NEWTON WATERPROOFING

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Proctor Group

Ground Gas Protection Specialists

TECHNICAL PAPER

CREATING A BARRIER TO GAS & WATER

Designing for Compliance & Protection

TECHNICAL ARTICLE

Creating a Barrier To Gas & Water

Designing for Compliance & Protection

CONTENTS

Endorsed by A. Proctor Group - Ground Gas Barrier Systems

Newton has partnered with market-leading Scottish manufacturer A. Proctor Group to supply their range of high-performance ground gas barriers across the UK.

We're proud to partner with another innovative family business who share our strong technical ethos and can provide reliable ground gas protection systems.

1. Introduction

When it comes to the challenge of waterproofing and gas proofing a below-ground structure, how do modern waterproofing products perform as an effective gas protection offering?

The answer to this question depends on several aspects, including the types of ground gases or contaminants that are present, as well as the contamination levels that are outlined in the site report that should be performed on any such project.

Saying this however, ground gas and contamination is an expansive subject and can be quite different to the waterproofing industry.

For instance, waterproofing designers tend to form a barrier against the water and then depressurise any water that still enters the structure. That is, we try to stop the water using Type A and/or Type B waterproofing products, and then, expecting defects, we manage the possibility of any remaining water ingress by depressurising it with a Type C cavity drain membrane system internally.

In contrast, the gas proofing industry tends to base its solutions on the identified circumstances at ground level (not below ground). The standard practice is therefore to depressurise the gasses first, then install a barrier to the gasses internally.

Whilst this is fine above ground, with below-ground scenarios, the normal external ventilation techniques that are used within gas proofing designs will not work. This is because we have to assume that the structure will be subject to a full head of hydrostatic pressure at some point in its life, which would result in the ventilation system being filled with groundwater.

Unfortunately, this is only one example of where the industry standards for gas protection, such as BR 211-2015 and BS 8485:2015, do not correlate very well with the industry standard for UK waterproofing BS 8102:2009. They do, however, contain some useful information that we can base our recommendations on.

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2. The Principles of Waterproofing

British Standard 8102:2009 is the 'Code of practice for protection of below ground structures against water from the ground', and it defines three "Grades" of waterproofing depending on the desired internal environment:

- Grade 1 - Car parking/plant rooms - where some seepage and damp areas are tolerable dependent upon intended use.
- Grade 2 - Plantrooms and workshops requiring a drier environment than Grade 1 (this includes storage areas) - No water penetration acceptable. Damp areas tolerable. Ventilation may be required.
- Grade 3 - Ventilated residential and commercial areas - No water penetration acceptable. Ventilation, dehumidification or air conditioning necessary appropriate to the intended use.

The British Standard also outlines three "Types" of waterproofing system that can be used, either standalone or in combination, in order to achieve these Grades:

- Type A (barrier protection)
- Type B (structurally integral protection)
- Type C (drained protection)

Consideration should be given to combining these Types of waterproofing in any scenario where the assessed risks are deemed too high, or where the consequences of failure are unacceptable.

As a result, we most commonly try to keep the water out using Type A and/or Type B systems, and where the consequences of failure are unacceptable, such as when a Grade 3 environment is required, we alleviate the risk of any water ingress whatsoever by also using an internal Type C system.

The reason we combine products like this is down to the fact that, as waterproofing designers, we must think ahead and anticipate potential defects and failures in the structure or the waterproofing – another recommendation of Section 4.3.2 of the British Standard.

2.1. How Does Waterproofing Best Practice Approach Gas Proofing?

When it comes to considering protection against both water and gas, the first paragraph of Section 4 of the British Standard states that:

> *"it is essential for the success of any project involving below ground structures that strategies for dealing with groundwater, soil gases and contaminants are considered."*

Consideration of gasses and contaminants should be considered at the earliest stages of a waterproofing design.

Consequently, where required, Newton will always recommend waterproofing products that possess the required level of third-party tested gas resistance. In turn, these systems may also be verified by an independent specialist depending on the gasses that are present.

From a waterproofing perspective, the safest designs will always seek to combine two or more forms of waterproofing, with one of those forms always being a Type C cavity drain membrane system, supported by the Type A and Type B products.

