

Operating Manual

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SPM series - OEM Programmable Syringe Pump

Advanced Microfluidics SA



Advanced Microfluidics
Small Volumes Matter



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1. Introduction

1.1 Foreword

The *Advanced Microfluidics SA*'s team thanks you for acquiring a SPM syringe pump. This operating manual is dedicated to help you make the most of this device and thus bring success to your microfluidic projects. We remain available for any questions or suggestions that you may have.

The SPM syringe pump system may only be operated after carefully reading and understanding this manual.

1.2 Application Purpose

The SPM syringe pump is a programmable, precision liquid handling system. It is designed to enable pipetting, diluting, and dispensing of different liquids. It is controlled by an external computer or microprocessor and is powered by a 18-24V power supply. .

1.3 Regulatory Considerations

1.3.1 English - Regulatory Considerations

Description

The SPM is a general laboratory module. It is not intended for medical purposes therefore not subject to FDA regulatory approval.



The SPM must not be used as a medical device or for medical purposes.

CE

CE certification is valid for the SPM product. This does not apply to prototypes that are lent for evaluation.

Equipment ratings

Environment	
Use & Operation	Indoor
Operating temperature	15 to 40°C (59 to 104°F)
Storage temperature	5 to 45°C (41 to 113°F)
Humidity range	20 to 80% non condensing
Altitude	0 to 2000 m
Mechanical Data	
Weight	1.6 kg
Dimensions (L x W x H)	136.7 x 50.5 x 212 mm
Shipping weight	2.7 kg
Shipping dimensions (L x W x H)	310 x 220 x 160 mm
Electrical Data	
Power requirements	90 to 260 VAC, 1A max, 50/60 Hz
Power rating	18-24 VDC, 2.2A, 40 W
Interfaces	
USB (mini connector)	1.1, 2.0 and 3.0
Serial	RS232 and RS485

TABLE 1.1 – Equipment ratings

1.3.2 Français - Considérations réglementaires

Description

La SPM est un module de laboratoire à usage général. Elle n'est pas prévue pour un usage médical et n'est donc pas sujette à l'approbation de la FDA.



La SPM ne doit pas être utilisée comme dispositif médical ou pour toute autre application médicale.

CE

La certification européenne CE est valable pour le produit SPM. Ceci n'est pas valable pour les prototypes prêts pour évaluation.

Caractéristiques de l'appareil

Environnement	
Utilisation	usage intérieur
Température de fonctionnement	15 à 40°C (59 à 104°F)
Température de stockage	5 à 45°C (41 à 113°F)
Taux d'humidité	20 à 80% sans condensation
Altitude	0 à 2000 m
Caractéristiques mécaniques	
Poids	1.6 kg
Dimensions (L x l x H)	136.7 x 50.5 x 212 mm
Poids de l'envoi	2.7 kg
Dimensions de l'envoi (L x l x H)	310 x 220 x 160 mm
Caractéristiques électriques	
Puissance requise	90 à 260 VAC, 1A max, 50/60 Hz
Puissance nominale	18-24 VDC, 2.2A, 40 W
Connectique	
USB (mini connecteur)	1.1, 2.0 et 3.0
Série	RS232 et RS485

TABLE 1.2 – Caractéristiques de l'appareil

1.3.3 Deutsch - Regulatorischen Betrachtungen

Beschreibung

Die SPM ist ein allgemeines Labor Modul. Sie ist nicht für medizinischen Gebrauch zugeordnet, deshalb ist sie nicht der FDA Zulassung unterlegen.



Die SPM darf nicht als medizinischem Gerät oder für medizinischen Gebrauch benutzt sein.

CE

CE Zertifizierung ist für das SPM Produkt gültig. Das gilt aber für Prototypen die für eine Auswertung geliehen sind nicht.

Gerät Spezifikationen

Umgebung	
Gebrauch und Operationen	Innenraum
Gebrauch Temperatur	15 bis 40°C (59 bis 104°F)
Lager Temperatur	5 bis 45°C (41 bis 113°F)
Feuchtigkeit Bereich	20 bis 80% nicht betauend
Höhe über dem Meer	0 bis 2000 m
Mechanische Angaben	
Gewicht	1.6 kg
Dimensionen (L x B x H)	136.7 x 50.5 x 212 mm
Versand Gewicht	2.7 kg
Versand Dimensionen (L x B x H)	310 x 220 x 160 mm
Elektrische Angaben	
Speisung	90 bis 260 VAC, 1A max, 50/60 Hz
Leistungsangaben	18-24 VDC, 2.2A, 40 W
Kopplung	
USB (mini Konnektoren)	1.1, 2.0 et 3.0
Serial	RS232 et RS485

TABLE 1.3 – Gerät Spezifikationen

1.3.4 Español - Consideraciones regulatorias

Descripción

El SPM es un módulo de laboratorio de propósito general. No se proporciona para el uso medial y por lo tanto no está sujeto a aprobación FDA.



El SPM no debe ser utilizado como un dispositivo médico u otra aplicación médica.

CE

La certificación CE es válida para el SPM producto. Esto no es válido para prototipos en préstamo para su evaluación

Características de la cámara

Ambiente	
Utilice	uso en interiores
Temperatura de funcionamiento	15 a 40°C (59 a 104°F)
Temperatura de almacenamiento	5 a 45°C (41 a 113°F)
Humedad	20 a 80% sin condensación
Altitud	0 a 2000 m
Propiedades mecánicas	
Peso	1.6 kg
Dimensiones (L x A x A)	136.7 x 50.5 x 212 mm
Peso del envío	2.7 kg
Dimensiones del artículo (L x A x A)	310 x 220 x 160 mm
Especificaciones eléctricas	
Los requisitos de alimentación	90 a 260 VAC, 1A máx, 50/60 Hz
Potencia nominal	18-24 VDC, 2.2A, 40 W
Conectores	
USB (mini conector)	1.1, 2.0 et 3.0
Serie	RS232 et RS485

TABLE 1.4 – Características de la cámara

1.3.5 Italiano - Considerazioni normative

Descrizione

La SPM è un modulo di laboratorio per uso generale. Quest'ultima non è pensata per scopi medici e pertanto non è soggetta all'approvazione FDA.



La SPM non deve essere utilizzata come dispositivo medico o per altri scopi medicali.

CE

La certificazione CE è valida per il prodotto SPM. Quest'ultima non è valida per i prototipi destinati ad essere valutati.

Caratteristiche dell'apparecchio

caratteristiche dell' apparecchio	
Utilizzo	Utilizzo interno
Temperatura di funzionamento	15 a 40°C (59 a 104°F)
Temperatura di conservazione	5 a 45°C (41 a 113°F)
Tasso di umidità	20 a 80% senza condensazione
Altitudine	0 a 2000 m
Caratteristiche meccaniche	
Peso	1.6 kg
Dimensioni (L x W x H)	136.7 x 50.5 x 212 mm
Peso dell'involucro	2.7 kg
Dimensioni dell'involucro (L x W x H)	310 x 220 x 160 mm
Caratteristiche elettriche	
Potenza richiesta	90 a 260 VAC, 1A max, 50/60 Hz
Potenza nominale	18-24 VDC, 2.2A, 40 W
Interfacce	
USB (mini connettore)	1.1, 2.0 e 3.0
Serie	RS232 e RS485

TABLE 1.5 – Caratteristiche dell'apparecchio

1.3.6 Nederlands - Regelgevende Overweging

1.1.1 Beschrijving

De SPM is een algemene laboratorium module. Hij is niet bedoeld voor medische doeleinden, en dus niet goedgekeurd volgens de FDA regelgeving.



De SPM moet niet als een medisch apparaat of voor medische doel gebruikt worden.

CE

CE-certificatie is geldig voor het SPM product. Dit is niet van toepassing voor de prototypen die gebruikt worden voor evaluatie.

Apparatuur details

Omgeving	
Gebruik en werking	Binnen
Functionerende temperatuur	15 tot 40°C (59 tot 104°F)
Opslag temperatuur	5 tot 45°C (41 tot 113°F)
Luchtvochtigheid	20 tot 80% zonder condensatie
Hoogte	0 tot 2000 m
Mechanische gegevens	
Gewicht	1.6 kg
Dimensies (L x W x H)	136.7 x 50.5 x 212 mm
Verzend gewicht	2.7 kg
Verzend dimensies (L x W x H)	310 x 220 x 160 mm
Elektrische gegevens	
Kracht vereisten	90 tot 260 VAC, 1A max, 50/60 Hz
Kracht rating	18-24 VDC, 2.2A, 40 W
Verbinding	
USB (mini connector)	1.1, 2.0 and 3.0
Seriële	RS232 and RS485

TABLE 1.6 – Apparatuur details

1.3.7 Português – Considerações reguladoras

Descrição

A SPM é um aparelho de laboratório de uso geral. Este não foi previsto para um uso medical, não está portanto sujeito à aprovação pela FDA.



A SPM não deve ser usada como dispositivo medical ou para qualquer outro uso medical.

CE

O certificado europeu CE é valido para o produto SPM. Este não é válido para os protótipos submetidos à avaliação.

Características do aparelho

Ambiente	
Utilização	Uso interno
Temperatura de funcionamento	15 a 40°C (59 a 104°F)
Temperatura de armazenamento	5 a 45°C (41 a 113°F)
Taxa de humidade	20 a 80% sem condensação
Altitude	0 a 2000 m
Características mecânicas	
Peso	1.6 kg
Dimensões (C x L x H)	136.7 x 50.5 x 212 mm
Peso do envio	2.7 kg
Dimensões do envio (C x L x H)	310 x 220 x 160 mm
Características elétricas	
Potência necessária	90 a 260 VAC, 1A max, 50/60 Hz
Potência nominal	18-24 VDC, 2.2A, 40 W
Portas de conexão	
USB (mini conector)	1.1, 2.0 e 3.0
Série	RS232 e RS485

TABLE 1.7 – Características do aparelho

1.4 Safety Considerations

1.4.1 English - Safety considerations

For proper handling and care of the SPM, it is essential that the operating personnel follow the general safety procedures and safety instructions described in this manual.

Environment of use

- The SPM syringe pump should only be used within the limits given by the equipment ratings
- The SPM syringe pump is intended for indoor use only
- The SPM syringe pump should not be used in an explosive atmosphere or with potentially explosive substances
- Transportation, storage or operation of the devices below 0°C with water in the fluid passages may cause damage to the modules
- Always work in a clean and open area to ease manipulation and avoid risk of injury

Intended use & operation

The SPM syringe pump is designed for precise pipetting, diluting and dispensing operations in the 0.5 nL to 5 mL range. Any other use is considered improper and may result in damage to the pump and/or unreliable test results.

Only the original approved parts and accessories may be used with the SPM syringe pump. Any alterations or modifications to the instrument may be dangerous and will void the warranty.

Operating the SPM

- When using the SPM, Good Laboratory Practices (GLP) should be observed
- Users should wear protective clothing, safety glasses and protective gloves, especially if working with radioactive, biohazardous or harsh chemicals
- During the operation of the SPM syringe pump, stand clear of moving parts
- Do not block moving parts
- Never try to remove valves, syringes or tubings when the pump or the valve is moving
- Never move the SPM while it is in operation



Electrical safety

- The SPM syringe pump must be disconnected from the power source when removing or replacing any mechanical components
- Use the provided power supply with the SPM syringe pump (GSM40A18-P1J)
- Never use a damaged power cord
- Do not try to open the housing
- Do not power a device with a damaged housing

Precautions with radioactive, biohazardous or harsh chemicals

Please use great care when manipulating any chemical that is potentially damaging to your health.



The SPM syringe pump does not provide any user protection against radioactive, biohazardous or harsh chemicals

- Always wear protective clothing, safety glasses and protective gloves

- Clean the fluid passages (including valve and syringe) immediately after using radioactive, biohazardous or harsh chemicals
- Make sure that the fittings are correctly tightened to avoid undesired leakage
- Make sure that the glass syringe is not damaged and correctly tightened



Any liquid output can produce a squirt of liquid if the pump is programmed to push liquid through this very output at a high flow rate. Do not forget to protect yourself.

Should an accidental spill occur, turn off the instrument and wipe it down with the appropriate disinfectant or chemical. Remember to take into account the nature of the spill and the necessary safety precautions.



1.4.2 Français - Considérations de sécurité

Pour une utilisation et un entretien correct de la pompe SPM, il est essentiel que l'utilisateur suive les procédures et instructions générales de sécurité décrites dans ce manuel.

Conditions d'utilisation

- La pompe-seringue SPM doit être utilisée dans les limites prescrites par les caractéristiques de l'appareil
- La pompe-seringue SPM est adaptée pour une utilisation en intérieur seulement
- La pompe-seringue SPM ne doit pas être utilisée en atmosphère explosive ou avec des substances potentiellement explosives
- Le transport, le stockage ou l'utilisation de l'appareil à une température inférieure à 0°C avec de l'eau dans les passages de fluide peut provoquer l'endommagement du module
- Il convient de toujours travailler sur une surface libre et propre afin de faciliter les manipulations et d'éviter tout risque de blessure

Utilisation prévue

La pompe-seringue SPM est conçue pour des opérations précises de pipetage, dilution et distribution d'échantillons de volume compris entre 0.5 nL et 5 mL. Tout autre utilisation est considérée comme inadaptée et peut causer des dommages à la pompe ou mener à des résultats d'analyse incorrects.

Seuls les accessoires et les pièces de rechange originaux peuvent être utilisés avec la pompe-seringue SPM. Toute autre modification portée sur l'instrument peut se révéler dangereuse et la garantie ne s'appliquera plus.

Utilisation de la pompe-seringue SPM

- Lors de l'utilisation de la pompe, il convient de respecter les bons usages de laboratoire
- Les utilisateurs doivent porter des habits de protection, des lunettes de sécurité et des gants adaptés, en particulier lors de l'utilisation de la pompe avec des produits radioactifs, toxiques ou agressifs.
- Pendant l'utilisation de la pompe, il convient de ne pas s'approcher des pièces en mouvement
- Le mouvement des pièces mobiles ne doit pas être entravé ou empêché
- Lorsque la pompe fonctionne, la vanne rotative, la seringue et les connecteurs microfluidiques ne doivent pas être manipulés
- La pompe ne doit pas être déplacée en fonctionnement



Sécurité électrique

- La pompe-seringue SPM doit toujours être déconnectée de l'alimentation électrique pour enlever ou remplacer un composant
- L'alimentation doit être assurée par le bloc d'alimentation fourni avec la pompe (GSM40A18-P1J)
- Il ne faut jamais utiliser un cordon électrique endommagé
- Le boîtier de la pompe ne doit pas être ouvert
- En cas de boîtier endommagé, la pompe ne doit pas être utilisée

Précautions particulières avec des liquides radioactifs, toxiques ou agressifs

Il convient d'utiliser des précautions particulières lors de la manipulation de produits pouvant porter atteinte à la santé.



La pompe SPM ne fournit pas de protection particulière contre les liquides radioactifs, toxiques ou agressifs

- Il faut toujours porter des habits de protection, des lunettes de sécurité et des gants adaptés
- Les passages de fluide (comprenant la valve et la seringue) doivent être nettoyés immédiatement après l'utilisation de produits radioactifs, toxiques ou agressifs.
- Pour éviter toute fuite, les connecteurs microfluidiques doivent être correctement serrés
- L'état de la seringue doit être régulièrement contrôlé et celle-ci correctement serrée



Chaque port de sortie liquide peut créer un jet de liquide si la pompe est programmée pour éjecter le liquide par ce port avec un débit important. Il convient donc de se protéger.

Si accidentellement, une flaque de liquide apparaît, il faut éteindre l'appareil et nettoyer la flaque avec le désinfectant ou le produit chimique approprié. La nature de la flaque doit être prise en compte afin de prendre les précautions de sécurité appropriées.



1.4.3 Deutsch - Sicherheit Betrachtungen

Für eine richtige Behandlung von dem SPM, ist es wesentlich, dass der Benutzer die allgemeine Sicherheit Verfahren und Sicherheit Anweisung folgt. Diese sind in diesem Manual beschrieben.

Verwendung Milieu

- Der SPM Syringe pump darf nur unter der Grenzbereich verwendet werden, die von den Gerät Messungen gegeben sind
- Der SPM Syringe pump ist nur für einen Innenraum Gebrauch zugelegt
- Der SPM Syringe pump darf nicht in einer explosiven Atmosphäre oder mit potentiell explosiven Substanzen gebraucht werden
- Transport, Lagerung oder Gebrauch des Geräts unter 0°C, mit Wasser in den Kanälen kann den Modul schaden
- Arbeiten Sie immer auf einem sauberen und offenen Platz, um Manipulationen vereinfachen und Verletzung Gefahren zu vermeiden

Vorgesehenen Gebrauch & Betrieb

Der SPM Syringe pump ist für präzises Pipettieren, Verdünnung und Abgabe Operationen im Bereich 0.5 nL bis 5 ml gedacht. Alle andere Verwendung ist missbräuchlich und kann die Pumpe beschädigen oder/und unzuverlässige Resultaten ergeben.

Nur originalen und anerkannten Teile und Zubehör dürfen mit dem SPM Syringe pump gebraucht werden. Jede Abänderung auf dem Instrument kann gefährlich sein und wird die Garantie aufheben.

SPM Betrieb

- Bei dem SPM Gebrauch, Good Laboratory Practices (GLP) muss eingehalten sein
- Der Benutzer muss Schutzkleider, Sicherheit Brillen und Schutzhandschuhe tragen, vor allem wenn er mit radioaktiven, Biogefährlichen oder harschen Chemieaktien arbeitet
- Während den SPM in Betrieb ist, halten Sie sich von bewegenden Teile fern
- Blockieren Sie bewegenden Teile nicht
- Wenn die Pumpe in Betrieb ist, darf das Ventil, die Spritze oder Verrohrung nie entfernt werden
- Bewegen Sie den SPM nie, wenn er in Betrieb ist



Elektrische Sicherheit

- Der SPM Syringe pump muss abgeschaltet werden bevor mechanischen Teile ersetzt oder entfernt werden
- Der SPM Syringe pump darf nur mit der mitgelieferten Speisung gebraucht werden (GSM40A 18-P1J)
- Brauchen Sie nie einen beschädigten Speisung Kabel
- Machen Sie nie das Gehäuse auf
- Schalten Sie eine mit beschädigten Gehäuse Gerät nie ein

Vorsorge mit radioaktive, Biogefährliche oder harsche Chemieaktien

Bitte seien Sie sehr vorsichtig wenn Sie mit Chemieaktien arbeiten die für die Gesundheit potenziell schädlich sind.



