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HOME OFFICE (FIRE DEPARTMENT)
SCOTTISH HOME AND HEALTH DEPARTMENT

TECHNICAL BULLETINS
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DEMOLITION AND REPAIR OF STORAGE TANKS: FIRE PRECAUTIONS AND FIRE FIGHTING

I INTRODUCTION

1. This bulletin describes the problems and dangers associated with the demolition or repair of tanks which have contained hazardous or combustible materials; and sets out the action which should be taken by the Fire Service when advising on the precautions to be taken in connection with such operations, or when fighting fires in such tanks. (This bulletin does not apply to the fighting of fires in, or precautionary cooling of, gasholders, which should be carried out in accordance with the advice of the employees of the gas undertaking).

2. It must be borne in mind that substances not normally regarded as presenting an explosion hazard can give off inflammable vapours when heated or as a result of reaction with other substances, and these inflammable vapours can form an explosive or combustible mixture when mixed with air. It is not practicable to give an extensive list, but examples are oils, paints, and even the less volatile solvents etc. In some cases old deposits adhering to the internal surfaces or sludge at the base of a tank may in this way be more hazardous than the original contents. Such deposits may not always be completely removed by cleaning processes. As a consequence, the demolition or repair of tanks which have contained such substances must always be regarded as a hazardous operation—see Technical Data Note 18 issued by H.M. Factory Inspectorate: copy attached for information.

Types of tanks

3. Generally, the hazard may vary according to the class of tank involved. Two classes of tank are common:

a. Vertical tanks which frequently have a roof of light construction, which may be fixed or floating and which in the event of an explosion will shear readily and vent the tank.

b. Horizontal or spherical tanks of uniform construction and with no lightweight section. These present a greater all-round hazard from lateral blast, a factor which should be borne in mind by fire-fighting officers when disposing their men.

II ADVICE ON PRECAUTIONS

4. There are two completely separate aspects of the precautions to be taken with regard to the demolition or repair of tanks:

a. site conditions and precautions;

b. process safety, e.g. inerting, cleansing and structural operations.

Site conditions and precautions

5. Should it come to the notice of the Fire Service, either during a visit for the purposes of Section 1 (1) (d) or (f) of the Fire Services Act 1947 or otherwise, that storage tanks are about to be demolished or repaired, advice about the fire prevention measures etc. necessary on the site (on the lines indicated in the following paragraph) should be given as quickly as possible. In some cases an immediate visit to the site may be called for, if one has not already been made. Even if demolition or repair is not immediately in prospect the occupier should still be warned to seek advice before such work is undertaken.

6. Advice on fire prevention should:

a. give details of appropriate first-aid fire-fighting equipment and the extent to which it should be used;

b. warn the occupier and, where appropriate, the site operator that facilities for calling the fire brigade should be readily available;

c. stress that the greatest practicable access for fire brigade appliances to all parts of the site should be maintained throughout the operation: and

d. emphasise the need for cleanliness on the site and the removal of all fire hazards at all times.

Process safety

7. Whether or not the occupier or, in the absence of the occupier, the operator asks for advice about process safety the Fire Service should always:

a. ensure that he is fully aware of the risks of fire and explosion involved in the demolition or repair of tanks;

b. ensure that he understands that it is his duty to ensure safety on the site, and advise him to appoint a person specifically to concern himself with this matter, including those aspects mentioned in paragraph 6;

c. inform him that advice on process safety should be obtained from H.M. District Inspector of Factories, whose responsibility this is under the Factories Act 1961, and recommend, if appropriate, that no demolition or repair work should begin or, if it has begun already, that it should be discontinued until the Inspector of Factories has visited the site. The Fire Service should not undertake to advise on process safety independently of the Inspector of Factories;

d. inform him that it is his duty to notify the Inspector of Factories and that the Fire Service will also advise the Inspector of the operation being carried out on the site.

Follow-up action

8. Immediately afterwards, the Fire Service should send the occupier or operator, or both if appropriate, written confirmation of the advice given on fire prevention measures (see paragraph 6), and of the advice set out in paragraph 7. A copy of the communication

sent to the occupier/operator should be sent to H.M. District Inspector of Factories. It would be convenient to the Factory Inspector if the notification sent to him could be in the form attached to this bulletin. It may in certain circumstances be desirable to give the Inspector immediate oral advice of the operation. In addition, it may be desirable to make a joint visit with the Inspector.

