Mem Natl Inst Polar Res
Ser F No 4 1982

MEMOIRS OF NATIONAL INSTITUTE OF POLAR RESEARCH

(formerly Japanese Antarctic Research Expedition Scientific Reports)

Series F Logistics No 4

Energy Saving at Syowa and Mizuho Stations

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National Institute of Polar Research
Tokyo Japan January 1982

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Abstract

At Syowa Station, which was opened in 1957, two diesel electric generators were installed, one of which was always operated as the main energy source. The electric capacity of each generator has been increased from 20 kVA to 110 kVA in accordance with the expansion of the station.

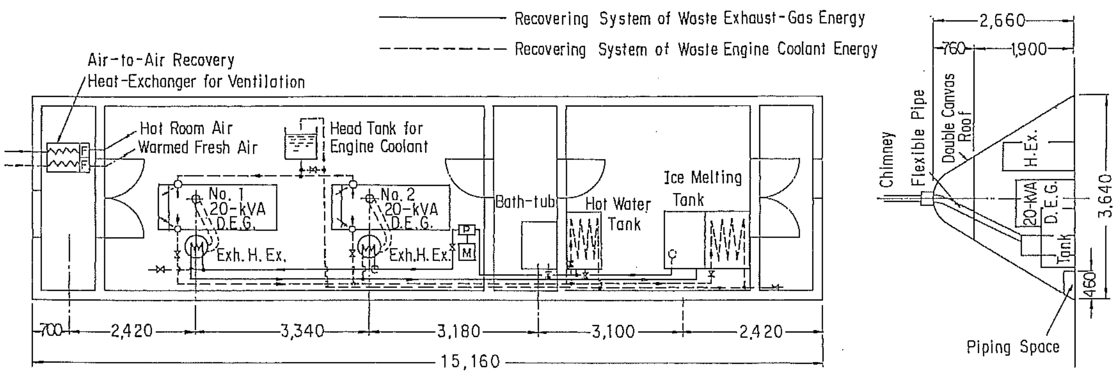
In order to save fuel consumption, the authors have developed some waste heat recovery systems of the diesel engines. By fully utilizing the waste heat of diesel engines, *i.e.*, their exhaust-gas energy and coolant energy, cold and hot water was made from ice or snow even in winter. The hot and cold water was supplied to the living quarters through insulated water pipes. The hot water was also supplied for bathing and heating of apartments of the buildings.

At Mizuho Station, which was opened in 1970, a system for recovering coolant heat of a diesel electric generator was installed. The cold and hot water is made by the similar system. The hot water is supplied to a bathtub and to a fan-coil unit in a trench living room. The heating by utilizing the waste coolant can ensure the safety of the personnel living in the trench room against fire, contamination by CO, CO_2 and lack of oxygen.

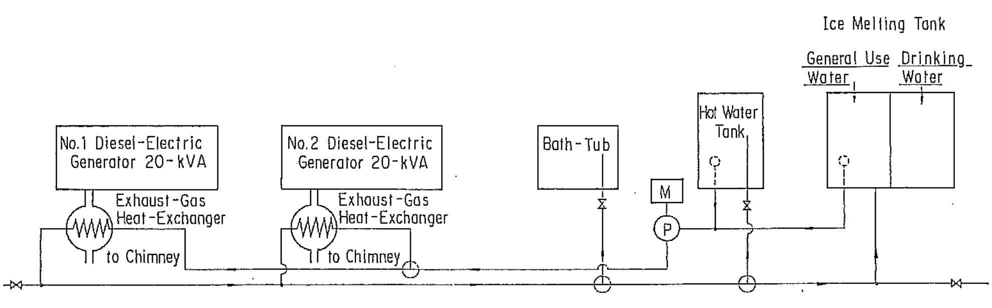
In this report, the technical problems and experiences on waste heat recovering, especially on exhaust-gas heat exchangers are described.

1. Historical Review of Development of Syowa Station

In 1955/56, S. AWANO, who was a member of the Special Committee on Mechanical Engineering for Japanese Antarctic Research Expedition (JARE) organized within Japan Society of Mechanical Engineers (JSME), designed and constructed a prototype system for producing cold and hot water as shown in Figs. 1 and 2 for JARE-1 (1956/58), utilizing the waste heat of exhaust gas from diesel engines coupled to 20-kVA electric generators as the main electric power source of Syowa Station.



a. Waste heat recovery system prepared for JARE-1.



b. Waste exhaust-gas energy recovery system actually rebuilt in JARE-1 engine room of Syowa Station.

Fig. 1. 20-kVA diesel-electric generators and waste heat recovery system prepared for JARE-1 (1956/58).

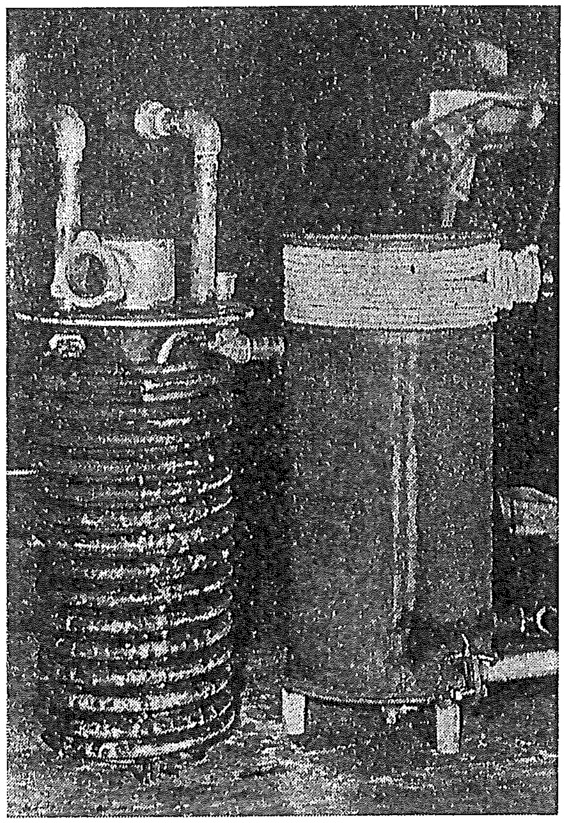


Fig. 2. Shell-and-coil type exhaust-gas heat exchanger prepared for JARE-1 (1956/58).

