1. **What are the **MAXIMUM** flow rates that can be achieved with blood or saline?**

**Standard Flow Set (24200 - No needle, catheter, or extension set attached to the distal port)**

The maximum flow rate observed when infusing cold, undiluted, packed erythrocytes (pRBCs) is about 27 L/h. However, moderately dilute pRBCs will infuse at about 33 L/h when pressurized to 300 mmHg (40 kPa). Normal saline and other crystalloid solutions will infuse at approximately 33 L/h at 300 mmHg.

Flow rates can be easily demonstrated using a full IV bag, pressure infusor, graduated cylinder, and a watch. In ten seconds you should collect about 92 mL of liquid. In 30 seconds you should collect about 280 mL. 

\[(33,000 \text{ mL/h}) (1\text{ h/3600s}) = 9.2 \text{ ml/s}.\]

**High Flow Set (24350 - No needle, catheter, or extension set attached to the distal port)**

The maximum flow rate observed when infusing cold, undiluted, packed erythrocytes (pRBCs) is about 36 L/h. However, moderately dilute pRBCs will infuse at about 48 L/h when pressurized to 300 mmHg (40 kPa). Normal saline and other crystalloid solutions will infuse at approximately 48 L/h at 300 mmHg.

2. **What amount of heat does the fluid in the Ranger warming set gain? How much power is used to heat the fluid? How much heat does the patient gain? What is the temperature change in the patient attributable to the heated, infused liquid?**

The power required to heat a fluid from the Ranger blood/fluid warming set may be determined using the following relation:

\[ Q = \dot{m}C_p\Delta T \]

Where

\[ Q = \text{heat loss or gain in Watts (J}\cdot\text{s}^{-1}), \]

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\( \dot{m} \) = mass flow in g/s⁻¹,
\( C_p \) = the specific heat of the fluid in J·Kg⁻¹°C⁻¹, and
\( \Delta T \) = the temperature change of the fluid in °C (K).

For the purposes of computing values, assume that the \( C_p \) of blood is about 4180 J·Kg⁻¹°C⁻¹ and that the mass of 1 ml of blood is about 0.001 Kg. \( \Delta T \) is determined experimentally.

The amount of heat stored by the fluid (or gained by the patient) may be computed using the following relation:

\[
E = mC_p \Delta T
\]

Where

E = energy in joules

Here are some examples:

Cool (18 °C) liquid enters the Ranger warming system at 18 L/h (5 ml/s) and exits at 38 °C. The power required to heat the fluid is

\[
Q = \frac{0.005 \text{Kg}}{s} \cdot \frac{4180 \text{J}}{\text{Kg} \cdot ^\circ \text{C}} \cdot \frac{20^\circ \text{C} - 18^\circ \text{C}}{s} = 418 \text{W} = 0.1 \text{Kcal/s} = 1426 \text{Btu/h}
\]

The energy stored (and imparted to the patient) by 1 L of liquid at 38 °C is

\[
E = 1\text{Kg} \cdot \frac{4180 \text{J}}{\text{Kg} \cdot ^\circ \text{C}} \cdot 38^\circ \text{C} = 159\text{KJ} = 151\text{Btu} = 38\text{Kcal}
\]

Now, suppose that this fluid was infused into a patient for 1 hour at a rate of 1 L/h.

An energy balance for this situation is developed below using the assumption that the final energy in the subject’s body is equal to the initial energy in the body plus the added energy infused by the warmed fluid. In mathematical terms the relationship is

\[
T_{\text{final}} \cdot m_{\text{final}} \cdot c_{p_{\text{final}}} = T_{\text{initial}} \cdot m_{\text{initial}} \cdot c_{p_{\text{initial}}} + T_{\text{infused}} \cdot m_{\text{infused}} \cdot c_{p_{\text{infused}}}
\]

The specific heat of the body is fairly close to that of the infused liquid, so the relationship can be simplified by factoring out the \( c_p \) and rearranging as follows:
\[ T_{\text{final}} = \left( T_{\text{initial}} \times m_{\text{initial}} + T_{\text{infusion}} \times m_{\text{infusion}} \right) / m_{\text{final}} \]

