



Government of Maharashtra

Report of the Commission of Enquiry appointed  
to inquire into the causes of the Explosion  
in the Gas Holder No. 4 at Lalbaug,  
Bombay



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The Bombay Gas Company produces gas by heating coal in Silica retorts from which air is excluded to a temperature of about 1000°. From the early days of the Gas Industry, a container for the gas produced has been used in order to enable gases of various qualities and characteristics produced at different times of each charging period to mix and to give gas of a more uniform quality and character. Considerable improvements have been made later in the technique of coal carbonization but the hourly production cannot be made to suit the variable demands during the 24 hours of the day. Consequently, a container called a gas holder plays an important part in the process of distribution of gas by providing accommodation for gas produced in excess of demand and by supplying gas required by the consumers for use in excess of contemporary production.

2. The holders which are used by the Bombay Gas Company are all Column Guided three lift holders. Such holders may conveniently be divided into three sections:—

(1) The Tank of water which forms a water seal preventing escape of the gas when the holder is inflated;

(2) The holder itself, that means the vessel which contains the gas; and

(3) The columns and the guides.

In the case of the holders used by the Bombay Gas Company, the container is made up of three lifts, so designed that the three lifts fit one inside another. They will all rest when the holder is empty of gas upon rests blocks at the base of the tank. As the gas is pumped into the holder through an inlet stand pipe which brings the gas into the holder at a level slightly higher than the level of the water, the inner lift will rise in order to accommodate the volume of the gas coming in. The inner lift will continue to rise until it is full. At this stage an open steel channel or cup provided circumferentially at the bottom edge of the inner lift will engage an inverted channel or grip on the top circumferential edge of the middle lift. Sufficient depth of water will be retained in the cup to ensure a seal to prevent the escaping of gas from the holder at this point. The pressure of the gas will then lift the two lifts, i.e., the inner lift and the middle lift together until the middle lift is fully inflated. The outer lift will then be engaged and, similarly, raised as more gas comes into the holder. These three lifts are sometimes called the top lift, the middle lift and the bottom lift also. As the lifts rise or come down, rollers of carriages fixed to the holder slide

upon guides attached to columns surrounding the holder. These columns are sometimes called standards also and are numbered. The space between each two columns is called a "Bay".

3. The Bombay Gas Company has three Holders—No. 2, No. 3 and No. 4. There used to be a holder bearing No. 1, but it was dismantled some years ago and there would be no further mention of it in this report. Each of the existing three holders has an indicator upon it to show the total quantity of the gas which the holder contains at any particular moment. Before the gas is sent out to the City, the gas from Holder Nos. 3 and 4 goes into the same main. The pressure of the gas in this main is recorded graphically by an automatic instrument. The record so made is not the record of the pressure either in Holder No. 3 or No. 4 but is the greater of the pressures in the two holders.

4. No. 2 Gas Holder is a three lift column guided holder in a masonry tank below the ground level, its capacity being 2,25,000 Cu. ft. The holder was erected in 1863 by Messrs. Thomas Piggot and Co. Ltd., and was resheeted by Messrs. Alcock Ashdown, Bombay in the year 1946-47. That holder is connected directly to the carburetted water-gas plant. That gas is not purified at that stage and the tar in the gas goes inside the holder, gets deposited on the inside and finds its way also on the outside. This tar protects the holder and the only portion of it which is not protected from corrosion is the outside of the crown. Consequently, the holder gives no trouble. It is just as well to mention, however, that an additional inlet valve for coal gas for this holder was provided in August 1960 to enable it to serve as coal gas holder at night because of the failure of Holder No. 4 on the 8th of July 1960.

5. Holder No. 3 is a three lift column guided holder in a masonry tank below the ground level with a capacity to contain 3,50,000 Cu. ft., of gas. It was erected by Messrs. S. Cuttler and Sons, London in 1912: and between 1951 to 1954 it was over-hauled by Messrs. Alcock Ashdown, Bombay. The middle and top lift side sheets and the crown sheets were renewed in the process of over-hauling. In the year 1957, inspite of the very young age of the holder, leaks were noted in the middle lift in the second, third and fourth row of sheets below the top thick plate and were patched. Further leaks were noticed in 1958 in the same lift and they were also patched. In the year 1959, the holder tank was oil filmed as a measure for preventing corrosion and in the month of September of that year Mr. King, an Inspector of Messrs. Clayton Sons and Co. Ltd., London who was called in for inspecting the holders of the Company and make his report, noticed that considerable external corrosion had affected three bays of the sheeting of the middle lift and extensive patching had been necessary inspite of the fact that the

age of the metal was only 4 years. Mr. King cut discs from three places in the middle lift. They showed no appreciable signs of internal corrosion. He, therefore, gave his opinion that the condition of the sheeting of this lift was due to the close proximity of the coke pile which was stored about 40 yards away from the holder for use in heating the Silica retorts in which gas is produced from coal. He also pointed out that there were two holes on the opposite side of the holder where oxide was heaped.

6. Holder No. 4 was again a three lift column guided holder on a steel tank. It was built by Messrs. Thomas Piggot & Co. Ltd., in 1927 and was commissioned in 1928. A brand of steel with the trade name 'Armco Iron' which was popular at that time for use in Gas holders was used throughout in the making of this holder. In the year 1954, isolated perforations were found on its crown seams which were patched. In the year 1955, isolated perforations on the inner lift side sheeting were noticed near Bay No. 21 and were patched using 4 patches. In the year 1957, further isolated perforations on the inner lift side sheeting were noticed between columns 24 to 21 and were patched. Next year, 4 patches were applied to the crown between columns 19 to 21 and 6 patches were put on the middle lift between columns 21 to 24. Six months later one patch was applied to the middle lift at column 21. Next year, a film of light diesel oil was floated on the tank water inside the holder to provide internal protection against corrosion. But as a result of so doing, a number of leaks were found in the joints between the plates which, according to the evidence of Mr. Ruggles, the Chief Engineer of the Bombay Gas Company, one would not expect to find when one uses a film of light diesel oil. It suggested to Mr. Ruggles the necessity of calling in an expert and the Bombay the Company there upon wrote to Messrs. Clayton Sons & Co. Ltd., London whose inspector, Mr. King arrived in India and inspected the Company's holders in September 1959. He found that the external condition of Holder No. 4 including the tank was satisfactory but he found heavy scale, on the inside of the water tank at the wind and water line and corrosion taking place there. He found also a large amount of sediment in the cups of the inner and middle lifts and had it removed so that the cup and the grip or the dip should engage in a proper manner. The major signs of weakness which he found, however, were in the sheeting of the crown and the inner and middle lifts. He found extensive patching had been carried out in 9 bays of the crown between standards 19 and 2. He removed eight discs from various places in the crown, and on inspecting their condition came to the conclusion that there was extensive wasting of metal, the reduction of thickness in most of the discs being at least 50 per cent. and in one case over 75 per cent. The discs taken out from the inner lift proved extensive wastage of metal, the reduction being over 50 per cent. in some cases. It appears, from the perusal of the thickness

of the discs given in the Annexure to the report of Messrs. Clayton Sons & Co. Ltd., London that in the case of one disc the thickness was reduced by over 80 per cent., but they do not seem to have thought this of sufficient importance to mention in their report. Extensive patching had been carried out in three bays of the middle lift, namely, between standards 21 and 22, 22 and 23 and 23 and 24 and the discs taken from it, and the hammer-testing employed showed that the corrosion extended from standard 18 to standard 25. It was more pronounced towards the dip.

