EXTENSION OF POWER STATION IN SUND
ON THE FAROE ISLANDS

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31, ØSTER ALLE - DK-2100 COPENHAGEN Ø - DENMARK
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BY 

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in cooperation with 

LANDSBYGGIFELAGID P/F, CONSULTING ENGINEERS 
THORSHAVN 

and 

B&W SCANDINAVIAN CONTRACTOR A/S 

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PREFACE

The present bulletin is dedicated to Hjalgrim Vinter, Civil Engineer M. Sc., General Manager of the Electric Company S.E.V. on the Faroe Islands since 1953.

Hjalgrim Vinter has been the innovative and dynamic leader in the development of the electrification of the Faroe Islands during the last 30 - 35 years. Starting off from a modest supply system after World War II, a total and differentiated supply system has been established covering all islands, industries as well as small communities, based on diesel power plants as well as water power plants exploiting the topography in the surroundings of Vestmanna, home town of Hjalgrim Vinter. The outstanding effort sacrificed on this development is obvious to those who are acquainted with the difficult geographical conditions met with on these rocky islands in the North Atlantic with a population spread out in a number of small communities. It is characteristic of Hjalgrim Vinter’s innovative activity, being a key person in the present construction phase of the Sund extension that new plans for further development of the water power sources have already taken shape.

Being a progressive scientist Hjalgrim Vinter is also deeply devoted to the environmental protection of the fascinating nature of the Faroe Islands. Many have enjoyed the company of Hjalgrim Vinter telling fabulous stories from Faroe life and nature in his office at the waterfront in Vestmanna with a view to the boat filled waters and the surrounding green hills.

We appreciate this opportunity to express our gratitude for many events of this kind, for an inspiring collaboration in connection with the Sund extension, and for many years of cooperation in connection with power supply to ISC assignments on Vagar Airport.

Hjalgrim Vinter
SUMMARY

This paper presents a description of the extension of the Sund Power Station on the Island Streymoy, the major island in the Faroe Islands group, with a new diesel power unit.

Sund is located at the coastside at the mouth of Kalbaksfjord 10 km north of Thorshavn, the capital of the Faroe Islands with a population of approximately 12,000.

The electric energy supply is partly covered by water power installations reaching 40% on a yearly basis in 1967 and partly by smaller diesel power units located on a number of islands.

The new power unit in Sund comprises two B&W two-stroke 12 L 55 - GSCA diesel engines with a total engine effect of 25.6 MW at 100% load. Fully outfitted the new Sund power unit will have a capacity to supply approximately 60% of the electric energy consumption on the major power-linked islands.

As the direct net efficiency in electric power output compared to the oil energy input is 43% a concept has been invented to achieve regaining of a substantial part of conventional heat loss by means of steam heat exchangers and steam turbines. Together with useful application of remaining waste heat in exhaust gas and cooling water in future fishing breeding grounds, this may increase net energy efficiency above 85%.

The natural topography of the rocky island with steep slope uphill from the waterfront, narrow access roads and poor quay landing facilities, required special adaption of the design concepts and construction methods as well as introduction of non conventional transport and landing operations of the heavy units.

ZUSAMMENFASSUNG

Dieser Beitrag beschreibt den Ausbau des Sunner Diesel-Elkraftwerks auf der Insel Streymoy, der größten Färöerinsel, der neulich gebaut worden ist.

Sund ist nahe der Küste bei der Mündung des Kalbaksfjords 10 km nördlich von Thorshavn gelegen. Thorshavn ist die Hauptstadt der Färöerinseln mit einer Einwohnerzahl von etwa 12,000.
Die Elkraftversorgung wird teils von Wasserkraftwerken, die im Jahre 1967 nahe 40% der Gesamtversorgung erreichte, und teils von kleineren Diesel-Elkraftwerken, die auf mehreren Inseln zerstreut sind, geliefert.

Die neue Kraftsektion in Sund enthält zwei B&W Zweitakt 12 L 55 - GSCA Dieselmotoren, die einen Gesamteffekt von 25.6 MW bei einer 100%-igen Belastung leisten. Völlig ausgebaut wird die neue Kraftsektion eine Leistungsfähigkeit haben, die etwa 60% der Gesamtelkraftversorgung der größeren Elkraft-verbundenen Inseln haben.


RÉSUMÉ

Cet article décrit une extension de la Centrale d'énergie électrique située à Sund, dans l'île de Streymoy, la plus grande des îles Féroé d'une nouvelle section d'énergie générée de moteur diesel et dynamo électrique récemment hâtie.

Sund est située sur la côte à l'estuaire du Fiord de Kalbaks à 10 km nord de Thórshavn, la capitale des îles Féroé avec une population d'environ 12.000.

L'approvisionnement de l'électricité est partiellement générée d'énergie hydraulique qui a atteint à 40% annuellement en 1967 et d'ailleurs par des centrales de moteur diesel distribuées dans plusieurs des îles.
La nouvelle extension de la centrale à Sund comprend deux B&W moteurs diesel à deux temps 12 L 55 - GSCA avec un effect de moteur total de 25.6 MW à 100% charge. Entièrement développée la nouvelle extension aurait la capacité à provisionner 60% de la consommation d'électricité aux grandes îles connectées électriquement.

Afin que l'effet net direct en énergie électrique comparé à l'énergie oléine consommée ne soit pas plus que 43% un système à été introduit pour regagner une part important de la déperdition de la chaleur au moyen des changeurs thermiques à vapeur et des turbines à vapeur. En connection d'exploitation utile de l'exhalaison thermique restant pour l'échauffage des piscicultures envisagées dans la future, l'effet net pourra augmenter au dessus les 85%.

La topographie naturelle de l'île rocheuse qui monte d'une pente escarpé de la côte, les étroits chemins d'entrée et facilité modeste de quai pour débarquement direct exigé une adaption particulière des conceptes d'étude de génie civil et des méthodes de construction, ainsi que l'introduction des opérations de débarquement et de transport local non conventionnel des lourdes sections d'équipement.

Figure 1. Chart of the Faroe Islands. Arrow indicates location of Sund.
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1. INTRODUCTION

The joint municipal electric company S.E.V. which originally included the major islands Streymoy, Eysturoy and Vagar was in 1963 extended to include all the boroughs on the Faroe Islands.

