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Requirements on the strength of rubber hose assemblies for high pressure acetylene

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Abstract

According to the German Technical Rules for Acetylene Installations and Calciumcarbide Stores (TRAC), TRAC 204 "Acetylene Pipelines" No. 5.3.7., hose assemblies for high pressure acetylene must be tested for sufficient strength to withstand the decomposition of acetylene at the maximum permitted pressure. Until now, all rubber hose assemblies produced for use in high pressure hydraulic systems have failed this approval test. The same rubber hose assemblies fitted with a spiral inside the hose on its full length have successfully passed this approval test. These rubber hose assemblies could be recommended for type approval by the Federal Institute of Materials Research and Testing (BAM) and have been type approved for use in installations for high pressure acetylene according to Article 10 of the German Acetylene Regulations by the competent approval authority in Germany. In this report we have summarized the experience of BAM resulting from experiments with decomposition of high pressure acetylene in tubes and rubber hose assemblies. On the basis of the results of these investigations appropriate requirements for rubber hose assemblies can be made so that in case of a hazard with a decomposition of high pressure acetylene there will be no failure of any rubber hose assembly within the installation.

Keywords: Rubber hose assembly; Acetylene decomposition; Detonation; Predetonation distance

1. Introduction

Acetylene is an unstable fuel gas that will decompose into its components if the energy necessary for ignition is supplied. Installations to handle acetylene must resist the stresses that will result from such an acetylene decomposition.

Within the high pressure part of acetylene installations the acetylene gas is handled at conditions where if ignition occurs the decomposition reaction will run up to a

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detonation, even in tubes or hoses with very small inside diameters. According to the German Technical Rules for Acetylene Installations and Calciumcarbide Stores (TRAC) the maximum acetylene pressure in cylinder manifolds and manifolds from cylinder bundles is limited to 26 bar (25 bar gauge) and in filling stations to 28.5 bar (cut off pressure for the acetylene compressor) and the maximum inside diameter of tubes is limited to 25 mm.

Since in Germany the cylinders and cylinder bundles can be connected to the high pressure pipeline of manifolds and filling stations by means of rubber hose assemblies, the following question arises: what are the requirements on rubber hose assemblies to resist the stresses that will result from a decomposition of high pressure acetylene?

To answer this question the author has made a large number of tests with a decomposition of high pressure acetylene in rubber hose assemblies of different types and with different inside diameters and burst pressure. The test results have been analyzed on the basis of the experience resulting from experiments with decomposition of high pressure acetylene in tubes and the explosion pressures determined from the static pressure needed to produce the same tube deformation as with the dynamic pressures generated by decomposition of acetylene. To analyze the test results we also must consider the distance necessary for running up to detonation with decomposition of acetylene (predetonation distance). But at the very beginning I must make some general remarks on the propagation of a flame front in reactive gas phases and give some definitions of the terms used in the paper.

2. General remarks on the propagation of a flame front in reactive gas phases

With the propagation of a flame front in a reactive gas phase we must differentiate between two fundamentally different mechanisms: deflagration and detonation.

With a deflagration the ignition of the gas in front of the flame front is effected by heat transmission and diffusion of active particles from the reaction zone to the adjoining unreacted gas. The velocity of the flame front is slower than the velocity of sound in the unreacted gas. Pressure rises effected by the progress of the reaction spread out in all directions of the whole system with the velocity of sound in the unreacted gas and in the reaction products respectively.

With a detonation the ignition of the gas in front of the flame front is effected by the increase in temperature due to the compression from a shock wave. The velocity of the flame front is several times the velocity of sound in the unreacted gas. In addition the reaction zone in the flame front (detonation front) is linked to the shock wave. At points of a sudden increase in cross-section the shock wave can be separated from the linked detonation front, dependent on the reaction capacity of the gas phase (laminar flame velocity, calorific value etc.). The flame front will continue in the form of a deflagration and run up to a detonation again.