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Furthermore, the structure itself can also be considered as the primary barrier to water and gas - most insurers will support a specification that includes a reinforced concrete structure designed to BS EN 1992 - Part 3 as a form of Type B waterproofing, provided that it minimises through-section crack widths to 0.2 mm, and that also uses Type C as an internal system for extra protection.

When designing a combined waterproofing and gas proofing system then, the important next step is to be able to accurately assess the level of gas protection that each element of your design provides.

3. Protecting Against Radon

The most important document to consider for radon protection is the BR 211 “Radon: Guidance on protective measures for new buildings”.

In previous editions, BR 211 stated that if a basement structure was “tanked” with a product of equal performance to a 1200-gauge DPM then it would provide sufficient protection against radon. As a result, Newton even has third-party test results for Radon resistance on some of our external waterproofing membranes.

However, in Section 6.12 of the most recent 2015 edition, BR 211 now recognises that:

> *“Below-ground waterproofing and radon management are specialist activities that can conflict. It is recommended that dual protection systems are designed and installed by specialists who are suitably qualified in both waterproofing and radon management.”*

The standard also makes two important points regarding Type C cavity drain systems, namely:

1. That cavity drain systems used in scenarios requiring radon management will need to be completely sealed:

   “using [cavity drain membrane systems] to line the internal surfaces of a basement could cause the gas to be simply displaced up the cavity into the ground floor accommodation. It is therefore important to ensure that the basement wall membrane fully closes the cavity at its head where it meets the radon barrier within the ground floor or external cavity wall above ground.”

2. And furthermore, that such Type C systems can also provide the opportunity to create ventilation:

   “The cavity behind the membrane could be used later as part of a subfloor depressurisation system.”

With point two in mind, Newton have had our cavity drain membranes third-party tested for radon resistance, and we developed the patented Newton PAC-500 system for high-risk radon sites (discussed in Section 6). By partnering with gas protection specialists Prestige Air, the PAC-500 system combines Type C waterproofing with a pressurised, positive air curtain (PAC) ventilation system that successfully controls both water and gas within any below-ground or earth-retaining structure, whether it is new or existing, domestic or commercial.

4. Protecting Against Methane & Carbon Dioxide

British Standard 8485:2015 is the "Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings", and when it comes to considering basement structures, in Section A4 it states:

> *"In general terms, a basement constructed of dense, cast in situ concrete appropriately designed to BS EN 1992 to provide integral waterproof protection normally represents the most impermeable of structural forms. Combining this with a waterproof membrane to create a fully tanked basement provides the best basement solution for preventing the ingress of ground gases."*

As with the previous editions of BR 211 we can see that "tanking" is also being used here as a rather catch-all term for waterproofing. In this case however, the word is intended to indicate what we would call an external or internal Type A waterproofing membrane.

However, as waterproofing designers, we must consider the gas protection capabilities of our entire design, including all three Types of waterproofing and the structure itself.

4.1. Assessing the Gas Capabilities of a Waterproofing Design

British Standard 8485:2015 provides us with all the tools we need in order to accurately assess the gas capabilities of our waterproofing designs, provided that we know the Characteristic Situation (CS) value of our site.

The CS value is a score that ranges from CS1 (very low risk) to CS6 (such high risk that some sites cannot be built on) and will be established during your site investigation. Once you have this value, you can then start using Tables 3 and 4 of BS 8485:

1. Table 3 (right) outlines four different building types with the identifiers A, B C and D. Once we have categorised our structure into one of these types, we can move on to Table 4.
2. Table 4 (below) cross-references the CS value of the structure with the building type that was established in Table 3, in order to calculate the minimum gas protection score that must be achieved by both the structure and its protective measures.

