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Anaesthetic nitrous oxide system loss mitigation and management

Technical update

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Document information

Purpose:	Technical document to facilitate a leaner physical provision and minimise system loss and waste of anaesthetic nitrous oxide.
Key words:	Nitrous oxide, climate crisis, greenhouse gas, climate duties reporting
Key actions:	Nitrous oxide mitigation and management
Importance:	High
Health board reporting and auditing schedules:	Annual Delivery Plans (ADPs) Public Bodies Climate Change Duties Reporting, annual National Sustainability Assessment Tool (NSAT), biennial Statutory Compliance and Risk Tool (SCART), ongoing Environmental Management Systems (EMS), under development
External evaluation, monitoring and reporting:	Quarterly tracking of nitrous oxide emissions by Health Infrastructure and Sustainability Division, Scottish Government Scottish Government, annual climate duties reporting
Key documents:	Scottish Health Technical Memorandum (SHTM 02-01) Nitrous oxide mitigation implementation plan Manifold decommissioning protocol Evidence Based Policy Report: piped nitrous oxide mitigation Appendix 1. Exemplar Standard Operating Procedure: Nitrous Oxide Decommissioning N_2O analytics dashboard under development

Executive summary

Anaesthetic nitrous oxide system loss and waste has been a key feature across many, if not most, NHS sites. Nitrous oxide is a medicinal agent with diminished use in contemporary anaesthesia, limited to complex dental cases, paediatric inductions and obstetric emergencies requiring gas anaesthesia.

Given the climate harm caused by nitrous oxide both as a greenhouse gas and ozone depleting substance, and its longevity as an atmospheric pollutant, all efforts to minimise its system loss should take high priority.

Every NHS Scotland (NHSS) Health Board should have now initiated a nitrous oxide mitigation programme. At the time of writing, 35 manifold systems have been decommissioned, or downsized, and a further 11 systems identified for decommissioning.

This, the second issue of this technical briefing, integrates further learning over the last 18 months from NHSS sites that have successfully minimised their anaesthetic nitrous oxide supply through the application of lean approaches. The application of “lean” ideas in healthcare serves to minimise waste in every process, procedure, and task through an ongoing system of improvement. As such this document is not exhaustive but provides suggestions on how Health Boards can practically minimise loss and waste in its supply arrangements and limit waste through the decommissioning process.

1. Background

1.1. NHSS, through its climate emergency and sustainability strategy, is working to become a net-zero emissions health service by 2040 or earlier if possible [1]. This requires significant reductions in NHSS greenhouse gas emissions.

1.2. Nitrous oxide (N_2O) is a potent greenhouse gas with a global warming potential 298 times that of carbon dioxide over a 100-year period and is the dominant ozone depleting substance globally. As a medical gas it is exhaled by the patient virtually unchanged into the environment and finds its way into the atmosphere, where it remains stable for up to 115 years [2,3].

1.3. In 2018/19 medical nitrous oxide products used by NHSS amounted to 28,274 tonnes in carbon equivalents (tCO_2e) of which 10,375 tCO_2e were attributed to anaesthetic N_2O (Table 1).

Table 1: Emissions of nitrous oxide product in carbon dioxide equivalents (determined by BOC data)

Fiscal year	Piped Entonox®	Portable Entonox®	Piped nitrous oxide	Portable nitrous oxide
2018/19	14,287	3,612	9,586	789
2019/20	14,677	3,511	9,385	790
2020/21	14,078	2,775	7,764	392
2021/22	14,666	3,350	6,717	733
2022/23	14,506	3,345	6,486	988
2022/23	13,314	3,265	5,439	1,052

1.4. By early 2021, it had been consistently proven that annual system loss of piped anaesthetic N_2O across NHS sites was between 83-100 percent [4-6], which is both costly and polluting.

1.5. Anaesthetic N_2O is typically supplied by a piped system within NHSS acute hospital sites. Scottish based research has demonstrated that anaesthetic N_2O is limited in contemporary anaesthetic practice and that these piped systems are often redundant. Much of the volume turnover is due to system loss, driven by system leaks, poor security, or stock management [4-6].