Der SPM Syringe pump stellt auf keinen Fall einen Schutz gegen radioaktive, Biogefährliche oder harsche Chemieaktien zur Verfügung

- Tragen Sie immer Schutzkleider, Sicherheit Brillen und Schutzhandschuhe
- Reinigen Sie die Kanäle (inkl. Ventil und Spritze) sofort nach einer Benutzung mit radioaktive, Biogefährliche oder harsche Chemieaktien
- Stellen Sie sicher, dass die Flüssigkeit Anschlüsse richtig gespannt sind, um Ausströmen zu vermeiden
- Stellen Sie sicher, dass das Glas der Spritze nicht beschädigt ist und dass es richtig gespannt ist.



Alle Flüssigkeit Output können eine Flüssigkeit Spritze verursachen, wenn die Pumpe eingestellt ist um einen grossen Durchfluss zu stossen. Vergessen Sie nicht sich zu schützen.

Sollte einen Unfall doch passieren, schalten Sie das Instrument aus und putzen Sie es mit einem geeigneten Desinfektionsmittel oder Chemikalie. Denken Sie daran die Natur des Störfalls zu berücksichtigen und nehmen Sie die nötige Sicherheit Vorsicht Massnahmen.



1.4.4 Español - Consideraciones de seguridad

Para un manejo adecuado y el cuidado de la SPM, es esencial hicieron personal de operación siguen los procedimientos generales de seguridad e instrucciones de seguridad descritas en este manual.

Verwendung Milieu

- El SPM bomba de jeringa solamente ser utilizado dentro de los límites dados por las calificaciones de equipo
- La única bomba de jeringa SPM es para uso en interiores
- El SPM bomba de jeringa no debe utilizarse en atmósfera explosiva o con sustancias potencialmente explosivas
- Transporte, almacenamiento o la cirugía de los dispositivos inferiores a 0°C con agua en los conductos de fluido pueden causar daño a los módulos
- Siempre se debe trabajar en un área limpia y abierta para facilitar la manipulación y evitar el riesgo de lesiones

Uso previsto y Operacional

El SPM bomba de jeringa está diseñada para el pipeteado preciso, diluir y dispensar en las operaciones los 0.5 nL a 5 mL gama. Cualquier otro uso es impropio considerado y puede dar lugar a daños en el bomba y / o resultados de la prueba no fiables.

Solamente las piezas y accesorios originales aprobados se pueden utilizar con la bomba de jeringa SPM. Cualquier alteración o modificación en el instrumento pueden resultar peligrosas y anular la garantía.

Funcionamiento de la SPM

- Cuando se utiliza el SPM, Buenas Prácticas de Laboratorio (BPL) Se deben observar
- Los usuarios llevan ropa protectora, gafas de seguridad y guantes de protección, especialmente si aman trabaja con productos radiactivos, biológicos peligrosos o químicos agresivos
- Durante la cirugía de la SPM bomba de jeringa, manténgase alejado de las piezas móviles
- No bloquear las piezas móviles
- No trate de retirar las válvulas, tubos o jeringas Cuando la bomba o la válvula se está moviendo
- Nunca mueva el SPM mientras está en funcionamiento



Seguridad eléctrica

- El SPM bomba de jeringa debe estar desconectado de la fuente de alimentación Cuando quite o la sustitución de cualquiera de los componentes mecánicos
- Utilice la fuente de alimentación suministrada con el SPM una bomba de jeringa (GSM40A18-P1J)
- Nunca utilice un cable de alimentación dañado
- No trate de abrir la carcasa
- No alimentar un dispositivo con una carcasa dañada

Precauciones con radiactivos, biológicos peligrosos o productos químicos agresivos

Por favor, use mucho cuidado al manipular cualquier producto químico que es potencialmente perjudicial para su salud.



! El SPM bomba de jeringa no proporciona ninguna protección del usuario contra radiactivo, productos químicos biopeligrosos o ásperos

- Siempre use ropa de protección, gafas de seguridad y guantes protectores
- Limpiar los conductos de fluido (incluyendo la válvula y la jeringa) inmediatamente después de usar radiactivo, productos químicos biopeligrosos o ásperos
- Hacer los acoples estén ajustados correctamente para evitar fugas no deseadas
- Hacer la jeringa de vidrio no está dañada y debidamente apretados



! Cualquier salida de líquido puede producir un chorro de líquido si la bomba está programada para empujar líquido a través de esta misma salida a una alta tasa de flujo. No se olvide de protegerse a sí mismo.

En caso de derrames accidentales en el caso, apague el instrumento y límpiela con la adecuada desinfectante o química. Recuerde que debe tener en cuenta la naturaleza del derrame y la necesaria Precauciones de seguridad.



1.4.5 Italiano - Considerazioni di sicurezza

Per un utilizzo e una manutenzione corretta della pompa SPM è necessario che l'utilizzatore segua le procedure e le istruzioni generali di sicurezza descritte in questo manuale.

Condizioni di utilizzo

- La pompa a siringa SPM deve essere utilizzata nei limiti prescritti dalle caratteristiche dell'apparecchio
- La pompa a siringa SPM è pensata solamente per uso interno
- La pompa a siringa SPM non deve essere usata in atmosfera esplosiva o in presenza di sostanze potenzialmente esplosive
- Il trasporto, la conservazione o l'utilizzo del dispositivo ad una temperatura inferiore a 0°C potrebbe causare il danneggiamento dei moduli in presenza di acqua nei canali microfluidici
- Al fine di evitare il rischio di ferite e di facilitare la manipolazione è consigliabile lavorare su superfici pulite e libere

Utilizzo previsto & operation

La pompa a siringa SPM è pensata per precise operazioni di pipettaggio, diluizione e dispensamento di campioni aventi un volume compreso tra 0.5 nL e 5 mL. Qualsiasi altro utilizzo è considerato improprio e potrebbe causare dei danni alla pompa o condurre a dei risultati di analisi incorretti.

Solo gli accessori e i pezzi di ricambio originali possono essere utilizzati con la pompa a siringa SPM. Qualsiasi altra modifica apportata sullo strumento potrebbe rivelarsi dannosa e comporterebbe la perdita della garanzia.

Utilizzo della pompa SPM

- Nel momento di utilizzo della pompa, è consigliabile osservare le buone pratiche di laboratorio
- E' consigliabile che gli utilizzatori indossino abiti protettivi, occhiali e guanti di sicurezza, specialmente in caso di utilizzo della pompa in presenza di prodotti radioattivi, tossici o aggressivi
- Durante l'utilizzo della pompa è consigliabile non avvicinarsi alle parti in movimento
- Il movimento delle parti mobili non deve essere impedito o ostacolato
- Non rimuovere le valvole, le siringhe e i tubi microfluidici quando la pompa è in funzione
- Non muovere la pompa SPM nel corso di un'operazione



Sicurezza elettrica

- La pompa a siringa SPM deve essere disconnessa dall'alimentazione elettrica nel momento in cui un componente meccanico deve essere sostituito o rimosso
- L'alimentazione deve essere assicurata dal blocco di alimentazione fornito con la pompa (GSM40A18-P1J)
- Non utilizzare un cavo elettrico danneggiato
- Non aprire la carcassa della pompa
- In caso di carcassa danneggiata la pompa non deve essere utilizzata

Precauzioni in presenza di liquidi radioattivi, tossici o aggressivi

E' opportuno prendere le giuste precauzioni di sicurezza qualora si abbia a che fare con la manipolazione di prodotti chimici potenzialmente dannosi per la salute.



La pompa a siringa SPM non fornisce alcun tipo di protezione contro i liquidi radioattivi, tossici o aggressivi

- Indossare sempre degli abiti di protezione, degli occhiali e dei guanti di sicurezza
- I canali microfluidici (compresi la valvola e la siringa) devono essere immediatamente puliti dopo l'utilizzo di prodotti radioattivi, tossici o aggressivi
- Al fine di evitare perdite indesiderate, accertarsi che i connettori microfluidici siano serrati correttamente
- Assicurarsi che la siringa di vetro sia serrata correttamente e che non sia danneggiata



Ogni porta di uscita dei liquidi potrebbe produrre un getto di liquido se la porta è programmata per espellere quest'ultimo con un'elevata velocità di flusso. E' consigliabile pertanto proteggersi.

Se accidentalmente si verifica la fuoriuscita di liquido, spegnere lo strumento e pulire la perdita con un disinfettante o con un prodotto chimico appropriato. La natura della perdita deve essere tenuta in conto al fine di prendere le giuste precauzioni di sicurezza.



1.4.6 Nederlands - Veiligheids Overwegingen

Voor het gepast gebruiken van en zorgen voor de SPM, is het essentieel dat het bedieningspersoneel de algemene veiligheidsprocedures en de veiligheidsinstructies, die in dit boek beschreven zijn, volgen.

Omgeving van gebruik

- De SPM injectiepomp mag alleen binnen de grenzen, die bij de apparatuur details gegeven zijn, gebruikt worden.
- De SPM injectiepomp is alleen bedoeld voor inpandig gebruik
- De SPM injectiepomp dient niet gebruikt te worden in een explosieve atmosfeer of met potentiële explosieve substanties.
- Vervoer, opslag en gebruik van de apparatuur onder 0 graden Celcius met water in de vocht passages kan schade veroorzaken aan de modules.
- Werk altijd in een schoon en open gebied om manipulatie te vergemakkelijken en het risico van letsel te verminderen.

Beoogd gebruik en werking

De SPM injectiepomp is ontworpen voor het precies pipetteren, verdunnen en afgeven van operaties in het 0.5 nL tot 5 mL gebied. Elk ander gebruik wordt beschouwd als onjuist en kan leiden tot schade aan de pomp en/of onbetrouwbare testresultaten.

Alleen de oorspronkelijke goedgekeurde onderdelen en accessoires kunnen gebruikt worden met de SPM injectiepomp. Enige verandering of aanpassing van het instrument kan gevaarlijk zijn en zal de garantie ongeldig maken.

Bedienen van de SPM

- Bij gebruik van de SPM moeten Good Laboratory Practices (GLB) gewaarborgd worden.
- Gebruikers moeten beschermende kleding, veiligheidsbrillen en beschermende handschoenen dragen, vooral wanneer men werkt met radioactieve, bio-gevaarlijke of agressieve chemicaliën.
- Tijdens de operaties van de SPM injectiepomp uit de buurt blijven bij bewegende onderdelen.
- Nooit bewegende onderdelen blokkeren.
- Probeer nooit de kleppen, spuiten of buizen te verwijderen als de pomp of de klep aan het bewegen zijn.
- Nooit de SPM verplaatsen terwijl deze in werking is.



Elektrische veiligheid

- De SPM injectiepomp moet van de krachtbron ontkoppeld zijn bij het verwijderen of vervangen van de mechanische onderdelen.
- Gebruik de meegeleverde stroomvoorziening met de SPM injectiepomp (GSM40A18-PIJ)
- Nooit een beschadigde kabel gebruiken.
- Probeer niet om de behuizing te openen.
- Zet nooit een apparaat met een beschadigde behuizing aan.

Voorzorgsmaatregelen bij radioactieve, bio-gevaarlijke of agressieve chemicaliën

Wees altijd extra voorzichtig bij het manipuleren van chemicaliën die schadelijk kunnen zijn voor uw gezondheid.



De SPM injectiepomp voorziet de gebruiker niet van bescherming tegen radioactieve, bio-gevaarlijke of agressieve chemicaliën.

- Draag altijd beschermende kleding, veiligheidsbrillen en beschermende handschoenen.
- De vloeistof kanalen altijd direct schoonmaken na het gebruik van radioactieve, bio-gevaarlijke of agressieve chemicaliën.
- Zorg ervoor dat de koppelstukken goed vastzitten om ongewenste lekkage te voorkomen.
- Zorg ervoor dat de glazen injectiespuit niet beschadigd en dat deze correct is aangedraaid.



Iedere vloeibare output kan spuitende vloeistof produceren als de pomp is geprogrammeerd om vloeistof op een hoog tempo door deze output te pompen. Vergeet niet om jezelf te beschermen.

Als er onbedoeld vloeistof wordt gemorst, zet het instrument uit en veeg het af met de juiste ontsmettingsmiddelen of chemicaliën. Vergeet niet om de aard van de lekkage te onderzoeken en de nodige voorzorgsmaatregelen te nemen.



1.4.7 Português – Considerações de segurança

Para uma utilização e manutenção correta da bomba SPM, é essencial que o utilizador siga os procedimentos e instruções gerais de segurança descritas neste manual.

Condições de uso

- A bomba-seringa SPM deve ser usada dentro dos limites descritos nas características do aparelho
- A bomba-seringa SPM é adaptada para uma utilização somente em ambiente interior
- A bomba-seringa SPM não deve ser utilizada em atmosfera explosiva ou com substâncias potencialmente explosivas
- O transporte, armazenamento ou utilização do aparelho a uma temperatura inferior a 0°C com água nas passagens de fluido pode provocar o dano do aparelho
- É conveniente trabalhar sempre numa superfície livre e limpa afim de facilitar as manipulações e evitar qualquer risco de ferimento

Utilização prevista

A bomba -seringa SPM foi concebida para operações precisas de pipetagem, diluição e distribuição de amostras de volume compreendidas entre 0.5 nL et 5 mL. Qualquer outra utilização é considerada como inadequada e pode causar danos à bomba ou levar a resultados de análise incorretos.

Apenas os acessórios e peças de substituição originais podem ser usados com a bomba-seringa SPM. Qualquer outra modificação efectuada no instrumento de tornar-se perigosa e a garantia não poderá ser aplicada.

Utilização da bomba-seringa SPM

- Aquando da utilização da bomba, devem ser respeitadas as boas práticas de laboratório
- Os utilizadores devem vestir roupa de proteção, óculos de segurança e luvas adaptadas, em particular aquando da utilização da bomba com produtos radioativos, tóxicos ou agressivos
- Durante a utilização da bomba, é recomendado não se aproximar das peças em movimento
- O movimento das peças móveis não deve ser dificultado ou impedido
- Quando a bomba está em funcionamento, a válvula rotativa, a seringa e os conectores de microfluidos não devem ser manipulados
- A bomba não deve ser deslocada em funcionamento



Segurança elétrica

- A bomba-seringa SPM deve estar sempre desligada da alimentação elétrica para remover ou substituir um componente
- A alimentação deve estar assegurada pelo bloco de alimentação fornecido com a bomba (GSM40A18-P1J)
- Não se deve usar um cabo elétrico danificado
- A caixa da bomba não deve ser aberta
- No caso da caixa estar danificada, a bomba não deve ser utilizada

Precauções particulares com fluidos radioativos, tóxicos ou agressivos

É recomendado por em prática as precauções particulares aquando da manipulação de produtos que podem provocar danos na saúde



A bomba SPM não fornece proteções particulares contra líquidos radioativos, tóxicos ou agressivos.

- Deve-se sempre usar equipamento de proteção, óculos de segurança e luvas
- As passagens dos fluidos (incluindo a válvula e a seringa) devem ser limpas imediatamente após à utilização de produtos radioativos, tóxicos ou agressivos
- Para evitar qualquer fuga, os conectores de microfluidos devem estar corretamente apertados
- O estado da seringa deve ser controlado regularmente e esta deverá estar devidamente apertada



Cada porta de saída de líquido pode criar um jato de líquido se a bomba estiver programada para ejetar líquido por essa via com um débito elevado. É recomendado proteger-se para esse efeito.

Se acidentalmente uma poça de líquido surgir, deve-se desligar o aparelho e limpar a poça com desinfetante ou outro produto químico apropriado. A natureza da poça deve ser tomada em consideração afim de tomar as precauções de segurança apropriadas.



1.5 Product Family Description

Advanced Microfluidics SA syringe pumps product family includes following references:

LSPone series			SPM series		
	LSPone / Low Volume	LSPone+ / High Volume		SPM / Low Volume	SPM+ / High Volume
Standard	P100-L	P101-L	Standard	P100-O	P101-O
HD	P110-L	P111-L	HD	P110-O	P111-O

- Low Volume refers to syringes between 50 and 1000 μL => SPM
- High Volume refers to syringes between 2.5 and 5 mL => SPM+
- Standard refers to a syringe actuation with standard flow rate range => SPM
- HD refers to a syringe actuation with enhanced low flow rate stability but lower high speed capability => SPM HD

This manual focuses on the SPM series that is intended for integration in an instrument for industrial microfluidics.

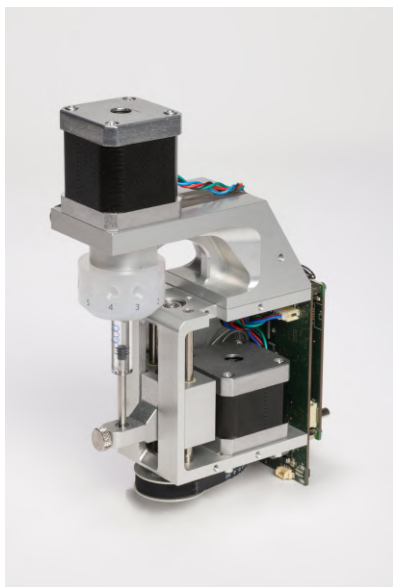


FIGURE 1.1 – SPM / P100-O



FIGURE 1.2 – SPM+ / P101-O

1.6 Functional Description

1.6.1 General Description

The device is made of the following parts:

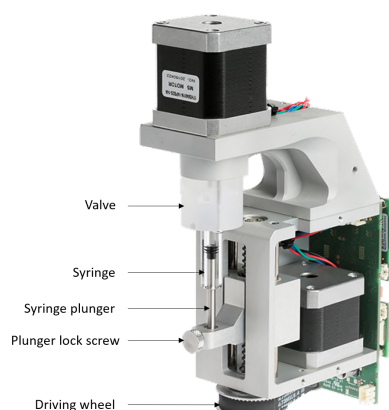


FIGURE 1.3 – SPM pump terminology 1/2

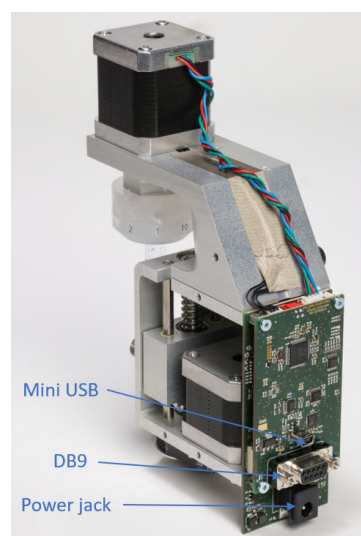


FIGURE 1.4 – SPM syringe pump terminology 2/2

1.6.2 Syringe and syringe drive

The syringe assembly is made of a UHMW-PE or PTFE plunger tip which travels inside a glass barrel. The plunger is moved by :

- a 1.8° stepper motor for the SPM/SPM+
- a 0.9° stepper motor with a 1:6.75 gearbox for the SPM HD/SPM+ HD

through an elastic transmission which enables a smoother displacement. The syringe plunger is tightened to the sliding part using a plunger lock screw.