If the reaction is started with a thermal ignition source (no shock wave), the flame front will always start to propagate in the form of a deflagration. After passing the distance necessary for running up to a detonation (so called predetonation distance) the reaction front will proceed as a detonation. Whether the reaction front will run up to a detonation or not depends on many parameters, mainly on the kind of gas, composition of the mixture, pressure, temperature, state of flow, tube diameter, geometry of the tube, ignition energy etc.

At the point of transition from deflagration to detonation and at points of reflection or partial reflection of the detonation front there will be a higher explosion pressure than in other parts of the tube.

The highest explosion pressure will result, if the flame front is reflected at the point of transition from deflagration to detonation.

At a tube length of some tube diameters to some ten tube diameters longer than the predetonation distance (dependent on the reaction capacity of the gas phase) the detonation front will overtake all pressure rises effected during the propagation of the flame front in the form of a deflagration. The detonation front travels into unreacted gas of unchanged initial conditions (stationary conditions). We have a stable detonation at stationary conditions. At the point of transition from deflagration to detonation the flame front travels into unreacted gas of extremely changed initial conditions. At this point we have an unstable detonation at extremely non stationary conditions.

3. Predetonation distances with decomposition of acetylene

Table 1 shows the distance necessary for running up to detonation with the decomposition of high pressure acetylene in tubes with a smooth surface, that means without any obstacles inside the tube (or hose) to produce additional turbulence in the gas ahead of the reaction front [1].

L_A is the predetonation distance determined in tubes with a length of tube L greater than L_A (L_A with $L/L_A > 1$). L_{crit} is the predetonation distance determined under the additional experimental condition of the length of tube L equal to the length of the predetonation distance L_A ($L_{crit} = L_A$ with $L/L_A = 1$). We call the predetonation distance determined by this method the critical length L_{crit}, because there will be the highest explosion pressure possible at the point of reflection of the reaction front (at a closed end of the tube) with the gas phase in question—here pure acetylene [2].

Table 1
Predetonation distance with decomposition of high pressure acetylene in tubes with smooth surfaces and fused wire as the ignition source

Inside diameter d_i (mm)	Initial pressure p (bar)	Predetonation distance		Ratio of L_A / d_i L_{crit} / d_i (−)
		L_A (mm)	L_{crit} (mm)	
20	26	1900	–	95
20	26	–	1670	84
20	21	–	2100	105
15	26	–	1500	100
10	30	–	1180	118
10	10	–	1920	192

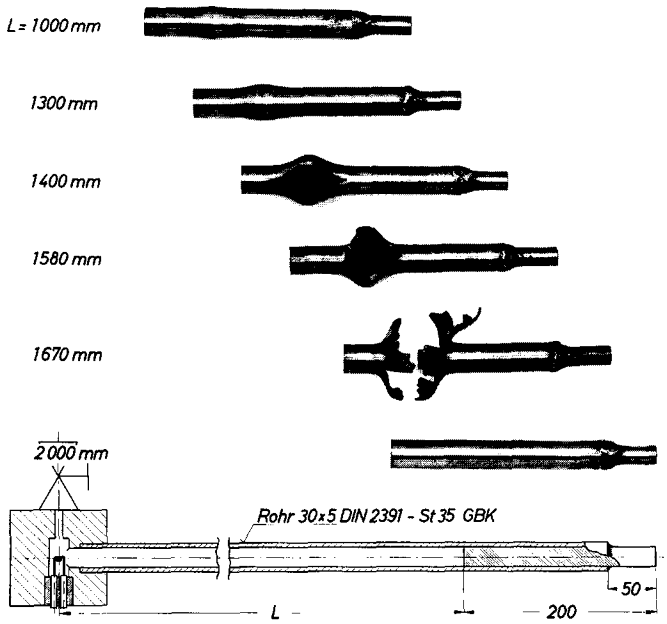


Fig. 1. Deformation at the closed end of tubes Ø 30×5 DIN 2391 made of St 35 GBK in tests with decomposition of high pressure acetylene at an initial pressure of 26 bar. Burst pressure of the tube is about 2000 bar.