9. The Fire Service should ascertain whether the site has at any time been licensed under the Petroleum (Consolidation) Acts 1928 and 1936, and, if so, should advise the occupier to contact the Licensing Authority lest the conditions of licence be infringed by the proposed demolition or repair. In addition, the Fire Service should themselves inform the Licensing Authority in writing of the proposed demolition or repair, and send copies of the fire prevention advice given under paragraph 6.

III FIRE-FIGHTING

Information for operational personnel

10. In all cases the Fire Officer who gives fire prevention advice should ensure that operational personnel, both in his own brigade and in neighbouring brigades as appropriate, are fully informed of any particular hazard arising, for example, from the nature of the site or from the operations to be carried out there.

11. For this purpose operational officers should be in possession of the following information, which may entail their making visits to the site:

a. details of the first attendance to be ordered on, including information about additional special appliances or equipment;

b. means of access to the premises and local topography;

c. method of demolition or repair being employed;

d. name of the Safety Officer or other person with whom they should make contact if called to the site;

e. nearest hydrants and other water supplies;

f. fire-fighting equipment on the site relevant to the operations;

g. the types, general condition, history of previous uses, of the tanks, and any special features, including properties and hazards of, and appropriate extinguishing methods for, the substances concerned; if required, advice on the properties etc. of any particular substances may be obtained from H.M. Chief Inspector of Explosives;

h. potential hazards which may arise at other points as a consequence of demolition or repair work being undertaken.

General Precautions

12. If the Fire Service is called to a fire which has broken out when a tank is being demolished or repaired it will be clear that the proper safety procedure has not been observed. (Although it is less likely, fire may occur in any empty storage tank not under demolition or repair; but the advice in the following paragraphs is equally relevant). The situation should be treated as potentially extremely hazardous. Normally for a fire to be sustained in a tank there must be openings in the tank to admit air. If these openings are limited the fire is likely to have extinguished itself before the brigade arrives. But even if

the fire has apparently gone out, the vapour mixture in the tank may still be highly dangerous because the fire may have caused decomposition or vaporisation of residue which may produce an inflammable or explosive mixture, probably with toxic hazards as well. It should *always* be assumed that there is a risk of a violent explosion except when the top or end of a tank has been previously removed.

13. In no circumstances should men go on the top of or inside a tank in which there is a fire or in which one has recently occurred unless it is essential for rescue purposes. (If it is essential to enter a tank, the probability of toxic hazards should be borne in mind, and breathing apparatus should be worn). If anyone is on top of a tank, he should be told to come down. Nor should anyone go on top of an adjacent tank unless it is essential for operational reasons. No attempt should be made to open or close manholes or other fitments, because this may adversely affect the atmosphere in a tank. If forced ventilation is being used, e.g. by means of a blower or ejector, it should be switched off if this can be done remotely.

Fire-fighting techniques

14. Neither water jets nor high or low pressure sprays must be directed into a tank in which there is a fire (or a fire is suspected) because entrainment of inflammable materials—i.e. gases or vapours—by the water can cause rapid mixing to give a potentially explosive mixture. Similarly, the cooling of the outside of a tank in which vapour has been ignited should be avoided, because of the danger of an intake of air following condensation of the vapours inside the tank.

15. The following paragraphs describe alternative situations in which either fire-fighting procedures are recommended (differing according to the system of venting or inerting in use during demolition or repair, the nature and location of the fire, or the size of the tank) or it is suggested that the fire should be allowed to burn out. The advice should be regarded as no more than a general guide, because the action to be taken must in the final analysis depend upon the circumstances of each case.

16. In addition to deciding whether the situation is one in which one of the recommended fire-fighting procedures is appropriate, fire-fighting officers should bear in mind that any attempt to tackle a fire will possibly involve some degree of risk to their men, and they must judge whether the need to save lives and/or to prevent further damage to the tank itself or the spread of fire to surrounding property justifies taking that risk.

17. In any event, whether the fire is fought or allowed to burn out, action should be taken to protect persons in the area from the effects of a possible explosion and to minimise the effect of radiant heat on adjacent property and installations.