The rated pressure for the syringe is 7 bars (0.7 MPa or 102 PSI).

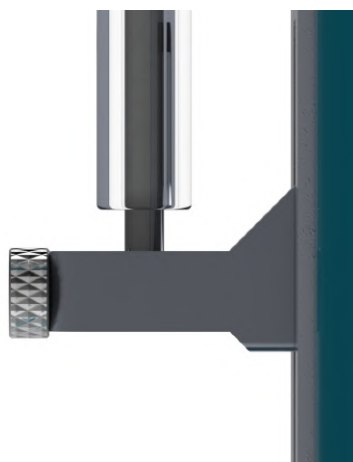


FIGURE 1.5 – Detail of plunger fixation when correctly tightened



Before performing any movements with the SPM pump, please check that the plunger is correctly fixed to the slider. The screw should be completely inserted in the thread.

The syringe volume is variable, between $50\ \mu\text{L}$ and $1'000\ \mu\text{L}$ for SPM and between 2.5 mL and 5

mL for SPM+. For all syringes, the travel length of the plunger is 30 mm. When the pump is not powered, the syringe is removable. The plunger can also be displaced using the driving wheel only if the pump is not moving.

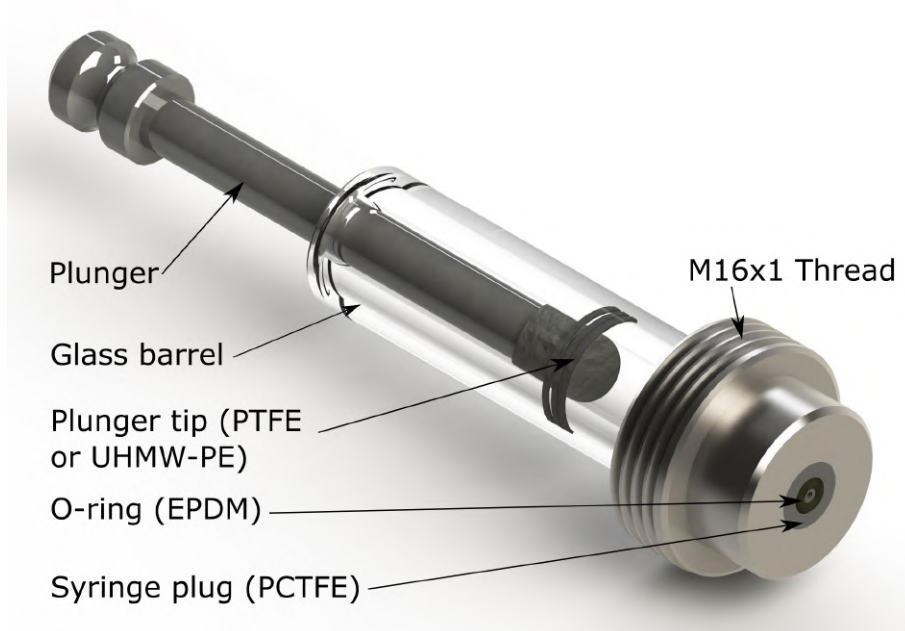


FIGURE 1.6 – Nomenclature for the syringe module for SPM / volumes: 50 to 1000 μL

The PCTFE plug and the EPDM O-ring form the first and second sealing parts for the syringe. Therefore they should be treated with care. The O-ring should not be removed.

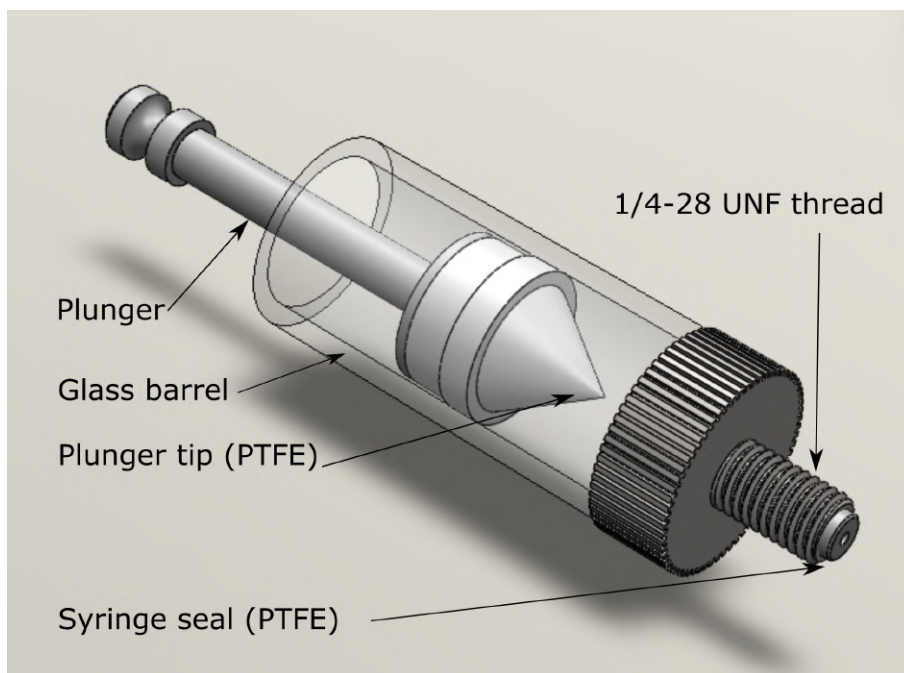


FIGURE 1.7 – Nomenclature for the syringe module for SPM+ / volumes: 2.5 and 5 mL

The PTFE syringe seal should be treated with care and clean before mounting to ensure best

performance.



When the plunger controller is at the very bottom, a strip sticks out the bottom, as shown in Figure 1.8. Do not approach it with a strong metal.



FIGURE 1.8 – Strip sticking out

1.6.3 Valve module

The valve module enables the selection between the microfluidic ports (only one port is connected to the syringe at a given time). The valve module is made of fluoropolymers which have an outstanding chemical resistance. The plug which selects the connected channel is made of PTFE and the outer part, called valve seat, where the user can connect standard microfluidic fittings, is made of PCTFE.

The valve module, which is a closed loop system, works as follows:

- The user sends a command to connect a specific port

- The plug is rotated by a 1.8° stepper motor through the plug drive
- A position sensor detects very precisely the position of the plug thanks to indexes integrated in the plug itself
- Using this feedback the stepper motor can be stopped when the plug has reached the desired position

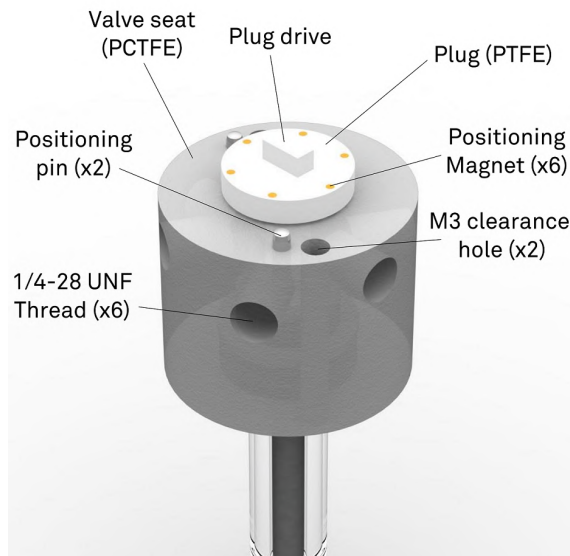


FIGURE 1.9 – Nomenclature for the valve module

When the pump is not powered, the valve module is removable by unscrewing the two M3x30 screws. The entire procedure is described in the maintenance section. The rated pressure for the valve module is 7 bars (0.7 MPa or 102 PSI).



Hardware

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2. Hardware description

2.1 Glossary

Carryover: Contamination of a volume of fluid by residual fluid from a previous pick up or dispense. Carryover causes variability in the final volume and concentration.

Carryover volume: Volume of liquid that will be mixed with the next liquid. It is not stuck, but will be swept next time a liquid passes.

Cavitation: Formation of vapor cavities in a liquid – i.e. small liquid-free zones ("bubbles" or "voids") – that are the consequence of forces acting upon the liquid. It usually occurs when a liquid is subjected to rapid changes of pressure that cause the formation of cavities where the pressure is relatively low.

Dead volume: Volume that is “stuck” in the system (dead end), which is not cleanly swept and relies on diffusion to clear out.

Internal volume: Volume inside the system, from entrance to exit.

Port: The connection or orifice through which sample may be injected or dispensed.

Priming: Completely filling the pump tubing and syringe with bubble-free fluid to allow sustained, reproducible pumping action.

Void volume: Sum of the carryover volume and dead volume.

Wetted surfaces: The surfaces which are contacted by the sample stream.

2.2 Cabling

2.2.1 Power supply

The SPM syringe pump must be supplied with the AC/DC adapter which is provided with the pump. Using a different power supply is at the user's own risk.



FIGURE 2.1 – GSM40A18-P1J adapter from MeanWell provided with the pump



FIGURE 2.2 – Ferrite 600 04 27 from Sibalco to be added with 4 loops around the power cable

2.2.2 Female Mini-USB

The SPM syringe pump can be controlled using a Mini-USB interface. In this case, the Mini-USB female connector works as a virtual serial port. The connection can be done by any mini-USB/USB cable provided that the provided ferrite of type 74271111S is locked around the cable.



FIGURE 2.3 – Ferrite 74271111S from Würth Elektronik to be locked around the USB cable connected to the SPM

2.2.3 Female DB9 connector

The SPM syringe pump can also be controlled using the DB9 connector¹.

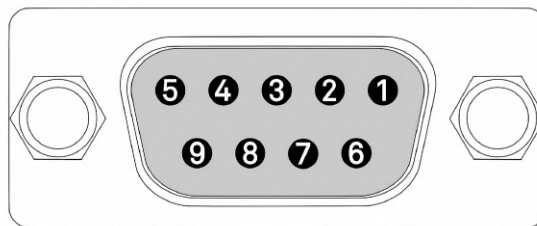


FIGURE 2.4 – DB9 pin-out on device side (SPM)

Different communication protocols can be implemented with this single connector: RS-232, RS-485 or RS-422. Only the first two are implemented in the SPM's software, but RS-422 can be implemented upon request.

Pin	Abbreviation	Name	Typical Purpose
1			
2	TX	Transmitted Data	Carries data from DCE (SPM) to DTE
3	RX	Received Data	Carries data from DTE to DCE (SPM)
4	DTR	Data Set Ready	Not implemented. Connect to DSR
5	GND	Ground	Zero voltage reference
6	DSR	Data Terminal Ready	Not implemented. Connect to DTR
7	CTS	Clear To Send	Not implemented
8	RTS	Request To Send	Not implemented
9			

TABLE 2.1 – Pin assignment of the DB9 connector female on the SPM for RS-232 protocol

¹Proper designation is DE-9 but the DB9 appellation is the most commonly used.

Pin	Abbreviation	Name	Typical Purpose
1			
2	D-	Data	Data. Negative driver
3			
4			
5	GND	Ground	Zero voltage reference
6			
7			
8	D+	Data	Data. Positive driver
9			

TABLE 2.2 – Pin assignment of the DB9 connector female on the SPM for RS-485 protocol

Pin	Abbreviation	Name	Typical Purpose
1			Not connected
2	TX-	Transmitted Data	Carries data from DCE (SPM) to DTE. Negative output
3	RX+	Received Data	Carries data from DTE to DCE (SPM). Positive input
4			
5	GND	Ground	Zero voltage reference
6			
7	RX-	Received Data	Carries data from DTE to DCE (SPM). Negative input
8	TX+	Transmitted Data	Carries data from DCE (SPM) to DTE. Positive output
9			Not connected

TABLE 2.3 – Pin assignment of the DB9 connector female on the SPM for RS-422 protocol

The pin assignment is always given from the point of view of the AMF module.

2.3 Chemical compatibility

The following parts can be in contact with the liquid:

1. The valve seat: PCTFE
2. The valve plug: PTFE or UHMW-PE
3. The syringe O-ring: EPDM
4. The syringe barrel: borosilicate glass
5. The syringe plunger tip: UHMW-PE or PTFE

These materials offer an excellent chemical compatibility. However Advanced Microfluidics SA cannot be held responsible for damages caused by the use of a specific chemical. Before using the device with a given chemical, please make sure that it is compatible with the aforementioned materials.



The pump should not be used to process explosive or highly flammable fluids.

3. Valve module description

The SPM syringe pump can be used with several valve head types:

- Ultra-low carryover volume. Variants: 6 ports
- Low carryover volume. Variants: 6, 8, 10, 12 ports
- Small carryover volume. Variants: 8, 10 ports

All of these valves have the particularity of having no dead volume.

3.1 Low and small carryover volume valves

3.1.1 Description

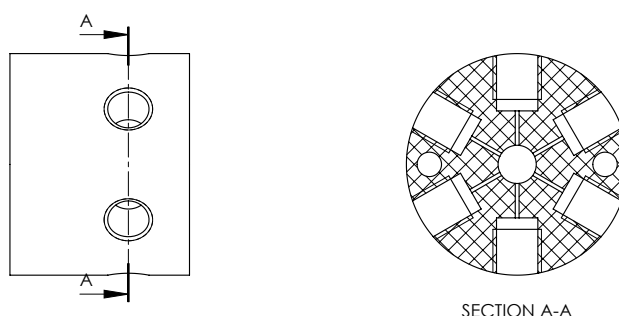


FIGURE 3.1 – Section view of the 6-port PCTFE valve seat revealing the microchannels

The 6-port low carryover volume valve (V-D-1-6-050-C-P) features 6 microfluidic ports that can be connected **one at a time** to the syringe content. The channels have a diameter of 0.5 mm in the valve seat and in the plug. Standard 1/4-28 UNF flat bottom fittings can be connected to these channels.

The very small dimension of the channels inside the valve module reduces the carryover volume of the pump. The ports are organised on 1 stage, as shown in Figure 3.1, separated by 60°.

The same concept can be applied for the other models.

The internal and carryover volume increase for the 10 and 12-port valves, as they required a physically bigger valve head (otherwise we cannot fit that many ports around the circumference of the valve).

3.1.2 Port numbering

You will find the port numbers for the VD1-6-050 in Figure 3.2 and Figure 3.3:

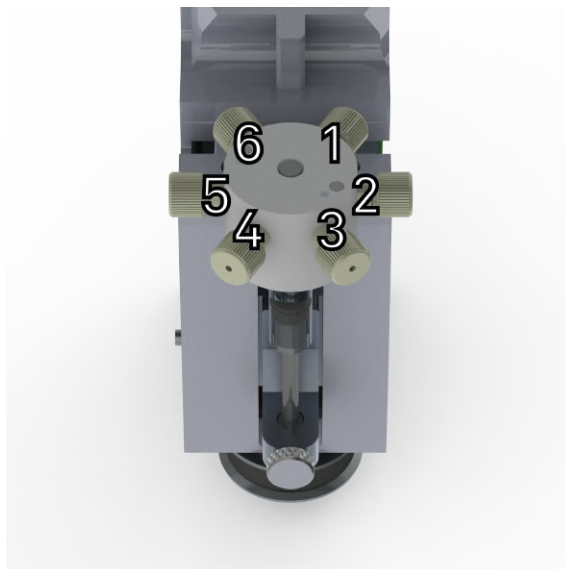


FIGURE 3.2 – Cut section revealing port numbering - VD1-6

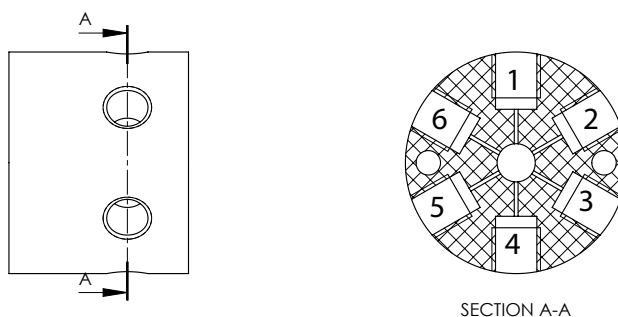


FIGURE 3.3 – Section view of the PCTFE valve seat with port numbering - VD1-6

Note — Direction of rotation.

The command $I\langle n \rangle$ corresponds to a clockwise rotation of 60° when incrementing the port number by 1. The command $O\langle n \rangle$ corresponds to a counterclockwise rotation of 60° when decrementing the port number by 1.

If you are on port 3, the command $I\langle 4 \rangle$ will be executed with a 60° rotation of the plug, while the command $O\langle 4 \rangle$ will be executed with a 300° rotation of the plug.

It is also possible to go to a port using the shortest way, regardless of the direction of rotation by using the command $B\langle n \rangle$.

3.2 Ultra low carryover volume valves

3.2.1 Description

This very specific valve design has been patented for allowing minimal carryover volume. Depending on the requirements of the application, the valve can be used as a standard 6-port valve leading to a carryover volume of $3\ \mu\text{L}$ for the entire pump (in the worst case) or with a specific port choice for input and output, the pump can feature a carryover volume of $1.5\ \mu\text{L}$.

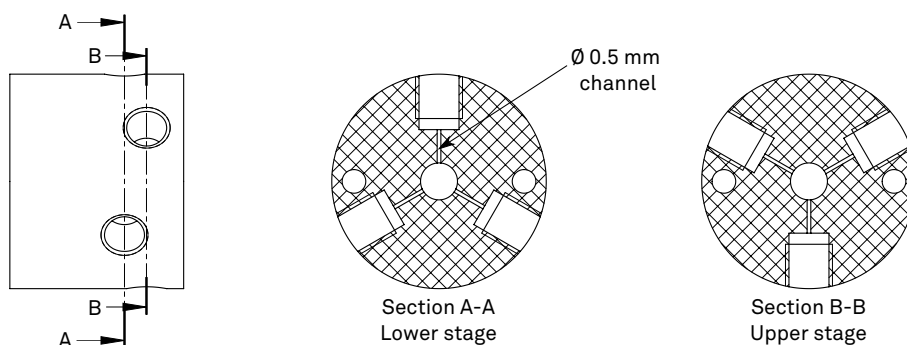


FIGURE 3.4 – Section view of the PCTFE valve seat revealing the microchannels - VD2-6

The 6-port ultra-low carryover volume valve features 6 microfluidic ports that can be connected **one at a time** to the syringe content. The channels have a diameter of 0.5 mm in the valve seat and in the plug. Standard 1/4-28 UNF fittings can be connected to these channels.