1.6. Maintenance of piped systems and minimisation of system loss are expectations of the SHTM 02-01 Part B and appropriate governance and management of the piped medical gas system are ensured through a Medical Gas Committee (MGC). The MGC should have representation from the following: Medical Gas Pipeline System (MGPS) Authorised Persons (AP), soft facilities designated porter leads, pharmacy services, anaesthetists and clinical engineers.

1.7. To fulfil the requirements of SHTM 02-01, Health Boards are fully expected to meet the costs associated with training designated porters, authorised and competent persons, the decommissioning or repair of piped systems and procuring any equipment needed to support a portable supply of N_2O that is proportionate to clinical need outlined in section 3.5 of this document.

1.8. All NHSS Health Boards should have already formed a nitrous oxide mitigation group in response to the implementation plan issued in May 2022. By March 2024, 35 manifold systems have been minimised or decommissioned across NHS sites with a further 11 scheduled for decommissioning.

1.9. This is a technical document to facilitate the discontinuation or a leaner physical provision of anaesthetic nitrous oxide within NHSS acute hospital sites. This document should be read in conjunction with the latest version of the nitrous oxide mitigation implementation plan.

2. Scope

2.1. This document aims to minimise system loss and waste of anaesthetic nitrous oxide.

2.2. This document does not address clinical use of this agent but emphasises that clinical need and supply should align and be well managed.

2.3. Technologies that destroy the N_2O molecule are of little value in theatres as the clinical use of anaesthetic nitrous oxide is low or non-existent. There may be some value for such technologies within dentistry with design adjustment. Such a product would need to be assessed against the quality of medicine delivery to the patient, ease of utility, infrastructure compatibility and emission reduction capability versus cost (including life cycle analysis).