3 — *Building types*

	Type A	Type B	Type C	Type D
Ownership	Private	Private or commercial/ public, possible multiple	Commercial/ public	Commercial/ industrial
Control (change of use, structural alterations, ventilation)	None	Some but not all	Full	Full
Room sizes	Small	Small/ medium	Small to large	Large industrial/ retail park style

- **Type A building**: private ownership with no building management controls on alterations to the internal structure, the use of rooms, the ventilation of rooms or the structural fabric of the building. Some small rooms present. Probably conventional building construction (rather than civil engineering). Examples include private housing and some retail premises.
- **Type B building**: private or commercial property with central building management control of any alterations to the building or its uses but limited or no central building management control of the maintenance of the building, including the gas protection measures. Multiple occupancy. Small to medium size rooms with passive ventilation of rooms and other internal spaces throughout ground floor and basement areas. May be conventional building or civil engineering construction. Examples include managed apartments, multiple occupancy offices, some retail premises and parts of some public buildings (such as schools, hospitals, leisure centres) and parts of hotels.
- **Type C building**: commercial building with central building management control of any alterations to the building or its uses and central building management control of the maintenance of the building, including the gas protection measures. Single occupancy of ground floor and basement areas. Small to large size rooms with active ventilation or good passive ventilation of all rooms and other internal spaces throughout ground floor and basement areas. Probably civil engineering construction. Examples include offices, some retail premises, and parts of some public buildings (such as schools, hospitals, leisure centres and parts of hotels).
- **Type D building**: industrial style building having large volume internal space(s) that are well ventilated. Corporate ownership with building management controls on alterations to the ground floor and basement areas of the building and on maintenance of ground gas protective measures. Probably civil engineering construction. Examples are retail park sales buildings, factory shop floor areas, warehouses. (Small rooms within these style buildings should be separately categorized as Type B or Type C).

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BS 8485:2015 **BRITISH STANDARD**

Table 4 **Gas protection score by CS and type of building**

CS	Minimum gas protection score (points)			
	High risk		Medium risk	Low risk
	Type A building	Type B building	Type C building	Type D building
1	0	0	0	0
2	3.5	3.5	2.5	1.5
3	4.5	4	3	2.5
4	6.5 A)	5.5 A)	4.5	3.5
5	— B)	6.5 A)	5.5	4.5
6	— B)	— B)	7.5	6.5

A) Residential buildings should not be built on CS4 or higher sites unless the type of construction or site circumstances allow additional levels of protection to be incorporated, e.g. high-performance ventilation or pathway intervention measures, and an associated sustainable system of management of maintenance of the gas control system, e.g. in institutional and/or fully serviced contractual situations.
B) The gas hazard is too high for this empirical method to be used to define the gas protection measures.

Now that the required gas protection score has been established, we can use Tables 5 (below) and 7 of BS 8485 to determine whether our structural design in combination with our waterproofing design is able to meet this minimum score or not.

Table 5 shows that any structural waterproofing design meeting the criteria for a Grade 3 basement will achieve 2.5 points. In our opinion, and in the opinion of many waterproofing design specialists (CSSW and/or WDS qualified) this is only achievable if a Type C cavity drain membrane system is included.

Table 5 **Gas protection scores for the structural barrier**

Floor and substructure design (see Annex A)	Score A)
Precast suspended segmental subfloor (i.e. beam and block)	0
Cast in situ ground-bearing floor slab (with only nominal mesh reinforcement)	0.5
Cast in situ monolithic reinforced ground bearing raft or reinforced cast in situ suspended floor slab with minimal penetrations	1 or 1.5 B)
Basement floor and walls conforming to BS 8102:2009, Grade 2 waterproofing C)	2
Basement floor and walls conforming to BS 8102:2009, Grade 3 waterproofing C)	2.5

A) The scores are conditional on breaches of floor slabs, etc., being effectively sealed.
B) To achieve a score of 1.5 the raft or suspended slab should be well reinforced to control cracking and have minimal penetrations cast in (see A.2.2.2).
C) The score is conditional on the waterproofing not being based on the use of a geosynthetic clay liner waterproofing product (see C.3, Note 4).

However, with the title of Table 5 being "Gas protection Scores for a Structural Barrier", the suggestion is that a Grade 3 basement is achievable with just the concrete structure. It is also assumed that the difference between a Grade 2 and a Grade 3 structural barrier is the width of any structural cracks, therefore it is essential that the concrete is designed to Part 1 or Part 3 of British Standard EN 1992.

