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1 Introduction

This report comprises the results from a survey of mercury and radioactivity in the production lines on the topside of Ekofisk 2/4T: the Ekofisk Tank.

The survey has been focused on identification and quantification of LSA scale and mercury contaminated areas in the production lines.

In order to properly assess correct precautions for the protection of the working environment during demolition and the best possible removal and waste storage/recycling options, special attention has been made to define the physical and chemical nature of the contaminated materials.

The survey and assessment work, including the preparation of this report, was performed by Per Varskog, Norse Decom AS.

The on-site radioactivity measurement work was performed on the installation in two rounds: 11-12 February 2005 and 02-04 May 2005.

The work was performed in comprehension with Bjørn Smits, Olav Borgar Midtveit and Eirik Jacobsen AF Decom AS.

1.1 List of Abbreviations

Al - Aluminium
Bq - Becquerel
Ca - Calcium
Cl - Chlorine
CM - Contamination Monitor
Cr - Chromium
Cu - Copper
CV-AFS - Cold Vapour Atomic Fluorescence Spectrophotometer
DNV - Det Norske Veritas
DRM - Dose Rate Meter
EWC/HWL - European Waste Catalogue/Hazardous Waste List
Fe - Iron
HDPE - High Density Polyethylene
Hg - Mercury
IFE - Institute for Energy Technology
K - Potassium
LSA - Low Specific Activity
µSv/hour - micro Sievert per hour (unit for dose rate)
µg - microgram
Mg - Magnesium
Mn - Manganese
mg/kg - milligram per kilogram
N - Number of samples
Na - Sodium
NAA - Neutron Activation Analysis
NILU - Norwegian Institute for Air Research
NRPA - Norwegian Radiation Protection Authority
O - Oxygen
Pb - Lead
PPCo - Phillips Petroleum Company
Ra - Radium
Rn - Radon
S - Sulphur
Si - Silicon
SEM - Scanning Electron Microscopy
SFT - Norwegian Pollution Control Authority
SH-12 - Strålevernhefte 12
V - Vanadium
Zn - Zinc

2 Instrumentation

2.1 Radioactivity measurements

The following instruments were used in this work to assess the presence or absence of radioactive materials:

- Instr. 1: NE Electra with DP2-probe – a contamination monitor (CM) measuring alpha/beta surface activity. Field instrument.
- Instr. 2: Automess 6150 AD6- a dose rate meter (DRM). Detection limit 0.01 µSv/h. Field instrument – here used for determination of background dose rate and screening only.
- Instr. 3: High purity Germanium detector with low-energy windows – high-resolution gamma spectrometry. Low-background laboratory – Department of Health and Safety, Institute for Energy Technology (IFE), Kjeller, Norway. The instrumentation is highly accurate and quantifies the different nuclides separately (e.g. ^{226}Ra, ^{228}Ra and ^{210}Pb).
- Instr. 4: Sodium Iodine detector with digiBASE® analysis and power supply unit. Analytical laboratory of Norse Decom AS. The instrumentation is calibrated with IAEA-standards and quantifies ^{226}Ra and ^{228}Ra separately.

2.2 Mercury measurements

The total content of mercury in the samples was determined by Norwegian Institute for Air Research (NILU), Kjeller using Cold Vapour Atomic Fluorescence Spectrophotometer (CV-AFS). Prior to analysis the samples were dissolved with suprapur nitric acid and hydrogen peroxide using microwave decomposition. The laboratory is accredited according to EN 45001 and NS-EN ISO/IEC 17025.

Mercury speciation was conducted using Scanning electron microscopy with energy dispersive X-ray spectrometer at the Department for Materials and Corrosion Technology, IFE, Kjeller.

The content of elemental mercury was determined by means of vacuum distillation followed by determination of mercury content in distillate fractions at the Department for Environmental Technology, IFE, Kjeller. The mercury determinations were performed using Neutron Activation Analysis (NAA).

3 Classification criteria – guidelines

3.1 LSA scale

In Norway Strålevernhefte 12 (SH-12) is used as a basis for classification of components and materials from oil and gas production.

Please note that the following criteria are defined independently and that they in some cases may seem to be in contradiction to each other.

3.1.1 Classification of components – Criterion 1

SH-12 defines "if the dose rate close to the equipment is higher than twice the background dose rate the equipment is to be classified as radioactive and to be cleansed as described in Ch. 3" as criterion for classification of components, tubes and other equipment.

The normal interpretation of this criterion is that it applies when the measurement is performed with a dose rate meter (DRM) on the outside of the component with the eventual radioactive material situated on the inside.

All measurements in relation to Criterion 1 are performed using a DRM type Automess AD6 (0.1 μSv/hour) (Instr. 2).

3.1.2 Classification of materials as waste – Criterion 2

SH-12 defines "if the activity concentration is higher than 10 Bq/gram for one of the substances ^{226}Ra, ^{228}Ra or ^{210}Pb, the material should be taken care of. If the activity concentrations is lower than 10 Bq/gram for all of the substances the material is free-classified." as the criterion for classification of materials as waste.

Applied in a field situation using a Contamination Monitor (CM) as the measurement device, the criterion can only be used when the CM probe can be brought in direct contact with the material/area in question.

Calibrated measurements were performed after calibration of the CM using IFE's LSA Scale Calibration Standards. The CM used in this work was a NE Elektra with DP2 alpha/beta sensitive probe.

3.1.3 Classification of components

When components are to be reused the classification is dependent on the reuse option in question. It is e.g. a substantial difference between reuse in connection with water for human consumption and reuse in oil production offshore.

In the scope of this work the classification was performed with oil industry related reuse or scrapping as the projected end use options.

For both reuse and recycling there are common practice in the industry that components should be "free of radioactivity" in any practical meaning of the term prior to entering the reuse or recycling streams.

For free-classification of a given component to be set, it was required that the component should be free classified with respect to both Criterion 1 and 2. In practice the free-classification criterion was set even lower requiring no detectable measurements above background as a general rule only allowing for small "spots" of below classification limit activity.

Due to the lower detection limit inherent in the CM measurements (Instr. 1), the classifications were based on this instrument whenever possible.

3.1.4 Classification for transport

For transport (e.g. from offshore installation to shore or transport on land) certain regulations apply as defined in the ADR/RID and the IMDG regulations.

3.2 Classification of mercury contamination

Mercury is regarded to be a highly toxic environmental pollutant. The Norwegian Pollution Control Authority (SFT) has given different classification criteria values for mercury depending on the situation and the physical appearance of the material.

An overview of a set of criteria that may be applicable here is given in SFT's "Classification of environmental quality in fjords and coastal waters". The criteria indicate that for sediment material a mercury content less than 0.15 mg/kg dry weight may be regarded as a "free classification limit" and that mercury contents higher than 5 mg/kg dry weight for such materials may be deemed as "extremely highly" contaminated. An other criterion, the SFT guideline for assessment of contamination of terrestrial ground, has a 1 mg/kg limit for unrestricted land use.

It should be noted, however, that the materials in question in this study is not regarded as "natural" materials in any way and is therefore very different from e.g. sediment material. Sediments or soil may be classified as non-contaminated and thereby be left as is. The steel and corroded materials studied here are already defined as waste leaving recycling or repository waste storage as the possible end solutions. Since no general classification criteria has been found for these materials, however, the criteria for natural materials are shown to indicate a possible agreeable mercury level. In this respect the 1 mg/kg threshold level might be viewed as a practical and safe limit as it seems to be a commonly accepted criterion. This level could therefore be regarded as the non-contamination level.

Mercury contaminated waste is classified as Hazardous Waste at mercury levels above 1 000 mg/kg. (Kartotek for kjemiske stoffer, Avfallsforskriften Ch. 11, Appendix 3, Part 1) According to the Norwegian implementation of The European waste List (EWC/HWL – European Waste Catalogue/Hazardous Waste List) namely Avfallsforskriften, the mercury contaminated materials studied here should be classified with the following waste codes:

- 16 01 08: Waste with mercury containing components.
- 16 01 17: Waste containing iron compounds.
- 17 09 01: Mercury containing waste from construction and demolition work.

The materials from the production lines will either be defined as mercury contaminated or non-contaminated. The latter is approved for recycling as scrap metal. When applying the acceptance criterion the following two factors are important to consider:

1. Chemical form of mercury.
   Mercury sulphide is considered less toxic than other mercury species.
   The presence of elemental mercury or the possibility for elemental mercury to be formed should invoke monitoring of the working atmosphere followed by protection of workers by means of fresh-air breathing equipment when necessary. This especially applies in connection with hot work.
2. Effective mercury concentration. When assessing the recycling option it is relevant to consider the mercury content as a contaminant in the steel sent for melting. Therefore the mercury concentration as found in the samples should be adjusted to also include the weight of the corresponding component steel.
   For the Debris material (for definition see Ch. 4.1) the classification is performed using the total mercury determinations without any adjustment: the effective concentration is the same as the sample concentration.

4 Sampling and measurements

4.1 Sampling

The sample material in this survey, operationally defined, consists of two different types:

i) Debris material – i.e. material easily sampled not strongly attached to the inner surface of the component. Typically this material was dispersed throughout the bottom of the samples components consisting of rust and debris sedimented within the equipment during the cleaning and flushing that was performed after shut-down (Fig. 1).

Fig. 1: Photo showing typical Debris material.

ii) Fixed material – Material that is fixed to the inner surfaces of the equipment. Samples of the fixed material are obtained by grinding it from the inner surface of the component itself (Fig. 2).

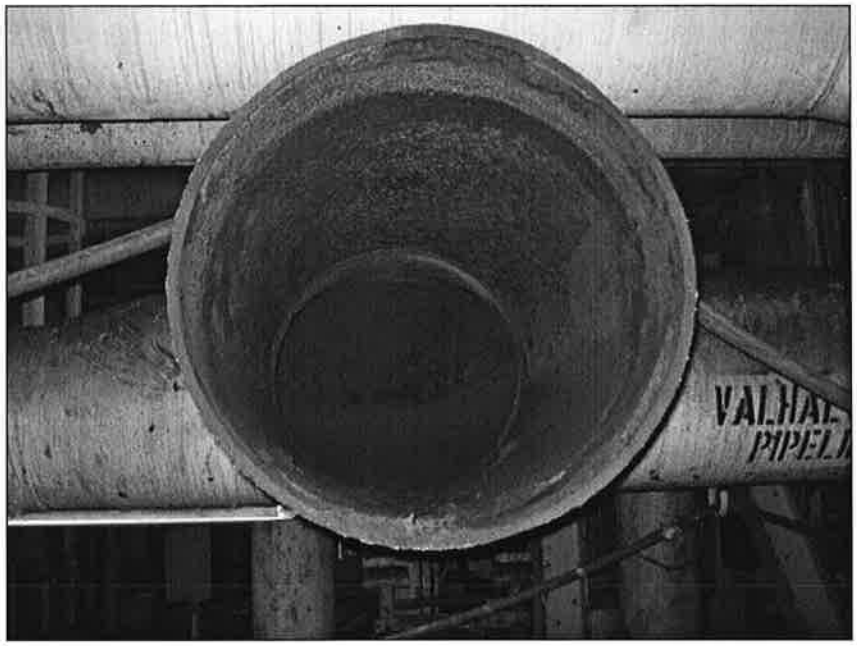

Fig. 2: Photo showing typical tube where rust material was sampled through grinding on the upper inside wall.

The samples were taken using steel brush or file and collected in plastic bags.

4.2 Radioactivity – Measurements and background

The background activity was repeatedly measured throughout the duration of the classification work. Typically the background was measured with the instrument kept 1.0 meter from the actual measurement area. The background activity level was always found to be in the region < 0.01 μSv/hour for the DRM (Instr. 2). Background measurements using the CM are given in Table A2.

Measurements using Criterion 1 were performed with the instrument in direct contact with the measured object. In this study there was no need to perform classifications using Criterion 2.

The summarised results from the radioactivity measurements (Table 1), both on-site and laboratory, show that LSA scale is present only in two units: The oil metering system (Unit 208) and the 32" Oil Export Pipe leaving the tank towards 2/4 P. It seems reasonable to believe that LSA scale in fact is formed from the Oil metering system and onwards. The LSA scale in the export pipe seems to have been formed on the lower third of the pipe cross-section indicating the possible existence of a small water phase in the tube. This is supported by what is seen by visual inspection (Fig. 3) and the absence of radiation on the upper tube walls as measured with the CM instrument. An additional sample (A-35b) was taken in the rust covered part of the pipe above the LSA scale covered bottom part. This sample did not contain measurable amounts of radioactivity (Table A2).

As seen in Fig. 4 the LSA scale in the Oil Export Pipe has a physical appearance that makes it easy to be removed by mechanical methods like scraping or grinding. While doing this, it is

important to protect workers in near-zone with dust masks to avoid inhalation of radioactive dust. The actual work should be performed within a radiologically defined Controlled Area. After removal of the LSA Scale, the cleaned pipe should be controlled and free-classified with the use of a CM instrument (e.g. Instrument 1).

Table 1: Summary of the results from the measurements of radioactivity in the production lines on 2/4T topside (See Table A2 for detailed results). The table comprises the results from both the on site and the laboratory measurements.

Unit No.	Unit Description	N	Classification	Remarks
A28	Water Drain Vent Tank	1	Not active	
201	Dry Gas Separator (pipe)	1	Not active	
202	Interstage Separator	1	Not active	
206	Crude Oil Coolers	2	Not active	
208	Oil Metering	12	Active, below limit	Slightly active scale in whole system
211	Gas to Gas Exch.	3	Not active	
214	Dehydration A	4	Not active	
215	Dehydration B	4	Not active	
216	Dehydration C	3	Not active	
222-1	Condensate Drain System	3	Active, below limit	1 loc. slightly active
301	West Ekofisk Separator	1	Not active	
302	Low Stage Separator	1	Not active	
303-2C	Dew Point No. 1	1	Not active	
315	Gas Pipeline Cooler	1	Not active	
350-D	Pipeline 48m Deck	1	Not active	
2/4-P	Export Pipe Papa Side	1	Active	

Usually, the radioactive lead isotope, ^{210}Pb, is present in "ordinary" LSA scale as a result of in-growth from ^{226}Ra. Ordinary LSA scale is formed during oil production in the presence of water; the formation mechanism being an ordinary precipitation of aqueous Group II cations.

During gas production, however, little or no water is present. While preventing formation of LSA scale precipitates, the fairly non-polar chemical environment in the gas stream facilitates and stabilises the non-polar daughter of ^{226}Ra: ^{222}Rn (radon gas) leading to the possibility of "lead-scale" formation. The lead scale can be formed when elemental ^{210}Pb from radioactive decay of ^{222}Rn is deposited on the inner steel walls of the production equipment. The lead scale, if present, is not found in visible amounts, but can be detected using contamination monitors (CM) or by gamma spectrometric analysis in the laboratory. The on-site measurements in this study would have revealed the presence of lead scale if there had been any. The non-existence of lead scale" on 2/4T topside is also supported by the laboratory measurements (Table A2).

Using measurements of the thickness of the material in the sample from the Oil Export Pipe (Sample A35) and the visual evidence of the abundance of the scaling (Fig. 4) the amount of LSA Scale in the Export Pipe could be estimated as follows:

- Scale thickness and density: 5 – 10 mm and X.Y g/cm^3, respectively.
- Abundance: ¼ of tube circumference (tube diameter 32").
- Tube length: 100 m
- LSA Scale mass: 830 kg (8.3 kg/meter tube).

Fig. 3: Photo of an opening in the oil metering system (A-19) containing scale below the free-classification limit.

Fig. 4: Photo of LSA scale at the bottom of the oil export pipe on the Papa side.

4.3 Mercury measurements

Due to the differences in toxicity and environmental hazard between the different Hg species samples were also subjected to additional analyses (beside total mercury analysis) in order to determine the chemical form of mercury in the studied systems, so-called mercury speciation (see 4.3.2 and 4.3.3).

When assessing possible methods for removal of the mercury contaminated material and the associated means for protection of the working environment it is also very useful to have information on the mercury speciation and the material's physical appearance and to know whether or not elemental mercury is present.

4.3.1 Total mercury concentrations

A frequency diagram showing the statistical distribution of the mercury content in the Debris samples are given in Fig. 5. The distribution shows the typical characteristics of a log-normal distribution with many extreme values. As the figure shows using the arithmetic mean as a mean value estimator would lead to a large overestimation of the "true" mean. For log-normal distributions the geometric mean is usually used as the mean value estimator. In this study, for the above-mentioned reasons, the geometric mean is used to represent the "mean value".

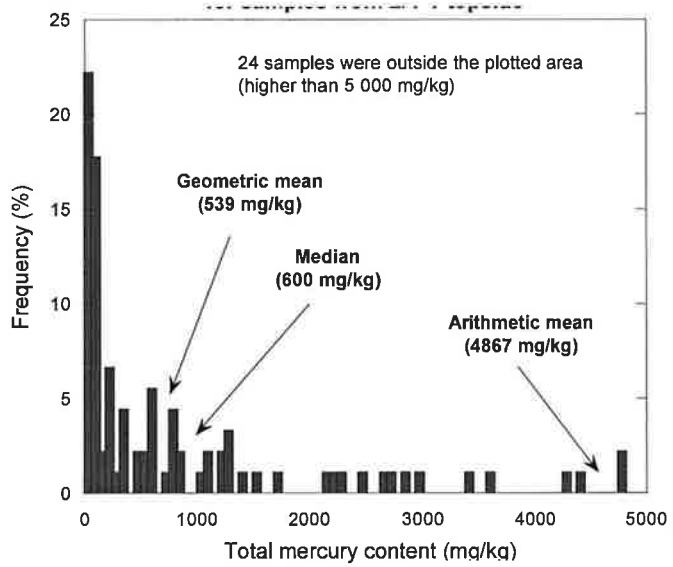

Fig. 5: Frequency diagram for total mercury content for 114 samples from 2/4T topside.

The results of the mercury analyses (Table 2) show that mercury contamination is present in all sampled units on 2/4T topside. The mercury concentrations may be considered to be high above what is usually defined as normal levels (Table 2). The average mercury concentration for all sampled systems based on the Debris samples was found to be as high as 538 ± 1 318 mg/kg. As seen from the values given in Table A3 and the calculated standard deviation (Table 2) the material is quite inhomogeneous with respect to the content of mercury.

The large variability most probably masks any trends and gradients in mercury concentrations that might be present throughout the systems and it therefore seems fruitless to further discuss the mercury data with respect to differences or similarities between the different production units. One thing seems fairly clear, though: the mercury concentrations seem to be lower in the oil containing systems than the gas systems.

Table 2: Summary of the results from the measurements of mercury samples of debris in the production lines on 2/4T topside (See Table A3 for detailed results). The table comprises the results from both the ND and the DNV study. The mean value estimators Arithmetic Mean, Geometric Mean and Median are all given for comparison (see Fig. 5). When possible ($N \geq 2$) Standard Deviation and Standard error of the mean ($N > 2$) were calculated for the individual investigated production units.

Unit	Unit Description	N	Mean Value Estimators			Uncertainty Estimators	
			Arithmetic	Geometric	Median	Std. Dev.	Std. Error of Mean
A28	Water Drain Vent Tank	2	74 385	52 581	74 385	74 409	
201	Dry Gas Separator (pipe)	1	367	367	367		
202	Interstage Separator	2	4 069	3 613	4 069	2 647	
203	Low Stage Sep. Pump	2	945	932	945	219	
206	Crude Oil Coolers	2	6 358	118	6 358	8 990	
207	Propane Reclaimer	1	40	40	40		
208	Oil Metering	14	295	84	83	603	161
211	Gas to Gas Exch.	3	22 124	17 949	20 472	15 693	9 060
214	Dehydration A	5	7 656	3 306	5 092	7 821	3 498
215	Dehydration B	11	3 812	384	296	10 643	3 209
216	Dehydration C	6	6 153	748	1 789	11 920	4 866
217	Propane Scrubber	2	1.9	1.7	1.9	1.1	
218	Flash gas scrubber	4	3 523	2 663	3 900	2 170	1 085
219	Glycol & Lube Oil Storage	3	82	80	90	16	9.4
222A	Valhall and Ula line	4	969	348	453	1 334	667
222B	Condensate Drain System	2	1 079	191	1 079	1 501	
301	West Ekofisk Separator	4	631	265	400	752	376
302	Low Stage Separator	1	1 300	1 300	1 300		
303	Dew Point No. 1	4	16 003	7 279	8 856	20 153	10 077
304	Stab Comp Recyc Cooler	3	6 500	6 475	6 500	700	404
307	Pipe No 3 HP Flare	1	1 300	1 300	1 300		
308	Pipe No.4 HP Flare	3	5 223	3 191	7 500	4 030	2 327
309	Propane No 2	2	411	232	411	479	
310	F/G Suction	2	4 800	4 648	4 800	1 697	
314	Gas Scrubbers	5	819	401	830	645	288
315	Gas Pipeline Cooler	2	16 386	11 034	16 386	17 132	
318	Hot Oil Return (48m D.)	1	43	43	43		
350A	Booster	8	444	175	321	475	168
350D	Pipeline (48m D.)	2	2 420	612	2 420	3 312	
1000	Bridge: Tank to Papa	6	1 063	275	204	2 083	850
1500	Bridge: G to Tank	1	190	190	190		
2000	Bridge: Riser to Tank	5	1 662	789	460	2 453	1 097
Total		**114**	**4 867**	**538**	**600**	**14 075**	**1 318**

The mean values calculated in Table 2 are based on a division of the samples referring to the spatially defined Units on the 2/4T topside. While this is a practical division seen from a decommissioning point of view it becomes more difficult to follow and make use of production-oriented knowledge in the interpretation of the mercury data. This study, however, focuses on the aspects important when dismantling the topside components and the Unit-based might be useful to implement precautions and make priorities during the actual dismantling work that will be more spatially oriented than production oriented.

In order to determine eventual differences in mercury content between the Debris material and the Fixed material (the material still attached to the inner steel surfaces) a comparison between these two materials were made. The results shown in Table 3 demonstrate that Debris material contains almost 5 times as much mercury as Fixed material. Also taking into account that there is at least twice as much Debris material than the Fixed material still attached to the steel walls, it seems likely to believe that more than 95 % of the total mercury mass in the production units is contained in the Debris material.

Table 3: Comparison of the mercury concentrations in samples of Debris material and Fixed material. The comparison is done to investigate possible differences in composition with respect to mercury content between the two material types.

Sample Location	**Hg Debris (mg/kg)**	**Hg Fixed (mg/kg)**	**Debris : Fixed Ratio (Multiples)**
2	338	62	5.5
5	30 367	8 322	3.6
6	2 478	290	8.5
10	10 597	3 279	3.2
87	770	81	9,5
101	46	43	1.1
102	*6500*	*7200*	*0.90*
Mean			**4.6**
7	2 846	4 370	0.65
7b		23 000	
7c		14 200	

When investigating the sample material in the laboratory it became clear that especially the Fixed material sample from Location 7 also contained great amounts of black scale flakes in addition to the typically red rust. Two extra sub samples of the black flakes from Fixed material at location 7 were therefore analysed in addition to the original sample aliquot. The results (Table 3, 7b and 7c) showed that this material indeed was heavily contaminated with mercury. It is probable that differences in mercury concentration between samples in this study (Table 2, 3 and A3) to a large degree can be explained by differences in the "flake : rust ratio" for the same samples. This topic is further discussed in connection with Figs. 9 and 10.

Even though the material at Location 7 may be viewed as an exception, other sampling locations did not have the same large occurrence of the black material on the inner tube walls, it elucidates some of the limitations of using operationally defined material definitions: Debris and Fixed material. This topic is further discussed in Ch. 4.3.4. pt. 5.

4.3.2

Mercury speciation

Three samples with high mercury content were selected for further investigation using Scanning electron microscopy with X-ray spectrometer in order to reveal the physical distribution and speciation of mercury in the samples.

Table 4: Elemental composition of the SEM investigated material of three samples. Data are given in atom %. The corresponding mass concentration in weight % is given in brackets.

Element	Sample A-3	Sample A-5	Sample A-8
Oxygen (O)	64.8 (36.0)	66.2 (38.83)	69.9 (39.3)
Sodium (Na)	2.3 (2.6)	1.6 (1.2))	1.8 (1.4)
Silicon (Si)	0.8 (0.8)	0.4 (0.4)	0.5 (0.4)
Sulphur (S)	2.8 (3.1)	0.7 (0.6)	0.7 (0.7)
Chlorine (Cl)	0.6 (0.7)	3.2 (3.3)	2.9 (3.2)
Chromium (Cr)	0.2 (0.3)	0.0 (0.0)	0.02 (0.04)
Iron (Fe)	26.7 (51.8)	24.8 (45.5)	22.3 (43.8)
Copper (Cu)	0.0 (0.0)	0.2 (0.5)	0.06 (0.1)
Zinc (Zn)	0.1 (0.3)	0.2 (0.5)	0.1 (0.3)
Cadmium (Cd)	0.1 (0.4)	0.06 (0.2)	0.02 (0.09)
Mercury (Hg)	0.07 (0.5)	1.8 (11.6)	1.44 (10.1)
Lead (Pb)	0.5 (3.6)	0.0 (0.0)	0.0 (0.0)

An overall investigation of the three samples indicated the same physical and chemical characteristics in all samples (Table 4). Further investigation was thereafter continued with detailed analysis of material from sample A-5.

The element distribution data from the SEM analyses as shown in Table 4 (and also Table 5 and 6) should primarily be used to assess the chemical composition of the investigated material. The data in Table 4 represents mean values for element distribution for particles in an area as e.g. shown in Fig. 6. With data given in "atom %" it is possible to guess which compounds that are most likely to be present. The data, therefore, are always assessed with a background of relevant chemical knowledge and knowledge regarding the systems studied. It should also be noted that what is studied here is amorphous particles i.e. particles without an exact stoichiometric composition.

As shown in Table 4 the elemental composition indicates that the dominating material, not surprisingly, is oxidised iron: rust. It may be important to note that the data implies that also other heavy metals than mercury may be present in significant amounts, i.e. copper, zinc, cadmium and lead.

SEM data is not regarded to be accurate at these low concentrations (< 1%). If the contents of heavy metals other than mercury is to be investigated, this should be done using other analytical methods e.g. spectrophotometric methods.

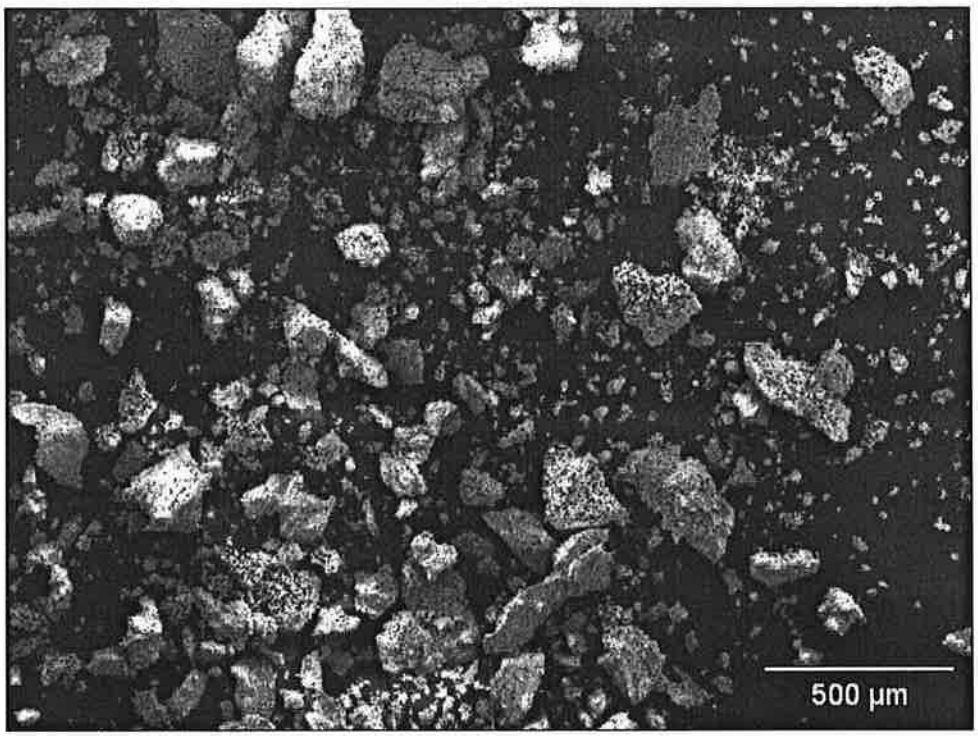

Fig. 6: Identification of mercury containing particles using X-ray spectrometer element mapping in connection with Scanning Electron Microscopy (SEM). High mercury content shown as green dots. Sample A-5.

As shown in Fig. 6 the mercury is unevenly distributed: some particles contain mercury, some don't. This again explains the large differences in total mercury content that is found both in this study (see 4.3.1) and the DNV study (DNV, 2005).

