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Corrigendum

LARGE SCALE PROPANE RELEASE EXPERIMENTS OVER LAND AT DIFFERENT ATMOSPHERIC STABILITY CLASSES

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This paper is a corrigendum to the paper published in the Special Issue of the Journal of Hazardous Materials on *Major Hazards in the Transport and Storage of Pressure Liquefied Gases*, Vol. 20, pp. 287-301 (1988).

To a great extent the determination of the Lower Flamability Distances (LFD) was affected by a systematic error due to the used infrared spectrometers.

- Up to March '86 only the extinction at 3.71 μm within a strong absorption band (with the maximum at 3.4 μm) had been examined with the IR instruments. To protect the open pathlength of 0.5 m from an additional extinction of water droplets (water vapour condensed by the cooling of evaporating liquid propane) a shield was used which let in gaseous propane but kept out the droplets. Of course by this a time constant of about 10 seconds arose.
- From March '86 on we reduced the time constant to about 1 s by using a second measuring channel at 3.97 μm wavelength outside the propane absorption band. The idea was to eliminate the additional absorption by water droplets by gaining two signals, one containing the influence of both propane and droplets together, the other one only the influence of droplets. In this case the porous shield can be omitted and the time constant decreases to 1 s.

This method had been tested by calculations and by measurements with spray droplets. The data evaluations for the two channel instruments had been performed on the assumption that besides the propane there is only a grey (not depending on wavelength) absorption.

Unfortunately this is not the case with ice crystals. The release of liquid propane results in a large temperature shock to the ambient air. Under this circumstance ice crystals with a size in the range of the used IR wavelengths occur in a large amount.

Due to Mie's theory they have an extinction strongly depending on wavelength and by this a larger amount of propane was pretended.

Accordingly, the following systematic errors have arisen:

- At low temperature the zero degree (Celsius) line inside the propane cloud was farther away from the spill point than at higher temperatures. In this

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case the ice crystals travelled a longer way and influenced even IR instruments far away, so that a large LFD was pretended.

- After nights with a cloudless sky, in the morning an inversion with comparatively low temperatures is formed. Under these circumstances ice crystals are transported relatively far.

Both effects together led to the conclusion that very stable atmospheric stratifications are connected with extremely large LFD.

After we had realized this falsification, the raw data of all measurements from March 1986 and onwards were re-evaluated.

A problem that turned out was that it did not always become clear how large the cloud with ice crystals (within the zero degree Celsius line) was extended. That is why we cannot give fixed distances but only ranges of the LFD.

The uncorrected LFD is a nearly linear function of the air temperature, which would mean that the LFD increases as the temperature decreases. Of course this is not the case with the corrected values.

The corrected LFD are shown in Table 1. Also the Richardson number has changed slightly due to a correction of a sign error in the formula of the Richardson number (eqn. (1) on p. 289 in Vol. 20).

The LFD of Table 1 are presented in Figs. 2 to 7.

A comprehensive overview leads to the following conclusions:

- There is a slight dependence of the LFD on the atmospheric stability.
- The dependence is stronger at releases with a cyclone than with a nozzle. In