7. The recommendation of Messrs. Clayton Sons & Co. Ltd., London upon the report of their inspector Mr. King was that in view of the very poor condition of the sheeting of the crown which was of 10 gauge thickness the whole of the crown should be resheeted in the near future or if the holder could not be put out of service a new set of flanged sheets fabricated to a patent of theirs should be secured by means of 'U' Bolts to the 6/6" thick row of plates which adjoined the outer row of plates of the crown. So far as the inner lift was concerned they recommended that the smaller patches should be replaced by larger patches of heavier gauge, patching which they expected would have to be resorted to further should be carried out as and when holes broke out and that a regular inspection for leakage should be made. On getting this report the Bombay Gas Company wrote to Messrs. Clayton Sons & Co. Ltd., London. With regard to Gas Holder No. 3 they said, that while the reason given by Mr. King for the rapid deterioration of the middle lift sheeting of this holder was possible it did not appear to them to be probable. They felt that if the corrosion had been due to the coke pile which was 40 yards from the holder or due to the oxide heap which was 10 yards from it, corrosion would be expected to be more uniform throughout the three lifts, whereas there was pronounced external corrosion of the middle lift but there was no external corrosion of the outer or of the inner lift. The Bombay Gas Company, therefore, suggested that the corrosion was entirely due to the use of inferior quality of metal in the sheets used for the middle lift.

8. As regards Holder No. 4, the Bombay Gas Company inquired from Messrs. Clayton Sons & Co. Ltd., London the quotation of the latter for the new patent crown to be fitted to the existing crown while the holder was in operation. As regards the side sheeting they inquired from Messrs. Clayton Sons and Co. Ltd., London as to what the life of the then existing sheeting would be, because its estimated future life was of much importance in relation to their overall gas holder policy.

9. Messrs. Clayton Sons & Co. Ltd., London, in reply adhered to their original view that the corrosion of the sheets of the middle lift of Holder No. 3 was due to the reasons mentioned by them

before and they pointed out that the inner lift sides and the crown were resheeted at the same time as the middle lift and considered it unlikely that a batch of inferior metal would find its way into the middle lift only. While expressing their view that their conclusion as regards the causes of the corrosion of the middle lift of this holder was the most likely, they suggested that the Bombay Gas Company could have an analysis made of the discs taken out of the middle lift of Holder No. 3 in order to check their theory. It is the evidence of Mr. Ruggles that subsequently Messrs. Clayton Sons and Co. Ltd., London sent their quotation for a false crown to be fitted on to the existing crown amounting to £ 5,600 and odd. In the mean while, the Bombay Gas Company had already placed an order with Messrs. Tata Iron and Steel Company for steel for Holder No. 3. They got a quota for it and also the steel itself in March, 1960. But their interpretation of the two letters of Messrs. Clayton Sons and Company Ltd., London was that there was no objection to the Bombay Gas Company repairing the side sheeting of the inner lift of Holder No. 4 in the year 1960, putting on a false crown on the existing crown of Holder No. 4 in 1961 and only patching up the leaks in the crown sheeting of that holder in 1960. In March 1960, therefore, they took a decision to clad the sheeting of inner and middle lifts of Holder No. 4 between columns 18 and 25 and to patch the crown sheeting in the months of May and June, 1960 which are the months in which the peak demand for gas in the city of Bombay is the lowest. They decided to carry out these repairs themselves because even though they had not carried on such extensive repair work before it was the same kind of work as they had done before though there was more of it. The work of cladding the side sheeting of the inner and middle lift of Holder No. 4 was consequently commenced on the 12th May 1960 and was finished on the 30th of May 1960. This work was done with the holder on air. Thereafter with the holder still on air, the crown sheeting was patched at the places where evidence of gas leakage indicated that patching was necessary. The whole of the work which was contemplated could not be carried out because the monsoon set in in Bombay early in 1960. They consequently decided to put the holder back into commission even if all the work had not been done. The holder was put into operation on the 24th of June 1960. It was in service from that day till the 8th of July 1960, on which date there was a failure of the crown sheeting of the Holder at about 6-00 a.m.

10. The circumstances attendant upon the failure, so far as they can be gathered from the evidence, are as follows.

11. The time at which the failure occurred is not clear even though the time of 6-12 a.m. finds mention in the report of Mr. Desai, Senior Inspector of Factories, who went to the scene when he got information of the failure and also occurs in the report of Messrs. Clayton

Sons and Co. Ltd., London upon the inspection of Mr. King who was called back again to Bombay after the failure of the holder. It is the evidence of Mr. Ruggles that the reason why this time finds a mention in these two documents is that when he himself went to the holder upon hearing of the failure, some one there mentioned to him that time as the time when the holder failed. He says that he has never believed in the accuracy of that time and that a further reason for refusing to believe it is furnished by the fact that an hourly record of the contents of each holder is made and one finds that the last record of the contents of the holder was made at 5-00 a.m. It is the evidence of Vishram Rane, whose duty it is to take certain readings including the contents of the gas holders at the end of each hour, that he had taken the readings which he had to take at 6-00 a.m. implying of course except the reading of the contents of Holder No. 4 and was going to what is called the governor house to record the readings which he had taken when he heard a noise like "Dhub" and saw flames over gas holder No. 4 reaching about 10 to 20 feet above that holder. He then ran—apparently for shelter—where the Water Gas meter was. The flames then went out by themselves and he returned to the Governor house and closed the valves of the main taking the gas to Holder No. 4. He did not make any record of the contents of holder No. 4 apparently because before he could do so, the holder had caught fire in the popular sense and came down.

12. The flames did not cause any appreciable damage to any property. The only property which caught fire was a piece of wood from a gable of the roof of a building nearby. Over 90 people were scorched either by radiation or by hot gases escaping from the holder. The holder came down as a result of the failure and became a complete wreck but the steel tank and the external guide frame could, according to Messrs. Clayton Sons and Co. Ltd., London, be used to accommodate the new gas holder shells and it would be possible to use the existing guide carriages and rails. The opinion of Messrs. Clayton Sons and Co. Ltd., London upon the report of Mr. King made on seeing Holder No. 4 after its failure is that the leakages referred to in their report of 2nd October 1959 were made good by the Gas Company and further patches were fixed to the crown sheeting between bays 19 and 3 along the radial and circumferential seams. This patching would stiffen the crown on that side of the holder and would tend to resist the normal movement of the crown sheeting caused by the increase or the decrease of the pressure when taking up or dropping a lift which would, in turn, throw more stress on the unstiffened side and probably cause the initial fracture of the sheeting. Mr. Ruggles, when cross-examined, admitted that this was a reasonable inference to draw now that the holder has failed.

13. It is the case of the Gas Company that they have always maintained the holders in good condition and that the external corrosion of the sheets of the middle lift of Holder No. 3 was due to the inferior

metal used for that lift by Messrs. Alcock Ashdown and Co., Bombay when working upon the holder from 1951 to 1954. They contend that the failure of Holder No. 4 was accidental.

14. Mr. Vyavaharkar for the State contends on the other hand that the Gas Company was wrong in not having an examination of the inside of Holder No. 4 made before 1959 inspite of the fact that that holder was 20 years old in 1948. He points in this connection to the practice followed in the United Kingdom where the first examination takes place at the end of 20 years after the holder or any lift of it is put into commission and subsequently an internal inspection is held once in 10 years. As regards the failure of Holder No. 4 he contends that the Gas Company had allowed the sheets of Holder No. 4 to go too thin. Secondly, it departed from the advice given to it by Messrs. Clayton Sons & Co. Ltd., London and erred in patching only one side of the crown with the result that that side became stiffer and the difference in the ductility of the two sides set up stresses which the side, which was not repaired and had already gone thin, was unable to bear.