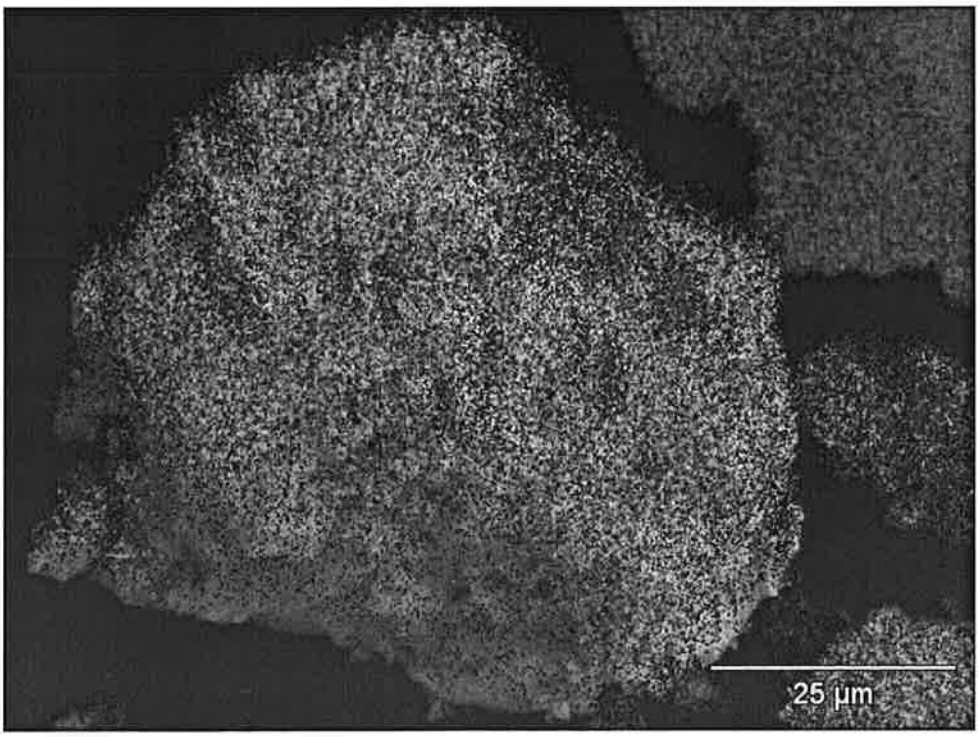

Fig. 7: Picture showing mapping of mercury (green) and iron (red) on particles from sample A-5. The mercury is clearly shown as being a surface coating. The red area in the upper right corner is a rust particle without mercury coating.

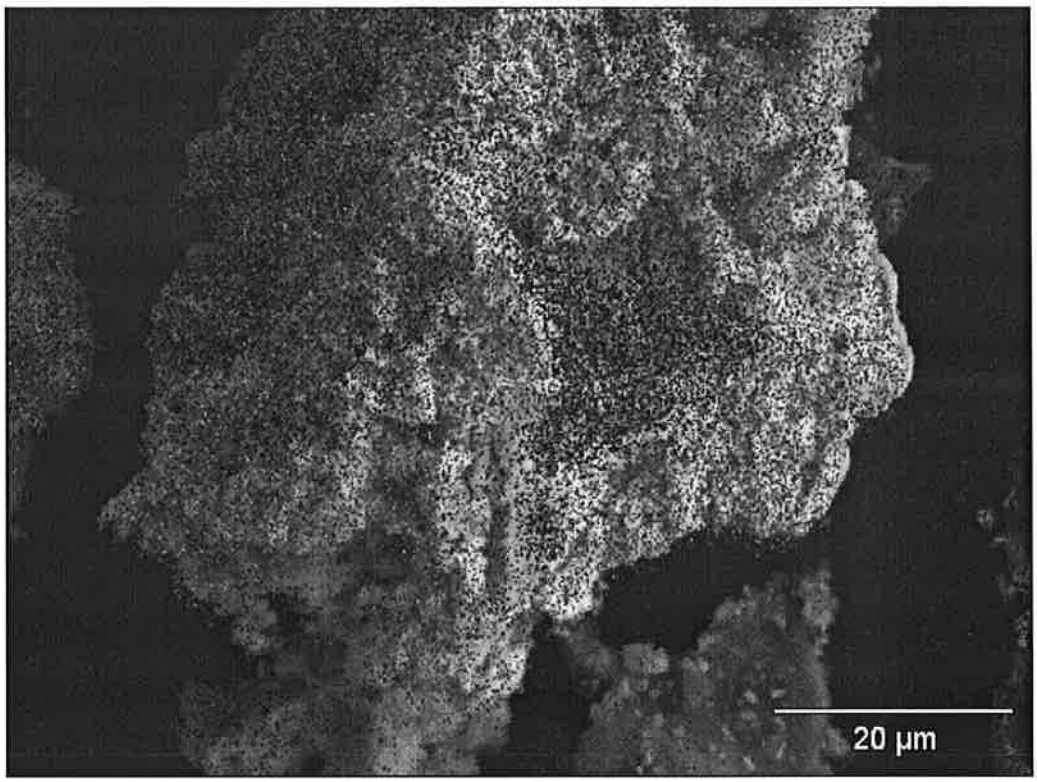

Fig. 8a: SEM picture showing mapping of mercury (green) and iron (red) on a selected particle from sample A-5. As in Fig. 5 the mercury is clearly shown as a coating on the surface. Analyses of the elemental composition at 8 different spots (see Fig. 7b below) were performed (See Table 5).

The mercury (Figs. 7 and 8a) clearly shows that the mercury is found as a thin layer (coating) on the surface of the mercury containing particles.

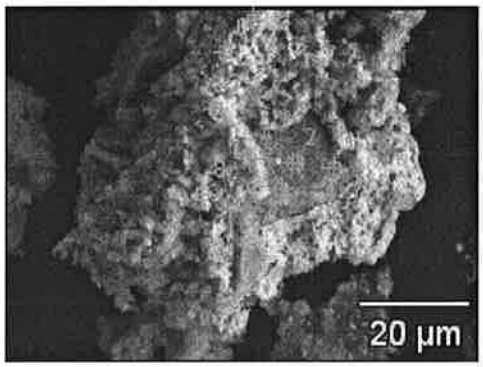

Fig. 8b: SEM picture showing the location of the spots where elemental analysis was performed.

To investigate the speciation of mercury individual element analyses were performed at 8 different locations (points) on the particle shown in Fig. 8a. The 8 points are indicated in Fig. 8b.

The analyses (Table 5) show that pt.1 and 2 consists of rust while 3 – 8 is composed of mercury sulfide with some chlorine. The presence of iron and oxygen at these points is most probably a result of X-ray penetration also into the rust below the mercury coating.

Table 5: Distribution of selected elements at 8 sample points on particle from sample A5 (fig. 5). Elemental data are given in atom %. The results show that pts. 1 and 2 consists of rust, while Pts. 3-8 consists of mercury sulphide with some association with chlorine.

	O	Na	Al	Si	S	Cl	Cr	Mn	Fe	Cu	Zn	Hg
Pt 1	64.68		0.92	0.50	0.36	0.10	0.00	0.22	32.83	0.08	0.05	0.20
Pt 2	62.9		0.82	0.42	0.44	0.13	0.00	0.24	34.61	0.09	0.00	0.27
Pt 3	63.20	0.00	0.71	0.45	0.68	0.18	0.00	0.23	33.94	0.03	0.03	0.35
Pt 4	48.37	0.55	2.31	0.22	12.41	6.13	0.04		18.64	0.15	0.05	11.12
Pt 5	43.43		2.80	0.21	19.23	7.50	0.00	0.19	9.62	0.28	0.00	16.74
Pt 6	50.66	0.42	1.99	0.40	12.13	5.48	0.04		17.79	0.12	0.00	10.97
Pt 7	45.64	0.65	2.62	0.27	16.82	5.59	0.05		13.99	0.22	0.03	14.13
Pt 8	51.67		1.69		12.28	4.20	0.00		19.98	0.18	0.11	9.88

The mercury most probably originates from deposition of mercury onto steel surfaces when in contact with the gas stream containing dissolved elemental mercury (Hg^0). During the years of production the outermost layer of the steel walls inside the production equipment may be regarded as having been saturated with mercury. After shutdown hydrocarbon residues in tubes and equipment were cleaned out and the systems were opened in numerous places thereby exposing the inner surfaces to the surrounding corrosive marine atmosphere.

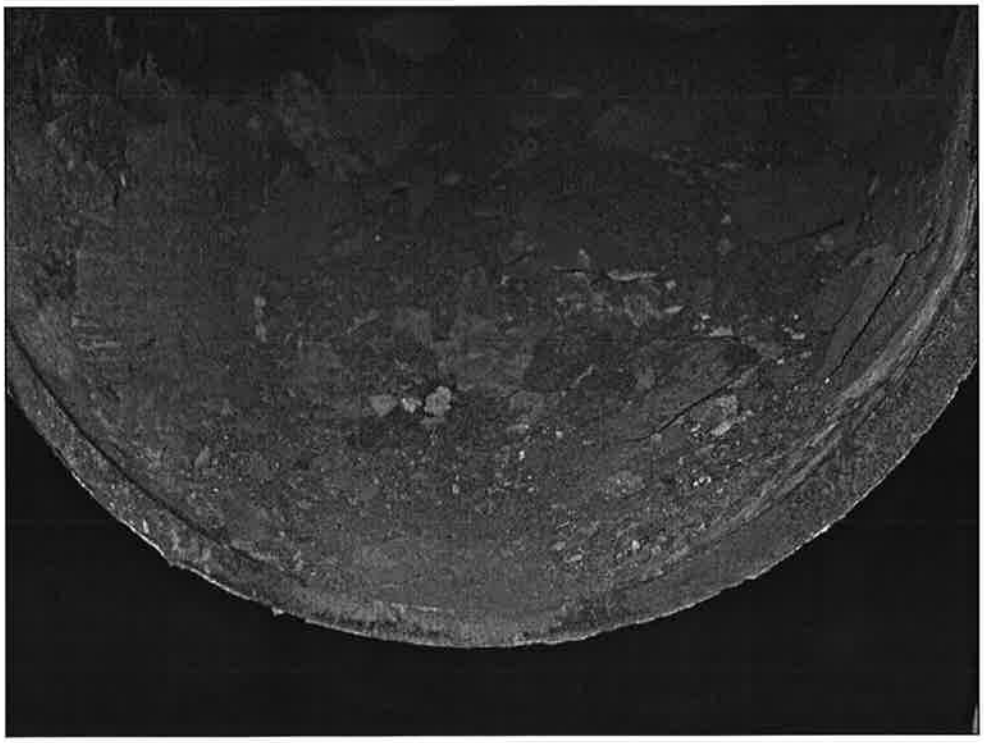

Fig. 9: Photo showing the scale flakes of corroded material at A-5. Note the black colour of the flakes.

The result is what is seen in Fig. 9: scale flakes of black coloured material mixed with ordinary rust. Black colour is typical for heavy metal sulphides, but black would also be the colour for solid materials coated with tar and wax.

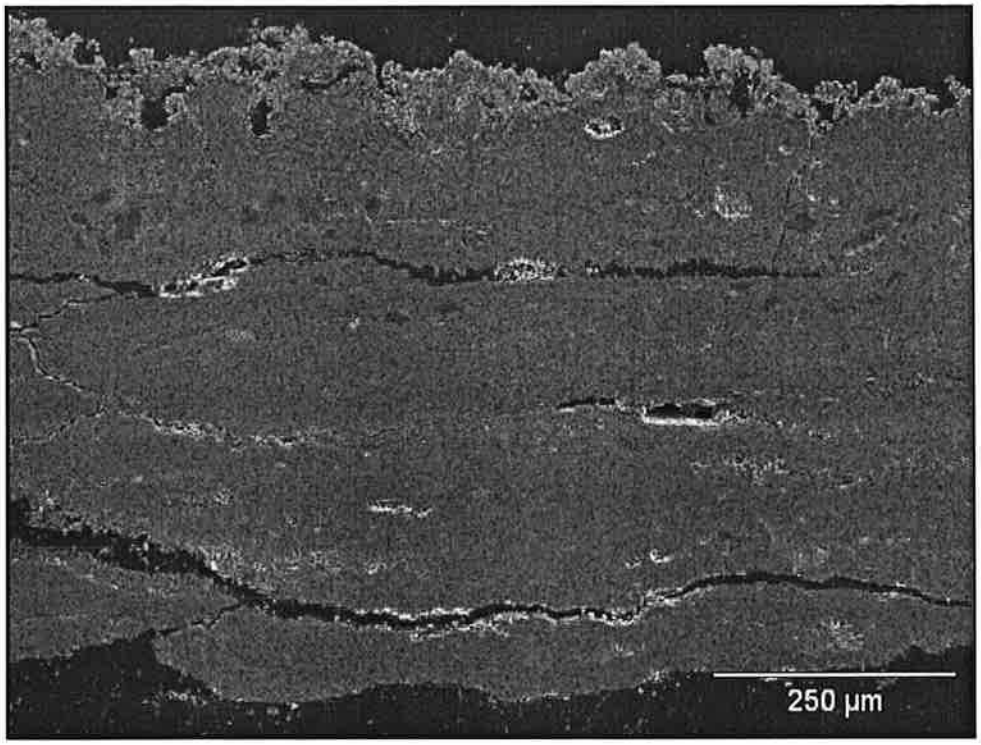

Fig. 10a: SEM picture showing mapping of mercury (green) on a cross-section of a scale flake from sample A-5. The mercury is clearly visible as a thin layer (30 – 60 µm) on the surface of the 0.6 – 0.7 mm thick scale flake. Analyses of the elemental composition at 10 different spots (see Fig. 9b below) were performed (See Table 6).

To further investigate the composition of the "black material" a scale flake from sample A-5 was moulded in a plastic composite material and subjected to element analysis of a cross-section of the flake using the Scanning Electron Microscope. A SEM picture of mercury mapping of a flake section area (Fig. 10a) shows that the mercury is associated with a thin layer (30 – 60 µm) on the outer surface of the flake.

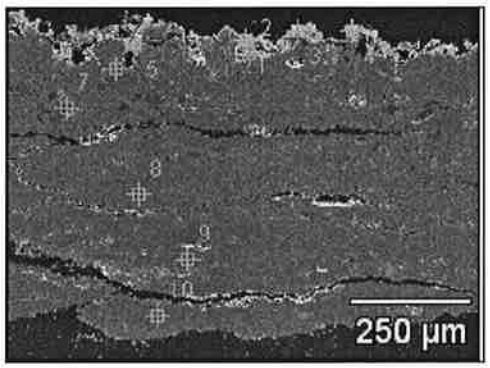

Fig. 10b: SEM picture showing the location of the 10 spots where elemental analysis was performed on the cross-section of the scale flake (See Fig. 10a).

The element distribution at 10 point of the same cross-section (Fig. 10b) were determined (Table 6) identifying the mercury rich surface (Pts. 1 – 4) as consisting primarily of mercury sulphide. Pt. 5 seems to represent an intermediate region where also iron is present in the sulphide form. The element distribution of Pt. 7 bears the characteristics of clay or sand. Pts. 6 and 8 – 10 show the element composition typical for rust as also was seen in Table 5.

Table 6: Distribution of selected elements at 10 sample points on a cross-section of a scale flake from sample A5 (fig. 9a). Elemental data are given in atom %. The results show that pts. 1 - 4 consists of mercury sulphide associated with chlorine, while Pts. 6, 8 - 10 consists of rust. It should be noted that the oxygen data for point 1 – 4 is probably due to noise from the rust and the surrounding plastic.

	O	Na	Mg	Al	Si	S	Cl	K	Ca	V	Mn	Fe	Cu	Hg
Pt 1	41.47			1.38	0.34	27.69	5.35					0.00		23.78
Pt 2	49.39			1.45	1.78	21.90	6.13		1.58			0.00		17.78
Pt 3	39.77			1.07		30.70	4.78					0.00		23.67
Pt 4	21.94			1.46		43.76				0.12	0.40	0.00		32.32
Pt 5	46.65			0.82	0.08	23.79	3.36				0.12	7.53		17.65
Pt 6	63.32		0.36	0.35	0.30	1.46	0.32		0.14		0.63	32.96		0.18
Pt 7	66.48	0.64		6.82	19.83	0.03		5.81				0.39		0.00
Pt 8	67.47			0.31	0.39	0.09					0.35	31.33		0.06
Pt 9	69.29			0.29	0.62	0.30					0.69	28.61	0.16	0.04
Pt 10	66.85			0.36	0.56	0.26				0.09	0.24	31.63		0.01

In order to check the validity of the SEM analyses a new round of SEM analyses were performed on 9 samples. The results from the new round confirmed the conclusions that were made based on the first round as described above. The SEM data from the second round of SEM-analyses are given in Appendix 3.

The identification of mercury in the form of mercury sulphide clearly indicates that the mercury that has been deposited on the inner steel surfaces were oxidised in the presence of sulphur-containing compounds before shut-down of production. After shut-down there has been little or no sulphur present that could facilitate the formation of mercury sulphide.

SEM-photos of cross-sections of Debris material flakes were also obtained during the SEM analyses. These photos and data as used to determine average thickness of Debris material is given in Appendix 2.

4.3.3 Elemental mercury

Apart from some of the organic mercury compounds (e.g. dimethyl mercury) mercury in its elemental form is regarded as the most hazardous mercury species.

Elemental Hg is highly adsorptive and adsorbs on metallic surfaces and on solid materials suspended in liquids. It reacts with iron oxide products (corrosion products) on pipe and equipment walls (Wilhelm and Bloom, 2000). As shown in Ch. 4.3.2 the present mercury has been identified to be in the form of mercury sulphide.

Elemental mercury forms drops that are quite easy to see by eyesight. There have been no observations of mercury drops neither during the sampling, during sample preparation or during the SEM analyses.

At the time the samples in this study more than four years has passed since the production lines were cleaned and thereafter opened in numerous places for giving access for fresh air to pass through production tubes and equipment. Due to the corrosive properties of the marine atmosphere, this continuous air stream through the systems has facilitated oxidation of the inner surfaces leading to the formation of rust from the component steel. It is deemed likely that any small or dispersed amounts of elemental mercury that (possibly) were present four years ago in these systems, now have been oxidised in the same way.

A possible exception is eventual drains or sinks where larger amounts of mercury could have been collected. These collections of mercury could (if they exist) be too large for all the

mercury to have been oxidised. No such drains or sinks were found during the two sampling rounds, but their existence cannot be ruled out especially in vessels with, until dismantling during decommissioning, limited or no access.

For use in this study a method for measurement of the content of elemental mercury in the samples was implemented at IFE to distillate any elemental mercury present in samples without decomposing or otherwise evaporate other mercury species. The distillation was carried out under low pressure at between 80 – 100 °C. The eventual evaporated mercury was collected in a cold-trap cooled with liquid nitrogen. Sample aliquots of four samples known to have high mercury content were selected for distillation. In addition an extra aliquot of one sample there was added a drop of liquid mercury to test the experiment setup. Each sample was held at the evaporation temperature for 2 hrs, and the eventual mercury vapour was collected in 0.2 g of aluminium thin foil at the bottom of the cold-trap. After end of experiment the aluminium foil was analysed with respect to mercury by NAA. The results (Table 7) show that elemental mercury was found in the cold-trap after distillation in one of the four samples (sample A5).

Table 7: Result from experiment to identify elemental mercury in samples by vacuum distillation.

Sample	Found in distillate
A14 one droplet Hg added	3 µg mercury
A5 no spike added	8.6 µg mercury
A8 no spike added	No mercury
A14 no spike added	No mercury
A33 no spike added	No mercury

The results in Table 7 are difficult to interpret. The A5 sample might however be viewed as a positive finding even if it should be regarded at least as likely that mercury found in the distillate can originate from mercury compounds with significant vapour pressure, e.g. mercury chloride, or from decomposition of amorphous mercury sulphide.

With relevance to the possible application of hot work on the tubes and equipment during dismantling, it is also important to notice that decomposes at high temperatures forming gaseous elemental mercury: Hg^0 (g). For the working environment it is not important whether the source of mercury vapour is elemental mercury itself or decomposing mercury compounds. It is therefore recommended that fresh-air breathing equipment is used in connection with hot work on tubes and equipment containing significant amounts of mercury regardless of form of mercury.

4.3.4 Interpretation of results from the mercury analyses

After more than 4 years of corrosion the inner surfaces of the 2/4T topside production lines are heavily corroded and mercury contamination is found as a mercury sulphide coating on rust particles and flakes, or contained in a black coloured coating on the inner surfaces of the production equipment. The mercury sulphide may have been formed as part of the corrosion process where steel-amalgamated mercury reacts with available sulphur from remaining hydrocarbons or the sulphide may have been formed during production from H_2S in the gas stream. Of these two possibilities the latter seems to be the most probable alternative. The thermodynamics for oxidation of mercury in the opened production lines should have been in favour of the formation of mercury oxides or hydroxides (Stumm and Morgan, Brookins)

instead of mercury sulphide, even though it may be possible that available oxygen was used to form rust.

Using an operational definition, two types of material were defined (see Ch. 4.1): Debris material and Fixed material. These definitions as they describe the material as it was found when sampled are important since the eventual remedial measures probably will be developed referring to these material types.

The operational definitions above, however, do not give any information on the factual chemical or physical form of the material. The material, therefore, could in addition also be defined according to the major findings of the mercury speciation analyses (SEM) resulting in two new categories: Rust material and Black coloured material.

It should be observed that in any sample or at any spot in the production systems the material found could be any combination of the two categorical sets.

The findings in the mercury analyses and field investigations could be summarised as follows:

1. Practically all production systems in contact with the produced oil and gas are mercury contaminated. The contamination is present in the form of corrosion products either as debris or material still attached to the inner surfaces of the production equipment. The mercury levels at some locations may be viewed as extremely high.
2. Gas production systems seem to have higher mercury levels than the oil systems.
3. The mercury is present in an oxidised form primarily as mercury sulphide, but there were also indications of some mercury chlorine. It should be noted that the mercury in any case is not present in the form of well-defined minerals, but as amorphous compounds without an exact stoichiometry. Generally, amorphous compounds are less stable, more soluble etc. than the corresponding crystallised minerals.
4. There were not found or identified any elemental mercury neither during fieldwork nor in the high mercury content samples subjected to SEM analysis. It was however detected small traces of what appeared to be elemental mercury in one of five samples subjected to a vacuum distillation experiment that was performed to identify any elemental mercury present in the samples. At this point it is not definitely clear which form the detected mercury had in the original sample: elemental mercury, a volatile mercury compound or elemental mercury formed by decomposition of a mercury compound. It is also well known that mercury sulphide decomposes to form gaseous elemental mercury at high temperatures. It is therefore recommended that fresh-air breathing equipment be used in connection with hot work on the production lines tubes and equipment. The exception is that fresh-air breathing equipment may be deemed superfluous if the mercury-contaminated material has been removed prior to the work.
   In addition: it is possible that quantities of elemental mercury may be found in isolated sumps of unopened production equipment like separators or condensers if such sumps exist.
5. A comparison between the mercury content in the Debris material and the Fixed material showed that the Debris material contained almost five times as much mercury as the Fixed material. It is likely that Fixed material samples contained more material from deeper steel layers than the Debris material samples. Both Debris material and Fixed material have the same physical and chemical characteristics, both being composed of 1) "clean" rust and 2) mercury sulphide coated rust.
   Differences in the mercury content of analysed samples are therefore believed to be primarily caused by differences in the portions of these two forms of rust in each sample.

6. It was documented by means of SEM analyses that the mercury was contained in mercury rich particles that were distributed among other mercury poor particles. It was further found that the mercury occurred as a coating on the mercury rich particles. The major composition of all particles was rust. Due to a visually observed difference between particles namely colour: a cross-section of a black coloured scale flake was subjected to SEM analysis. The analysis clearly showed that mercury sulphide was deposited in a thin layer on the surface of the flake.
7. From 5) and 6) above it is concluded that the mercury that has been deposited onto the inner surfaces of the production equipment now is found in dark coloured particles or flakes either as Debris material or Fixed material (still attached to the inner surfaces).
8. Comparison of the mercury content between the Debris and the Fixed material indicate that as much as 95 % or more of the total mercury mass could be contained in the Debris material. This estimate is based on a combination of the 5 : 1 enrichment factor from pt. 5 and the visual observations that the amounts of Debris material at all sampling locations always were far greater than the Fixed material. A conservative estimate could be 4 : 1 mass ratio between Debris material and Fixed material. It should be noted that it is assumed that the sample locations in this study gives a representative picture of the corrosion rate throughout the production lines.

5 Mercury inventory and assessment of material streams

5.1 Mercury inventory

As described in previous chapters the mercury contamination is situated in a thin layer on the outermost corroded part of the production lines' inner surfaces. In order to assess the magnitude of the mercury contamination it is therefore essential to estimate the inner surface areas.

Table 8: Estimates of inner surface areas in the production lines of 2/4T topside. Equipment marked in **bold** is to be separately treated for dismantling and cleaning.

No.	Name	length (m)	radius (m)	Inner surface (m^2)	No. of Units	Total inner surface (m^2)
Equipment						
41-353	Quench water cooler	4,00	0,20	5,3	9	47
95-200	**Dew point unit separator**	**19,60**	**1,40**	**184,6**	**3**	**554**
95-203	*Dewpoint unit stabiliser*	*1,00*	*0,20*	*1,5*	*3*	*5*
95-206	Stab. Compressor inlet scrubber	3,00	0,60	13,6	1	14
95-306	Flash gas compr. l. stage scrubber	5,50	1,20	50,5	1	50
95-307	Flash gas compr. 1. stage scrubber	6,00	1,50	70,7	1	71
95-311	Glycol absorber separator	11,00	1,60	126,6	6	760
41-212	**Propane chiller**	**17,80**	**1,65**	**201,5**	**3**	**605**
95-211	*Propane flash tank*	*1,00*	*0,20*	*1,5*	*1*	*2*
41-200A	**Gas to gas exchanger**	**20,70**	**0,75**	**101,0**	**6**	**606**
41-311A	*Gas cooler*	*1,00*	*0,20*	*1,5*	*21*	*32*
95-215	*Propane surge tank*	*1,00*	*0,20*	*1,5*	*1*	*2*
95-117	*Degassing Pot*	*1,00*	*0,20*	*1,5*	*3*	*5*
95-342	*Vent gas scrubber*	*1,00*	*0,20*	*1,5*	*3*	*5*
41-300	Interstage oil cooler	7,00	1,00	50,2	1	50
95-300	Dry gas separator	31,50	2,70	579,9	1	580
95-302	Interstage separator	32,80	3,20	723,5	1	723
41-215	*Stab. compressor recycle cooler*	*1,00*	*0,20*	*1,5*	*1*	*2*
41-306	*Interstage cooler*	*1,00*	*0,20*	*1,5*	*2*	*3*
41-5006	**Gas pipe comp. disch. Cooler**	**15,40**	**0,75**	**76,1**	**4**	**304**
95-301	West ekofisk separator	20,00	2,00	276,3	1	276
95-304	Low stage separator	25,00	2,20	375,8	2	752
41-378	*Booster cooler*	*1,00*	*0,20*	*1,5*	*6*	*9*
95-350	Center fuel gas scrubber	5,00	0,75	27,1	1	27
95-351	Start gas scrubber	3,00	0,60	13,6	1	14
95-354	Pipeline fuel gas scrubber	5,00	0,75	27,1	1	27
95-320	Booster compressor gas scrubber	5,50	1,25	53,0	3	159
95-305	**Water drain vent tank**	**3,00**	**0,75**	**17,7**	**1**	**18**
Total Inner Surface Production Units						5681
Area of units removed for separate dismantling and cleaning						2087
Net Inner surface area for production units						**3594**
Tubes						
	Gas pipeline meter, 20" 48 m	46,4	0,23	67	4	268
	Gas pipeline meter, 24" 48 m	46,4	0,28	82	8	653
	All other tubes	50	0,36	113	30	3391
Net inner surface for tubes						**4312**

Table 8 shows an estimation of the production lines inner surfaces. The table is divided in two parts: Equipment and Tubes. In the equipment part the estimations of inner surfaces have been made for all major production units. Some units that have to be cleaned separately for practical reasons have been tagged and their part of the inner surface area have been subtracted from the net inner surface.

The area of the inner surfaces in the topside tubes has been calculated based on rough estimations of tube length

Table 9: Estimation of mercury concentration and uncertainty estimators after removal of Production Units that is treated separately for dismantling and cleaning. The removed units are those marked with **bold** in Table 8.

Description	**N**	**Mean Value Estimators**			**Uncertainty Estimators**	
		Arithmetic	**Geometric**	**Median**	**Std. Dev.**	**Std. Error of Mean**
Separately Treated Equipment	105	34 014	21 857	21 770	37 418	12 473
Remaining Equipment and Tubes	**9**	**2 369**	**392**	**560**	**5 267**	**514**
Total	114	4 867	538	600	14 075	1 318

The production equipment that is to be treated separately with respect to cleaning and dismantling or disposal at a licensed hazardous waste repository are also among the most heavily mercury contaminated equipment. This equipment, a total of 17 vessels, consists of the Dew Point Unit Separators (3), the Propane Chillers (3), the Gas to Gas Exchangers (6), the Gas Line Compression Discharge Coolers (4) and the Water Drain tank (1). Since these vessels are to be treated separately from the rest of the production lines, the mean value for the rest of the equipment and tubes was therefore recalculated (Table 9) giving the mean value mercury content of Debris material in 2/4T topside equipment and tubes to be 392 ± 514 mg/kg. This value is hereafter used as the mean value for mercury contamination for the tubes and equipment that is to be handled (cleaned and dismantled) during normal operation.

Except from the Water Drain Tank, the other vessels tagged for special treatment has been chosen due to their complex internal construction that inhibits decontamination and dismantling in the same way as the rest of the equipment. It is also believed that these vessels of the same reason may have large inner surface areas. Even though samples have been taken in openings, it has not been possible to assess neither the contamination level within these vessels or the amounts of contaminated materials and mercury due to lack of access to the internals of any of these vessels. The Water Drain Tank was chosen for separate treatment because of its extremely high mercury content, which necessitates especially thorough cleaning measures.

