

For new installations, use the largest pipe practicable. Coherent recommends an inner diameter of 19 mm (3/4 inch) or greater.

TYPES OF WATER SYSTEMS

Water systems for laser cooling can be grouped into three major types:

- **Flow through:** The water passes through the laser once and does not return. Tap water is an example.
- **Closed-loop heat exchanger:** The cooling water circulates around a closed path that includes the laser and a heat exchanger. The heat generated by the laser is removed in the heat exchanger, which must itself be cooled by either liquid or air.
- **Closed-loop chiller:** The cooling water circulates around a closed path that includes the laser and a chiller. The heat generated by the laser is removed in the chiller, typically a refrigeration unit which discharges its excess heat into air or liquid.

Each type of system has advantages and disadvantages for cooling ion lasers as detailed in the paragraphs below.

Flow-Through Cooling Systems

In a flow-through system, tap water passes through the laser and into a drain pipe. Flow-through systems are convenient, simple, and inexpensive, but suffer from several inherent drawbacks. They consume large amounts of water. If the water is of poor quality or at the wrong temperature, it is very difficult to treat it. Tap water frequently shows pressure variations resulting from the activities of other users on the system. Furthermore, many locations have laws that restrict the discharge of cooling water into the sewer system.

Closed-Loop Heat Exchanger

Closed-loop systems involve constantly recirculating a fixed volume of water through the laser. This offers important advantages: the laser cooling water can be easily monitored and treated to give it optimum quality, while its flow rate, temperature, and pressure can be controlled for optimum laser performance.

Water-to-water heat exchangers are often used in laser cooling systems. Inside the heat exchanger, heat is transferred out of the closed-loop water into another water source, which may be a large reservoir (such as a building water supply) or a flow through system. Since this other water source does not come into contact with the laser, it can be of relatively low quality.

Coherent manufactures a family of compact, closed-loop heat exchanger systems, designed to match the operating requirements of ion lasers. Details are given in Appendix A: Coherent Cooling Options.

Closed-Loop Chiller

Chillers have many of the same advantages of heat exchangers insofar as a fixed volume of water is recirculated through the laser. Unlike heat exchangers, they do not require a second supply of water to carry off the heat generated in the laser system. They are, in general, more expensive than heat exchangers and their relative complexity makes them less reliable. They are preferred, however, in locations where a large reservoir is not available and/or where minimizing water consumption is important.

EVALUATING AN EXISTING WATER SYSTEM

This section provides a step-by-step procedure for evaluating an existing water system. This procedure should be followed before installation of the laser in order to insure that the cooling water meets all specifications. It may be helpful to consult with your plant engineer, plumber, the local water company, and/or a water quality lab.

1. Insure that the system provides the proper flow.
 - a. Consult Table 1, Flow Specifications, to determine the correct flow and pressure requirements for your laser system. All of the flow parameters can be measured using the test fixture shown in Figure 1.

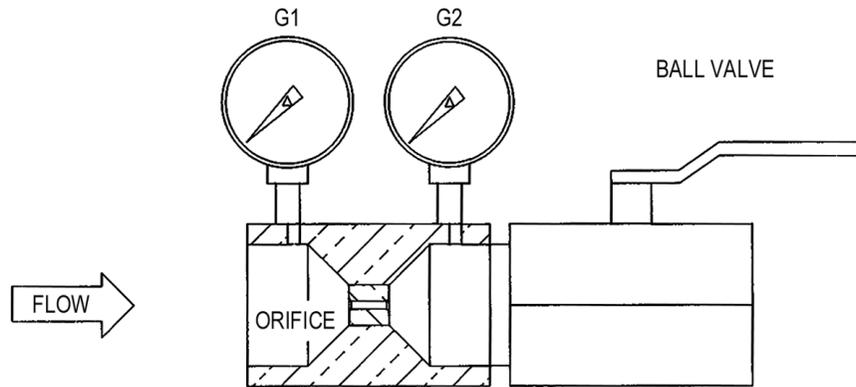


Figure 1. Flow Test Fixture



The Flow Test Fixture must be removed from the cooling water supply before connecting the laser system.

- b. Insure that the static pressure is within specification. Be aware that it may vary over time.