18. The alternative situations could be as follows:—

(i) *Fire in tank being steamed*

If a fire occurs in a tank which is being steamed, the supply of steam should at least be maintained, and if possible increased, as a means of both inerting the tank and purging it of hazardous vapours. If this is unsuccessful the fire should be allowed to burn out, notwithstanding the possibility of explosion. Water should under no circumstances be used in or on the tank, for the reasons given in paragraph 14 above.

(ii) *Fire in tank not being steamed*

If a fire occurs in a tank not being steamed, then, unless it is clear, when the brigade arrives, that the fire has gone out, one of the following procedures may be appropriate.

a. *If there is a gas or vapour flame burning outside an opening on the top of the tank,* an attempt should be made to achieve quick extinction by means of a high pressure jet from a distance in order to remove the risk of a flash-back. The jet should be swept quickly across the aperture, care being taken to avoid as far as possible large quantities of water either entering the tank or cooling the outside surfaces, for the reasons given in paragraph 14. If the attempt shows no sign of immediate success, or, after initial success, the flame re-appears, the attempt should be discontinued since the implication is that the primary source of the fire is inside the tank, and in these circumstances the fire should be allowed to burn out notwithstanding the possibility of explosion.

b. *If there are signs of fire but no external flames are visible,* the fire may have to be allowed to burn out notwithstanding the possibility of explosion. But, *if a bottom manhole is open*, and it is felt that, e.g. because of surrounding risks, the fire must be tackled, this may be practicable in the following circumstances. Although assessment of the location of the fire within the tank will be difficult because only a very restricted view of the inside of the tank can be obtained from a distance, and even this is likely to be obscured by smoke, it is still possible that the source of the fire inside the tank may either be visible or can be confidently estimated from a safe distance. If so, and if the fire is at the base of the tank, low expansion foam may be introduced. If, however, the fire is higher up and high expansion foam is available, it can be used, provided its application does not entail undue risk to personnel and is operationally feasible. If available, the use of carbon dioxide may be considered as an alternative to foam, *but only if the tank is known to be on fire*, because of possible static hazards during discharge operations which may themselves give rise to fire or explosion. Even if the foam or carbon dioxide does not succeed in extinguishing the fire it should have the effect of restricting it. Whatever extinguishing agent is used, it must be introduced only at any points that are already open at the base of the tank.

(iii) *Fire in a small tank*

If a fire occurs in a small tank (which as a general rule should be regarded as one having a maximum capacity of approximately 2,000 cu.ft. (about 60 cu.m.) or 12,500 gallons) which has only one manhole open, the fire can only be attacked by playing a low expansion foam jet through the manhole from a distance. It should be appreciated that this is a difficult operation to carry out.

(iv) *Fire in tank with top or end off*

If the top or end of the tank has been completely removed, normal fire-fighting procedure with low expansion foam or water spray should be effective, and there should be no risk of a disruptive explosion. Water should not be used if light residues are likely to float out.

Subsequent action

19. In all cases the situation should be treated as hazardous. The period of danger must be regarded as lasting until the whole of the tank and its contents are cold—24 hours should be sufficient for this. It will not always be easy to tell whether the fire has in fact been extinguished. It must also be remembered that the atmosphere in a tank in which a fire has occurred may still be both explosive and toxic and strict precautions must be observed before such tanks are entered.

20. The operator should be warned that it is essential that all materials involved in a fire should be removed from the tank or other positions before demolition or repair work is resumed. He should also be advised to get expert guidance on what to do next and to consult the District Inspector of Factories as to sources of advice. He should be particularly warned against further use of any heating device until expert advice has been obtained.

HOME OFFICE (FIRE DEPARTMENT)
SCOTTISH HOME AND HEALTH DEPARTMENT
June 1972

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To H.M. District Inspector of Factories

DEMOLITION AND REPAIR OF STORAGE TANKS

1. The following operation has come to the notice of the Fire Service . . . . . .
   (state the nature of the operation and the location of the site).

2. A copy of the advice on fire prevention which has been sent to the operator is attached.

3. You will see that the occupier/operator has been told:—
   a. that it is his duty to ensure safety on the site;
   b. that he should obtain any advice on process safety from you;
   c. that the Fire Service would inform you of the operation forthwith.