The very small dimension of the channels inside the valve module reduces the carryover volume of the pump. The ports are organized on 2 stages as shown in Figure 3.4. This configuration also minimizes the leakage rate since the ports are separated by 120° .

3.2.2 Port numbering

This feature requires a specific geometry for the microchannels and explains the specific port numbering depicted in Figure 3.5.

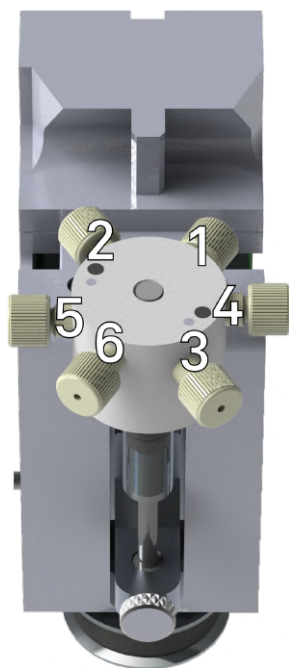


FIGURE 3.5 – Cut section revealing port numbering - VD2-6

Since the ports are located on 2 stages, the rotations from one port to the other when they are located on different stages may be counterintuitive. The port numbering is established as follows: between two consecutive ports (e.g. $1 \Rightarrow 2$) the plug rotates in a clockwise manner of 60° (smallest possible rotation) unless asked to turn in the opposite direction (i.e. the counterclockwise direction). Additionally, odd-numbered ports are positioned below even-numbered ports according to Figure 3.6.

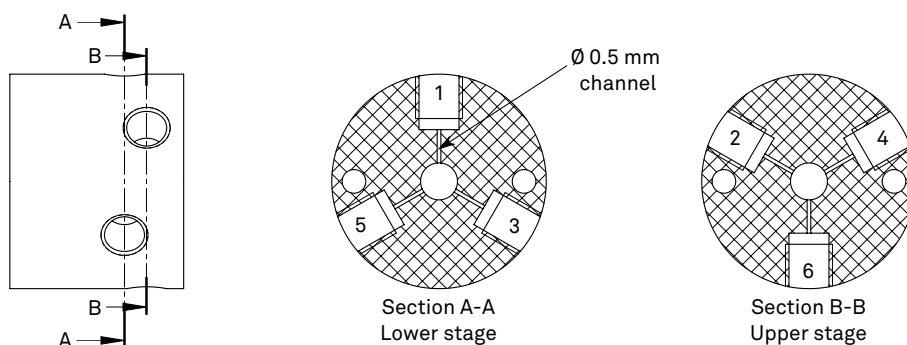


FIGURE 3.6 – Section view of the PCTFE valve seat with port numbering

Note — Direction of rotation.

The definition for rotating direction is given in Figure 3.7. The default rotation is triggered by the command `I<n>` which leads to a clockwise rotation of the plug. Moving from port 3 to port 4 will be done by a 60° clockwise rotation of the plug if called by the command `I<4>`. On the other hand, the user might want to rotate the plug in the counterclockwise direction with command `O<4>`. This will result in a 300° rotation of the plug for moving from port 3 to port 4.

**Clockwise rotation
(cmd I<n>)**



FIGURE 3.7 – Direction of rotation definition for the plug - clockwise rotation corresponds to a 60° rotation when incrementing the port number by 1, counterclockwise rotation corresponds to a 60° rotation when decrementing the port number by 1

3.2.3 Standard use of the 6-port ultra-low carryover volume valve

In many applications, the valve can be used as a standard 6-port valve. Each port can be used as an input or an output similar to competitors' valves but the pump's carryover volume will remain below 5 μL . This low carryover volume will prevent the appearance of an undesired air layer in the syringe.

In this mode, you can pick up up to 5 samples and dispense them through the remaining port for the desired microfluidic application.

■ Application Notes

You can find various application notes on our website at: <https://amf.ch/new/applications/>

3.3 Unleashing the minimal carryover volume capabilities of the ultra-low carryover volume valve

For some applications, the user will desire to use the specific feature of the SPM syringe pump. The minimal carryover volume offered by our innovative construction enables maximum precision and reduced contamination between samples. Cleaning steps are thus made easier and more efficient.

3.3.1 Carryover volume

The typical evidence of the carryover volume of a pump is the apparition of an air layer at the bottom of the plunger as illustrated in Figure 3.8. This air layer is tricky to remove and will cause inaccuracy in dispensed volumes. The SPM syringe pump will already reduce this issue in the standard configuration since its carryover volume is extremely small. For more demanding applications, the pump offers a specific way to further reduce the carryover volume and its consequences.

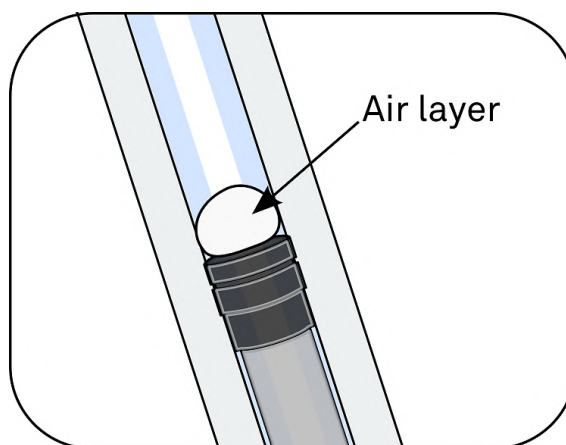


FIGURE 3.8 – Air layer appearing with conventional syringe pumps

3.3.2 Simplified priming process

A minimal carryover volume offers several advantages. The chosen case, here, is the priming where the user wants to have the microfluidic tubings filled with the right reagent for his experiment. The priming step is usually an exhausting task with conventional syringe pumps due to the air layer.

The patented valve design offers a simplified procedure to prime your tubings before starting the experiment. This principle of operation is based on the two stages of the valve module. It should be performed with the input and the output ports on separate stages. The input tubing can be connected on the lower and the output port on the upper tubing or vice versa. The two solutions are equivalent. The complete process is described in Figure 3.9.

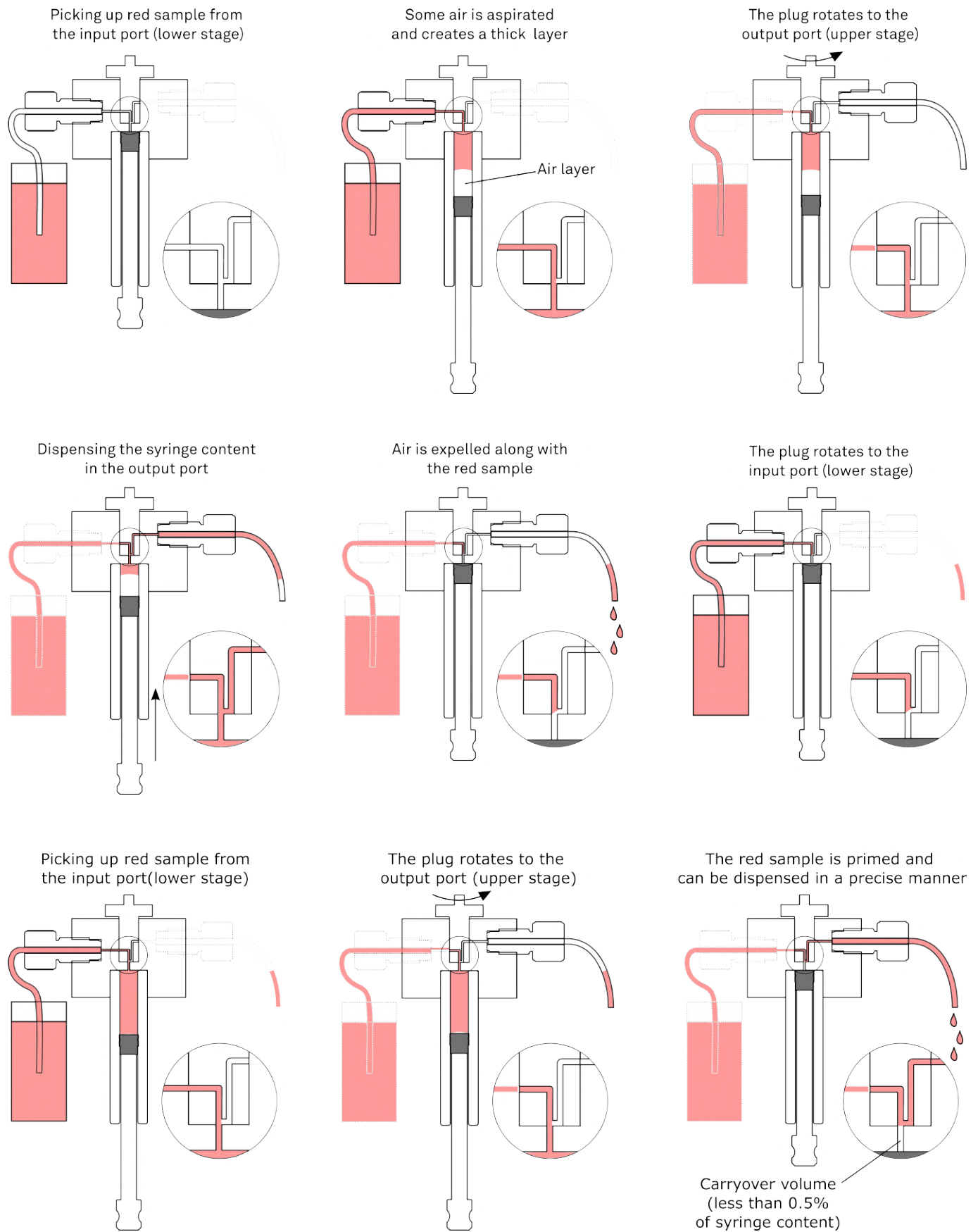


FIGURE 3.9 – Automated priming process with SPM



4. Maintenance operations

4.1 Good practices

In order to avoid premature damage of the SPM or the valve, there is some good practice to have when you are using the pump:

- Try to avoid as much as possible dust entering the fluidic system because it can get stuck into the valve and create a groove in it. This would lead to leakage or bubble creation
 1. When you are screwing your tubing to the valve port, make sure to not have dust in the port. You can use dust free cleaning spray
 2. Filter your solutions before introducing them in the pump
 3. If you don't use one of the port of the valve, put a lid on it
 4. You can put the pump under a laminar flow to reduce the amount of dust
- Avoid overpressure, it can damage the valve or the syringe. Make sure the outlet is not blocked when you are dispensing
- Avoid solution that can crystallize in your microfluidic system. If you have to use this solution, clean your system after usage (see section 4.2)

4.2 Cleaning procedure

A cleaning procedure should be **performed at the end of each day or in between two different experiments**. An effective cleaning can be performed in the following manner:

- Bleach solution to kill microorganisms
 1. Prepare a solution of 1% chlorine bleach and deionized water
 2. Prepare a reservoir and place 1 tubing in the bleach solution and 5 tubings in a waste recipient
 3. Pick up the bleach solution through 1 port to entirely fill the syringe
 4. Sequentially output the syringe content through the remaining ports and throw it to the waste
 5. Repeat operation at least 2 times

Note: You can also use BD FACS clean solution that is typically used to clean flow cytometers

- Detergent solution to remove debris
 1. Prepare a solution of detergent (1% Mucosol) and deionized water
 2. Move the tubing from the bleach solution reservoir and place it into a reservoir of detergent solution
 3. Pick up the detergent solution through 1 port to entirely fill the syringe
 4. Sequentially output the detergent solution through the remaining ports into the waste recipient
 5. Repeat operation at least 2 times

Note: 2% RBS 25 can also be used. For blood or plasma manipulation, you may use 1% Alconox. For the valve, you can make this washing step into an ultrasonic bath after a long period of using it.

- Rinsing water to prepare the pump for your next experiment

1. Move the tubing from the detergent solution reservoir and place it into a reservoir of deionized water
2. Pick up the rinsing solution through 1 port to entirely fill the syringe
3. Sequentially output the rinse water through the remaining ports into the waste recipient
4. Repeat operation at least 2 times

Note: Before the rinsing step with the deionized water, you can add a washing step with a solvent such IPA or 70% ethanol (same manipulations as for the rinsing step)

Note

Thanks to our small internal volume, each cleaning cycle is extremely efficient.

4.3 Gas bubbles

Gas bubbles in a microfluidic setup is a very common issue and it can be quite difficult to address it. The bubbles can be trapped or directed into a waste output, but there is always a risk of some gas bubbles being created in the setup. The goal of the following section is to give you some hints to avoid them as much as possible and to remove them if they are trapped.

4.3.1 Bubble sources

Gas coming from leakage

The first possible source of gas bubble comes from the aspiration by the pumping system of external air. This is possible when some part of the microfluidic setup is not air tight. We propose a methodical approach to identify the leakage source. First check the following elements of the microfluidic setup:

- **Connectors:** Verify that every connector is tightly screwed/connected and that it suits well with the tubing you are using. We advise using connectors with a PTFE ferrule that is compressed when the connector is screwed. Make sure that the mating surfaces (PTFE ferrule and valve port surface) are clean and without scraps. To test if the leakage comes from a specific connector, spray a solution containing detergent around the connector and pressurize at 1 or 2 bars the connection with a syringe full of air for example. If there is a leakage, you will see some bubbles around the connector.
- **Valve:** Keep the solution you are passing through the valve as clean as possible. If dust or solid particles pass through your tubing and get stuck in the valve, it can create groove in the valve when this one is rotating. This will eventually lead to leakage and the valve will have to be changed. If you suspect that the valve is leaking, you can plug the port you are not using with a cap to see if it reduces the leakage. If the leakage is reduced, it means that the valve is damaged. After running a lot of cycles, the valve can wear out and the sealing between the rotor and the stator may be defective.
- **Syringe:** As for the valve, the syringe can wear out after a lot of cycles. Check the glass barrel for cracks especially after a shock. If you see a crack on the glass barrel, the syringe has to be replaced as the crack is a source of leakage. If the syringe looks good but you experience leakage, make sure that the small O-ring is correctly installed between the valve and the syringe.

As a general rule, to check if the valve or the syringe is the source of your bubble problem, change them one at a time and check if the situation is better.

Gas coming from the solution

The concentration of air molecule is given by the Henry's law: $c_s = H(T)p_g$ where $H(T)$ is the solubility constant (increases if the temperature T decreases) and p_g is the pressure of the gas in vapor phase. We have an equilibrium when the actual concentration of gas in the liquid c is equal to c_s . When the temperature or the pressure changes, there is some variation of c_s which leads to a non-equilibrium state described by: $\zeta = c/c_s - 1$. When $\zeta < 0$, we have an undersaturation situation and the gas wants to go in the solution (would reduce the size of the bubbles) and when $\zeta > 0$, we have a supersaturation situation and the gas wants to go out of the liquid and this makes bubbles grow. This supersaturated situation occurs when we reduce the pressure (by aspirating the liquid with a pump for example) or when we increase the temperature.

The bubbles created in the solution have a starting point called a nuclei and when this nuclei is formed, the bubbles start growing due to a supersaturated situation. Those nuclei can appear in the bulk of the solution if we have a strong supersaturated solution ($\zeta \gg 0$) and this results in microbubbles flowing continuously through your tubing, or they can appear on the surface of your

tubing/connector/valve/syringe due to strong supersaturated solution (nuclei form on the surface and then in the bulk because the surface acts as a nuclei catalyzer) or due crevices or sharp edges during the wetting as shown in figure 4.1 (source : Pereiro, Iago, et al. "Nip the bubble in the bud: a guide to avoid gas nucleation in microfluidics." Lab on a Chip 19.14 (2019): 2296-2314).

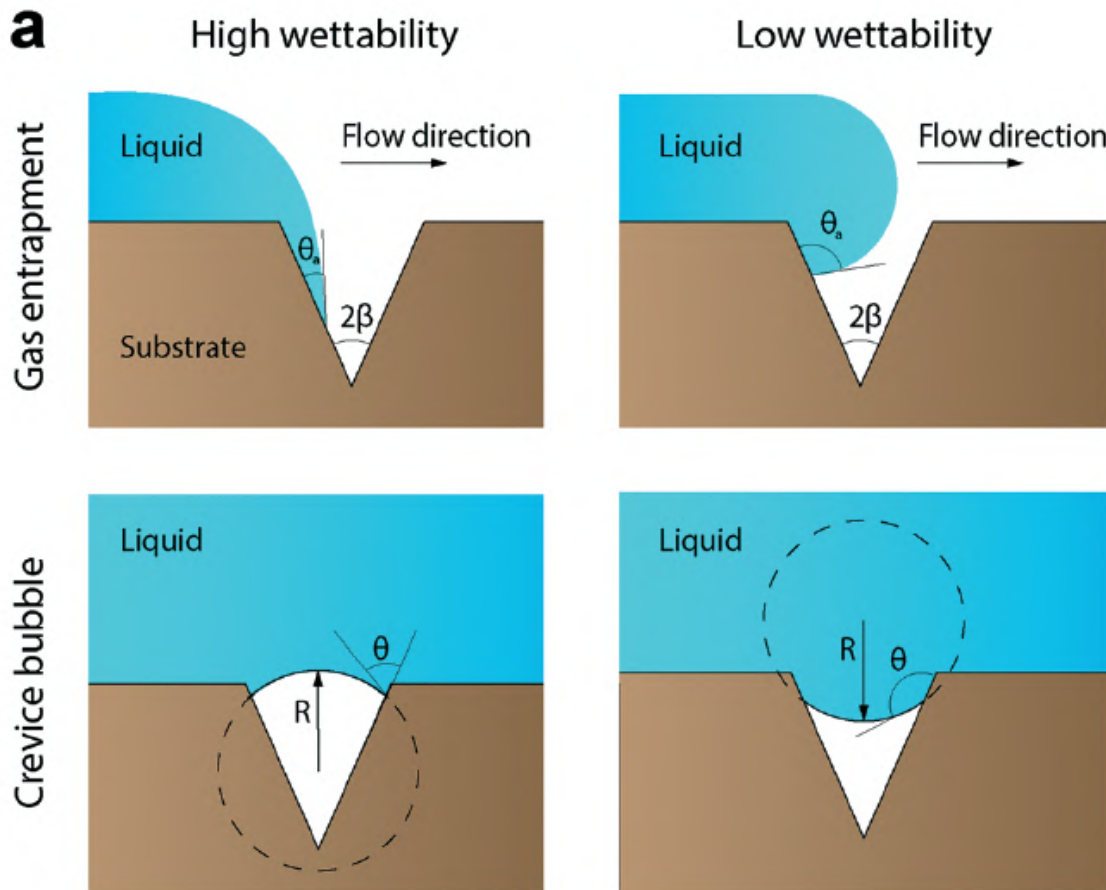


FIGURE 4.1 – Image that describes the formation of bubble due to a crevice during the wetting of the microfluidic network (source : Pereiro, Iago, et al. "Nip the bubble in the bud: a guide to avoid gas nucleation in microfluidics." Lab on a Chip 19.14 (2019): 2296-2314)

The crevice or sharp edge bubbles are the main source of "in solution created" bubbles. It acts as gas tank and when we have a supersaturation situation, the gas volume increases until the bubble is too big to stay trapped by the surface and part of bubble is released. This gas tank is a continuous source of bubble and more you are in a supersaturation situation, more often you will have bubble released from this gas tank. The surface nuclei are maintained on the surface due to the surface tension (the more hydrophobic the surface is, the more the gas bubble will stay trapped) and act as a trap for the microbubbles that are flowing through the tubing. Because of this we have an accumulation effect, the surface bubbles become bigger and bigger until they are too big to be maintained by the surface and they are then released.