The details of the system have already been reported by AWANO and MAITA (1963) and SPECIAL COMMITTEE ON MECHANICAL ENGINEERING FOR JARE (1959). This system was used satisfactorily from JARE-1 to JARE-5 (1960/62).

Syowa Station was closed from February 1962 to December 1965. During these unmanned years, the system was left as it was. However, it was paid a special attention so as to facilitate the future reopening of the station.

Another JARE-7 engine room was newly built in January 1966. Two 45-kVA diesel-electric generators were set with a new system for making cold and hot water utilizing the waste heat of exhaust gas and coolant of diesel engines. In the 1967 wintering season, to satisfy the expanded requirement for electric power, one of the old two 20-kVA diesel-electric generators was used for scientific purpose. One of the new two 45-kVA generators supplied the electric power for general use.

Another new JARE-9 engine room was built in 1968, which contained two 65-kVA diesel-electric generators and a cold and hot water making system utilizing their waste heat. One of the two 45-kVA generators supplied the electric power for scientific instruments, and one of the two 65-kVA generators supplied the power for general use. The two engine rooms, JARE-7 and JARE-9, were separated about 40 m and connected by a corrugated passage. The surveillance

Table 1. Data on the logistics of JARE.

	Year	Number of wintering members	Total area of laboratories (m^2)	Total weight of cargo (t)	Total weight of fuels (t)	Water consumption (*l*/day·person)
JARE-1	1956/58	11	184	141	37	14.5
-2	1957/58	0	184	0	0	0
-3	1958/60	14	194	52	15	15
-4	1959/61	15	251	154	63	21
-5	1960/62	16	256	121	98	21
-6	1961/62	0	256	0	0	0
-7	1965/67	18	778	390	122	40
-8	1966/68	24	1283	463	149	56
-9	1967/69	29	1827	526	235	60
-10	1968/70	29	2322	560	231+ 64*	50
-11	1969/71	30	2772	572	160+ 88*	49.5
-12	1970/72	29	2810	500	270	38.4
-13	1971/73	30	3026	468	258	53.9
-14	1972/74	30	3221	488	258	53.2
-15	1973/75	30	3322	496	283+ 12**	43.2
-16	1974/76	30	3394	473	333+ 11**	42.6
-17	1975/77	29	3422	493	307	77.3
-18	1976/78	30	3522	494	304+ 4**	41.2
-19	1977/79	30	3622	487	290+144*	51.5
-20	1978/80	30	3492	462	237+ 19**	
-21	1979/81	33	3794	459	141+ 54**	

* Transferred gas oil from the fuel of icebreaker Fuji.
** Aeronautical gasoline.

Table 2. An example of yearly consumed fuel and oil in JARE-19 (1978/79).

Items	Purposes	Consumption (k*l*/year)
JARE gas oil	Vehicles	30
Gas oil	Diesel-electric generators	150
Kerosene	Hot-air heaters for room-heating	60
Gasoline	Vehicles	30
	Air heaters	
	300 W engine generator	
	1-kVA engine generator	
	Torch lamp	
	Total	270
JARE lubricating oil	Vehicles, 16-kVA diesel-electric generator etc.	4.2
Lubricating oil	110-kVA diesel-elcetric generators	0.4
Anti-freezing liquid	Vehicles, 16-kVA diesel-electric generator	1
	Total	5.6

of the two power plants was a very troublesome task for maintenance.

In JARE-19 (1977/79), one of the two 65-kVA generators was replaced by a 110-kVA diesel-electric generator, which supplied all of the power for scientific and general uses.

In JARE-20 (1978/80), the remaining 65-kVA generator was also replaced by the same type 110-kVA diesel-electric generator, and one of them has supplied all of the necessary electric power of the station and other is kept in reserve.

During 1977/79, the waste heat recovery system was also rearranged by TAKEUCHI, one of the authors. By simplifying the binary power sources in the two separated engine rooms to a single source, firstly the fuel consumption was decreased remarkably as compared to that of binary sources and secondly, mechanics were freed from troublesome work.

Table 1 shows the development of logistics capacity at Syowa Station. Recently, the weight of fuels amounts to about 50–60% of the total cargo. The water consumption at Syowa Station is also shown in Table 1.

Table 3. Diesel-electric power generators used in JARE-1/20 (1956/81).

Station	Syowa				Mizuho	
Type	ZX-111 20 kVA	ZX-140 45 kVA	ZX-75 65 kVA	ZX-125 110 kVA	ZX-500B 12 kVA	ZX-20A 16 kVA
Engine room	JARE-1	JARE-7	JARE-9	JARE-9	trench	trench
Generator Maker: Meidensha, Model: E-AF, Pole:4-poles, Phase: 3 phase, Cycle: 50 Hz, Power factor: 80%, Engine speed: 1500 rpm						
Voltage (V) AC	100	200	200	200	200	200
Current (A)	160	130	187	318	34.6	46.2
Max. output (kW)	16	36	52	88	9.6	12.8
Diesel engine Maker: Isuzu, Stroke cycle: 4, Type: in-line, Cooling system: liquid cooling						
Model	DA-220	DA-120	DA-640T	73E-120	C221	C240
Combustion chamber	pre-comb.	pre-comb.	pre-comb.	direct inj.	voltex	voltex
Compression ratio	19.5	22	22	16.5	20	20
Cylinders	4	6	6	6	4	4
Bore (mm)	100	100	102	135	83	86
Stroke (mm)	130	130	130	140	102	102
Piston displacement volume (cc)	4084	6126	6373	12024	2207	2369
Output power PS/1500 rpm	33	65.5	82	140	21	25
Min. SFC (gr/PSh)	200	190	198	170	205	205
Turbocharging	none	none	turbo-charged	none	none	none
Starter (V/kW)	24/3	24/3.7	24/3.7	24/7.4	24/2.2	24/2.2
Generator for (V)	24	24	24	24	24	24
charging battery (A)		25	25	25	300 W	30
Battery (V)	12	12	12	12	12	12
(Ah)	150×2	120×2	120×2	150×2	100×1	100×1

Table 2 shows an example of yearly fuel consumption. About 150 k*l* of diesel fuel is consumed ordinarily by the diesel engines for electric generators, representing 56% of total fuel supply of 270 k*l*.

Tables 3 and 4 show the electric power plants and their yearly mean and peak electric load at Syowa Station, which reaches 42–49 kW and 71–82 kW respectively at present.

