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AN EXAMINATION OF DETERIORATION OF AMMUNITION BY STORAGE

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SUMMARY

Ammunition deterioration during storage is of considerable economic consequences, and for long-range planning purposes it is important to have reliable data for various types of ammunition and for various storage sites. With this background long-term storage trials have been going on for 9 years with 6 types of ammunition at 3 aboveground and 3 underground storage sites. During this time visual inspection, laboratory analyses and tests, and functioning trials have been carried out. Several differences in the deterioration rate have been revealed both between ammunition types and between storage sites. It is proposed that the original time frame for the trials (10 years) should be extended.

1 INTRODUCTION

The background for this examination was an analysis of the costs of ammunition storage, with a particular view to an economical comparison of aboveground and underground storage sites (1). These costs can be divided into five main groups:

- Amortization of constructional costs
- Operational costs (guards, electricity, snow clearence etc)
- Constructional maintenance
- Maintenance of ammunition
- Procurements as a compensation for ammunition which has to be scrapped as a consequence of deterioration

The last two groups are both closely connected with the technical lifetime of the ammunition, i e the time span before maintenance or scrapping is necessary. If the technical lifetime is shorter than the operational lifetime, these costs should be taken into consideration.

The most important deterioration processes occuring to ammunition during storage are corrosion of metallic components and chemical and physical changes of the explosives, which may result in reduced stability and performance. The factors which have the greatest influence on these deterioration processes are temperature and humidity.

In the already mentioned analysis of the total costs of ammunition storage it turned out to be difficult to provide reliable data for costs connected with the deterioration of ammunition. It seemed clear, however, that it could be a matter of a considerable amount of money. Various estimates ranged from 35 to 50 per cent of the total costs.

For long-range planning purposes it seemed obvious that it would be advantageous if more reliable data could be made available concerning the economical consequenses of ammunition deterioration. This could be achieved by regular inspections of representative types of ammunition subjected to controlled long-term storage under different conditions, geographicly and constructionally.

Another useful result of such trials would be to establish an improved basis for planning of procurement, use and disposal of ammunition.

It was then decided to start long-term storage trials in the autumn 1968. It was a condition that the trials should not violate the usual routines and duties imposed on the staff at the selected storage sites. Also other practical considerations have to some extent been in conflict with the requirements of the trials. For instance, it has in some cases been necessary to move the ammunition from the original storage building to another one in the same or an adjacent area.

Details of these trials have been presented in a number of status reports (2-9). It is felt, however, that at the present stage a survey of the most important results obtained so far would be useful. This, then, is the purpose of the present report.

2 STORAGE SITES INCLUDED IN THE TRIALS

Three aboveground and three underground storage sites are included in the trials.

The aboveground sites are:

- Dombås, simple wooden building, dry, inland climate
- Melshei, isolated wooden building, wet, coastal climate,south
- Salangen, simple wooden building, wet, coastal climate,north

The underground sites are:

- Førde, old, technically in a poor shape, dehumidification
- Knappen, modern, high standard, dehumidification
- Trøgstad, old, technically in a poor shape,no dehumidification

The geographical locations are shown in Figure 2.1.

Incorporated in the trials are also dehumidified storage of a minor part of the ammunition under tightened plastic foils. Dehumidification is achieved by the use of silica gel, which according to the instructions should be replaced when the relative humidity exceeds 50%. This type of dehumidification is included as a part of the programme at all storage sites except at Knappen.

3 TYPES OF AMMUNITION

Six types of ammunition are included in the trials as shown by Table 3.1.

Ammunitive type	Number of units at each storage site	Number of units for dehumidified storage under plastic foil
105 mm HE	600	96
90 mm HE	600	-
57 mm RF, HE	100	8
40 mm L/70, HE	88	-
Hand grenades Mk2	300	50
Antitank mines M6A2	300	10

Table 3.1 Types of ammunition in the storage programme

It should be noticed that 105 mm is a separate-loaded round so that air humidity has rather free access to the primer and propelling charge. The recoilless 57 mm ammunition is also of such a design that humid air can easily affect the primer and the propelling charge. On the other hand, the 90 mm and 40 mm ammunition are both of the fixed round type which provides better protection against humidity.

The 40 mm ammunition is packed in steel boxes with rubber strips. The other types are kept in wooden boxes.

It should be noticed that the propellant charge in 105 mm ammunition consists of a base charge and six increment charges. Although the nominal composition is the same, there are differences in powder geometry and production lots. Two samples were therefore usually taken for testing and analysis. These are designated I and IV respectively.

All types of ammunition were 3-4 years old when the trials were started. An inspection certified that the quality was satisfactory.

4 CLIMATIC INVESTIGATION

In each storage building (aboveground) or storage chamber (underground) air temperature and humidity were recorded by thermo-hygrographs. Regular adjustments of these instruments were necessary. It seems more than possible that the staff at the storage sites has not solved this task satisfactorily. The data are therefore rather unreliable, particularly the humidity records. Direct measurements during inspectional visits make some corrections possible. However, there is no point in going into the details of these measurements, but rather concentrate on the general picture.

It is clear that the temperature in the underground storage sites remains fairly constant from day to night, and also that the temperature variation during the year is quite small, 3-6°C, the highest variation at Trøgstad, lowest at Knappen. The mean temperature during the year was:

Førde : 5.1°C (7 Oct 1968 - 3 Oct 1969)
Knappen : 9.5°C (2 June 1969 - 31 May 1970)
Trøgstad: 7.3°C (13 Nov 1969 - 15 Nov 1970)

In the aboveground storage sites the main difference is the much larger temperature variations, which during the year may result in differences between maximum and minimum temperature of about 50°.

The relative humidity of the two underground sites with dehumidification (Førde and Knappen) appears to be about 60%, whereas 80% seems to be a reasonable average for Trøgstad. For the aboveground sites the variations during the day and during the year are much greater, and it is therefore difficult to give quantitative estimates. It is clear, however, that Dombås with a typical inland climate provides much drier storage conditions than Melshei and Salangen.

5 PROGRAMME FOR THE INSPECTION OF AMMUNITION QUALITY

The programme covers visual inspection, laboratory methods and functioning trials.

5.1 Visual inspection

The primary purpose is to reveal corrosional defects, possibly also exudates or other visible defects. Usually a qualitative description of the state of the ammunition is given, in one case it has been possible to present quantitative results.

5.2 Laboratory methods

The most comprehensive programme concerns the artillery ammunition. The details are presented in Table 5.1.

