FUEL RESEARCH INSTITUTE OF SOUTH AFRICA.

TECHNICAL MEMORANDUM NO. 22 OF 1962.

WEATHERING OF ANTHRACITE.

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1. PURPOSE OF TESTS.

During 1959 it was observed that anthracite stored at the Bluff, Durban, discoloured appreciably while awaiting shipment. Since the stockpile consisted of a pooled consignment, the origin of the offending component could not be determined. Also, the opinion was advanced that this discoloration, usually of a rusty brown colour, was partially or wholly brought about by dust produced when loading manganese ore or pig iron.

Since discoloration distracted so much from the appearance of the product that it was considered to be unfit for shipment (though the intrinsic value was hardly affected) it was decided that the Fuel Research Institute should undertake a systematic investigation on behalf of the Anthracite Producers Association (Pty.) Ltd., of changes occurring in anthracite during an extensive exposure to the atmosphere.

2. THE TEST PROGRAMME:

When considering the programme it was concluded that attention should be concentrated on effects of exposure that would tend to decrease the commercial value of the anthracite, viz.:

(a) the discoloration mentioned above;
(b) the possible increase in friability of the anthracite when exposed to the sun, wind and rain. This might become evident by the formation of undersize even in the undisturbed anthracite or by enhanced degradation during handling;
(c) the possible decrease in calorific value of the fuel due to atmospheric oxidation;

(d) .../

(d) possible spontaneous heating that may occur in stacks of the fuel. Even if this does not result in an outright fire, this might lead to an appreciable decrease in the quality of the fuel.

A programme incorporating these matters was drawn up in consultation with the Association's Technical Officer. Full particulars are contained in the Institute's letter GAWvD/JAvR of the 16th. January, 1961, and the programme outlined was followed with only comparatively minor modifications.

2.1 SCOPE OF THE TESTS.

It was oringinally planned to study anthracite from three collieries, but as one of these was installing a washing plant and the anthracite available at the time might not be representative of the colliery's future output, this colliery was excluded.

Of the remaining two collieries, Natal Ammonium and Natal Anthracite, three commercial size ranges viz.: large nuts, small nuts and peas were studied separately.

It was also considered advisable to determine the effect of exposure at the collieries as well as at Durban, so as to determine whether the more humid and salty conditions at the coast would accelerate the weathering.

Bulk samples of the anthracite were to be placed in heaps at the two sites and the progress of weathering was to be followed by determining:

(a) the extent and progress of discolouration;
(b) the increase in friability;
(c) the decrease in calorific value;
(d) the tendency towards spontaneous heating.

3. MECHANISM OF TESTS.

A full description will be found in Appendix No. 1, which is a copy of instructions and explanations given to the officials concerned with the investigation. Only the main points need, therefore, be briefly mentioned at this stage.

(a) Stockpiles. .../

(a) Stockpiles.

At each colliery, a pile of approximately 40 tons, of roughly circular shape and 4 ft. high was formed for each of the three products.

At Durban, six stockpiles, again of 40 tons each, 4 feet high and about as long as a 40 ton railway truck, were deposited on a site at Bayhead, leased from the South African Railways. Although this site did not appear to be ideal (loose sandy soil, unfenced and close to the pig iron dumper), very little contamination of the anthracite by sand or rust actually occurred and there was no evidence of tampering with the anthracite by unauthorised persons.

(b) Discoloration.

At the beginning of the test, samples of fresh products were taken and kept in shallow boxes (about 18 in. x 18 in. x 4 in. deep), equipped with sliding lids. The samples that were to serve as colour standards were stored in the laboratory. The contents of each box were compared every three months with that of the coal on the dump. Colour photographs, showing a part of the dump and the anthracite in the box were taken so as to obtain a permanent record.

As far as could be ascertained, the colour of the anthracite in the box did not change.

(c) Weathering.

Suitably prepared samples (c.f. section 4 and Appendix No. 1) were deposited in shallow metal trays (approximately 36 in. x 36 in. x 3 in. deep) and exposed to the weather. Samples from these trays were taken at quarterly intervals and despatched to the Institute so that the deterioration in quality could be determined by a determination of the calorific value and the friability.

(d) Spontaneous heating.