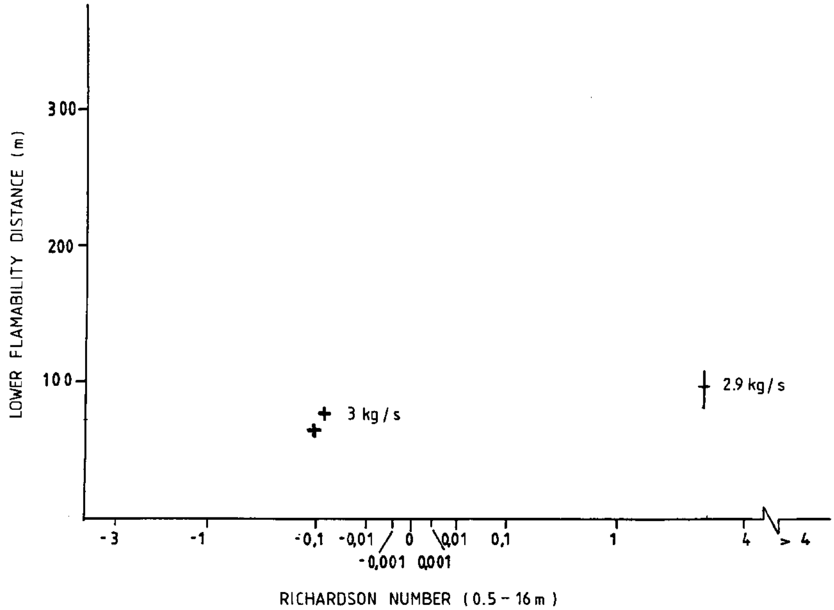

Fig. 2. Relationship between LFD and *Ri*. Spill rate 2.5 kg/s, cyclone.

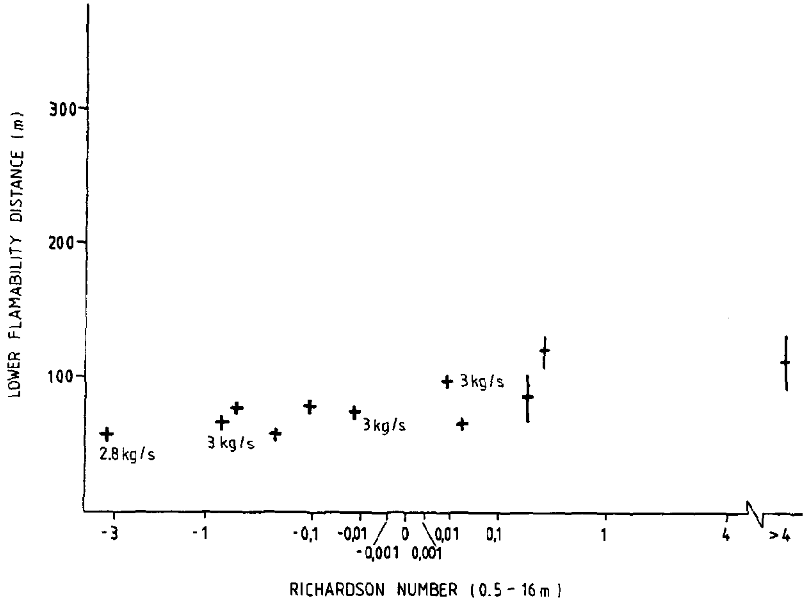

Fig. 3. Relationship between LDF and *Ri*. Spill rate 2.5 kg/s, nozzle.

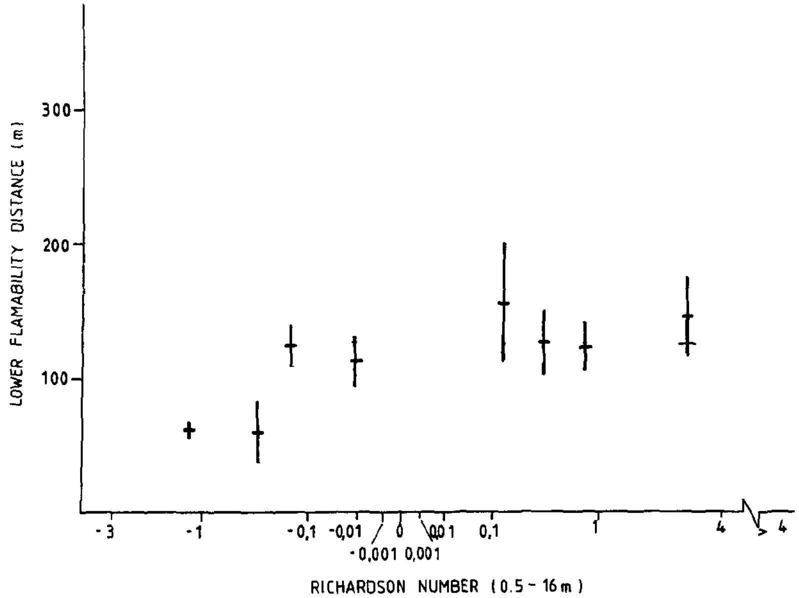

Fig. 4. Relationship between LFD and *Ri*. Spill rate 6 kg/s, cyclone.