The electric diesel power station in Sund on the island Streymoy, the major island in the Faroe Islands group, constitutes an integrated part of the electric power producing plants which supplies electricity to the neighbour islands Streymoy, Eysturoy, Vagar, Sandoy and Norduroyar. Sund is located at the coastside at the mouth of Kalsaksfjord 10 kilometres north of Thorshavn, the capital of the Faroe Islands with a population of approximately 12,000.

Within this main distribution area the islands are interconnected with aerial high voltage cable spans of which the longest is 2800 m as well as subsea cables.

The existing power station in Sund has an el-power capacity of 17.1 MW delivered from three four-stroke Meerless diesel engines.

However, the major power centre for these three islands is located in the Vestmanna area comprising water power stations, Fossa with a turbine capacity of 9000 HK (1956), Heyga with a turbine capacity of 7000 HK (1963) and Myru with a turbine capacity of 3500 HK (1963).

Besides the water power, minor diesel power stations located in the city Klaksvik and in Thorshavn are integrated in the system.

On a yearly basis approximately 40% of the el-power is presently covered by means of water power (1978 figures) and 60% is covered by diesel-power. Compared with nearly 100% cover by means of water power in 1963 a substantial increase in diesel generated el-power has taken place. The Sund power station predominantly supplies the city of Thorshavn with electricity but is further linked to the power centre in Vestmanna and the minor units on the other islands.

The extension of the power station in Sund is shaped to make room for the installation of two B&W two stroke 12L55-GSCA diesel engines produced at Götaverken Motor AB with a total engine effect of 25.6 MW at 100% load generated through alternators of make Jeumont-Schneider. The net efficiency in electric power output compared to the oil energy input is 43%. The remaining 57% covers heat transmission to air, heat transfer in exhaust system and heat transfer in cooling water. The system is however developed to regain a major part of the heat from exhaust air via heat exchangers to hot water steam and central heating. Further the cooling water heat is expected to be usefully applied in connection with a planned future fish breeding ground.

Figure 3. Energy Distribution Flow Diagram for Power Station with two B&W 12L55GSCA Diesel Engines at 100% load.
In the first stage only one engine will be installed whereas all civil works and installations will be prepared for the installation of a second engine when required. Fully outfitted the Sund power station will have capacity to supply approximately 60% of the electric energy consumption on the three islands. However, the four-stroke Meerless engines are anticipated mostly to be emergency stand-by in the future due to frequent maintenance requirements when in continuous service.

As the unit price per kWh generated by diesel power is far more expensive than if generated by water power, future increase of capacity in electric power is expected to be achieved by further exploitation of the water power resources.

This paper deals primarily with the civil works and the complex of installations developed to meet the functional and environmental criterias as well as adaptability to the existing power station set up.

The natural topography shows a level difference between the waterfront border of the building site and the inland border along the coast road of approximately 20 m. Establishing of a suitable area for the extension therefore required rock blasting and excavation of nearly 30000 m³ volcanic rock.

The extension comprises the following major items: engine hall, engine foundations, control room building, oil storage, chimney, pump station, trafo station and covered pipeline system.

The new engine hall is separated from the existing engine hall by means of a lower joint building making room for central control, 20 kV switchboard, electronic equipment and ventilation. The orientation and shape of the engine hall is adapted to the existing building complex and the location chosen to allow for possible later extension. The height of the engine hall from cellar floor to roof edge is approximately 22.5 m, which with the 26.6° roof slope is required to provide room for engine foundation, engine and a 50 t overhead travelling crane installed to service engine overhaul.

A tight schedule for the construction phase called for the invention of a combined steel/concrete structure for the engine hall with concrete substructure in the two storeys matching the height of the engine foundation and steel framed superstructure with light weight roof cover and facade cladding. The applied concept allowed for continuous installation of major equipment units in the construction phase as well as closure of the building as soon as the engine foundation reached the cube strength required and base beams were ready aligned for mounting of the engine.
Figure 4. Energy Distribution Flow Diagram for Power Station with two B&W 12L55GSCA Diesel Engines at 100% Load with Energy Regaining Provisions.

Figure 5. North and South Facades.
Major components such as chimney, engine, alternator etc. had to be landed directly on a small quay within the site. This handling of up to 400 t heavy items called for special precautions due to strong current, deep water and gust winds, which can reach a velocity of up to 220 kilometres/hour.

The design was started in May 1981 and carried out simultaneously with the excavation and clearing of the building site. Construction was started in September the same year and terminated in the spring of 1983. After a three months test period the power station is expected into service in June 1983.

2. GENERAL LAY-OUT

The general lay-out of Sund power station is shown on figure 2 in the extended shape with a legend indicating existing and new items. The required land for the extension has been provided by rock blasting and excavation into the mountain side and partly by regaining area through dumping of the approximately 30,000 m³ excavated rock at the waterfront. To minimize excavation and due to the nearby uphill coastal road, the engine hall has been located 15 m off set the existing engine hall towards the sea. This further enables the local road from the pier around the landside of the existing hall to be continued around the south facade and the east gable of the extension in a steep slope to the plane along the north facade levelled 8 m below floor level in existing engine hall. The upper inspection platform around the engine is located in level with the floor in the existing engine hall. The height of the engine and the required foundation height of 4.5 m consequently desides the excavation depth, the cellar floor level 4.70 and the level 4.55 at the planum along the north facade. The engine base is located in level 8.75 with the first gallery floor. The cellar floor in the new engine hall is lowered 5.5 m compared to the cellar floor in the existing engine hall due to the increased height of the engine foundation for the heavier new installed two stroke engines. To ease construction a two storey building has therefore been arranged between the engine halls separating the gables by 3 m and thereby providing a smooth transition in the excavation.

The size of the engine hall is shaped to provide room for the two engines and the required auxiliary equipment. The length of the hall is 30 m and the total width 35 m corresponding to a ground floor area of approximately 1100 m².
Figure 6. East and West Gables.