Fig. 1 is an example of the results of the experiments performed to determine L_{crit} in tubes with a smooth surface, 20 mm inside diameter and acetylene decomposition at 26 bar initial pressure (25 bar gauge). With these experiments only the length of the tube (the distance between the point of ignition and the point of reflection) has been changed. The burst pressure for the tube with 30 mm outside diameter and 5 mm wall thickness made from St 35 GBK [3] (heat treatment by bright annealing) is about 2000 bar.

4. Explosion pressure with decomposition of high pressure acetylene in steel tubes with 20 mm inside diameter

As can be expected from Fig. 1 it will be difficult to measure the explosion pressure produced from the decomposition of acetylene at high initial pressures. Therefore we have found it useful to determine the static pressure that results in the same deformation work as with the dynamic loading by detonative acetylene decomposition. The explosion pressures determined in this way may be used to design steel tubes for use with acetylene provided that a steel with a comparable deformation behaviour (at least 20% elongation at break) will be selected for the tubes. It should be noted that the static pressures only roughly correspond to the comparable theoretically calculated CJ pressure [4] for detonative acetylene decomposition.

From the results of experiments with decomposition of high pressure acetylene in tubes with 20 mm inside diameter of different thickness of the wall made of St 35 GBK we can conclude from the static pressure needed to produce the same tube deformation as that resulting from the decomposition reaction [1]:

1) that the explosion pressure is 16 times the initial pressure with the reaction front passing along the tube as a stable detonation at stationary conditions, ($L \gg L_A$),

2) that the explosion pressure can be up to 32 times the initial pressure with the reaction front passing along the tube as an unstable detonation at extremely non stationary conditions, that means passing along the tube at the point of transition from deflagration to detonation ($L = L_A$),

3) that the explosion pressure is about 32 times the initial pressure with the reaction front being reflected at the closed end of the tube as a stable detonation at stationary conditions ($L \gg L_A$) and

4) that the explosion pressure is up to 120 times the initial pressure with the reaction front being reflected at the closed end of the tube as an unstable detonation at extremely non stationary conditions, that means reflected at the point of transition from deflagration to detonation ($L = L_{crit}$).

With decreasing critical length (predetonation distance $L_A = L_{crit}$ with $L/L_A = 1$) the explosion pressure will decrease. If you have a tube with 20 mm inside diameter, 26 bar initial pressure and a spiral inside the tube to accelerate the progress of reaction, the critical length will decrease from $L_{crit} = 1670$ mm (see Fig. 1) to $L_{crit} = 320$ mm. With an initial pressure of 26 bar and a critical length of only $L_{crit} = 320$ mm (spiral) we have got an explosion pressure of about $p_{expl} = 760$ bar at the closed end of the tube (of only 29 times the initial pressure!!), determined from static pressure needed to produce the same tube deformation.

With a spiral inside the tube to accelerate the progress of acetylene decomposition at high initial pressures the explosion pressure can be reduced from up to 120 times the initial pressure possible in the worst case with reflection of the reaction front at $L = L_A = L_{crit}$ to only 30 times the initial pressure.

With decreasing pressure the critical length will increase again. With a spiral inside the tube and an initial pressure of only 3.3 bar the critical length will be $L_{crit} = 1800$ mm. With these conditions we have got an explosion pressure of $p_{expl} = 325$ bar at the closed end of the tube (about 98 times the initial pressure).

In the literature [4] such a spiral is called "Shchelkin spiral". It seems that Shchelkin was the first person to insert spirals into tubes to accelerate the run up to detonation. In this paper the spiral has been used to reduce the maximum pressure possible with reflection of detonations at high initial pressures by reducing the transition distance. The spiral promotes rapid transition to detonation thus preventing damaging overpressures even in case of transition near the vulnerable end connectors.