At Durban, stack temperatures were taken by the Institute's sampler at weekly intervals. Care was taken to measure the temperatures in each stack always at approximately the same time of the day. Some observations on the weather experienced during the past week were added.

In .../

In the Vryheid area, the local technical officer of Anthracite Producers Association was to have recorded similar observations, but this part of the programme could not be ahdered to.

Temperature observations are, therefore, limited to a few readings taken by members of the Institute's staff during periodic visits to the sites, since these readings showed, without exception, complete absence of self-heating, not much information was apparently lost.

Some remarks on a bunker test in Pretoria are found in section 5.

4. ANALYTICAL TREATMENT.

4.1 The samples originating from the trays were subjected to the normal analytical procedures for the determination of calorific value, ash and moisture contents, etc. It will, therefore, suffice to refer to the results as tabulated in Tables No. 1 - 3.

4.2 Determinations of friability are not frequently made, and therefore, a full description of the adopted procedure is incorporated in this report. The principle is, very briefly, to subject a sample of accurately known size distribution to a standardised mechanical treatment. After the treatment a size analysis of the material is again carried out, and the mean sizes, before and after the treatment, are compared.

The procedure followed a method proposed by the American Society for the Testing of Materials (c.f. A.S.T.M. Standards, 1946 edition, Part IIIa, page 54).

The apparatus consists of a cylindrical drum (see Figure 1), which can be rotated at 40 revolutions per minute about the horizontal axis; 1 kilogram of the material, which must be of well known size range, is loaded into the drum which is then rotated for one hour.

The specification requires that the material be in the size range 1.06 to 1.50 inches, which clearly was not practicable in the present case. It is further considered desirable that the average size of the material

should .../

should be equal to the mean of the apertures of the two screens used to limit the size range.

Thus, for the large nuts (-60 +35mm), the mean size should be 47.5 mm. Since a screen of 47.5 mm aperture is not readily available, the material fed into the drum was made to consist of two parts by weight of particles in the range -60 +50 mm and of three parts in the range -50 +35 mm. The original sample, deposited in the weathering trays, was made up in the same manner.

On receipt of the quarterly batch, the anthracite was carefully divided, so as to minimise breakage, into the ranges -60 +50 mm, -50 +35 mm, and -35 mm. The latter represents the material already broken up by "natural" causes and is weighed but not treated further.

Of the larger material, 400 grams lots of the coarse product and 600 grams of the finer anthracite were combined to form a test batch of 1000 grams (within about 1 gram, as the finite particle size prevented adjustment to 1000 grams exactly). This batch was then tumbled in the drum.

The test was repeated until the batch was exhausted.

For the small nuts (-35 +20 mm), 333 grams of -35 +30 mm anthracite was combined with 667 grams of -30 +20 mm material; for the peas the proportions were 625 grams of -20 +15 mm, 375 grams of -15 +12 mm material. Otherwise, the treatment was as for the large nuts.

After tumbling, the material was screened as follows:

Large Nuts (			-60 +50 mm
(			-50 +35 "
(	Small Nuts (		-35 +30 "
(	(		-30 +20 "
(	(	Peas (	-20 +15 "
(	(	(	-15 +12 "
(	(	(	-12 mm +$\frac{3}{8}$ inch
(	(	(	-$\frac{3}{8}$ inch +14 mesh (B.S.)
(	(	(	-14 mesh +50 mesh
(	(	(	- 50 mesh

4.3 <u>Evaluation</u> .../

4.3 Evaluation of Tumbler Test Results.

The friability index F is defined as

$$F = 100 \left[1 - \frac{\sum_{i=1}^{n} S_i W_i}{S.W.} \right] \%$$

where S denotes the mean size of the original sample.
W denotes the weight of the original sample.

S_i the mean size of the i-th sieve range (e.g. 32.5 mm for the range 30 to 35 mm)
W_i the weight of all the anthracite in this range.

In other words, the weighted mean size of the product after tumbling, which is the sum of the product of (mean size of each sieve fraction) and (weight of material in the corresponding sieve fraction) is compared with the weighted mean size S.W. of the original product.

A high value of the index F denotes that considerable degradation in size has occurred.