Using the fixture of Figure 1:

- Close the ball valve.
 - Open the inlet valve.
 - Record the pressure on the gauge G1 and G2. They should read the same for calibration purposes.
- c. Insure that the system will provide the appropriate pressure delta (pressure drop) when the laser is installed. The value of C_v and the equivalent orifice given in Table 1 will assist you in making this determination without the need to connect the laser system itself.

Figure 1 illustrates how an equivalent orifice can be used to mimic the effect of the laser system. Using this fixture:

1. Open the outlet valve (if present).
2. Open ball valve.
3. Open the inlet valve.
4. Record the pressure readings on gauges G1 and G2. The difference in pressure (G1 minus G2) is the pressure delta and should fall within the range specified in Table 1.

If the pressure delta falls within the specified range, the flow rate will also fall within the specified range.

The pressure delta must be measured while the water is flowing. The static inlet pressure and the static drain pressure do not give a reliable indication of the flowing delta pressure, since the size of the inlet pipe may restrict flow.

2. Insure that the water temperature remains within the specified range at all times.
 - a. If you are using tap water, be aware of seasonal variations in temperature. Your plant engineer or local water company may be able to provide information about typical temperature ranges for the tap water in your area.
 - b. Be sure that temperature fluctuations during operation do not exceed the value specified in Table 2.

3. Insure that the water temperature is always above the ambient dew point.
 - a. Plan for seasonal variations in the relative humidity of the laser environment. For more information with respect to dew point, please refer to the “Marks Standard Handbook for Mechanical Engineers” or equivalent (Appendix C).
 - b. Determine the maximum expected dew point and insure that the water temperature cannot fall below this value.
4. If you are using a closed loop cooling system, insure that its capacity meets or exceeds the laser heat load in Table 3.
5. Insure that the water meets or exceeds the quality standards in Table 4.
 - a. All of the parameters in Table 4 can be determined by sending a sample of your water to a standard water quality lab.

If you prefer, you can measure resistivity yourself using a resistivity meter.

The pH can be easily measured using pH paper or a pH meter.
6. If you are using a building or facility water supply, insure that it contains no additives or biocides.
7. Always use the 60 μm water filter provided by Coherent (or equivalent) on the inlet to the laser.
8. Inspect the water for signs of cloudiness, suspended particulates, or discoloration.

PROBLEMS AND SOLUTIONS

This section contains a brief list of the most commonly encountered water problems and suggested remedies for each.

1. Flow Rate Too Low:

If the flow rate is slightly too low, shorten the hoses leading to and from the laser. Avoid kinks or coils in the hoses.

Eliminate restrictions in the system such as elbows, tees, reducers, and valves.

Eliminate any quick disconnects (they create pressure drops).

Use a boost pump and a surge tank on the inlet side of the laser.



Use of a boost pump may cause power/frequency instability on the laser light output).

If the flow rate is insufficient but the water temperature is low, the water may have sufficient cooling capacity to effectively cool the laser. In this case, a closed cycle heat exchanger can be used to provide faster flow at a higher temperature.

A heat exchanger may solve the problem if the pressure is low but the available flow rate is high. The Coherent LaserPure (see Appendix A) is designed to operate at 10 psig inlet pressure and thus to utilize low pressure, high flow water sources.

2. Flow Rate Too High or Pressure Too High:

Use a pressure regulator.

3. Flow Rate or Pressure Fluctuates:

Use a pressure or flow regulator.

4. Temperature Too Low:

Use a closed cycle heat exchanger and set the temperature of the closed cycle loop within the specified temperature range of the laser.

5. Temperature Falls Below Dew Point:

Use a closed cycle heat exchanger capable of temperature adjustment.

Lower the dew point by installing a dehumidifier.

Raise the temperature of the water by pre-heating.

6. Resistivity Too Low or Hardness is Too High:

Use a closed cycle heat exchanger. Do not use water softeners.

7. Water Shows Signs of Biological Growth (i.e., Algae, Discoloration, Cloudiness):

Assume that the contamination is inorganic. Many products of corrosion, particularly oxides of copper, iron, and zinc, are greenish in color and are often mistaken for biological growth. The best course of action is to send the water to a chemical analysis lab to determine the exact nature of the contamination, then take steps to eliminate its source.