The width of the centre bay is 23 m, sufficient to provide free space for the 20 m long foundation block for engine and alternator. Sidebays of 6 m width are arranged along both sides of the centre bay and in three storeys providing room for at number of equipment modules and workshop. The upper gallery floor in level 12.75 m is the transition plan between the concrete substructure and the steel superstructure. The gallery floors in concrete are horseshoe-shaped with a 5 m wide connection strip along the west gable. An entrance gate is arranged in the south facade between line 6 and 7, and the floor strip is designed for heavy lorry traffic. The centre bay is equipped with a 50 t overhead travelling crane for mounting of alternator and replacing of parts during maintenance and overhaul. Platforms are arranged around the engines in plane with the gallery floors in level 12.75 with connection bridges to the galleries. The concrete wall along the facades reaching level 12.75 is in the gable replaced by easy demountable curtain wall cladding between level 8.75 and level 12.75 to provide entrance space for sliding in of the engines. The west gable structure is further arranged independently of the main structural system to achieve easy demounting in case of extension or later installation of the second engine.

The two storey building between the engine halls has a width of 8 m and a length of 32 m, approximately 2 m less than the width of the existing hall. This joint building with flat roof makes room for high voltage panels, control panels, ventilation units, batteries, store and corridor connecting the two halls. The central location of these facilities meets the demand for access and short distance to all positions in both halls.

A 40 m high chimney is located in front of the north facade receiving the exhaust air from the engines via a heat exchanger placed on the first gallery floor.

The cooling water intake and pump station are arranged on a caisson at the waterfront north east of the engine hall. The pipeline is passed through the north facade of the engine hall. The cooling water consumption for each engine is 306 m³/h requiring 200 mm dia. pipes.

The buffer fuel oil storage is located outside the east gable including 6 m³ and 30 m³ tanks. A new fuel oil pipeline tracing has been built from the main fuel oil storage with a capacity of 2500 m³ to the buffer storage.

The existing fuel oil pipelines have been relocated in the new covered channel. The 60 kV transformerstation has been placed at the south east corner of the site providing easy outlet of the aerial cables uphill across the coastal road.
Figure 8. Longitudinal Section. 1.3 Joint Building. 2. Gate. 4. Existing Engine Hall. 5. Interior Workshop Wall. 6. Purlin. 7. Insulation. 8. Corrugated Steel Sheets. 9. Gallery Floors. 10. Fire Wall.

Auxiliary equipment for fuel- and lubricating oil treatment which was delivered as compact units ready for installation and inter-connection with pipes is primarily placed in the north end of the building. The lubricating oil units comprising tanks, separators, filters, pumps etc. are located in the cellar at level 4.70.

The fuel oil treatment units are located in a separate room at level 8.75 adjacent to the day tankyard along the east gable. Fuel oil passes through separators prior to being stored in the daytank and waste oil is led to the sludge tank below separator room to be burnt in the waste oil combustion building placed next to the chimney. In the area along the west gable level 4.70 starting air compressors and receivers are located while the area along the southern facade at level 4.70 primarily is used to ventilating ducts and cable tracing.

At level 8.75 low voltage switchboards are located as well as the 20/0.4 kV station transformers.

A workshop with a floor area of approximately 80 m² is placed at level 12.75 along the southern facade. The workshop is located near the joint building and the existing hall since the new workshop is planned as a supplement to the workshop in the existing engine hall.

The energy exploitation concept for the plant includes regaining or direct application of heat generated in exhaust gas and in cooling water to improve efficiency. As shown in the energy flow diagram on figure 3, the el-power efficiency is only 43% in a conventional diesel power system, whereas heat loss in cooling water, exhaust gas and direct heat transmission covers 57%. The concept introduced for the present plant is shown on figure 4, in which nearly all conventional heat loss is planned exploited for usefull applications. Heat exchangers are provided in the exhaust system to develop steam to central heating of the power plant as well as steam to a turbine generator improving the el efficiency with 2%. Heat energy assimilated in the cooling water which covers 38% of the total fuel energy input is planned exploited in a future fish breading production. As it occurs from the energy distribution shown on the flow diagram on figure 4, the efficiency will pass the 62% and may fully developed exceed the 85% achieved in modern coal/oil fired steam turbine el-power/heating plants (4).

Figure 12. View of Partly Erected Steel Structure.

Figure 13. View of Partly Erected Steel Structure from West.
3. STRUCTURES

3.1 Engine Hall

The engine hall structure is clearly divided into a two-storey concrete substructure below level 12.75 and a steel superstructure above this level with the ridge reaching level 26.0. This choice of material met the requirement to rational construction, flexibility for later modifications and adequacy to the specific design considerations in engine halls equipped with a heavy overhead travelling crane.

3.1.1 Steel Superstructure

The structural system in the Sund power station is similar to a concept developed by ISC and introduced in other power station assignments abroad (1). Characteristic features of the system are static interaction of cladding diaphragms and steel skeleton, compact transportation by application of throughout bolted connections and easy erection due to subdivision into straight members with a maximum section length of 12 m. Plan lay-out, sections and overall dimensions occur from figures 7-11.

The primary structures in the centrebay are designed as two hinged frames in mutual distance 5.0 m and span 23.0 m. The frames are built up of IPE 600 sections assembled with high tensile friction grip bolts class 10.9 in the frame corners and at the ridge. The primary structures of the sidebays consist similarly of two hinged half frames with span 6.0 m built up of IPE 300 sections with hinged support at the centrebay columns and at the concrete floor. Bolted butt plate joints with class 8.8 bolts are arranged in the corners. The crane runway girders for the 50 t overhead travelling crane in the centrebay are HEA 500 wide flange sections continuous over six spans of 5.0 m. The max. static wheel pressure is 14 t resulting in a reaction on the column brackets of 53 t. The crane girders are subdivided into three sections by means of two lap plate erection joints with close tolerance bolts. Crane girders of HEA 160 are further provided in the southern sidebay for a 2 t overhead crane to service the workshop. The three bay frames are mutually interconnected via the crane girders and tubular members between the ridge joints and between the frame corners and finally the corrugated steel roof cover. The linking of the primary structural planes through the roof diaphragms has been considered in the analysis to achieve a distribution of lateral impact from the cranes and antinetic vertical loads to more frames. A considerable reduction in peak moments is thereby gained in the centrebay frame keeping the required section size within the rolling program for IPE-sections.
Figure 14. Bolted End Plate Joint in Centre of Frame.

Figure 15. Bolted Joint in Corner of Centre Bay Frame.
Figure 16. Centre Frame Column Base.