15. It would be just as well to go into these points of controversy between the two sides at this stage.

16. The principal care which has got to be taken of the externals of the holders is in regard to painting the holders from the out-side, oiling the axles of the carriages of holders and seeing that none of the rollers gets flat at its circumference. The Gas Company keeps record of the things done to the holders but apparently only when anything special has been done, for example, there are patches put upon perforations noticed. Even then the record is not complete e.g. it does not always mention how many perforations were noticed or how many patches were applied. When an external inspection is made and nothing particular is noticed, no record is kept. I am suggesting below that even when nothing particular is noticed when an inspection is made, or when routine things like painting and oiling are done, a complete record should be kept. But no record is kept at present, unless anything special is noticed and any special action like patching is taken. One means, therefore, by which one could ascertain whether external inspection which in the United Kingdom has to be made once in two years has been made at proper intervals or the various annual repairs are done punctually and satisfactorily is not available at present. But it is the evidence of Mr. Ruggles that a certain routine is followed in regard to painting and oiling and that routine is punctually carried out. There is some corroboration to this evidence of Mr. Ruggles in the report of Messrs. Clayton Sons & Co. Ltd. London who said that so far as external condition of Holder No. 4 was concerned, it appeared to be satisfactory. Messrs. Clayton Sons & Co. Ltd., London said that their inspection revealed



that the gasholder had been maintained in a satisfactory manner, the holder having been well cleaned and painted during its life. So far as Gas holder No. 3 was concerned, their Inspector found external corrosion on the middle lift of that holder. He found the external condition of the outer lift satisfactory and the report of Messrs. Clayton Sons & Co. Ltd. London does not mention anything about the external condition of the crown or inner lift of that holder. Messrs. Clayton Sons & Co. Ltd. say that the external corrosion which Mr. King found on the middle lift of Holder No. 3 was due to the coke pile which is 40 yards away from that holder and point out there were two holes on the opposite side where the oxide was heaped. Some doubt has been thrown upon the question, how far the Gas Company had taken all the necessary care about keeping the gas-holders in good external repair, by the evidence of Dr. Mitra who was examined by the State of Bombay at the end of the inquiry. He deposed that he was not satisfied that the corrosion of the sheets of the middle lift of Holder No. 3 was not internal corrosion but was external corrosion. The reason he gave was that if the corrosion was external, the Bombay Gas Company could have taken care of it by taking appropriate steps, for example, by painting sufficiently frequently with anti-corrosion paint. The difficulty with this evidence is that it is principally directed towards throwing a doubt on the contention that the corrosion was external. The question of the Bombay Gas Company taking care of the external corrosion has been raised only incidentally. Now, Dr. Mitra never saw the gasholder before its cladding which was completed during the course of the present inquiry. On the other hand, Mr. King saw the holder when he could see the external corrosion which he has recorded on the sheets of the middle lift of Holder No. 3. He also took out three discs from the middle lift and found slight pitting or grooving on the inside but deep pitting on the outside. The sheeting of the middle lift was renewed only between 1951-54. The age of the metal at the time of Mr. King's inspection was about 4 years. I am satisfied, therefore, that the corrosion which was noticed upon the middle lift of the holder was external. The question how the Bombay Gas Company could not take care of it by scraping out the sheets and painting the sheets of the middle lift oftener than usual and as often as necessary then arises. The record of repairs done to this holder shows that after the crown the inner and middle lifts were resheeted the holder was put back in use in November 1954. The painting of the outer lift was started in December 1954 and completed in February 1955. All the three lifts and crown were repainted in September 1956 and it was noticed at this time that there was external metal wastage in the middle lift. There was again wastage apparently external because in October 1957, 4 patches were applied to the middle lift. There is no record of repainting in 1957 or in 1958 though 19 patches had to be used in April 1958. There is as a matter of fact, no record of repainting of this holder any time after

September 1956 till July-August 1960 when the extract from the record supplied to the Commission comes to an end. If the Gas Company was painting the holders about once a year it is strange that there should be no record of the repainting of the holder No. 3 after 1956. On the other hand if there was no repainting after April 1953 inspite of it having been necessary to use 19 patches in that month it is strange that no patching was required thereafter until July-August 1960 and no signs of absence of proper painting were noticed by Mr. King in September 1959.

17. It follows that either the record is defective or the Company did not repaint this holder about once a year. It does not in any case seem to have attempted to minimise the corrosion by repainting holder No. 3 more frequently than usual. It is possible that when inspite of the fact that the age of the metal was only 3 years and inspite of the repainting in September 1956, 4 patches had to be used in October 1957 and 19 patches in April 1958 the Gas Company did not think that repainting even more than once a year would prevent further corrosion. It has to be remembered that resheeting is likely to be more expensive than repainting and the question whether to combat the corrosion by more frequent repainting or to renew the sheeting must be left to the judgment of the Company subject to the over-riding consideration of safety. Messrs. Clayton Sons and Co. Ltd., London do not seem to have suggested that more frequent painting should be resorted to though by then the corrosion may have advanced much more than in 1958. I am not satisfied therefore that the Gas Company could have prevented the corrosion of the sheets of the middle lift by frequent painting unless of course they had painted the sheets so frequently that it would have been more economic to resheet the middle lift.

18. It is when we come to the inspection of inside of the holders that the Bombay Gas Company was definitely in fault. It is admitted that in the factories Act of 1937 of the United Kingdom there is a section No. 33 which requires that when any lift of a gas-holder has been in use for more than 20 years, the internal state of the sheeting should within 2 years after the coming into operation of the section, be examined by a competent person by cutting samples from the crown and the sides of the holder or by other sufficient means. The section further provides that a similar examination should be made thereafter at least once in every period of 10 years. When Mr. Ruggles arrived in India to take his post in the year 1951, he was aware of the practice because he was a gas engineer in the United Kingdom. He said that even though he was aware of the practice and more than 20 years had elapsed after the installation of Holder No. 4 by the time he joined the Bombay Gas Company, he did not suggest to the Gas Company, that there should be an inspection of the inside of the holder made, because