The 17 vessels here referred to as Separately Treated Equipment is therefore not further assessed in the following chapter, even though it is likely that this equipment contain a substantial part of the total masses of contaminated material.

5.2 Assessment of material streams

In order to assess the end solution options for the mercury contaminated process equipment the effective mercury concentrations where the steel weight are included, should be estimated. Such estimation is performed in Table 10 showing the effective mercury concentration for the steel as it is found at present and the projected resulting concentrations after removal of 50 % and 75 %, respectively of the total amounts of Debris and Fixed material mass combined.

To estimate the amounts of contaminated material in the lines the thickness of selected flakes of Debris material were measured based of SEM photos. Knowing that Fixed material is Debris material that not yet has fallen off, the flake thickness values together with measurements of the density of the flakes have been used to estimate the masses of mercury contaminated material (Debris + Fixed) within the lines. The SEM photos and the corresponding thickness and density data are collected in Appendix 2. The Appendix also contains data from flakes of deep-seated rust typically from areas nearest the openings e.g. manholes. Those data are not representative and are therefore omitted from the estimations of mean thickness and density of the contaminated material.

Table 10: Summary of key parameters for the assessment of the accept criterion for mercury content in the production lines on 2/4T topside. Estimations of Inner Surface Areas are based on the figures given in Table 8. The steel masses have been calculated using 7.8 kg/dm^3 as steel density, 2.0 kg/m^2 as the Debris and Fixed material abundancy (see Appendix 2), and an average steel thickness of 2" and 1" for Production Units and Tubes, respectively. *-Fixed material mass is also included.

	Inner Surface Area	**Steel Mass**	**Debris Material Mass***	**Hg conc. Debris Material**	**Effective Hg conc.**		
					No removal	**50% removal**	**75% removal**
	m^2	**tons**	**tons**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**
Production Equipment	3 594	1 402	7.2	392	2.0	1.0	0.5
Tubes	4 312	841	8.6	392	4.0	2.0	1.0

The values for Effective mercury concentrations that is given in Table 10 is independent of the different possible decontamination strategies – it simply shows the relation between effective mercury concentration and total removed material mass.

It is likely that a major part of the mercury mass is contained in the Debris material. Previously it has been estimated that probable more than 95 % of the mercury is contained in this material fraction. If accessible through openings the Debris material should be easy to remove using vacuum cleaners possibly somewhat modified to reach far into the tubes. If the vacuum cleaning also is assisted by brushing and scraping of the equipment's inner surfaces it should also be possible to remove a substantial part of the Fixed material. Doing so would make room for performing no cleaning at all at locations with very limited access and e.g. small tubes.

The mass of the mercury-contaminated Debris and Fixed material has been estimated to be 7.2 tons and 8.6 tons for production equipment and tubes, respectively. The mass of the mercury itself can correspondingly be estimated based on the mean mercury value in Table 10 as 2.8 kg and 3.4 kg, respectively. It should be noted that the mass calculations are based on the assumptions that the amounts of corroded material are evenly distributed throughout the systems. Please note that the Separately Treated Equipment is not taken into the above estimates.

The effective concentration of mercury in the production lines as they appear today is slightly above what can be view as the non-contamination level of 1 mg/kg (Table 10). It is apparent that removal of between 50 % and 75 % of the mercury contaminated Debris and Fixed material throughout the production lines would result in a mercury concentration in the remaining steel below the non-contamination level. Using the Unit based data given in Table 2 it should be possible to enhance mercury removal by giving priority to the most contaminated Units.

Summary of material streams:

- Steel with mercury concentration below the non-contamination level (1 mg/kg) is classified as non-contaminated.
  Given that the proper decontamination measures are performed total mass of non-contaminated steel in the production lines will be 2 227 tons (99.3 % of total weight of the 2/4T topside production lines).
- The removed Debris and Fixed material could be classified either as "Mercury contaminated waste" (Waste Codes: 16 01 08 or 17 09 01) or as "Waste containing iron compounds" (Waste Code: 16 01 17). The former classification relating to the mercury content would be a conservative classification taking into account that there will be pockets of "above 1 000 mg/kg mercury material" in the removed material even though the average mercury concentration will be far below (392 mg/kg). The latter classification simply defining the material as rust is a classification directly in accordance with the "Farlig avfall" definition. In either case the waste material could go to a licensed repository e.g. NOAH Langøya.
  Somewhat depending on the decontamination strategy the total mass of the removed waste material will be 8 – 15.2 tons (0.4 – 0.7 % of total weight of the 2/4T topside production lines).
- The waste stream from the Separately Treated Equipment (See Ch. 5.1: Table 8 and 9) could not be assessed here due to lack of data. It is known however that even though their total steel mass is low compared to the total mass of the production lines the amounts of mercury contaminated material form these vessels could be substantial due to their large inner surface areas.
- Finally, there exist an alternative to removal of the mercury-contaminated material, namely to dispose of the production lines' steel as it is. This possible end solution will be dependent on acceptance from the steel smelter to receive steel above the non-contamination level. Alternatively, the production lines' steel could be classified as "Waste containing iron compounds" (Waste Code: 16 01 17) and be sent to a licensed hazardous waste repository.

6 Conclusions

This work comprises the results of a survey of radioactivity and mercury in the gas and oil production lines on Ekofisk 2/4T topside.

The work can be concluded as follows:

1. LSA Scale was only found at one location: the Oil Export Pipe that runs out of the 2/4T topside towards 2/4-P. It is recommend that the LSA Scale is removed on-site by mechanical methods like brushing and vacuum cleaning. The LSA Scale material should be stored in high-density polyethylene (HDPE) drums in a radiologically defined Controlled Area until transport to a licensed storage facility. Total mass of LSA Scale has been estimated to less than a ton: 830 kg.
2. There was also found activity above background but below the free-classification limit at the Oil Metering System. No cleaning is recommended.
3. All studied systems were found to contain mercury contaminated material. The contaminated material can best be described as being composed of "corrosion products" with the mercury predominantly associated with a black coloured material containing mercury sulphide.
4. A total of 17 vessels have been tagged for separate treatment (in the text referred to as (Separately Treated Equipment) due to their complex internal construction and their high mercury levels. It has not been possible to further assess this equipment due to lack of data. It is known however that even though their total steel mass is low compared to the total mass of the production lines the amounts of mercury contaminated material from these vessels could be substantial.
5. The physical appearance of the contaminated material is so that the material probably can be easily removed by simple means like brushing and light grinding and/or scraping followed by vacuum cleaning to collect the material in UN-certified dustproof bins.
6. Removal of more than 50 - 75 % of the mercury-contaminated material (Vessels in pt. 4 excluded) would result in a mercury concentration in the production line steel less than the non-contamination level (1 mg/kg). The steel in the decontaminated lines can thereafter be classified as non-contaminated with respect to mercury. The total mass of non-contaminated steel in the production lines is 2 227 tons (99.3 % of total weight of the 2/4T topside production lines).
7. It is likely that after cleaning (Pt. 5) any elemental mercury in the production lines would also have been removed. Possible sumps and drains throughout the systems (typically in separators and condensers) should be inspected (if there are any) in order to collect any elemental mercury that may have been assembled there.
8. Due to the possibility for mercury vapours to be formed it is recommended that fresh-air breathing equipment will be used in connection with hot work on the production lines tubes and equipment. The exception is that fresh-air breathing equipment may be deemed superfluous if the mercury-contaminated material has been removed prior to the work.
9. After eventual cleaning (Pt. 6) it should be verified that the criterion for mercury-decontamination material actually has been fulfilled. This could be accomplished by registering mass inventories for the removed material combined with visual inspection of the cleaned production lines to verify the non-presence of substantial amounts of loose material.

10. The eventually removed material (from 6) could be classified as "Mercury contaminated material" (Waste Codes: 16 01 08 or 17 09 01) or as "Waste containing iron compounds" (Waste Code: 16 01 17). In either case the waste material should be deposited in a licensed hazardous waste repository, e.g. Langøya, or otherwise disposed of in mutual agreement with Norwegian authorities.
    Somewhat depending on the eventual decontamination strategy the total mass of the removed waste material is 8 – 15.2 tons (0.4 – 0.7 % of total weight of the 2/4T topside production lines).
11. As an alternative to removal of the mercury-contaminated material the production lines' steel could be disposed of as it is. This end solution, however, will depend either on acceptance from the steel smelter to receive steel above the non-contamination level, or the production lines' steel could have to be classified as "Waste containing iron compounds" (Waste Code: 16 01 17) and be sent to a licensed hazardous waste repository.

7 References

(Not all references have been directly cited in the text.)

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Appendix 1

Table A1: Overview of sample locations and samples for the survey of radioactivity (LSA scale) and mercury in the oil and gas production lines on 2/4T topside. The locations for samples taken in a previous survey conducted by Det Norske Veritas (DNV) are also given.

Sample Location	Description	Module	ND SampleID	DNV Sample ID
1	Valhall line ("not scale")	222-1	A-1	EKOT08
2	Ula to line	222-1	A-2	EKOT09
3	Crude oil coolers	206	A-3	
4	Interstage separator	202	A-4	EKOT10
5	Dehydration C1 out (21m)	216	A-5	
6	Dehydration C1 in (21m)	216	A-6	
7	Dehydration C2 out	216	A-7	
8	Dehydration B2 in dehydration	215	A-8	
9	Dehydration B1out dehydration	215	A-9	
10	Dehydration A2 out dehydration	214	A-10	
11	Dehydration A2 in dehydration	214	A-11	
12	Dehydration A1 in dehydration	214	A-12	
13	Dehydration A1 out dehydration	214	A-13	
14	Water drain vent tank Unit 95-305	A28	A-14	EKOT13
15	Oil Metering	208	A-15	EKOT12
16	Ula line in at pillar B11	208	A-16	
17	LSA line from Doris Pit (end of pipe)	208	A-26	
18	FTP line A (end tube inlet)	208	A-17	
19	FTP line C (end tube inlet)	208	A-18	
20	FTP line A (start tube cont.)	208	A-19	
21	FTP line B (start tube cont.)	208	A-20	
22	FTP line C (start tube cont.)	208	A-21	
23	Export line A (end tube)	208	A-22	
24	Export line A (inlet to manifold)	208	A-23	
25	FTP A (inlet to manifold)	208	A-24	
26	LSA line (inlet to manifold)	208	A-25	
27	Dew. Point No. 1	303-2C	A-27	EKOT06
28	Pipeline 48 m deck gas from WE to dehydration (303-LC)	350-D	A-28	EKOT04
29	Gas pipeline cooler 41-5008	315	A-29	EKOT01
30	Vent gas Scrubber (mixture water, glycol) 95-343	215	A-30	
31	Glycol re-boiler B1 95-329	215	A-31	
32	Gas to gas exchangers (+34 m) 41-200-A	211	A-32	
33	Gas to gas exchangers (ca. +30 m) 41-200-B	211	A-33	
34	Propane Chiller (+25m)	211	A-34	
35	Bridge 2/4-P til 2/4T: Oil export tube	2/4-P	A-35	
36	Liquid drain tank	222-1	A-36	EKOT14
37	Gas pipeline cooler (adjacent A-29)	315		
38	West Ekofisk separator	301		EKOT02
39	Low stage separator 95-304	302		EKOT03
40	Pipline 25m deck Gas coolers	215		EKOT05
41	Pipeline connected to tank dry gas separator	201		EKOT07
42	Crude oil coolers	206		EKOT11
43	Dehydration til celle B south hole	215		EKOT15
44	Pipeline metering, Dry gas	303	A-37	
45	WE Gas metering	303	A-38	
46	Hot oil furnace no.1	318	A-39	

Table A1: Continued.....

Sample Location	Description	Module	ND SampleID	DNV Sample ID
47	Hot oil furnace no. 2	318	A-40	
48	Hot oil furnace no. 3	318	A-41	
49	Booster compressot Gas scrubber 95-3022	314	A-42	
50	Booster compressot Gas scrubber 95-3021	314	A-43	
51	2-3" rør fra/til Booster scrubber 95-3021	314	A-44	
52	Booster compressot Gas scrubber 95-3020	314	A-45	
53	Pipeline fuel gas scrubber	314	A-46	
54	Center fuel gas scrubber	314	A-47	
55	Start gas scrubber	314	A-48	
56	Hot oil return 48m deck	318	A-49	
57	Propane scrubber 95-208	217	A-50	
58	Propane scrubber 95-207	217	A-51	
59	Flash gas compressor intermediate stage scrubber 95-307	218	A-52	
60	Flash gas compressor low stage scrubber 95-306	218	A-53	
61	Stab compressor inlet scrubber 95-206	218	A-54	
62	Methanol storage tank 95-216	218	A-55	
63	Vent gas scrubber 95-344	216	A-56	
64	Quench water cooler 41-360	216	A-57	
65	Quench water cooler 41-361	216	A-58	
66	Glycol cooler 41-348	215	A-59	
67	Glycol cooler 41-349	215	A-60	
68	WE separator, Man hole at end	301	A-61	
69	WE separator, tube outlet at bottom	301	A-62	
70	Tube from/to gas pipeline cooler package	315	A-63	
71	Tube from/to gas pipeline cooler no 3	315	A-64	
72	F/G no 2 suction 16-301	310	A-65	
73	F/G no 2 discharge 16-301	310	A-66	
74	Interstage cooler outlet, 30 m	310	A-67	
75	Propane no 2 suction	309	A-68	
76	Propane no 2 discharge	309	A-69	
77	P/l no 4 suction	308	A-70	
78	Recycle cooler	304	A-71	
79	Inn til stab. comp. recycle cooler	304	A-72	
80	P/L no 4 discharge (hp flare)	308	A-73	
81	P/L no 4 discharge	308	A-74	
82	P/L no 1 suction	306	A-75	
83	P/L no 3 discharge	307	A-76	
84	P/L no 3 discharge HP flare	307	A-77	
85	Booster A suction	350A	A-78	
86	Booster A discharge	350A	A-79	
87	Booster C suction	350A	A-80	
88	Booster C discharge	350A	A-81	

Table A1: Continued.....

Sample Location	Description	Module	ND SampleID	DNV Sample ID
89	Hot oil surge tank 95-349	219	A-82	
90	Glycol storage tank 95-332	219	A-83	
91	Lube oil storage	219	A-84	
92	Low stage separator pump 67-300	203	A-85	
93	Low stage separator pump 67-305	203	A-86	
94	WE to WE pumps	301	A-87	
95	Glycol reboiler 95-328	215	A-88	
96	Degassing Pot 95-318	215	A-88-B	
97	Glykol absorber 95-314	215	A-89	
98	Degassing Pot 95-317)	214	A-90	
99	Propane reclaimer 95-209	207	A-91	
100	Bridge 2 from 2/4-R to 2/4T, Ula oil	bridge	A-92	
101	Booster B suction, flake from surface	350A	A-93	
102	Stab comp recycle cooler same as A72, different location	304	A-94	
103	Recycle cooler II sump	304	A-95	
104	Bridge 2/4-P to 2/4T: Oily water from sep FTP	bridge	A-96	
105	Bridge 2/4-P to 2/4T: Gas from FTP to Tank	bridge	A-97	
106	Bridge 2/4-P to 2/4T: C Injection gas from Tank to Charlie	bridge	A-98	
107	Bridge 2/4-P to 2/4T: Oil from crude oil pump to Papa	bridge	A-99	
108	Bridge 2/4-G to 2/4T: Valhall oil to pipe line	bridge	A-100	
109	Bro 1 from 2/4-R to 2/4T: Oil to WE sep.	bridge	A-101	
110	Bro 1 from 2/4-R to 2/4T: From P/L to Emden	bridge	A-102	
111	Bro 1 from 2/4-R to 2/4T: To D.G.S	bridge	A-103	
112	Bro 1 from 2/4-R to 2/4T: HP Flare	bridge	A-104	
113	Bro 1 from 2/4-R to 2/4T: LP Flare	bridge	A-105	

Table A2: Results from the measurements of radioactivity in the production lines on 2/4T topside. On site measurements were conducted using a contamination monitor (Instr. 1) at the sample locations: columns "Background" and "Activity". Determinations of the activity concentrations of ^{226}Ra, ^{228}Ra and ^{210}Pb were performed in selected samples.

Sample Location	SampleID	Module	Background (cps)	Activity (cps)	Ra-226 (Bq/g)	Ra.228 (Bq/g)	Pb-210 (Bq/g)
1	A-1	222-1	1.5	n.a.b.			
2	A-2	222-1	2.0	12.7	0.9 ± 0.3	0.2 ± 0.1	
3	A-3	206	1.7	n.a.b.			
4	A-4	202	1.9	n.a.b.			
5	A-5	216	2.2	n.a.b.			
6	A-6	216	0.9	n.a.b.			
7	A-7	216	1.1	n.a.b.			
8	A-8	215	2.1	n.a.b.			
9	A-9	215	1.7	n.a.b.			
10	A-10	214	1.9	n.a.b.			
11	A-11	214	1.5	n.a.b.			
12	A-12	214	2.1	n.a.b.			
13	A-13	214	1.3	n.a.b.			
14	A-14	A28	1.8	n.a.b.			
15	A-15	208	1.8	10.0	2.1 ± 0.1	0.4 ± 0.05	
16	A-16	208	2.1	n.a.b.			
17	A-26	208	2.0	n.a.b.	0.51 ± 0.17	< 0.04	< 0.2
18	A-17	208	2.0	25.0	4.43 ± 0,24	0.32 ± 0.04	1.06 ± 0.20
19	A-18	208	2.0	23.0	2.70 ± 0.23	0.5 ± 0.1	
20	A-19	208	1.8	27.0	1.5 ± 0.2	1.1 ± 0.4	
21	A-20	208	19.0	25.0	2.8 ± 0.3	0.3 ± 0.1	
22	A-21	208	2.2	7.0	2.7 ± 0.4	0.4 ± 0.1	
23	A-22	208	2.0	15.0			
24	A-23	208	2.0	10.0	3.3 ± 0.4	0.6 ± 0.2	
25	A-24	208	1.9	n.a.b.			
26	A-25	208	2.0	13.0			
27	A-27	303-2C	1.9	n.a.b.			
28	A-28	350-D	1.5	n.a.b.			
29	A-29	315	1.7	n.a.b.			
30	A-30	215	1.7	n.a.b.			
31	A-31	215	1.5	n.a.b.			
32	A-32	211	1.9	n.a.b.			
33	A-33	211	1.9	n.a.b.			
34	A-34	211	2.0	n.a.b.			
35	A-35	2/4-P	2.0	55.0	22.9 ± 1.1	1.46 ± 0.09	3.8 ± 0.5
35	A-35b	2/4-P			< 0.05	< 0.01	0.07 ± 0.03
36	A-36	222-1	2.1	n.a.b.			
37		315	1.7	n.a.b.			
38		301	2.0	n.a.b.			
39		302	1.7	n.a.b.			
40		215	1.7	n.a.b.			
41		201	1.8	n.a.b.			
42		206	1.8	n.a.b.			
43		215	1.9	n.a.b.			

Table A3: Results from the measurements of mercury in the production lines on 2/4T topside. The measurements were performed on samples of "loose" material found in open ends on the production equipment at the sample locations (Column "Hg"). Additional samples were obtained of material that were grinded from the inner surfaces of the production equipment at selected locations (Column "Hg (C)"). For comparion results from a survey conducted by Det Norske Veritas (DNV, 2005) are given in Column "Hg (DNV)".

Sample Location	SampleID	Module	Hg (mq/kg)	Hg (C) (mq/kg)	Hg (DNV) (mq/kg)
1	A-1	222-1	2942		26
2	A-2	222-1	338	62	568
3	A-3	206	12715		
4	A-4	202	2197		5940
5	A-5	216	30367	8322	
6	A-6	216	2478	290	
7	A-7	216	2846	4370	
8	A-8	215	35811		
9	A-9	215	2744		
10	A-10	214	10597	3279	
11	A-11	214	2639		
12	A-12	214	5092		
13	A-13	214	19813		
14	A-14	A28	21770		127000
15	A-15	208	330		83
16	A-16	208	66		
17	A-26	208	60		
18	A-17	208	28		
19	A-18	208	88		
20	A-19	208	3.3		
21	A-20	208	92		
22	A-21	208	63		
23	A-22	208	2274		
24	A-23	208	763		
25	A-24	208	5.7		
26	A-25	208	193		
27	A-27	303-2C	12912		45300
28	A-28	350-D	4762		78.6
29	A-29	315	4272		
30	A-30	215	869		
31	A-31	215	113		
32	A-32	211	20472		
33	A-33	211	38577		
34	A-34	211	7322		
35	A-35	2/4-P	209		
36	A-36	222-1	17		2140
37		315			28500
38		301			200
39		302			1300
40		215			296

Table A3: Continued.....

Sample Location	SampleID	Module	Hg (mq/kg)	Hg (C) (mq/kg)	Hg (DNV) (mq/kg)
41		201			367
42		206			1.1
43		215			50
44	A-37	303	4800		
45	A-38	303	1000		
46	A-39	318			
47	A-40	318			
48	A-41	318			
49	A-42	314			
50	A-43	314			
51	A-44	314	350		
52	A-45	314	17		
53	A-46	314	1400		
54	A-47	314	1500		
55	A-48	314	830		
56	A-49	318	43		
57	A-50	217	1.1		
58	A-51	217	2.7		
59	A-52	218	4400		
60	A-53	218	3400		
61	A-54	218	5700		
62	A-55	218	590		
63	A-56	216	1100		
64	A-57	216	120		
65	A-58	216	6.2		
66	A-59	215	70		
67	A-60	215	23		
68	A-61	301	24		
69	A-62	301	600		
70	A-63	315			
71	A-64	315			
72	A-65	310	6000		
73	A-66	310	3600		
74	A-67	310			
75	A-68	309	750		
76	A-69	309	72		
77	A-70	308	7600		
78	A-71	304			
79	A-72	304			
80	A-73	308	570		
81	A-74	308	7500		
82	A-75	306			
83	A-76	307			
84	A-77	307	1300		

Table A3: Continued.....

Sample Location	SampleID	Module	Hg (mq/kg)	Hg (C) (mq/kg)	Hg (DNV) (mq/kg)
85	A-78	350A	740		
86	A-79	350A	560		
87	A-80	350A	770	81	
88	A-81	350A	1300		
89	A-82	219	63		
90	A-83	219	90		
91	A-84	219	92		
92	A-85	203	790		
93	A-86	203	1100		
94	A-87	301	1700		
95	A-88	215	160		
96	A-88-B	215	1200		
97	A-89	215	600		
98	A-90	214	140		
99	A-91	207	40		
100	A-92	bridge	52		
101	A-93	350A	46	43	
102	A-94	304	6500	7200	
103	A-95	304	5800		
104	A-96	bridge	550		
105	A-97	bridge	200		
106	A-98	bridge	5300		
107	A-99	bridge	69		
108	A-100	bridge	190		
109	A-101	bridge	460		
110	A-102	bridge	6000		
111	A-103	bridge	1200		
112	A-104	bridge	210		
113	A-105	bridge	440		

