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The Latest Trend of Electric Equipment in Relation to Energy Conservation

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Since the oil crisis in 1973, Japanese industrial fields have put many energy conservation schemes into practice and obtained fruitful results. This artical deals with the latest trend in Japan of energy conservation in electrical equipment and introduces some examples of new systems.

1. Improvements of Plant Systems

Regarding improvements of energy conservation in plant systems, we can use two methods; one is reduction of energy consumption and the other is recovery of waste energy and materials.

(1) Variable speed system of pumps and blowers control flow quantity by changing the speed of driving motors can reduce more electric power consumption than the control by valves or dampers. Inverter drive systems for a.c. motors are used widely for this purpose.

(2) Electric power generation by recovery of waste energy and materials. Objects of recovery are as follows:

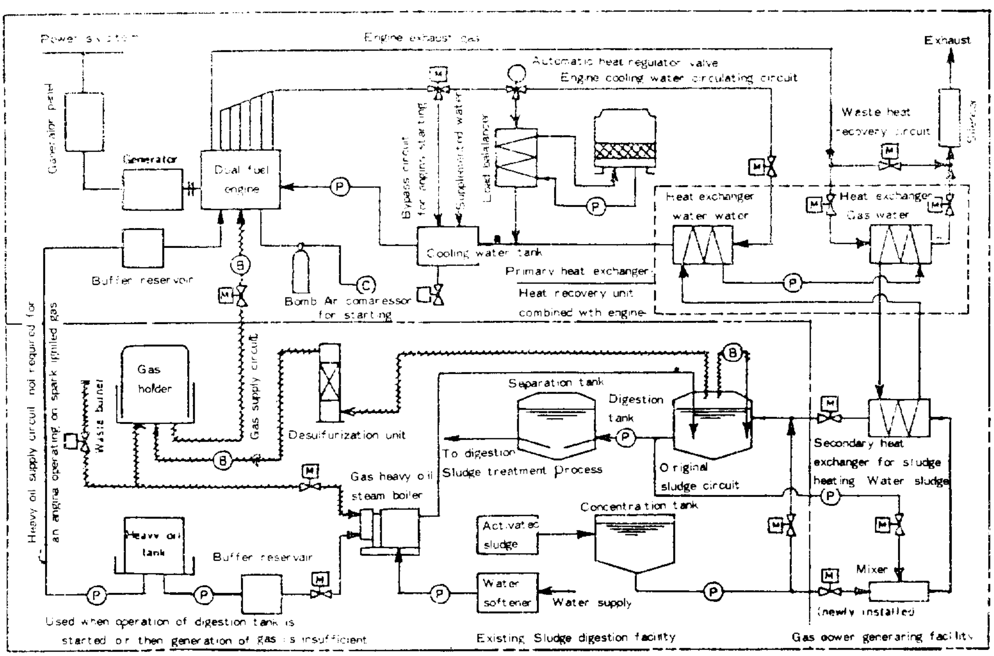

Fig. 1. Sludge digestion gas power generating system flow

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(a) gas pressure at the top of blast furnace.
(b) pressure throttled by a reducing valve.
(c) waste heat of gas exhausted from various furnaces.
(d) heat produced by burning waste materials
(e) digestion gas generated from sludge in sewage treatment plants.

The power generating system utilizing sludge digestion gas is introduced in this paper.[1] Sludge from sewage system containes a large volume of organic matter which includes bacteria accompanying a serious health hazzard. Therefore the Japanese law prohibits disposal of untreated sewage sludge into rivers and sea. All sludge must be treated.

At present the two major methods of sludge treatment are proposed in Japan as described below. The first one is the method involving the processes of concentration, mechanical dehydration, and incineration. The second one is the digestion method which involves the processes of concentration, anaerobic digestion, and dehydration. for the energy conservation the latter is more valuable. Fig. 1 shows and example of the digestion system. The gas generated in the digestion tank is gathered into the gas holder, and is then used to drive a gas engine. In this system, the heat recovered from cooling water and engine exhaust gas is used to heat up the sludge in the digestion tank. Fig. 2 shows an example of the combination of gas engine and generator set used for the field testing of a digestion gas generating plant. The output of this engine is 160kW.