he was new to the Country. Now one can understand Mr. Ruggles hesitating to suggest such a procedure immediately upon his arrival because the procedure is a costly one. It appears that inspection of the inside of a holder can be made in two ways—one internal visual inspection and the other by means of hammer testing and disc cutting. Internal visual inspection is a matter of considerable difficulty even if a holder can be spared. Either the water must be pumped out of the tank of the holder which takes about three weeks and pumped in again before putting back the holder in use or an air lock must be arranged before a person is sent inside the holder to look at it from the inside and some arrangement like a raft on the tank must be made to ensure his safety if he were to fall in the tank. The process of hammer testing enables a person who is well versed in finding the thickness of the metal by the sound it emitted in the process to tell what wastage of the metal of the sheeting, if any, is. It is not in dispute that there are even now no persons in India who are trained in hammer testing. If a disc is taken out either from the crown or the side sheeting of the holder, one can have a look at it and see whether there are any signs of corrosion and after removing the corrosion find out how much the metal has wasted in the area. But in order to cut discs there must be with one the necessary apparatus and there must also be a person who can take out discs. It is the evidence of Mr. Ruggles that till 1959 when Messrs. Clayton Sons and Co. Ltd., London having been called to advise, Mr. King came to India and brought with him the disc cutting apparatus, no one in India had got such apparatus. He also deposed that, Mr. King trained employees of the Bombay Gas Company how to take out the discs and till he did so there was no one in India who could take out discs from the gas-holder even if he had the necessary apparatus made available to him. There is no reason to doubt this evidence and I accept it. One can always call of course an expert in these things from outside, but that is a costly procedure. One would not therefore expect Mr. Ruggles to suggest immediately upon his arrival to the Bombay Gas Company that an examination of the internal condition of the gas holders be made by this method of hammer testing and disc cutting. But in course of time he became aware that patching of the crown as well as the sides of Holder No. 4 had become necessary. He says that he had seen patches before and there is no cause of alarm even if it is necessary to put on more than one or two patches. But it appears from the evidence that in the case of Holder No. 4, perforations described as isolated were found on the crown in the year 1954 and on the inner lift side sheeting in 1955. The number of patches required in 1954 is not clear, but 4 patches were used in 1955. Further isolated perforations were found on the inner lift side sheeting in 1957 and were patched, but the number of patches put on has not been mentioned. Next year, 4 patches were applied to the crown and 6 patches

were put on the middle lift. Six months later one patch was applied to the inner lift and when in the year 1959 Mr. King inspected the holder the patching which he found on the crown was described by him as extensive. It is obvious, therefore, that even before Mr. Ruggles got alarmed because the oil which was floated upon the surface of the water tank of the holder led to leakages at the joints of the side sheeting there were strong reasons for making an inspection of the inner side of Holder No. 4 by disc cutting and hammer testing. It is possible that perforations may be due to local wastage but they may be due to general deterioration also and when extensive patching had to be restored to an inspection of the internal condition of the sheeting was imperative. It has been pointed out that the life of a holder is from 60 to 100 years but it is doubtful if this is true of a hot and humid climate like that of India. Holder No. 3 had to be resheeted except as regards the bottom lift in 39 years. The Bombay Gas Company, consequently, erred grievously when they did not have such examination of the holder made before 1959. It was principally, of course the fault of the Chief Engineer, because he does not suggest that he recommended that such an examination should be made; on the other hand, he says that he made no such suggestion.

19. The result of this failure, to have an examination of the internal state of the sheeting of Holder No. 4 made before 1959 was that when such an inspection was made the Bombay Gas Company was placed in the situation that the crown had to be resheeted or if the holder could not be put out of use a false crown had got to be placed upon it in the very near future as Messrs. Clayton Sons and Co., Ltd., London advised. The Company at this stage maintained that they could not put Gas Holder No. 4 out of use. It is true that after Holder No. 4 failed the Company has had to carry on with the remaining two holders, but that does not mean that even before the failure, the Company could expect that they would be able easily to carry on even if Holder No. 4 was put out of use. On the other hand, the false crown could not have possibly arrived immediately its price was ascertained. An import licence had to be obtained for it and then an order placed for supplying, if not, manufacturing the false crown. The danger to the gas-holder on account of further wastage of metal would all the while be on the increase.

20. The Bombay Gas Company blundered next when they decided that they would carry out repairs to the side sheeting of that holder in 1960 and put on a false crown upon its crown in 1961, patching in the mean while the crown where there was evidence of leakage of gas.

21. It is quite clear from the report of Messrs. Clayton Sons and Co., Ltd., that when they read the report of Mr. King they came to the conclusion that what the Bombay Gas Company had to do first was to resheet the crown or if that was not possible because the holder could not be put out of use, to put a false crown upon the then existing crown. So far as the side sheeting is concerned, all that they had recommended was that the existing smaller patches should be replaced by larger patches of heavier gauge, further patching should be carried on as and when holes broke out and that regular inspection for leakages should be made. Mr. Ruggles says in his evidence that they themselves thought from the report of the discs which had been attached to this report that the side sheeting wanted more attention than the crown itself. The reason which he gives for this view of his which seems to have been accepted by the Bombay Gas Company, according to his evidence, was that one of the discs taken out from the inner lift showed wastage of more than 80 per cent. He admits, however, that if we look to the report about the discs taken out by Mr. King in the case of the inner lift comparatively fewer discs showed considerable damage, while in the case of the crown a comparatively larger number showed considerable wastage. It seems obvious, therefore, that greater wastage of one disc taken out from the inner lift was not representative of the comparative condition of the sheeting of that lift. One cannot accept therefore his evidence that the crown was not in a worse condition than the sheeting of the inner lift because one disc showing a comparatively higher wastage had been taken out from the inner lift. It is to be remembered that even though cases of failure of a gasholder are rare, cases of the failure of the crown are more frequent than the cases of failure of the side sheeting, and that might have been another reason for the advice which Messrs. Clayton Sons and Co. Ltd., London, gave viz. to place a false crown at least upon the existing crown in the very near future and to replace the smaller patches upon the sheeting of the inner lift with larger patches of heavier gauge.

22. It is no doubt true that Messrs. Clayton Sons and Co. Ltd., London, gave no indication to the Bombay Gas Company of any immediate danger to the crown. The expression which they have used, however, "in the very near future" cannot reasonably be interpreted to mean the months of May and June 1961.

23. It is no doubt also true that if a false crown had been put upon the existing crown first then the pressure of the gas in the holder when fully inflated, using the words 'fully inflated' in the sense "inflated to the maximum extent to which it was allowed to be inflated in the past" would have increased by about 1" water gauge. Mr. Ruggles says that he was doubtful whether the sheeting of the inner lift was in a condition to bear this additional pressure. But in that case, what one would expect is that the Bombay Gas

Company would write to Messrs. Clayton Sons and Co. Ltd. and inquire whether in view of the condition of the sheeting of the inner lift it would not be better to re-inforce that sheeting first before a false crown was put upon the then existing crown. Even though the Bombay Gas Company has written to Messrs. Clayton Sons and Co. Ltd., London upon getting their report, there is no inquiry made in this connection. On the other hand, the letter merely asked the quotation for a crown and inquired how long the side sheeting of the inner lift may be expected to last. The reply which Messrs. Clayton Sons and Co. Ltd. gave to this query was that the patching which the Bombay Gas Company would have to make would give them a better idea of the life of the sheeting of the inner lift, but so far as Messrs. Clayton Sons and Co. Ltd., London could say upon the evidence before them, the probable life of the sheeting would be three to five years. They did not, inspite of the query as to the life of the sheeting of the inner lift, entertain any doubts whether the sheeting would be able to bear the extra pressure due to a false crown being super-imposed on the then existing crown. Mr. Ruggles is a competent Gas Engineer and I have no doubt that when a decision was taken as to what repairs should be made to the crown and the inner lift in 1960, the repairs which were carried out to the holder under his supervision were carried out as competently as they would have been carried out by employing a firm of contractors to do that work. But when very extensive repairs had to be made to a holder, there are a number of factors involved and the expert upon whose opinion the repairs are to be undertaken, must be an expert who is competent to advise as to what should be done. And what follows leaves no doubt in my mind that Mr. Ruggles is not such an expert.