Appendix 2

Cross-section SEM pictures

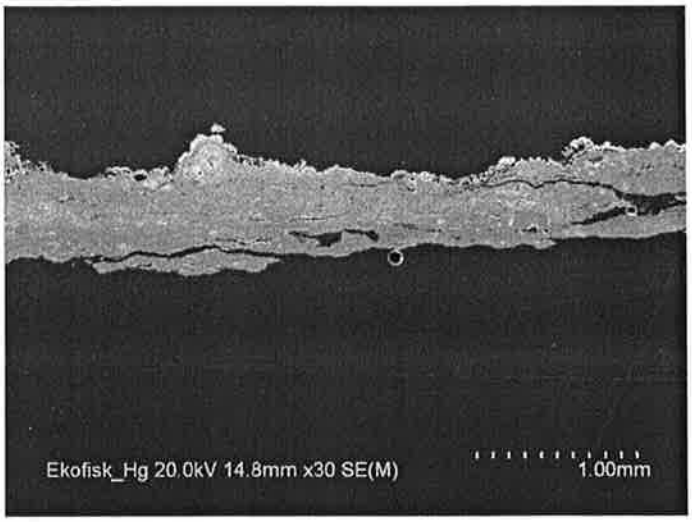


Fig A1-1: Cross-section Flake from sample A05

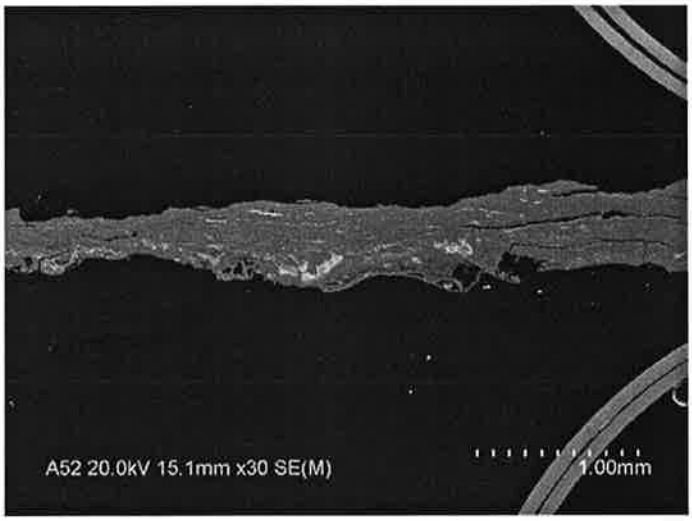


Fig A1-2: Cross-section Flake from sample A52

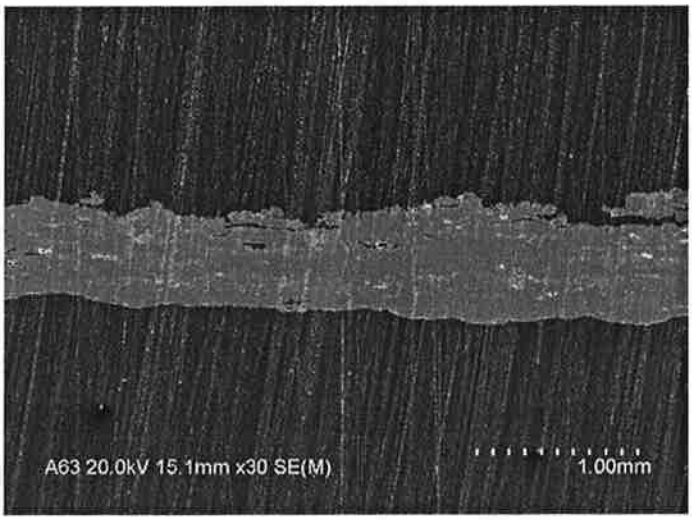


Fig A1-3: Cross-section Flake from sample A63

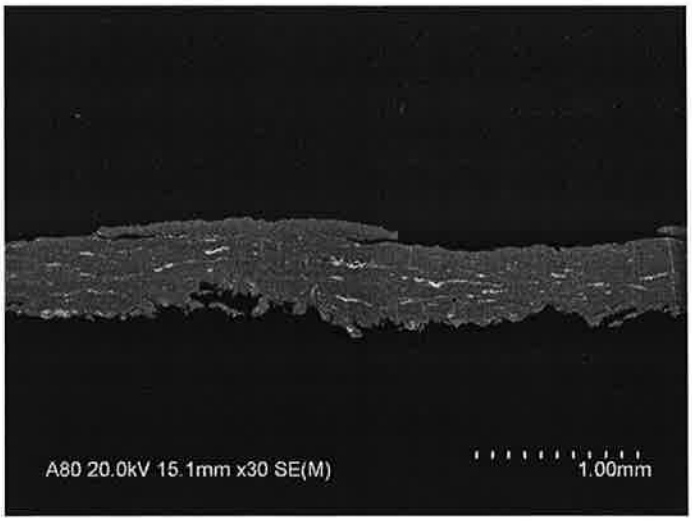


Fig A1-4: Cross-section Flake from sample A80

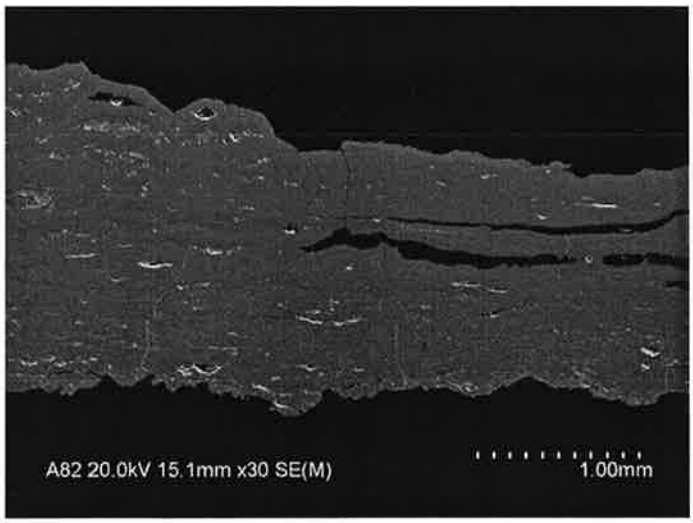


Fig A1-5: Cross-section Flake from sample A82

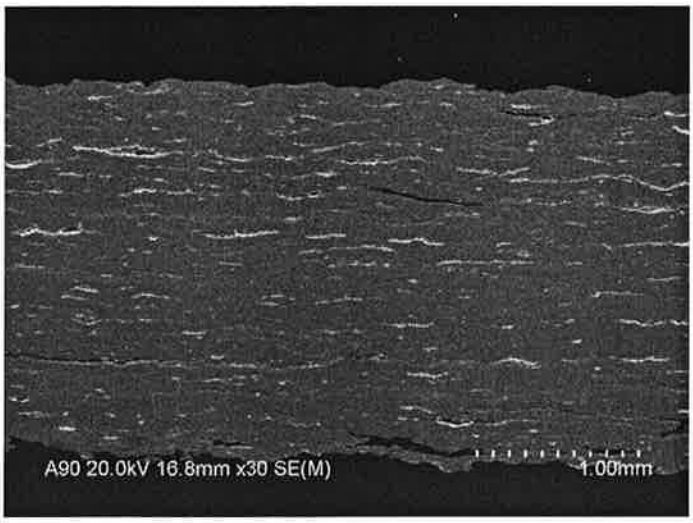


Fig A1-6: Cross-section Flake from sample A90

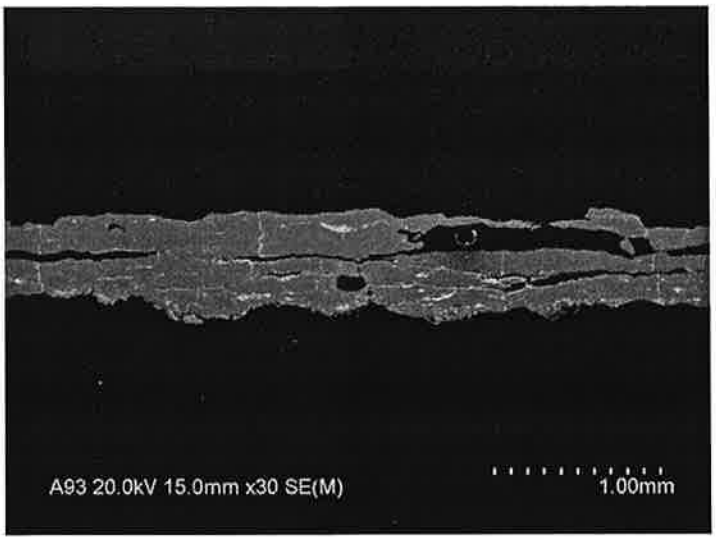


Fig A1-7: Cross-section Flake from sample A93

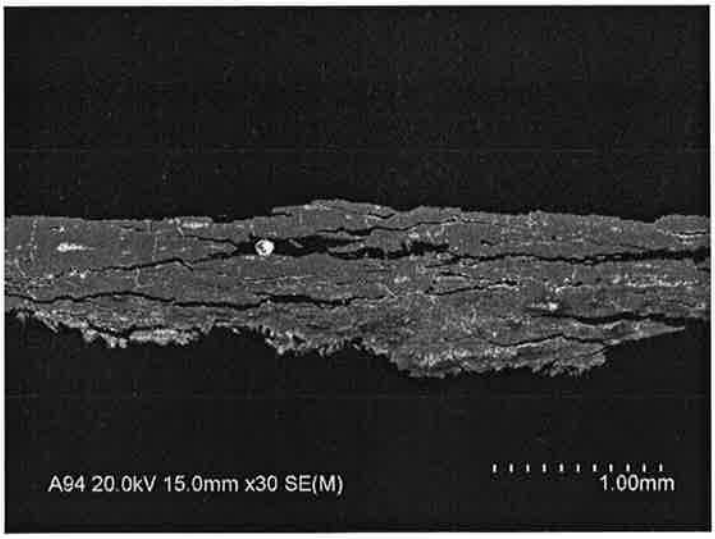


Fig A1-8: Cross-section Flake from sample A94

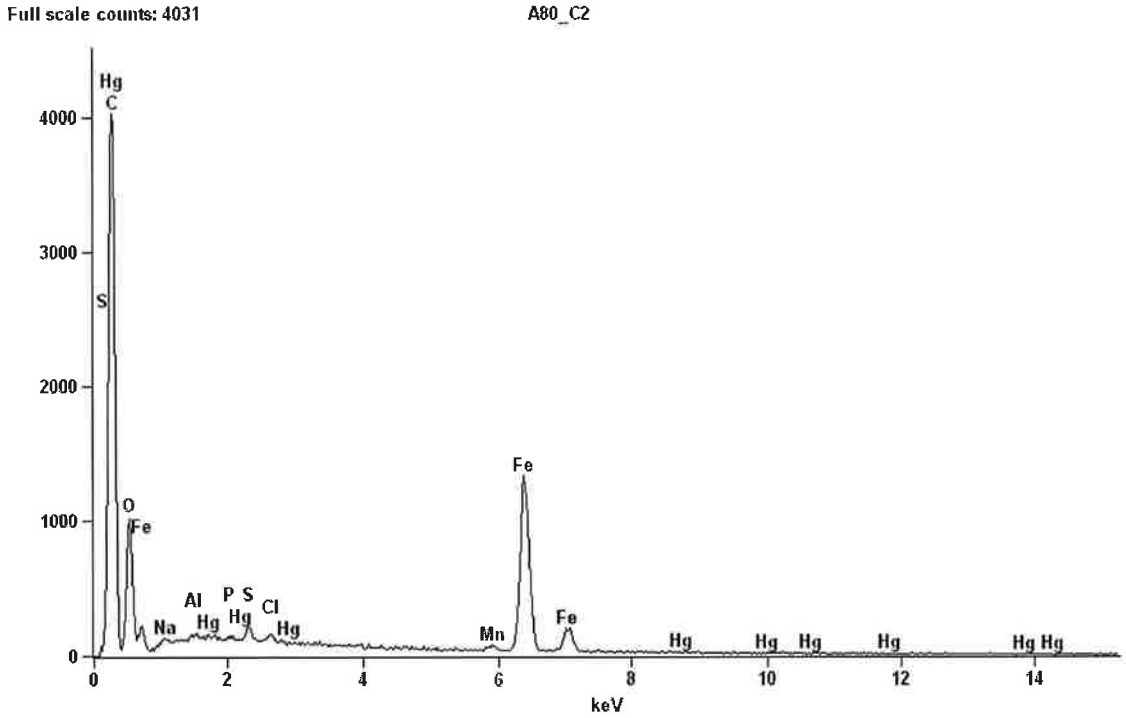
Table A1-1: Mean thickness and density of specimen of Debris material. Thickness estimates was obtained from SEM-photos of Debris specimen cross-sections. Density was measured through water displacement.

Sample No.	Thickness range (mm)	Mean Thickness (mm)	Density (g/cm^3)	Unit Mass kg/m^2
A05	0.43 – 0.65	0.54	3.1	1.7
A52	0.22 – 0.57	0.40	3.3	1.3
A63	0.57 – 0.74	0.66	3.8	2.5
A80	0.52 – 0.65	0.59	3.9	2.3
A82	1.30 – 1.87	1.59	3.7	*5.8*
A90	2.26 – 2.30	2.28	3.9	*8.9*
A93	0.48 – 0.65	0.57	4.0	2.2
A94	0.70 – 0.96	0.83	not enough sample	n.a.
Average		**0.93 ± 0.23**	**3.81 ± 0.20**	**2.00 ± 0.22**

Appendix 3

Project: Norse_Decom
User Name: Trygve Furuseth

Sample A 80 C2

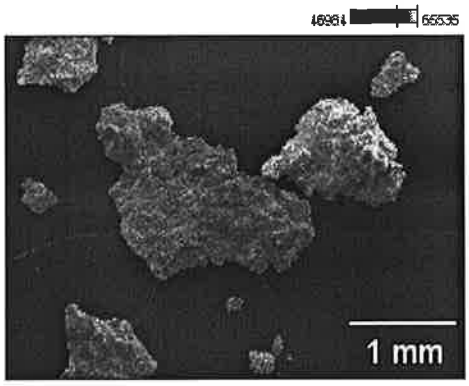


Quantitative Results A80_C2

Element	*Weight Conc %*	*Atom Conc %*
O	42.77	70.05
Na	3.12	3.56
Al	0.62	0.61
P	0.29	0.24
S	1.12	0.91
Cl	0.69	0.51
Mn	1.06	0.51
Fe	50.32	23.61
Hg	0.00	0.00
Total	100.00	100.00

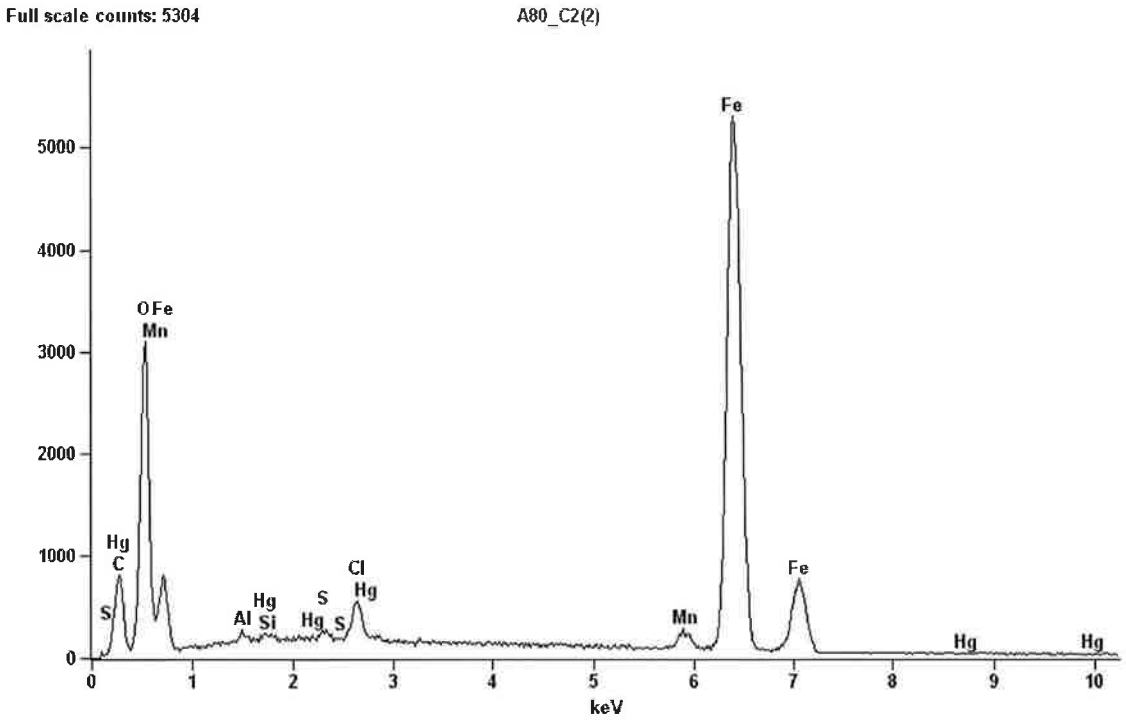
Project: Norse_Decom
User Name: Trygve Furuseth

A80_C2(1)



Data Type: Counts Mag: 30 Acc. Voltage: 20.0 kV

Project: Norse_Decom
User Name: Trygve Furuseth



Quantitative Results A80_C2(2)

Element	*Weight Conc %*	*Atom Conc %*
O	38.12	67.75
Al	0.28	0.30
Si	0.21	0.21
S	0.25	0.22
Cl	1.31	1.05
Mn	1.37	0.71
Fe	58.46	29.76
Hg	0.00	0.00
Total	100.00	100.00

Project: Norse_Decom
User Name: Trygve Furuseth

A80_C2(4)

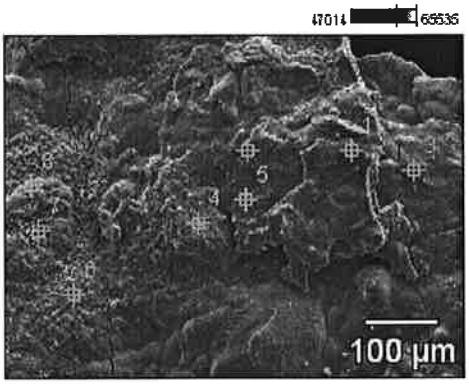


Image Name: A80_C2(4)

Accelerating Voltage: 20.0 kV

Magnification: 200

Weight Concentration %

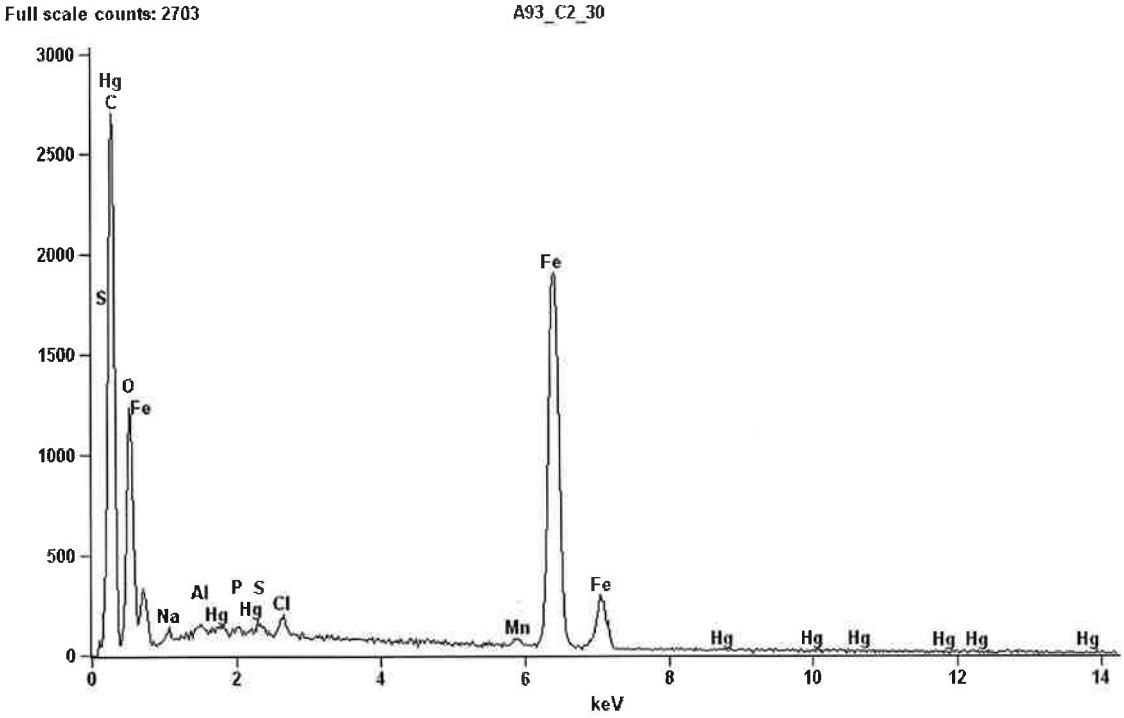
	O	Al	Si	S	Cl	Mn	Fe	Hg
A80_C2(4)_pt1	38.43	0.47	0.12	0.44	3.02	0.41	57.12	0.00
A80_C2(4)_pt2	39.08	0.32		0.29	3.27	0.54	56.41	0.10
A80_C2(4)_pt3	39.38	0.20	0.11	0.51	1.54		58.26	0.00
A80_C2(4)_pt4	34.96	0.13	0.09	0.15	0.17	0.44	64.05	0.00
A80_C2(4)_pt5	43.55	0.41		0.47	4.20	4.40	46.92	0.05
A80_C2(4)_pt6	36.09	0.20	0.07	0.12	0.88	1.89	60.10	0.64
A80_C2(4)_pt7	35.42	0.21	0.21	0.13	1.05	0.53	62.37	0.08
A80_C2(4)_pt8	33.92	0.15	0.14	0.10	0.25	0.97	64.47	0.00

Atom Concentration %

	O	Al	Si	S	Cl	Mn	Fe	Hg
A80_C2(4)_pt1	67.62	0.49	0.12	0.39	2.39	0.21	28.79	0.00
A80_C2(4)_pt2	68.30	0.33		0.25	2.58	0.27	28.25	0.01
A80_C2(4)_pt3	68.84	0.21	0.11	0.45	1.21		29.18	0.00
A80_C2(4)_pt4	65.08	0.15	0.10	0.14	0.15	0.24	34.15	0.00
A80_C2(4)_pt5	71.81	0.40		0.39	3.12	2.11	22.16	0.01
A80_C2(4)_pt6	66.19	0.22	0.07	0.11	0.73	1.01	31.58	0.09
A80_C2(4)_pt7	65.31	0.22	0.22	0.12	0.87	0.29	32.95	0.01
A80_C2(4)_pt8	64.00	0.17	0.15	0.09	0.21	0.53	34.84	0.00

Project: Norse_Decom
User Name: Trygve Furuseth

Sample A 93 C2

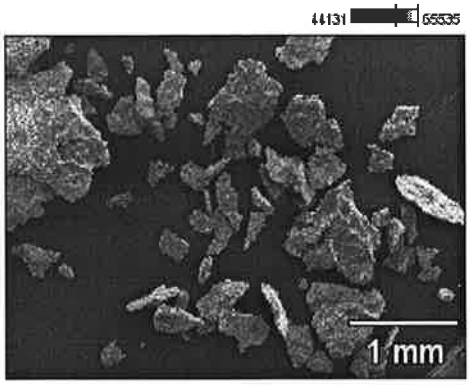


Quantitative Results A93_C2_30

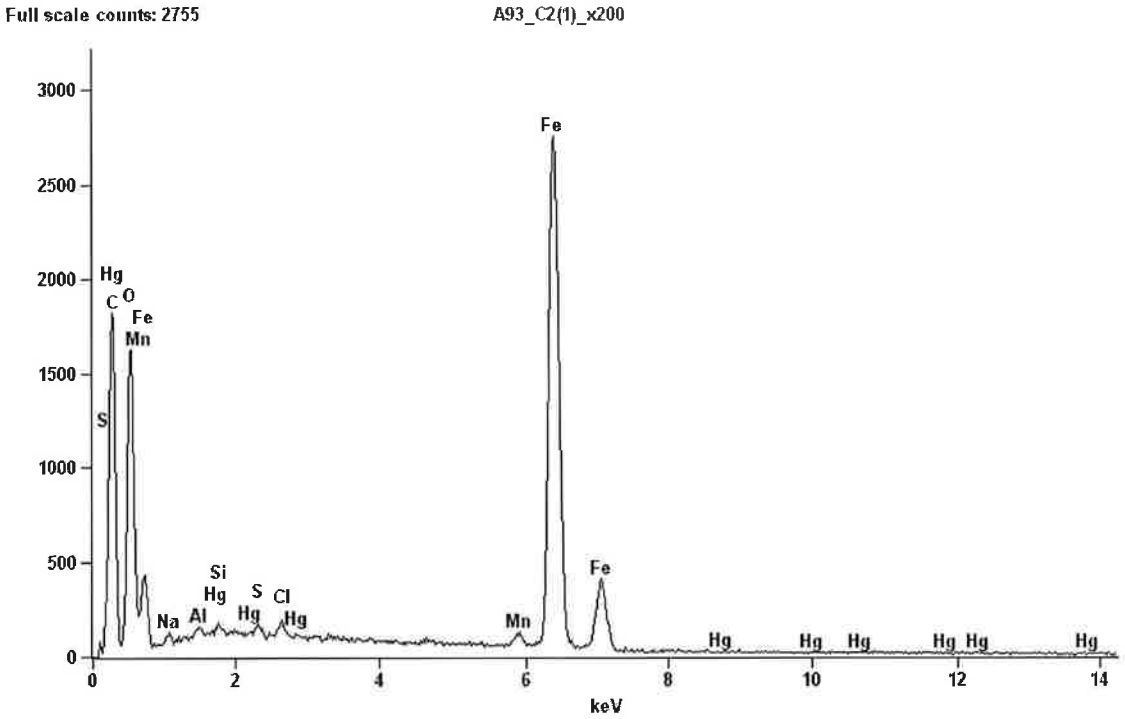
Element	*Weight Conc %*	*Atom Conc %*
O	39.60	68.14
Na	1.87	2.24
Al	0.56	0.57
P	0.24	0.22
S	0.39	0.33
Cl	0.77	0.60
Mn	0.95	0.47
Fe	55.63	27.43
Hg	0.00	0.00
Total	100.00	100.00

Project: Norse_Decom
User Name: Trygve Furuseth

A93_C2



Project: Norse_Decom
User Name: Trygve Furuseth

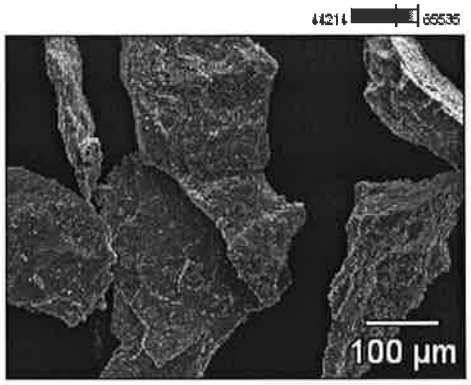


Quantitative Results A93_C2(1)_x200

Element	*Weight Conc %*	*Atom Conc %*
O	39.32	68.23
Na	1.45	1.75
Al	0.37	0.38
Si	0.28	0.27
S	0.30	0.26
Cl	0.45	0.35
Mn	0.97	0.49
Fe	56.87	28.27
Hg	0.00	0.00
Total	100.00	100.00

Project: Norse_Decom
User Name: Trygve Furuseth

A93_C2(2)



Project: Norse_Decom
User Name: Trygve Furuseth

A93_C2(3)

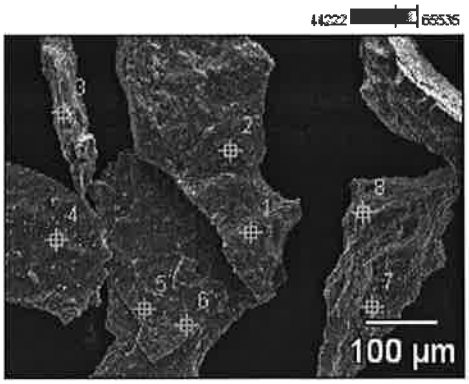


Image Name: A93_C2(3)

Accelerating Voltage: 20.0 kV

Magnification: 200

Weight Concentration %

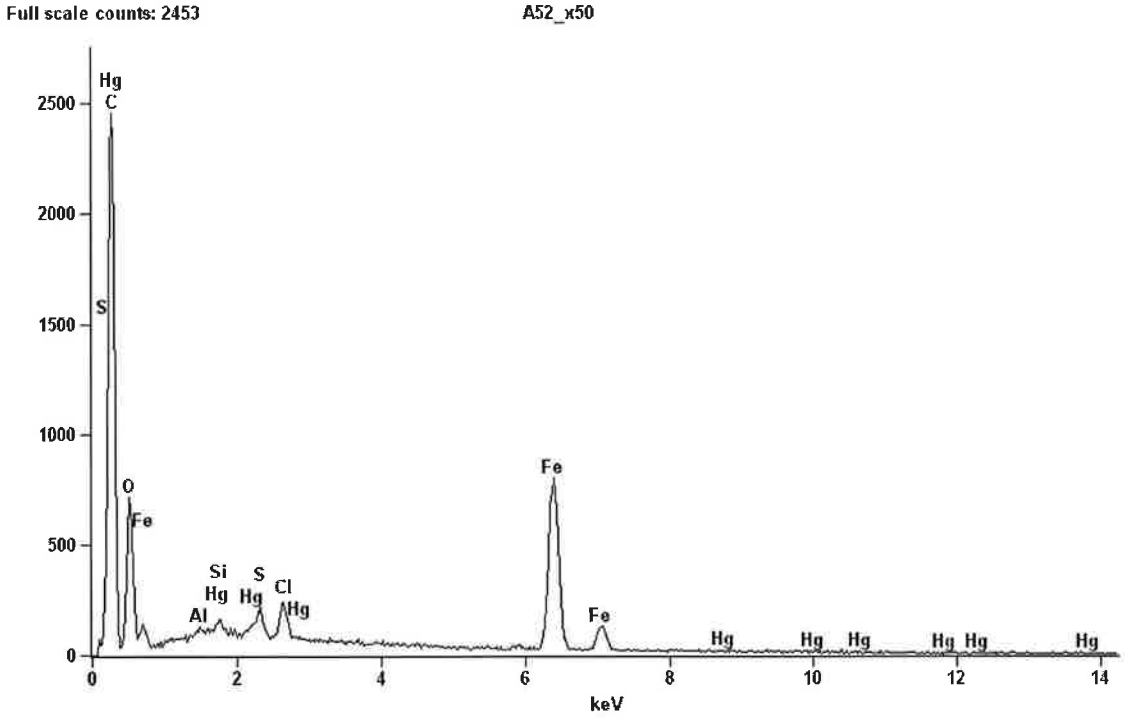
	O	Na	Mg	Al	Si	S	Cl	Mn	Fe	Y	Hg
A93_C2(3)_pt1	37.83	0.61	0.12	0.19	0.20	0.15	0.18	0.43	60.06		0.22
A93_C2(3)_pt2	38.78			0.27	0.13	0.31	0.36	1.02	58.90		0.23
A93_C2(3)_pt3	38.47	0.56		0.21	0.07	0.44	1.14		59.11		0.00
A93_C2(3)_pt4	37.90			0.18	0.29	0.05	0.87	0.51	60.21		0.00
A93_C2(3)_pt5	39.83	0.79		0.16	0.14	0.01	0.07	0.55	58.35		0.10
A93_C2(3)_pt6	36.75	0.80		0.17	0.26	0.00		0.45	61.56		0.00
A93_C2(3)_pt7	33.50			20.16		0.23			46.11	0.00	0.00
A93_C2(3)_pt8	35.57	0.47		0.29		0.06	0.64	0.86	61.36		0.75

Atom Concentration %

	O	Na	Mg	Al	Si	S	Cl	Mn	Fe	Y	Hg
A93_C2(3)_pt1	67.46	0.76	0.15	0.20	0.21	0.13	0.15	0.22	30.69		0.03
A93_C2(3)_pt2	68.61			0.28	0.13	0.27	0.29	0.53	29.85		0.03
A93_C2(3)_pt3	67.85	0.69		0.22	0.07	0.39	0.91		29.87		0.00
A93_C2(3)_pt4	67.69			0.19	0.29	0.05	0.70	0.26	30.81		0.00
A93_C2(3)_pt5	69.30	0.96		0.16	0.14	0.01	0.05	0.28	29.08		0.01
A93_C2(3)_pt6	66.42	1.01		0.19	0.27	0.00		0.24	31.87		0.00
A93_C2(3)_pt7	56.99			20.34		0.20			22.47	0.00	0.00
A93_C2(3)_pt8	65.54	0.60		0.31		0.06	0.53	0.46	32.39		0.11

Project: Norse_Decom
User Name: Trygve Furuseth

Sample A 52

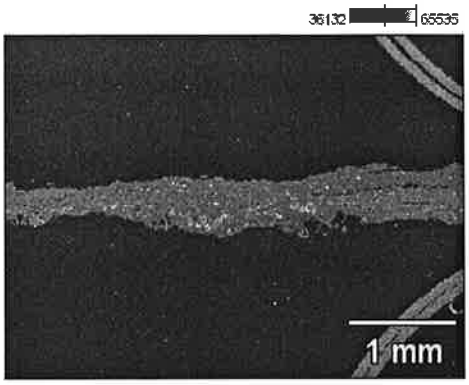


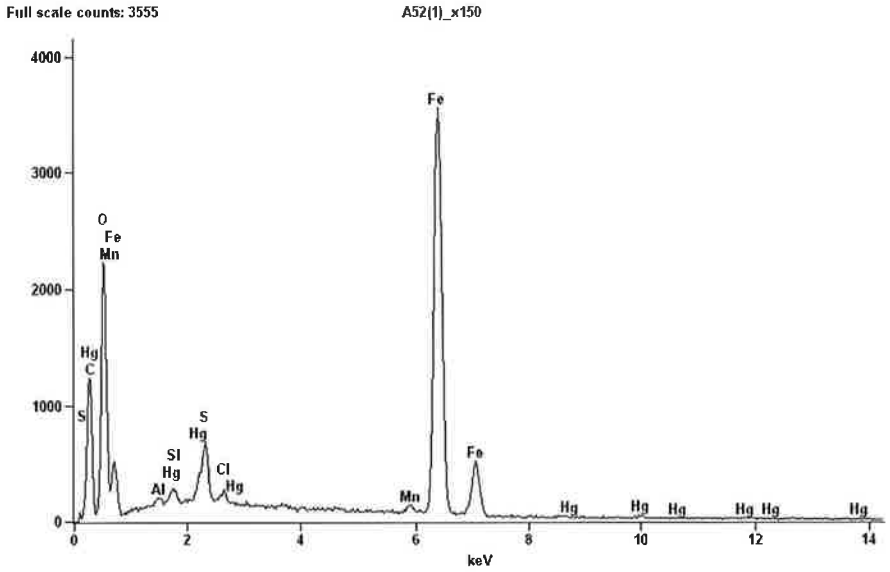
Quantitative Results A52_x50

Element	*Weight Conc %*	*Atom Conc %*
O	46.65	74.42
Al	0.38	0.36
Si	0.66	0.60
S	1.51	1.20
Cl	3.01	2.17
Fe	45.97	21.01
Hg	1.81	0.23
Total	100.00	100.00