Mizuho Station located at 70°41′53″S and 44°19′54″E inland isolated from Syowa Station by about 270 km, has four prefabricated huts and two trench engine rooms under the snow. In the trench engine rooms, two diesel-electric generators, 16 kVA and 12 kVA, are installed independently and one of them supplies all of the electric power. The coolant heat of the diesel engines, which has been also fully used for making cold and hot water by melting the snow, and the

Table 4. Diesel-electric power generators at Syowa and Mizuho Stations and the yearly mean and peak loads.

Year		Syowa Station				Mizuho Station (kVA)
		JARE-1 (kVA)	JARE-7 (kVA)	JARE-9 (kVA)	Yearly mean/peak load (kW)	
JARE-1	1956/58	20×2			2/4	
-2	1957/58	20×2			0	
-3	1958/60	20×2			5/7	
-4	1959/61	20×2			7/14	
-5	1960/62	20×2			9/14	
-6	1961/62	20×2			0	
-7	1965/67	20×2	45×2		27/43	
-8	1966/68	20×2	45×2		40/53	
-9	1967/69		45×2	65×1	42/87	
-10	1968/70		45×2	65×2	48/87	
-11	1969/71		45×2	65×2	50/82	1, 0.3
-12	1970/72		45×2	65×2	(21.2+29.5)/(26+48)*	12, 1
-13	1971/73		45×2	65×2	(22.5+26.3)/(29+52)*	12, 1
-14	1972/74		45×2	65×2	(22.5+26.2)/(36+53)*	12, 1
-15	1973/75		45×2	65×2	(21.2+24.8)/(33+53)*	12, 1
-16	1974/76		45×2	65×2	(22.2+28.8)/(31+58)*	12, 1
-17	1975/77		45×2	65×2	(23.3+28.8)/(34+64)*	12, 16
-18	1976/78		45×2	65×2	(20.2+27.1)/(28+55)*	12, 16
-19	1977/79		45×2	110×1	(48.9/82)**	16, 12
-20	1978/80			110×2	(42.1/71)**	16, 12
-21	1979/81			110×2		16, 12

* (45+65 kVA)/(45+65 kVA).
** (110 kVA/110 kVA).

hot water has also been used for heating a living room and for a bathtub.

The hot-water room-heating system ensures the safety of the wintering members, who are freed from the contamination of CO and CO_2 and the lack of oxygen which would be inevitable if the oil furnaces were used.

In the following articles, details of the waste heat recovering systems developed by the authors will be described.

2. A 45-kVA Diesel-Electric Power Generating Plant with Waste Heat Recovery System

A prefabricated power plant hut was built by JARE-7 in 1966. There were two sets of 45-kVA diesel-electric generators, two sets of exhaust-gas heat exchangers, two sets of shell-and-tube type horizontal coolant-to-water heat ex-

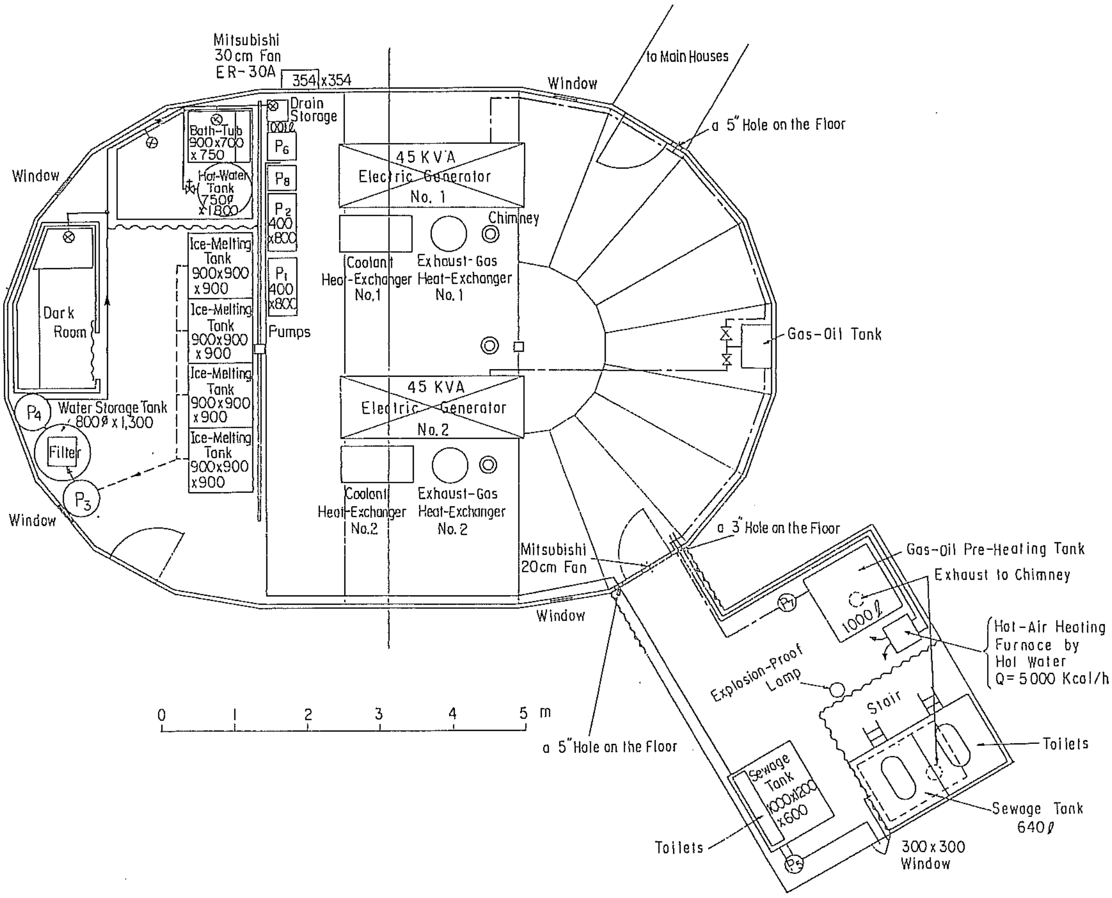


Fig. 3. JARE-7 engine room containing two sets of 45-kVA diesel-electric generators (Meidensha ZX-140 type, diesel engine Isuzu DA-120) and waste heat recovery systems for making cold and hot water, prepared for JARE-7 (1965/67).