Selecting the Correct Cooling Water Temperature

The cooling water of any ion laser can condense moisture from the air when the temperature of the cooling water is lower than the dew point of the air. The system must not operate under these conditions since it will lead to catastrophic failure in the power supply. Under most conditions, it is recommended to select the inlet cooling water temperature to 30°C (86°F). The following information provides recommendations for operating conditions outside of the normal temperature and humidity range.

The conditions that lead to a situation where there can be condensation are warm and humid weather combined with water that is cooler than the surroundings. High risk conditions which will lead to condensation are:

- Operating the laser in a room that is not air conditioned in high humidity conditions
- Using cooling water that is not temperature controlled
- Leaving the cooling water on when the laser is not operating for extended time periods

The parameters required to determine if the cooling water temperature will lead to condensation is:

- Room temperature
- Relative humidity

Since the weather conditions change, these factors need to be periodically check especially in the spring and summer seasons. In environments that are air conditioned, we recommend setting the cooling water temperature to 30°C (86°F). As explained below for condi-

tions that are not air conditioned, we recommend that the cooling water temperature be increased to the air temperature to avoid condensation in humid climates.

The recommended minimum inlet cooling water temperature is provided in Table 7 and Table 8 for the complete operating temperature range of the ion laser series. Note that the first table is for temperature on the Celsius scale and the second is for temperatures on the Fahrenheit scale. To use this chart, find the row with the closest room temperature. Next read across until you find the column with the nearest relative humidity for the room with the laser. The number in the box is the recommended temperature for the inlet cooling water. If a closed loop cooling system is being used then select this temperature as the temperature set point. As an example, if the current room temperature is 28°C and the relative humidity is 68%, then the recommended inlet cooling water temperature is 35°C and the nearest relative humidity is 70%.

Table 7. Recommended Minimum Inlet Cooling Water Temperature for Celsius Temperature Scale

ROOM TEMPERATURE (°C)	MAXIMUM RELATIVE HUMIDITY							
	30%	40%	50%	60%	70%	80%	90%	95%
10	20	20	20	20	20	20	20	20
15	20	20	20	20	20	20	20	20
20	20	20	20	20	25	25	25	25
25	25	25	25	25	30	30	30	30
30	30	30	30	30	35	35	35	35

1. The minimum inlet cooling water temperature should account for variations in cooling water temperature with the thermal load, temperature stability of the cooling water system, and seasonal variations in cooling water temperature.

Selecting the cooling water temperature must also take into account changes in the cooling water temperature. For a closed loop cooling water system, there can be variations in the water temperature due to changes in the thermal load and the response time of temperature controller. The number given by the table will be the minimum water temperature that should be observed for the current room temperature and humidity conditions.

Table 8. Recommended Minimum Inlet Cooling Water Temperature for Fahrenheit Temperature Scale

ROOM TEMPERATURE (°F)	MAXIMUM RELATIVE HUMIDITY							
	30%	40%	50%	60%	70%	80%	90%	95%
50	68	68	68	68	68	68	68	68
60	68	68	68	68	68	68	68	68
70	70	70	70	70	77	77	77	77
80	77	77	77	77	86	86	86	86
90	86	86	86	86	95	95	95	95

1. The minimum inlet cooling water temperature should account for variations in cooling water temperature with the thermal load, temperature stability of the cooling water system, and seasonal variations in cooling water temperature.

In many climates, the cooling water temperature should be changed due to seasonal variations in the ambient conditions. For example in times of high relative humidity and high room temperatures, the cooling water temperature will have to be increased to avoid problems with condensation.



Under extreme conditions of temperature and humidity, the laser should not be operated outside the range of Table 7 or Table 8.

This can be solved by air conditioning the room with the laser to reduce both the room temperature and the humidity.

When using tap water as cooling source, seasonal variations in the water temperature often can lead to conditions that will produce condensation. In this case, mixing some hot water with the inlet cooling water will be required to eliminate condensation or alternatively reducing the room temperature and humidity with an air conditioning system.

APPENDIX A: COHERENT COOLING OPTIONS

Coherent offers several cooling options which are recommended accessories for all Coherent Innova lasers. All Coherent cooling systems have been designed to extend the life of ion laser tubes, minimize beam fluctuations due to thermal changes, and protect the laser from premature failure. There are several models available that provide the proper coolant flow and regulation for consistent and reliable laser operation.