Project: Norse_Decom
User Name: Trygve Furuseth

A52



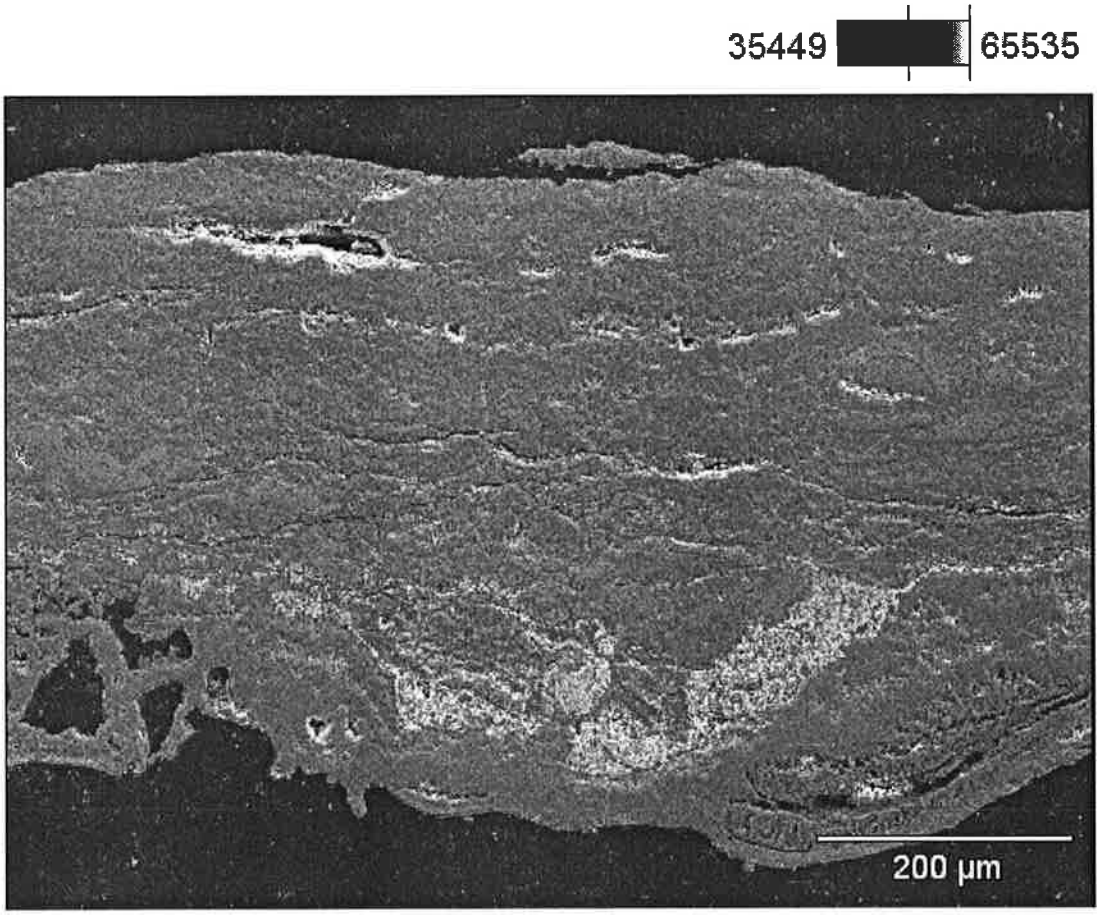


Quantitative Results A52(1) x150

Element	*Weight Conc %*	*Atom Conc %*
O	39.59	69.42
Al	0.35	0.36
Si	0.59	0.59
S	2.06	1.80
Cl	0.53	0.42
Mn	0.78	0.40
Fe	52.86	26.55
Hg	3.24	0.45
Total	100.00	100.00

Project: Norse_Decom
User Name: Trygve Furuseth

A52(2)



Project: Norse_Decom
User Name: Trygve Furuseth

A52(3)

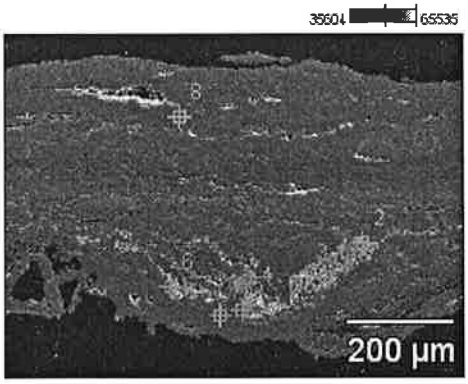


Image Name: A52(3)

Accelerating Voltage: 20.0 kV

Magnification: 150

Weight Concentration %

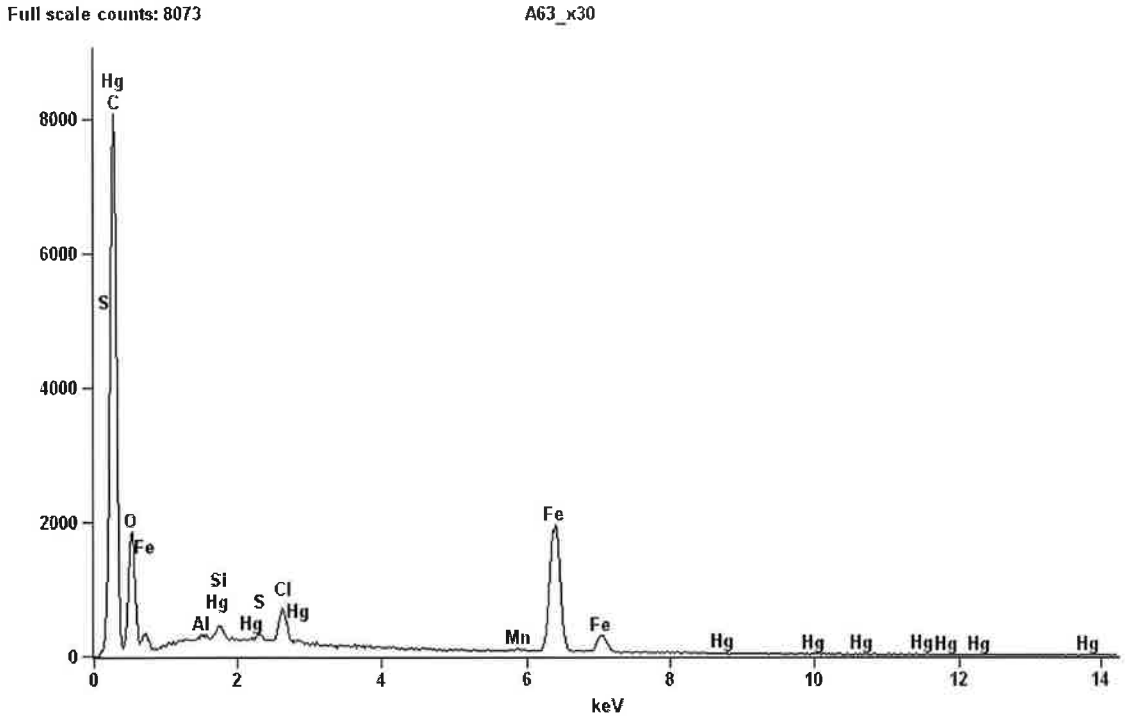
	O	Al	Si	S	Cl	Mn	Fe	Zn	Hg
A52(3)_pt1	18.28	0.38	0.08	11.14			21.85		48.27
A52(3)_pt2	10.81	0.43	0.01	18.53			6.42	13.51	50.28
A52(3)_pt3	13.68	0.62	0.07	16.47			11.40	6.02	51.74
A52(3)_pt4	20.61	0.36		11.35			25.15	2.08	40.45
A52(3)_pt5	9.49	0.48		20.24			0.00	8.49	61.30
A52(3)_pt6	14.61	0.29	0.01	14.78			9.47	2.12	58.71
A52(3)_pt7	40.79	0.23	0.21	0.69	0.39	1.02	56.66		0.00
A52(3)_pt8	40.24	0.25	0.23	0.43		0.89	57.61		0.35

Atom Concentration %

	O	Al	Si	S	Cl	Mn	Fe	Zn	Hg
A52(3)_pt1	53.41	0.66	0.14	16.25			18.29		11.25
A52(3)_pt2	36.68	0.86	0.03	31.37			6.24	11.21	13.61
A52(3)_pt3	43.90	1.18	0.12	26.36			10.48	4.73	13.24
A52(3)_pt4	55.06	0.58		15.13			19.25	1.36	8.62
A52(3)_pt5	35.36	1.07		37.62			0.00	7.73	18.21
A52(3)_pt6	48.57	0.57	0.03	24.52			9.02	1.73	15.57
A52(3)_pt7	70.21	0.23	0.20	0.60	0.31	0.51	27.94		0.00
A52(3)_pt8	69.95	0.25	0.23	0.38		0.45	28.69		0.05

Project: Norse_Decom
User Name: Trygve Furuseth

Sample A 63



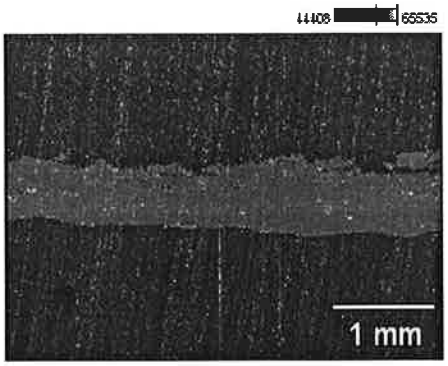
Quantitative Results A63_x30

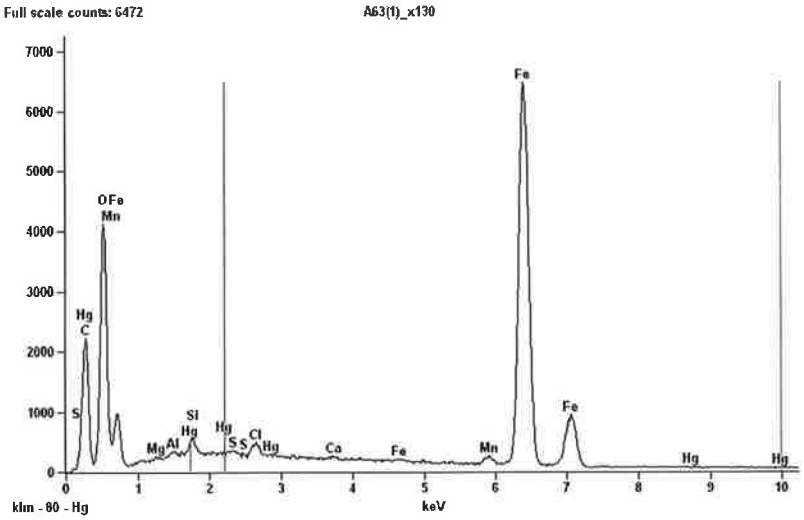
Element	*Weight Conc %*	*Atom Conc %*
O	47.32	74.71
Al	0.38	0.36
Si	1.20	1.08
S	0.45	0.36
Cl	3.38	2.41
Mn	0.67	0.31
Fe	45.69	20.67
Hg	0.89	0.11
Total	100.00	100.00

Prøve A63 er litt grovt slipt, men det har liten betydning for denne analysen. Hilsen Trygve.

Project: Norse_Decom
User Name: Trygve Furuseth

A63



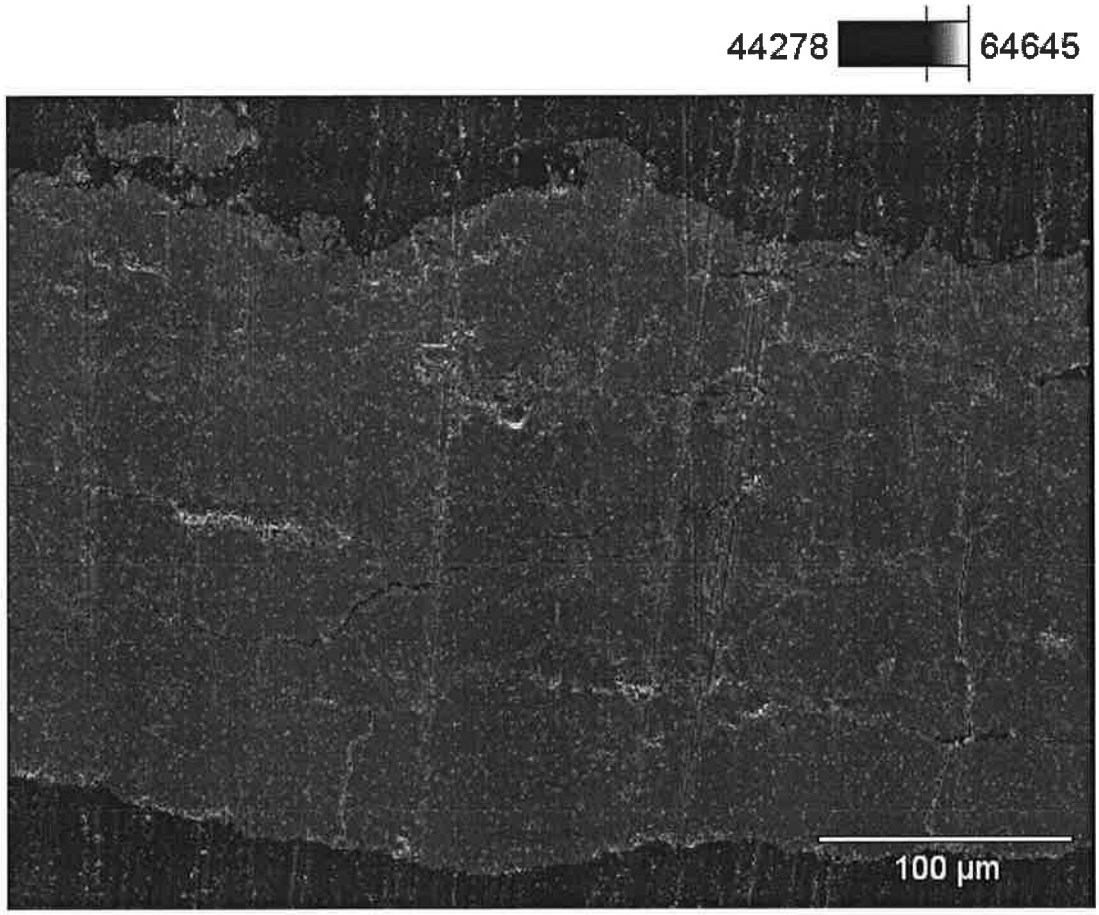


Quantitative Results A63(1) x130

Element	*Weight Conc %*	*Atom Conc %*
O	39.76	69.19
Mg	0.18	0.21
Al	0.21	0.22
Si	0.68	0.68
S	0.10	0.09
Cl	0.64	0.50
Ca	0.12	0.08
Mn	0.71	0.36
Fe	57.50	28.67
Hg	0.11	0.01
Total	100.00	100.00

Project: Norse_Decom
User Name: Trygve Furuseth

A63(2)



Accelerating Voltage: 20.0 kV Magnification: 130

Project: Norse_Decom
User Name: Trygve Furuseth

A63(3)

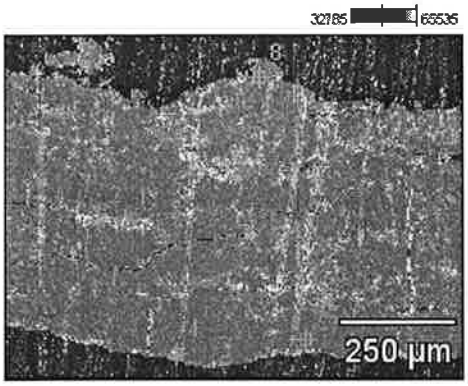


Image Name: A63(3)

Accelerating Voltage: 20.0 kV

Magnification: 130

Weight Concentration %

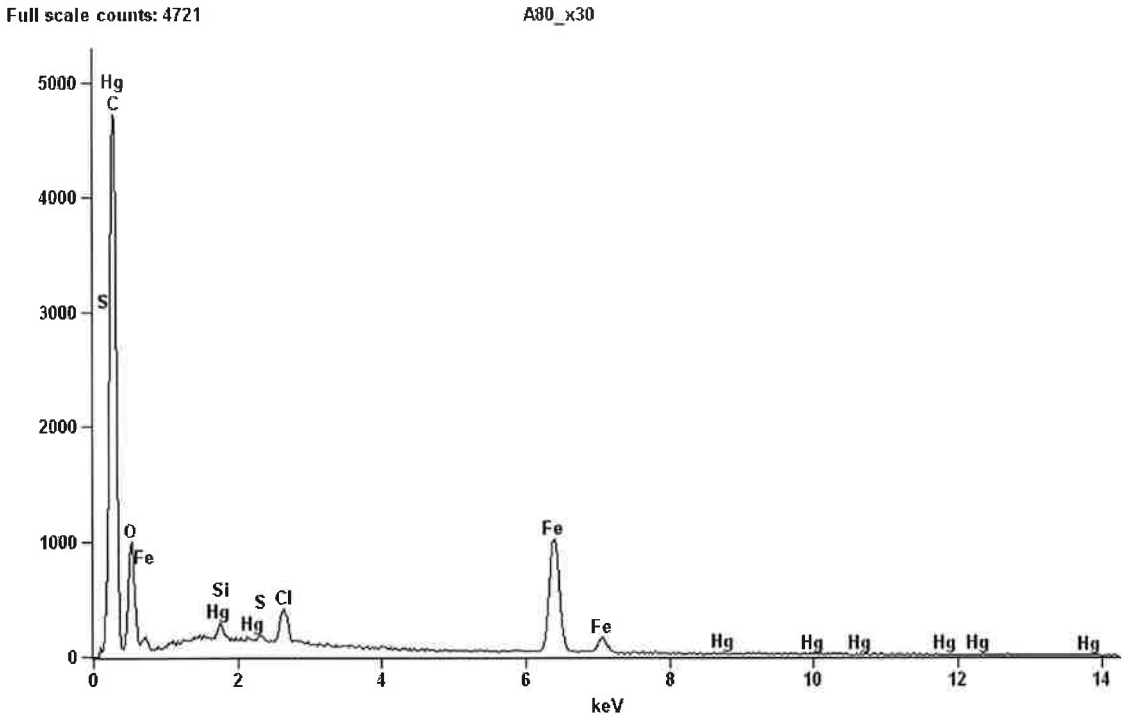
	O	Na	Mg	Al	Si	S	Cl	Ca	Mn	Fe	Zn	Hg
A63(3)_pt1	37.75	0.40		0.18	0.58	0.07	0.37	0.19	0.53	59.93		0.00
A63(3)_pt2	40.68			0.14	0.65	0.11	0.14	0.17	0.88	57.14		0.10
A63(3)_pt3	37.92	0.67	0.17	0.12	0.62	0.08	0.18	0.09	0.90	59.05		0.20
A63(3)_pt4	37.09			0.25	0.89	0.06	0.27	0.23	1.17	59.82		0.23
A63(3)_pt5	35.30	0.43	0.09	0.11	0.23	0.11	0.33		0.45	62.77		0.17
A63(3)_pt6	36.41			0.15	0.22	0.03	0.26	0.09	0.67	62.04		0.14
A63(3)_pt7	40.45			0.28	0.29	0.06	0.12		0.67	58.12		0.00
A63(3)_pt8	38.86			0.20	0.52	0.19	0.28	0.26	0.72	58.56	0.23	0.20

Atom Concentration %

	O	Na	Mg	Al	Si	S	Cl	Ca	Mn	Fe	Zn	Hg
A63(3)_pt1	67.33	0.50		0.19	0.59	0.06	0.30	0.13	0.27	30.62		0.00
A63(3)_pt2	70.19			0.15	0.64	0.09	0.11	0.12	0.44	28.25		0.01
A63(3)_pt3	67.38	0.83	0.20	0.12	0.62	0.07	0.15	0.06	0.46	30.07		0.03
A63(3)_pt4	66.85			0.27	0.91	0.05	0.22	0.16	0.61	30.89		0.03
A63(3)_pt5	65.14	0.56	0.11	0.12	0.24	0.10	0.27		0.24	33.19		0.03
A63(3)_pt6	66.48			0.16	0.22	0.03	0.21	0.07	0.35	32.46		0.02
A63(3)_pt7	70.09			0.29	0.29	0.05	0.10		0.34	28.85		0.00
A63(3)_pt8	68.59			0.21	0.52	0.17	0.22	0.18	0.37	29.61	0.10	0.03

Project: Norse_Decom
User Name: Trygve Furuseth

Sample A 80

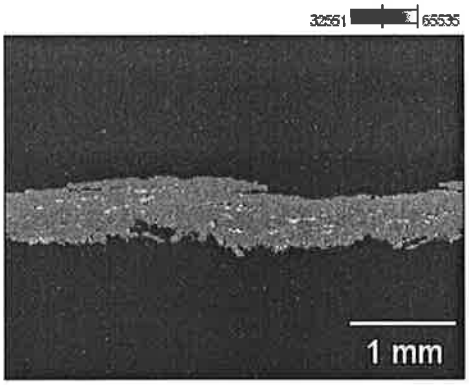


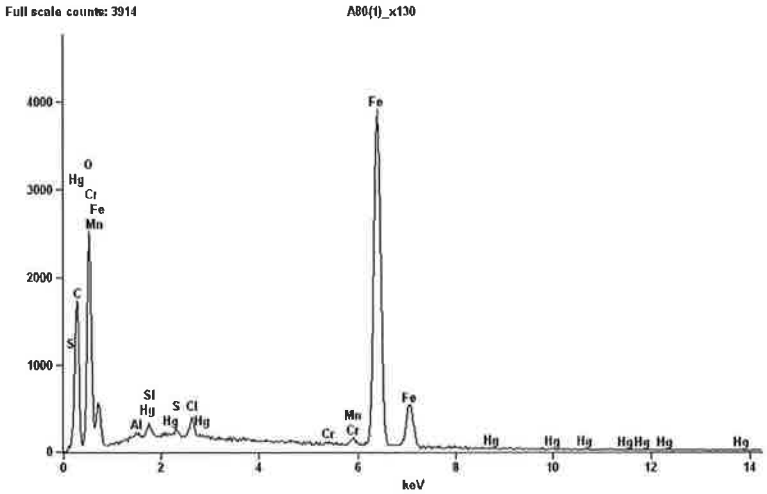
Quantitative Results A80_x30

Element	*Weight Conc %*	*Atom Conc %*
O	50.69	77.11
Si	1.26	1.09
S	0.51	0.38
Cl	4.41	3.02
Fe	41.81	18.22
Hg	1.32	0.16
Total	100.00	100.00

Project: Norse_Decom
User Name: Trygve Furuseth

A80





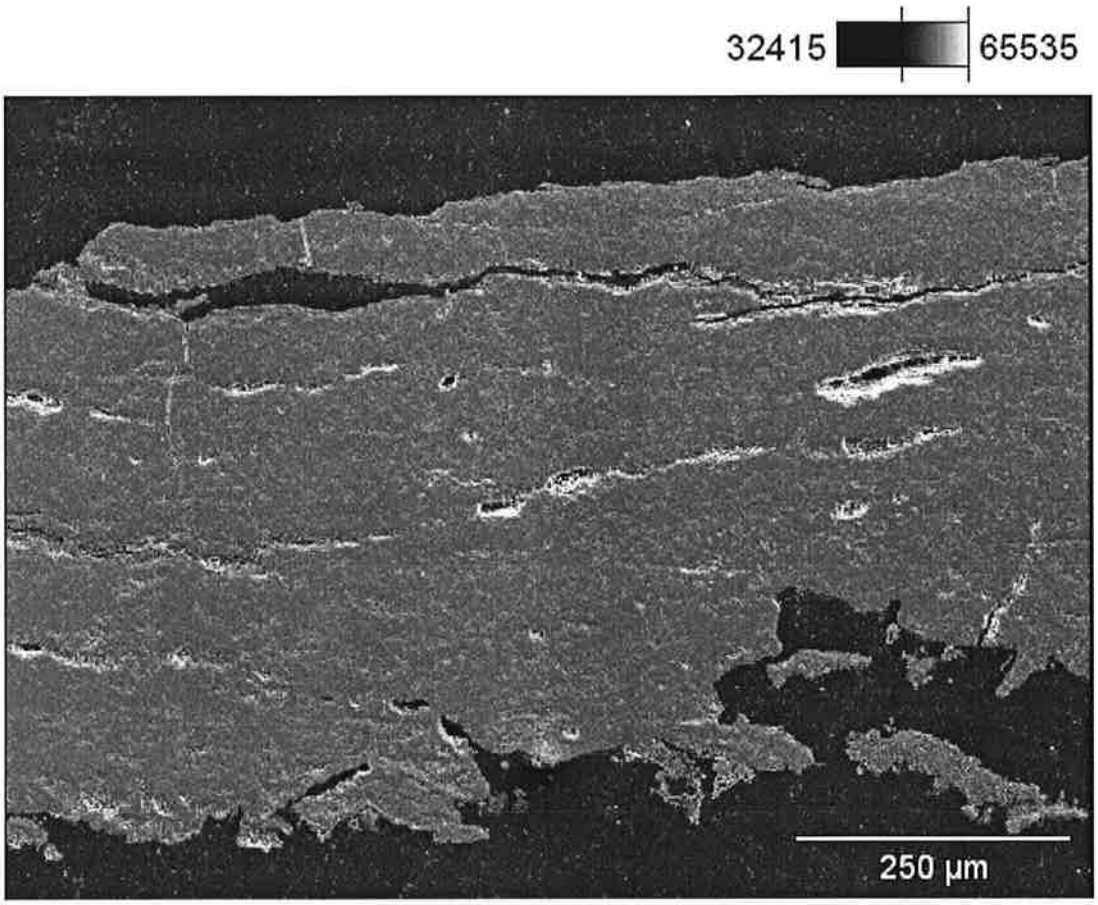
Project: Norse_Decom
User Name: Trygve Furuseth

Quantitative Results A80(1)_x130

Element	*Weight Conc %*	*Atom Conc %*
O	31.03	60.45
Al	0.29	0.34
Si	0.75	0.83
S	0.31	0.30
Cl	1.14	1.00
Cr	0.21	0.12
Mn	1.01	0.57
Fe	65.15	36.36
Hg	0.11	0.02
Total	100.00	100.00

Project: Norse_Decom
User Name: Trygve Furuseth

A80(2)



Accelerating Voltage: 20.0 kV Magnification: 130

Project: Norse_Decom
User Name: Trygve Furuseth

A80(3)

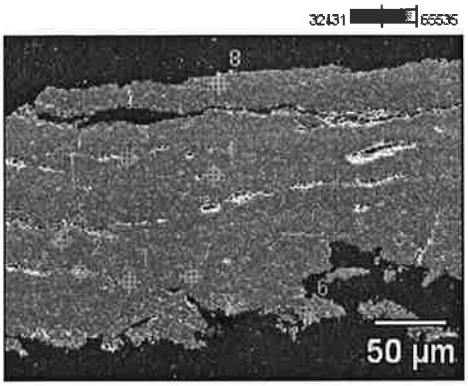


Image Name: A80(3)

Accelerating Voltage: 20.0 kV

Magnification: 130

Weight Concentration %

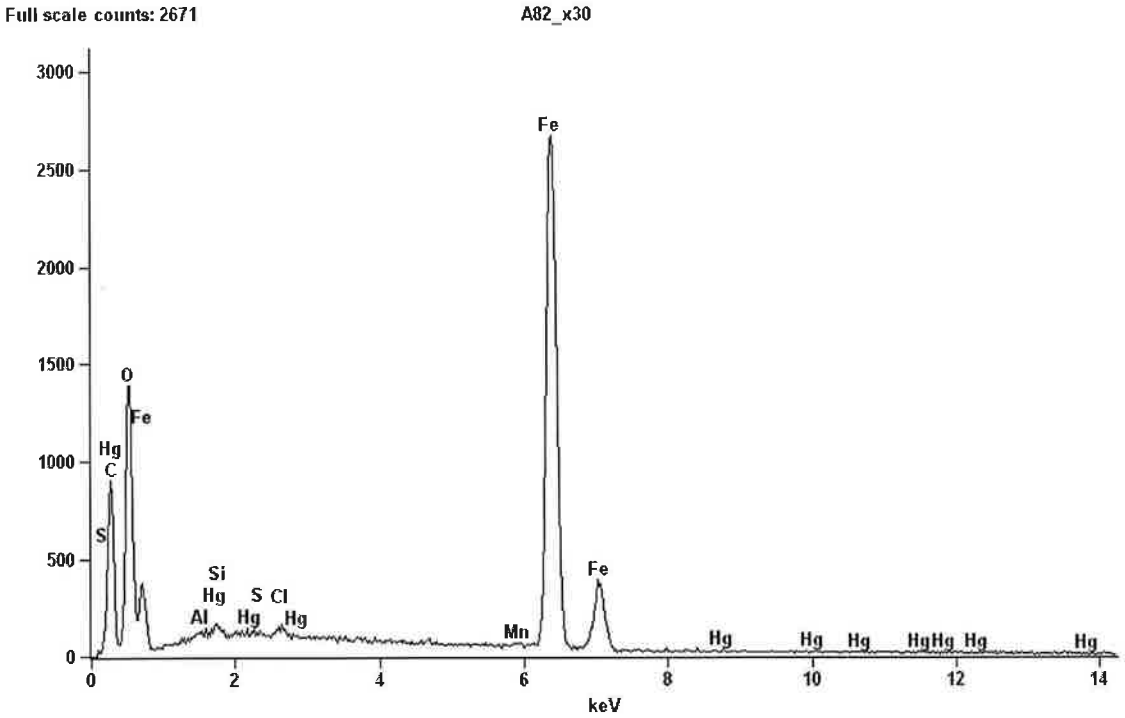
	O	Na	Mg	Al	Si	S	Cl	Cr	Mn	Fe	Hg
A80(3)_pt1	39.22			0.30	0.30	0.21	0.50		0.77	58.70	0.00
A80(3)_pt2	35.76	0.26		0.17	0.50	0.11	0.18		0.54	62.42	0.06
A80(3)_pt3	38.55			0.22	0.37	0.09	0.40		0.40	59.97	0.00
A80(3)_pt4	39.48			0.22	0.36	0.12	0.41		1.20	58.22	0.00
A80(3)_pt5	37.11	0.28		0.26	2.86	0.11	0.36		0.55	57.91	0.55
A80(3)_pt6	35.91			0.21	0.44	0.91	0.21		0.27	61.74	0.32
A80(3)_pt7	40.20			0.28	0.49	0.12	0.43		1.71	56.78	0.00
A80(3)_pt8	31.74		0.21	0.30	0.66	0.11	0.30	0.23	1.16	65.27	0.00