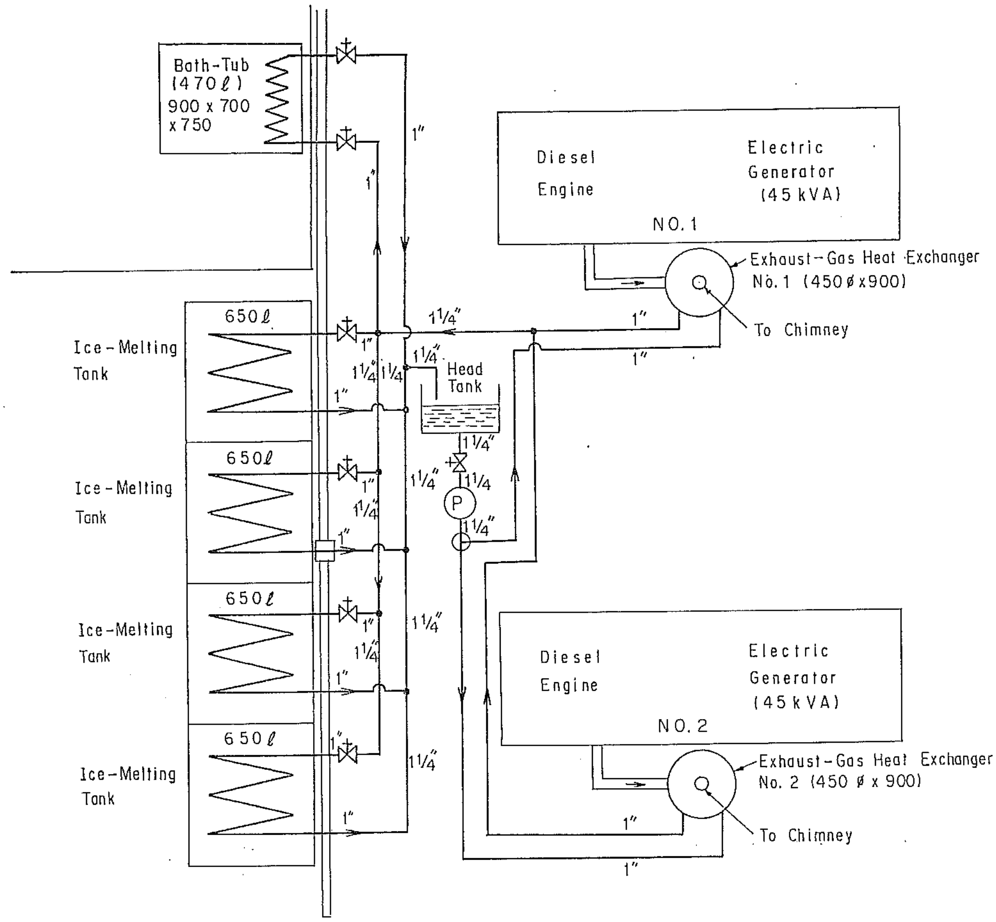


Fig. 4. Exhaust-gas heat recovery system in JARE-7 engine room.

changers for recovering the waste coolant heat of diesel engines, one hot-water storage stainless-steel tank (750 mm diam. × 1800 mm H, capacity 79 *l*), four ice-melting stainless-steel tanks (each measuring 900 × 900 × 900 mm, capacity 650 *l*), and one bathtub in this JARE-7 engine room (Figs. 3, 4).

2.1. Ice or snow-melting plant utilizing exhaust-gas energy of diesel engines

One of the two sets of the 45-kVA diesel-electric generators was run continuously until 1978. The greater part of the waste exhaust-gas energy of the diesel engines was recovered by the shell-and-coil type heat exchangers as shown in Figs. 5 and 6. Hot water of about 45°C was heated to 55–60°C by the exhaust of the diesel engines while flowing through the coils. The external diameter of stainless coil pipe was 18 mm, the total length of which was 94.3 m, and the total outer surface area was 5.33 m² (see Table 7). By this system, Q_r=9000–18000 kcal/h heat was recovered from the waste exhaust-gas energy, and 1–2 k*l*/day of cold water could be supplied by melting ice and snow.

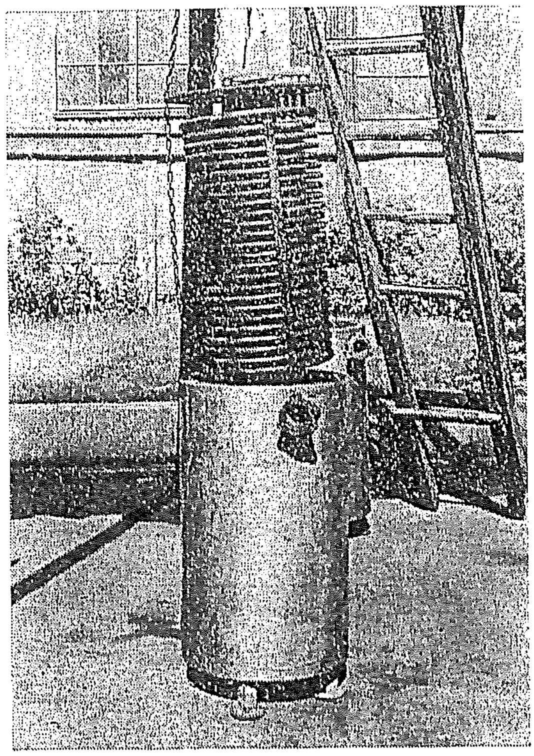


Fig. 5. Shell-and-coil type exhaust-gas heat exchanger prepared for JARE-7 (1965/67).