24. The actual repairs which were made to the crown were to put on patches on one side of it. It is the evidence of Mr. Ruggles that the patches were put at the seams wherever there was evidence of leakage of gas and so far as the plates themselves were concerned, a patch was put on only when it was necessary. But even if we accept that the seams were strengthened only in those places where there was evidence of gas leakage and only to the extent necessary to prevent it, the result of what was actually done was to stiffen the crown on one side. The other side was left unstiffened and as a matter of fact, some areas where there was extensive wastage as shown by the discs cut by Mr. King, were left un-repaired. That may possibly be due to the fact that the monsoon set in in Bombay a little earlier in June 1960. But the two facts remain; viz. one side was stiffened more than the other and some areas on the un-repaired side were left thin and it is no longer in dispute that the probable cause of the failure of Holder No. 4 was the stiffening of only one side of the crown of the gasholder. Such stiffening makes for a difference in the ductility of the two portions, the portion which was repaired and the portion which was not, and this difference in ductility admittedly causes

stresses which would not have been caused if one side only of the crown sheeting had not been stiffened. This, as a matter of fact, is admittedly the view which was taken in a number of the Gas Times which was produced on behalf of the Gas Company but has not been exhibited in these proceedings because it contained a number of matters of opinion in other respects of a controversial nature. But so far as the difference of ductility leading to extra stresses is concerned, there is no dispute. Mr. Ruggles as a matter of fact has admitted that this Gas Times was received in the Bombay Gas Company in the year 1957 and Mr. Ruggles said that he must have perused it when it arrived. I do not want to lay much stress upon Mr. Ruggles' admission though he may have read it because one does not always find time amidst duties one must perform to read all the technical literature which comes to one's hands as carefully as one would wish and the significance of the passage may have escaped him. It is obvious that he was not mindful of the principle enunciated at the time when he advised and undertook the repairs of that Gasholder No. 4 in 1960. That shows quite clearly that he was not an expert competent enough to advise as to what repairs should be done. Such advice can properly be given only by an expert of the makers. They would naturally be constantly referred to by Gas Companies whenever extensive repairs have to be made and one would expect that they would be more familiar with the problems which arise and would be more capable of dealing with them. Mr. Ruggles says that Messrs. Clayton Sons and Co. Ltd., London gave no indication to him of the danger of further patching the crown but they expected a false crown to be super-imposed in the very near future and the contention loses most of its force if one remembers that no patching was required or made till May 1960.

25. It has occurred to me that when Messrs. Clayton Sons and Co. Ltd., London advised the putting up of a false crown upon the then existing crown, they offered to sell to the Bombay Gas Company their patent crown for which the estimate was £ 5600 and odd, and a suspicion might at that time had arisen in the minds of those in control in the Bombay Gas Company as to whether Messrs. Clayton Sons and Co. Ltd., London were not selling them something. But in that case the only thing to do was to call in another expert or if it was thought that that might itself be too expensive considering the cost of the patent crown which Messrs. Clayton Sons and Co. Ltd., London offered to supply, then to buy that crown ignoring what extra cost its purchase might involve.

26. The Bombay Gas Company consequently blundered when they departed from the advice given by Messrs. Clayton Sons and Co. Ltd., London as to the repairs to be made to the Gasholder No. 4. In doing so they put in jeopardy even if they may not have been conscious of it the persons and the property in the neighbourhood of the

Gas Works because fires even when an explosion does not accompany them are known to have caused wide-spread damage. It was a stroke of pure luck that more extensive damage to persons and property was not caused, though the damage actually caused, viz. injuries to more than 90 persons due to scorching is not small damage.

27. The report of Messrs. Clayton Sons & Co. Ltd., London based upon the observations of their inspector in September 1959 does show that a considerable wastage of the sheeting had taken place. Mr. Ruggles deposed that in the case of steel the factory of safety is 6 : 1 and relies upon Kent's Engineer's Hand-book. It is argued from this that it could not be said that the Company had allowed the sheeting of Holder No. 4 to go too thin because in no case was the thickness reduced to 1/6th of the thickness which the metal had when the gasholder was erected. There is nothing to show however that when Kent's Engineer's Hand-book mentions the safety factor in case of steel to be 6 : 1 what is intended is that it is permissible in the case of sheeting of gasholders to allow the thickness which would remain after the corrosion had been removed to be as low as 1/6th of the original thickness. On the other hand, it is the evidence of Dr. Mitra that even though steel has got a point of ultimate strength, it is not permissible to load it upto that point or just short of it. The steel has also got a yield point, a point at which there is plastic deformation of the metal i.e. the metal starts extending even without any further increase in the load though there is a limit to this extension. The yield point in the case of Armco Iron would be 2/3rds of the ultimate tensile strength or a little lower; one cannot however load steel up to or just short of this yield point. The maximum safe allowable stress is 1/4th the ultimate stress. The practice which the Burmah Shell follow in the case of pressure vessels used at the Oil Refineries where Dr. Mitra serves is to find out what the corrosion limit in respect of the sheeting of their metal is and to discard the sheeting immediately this corrosion limit is reached. When a vessel is manufactured, the manufacturer, in the first instance, chooses a thickness at which the vessel is to be worked which is usually based upon the ultimate strength of the sheeting. To this is then added the corrosion allowance. Where it is not known, i.e. in the case of truss stressed structures of the older installations, they usually discard when there is a wastage of 42 to 47 per cent.

28. Relying upon this evidence, it is argued on behalf of the State that Holder No. 4 should have been taken as unsafe when there was a wastage of 47 per cent. In the alternative, it is suggested that where the sheeting used was 1/8th of an inch in thickness, 1/16th of an inch should be taken as the thickness at which the manufacturer wanted the gasholder to work and 1/16th of an inch as the corrosion allowance. Taking up then the thickness of the ultimate stress i.e., the stress at which it would break as 1/64th of



an inch, the yield point is reached when the thickness was reduced to  $1/64 \times 10/6$  or 0.026th of an inch thickness. It is contended that it must have been clear from the wastages of the discs cut out by Mr. King that the sheeting had gone down so much in thickness that the yield point would be reached very soon if it has not been reached already and the holder should have been discarded.

29. Now, in my opinion, there are a number of assumptions involved in this working out of the yield point of sheeting of the Gasholder No. 4 which was 10 I. W. G. or  $1/8$ th of an inch in thickness approximately. There is no reason for assuming that when the manufacturer designed the sheeting he had made a corrosion allowance of  $1/16$ th of an inch of thickness or for assuming that  $1/16$ th of an inch was the thickness at which he intended the gasholder to work. It is true that  $1/16$ " is the minimum corrosion allowance at present and they know now more of corrosion and make less allowance for it than formerly, but even though the present practice may be what Dr. Mitra deposes, we do not know whether the manufacturers were following the method of determining first at what thickness the vessel should work and adding the corrosion allowance when designing gasholders in 1927. No doubt, the Burmah Shell practice in the case of truss stressed structures of which the corrosion allowance is not known is to discard them when there is a reduction of 42 to 47 per cent. in respect of the metal. But Dr. Mitra deposes that one cannot say that a particular vessel should not be used after wastage of thickness of 50 per cent. because each case has got to be dealt with on an individual basis and one must find out what the corrosion allowance of that vessel in the condition in which it is used is. I have not considered it necessary, therefore, to follow up this line of investigation. But the effect of the evidence of Dr. Mitra is to negative the contention which has been advanced on behalf of the Gas Company that inasmuch as the thickness of the sheeting used had not gone below  $1/6$ th of the original thickness, the Gas Company had sufficient safety margin. It has been pointed out on behalf of the Company that when Messrs. Clayton Sons & Co., Ltd., London gave their advice upon the report of Mr. King in October 1959 they did not say that the Gasholder No. 4 had become unsafe for use. On the other hand, when they said that a false crown should be put upon the existing crown of that holder in the very near future they implied that the holder was safe for use. In my opinion, that contention is sound though I do not agree with the contention advanced on behalf of the Gas Company that 'very near future' meant May and June 1961. Messrs. Clayton Sons & Co. Ltd. London must have known that there would be time required for getting an import licence, placing an order and subsequently supplying a false crown, and one would expect that they would allow for 6 months for these things to be carried out and they implied that up to that time the holder was

safe to use. Some corroboration, though not much, is given to this conclusion by the fact that the holder was in use upto the 12th of May 1960 and did not actually give way and the consideration that the stiffenning of the crown due to the repairs effected in the months of May and June 1960 had a lot to do with the ultimate failure of the sheeting. I do not intend to suggest that the Gas Company may not have been too near the edge, but if they had actually acted up to the advice given by Messrs. Clayton Sons & Co. Ltd., London, there might not have been any failure of the holder.