Fig. 2. 160kW gas engine generator set

2. Improvements of Efficiencies of Machines

(1) Development of high-efficiency gas turbines

Improvement of efficiency of gas turbine is expected by raising firing temperature. At present firing temperature of the heavy duty gas turbine is about 1080°C and its thermal efficiency is about 30%. In 1978, a 35MW gas turbine generator plant was installed for the purpose of testing its high efficiency and low pollution.[2]

As shown in Fig. 3, The gas turbine is the split shaft type composed of a gas generator designed on the basis of jet engine having a firing temperature of approximately 1200°C and high efficiency

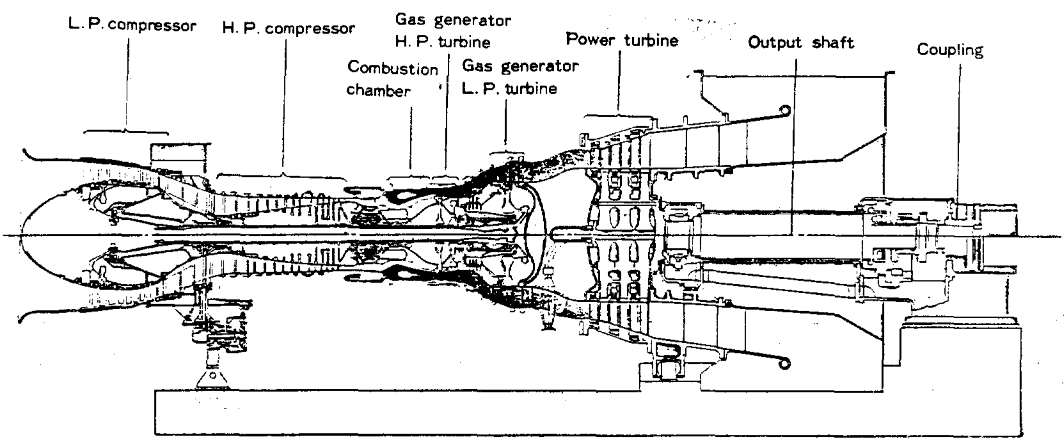


Fig. 3. Sectional assembly of IM 5000 gas turbine

power turbine. The thermal efficiency of the complete gas turbine amounted to 35% based on LHV at the generator terminals, even accompanied with water injection for NOx suppression purpose. Fig. 4 shows the general view of this plant.

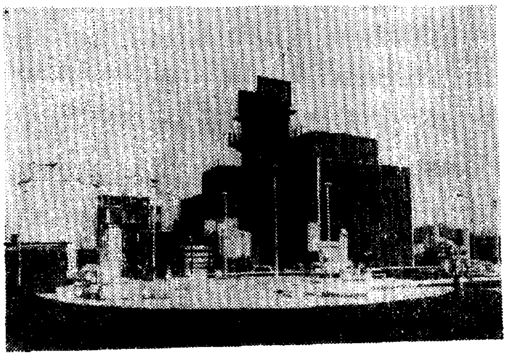


Fig. 4. General view 35MW high efficiency gas turbine power plant

(2) Improvement of efficiency of electric machines. The followings are put into practice for the reduction of losses:

(a) use of lower loss materials and development of new materials.

(b) application of advanced analytical technique like the finite element method to the design of electric machines.

(c) reduction of bearing loss by the adoption of magnetic suspension.

(d) reducion of windage loss by improvement of ventilation structure.

3. Advanced Systems for Energy Conservation

(1) Combined cycle power plant for repowering old generating plant.

A combined cycle power plant was installed in place of an old thermal power plant after the old boiler and steam turbine had been removed at the Kawasaki Power Station of the Japanese National Railways.[3]

Table 1. shows the specification and performance of this plant. The thermal efficiency at the generator terminal was improved relatively by 22% or more and the output could be more than doubled. These improvements have made it possible to save fuel a great deal.

As shown in Fig. 5, this plant consists of a heavy duty type gas turbine and a generator, an exhaust heat recovery boiler, a steam turbine generator, and their auxiliareis. Fig. 6 shows the heat cycle of the plant. The gas exhausted from the gas turbine (553°C at peak output) produces 163t/h of steam pressurized at 55bar in the boiler and is discharged from the stack at 218°C. The 55bar and 473°C steam enters the steam turbine to drive the generator.