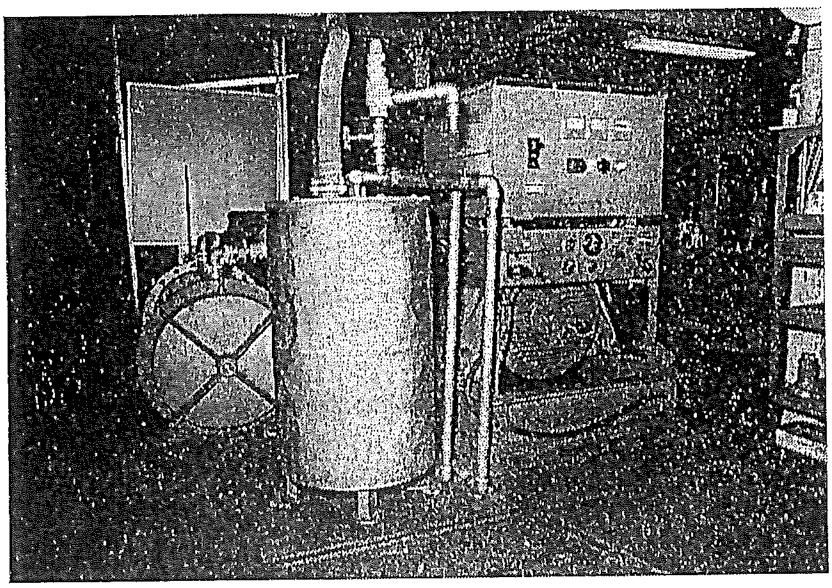


Fig. 6. Inside view of JARE-7 engine room (45-kVA diesel-electric generator, shell-and-coil type exhaust-gas heat exchanger, and horizontal shell-and-tube type coolant-to-water heat exchanger to recover coolant heat of DA-120 diesel engine from right to left).

2.2. System for making hot water with coolant of diesel engines

The coolant heat of diesel engines was utilized for making hot water of about 60–70°C. Two sets of horizontal stainless-steel shell-and-tube type heat exchangers were prepared for this purpose. As shown in Fig. 7 a new high temperature automatic thermo-valve, which opens at about 90°C, was installed at the inlet of an engine radiator, in addition to an ordinary low temperature automatic thermo-valve, which opens at about 65°C. The engine coolant flowing through the low temperature thermo-valve was bypassed to the shell side of a shell-and-tube type heat exchanger at the inlet of the high temperature thermo-valve. The engine coolant of 65–80°C transferred its heat to the low temperature water flowing through the inside of tubes and returned to the inlet of coolant pump of engine. Although the high temperature thermo-valve is closed normally, it opens when the coolant temperature rises abnormally, and some of the hot coolant from the engine is bypassed to the engine radiator to protect the engine from overheating.

A water pump P_1 (1.5 kW, capacity 0.07 m^3/min at $H = 24$ m H_2O) shown in Fig. 8 recirculated the hot water between the hot-water storage tank and the shell-and-tube type heat exchangers. Another water pump, P_2, was used for recirculating the hot water between the hot-water storage tank and heating radiators provided at the inlet of heating furnaces for warming the fuel preheating room and the living and cooking quarters.

Hot water was also supplied to washstands in the living quarters. The water level of the hot-water tank was always kept at a constant level by charging automatically thereinto cold water from the cold-water tank.

2.3. Insulated hot and cold water feeding pipe

The hot and cold water made in the JARE-7 engine room was fed to the living quarters which were separated therefrom by about 160 m. For this purpose, two kinds of insulated piping units were developed by the authors. Fig. 9a shows one piping unit and its section. The piping unit was 140 mm in diameter and 4 m in length. A polyethylene outer pipe contained four aluminum pipes of 32-mm external diameter, and the space between them was filled with polyurethane foam insulator. The lower two aluminum pipes were used as feed and return pipes for hot water, and the remaining two as the feed and return pipes for cold water.

The other type of piping unit had three aluminum pipes as shown in Fig. 9b. The lower two pipes were used as feed and return pipes for hot water, and the remaining one was used for feeding cold water to messroom and living quarters. In each case, the heat loss from the two hot-water pipes prevented the freezing of cold water. Thus, we succeeded in supplying hot and cold water to messroom and living quarters (Fig. 10). The temperature drop of hot water at 45°C was

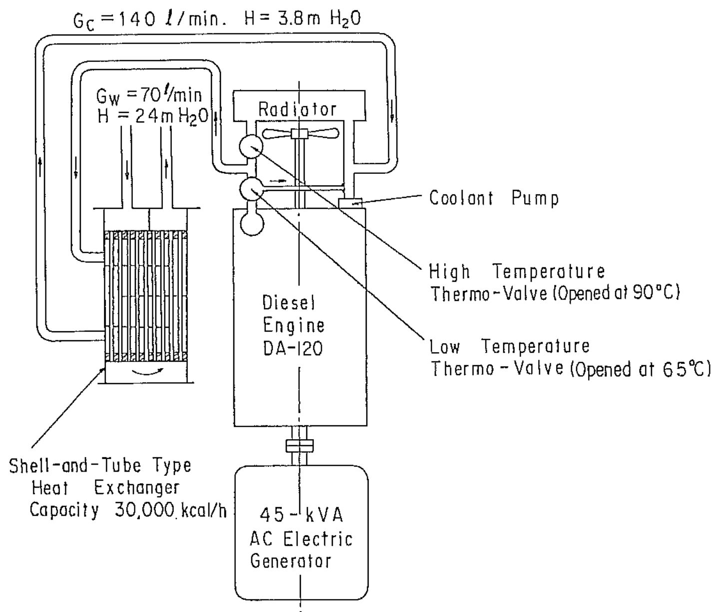


Fig. 7. Piping for coolant heat recovery system in JARE-7 engine room.