TABLE 1

LFD of 59 spills[a]

n	date	time	spr	spt	dia	wv	st sr	*Ri*	LFD
1985									
11	14/11	14.49	2.8	300	15 noz	0.2	A	−3.26	56
12	12/11	15.28	3.9	300	15 cyc	1.6	A	−2.11	84
14	15/11	15.40	29.5	200	50 noz	2.9	B	−0.08	210
15	15/11	15.55	27.5	270	50 cyc	3.2	C	−0.035	190
16[b]	05/12	16.25	31/43	20/20	80 cyc	3.5	D	+0.146	190
18	12/12	13.00	19.0	200	50 noz	3.7	B	−0.32	205
19	12/12	13.24	21.0	180	50 cyc	3.7	B	−0.25	100
20	12/12	16.39	31.0	185	80 noz	2.2	A	−0.25	270
21	12/12	16.59	29.5	21.0	80 cyc	2.5	B	−0.14	245
1986									
22[c]	09/01	16.32	2.7	240	15 noz	1.6	F	+1.75	58
24	29/01	10.05	3.0	240	15 noz	5.4	D	+0.01	96
26	04/02	08.05	3.0	300	15 noz	4.8	D	−0.73	66
27	05/02	07.46	3.0	300	15 noz	2.0	E	−0.014	76
28	05/02	08.14	3.0	260	15 cyc	1.4	E	−0.069	75
29	06/02	07.34	2.4	240	15 noz	5.1	D	−0.6	76
30	06/02	07.50	30.0	23	80 noz	4.2/4.6	D	−0.086	210
31	06/02	09.00	2.4	170	15 noz	3.8	D	−0.264	58
32	07/02	07.45	2.4	240	15 noz	2.5/3.6	D	−0.113	78
33	07/02	08.15	2.4	300	15 cyc	2.9	D	−0.096	64
34	12/02	09.04	2.4	150	15 noz	1.7	E	+0.023	66
35	12/02	15.36	6.0	210	50 cyc	3.7/6.0	D	−0.14	115
36	13/02	07.45	6.0	150	50 noz	2.0	E	+0.43	135
37[d]	13/02	08.10	6.0	267	50 cyc	1.6/3.0	E	+0.33	90
42	22/05	07.04	6.0	150	50 noz	4.0	D D	−0.20	120–170
43	22/05	07.26	6.0	150	50 cyc	4.7	D D	−0.35	40–82
44	23/05	07.05	6.0	150	50 noz	2.0	F D	−0.017	85–160
45[e]	23/05	08.22	30	120	50 noz	2.1	F D	−0.56	160–210
46[f]	23/05	09.02	30	60	50 cyc	1.7	E C	−0.21	85–120
51	10/09	07.14	6	200	50 noz	0.2	F E	+1.02	110–150
52	10/09	08.08	6	300	50 cyc	1.5	F D	+0.79	100–140
53	11/09	06.42	10	300	50 noz	0.6	F	+3.46	160–190
54	11/09	07.06	10	210	50 cyc	0.7	F	+1.19	120–170
55[g]	11/08	08.02	4	300	15 noz	0.6	F	+0.73	-
56[h]	12/09	08.41	15	510	50 noz	0.4	(F) (E)		120–180
57[i]	19/09	06.50	10	300	50 noz	0.4	F	+1.20	150–170
58	19/05	07.17	10	360	50 cyc	0.5	F	+1.91	100–120
59	24/09	07.13	6	300	50 noz	0.5	E D	+0.93	105–180
60[j]	14/09	07.42	6	300	80 cyc	0.2	E D	+0.38	140–160
61[k]	25/09	06.44	2.5	600	15 noz	0.1	F F	+40.0	90–130
62[l]	25/09	07.17	61	60	80 cyc	0.2	F F	+42.0	160–210
63[m]	25/09	07.39	12.0	520	80 cyc	0.4	F F	+44.0	120–205
64[n]	25/09	08.29	6	120	80 cyc	0.1	F D	+3.00	115–170
65	26/09	06.50	2.4	600	15 noz	0.3	F E	+0.24	65–100