Primer	Impact sensitivity Chemical analysis Calorimetric value Closed vessel test
Propelling charge	Chemical analysis Stability tests Calorimetric value Closed vessel test
Shell	X-ray inspection

Tabell 5.1 Laboratory testing of artillery ammunition

For the hand grenade the following tests are applied:

- release force for safety pin
- impact sensitivity of primer
- ignition delay
- spring characteristics

No laboratory test was planned for the antitank mine.

A comprehensive inspection by laboratory methods was performed after 5 years of storage. Less extensive tests have been carried out more frequently.

5.3 Functioning trials

For the artillery ammunition firing trials were planned with measurement of maximum chamber pressure and muzzle velocity, and in addition observation of fuze performance.

For the hand grenade and the mine,fuze functioning tests were planned.

6 RESULTS

6.1 Visual inspection

As already mentioned visual inspection covered mainly corrosional attack. After 9 years storage.there are great difference between ammunition types, partly also between storage sites.

The slightest attack shows the 40 mm L/70 ammunition. Of the other artillery ammunition types the 57 mm is most seriously corroded. The only storage site which clearly stands out among the others, is Trøgstad with the poorest results.

The antitank mines show an appreciable corrosion. In this case Salangen stands out among the others with the poorest result. The reason seems to be wooden boards placed between the mines.

For the hand grenades a more thorough inspection was carried out after 5 years storage. From each storage site 75 grenades were selected, and additionally 25 grenades from each dehumidified storage. The results are shown in Table 6.1 and 6.2.

Storage site	Percentage of grenades with adequate quality	
	At start	After 5 years
Dombås	97	67
Førde	91	59
Knappen	95	79
Melshei	95	17
Salangen	87	36
Trøgstad	100	0

Table 6.1 Visual inspection of hand grenades

Storage site	Percentage of grenades with adequate quality	
	At start	After 5 years
Dombås	88	64
Førde	84	44
Melshei	100	64
Salangen	100	28
Trøgstad	100	92

Table 6.2 Visual inspection of hand grenades in dehumidified storage

There is a significant difference between the storage sites. Further, there is an appreciable quality reduction for all storage sites. Even for Knappen, which shows the best result, the difference is significant at a 1% level.

The results presented in Table 6.2 show considerable variation. For Dombås, Førde and Salangen there is no improvement compared to ordinary storage, whereas the improvement is highly significant for Melshei and Trøgstad. There is reason to suspect that the staff members at the various storage sites have not been equally painstaking in tightening the plastic foils and in replacing the desiccator.

6.2 Laboratory results

Some of the laboratory results are of little interest, and they will not be mentioned here. This applies to the calorimetric measurements and most of the chemical analyses. Ref (6) gives the detailed results after 5 years storage.

6.2.1 Stability tests

Two tests were carried out:

- Vacuum stability test (ml gas developed after 40 hours at 90^{o}C). The requirement is that the gas development shall be less than 5.0 ml

- Reduction of stabilizer after 2 months at 65.5^{o}C. The requirement is that the reduction of stabilizer shall not exceed 0.5 per cent, and remaining stabilizer shall be at least 0.3 per cent.

The results after 5 years storage are presented in Tables 6.3 and 6.4.

Storage site	105 mm Propelling charge		90mm	57mm	40mm	Ranking
	I	IV				
Dombås	0.56	0.36	0.99	2.25	0.83	1(G)
Førde	0.58	0.48	1.24	2.72	0.89	4(P)
Knappen	0.49	0.46	0.99	2.46	0.69	2(G)
Melshei	0.59	0.50	1.19	2.53	0.89	3(P)
Salangen	0.53	0.50	1.20	2.95	0.78	5(P)
Trøgstad	0.56	0.52	1.57	2.76	0.78	6(P)

Table 6.3 Results of vacuum stability tests. Ranking indicated by numbers and by G: good (above average) or P: poor (below average)

An analysis of variance shows that the difference between storage sites is significant at the 5% level.

Storage site	105 mm Propelling charge		90mm	57mm	40mm	Ranking
	I	IV				
Dombås	0.17	0.15	0.21	0.45	0.11	4(G)
Førde	0.16	0.16	0.20	0.40	0.12	1(G)
Knappen	0.20	0.14	0.18	0.37	0.17	2-3(G)
Melshei	0.20	0.17	0.16	0.36	0.17	2-3(G)
Salangen	0.18	0.15	0.19	0.50	0.13	5(P)
Trøgstad	0.20	0.16	0.15	0.50	0.16	6(P)

Table 6.4 Reduction of stabilizer. Ranking indicated by numbers and by G: good (above average) or P: poor (below average)

An analysis of variance shows that the difference between storage sites is not significant. Thus, the ranking in the last column need not be real. However, it is of some interest to note that also in this test Salangen and Trøgstad seem to show the poorest results.

It is of further interest to note that the 57 mm clearly stands out as the poorest ammunition type by both stability tests.

6.2.2 Stabilizer content of propellant charge in 57 mm ammunition

As stated in the previous section the stability of the propellant charge in the 57 mm is questionable. This is confirmed by chemical analysis, showing that a drastic reduction in stabilizer content may occur after 9 years storage. For the other ammunition types no significant reduction was found.

Complete analysis was carried out only for two of the storage sites. The results are shown in Table 6.5.

Storage site	1 year	5 years	7 years	9 years
Dombås	0.95	0.96	0.91	0.91
Trøgstad	0.95	0.86	0.86	0.58

Table 6.5 Stabilizer content, per cent, 57 mm ammunition

6.2.3 Water content

The water content has been determined both in the primer charge and in the propellant charge. It should be remarked that what is actually determined, is the total amount of volatile ingredients. However, after some time water will be the completely dominating part of these ingredients.

For the primer charge we will first consider the results after 1 and 5 years storage (Table 6.5). This comparison encompasses only three ammunition types since 40 mm was not analyzed after one year.

Storage site	1 year			5 years			Ranking
	105mm	90mm	57mm	105mm	90mm	57mm	
Dombås	0.32	0.37	0.43	0.70	0.65	0.47	2(G)
Førde	0.31	0.42	0.46	0.64	0.68	0.45	3(G)
Knappen	0.34	0.39	0.44	0.61	0.65	0.49	1(G)
Melshei	0.32	0.37	0.41	0.73	0.69	0.61	5(P)
Salangen	0.31	0.42	0.49	0.68	0.69	0.52	4(P)
Trøgstad	0.43	0.48	0.47	0.74	0.68	0.62	6(P)

Table 6.6 Water content in primer, per cent. Ranking indicated by numbers and by G: good (above average) or P: poor (below average)

An analysis of variance shows strong interaction between the factors Time and Ammunition Type, and a weaker, but significant interaction between the factors Time and Storage Site. The ranking in the last column is accordingly not significant. However, it is of some interest because it strengthens the tendency from other results.