Figure 17. Support Brackets and Crane Runway Girders in the Centre Bay.
The gable columns are IPE sections (500-600) simple supported on the concrete structure in level 12.75 in the east gable and in level 8.75 in the west gable. A sliding joint has been provided between the column tcp and the frame to prevent interaction with the frame for vertical load.

The spatial stability of the structure has been achieved by means of a combination of bracing, framing and diaphragm action of the roof cover. In the transverse direction horizontal loads from wind and crane are resisted by frame action. In the longitudinal direction wind loads on the gables and braking forces from the cranes are transferred via lattice girders in the roof and bracing in the columns lines to the concrete substructure. Restraints of the frames to prevent torsional flexural buckling have been provided at the three corners and at two intermediate locations 3 m from the ridge. The dominating loads to be considered in the design are crane loads and wind load based on a design velocity pressure of 2.3 kN/m² at level 10.00. Analysis has been carried out for the temporary stage with open west gable as well as the permanent stage as closed building. The steel structures have been designed according to DS 412. The crane runway girders are executed in steel grade 42.3/DIN 17.100 whereas the remaining primary structure is executed in steel grade 42.2/DIN 17.100.

3.1.2. Roof cover

The roof cover consists of a double layer of trapezoid corrugated steel sheets separated by means of 100 mm high cold rolled z-purlins and 100 mm mineral wool insulation. The bottom sheets with a height of 115 mm span 5 m between the main frames. Fastening of the plates has been performed with special attention to the high wind suction and the integration of the roof diaphragm in the main structural system. Natural ventilating has been provided for along the ridge of the engine hall by elevating of the roof cover 5 m to each side of the ridge, and hence achieving an outlet between the overlaps. The opening area is balanced to the heat transmission conditions in the engine hall. The transmission coefficient for the insulation is smaller than 0.4 but anyhow increased compared to the requirements in the Danish building code because the major problem in the present building is to get rid of the heat emission.

3.1.3. Facades

The facade cladding consists of a double layer of trapezoid corrugated steel sheets enclosing 150 mm mineral wool thermal insulation supported on z-rails of 200 mm depth spanning 5.0 m between the main frames. All interior cladding sheets in facade and
Figure 18. Bolted Erection Joint in Crane Runway Girder.

Figure 19. View of Centre Bay Latticework Crane Mounted on Crane Girders.
Figure 20. Bolted Joint in Facade Bracing.

Figure 21. Centre Joint in Roof Bracing.
roof are provided with 15% perforation to improve sound absorption. Only the firewall towards the joint building is made as 200 mm thick concrete brickwall covered with 50 mm insulation and perforated corrugated steel sheets towards the engine hall. Interior walls around the workshop are of similar built-up whereas fire sectioning walls at the lower storeys are brickwalls. The 4 x 4 m entrance gate in the south facade to floor in level 12.75 is an el-driven roller type.

3.1.4 Concrete substructure

The concrete substructure below level 12.75 comprises a two storey building with first floor in level 8.75 corresponding to the top level of the engine foundation and the cellar floor in level 4.70. The concrete floors have a width of 6 m along the two facades corresponding to the width of the two side bays and a width of 5 m along the east gable. Along the west gable a 5 m wide floor in level 8.75 tops the concrete structure to provide easy access to the installation of present and future engines. The substructure is performed as a conventional reinforced concrete slab/frame system, cast in situ with the facades cast in 250 - 400 mm reinforced concrete as well. The beam/column system configuration occur from figure 7 and figure 8. The substructure is a spatial stable system which carries the horizontal load from earth pressure and from the steel superstructure via the floor and wall diaphragms to the foundations. A distributed vertical load of 10 kN/m² is considered on the floors besides specific loads from equipment, tanks and installation units. The interior columns are restrained in the floor/beam diaphragms and do consequently only carry vertical load to the foundations. The special characteristics of gravel, sand and stone material available have been taken into account in the determination of concrete mix and strength parameters. All foundations are founded directly on rock.

3.3 Engine foundation

The design concept and anchorage system is developed in cooperation with BW-diesel A/S.

3.3.1 Geometry

Each engine foundation has a total length of approximately 20.2 m, a height of 4.5 m, a width of 5.0 m at the engine and 9.4 m at the alternator. The total volume of concrete in each foundation block is 450 m³.

The foundation block is provided with two longitudinal tunnels 1.8 x 1.0 m below engine for mounting and hydraulic prestressing of anchorbolts. An open recess below the generator is required to
Figure 22. Roof Structure in Centre Bay with Air Outlet Provisions.

Figure 23. Side Bay during Erection.
Figure 24. Elevation and Cross Section of Engine mounted on the Foundation. 1. Engine. 2. Anchor Bolts. 3. Tubular Enclosure for Anchor Bolt. 4. Side Chock. 5. Embeco Grout. 6. Concrete Block. 7. Alternator.
make room for the lower part of generator, radiator coolers, prestressing purposes etc. Edgerails are connected to the upper boundary of the foundation to provide support for the chequer plate dock.

3.3.2 Dynamic analysis and design

The design of the foundation block i.e. dimensions, mass of the integrated system engine/generator/foundation block, has been balanced to minimize the vibrations transferred to the surroundings, keeping amplitudes from the forces and couples excited during running of engine/generator within acceptable limits.

Dynamic calculations showed that no special damping provisions were required for the present 12 cylinder slow running (150 rpm) two stroke diesel engine, apart from effect of the mass and configuration of mass of the foundation block. All natural frequencies of the integrated system engine/generator/foundation have been sufficiently harmonized apart from the frequencies of the forces and couples excited during the running of the diesel generator set. The permissible limits of interference of excited and natural frequencies have been predicted on basis of the calculated amplitudes for the motions of mass. In the present case the engine foundation is founded on a 1.5 - 2.0 m thick mass concrete foundation which is founded directly on solid Faroe basalt. Between engine foundation and mass concrete a membrane of asphalt felt has been inserted and the foundation block is further separated from the surrounding floors by means of elastic joints.