In addition, the percentage of undersize material, generated during the tumbling process, was reported, (where 'undersize' means -35 mm material for the large nuts, -20 mm for the small nuts and -12 mm for peas). This expresses the tumbler test results in a manner which can be related more easily to practical experience.

Further, the weight of the 'naturally arising' undersize material is given in Tables 1 - 5.

5. SPONTANEOUS HEATING IN TEST BUNKER.

A consignment of Alpha duff was already under test in the Institute's test bunker before the present test programme had been decided upon.

The test bunker is a cylindrical metal container, 8 ft in diameter and 8 ft high, insulated by a 2 ft. thickness of slag wool. Approximately 10 tons of Alpha anthracite was placed in this bunker; air at a rate of 500 litres per hour was percolated through the charge. A number of thermocouples were placed in the tank so that the temperature rise could be followed.

After .../

After the experiment it was found that the galvanometer by means of which the temperature rise was indicated had not operated properly. Interpretation of the observations is, therefore, reduced to the statement that the temperature rose slowly, but steadily during the first two months, the maximum temperature attained being of the order of 75°C. The temperature stayed at this level for a further month and did not tend to decrease.

This result suggests that a long term storage of this product should be avoided.

6. DISCUSSION OF TEST RESULTS.

6.1 Discoloration.

The discoloration generally increased with the period of exposure, but not at a steady rate. Actually two processes could be distinguished.

(a) a general loss of gloss and lustre, giving the anthracite a drab greyish appearance;
(b) the appearance of bright yellow, brown and red spots on some of the lumps.

The first appears to be due to the formation of a thin film, partly consisting of extraneous material. This film disappeared almost completely after a heavy shower.

The second effect was permanent. Some of the coloured material was scraped off and analysed. The ash content of these scrapings was 15%, of which more than half (54%) was iron oxide (Fe_2O_3). The lump of anthracite from which the coloured material was scraped off actually had an ash content of 4.8%. of which only 4.3% was Fe_2O_3.

The formation of these coloured spots was accelerated by damp conditions, in dry weather hardly any change occurred.

In Durban, discoloration was first observed in the Natal Ammonium Large Nuts after 4 weeks of exposure. After three months some signs were also observed in Natal Anthracite Large Nuts, but discoloration only became fairly conspicuous after approximately five months. Natal Anthracite Peas resisted discoloration for a long period and remained the least affected product. On the whole, though

ultimately .../

ultimately all products were affected, discoloration was decidedly more conspicuous in the Natal Ammonium products. However, even in the worst case, that of Natal Ammonium Large Nuts, the incidence did not exceed one particle discoloured per square yard of exposed surface.

Though colour photographs were taken, these were not of much use because of the low concentration of affected particles.

Both types of discoloration were confined to surface layers of a depth of a few particles only.

At the collieries, discoloration was absent in Natal Ammonium and very slight in Natal Anthracite.

While the exact mechanism of the discoloration process has not been established, it is evident that the effect is promoted by moisture which appears to bring about a conversion of the iron compounds to Fe_2O_3, and may cause a migration of iron to the surface of the particle.

6.2 Friability.

The tumbler test is admittedly a rather artificial method of establishing the friability and it tends to give slightly variable results. In order to increase the reliability as many repeat tests as the quantity of material permitted were therefore performed. In this manner, consistent and acceptable results were obtained, with only a few exceptions, c.f. Table 1 to 3.

The main conclusions are:

Friability increases with the period of storage but is more rapid initially. Roughly, the deterioration during the first three months is as much as that in the next nine months. As one might expect, the peas are more resistant than the larger sizes.

Rather surprisingly the samples exposed in Vryheid suffered more in this respect than those exposed in Durban.

The anthracite in the interior of the dump was less affected than the tray samples, which are representative for the surface layer only. This is clearly shown by the figures in the last row in Table 3, which refer to material recovered from the interior of the dumps when the experiment was completed. Yet, the increase in friability of the

material ..../

material in the dumps was by no means negligable. One may roughly say that the friability after one year's exposure in the dump equals that obtained in the trays after three months. The amount of undersize after tumbling shows a similar increase, especially for the larger sizes.

Long term storage thus causes an appreciable deterioration in mechanical strength.