In Table 6.7 the results after 5 years storage are repeated now with the inclusion of 40 mm.

Storage site	105mm	90mm	57mm	40mm	Ranking	
					All types	105&57mm only
Dombås	0.70	0.65	0.47	0.64	3(G)	3(G)
Førde	0.64	0.68	0.45	0.58	1(G)	1(G)
Knappen	0.61	0.65	0.49	0.64	2(G)	2(G)
Melshei	0.73	0.69	0.61	0.69	6(P)	5(P)
Salangen	0.68	0.69	0.52	0.67	4(P)	4(G)
Trøgstad	0.74	0.68	0.62	0.59	5(P)	6(P)

Table 6.7 Water content in primer after 5 years, per cent. Ranking indicated by numbers and by G: good (above average) or P: poor (below average

An analysis of varians shows a significant difference between the storage sites at the 5% level. Interaction between Storage site and Ammunition Type does not quite reach this significance level, but is strong enough to indicate that the factor Storage Site is of greater importance for 105 mm and 57 mm than for 90 mm and 40 mm. We can examine this effect by dividing the ammunition in two groups, A: 105 mm and 57 mm, and B: 90 mm and 40 mm. It then turns out that the factor Storage Site is significant only for Group A. This will be the result if we consider the storage sites individually, and also in the case when we divide the storage sites into two groups consisting of (i) Dombås, Førde, Knappen, and (ii) Melshei, Salangen, Trøgstad.

After 9 years storage the water content in the primer charges was again determined for ammunition from Dombås and Trøgstad. The results are presented in Table 6.8 and do not alter the previous conclusion.

Storage site	105 mm	90 mm	57 mm
Dombås	0.61	0.78	0.67
Trøgstad	0.74	0.75	0.73

Table 6.8 Water content in primer after 9 years, per cent

We find this same difference between the two groups of ammunition when we consider the water content in the propellant charge. In this case we have results after 1, 5 and 7 years storage, for two storage sites also after 9 years. The water content as a function of storage time is shown in Figures 6.1 - 6.3.

6.2.4 Impact sensitivity of primers

We shall consider the results for 105 mm and for 90 mm (6) For the other two types of artillery ammunition the number of trials is so small that the results are of little interest. Tables 6.9 and 6.10 show the results.

Storage site	Percentage functioning (Number of trials)			
	10 in height of fall		12in height of fall	
	Start	5 years	Start	5 years
Dombås	45 (20)	40 (20)	70 (20)	67 (15)
Førde	45 (20)	20 (20)	70 (20)	63 (19)
Knappen	45 (20)	20 (20)	70 (20)	85 (20)
Melshei	45 (20)	35 (20)	70 (20)	75 (20)
Salangen	45 (20)	20 (20)	70 (20)	70 (20)
Trøgstad	45 (20)	15 (20)	70 (20)	75 (20)

Table 6.9 Impact sensitivity of primers, 105 mm HE

Storage site	Percentage functioning (Number of trials)			
	10 in height of fall		12 in height of fall	
	Start	5 years	Start	5 years
Dombås	50 (20	45 (20)	80 (20)	80 (20)
Førde	50 (20)	28 (18)	80 (20)	58 (19)
Knappen	50 (20)	15 (20)	80 (20)	85 (20)
Melshei	50 (20)	28 (18)	80 (20)	79 (19)
Salangen	50 (20)	11 (18)	80 (20)	44 (18)
Trøgstad	50 (20)	41 (17)	80 (20)	82 (17)

Table 6.10 Impact sensitivity of primers, 90 mm HE

Here we can use a χ^2-test to determine if the sensitivity has been significantly reduced after 5 years storage. If we pool the results from both heights of fall, there is no significant reduction. This is true both when we consider each ammunition type separately and when we pool the results. However, it appears as if the results for 10 inch height of fall are more dependent on the storage time than the results for 12 inch height of fall. If we consider only the former results, there is still no significant reduction for the two ammunition types separately. For the pooled results the reduction in sensitivity reaches the 5% significance level.

There is no significant difference between the storage sites. Neither is it possible to prove any correlation between impact sensitivity and the water content of the primers.

6.2.5 Closed vessel test

The details of this investigation have been described in Ref(10). Based on measurements in a closed vessel various propellant characteristics can be determined. Here we will consider the burning rate at a pressure of 1500 bars determined at two different loading densities, and the vivacity, defined as the ratio between the pressure increase dp/dt at a certain pressure and the maximum pressure after completed burning. The latter parameter is usually presented as the relative vivacity compared to a reference propellant.

Measurements have only been made for the propellant from the 57 mm ammunition. The results after 7 years storage are presented in Table 6.11. For comparison the water content is also included.

Storage site	Burning rate at 1500 bars		Relative vivacity	Water Content
	LD=0.2 g/cm^3	LD=0.267 g/cm^3		
Dombås	10.71 cm/s	11.38 cm/s	1.000	0.87%
Førde	10.64 "	11.20 "	0.985	0.94"
Knappen	10.63 "	11.44 "	0.982	0.87"
Melshei	10.23 "	11.12 "	0.954	1.18"
Salangen	10.53 "	11.23 "	0.964	1.12"
Trøgstad	10.10 "	10.90 "	0.941	1.31"

Table 6.11 Parameters from closed vessel test compared with water content

All the three propellant parameters are significantly correlated with the water content. The relative vivacity has the highest correlation.

6.3 Functioning trials

6.3.1 Artillery ammunition

The first functioning trials were carried out after 6 years storage and involved 105 mm, 90 mm and 57 mm ammunition from Dombås and Trøgstad. These were selected as one of the best and one of the poorest storage sites according to the laboratory results.

Ten rounds from each storage site were fired. Muzzle velocity was measured for all ammunition types, for 105 mm also the maximum pressure. The results are shown in Table 6.12.

Storage site	105 mm		90 mm	57 mm
	Muzzle velocity	Max pressure	Muzzle velocity	Muzzle velocity
Dombås	481.0 m/s	2302 bars	795.3 m/s	351.2 m/s
Trøgstad	479.2 "	2272 "	795.8 "	341.9 "

Table 6.12 <u>Firing trials after 6 years storage</u>

The difference between the two storage sites is significant for 105 mm and 57 mm, not for 90 mm.

Primers and fuzes functioned satisfactorily, except for two duds for 57 mm. These two rounds had both been stored at Trøgstad.

It was then decided to have a complete firing trial involving all storage sites after 7 years storage. As a rule 9 rounds of each ammunition type from each storage site were fired. The results are presented in Tables 6.13 - 6.15. Reference ammunition was not fired, so the results are not directly comparable to the results in Table 6.12.