3. Minimising system loss and waste of anaesthetic nitrous oxide

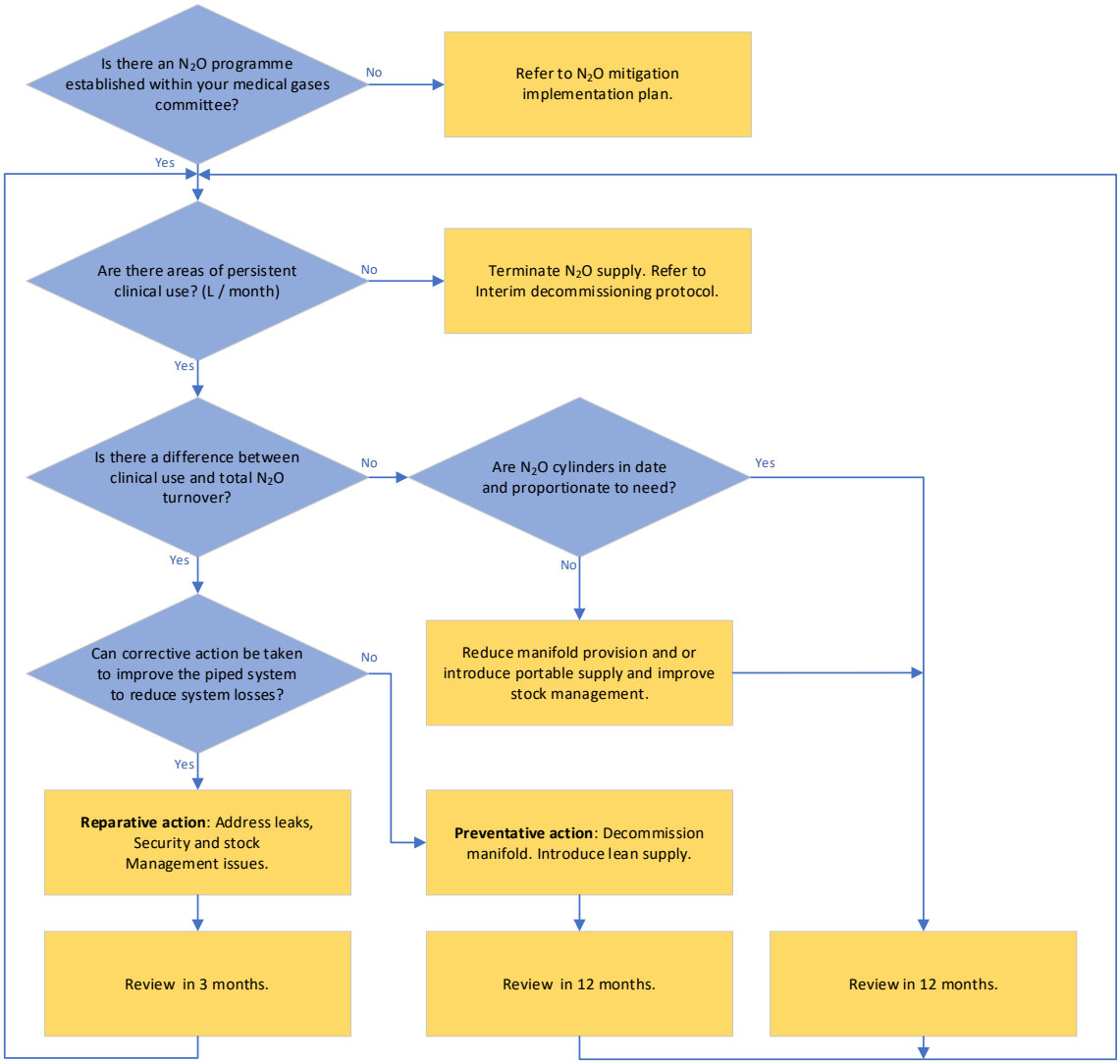
3.1. Improvement approach

3.1.1. It is recommended that a quality improvement (QI) approach is taken to minimise loss of this agent. NHS sites should establish a project team with a project lead and with subject matter experts. These should include MGPS AP, soft facilities designated porter leads, pharmacy services representatives and clinical engineers.

3.1.2. Piped nitrous oxide systems are serviced by 141-G and 141-J BOC cylinders. NHSS Health Boards can email requests for monthly nitrous oxide product data updates (email: nss.nppharmacy@nhs.scot) or the National Green Theatre programme (email: cfsdgreentheatres@gjnh.scot.nhs.uk). Health Boards should consider this data, system logs and potentially utilise other QI tools such as process mapping to understand the granular management of this agent at a site and identify the problem(s) within a local context.

3.1.3. Decision making pathway.

Figure 1 Decision making framework for system minimisation or decommissioning.



3.2. Termination or minimisation of a piped nitrous oxide system

3.2.1. NHSS sites have found that superfluous outlets and low demand for anaesthetic N_2O as a clinical agent mean that the presence of a piped supply may be surplus to need and creates a management burden and/or an unnecessary leak risk.

3.2.2. Where the local nitrous oxide working group are satisfied that a piped N_2O system is redundant a formal request to decommission an N_2O manifold, should be issued (email is suitable) from the clinical director of anaesthesia to the director of estates. All relevant stakeholders should be copied into the correspondence including the authorising engineer for the site, the chair of the medical gases committee and the director of pharmacy.

3.2.3. Where a segment of the piped nitrous oxide supply has been deemed redundant, the same request procedure should be followed. The redundant piped supply can be terminated at the Area Valve Service Unit (AVSU).

3.2.4. When terminating or minimising a piped supply, 141-G and 141-J cylinders should be used optimally to minimise stock being returned to the supplier where it will be vented. Manifold bank size can be gradually reduced in size by replacing 1-2 fewer cylinders once a bank is depleted and reducing stockholding arrangements with the medical gas supplier accordingly.

3.2.5. Intact and in-date cylinders can be redistributed to other acute sites on arrangement with your medical gas supplier.

3.3. Planned preventative maintenance of piped nitrous oxide system

3.3.1. System loss through leaks has consistently demonstrated to be the single biggest cause of N_2O loss. Loss through the pipeline infrastructure is more likely at terminal units (wall or pendant outlets) and valves. The Estates department has the responsibility for this and should choose the best course of action.

3.3.2. Medical devices, anaesthetic machines or flow meters connected to the terminal units may be defective and can be a source of loss and clinical engineering (Medical Physics) has oversight to ensure that all equipment is maintained and functional.

3.3.3. Medical devices, anaesthetic machines or flow meters should be disconnected from the N_2O gas supply when not in active use as this can be a source of loss and clinical teams should develop a local protocol to ensure unnecessary loss does not occur.