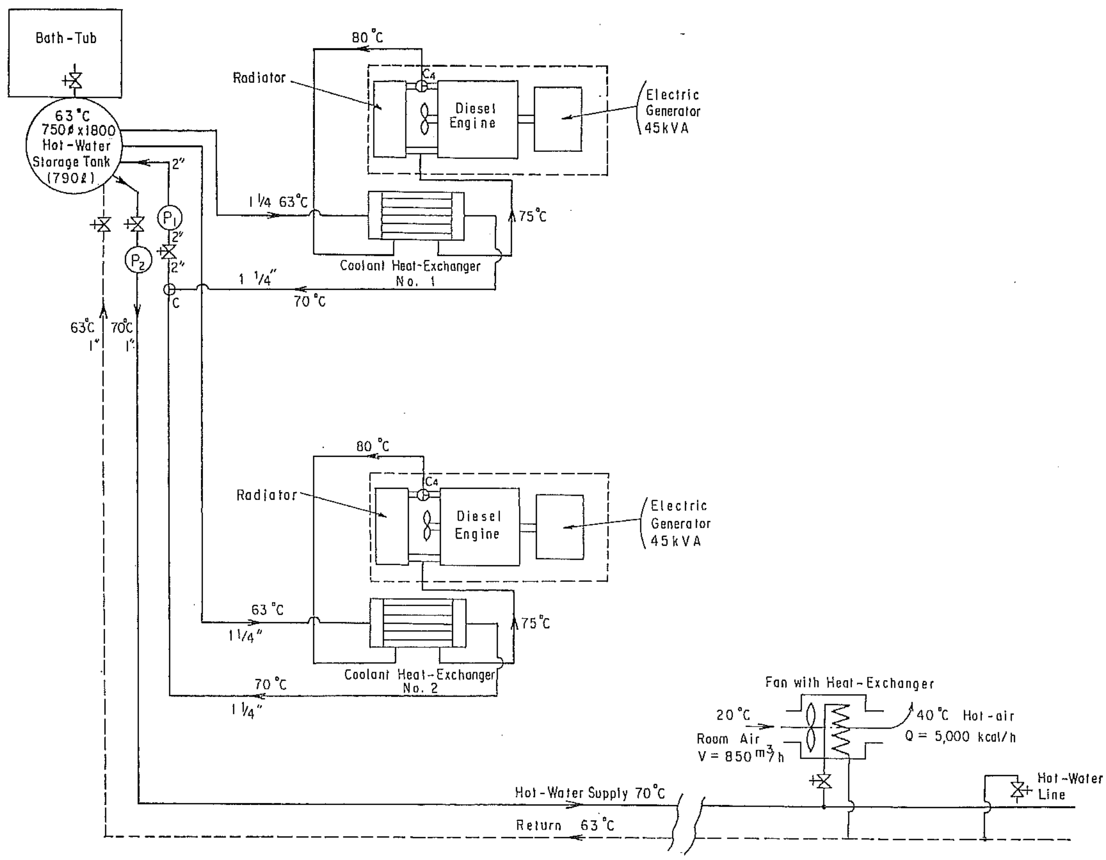
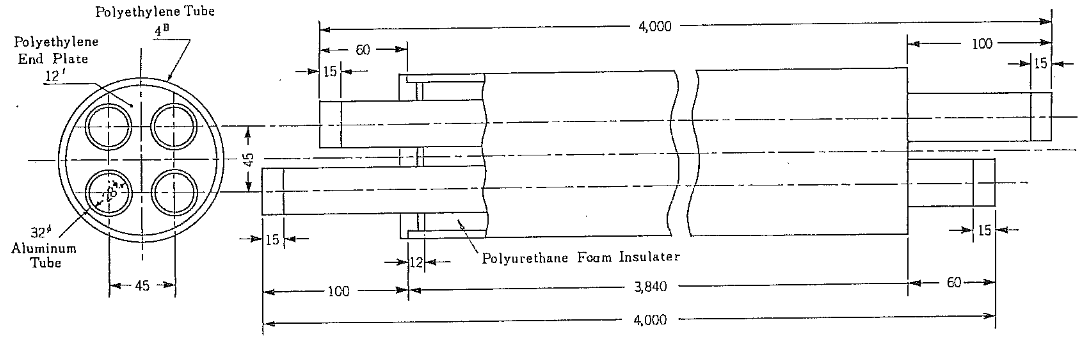
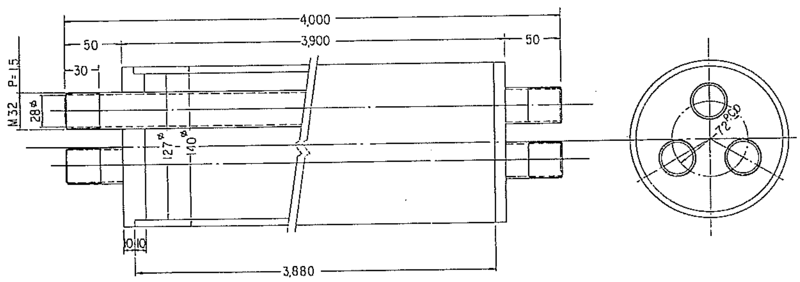


Fig. 8. Coolant heat recovery system in JARE-7 engine room.



(*a*) *Four-tube type.*



(*b*) *Three-tube type.*

Fig. 9. Insulated hot and cold water feeding pipes developed for JARE-7 (1965/67).

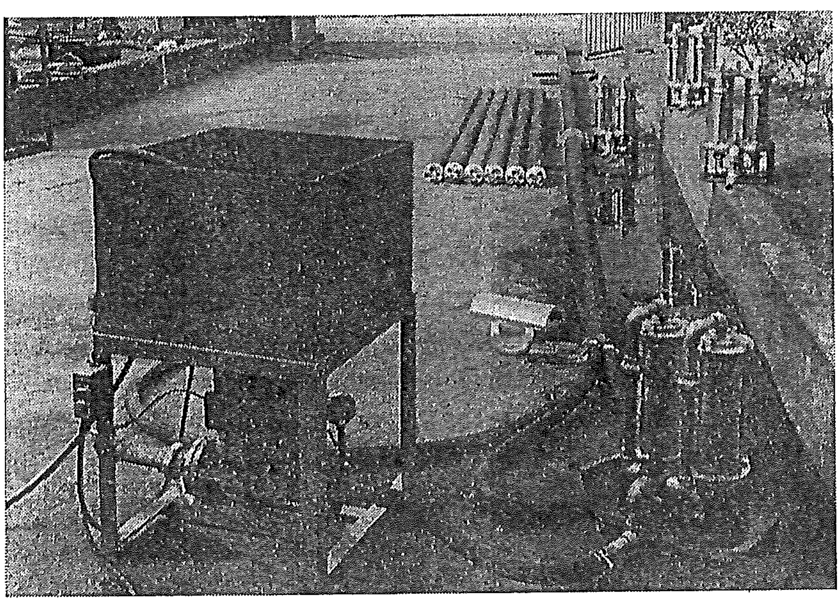


Fig. 10. Insulated hot and cold water feed pipes, feed pump with head-tank, and water filter using organic filter elements.

only 1.0–1.5°C during its flow through the insulated duct of 100-m length at a flow rate of 100–200 *l*/min at Syowa Station (SATO, 1967).

Experiments on the effectiveness of these piping units were done in a low-temperature testing room of the Research Institute of Transportation Technology, Tokyo, by the authors in August 1965. The data obtained and the results of theoretical analysis are shown in Appendix 1.

2.4. Fuel preheating room and toilet

As shown in Fig. 3, a fuel preheating room was built adjacent to the JARE-7 engine room. This room was warmed to about 10°C at floor level by hot air transferred by an axial fan from the engine room and by a heating furnace described in Subsection 2.2.