Since the plant supplies electricity to locomotives

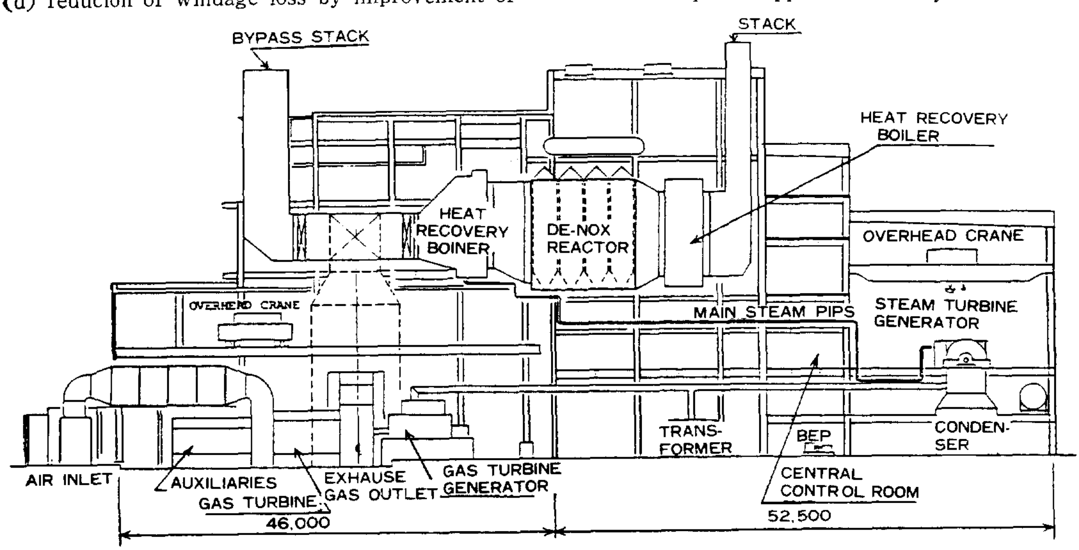


Fig. 5. Cross sectional view of Kawasaki power plant

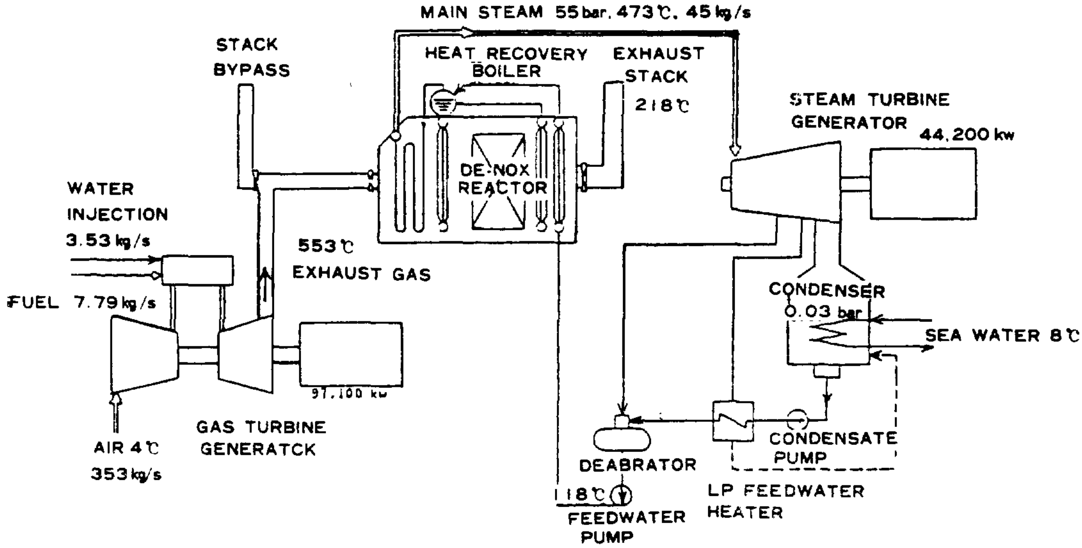


Fig. 6. Heat cycle of combined cycle power plant

and trains, it is designed to operate easily in the daily start and stop mode and demonstrate performance of a quick response to frequently changing electric power, thus meeting the requirements of railway load. In order to achieve very reliable operation with reduced man-hours and minimal maintenance personnel and also to keep high response, to quick load variation, a control computer system was installed for data logging and automatic plant start-up and stop operations.