Atom Concentration %

	O	Na	Mg	Al	Si	S	Cl	Cr	Mn	Fe	Hg
A80(3)_pt1	68.87			0.31	0.30	0.19	0.40		0.39	29.53	0.00
A80(3)_pt2	65.61	0.33		0.18	0.52	0.10	0.15		0.29	32.81	0.01
A80(3)_pt3	68.33			0.23	0.38	0.08	0.32		0.21	30.46	0.00
A80(3)_pt4	69.16			0.22	0.36	0.10	0.32		0.61	29.22	0.00
A80(3)_pt5	66.15	0.35		0.27	2.90	0.10	0.29		0.28	29.57	0.08
A80(3)_pt6	65.74			0.22	0.46	0.83	0.18		0.14	32.38	0.05
A80(3)_pt7	69.72			0.29	0.48	0.11	0.34		0.86	28.21	0.00
A80(3)_pt8	61.35		0.27	0.35	0.73	0.11	0.27	0.14	0.65	36.14	0.00

Project: Norse_Decom
User Name: Trygve Furuseth

Sample A 82

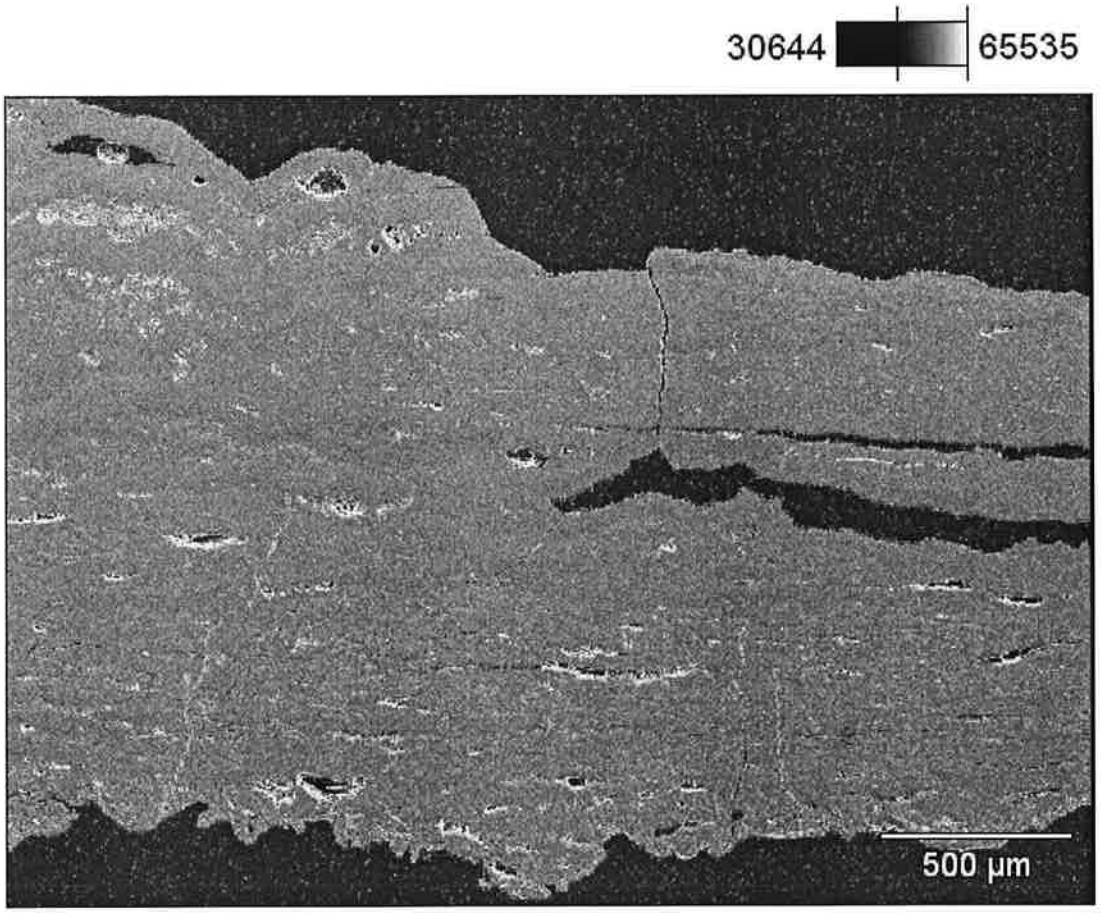


Quantitative Results A82_x30

Element	*Weight Conc %*	*Atom Conc %*
O	38.37	68.15
Al	0.24	0.25
Si	0.46	0.47
S	0.04	0.04
Cl	0.38	0.31
Mn	0.41	0.21
Fe	60.08	30.57
Hg	0.00	0.00
Total	100.00	100.00

Project: Norse_Decom
User Name: Trygve Furuseth

A82(1)



Accelerating Voltage: 20.0 kV Magnification: 45

Project: Norse_Decom
User Name: Trygve Furuseth

A82(2)

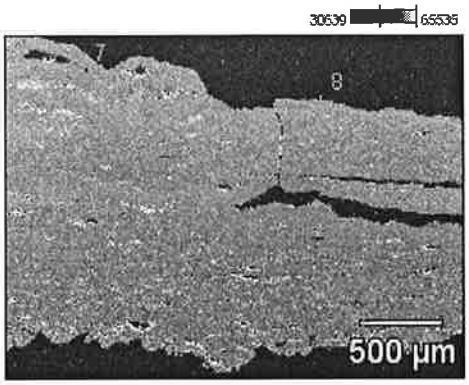


Image Name: A82(2)

Accelerating Voltage: 20.0 kV

Magnification: 45

Weight Concentration %

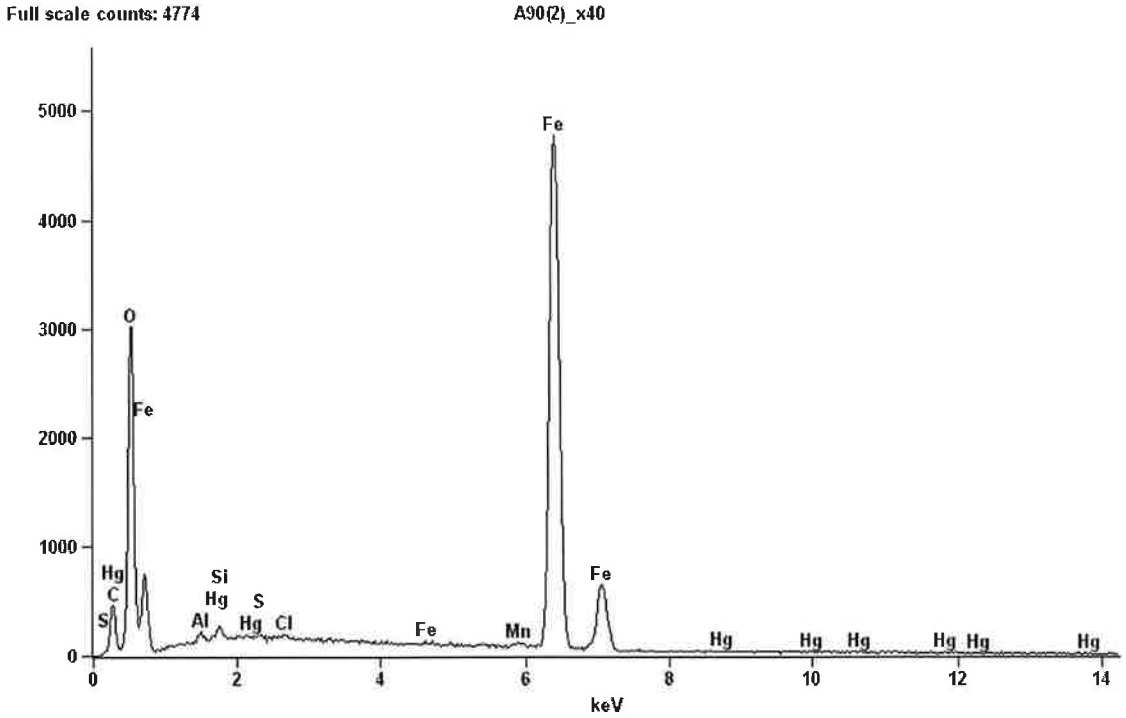
	O	Na	Mg	Al	Si	S	Cl	Ca	Mn	Fe	Hg
A82(2)_pt1	29.99				40.70	0.12	0.35	0.12		28.73	0.00
A82(2)_pt2	35.62			0.34	0.35	0.00	0.10		0.24	63.36	0.00
A82(2)_pt3	37.38		0.25	0.17	0.38	0.11	0.47	0.11		60.75	0.38
A82(2)_pt4	39.21			0.31	0.39	0.04			0.22	59.84	0.00
A82(2)_pt5	34.98			0.36	0.33	0.03		0.16	0.95	63.15	0.05
A82(2)_pt6	32.87	4.18		0.22	0.16	0.06	1.52			60.91	0.08
A82(2)_pt7	34.76			0.31	0.17	0.05			0.47	64.25	0.00
A82(2)_pt8	33.60			0.20	0.11	0.00			0.25	65.84	0.00

Atom Concentration %

	O	Na	Mg	Al	Si	S	Cl	Ca	Mn	Fe	Hg
A82(2)_pt1	48.63				37.59	0.10	0.25	0.08		13.35	0.00
A82(2)_pt2	65.62			0.37	0.37	0.00	0.08		0.13	33.44	0.00
A82(2)_pt3	67.22		0.30	0.18	0.39	0.10	0.38	0.08		31.30	0.05
A82(2)_pt4	68.98			0.33	0.39	0.03			0.11	30.16	0.00
A82(2)_pt5	64.98			0.40	0.35	0.02		0.12	0.51	33.61	0.01
A82(2)_pt6	60.68	5.37		0.24	0.16	0.05	1.27			32.21	0.01
A82(2)_pt7	64.84			0.35	0.18	0.04			0.25	34.34	0.00
A82(2)_pt8	63.74			0.22	0.12	0.00			0.14	35.78	0.00

Project: Norse_Decom
User Name: Trygve Furuseth

Sample A 90



Quantitative Results A90(2) x40

Element	*Weight Conc %*	*Atom Conc %*
O	37.84	67.71
Al	0.31	0.33
Si	0.43	0.44
S	0.06	0.05
Cl	0.10	0.08
Mn	0.46	0.24
Fe	60.73	31.13
Hg	0.06	0.01
Total	100.00	100.00

Project: Norse_Decom
User Name: Trygve Furuseth

A90(4)

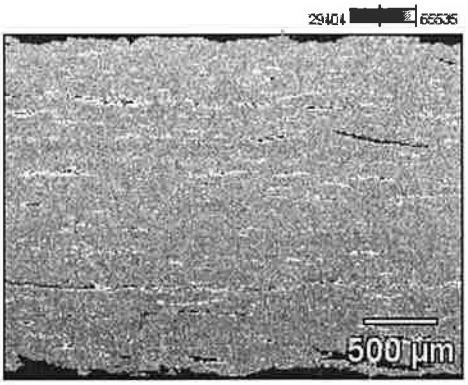


Image Name: A90(4)

Accelerating Voltage: 20.0 kV

Magnification: 40

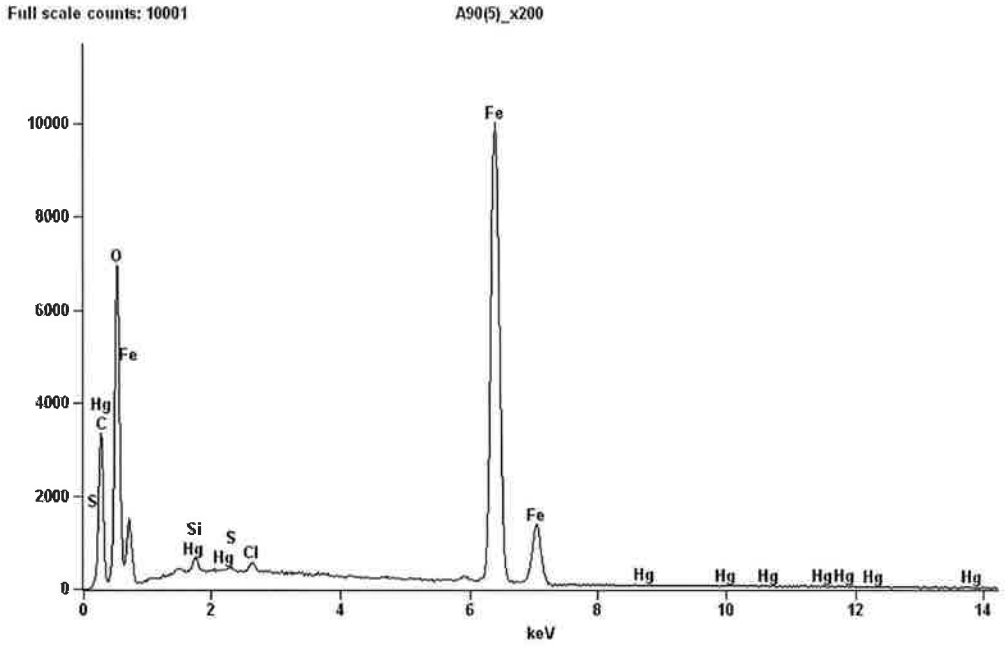
Weight Concentration %

	O	Al	Si	S	Cl	Mn	Fe	Hg
A90(4)_pt1	39.10	0.26	0.29	0.03	0.10	0.48	59.74	0.00
A90(4)_pt2	38.17	0.27	0.49	0.01		0.26	60.80	0.00
A90(4)_pt3	36.37	0.30	0.26	0.05		0.59	62.43	0.00
A90(4)_pt4	37.44	0.26	0.23	0.02	0.07	0.39	61.60	0.00
A90(4)_pt5	35.73	0.27	0.21	0.05		0.69	62.81	0.24
A90(4)_pt6	40.58	0.19	0.54	0.03			58.29	0.38
A90(4)_pt7	40.02	0.21	0.34	0.02		0.36	58.69	0.37
A90(4)_pt8	39.18	0.32	0.43	0.10		0.62	59.35	0.01

Atom Concentration %

	O	Al	Si	S	Cl	Mn	Fe	Hg
A90(4)_pt1	68.92	0.27	0.30	0.03	0.08	0.25	30.17	0.00
A90(4)_pt2	68.02	0.29	0.50	0.01		0.13	31.04	0.00
A90(4)_pt3	66.39	0.33	0.27	0.04		0.31	32.65	0.00
A90(4)_pt4	67.43	0.28	0.24	0.02	0.05	0.20	31.79	0.00
A90(4)_pt5	65.86	0.29	0.23	0.04		0.37	33.17	0.04
A90(4)_pt6	70.27	0.19	0.53	0.02			28.92	0.05
A90(4)_pt7	69.85	0.22	0.33	0.02		0.18	29.35	0.05
A90(4)_pt8	68.92	0.34	0.43	0.08		0.32	29.91	0.00

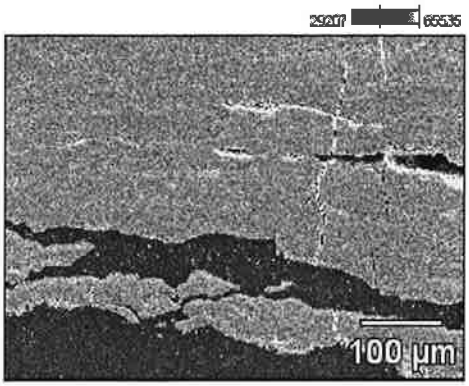
Project: Norse_Decom
User Name: Trygve Furuseth



Quantitative Results A90(5) x200

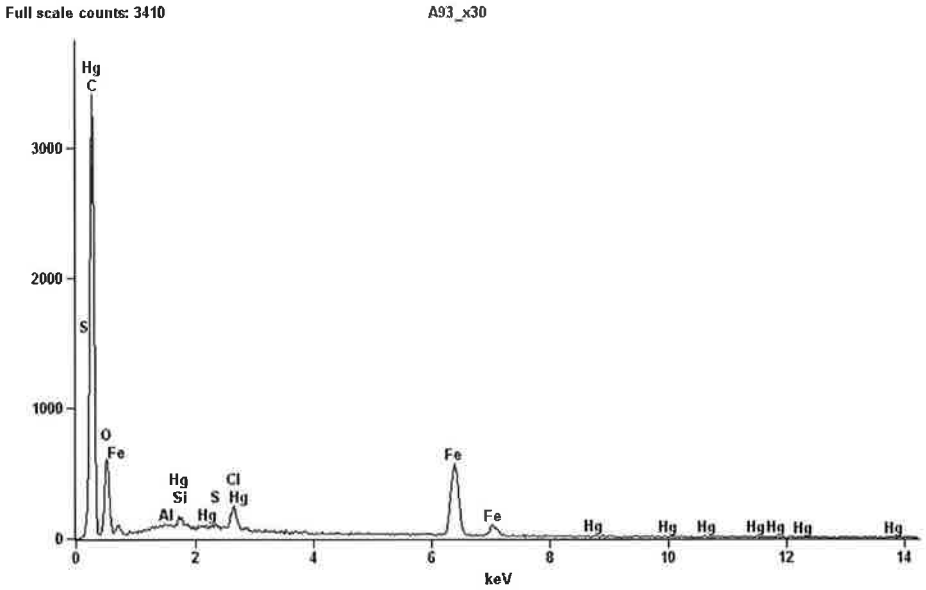
Element	*Weight Conc %*	*Atom Conc %*
O	40.19	69.86
Si	0.48	0.48
S	0.09	0.08
Cl	0.33	0.26
Fe	58.90	29.33
Hg	0.00	0.00
Total	100.00	100.00

A90(5)



Project: Norse_Decom
User Name: Trygve Furuseth

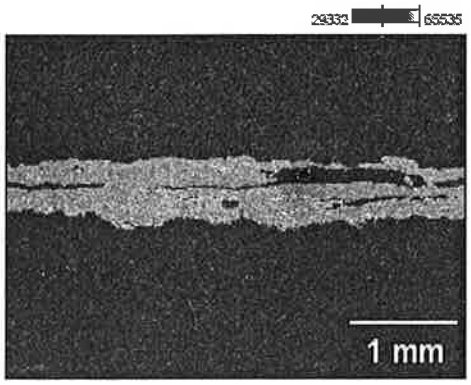
Sample A 93



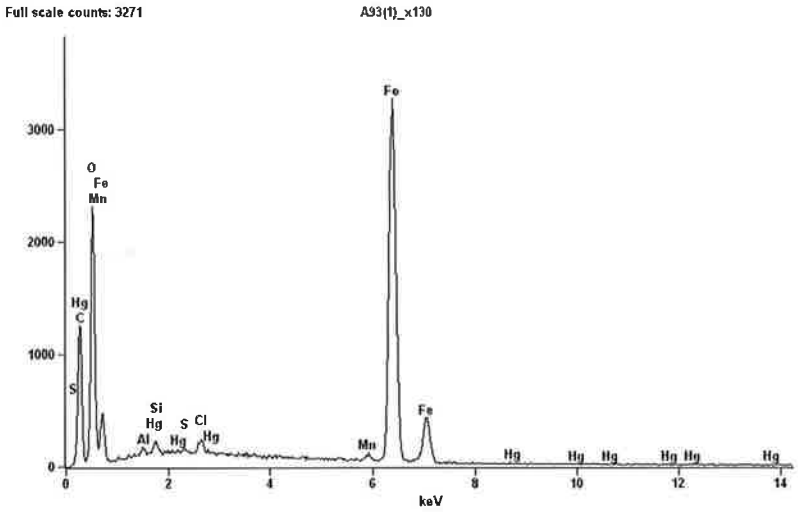
Quantitative Results A93_x30

Element	*Weight Conc %*	*Atom Conc %*
O	48.13	75.28
Al	0.38	0.35
Si	1.24	1.10
S	0.41	0.32
Cl	3.66	2.59
Fe	45.17	20.24
Hg	1.02	0.13
Total	100.00	100.00

A93



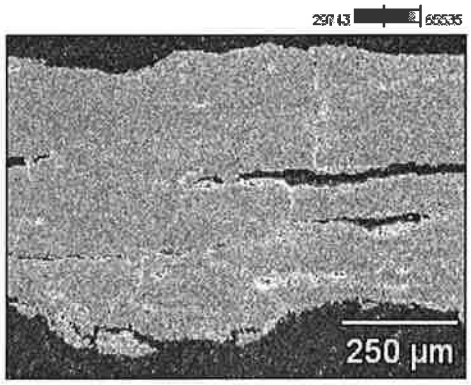
Project: Norse_Decom
User Name: Trygve Furuseth



Quantitative Results A93(1)_x130

Element	*Weight Conc %*	*Atom Conc %*
O	40.06	69.54
Al	0.31	0.32
Si	0.58	0.57
S	0.12	0.10
Cl	0.63	0.50
Mn	0.87	0.44
Fe	57.38	28.53
Hg	0.05	0.01
Total	100.00	100.00

A93(2)



Project: Norse_Decom
User Name: Trygve Furuseth

A93(3)

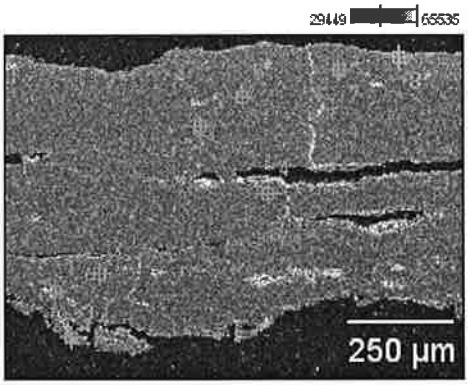


Image Name: A93(3)

Accelerating Voltage: 20.0 kV

Magnification: 130

Weight Concentration %

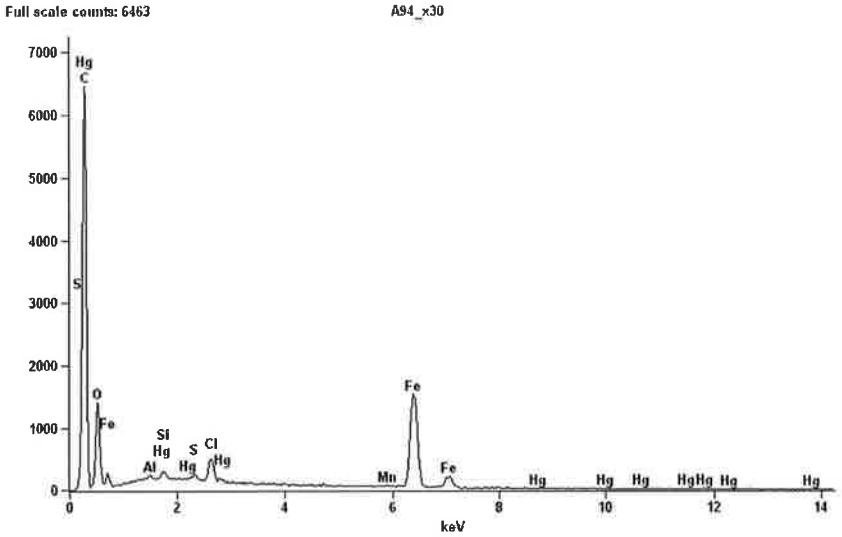
	O	Al	Si	S	Cl	Ca	Mn	Fe	Hg
A93(3)_pt1	36.47	0.25	0.57	0.26	0.55		1.08	60.05	0.77
A93(3)_pt2	38.35	0.28	0.40	0.05	0.25		0.70	59.95	0.00
A93(3)_pt3	35.19	0.35	0.29	0.11			0.52	63.54	0.00
A93(3)_pt4	40.19	0.23	0.33	0.08	0.20		1.03	57.64	0.30
A93(3)_pt5	35.10	0.23	0.15	0.02			0.58	63.23	0.69
A93(3)_pt6	40.41	0.22	0.40	0.05	0.22		0.61	57.75	0.34
A93(3)_pt7	39.50	0.26	0.33	0.05	0.26		0.77	58.83	0.00
A93(3)_pt8	38.32	0.19	0.33	0.07	0.56	0.04	0.68	59.81	0.00

Atom Concentration %

	O	Al	Si	S	Cl	Ca	Mn	Fe	Hg
A93(3)_pt1	66.42	0.27	0.59	0.24	0.45		0.57	31.34	0.11
A93(3)_pt2	68.16	0.30	0.41	0.04	0.20		0.36	30.52	0.00
A93(3)_pt3	65.20	0.39	0.30	0.11			0.28	33.72	0.00
A93(3)_pt4	69.92	0.23	0.32	0.07	0.16		0.52	28.73	0.04
A93(3)_pt5	65.40	0.26	0.15	0.02			0.31	33.75	0.10
A93(3)_pt6	70.10	0.22	0.40	0.04	0.17		0.31	28.70	0.05
A93(3)_pt7	69.22	0.27	0.33	0.04	0.21		0.39	29.54	0.00
A93(3)_pt8	68.11	0.20	0.33	0.06	0.45	0.03	0.35	30.46	0.00

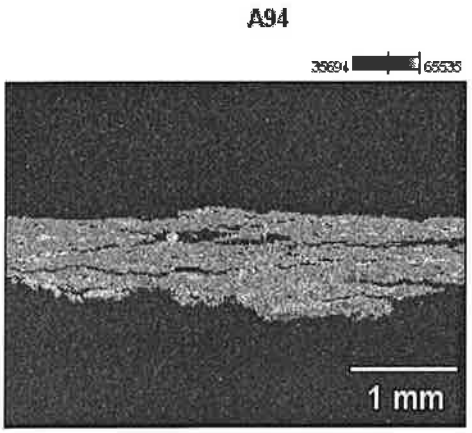
Project: Norse_Decom
User Name: Trygve Furuseth

Sample A 94

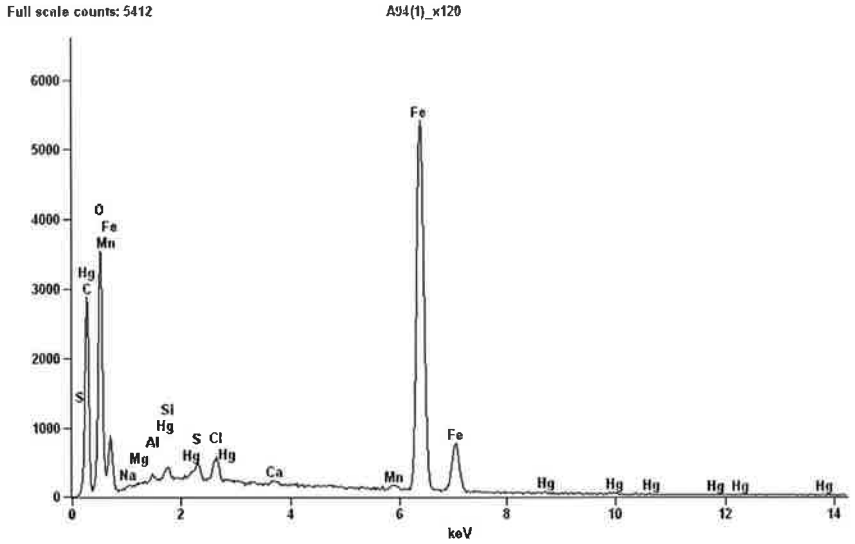


Quantitative Results A94_x30

Element	*Weight Conc %*	*Atom Conc %*
O	46.55	73.76
Al	0.62	0.58
Si	1.30	1.18
S	0.78	0.62
Cl	3.53	2.52
Mn	0.70	0.33
Fe	46.20	20.97
Hg	0.31	0.04
Total	100.00	100.00



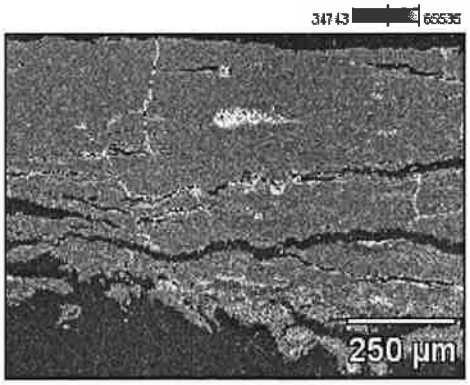
Project: Norse_Decom
User Name: Trygve Furuseth