A diesel fuel tank (capacity 1 k*l*), toilets, and a sewage tank (capacity 75 *l*) were also installed in this room. The toilets were designed by Ebara Infilco Co., Ltd., and were similar to those of airplanes. The sewage from the bathtub and the toilets was mixed and pumped to a tide crack by a monoflex pump. The sewage was lifted vertically first to a roof level and then transported through an inclined 1.5B plastic pipeline of 80-m length. After the pumping was finished, the contents of the pipe were entirely drained off to protect it from freezing. The slope of inclination should be greater than 2°, and an air-cock should be installed at the foot of each end of the pipeline. This simple and most effective method for pumping water outdoors was developed by the members of JARE-7 (SATO, 1967). This pumping transportation of sewage made unnecessary the troublesome work of transporting it to tide crack by a vehicle with a vacuum tank.

2.5. A 10-k*l* snow or ice-melting and cold-water storage tank installed outdoors

To eliminate the laborious work of transporting and throwing snow or ice into the melting tank in the JARE-7 engine room, a 10-k*l* prefabricated outdoor tank was developed by the authors for JARE-8 in 1966. As shown in Figs. 11 and 12, eight steel pillars having U-grooves were placed vertically on the ground, and eight sidewall panels were inserted into the U-grooves to form a square bottomless tank support measuring 4.06×3.96×1.00 m. The steel panels for the sidewalls were filled with glass fiber as an insulator and were thoroughly waterproofed. The dimensions of each were 1.0×0.9×0.078 m. Furthermore, a water-proofed canvas sheet tank was extended inside the tank support and was fixed to the pillars by ropes. The pressure of water in the tank was sustained by the walls, pillars and four tension stays connecting the basic members of the tank support and not by the canvas itself. Another water-proof canvas sheet covered and insulated the tank from the cold atmosphere. Hot water was led to a stainless-steel tube type radiator submerged in the water and was recirculated to an

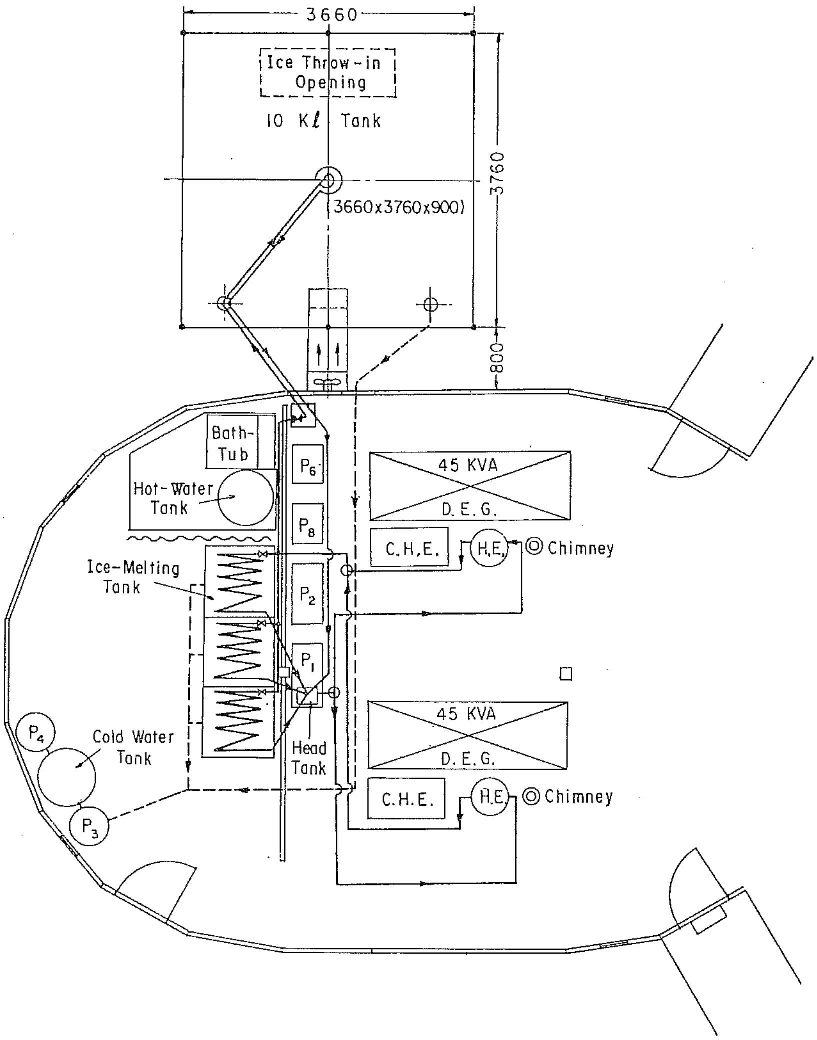


Fig. 11. Ten-kl outdoor ice-melting and cold water storage tank prepared for JARE-8 (1965/68).

exhaust-gas heat exchanger in the JARE-7 engine room.

This water making and storage system has been used successfully during the past 13 years. The water temperature in the tank was kept at 20–30°C even in winter. As the submerged heating radiator, a stainless-steel tube type radiator was most suitable because of its high resistance to hard ice, sand, dust and rust.