Also in this plant, a catalytic NOx reducing system was successfuly put into commercial use.

(2) **Electric power generation by recovery of lower temperature waste heat.**

Recovery of higher temperature waste heat at more than 400°C is adopted popularly for steam. generation and turbine generator drive. In the case of lower temperature waste heat below 400°C however, steam generation is not effective, and it is desirable to use a suitable fluid capable of evaporating at a temperature lower than that of water a at a certain pressure.

For this purpose, a plant using Flourenol 85 as the fluid has been developed.[4] Flourenol 85 is an organic liquid at normal temperature, having physical properties shown in Table 2. By using Flourenol 85 as the medium of a Rankin cycle, a higher pressurized vapor is obtained at low and medium temperatures.

Fig. 7 shows the block diagram of this plant. Superheated vapor of Flourenol 85 from the vapor

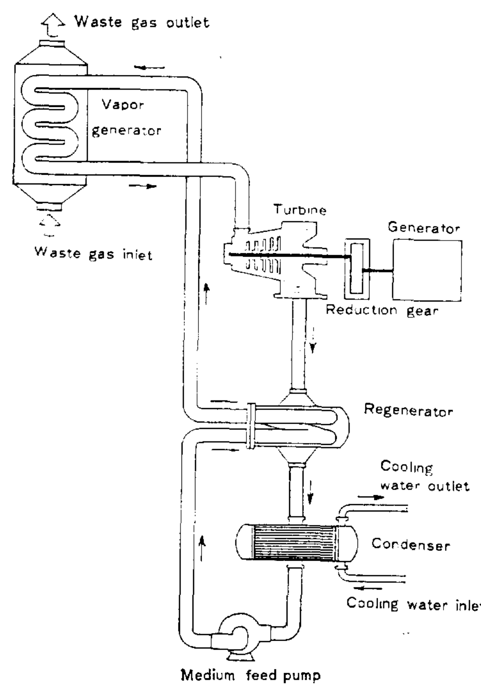


Fig. 7. Block diagram of waste heat recovery system using organic medium

generator enters the turbine to drive the generaton. The vapor discharged from the turbine pre-heats the liquid of Flourenol 85 at the regenerator and is then turned into the liquid at condenser. Flourenol 85 in liquid state is pressurized by the medium feed pump, heated at the regenerator, and sent to the vapor generator.

Fig. 8 shows the general view of this plant. succeeding the verification by a 500kW prototype plant, a 14MW power plant is under construction. This plant is to recover heat energy from an exhaust gas of 370°C and 690,000Nm³/h, discharged from a sintering plant of steal mills.

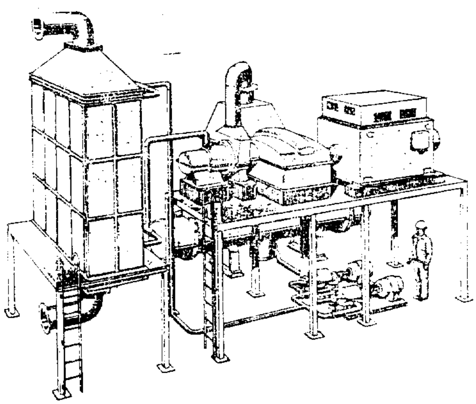
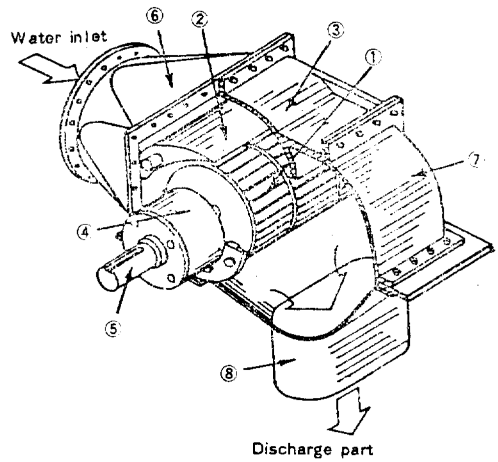


Fig. 8. General view of wast heate recovery power plant

(3) Mini-hydralic power generation

The liquid pressure energy lost at the reducing valve can be recovered using the water turbine instead of the reducing valve. Also, in the case of a hollow jet valve used to defeat energy of discharge at multi-purpose dams, it is possible to recover the wasted discharge energy by installation of a water turbine generator.