Quantitative Results A94(1)_x120

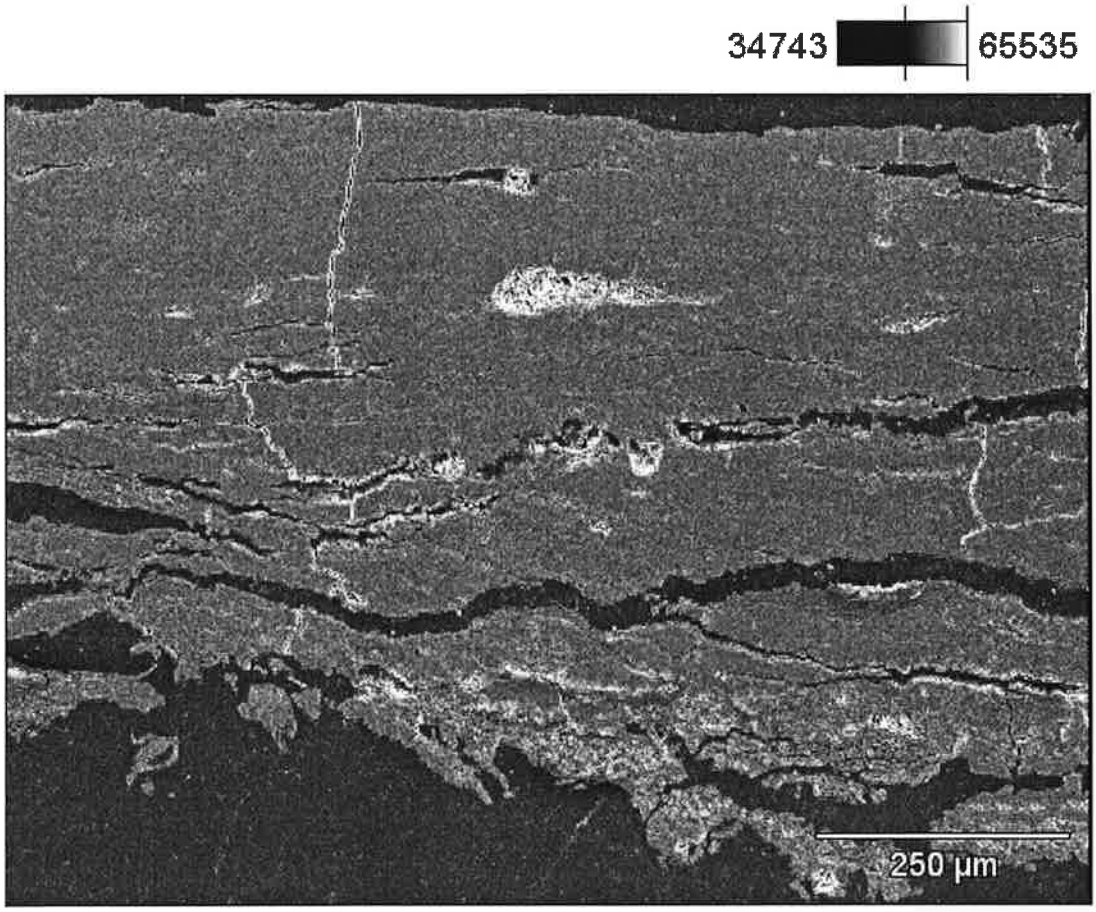
Element	*Weight Conc %*	*Atom Conc %*
O	38.43	68.01
Na	0.27	0.34
Mg	0.18	0.21
Al	0.36	0.37
Si	0.62	0.63
S	0.49	0.44
Cl	1.16	0.93
Ca	0.15	0.11
Mn	0.58	0.30
Fe	56.06	28.42
Hg	1.68	0.24
Total	100.00	100.00

A94(2)



Project: Norse_Decom
User Name: Trygve Furuseth

A94(2)



Accelerating Voltage: 20.0 kV Magnification: 120

Project: Norse_Decom
User Name: Trygve Furuseth

A94(3)

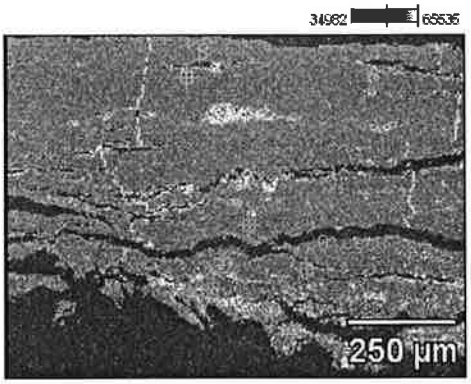


Image Name: A94(3)

Accelerating Voltage: 20.0 kV

Magnification: 120

Weight Concentration %

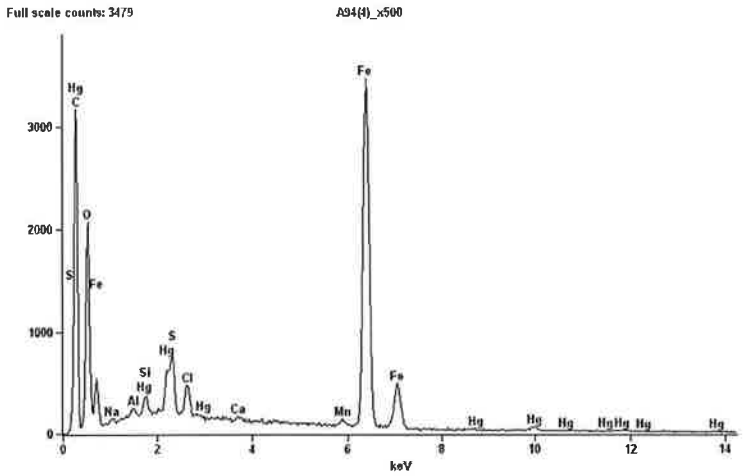
	O	Na	Mg	Al	Si	S	Cl	Ca	Cr	Mn	Fe	Zn	Hg
A94(3)_pt1	35.91	0.45		0.28	0.15	0.66	0.57	0.09		0.93	59.37	1.13	0.46
A94(3)_pt2	38.27			0.35	0.29	1.39	1.06			2.22	53.48	1.93	1.00
A94(3)_pt3	14.15			0.56		12.62	3.80	0.16			6.26	1.58	60.86
A94(3)_pt4	22.37		0.36	2.96	6.31	9.53	3.74				10.63	2.55	41.56
A94(3)_pt5	16.06			0.56		12.44	2.70	0.52			11.53	1.39	54.79
A94(3)_pt6	37.88		0.22	0.19	0.32	0.31	0.29	0.29		0.44	60.05		0.01
A94(3)_pt7	38.25	0.36		0.54	1.45	0.42	0.43	0.22	0.13		58.01		0.19
A94(3)_pt8	40.26	0.23		0.27	0.35	0.19	0.46	0.28		0.76	56.97		0.22

Atom Concentration %

	O	Na	Mg	Al	Si	S	Cl	Ca	Cr	Mn	Fe	Zn	Hg
A94(3)_pt1	65.66	0.57		0.30	0.16	0.60	0.47	0.07		0.50	31.10	0.51	0.07
A94(3)_pt2	67.93			0.36	0.29	1.23	0.85			1.15	27.20	0.84	0.14
A94(3)_pt3	47.82			1.13		21.28	5.80	0.21			6.06	1.31	16.40
A94(3)_pt4	54.05		0.57	4.24	8.68	11.49	4.08				7.36	1.51	8.01
A94(3)_pt5	50.13			1.04		19.37	3.80	0.64			10.31	1.07	13.64
A94(3)_pt6	67.58		0.26	0.20	0.32	0.27	0.23	0.20		0.23	30.69		0.00
A94(3)_pt7	67.33	0.44		0.57	1.45	0.37	0.35	0.16	0.07		29.26		0.03
A94(3)_pt8	69.71	0.27		0.28	0.35	0.17	0.36	0.19		0.38	28.26		0.03

Project: Norse_Decom
User Name: Trygve Furuseth

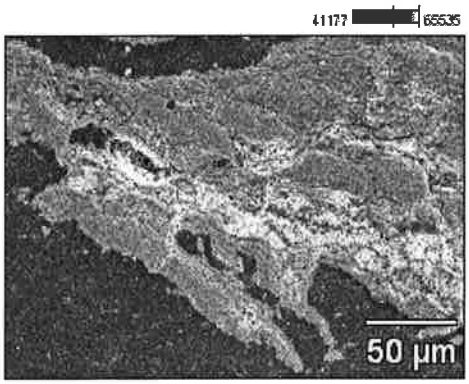
Sample A 94



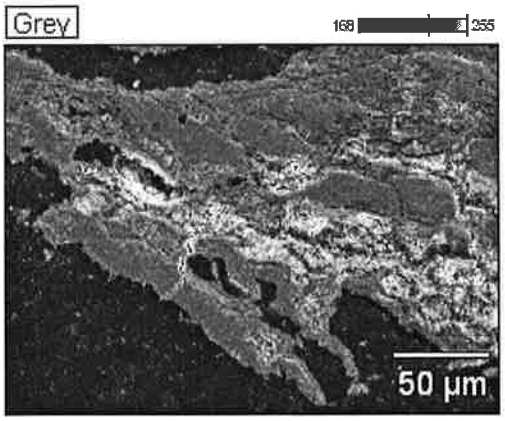
Quantitative Results A94(4)_x500

Element	*Weight Conc %*	*Atom Conc %*
O	38.73	68.80
Na	0.58	0.72
Al	0.36	0.38
Si	0.65	0.66
S	1.74	1.54
Cl	1.77	1.42
Ca	0.19	0.13
Mn	0.74	0.38
Fe	49.43	25.15
Hg	5.82	0.82
Total	100.00	100.00

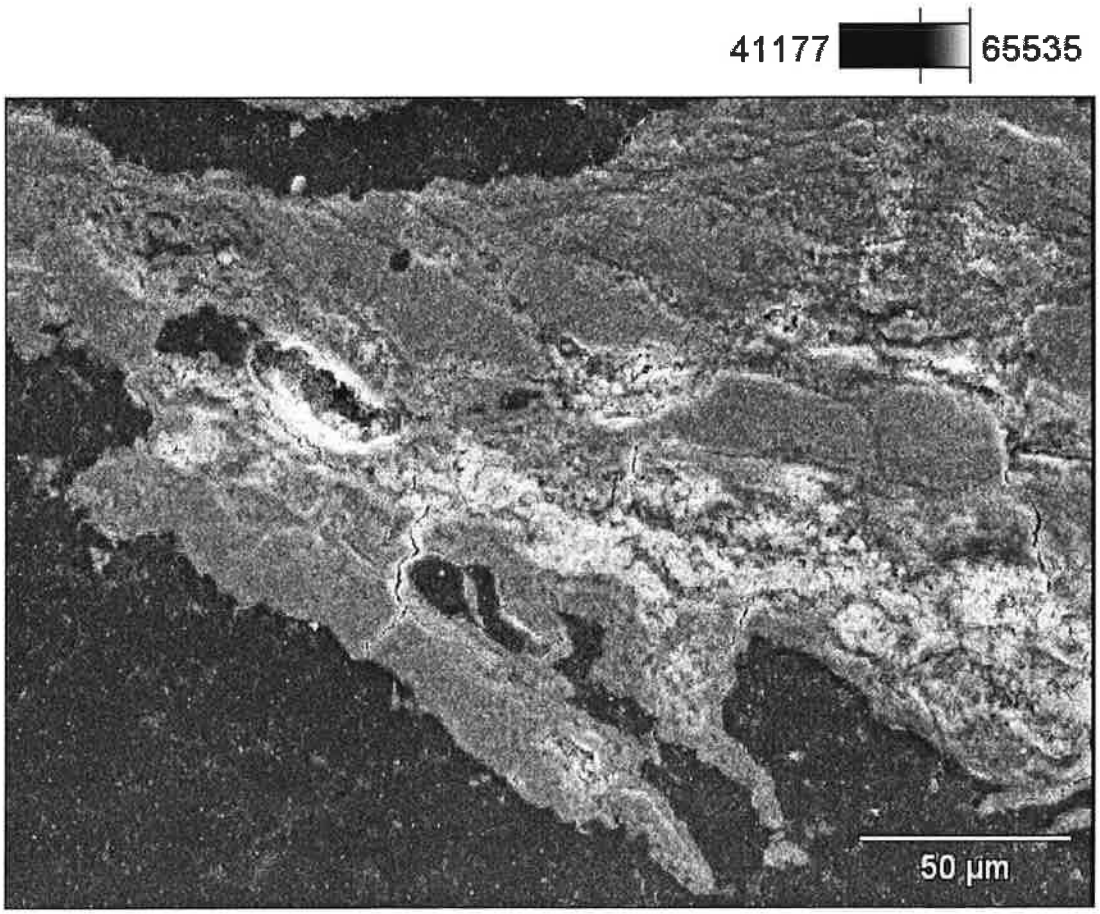
A94(5)



Project: Norse_Decom
User Name: Trygve Furuseth



A94(5)



Accelerating Voltage: 20.0 kV Magnification: 500

Appendix 4

Norsk institutt for luftforskning
Norwegian Institute for Air Research
NILU

Norse Decom
v/ Per Varskog
P.O.Box 112
2027 Kjeller

Deres ref./*Your ref.*:	Vår ref./*Our ref.*:	Kjeller,
Innkjøpsordre 109/05	HTU/ZMo/O-2216	11. april 2005

Analyserapport

Vi viser til mottak av prøve for analyse 16. februar 2005.

Vedlagt oversendes målerapporten NILU-U-1056-05.

Med hilsen

Ole-Anders Braathen
Avd. leder, Kjemisk analyse

Hilde Th. Uggerud
Forsker

Vedlegg: Målerapporten U-1056-05

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Bank: 5102.05.19030
Foretaksnr./Enterprise no. 941705561

Norsk institutt for luftforskning
Postboks 100, N-2027 Kjeller

Målerapport nr. U-1056-05

Oppdragsgiver: Norse Decom
v/ Per Varskog
P.O.Box 112, 2027 Kjeller

Prosjekt nr.: O-2216 **Journalnr.:** 05-24
Innkjøpsordre: **109/05**

Prøvetaking:
Sted:
Ansvar: Oppdragsgiver
Kommentar:

Prøveinformasjon:
Prøvetype: Avskrap fra rør (Ekofisk 2/4-T)
Prøver mottatt: 16.02.2005
Antall prøver: 41
Kommentar: NILU har ingen spesielle kommentarer til prøvens tilstand ved mottak

Analyser:
Utført av Norsk institutt for luftforskning
Postboks 100
N-2007 KJELLER

Målemetode:
NILU-U-62: Forskrift for bestemmelse av Hg i prøver av fast materiale ved kalddampgenerering/atomfluorescens-spektrofotometri

Kommentar:

Kontaktperson: Hilde Th. Uggerud Forsker eller Marit Vadset, Ingeniør Torunn Berg (Hg) Seniorforsker

Norsk institutt for luftforskning
Postboks 100, N-2027 Kjeller

Godkjenning: Kjeller, 11.04.2005

Hilde Th. Uggerud
Forsker

Vedlegg: Analyseresultater: 1 side
Målerapporten og vedleggene omfatter totalt 3 sider

Måleresultatene gjelder bare de prøvene som er analysert. Denne rapporten skal ikke gjengis i utdrag, uten skriftlig godkjenning fra laboratoriet.

Analyseresultatene for ICPMS følger som et eget vedlegg med overskrift "NILU ICPMS RAPPORT".

Oppdragsgivers prøveidentifikasjon er angitt i målerapporten for hver enkelt prøve. Analyseresultatene i rapportvedlegget er gitt med varierende antall gjeldende siffer. Med metodens beregnede usikkerhet som grunnlag, anbefales det å ikke benytte mer enn 3 gjeldende siffer ved vurdering eller i presentasjon av resultatene.

Usikkerheten i måleresultatene fås ved henvendelse til NILUs laboratorium.

Et minus "-" foran måleresultatet, betyr at det er mindre enn deteksjonsgrensen for analysemetoden. Er måleresultatet oppgitt som f.eks. "-0.01", betyr det at deteksjonsgrensen for metoden er 0.01.

Prosjektnr:	O-2216		
Prøve ID	**Journal-nr**	**Kons. Hg**	**Enhet**
A1	05-24-1	2941.567	mg kg^{-1}
A2	05-24-2	338.2592	mg kg^{-1}
A3	05-24-3	12714.89	mg kg^{-1}
A4	05-24-4	2196.664	mg kg^{-1}
A5	05-24-5	30366.95	mg kg^{-1}
A6	05-24-6	2478.078	mg kg^{-1}
A7	05-24-7	2845.943	mg kg^{-1}
A8	05-24-8	35811.14	mg kg^{-1}
A9	05-24-9	2744.39	mg kg^{-1}
A10	05-24-10	10597.46	mg kg^{-1}
A11	05-24-11	2638.99	mg kg^{-1}
A12	05-24-12	5091.785	mg kg^{-1}
A13	05-24-13	19813.18	mg kg^{-1}
A14	05-24-14	21770.39	mg kg^{-1}
A15	05-24-15	329.6038	mg kg^{-1}
A16	05-24-16	66	mg kg^{-1}
A16B	05-24-17	60.1	mg kg^{-1}
A17	05-24-18	27.6	mg kg^{-1}
A18	05-24-19	87.8	mg kg^{-1}
A19	05-24-20	3.3	mg kg^{-1}
A20	05-24-21	91.5	mg kg^{-1}
A21	05-24-22	62.6	mg kg^{-1}
A22	05-24-23	2273.5	mg kg^{-1}
A23	05-24-24	762.6	mg kg^{-1}
A24	05-24-25	5.7	mg kg^{-1}
A25	05-24-26	193.0	mg kg^{-1}
A27	05-24-27	12912.3	mg kg^{-1}
A28	05-24-28	4761.7	mg kg^{-1}
A29	05-24-29	4272.0	mg kg^{-1}
A30	05-24-30	868.6	mg kg^{-1}
A31	05-24-31	113.0	mg kg^{-1}
A32	05-24-32	20472.0	mg kg^{-1}
A33	05-24-33	38577.2	mg kg^{-1}
A34	05-24-34	7322.2	mg kg^{-1}
A35	05-24-35	209.1	mg kg^{-1}
A36	05-24-36	< 17.3	mg kg^{-1}
2C	05-24-37	62.1	mg kg^{-1}
6C	05-24-38	289.8433	mg kg^{-1}
7C	05-24-39	4370.294	mg kg^{-1}
10C	05-24-40	3279.078	mg kg^{-1}
A5C	05-24-41	8321.99	mg kg^{-1}

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Kundenr.: 51102
Ordrenr.: 350461

Mott. dato: 2005.05.11

ANALYSERAPPORT

Rekvirent.....: AF Decom AS
Postboks 34 Grefsen, 0409 Oslo, Norge
Prøvested.....: **Hg-analyser i rust**
Prøvetype.....: Annet
Prøvetaking.....:
Prøvetaker.....: Ikke oplyst
Kundeopplysninger:
Analyseperiode...: 2005.05.11 - 2005.05.24

Prøvemerking:	A 37	A 38	A 39	A 40	Enheter	Deteks. grense	Metoder
Tørrstoff	94.9	95.5	95.5	96.6	%	0.0020	MK3001-DS204
Kvikksølv (Hg)	4800	1000	1400	1700	mg/kg ts.	0.010	MK1090-Coldvap.

Tegnforklaring:
RSD : Relativ Analyseusikkerhet.
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Prøvetaker.....: Ikke oplyst
Kundeopplysninger:
Analyseperiode...: 2005.05.11 - 2005.05.24

Prøvemerking:	A 41	A 42	A 43	A 44	Enheter	Deteks. grense	Metoder
Tørrstoff	94.7	94.1	94.4	94.8	%	0.0020	MK3001-DS204
Kvikksølv (Hg)	6700	6500	5700	350	mg/kg ts.	0.010	MK1090-Coldvap.

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Kundeopplysninger:
Analyseperiode...: 2005.05.11 - 2005.05.24

Prøvemerking:	A 45	A 46	A 47	A 48	Enheter	Deteks. grense	Metoder
Tørrstoff	95.0	95.6	95.0	97.2	%	0.0020	MK3001-DS204
Kvikksølv (Hg)	17	1400	1500	830	mg/kg ts.	0.010	MK1090-Coldvap.

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Kundeopplysninger:
Analyseperiode...: 2005.05.11 - 2005.05.24

Prøvemerking:	A 49	A 50	A 51	A 52	Enheter	Deteks. grense	Metoder
Tørrstoff	89.8	95.1	94.4	95.6	%	0.0020	MK3001-DS204
Kvikksølv (Hg)	43	1.1	2.7	4400	mg/kg ts.	0.010	MK1090-Coldvap.

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Prøvetaker.....: Ikke oplyst
Kundeopplysninger:
Analyseperiode...: 2005.05.11 - 2005.05.24

Prøvemerking:	A 53	A 54	A 55	A 56	Enheter	Deteks. grense	Metoder
Tørrstoff	**93.9**	**95.3**	**90.9**	**96.1**	%	0.0020	MK3001-DS204
Kvikksølv (Hg)	**3400**	**5700**	**590**	**1100**	mg/kg ts.	0.010	MK1090-Coldvap.

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Prøvetaker.....: Ikke oplyst
Kundeopplysninger:
Analyseperiode...: 2005.05.11 - 2005.05.24

Prøvemerking:	A 57	A 58	A 59	A 60	Enheter	Deteks. grense	Metoder
Tørrstoff	95.6	96.7	94.6	94.0	%	0.0020	MK3001-DS204
Kvikksølv (Hg)	120	6.2	70	23	mg/kg ts.	0.010	MK1090-Coldvap.

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Prøvetaker.....: Ikke oplyst
Kundeopplysninger:
Analyseperiode...: 2005.05.11 - 2005.05.24

Prøvemerking:	A 61	A 62	A 65	A 66	Enheter	Deteks. grense	Metoder
Tørrstoff	95.5	94.9	94.2	93.8	%	0.0020	MK3001-DS204
Kvikksølv (Hg)	24	600	6000	3600	mg/kg ts.	0.010	MK1090-Coldvap.

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Prøvetaking.....:
Prøvetaker.....: Ikke oplyst
Kundeopplysninger:
Analyseperiode...: 2005.05.11 - 2005.05.24

Prøvemerking:	A 68	A 69	A 70	A 73	Enheter	Deteks. grense	Metoder
Tørrstoff	94.1	94.2	93.5	95.2	%	0.0020	MK3001-DS204
Kvikksølv (Hg)	750	72	7600	570	mg/kg ts.	0.010	MK1090-Coldvap.

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Prøvetaker.....: Ikke oplyst
Kundeopplysninger:
Analyseperiode...: 2005.05.11 - 2005.05.24

Prøvemerking:	A 74	A 77	A 78	A 79	Enheter	Deteks. grense	Metoder
Tørrstoff	95.3	94.0	94.1	96.5	%	0.0020	MK3001-DS204
Kvikksølv (Hg)	7500	1300	740	560	mg/kg ts.	0.010	MK1090-Coldvap.

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Prøvetaker.....: Ikke oplyst
Kundeopplysninger:
Analyseperiode...: 2005.05.11 - 2005.05.24

Prøvemerking:	A 80	A 80 C1	A 80 C2	A 81	Enheter	Deteks. grense	Metoder
Tørrstoff	93.4	93.7	94.3	94.9	%	0.0020	MK3001-DS204
Kvikksølv (Hg)	770	81	13	1300	mg/kg ts.	0.010	MK1090-Coldvap.

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Prøvetaking.....:
Prøvetaker.....: Ikke oplyst
Kundeopplysninger:
Analyseperiode...: 2005.05.11 - 2005.05.24

Prøvemerking:	A 82	A 83	A 84	A 85	Enheter	Deteks. grense	Metoder
Tørrstoff	95.8	94.0	92.0	91.3	%	0.0020	MK3001-DS204
Kvikksølv (Hg)	63	90	92	790	mg/kg ts.	0.010	MK1090-Coldvap.

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Prøvetaker.....: Ikke oplyst
Kundeopplysninger:
Analyseperiode...: 2005.05.11 - 2005.05.24

Prøvemerking:	A 86	A 87	A 88	A 88 B	Enheter	Deteks. grense	Metoder
Tørrstoff	**94.5**	**93.8**	**96.7**	**96.0**	%	0.0020	MK3001-DS204
Kvikksølv (Hg)	**1100**	**1700**	**160**	**1200**	mg/kg ts.	0.010	MK1090-Coldvap.

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Prøvetaker.....: Ikke oplyst
Kundeopplysninger:
Analyseperiode...: 2005.05.11 - 2005.05.24

Prøvemerking:	A 89	A 90	A 91	A 92	Enheter	Deteks. grense	Metoder
Tørrstoff	95.0	95.9	95.2	93.8	%	0.0020	MK3001-DS204
Kvikksølv (Hg)	600	140	40	52	mg/kg ts.	0.010	MK1090-Coldvap.

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Kundeopplysninger:
Analyseperiode...: 2005.05.11 - 2005.05.24

Prøvemerking:	A 93 C1	A 93 C2	A 94	A 94 C1	Enheter	Deteks. grense	Metoder
Tørrstoff	94.0	94.7	96.2	96.6	%	0.0020	MK3001-DS204
Kvikksølv (Hg)	46	43	6500	7200	mg/kg ts.	0.010	MK1090-Coldvap.

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Postboks 34 Grefsen, 0409 Oslo, Norge
Prøvested.....: **Hg-analyser i rust**
Prøvetype.....: Annet
Prøvetaking.....:
Prøvetaker.....: Ikke oplyst
Kundeopplysninger:
Analyseperiode...: 2005.05.11 - 2005.05.24

Prøvemerking:	A 95	A 96	A 97	A 98	Enheter	Deteks. grense	Metoder
Tørrstoff	94.2	95.8	95.8	97.7	%	0.0020	MK3001-DS204
Kvikksølv (Hg)	5800	550	200	5300	mg/kg ts.	0.010	MK1090-Coldvap.

Tegnforklaring:
RSD : Relativ Analyseusikkerhet.
< : mindre enn. i.p.: ikke påvist.
> : større enn. i.m.: ikke målbart.
: ingen av parametrene er påvist.

Eurofins Norge
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eurofins

AF Decom AS

Postboks 34 Grefsen
0409 Oslo
Norge
Att.: Eirik Jacobsen

Registernr.: 355621
Kundenr.: 51102
Ordrenr.: 350461

Mott. dato: 2005.05.11

ANALYSERAPPORT

Rekvirent.....: AF Decom AS
Postboks 34 Grefsen, 0409 Oslo, Norge
Prøvested.....: **Hg-analyser i rust**
Prøvetype.....: Annet
Prøvetaking.....:
Prøvetaker.....: Ikke oplyst
Kundeopplysninger:
Analyseperiode...: 2005.05.11 - 2005.05.24

Prøvemerking:	A 99	A 100	A 101	A 102	Enheter	Deteks. grense	Metoder
Tørrstoff	87.1	95.1	94.2	95.6	%	0.0020	MK3001-DS204
Kvikksølv (Hg)	69	190	460	6000	mg/kg ts.	0.010	MK1090-Coldvap.

Tegnforklaring:
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: ingen av parametrene er påvist.

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Mott. dato: 2005.05.11

ANALYSERAPPORT

Rekvirent.....: AF Decom AS
Postboks 34 Grefsen, 0409 Oslo, Norge
Prøvested.....: **Hg-analyser i rust**
Prøvetype.....: Annet
Prøvetaking.....:
Prøvetaker.....: Ikke oplyst
Kundeopplysninger:
Analyseperiode...: 2005.05.11 - 2005.05.24

Prøvemerking:	A 103	A 104	A 105	Enheter	Deteks. grense	Metoder
Tørrstoff	94.7	94.7	95.5	%	0.0020	MK3001-DS204
Kvikksølv (Hg)	1200	210	440	mg/kg ts.	0.010	MK1090-Coldvap.

Tegnforklaring:
RSD : Relativ Analyseusikkerhet.
< : mindre enn. i.p.: ikke påvist.
> : større enn. i.m.: ikke målbart.
: ingen av parametrene er påvist.

24. mai 2005

Einar Richter Jordfald

IFE Institutt for energiteknikk

Norse Decom AS
Postboks 112
2027 KJELLER

Att.: Per Varskog

NORSEDECOM
23 MARS 2005
Ark.nr. 3847 Saksbeh.

Instituttveien 18
Postboks 40, NO-2027 Kjeller
Tlf: +47 63 80 60 00
Faks: +47 63 81 25 61
Org. nr.: NO 959 432 538
Web: www.ife.no

Vår ref.: EStr
Dir. tlf: +47 63 80 60 95
E-mail: elisas@ife.no

Deres ref.: PV
Best. nr.: 107/05

Dato: 2005-03-18

Gammaanalyse av prøver fra Ekofisk 2/4-T
Oppdragsnr. 2004-379

Prøvene har blitt målt for innhold av ^{226}Ra, ^{228}Ra og ^{210}Pb ved hjelp av høyoppløselig gammaspektrometri. Resultatene er gitt i tabell 1. Rapportert usikkerhet er en utvidet usikkerhet basert på en standard usikkerhet multiplisert med en dekningsfaktor på 2, som gir et dekningsnivå på tilnærmet 95%.