4.3.2 How to avoid/reduce the creation of nuclei

- Degas your solutions before using them and in the best case, keep them in this low gas concentration until they are used (for example, keep them under vacuum)
- Avoid big change of pressure and high velocity flow

- Try to keep your lab and your setup under a constant temperature (for example during the night, the temperature may decrease and re-increase in the morning leading to bubble creation)
- **Connectors:** Try to avoid as much as possible sharp edges and dead volume in your connectors and try to avoid change of diameter in your tubing
- **Valve:** As for the leakage, try to avoid dust and particles in the valve because it would create groove that are source of crevice nuclei and leakage. Also, try to fit the diameter of your valve port with the diameter of your tubing
- **syringe:** During the priming of your system, a bubble is created in the syringe due to the inner volume of the pump. This bubble may be washed away during the priming but can also remain trapped by the plunger (more hydrophobic than the syringe wall in glass), is never released and act as a bubble source under supersaturation situation. The solution for this is to prime your system with a solution that has a lower surface tension such as ethanol or SDS.
- **Wetting:** To avoid the crevice nuclei during the priming, it is important to prime your system with a low flow velocity. It also helps if you are using a solution with a lower surface tension such as ethanol or SDS for the wetting of your system

4.3.3 Remove the trapped bubbles

To remove the bubbles trapped in your system, you can tap on the tubing or induce vibration to your system. The most efficient way we have found is to flow a large gas (air) bubble followed by a solution containing ethanol: The air train picks up all the trapped bubbles and the ethanol brings a good wetting on the surfaces.

4.4 Changing the syringe

The user has the possibility of changing the syringe of the SPM syringe pump. Different volumes are offered and can be ordered to match the application's requirements. To extend the lifetime of the pump, please follow the instructions below carefully when changing the syringe.

The pump layout is given hereafter as a reminder, so as to simplify the syringe change.

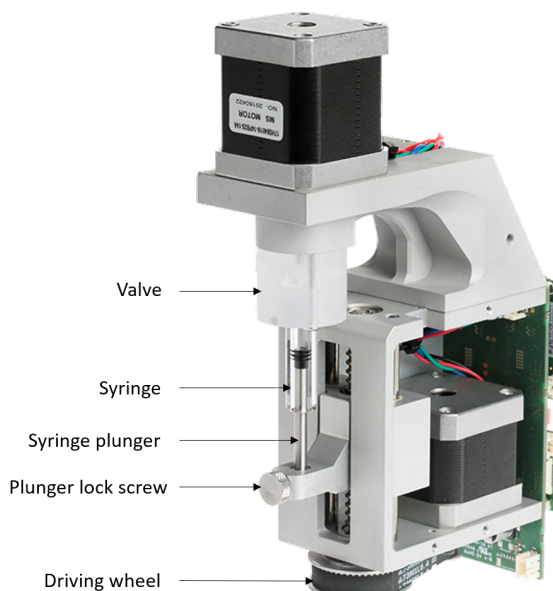


FIGURE 4.2 – SPM pump terminology

1. Clean the syringe and the valve using an appropriate solvent, then rinse them using either DI water or isopropanol.
2. Disconnect the syringe pump from the power supply.
3. Position the syringe pump on an open and clean area.
4. Unscrew the plunger lock screw (see Figure 4.3).
5. Use the driving wheel to move the slider in its lowest position (see Figure 4.4).
6. For syringe sizes between 25 and 1000 μL , insert the syringe removal tool and align the pins of the tool with the two appropriate bores at the syringe basis. (see Figure 4.5). For 2.5 and 5 mL syringes, no specific tool is required, the knurling on these two syringes enable to fasten/unfasten by hand directly.
7. To remove the syringe, unscrew the glass barrel using the removal tool, for syringe sizes between 25 and 1000 μL (see Figure 4.6a), or using the knurling for 2.5 and 5 mL syringes. After many cycles, using pliers may be necessary. If using pliers, be careful not to damage the glass barrel (see Figure 4.6b).
8. After removal of the syringe, make sure that the black O-ring is correctly fitting in its groove for syringe sizes between 25 and 1000 μL and that it is not damaged (see Figure 4.7a). For 2.5 and 5 mL syringes, check that the PTFE seal is clean and not scratched (see Figure 4.7b).
9. Control the glass barrel. No crack or fissure should be seen on the glass.
10. If the removed syringe is in good condition, store it carefully.
11. Perform the same quality check on the syringe that you plan to install.
12. Screw the syringe in the valve seat. Do not force the thread, the screwing process should be smooth (see Figure 4.8). Use the syringe removal tool to hand tighten the syringe for syringe

sizes between 25 and 1000 μL . Directly hand tighten the syringe for 2.5 and 5 mL volumes. Do not use pliers or other tool when screwing the syringe as it might result in breaking the glass.



The syringe is designed to be tightened by hand. A good seal is only guaranteed if you follow this procedure.

13. When the syringe is correctly tightened in position, use the driving wheel to come over the plunger (see Figure 4.9).
14. Align the plunger bottom with the holder, according to Figure 4.11. The two surfaces marked in orange should be coplanar.
15. Screw the plunger lock screw and tighten it by hand (see Figure 4.10).
16. Make sure that the plunger lock screw's thread is not visible anymore thus guaranteeing a safe fixation (see Figure 4.12 and Figure 4.13).
17. The power supply can be reconnected.

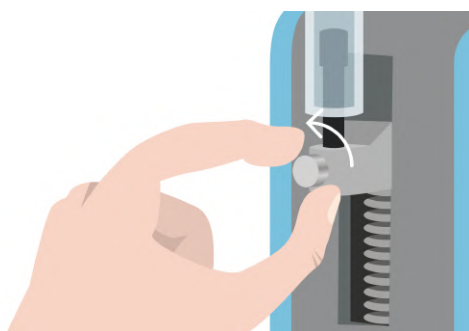


FIGURE 4.3 – Unscrew the syringe by turning in the shown direction



FIGURE 4.4 – Move the slider down, using the driving wheel

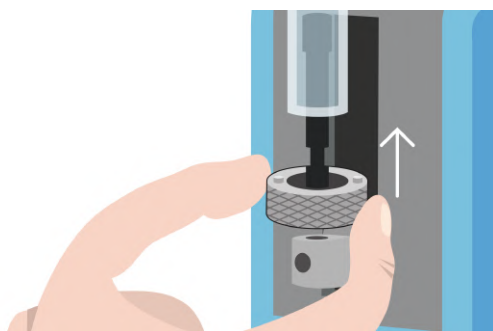
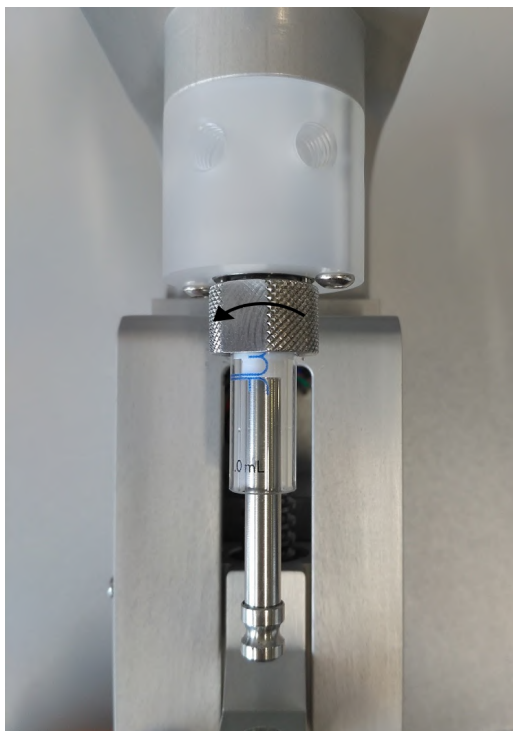


FIGURE 4.5 – Insert the syringe removal tool (for syringe sizes between 25 and 1000 μL only)



(A) Syringe removal for 25 - 1000 μL syringes



(B) Syringe removal for 2.5 - 5 mL syringes

FIGURE 4.6 – Unscrew the syringe by turning in the shown direction



(A) For 25 - 1000 μL syringes, ensure that the black O-ring is correctly inserted in the groove as shown here



(B) For 2.5 - 5 mL syringes, ensure that the PTFE surface is clean and not scratched

FIGURE 4.7 – Syringe seal check

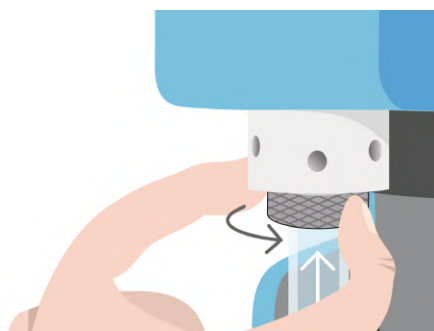


FIGURE 4.8 – Screw the syringe using the specific tool for 25 - 1000 μL syringes or using the knurling for 2.5 and 5 mL syringes. Tighten by hand only

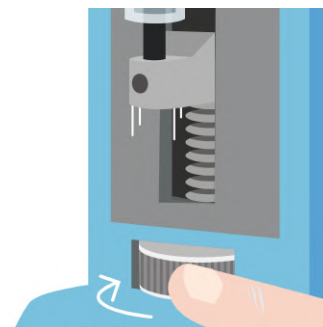


FIGURE 4.9 – Move the slider up using the driving wheel

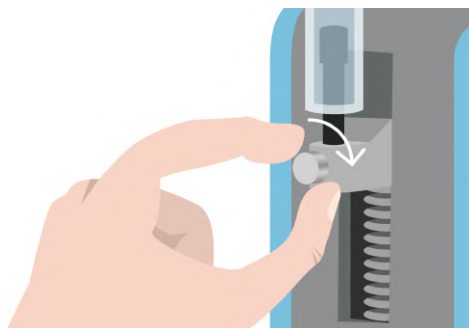


FIGURE 4.10 – Once aligned, tighten the plunger lock screw



FIGURE 4.11 – Alignment to be obtained when screwing the plunger lock screw



FIGURE 4.12 – Correct plunger lock screw fixation



FIGURE 4.13 – Incorrect plunger lock screw fixation

4.5 Changing the valve

The user has the possibility of changing the valve of the SPM syringe pump. Different numbers of ports are offered and can be ordered to match the application's requirements. To extend the lifetime of the pump, please follow the instructions below carefully when changing the valve.

1. Follow steps 1-10 described in section 4.4 to remove the syringe from the pump.
2. Remove the valve from the pump. Hold it by hand and unscrew the 2 screws holding the valve, using a hex key (2 mm hex key for 25 - 1000 μ L syringes, 2.5 mm hex key for 2.5 - 5 mL syringes) (see Figure 4.14).
3. Store the valve in a clean dust-free container.
4. Align the new valve with the motor shaft (see Figure 4.15).
5. Turn the valve until the pins of the valve are aligned with the matching bores on the pump (see Figure 4.16).
6. Screw both screws using a hex key to attach the valve on the pump (see Figure 4.17).
7. Follow steps 12-17 described in section 4.4 to mount the syringe on the pump
8. If the number of ports of the valve was changed, configure the pump accordingly by sending the command `"/_!80<n>"`, where `<n>` is the number of ports.

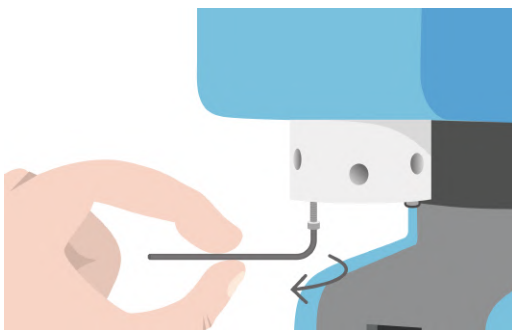


FIGURE 4.14 – Remove the 2 screws holding the valve

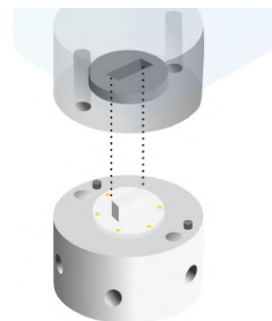


FIGURE 4.15 – Align the valve with the motor shaft

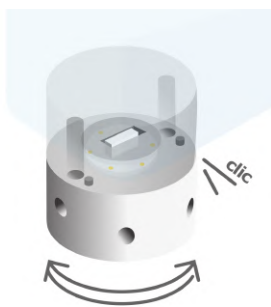


FIGURE 4.16 – Turn the valve until the pins are aligned

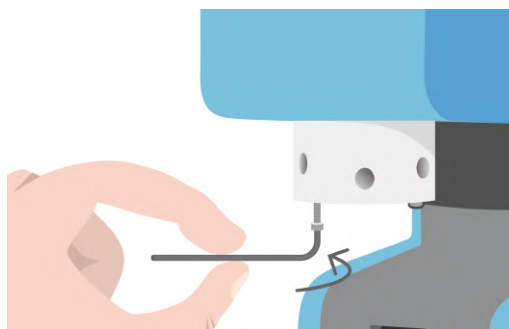


FIGURE 4.17 – Attach the valve using the 2 screws

4.6 Overpressure management

AMF pumps are rated for a pressure up to 7 bars (0.7 MPa or 102 PSI). As our pumps use a volumetric approach, dispensing on a blocked outlet will easily generate a pressure exceeding the rated pressure. Precautions must be taken to remain below this pressure. In addition to not dispensing on blocked ports, one should also take precautions to avoid clogging and the flow rate should be adapted depending on the fluidic resistance of the system.

If the pressure inside the syringe and the valve head exceeds the rated pressure, the rotor can be ejected from the stator, as shown in Figure 4.18. The pump should not be used when the rotor is ejected.

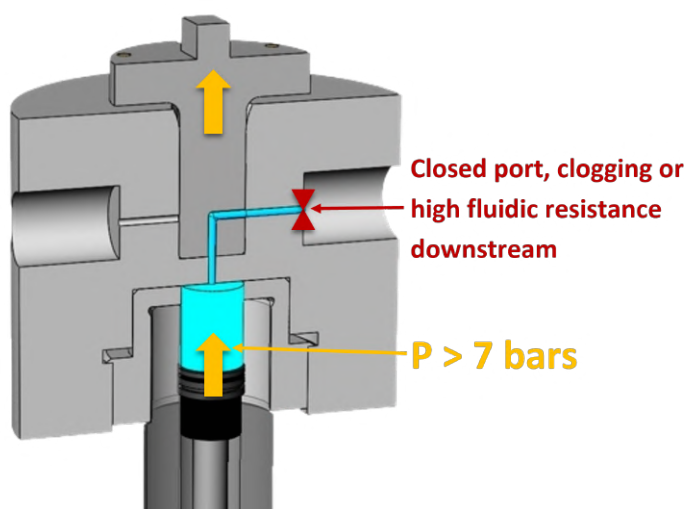


FIGURE 4.18 – Rotor ejection when there is an overpressure into the valve head

Using the positioning magnets, it is possible for the pump to detect this undesired rotor movement and to block the pump once it occurred. See section 6.1.3 for the command to activate this overpressure detection feature. This feature is enabled by default and we strongly recommend leaving it enabled, especially if you face cloggings or if you have important fluidic restriction in your setup. If the feature is disabled, an overpressure can occur without being detected. Using the pump while the rotor is ejected can damage the valve head permanently.

Once an overpressure occurred, a manual maintenance is needed to check that no part is damaged and to put the rotor back in its correct position.

1. Follow steps 1-2 described in section 4.5 to remove the syringe and the valve from the pump.
2. Check the visual aspect of the rotor. If the rotor is correctly inserted, there should be a gap of 0.5 mm between the collar of the rotor and the stator, as shown in Figure 4.19. The magnets of the rotor should also be flush with the bottom surface of the collar.

If an overpressure occurred, it is very likely that the gap between the rotor and the stator will be greater than 0.5 mm. First, it is important to ensure that the magnets are flush with the bottom surface of the collar. If the rotor was ejected several times or if the valve moved while the rotor was ejected, the magnets can be slightly pushed down. If the magnets are protruding from the bottom as shown in Figure 4.20, you can carefully push them back in place using a thin tool, until they are placed as in Figure 4.21. If the rotor looks damaged, a valve head replacement is recommended. You can contact support@amf.ch for further assistance.

3. Push the rotor back in place, as shown in Figure 4.21b. You should feel a slight movement and the rotor should now look as in Figure 4.19.

4. Follow steps 4-7 described in section 4.5 to reassemble the valve and the syringe on the pump.
5. Send the command `"/_@RSTOVERPRESSR"` to the pump to clear the error flag.