Since the capacity of each water turbine for this purpose is very small, less than several hundred kW, application of a convertional water turbine is economically disadvantageous and required much maintenance work. The mini-turbine for these applications, with a simple construction and features of easy operation and maintenance, has been developed against this background. One is a cross flow water turbine generator, while the other is a



① Runner　⑤ Shaft
② Guide vane　⑥ Inlet pipe
③ Casing　⑦ Cover
④ Bearing　⑧ Discharge pipe

Fig. 9. Construction of cross-flow turbine

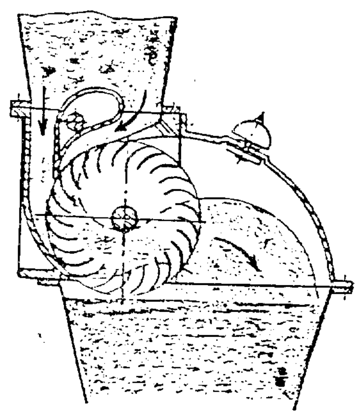


Fig. 10. Trace of water flow

built-in type water turbine generator.[5]

As shown in Fig. 9, the main parts of a cross flow water turbine are the runner and the quide vane. Water flows into the runner through the quide vane and goes out of the runner. Fig. 10 shows the water flow at the runner. In this case water flows into the runner at the upper left side, goes around the shaft inside the ruuner, and flows out of the right side.

In spite of such a simple construction, its maximum efficiency is more than 80%. Fig. 11 shows performance compared with that of the conventional Francis turbine.

Although we can use this turbine in a wide range of effective head, it is not economically advantageous if its head is lower than 20 meters. For such a lower head propeller turbines are used popularly, but conventional types are not econcmic for mini-water turbines. Built-in type water turbine generators have been developed under these circumstances. As shown in Fig. 12, the propeller turbine is housed in the rotor of induction generator so that it is very compact, economic and easily maintainable. In Fig. 12 the dark part shows the rotating members Fig. 13 shows the runner vanes incorporated in a cage rotor.

As known from Fig. 12, the rotor rotates in water. However no problem arises in electrical performance of a cage rotor rotating under water, and also mechanical loss is very small because of its smooth shape. The stator having insulated windings is saled against water. Fig. 14 is the photograph showing the rotor incorporated into the stator. Thanks to its simple construction, it is mounted on the penstock at either horizontal or vertical shaft.