TABLE 1 (continued)

n	date	time	spr	spt	dia	wv	st sr	Ri	LFD
66	26/09	07.17	6	300	50 noz	0.2	F E	+1.00	105-170
67[o]	26/09	07.59	2.9	420	15 cyc	0.5	F D	+3.2	80-105
68	26/09	08.18	6.2	500	50 cyc	0.7	F D	−0.14	110-140
69	01/10	06.03	2.4	600	15 noz	0.4	F F	+0.33	110-130
70	01/10	06.31	6	600	50 noz	1.6	F E	+0.09	90-140
71	01/10	07.08	6	600	50 cyc	0.8	F E	+0.15	110-200
72	01/10	07.39	6	600	50 cyc	0.9	F D	−0.01	90-130
73	10/10	13.56	6	300	50 noz	2.7	B C	−2.66	85-125
74	01/10	14.18	6	300	50 cyc	3.0	B C	−1.15	58-65
75[p]	03/10	05.50	36	30	80 noz	0.6	F E	+0.08	120-170
76[q]	03/10	06.06	36	60	80 noz	0.3	F E	+0.68	180-220
78	03/10	06.58	36	240	80 cyc	0.8	F E	+2.90	160-240
79	09/10	11.02	36	80	80 noz	4.0	B C	−0.46	220-260
80	09/10	11.25	7.5	120	50 noz	3.2	B C	−1.02	130-150
81	09/10	11.46	53	80	80 cyc	4.0	B C	−1.38	160-190
82	10/10	09.44	36	120	80 noz	3.4	C D	−0.13	200-270
83	10/10	10.03	36	120	80 cyc	3.4	B C	−0.35	130-210

[a]The following abbreviations are used in the table

- n number of individual spill
- spr spill rate (propane outflow), kg/s
- spt spill time (duration of the vent), 2
- dia diameter of nozzle or of the end inside the cyclone, mm
- noz spill with nozzle
- cyc spill with cyclone
- wv wind velocity 2 m above ground, m/s
- st stability class (Pasquill) by temperature profile
- sr stability class by net radiation
- Ri Richardson number by temperature and wind profile between 0.5 and 16 m.

[b]Two nearly instantaneous releases with only a short interval between them. The LFD relates to the second release.

[c]The direction of the nozzle and the wind direction were at right angles.

[d]Sunrise was at 7.33 a.m. Probably the lowest layer already was unstable.

[e]The lowest layer probably was unstable due to solar radiation.

[f]No steady state was reached.

[g]Nozzle upwards.

[h]Stability class estimated.

[i]Very flat cloud, about 5 m.

[j]Circular cloud.

[k]Height of the visible cloud about 1 m.

[l]The height of the circular cloud was only 0.4 m. No steady state reached.

[m]Circular cloud.

[n]Circular cloud.

[o]The lowest layer became unstable during the spill from solar radiation.

[p]No steady state reached.

[q]No steady state reached.

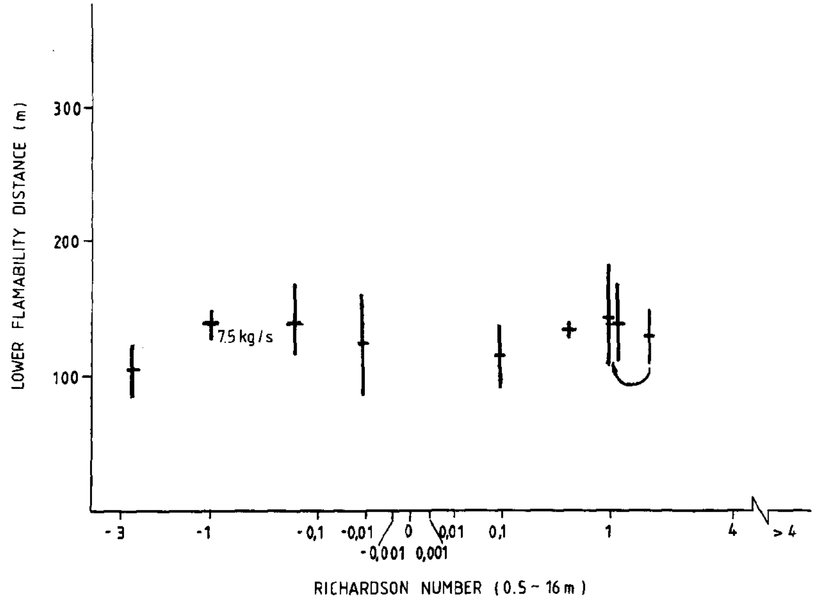

Fig. 5. Relationship LFD and *Ri*. Spill rate 6 kg/s, nozzle.