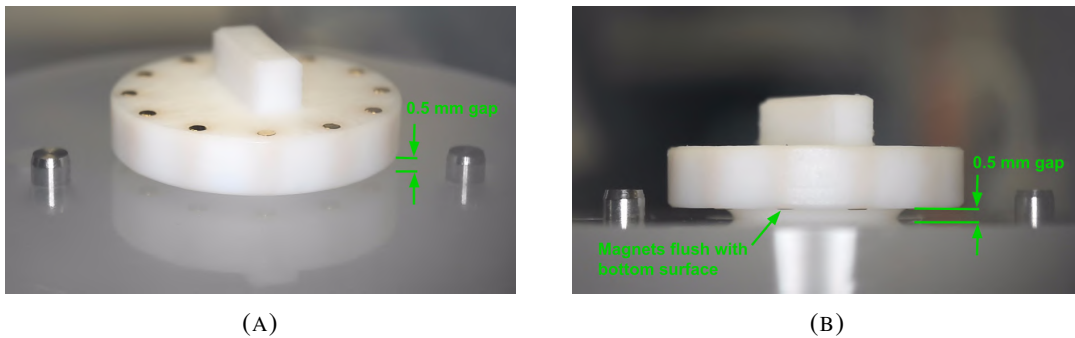


FIGURE 4.19 – Rotor properly inserted into the stator

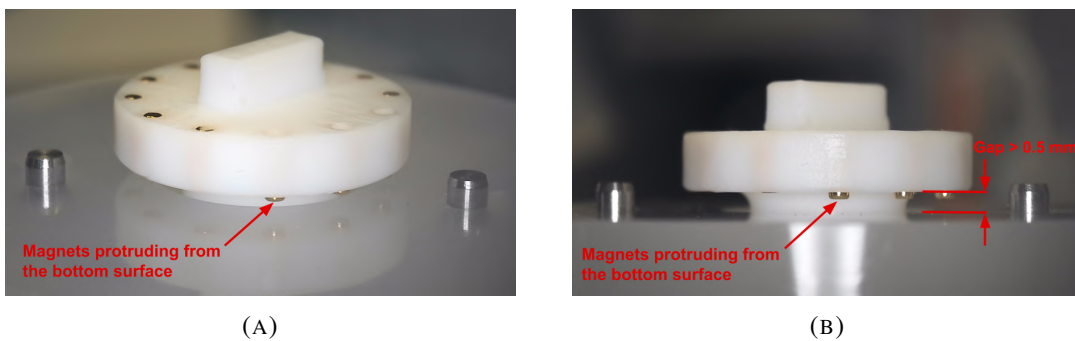


FIGURE 4.20 – Ejected rotor with magnets protruding at the bottom

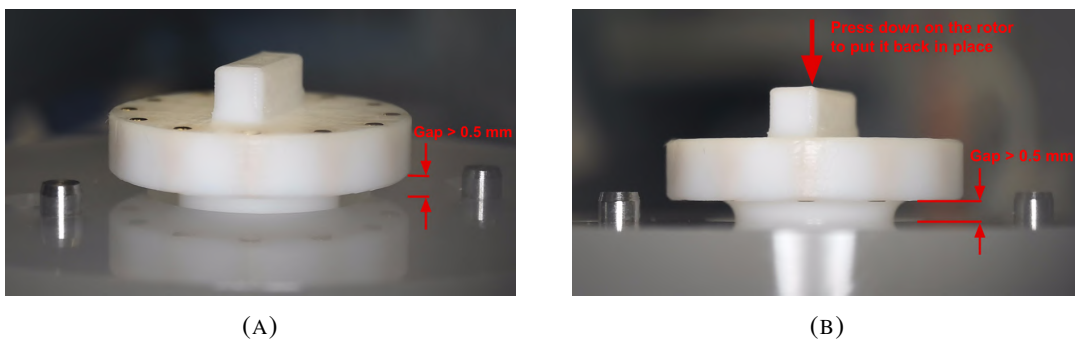


FIGURE 4.21 – Ejected rotor with magnets properly placed

5. Hardware configurations

5.1 Valve configuration

Rated pressure: 7 bars

Reference	Nb of ports	Wetted materials	Internal volume	Carryover volume	Channel $\varnothing$
V-D-2-6-050-C-P	6	PCTFE, PTFE	5.2 μL	1.5 μL	0.5 mm
V-D-1-6-050-C-P	6	PCTFE, PTFE	3.6 μL	2.6 μL	0.5 mm
V-D-1-8-050-C-P	8	PCTFE, PTFE	3.6 μL	2.6 μL	0.5 mm
V-D-1-8-100-C-P	8	PCTFE, PTFE	15 μL	8 μL	1 mm
V-D-1-10-050-C-P	10	PCTFE, PTFE	4.6 μL	2.8 μL	0.5 mm
V-D-1-10-100-C-P	10	PCTFE, PTFE	15 μL	8 μL	1 mm
V-D-1-12-050-C-P	12	PCTFE, PTFE	4.6 μL	2.8 μL	0.5 mm

TABLE 5.1 – Valve types for SPM & SPM HD

Reference	Nb of ports	Wetted materials	Internal volume	Carryover volume	Channel $\varnothing$
V-D-1-6-050-C-P	6	PCTFE, PTFE	14.4 μL	13.4 μL	0.5 mm
V-D-1-10-050-C-P	10	PCTFE, PTFE	15.4 μL	13.6 μL	0.5 mm
V-D-1-10-100-C-P	10	PCTFE, PTFE	25.7 μL	18.6 μL	1 mm
V-D-1-12-050-C-P	12	PCTFE, PTFE	15.4 μL	13.6 μL	0.5 mm

TABLE 5.2 – Valve types for SPM+ & SPM+ HD

5.2 Syringe configuration

The syringe have a rated pressure of 7 bars (102 PSI). They should not be operated above this rated pressure. Please make sure that you are not pushing liquid towards a closed output with the syringe as the pressure in the glass barrel is likely to reach higher pressures in such a case.

The 25 μL syringe is not sold as standard. It is presented in the table as it is available for a custom build if there is no other solution.

Syringe Vol. [μ L]	Part Number	Plunger Material	Min. Flow Rate [μ L/min]	Max. Flow Rate [μ L/min]	Min Dosing volume [μ L]
25	S-25-P	PTFE	0.00373	750	0.05
50	S-50-P	PTFE	0.00745	1 500	0.1
100	S-100-P	PTFE	0.0149	3 000	0.2
100	S-100-U	UHMW-PE	0.0149	3 000	0.2
250	S-250-P	PTFE	0.0373	7 500	0.5
500	S-500-P	PTFE	0.0745	15 000	1
500	S-500-U	UHMW-PE	0.0745	15 000	1
1000	S-1000-P	PTFE	0.149	30 000	2

TABLE 5.3 – Syringe types for SPM

Syringe Vol. [μ L]	Part Number	Plunger Material	Min. Flow Rate [μ L/min]	Max. Flow Rate [μ L/min]	Min Dosing volume [μ L]
25	S-25-P	PTFE	0.00359	200	0.05
50	S-50-P	PTFE	0.00717	400	0.1
100	S-100-P	PTFE	0.0144	800	0.2
100	S-100-U	UHMW-PE	0.0144	800	0.2
250	S-250-P	PTFE	0.0359	2 000	0.5
500	S-500-P	PTFE	0.0717	4 000	1
500	S-500-U	UHMW-PE	0.0717	4 000	1
1000	S-1000-P	PTFE	0.143	8 000	2

TABLE 5.4 – Syringe types for SPM HD

Syringe Vol. [μ L]	Part Number	Plunger Material	Min. Flow Rate [μ L/min]	Max. Flow Rate [μ L/min]	Min Dosing volume [μ L]
2500	S-2500-P	PTFE	0.373	75 000	5
5000	S-5000-P	PTFE	0.745	150 000	10

TABLE 5.5 – Syringe types for SPM+

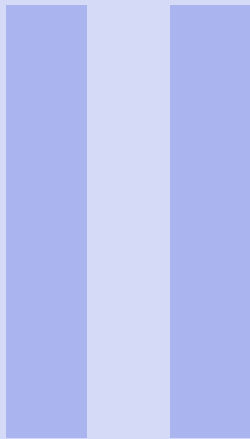
Syringe Vol. [μ L]	Part Number	Plunger Material	Min. Flow Rate [μ L/min]	Max. Flow Rate [μ L/min]	Min Dosing volume [μ L]
2500	S-2500-P	PTFE	0.359	20 000	5
5000	S-5000-P	PTFE	0.717	40 000	10

TABLE 5.6 – Syringe types for SPM+ HD

5.3 Syringe actuation

The SPM+ series is available with two syringe actuation options:

- **Standard:** the SPM/SPM+ slider is operated via a NEMA17 stepper motor with 200 steps per motor axis rotation.
- **HD:** the SPM HD/SPM+ HD is slider is operated via a NEMA17 stepper motor with 400 steps per motor axis rotation and a gearbox 1:6.75. The HD variant provides enhanced low flow rate stability but the speed is limited in the higher range due to the gearbox.



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6. Software Communication

6.1 Communication Protocol

The SPM syringe pump offers a data terminal protocol.

6.1.1 Data Terminal Protocol

The data terminal protocol enables communication through the following pattern:

Character Format	
Parameter	Setting
Baud rate	9600
Data bits	8
Parity	None
Stop bit	1
Command Block	
1	Start command (ASCII “/”)
2	Pump address (1 by default, “_” is broadcast address)
3	
...	
3+n-1	
3+n	Carriage Return (<CR>)
Answer Block	
1	Start answer (ASCII “/”)
2	Master address (ASCII “0”)
3	Error/Status character
4	
...	
4+n-1	
4+n	ETX (0x03)
5+n	Carriage Return (<CR>)
6+n	Line feed (0x0A)

TABLE 6.1 – Data Terminal Protocol Format

Please note that due to the buffer size limitation, the length of the command block is limited to 512 characters. If necessary, the command string has to be split to avoid overflow. The looping functions will also help to reduce the number of required characters for a given sequence.

Example 6.1 “/1ZR<CR>” will be sent to initialize the pump (see serial command description). In return, the pump will answer with “/0@<ETX><CR><LF>”. ■

6.1.2 Using DT Protocol with Microsoft Windows

The SPM can be controlled in the following manner:

1. Power on the pump (applying power will automatically switch on the pump).
2. Connect the SPM to a communication port of the PC.
3. Open the *Device Manager* to identify which COM port is connected.
4. Open a Terminal or Terminal emulator such as RealTerm or HTerm.
5. Establish the connection by selecting the baud rate (9600), the correct communication port (here for example COM5), 8 data bits, 1 stop bit, no parity and no flow control.

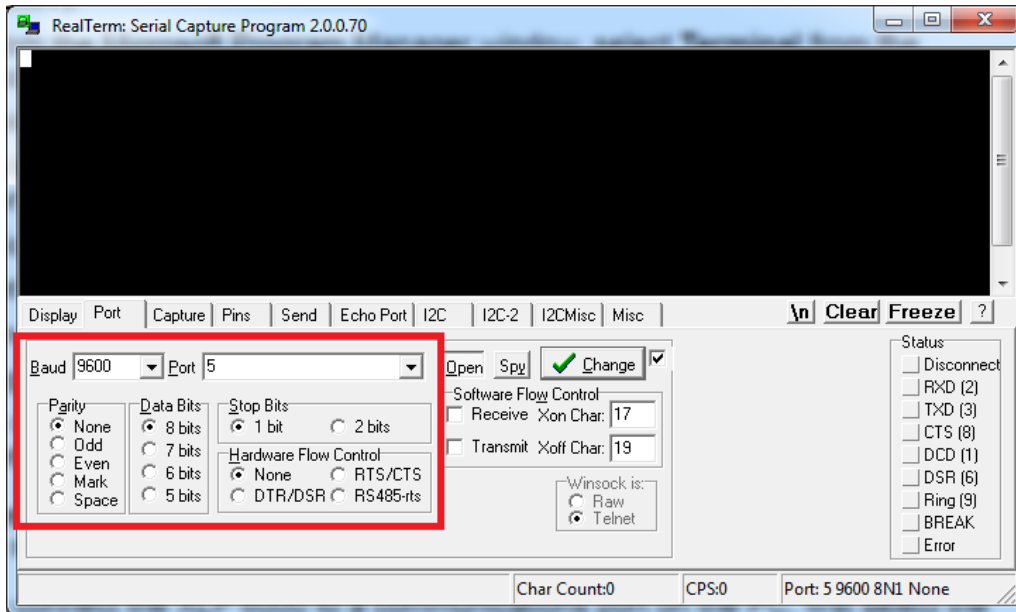


FIGURE 6.1 – Settings for serial communication

6. Press *Change* to start the connection.
7. Send `/1ZR<CR>` with the *Send ASCII* button. The *End of Line* chars can usually be added automatically (here by ticking the +CR box).

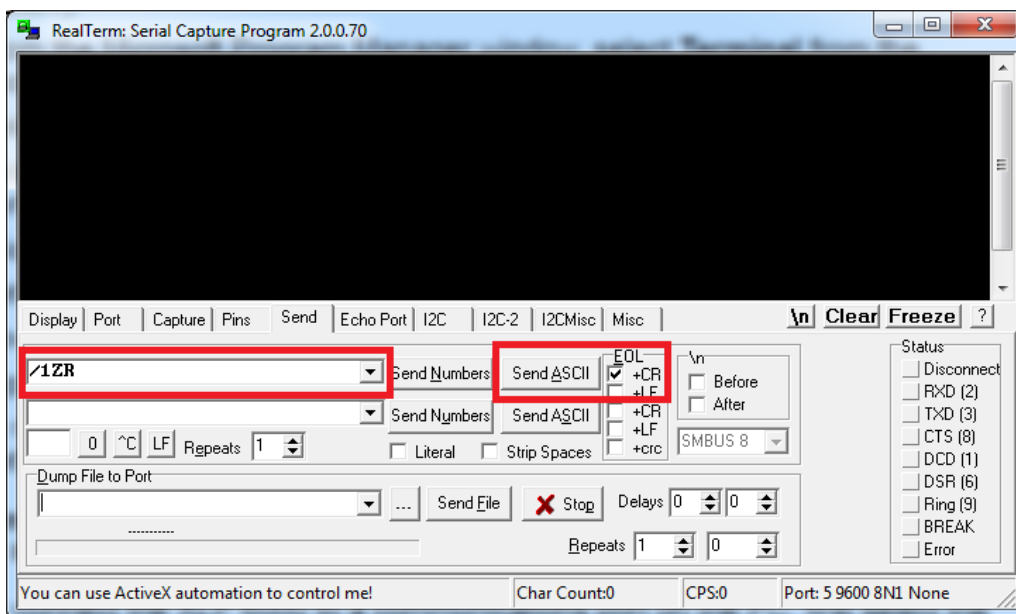


FIGURE 6.2 – Sending command configuration

8. Refer to the complete set of commands to use the pump according to your need.

6.1.3 SPM Command Set

The SPM simplifies your microfluidic automation thanks to a wide and well-tried command set. Many of the commands have default values; however, the default values may not provide the optimal settings for your application. Therefore it would be advantageous to spend some time exploring the many possibilities offered by the pump.



This document describes the command set for the version L1.1.1 of the firmware. Some functionalities may not be supported with older versions. If the pump returns an error when a correct command is sent, it is likely that the firmware needs to be updated. The latest version of the firmware can be downloaded on our website at the following address: <https://amf.ch/resources/>.

Command Execution Guidelines

- All commands, apart from those starting with "?" or "!" and from the abort command T, must be followed by the character [R] to be run.
- During the execution of a command, no new command is accepted, except for interrupt commands and report commands starting with "?".
- The pump answers immediately after a command was sent. If an invalid command has been sent in the command string, the pump reports an error immediately.
- To reduce wear, avoid running the plunger dry in the glass cylinder.
- Keep your fingers out of the syringe slot for safety reasons.

Pump & Valve Configuration Commands

These commands are used to change your pump's setup. If you are unsure, please do not change these commands and ask us instead. You can also verify your setup using the report commands in section 6.1.3.

Unless otherwise stated in the description, these settings are stored in non volatile memory and are retained after a power cycle.

Command	Operand Range	Default Value	Operand Description	Command Description
!30<n>	0,1, 2, or 3	2	Plunger force	Setting of the plunger force "0" being high force, "1" being normal force, "2" being medium force, "3" being low force (no trailing [R])
!50<n>	0,1 or 2	0	Answer mode	Synchronous mode "0" : answer once when the command has been processed / Asynchronous mode "1" : answer when the command starts, for each query and when command is completed / Asynchronous mode + command counter "2" : same as asynchronous but add number of subcommand processed in its last answer (no trailing [R]). This setting is not stored in non volatile memory. It will be reset after each power cycle.
!80<n>	6, 8, 10 or 12	6	Number of valve positions, No trailing [R]	Valve configuration (no trailing [R])
!17	N/A	N/A	N/A	Reset valve motion counter (no trailing [R])
@ADDR=<n>	1..9 or A..E	1	1-character address	Pump address, "_" is broadcast address
@RS232	N/A	Enabled	N/A	Activate RS-232 communication or serial-over-USB communication (activated by default) and deactivate RS-485 communication. (RS-232 communication will not work if the mini USB cable remains plugged)
@RS485T	N/A	Disabled	N/A	Activate RS-485 communication with answers terminated by <LF> (RS-485 communication will not work if the mini USB cable remains plugged)
@RS485F	N/A	Disabled	N/A	Activate RS-485 communication without <LF> ending (RS-485 communication will not work if the mini USB cable remains plugged)
@CORRDIST=<n>	0 or 1	1	Activation of relative move distance correction	Disabling the correction (operand set to 0) will favor the accuracy of each relative move but some error may accumulate over time. Enabling it (operand set to 1) will correct any previous positioning error even if relative move commands are used. See the Plunger Movement Commands (section 6.1.3) for more details.
@OVERPRESS=<n>	0 or 1	1	Activation of overpressure protection	If the pressure exceeds the rated pressure, the rotor of the valve head can be ejected from the stator. This can occur when the pump is dispensing on a blocked port (closed or clogged). If the overpressure protection is enabled, the pump will be blocked until the rotor is put back in place and the error flag is cleared. See section 4.6 for more details. If the overpressure protection is not enabled and an overpressure occurs, the valve may leak and may be damaged.

Command	Operand Range	Default Value	Operand Description	Command Description
@SYRINGE=<n>	0, 25, 50, 100, 250, 500, 1000, 2500 or 5000	0	Syringe volume in μL	Volume of the syringe mounted on the pump. It is not used by the pump but it can be used to compute the flowrate in a software.



We strongly advise using low force only when a small volume syringe (25, 50 or 100 μL) is used. Medium or normal forces can be used for syringe of 250 and 500 μL . High force is adapted to 1 to 5 mL syringes and for applications exhibiting high fluidic resistance.

When RS-485 communication mode is activated, the module will not answer nor respond to query addressed via broadcast. But any command sent via broadcast will be performed. Hence if several modules are connected on a RS-485 communication line, all the modules can be controlled with the broadcast address but no answer will be sent. In order to receive an answer from a specific module, each module has to have a unique address and it has to be addressed specifically.

When the module has RS-485 communication mode activated, it cannot be used with the LSPoneQuick software: it will display a broken firmware error.



If a pump is not answering to requests sent by the broadcast command, it is likely that the module has RS-485 communication activated.