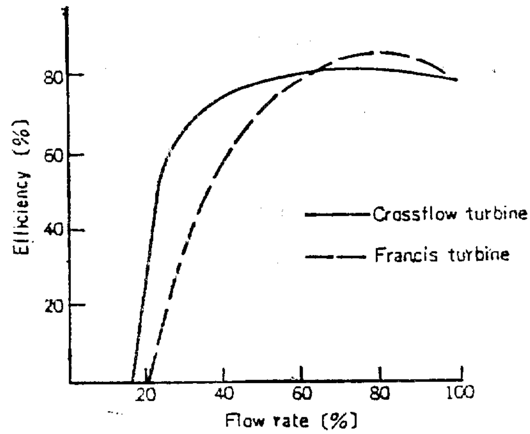


Fig. 11. Efficiency characteristics

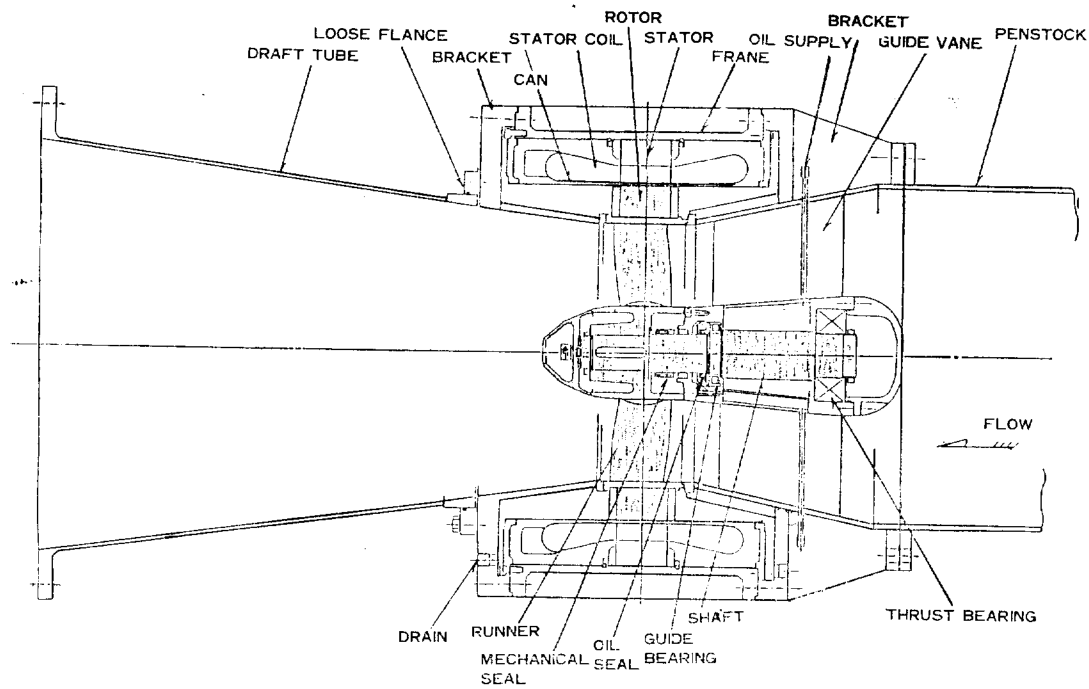


Fig. 12. Cross section of built-in turbine

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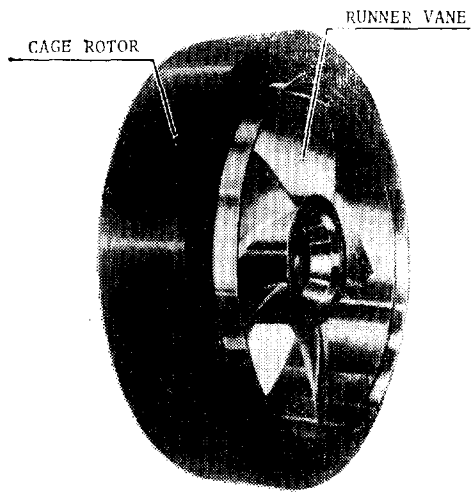

Fig. 13. Runner vanes incorporated in cage rotor

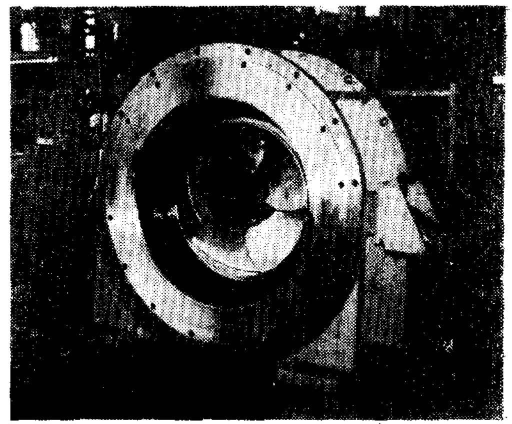

Fig. 14. Assembly of stator and rotor

Table 1. Plant specification and performance

		Retired	Repowered	
Specifications				
Gas Turbine		—		MS-9001
Steam Turbine		TCDF-20		TCSF-23
Steam Press.	bar. abs.	86		55
Steam Temp.	°C	510		473
Exhaust Press.	bar. abs.	0.04		0.03
Feedwater Temp.	°C	220		116
Boiler				
Evaporation	kg/s (T/h)	71 (255)		45 (163)
Performance				
Output	MW		Max./peak	Rated/basec
Gas Turbine		—	97.1	81.5
Steam Turbine		60	44.2	37.4
Total		60	141.3	118.9
Thermal Efficiency at generator terminal	%	32	40	39

Table 2. Physical properties of fluorenol 85

Molecular Weight	87.74
Specific Gravity	1.37
Boiling Point	76.1°C
Freezing Point	−63.3°C
Flashing Point	42.8°C

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