Coherent LaserPure™ Heat Exchanger

The Coherent LaserPure is a family of closed cycle water- to-water or water-to-air heat exchanger systems designed especially for the cooling requirements of ion lasers.

The LaserPure, while compact enough to fit under the lab bench, affords optimum laser performance by controlling the flow rate, pressure, and temperature of the cooling water. By also controlling the resistivity of the cooling water, LaserPure eliminates any concerns with water quality.

Among the standard features of LaserPure are audible and visible indicators for the water reservoir level, temperature, and filter change. An interlock connection can be used to shut down the laser in case of over temperature or low water, providing an extra measure of safety in addition to those already present in the laser system itself. The LaserPure comes with a deionizing/de-oxygenating filter, an in-line water strainer, and two 3.7 m (12 feet) hoses.

There are four models in the LaserPure family, the LaserPure 5i, the LaserPure 20, the LaserPure 40, and the LaserPure 60. Performance specifications for all four models are described in Table 11, and electrical specifications are provided in Table 9.

Table 9. LaserPure Electrical Specifications

	LP 20, 40, 60	LP 5
Input single-phase AC	208/220/240 VAC, 50/60 Hz	100 VAC/60 Hz, 230 VAC 50/60 Hz
Maximum operating load	7.1 A @ 60 Hz, 7.8 A at 50 Hz	5.5 A @ 110 VAC, 3.5 A @ 230 VAC
Interlock contact rating	5 A @ 28 VAC	10 A @ 120 VAC/28 VDC

The LaserPure 5i

This water-to-air chiller is recommended for use with Coherent lasers with a heat load of up to 5 kilowatts.

The LaserPure 20

This heat exchanger is recommended for use with Coherent lasers with a heat load of up to 20 kilowatts.

The LaserPure 40

This heat exchanger is recommended for use with Coherent laser with a heat load of up to 40 kilowatts except for the Sabre series. You may also use the LaserPure 40 to connect to any laser or combination of lasers providing the cumulative heat load does not exceed 40 kilowatts.

The LaserPure 60

This heat exchanger is recommended for use with Coherent laser with a heat load of up to 60 kilowatts except for the Sabre series. You may also use the LaserPure 60 to connect to any laser or combination of lasers providing the cumulative heat load does not exceed 60 kilowatts.

To obtain further information on the LaserPure Heat Exchangers, please visit the Coherent Instrument Division web pages.

Coherent Small Frame Heat Exchanger

A new cooling option now available as an accessory to the Innova C-Series ion lasers is the Small Frame Heat Exchanger. Manufactured by Coherent, the Small Frame Heat Exchanger is powered and controlled by the C-Series power supply via an interface cable which eliminates the need for a separate electrical service. This unit is compatible and is recommended to be used with the Innova 70C, StarC, 90C, 90C-FreD, 300C FreD/MotoFreD or any 3XX/3XXC series laser system.

Cooling Water Requirement

The Innova C-Series ion laser requires a flow of water to cool the laser head and electrical components inside the power supply. Because the properties of the cooling water are critically important to the performance of the laser, the Innova C-Series ion laser supports a fully integrative separate heat exchanger that connects to the power supply and your facility to form a closed water loop. This allows the quality of the water through the laser system to be carefully controlled which translates to longer life span of the plasma tube. It also eliminates condensation as a source of system failure.

The use of this heat exchanger also improves beam pointing and power stability since the heat exchanger regulates the cooling water temperature within $\pm 1^{\circ}\text{C}$ ($\pm 1.8^{\circ}\text{F}$). The plant water required for the water to water integrated heat exchanger can be either tap water or any closed loop water cooling system. The requirements for the plant water are illustrated in Figure 2, Figure 3 or Figure 4 based on typical heat loads generated by the laser. Refer to Table 3 for your specific laser to determine the maximum heat load and use the graph that is closest to your value.