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DEPARTMENT OF EMPLOYMENT AND PRODUCTIVITY
H.M. Factory Inspectorate

Technical Data Note 18

REPAIR AND DEMOLITION OF LARGE STORAGE TANKS

INTRODUCTION

Section 31(4) of the Factories Act 1961 states "No plant tank or vessel which contains or has contained any explosive or inflammable substance shall be subjected to any welding, brazing or soldering operation or to any cutting operation which involves the application of heat, until all practicable steps have been taken to remove the substances and any fumes arising therefrom or to render them non-explosive or non-inflammable" and where work involving the application of heat to vessels or tanks is undertaken on factory premises this section must be complied with. The reason for the requirements of this sub-section is, of course, the very high risk of fire or explosions occurring where partially closed vessels which might contain inflammable materials are subject to such operations. The risk of explosion can practically be eliminated by the use of cold-cutting methods using wetted pneumatic chisels, and although this is often more laborious and costly than hot cutting, in certain cases it may be the only safe method of operation. In demolition work the more general requirements of regulation 40 of the Construction (General Provisions) Regulations 1961 will apply.

Irrespective of the statutory position, the requirements of section 31(4) of the Factories Act 1961 can be regarded as giving a good safety standard wherever such operations are carried out. Advice on first-aid fire-fighting equipment and techniques should be sought from the Fire Service by the occupier, whose duty it is to ensure safe working conditions on the site. Advice on other aspects of the matters dealt with in this note is readily available from HM Inspectors of Factories.

SMALL TANKS AND VESSELS

In the case of small vessels from motor-car fuel tanks up to tanks of about 6,000 galls, both vapours and residues can usually be readily removed by steaming out. Cleaning and gas freeing procedures for this range of tanks are dealt with in the Health and Safety at Work Booklet No. 32, 'Repair of Drums and Small Tanks: Explosion and Fire Risk'* and the dangers associated with the application of heat to such vessels are dealt with in Warning Notice SHW 386 'Drum and Tank Explosions'.*

The incidence of such accidents is still alarmingly high, mainly because correct gas freeing and cleaning procedures are not followed.

LARGE TANKS AND VESSELS

Removal of vapours

With larger tanks, the problem is somewhat different. Owing to the high heat capacity of the tank, steaming out cannot be relied upon to volatilise all residues unless very large quantities of steam are readily available. However in the case of these tanks it is generally a relatively easy matter to eliminate any explosive concentrations of vapour within the tank by either forced ventilation, using a blower or eductor system, or in the case of a vertical tank even by natural ventilation by removing top and bottom manholes. With volatile materials such methods will fairly rapidly reduce vapour concentrations to orders of a few hundred parts per million. With less volatile materials for example, those with flash points above ambient temperatures, there is never an explosive concentration of vapours even under equilibrium conditions and the evaporation rate of such materials is easily overtaken by ventilation. The danger of an initial explosion occurring can thus quite readily be avoided. This of itself paradoxically leads to considerable dangers in this particular field, because the problem of residue fires still remains.

Solid residues

Ventilation by itself will ultimately only remove the volatile materials present in a tank

* *Obtainable from Her Majesty's Stationery Office price 15p and 2½p respectively.*

and will never remove heavy ends or solid residues and tars. These types of residues themselves can contain considerable quantities of volatiles and unless they are removed, can and do give rise to a very high fire risk. Sparks and slag from the welding or cutting torch or direct heat from the torch itself can serve as very effective sources of ignition and fires can readily occur. The heat from these welding sources is never sufficient, of itself, to vaporise sufficient material to give rise to a vapour explosion risk but if residues catch fire in such a tank, the heat from the fire can be sufficient to cause decomposition and volatilisation of these residues. Very often a fire occurs in a tank in which the oxygen supply to feed the fire is limited and combustible breakdown products can be formed. Under these conditions especially if further air is introduced into the tank by water sprayer or by other means a devastating explosion can occur. It is essential, therefore, that such residues must be removed from tanks before any hot cutting or welding operations are carried out or that the residues are, in the words of section 31(4), "rendered non-inflammable or non-explosive".