Example 6.2 How to use answer mode:

Answer mode	Description	Example	Answer	Timing
Synchronous	Only answer once when the command has been processed, can't have embedded queries	/_P100D50R	/0@	Immediate
Asynchronous	Answer when command starts, for each query and when command has ended, can have embedded queries	/_P100?4?49D50R	/0@ /0'100 /0c /0'	Immediate + after each query + after last command
		/_P100D50R	/0@ /0'	
Asynchronous + command counter	Same as asynchronous but add number of subcommand processed in its last answer	/_P100?4?49D50R	/0@ /0'100 /0c /0'4	Immediate + after each query + after last command
		/_P100D50R	/0@ /0'2	

Control Commands

Command	Operand Range	Operand Description	Command Description
R	N/A		Execute command string
X	N/A	No trailing [R]	Re-execute last executed command string
G<n>	0...60000	0 = Loop forever	Repeat command sequence
g	N/A	Loop depth = max 10	Mark the start of a repeat sequence
M<n>	0..86400000	Milliseconds	Delay command execution
H	N/A	No trailing [R]	Halt command - Pause the sequence after finishing the current move. The paused sequence will resume with "/IR<CR>" or alternatively the user can send a new command. The command H can also be integrated in a sequence to introduce a pause before the execution of the remaining commands
T	N/A	No trailing [R]	Hardstop - Interrupt the current move and suppress it from the sequence. The interrupted sequence will resume with "/IR<CR>" after the interrupted command or alternatively the user can send a new command
@POWEROFF	N/A		Shut down the pump
@RSTFACTORY	N/A		Reset pumps settings to default values, except for move counters that can be reset individually. Some settings (e.g. number of valve positions) may need to be configured again for the product to work properly
@RSTOVERPRESS	N/A		Clear the overpressure flag in order to be able to use the pump after an overpressure event occurred. The rotor should be put back in place before sending this command, otherwise the flag will be raised again. We also recommend finding and eliminating the overpressure source (e.g. clogging) before moving the pump again. See section 4.6 for more details about this operation

Example 6.3 "/1gP2000D2000G3R<CR>" will trigger 3 back-and-forth 2000-step moves from the plunger.

"/1P2000HD2000R<CR>" will trigger a pick-up move of 2000 steps. The pump will then wait for "/IR<CR>" before executing the 2000-step dispense. The Halt command can also be executed on the fly. ■

Initialization Commands

Command	Operand Range	Operand Description	Command Description
Z<n>	(void) or 0..3	void: current force used, 0 = high force, 1= normal force, 2=medium force, 3=low force	Home the valve to port 1 and initialize the plunger drive (with high, normal, medium or low plunger force). The plunger force is then stored.
Y<n>	(void) or 0..3	void: current force used, 0 = high force, 1= normal force, 2=medium force, 3=low force	Home the valve to port 1 and initialize the plunger drive (with high, normal, medium or low plunger force). The plunger force is then stored.



Valve homing is always done on port 1. This means that the potential remaining syringe content will be expelled via port 1 during a system homing. This is thus a

*good practise to have a waste port on port 1.
In our case, there is no difference between the two initialisation commands Z and Y.
Both exist to be compatible with the Cavro standard.*

Valve Commands

Command	Operand Range	Operand Description	Command Description
B<n>	1..12	Enforced shortest plug movement	Move to valve port with shortest path independently of the current valve position. Clockwise/incremental direction preferred
b<n>	1..12	Shortest plug movement	Move to valve port with shortest path if target port is different from current port. Clockwise/incremental direction preferred
I<n>	1..12	Enforced incremental plug movement	Move to valve port independently of the current valve position. Clockwise/incremental direction
i<n>	1..12	Incremental plug movement	Move to valve port if target port is different from current port. Clockwise/incremental direction
O<n>	1..12	Enforced decremental plug movement	Move to valve port independently of the current valve position. Counter-clockwise/decremental direction
o<n>	1..12	Decremental plug movement	Move to valve port if target port is different from current port. Counter-clockwise/decremental direction

Example 6.4 “/1M10000I2R<CR>” will be sent to wait 10 seconds before moving the plug to port 2 in a clockwise direction. In return, the pump will answer with “/0@<ETX><CR><LF>”

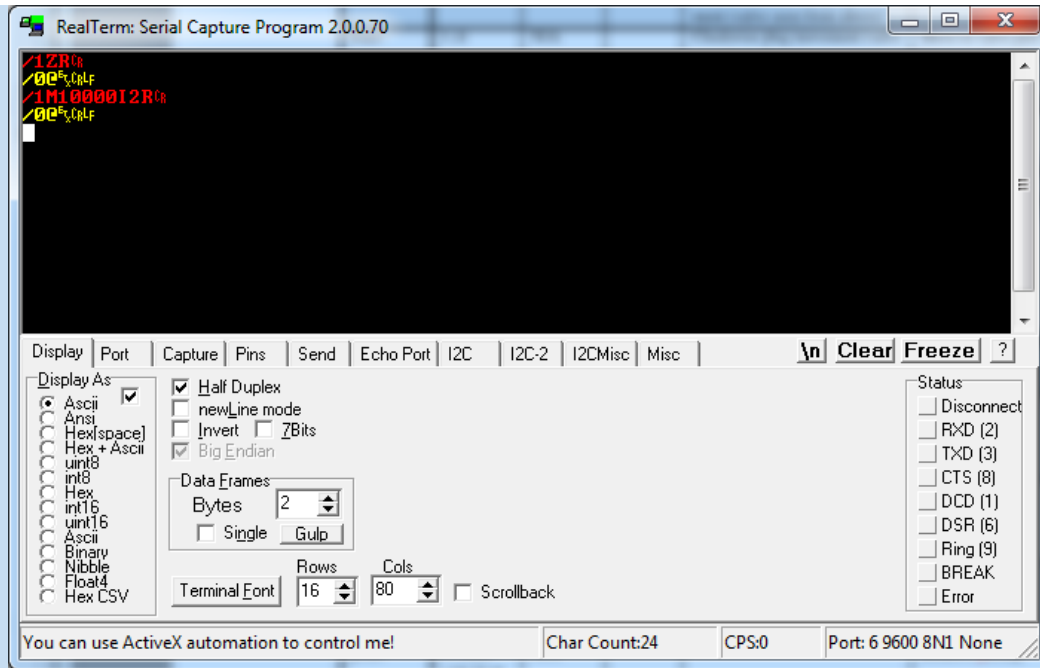


FIGURE 6.3 – Sending command via the terminal after starting the pump

Note in this example that the pump requires a homing command after power up.

Plunger Movement Commands

The plunger of the pump can be moved using absolute or relative move commands. When a move is performed, the exact plunger position at the end of the move may be slightly different than the target position. This potential position difference can be observed by comparing the theoretical and actual plunger positions (respectively report commands "?0" and "?4").

When using absolute commands, a potential position difference from a previous move is always corrected.

When using relative commands (Pickup or Dispense), this potential position difference is not always corrected, it will depend on the value of the "CORRDIST" setting. This setting enables or disables an automatic distance correction feature. If this feature is disabled, the target position after a move will be equal to the actual position +/- the relative distance. This behaviour will favor the accuracy of each relative move but some error may accumulate over time.

If this feature is enabled, the pump will automatically correct any potential error even with relative moves. This feature can be disabled by sending the "/_@CORRDIST=0R" command and enabled with the command "/_@CORRDIST=1R". The activation state of this feature is stored in a non-volatile memory so it will be kept after a power cycle.

Command	Operand Range	Operand Description	Command Description
A<n> a<n>	0..3000 with N=0 0..24000 with N=1	Absolute Position in step	Absolute Position
P<n> p<n>	0..3000 with N=0 0..24000 with N=1	Relative Pickup in step	Relative Pickup
D <n> d<n>	0..3000 with N=0 0..24000 with N=1	Relative Dispense in step	Relative Dispense



In our case, there is no difference between the upper and lower caps for these positioning commands. Both exist to be compatible with the Cavro standard.

Set Commands

Command	Operand Range	Power Up Default	Operand Description	Command Description
L<n> for standard series	100..59590	1557	Acceleration rate (Pulses/sec ²)	Set acceleration rate
L<n> for HD variant	100..59590	20000	Acceleration rate (Pulses/sec ²)	Set acceleration rate
I<n>	100..59590	59590	Deceleration rate (Pulses/sec ²)	Set deceleration rate
N<n>	0..1	0	<0> = Microstep 0.01 mm resolution <1> = Microstep 0.00125 mm resolution	Scaling of dispense/pickup arguments. The motor is always driven in microstep mode
S<n> for standard series	10..40	22	See Table 6.2	Set peak speed code Only present to be compatible with other syringe pumps. Does not offer as many possibilities as the command V.
S<n> for HD variant	16..40		See Table 6.2	Set peak speed code Only present to be compatible with other syringe pumps. Does not offer as many possibilities as the command V.
u<n> for standard series	1..214750		Peak speed (0.00745 Pulses/sec = 74.5 nm/s)	Set peak speed with ultra low flow rate resolution with standard series
u<n> for HD variant	13..905970		Peak speed (0.000552 Pulses/sec = 5.52 nm/s)	Set peak speed with ultra low flow rate resolution with HD variant (with the gearbox, higher speeds cannot be reached)
U<n> for standard series	1..32000		Peak speed (0.05 Pulses/sec = 500 nm/s)	Set peak speed with low flow rate resolution Setting the speed with a factor 20 compared to V command
U<n> for HD variant	1..10000		Peak speed (0.05 Pulses/sec = 500 nm/s)	Set peak speed with low flow rate resolution Setting the speed with a factor 20 compared to V command
V<n> for standard series	0..1600	150	Peak speed (Pulses/sec = 0.01 mm/s)	Set peak speed V0 is a special setting and corresponds to 0.5 Pulse/sec
V<n> for HD variant	0..500	75	Peak speed (Pulses/sec = 0.01 mm/s)	Set peak speed V0 is a special setting and corresponds to 0.5 Pulse/sec



*The peak speed may not be reached depending on acceleration/deceleration settings, plunger force settings and length of the movement.
The HD variant provides a more stable flow rate at low speeds but the maximum speed is lower than for the standard series*

Example 6.5 “/1N1R<CR>” will be sent to choose the 0.00125 mm resolution microstepping mode. In return, the pump will answer with “/0‘<ETX><CR><LF>”

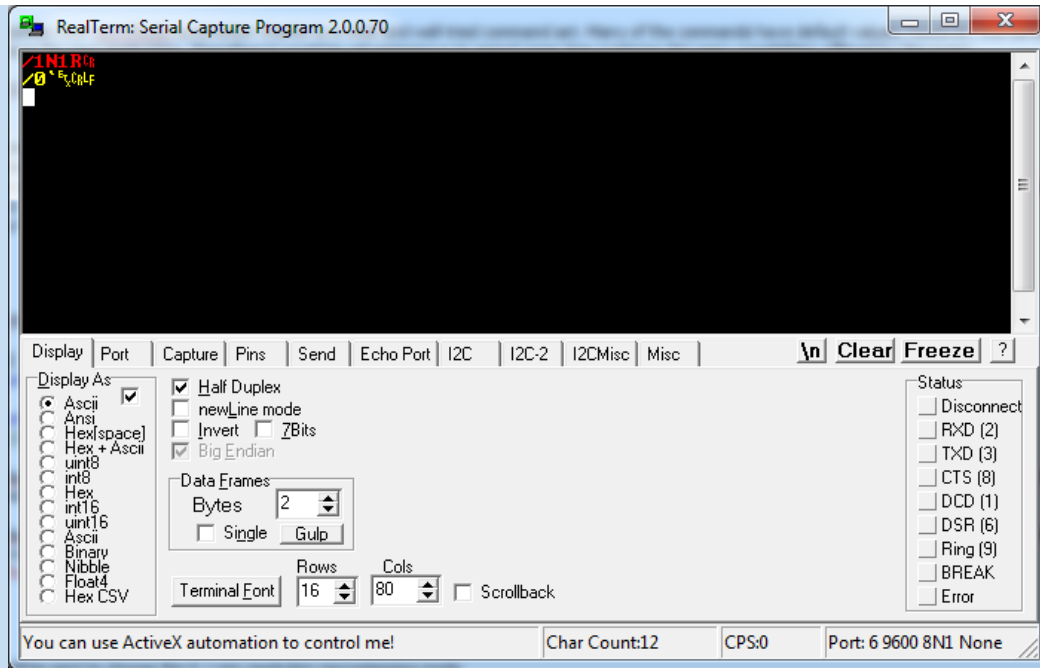


FIGURE 6.4 – Sending command via the terminal



The speed setting is a delicate process since it is highly dependent on the microfluidics setup. Tubings of small inner diameter will act as restrictions for the flow and pushing liquids at high speed through such tubings will lead to high pressure in your microfluidic circuit.

High pressure will increase the leakage in the circuit and could even block the pump as too much force would be required to dispense the syringe content. Last but not least, high pressure can blow up the weakest part of a microfluidic setup. An overpressure of the valve head could also occur, requiring a manual maintenance. See section 4.6 for more details.

Therefore we recommend choosing speeds according to a pressure estimation.

Speed Code	Value (puls- es/sec)	Seconds/stroke (N=0, N=1) with standard series	Seconds/stroke (N=0, N=1) with HD variant
10	1600	1.885	N.A
11	1400	2.15	N.A
12	1200	2.5	N.A
13	1000	3	N.A
14	800	3.75	N.A
15	600	5	N.A
16	400	7.5	7.5
17	200	15	15
18	190	15.79	15.79
19	180	16.665	16.665
20	170	17.645	17.645
21	160	18.75	18.75
22	150	20	20
23	140	21.43	21.43
24	130	23.075	23.075
25	120	25	25
26	110	27.275	27.275
27	100	30	30
28	90	33.335	33.335
29	80	37.5	37.5
30	70	42.855	42.855
31	60	50	50
32	50	60	60
33	40	75	75
34	30	100	100
35	20	150	15
36	18	166.665	166.665
37	16	187.5	187.5
38	14	224.235	224.235
39	12	250	250
40	10	300	300

TABLE 6.2 – Speed code for plunger movement

To better understand the relations between the motor speed, flow rate, plunger displacement and volume dispense, please refer to the appendix called “Resolution” in the user manual.

Report Commands

These commands do not need a trailing [R] character.

Command	Description
Q	Current status
? or ?0	Report theoretical plunger position in step
?2	Report maximal speed (unit changes with speed mode)
?4	Report actual plunger position in step (read by the encoder)
?5	Report speed mode (u = 0, U = 1, V = 2)
?6	Report valve position
?17	Report number of valve movements
?18 or %	Report number of valve movements (since last report)
?20 or #	Report firmware checksum
?23 or &	Report firmware version
?25	Report acceleration slope setting (plunger movement)
?26	Report pump address
?27	Report deceleration slope setting (plunger movement)
?28	Report resolution mode (fine positioning or microstep)
?29	Same as Q (query, status and error bytes)
?76	Report pump configuration
?300	Report plunger current (x10 mA)
?333	Report reduction ratio (x100)
?500	Report answer mode
?600	Report the volume of the syringe in μL
?801	Number of valve positions
\$	Internal reset
?9000	Unique ID
?9010	Answers 1 if pump is initialized, 0 if not
?9100	Detailed status of the syringe
?9200	Detailed status of the valve
@CORRDISTR	Activation state of the relative move distance correction
@OVERPRESSR	Activation state of the overpressure protection
@RSMODER	RS communication mode (RS-232 or RS-485)

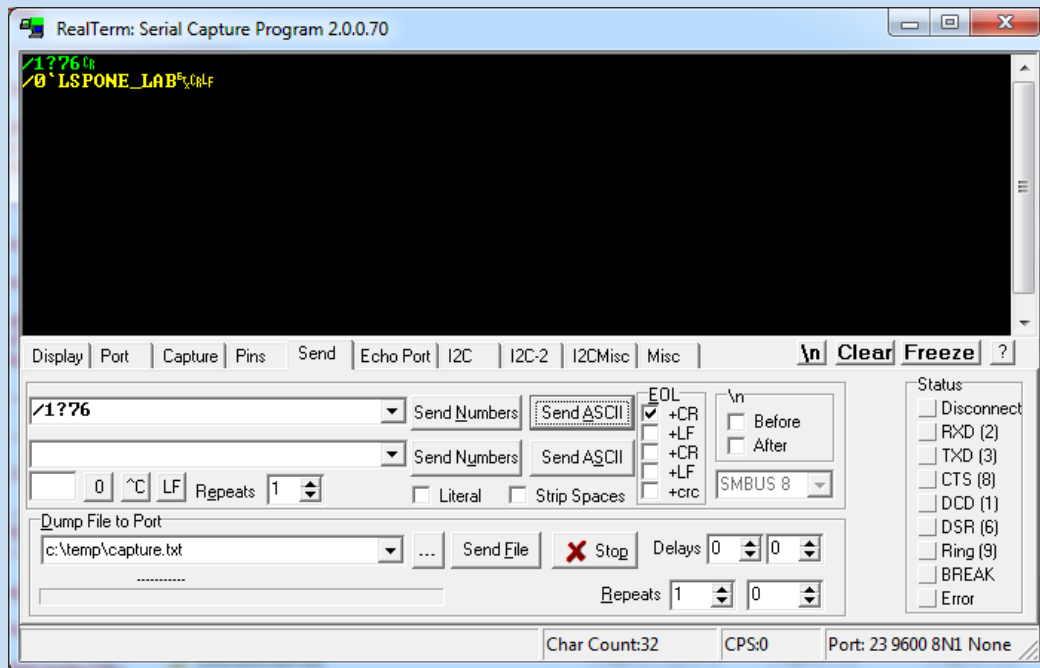


FIGURE 6.5 – Asking for the pump configuration

Example 6.6

6.2 Debugging software problems



Before looking in more detail at what caused an unexpected behavior of the pump, please make sure that:

- *The pump is correctly powered. If the Power-On button emits no light at all, please check the power supply and the electrical connections.*
- *Check the hardware situation. The valve, the syringe and the plunger must be correctly tightened in their respective position.*
- *Make sure that you have sent an initialization command before running any other instructions.*
- *Do not forget to address the command to the pump by writing “/I<command>” (if the pump has the address “1”, in case you are not sure of the pump address, use “_” which is the broadcast address) otherwise the pump will not be affected by the message.*
- *Do not forget to add R at the end of your command and to communication using the carriage return <CR> or \r*

After checking these first level errors, it is possible to explicit the error message using the report commands.

6.2.1 Error Codes and Pump Status

The pump reports immediately after it receives a command. This principle allows to check whether the command was accepted or not by the pump or whether it encountered any problem during the task.