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Using this logic, if it is agreed that a concrete structure designed to 0.2 mm crack widths can achieve a Grade 3 internal environment, then our design can achieve 2 gas protection points from Table 5 just by using the third-party certified Newton 315 Polymer Waterbar in the construction joints of a concrete structure. We could also upgrade this design to achieve 2.5 points by using the Newton HydroTank System, which uses injectable waterbars, to protect an engineer-designed 0.2 mm crack width structure.

Another alternative to achieve 2.5 points from Table 5 with just our concrete would be to use the third-party certified Newton RASCOtank System, an engineered waterproofing approach which guarantees that the concrete acts as both the structure and the waterproofing.

Finally, once the gas protection score of the structure has been determined, Table 7 of BS 8485 (below) can be used to give us an additional 2 points through the use of a gas-resistant membrane that meets all of the necessary criteria.

Table 7 **Gas protection score for the gas resistant membrane**

Protection element/system	Score	Comments
Gas resistant membrane meeting all of the following criteria: • sufficiently impervious to the gases with a methane gas transmission rate <40.0 ml/day/m²/atm (average) for sheet and joints (tested in accordance with BS ISO 15105-1 manometric method); • sufficiently durable to remain serviceable for the anticipated life of the building and duration of gas emissions; • sufficiently strong to withstand in-service stresses (e.g. settlement if placed below a floor slab); • sufficiently strong to withstand the installation process and following trades until covered (e.g. penetration from steel fibres in fibre reinforced concrete, penetration of reinforcement ties, tearing due to working above it, dropping tools, etc); • capable, after installation, of providing a complete barrier to the entry of the relevant gas; and • verified in accordance with CIRIA C735 [N1]	2	The performance of membranes is heavily dependent on the quality and design of the installation, resistance to damage after installation and integrity of joints. For example, a minimum 0.4 mm thickness (equivalent to 370 g/m² for polyethelene) reinforced membrane (virgin polymer) meets the performance criteria in Table 7 (see **C.3**). If a membrane is installed that does not meet all the criteria in column 1 then the score is zero.

5. Utilising Waterproofing Products for Gas Proofing

There are several products within the Newton range that have undergone the necessary testing and meet the necessary standards for use as protection against gas in below-ground scenarios. However, as we will go on to explain, with gas proofing as in waterproofing, the most effective designs combine multiple forms of protection, and always include a Type C cavity drain membrane system.

To begin with, the third-party certified Newton 403 HydroBond-GB (gas barrier) meets with Section C2 'Available Membranes' of British Standard 8485, and exceeds the performance levels of the 0.4 mm polythene sheet which is recommended by the standard for above-ground scenarios (not suitable for below-ground use).

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The membrane has also been tested in accordance with the manometric vapour pressure testing method, as required in Section 7.2.4 of British Standard ISO 15015-1, and far exceeds the required methane permeability figure for the membrane.
Newton 403 HydroBond-GB also has lap tests for methane and carbon dioxide, and it is important that the figures for the tests (along with any other discontinuities such as pile heads or foundations) are taken into account and averaged over the whole basement area.

A calculation such as the one shown below is useful for working out this average, and can be used as part of the design proposal to be accepted by the projects' verification specialists:

- **Methane**: (1.43 x 0.44) + (0.07 x 91) = **6.99** ml/(m^2.d.atm)
- **Carbon Dioxide**: (1.43 x 1.97) + (0.07 x 20) = **4.21** ml/(m^2.d.atm)

For reference, this average calculation has been made using the following information:

- The figures for gas transmission through both the membrane and the joints in ml/(m^2.d.atm) for the Newton 403 HydroBond-GB (millilitres per square metre per day under a pressure difference of 1 atm):
  - Methane = **0.44** through the membrane and **91** through the joints
  - Carbon Dioxide = **1.97** through the membrane and **20** through the joints
- Assuming that 70mm laps occur every 1.5 metres, which is the width of one length of 403 HydroBond-GB

5.1. Designing for Defects

In waterproofing, the legal precedent set by the 'Outwing vs Weatherald' high court case states that:

> *"overlapping self-adhesive membranes cannot be expected to achieve a total or absolute watertight bond capable of resisting penetration by water pressure."*

Therefore, regardless of a products' laboratory testing, we must still expect defects in such membranes and ensure that our waterproofing design accounts for this. It is for this reason that best practice in the waterproofing industry is to combine systems, and the safest designs emphasise the importance of both a correctly designed reinforced concrete structure and an internal Type C waterproofing system.