Further, it would appear that peas keep rather better in Durban than at the colliery, where spalling occurred to a considerable extent. Tentatively, one might assume that the peas, having a large surface area in relation to the mass, follow variations in atmospheric humidity more rapidly. In the Vryheid area, these variations are likely to be more extreme than at the coast. Incidentally, it may be mentioned that the air dried moisture content of the anthracite increased more in the case of the Durban samples.

6.3 Calorific Value.

The decrease in calorific value, at about 1% over 1 year exposure, is very slight and only for the tray samples does it exceed the possible errors that may arise from sampling, sample preparation and analysis.

In the dump the change is considerably lower and is so small that no reliable figure can be quoted. Originally, it was intended to obtain samples at various depths in the dump, but in view of the small reduction in calorific value, it was considered useless to do so.

6.4 Spontaneous Heating.

No hot spots or other evidence of spontaneous heating were observed in any of the dumps. For Durban, complete temperature records were obtained. The temperature observations are presented in Figure 2, which indicates that climatic variations were followed by the coal. (The air temperatures indicated were recorded at approximately 11 a.m. and may thus not be indicative of the daily mean temperature.)

Initially, the peas were 2 to 3°C warmer than the larger anthracite, but after about 2 weeks, all anthracite temperatures assumed very nearly the same value.

After .../

After one year, the same conditions as prevailing initially were found to exist, which is not indicative of spontaneous heating. During the hot season, the anthracite temperature tended to rise roughly 2°C above that of the air (at 11 a.m.), which is considered to have been caused by insolation and heat absorption rather than spontaneous heating, as no progressive increase in the temperature difference between anthracite and air was observed.

However, as indicated by the reduction in calorific value, some heat must have been generated, but the rate was too small to create an appreciable temperature rise in the small stockpiles under test.

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CHIEF OF DIVISION.

G. S. VAN EEDEN.
ASSISTANT TECHNICAL OFFICER.

PRETORIA.
12th. November,1962.

APPENDIX NO. 1.

INSTRUCTIONS FOR TREATMENT OF SAMPLES.

1. Mechanism of Tests.

While the dumps are formed, a sample is taken by means of regular increments. The sample must be at least 400 lb. There will thus be 3 samples at each colliery, 6 at the Bluff, 12 total. Store in a dry shady place until required.

As soon as feasible after the dumps have been formed, the samples are treated as follows:

The sample is spread on a clean smooth surface (preferably a concrete floor, otherwise a tarpaulin) and enough extracted (by increments spread over the entire mass) to fill the wooden box used in the discoloration test (described hereunder). Approximately 50 - 60 lb. will be required. Label and date the box so that contents may be identified.

The remainder is screened as follows:

i. Peas: screen at 20, 15 and 12 mm. discard undersize and oversize material. Recombine the screened material in the following proportions: 5 parts of -20 +15 mm material to 3 parts -15 +12 mm. Mix well, but carefully so as not to break the lumps. Two of the metal trays, used for the friability test, should be filled (± 120 lbs. total). The remainder of the correctly mixed material can be replaced in a bag, any left overs are discarded. Label and date the trays.

ii. Small Nuts: screen at 35, 30 and 20 mm. Take 1 part of -35 +30 mm to 2 parts of -30 +20mm material, and treat as for peas.

iii. Large Nuts: screen at 60, 50 and 35 mm. Take 2 parts of -60 +50 mm to 3 parts of -50 +35 mm material, and treat as for peas.

4. Discoloration ..../

4. <u>Discoloration Test</u>.

After filling the box, the lid is closed, the box carried to the dump and put on the sloping side. The lid is then opened and the box and dump are viewed from a suitable distance. See whether the colours of the dump and the contents of the box match, if necessary experiment to find most suitable angle of view and of lighting, and note full particulars thereof. The box is then closed and returned to a dry and reasonably cool place of storage.

This experiment is repeated at quarterly intervals, or more frequently if this appears to be expedient. It would be desirable to take colour photographs of the dump and box.

Should, for some reason, the contents of the box change colour, some freshly mined anthracite of the right type could be spread over a few square feet of the dump (between two boards, or in a wooden frame, which upon removal will produce a sharp boundary between fresh and exposed coal).

This alternative will only be feasible at the colliery.

5. <u>Friability increase</u>.