30. I have had to touch incidentally upon what caused the failure of the holder on the 8th of July 1960. It would be convenient to deal with it at length now. When a holder is erected, the crown rests upon the crown framing but when it is inflated the crown sheeting leaves the crown framing and is upheld by the pressure of the gas alone. It is however not flat but has a curvature and the result of the pressure of the gas upon the crown sheeting is that it is in tension all along when the holder is inflated. In order to enable it to withstand this tension it must have the necessary tensile strength. Secondly, when any lift is picked up or let down there is a change of pressure and, consequently, whenever a lift is picked up or let down, the crown sheeting changes its shape, that means, its curvature increases or decreases. There would consequently be bending of the different portions of the crown. It is in evidence that when it becomes necessary after extensive repairs have been made to the crown to take a decision as to whether to patch the crown further or to resheet it, it has got to be borne in mind that extensive patching may make difference to the ductility of the different portions which would make those portions bend differently under the same pressure, and cause additional stresses especially when there is a change of pressure in picking up or letting down the lift; and Mr. Ruggles has admitted that now that there had been a failure of the crown, it is a reasonable inference that the crown sheeting failed owing to the additional stresses set up by the stiffenning of one side of the crown having proved too much for the weakened sheeting on the other side. This was the opinion which was given by Messrs. Clayton Sons & Co. Ltd., London and, in my opinion, the crown sheeting failed because of the setting up of stresses due to the stiffening of the crown. At the place where there was an initial fracture of the crown sheeting wherever this place may have been the metal had gone so thin that it was unable to bear the stress imposed upon it including the additional stress due to the stiffenning of the crown. The holder had been worked safely upto the 11th of May 1960. It was put into commission after repairs on the 24th of June 1960 and it was in use till the morning of the 8th of July 1960. There was nothing to show that it was subjected to more than the usual pressure to which it was being subjected before it was put out of commission for repairs. We do not know

what exactly was the gas in it at 6-00 a.m., on the 8th July 1960, but we know the gas which it contained at 5-00 a.m. and its quantity was normal. It is the evidence of Vishram Rane that at 6-00 a.m. the quantity of gas in the holder should have been less than that at 5-00 a.m. because at 5-30 a.m. he had, as usual, started the boosters for sending out the gas to the main and the quantity of the gas going out of the holder thereafter was more than the quantity of gas coming in. I have already mentioned that a record of the pressure of the gas in the combined main for Holder Nos. 3 and 4 is maintained. It does not show the pressure of gas in either holder at the time when the record is made, but it shows whichever is the greater of the pressures in the two holders. That record shows that the pressure of gas in Holder No. 4 at 6-00 a.m. would not have been greater than 9" water gauge. Mr. Ruggles says that the maximum height to which Holder No. 4 rose was at about 6-00 a.m. which is a little different from what Rane implies, viz., 5-30 a.m. But even so there is no reason for supposing that at the time of the failure the holder had risen more than the usual maximum it reaches about this time. The inference, consequently, is that the sheeting of the crown failed because at the place where the fracture started the metal had gone too thin for bearing the stresses imposed upon it including the stresses set up by one side of the crown being stiffened.

31. It must be borne in mind that the metal at any particular point has to bear the whole stress set up at that point including any additional stress set up because of the stiffening of the one side of the crown and it is not now possible to say that the metal had gone so thin at the site of the initial fracture at the moment of the failure that there would have been a failure even if there had been no stiffening of one side of the crown. It is possible of course that the metal at that point had gone so thin that even if one side of the crown had not been stiffened, there might have been a failure with a just little further loss in thickness soon after the 8th of July 1960. But that would now be all the speculation and it is unnecessary to enter into it.

32. I shall now come to certain circumstances attendant upon the failure. The crown sheeting gave way first in that portion of the crown which had not been repaired and subsequently it extended radially and circumferentially. Ultimately, it was separated from the rest of the sheeting on that side and thrown back upon the portion of the crown which had been repaired and which side remained intact after the failure. It is the evidence of Mr. Ruggles that this throwing back of the crown sheeting upon the portion which had been repaired was due to the pressure of the gas when it was escaping from the holder. He says that it is true that the pressure was only 9" water gauge, but even that much pressure exerted upon the very large area of the sheeting which was thrown back

upon the repaired portion was sufficient to bend the crown sheeting and throw it back upon the repaired portion. There is nothing against this in the evidence and I, therefore, accept it. There was damage caused to the sides of the holder, but that is explained by concussion due to the holder coming down and hitting the rest blocks upon which it rests with force. The damage to the crown framing is explicable by such concussion and weight of the sheeting which was thrown back upon the repaired portion. How the gas caught fire is not known. But fire has been known to have occurred in case of reported failures of the sheeting of the crown. One of the Assessors Prof. Kamath had suggested that what happened in this case was that the gas was ignited by a spark and burnt in a flame. There was no fire, however, in the technical sense as in order that there should be a fire in such sense there should be burning at a surface. I accept this conclusion of his.

33. Then the question is what caused the fire which a piece of wood of the gable of a nearby building caught and scorching of the persons who were in the neighbourhood. It may be that the piece of wood from the gable of the nearby building might have caught fire from a spark from the burning gas. But so far as scorching of persons in the neighbourhood is concerned, the only thing which is certain is that they did not come into contact with any burning gas. As one of the victims himself pointed out in his evidence there were between him and the gas holder pieces of gunny sacking or clothes hung in order to dry and no damage was caused to them. The scorching of the bodies of these persons must necessarily, therefore, be due either to radiation or a hot blast. Assessor Prof. Kamath says that clothing, because of its very texture, permits the blast to pass through it. If the effect was due to radiation the clothing should also have been scorched which has not been the case. The effect was more probably due, therefore, to the hot blast rather than radiation. I agree with this view of his.

34. There is no evidence that there was an explosion in the technical sense. Such an explosion requires an explosive mixture which is a mixture of gas in air of 6 to 31 per cent. When the crown sheeting failed the pressure of the escaping gas would not allow the air to come into the holder. Then the holder started coming down. It is the evidence of Mr. Ruggles that no explosive mixture could be formed during the short time the holder required to come to the rest blocks and thereafter there would be no confined space for any explosive mixture which could then form to explode. In any case the damage caused to holder itself is explicable otherwise. No one speaks of a noise as of an explosion. No damage was caused to any neighbouring property; the panes of the windows of a building 40 feet away were in tact. This evidence suggests that there was no explosion in the technical sense.