Tabell 1. Måleresultater

Prøve	**Målt aktivitet (Bq/g)**		
	^{226}Ra	**^{228}Ra**	**^{210}Pb**
Ekofisk 2/4-T; nr. 18	4,43 ± 0,24	0,32 ± 0,04	1,06 ± 0,20
Ekofisk 2/4-T; nr. 26	0,51 ± 0,17	≤ 0,04	≤ 0,2
Ekofisk 2/4-T; nr. 35	22,9 ± 1,1	1,46 ± 0,09	3,8 ± 0,5

Mengden av ^{226}Ra og ^{210}Pb ble bestemt direkte, mens mengden av ^{228}Ra ble bestemt ved å måle aktiviteten til datternukliden ^{228}Ac. Ved radioaktiv likevekt er aktivitetene av ^{228}Ra og ^{228}Ac like. Det ble tatt hensyn til selvabsorpsjon i prøvene for ^{226}Ra og ^{210}Pb.

Statens stråleverns friklassifiseringsgrense er på 10 Bq/g for hver av de tre nuklidene ^{226}Ra, ^{228}Ra og ^{210}Pb. Denne grensen er overskredet for prøven merket "*Ekofisk 2/4-T; nr. 35*".

Hvis ikke annet er avtalt, vil prøvene bli oppbevart i to uker og deretter avhendet.

Vennlig hilsen

Elisabeth Strålberg
Forsker, Miljøovervåking
Avd. Miljø- og strålevern

IFE Institutt for energiteknikk

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Web: www.ife.no

Vår ref.: EStr
Dir. tlf: +47 63 80 60 95
E-mail: elisas@ife.no

Deres ref.: PV
Best. nr.: 111/05

Dato: 2005-04-15

NORSEDECOM
16 APR. 2005
Ark.nr. | Saksbeh.

Gammaanalyse av prøve merket "Papa Exportrør 'Oppe' "
Oppdragsnr. 2005-383

Prøven har blitt målt for innhold av ^{226}Ra, ^{228}Ra og ^{210}Pb ved hjelp av høyoppløselig gammaspektrometri. Resultatene er gitt i tabell 1. Rapportert usikkerhet er en utvidet usikkerhet basert på en standard usikkerhet multiplisert med en dekningsfaktor på 2, som gir et dekningsnivå på tilnærmet 95%.

Tabell 1. Måleresultater

Prøve	Målt aktivitet (Bq/g)		
	^{226}Ra	^{228}Ra	^{210}Pb
Papa Exportrør 'Oppe'	≤ 0,05	≤ 0,011	0,072 ± 0,031

Mengden av ^{226}Ra og ^{210}Pb ble bestemt direkte, mens mengden av ^{228}Ra ble bestemt ved å måle aktiviteten til datternukliden ^{228}Ac. Ved radioaktiv likevekt er aktivitetene av ^{228}Ra og ^{228}Ac like. Det ble tatt hensyn til selvabsorpsjon i prøven for ^{226}Ra og ^{210}Pb.

Statens stråleverns friklassifiseringsgrense er på 10 Bq/g for hver av de tre nuklidene ^{226}Ra, ^{228}Ra og ^{210}Pb. Denne grensen er ikke overskredet for prøven.

Hvis ikke annet er avtalt, vil prøvene bli oppbevart i to uker og deretter avhendet.

Vennlig hilsen

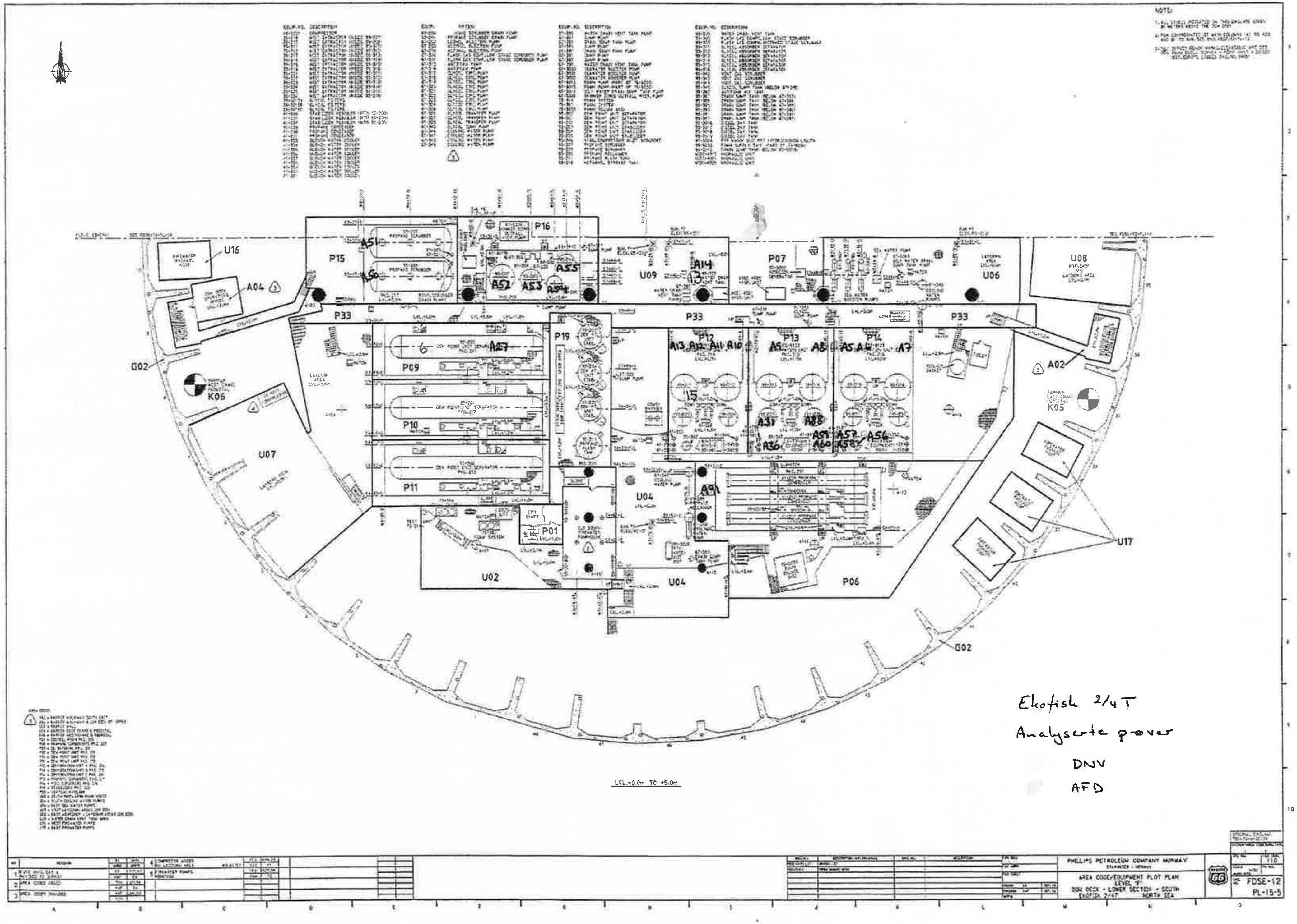
Elisabeth Strålberg
Forsker, Miljøovervåking
Avd. Miljø- og strålevern

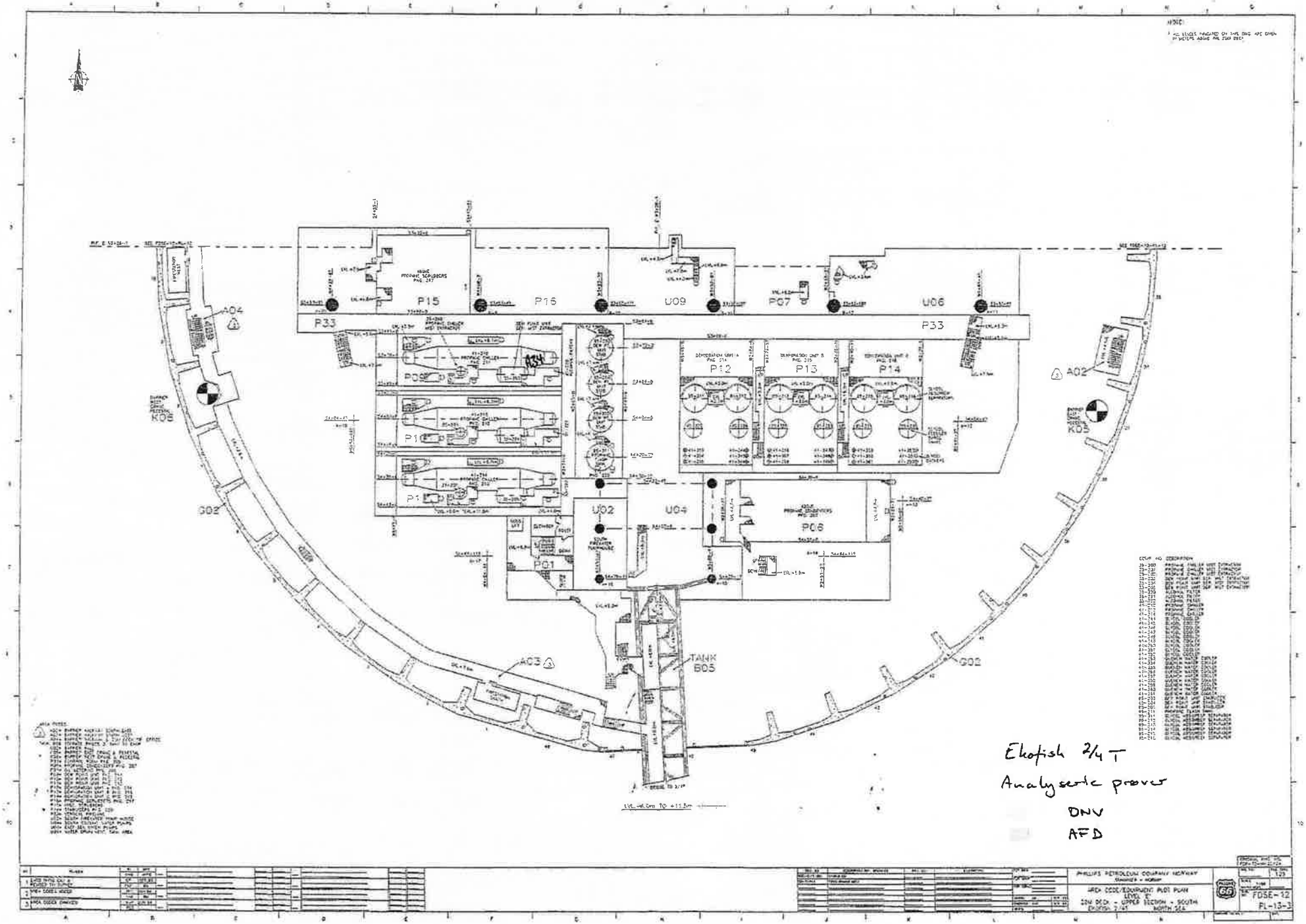
Norse Decom AS
Postboks 112
2027 KJELLER

Analyserapport-LRA

08.04.05

Prøve	ND-ID	Analysert dato	Vekt g	Radium-226 Bq/g	± Bq/g	Radium-228 Bq/g	± Bq/g
AF Decom 2/4-T A-2	0046	05.04.05	64.61	0.9	0.26	0.2	0.14
AF Decom 2/4-T A-15	0047	05.04.05	66.16	2.1	0.13	0.4	0.05
AF Decom 2/4-T A-18	0048	08.03.05	73.44	2.7	0.23	0.5	0.08
AF Decom 2/4-T A-19	0049	06.04.05	58.15	1.5	0.24	1.1	0.40
AF Decom 2/4-T A-20	0050	06.04.05	74.17	2.8	0.33	0.3	0.14
AF Decom 2/4-T A-21	0051	06.04.05	69.78	2.7	0.35	0.4	0.13
AF Decom 2/4-T A-23	0052	06.04.05	62.15	3.3	0.39	0.6	0.16


U16
A04
P15
A51
A50
P16
A52
A53
A54
A55
U09
A14
P07
U06
U08
P33
P33
P33
G02
K06
P09
A27
P10
P11
P19
P12
A13 A12 A11 A10
P13
A9 A8
P14
A5 A4 A7
A02
K05
A31
A36
A38
A59
A60
A57
A58
A56
U07
U04
A91
P01
U02
U04
P06
U17
G02
Ekofisk 2/4T
Analyserte prøver
DNV
AFD
LVL.+0.0m TC +5.0m
PHILLIPS PETROLEUM COMPANY NORWAY
STAVANGER - NORWAY
AREA CODE/EQUIPMENT PLOT PLAN
LEVEL "F"
2/4T DECK - LOWER SECTION - SOUTH
EKOFISK 2/4T NORTH SEA
FDSE-12
PL-15-5



Ekofisk 2/4 T

Analyserte prøver

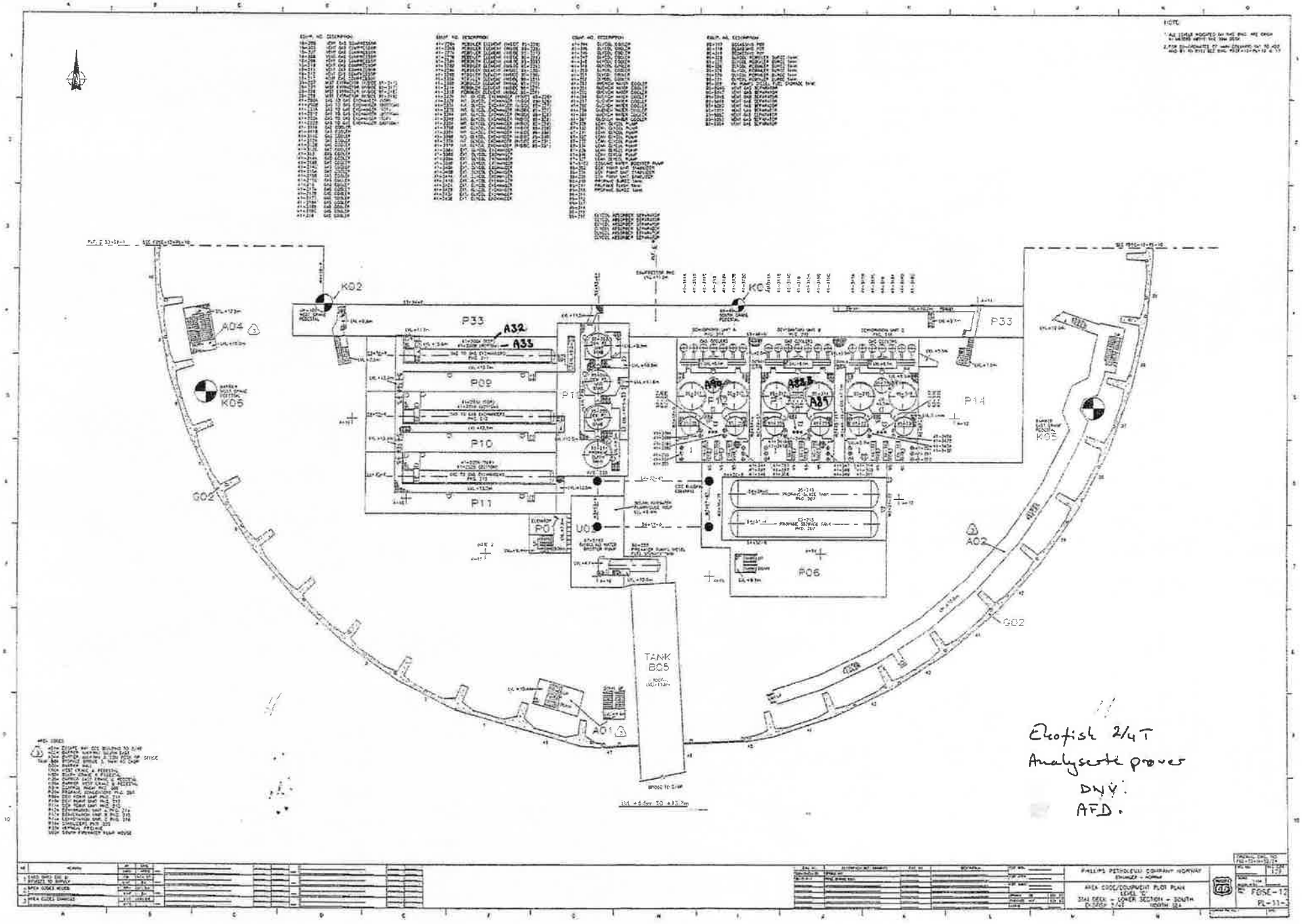
DNV

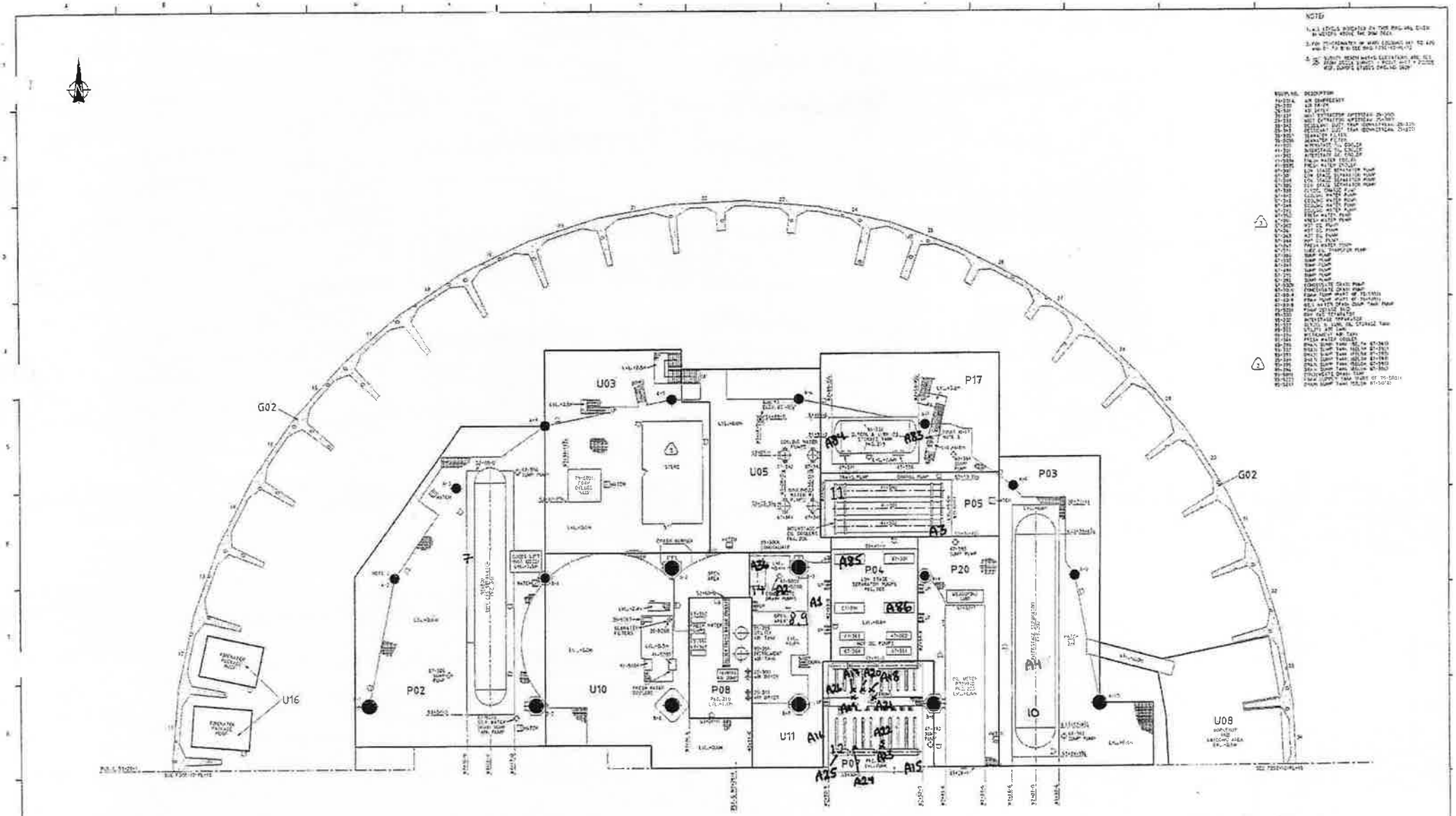
AFD

PHILLIPS PETROLEUM COMPANY NORWAY

AREA CODE/EQUIPMENT PLOT PLAN
LEVEL 'E'
SAW DECK - UPPER SECTION - SOUTH
EKOFISK 2/4T NORTH SEA

FDSE-12
FL-13-3

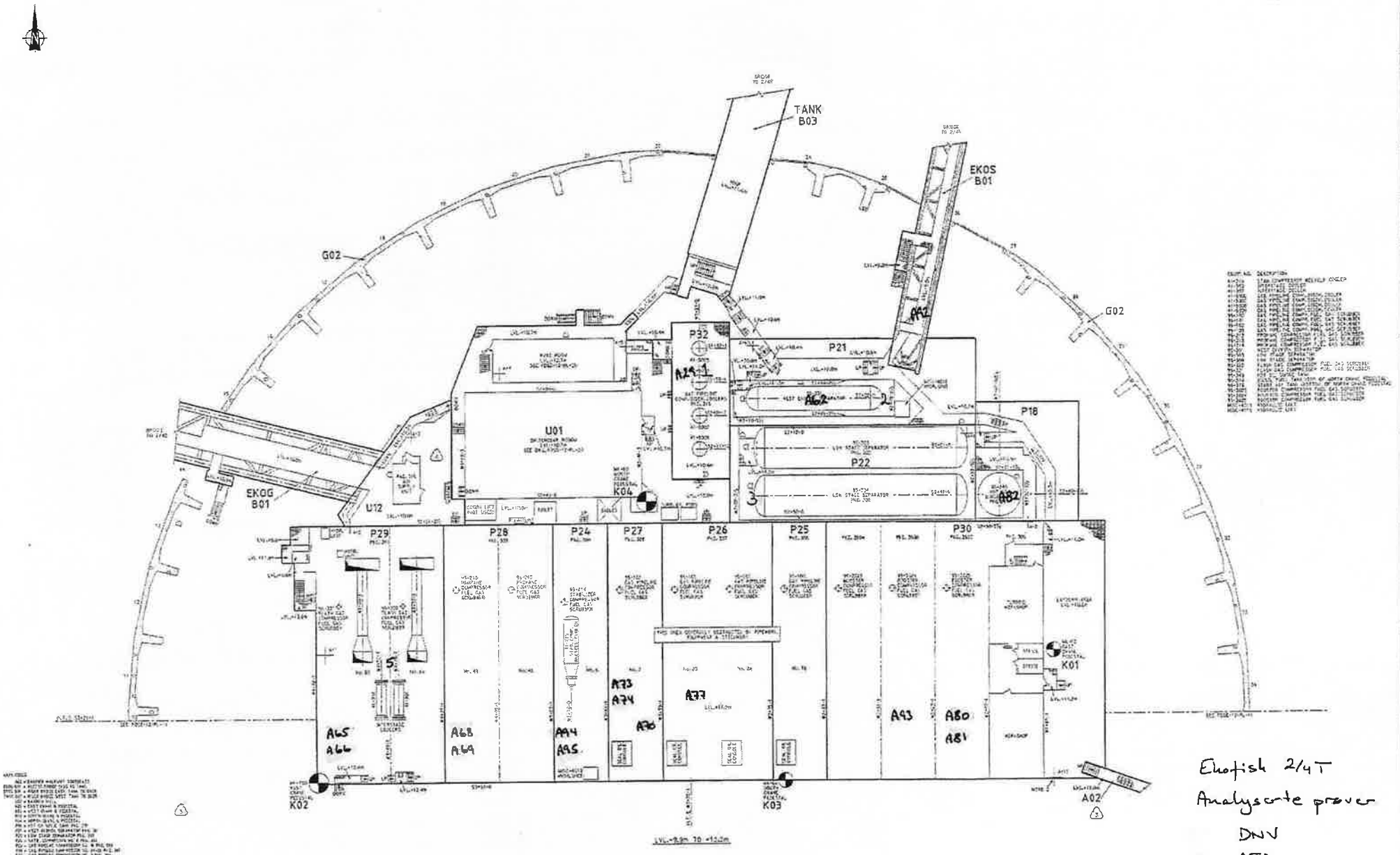

K02
K01
K05
A04
A32
A33
P33
P09
P10
P11
P14
P06
P01
U01
G02
A02
A01
TANK
B05
Ekofisk 2/4T
Analysekode prover
DNV.
AFD.



PHILLIPS PETROLEUM COMPANY NORWAY
STAVANGER - NORWAY

AREA CODE/EQUIPMENT PLOT PLAN
LEVEL +
20M DECK - LOWER SECTION - NORTH
EKOFISK 2/4T NORTH SEA

FDSE-12
PL-14-3

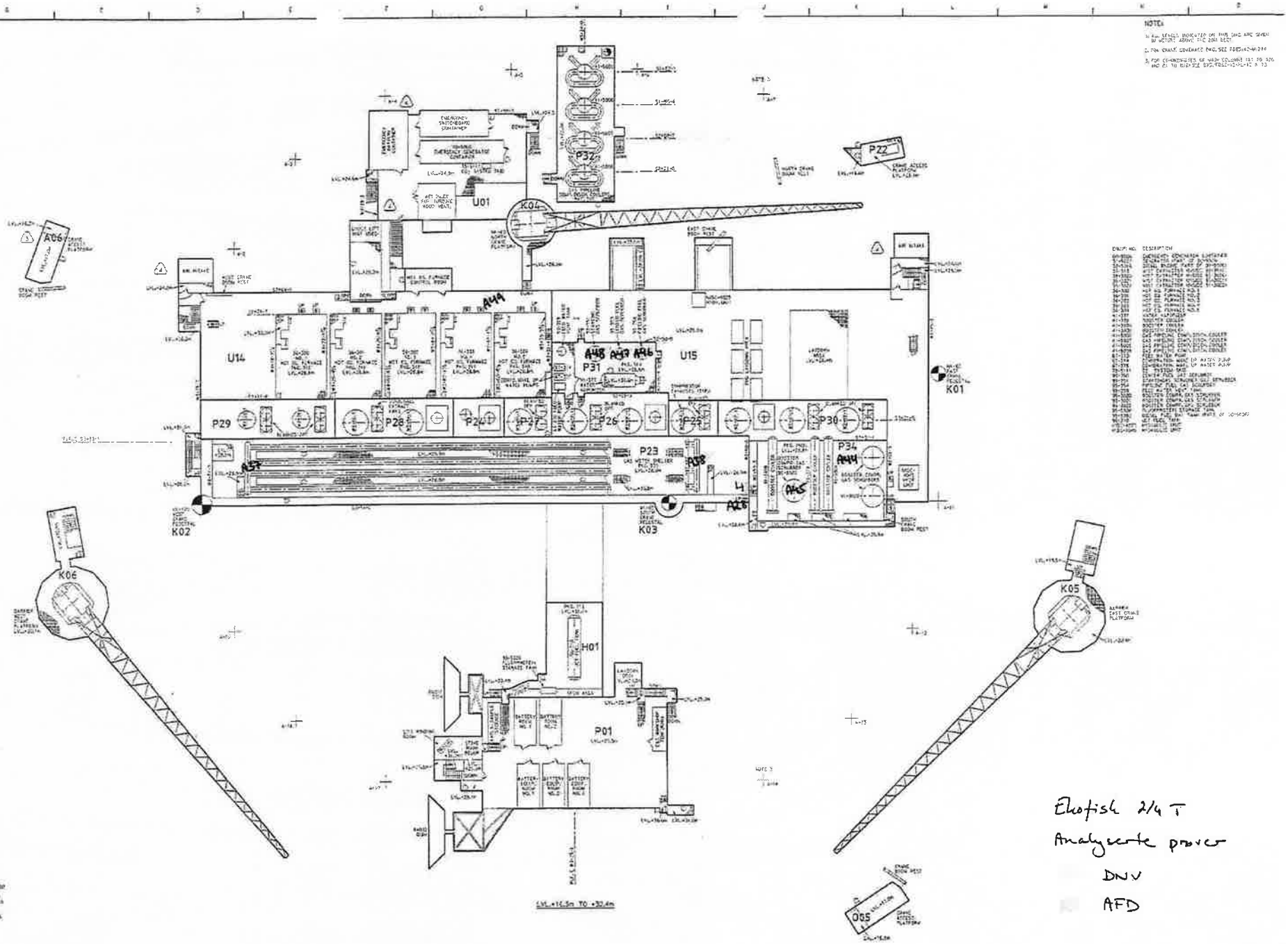


Ekofisk 2/4T
Analysorte prøver
DNV
AFD

PHILLIPS PETROLEUM COMPANY NORWAY
STAVANGER - NORWAY

AREA CODE/EQUIPMENT PLOT PLAN
LEVEL
30M DECK - LOWER SECTION - NORTH
EKOFISK 2/4T NORTH SEA

FDSE-12
PL-10-4



NOTES

1. ALL LEVELS INDICATED ON THIS DWG ARE GIVEN IN METERS ABOVE MSL DATUM.
2. FOR CRANE COVERAGE DWG. SEE
3. FOR CHARACTERISTICS OF MAIN COLUMNS SEE

Ekofisk 2/4 T

Analyserte prover

DNV

AFD

NO	REVISION	BY	DATE	APPD
1	AUTO AREA CAD & REVISED TO SURVEY			
2	AREA BOUND. ADDED			
3	AREA CODES CHANGED			

PHILLIPS PETROLEUM COMPANY NORWAY
STAVANGER - NORWAY

AREA CODE/EQUIPMENT PLOT PLAN
LEVEL +51
39 METER DECK - UPPER SECTION
EKOFISK 2/4T NORTH SEA

FDSE-12
PL-742