3.3.3 Anchorage system

A prefab anchorage system has been developed to comply with the tolerances allowed in each single operation during casting of the concrete, grouting of basebeams and erection of engine. The prefab system shaped as a torsionally rigid lattice box girder includes tubular members serving as templates for later installation of anchorbolts. The lattice girder is demountable for easy compact transport and reassembly on site. The lattice box girder is prepared for easy fixing to the scaffolding system. Consequently internal tolerances for positioning of bolts are governed by the steel workshop and independent of any error done by the civil contractor. The oversize tubes further allow for minor deviations from accurate positioning in the scaffolding as well as a reliable prestressing with a minimum relaxation assuring longtime fatigue life and safety.

The basebeams for the engine are designed to provide maximum flexibility during erection of engine/generator. The basebeams
are during the grouting interconnected with channel sections securing the mutual correct positioning of bolt holes QA checked in the workshop before shipment.

Generally spoken the system is a two way prefab solution meeting the requirements to easy and accurate mounting for casting in the concrete block and easy adjustment and fastening of the engine base.

3.3.4. Engine alignment and prestressing

The final alignment of the engine is executed using individually machined supporting chocks between engine base and basebeam to achieve final accuracy of the levelling of the crankshaft. The anchorbolts ø 90 in steel RR 52.3/DIN 17100 are designed to give a direct bond between engine base and foundation. Each bolt is by means of hydraulic tools prestressed from beneath to a max. force of 1200 kN to achieve minimum stress variation. The prestressing is carried out in two terms in order to compensate for the relaxation in prestressing due to shrinkage and creep in the concrete.

3.3.5. Concrete compound and heat control

Casting of a foundation block of the present size arise a number of problems to be dealt with such as available aggregates for the concrete, cement types, capacity, quality assurance, heat and moisture control. The available aggregates on the Faroe Islands which consist of crushed basalt calls for special attention regarding achievement of both a fluid consistency for workability and a low water cement ratio required for a tight concrete. Further cement consumption shall be minimized to decrease heat generation from hydration without a violation of the strength criteria. A flyash type cement was used to improve the workability and to give a slight reduction of the heat generation. Plasticizers were added at the concrete mixing plant and to the trucks before unloading at the site. The use of plasticizers retarded the setting but caused an increase of the heat generation in the first hours after setting which called for proper insulation of the foundation block immediately after setting.

The control of temperature was executed by means of termoelectric devices. The temperature of selected sensitive locations in the foundation block was registered to assure that max. differential temperatures in the foundation block were kept within specified values, i.e. to prove that the foundation block was properly insulated and to give the precise time at which formwork could be demounted with respect to outdoor temperature and max. temperature in the foundation block. The max. temperature in the block reached 60°C in 3 days and the following cooling down period lasted for 3 weeks.

Figure 27. Anchorage Template System Test mounted in the Workshop.
Figure 28. Anchorage Template System Compact assembled for Transport.

Figure 29. Anchorage Template System mounted in the Scaffolding ready for Casting of Concrete.
3.4 Joint building

The two storey joint building has a length of 32.3 m and a width of 8.6 m.

The structural system above level 12.75 consists of concrete walls provided as fire walls in the west gable of the new hall and in the east gable of the new engine hall together with steel roof girders spanning 8.6 m in between. The spatial stability is achieved by means of diaphragm action in the roof and facade walls and lateral support to the gable columns of the new engine hall.

The substructure below level 12.75 is made in reinforced concrete, which includes the foundation wall of the existing engine hall provided with heavy vertical stiffening ribs to resist earth pressure.

The roof cover consists of trapezoid corrugated steel sheets with a depth of 115 mm supported on the roof girders with a mutual distance of 5 to 6 m. The 135 mm mineral wool insulation is topped with a 5 mm fibre board to allow a mechanical fastening of the insulation to the steel sheets and three layers of asphalt felt. The exterior walls are in situ cast concrete except the north facade towards the waterfront which is of the light weight insulated type with exterior cover of plane PVC-aggregate board. Foundations for the joint building are cast directly on basalt rock.

3.5 Chimney

The chimney height of 40 m was determined in correlation with the environmental criteria as specified in the Danish code of practice. The diameter of 3.4 m was required to provide room for two $\phi$ 1540 mm/1300 mm diameter exhaust air flues and one $\phi$ 515 mm/315 mm diameter flue to serve the combustion oil burner.

The chimney is designed to resist wind load corresponding to a max. wind velocity of 60 m/sec. The wall thickness of the steel cylinder varies between 10 mm at the top to 14 mm at the bottom. Steel material is St. 37.2/DIN 17100 except the lower 4 m comprising the anchorage detailing supplied as St. 37.3/DIN 17100. The chimney is provided with two bolted erection joints dividing it into three transportable sections of max. length 14 m.

The first natural mode of vibration is in resonance with the lateral oscillation force initiated by the wind at a velocity of 36 m/sec. As a laminar flow initiating alternating oscillation forces at this high wind velocity is not probable fatigue criteria consequently do not govern the design.
Figure 31. Fire Detection Diagram.

Figure 30. Chimney mounted. Height 40 m. Diameter 3.4 m.
4. **BUILDING INSTALLATIONS**

4.1 **Heating and ventilating**

4.1.1 **Engine hall**

The ventilating unit supplying fresh air for cooling of the engine hall is located in level 10.15 in the cellar of the joint building.

The air intake is placed on the roof of the joint building. The air is filtered in a separate ventilating room and ducted along the southern facade in the cellar level for cooling of the engine hall. The ventilating air passes through perforated steelplates in the chequerplate deck to the outlets located along the ridge of the building. Approximately 60,000 m$^3$/h are required keeping the temperature below 40°C for max. outdoor temperature. The two ventilating fans, one for each engine, have two operating speeds and are automatically regulated via thermostats in the engine hall.

The ventilating of the existing engine hall has been rebuilt in a similar way as described above using the same intake above the roof of the joint building. Fire dampers connected to the integrated fire detecting system have been installed separating the engine halls if the fire alarm is released.

4.1.2 **Workshop and separator room**

The ventilating system for the workshop is provided for heating and cooling with fresh air. The air intake is placed in the southern facade. Via heating surfaces placed in the ducts fresh air is blown into the workshop. The air is ejected through a roof mounted fan.

The ventilating of the separator room is provided for cooling and for firetechnical reasons. The ventilating capacity is 3000 m$^3$/h keeping the temperature below 25°C. The ventilating is automatically switched off in case of fire.