3.3.4. Manifolds should be checked regularly for leakages and faults. Leak tests with an approved detection fluid should occur weekly and when a bank of cylinders is changed. Logbooks should be maintained for both cylinder changes and leak tests. Designated porters or Estates operatives should perform and log these checks as they are carried out.

3.3.5. An increase in frequency of cylinder bank changes should be reported by Designated Medical Gas Porters to the Estates department, for investigation.

3.4. Introduction of a portable anaesthetic nitrous oxide supply

3.4.1. Portable anaesthetic N_2O cylinders have been introduced across many sites that have determined their piped supply to be superfluous to need and/or as a cautious step down prior to removing anaesthetic N_2O altogether. A portable supply should be well managed and proportional to clinical need. Several supply arrangements are itemised below.

3.4.2. Option 1: Portable cylinders at back of anaesthetic machines.

This approach may require retrofitting of N_2O yokes if these are not already fitted to machines. Costs will vary, for example GE who manufactures for Aisys CS^2 and Carestation 600 & 700 series anaesthetic machines may be able to supply and fit a yoke for approximately £1,500 per machine. These can accommodate either a 141-D and 141-E sized cylinders. Sites may need to retrofit additional anaesthetic machines to ensure resilience in event of machine failure and that machines can undergo scheduled maintenance by clinical engineering or manufacturer.

Retrofitting should be arranged through clinical engineering. New supply requests for 141-D or 141-E cylinders must be made to pharmacy procurement.

3.4.3. Option 2: Portable cylinder on a trolley.

These can accommodate a 141-E or 141-F N_2O cylinder based on anticipated clinical use. An N_2O cylinder trolley can be kept in a theatre/s that has persistent use of N_2O. Clinical engineering can arrange the appropriate trolley (approximately £110) and regulator (approximately £150) for intended use and pharmacy procurement will need to be advised on cylinder size requirements.

3.4.4. Option 3: Fixed bracketing 141-E and 141-F cylinders vertically to theatre wall.

Pharmacy can arrange the correct cylinders. Estates will need to arrange bracketing and clinical engineering can source the appropriate regulators. 141-G is also tenable for bracketing but requires training in its handling requirements. If this is a desired option, then theatre managers will need to ensure key staff are trained to facilitate 141-G cylinder changes safely.

3.4.5. Option 4: Specific for dentistry, RA Medical Services Ltd supply a mobile 4-cylinder stand.

These can hold 141- E N_2O cylinders with 101-E oxygen cylinders. This item will not be appropriate in all localities and assessment should be made with your local Medical Physics department or approval group such as the MGC.

3.5. Stock management

3.5.1. Facilities, pharmacy, and clinical teams must establish safe and secure storage for this product throughout NHSS facilities. Local cylinder storage may be restrictive with limited space to adequately store cylinders in clinical departments where the cylinder store must comply with SHTM 02-01, Part B, Section 8 and take into consideration fire safety.

3.5.2. Security has shown to be a problem in some NHS England sites and theft can be external or internal. N_2O is a recreational drug and chronic use is extremely harmful. Theft should be considered if system loss cannot be accounted for, and this should be escalated by the MGC to the Director of Pharmacy and the site's senior manager or director.

3.5.3. Waste minimisation can be facilitated through prudent procurement and stock management to ensure that correct supply arrangements are in place. Such arrangements include cylinders being rotated from the emergency reserve supply into the active banks.

3.5.4. Manifold systems that are scheduled to be phased out should gradually reduce in size with Facilities and Estates teams replacing fewer cylinders on the depleted bank

in order to gradually run down 141-G and 141-J stock. Pharmacy should adjust stock holdings accordingly with the medical gas supplier.

4. Financial implications

4.1. NHSS Health Boards are expected to provide the necessary resources to drive down system loss of N_2O as a strategic priority. However, in practice NHS sites have found decommissioning manifolds to be a cost saving measure. Costs implications will vary and are dependent on a respective NHS site's piped medical gas management and maintenance contracts and the choice of lean N_2O supply sites may choose to opt for.