Considering first Tables 6.13-14 we find that the difference between storage sites is highly significant for both ammunition types. It appears that one group of storage sites (Dombås, Førde, Knappen) has higher velocities than the other one (Melshei, Salangen, Trøgstad). The difference is greatest for 57 mm.

Storage site	Muzzle velocity	Stand dev	Max pressure
Dombås	467.9 m/s	0.67 m/s	2018 bars
Førde	468.6 "	1.32 "	2043 "
Knappen	469.1 "	1.52 "	2047 "
Melshei	466.8 "	1.16 "	1999 "
Salangen	466.6 "	0.48 "	1997 "
Trøgstad	466.0 "	1.94 "	1982 "

Table 6.13 Firing trials after 7 years storage, 105 mm HE

Storage site	Muzzle velocity	Stand dev	Misfires	Duds
Dombås	345.2 m/s	3.3 m/s	3	2
Førde	346.3 "	3.2 "	1	2
Knappen	345.2 "	2.3 "	1	2
Melshei	341.8 "	1.1 "	0	2
Salangen	342.5 "	1.5 "	0	1
Trøgstad	339.7 "	3.9 "	0	1

Table 6.14 Firing trials after 7 years, 57 mm RF, HE

Figure 6.4 shows a clear correlation between muzzle velocity and water content of the propellant.

Figure 6.5 shows the correlation between muzzle velocity and propellant parameters determined by the closed vessel test for 57 mm ammunition.

Storage site	90 mm		40 mm	
	Muzzle velocity	St dev	Muzzle velocity	St dev
Dombås	793.6 m/s	2.3 m/s	1004.3 m/s	5.7 m/s
Førde	794.2 "	1.9 "	1008.5 "	5.2 "
Knappen	796.5 "	4.9 "	1011.4 "	7.3 "
Melshei	794.4 "	1.9 "	1011.1 "	5.2 "
Salangen	793.4 "	2.7 "	1003.6 "	5.3 "
Trøgstad	795.6 "	4.0 "	1009.6 "	5.5 "

Table 6.15 Firing trials after 7 years
90 mm HE and 40 mm L/70, HE

The difference between the storage sites is also in table 6.15 significant although not so pronounced as in Table 6.13 and 6.14. There is no correlation between the muzzle velocity and the water content. Since the ranking of the storage sites is quite different from those of Table 6.13 and 6.14, there is reason to suspect irrelevant factors to be responsible for the difference. One such factor is the order of fire, which was the same for the two ammunition types. Table 6.16 illustrates the relationship.

Storage site	Ranking		Firing order
	90 mm	40 mm	
Dombås	5	5	5
Førde	4	4	1
Knappen	1	1	2
Melshei	3	2	3
Salangen	6	6	6
Trøgstad	2	3	4

Table 6.16 Comparison of muzzle velocity
ranking and firing order

It appears to be some agreement between the ranking and the firing order. In addition, a thorough examination of the details of the firing trials proved that the firing order is a significant factor. However, it seems not to be a simple relationship, so no attempt has been made to correct for this effect.

After 9 years storage firing trials were again performed, this time only with ammunition from Dombås and Trøgstad. The number of rounds fired from each storage site were as follows:

105 mm: 20
90 " : 20
57 " : 9
40 " : 15

Primers and fuzes functioned satisfactorily. Other results are presented in Table 6.17.

Again reference ammunition was not fired so the results are not comparable to previous data.

Storage site	105 mm		90 mm	57 mm	40 mm
	Muzzle vel	Max press	Muzzle vel	Muzzle vel	Muzzle vel
Dombås	481.3 m/s SD=1.35 "	2330 bars SD=44 "	791.6 m/s SD=2.52 "	348.7 m/s SD=2.15 "	1002.7 m/s SD=7.38 "
Trøgstad	480.9 m/s SD=1.15 "	2309 bars SD=62 "	790.8 m/s SD=2.75 "	338.8 m/s SD=3.21 "	1002.6 m/s SD=4.81 "

Tabel 6.17 Firing trials after 9 years storage

There is good agreement with previous results for 57 mm (significant difference between storage sites) and for 90 mm and 40 mm (no significant difference).

For 105 mm the picture is not quite clear. Again we have the highest velocity for the Dombås rounds, but the difference is too small to be significant. There is no evidence that this is due to the firing order. A thorough examination of the details of the trial reveals that some irregularities may have taken place during the first part of the trial. If we count only the last 10 rounds from each storage site, the difference is highly significant (1% level) in favour of the Dombås rounds.

6.3.2 Hand grenades

After 5 years storage a comprehensive examination of the hand grenades was performed without giving many results of particular interest. Here we shall only consider the results of the primer impact sensitivity test, Table 6.18. A number of 25 primers from each storage site were tested.

Storage site	Percentage functioning	
	At start	After 5 years
Dombås	76	92
Førde	76	88
Knappen	76	64
Melshei	76	52
Salangen	76	80
Trøgstad	76	72

Table 6.18 Impact sensitivity of primers for hand grenades

There is no significant reduction of the sensitivity after 5 years storage. Neither is there a significant difference between the storage sites. However, there is some indication that the storage site group Dombås, Førde, Knappen exhibits a better performance than the group Melshei, Salangen, Trøgstad (10% significance level).

7 CONCLUSIONS

Based on the results obtained so far we can draw the following conclusions:

a) The visual inspection has revealed a considerable difference in corrosion attack between the ammunition types. The 40 mm ammunition is only slightly corroded, whereas the hand grenades are seriously attacked. For this last type there is a significant difference between the storage sites.

b) After 5 years there is a significant difference between the storage sites with regard to the stability of the propellant charge. Of the four artillery ammunition types involved the 57 mm is conspicuously the poorest one. For two of the storage sites the stability is on the border of being permissible.

c) Calorimetric measurements and most of the chemical analyses are of little interest and should be postponed to the end of the storage trials. An exception is the measurement of stabilizer content in the propellant charge for 57 mm, where a drastic reduction has been found for one of the storage sites after 9 years storage.

d) It is not quite clear if the impact sensitivity of the primers has been reduced after 5 years storage. Differences between storage sites are not significant. However, they are consistent with other results, so the non-significance is probably due to the rather small samples.