4.1.3 **Joint building**

The ventilating of rooms in the joint building is operated from a ventilating unit installed in the separator room level 12.75.

Inlets are located on the roof of the joint building and the air is ducted to control room and battery room. Ventilating air is
Figure 32. View of Heat Exchanger installed on the first Gallery.

Figure 33. View of Low Voltage Switchboard.
blown into the control room through grids in the floor along the wall next to the existing building and sucked via lighting fixtures installed in the lowered ceiling through roof-mounted fans. The unit automatically mixes fresh air and return air keeping the temperature at 22°C. Heat is supplied via heat surfaces in the ducts. The ventilating capacity is 3000 m³/h.

4.2 Fire detecting and fire fighting

It is of vital importance for the safety of the electric supply on the Faroe Islands that a prospective fire is immediately detected and brought under control. The power station has therefore been divided into fire sections and equipped with an automatic fire detecting system, automatic and manual alarm and automatic and manual fire fighting equipment.

4.2.1 Fire sections

Customer's demands for flexibility in the location of auxiliary equipment and tanks, piping installations and future extension of the engine hall have led to fire wall BS60 sectioning of only specially sensitive areas such as oil treatment room and workshop. To compensate for the modest sectioning in the engine hall, the detection alarm and fire fighting equipment have been extended. Further control room, electronic room and the 20 kV-room have been located in a joint building between the two engine halls and enclosed by firewalls BS60. Outlook from control room to engine hall is achieved by means of firesafe BS60 window panes in the fire wall.

4.2.2 Automatic fire detecting and fire alarm

All sections in the power station are provided with smoke- and thermal detectors with connection to the automatic fire alarm panel.

In case of fire or smoke generation the fire alarm panel will send signals to the geographic mimic and the alarm matrix installed in the control room. Further the automatic fire fighting/fire retarding equipment and the acoustic/visual alarm system will be activated. The detection and alarm system for the existing power station has been connected to the new fire alarm panel. All smoke detectors are installed with double loops to prevent fault alarms in case of e.g. welding and smoking.

The thermal detectors in the engine hall have fixed release at 70°C because of the variations in temperature which may occur under normal service conditions.
In all other rooms thermal detectors have differential indicators with quick release in case of a sudden raise in temperature.

4.2.3 _Halon extinguishing systems_

The control room, the electronic room and the 20 kV room have been equipped with Halon 1301 extinguishing systems because of the efficient protection achieved by such systems in cases where electrically non-conductive and non-corrosive fire fighting medium is desirable.

As the Halon 1301 is an odourless and colourless gas, which is slightly toxic in the applied concentrations, alarms have been installed to warn the personnel in case of release or leakage.

4.2.4 _Fire ventilating_

In case of fire and smoke generation it is essential that the location of the source is retained and that smoke-gas explosions are avoided. Consequently the power station has been provided with fire ventilators at the ridge. The fire ventilators have a total aerodynamic area of approximately 30 m². They are designed in accordance with the theoretical and full scale experimental investigations carried out by Colt. The fire ventilators are provided with opening cylinders with CO₂ cartridges built-in, which can be released by signals from the fire alarm panel or by manual activating.

4.2.5 _Alarms_

Sirens and bells are adequately distributed to cover the power station for safe alarm of the personnel in case of fire, halon release or leakage etc. In addition to these acoustic alarms electron-flashes are installed in the engine hall because of the high noise level near the engines. All alarms can be released automatically by signals from the fire alarm panel besides manual release activated by push buttons located in all rooms.

4.2.6 _Hosereels and fire valves_

Waterfilled hosereels are installed in accordance with the normal rules for locating of these in buildings with stores and treatment of inflammable fluids. The hosereels are provided with 30 m/20 m long 1" hoses and 8 mm spray nozzles. In addition to
the waterfilled hose reels, 2" fire valves have been installed at the engines, at the tankyard etc. primarily for cooling purposes. 30 m long 2" fire hoses with 9 mm spray nozzles are connected to the valves.

4.2.7 Mediumfoam systems

Mediumfoam systems for manual fighting of oil fires are installed at the oil storage in the cellar, on the galleries, in the oil treatment room and at the tankyard. Each system consists of a \( \phi 240 \times 650 \) mm foam container and a 30 mm long, 2" hose. The foam fluid admixture is 2-3% of the water quantity and the output is approximately 16 m\(^3\) foam per minute with a discharge range of 6 m.

4.2.8 Powder systems

Two mobile powder systems for fighting of engine, alternator and oil fires are installed. Each system consists of a pressure vessel, 50 kilo powder and a hose with a powder spray gun reaching a discharge range of 12 m.

4.2.9 Hand fire extinguisher

Hand fire extinguishers are set up with a suitable short mutual distance to allow for a quick operation which often is required to prevent a fire to develop. The used types are 6 kilo CO\(_2\) and 6 kilo powder extinguishers with a discharge range of 3-5 m and 6-8 m.

4.3 Sanitary installations

4.3.1 Water installations

The water installations have been provided as two separate systems. One system for ordinary sanitary installations, auxiliary equipment for engines etc. and another system for the supply of water to the hose reels to the fire valves and to the medium foam systems.
4.3.2 Drainage

Floor drains, visible pipes and drain pipes below the cellar floor in the engine hall are made of cast iron to resist any accidental waste of hot oil, which may reach a temperature of approximately 100°C. Other drainpipes for ordinary black- and grey wastewater are of PVC-make.

4.3.3 Water supply

The water supply to the power station descends from a natural reservoir situated approximately 160 m above sea level. The water is led to the power station through hot dip galvanized steel pipes and PVC-pipes. At the station the pressure is reduced to 10 and 6 atmospheres respectively for fire water and sanitary/process water.

4.4 Electrical installations

The lighting and power installation and the high voltage installations for the equipment are designed in accordance with the Danish and Faroe Regulations and Standards.

Ex-proof electrical components have been required in hazardous areas of the engine hall in which oil may be heated to a temperature above the flash point.

4.4.1 Lighting

The lighting fixtures are in general installed in lightbands to achieve uniform light intensity. This is important in the engine hall in which daylight only penetrates the transparent acrylic domes mounted in the fire ventilators at the roof ridge.