Table 2 gives a summary of the explosion pressures determined from the static pressure needed to produce the same tube deformation as with the dynamic pressure generated by the decomposition of acetylene propagating or being reflected as a stable detonation at stationary conditions ($L \gg L_A$) or as an unstable detonation at extremely non stationary conditions ($L = L_A$ and $L = L_{crit}$).

For the case of a reaction front propagating as a detonation there was always an

Table 2

Explosion pressure determined from static pressure needed to produce the same tube deformation as resulting from propagation and reflection of a detonative acetylene decomposition at point $L \gg L_A$ (stable detonation at stationary conditions) and $L = L_A$ and $L = L_A = L_{crit}$ (unstable detonation at extremely non stationary conditions)

Inside tube diameter d_i (mm)	Initial pressure p_i (bar)	Predetonation distance		Ratio L_A / d_i L_{crit} / d_i (−)	Explosion pressure determined from static pressure needed to produce the same tube deformation			
					with passing along of the reaction front at		with reflection of the reaction front at	
		L_A (mm)	L_{crit} (mm)		$L > L_A$ p_{expl} (bar)	$L = L_A$ p_{expl} (bar)	$L \gg L_A$ p_{expl} (bar)	$L = L_A = L_{crit}$ p_{expl} (bar)
20	26	1900		90	$16 \times p_i$ [a]	$32 \times p_i$	$32 \times p_i$	
			1670	84				$120 \times p_i$
10	30		1180	118				$100 \times p_i$
10	10		1920	192				$125 \times p_i$
437	2.5	36000		83		$60 \times p_i$		
20 [b]	26		320	16				$29 \times p_i$
20 [b]	3.3		1800	90				$98 \times p_i$

[a] Additional deformation of the tube wall in the form of a spiral with a pitch of about $p = 3 \times d_i$ produced by the spin of the detonation (see Fig. 2).

[b] Spiral inside the tube for its total length.

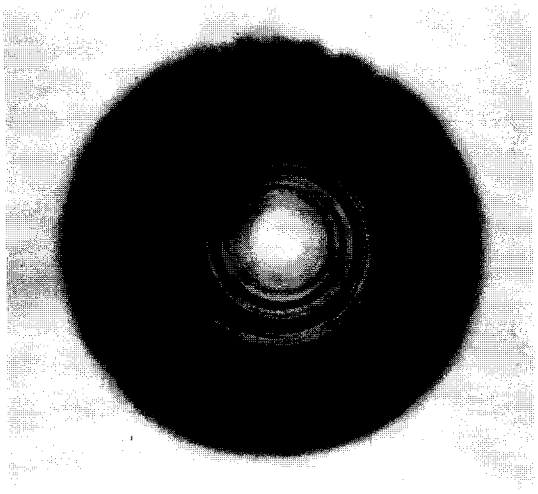


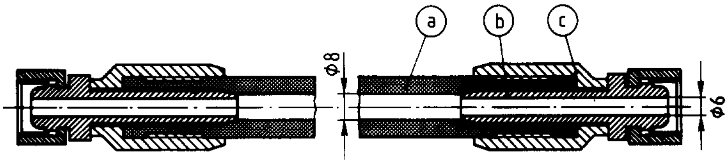
Fig. 2. Photo with a glance into a tube Ø 22×1 from St 35 GBK with an additional spiral deformation after the passing along of a detonative acetylene decomposition at an initial pressure of 21 bar [1].

additional deformation of the tube wall in the form of a spiral with a pitch of about three times the internal tube diameter which was produced by the spin of the detonation, (see Fig. 2 [1]).

It should be noted that the explosion pressure increases with increasing diameter (compare lines 1 and 5 in Table 2).