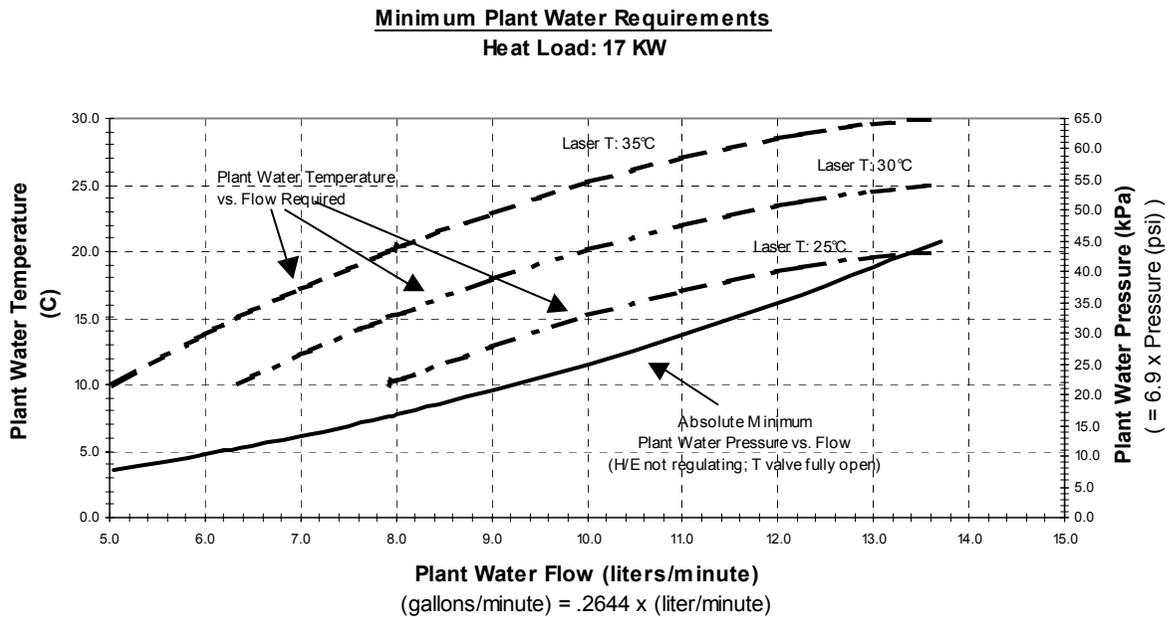


Figure 2. Plant Water Requirements for Small Frame Heat Exchanger (17 kW heat load)

It is important to note that the minimum temperature delta between the plant side of the Small Frame heat exchanger and the laser side is 5°C (9°F).

Determining Facility Water Requirements

To determine the minimum pressure requirements of the facility water, the temperature of the water must first be determined. The following illustrates, through example, how to use the graph in Figure 4 to determine the facility water requirements. Note that this graph is used for maximum heat loads of 22 kW.