The sample size was largest for 105 mm and 90 mm ammunition. For these ammunition types the results seem to be more sensitive to storage time for 10 inch than for 12 inch height of fall.

e) The water content both in the primer and the propellant charges is significantly dependent on the storage.

f) For 57 mm ammunition the burning rate and the vivacity of the propellant are determined by the closed vessel test. These parameters are significantly correlated with the water content.

g) Measurement of muzzle velocity after 6, 7 and 9 years storage shows a remarkable difference between the various types of artillery ammunition. For 90 mm and 40 mm the velocity is not dependent on the storage conditions. For 105 mm and particularly for 57 mm there is a significant difference between storage site. For these ammunition types there is a clear correlation with the water content of the propellants, and for 57 mm also with the propellant characteristics determined by the closed vessel test.

h) Considering the results all together it is obvious that the storage sites in many cases can be divided into two groups, one consisting of Dombås, Førde and Knappen, and one consisting of Melshei, Salangen and Trøgstad, with a significantly greater deterioration of ammunition in the latter group. Within this group Trøgstad frequently shows the poorest results.

i) It is difficult to detect such a difference between the two storage groups for 90 mm and 40 mm ammunition. This is not surprising in view of the fact that these two types represent fixed ammunition with a much better protection against humidity. For 40 mm the better packing may also be important.

j) Dehumidified storage under tightened plastic foils has not quite come up to expectations. The reason for this should be further examined.

8 FUTURE WORK

The original time frame for these trials was 10 years with a possibility to extend the programme at the end of that period. We are now close to the point when such a decision should be made. It seems obvious that great benefits could be gained by extending the work for another 5 or 10 years.

However, the programme has so far for some periods of time drawn heavily on manpower and other resources. It will therefore be necessary to work out detailed plans for the new period based on the experience obtained so far. One should then consider the remaining amount of ammunition at the various storage sites, the labour involved in the various inspection methods, and how this is related to the usefulness of the results obtained.

References

(1) Strømsøe, E - Lagring av ammunisjon i Forsvaret, Intern rapport X-113, FFI (1966)

(2) Jacobsen, K O - Langtidslagring av ammunisjon, Statusrapport nr 1, TN X-229, FFI (1969

(3) Eriksen, S, M Helgesen - Langtidslagring av ammunisjon, Statusrapport nr 2, TN VM-8, FFI (1971)

(4) Eriksen, S - Langtidslagring av ammunisjon, Visuell kontroll etter 3 års lagring, Statusrapport nr 3, TN VM-45, FFI (1972)

(5) Eriksen, S - Langtidslagring av ammunisjon, Visuell kontroll etter 4 års lagring ved Trøgstad ammunisjonslager - Statusrapport nr 4, TN VM-70, FFI (1972)

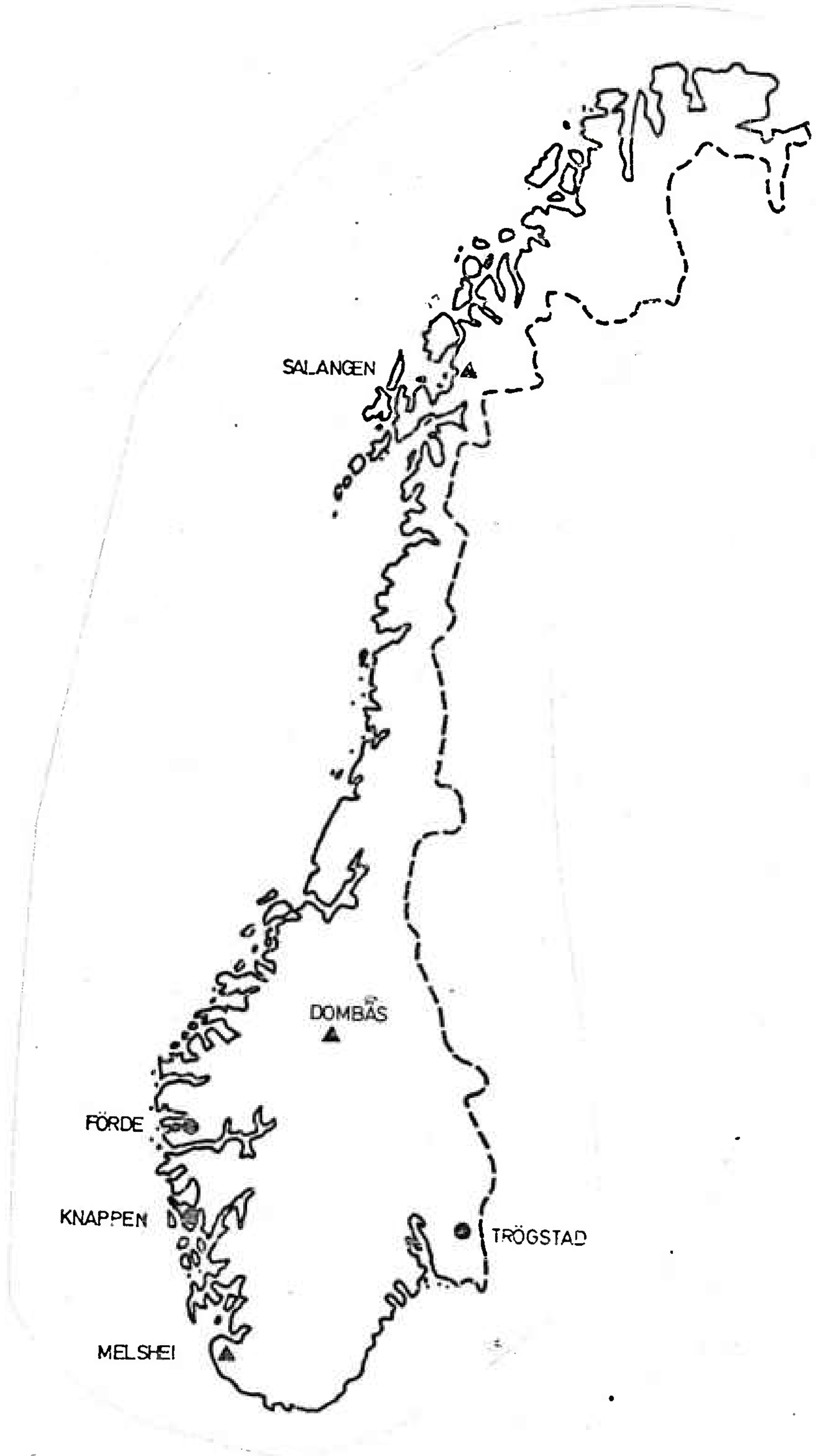
(6) Sværen, A
S Eriksen
- Langtidslagring av ammunisjon, Statusrapport nr 5, TN VM-168, FFI (1974)

(7) Eriksen, S
A Sværen
- Langtidslagring av ammunisjon, Statusrapport nr 6, TN VM-193, FFI (1975)

(8) Eriksen, S
- Langtidslagring av ammunisjon, Statusrapport nr 7, TN VM-261, FFI (1977)

(9) Eriksen, S
- Langtidslagring av ammunisjon, Statusrapport nr 8, (will be published)