35. I shall now take up the question whether the other gas holders of the Bombay Gas Company are in good condition.

36. I have already mentioned why Holder No. 2 causes no trouble. Recently, however, it is used for storage of coal gas during night time. There is protection provided against corrosion both to the inside and the outside of the holder except the outside of the crown sheeting by the tar from the gas from the carburetted water gas plant which deposits upon the inside of the holder and finds its way also to the outside, but it would be necessary to watch whether its use for storing coal gas at night makes any difference.

37. So far as Holder No. 3 is concerned, there was external corrosion to the sheeting of the middle lift and Messrs. Clayton Sons and Co. Ltd., London, recommended that the sheeting of that lift should be renewed. As a matter of fact, the Bombay Gas Company had obtained steel for this purpose in March 1960. They postponed the resheeting of the middle lift of this holder because they wanted to repair Gas Holder No. 4 in the months of May and June 1960, while that holder was on air so that there should be no risk to the workmen working upon it owing to the gas which would have been escaping if the holder was repaired while still on gas. Subsequently, however, Holder No. 4 failed and they could not put Holder No. 3 also out of use for the purpose of resheeting because there would then have been no supply of gas to the consumers in the city. That does not mean, of course, that any risk of failure should be taken. But Messrs. Clayton Sons and Co.'s representative came down to Bombay again after the failure of Holder No. 4 and advised that it would be sufficient to clad the middle lift of Holder No. 4 as an interim measure as that holder could not be put out of commission for the purpose of resheeting. The Bombay Gas Company has reclad the middle lift and finished the work during the course of this inquiry.

38. If the external corrosion of the sheeting of the middle lift of this holder is due to the coke pile which is stacked about 40 yards away from the holder on one side or the oxide heap which is stacked about 10 yards from the holder on the other side then, of course, external corrosion of even the new sheeting which has been super-imposed upon the old may take place. But the Bombay Gas Company contends that these two heaps have nothing to do with the external corrosion which they contend was due to the inferior quality of the metal used in the resheeting of the middle lift when this holder was over-hauled between 1951 to 1954. Messrs. Clayton Sons and Co. Ltd., London did not agree with this view on the ground that the sheeting of the inner lift and of the crown of this holder was renewed at the same time and they did not think it likely a batch of inferior metal would find its way

in the middle lift alone. They suggested consequently to the Bombay Gas Company that if they were of the view that the metal used for resheeting the middle lift was of inferior quality, they could get analysed the discs which were taken out from this holder. This disc could not be analysed because they were lost in transit. That need not have made any difference because further discs could have been taken out. But the middle lift has now been reclad. Messrs. Clayton Sons and Co. Ltd. London gave their advice as to how this should be done and it is not suggested in this inquiry that their advice in this respect was not followed. The record of repairs made to this holder says "side cladding with 3/32" M. S. Sheets secured by 3" long 'U' bolts started as per Mr. King's advice". If the external corrosion of the old sheeting is due to the coke pile or the oxide heap and not the quality of the metal then one would expect that there would be external corrosion of the new sheeting super-imposed upon the old one. As Dr. Mitra has pointed out, external corrosion is not very difficult to deal with because it can be seen. Even if the external corrosion is such that painting the outside of the sheeting of the middle lift more frequently than once a year has no effect, that can soon be discovered. The Bombay Gas Company intends to give the contract of supplying the lifts and the crown for Holder No. 4 and erecting it to Messrs Clayton Sons and Co. Ltd., London and they expect the work to be done in about 8 months from the date of receipt of the licence which is expected in about a fortnight. Holder No. 3 would then be available for resheeting the middle lift for which the Bombay Gas Company has already got the sheets with it. The Bombay Gas Company also tells me that it intends to have the middle lift of Holder No. 3 resheeted after Holder No. 4 is put back into commission. I have no reason for supposing that the new sheeting which has been put on it would not be sufficient to withstand the corrosive effect of the coke pile and the oxide heap during the next 8 or 9 months. Even if it is unable to do so, the corrosion due to these heaps would be external and suitable steps can be taken by the Company after it is noticed, to tide over the period till the middle lift is resheeted.

39. If it is proved that the external damage is due to the effect of the coke pile of the oxide heap, then they shall have of course, to be removed from where they are at present. This may cause addition to the costs of labour for bringing the coke and the oxide to the place where they are required, but that cannot be helped.

40. Then I come to the question as to what measures should be taken to prevent recurrence of a failure.

41. The first question which must be dealt with in this regard is what causes corrosion owing to which the sheets of the crown and the side sheeting become weaker and have to be strengthened with

patches or resheeting has to be resorted to. It is necessary to mention in this connection that corrosion to start with adds to the thickness of metal. It is only when corrosion is removed that the sheeting of the plate is found to have gone thinner. It is the evidence of Dr. Mitra that if the corrosion is separable it would be separated owing to the velocity of the gases hitting against the corroded portion and then the area beneath the corrosion which has been separated would be liable to be attacked again by the same entities which cause the corrosion. Mr. Ruggles denies that any internal corrosion could be caused by the impurities in the gas because of the gas coming in impinging with different velocities the areas on the inside of the sheeting. No expert has been examined before me who can say what would be the pattern of flow of the gas coming in with the usual velocity in the holder from the inlet stand pipe having a particular diameter. But it is admitted that there would be differences in the local velocities. The gas which is at any moment coming in may not itself strike the sides of the vessel or the crown sheeting, but it would set up a sort of a wave which would make the gas nearest the side sheeting or the sheeting of the crown strike the sheeting with different velocities. Mr. Ruggles gave a reason for not accepting this as one of the causes of corrosion. That is, there is no internal corrosion at present of the sheeting of Holder No. 3. He also claimed there are only two impurities in the gas, which possibly cause corrosion, viz., Oxygen and Hydrogen Sulphide. So far as hydrogen sulphide is concerned he says that it goes into the gasholder only when the purification boxes are changed. So far as Oxygen is concerned he admitted that a certain amount of it cannot be kept out of the gas which goes into the holders. The result consequently is that it is possible that some hydrogen sulphide goes into the holders at the time when the purification boxes are changed; some oxygen always goes into the holder. The gas which goes into the holder comes into contact with the water seal at the bottom and is saturated with water. There may be water deposited on the sides of the holder owing to differences in the day and night temperatures. It is the evidence of Dr. Mitra that in these circumstances owing to the galvanic effect there may be formed acids which cause corrosion on the insides of the holder. Dr. Rajan, the Works Superintendent of the Gas Company admits that the internal corrosion in Holder No. 3 for which its crown, inner lift and middle lift were resheeted from 1951 to 1954 was due to the usual impurities in the gas. Internal corrosion was taking place in Holder No. 4 and if it was not due to the impurities in the gas there is no explanation forthcoming as to how the corrosion took place. It is true that at present there is no indication of any corrosion of the insides of the crown and the sheeting of Holder No. 3, but, in the first instance, that holder is young. Mr. Ruggles suggested that the corrosion is caused because of the sunshine between which and the corrosion there was some relation unknown at present because the corrosion

was all on one side of that holder, viz., the South-East. Now, it is not possible to say that this contention has been disproved because the corrosion does appear to be mostly on the South-East. But it is difficult to understand what the relationship between the sun shine and the corrosion is. Dr. Mitra points out that it cannot possibly be said that there is no sun shine, for example, on the Western side. Dr. Mitra says that some difference might, however, be made by the wind because the wind may take away the heat and the heat would make a difference. But there is nothing to show that the heat would cause corrosion by itself unless there are impurities in the gas. It has got to be remembered besides that when the Gas Company is talking removing of impurities it is talking of those impurities which they are anxious to keep out of the gas, because they do not want them to cause damage to the consumers' apparatus. There may still be impurities in the gas which cannot be found by ordinary Chemical analysis and at the same time cause corrosion. There have been failures of holders in the United Kingdom; there is evidence that extensive patching had been made to the sheeting of a holder there and that was, presumably, the result of corrosion which seems to take place in that country. The conditions there may differ for example there may be plenty of fog in that country, which one does not find at any rate frequently in this country. I am, therefore, of the opinion that in the state of the evidence before me, the only conclusion which I can draw is that corrosion is being caused by the impurities in the gas which impinge the sheeting with different velocities.