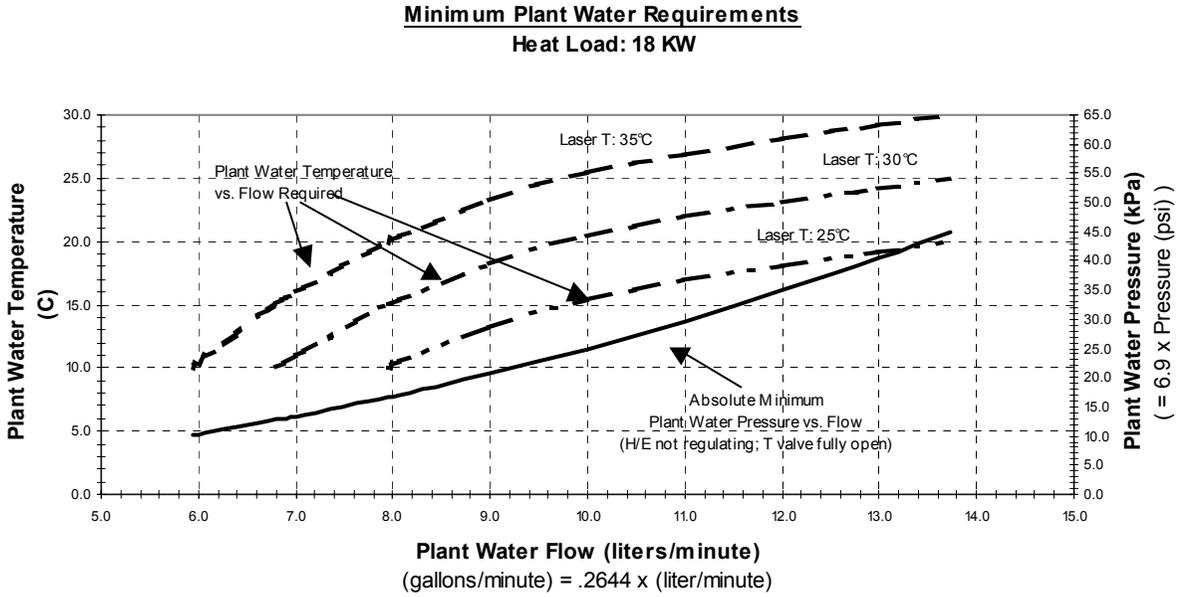


Figure 3. Plant Water Requirements for Small Frame Heat Exchanger (18 kW heat load)

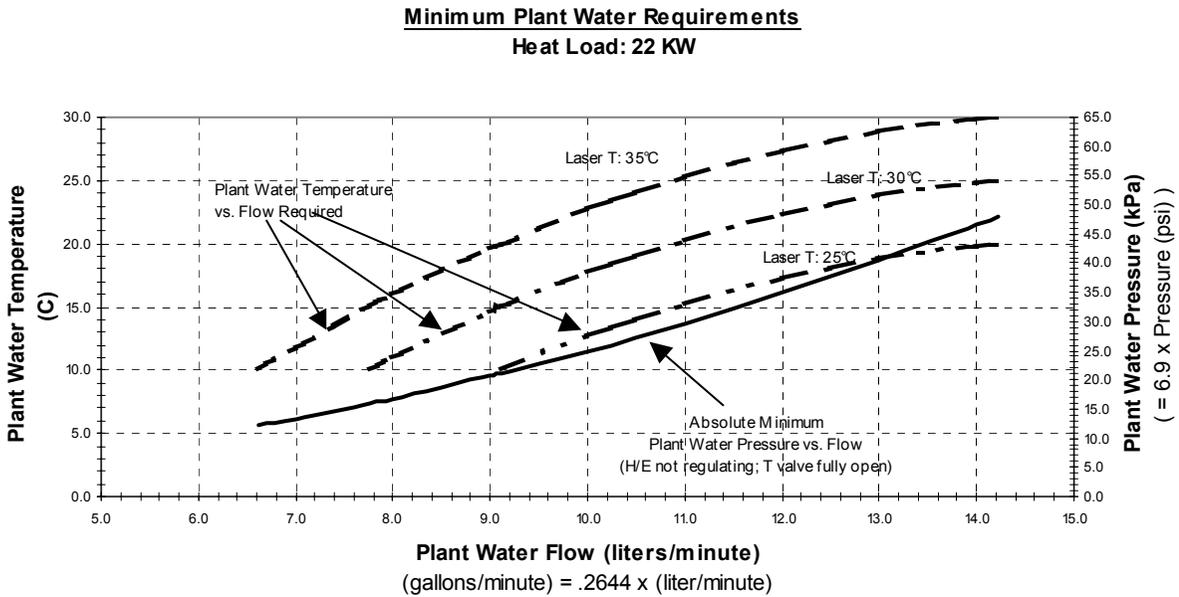


Figure 4. Plant Water Requirements for Small Frame Heat Exchanger (22 kW heat load)



Do not use de-ionized water in the internal cooling loop.

Water that is high in resistivity (>2 MΩ-cm) will slowly dissolve metal components in the cooling path. Dissolved metals, as with dissolved salts and minerals, can result in these materials depositing on the envelope of the plasma tube, and thereby lead to possible tube failure.

Typical: The Innova C-series system is factory set (referring to the Customer data sheet delivered with the system) for operation at 30°C (86°F). The temperature of the plant (facility) water is measured to be 20°C (68°F).

1. Determination of required facility water flow:

From the “Plant Water Temperature” axis draw a level horizontal line connecting the 20°C mark to the 30°C “Laser T” curve. From the point where the horizontal line intersects the 30°C curve, drop a vertical line down to the “Water Flow” axis. The point of intersection on the flow axis gives the flow requirement for the facility water, which in this case is read to be 10.8 liters/minute (1.8 GPM).