(10) Eriksen, S
A Syverhuset
- Beregning av indreballistiske størrelser ved closed vessel test, TN VM-274, FFI (1974)



Figur 2.1 Geographical location of the storages sites

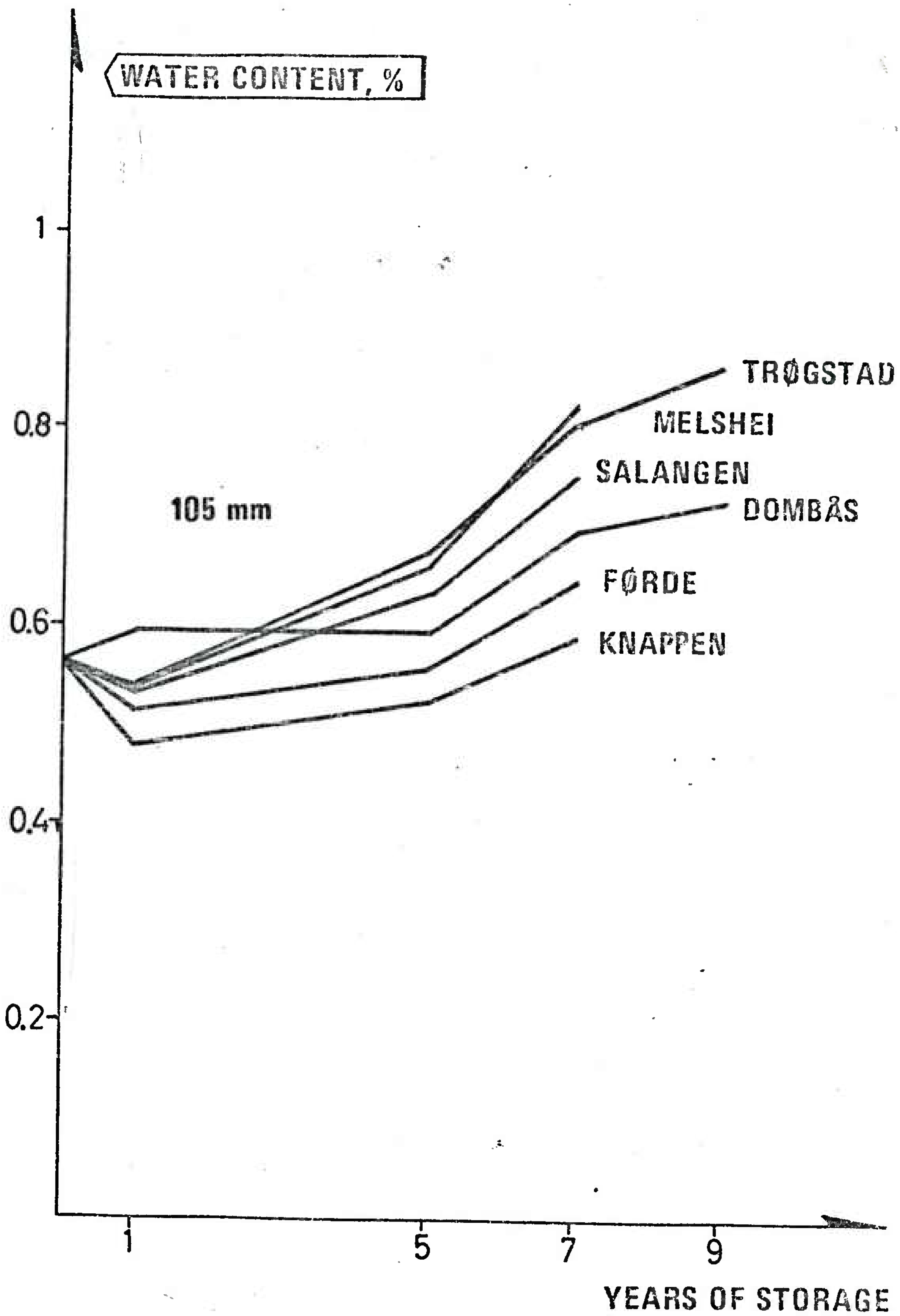