The coal, not loaded into trays, but returned to the bag, is conveyed to Pretoria, taking due care that no degradation occurs en route. If necessary, the quantity is reduced to a size which can be easily managed; it may be advisable to use clean sample bags (say 2 containing 30 lb. each). In Pretoria these samples are subjected to a tumbler test (described separately).

The trays are installed at a slight slope (drain holes at lowest point) in a place where they will not be tampered with, but well exposed to the weather. After 3 months, half the coal is removed. This coal must be taken from 2 diagonally opposed quarters of the tray, and the contents conveyed to Pretoria, taking the precautions indicated above.

After .../

After 6 months, the remainder is removed, after 9 months, one half of the contents of the 2nd tray; after 1 year the last anthracite is taken away, all batches being taken to Pretoria for tumbler tests.

6. Spontaneous Heating of the Dumps.

Temperatures in the dump should be checked weekly by inserting a thermocouple in the dump at various places, say on a grid of 8 ft. squares. If a hot spot is noted, more frequent observations may be necessary.

Readings should be noted in rows and columns so as to correspond with the location of the measuring points on the dump.

When performing these measurements, signs of discoloration should be looked for.

TUMBLER TEST FOR COAL

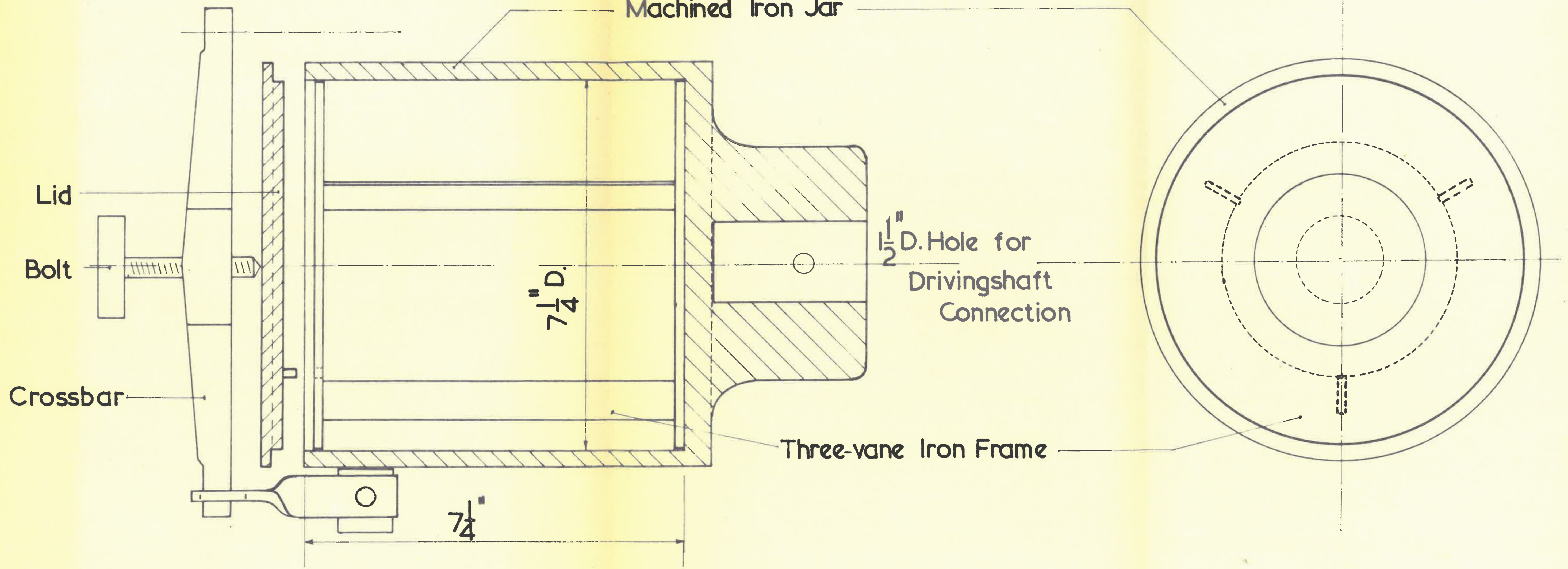
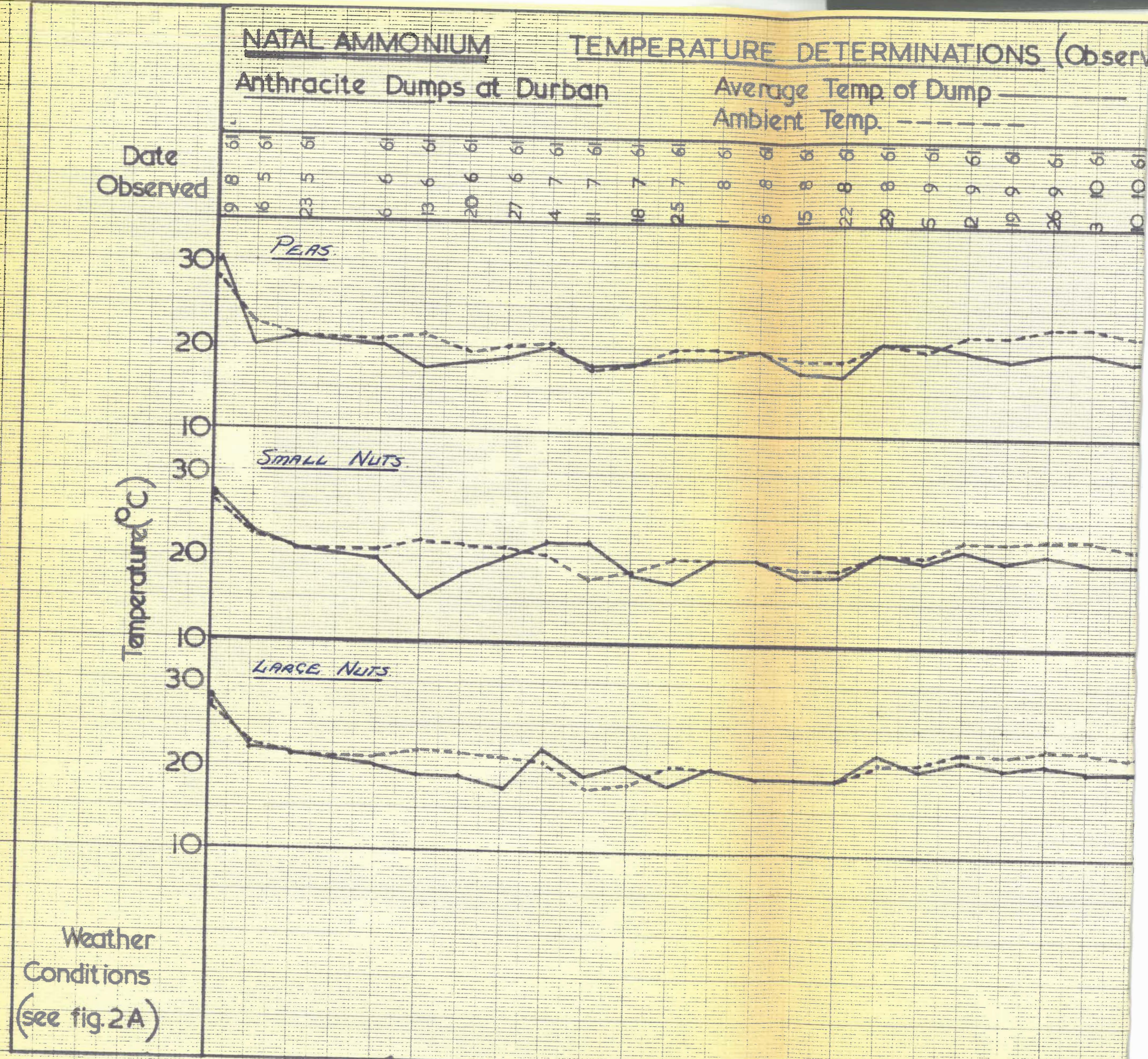