5. Tests with rubber hose assemblies and decomposition of high pressure acetylene

Fig. 3 shows a sketch with a section through a hose assembly for a hose of 8 mm inside diameter. At one end of the hose assembly there is an increase in diameter from



ⓐ Rubber hose with:
1) textile plait for reinforcement or
2) stainless steel wire plait for reinforcement or
3) coating of stainless steel wire plait for reinforcement

ⓑ Hose tail

ⓒ Hose clip

Fig. 3. Section through a rubber hose assembly DN8.

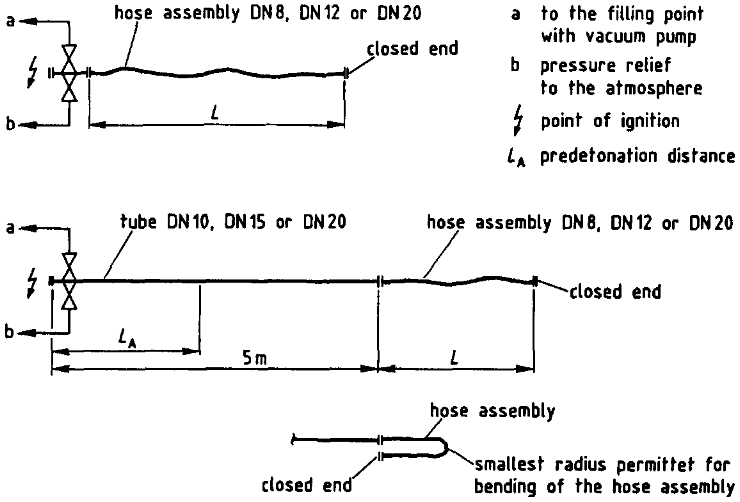


Fig. 4. Test assembly.

the inside diameter of the hose tail to the inside diameter of the hose for the reaction front passing along. At the other end of the hose assembly there is a decrease in diameter for the reaction front passing along, a point where a part of the reaction front will be reflected. This point is the critical part of the hose assembly when stressed by the reaction front of an acetylene decomposition.

Table 3

Experiments with decomposition of high pressure acetylene in rubber hose assemblies DN8 of different stability with length $L \gg L_A$ (predetonation distance)

Test No.	Hose Assemblies DN 8			Initial Pressure (bar)	Result: Hose destroyed at
	Type [a]	Burst Pressure (bar)	Length L (mm)		
1	2 ST	1750	5020	26	Second hose tail
2			5000	21	Second hose tail
3			4900	19	No deformation
4			4900	20	Second hose tail
5			4700	19	No deformation
6	3TE	500	10040	11	Second hose tail
7			10000	9	No deformation
8			10000	10	Second hose tail
9			9960	9	No deformation
10			9960	10	Second hose tail
11	2 TE	300	5000	20	Point $L = L_A$ = 740 mm and at 8 additional points
12			5000	12	Second hose tail
13			4850	15	Second hose tail
14			4700	18	Second hose tail

[a] Type of hose according to the German Standard DIN 20021 and 20022.

As has been shown from the results of experiments with detonative decomposition of high pressure acetylene in systems assembled from different tubes, the shock wave in the detonation front will be separated from the linked reaction front at points with a sudden increase in diameter and at T-pieces in the system. The shock wave will go on ahead and the reaction front will run up to a detonation again [5]. The new predetonation distance will be somewhat shorter than with ignition at the end of the tube, due to changes in the state of the gas caused by the shock wave going on ahead.

Fig. 4 shows the test assembly used for the experiments with a decomposition of high pressure acetylene in rubber hose assemblies.

The results of the experiments are listed in the Tables 3–5.

There is no significant difference in the results of the experiments, if the acetylene decomposition is started at the beginning of the hose assembly or at the beginning of the 5 m long tube in front of the hose assembly. After running up to a detonation in the tube, the shock wave in the detonation front is separated from the linked reaction front when passing the point of sudden increase in diameter from the inside diameter of the hose tail to the inside diameter of the hose (compare the results of the experiments No. 2 and 3 in Table 5).