4.2. The cost of upkeep of manifolds is a core expense. Contract costs for external medical gas contractors for annual inspections to meet Planned Preventative Maintenance (PPM) requirements is £4,000 - £6,000, the replacement of ageing manifolds £6,000-£10,000 and the installation of new manifolds with associated piped infrastructure around £45,000. Additionally, piped infrastructure requires the oversight by the MGC and evaluation by the Authorised Person and Authorising Engineer, all of which will have an impact on costs and time.

4.3. The Western General Hospital in NHS Lothian was the primary investigative site for the nitrous oxide project and their hard facilities management is an NHS Lothian service. In 2019/20 the system registered loss of 792,000 litres per annum. The decision to decommission, rather than refurbish, the failing and redundant piped system cost them £150. Conservatively, the site avoided £6,000 expenditure on refurbishment and recurring annual costs associated with medicine purchase, cylinder rental and PPM approximating £6,500. Moreover, they have mitigated an environmental impact cost of £35,000 attributed to nitrous oxide emissions.

5. Barriers and facilitators

5.1. Specific training is a requirement within SHTM 02-01 Part B for specialist 'designated porters' or 'persons responsible' that are accountable for moving and replacing cylinders for a piped medical gas system. This training includes stock and manifold management and safe handling of large cylinders to minimise injury. The MGC within their Terms of Reference are obliged to ensure safe handling of all medical gas cylinders by NHS staff and ensure that soft facilities understand all training requirements and are compliant.

5.2. Specific training must be provided for all clinical staff who handle portable cylinders. The MGC must ensure and support such training. Anaesthetic nitrous oxide is not an emergency agent and portable cylinders should be utilised fully with a spare cylinder in a secure store nearby should the agent deplete.

5.3. All staff should be made aware that N_2O is a greenhouse gas and that surplus residual gas within cylinders are vented, under MHRA obligations, when returned to the medical gas supplier prior to refilling and as such forms part of our emission footprint.

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Appendix 1.

Exemplar Standard Operating Procedures: Nitrous Oxide Decommissioning

Written by Ian Sandford, Authorising Engineer

1. Purpose

This procedure sets out the process and responsible parties deemed necessary to facilitate the isolation and decommissioning of Nitrous Oxide medical gas source supply and distribution systems (MGPS).

2. Roles & Responsibilities

The parties responsible are as follows:

1. NHS Board – Executive Board
2. NHS Board – Clinical Governance
3. NHS Board – Medical Gas Committee (MGC)
4. NHS Board – Estates Directorate
5. NHS Board – Site specific Clinical Management
6. NHS Board – Designated Nursing or Medical Officer DNO/DMO(MGPS).The person responsible for their department in relation to piped medical gases and to provide permission for work to commence under a medical gas Permit to Work
7. NHS Board – Pharmacy
8. NHS Board – Quality Controller QC (MGPS)
9. NHS Board – Estates Department, Authorised Person AP(MGPS) The person appointed by the Board to manage the day-to-day operation of the piped medical gas systems. The AP (MGPS) will liaise with the
10. NHS Board – Appointed Independent Authorising Engineer AE (MGPS)
11. NHS Board – Estates Department Specialist Medical Gas Contractor Competent Person CP(MGPS)

3. Source plant

The Nitrous Oxide distribution system includes the following:

1. Source plant consisting of an auto-change manifold with 2 banks of [ADD NUMBER OF CYLINDERS] of size [G or J] cylinders and a manual Emergency Reserve Manifold with [ADD NUMBER OF CYLINDERS] of size [G or J] cylinders. The manifold is located in a purpose build manifold room located within [enter location].

2. From the Nitrous Oxide plant, the Nitrous Oxide mains pipeline is routed to the main hospital via service routes and distributes to the relevant departments.

3. The pipeline distribution system consists of Isolating Valves, usually provided in mains distribution, service risers, Area Valve Service Units (AVSUs) are typically found on walls, behind enclosures with break glass panels and finally Terminal Units either set in bedhead trunking or ceiling mounted pendants.

Medical Gas alarm systems are provided to indicate Normal and Alarm conditions, and are as follows:

4. Plant (Central) Alarms – These monitor the medical gas source supply, in this case the Nitrous Oxide plant described in 3.1.