2. Determination of absolute minimum facility water pressure:

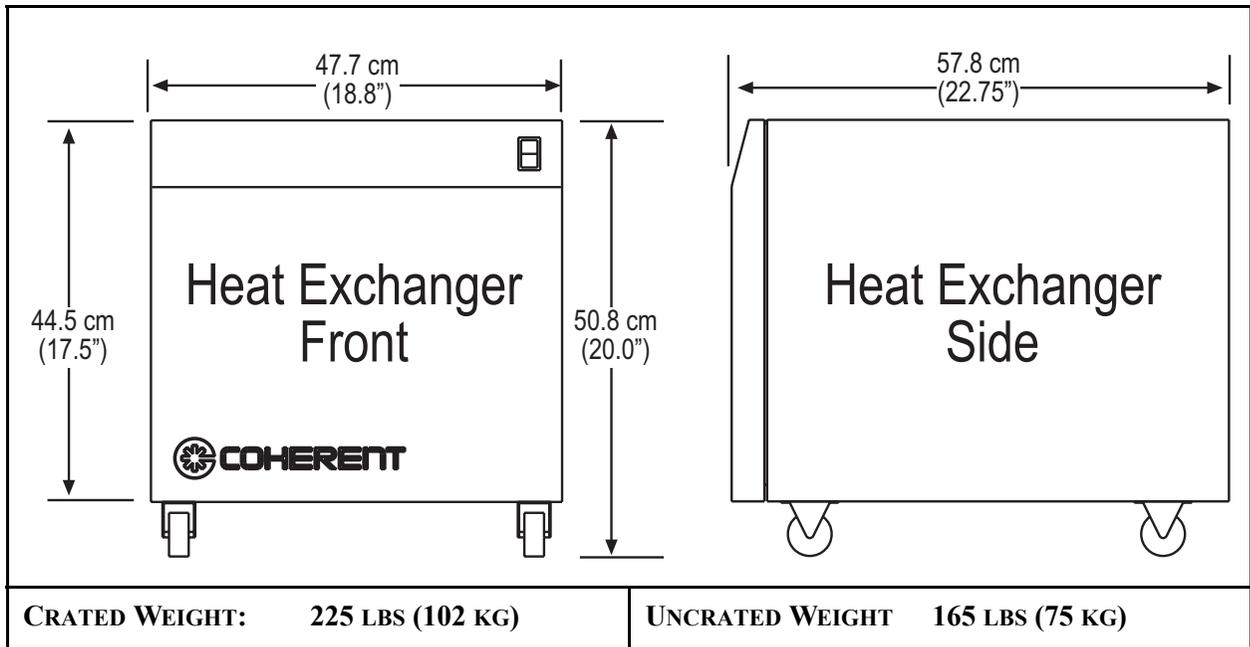
Draw a vertical line from the required facility water flow (determined in the previous step) to the “Plant Water Pressure” curve. From the point where the vertical line intersects the pressure curve, draw a level horizontal line over to the “Plant Water Pressure” axis (right side). The point where the horizontal line intersects the pressure axis gives the required facility water pressure, which in this case is read to be 29 kPa (4.2 psi).

This is the absolute minimum pressure required to cool the laser to 30°C with the heat exchanger temperature valve fully open and not regulating. To properly operate the heat exchanger with the valve regulating, it is recommended that the facility pressure exceed this minimum by at least 10 to 20 psi.

Weights and Dimensions

The Small Frame Heat exchanger weights and Dimensions are given in Table 10.

Table 10. Small Frame Heat Exchanger Weights and Dimensions



Sabre Heat Exchanger

All Sabre laser systems include an integral Heat Exchanger which is powered and controlled by the Sabre power supply via an interface cable. Please refer to the Sabre Operators manual provided with the laser system for all related operational and functional information.