Removal of residues

The removal of inflammable residues from these tanks can be very costly and time consuming. If the tank is undergoing repair for further use it obviously has a commercial value and thorough cleaning is probably a practicable proposition. Where the tank is for demolition and it is only of scrap value the economic considerations are such that thorough hand cleaning might not be carried out and considerable dangers can arise.

The methods of removal of tank residues depends to a very large extent on the physical characteristics of the material in the tank and also to some extent on the construction of the tank, the position of manhole openings etc. In the vast majority of cases, residues will be found mainly at the bottom of storage tanks but in certain cases 'hang-up' can occur on side walls. In some cases a thin evenly distributed film of inflammable material can occur over the whole of the tank walls and this material can be particularly hazardous as a rapidly propagating skin fire can occur which can lead to very fierce fires or to minor explosions in tanks which are closed except for manhole openings. In a few very special cases where the material stored can polymerise solid polymers can be formed in the ullage space of the tank. Such materials are normally inhibited in the liquid phase but the vapours in the ullage space can start to polymerise on the walls and roof of the tank and this together with diurnal breathing can cause more vaporisation and more polymerisation until a tough waxy or even rubbery deposit can be formed.

Alternatives to hot cutting

The work involved in cleaning the residues might be such that the use of hot-cutting techniques might have to be abandoned and cold cutting of the top of the tank resorted to, and under certain circumstances cold cutting may be the only acceptable method. Once the whole of the top of such a tank has been removed the explosion risk is nil. There might still remain a very high fire risk from the residues if hot cutting is then resorted to but this would result in a contained fire which, if properly tackled initially, should not prove difficult to extinguish.

Machine cleaning

If hot cutting is to be employed the removal of all residues must be considered. If the residues are not too viscous but are on both walls and bottom of the tank it may be possible to wash them down from the walls of the tank by means of water jets operated from outside the tank via manholes and similar openings, the resulting residues and water bottoms being removed by a stripping pump and settled preferably in a second tank the top of which has already been removed. This tank could then serve as a slops tank for its neighbours if there is a site clearance demolition proceeding. A more effective technique but one which is not widely used for storage tank cleaning would be high pressure hot or cold water mechanical washing by a 'Butterworth' or similar washing machine. This is widely used for cleaning and gas freeing of oil tanker cargo tanks and there seems little reason why this type of system should not be used, and in fact, catered for in the basic design of storage tanks by the provision of 'Butterworth' openings. Such a system would wash down all but the most recalcitrant type of deposits and would probably enable most 'bottoms' to be removed simultaneously by means of a pump.

Hand cleaning and toxic risks

If these measures are unsuccessful or impracticable, hand cleaning of the tank may have to be considered. Here entry is made into the tank and the residues in most cases consisting of heavy sludge bottoms must be removed by bucket and shovel. Obviously this is extremely arduous and dirty work and additionally steps must be taken to ensure that personnel engaged in such work are protected against toxic risks. This latter is essential especially in cases such as leaded petrol tanks, as volatile material may be occluded in the residues and their disturbance can lead to toxic concentrations of vapours being evolved and, in certain cases inflammable concentrations of vapours arising in the vicinity of the sludge. Because of these risks the hand cleaning of tanks, without thorough prior mechanical washing, is not to be encouraged unless carried out by specialists in this work. In any case section 30 of the Factories Act 1961, which deals with the entry into confined spaces which are liable to contain dangerous fumes, must be complied with. More general requirements are also laid down in regulation 21 of the Construction (General Provisions) Regulations 1961. In certain cases the complete removal of 'bottoms' residues may not be required. If the side walls of the tank are clean and the residues are firmly coherent in the bottom of the tank, it may be possible to render them non-inflammable or non-explosive as allowed under section 31(4) merely by covering them with a layer of a few inches of water. If, of course, the residues float on top of the water this method is completely useless. It can, however, very often be successfully applied after mechanical washing and stripping has removed most of the loose and volatile residues. In this type of case it is obviously essential to ensure that any inflammable vapours have also been removed from the tank before any cutting commences. Again normal foam can be used to blanket residues on tank bottoms and the risk of flotation is generally less than with water.