The controlroom is provided with special ventilux-fixtures with asymmetric reflectors in which the fixtures serve as exhaust grids for the ventilating air. This concept increases the service life of the fixtures because of the cooling effect. Due to the flexibility of the reflectors, unpleasant reflections can be avoided at the control desk and alarm panel installations.

The area around the power station is lighted by means of high pressure dosium flood lights and high pressure mercury vapour lamps mounted on steel masts and on buildings.
4.4.2 Inspection and emergency light

For maintenance and service purposes, outlets with 110 V-AC for inspection light are provided at the engines and at the auxiliary units.

Emergency lighting is installed all around the power station connected by means of fireproof cables to a 220 V-DC battery station.

4.4.3 Power installations

The power installations comprise installations for cranes, ventilating units, welding outlets, outlets for tools in workshop and other building installations.

4.4.4 Switchboards

Three switchboards are installed for the plant installations. One is mechanically and electrically connected to the low voltage main switchboard for the power station. A 800 kVA 20/0.4 kV station transformer supplies the low voltage main switchboard which then again supplies the two other switchboards located in the workshop and in the 20 kV room respectively.

The switchboards are designed partly as fuseless panels by provision of circuit breakers or mini circuit breakers for hand operation. Only the main feeders are constructed as switches with fuses.

The control power supply is 220 V-DC and all auxiliary relays are of snap socket type.

All important alarms are transmitted directly to the main alarm panel located in the control room, while secondary alarms are assembled in a common group from which the signals are transmitted to the main alarm panel.

Internal connections in the switchboards are made with heat-resistant cores, and all outlet cores are located in separate terminals in the bottom of the switchboards, where all cables enter.

Automatic control equipment for ventilating and other building installations are located inside the switchboards all of which are of metal cladded box types IP 54.
Figure 34. High Voltage System Diagram.

Figure 35. View of Cooling Water Intake.
5. **HIGH VOLTAGE SYSTEM**

The extension of the high voltage system is executed as shown schematically on figure 34. The existing power station generates electric power at a voltage output of 20 kV and 60 kV alternatively.

Power from the new Jeaumont-Schneider generator has an output voltage of 10 kV. Since the power in the existing station is generated at 6.6/20 kV, cables are ducted directly to the new 60 kV-station for transformation to 60 kV by means of a 10/60 kV transformer. From the new 60 kV station the power can be transmitted to the 60 kV lines or alternatively to the extended 20 kV switchboard via the 60/20 transformers.

From the 20 kV switchboard power is transmitted to the 20 kV transmission line and/or to the 20/0.4 transformers which supply electricity to the local low voltage switchboard.

6. **DRAIN- AND SEWER SYSTEM**

6.1 **Drain**

Below cellar floors and around buildings a layer of crushed rock has been laid out to drain away the oozing-in water which descends from fine cracks in the basalt mass. Drain pipes have been avoided because of the probability of mudblocking of the pores in the pipes.

6.2 **Rainwater**

Rainwater from roofs is drained off to the Fjord via the mains in the earth. The remaining surface water is drained off via canals along the rockside or it is drained off directly over the rock-face to the Fjord.

6.3 **Black and grey waste water**

Black and grey waste water from toilet and washbasins are drained off to the inlet over a trixtank for mechanical purification. The trixtank is located in such a way that space is provided for a possible future extension with a biological plant as flush towers or similar for 15 to 60 person equivalents.
6.4 Oleaginous water

Oleaginous water, which may descend from the engine hall, place for filling of tanks, tankyard etc. is drained through a high capacity oil separator of 19 l/sec. and a smaller oil separator with a capacity of approximately 3 l/sec. The small oil separator is installed to have an extra security for detention of oil products because of planned salmon breeding in the Fjord.

The oil is accumulated in a well and pumped into the regaining tank which is located in the tankyard. After treatment in the oil treatment plant the regained oil is used as combustion oil.

6.5 Modifications of existing pipes and cables

The extension has required various diversions and replacements of the existing pipes and cables to achieve integrated functions of the extension and the existing power complex. As such, replacement of sections of water main, modifications of drainage system for rainwater and oleaginous water by provision of a regaining pumpwell and finally new tracing for 20 kV-cables and cooling water pipes.

7. COOLING WATER SYSTEM

A new pumping station for the sea cooling water system has been built at the waterfront north-east of the extension.

The pumping station has been erected upon a 7 m long, 5 m wide and 3.6 m high precast concrete caisson built at the Skala Shipyard from where it has been towed to be immersed at the bottom of the Fjord in the depth of approximately 3 m.

The lower part of the pumping station comprises six chambers individually connected.

Each chamber contains approximately 11 m$^3$ and can be separated from one another to be drained for cleaning. Special arrangements have been carried out to reduce the growth of microorganisms, shells etc. in the cooling water system.

The water is filtered before entering the chambers to prevent larger organisms to enter the system. The growth of microorganisms is reduced keeping the inside of the pumping station in complete darkness.
However, under these conditions certain types of shells still manage to survive and experiences from similar plants and the existing plant have shown that one of the most efficient methods of reducing growth of shells in the system is to flush periodically with fresh water.

The seawater for the cooling water system is sucked through pumps placed on a platform inside the pumping station. The water is pumped through 200 mm diameter PEH-pipes to the diesel generator units supplying 5 coolers in parallel as follows: the fresh water cooler, the scavenge air cooler, the main lube oil cooler, the camshaft lubrication cooler and the generator cooler placed below the generators.

The temperature of the cooling water before entering the system is approximately 8°C which provides sufficient cooling for the above mentioned coolers at a flow rate of 306 m³/h per engine. At the outlet the cooling water has a temperature of 30-35°C and as previously mentioned it has been planned to use this energy source for fish breeding production in the Fjord.

8. OIL SYSTEMS

8.1 Fuel oil system

The fuel oil system is primarily based on the use of heavy fuel oil (600 cst at 50°C). The system is however designed to the use of diesel fuel oil as an alternative. This facility is provided to make overhauls of the heavy fuel oil system possible without shut down of the power supply. The heavy fuel oil system is shown schematically on figure 36. The system can be divided into a fuel oil separator system (1-2-3-9-10-11) and a fuel oil supply system.