Figure 6.1 Water content as a function of storage time 105 mm

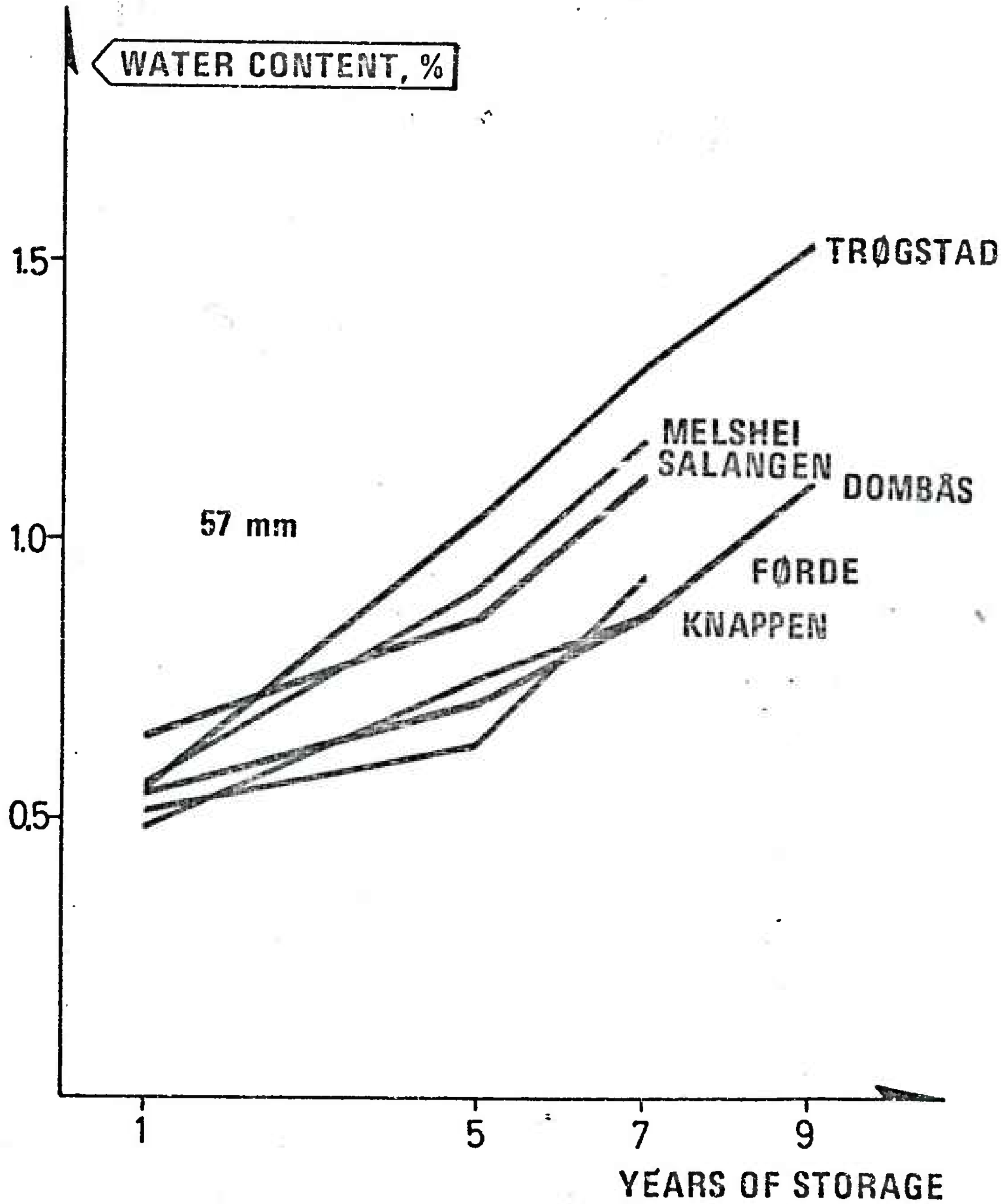


Figure 6.2 Water content as a function of storage time 57 mm

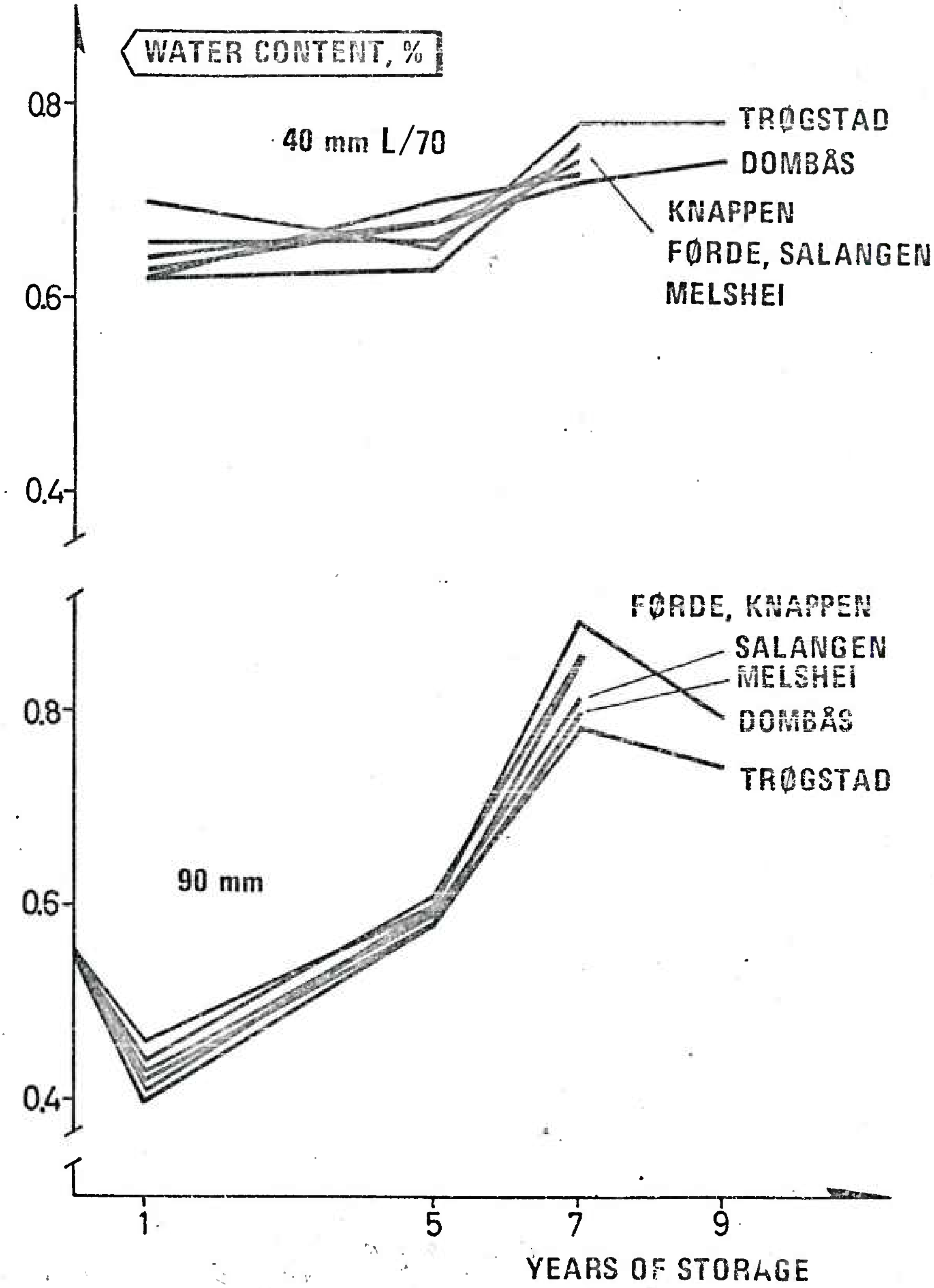


Figure 6.3 Water content as a function of storage time 90 mm and 40 mm