Inerting

Another method is to inert the tank by the displacement of the air thus reducing the overall oxygen content. As stated previously large storage tanks are difficult to steam out adequately unless copious supplies of steam are available but if this is, in fact, the case, prolonged steaming out can get rid of any volatiles present in any residues. Subsequent to this, continued steaming can then provide an inert atmosphere. In order to ensure inertness it is essential that the temperature of the whole system should attain and be maintained in excess of 80°C throughout the operations. This temperature ensures that the partial pressure of the water vapours present is sufficient to reduce the oxygen content well below that required for combustion. It must be emphasised that this method requires a very copious supply of steam. **It is also extremely important that, if this method of inerting is used, any fire which might occur in or on the tank is *not* tackled by the application of water or water jets inside or outside the tank.** This is because of the danger of condensation of the steam by the cold water spray and the consequent intake of air. Additionally, entrainment of the gas mixture by the water jet can cause rapid mixing to give an inflammable concentration throughout the tank. Tanks may also be inerted by the use of nitrogen, carbon dioxide or other inert gas. In these cases it is essential that the atmosphere in the tank is thoroughly tested to ensure that the oxygen level is below 10 per cent and in such a fashion as to ensure the absence of local pockets of air. Where carbon dioxide is used, for example, it is often suggested that solid CO_2 is a convenient method of handling. Cold CO_2 evolved from the solid material 'layers' very heavily and considerable losses may have occurred before the whole tank is fully inerted. In this case, the calculated amount of CO_2 to give the necessary lowering of oxygen content throughout the tank will merely result in the bottom half being

100 per cent inerted and the top half unaffected. A further hazard is introduced by inerting in that personnel will be engaged in cutting into a tank containing an asphyxiating atmosphere and there may be attendant or subsequent risks of gassing when the tank is opened.

Other methods

There are two other methods which can be considered in addition to the foregoing. The first consists of filling the tank as full as possible with water and then carefully working from the crown down removing relatively small sections of the roof. This method depends on reducing the vapour space in the tank to such a relatively small volume that even a vapour propagation in this space would be relatively innocuous. Again the method requires that the tank must be sufficiently strong and in suitable condition to withstand the not insignificant hydrostatic force of water used and the work must be carefully planned so that the water level is maintained at as high a level as possible. This requirement makes it a rather difficult technique to adopt.

The second method is a technique which by comparison is cheap and simple to employ, but which has not been used on large tanks, this entails filling the tank with high-expansion foam. Such foam could readily be injected into a tank via a manhole and if bottom injection were used, it is very probable that any vapour would be effectively removed as the foam built up. Certainly with a vapour-freed tank complete filling with high-expansion foam and the maintenance of a slight positive flow into the tank should completely obviate any risk of fire or explosion. Undoubtedly the technique would have to be perfected to give a quick fill rate followed by a slower top-up rate but if this can be done this method appears to be relatively much safer than other techniques. Preparative cleaning other than perhaps ventilation would be obviated, and the foam could probably be maintained adequately until the tank walls are cut vertically ready for pulling over.

Such a method would obviously deal with bottom residues and wall deposits and would be invaluable in the case of polymerised material which had formed in the ullage space and under the tank roof. This type of deposit is almost always impervious to steam or washing and the polymer once formed cannot be readily broken down. The only other method of attack for this type of deposit, if hot work is to be done, is virtual hand stripping of the surfaces, a task which is obviously economically prohibitive.

The use of foam could also be extended to bunds which are impregnated with inflammable oils from seepage and a foot or so of foam would make the bund area outside the tank sufficiently safe for hot work to be carried out.

CONCLUSIONS

It is obvious that the question of cleaning and preparing large tanks so that hot work can be done on them is extremely complex. It is relatively easy to ensure that an inflammable concentration of vapour is not present in the tank and cannot build up unless a residue fire occurs, but it can be relatively difficult to remove these residues. There is little doubt that these are the reasons why comparatively few large storage tank explosions occur but there are undoubtedly very many residue fires in tanks during demolition. Such fires are 'contained' fires and should be relatively easy to deal with. In certain circumstances they can even be allowed to burn themselves out or can be left to inert the tank with products of combustion. Remedial action of the wrong kind can, however, introduce a very great hazard of a vapour explosion and for this reason methods which might give rise to tank fires are obviously best avoided. With high-expansion foam properly injected a particularly safe system of work can be established quickly and cheaply and all danger of fire or explosion should be removed.

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