8.1.1 Fuel oil separator system

From the storage tank (2500 m³) in the tankfarm east of the existing building, fuel oil is transported through isolated and electrically heated pipes in the covered pipe-tracing to the 10 m³ buffer tank in the day tankfarm north of the joint building. From the buffer tank fuel oil is either recirculated to the storage tank or pumped into the separator units placed adjacent to the day tankfarm at level 8.75 inside the building. Waste oil, sediments, water etc. is led to the sludge tank below the separators at level 4.70.

and further to the waste oil combustion building located adjacent
to the new 40 m high chimney. Exhaust smoke from the combustion
building is led through a separate 315 mm diameter steel flue
provided in the chimney. The regained and cleaned oil is stored
in a 30 m³ service tank in the day tankfarm.

8.1.2 Fuel oil supply system

This system is supplied from the service tank and comprises a
separate system for each diesel generator unit.

From the service tank the fuel oil passes through a preheater,
raising the temperature of the fuel oil to approximately 130°C,
and a viscosator unit to the engine. Drained fuel oil is collected
in a drain tank as shown on the figure before recirculation
into the system via the fuel oil separator.

8.2 Lubricating oil system

The lubricating oil system is shown schematically on figure 37.
Two service tanks each containing 30 m³ placed in the day tank-
farm supply lubricating oil for cylinder-, camshaft- and main
lubricating oil systems. The lubricating oil from the three
systems is separated (9, 10) in clean oil which is reused in the
process and waste oil, sediments, water etc., which is led to
the sludge tank and further to the waste oil combustion building
common for fuel- and lubricating waste oil.

9. CONSTRUCTION PHASE

The rock blasting and excavation for clearance of the site already
started in 1980 and was terminated in August 1981. Construction
of concrete foundations and structures commenced shortly after
in September. Practically all reinforcing steel bars were de-
ivered prebent, and the slab reinforcement as prewelded nets
from Aalborg in Denmark and landed on quay in Thorshavn.

The supply of concrete was handled by mixing plants located
nearby in Thorshavn and transported by means of lorry mixers for
unloading in concrete buckets suspended in a tower crane which
covered the whole casting area around the engine hall.
Figure 38. Concrete Substructure during Construction.

Figure 39. Engine Foundation after Casting of Concrete.
Figure 40. Concrete Caisson for Cooling Water Intake.

Figure 41. Mounting of Steel Superstructure and Cladding.
The engine foundations each consuming approximately 450 m$^3$ were executed in continuous casting within 36 hours per foundation from the base slab to the top. The anchorage system was fabricated in Denmark and prepared for easy assembly to a 12.7 m long unit on site by means of bolted connections and mounted in the scaffolding system prior to the casting.

The steel superstructure above level 12.75 was fabricated by Sønderjyllands Maskinfabrik in workshops in Hjørdkær, Denmark. The shopwork required for the system applied predominantly consisted of joint preparation by means of cutting, drilling and welding on rolled section components.

As the whole structure is built up of prefab. straight shop components with a max. transport length of 17.5 m and application of bolted erection joints throughout, special attention was aimed at the accuracy of shop fabrication to meet the required tolerances. A successive shop preassembly was carried out to ascertain fitness before shipment.

Various precautions were taken to allow for minor adjustments of all important connections to eliminate inevitable errors in manufacture and deviations from exact location of cast in anchorbolts such as:

a. Generally all bolted connections have been made with 1.5 mm oversize holes except for joints in the crane girders made with close tolerance bolts.

b. All frame joints are of the end plate type allowing for max. 8 mm filler plates.

c. Adjustable bearings for the crane girders allowing for exact alignment and levelling of the crane girders.

The steel collies comprising approximately 5 t were landed in Thorshavn, transported by truck to the plant area and mounted with a tower slewing crane with capacity 150 t m and a 36 t mobile hydraulic crane in about 4 weeks. The successful fast erection of the steel superstructure despite difficult weather conditions was mainly ascribed to the adequate partitioning of the system and assembly method. Roof and facade cladding followed steel mounting and terminated with closure of the west gable in November 1982 after sliding in of the 350 t engine unit.

The engine was fabricated under B&W licence in Gothenburg, Sweden and fully equipped transported on a heavy load multi-wheel waggon from the workshop to the sea transporter specially equipped for heavy launching purposes. The engine was launched
Figure 42. Engine Transport in the City of Gothenborg, Sweden.

Figure 43. Unloading of Engine at Quay at the Site.
Figure 44. Engine in Position above Foundation in Engine Hall.

Figure 45. Exterior View from West of Power Station after Closure.
Figure 46. Interior View of Engine Hall after installation of Engine and Alternator.

Figure 47. Exterior View across the Fjord from Kalbak.
on the plant quay tied to the multiwheel waggon and pulled through the narrow and steep, curved road to a plateau provided outside the west gable of the engine hall. A steel beam plateau was arranged between the gable and the engine foundation supported on permanent structures and provisional additional supports as well. The 50 t overhead travelling crane delivered the tensile force required to slide the engine block along the steel beam layer to the position above the foundations from where it finally was lowered to the permanent position on the base beams.

Major equipment such as the 125 t heavy alternator, the 52 t heavy heat exchanger, tanks and other auxiliary equipment were placed in the engine hall before closure of the west gable. Final mounting of equipment units, piping and el-installation were executed after closure of the building.

The 40 m high, 3.40 m diameter chimney was fabricated in Jutland and landed in three sections of 13 m and 14 m length respectively and mounted section by section. The two erection joints were of the butt plate type with prestressed high tensile bolts class 10.9 located only along the interior boundary of the chimney shell.

Testing of the engine set will be carried out in May – June 1983 and final commissioning scheduled to take place in June 1983.

The frequent rough weather conditions on this remote site location near the waterfront represented a challenge which called for special precautions and skill during landing operations and mounting of the superstructure. This challenge was excellently met by innovative professional workmanship by all the contractors involved to a successful termination within the tight building schedule.

10. ACKNOWLEDGEMENTS

The authors wish to express their appreciation to the client's technical staff, to Landsbyggfelagid P/F and to B&W Scandinavian Contractor A/S for a creative collaboration in the design phase.

The selected group of contractors approached the construction jobs with professional planning and excellent craftsmanship and proved the adequacy of the design concepts despite the frequent difficult climatic conditions.
B&W Scandinavian Contractor A/S has kindly made available photos and special technical information regarding auxiliary equipment and engine installations appearing in this article.

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