5. Area Alarms – These alarms are located in clinical departments where medical gases is provided. The alarms provide system (pressure) status for the clinical team, e.g. Normal, High and Low pressure. These alarms are not monitored by Estates and there is no remote monitoring station. Note, where sites have remote monitoring of Area Alarm, these typically provide a common alarm condition.

4. Other considerations

Although Nitrous Oxide may not be supplied via piped medical gas, there may still be a need for use of Nitrous Oxide, for example, in Operating Theatres. This can be facilitated by using portable cylinders. It is therefore necessary for the Clinical Team to review where Nitrous Oxide will still be administered and if this is directly from portable cylinders or via medical devices, e.g. anaesthetic machines.

Where portable cylinders are to be used to for direct administration, adequate cylinder holders or secured trolleys should be considered. Note, the cylinders should be stored in an approved location.

Where Nitrous Oxide is to be administered via medical devices, it may be necessary for the Medical Engineering department to review existing medical devices for retrofitting of Nitrous Oxide cylinders.

5. Decommissioning Process

The following flowchart sets out the process to decommission the Nitrous Oxide source and pipeline systems described in 3.1 to 3.4 inclusive. The process describes the various parties involved and at what stage of the process.

The method of decommissioning the piped Nitrous Oxide system is as follows:

1. All work to be carried out under a Low Hazard permit prepared by the AP (MGPS)

2. By signing Part 1 of the Low Hazard Permit, permission to commence to be provided by the DNO or DMO

3. The MGPS Contractor CP (MGPS) will complete Part 2 of the permit and commence with decommissioning the Nitrous Oxide system as instructed and set out in the Risk Assessment and Method Statement (RAMS), generally as follows:

   a. Deactivate all related Nitrous Oxide Plant alarms and Area Alarms
   b. Isolate each of the Nitrous Oxide manifold cylinders at the cylinder valves
   c. Depressurise the Nitrous Oxide pipeline via the Manifold Test Point Terminal Unit. The evacuated Nitrous Oxide is to be discharged to a safe, external location, for example, a hose connected to the manifold Test Point and routed externally. Note, this should be assessed by the site appointed AP (MGPS).
   d. Insert “DO NOT USE” Terminal Unit blank plugs on all Nitrous Oxide Terminal Units
   e. Provide signage at all Nitrous Oxide AVSUs to indicate “NOT IN USE”.
   f. Where a section of the piped system is to be decommissioned.

      i. the AVSU will be isolated
      ii. the alarm deactivated
      iii. the pipeline depressurised
      iv. a blank spade inserted into the downstream flange of the AVSU and a “NOT IN USE” sign applied, as in e) above. The CP (MGPS) will test that there is no leakage from the downstream flange by applying a leakage test using an approved leak detection fluid
      v. all terminal units to be provided with “DO NOT USE” as d) above