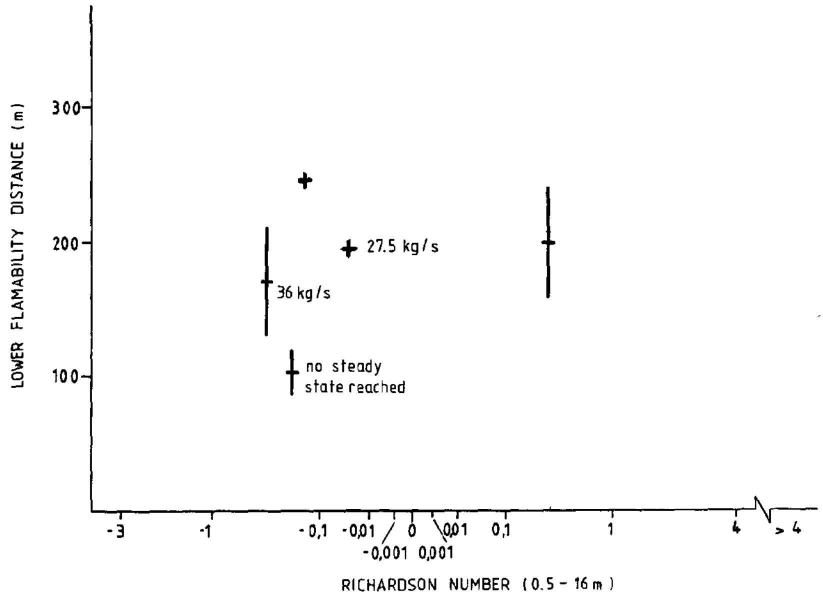

Fig. 6. Relationship between LFD and *Ri*. Spill rate 30 kg/s, cyclone.

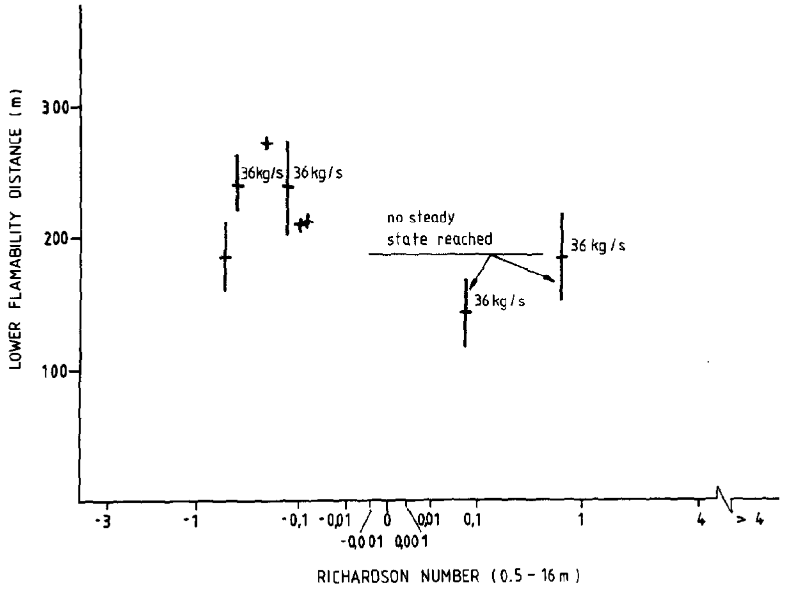

Fig. 7. Relationship between LFD and *Ri*. Spill rate 30 kg/s, nozzle.

using a nozzle, the atmospheric stratification is disturbed by the turbulent free jet of the propane outflow.

- The lower the spill rate is, the stronger the influence is of the stability.

At the moment we carry out release experiments with artificial obstacles together with the Department of Meteorology and Wind Energie, Risø National Laboratory. About this projekt M. Nielsen and N.O. Jensen have reported recently (see this Journal Vol. 21, pp. 101–104).

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