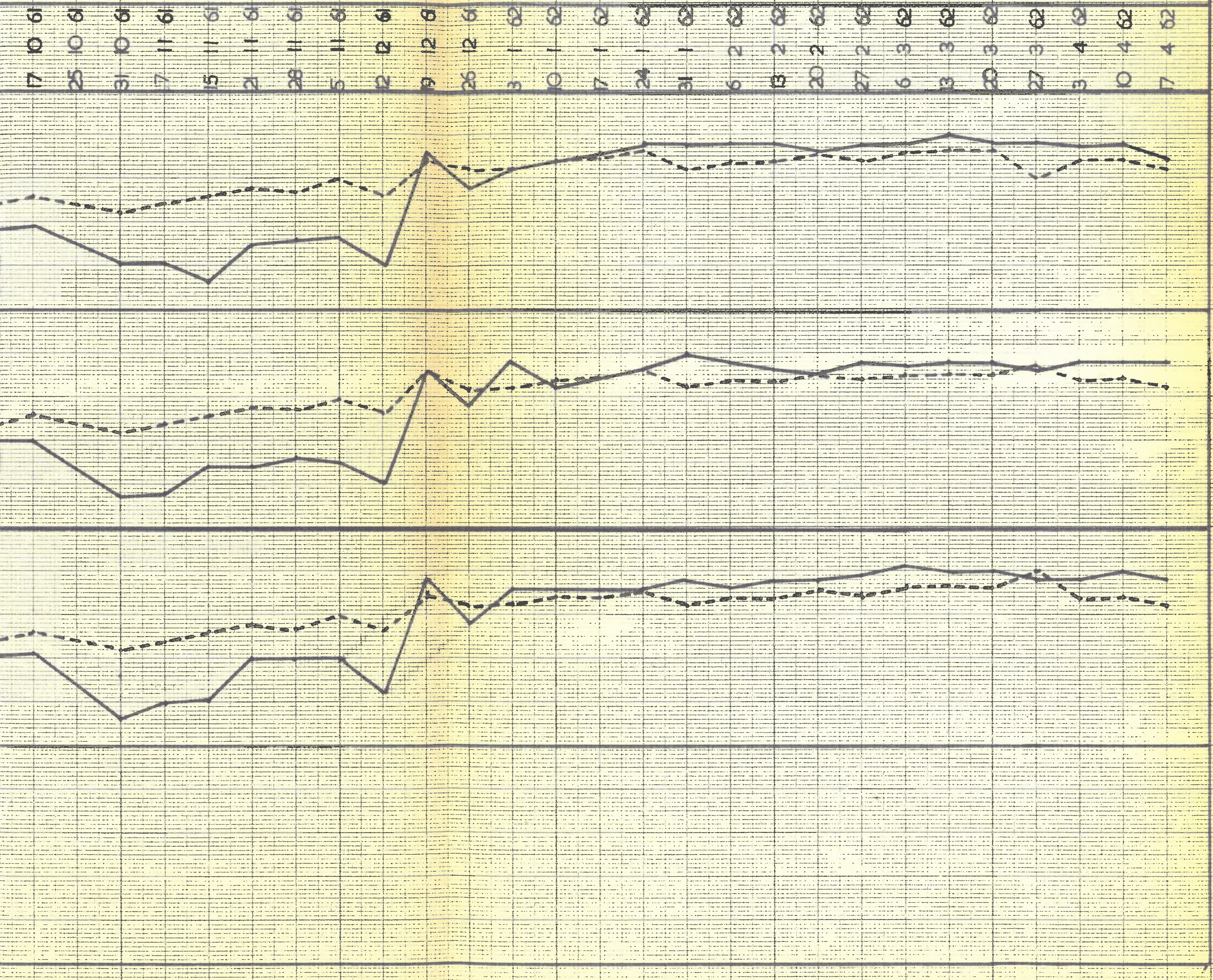
FIG.I.