In contrast, based on the gas protection standards that we have discussed so far, in theory we could employ only Type A and Type B waterproofing products, such as 403 Hydrobond-GB and the RASCOtank System, in order to achieve 4.5 gas protection points (as per Table 5 of BS 8485). This is theoretically sufficient to provide the required level of gas protection to residential projects with a CS3 rating, or commercial projects with a CS4 rating (as per Table 4 of BS 8485).

However, in a below-ground scenario at risk from both water and gas, we must consider that there is a risk that this design will leak. And if a below-ground structure is capable of leaking water, then it is definitely capable of leaking gas, either in a period of dry ground conditions or by transmission of water soluble gasses which then evaporate once inside the building.

Therefore, as with waterproofing best practice, for the best levels of protection we recommend that a Type C cavity drain membrane system is included, which is actually safer and better than the solutions currently allowed by the gas protection standards.

5.2. Issues of Ventilation

Table 6 of British Standard 8485 outlines how additional gas protection points can be achieved by using various forms of external ventilation. However, this clashes with below-ground waterproofing best-practice, where we design to account for a full head of groundwater pressure coming to bear against the structure at some point in its design life.

Such a scenario would mean that ventilation that is external to the structure will fill with water, and yet despite this obvious discrepancy, it is still theoretically possible for a below-ground concrete car park with just a RASCOtank Type B waterproofing system installed to achieve 6.5 gas protection points (according to Table 5 and Part (e) of Table 6, as shown on the following page).

(d) Active positive pressurization by the creation of a blanket of external fresh air beneath the building floor slab by pumps supplying air to points across the central footprint of the building into a permeable layer, usually formed of a thin geocomposite blanket	1.5 to 2.5	This system relies on continued operation of the pumps, therefore alarm and response systems should be in place. The score assigned should be based on the efficient "coverage" of the building footprint and the redundancy of the system. Active ventilation should always be designed to meet at least "good performance".
(e) Ventilated car park (floor slab of occupied part of the building under consideration is underlain by a basement or undercroft car park)	4	Assumes that the car park is vented to deal with car exhaust fumes, designed to *Buildings Regulations 2000, Approved Document F* [9].

Although a car park would generally only be expected to attain either a Grade 1 or Grade 2 internal environment as per BS 8102:2009, in areas where a Grade 3 environment is expected the waterproofing strategy will likely include both Type B and the failsafe Type C waterproofing system. However, such a design should not be used to gain more gas protection points by being technically consistent with the recommendations of BS 8485, as in reality all other ventilation techniques (other than Part (e) of Table 6) are subfloor and would be subject to flooding.

In waterproofing terms, Newton would always specify a Type C system where the consequences of failure are unacceptable, and in our opinion the gas protection points available for a Grade 3 basement in Table 5 of BS 8485 definitely should not be attributed without the use of a Type C system.

Despite this, in Section A4 of BS 8485 it specifically states that:

> *"Basements using Type C protection (i.e. drained cavities) might pose an unacceptably high risk on sites affected by ground gas. Infiltrating water might contain dissolved gas and/or contain organic compounds that can degrade to form methane and/or carbon dioxide."*

This is despite the fact that Type C systems are the most failsafe waterproofing method, and without one a below-ground structure would be vulnerable to the exact same risks from dissolved gas as a result of water penetrating through potential defects in the Type A and Type B systems.