If the patient’s mass is initially 70 Kg, at the end of 1 hour the patient’s mass will be 71 Kg. Assume that the patient had a uniform initial temperature of 35.00 °C. What is the patient’s temperature at the end of the hour (assuming no metabolic heat gain)?

\[ T = \frac{\left[ (35°C)(70\text{Kg}) + (38°C)(1\text{Kg}) \right]}{71\text{Kg}} = 35.04°C \]

The patient’s temperature change attributable to the infusion of warmed fluid is 0.04 °C.

3. **Why is the needleless access port on the high flow set inverted?**
   **Does the inverted orientation interfere with the administration of drugs?**

The needleless access port on the high flow set is inverted because this orientation produces a lower pressure drop and permits higher flow rates through the system. The inverted orientation does not alter the dead space imposed by the port.

4. **Is the needle access port compatible with a blunt needle?**

Not currently, although this feature is being reviewed.

5. **How often should the blood filter be changed?**

The rate at which the filter clogs is extremely variable and depends on the amount of blood clots and debris in the infusate. It should be replaced once it becomes clogged or according to the institutional protocol. The American Association of Blood Banks (AABB) suggests that the filters should be replaced after 4 hours of use or after infusing two to four units of blood, whichever occurs first. (Technical Manual. 13th Edition. American Association of Blood Banks, Bethesda, MD.)

6. **Which drugs are compatible with the injection ports?**

The I.V. tubing and disposable heat exchanger are constructed from polyvinylchloride (PVC). The needle access port is constructed from rigid PVC and polyisoprene. The needleless access port is constructed from polycarbonate and silicone. These compounds are chemically inert to biocompatible drugs and compounds.

All Arizant Healthcare products undergo extensive biocompatibility testing including evaluations for hemolysis, cytotoxicity, acute systemic toxicity, sensitization, intercutaneous irritation, and pyrogenicity.

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7. **When using the needleless luer port the syringe tends to slip out of the connector.**

The syringe must have a Luer LOK® or similar fitting on the end that mates with the needleless access port. The needleless access port does not lock onto a luer taper.

8. **Why doesn’t the Ranger Blood/Fluid Warming system fit the pressure infusor pole?**

The standard Ranger clamp can accommodate an I.V. pole size up to 1.375 inch (3.49 cm) in diameter. We have a special clamp that can accommodate an I.V. pole up to 1.75 inch (4.45 cm) in diameter.

9. **What is the significance of bubble formation in the distal line of the Ranger I.V. Blood/Fluid Warming Set?**

The formation of tiny nitrogen bubbles within the distal line of the warming set is caused by the change in the solubility coefficients of the nitrogen dissolved in the blood solution.\(^1\) A significant volume of nitrogen produced in this manner is removed by the bubble trap; however, a few very small bubbles may still form on the tubing distal to the bubble trap because the equilibration of the gas solubility is not as rapid as the change in temperature of the blood solution. In most cases, these microbubbles are strongly adhered to the interior of the i.v. tubing and do not move or coalesce unless they are vigorously shaken. Even then, the microbubbles are so buoyant that they tend to move away from the distal outlet of the warming set.

The more important question is whether these microbubbles pose a threat to the patient as a cause of venous air embolism (VAE).

Several reports of unintentional venous air embolism have appeared in the scientific literature.\(^2\)-\(^6\) Many of these reports concern massive VAE where more than 3.5 ml/kg of air was unintentionally introduced in either peripheral or central venous lines. In none of these cases did the patients suffer from any permanent morbidity as a result of VAE.

While massive VAE is likely to cause significant morbidity or mortality, the introduction of a very small amount of air into the venous circulation is not likely to cause any symptomatology, even in patients who have right-to-left shunt. As always, care should be taken to prevent the introduction of any air into the venous circulation by using bubble traps, confirming the integrity of all clamps and connections, and checking the status of the fluid bags during any infusion therapy.