As to the requirements on the strength of rubber hose assemblies for high pressure acetylene we can conclude from the results of these experiments:

1) Rubber hoses DN8 with a burst pressure of 300 bar can resist the stresses of acetylene decomposition up to an initial pressure of 18 bar (see experiments No. 11 and 14 in Table 3) with the reaction front passing along as an unstable detonation at extremely non stationary conditions ($L = L_A$). That means the burst pressure must be at least 17 times the initial pressure for this kind of stress.

2) Rubber hose assemblies DN8 with a burst pressure of 500 bar can resist the stresses of an acetylene decomposition up to an initial pressure of 9 bar (see experiments No. 6 to 10 in Table 3) with the reaction front being reflected as a stable detonation at stationary conditions ($L \gg L_A$). That means the burst pressure must be at least 56 times the initial pressure for this kind of stress.

In experiments with a decomposition of high pressure acetylene in steel tubes we obtained about the same tube deformation with these two different stresses: either the transmission of the reaction front as an unstable detonation at extremely non-stationary conditions at point $L = L_A$ or the reaction front being reflected as a stable detonation at stationary conditions with $L \gg L_A$.

In experiments with a decomposition of high pressure acetylene in rubber hose assemblies we now get quite different hose deformation with these two different stresses.

We must conclude that in both cases we have a very different kind of stress. With reflection of the reaction front at a closed end or at a hose tail we get a greater part of shearing stresses than with the transmission of the reaction front at point $L = L_A$. The material of the steel pipe (St 35 GBK) can yield these shearing stresses to a certain extent with deformation, the material of the rubber hose can not do this.

3) Rubber hose assemblies DN8 with a burst pressure of 1750 bar can resist the stresses of acetylene decomposition up to an initial pressure of 19 bar (see experiments No. 3 to 5 in Table 3), with the reaction front being reflected as a stable detonation at

Table 4
Experiments with decomposition of high pressure acetylene in rubber hose assemblies DN8 of different stability and with a spiral inserted within. Spiral with outside diameter of 8 mm, wire diameter of 0.5 mm and a pitch of 5 mm

Test No.	Hose Assembly DN8				Initial Pressure (bar)	Result: Hose destroyed at
	Type [a]	Burst Pressure (bar)	Length L (mm)	Length of Spiral (mm)		
1	2 ST	1750	500	500	26	No deformation
2			500	No spiral	26	Second hose tail
3	3 TE	500	500	500	21	No deformation
4				500	26	No deformation
5				No spiral	21	Second hose tail
6				500	28.5	No deformation
7				500	31	No deformation
8			500 [b]	500	26	No deformation
9			500 [c]	500	26	No deformation
10			500 [c]	No spiral	26	Second hose tail
11	2 TE	300	500	500	26	Second hose tail and 10 mm behind first hose tail
12				500	22	Second hose tail and 45 mm behind first hose tail
13				500	21	No deformation
14	3 TE	500	45	45	22	No deformation
15	2 TE	300	45	45	22	Second hose tail
16	3 TE	500	45	45	26	No deformation
17	1 ST	790	700	2×100 [d]	26	Second hose tail and at 90 mm in front of second hose tail
18	2 ST	1750	700	2×100 [d]	26	No deformation
19				1×100 [e]	26	Hose ripped open at second hose tail and at 90 mm in front of second hose tail

[a] Type of hose according to the German Standard DIN 20021 and 20022.

[b] Hose turned round with $R = 55$ mm.

[c] Hose turned round with $R = 55$ mm and reaction front running in from a 5 m long tubeDN10.

[d] 100 mm long spiral at both hose tails.

[e] 100 mm long spiral at the second hose tail.

