High-Temperature Heat Flux Heat Reduction Technology

(1) Aims

Selecting the heat removal limit heat flux that may serve as the general-purpose parameter showing the forefront and limit of temperature control, heat transfer enhancement, heat removal, and heat exchanging technologies, which are the key technologies in the heat engineering field, and clarifying the needs and consistent changes in numeric values, possibility of increases in the future, mechanical limits, and the form of society if these parameters increase in the future in order to provide engineers with social and academic meaning and quantitative targets and contribute to further progress of mechanical engineering.

(2) Social and technical needs

The following show the social and technical needs aroused by the increase in heat reduction fluxes:

- Heat fluxes of boilers (for preventing overheat of boiler piping)
- Cooling of spaceships when entering earth's atmosphere (for guaranteeing the thermal durability of spaceships)
- Cooling of nuclear reactors in case of accidents (for preventing breakage of fuel rods)
- Cooling of electronics, size reduction in cooling electronic devices, and higher-density heat generation (for reducing computer sizes)
- Hundreds of W/cm^2 are required for stable emission of cooled semiconductor lasers. However, the total heat generation amount is several watts or so. (For actualizing small solid semiconductor lasers for machining)
- Cooling in laser emission and X-ray emission is also a problem in the future. (High-power X-ray emission is needed.)

(3) Future directions for determining key mechanisms and parameters

The following show the possibilities for increasing heat removal heat fluxes:

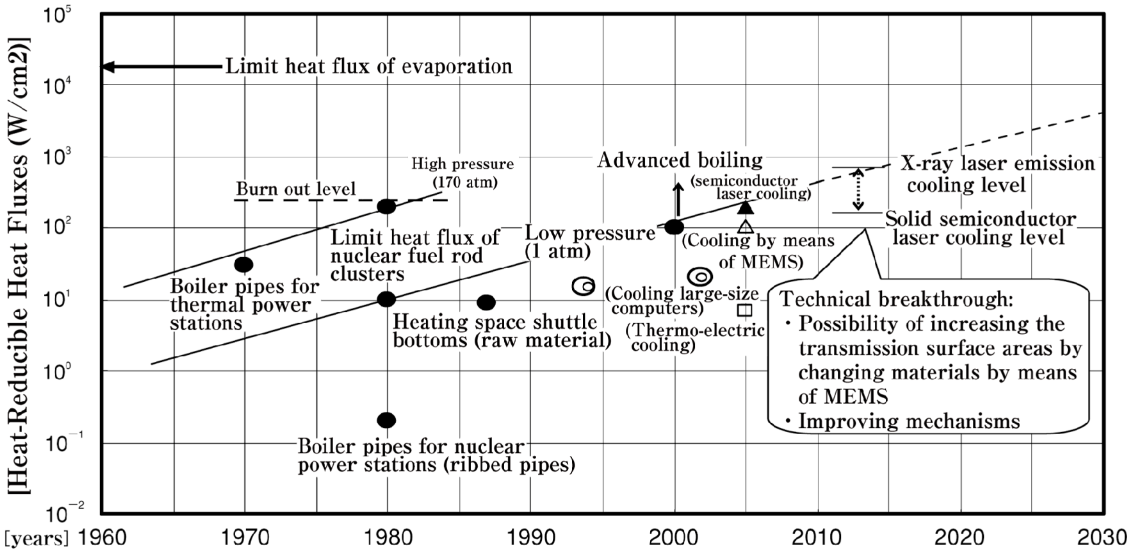
- The limit heat fluxes for pool boiling at the atmospheric pressure are up to 100 to 200 W/cm^2. A maximum of 400 W/cm^2 is approximately the limit heat flux for pool boiling at 80 atm, approximately one-third the critical pressure.
- The limit heat flux for forced convection sub-cool boiling may be increased up to 2 x 10^4 W/cm^2. The limit heat flux of evaporation is also 2 x 10^4 W/cm^2, showing promising utilization of the evaporation limit.
- In single-phase collision jet heat transmission of the normal convection heat transmission, the temperature difference is 150 K, flow velocity is 35 m/s, nozzle diameter is 1 mm, and heat flux using the property value of fluid water is 5000 W/cm^2.
- The area of the heat transmission surface is increased by means of MEMS. However, restrictions may be in place after increasing the area.
- The thermo-electric cooling value is approximately 10 W/cm^2 at present. How can we increase it? What is the technical breakthrough?

(4) Contributions to society

- Developing wearable lightweight computers. (Pocket-size computers and watches equipped with computer functions. However, such computers generate heat like pocket heaters and may break down due to overheating.)
- Further size reduction in computers will improve computer functions significantly. (Mobile computers will have the same performance as desktop computers. Besides, electric and electronic appliances and car-mounted microcomputers will have enhanced performance.)
- Developing portable high-power laser machine tools. Small machine tools may be carried and installed near materials to be machined. (This is the micro-factory concept. Lenses of glasses may be processed in convenience stores, for example. Small high-power lasers may also serve as weapons.

Social & Technical Needs

1960～1970	・Cooling boilers in thermal power stations
1970～1980	・Cooling electronic devices
1980～1990	・Cooling boilers in nuclear power stations ・Development of higher-density electronic devices
1990～2000	・Development of higher-density electronic devices ・Reduction of super computer sizes
2000～2010	
2010～2020	・Size reduction (of handy laser machine tools, etc.) & development of wearable computers
2020～2030	



Technical Breakthrough

1960～1970	・Pipes with internal grooves (ribbed pipes) and circling flow of boiler water
1970～1980	
1980～1990	・Vertical rising pipe structure (rifle pipes) ・[Heat insulating materials for space shuttles (withstand temperature, strength and attaching method)]
1990～2000	
2000～2010	
2010～2020	・Possibility of increasing the transmission surface areas by changing materials by means of MEMS (area increasing process technology)
2020～2030	

Changes in Society and Markets

1960～1970	・Large-size computers were released first in Japan (by NEC). ・Transistor TV sets were released first in the world (by Sony). ・Space shuttle landed on the moon.
1970～1980	・LCD LSI portable calculators were released (by Sharp). ・Word processors were released (by Toshiba and Sharp). ・NEC PC computers were released.
1980～1990	・Laser machining products were developed. ・Static weather satellite Himawari No. 2 and broadcast satellite BS-2 were launched. ・PC communication services [ASCII-NET] started. ・Notebook PCs were released (by Toshiba and Fujitsu).
1990～2000	・Test broadcasting of BS high-visions started. ・Commercial providers were founded and Internet expanded.
2000～2010	・Scale of wearable computers in the U.S. market reached 600 million dollars even in 2003. ・Japanese experimental booth (Kibo) of international space station was launched. ・Mass production of notebook PCs with fuel batteries ・Changing the Internet device standard into IPV6 (next-generation communication standard) was started mainly by Government.
2010～2020	・Individual-customized electronic magazines and newspaper were propagated. ・Portable PCs with solar and fuel batteries were put into practical use. ・One-chip ubiquitous computers were put into practical use. ・Nanometer-scale 3D IC processing technology ・About 50% of notebook PCs were changed into PCs with semiconductor drive (SSD) units.
2020～2030	・Super high-vision broadcasting was put to practical use. ・Wearable automatic voice translators were put to practical use. ・Quantum information optical transmission system was put to practical use. ・Tele-work population doubled. ・Desktop PCs had supercomputer-level performance.