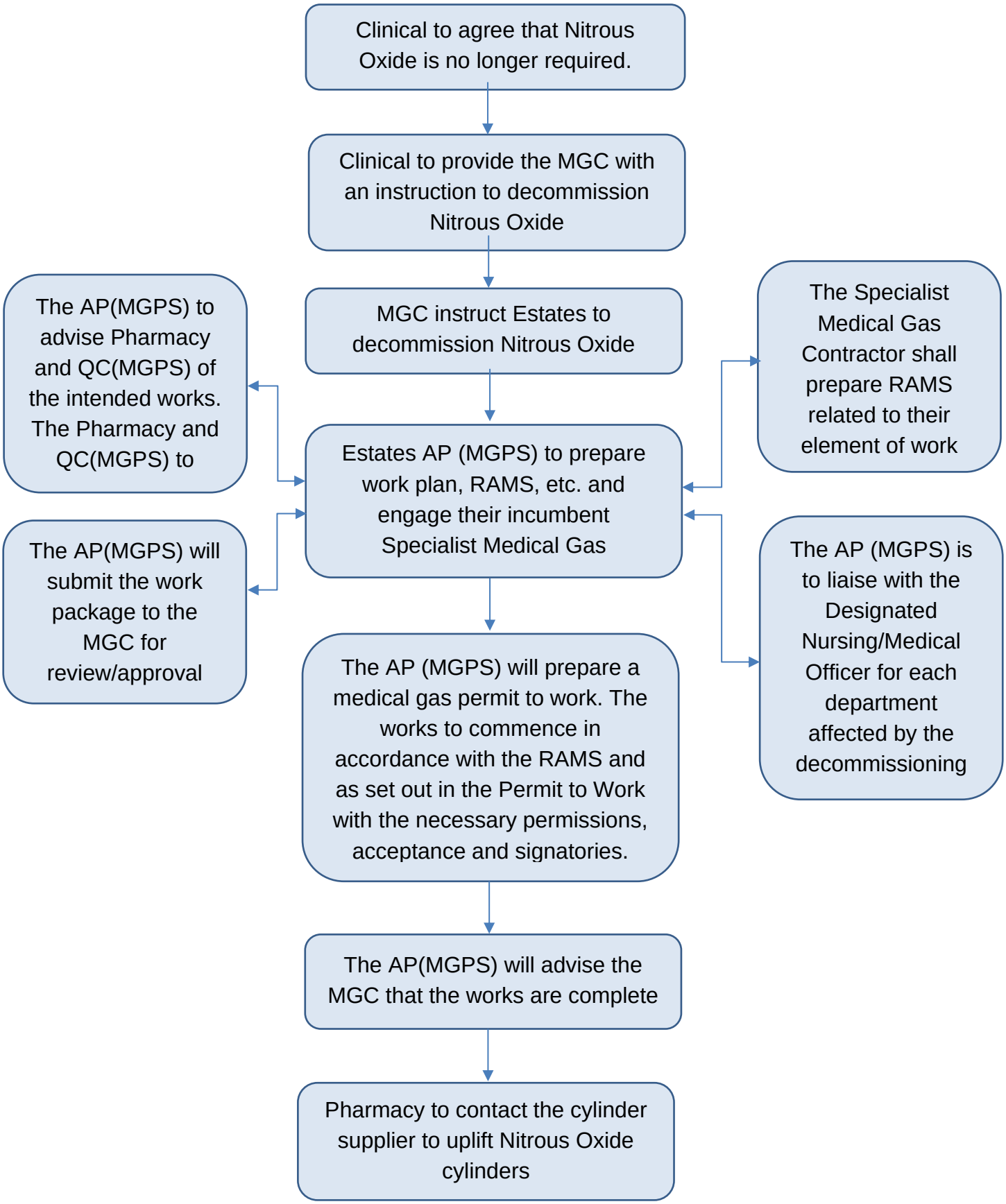
   g. The CP(MGPS) will complete Part 3 of the permit indicating that the systems are fully decommissioned

4. The AP (MGPS) will acknowledge that the system has been decommissioned and complete Part 4 of the permit

5. The AP (MGPS) shall request the DNO or DMO, who signed Part 1 of the permit, to complete Part 5 of the Low Hazard Permit to acknowledge that the Nitrous Oxide system is now not in use.

6. The DMO will advise the relevant clinical staff that the system is now not in use.

7. The Medical Gas Group shall be informed that the Nitrous Oxide system has been decommissioned.


Clinical to agree that Nitrous Oxide is no longer required.
Clinical to provide the MGC with an instruction to decommission Nitrous Oxide
MGC instruct Estates to decommission Nitrous Oxide
Estates AP (MGPS) to prepare work plan, RAMS, etc. and engage their incumbent Specialist Medical Gas
The AP(MGPS) to advise Pharmacy and QC(MGPS) of the intended works. The Pharmacy and QC(MGPS) to
The AP(MGPS) will submit the work package to the MGC for review/approval
The Specialist Medical Gas Contractor shall prepare RAMS related to their element of work
The AP (MGPS) is to liaise with the Designated Nursing/Medical Officer for each department affected by the decommissioning
The AP (MGPS) will prepare a medical gas permit to work. The works to commence in accordance with the RAMS and as set out in the Permit to Work with the necessary permissions, acceptance and signatories.
The AP(MGPS) will advise the MGC that the works are complete
Pharmacy to contact the cylinder supplier to uplift Nitrous Oxide cylinders