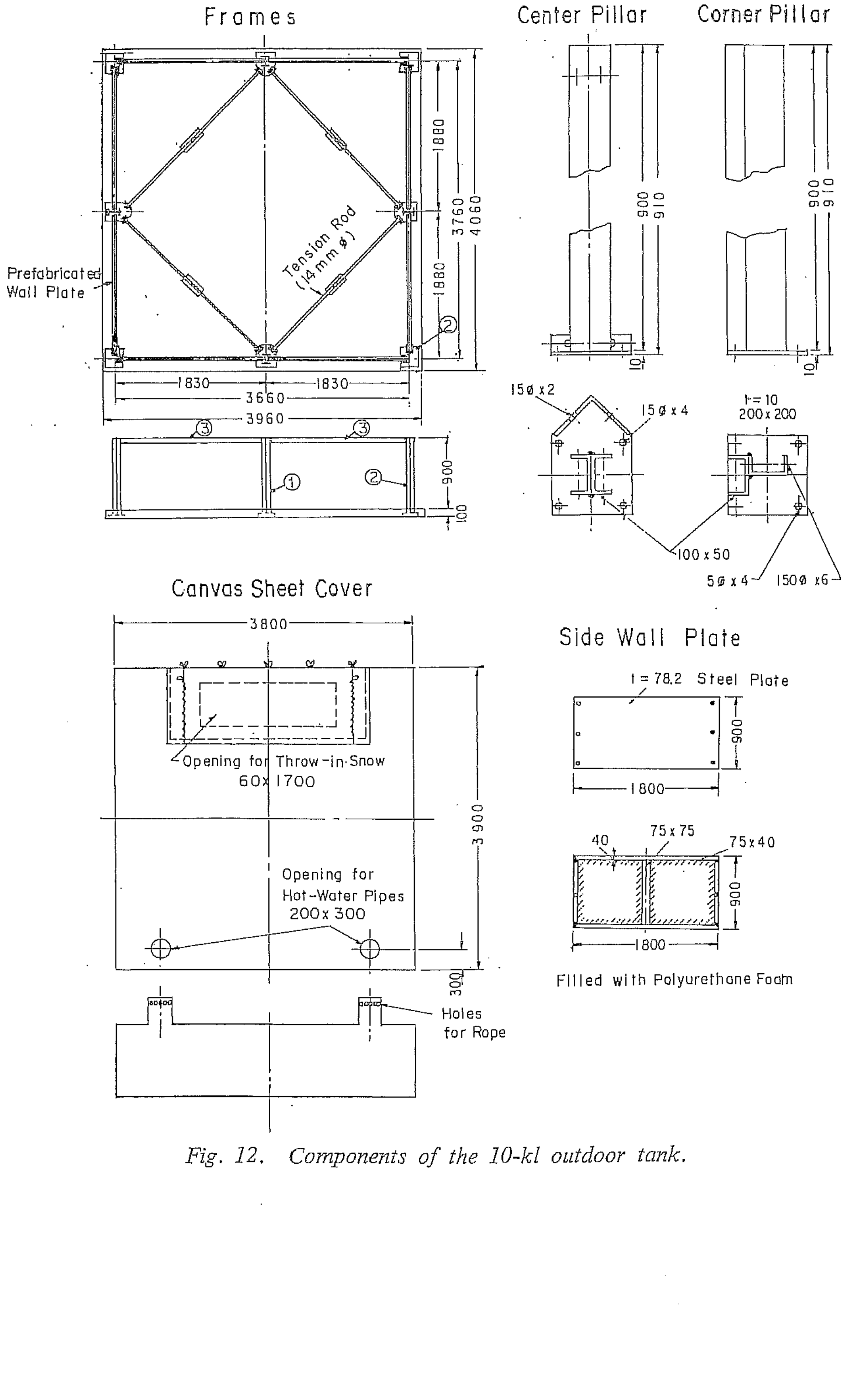


Fig. 12. Components of the 10-kl outdoor tank.

3. A 65-kVA Diesel-Electric Power Generating Plant with Waste Heat Recovery System

A new JARE-9 engine room was built in 1968. It contained a 65-kVA diesel-electric generator set and a coolant heat recovery system. As shown in Fig. 13 (TSUCHIYA, 1969), the engine coolant was led to a headtank and returned to the inlet of the water pump of the diesel engine. The hot water in the headtank was pumped to a hot-water tank installed at a corner of the engine room

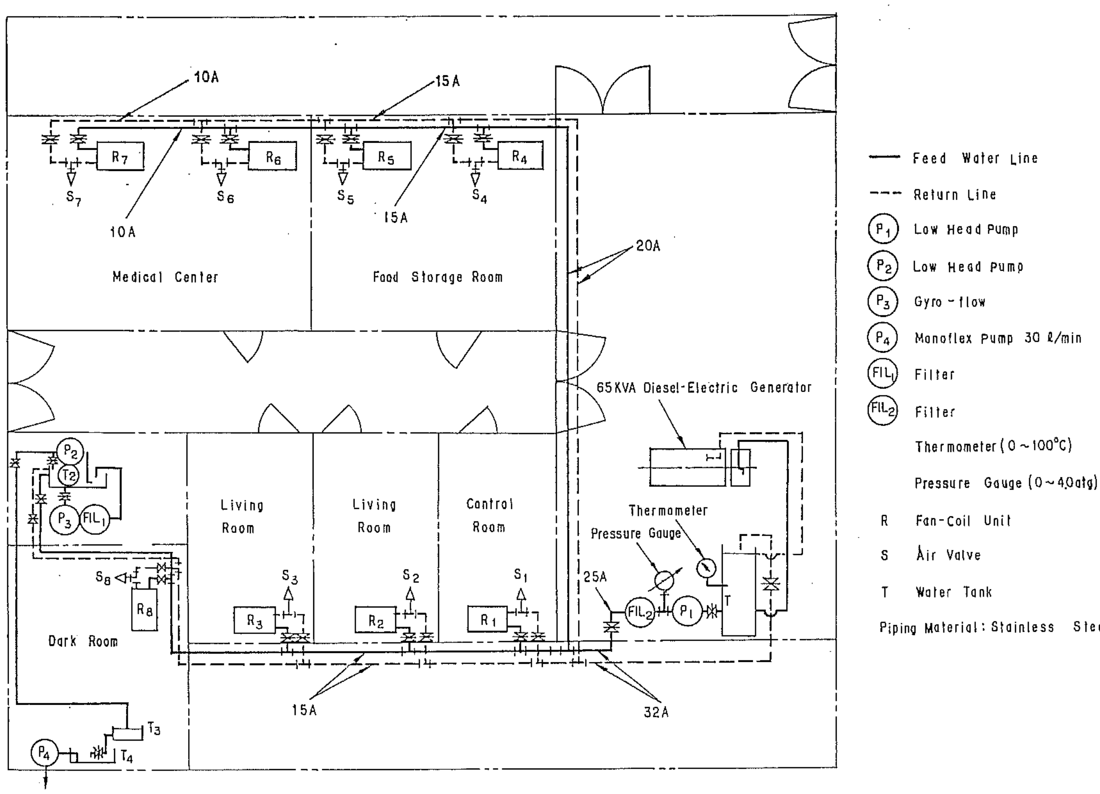


Fig. 13. JARE-9 engine room containing 65-kVA diesel-electric generator (Meidensha ZX-75 type diesel-electric generator) and coolant heat recovery system for making hot water used for heating of living rooms and other purposes.