42. The first thing consequently to do is to take steps to minimise each impurities. I do not suggest that all such impurities can be eliminated. I notice that Mr. Ruggles admits that it is possible that owing to the action of the exhaustors some flue gases, i.e. gases arising from the coke which is used in the producer to heat the Silica retorts, may be getting into the gas which goes into the holder through the joints in the Silica. This must obviously be stopped and as Assessor Prof. Kamat says if this requires any adjustment in the process of manufacture of gas such adjustment must be made.

43. The caustic soda used to remove blockage from the stand pipes has no effect whatsoever on steel and there is no reason to object to its use by the Gas Company.

44. The next measure to be taken in order to prevent failures is to make more frequent inspection of the internal condition of the sheeting of holders. It appears that in the United Kingdom, inspection of the inside is made by disc cutting and hammer testing. But even there it is provided, though not by the Factory Act itself, that internal visual inspection should be made if it becomes necessary. There are, however, more modern methods of finding out the thickness of a sheeting, i.e. by the use of electronic ultra-sonic instruments. These instruments enable the thickness of metal to be



determined within an error of 1 per cent. They vary in cost and it is possible that it would be necessary to have an expert in order to use them. But as against this it must be remembered that the Gas Works of the Bombay Gas Company are located in a densely populated area and when it is a question between the safety of the persons and the property in the neighbourhood of the Gas Works especially the former, all questions of costs incurred and expense incurred or to be incurred for ensuring safety are subordinate considerations. The Burmah Shell Refineries appear to be using these instruments in order to find out corrosion of their pressure vessels in Bombay and there is no reason why similar instruments should not be obtained and used by the Bombay Gas Company. The corrosion which pressure vessels in the Burmah Shell suffer is faster than the corrosion which the gasholders of the Bombay Gas Company suffer. But that does not seem to me to make much difference. The use of such machines will give a timely warning. In the second instance, they will enable the rate of corrosion to be established which would be of further assistance. In the method of inspection of the inside by way of disc cutting, one cannot take out too many discs for fear of weakening the holder. On the other hand, electronic or ultra-sonic instruments can be used all over the holder and the inspection made with their assistance is therefore far more satisfactory.

45. When the Bombay Gas Company orders out a new crown or new lifts, they can obtain from the maker the limit to which it will be permissible to allow the sheeting to waste before discarding it. In that case, if the rate of corrosion is not established, the use of electronic or ultra-sonic machines will give timely warning and steps can be taken to clad or resheet the crown or the side sheeting in time.

46. If the Bombay Gas Company is required to use such instruments, there will be more expenditure involved. If they cannot possibly undertake it without raising the price of the gas which they supply to the consumer then it will be necessary to permit them to do so. Here again, the cost to the consumers is a question which must be subordinated to the risk to the persons and property in the neighbourhood of the Gas Works.

47. It is only in case it is found impossible to provide for the use by the Bombay Gas Company of such instruments that provision should be made requiring an inspection of the inside by means of disc cutting on the lines of section 33 of the English Act. This is a hot country, however, and provision for earlier first inspection and more frequent subsequent inspection must be made, I think 10 years after a lift has been put in use for the first time and once in every subsequent period of 4 years would be necessary and adequate.

48. It should be provided by statute that internal visual inspection must be made when necessary, i.e. where a decision is taken because of inspection made by other means to resheet the crown or sides, it need not be made. But when the inspection made raises a doubt internal visual examination must be made.

49. So far as external inspection is concerned, it should be done once every year and a complete record should be maintained whether anything special has been noticed or not and made available, along with the record made under paragraph 43, for inspection by the factory Inspector. The result of the inspections of the inside and outside must be entered in a register; the details of the particulars to be entered in it should be prescribed by rules. There should also be a complete record available for inspection for the Inspector of Factories as to the painting, oiling or other repairs made to the holder.

50. Repairs to the holders must be made only upon the advice of a person who is competent to say what repairs should be made. They must be made under the supervision of a person who is competent to supervise by his training and experience and his knowledge of the necessary precautions to be taken against risks of explosion and of persons being overcome by gas.

51. I have not gone into the question whether new gas-holders should have welded joints or rivetted joints. The Bombay Gas Company has taken up that question with the makers. Similarly, I have not gone into the question of what type the lap joints should be. There are two opinions on the former question and such questions are best left to the makers. In any case such questions could not be gone into without examining an expert or experts in making gas-holders and I did not think they could be gone into by this Commission without causing delay which in the circumstances would not be reasonable.

52. Mr. Boda, who has appeared for the Labour Union, has also raised the question how far the Factory Inspector has discharged his duties properly in the past and how far it will be necessary to direct him to do certain things in regard to the safety of the holder in future. The Factory Inspector would naturally be concerned with the question whether there is any infringement of any provision of the Factories Act or Rules if any made thereunder. It does not appear to me that in this case the factory Inspector has been in fault in regard to this duty of his. It has been pointed out that even though the Company had made extensive repairs in the month of May and June 1960 the Inspector of Factories did not become aware of them. But there was no duty laid upon him in regard to these repairs and

there would be no particular reason for him to enquire if there were any repairs being made. It is possible that he has so many factories to inspect in Bombay that he does not visit the Gas Works of the Company frequently.

53. If it is provided by an Act that the Gas Company should have its holders inspected in any particular manner, it would be the duty of the Factory Inspector to see that these provisions are carried out. Providing for an examination of the inside and external inspection by an amendment to the Factories Act is the best way of ensuring that the Factory Inspector pays more attention to the safety of gas-holders than he does at present.

54. I also notice that even though there has been a provision in regard to the inspection of the inside and external inspection of gas-holders in the United Kingdom, at least, since 1937 no such provision has been made in the Indian Act. There are gas-holders in Bombay and Calcutta, and I think the duty of examining the provisions made in other countries in order to ensure safety of the holders because of the experience gained must be laid upon some one in this country. The Factory Act is a Central Act but its administration seems to be with the State Government. It would be more appropriate, therefore, if the State Government were to lay the duty of seeing whether the amendments made elsewhere should be incorporated in the legislation in this country upon some officer of its. In any case such duty must be imposed on some officer subordinate either to the Central Government or the State Government.

55. Finally, I must thank the Assessors, Messrs. Gadkari and Kamath who have given invaluable help in enabling me to understand the technical aspects of the questions which arose and Messrs. Vyavaharkar, Madon and Tulsi Boda for their assistance in the conduct of this inquiry but for which it could not have been concluded in the time actually taken.

(Signed) R. S. BAVDEKAR,  
Commissioner.

Bombay, 5th November 1960.