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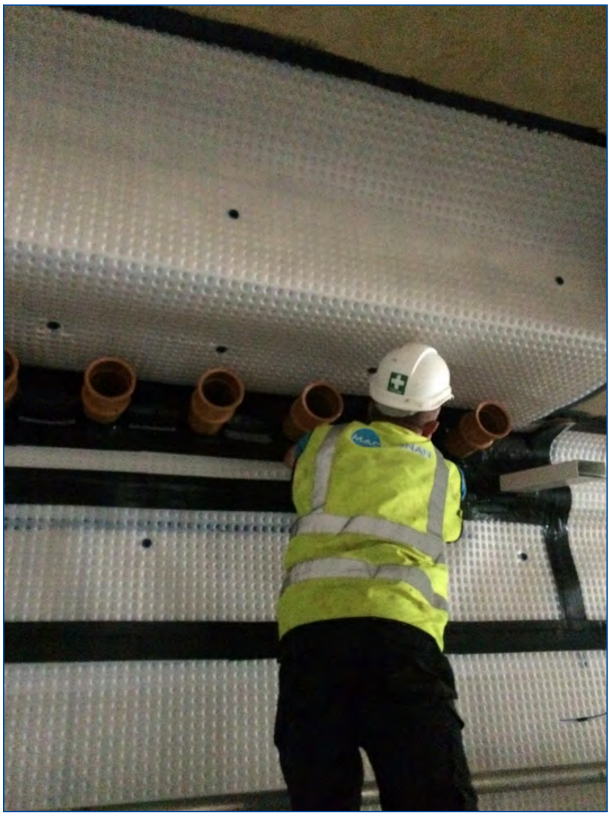
6. The 'Positive Air Curtain' Solution



Despite the potentially problematic statements within BS 8485:2015, generally speaking one would not normally specify a single form of waterproofing, especially in instances where there is both water and gas present.

For a Type C system to form an effective gas barrier, it would need all of the laps to be sealed and the condensation strip removed, which would also place much greater importance on the internal dehumidification and ventilation systems.

A third-party tested Type C membrane would also be required, such as Newton 508R, which has been tested for methane, carbon dioxide and radon resistance.

Where the highest level of protection is required, the Newton Type C System can be upgraded into a Newton PAC-500 positive air curtain system.

The Newton PAC-500 System is a patented, serviceable and high-performance solution that combines both Type C basement waterproofing and ground gas mitigation, and which can be accepted by the design team to achieve further gas protection points from Table 6 of British Standard 8485.
Newton works directly with gas protection specialist Prestige Air Technology to install a positive air pressure delivery system behind the Type C membranes, which are fully sealed and undergo comprehensive integrity testing before the entire installation can be passed as fit for purpose.

As a result of this innovative solution, Prestige Air have successfully attributed 2.5 gas protection points to these installations from Part (d) of Table 6 on numerous projects to date, in recognition of the exceptional performance of the PAC-500 system. This is despite the fact that the table itself states that such systems are for below the basement slab.

7. Summary

Overall, one of the main conclusions that can be taken from this report is that the British Standard recommendations and requirements for gas protection and waterproofing (as outlined by BS 8485:2015 and BS 8102:2009) must be viewed and considered in combination.

Whilst the requirements of BS 8485 are perfectly designed for above-ground scenarios, there are ways in which these recommendations fall short when viewed from the context of trying to protect a below-ground structure (that is subject to a full head of hydrostatic pressure) against both gas and water ingress.

Despite this, for those wishing to protect their below-ground structure, there still remains multiple options by which they can achieve the required level of protection, in accordance with both the gas protection scores of BS 8485 and the Grades of internal environment defined by BS 8102 – whether they plan on using external, gas-tested membranes, a correctly designed concrete structure, an internal PAC-500 positive air curtain, or a combination of these methods.

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Regardless of the chosen method however, it is an absolute necessity that the installation is verified by an independent gas specialist, as outlined by CIRIA 735, 'Good practice on the testing and verification of protection systems for buildings against hazardous ground gases'.

Fortunately, the gas specialist who wrote the site report is often able to undertake this role as well, and Newton can also supply a list of verification companies from the British Verification Council who can fulfil this important responsibility.

Finally, as well as all of the gas considerations that have been discussed in this paper, it is important not to forget potential contaminants in the ground such as VOCs (volatile organic compounds).

With this in mind, Newton has a third-party testing letter that outlines the suitability of Newton 403 HydroBond-GB for resistance to VOCs. And whilst we have not specifically undertaken submersion and vapour testing for the chemicals outlined in the CIRIA 748 document, 'Guidance on the use of plastic membranes as VOC vapour barriers', the solutions that have been outlined and discussed in this paper are still suitable.

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