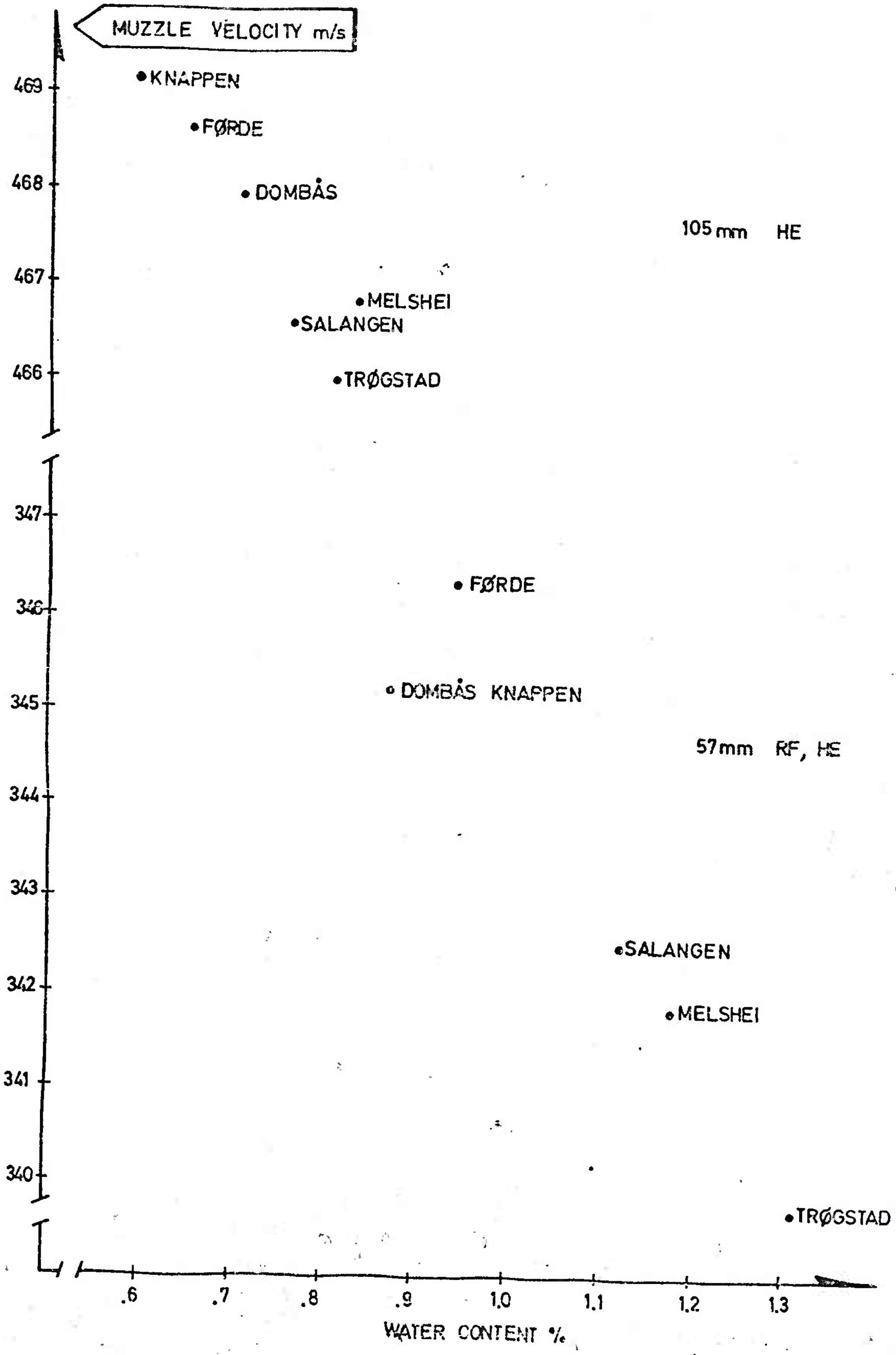


Figure 6.4 Correlation between muzzle velocity and water content

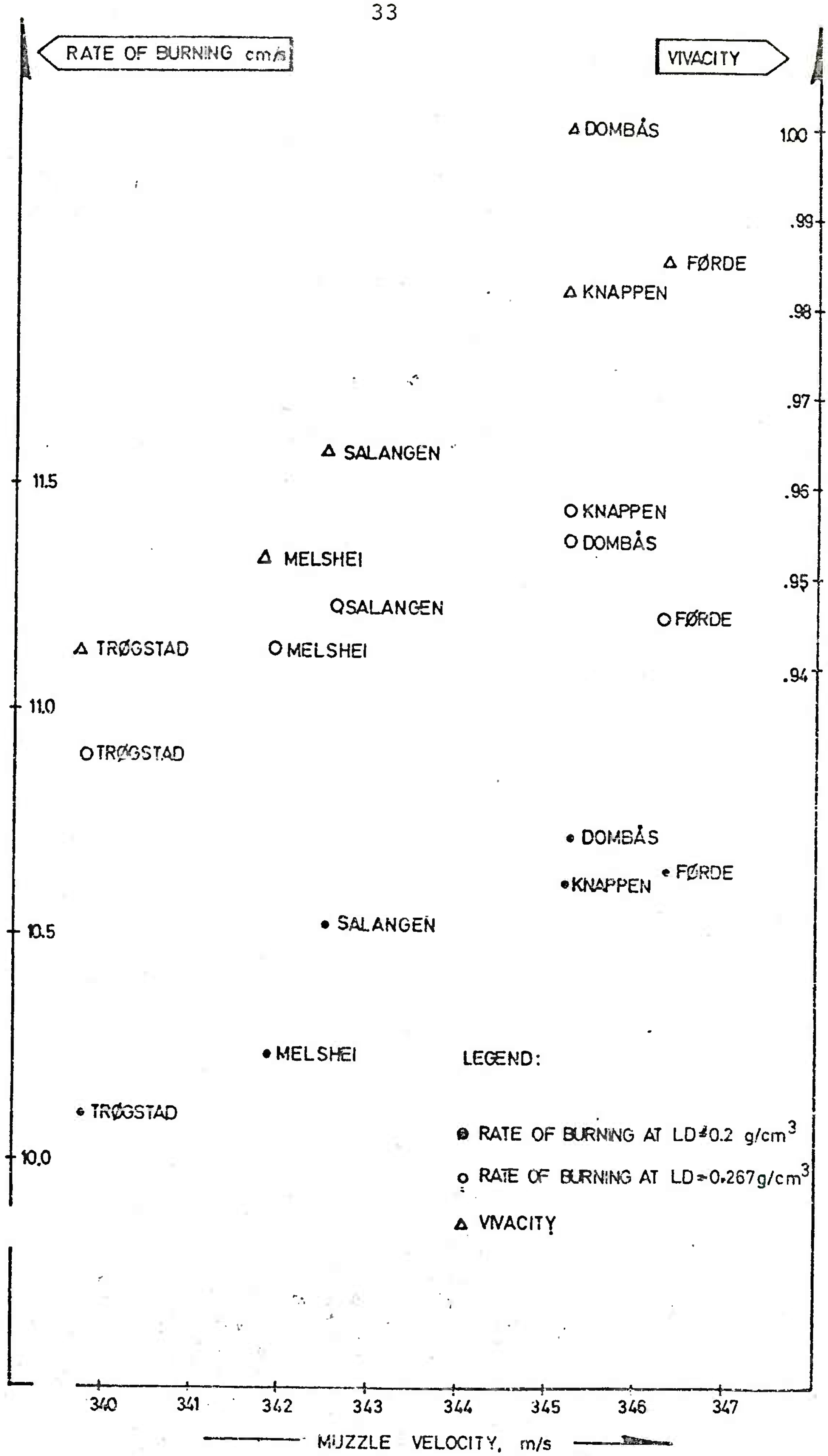


Figure 6.5 Correlation between muzzle velocity and parameters from closed vessel test 57mm