Note — Coding best practice. A good coding practice when using this communication protocol is to check the pump status and catch possible errors with the [Q] command after each instruction.

Error Byte description

The error code has a length of 1 byte, i.e. 8 bits. The bit 5 is the status bit and serves for indicating whether the pump is busy or not. The error code is included in bits 0-3.

Bit	7	6	5	4	3	2	1	0
Value	0	1	Status Bit	0	Error Code			

TABLE 6.3 – Detail of the error byte as returned after a query “/1Q”

Note — Interest of the (Q) query. The answer block which is automatically sent by the pump features a status bit. However the status bit should not be used to know whether the pump is busy or not. A [Q] command is the only mean to know the current status of the pump.

Status bit description

These statuses shown as a direct answer when you send a command to the pump.

Status Bit 5	Description
X=0	The pump will only accept report commands or terminate command [T]
X=1	The pump is ready to accept new instructions

TABLE 6.4 – Status bit description

Note — Error byte after Terminate command. After sending a terminate command, the status is busy but in this very case, the user can still send a new command

Error Byte	Symbol ASCII		Error	
7 6 5 4 3 2 1 0	if Bit 5 = 0	if Bit 5 =1	Code	Description
0 1 X 0 0 0 0 0	@	`	0	No Error
0 1 X 0 0 0 0 1	A	a	1	Initialization
0 1 X 0 0 0 1 0	B	b	2	Invalid command
0 1 X 0 0 0 1 1	C	c	3	Invalid operand
0 1 X 0 0 1 0 0	D	d	4	Missing trailing [R]
0 1 X 0 0 1 1 1	G	g	7	Device not initialized
0 1 X 0 1 0 0 0	H	h	8	Internal failure (valve)
0 1 X 0 1 0 0 1	I	i	9	Plunger overload
0 1 X 0 1 0 1 0	J	j	10	Valve overload
0 1 X 0 1 0 1 1	K	k	11	Plunger move not allowed
0 1 X 0 1 1 0 0	L	l	12	Internal failure (plunger)
0 1 X 0 1 1 1 0	N	n	14	A/D converter failure
0 1 X 0 1 1 1 1	O	o	15	Command overflow or input voltage too low

TABLE 6.5 – Error codes

Error Types

Immediate errors include Error 2 and 3. The automatic answer block sent after an instruction will feature the error character. No [Q] query is required to get a description of the error.

Example 6.7 “/1014R<CR>” will trigger the following answer “/0c<ETX><CR><LF>” which means that an invalid operand has been used in the instruction. Here port “14” which does not exist on the valve. ■

To get detailed information about other errors, the user has to send the [Q] command and analyze the subsequent answer. **Initialization errors** appear when the initialization could not be performed. Therefore the pump cannot be used until the error was cleared and a successful initialization completed.

Command overflow errors are caused by a Move command, a Set command (except [V]), or a Valve command being sent while the plunger is moving. The pump ignores the command and issues an error 15. The user should use the [Q] query to be informed when additional commands can be sent.

Error codes given by ?9100

Status code	Name	Description
0xFF = 255	Busy	Pump currently executing an instruction
0x00 = 0	Done	Pump available for next instruction
0x80 = 128	Unknown command	Check that the command is written properly.
0x90 = 144	Not homed	You forgot the homing! Otherwise, check that you have the right port configuration and try again.
0x91 = 145	Move out of range	You're probably trying to do a relative positioning and are too close to the limits.
0x92 = 146	Speed out of range	Check the speed that you're trying to go at.
0xE0 = 224	Blocked	Something prevented the plunger to move.
0xE1 = 225	Sensor error	Unable to read position sensor. This probably means that the cable is disconnected.
0xE2 = 226	Sensor error	Communication error with the position sensor. Please check if it is properly connected.
0xE3 = 227	Position drift	The position read by the position sensor is different from the theoretical one. It can occur if the pump was manually moved. If distance correction is disabled, we recommend enabling it (see section 6.1.3 for more details). If the problem persists, contact support@amf.ch.
0xE4 = 228	Move too fast	It can occur if the pump is manually moved during a move.

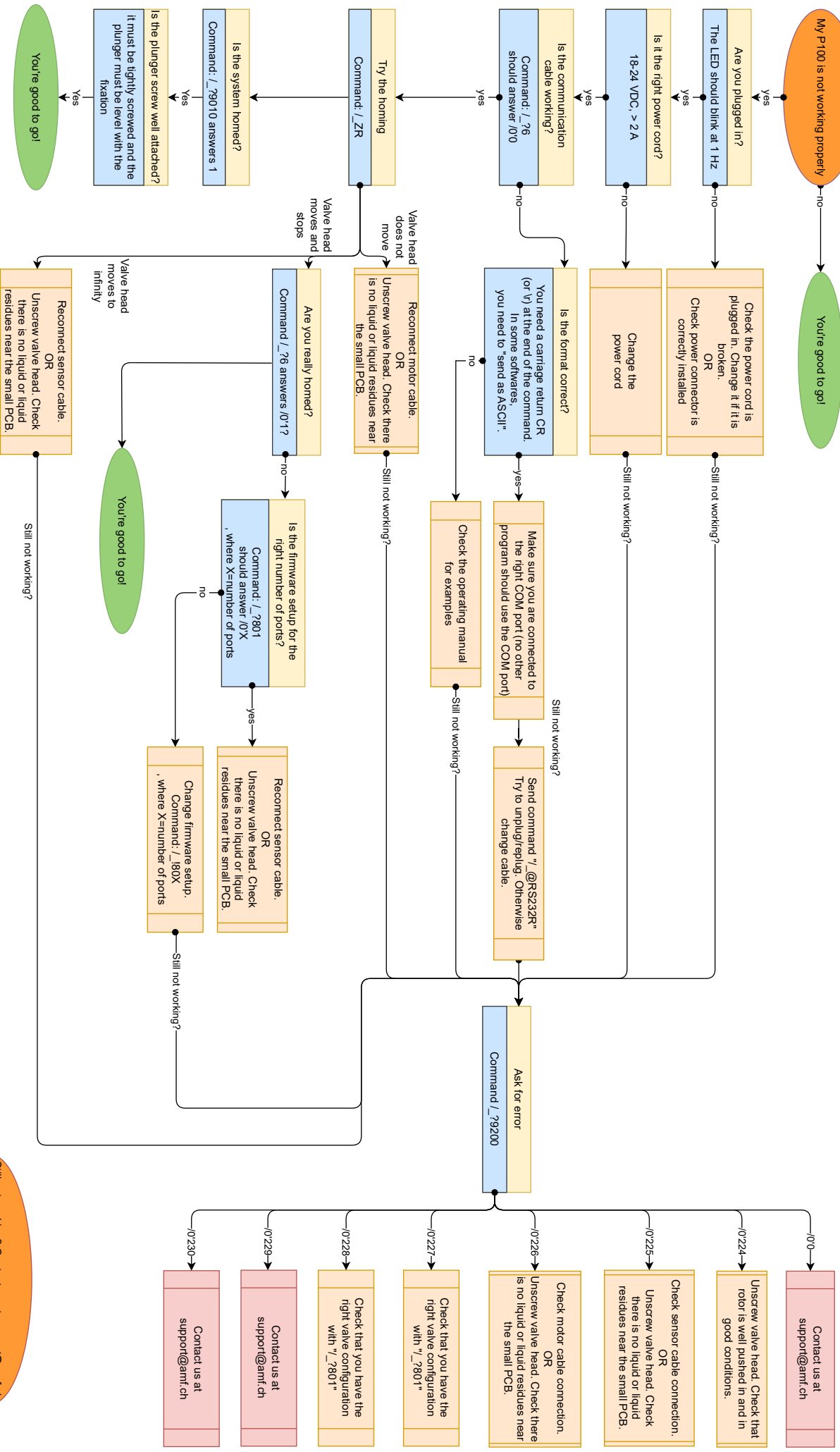
TABLE 6.6 – Detailed status of the pump (plunger) (see command ?9100)

Error codes given by ?9200

Status code	Name	Description
0xFF = 255	Busy	Valve currently executing an instruction
0x00 = 0	Done	Valve available for next instruction
0x80 = 128	Unknown command	Check that the command is written properly.
0x90 = 144	Not homed	You forgot the homing! Otherwise, check that you have the right port configuration and try again.
0xE0 = 224	Blocked	Something prevented the valve to move.
0xE1 = 225	Sensor error	Unable to read position sensor. This probably means that the cable is disconnected.
0xE2 = 226	Missing main reference	Unable to find the valve's main reference magnet during homing. This can mean that a reference magnet of the valve is bad/missing or that the motor is blocked during homing. Please also check motor cables and crimp.
0xE3 = 227	Missing reference	Unable to find a valve's reference magnet during homing. Please check that you have the correct valve number configuration with command "/1?801". If not, change it according to the valve you are working with. This can also mean that a reference magnet of the valve is bad/missing or that the motor is blocked during homing.
0xE4 = 228	Bad reference polarity	One of the valve's reference magnets has a bad polarity. Please check that you have the correct valve number configuration with command "/1?801". If not, change it according to the valve you are working with. This can also mean that a reference magnet has been assembled in the wrong orientation in the valve.
0xE5 = 229	Bad position homing	The valve's main reference magnet has a bad polarity or is too weak. Please check that you have the correct valve number configuration with command "/1?801". If not, change it according to the valve you are working with. Please also check that the valve head is properly fastened to the motor. If the problem persists, contact support@amf.ch.
0xE6 = 230	Bad position moving	One of the valve's reference magnets has a bad polarity or is too weak. Please check that you have the correct valve number configuration with command "/1?801". If not, change it according to the valve you are working with. Please also check that the valve head is properly fastened to the motor. If the problem persists, contact support@amf.ch.
0xE7 = 231	Valve overpressure	Valve overpressure occurred, a valve maintenance is required. See section 4.6 for maintenance instructions. If the problem persists, contact support@amf.ch for further information.

TABLE 6.7 – Detailed status of the valve (see command ?9200)


```
graph TD; A([My P100 is not working properly]) -- no --> B([You're good to go!]);
```



Still not working? Contact us at support@amf.ch
And tell us which steps you tried already!



Advanced Microfluidics
Small Volumes Matter

7. Python scripting

7.1 Description

Serial commands can be sent via python scripting using the *pySerial* library. A very simple example is shown below. Python scripting will be of specific interest when using different devices and trying to automate a sequence involving these devices.

```
#!/usr/bin/env python
'''
~~~~~
Script for SPM - Example code
~~~~~
'''

import serial
import time

COM_PORT = "COM10" # WILL BE DIFFERENT ON YOUR SYSTEM
BAUDRATE = 9600
TIMEOUT = 1000 # [ms]

# # SPM initialization
spm = serial.Serial(COM_PORT, BAUDRATE, timeout=TIMEOUT)
print(spm.name)
spm.write(b"/1ZR\r")
```

FIGURE 7.1 – Python example script

7.2 Requirements

Python has to be installed on your computer. Additionally, the script requires the *pySerial* library (<https://pythonhosted.org/pyserial/>).

7.3 Python library : AMFTools

For more advanced Python automation of Advanced Microfluidics SA products, we advise using our Python library. AMF TOOLS Python Library is a python library to control AMF products (RVMFS, RVMLP, SPM and LSPone) with a serial connection protocol. Detailed information can be found at (<https://pypi.org/project/AMFTools/>).

A. Resolution

A.1 Definitions

Full stroke Movement of the plunger from top to bottom (i.e. 30 mm)

Pulse Displacement of 0.01 mm of the plunger

Step Subdivision of a pulse

Step resolution Displacement of a step

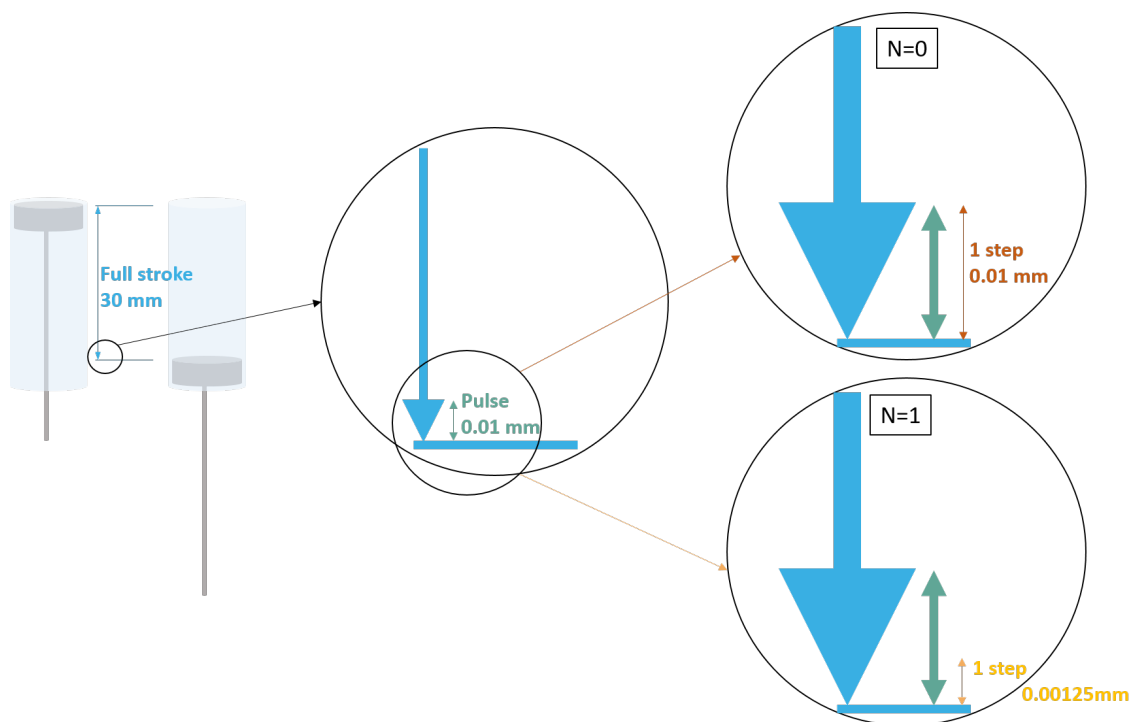


FIGURE A.1 – Definitions in image

A.2 Flow rate as a function of plunger speed

The speed of the plunger is always defined in pulses/s = displacement of the plunger per second. A relation can be found with the flow rate of the liquid.

Plunger speed [puls- es/s] for SPM	Syringe size [μL]						
	25	50	100	250	500	1'000	
0.00745 (speed "u1")	0.00373	0.00745	0.0149	0.0373	0.0745	0.149	Flow rate [$\mu\text{L}/\text{min}$]
0.05 (speed "U1")	0.025	0.05	0.1	0.25	0.5	1	
1 (speed "V1")	0.5	1	2	5	10	20	
5 (speed "V5")	2.5	5	10	25	50	100	
10	5	10	20	50	100	200	
50	25	50	100	250	500	1'000	
100	50	100	200	500	1'000	2'000	
500	250	500	1'000	2'500	5'000	10'000	
1'000	500	1'000	2'000	5'000	10'000	20'000	
1'500	750	1'500	3'000	7'500	15'000	30'000	

TABLE A.1 – Flow rate as a function of plunger speed for SPM

Example A.1 For a 100 μL syringe mounted on a SPM

5 pulses/s = 10 $\mu\text{L}/\text{min}$ = 10 $\mu\text{L}/60\text{s}$ = 1/6 $\mu\text{L}/\text{s}$

In 1 second, the plunger does 5 pulses (= 5*0.01 mm), during which 0.17 μL are delivered.

Plunger speed [puls- es/s] for SPM HD	Syringe size [μL]						
	25	50	100	250	500	1'000	
0.00717 (speed "u13")	0.00359	0.00717	0.0144	0.0359	0.0717	0.143	Flow rate [$\mu\text{L}/\text{min}$]
0.05 (speed "U1")	0.025	0.05	0.1	0.25	0.5	1	
1 (speed "V1")	0.5	1	2	5	10	20	
5 (speed "V5")	2.5	5	10	25	50	100	
10	5	10	20	50	100	200	
50	25	50	100	250	500	1'000	
100	50	100	200	500	1'000	2'000	
400	200	400	800	2'000	4'000	8'000	

TABLE A.2 – Flow rate as a function of plunger speed for SPM HD

Plunger speed [puls- es/s] for SPM+	Syringe size [μL]		
	2'500	5'000	
0.00745 (speed "u1")	0.373	0.745	Flow rate [$\mu\text{L}/\text{min}$]
0.05 (speed "U1")	2.5	5	
1 (speed "V1")	50	100	
5 (speed "V5")	250	500	
10	500	1'000	
50	2'500	5'000	
100	5'000	10'000	
500	25'000	50'000	
1'000	50'000	100'000	
1'500	75'000	150'000	

TABLE A.3 – Flow rate as a function of plunger speed for SPM+

Plunger speed [puls- es/s] for SPM+ HD	Syringe size [μL]		
	2'500	5'000	
0.00717 (speed "u13")	0.359	0.717	Flow rate [$\mu\text{L}/\text{min}$]
0.05 (speed "U1")	2.5	5	
1 (speed "V1")	50	100	
5 (speed "V5")	250	500	
10	500	1'000	
50	2'500	5'000	
100	5'000	10'000	
400	20'000	40'000	

TABLE A.4 – Flow rate as a function of plunger speed for SPM+ HD

A.3 Volume as a function of plunger displacement

The position at which the plunger can stop can be changed, i.e. a pulse can be subdivided into steps of various sizes. This allows us to attain different precisions in the quantity of volume delivered.

Resolution type	Resolution command N	Resolution [steps/stroke]	Resolution [steps/pulse]	Resolution [mm/step]
Standard	N=0	3'000	1	0.01
High	N=1	24'000	8	0.00125

TABLE A.5 – Resolution in different units

Resolution [steps]	Syringe size [μL]								
	25	50	100	250	500	1'000	2'500	5'000	
3'000	8.33	16.67	33	83.3	166.7	333	833	1666	Volume per 1 step [nL]
24'000	1.04	2.08	4.2	10.4	20.8	41.7	104.2	208.3	

TABLE A.6 – Minimal volume delivered as a function of plunger course resolution

Example A.2 For a 100 μL syringe:

100 μL = 3'000 steps $\Rightarrow$ 1 step = 0.033 μL = 33 nL

100 μL = 24'000 steps $\Rightarrow$ 1 step = 0.0042 μL = 4.2 nL

In standard resolution, 1 step corresponds to a volume of 33 nL.

In high resolution, 1 step corresponds to a volume of 4.2 nL. ■