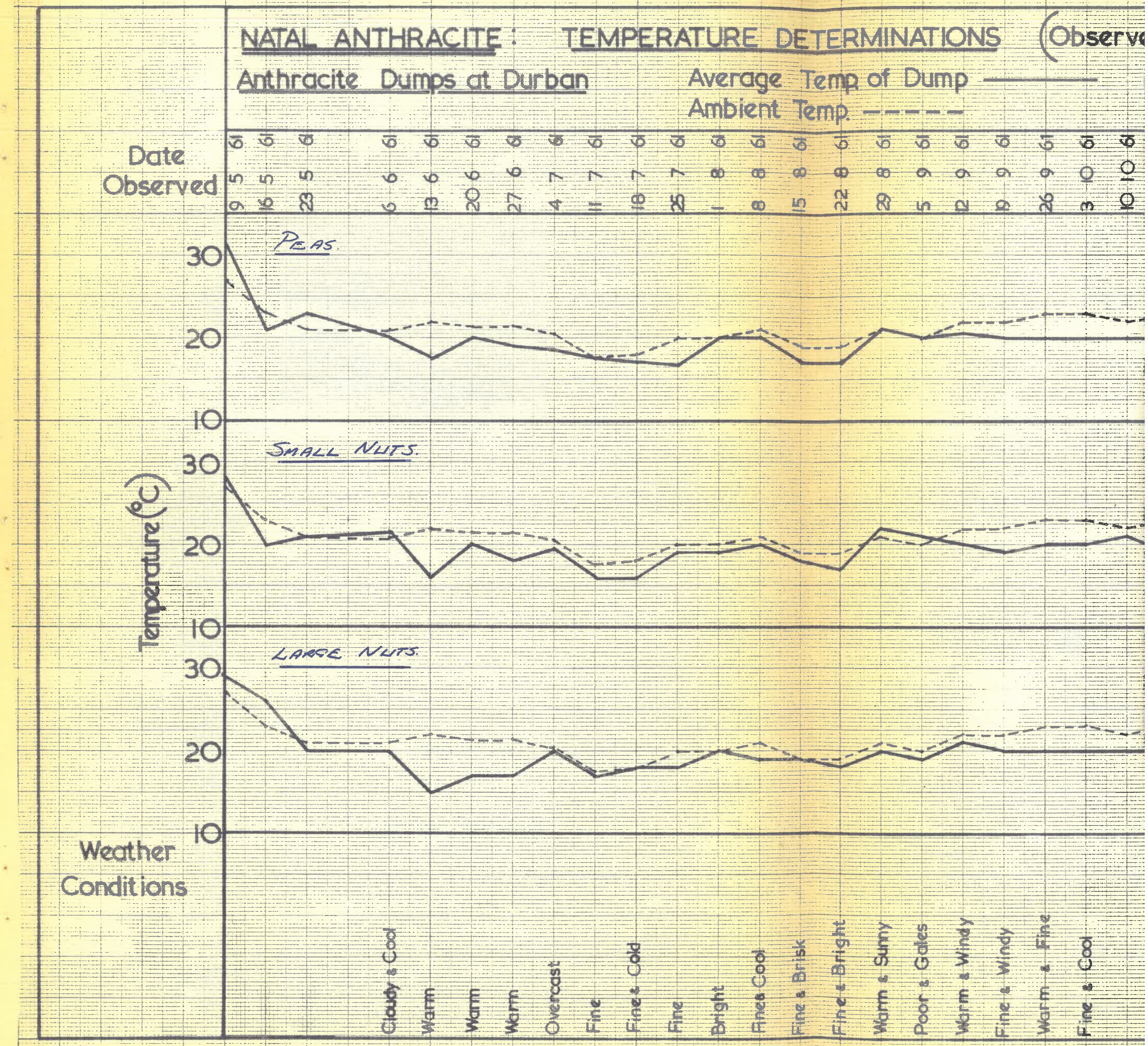


NATAL AMMONIUM
TEMPERATURE DETERMINATIONS (Observ
Anthracite Dumps at Durban
Average Temp. of Dump
Ambient Temp.
Date Observed
PEAS.
SMALL NUTS.
LARGE NUTS.
Temperature (°C)
30
20
10
Weather Conditions (see fig. 2A)

ed Weekly)

Fig 2 B.




NATAL ANTHRACITE: TEMPERATURE DETERMINATIONS (Observe
Anthracite Dumps at Durban
Average Temp of Dump
Ambient Temp.
Date Observed
Peas.
Small Nuts.
Large Nuts.
Temperature (°C)
30
20
10
Weather Conditions
Cloudy & Cool
Warm
Warm
Warm
Overcast
Fine
Fine & Cold
Fine
Bright
Fine & Cool
Fine & Brisk
Fine & Bright
Warm & Sunny
Poor & Gales
Warm & Windy
Fine & Windy
Warm & Fine
Fine & Cool

d Weekly)

Fig.2 A.