Table 5

Experiments with decomposition of high pressure acetylene in rubber hose assemblies DN12 and DN20 with different stability and with or without a spiral inserted within

Test No.	Hose assembly					Initial pressure (bar)	Test assembly c), d) or e)	Result: Hose destroyed at
	Diameter nominal (mm)	Type a)	Burst pressure b) (bar)	Length L (mm)	Spiral within yes/no			
1	20	2 ST	850	2000	yes	28.5	c)	5 Points, not at the hose tail. First rupture 70 mm behind first hose tail
2					no	28.5	c)	$L = L_A = 710$ mm. Rest of the hose destroyed as far as to a 500 mm long part with cracks in form of a spiral with a pitch of about 65 mm, see Fig. 5
3					no	28.5	d)	$L = L_A = 800$ mm. Rest of the hose destroyed
4	20	2020 ST	1050	2000	yes	28.5	c)	30 seconds after ignition cracks in the hose at $L = 750$ mm and 830 mm/f
5							e)	80 seconds after ignition crack in the hose at $L = 1175$ mm/f
6							d)	60 seconds after ignition crack in the hose at $L = 300$ mm/f
7	20	4 SP	1400	2000	yes	28.5	c)	No deformation
8							e)	No deformation
9							d)	No deformation
10	12	2 ST	1100	1500	yes	28.5	c)	No deformation
11							e)	No deformation
12							d)	No deformation
13	12	4 SP	1660	1500	no	28.5	c)	Second hose tail
14					no	28.5	d)	Second hose tail

a) Type of hose according to the German Standard DIN 20022 and 20023.

b) Minimum burst pressure of the hose according to DIN 20022 and 20023.

c) Test assembly c): Part with valves and ignition source/5 m long tube DN 15 or DN 20/hose assembly/closed end.

d) Test assembly d): Part with valves and ignition source/hose assembly/closed end.

e) Test assembly e): equal to test assembly c, but hose turned round with smallest permitted radius for bending.

f) The cracks formed 30 seconds or more after ignition result from thermal stress too high for the material polyamid PA 11/12, used for the inner part of the hose. The spiral with a wire diameter of 1.3 mm and a pitch of only 5 mm had too much mass to store the heat released by the decomposition reaction at points where material of the spiral is crowded together after the passing along of the reaction front.

Fig. 5. Crack in the form of a spiral in the rubber hose DN20, type 2 ST after passing along of a detonative decomposition of high pressure acetylene at an initial pressure of 28.5 bar (see Table 5, test No. 2).

stationary conditions ($L \gg L_A$) at the hose tail. That means the burst pressure must be at least 92 times the initial pressure for this kind of stress.

Hoses of type 3TE have three layers of textile plait for reinforcement, the hoses of type 2ST have two layers of stainless steel wire plait for reinforcement. It seems that hoses with textile plaits can resist stress of this kind better than hoses with stainless steel wire plaits.

4) Rubber hoses DN20 with a minimum burst pressure of 1050 bar can resist the stresses of acetylene decomposition up to a pressure of 28.5 bar (compare experiments No. 1 to 3 with experiments No. 4 to 6 in Table 5) with the reaction front proceeding as an unstable detonation at extremely non stationary conditions ($L = L_A$). That means the minimum burst pressure must be at least 37 times the initial pressure for this kind of stress.

Fig. 5 shows part of a rubber hose DN20 with a crack in form of a spiral, produced by the spin of the detonation.

With this kind of stress too, hoses with textile plaits need a lower minimum burst pressure than hoses with stainless steel wire plaits do (compare conclusions 1 and 4).

The wire plaits for reinforcement are made from a stainless steel wire with a very high tensile strength but practically no elongation at break.

Perhaps hoses with stainless steel wire plaits for reinforcement will need a much lower minimum burst pressure with the stresses from decomposition of high pressure acetylene than the hoses used in the experiments do, if more ductile wire is used as reinforcement.

5) Rubber hose assemblies with highest possible minimum burst pressure produced today can not resist the stresses of acetylene decomposition at the maximum permitted pressure of 26 bar or 28.5 bar even with the reaction front being reflected as a stable detonation at stationary conditions ($L \gg L_A$) only. The stress will increase very much as $L \to L_A$.