Table 11. Heat Exchanger Performance Specifications

SPECIFICATION	WATER-TO-WATER					WATER-TO-AIR
	SMALL FRAME H/E	LP 20	LP 40	LP 60	SABRE H/E	LP 5i
Cooling capacity at maximum plant side flow rate	26 kW	26 kW	40 kW	60 kW	55 kW	5 kW max @ 2 gpm @ 40°C ambient
Temperature delta at maximum plant side flow rate	4°C	4°C	5°C	5°C	5°C	N/A
Maximum plant side static pressure	60 psi	100 psi	100 psi	100 psi	90 psi	N/A
Plant water temperature range	10° - 30°C	5° - 30°C	5° - 30°C	5° - 30°C	10° - 30°C	N/A
Plant water flow range	2 - 8 gpm	2 - 8 gpm	2.5 - 10 gpm	5 - 15 gpm	5 - 15 gpm	N/A
Approved plant water additives	None Not designed for seawater.	Glycol OK. Not designed for seawater.	Glycol OK. Not designed for seawater.	Glycol OK. Not designed for seawater.	None Not designed for seawater.	N/A
Laser side flow (nominal)	2 - 3 gpm	2 - 3 gpm	5 - 7 gpm	6 - 8 gpm	6 - 8 gpm	2.0 gpm
Laser side flow (maximum)	5 gpm	5 gpm	15 gpm	15 gpm	10 gpm	2.5 gpm
Maximum laser side return temperature	70°C	70°C	70°C	70°C	70°C	68°C @ 2 gpm @ 40°C Ambient
Laser side temperature regulation (at input to laser)	±1°C	±1°C	±1°C	±1°C	±1°C	None
Laser loop resistivity	Maintained between 50 kΩ-cm & 2 MΩ-cm	Maintained between 500 kΩ-cm & 2 MΩ-cm	Maintained between 500 kΩ-cm & 2 MΩ-cm	Maintained between 500 kΩ-cm & 2 MΩ-cm	Maintained between 50 kΩ-cm & 2 MΩ-cm	Optional external filter-deionizing/de-oxygenating.
Maximum ambient air temperature	N/A	N/A	N/A	N/A	N/A	100°F (40°C)
Approved laser side additives	None	None	None	None	None	None
Coherent Part Number	0171-492-50	0301-120-00	0214-485-00 (50 Hz) 0302-056-00 (60 Hz)	0214-486-00 (50 Hz) 0301-100-00 (60 Hz)	0166-597-50	0214-482-00

Terms used in this table:

Delta: The difference in water temperature between the laser cooling loop and the input (flow through) water source.

Plant side: The side of the heat exchanger cooled by the flow through water source.

Laser side: The closed water loop that cools the laser.

APPENDIX B: OPERATING TIPS

1. When using a water system that has a positive pressure drain, always turn on the drain before the supply.

Turning on the supply when the drain is closed subjects the laser system to the full static supply pressure.

2. After turning the laser off, wait at least 5 minutes before shutting off the water supply.

Continually flowing water through a laser that is turned off increases the likelihood of condensation.

This applies to closed loop water systems as well. Many closed loop systems are designed to regulate the temperature of the closed loop water, but most designs depend on the presence of a heat load in the closed loop to achieve regulation. When the laser is turned off, the temperature of the closed loop may drop out of regulation and fall below the dew point.

3. If the laser will not be used for months at a time, drain the water.

Water left standing in the laser cooling path gradually becomes corrosive.

APPENDIX C: BIBLIOGRAPHY

ASCO Solenoid Valves Catalog No. 31. Automatic Switch Company, Floram Park, NJ.

Avallone, A. A. and Baumeister, T., ed., *Marks Standard Handbook for Mechanical Engineers*, Ninth Edition, McGraw-Hill, New York 1987. Barnstead General Catalog, Barnstead Co., Boston, MA.

Betz, W. H., and Betz, L. D., ed., *Handbook of Water Conditioning*, Betz 1950.

Fluid Power Handbook and Directory, National Fluid Power Association, Thiensville, WI 1975.

Hamer, Jackson, and Thurmond, *Industrial Water Treatment Practices*, Butterworths, New York 1961.

Nordel, Eskel, *Water Treatment for Industrial and Other Uses*, Reinhold, New York 1961.

Vukobratovich, Daniel, *Introduction to Opto-Mechanical Design*, University of Arizona, Optical Sciences Center, Tucson, AZ 1986.

Laser Cooling Water Guidelines for Innova Ion Laser Systems
© Coherent, Inc. 07/2003, Printed in the U.S.A.
Coherent Part No. 0176-048-00, Rev. DB