6) Rubber hose assemblies with a minimum burst pressure of 1000 bar that are fitted with a spiral inside on the whole length can resist all stresses that are possible with an acetylene decomposition at the maximum permitted pressure of 28.5 bar.

The minimum burst pressure can be reduced for rubber hoses reinforced with a textile plait and possibly for rubber hoses reinforced with stainless steel plaits made from a stainless steel wire with less tensile strength but much more elongation at break than the one used in the plaits of the rubber hoses for the experiments.

6. Conclusions

According to the test results listed in the Tables 3–5, rubber hose assemblies for high pressure acetylene with a maximum inside diameter of 20 mm and fitted with stainless steel wire plaits for reinforcement must have a minimum burst pressure of 1000 bar. Rubber hose assemblies with an inside diameter of 8 mm or less and fitted with textile plaits for reinforcement must have a minimum burst pressure of 500 bar.

But normal hydraulic rubber hose assemblies of that pressure rating will not resist the stresses caused by the decomposition of high pressure acetylene with the reaction front being reflected at the hose tail, see Fig. 6.

According to the German Technical Rules for Acetylene Installations and Calcium-carbide Stores (TRAC), here TRAC 204 "Acetylene Pipelines" No. 5.3.7, hose assemblies for high pressure acetylene must be tested for sufficient strength with decomposition of acetylene at the maximum permitted pressure.

With the opening up of the European Internal Market, these National Regulations will have to be incorporated within European Standards.

In No. 7.1.2 "Acetylene hose" of the final draft of the new European Standard prEN ISO 14113 [6] the requirement is: "Hoses for high pressure acetylene shall have a minimum burst pressure of 1000 bar (100 MPa). Hose assemblies for high pressure acetylene shall resist an acetylene decomposition at an initial pressure of 26 bar (25 bar gauge) according to the test method in Annex A". (Annex A describes the acetylene decomposition test for hose assemblies used in high pressure acetylene installations. It is the same test procedure as required according to TRAC).

Until now, only rubber hose assemblies of a pressure rating mentioned above and fitted with a spiral inside the hose on its full length—as proposed by the author—have successfully passed this acetylene decomposition test. These rubber hose assemblies could be recommended for type approval by BAM and have been type approved for use in high pressure acetylene installations according to Article 10 of the German Acetylene Regulations by the competent approval authority in Germany.

Constructional proposals such as inserting a spiral inside the hose can not be made in

Fig. 6. End of rubber hose assembly DN12, type 4 SP with length $L = 1500$ mm ($p_{\text{burst, min}} = 1660$ bar) after a test with decomposition of high pressure acetylene at an initial pressure of 26 bar. [a] Normal high pressure rubber hose assembly. [b] Same high pressure rubber hose assembly with a spiral inserted inside.

National Regulations or in National or International Standards. There might be other technical solutions which enable rubber hose assemblies to withstand a decomposition of high pressure acetylene.

On the basis of the results of these investigations rubber hose assemblies can be produced that will withstand a decomposition of acetylene at the maximum permitted pressure so that in case of a hazard with a decomposition of high pressure acetylene in cylinder manifolds or filling stations there will be no failure of any rubber hose assembly within the installation.

References

[1] D. Lietze, Arbeitsschutz, 2 (1972) 61 (in German).
[2] D. Lietze, Investigations on the running up of detonations inside closed systems, BAM-report of investigations No. 196, Verlag für neue Wissenschaft GmbH, Bremerhaven 1993 (in German).
[3] German Standard DIN 2391, part 2, Seamless precision steel tubes, technical specifications of delivery 1994 (in German).
[4] M.A. Nettleton, Gaseous Detonations: their nature, effects and control, Chapman and Hall, London, 1987.
[5] D. Lietze, Chem.-Ing.-Techn., 62(3) (1990) 238 (in German).
[6] pr EN ISO 14113 Gas welding equipment—Rubber and plastic hoses assembled for compressed or liquefied gases up to a maximum design pressure of 450 bar, April 1996.